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Two-Dimensional Cross-Section Sensitivity and Uncertainty Analysis For Fusion Reactor Blankets

Mark Julien Embrechts



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NOMENCLATURE

E	reflects energy function
Ω	reflects angular distribution
σ	microscopic cross section
Σ _x	macroscopic cross section, where x indicates the
	material and/or the type of cross section
Σ _{x,s}	macroscopic scattering cross section for material x
Σ _{x,T}	total cross section for material x
φ	angular flus
Ф _m	angular flux in discrete ordinates representation
$\Phi_{\mathcal{L}}^{\mathbf{k}}$	spherical harmonics representation for the angular
	flux
₽ ^k ℓ	spherical harmonics function
₽ _ℓ	Legendre polynomials
₽ ^k ℓ	associated Legendre polynomials
L	transport operator
Ľ*	adjoint transport operator
Q	source
R	response function
I	integral response
v	volume
F	fractional uncertainty for the secondary angular
	distribution
x	part of the loss term in the sensitivity profile
Ψ	part of the gain term in the sensitivity profile

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^F Σ _x	cross-section sensitivity function for cross section
^{pg} Σx	$\boldsymbol{\Sigma}_{_{\mathbf{X}}}$ cross-section sensitivity profile for a cross-section
	$\Sigma_{\rm X}$ for group g
Δu ^g	lethargy width for group g
w	quadrature weight

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TWO-DIMENSIONAL CROSS-SECTION SENSITIVITY AND UNCERTAINTY ANALYSIS FOR FUSION REACTOR BLANKETS

by

Mark Julien Embrechts

ABSTRACT

Sensitivity and uncertainty analysis implement the information obtained from a transport code by providing a reasonable estimate for the uncertainty for a particular response (e.g., tritium breeding), and by the ability to better understand the nucleonics involved. The doughnut shape of many fusion devices makes a two-dimensional calculation capability highly desirable. Based on first-order generalized perturbation theory, expressions for a two-dimensional SED (secondary energy distribution) and cross-section sensitivity and uncertainty analysis were developed for x-y and r-z geometry. This theory was implemented by developing a two-dimensional sensitivity and uncertainty analysis code, SENSIT-2D. SENSIT-2D has a design capability and has the option to calculate sensitivities and uncertainties with respect to the response function itself. SENSIT-2D can only interact with the TRIDENT-CTR code.

A rigorous comparison between a one-dimensional and a two-dimensional analysis for a problem which is one-dimensional from the neutronics point of view, indicates that SENSIT-2D performs as intended.

A two-dimensional sensitivity and uncertainty analysis for the heating of the TF coil for the FED (fusion engineering device) blanket was performed. The uncertainties calculated are of the same order of magnitude as those resulting from a one-dimensional analysis. The largest uncertainties were caused by the cross section uncertainties for chromium.

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1. INTRODUCTION TO SENSITIVITY THEORY AND UNCERTAINTY ANALYSIS

In a time characterized by a continuously growing demand for sophisticated technology it should not be surprising that the production of fusion energy might materialize more rapidly than commonly predicted. With fusion devices going into a demonstration phase there is a need for sophisticated nucleonics methods, tailored to the fusion community. In a relatively short time frame fusion nucleonics has established itself as a more or less mature subfield. In this context sensitivity theory has become a widely applied concept which provides the reactor designer with a deeper understanding of the information obtained from transport calculations.

Under the term sensitivity theory usually algorithms based upon classical perturbation and variational theory are understood. The scope of this work will be limited to cross-section and design sensitivity analysis with respect to fusion reactors. Since fusion nucleonics do not involve eigenvalue calculations, the mathematical concepts utilized will be simpler than those required by the fission community.

Sensitivity theory determines how a design quantity changes when one or more of the design parameters are altered. Uncertainty analysis

provides the error range on a design quantity due to errors on the design parameters. Sensitivity information can easily be incorporated into an uncertainty analysis by introducing covariance matrices.

Cross-section sensitivity and uncertainty analysis will give error estimates of response functions (such as tritium breeding ratio, heating and material damage) due to uncertainties in the cross-section data. Such a study will reveal which partial cross sections and in what energy range contribute most to the error and will recommend refinements on cross-section evaluations in order to reduce that error. Although those results will depend on the particular response and the particular design, general conclusions can still be drawn for a class of similar designs.¹⁸ Sensitivity theory is a powerful design tool and is commonly applied to cross-section adjustment procedures.¹⁻³ Design sensitivity analysis is frequently used to reduce the many and expensive computer runs required during the development of a new reactor concept.

1.1 Motivation

The purpose of this work is to assess the state of the art of sensitivity and uncertainty analysis with respect to fusion nucleonics, fill existing gaps in that field and suggest areas which deserve further attention.

At this moment the literature about sensitivity theory is scattered between various journal articles and technical reports. Therefore, the

author considered it as one of his responsibilities to provide a consistent monograph which explains, starting from the transport equation, how analytical and explicit expressions for various sensitivity profiles can be obtained. Current limitations with respect to the applicability of sensitivity theory are pointed out and the application of sensitivity theory to uncertainty analysis is explained. At the same time the scope has been kept limited to those algorithms which are presently used in calculation schemes.

Due to the particular geometry of fusion devices (toroidal geometry, non-symmetric plasma shape, etc.), a one-dimensional transport code (and therefore a one-dimensional sensitivity analysis) will generally be inadequate. In order to mock-up a fusion reactor more closely, a two-dimensional analysis is required. Although a two-dimensional sensitivity code - $VIP^{4,5}$ - already exists, VIP was developed with a fission reactor in mind, and does not include an r-z geometry option, nor a secondary energy distribution capability. To answer the needs of the fusion community, a two-dimensional sensitivity and uncertainty analysis code, SENSIT-2D, has been written.

A sensitivity code uses the regular and adjoint fluxes of a neutron transport code in order to construct sensitivity profiles. SENSIT-2D requires angular fluxes generated by TRIDENT-CTR.^{6,7} TRIDENT-CTR is a two-dimensional discrete-ordinates neutron transport code specially developed for the fusion community. Since SENSIT-2D incorporates the essential features of TRIDENT-CTR, i.e., triangular meshes and r-z geometry option, toroidal devices can be modeled quite accurately. SENSIT-

2D has the capability of group-dependent quadrature sets and includes the option of a secondary energy distribution (SED) sensitivity and uncertainty analysis. An option to calculate the loss term of the crosssection sensitivity profile based on either flux moments or angular fluxes is built into SENSIT-2D. The question whether a third-order spherical harmonics expansion of the angular flux will be adequate for a 2-D sensitivity analysis has not yet been adequately answered.⁸ The flux moment/angular flux option will help provide an answer to that question.

As an application of the SENSIT-2D code, a two-dimensional sensitivity and uncertaintly analysis of the inboard shield for the FED (<u>fusion engineering device</u>), currently in a preconceptual design stage by the General Atomic Company, was performed.

1.2 Literature Review

The roots of cross-section sensitivity theory can be traced to the work of Prezbindowski.^{9,10} The first widely used cross-section sensitivity code, SWANLAKE,¹¹ was developed at ORNL (Oak Ridge National Laboratory). In order to include the evaluation of the sensitivity of the response to the response function, SWANLAKE was modified to SWANLAKE-UW by Wu and Maynard.⁷⁷ Already early in its history, sensitivity theory was applied to fusion reactor studies.¹²⁻¹⁶ It has now become a common practice to include a sensitivity study in fusion neutronics.^{17-23,54}

The mathematical concepts behind sensitivity theory are based on variational and perturbation theory.²⁴⁻²⁹ The application of sensitivity profiles to uncertaintly analysis was restricted not due to a lack of adequate mathematical formulations, but due to the lack of crosssection covariance data. An extensive effort to include standardized covariance data into ENDF/B files has recently been made.³⁰⁻³⁴

The theory of design sensitivity analysis can be traced to the work of Conn, Stacey, and Gerstl.^{14,26,35,40} The current limitation of design sensitivity analysis is related to the fact that the integral response is exact up to the second order with respect to the fluxes, but only exact to the first order with respect to design changes. Therefore, only relatively small design changes are allowed. The utilization of Padé approximants⁴² might prove to be a valuable alternative to higher-order perturbation theory, but has not yet been applied to design sensitivity analysis.⁶³

The two-dimensional sensitivity code VIP^{4,5} was developed by Childs. VIP is oriented towards fission reactors and does not include a design sensitivity option, nor a secondary energy distribution capability.

The theory of secondary energy distribution (SED) and secondary angular distribution (SAD) sensitivity and uncertainty analysis was originated by Gerstl⁴³⁻⁴⁵ and is incorporated into the SENSIT⁴⁶ code. The FORSS⁴⁷ code package has been applied mainly to fast reactor studies^{48,49} but can be applied to fusion reactor designs as well. Higherorder sensitivity theory^{42,50-51,78} still seems to be too impractical to

be readily applied. Recently however, the French developed a code system, SAMPO,⁵² which includes some higher-order sensitivity analysis capability.

2. SENSITIVITY THEORY

In this chapter the theory behind source and detector sensitivity, cross-section and secondary energy distribution (SED) sensitivity, and design sensitivity analysis will be explained. Starting from the transport equation, expressions for the corresponding sensitivity profiles will be derived. Those formulas will then be made more explicit and applied to a two-dimensional geometry. The theory presented in this and the following chapter is merely a consistent combination and reconstruction of several papers and reports.^{3,13,16,17,18,43-46,53}

Since up to this time no single reference work about the various concepts used in sensitivity and uncertainty analysis has been published, the author uses the most commonly referred to terminology. In an attempt to present an overview with the emphasis on internal consistency, there might be some minor conflicts with the terminology used in earlier published papers.

2.1 Definitions

2.1.1 Cross-section sensitivity function, cross-section sensitivity profile and integral cross-section sensitivity

Let I represent a design quantity (such as a reaction rate, e.g., the tritium breeding ratio), depending on a cross-section set and the angular fluxes. The <u>cross-section sensitivity function</u> for a particular cross section Σ_x at energy E, F_{Σ_x} (E), is defined as the fractional change of the design parameter of interest per unit fractional change of

cross section $\Sigma_{\mathbf{x}}$, or

$$F_{\Sigma_{x}}(E) = \frac{\partial I/I}{\partial \Sigma_{x}/\Sigma_{x}} \qquad (1)$$

In a multigroup formulation the usual preference is to work with a <u>sensitivity profile</u> $P_{\Sigma_x}^g$, which is defined by

$$P_{\Sigma_{x}}^{g} = \frac{\partial I/I}{\partial \Sigma_{x}^{g}/\Sigma_{x}^{g}} \cdot \frac{1}{\Delta u^{g}}, \qquad (2)$$

where Δu^g is the lethargy width of group g and Σ_x^g is the multigroup cross section for group g. The sum over all the groups of the sensitivity profiles for a particular group cross section Σ_x^g , multiplied by

the corresponding lethargy widths, is called the <u>integral cross-section</u> <u>sensitivity</u> for cross section Σ_{v} , or

$$S_{\sum_{\mathbf{x}}} = \sum_{\mathbf{g}} P_{\sum_{\mathbf{x}}}^{\mathbf{g}} \cdot \Delta u^{\mathbf{g}} ,$$

= $\int dE F_{\sum_{\mathbf{x}}}(E) .$ (3)

The integral cross-section sensitivity can be interpreted as the percentage change of the design parameter of interest, I, resulting from a simultaneous one percent increase of the group cross sections Σ_x^g in all energy groups g.

2.1.2 Vector cross section

The term "vector cross section" describes a multigroup partial cross-section set with one group-averaged reaction cross section for each group. Such a cross-section set can be described by a vector with GMAX elements, where GMAX is the number of energy groups. The term vector cross section was introduced by Gerstl to discriminate it from the matrix representation of a multigroup cross-section set. Differential scattering cross sections can obviously not be described in the form of a vector cross section.

2.1.3 Geometry related terminology

Under the term <u>region</u> we will understand a collection of one or more zones. A <u>zone</u> will always describe a homogeneous part of the reactor. We will make a distinction between <u>source regions</u>, <u>detector</u> <u>regions</u> and <u>perturbed regions</u>, and as a consequence between <u>source</u>, <u>detector</u> and <u>perturbed zones</u>. We will introduce the term <u>blank region</u> for a region that is neither a detector, source or perturbed region. A zone will further be divided into intervals.

The source region will describe that part of the reactor which contains a volumetric source. The detector region indicates the part of the reactor for which an integral response is desired. In the perturbed region changes in one or more cross sections can be made.

A source or a detector regions can contain more than one zone, and each zone can be made up of a different material. Due to the mathematical formulations a perturbed region can still contain more than one zone, but in this case all the zones have to contain identical materials. If there is more than one perturbed region, all those regions should contain the same materials.

The geometry-related terminology is illustrated in Fig. 1. In this case, there are six regions; a source region, two perturbed regions, one detector region and two blank regions. The source region contains three zones (identified by \underline{a} , \underline{b} , and \underline{c}). The first zone, \underline{a} , is a vacuum, while the other two zones are made up of iron. Note that both perturbed regions satisfy the requirement that the zones in these regions contain

				h	<u>1</u>				و	
	<u>b</u>	<u>d</u>	<u>e</u>						r	
				j	<u>k</u>			_		
<u>a</u>						<u>n</u>	<u> </u>	P		
	<u> </u>	<u>f</u>	<u>8</u>	<u>1</u>	<u>m</u>				<u>s</u>	<u>t</u>
REGI	REGION I REGION II REGION III REGION IV REGION V REGION VI									
Source Blank Region Region		Perturbed Blank Perturbed Region Region Region		Detector Region						
MATERIALS					ZONE	S ·				
vacuum iron copper copper + iron beryllium				a,e, b,c,j q,r s,t d,g	<u>f</u> n,o,p,h, <u>i</u> ,j	<u>, k, 1, n</u>	<u>1</u>			

Illustration of the terminology: blank region, source region, perturbed region and detector Figure 1. region

identical materials. This requirement does not have to be met for source and detector regions.

2.2 Cross-Section Sensitivity Profiles

2.2.1 Introduction

Perturbation theory is most commonly applied in order to derive analytical expressions for the cross-section sensitivity profile. We therefore will follow in this work Oblow's approach.^{11,25} Based on the analytical expression, an explicit formula for the cross-section sensitivity profile in discrete ordinates form for a two-dimensional geometry will then be derived.

During the last few years there has been a trend towards using generalized perturbation theory for sensitivity studies.^{5,55,61} Generalized perturbation theory has the advantage that it can readily be applied to derive expressions for the ratio of bilinear functionals and that it can be used to study nonlinear systems.^{59,60} Also, higher-order expressions, based on generalized perturbation theory, have been derived.^{57,58,61}

The differential approach is closely related to generalized perturbation theory and has been applied to cross-section sensitivity analysis by Oblow.²⁸ A more rigorous formulation of the differential approach was made by Dubi and Dudziak.^{50,51} Although higher-order expressions

for cross-section sensitivity profiles can be derived, 50,51 the practicality of its application has not yet been proved. 50,51,78

The evaluation of a sensitivity profile will generally require the solution of a direct and an adjoint problem. Such a system carries more information than the forward equation and it is therefore not surprising that this extra amount of information can be made explicit (e.g., through sensitivity profiles).

The higher-order expressions for the cross-section sensitivity profiles derived by Dubi and Dudziak involve the use of Green's functions.^{50,51} The Green's function - if properly integrated - allows one to gain all possible information for a particular transport problem. It therefore can be expected that higher-order sensitivity profiles can be calculated up to an arbitrary high order by evaluating one Green's function. For most cases, the derivation of the Green's function is extremely complicated, if not impossible. It therefore can be argued that the Green's function carries such a tremendous amount of information that it is not surprising that higher-order expressions for the sensitivity profile can be obtained, and that while the use of Green's functions can prove to be very valuable for gaining analytical and physical insight, they will not be practical as a basis for numerical evaluations.

From the study done by Wu and Maynard,⁷⁸ it can be concluded that a first-order expression allows for a 40% perturbation in the cross sections (or rather the mean free path) and will still yield a reasonably accurate integral response (less than 10% error). Larger perturbations give rapidly increasing errors (the error increases roughly by a power

of three). Expressions exact up to the second order allow a 65% perturbation, and a sixth-order expression allows a 190% perturbation, both for an error less than 10%. Also, for higher-order approximations, if was found that the error on the integral response will increase drastically once the error exceeds 10%. It can be concluded therefore that the higher-order expressions do not bring a tremendous improvement over the first-order approximation (unless very high orders are used), while the computational effort increases drastically. Higher-order sensitivity analysis can only become practical when extremely simple expressions for the sensitivity profiles can be obtained, or when a suitable approximation for Green's functions can be found.⁷⁹

2.2.2 Analytical expression for the cross-section sensitivity profile

Consider the regular and adjoint transport equations

$$L.\Phi = Q \quad , \tag{4}$$

and

$$L^{\star}.\Phi^{\star} = R , \qquad (5)$$

where Φ and Φ^{\star} represent the forward and the adjoint angular fluxes, L and L^{\star} are the forward and adjoint transport operator, Q is the source, and R is the detector response function. The integral response, I, can then be written as

$$I = \langle R, \phi \rangle \tag{6}$$

or

$$I^{\dagger} = \langle Q, \varphi^{\dagger} \rangle , \qquad (7)$$

where the symbol < , > means the inner product, i.e., the integral over the phase space. In a fully converged calculation I^{\star} will be equal to I. For the perturbed system, similar expressions can be obtained:

$$L_{p}\Phi_{p} = Q , \qquad (8)$$

$$L_{p}^{\dagger} \Phi_{p}^{\dagger} = R , \qquad (9)$$

$$I_{p} = \langle R, \Phi_{p} \rangle$$
 , (10)

and
$$I_{p}^{*} = \langle Q, \phi_{p}^{*} \rangle$$
, (11)

where

$$\Phi_{\rm p} = \Phi + \delta \Phi \quad , \tag{12}$$

$$\Phi_{p}^{*} = \Phi^{*} + \delta \Phi^{*} , \qquad (13)$$

and
$$I_p = I + \delta I$$
 . (14)

From Eqs. (9), (13), and (5) we have

$$L_{p}^{*}.\delta \Phi^{*} = (L^{*} - L_{p}^{*}).\Phi^{*}$$
 (15)

Further, we have from Eqs. (14), (11), (6), (12), and (9)

$$\delta I = I_{p} - I ,$$

$$= \langle R, \Phi_{p} - \Phi \rangle ,$$

$$= \langle R, \delta \Phi \rangle ,$$

$$\delta I = \langle L_{p}^{*} \Phi_{p}^{*}, \delta \Phi \rangle . \qquad (16)$$

Using the definition of the adjoint transport operator and Eqs. (15) and (16) transforms to

$$\delta I = \langle \Phi_p, L_p^* \delta \Phi^* \rangle$$
,

or

or

$$\delta I = \langle \Phi_{p}, (L^{\star} - L_{p}^{\star}) \Phi^{\star} \rangle \qquad (17)$$

It is assumed that the perturbed differential scattering cross section can be expressed as a function of the unperturbed differential scattering cross section by

$$\Sigma_{\rm sp}(\underline{r},\underline{\Omega},\underline{\Omega}',E\rightarrow E') = C.\Sigma_{\rm p}(\underline{r},\underline{\Omega},\underline{\Omega}',E\rightarrow E') , \qquad (18)$$

and similarly for the total cross section

$$\Sigma_{\mathrm{Tp}}(\underline{r}, \mathrm{E}) = \mathrm{C}.\Sigma_{\mathrm{T}}(\underline{r}, \mathrm{E}) \quad , \tag{19}$$

.

.

where C is a small quantity, which can be a function of E and Ω . Defining $\delta C = C - 1$, we have

$$\delta C = \frac{\Sigma_{\mathrm{Tp}}(\underline{r}, E) - \Sigma_{\mathrm{T}}(\underline{r}, E)}{\Sigma_{\mathrm{T}}(\underline{r}, E)} = \frac{\Sigma_{\mathrm{sp}}(\underline{r}, \underline{\Omega} \rightarrow \underline{\Omega}', E \rightarrow E) - \Sigma_{\mathrm{s}}(\underline{r}, \underline{\Omega} \rightarrow \underline{\Omega}', E \rightarrow E')}{\Sigma_{\mathrm{s}}(\underline{r}, \underline{\Omega} \rightarrow \underline{\Omega}', E \rightarrow E')}$$
(20)

so that

$$\delta I(E) = \delta C \int d\underline{r} \int d\underline{\Omega} \cdot \Phi_{p} \{ -\Sigma_{T}(\underline{r}, E) \cdot \Phi^{*}(\underline{r}, \underline{\Omega}, E) + \int dE' \int d\underline{\Omega}' \Sigma_{s}(\underline{r}, \underline{\Omega} \cdot \underline{\Omega}', E \cdot E') \cdot \Phi^{*}(\underline{r}, \underline{\Omega}', E') \} .$$
(21)

The cross-section sensitivity function $F_{\sum_{X}}(E)$ is defined by

$$F_{\Sigma_{x}}(E) = \frac{\partial I/I}{\partial \Sigma_{x}/\Sigma_{x}} , \qquad (22)$$

and can be approximated by

$$F_{\Sigma_{\mathbf{X}}}(\mathbf{E}) \cong \frac{1}{\mathbf{I}} \int d\mathbf{\underline{r}} \int d\Omega \left\{ -\Phi(\underline{\mathbf{r}}, \underline{\Omega}, \mathbf{E}) \cdot \Sigma_{\mathbf{X}, \mathbf{T}}(\underline{\mathbf{r}}, \mathbf{E}) \cdot \Phi^{\star}(\underline{\mathbf{r}}, \underline{\Omega}, \mathbf{E}) \right.$$
$$+ \int d\Omega' \int d\mathbf{E}' \Phi(\underline{\mathbf{r}}, \underline{\Omega}, \mathbf{E}) \cdot \Sigma_{\mathbf{X}, \mathbf{S}}(\underline{\mathbf{r}}, \underline{\Omega} \cdot \underline{\Omega}', \mathbf{E} \cdot \mathbf{E}') \cdot \Phi^{\star}(\underline{\mathbf{r}}, \underline{\Omega}', \mathbf{E}') \right\} . (23)$$

The sensitivity function $F_{\sum_{X}}(E)$ represents the dependence or sensitivity of a design parameter of interest to a particular cross section Σ_{x} at energy E. The first term is usually referred to as the loss term and the second term is called the gain term.²⁷

The cross-section sensitivity profile $P^g_{\sum\limits_{\mathbf{X}}}$ is then defined as

$$P_{\Sigma_{x}}^{g} = \frac{1}{\Delta u^{g}} \int_{E_{g}}^{E_{g}-1} dE F_{\Sigma_{x}}(E) . \qquad (24)$$

The scaling factor Δu^g is the lethargy width of group g and is introduced as a normalization factor in order to remove the influence of the choice of the group structure.

Remarks

1. In the previous section Σ_{χ} represents a partial cross section for a particular material. Σ_{χ} can be an absorption cross section, a total cross section, a differential scattering cross section, a reaction cross section, etc. Therefore Σ_{χ} has a surpressed index which indicates the specific partial cross section. When evaluating the cross-section sensitivity profile for a partial cross section only the appropriate part, either the loss term or the gain term, will have to be considered in Eq. (23). When the partial cross section is not related to the production of secondary particles (e.g., a differential scattering cross section) the sensitivity profile in the multigroup form is referred to by Gerstl as a vector cross-section sensitivity profile. Obviously such cross sections contribute only to the loss term.

- 2. It is possible to define a net or a total sensitivity profile, which can be obtained by summing the loss and the gain terms for various partial reactions. The net sensitivity profile can be used to determine how important a particular element is with respect to a particular response.
- 3. Note that while deriving an expression for the cross-section sensitivity profile, we implicitly assumed that the response function was independent from the partial cross section for which a sensitivity profile is desired. If this assumption does not hold, an extra term has to be added to the previously obtained expressions. When the response function is also the cross section for which a sensitivity profile is sought, the sensitivity function will take the form

$$\frac{\partial I/I}{\partial \Sigma_{x}/\Sigma_{x}} = \frac{\langle R, \Phi \rangle}{I} + \frac{\langle \Phi, L_{\Sigma}, \Phi^{*} \rangle}{I} , \qquad (25)$$

where L_{Σ_X} represents that portion of the transport operator that contains the cross-section set $\{\Sigma_X\}$. In this expression the first term is a direct effect and the second term is an indirect effect. If the direct effect is present, the indirect effect will usually be negligible. A summary of the various possibilities is given in Table I.

4. The spatial integration in Eq. (23) has to be carried out over the perturbed regions only.

2.2.3 Explicit expression for the cross-section sensitivity profile in discrete ordinates form for a two-dimensional geometry representation -

Coordinate system

The coordinate systems for x-y and r-z geometry are shown in Figs. 2a and 2b.⁵³ In both geometries ϕ was chosen to be the angle of rotation about the μ -axis such that $d\Omega = d\mu . d\phi$, and since $\xi^2 + \mu^2 + \nu^2 = 1$, we have

TABLE I: FORMULAS FOR THE SENSITIVITY FUNCTION

Case	Sensitivity Function				
a. I = $\langle R, \Phi \rangle$, where $\Sigma_i \neq R$	$F_{\Sigma_{i}} = \langle \phi^{\dagger}, L_{\Sigma} \phi \rangle / I$				
b. I = <r,<math>\phi>, where $\Sigma_i = R$ and $\Sigma_i \not \subset L$</r,<math>	$F_{\Sigma_i} = \langle R, \Phi \rangle / I$				
c. I = <r,<math>\phi>, where $\Sigma_i = R$ and $\Sigma_i \subset L$</r,<math>	F _{Σ_i} = <r,φ>/I + <Φ[*],L_Σ,Φ>/I direct indirect effect effect The direct effect is usually dominant</r,φ>				
<pre>< > indicates the inner product over the phase space \$ L stands for the transport operator</pre>					
${}^{L}\!\Sigma_{i}$ represents that portion of the transport operator which contains cross-section $\{\Sigma_{i}^{}\}$					
⊂ means is included in ✓ means is not included in					



Figure 2. a. Coordinates in x-y geometry


Figure 2. b. Coordinates in r-z geometry

$$\xi = (1 - \mu^2)^{\frac{1}{2}} . \sin \phi$$
,

and

$$\eta = (1 - \mu^2)^{\frac{1}{2}} . \cos \phi$$

Therefore both the x-y and the r-z geometry representation will lead to identical expressions for the sensitivity profile, with the understanding that in x-y geometry the angular flux is represented by $\Phi(x,y,\mu,\phi)$, and by $\Phi(r,z,\mu,\phi)$ in the case of r-z geometry.

We now will derive an expression for the sensitivity profile in an x-y or in an r-z geometry representation.

Method

Before deriving an expression in a discrete-ordinates formulation and a two-dimensional geometry for Eq. (23), a brief overview of the methods used is outlined.

Gain term:

In order to represent the differential scattering cross section in a multigroup format, the common approach to expand the differential scattering cross section in Legendre polynomials is used. The number of terms in the expansion is a function of the order of anisotropic scattering. The Legendre polynomials are a function of the scattering angle μ_{o} (Fig. 2). Introducing spherical harmonics

functions and applying the addition theorem for spherical harmonics, the dependence on μ_0 can be replaced by μ 's and ϕ 's. The angular fluxes are expanded in flux moments. The integrals are replaced by summations. Defining multigroup cross sections an expressions for the gain term can be obtained.

Loss term:

An explicit expression for the loss term can be derived based on angular fluxes or based on flux moments. In order to check the internal consistency in SENSIT-2D both methods will $b_{<}$ applied. The derivation of an expression based on angular fluxes is straightforward: the integrations are replaced by summations and the appropriate multigroup cross sections are defined. An expression as a function of flux moments can be obtained by expanding the fluxes in flux moments, using spherical harmonics functions. The orthogonality relation of spherical harmonics is applied, the integrations are replaced by summations and appropriate multigroup cross sections are defined. Finally an expression for the loss term is the result.

Analytical derivations

Expand the differential scattering cross section in Legendre polynomials according to

$$\Sigma_{\mathbf{x},\mathbf{s}}(\underline{\Omega} \rightarrow \underline{\Omega}', \mathbf{E} \rightarrow \mathbf{E}') = \Sigma_{\mathbf{x},\mathbf{s}}(\mu_{0}, \mathbf{E} \rightarrow \mathbf{E}') = \sum_{\ell=0}^{\text{LMAX}} \frac{2\ell+1}{4\pi} P_{\ell}(\mu_{0}) \Sigma_{\mathbf{s},\ell}(\mathbf{E} \rightarrow \mathbf{E}') , \quad (26)$$

where the $P_{\ell}(\mu_{o})$'s are the Legendre polynomials and LMAX the order of anisotropic scattering. Here, the scattering angle μ_{o} can be written as

$$\mu_{o} = \underline{\Omega} \cdot \underline{\Omega}' = \Omega_{x} \Omega_{x}' + \Omega_{y} \Omega_{y}' + \Omega_{z} \Omega_{z}' ,$$

or

 $\mu_{o} = \mu\mu' + \eta\eta' + \xi\xi'$,

$$= \mu \mu' + (1-\mu^2)^{\frac{1}{2}} (1-\mu'^2)^{\frac{1}{2}} \cos\phi \, \cos\phi' \, + \, (1-\mu^2)^{\frac{1}{2}} (1-\mu'^2)^{\frac{1}{2}} \sin\phi \, \sin\phi \, ,$$

or

$$\mu_{o} = \mu \mu' + (1 - \mu^{2})^{\frac{1}{2}} (1 - \mu'^{2})^{\frac{1}{2}} \cos(\phi - \phi')$$

The spherical harmonics addition theorem states that (see e.g., Bell and $Glasstone^{62}$)

$$P_{\ell}(\mu_{o}) = P_{\ell}(\mu)P_{\ell}(\mu') + 2 \sum_{k=1}^{\ell} \frac{(\ell-k)!}{(\ell+k)!} P_{\ell}^{k}(\mu)P_{\ell}^{k}(\mu')\cos[k(\phi-\phi')] , \quad (27)$$

where the $P^{\bf k}_{\ell}(\mu)$'s are the associated Legendre polynomials. The above expression can then be reformulated as

$$P_{\ell}(\mu_{o}) = \sum_{k=0}^{\ell} \frac{(2-\delta_{ko})(\ell-k)!}{(\ell+k)!} P_{\ell}^{k}(\mu)P_{\ell}^{k}(\mu')\cos[k(\phi-\phi')]$$

$$= \sum_{k=0}^{\ell} \left[\frac{(2-\delta_{ko})(\ell-k)!}{(\ell+k)!} \right]^{\frac{1}{2}} \left[\frac{(2-\delta_{ko})(\ell-k)!}{(\ell+k)!} \right]^{\frac{1}{2}} P_{\ell}^{k}(\mu)P_{\ell}^{k}(\mu')$$

$$\times (\cos k\phi \cos k\phi' + \sin k\phi \sin k\phi') . \qquad (28)$$

We define

$$R_{\ell}^{k}(\mu,\phi) = \left[\frac{(2-\delta_{k0})(\ell-k)!}{(\ell+k)!}\right]^{\frac{1}{2}} P_{\ell}(\mu)\cos k\phi , \qquad (29)$$

and

$$Q_{\ell}^{k}(\mu,\phi) = \left[\frac{(2-\delta_{k0})(\ell-k)!}{(\ell+k)!}\right]^{\frac{1}{2}} P_{\ell}^{k}(\mu)\sin k\phi \quad . \tag{30}$$

so that

$$P_{\ell}(\mu_{o}) = \sum_{k=0}^{\ell} \{R_{\ell}^{k}(\mu,\phi)R_{\ell}^{k}(\mu',\phi') + Q_{\ell}^{k}(\mu,\phi)Q_{\ell}^{k}(\mu',\phi')\} . \qquad (31)$$

The Q terms will generate odd moments which will vanish on integration, thus the Q terms will be omitted in the following discussion. The $R_{\mathcal{Q}}^k$ terms are the spherical harmonics polynomials. Using the above expression for $P_{\mathcal{Q}}(\mu_0)$ in the expansion of the scattering cross section, we have

$$\Sigma_{\mathbf{x},\mathbf{s}}(\underline{\Omega} \rightarrow \underline{\Omega}', \mathbf{E} \rightarrow \mathbf{E}') = \sum_{\ell=0}^{\text{LMAX}} \frac{2\ell+1}{4\pi} \Sigma_{\mathbf{s},\ell} \quad (\mathbf{E} \rightarrow \mathbf{E}') \quad \sum_{k=0}^{\ell} R_{\ell}^{k}(\mu,\phi) R_{\ell}^{k}(\mu',\phi') \quad , \quad (32)$$

where LMAX is the order of anisotropic scattering.

The second term of the sensitivity profile, Eq. (24), becomes

$$\frac{1}{I\Delta u^{g}} \int_{E_{g}}^{E_{g}-1} dE \int_{V} d\underline{r} \int_{0}^{\infty} dE' \sum_{\ell=0}^{LMAX} \frac{2\ell+1}{4\pi} \Sigma_{s,\ell}(E \rightarrow E') \sum_{k=0}^{\ell} 2 \int_{-1}^{1} d\mu \int_{0}^{\pi} d\phi$$
$$\cdot R_{\ell}^{k}(\mu,\phi)\phi(\underline{r},\underline{\Omega},E) \cdot 2 \int_{-1}^{1} d\mu' \int_{0}^{\pi} d\phi' R_{\ell}^{k}(\mu',\phi')\phi^{*}(\underline{r},\underline{\Omega}',E') \quad . (33)$$

Note that

$$\int_{-1}^{1} d\mu \int_{0}^{\pi} d\phi R_{\ell}^{k}(\mu,\phi)R_{m}^{n}(\mu,\phi) = \frac{2\pi}{2\ell+1} \delta_{\ell m}\delta_{kn} , \qquad (34)$$

and therefore the angular flux can be expanded according to

$$\Phi(\underline{\Omega}, E) = \sum_{\ell=0}^{\infty} (2\ell+1) \sum_{k=0}^{\ell} R_{\ell}^{k} \Phi_{\ell}^{k}(E) , \qquad (35a)$$

where
$$\Phi_{\ell}^{k}(E) = \int_{-1}^{1} d\mu \int_{p}^{1} d\phi R_{\ell}^{k} \Phi(\Omega, E)/2\pi$$
, (35b)

and similarly for the adjoint angular flux

$$\Phi (\underline{\Omega}, E) = \sum_{\ell=0}^{\Sigma} (2\ell+1) \sum_{k=0}^{\ell} R_{\ell}^{k} \phi_{\ell}^{*k}(E) , \qquad (36a)$$

where
$$\Phi_{\ell}^{\star k}(E) = \int_{-1}^{1} d\mu \int_{0}^{\pi} d\phi R_{\ell}^{k} \Phi(\Omega, E)/2\pi$$
, (36b)

Introducing these expansions in the sensitivity profile, the gain term becomes

$$P_{\Sigma_{x,gain}}^{g} = \frac{4\pi}{I\Delta u^{g}} \int_{V} d\underline{r} \int_{g'=1}^{GMAX} \int_{E_{g'}} d\underline{E}' \int_{g'=1}^{E_{g'-1}} d\underline{E}' \int_{g'=0}^{E_{g-1}} d\underline{E} \sum_{\ell=0}^{LMAX} (2\ell+1) \Sigma_{s,\ell}(\underline{E} \rightarrow \underline{E}')$$

$$\cdot \int_{k=0}^{\ell} \phi_{\ell}^{k}(\underline{E}) \phi_{\ell}^{\star k}(\underline{E}') , \qquad (37)$$

where GMAX is the number of energy groups. Defining

$$\Sigma_{s,\ell}^{g \to g'} \phi_{\ell}^{kg} \phi_{\ell}^{\sharp kg'} = \int_{E_{g'}}^{E_{g'-1}} dE' \int_{E_{g}}^{E_{g-1}} dE \Sigma_{s,\ell}^{(E \to E')} \phi_{\ell}^{k}(E) \phi_{\ell}^{\sharp k}(E') , \quad (38)$$

and discretizing over the spatial variable we have

$$P_{\Sigma_{x,gain}}^{g} = \frac{4\pi}{I\Delta u^{g}} \sum_{\substack{g'=1 \\ g'=1}}^{GMAX} \sum_{\substack{\ell=0 \\ \ell=0}}^{LMAX} \sum_{\substack{g'=1 \\ k=0}}^{\chi} \sum_{\substack{g'=1 \\ k=0}}^{\chi}$$

where IPERT is the number of perturbed spatial intervals and i indicates the spatial interval. If there is no upscattering, and introducing

$$\Psi_{\ell}^{gg'} = 4\pi \sum_{k=0}^{\ell} (2\ell+1) \sum_{i=1}^{\text{IPERT}} V_i \Phi_{\ell}^{kg}(i) \Phi_{\ell}^{kg'}(i) , \qquad (40)$$

we have

$$P_{\Sigma_{x,gain}}^{g} = \frac{1}{I\Delta u^{g}} \begin{array}{c} LMAX & GMAX \\ \Sigma & \Sigma \\ \ell = 0 & g' = g \end{array} \Sigma_{s,\ell}^{g \to g'} \psi_{\ell}^{gg'} \quad .$$

$$(41)$$

The loss term of the sensitivity profile is given by

$$P_{\Sigma_{x,loss}}^{g} = \frac{1}{I\Delta u^{g}} \int_{E_{g}}^{E_{g-1}} dE \int_{V} d\underline{r} \int d\underline{\alpha} \{-\Phi(\underline{r},\underline{\alpha},E)\Sigma_{x,T}(E)\Phi^{\dagger}(\underline{r},\underline{\alpha},E)\} , \quad (42)$$

$$= \frac{1}{I\Delta u^{g}} \int_{e_{g}}^{E_{g}-1} dE \int_{V} d\underline{r} 2 \int_{-1}^{1} d\mu \int_{o}^{\pi} d\phi \left\{-\phi(\mu,\phi,E)\Sigma_{x,T}(E)\phi^{\star}(\mu,\phi,E)\right\},$$
(43)

$$= \frac{-4\pi}{I\Delta u^g} \int_{E_g}^{E_{g-1}} dE \int_{V} d\underline{r} \Sigma_{x,T}(E) \int_{m=1}^{MM} w_m \phi(\mu_m, \phi_m, E) \phi^{\star}(\mu_m, \phi_m) , \quad (44)$$

where
$$\phi_{\rm m} = \tan^{-1}(1 - \mu_{\rm m}^2 - \eta_{\rm m}^2)^{\frac{1}{2}}/\mu_{\rm m}$$
 for $\mu_{\rm m} > 0$, (45)

$$\phi_{\rm m} = \tan^{-1} (1 - \mu_{\rm m}^2 - \eta_{\rm m}^2)^{\frac{1}{2}} / \mu_{\rm m} + \pi \quad \text{for } \mu_{\rm m} < 0 \quad , \tag{46}$$

and MM is the number of angular fluxes per quadrant. Define

so that

$$P_{\Sigma_{\mathbf{x},\text{loss}}}^{\mathbf{g}} = \frac{-4\pi}{I\Delta u^{\mathbf{g}}} \Sigma_{\mathbf{x},T}^{\mathbf{g}} \sum_{i=1}^{\text{IPERT}} V_{i} \sum_{m=1}^{\text{MM}} w_{m} \phi_{m}^{\mathbf{g}}(i) \phi_{m}^{\mathbf{\dot{x}}g}(i) .$$
(48)

Introducing

$$\chi^{g} = 4\pi \sum_{i=1}^{IPERT} \bigvee_{i=1}^{MM} \bigvee_{m=1}^{M} \bigvee_{m=1}^{m} \psi_{m}^{\dagger g}(i) \phi_{m}^{\dagger g}(i) , \qquad (49)$$

we have

$$P_{\Sigma_{x},loss}^{g} = \frac{-1}{I\Delta u^{g}} \Sigma_{x,T}^{g} \chi^{g} .$$
⁽⁵⁰⁾

Note that the gain term was expressed as a function of flux moments, while the loss term was expressed in terms of angular fluxes. When the gain term is expressed as a function of flux moments, a very useful relationship between the Ψ 's and the χ 's will be obtained. For this case, substituting Eqs. (36) and (38) into Eq. (42), the loss term can be expanded as

$$P_{\Sigma_{x,loss}}^{g} = \frac{-2}{I\Delta u^{g}} \int_{E_{g}}^{E_{g-1}} \int_{V} d\underline{r} \Sigma_{x,T} \int_{-1}^{1} d\mu \int_{0}^{\pi} d\phi \sum_{\ell=0}^{\infty} \left\{ (2\ell+1) \sum_{k=0}^{\ell} R_{\ell}^{k} \phi^{k} \right\}$$

$$\sum_{\ell=0}^{\infty} \left\{ (2\ell+1) \sum_{k=0}^{\ell} R_{\ell}^{k} \phi^{*k} \right\} .$$
(51)

Using the orthogonality relations Eq. (34) and defining the multigroup total cross section for group g by

$$\underset{\ell=0}{\overset{\text{LMAX}}{\sum}} \sum_{k=0}^{\ell} \sum_{k=0}^{\chi} \sum_{k=0}^{g} \sum_{k=0}^{kg} \sum_{k=0}^{\ell} \sum_{k=0}^{kg} \sum_{k=0}^{\ell} \sum_{k=0}^{kg} \sum_{k=0}^{\ell} \sum_{k=0}^{kg} \sum_{k=0}^{\ell} \sum$$

we have after discretizing the spatial variable, \underline{r} , and truncating the summation over l,

$$P_{\Sigma_{x,loss}}^{g} = \frac{-4\pi \sum_{i=0}^{g} I}{I\Delta u^{g}} \sum_{\ell=0}^{LMAX} (2\ell+1) \sum_{i=1}^{IPERT} V_{i} \phi_{\ell}^{kg}(i) \phi_{\ell}^{kg}(i) .$$
(53)

Introducing

$$\chi^{g} = \sum_{\ell=0}^{\text{LMAX}} \Psi_{\ell}^{gg} , \qquad (54)$$

the expression for the loss term reduces to Eq. (50) again.

Summary

$$P_{\Sigma_{x}}^{g} = \frac{1}{I \cdot \Delta u^{g}} - \Sigma_{x,T}^{g} \chi^{g} + \frac{\sum_{\ell=0}^{LMAX} \sum_{\ell=0}^{GMAX} \Sigma_{s,\ell}^{g \to g'} \psi_{\ell}^{gg'}}{\xi_{s,\ell}^{g \to g'}}, \qquad (55)$$

where

$$\begin{split} \Sigma_{x,T}^{g} &= \text{total macroscopic cross section for reaction type x,} \\ \Sigma_{s,\ell}^{g \div g'} &= \ell' \text{th Legendre coefficient of the scattering matrix element for energy transfer from group g to group g', as derived from the differential scattering cross section for reaction type x,} \\ \Psi_{\ell}^{gg'} &= 4\pi(2\ell+1) \sum_{\substack{\Sigma \ \Sigma \ V}} \nabla_{i} \Phi_{\ell}^{kg}(i) \Phi_{\ell}^{\star kg'}(i) \qquad (56) \\ &= \text{spatial integral of the product of the spherical harmonics expansions for the regular and adjoint angular fluxes,} \\ \chi^{g} &= 4\pi \sum_{\substack{\Sigma \ V_i \ \Sigma \ m=1}} \Phi_{m}^{g}(i) \Phi_{m}^{\star g}(i) w \qquad (57) \\ &= \text{numerical integral of the product of forward and adjoint angular fluxes over all angles and all spatial intervals described by i=1 . . . , IPERT, \\ &= \sum_{\substack{L \ MAX \ \ell=0}} \Psi_{\ell}^{gg} &. \qquad (58) \end{split}$$

Note that expression (55) is identical with the expression for the cross-section sensitivity profile in a one-dimensional formulation.⁴⁶ The flux moments can be expressed in terms of angular fluxes corresponding to

$$\Phi_{\ell}^{kg} = \int_{-1}^{1} d\mu \int_{0}^{\pi} d\phi R_{\ell}^{k} \Phi^{g}(\underline{\Omega})/2\pi = \sum_{m=1}^{MM} \Phi_{m}^{g'} R_{\ell}^{k}(\mu_{m}, \phi_{m})w_{m} , \qquad (59)$$

and

$$\Phi_{\ell}^{\star kg'} = \int_{-1}^{1} d\mu \int_{0}^{\pi} d\phi R_{\ell}^{k} \Phi^{\star g'}(\underline{\Omega})/2\pi = \sum_{m=1}^{MM} \Phi_{m}^{g'} R_{\ell}^{k}(\mu_{m}, \phi_{m}) w_{m} \quad .$$
 (60)

$$\begin{split} R_{\ell}^{k}(\Omega) &= \text{ spherical harmonics function} \\ V_{i} &= \text{ volume of rotated triangles} \\ \Delta u^{g} &= \text{ lethargy width of energy group g} \\ &= \ln (E^{g}/E^{g+1}), \text{ where } E^{g} \text{ and } E^{g+1} \text{ are upper and lower energy} \\ &= \text{ integral response as calculated from forward fluxes only} \\ &= \sum_{i=1}^{IDET} IGM_{i} V_{i}R_{i}^{g}\phi_{0}^{0g}(i) \\ &= \sum_{i=1}^{\Sigma} \sum_{g=1}^{\Sigma} V_{i}R_{i}^{g}\phi_{0}^{0g}(i) \\ &R_{i} &= \text{ spatially and group-dependent detector response function.} \end{split}$$

2.3 Source and Detector Sensitivity Profiles 46

Source and detector sensitivity profiles indicate how sensitive the

integral response I or I^{\star} is to the energy distribution of the source, or to the detector response R. The integral response I can be calculated from the forward flux, according to Eq. (63), or from the adjuint flux, according to Eq. (64). When the integral response is calculated from the adjoint flux it will be denoted as I^{\star} . Ideally, I will be equal to I^{\star} .

The sensitivity of the integral response to the energy distribution of the detector response function or the source can therefore be expressed by the sensitivity profiles

$$P_{R}^{g} = \int_{V_{d}} d\underline{r} \int_{E_{g}}^{E_{g-1}} dE \int d\underline{\Omega} R(\underline{r}, E) \cdot \underline{\Phi}(\underline{r}, \underline{\Omega}, E) / I \cdot \Delta u^{g}$$
(61)

and

$$P_{Q}^{g} = \int_{V_{g}} d\underline{r} \int_{E_{g}}^{E_{g}-1} dE \int d\underline{\Omega} Q(\underline{r}, \underline{\Omega}, E) \cdot \phi^{\dagger}(\underline{r}, \underline{\Omega}, E) / I^{\dagger} \cdot \Delta u^{g} , \qquad (62)$$

where $R(\underline{r},E)$ is the detector response and $Q(\underline{r},\underline{\Omega},E)$ is the angular source, and V_d and V_s are the volumes of the detector and the source region. I was used in the denumerator of P_R^g and I^{\star} was used in the denominator of P_Q^g for internal consistency. It is obvious that the integral source and detector sensitivities, S_Q and S_R , will be equal to one. It is possible to derive an expression similar to Eq. (61) for the sensitivity of the integral response to the angular distribution of the source. The derivation of explicit expressions for P_R^g and P_Q^g is straightforward. The detector sensitivity profile as a function of the scalar fluxes becomes

$$P_{R}^{g} = \sum_{i=1}^{IDET} V_{i} \cdot R_{i}^{g} \cdot \Phi_{0}^{0g}(i) / I \cdot \Delta u^{g} , \qquad (63)$$

where the $\Phi_0^{0g}(i)$ are the scalar fluxes for group g at interval i, IDET is the number of detector intervals, and R_i^g is the detector response at interval i for group g.

For the source sensitivity profile in case of an isotropic source Eq. (62) transforms into

$$P_{Q}^{g} = \sum_{i=1}^{ISRS} V_{i} Q_{i}^{g} \Phi_{0}^{0}(i) / I^{*} \Delta u^{g} , \qquad (64)$$

where Q_i^g is the voluminar source for group g at source interval i. In the case of an anisotropic source we defined $Q^g(\underline{r},\underline{\Omega})$ by

$$Q^{g}(\underline{r},\underline{\Omega}).\phi^{\ddagger g}(\underline{r},\underline{\Omega}) = \int_{E_{g}}^{E_{g-1}} dE \ Q(\underline{r},\underline{\Omega},E).\phi^{\ddagger}(\underline{r},\underline{\Omega},E) , \qquad (65)$$

and expand the angular source according to

$$Q^{g}(\underline{r},\underline{\Omega}) = Q^{g}(\underline{r},\mu,\Phi) = \sum_{\ell=0}^{IQAN} (2\ell+1) \sum_{k=0}^{\ell} R^{k}_{\ell}(\mu,\Phi) \cdot Q^{kg}_{\ell}(\underline{r})/2\pi , \quad (66)$$

where IQAN is the order of anisotropy of the source.

Substituting Eqs. (65) and (66) in Eq. (63), discretizing the spatial variable and using Eq. (36), the expression for the source sensitivity profile becomes

$$P_{Q}^{g} = 2. \sum_{i=1}^{ISRS} V_{i} \sum_{\ell=0}^{IQAN} (2\ell+1) \sum_{k=0}^{\ell} Q_{\ell}^{gk}(i) \phi_{\ell}^{*gk}(i) / I^{*} \Delta u^{g}$$

As in Eq. (61) we can also define an angular source sensitivity function. The angular source sensitivity function indicates how sensitive the integral response I^{*} is to the angular distribution of the source, or

$$F_{Q}^{\Omega} = \frac{1}{I} \int_{V_{s}} d\underline{r} \int_{0}^{\infty} dE \ Q(\underline{r}, \underline{\Omega}, E) \cdot \Phi^{\dagger}(\underline{r}, \underline{\Omega}, E) / I^{\dagger}$$
(68)

2.4 Sensitivity Profiles for the Secondary Energy Distribution and the Secondary Angular Distribution

The theory of the secondary energy distribution (SED) and the secondary angular distribution (SAD) sensitivity analysis was originated by Gerst1.⁴³⁻⁴⁶ Physically the only difference between a secondary energy distribution and a cross-section sensitivity profile is the way in which the integration over the energy variable is carried out. The "hot-cold" and the "forward-backward" concepts lead to a simple formulation of secondary sensitivity theory and can easily be incorporated in an uncertainty analysis. Even when both those concepts are a rather coarse approximation they have the advantage that they are simple and can be physically understood.

A more rigorous formulation might be possible, but its simple physical interpretation would be lost.⁶³ The primary restriction on the application of secondary energy distribution and secondary angular distribution sensitivity profiles is the lack of cross-section uncertainty information in the proper format.

2.4.1 Introduction

The expression for the sensitivity profile for the differential scattering cross section is part of the gain term of the cross-section sensitivity profile and takes the form

$$P_{\sum_{\mathbf{x}}}(\underline{\Omega} \rightarrow \underline{\Omega}', \mathbf{E} \rightarrow \mathbf{E}') = \frac{1}{\Delta u^{g} \cdot \mathbf{I}} \int d\underline{\mathbf{r}} \int d\underline{\Omega} \int_{\mathbf{E}_{g}}^{\mathbf{E}_{g}-1} d\mathbf{E} \int_{\mathbf{0}}^{\infty} d\mathbf{E}' \int d\underline{\Omega}'$$

$$\times R_{\sum_{\mathbf{x},gain}}(\underline{\mathbf{r}}, \underline{\Omega} \rightarrow \underline{\Omega}', \mathbf{E} \rightarrow \mathbf{E}') , \qquad (69)$$

where $R_{\sum_{x,gain}}(\underline{r},\underline{\Omega},\underline{\Omega},\underline{E},E)$ is a shorthand notation for

$$R_{\sum_{x,gain}}(\underline{r},\underline{\Omega},\underline{\Omega}',E\rightarrow E') = \Phi(\underline{r},\underline{\Omega},E)\Sigma_{x,s}(\underline{r},\underline{\Omega},\underline{\Omega}',E\rightarrow E')\Phi(\underline{r},\underline{\Omega}',E')$$
(70)

and similarly,

$${}^{R}\Sigma_{x,gain}(\underline{r},\underline{\Omega}'\rightarrow\underline{\Omega},E'\rightarrow E) = \Phi(\underline{r},\underline{\Omega},E)\Sigma_{x,s}(\underline{r},\underline{\Omega}'\rightarrow\underline{\Omega},E\rightarrow E)\Phi^{\tilde{r}}(\underline{r},\underline{\Omega},E) \quad . \tag{71}$$

Equation (70) gives the contribution to the integral detector response, I, from the particles born at position <u>r</u> with energy E', traveling in direction Ω ', since

$$I = \langle \Phi, L^{\dagger} \Phi^{\dagger} \rangle = \langle \Phi^{\dagger}, L \Phi \rangle$$
 (72)

Similarly, $R_{\sum_{x,gain}}(\underline{r},\underline{\Omega},\underline{\Omega},\underline{\Gamma},E'\rightarrow E)$ gives the contribution to the integral detector response from the particles born at position \underline{r} , with energy E, traveling in direction Ω .

As it turns out, up to this point there is no difference in the physical interpretation of Eqs. (70) and (71). The way the integrations

are carried out will distinguish between the differential scattering cross-section sensitivity profile and the secondary energy distribution and secondary angular distribution sensitivity profile.

2.4.2 Further theoretical development

In this section we will elaborate on the physics behind the derivation of SEDs and SADs. Consider

$$F_{\sum_{x,s}}(E,E') = \frac{1}{I} \int d\underline{r} \int d\underline{\Omega} \int d\underline{\Omega}' R_{\sum_{x,gain}}(\underline{r},\underline{\Omega},\underline{\Omega}',E,E') .$$
(73)

In this expression $F_{\sum_{x,s}}$ represents the fractional change in the integral response per unit fractional change in the differential scattering cross section $\sum_{x,s} (E \rightarrow E')$; i.e., it is the fractional change in the integral response when the number of particles that scatter from E into E' is increased by one percent. Obviously this will always be a positive effect and will therefore be included in the gain term.

Similar to Eq. (73),

$$\widetilde{P}_{\Sigma_{x,s}}^{g} = \frac{1}{I} \int_{E_{g}}^{E_{g-1}} dE \int_{0}^{\infty} dE' \int d\underline{\Omega} \int d\underline{\Omega}' R_{\Sigma_{x,gain}}(\underline{r},\underline{\Omega},\underline{\Omega}',E,E')$$
(74)

represents the fractional change in the integral response when the number of particles that scatter from group g is increased by one percent. The tilda in Eq. (74) is introduced to distinguish from a lethargy normalized sensitivity profile.

In the adjoint formulation the equivalent of Eq. (73) will be

$$F_{\sum_{x,s}}(E',E) = F_{SED}(E',E) = \frac{1}{I} \int d\underline{r} \int d\underline{\Omega} \int d\underline{\Omega}' R_{\sum_{x,gain}}(\underline{r},\underline{\Omega}' \rightarrow \underline{\Omega},E' \rightarrow E) ,$$
(75)

which represents the fractional change in the integral response per unit fractional change in differential scattering cross section $\Sigma_{x,s}(E' \rightarrow E)$, i.e., it is the fractional change in the integral response when the number of primary particles that scatter from E' to E is increased by one percent, or for that matter that the number of secondary particles that were scattered from E into E' were increased by one percent. Again, this will always have a positive effect and will therefore constitute a gain term in the sensitivity profile.

Define

$$\tilde{P}_{SED}^{g} = \frac{1}{I} \int_{E_{g}}^{E_{g-1}} dE \int_{0}^{\infty} dE' \int d\underline{\Omega} \int d\underline{\Omega}' R_{\sum_{x,gain}}(\underline{r} \cdot \underline{\Omega}' \rightarrow \underline{\Omega}, E' \rightarrow E) \quad .$$
(76)

While there is no difference in the physical meaning of Eqs. (73) and (75), the formulations (74) and (76) are different. Equation (74)

represents the fractional change in the integral response when the number of secondary particles that were scattered into group g have been increased by one percent.

It is clear from these examples that, depending on the way the integrations are done, several different sensitivity profiles can be constructed. In order to study the secondary angular distribution, we can introduce

$$F_{\sum_{x,gain}}(\underline{\Omega},E') = F_{SAD}(\underline{\Omega},E') = \frac{1}{I} \int d\underline{r} \int_{0}^{\infty} dE \int d\underline{\Omega}' R_{\sum_{x,gain}}(\underline{r},\underline{\Omega}' \rightarrow \underline{\Omega},E' \rightarrow E)$$
(77)

This expression gives the fractional change in the integral response when the number of secondary particles scattered from initial energy E' into final direction $\underline{\Omega}$ is increased by one percent. It will therefore be clear that

$$\tilde{P}_{SAD}(\underline{\Omega}) = \int dE' F_{SAD}(\underline{\Omega}, E')$$
(78)

is the fractional change in the response function when the number of secondary particles which were scattered into direction $\underline{\Omega}$ was increased by one percent.

2.4.3 Secondary energy and secondary angular distribution sensitivity profiles

A double secondary energy distribution (SED) sensitivity profile is defined by

$$P_{SED}^{g'g} = \frac{1}{I\Delta u^{g}\Delta u^{g'}} \int_{E_{g}}^{E_{g-1}} dE \int_{g'}^{E_{g'-1}} dE' \int d\underline{r} \int d\underline{\Omega} \int d\underline{\Omega}' R_{\sum_{x,gain}}(\underline{r},\underline{\Omega}' \rightarrow \underline{\Omega},E' \rightarrow E) ,$$
(79)

The energy integrated SED sensitivity profile becomes

$$P_{\text{SED}}^{g} = \frac{1}{I\Delta u^{g}} \int_{0}^{\infty} dE' \int_{E_{g}}^{E_{g-1}} dE \int d\underline{r} \int d\underline{\Omega}' R_{\sum_{x,gain}}(\underline{r},\underline{\Omega}' \rightarrow \underline{\Omega},E' \rightarrow E) . \quad (80)$$

The differential sensitivity profile for the angular distribution of secondary particles scattered from initial energy E' is

$$P_{SAD}^{g'}(\underline{\Omega}) = \frac{1}{I\Delta u^g} \int_{e_g}^{E_{g'-1}} dE' \int_{0}^{\infty} dE \int d\underline{r} \int d\underline{\Omega}' R_{\sum_{x,gain}}(\underline{r},\underline{\Omega}' \rightarrow \underline{\Omega}, E \rightarrow E') \quad (82)$$

An energy integrated SED sensitivity profile can be defined by

$$P_{SAD}(\underline{\Omega}) = \frac{1}{I} \int_{0}^{\infty} dE' \int_{0}^{\infty} dE \int d\underline{r} \int d\underline{\Omega}' R_{\sum_{s,gain}}(\underline{r},\underline{\Omega}' \rightarrow \underline{\Omega}, E \rightarrow E') \quad . \tag{82}$$

2.4.4 Integral sensitivities for SEDs and SADs

In order to make the sensitivity and uncertainty analysis for secondary energy distributions and secondary angular distributions less tedious, Gerstl introduced the concepts of the "hold-cold" SED and the "forward-backward" SAD integral sensitivity:

$$s_{SED}^{g'} = \int_{HOT} dE \tilde{P}_{SED}^{g'}(E) - \int_{COLD} dE \tilde{P}_{SAD}^{g'}(E) ,$$
 (83)

and

$$S_{SAD} = \int_{forward} d\Omega P_{SAD}(\Omega) - \int_{backward} d\Omega P_{SAD}(\Omega) .$$
(84)
angles
(µ>0) (µ<0)

The forward-backward SAD integral sensitivity can be interpreted as the fractional change in the integral response when the number of secondaries which were scattered forward is increased by one percent, while the number of secondaries that were scattered backwards (μ <0) is decreased by one percent. The integral SAD sensitivity is a positive number which is labeled "forward" or "backward" depending whether the first or the second term in Eq. (84) is the larger one. Physically, that positive number indicates how much more sensitive the response function is to forward scattered particles than to backward scattered particles, or vice versa.

For the hot-cold integral SED sensitivity, the concept of the <u>median energy</u> has to be introduced. In the multigroup formulation, the median energy defines the energy boundary which roughly divides the cross-section profile into two equal parts. The median energy and the integral SED sensitivity are illustrated in Fig. 3.⁴³ Note that the median energy g' is a function of the primary energy group g'. For that reason also the integral SED sensitivity will depend on g'.

The hot-cold integral SED sensitivity expresses the fractional change in integral response when the number of secondaries which scatter in the "hot" part of the secondary energy distribution is increased by one percent while the number of secondaries scattered into the "cold" part is decreased by one percent. The integral hot-cold SED sensitivity is a positive number, labeled "hot" or "cold" depending on which term dominates in Eq. (83). That number indicates how much more sensitive the integral response is to particles scattered into the hot part of the secondary energy distribution than to particles scattered into the cold part, or vice versa.



Figure 3. Definition of median energy and integral SED sensitivity 43

2.4.5 Explicit expressions for integral SED sensitivity profiles in a two-dimensional geometry representation

The expression for the double SED sensitivity profile, Eq. (79), is similar to the gain term of the cross-section sensitivity profile, Eq. (24). By comparing Eq. (79) with Eq. (24) and using Eq. (41), the explicit expression for the double SED sensitivity profile becomes

$$P_{SED}^{g',g} = \frac{1}{I\Delta u^{g}\Delta u^{g'}} \sum_{\ell=0}^{LMAX} \Sigma_{s,\ell}^{g' \rightarrow g} \Psi_{\ell}^{g'g} , \qquad (85)$$

From Eqs. (85) and (80), it follows that the energy integrated SED sensitivity profile for the case of no upscattering can be represented by

$$P_{\text{SED}}^{g} = \frac{1}{I\Delta u^{g}} \sum_{\substack{g'=1 \ \ell=0}}^{g} \sum_{\substack{g'=1 \ \ell=0}}^{\text{LMAX}} \sum_{\substack{g' \neq g' \neq g \\ g' \neq \ell}}^{g' \neq g' \neq g' g} .$$
(86)

Using the definition for the integral SED sensitivity (83), it becomes clear that

$$S_{SED}^{g'} = \sum_{g=g'}^{\Sigma} \Delta u^{g} \cdot P_{SED}^{g} - \sum_{g=g_{m}(g')+1}^{GMAX} \Delta u^{g} \cdot P_{SED}^{g} , \qquad (87)$$

where $g_m(g')$ is defined in Fig. 1.

2.6 Design Sensitivity Analysis

Design sensitivity analysis provides a method to estimate changes in integral response for a slightly altered design. The results are exact up to the second order with respect to the corresponding flux changes, but only exact up to the first order with respect to design changes. The theory presented in this section is applicable only when the design changes can be expressed in terms of macroscopic crosssection changes. Methods based on generalized perturbation theory have been applied to design sensitivity analysis.^{14,37}

The integral response for the perturbed system can be expressed by Eq. (88) for the adjoint difference formulation, 35

$$I_{AD} = \langle R, \Phi \rangle - \langle \Phi^{\dagger}, \Delta L \Phi \rangle = I - \delta I_{AD} , \qquad (88)$$

and by Eq. (89) in the forward difference formulation

$$I_{FD} = \langle Q, I^{*} \rangle - \langle \Phi, \Delta L^{*} \Phi^{*} \rangle = I - \delta I_{FD} \quad .$$
(89)

Proceeding in a manner similar to the derivation of the crosssection sensitivity profile, the second-order term in the right hand side of Eqs. (88) and (89) can be written as

$$\delta I_{AD} = \int_{0}^{\infty} dE \int_{V_{d}} d\underline{r} \int d\underline{\Omega} \{ \Phi(\underline{r}, \underline{\Omega}, E) \delta \Sigma_{x, T}(\underline{r}, E) \Phi^{\dagger}(\underline{r}, \underline{\Omega}, E)$$

+
$$\int_{0}^{\infty} dE' \int d\underline{\Omega}' \Phi(\underline{r}, \underline{\Omega}', E') \delta \Sigma_{x, s}(\underline{r}, \underline{\Omega}' \rightarrow \underline{\Omega}, E' \rightarrow E) \Phi^{\dagger}(\underline{r}, \underline{\Omega}, E) \} , \qquad (90)$$

and

$$\delta I_{FD} = \int_{0}^{\infty} dE \int_{V_{s}} d\underline{r} \int d\underline{\Omega} \{ \Phi(\underline{r}, \underline{\Omega}, E) \delta \Sigma_{x, T}(\underline{r}, E) \Phi^{\dagger}(\underline{r}, \underline{\Omega}, E)$$

+
$$\int_{0}^{\infty} dE' \int d\underline{\Omega}' \Phi(\underline{r}, \underline{\Omega}, E) \delta \Sigma_{x, s}(\underline{r}, \underline{\Omega} \cdot \underline{\Omega}', E \cdot E') \Phi^{\dagger}(\underline{r}, \underline{\Omega}', E') \quad . \tag{91}$$

In the above expressions we used

$$\delta \Sigma_{\mathbf{x},\mathbf{T}} = \Sigma_{\mathbf{x},\mathbf{T}} - \bar{\Sigma}_{\mathbf{x},\mathbf{T}} , \qquad (92)$$

and

$$\delta \Sigma_{\mathbf{x},\mathbf{s}} = \Sigma_{\mathbf{x},\mathbf{s}} - \bar{\Sigma}_{\mathbf{x},\mathbf{s}} , \qquad (93)$$

where Σ refers to a perturbed cross section and $\bar{\Sigma}$ to a reference cross section.

A design sensitivity coefficient X can be defined as the ratio of the integral response for the altered design over the integral response for the original model. Depending whether the forward or the adjoint difference method are used, the design sensitivity coefficient equals

$$X_{AD} = I_{AD}/I = 1 - \delta I_{AD}/I$$
, (94)

or

$$X_{FD} = I_{FD} / I^* = 1 - \delta I_{FD} / I^*$$
 (95)

Note that respectively, I and I^{*} were used in the denominator of Eqs. (94) and (95) for internal consistency. Numerically δI_{AD} and δI_{FD} are identical; I and I^{*}, however, can be different. Gerstl and Stacey³⁵ indicate that the adjoint formulation is more accurate for perturbations closer to the detector, while the forward difference method gives better results for perturbations closer to the source. If both reference fluxes ϕ and ϕ^* are completely converged, Eqs. (94) and (95) will give identical results.

Explicit expressions for Eqs. (94) and (95) can be formulated. The procedure for the evaluations of δI_{AD} and δI_{FD} is similar to the derivation of the cross-section sensitivity profile and leads to the equations

$$\delta I_{AD} = \sum_{g=1}^{IGM} \left\{ \delta \Sigma_{x,T}^{g} \chi^{g} - \sum_{\ell=0}^{LMAX} \sum_{g'=1}^{g} \delta \Sigma_{s,\ell}^{g' \to g} \psi_{s,\ell}^{g' \to g} \right\} , \qquad (96)$$

$$\delta I_{FD} = \sum_{g=1}^{IGM} \left\{ \delta \Sigma_{x,T}^{g} \chi^{g} - \sum_{\ell=0}^{LMAX} \sum_{g'=g}^{GMAX} \delta \Sigma_{s,\ell}^{g \to g'} \psi_{\ell}^{gg'} \right\} .$$
(97)

and

3. APPLICATION OF SENSITIVITY THEORY TO UNCERTAINTY ANALYSIS

Sensitivity theory can be used to do an uncertainty analysis by introducing the concepts of cross-section covariance matrices and fractional uncertainties for SEDs. In this chapter we will explain how sensitivity profiles can be used in order to calculate the uncertainty of a reaction rate due to the uncertainties in the cross sections.

3.1 Definitions

Let I represent a design parameter depending on a multigroup crosssection set $\{\Sigma_i\}$, so that

$$I = I(\Sigma_{i}) , \qquad (98)$$

where the index i can reflect a group, a partial cross section or a material.

The <u>variance</u> of I is defined as the expected value of the square of the difference between the actual value of I and the expected value of I, or

$$Var(I) \equiv E\{(\delta I)^2\} = E\{(I - E\{I\})^2\} .$$
(99)

The standard deviation of I is the square root of the variance,

$$\Delta I = \left[Var(I) \right]^{\frac{1}{2}} . \tag{100}$$

The covariance of a and b is defined as

$$Cov(a,b) \equiv E\{\delta a \cdot \delta b\} \equiv \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} da.db.(a - E\{a\}).(b - E\{b\}).f(a,b),$$
(101)

where f(a,b) is a joint probability density function. A nonzero covariance between the quantities a and b indicates a mutual dependence on another quantity. Obviously we have

$$Cov(a,a) = Var(a) , \qquad (102)$$

since f(a,a) = 1.

A relative covariance element is defined by

$$R(a,b) \equiv Cov(a,b)/a.b \quad . \tag{103}$$

3.2 Cross-Section Covariance Matrices

During the experimental evaluation of cross-section data, statistical errors arise from the fact that two similar experiments never agree completely. Also a systematic error reflects the fact that no equipment and no evaluation procedure is perfect, and that - among other factors - reference standards are used.

Cross-section covariance data describe the uncertainties in the multigroup cross sections and the correlation between those uncertainties. A nonzero nondiagonal covariance matrix element indicates that there was a common reason why an uncertainty in two different (e.g., partial cross sections or energy range) cross section was introduced. The evaluation procedure for covariance data is tedious and requires a sophisticated statistical analysis.^{2,30,31}

Multigroup cross-section covariance data are ordered in covariance matrices. Such a covariance matrix contains GMAX rows and GMAX columns, where GMAX is the number of energy groups. A covariance matrix can contain covariance data of a particular partial cross section with itself over an energy range , with a different cross section for the same element, or with a partial cross section of a different element.

It has become a common practice to include formatted uncertainty data in the ENDF/B data files. Even though the uncertainty files are

still missing for many materials in ENDF/B-V, extensive work is underway. Based on these uncertainty data, covariance libraries can be constructed. 32,33 A 30-group covariance library based on ENDF/B-V which contains most of the elements commonly used in reactor shielding has been constructed by Muir and LaBauve. 33 The covariance data in this library were processed into a 30-group format by using the NJOY code. 64,65 In this particular library, called COVFILS, the multigroup cross sections and the relative covariance matrices for 1 H, 10 B, C, 16 O, Cr, Fe, Ni, Cu, and Pb are included. Another covariance library was set up by Drischler and Weisbin. 32

3.3 Application of Cross-Section Sensitivity Profiles and Cross Section Covariance Matrices to Predict Uncertainties

Using first-order perturbation theory, the change in the integral response I, δI , as a consequence of small changes in Σ_i can be approximated by

$$\delta I \cong \sum_{i} \frac{\partial I}{\partial \Sigma_{i}} \delta \Sigma_{i} \quad . \tag{104}$$

We further have

$$Var(I) = E\{\delta I^{2}\} = E\{\sum_{i,j} \frac{\partial I}{\partial \Sigma_{i}} \frac{\partial I}{\partial \Sigma_{j}} \delta \Sigma_{i} \delta \Sigma_{j}\}, \qquad (105)$$

$$Var(I) = \sum_{i,j} \frac{\partial I}{\partial \Sigma_i} \frac{\partial I}{\partial \Sigma_j} Cov(\Sigma_i, \Sigma_j) . \qquad (106)$$

From Eqs. (100) and (106) it now becomes obvious that

$$\begin{bmatrix} \Delta I \\ \overline{I} \end{bmatrix}_{xs}^{2} = \sum_{i,j} \underbrace{P_{\Sigma_{i}} P_{\Sigma_{j}}}_{I} \underbrace{\frac{Cov(\Sigma_{i}, \Sigma_{j})}{\Sigma_{i}\Sigma_{j}}}_{I I I}, \qquad (107)$$

where $P_{\sum_{i} \sum_{j}}$ and $P_{\sum_{j}}$ are sensitivity profiles, and the subscript xs refers to reactor cross sections.

The concept of covariance data and sensitivity profiles leads to a simple way to evaluate the error in I. The first part in the summation requires sensitivity profiles and is highly problem dependent. The second part requires cross-section uncertainty information and is problem independent.

When trying to apply the theory presented here, very often covariance data will be missing for certain materials. One way of going around this problem would be to substitute the covariance file of the missing material by a covariance file for another material for which the cross sections are less well known.⁴⁵ Other methods to eliminate this problem would be to make very conservative estimates.^{16,17}

The most conservative method would be to assume that the error in the cross section is the same for all groups and equal to the largest error for any one group. In that case it can be shown that 16,17

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or

$$\begin{bmatrix} \Delta I \\ \overline{I} \end{bmatrix}_{\max} \leq \frac{\Delta \Sigma_{\overline{I}}}{\Sigma_{\overline{I}}} \quad \begin{array}{c} \Sigma & |P_{\Sigma_{\overline{I}}}| \\ i & i \end{array}$$
(108)

3.4 Secondary Energy Distribution Uncertainty Analysis

For evaluating uncertainties in the integral response due to uncertainties in the secondary energy distribution we will follow Gerstl's approach^{44,46} and introduce the <u>spectral shape uncertainty parameter</u> for the hot-cold concept.

When the total number of secondaries scattered from group g' are held constant, then necessarily

$$\frac{\delta \Sigma_{\text{HOT}}}{\Sigma_{\text{HOT}}} = -\frac{\delta \Sigma_{\text{COLD}}}{\Sigma_{\text{COLD}}} \equiv f_{g}, \quad .$$
(109)

Therefore f_g , quantifies the uncertainty in the shape of the SEDs and is called the spectral shape uncertainty parameter (Fig. 4)⁴⁴.

It now becomes possible to express the relative change in integral response due to the uncertainty in the secondary energy distribution in a form similar to Eq. (107):

$$\begin{bmatrix} \delta I \\ \overline{I} \end{bmatrix}_{SED} = \sum_{g',g} P_{SED}^{g'g} \frac{\delta \Sigma_{g' \to g}}{\Sigma_{g' \to g}} .$$
(110)



Figure 4. Interpretation of the integral SED uncertainty as spectrum shape perturbations and definition of the spectral shape uncertainty parameter "f" (ref. 44)
Substituting Eqs. (87) and (109) in Eq. (110), it follows that

$$\left[\frac{\delta I}{I}\right]_{SED} = \sum_{g'} S_{SED}^{g'} f_{g'} .$$
(111)

Denote $f_{g'}$ by f_{j} , where the index j refers to a particular nuclear reaction, e.g., (n,2n), at specific incident energy g', and let f_{i} represent some different reaction/primary energy combination. Then the uncertainty in integral response corresponding to correlated uncertainties of all SEDs for a specific isotope is

$$\left[\frac{\Delta I}{I}\right]_{SED}^{2} = \frac{Var(I)}{I^{2}} = E\left\{\frac{(\delta I)^{2}}{I^{2}}\right\} = E\left\{\sum_{i,j} s_{SED}^{i} s_{SED}^{j} f_{i} f_{j}\right\}$$
(112)

or

$$\left[\frac{\Delta I}{I}\right]_{SED}^{2} = \sum_{i,j} S_{SED}^{i} S_{SED}^{j} Cov(f_{i},f_{j}) .$$
(113)

If the spectral shape uncertainty parameters for a specific particle interaction, identified by the subscript ℓ , are assumed to be fully correlated, it can be shown that⁶⁷

$$Cov(f_{i},f_{j})_{cor(+1)} = [Cov(f_{i},f_{i})]^{\frac{1}{2}} \cdot [Cov(f_{j},f_{j})]^{\frac{1}{2}}, \qquad (114)$$

so that

$$\left[\frac{\Delta I}{I}\right]_{\ell} = \left| \sum_{g'} S_{SED}^{\ell,g'} [Cov(f_{\ell g'}, f_{\ell g'})]^{\frac{1}{2}} \right|$$
(115)

or,

$$\begin{bmatrix} \Delta I \\ \overline{I} \end{bmatrix}_{\ell} = \sum_{g'} |S_{SED}^{\ell,g'}| [Var(f_{\ell g'})]^{\frac{1}{2}} .$$
(116)

If N independent measurements of the same SED are available, the values for $Var(f_{lg'})$ can easily be evaluated. For each cross-section evaluation, weights, w_n , are assigned, then

$$f_{g}^{n} = \frac{\sigma_{HOT}^{n} - \sigma_{COLD}^{n}}{E\{\sigma\}} , \quad \text{for } n = 1, 2...N \qquad (117)$$

with

$$E\{f_{g}^{n},\} = \sum_{n=1}^{N} w_{n}f_{g}^{n}, = 0 .$$
 (118)

The variance of fg, will be

$$Var(f_{g'}) = E\{f_{g'}^2\} = \sum_{n=1}^{N} w_n \frac{(\sigma_{HOT}^2 - \sigma_{COLD}^2)}{[E\{\sigma\}]^2}$$
(119)

 $Var(f_{g'})$ is called the <u>fractional uncertainty for the secondary energy</u> <u>distribution</u> and is identified by the symbol F. A short program which evaluates the values of F has been written by Muir;⁶⁶ the results for the 30-group neutron structure⁴⁵ is shown in Table II.

TABLE II

MEDIAN ENERGIES (E', IN MEV) AND FRACTIONAL UNCERTAINTIES (F) FOR SECONDARY ENERGY DISTRIBUTIONS AT INCIDENT NEUTRON ENERGIES E₀

(Ref. 45)

	¹² c		¹⁶ 0		Cr		Fe		Ni		Cu		W	
E _o	E'm	F	E'm	F	E'm	F	Ē'	F	E' m	F	E'm	F	ET m	F
16.0	14.71	0.071	14.62	0.088	3.27	0.17	4.49	0.11	14.95	0.13	3.42	0.11	1.86	0.12
14.25	13.00	0.059	13.33	0.072	8.65	0.15	5.99	0.10	13.97	0.11	3.51	0.10	2.17	0.10
12.75	11.71	0.054	11.93	0.062	11.42	0.13	11.17	0.10	12.67	0.11	4.30	0.10	1.91	0.10
11.00	9.77	0.060	9.82	0.057	10.48	0.11	10.57	0.09	10.91	1.10	10.42	0.09	1.57	0.09
8.90	7.35	0.048	7.90	0.050	8.79	0.09	8.77	0.08	8.85	0.09	8.81	0.08	1.24	0.08
6.93	5.96	0.035	6.04	0.030	6.83	0.08	6.86	0.07	6.88	0.08	6.86	0.07	6.66	0.07
4,88	4.46	0.010	4.57	0.010	4.81	0.07	4.81	0.07	4.83	0.07	4.82	0.07	4.83	0.07
3.27	2.63	0.010	3.09	0.010	3.21	0.06	3.21	0.06	3.24	0.06	3.22	0.06	3.25	0.06
2.55	2.16	0.010	2.31	0.010	2.48	0.05	2.49	0.06	2.49	0.05	2.50	0.06	2.51	0.06
1.99	1.73	0.005	1.79	0.010	1.93	0.04	1.93	0.06	1.94	0.04	1.94	0.06	1.96	0.05
1.55	1.34	0.005	1.35	0.010	1.50	0.03	1.51	0.05	1.50	0.03	1.51	0.05	1.51	0.05
1.09	0.95	0.005	0.94	0.010	1.05	0.02	1.06	0.03	1.06	0.02	1.06	0.03	1.06	0.05
0.66	0.57	0.005	0.60	0.010	0.64	0.02	0.63	0.02			0.64	0.02	0.66	0.04
0.40	0.35	0.005	0.34	0.010			0.39	0.02			0.39	0.02	0.38	0.03
0.24	0.21	0.005	0.22	0.010							0.24	0.02	0.22	0.02
0.13	0.12	0.005	0.12	0.010							0.12	0.02	0.12	0.01

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3.5 Overall Response Uncertainty

The overall response uncertainty will be of the form

$$\begin{bmatrix} \Delta I \\ \overline{I} \end{bmatrix} = \sqrt{\begin{bmatrix} \Delta I \\ \overline{I} \end{bmatrix}_{SED}^{2} + \begin{bmatrix} \Delta I \\ \overline{I} \end{bmatrix}_{XS}^{2}}$$
(120)

where

$$\left[\frac{\Delta I}{I}\right]_{SED}^{2} = \sum_{i} \left[\frac{\Delta I}{I}\right]_{SED,i}^{2}$$
(121)

and

$$\left[\frac{\Delta I}{I}\right]_{XS}^{2} = \sum_{i,k} \left[\frac{\Delta I}{I}\right]_{XS,i,k}^{2} .$$
(122)

The index i reflects the uncertainties in the various materials. It was assumed that the effects from SED uncertainties for all possible reactions which generate secondaries are uncorrelated. It is also assumed that the uncertainties due to the SEDs are uncorrelated with other uncertainties due to reaction cross sections (XS), and that the uncertainties between the reaction cross sections themselves are uncorrelated.

Remarks

- To be absolutely correct, a term reflecting the uncertainty in the secondary angular distribution should be included. Due to the difficulty in generating uncertainty data from ENDF/B-V in the proper format, we do not include that term.
- 2. In order to evaluate the sensitivity profiles, we should keep in mind that the form of the sensitivity profile will depend on the particular reaction cross section for which a response is desired (Table I).

4. SENSIT-2D: A TWO-DIMENSIONAL CROSS-SECTION AND DESIGN SENSITIVITY AND UNCERTAINTY ANALYSIS CODE

4.1 Introduction

The theory explained in the previous chapters has been incorporated in a two-dimensional cross-section and design sensitivity and uncertainty analysis code, SENSIT-2D. This code is written for a CDC-7600 machine and is accessible via the NMFECC-network (National Magnetic <u>Fusion Energy Computer Center</u>) at Livermore. SENSIT-2D has the capability to perform a standard cross-section and a vector cross-section sensitivity and uncertainty analysis, a secondary energy distribution sensitivity and uncertainty analysis, a design sensitivity analysis and an integral response (e.g., dose rate) sensitivity and uncertainty analysis. As a special feature in the SENSIT-2D code, the loss term of the sensitivity profile can be evaluated based on angular fluxes and/or flux moments.

SENSIT-2D is developed with the purpose of interacting with the TRIDENT-CTR⁶ code, a two-dimensional discrete-ordinates code with triangular meshes and an r-z geometry capability, tailored to the needs of the fusion community. Angular fluxes generated by other 2-D codes, such as DOT, TWODANT, TRIDENT, etc., cannot be accepted by SENSIT-2D due to the different format. The unique features of TRIDENT-CTR (group dependent quadrature sets, r-z geometry description, triangular meshes) are reflected in SENSIT-2D. Coupled neutron/gamma-ray studies can be performed. In contrast with TRIDENT-CTR however, SENSIT-2D is restricted to the use of equal weight (EQ_n) quadrature sets, ⁶⁸ symmetrical with respect to the four quadrants. Upscattering is not allowed.

Many subroutines used in SENSIT-2D are taken from SENSIT⁴⁶ or TRIDENT-CTR. SENSIT-2D is similar in its structure to SENSIT, but is an entirely different code. Unlike SENSIT, SENSIT-2D does not use the BPOINTR⁶⁹ package for dynamical data storage allocation, but rather uses a sophisticated pointer scheme in order to allow variably dimensioned arrays. As soon as an array is not used any more, its memory space becomes immediately available for other data. SENSIT-2D does not include a source sensitivity analysis capability and cannot calculate integral responses based on the adjoint formulation. This has the disadvantage that no check for internal consistency can be made. Therefore, other ways have to be found in order to determine whether the fluxes are fully converged. One way for doing so would be to calculate the integral response based on the adjoint formulation while performing

the adjoint TRIDENT-CTR or the adjoint TRDSEN run, and compare with the integral response based on the forward calculation.

SENSIT-2D requires input files which contain the angular fluxes at the triangle midpoints multipled by the corresponding volumes, and the adjoint angular fluxes at the triangle midpoints. A modified version of TRIDENT-CTR, TRDSEN, was written by T. J. Seed⁷⁰ to generate these flux files. A summary of these modifications was provided by T. J. Seed and is included as Appendix B. After a TRIDENT-CTR run, the TRDSEN code will use the dump files generated by TRIDENT-CTR, go through an extra iteration, and write out the angular fluxes in a form compatible with SENSIT-2D. Both SENSIT-2D and TRDSEN use little computing time compared with the time required by TRIDENT-CTR.

The features of SENSIT-2D are summarized in Table III. The SENSIT-2D source code is generously provided with comment cards and is included as Appendix A.

4.2 Computational Outline of a Sensitivity Study

A flow chart (Fig. 5) illustrates the outline for a two-dimensional sensitivity and uncertainty analysis. From this figure it becomes immediately apparent that a sensitivity analysis requires elaborate data management. The data flow can be divided into three major parts: a cross-section preparation module, in which the cross sections required by TRIDENT-CTR and SENSIT-2D are prepared, a TRIDENT-CTR/TRDSEN block,

TABLE III: SUMMARY OF THE FEATURES OF SENSIT-2D (PART I)

SENSIT-2D: A Two-Dimensional Cross-Section and Design Sensitivity and Uncertainty Analysis Code

Code Information:

- * typical storage, 20K (SCM), 80K (LCM)
- * number of program lines, 3400
- * used with the TRIDENT-CTR transport code
- * typical run times, 10-100 sec

Capabilities:

- * computes sensitivity and uncertainty of a calculated integral response (e.g., dose rate) due to input cross sections and their uncertainties
- * cross-section sensitivity
- * vector cross-section sensitivity and uncertainty analysis
- * design sensitivity analysis
- secondary energy distribution (SED) sensitivity and uncertainty analysis

TABLE III: SUMMARY OF THE FEATURES OF SENSIT-2D (PART 2)

SENSIT-2D

TRIDENT-CTR Features Carried Over into SENSIT-2D:

- * x-yor r-z geometry
- * group-dependent S_n order
- * triangular spatial mesh

Unique Features:

- * developed primarily for fusion problems
- # group dependent quadrature order and triangular mesh
- * can evaluate loss-term of sensitivity profile based on angular fluxes and/or flux moments

Current Limitations:

- * can only interact with TRIDENT-CTR transport code
- * not yet implemented on other than CDC computers
- * based on first-order perturbation theory
- * upscattering not allowed



Figure 5. Computational outline for a two-dimensional sensitivity analysis with SENSIT-2D

where the angular fluxes in a form compatible with SENSIT-2D are generated, and a SENSIT-2D module, which performs the calculations and manipulations necessary for a sensitivity and uncertainty analysis.

4.2.1 Cross-section preparation module

There are many possible ways to generate the multigroup crosssection tables required by SENSIT-2D and TRIDENT-CTR. The flow chart of Fig. 5 illustrates just one of these possibilities. All the codes mentioned here are accessible via the MFE machine. Basically, three codes are required: NJOY, TRANSX, and MIXIT. Starting from the ENDF/B-V data file, the NJOY code system⁶⁴ generates a multigroup cross-section library (MATXS5) and a vector cross-section and covariance library (TAPE10). A covariance library can be constructed by using the ERROR module in the NJOY code system.³³

From the multigroup cross-section library (MATXS5), the desired isotopes can be extracted by the TRANSX code⁷² and will be written on a file with the name XSLIBF5. The MIXIT code⁷³ can make up new materials by mixing isotopes from the XSLIBF5 library. The cross sections used in SENSIT-2D have to be written on a file called TAPE4. The cross sections used in TRIDENT-CTR and TRDSEN will be on file GEODXS. SENSIT-2D and TRIDENT-CTR include the option to feed in cross sections directly from cards.

4.2.2 The TRIDENT-CTR and TRDSENS block

SENSIT-2D requires regular angular fluxes at the triangle centerpoints, multipled by the corresponding volumes, and adjoint angular fluxes at the triangle centerpoints. TRIDENT-CTR does not write out angular fluxes. Therefore the TRDSEN version of TRIDENT-CTR was written by SEFD. TRDSEN makes use of the flux moment dump files, generated by TRIDENT-CTR. These dump files will be the starting flux guesses for TRDSEN. TRDSEN will perform one more iteration and write out the angular fluxes. In this discussion we will represent the dump file families by DUMP1 for the regular flux moments, and DUMP2 for the angular flux moments. Except for a different starting guess option, TRDSEN requires the same input as TRIDENT-CTR.

4.2.3 The SENSIT-2D module

The SENSIT-2D code performs a sensitivity and uncertainty analysis. When vector cross sections and their covariances are required, they have to be present on a file with the name TAPE10. If the cross section data are read from tape, they have to be written on a file called TAPE4. The regular angular fluxes at the triangle centerpoints multiplied by the corresponding volumes (TAPE11, TAPE12,...) and the adjoint angular fluxes at the triangle centerpoints (TAPE15, TAPE16,...) can be quite voluminous. Writing out large files can be troublesome on the MFE

machine when there is a temporary lack of continuous disk space. Therefore TRIDENT-CTR and SENSIT-2D have the built-in option to specify the maximum number of words to be written on one file. This limit has to be set high enough to ensure that all the flux data related to one group can be written on one file. 1 000 000 words per file is usually a practical size and is the default in TRIDENT-CTR.

SENSIT-2D can generate four more file families:

- 1. TAPE1, which contains the regular scalar fluxes at the triangle centerpoints.
- 2. TAPE20, TAPE21,..., which are random access files and contain the adjoint angular fluxes at the triangle centerpoints,
- 3. TAPE25, TAPE26,..., containing the regular flux moments at the triangle centerpoints, multipled by the corresponding volumes,
- 4. TAPE30, TAPE31,..., which contain the adjoint angular fluxes at the triangle midpoints.

SENSIT-2D has the option of not generating those file families, but using those created by a former run. The flux moments are constructed from the angular fluxes according to the formula

$$\Phi_{\ell}^{k}(x,y) = \sum_{m=1}^{MN} w_{m} R_{\ell}^{k}(\mu_{m},\phi_{m}) \Phi_{m}(x,y)$$

where the w_m 's are the quadrature weights, the R_{ℓ}^k 's the spherical harmonics functions, and MN the total number of angular fluxes.

4.3 The SENSIT-2D Code

In this section the structure of the SENSIT-2D code, its options and capabilities will be explained in more detail. SENSIT-2D is a powerful sensitivity and uncertainty analysis code. The description of this code from the user's point of view is given in the user's manual.⁷¹

4.3.1 Flow charts

The overall data flow within the SENSIT-2D module is repeated in Fig. 6. A simplified flow chart is illustrated in Fig. 7. The main parts of the flow chart include these steps:

- * The control parameters and the geometry related information are read in.
- * The quadrature sets and the spherical harmonics functions required to generate the flux moments are constructed.
- * The adjoint angular fluxes at the triangle centerpoints are written on random access files, flux moments are generated and scalar fluxes are extracted.
- * A detector sensitivity analysis is performed; if desired an uncertainty analysis is done.
- * The χ 's and ψ 's which form the essential parts of the cross-section and secondary energy distribution sensitivity profiles are calculated for each perturbed zone and for the sum over all perturbed zones.







Figure 7. Flow chart for SENSIT-2D (part 1)



Figure 7. Flow chart for SENSIT-2D (part 2)



Figure 7. Flow chart for SENSIT-2D (part 3)

Up to this point, all the subroutines used are different from those used in the SENSIT code. The remaining calculations are done with SENSIT subroutines.

- * Cross sections are read in.
- * Vector cross sections are extracted.
- * Sensitivity profiles are calculated used in the appropriate ψ 's and χ 's.
- * If desired to do so, an uncertainty analysis is performed.
- * A vector cross-section sensitivity and uncertainty analysis can be performed and partial sums of individual response variances can be made.

4.3.2 Subroutines used in SENSIT-2D

Table IV summarizes the subroutines used in SENSIT-2D and indicates their origin in case they were taken over or adapted from another code. The essential difference between SENSIT and SENSIT-2D is the way that the geometry is described and how the ψ 's and the χ 's are calculated. Basically, all the subroutines are called from the main program with a few exemptions when subroutines are called from other subroutines. The subroutines for SENSIT-2D which were not taken over from other codes will now be described. For the SENSIT subroutines we refer to the user's manual.⁴⁶

Name Subroutine	Origin	If Taken From Another Code, Were Changes Made?		
EBND	SENSIT-2D	-		
GEOM	SENSIT-2D	-		
SNCON	TRIDENT-CTR	yes		
TAPAS	SENSIT-2D	-		
PNGEN	TRIDENT-CTR	yes		
FLUXMOM	SENSIT-2D	-		
DETSEN	SENSIT-2D	-		
CHIS	SENSIT-2D	-		
POINT4B	SENSIT-2D	-		
PSIS	SENSIT-2D	-		
POINT8	SENSIT-2D	-		
SUB5	SENSIT	yes		
SUB6	SENSIT	no		
TEXT	SENSIT	no		
TESTA	SENSIT	no		
SUB8	SENSIT	yes		
SUB11	SENSIT	yes		
SUB8V	SENSIT	no		
SUB9	SENSIT	no		
SUB9V	SENSIT	no		
SUB5V	SENSIT	no		
COVARD	SENSIT	no		
SETID	SENSIT	no		

TABLE IV: LIST OF SUBROUTINES USED IN SENSIT-2D

1. Subroutine EDNB. Neutron and gamma-ray energy group structures are read in from cards and the lethargy widths for each group are calculated.

2. Subroutine GEOM. Geometry related information is read in and edited.

<u>3. Subroutine SNCON</u>. This routine was taken and adapted from the TRIDENT-CTR code. The EQ_n cosines and weights are calcualted. The quadrature information is edited whenever IOPT is 1 or 3.

4. Subroutine TAPAS. Files are assigned to the various flux data. The filenames for the angular fluxes are read from the input file. Those filenames will have to be of the form TAPEXY, where XY will be the input information. Filenames in the same format will then be assigned to the adjoint angular fluxes (on sequential files in this case), and the flux moments. The maximum number of words to be written on each file is controlled by the input parameter Groups will never be broken up between different files. MAXWRD. 5. Subroutine PNGEN. This subroutine originates from the TRIDENT-CTR code. Spherical harmonics functions, used for constructing flux moments, are calculated. For the adjoint flux moment calculation the arrays related to the spherical harmonics will be rearranged to take into account the fact that the numbering of the angular directions was not symmetric with respect to the four quadrants in TRIDENT-CTR.

<u>6. Subroutine FLUXMOM</u>. The adjoint angular fluxes will be rewritten on a random access file. The direct and adjoint flux

moments are constructed and written on sequential files. In the case that the input parameter IPREP1, it is assumed that those manipulations are already performed in an earlier SENSIT-2D run. In this case one has to make sure that the parameter MAXWRD was not changed. While creating the regular flux moments, the scalar fluxes will be extracted and written on a file named TAPE1.

7. Subroutine DETSEN. From the scalar fluxes, the integral response for each detector zone is read from input cards. The detector sensitivity profile is calculated and edited. In the case that the input parameter DETCOV equals one, a covariance matrix has to be provided, subroutine SUB9 will be called and a detector response uncertainty analysis is performed.

<u>8. Subroutine CHIS</u>. The χ 's are calculated for each perturbed zone and for the sum over all perturbed zones based on angular fluxes. In the case that the parameter ICHIMOM equals one, this subroutine will be skipped and the χ 's will be calculated based on flux moments via the ψ 's.

<u>9. Subroutine POINT4B</u>. This subroutine sets LCM pointers for the flux moments which will be used in SUB4B.

<u>10.</u> Subroutine PSIS. The ψ 's are calculated for each of the perturbed zones and for the sum over all perturbed zones based on flux moments. In the case that ICHIMOM is not equal to zero also the χ 's will be calculated from flux moments. In the case that parameter IPREP equals one, the ψ 's will be read in from file TAPE3.

11. Subroutine POINT8. This subroutine sets pointers for the appropriate χ 's and ψ 's, used in subroutine SUB8.

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5. COMPARISON OF A TWO-DIMENSIONAL SENSITIVITY ANALYSIS WITH A ONE DIMENSIONAL SENSITIVITY ANALYSIS

Before applying SENSIT-2D to the FED (fusion engineering device) inboard shield design, currently in development at the General Atomic Company, it was necessary to make sure that SENSIT-2D will provide the correct answers. One way for checking on the performance of SENSIT-2D is to analyze a two-dimensional sample problem, which is one-dimensional from the neutronics point of view, and then to compare the results with a one-dimensional analysis. In this case ONEDANT⁷⁴ and SENSIT⁴⁶ are used for the one-dimensional study, while TRIDENT-CTR, TRDSEN, and SENSIT-2D are used for the two-dimensional analysis.

Two sample problems will be studied. The first sample problem uses real cross-section data, while the second sample problem utilizes artificial cross sections. Computing times, the influence of the quadrature set order, and the performance of the angular fluxes versus the flux moments option for the calculation of the chi's will be discussed.

5.1 Sample Problem #1

The first sample problem is a mock-up of a cylindrical geometry (Fig. 8). There are four zones present: a source zone (vacuum), a perturbed zone (iron), a zone made up of 40% iron and 40% water, and a detector zone (copper). The reaction rate of interest is the heat generated in the copper region. The source was assumed isotropic and had a neutron density of one neutron per cubic centimeter (1 neutron/cm³). The source neutrons are emitted at 14.1 MeV (group 2). The left boundary is reflecting, and on the right there is a vacuum boundary condition. Thirty neutron groups were used with a third order of anisotropic scattering. The cross sections were generated using the TRANSX⁷² code. The energy group boundaries are reproduced in Table V.

In the two-dimensional model (TRIDENT-CTR) two bands--each 0.5-cm wide--are present. In order to be consistent with the one-dimensional analysis the upper and the lower boundaries were made reflective (Fig. 9). Each band is divided into 35 triangles (5 triangles for the source zone, 10 triangles for each of the other three zones). The automatic mesh generator in TRIDENT-CTR was used. The convergence precision was set to 10^{-3} . A convergence precision of 10^{-3} means here that the average scalar flux for any triangle changes by less than 0.1% between two consecutive iterations. A similar criterion is used in ONEDANT. The calculation is performed with the built-in EQ_n -8 (equal weight) quadrature set. The mixture densities are given in Table VI. For the adjoint calculation the source is in zone IV and consists of the copper



Figure 8. Cylindrical geometry representation for sample problem #1

TABLE V: 30-GROUP ENERGY STRUCTURE

Neutrons					
E-Upper (MeV)	Group	E-Lower (MeV)	E-Upper (MeV)	Group	E-Lower (McV)
1.700+01	1	1.500+01	6.140-05	24	2.260-05
1.500+01	2	1.350+01	2.260-05	25	8.320-06
1_350+01	3	1.200+01	8.320-06	26	3.060-06
1.200+01	4	1.000+01	3.060-06	27	1.130-06
1.000+01	5	7.790+00	1.130-06	28	4.140-07
7.790+00	6	6.070+00	4.140-07	29	1.520-07
6.070+00	7	3.680+00	1.520-07	30	1.390-10
3.680+00	8	2.865+00			
2.865+00	9	2.232+00			
2.232+00	10	1.738+00			
1.738+00	11	1_353+00			
1.353+00	12	8.230-01			
8.230-01	13	5.000-01			
5.000-01	14	3-030-01			
3.030-01	15	1.840-01			
1.840-01	16	6.760-02			
6.760-02	17	2.480-02			
2.480-02	18	9.120-03			
9.120-03	19	3.350-03			
3.350-03	20	1.235-03			
1.235-03	21	4.540-04			
4.540-04	22	1.670-04			
1.670-04	23	6.140-05			



REFLECTING BOUNDARY

30 neutron groups neutron source: 1 neutron / cm³ in group2 (14.1 MeV) P-3, EQ_n-8 : third-order of anisotropic scattering 8th-order equal weight quadrature set response function:copper kerma factor in zone #IV convergence precision : 10⁻³

Figure 9. Two-dimensional (TRIDENT-CTR) representation for sample problem #1

TABLE VI. ATOM DENSITIES OF MATERIALS

			Atoms/m ³		
ZONE	# 1	Vacuum			
ZONE	# II	Fe	8.490	+	28 ^a
ZONE	#III ^b	Fe	3.396	+	28
		Н	4.020	+	28
		0	1.900	+	28
ZONE	#IV	Cu	8.490	+	28

$$a 8.490 + 28 = 8.49 \times 10^{28}$$

 $^{\rm b}$ 40 vol % Fe and 40 vol % water.

kerma factors. The response is calculated in that case in zone I. It was found that the adjoint calculation required more iterations and time in order to reach convergence. Originally the forward calculation was done using 20 triangles per band. The adjoint problem, however, did not converge. In the evaluation process of the kerma factors, the kermas for some groups are made negative in order to satisfy energy balance. Making those negative sources zero in the TRIDENT-CTR run did not lead Subsequently, 35 triangles per band were used. to any improvement. When the negative sources were set to zero convergence was reached. Ignoring the negative kerma factors leads to a 20% increase in the total heating. The forward calculation required about 11 minutes cpu time (central processor unit time on a CDC-7600), while the adjoint calculation required about 13.5 minutes. Generating the angular fluxes using the TRDSEN code required about 20 seconds of cpu time for each case.

TRDSEN does on extra iteration in order to generate the angular fluxes. The convergence criterion in TRIDENT-CTR is based on the scalar fluxes, and therefore one extra iteration in TRDSEN should be adequate. However, restarting TRIDENT-CTR with the flux moments as starting guesses, revealed that for some groups two extra iterations were necessary to reach a convergence precision of 10^{-3} . No explanation for this could be found.

The one-dimensional model (ONEDANT) contains 35 intervals (5 for the source zone, 10 intervals for each of the remaining zones). The one-dimensional description for the forward problem is summarized in



Figure 10. One-dimensional (ONEDANT) .epresentation for sample problem #1

Fig. 10. Again it was found that the use of negative sources in the adjoint calculation caused difficulties with respect to the convergence. In that case, groups 18 and 19 triggered the message "TRANSPORT FLUXES BAD"; groups 4, 5, 6, 7, and 19 did not converge (max. number of inner iterations 300/group). However, the overall heating in the copper region was within 0.1% of the heating calculated by the forward run. A coupled neturon/gamma-ray calculation (30 neutrons groups and 12 gamma-ray groups) in the adjoint mode led to some improvement. In that case, only group 2 did not converge. The required convergence precision in the ONEDANT runs was set to 10^{-4} . The built-in S-8 Gaussian quadrature sets were used. In order to be consistent with the TRIDENT-CTR calculations, the negative sources in the adjoint case were set to zero, even though this did not seem to be necessary. Each run required about six seconds of cpu time.

A standard cross-section sensitivity analysis (the cross sections in zone II are perturbed) was performed using the SENSIT code and the SENSIT-2D code. A comparison between the SENSIT and the SENSIT-2D results revealed that SENSIT⁷⁶ does not rearrange the angular fluxes correctly (in cylindrical geometry). To correct this error, a shuffling routine which takes case of this deficiency was then built into SENSIT. The SENSIT results are in good agreement with those obtained from SENSIT-2D. The flux moments versus the angular flux option was tested out for the calculation of the loss term. Again there is good agreement. Finally, an uncertainty analysis was performed for the heating in the copper zone. The SENSIT-2D analysis matches the SENSIT analysis.

5.1.1 TRIDENT-CTR and ONEDANT results

A comparison of the heating in the copper region (zone IV) between TRIDENT-CTR (and SENSIT-2D) and ONEDANT (and SENSIT) is summarized in Table VII a. The adjoint calculations yield a 20% higher heating rate due to the fact that the negative kerma factors were set equal to zero. The one-dimensional and the two-dimensional analysis are in agreement. The computing times for those various runs are given in Table VII b.

Each ONEDANT run requires about 8 seconds of total computing time (LTSS time), whereas it takes about 12 minutes to do the TRIDENT-CTR runs. The TRIDENT-CTR runs were done with a convergence precision of 10^{-3} , whereas for the ONEDANT runs a convergence precision of 10^{-4} was specified. In order to obtain the same convergence precision in TRIDENT-CTR about eight additional minutes of cpu time are required. It was found that a forward coupled neutron/gamma-ray calculation (30 neutron groups and 12 gamma-ray groups) required only 8 minutes of computing time with TRIDENT-CTR (convergence precision 10^{-3}). An explanation for this paradoxial behavior is related to the fact that $\sigma_{\rm g}/\sigma_{\rm T}$ has a different (smaller) value in a coupled neutron/gamma-ray calculation.

The flux moments generated by TRIDENT-CTR and ONEDANT were compared. In the ONEDANT geometry the angular fluxes are assumed to be symmetrical with respect to the z-axis,⁷⁵ so that the odd flux moments $(\phi_1^0, \phi_2^1, \phi_3^0, \text{ and } \phi_3^2)$ vanish. Since TRIDENT-CTR performs a real twodimensional calculation the odd moments will not be zero in that case. In our sample problems there is still symmetry with respect to the

TABLE VIIa. COMPARISON OF THE HEATING IN THE COPPER REGION CALCULATED BY ONEDANT AND TRIDENT-CTR

	FORWARD	ADJOINT
ONEDANT ^a	2.37382 + 7	2.40541 + 7
ONEDANT	2.01189 + 7	2.01882 + 7
TRIDENT-CTR	2.01175 + 7	2.39263 + 7
SENSIT	2.01011 + 7	2.40541 + 7
SENSIT-2D	2.01098 + 7	

^a negative KERMA factors set to zero

TABLE VIID. COMPUTING TIMES ON A CDC-7600 MACHINE

	CPU-TIME ^a	I/O TIME ^b	LTSS TIME ^C
ONEDANT FORWARD	5.80 sec.	1.87 sec.	7.65 sec.
ONEDANT ADJOINT	6.09 sec.	1.82 sec.	7.97 sec.
TRIDENT-CTR FORWARD			13.5 minutes
TRIDENT-CTR ADJOINT			11.1 minutes
SENSIT	4.92 sec.	0.55 sec.	6.08 sec.
SENSIT-2D	8.50 sec.	9.02 sec.	17.84 sec.

^a central processor unit time

^b input/output time

^C Livermore time sharing system time (total computing time)

z-axis. For that reason, the odd moments in TRIDENT-CTR will have opposite signs in band one and band two. For some zones and some groups this was not completely the case. There was about 30% difference in the absolute values of some flux moments in band one and band two, which indicates that the problem was not in a sense truly converged. The convergence criteria in ONEDANT and TRIDENT-CTR test only for the scalar fluxes between two consecutive iterations. Even when the convergence criteria are satisfied in both codes, a true convergence of the angular flux is not guaranteed. The even moments in band one are exactly the same as those for band two. Because the contribution of the odd moments is small compared to the contribution of the even moments (about one thousandth), the problem can be considered fully converged.

The scalar flux moments calculated by TRIDENT-CTR and ONEDANT are in very good agreement. The higher-order moments are different. Since TRIDENT-CTR and ONEDANT do not use the same coordinate system, they do not calculate the same physical quantity for the higher-order flux moments. As long as TRIDENT-CTR is consistent with SENSIT-2D, and ONEDANT consistent with SENSIT, the results from the one-dimensional sensitivity analysis should match those obtained from a two-dimensional sensitivity analysis.

5.1.2 SENSIT and SENSIT-2D results for a standard cross-section sensitivity analysis

A standard cross-section sensitivity analysis was performed using
SENSIT and SENSIT-2D. The sensitivity of the heating in zone IV to the cross sections in zone II was studied. SENSIT-2D requires about three times more computing time than SENSIT in this case (Table VII b). The main part of the calculation involves the evaluation of the ψ 's (gain term). A complete sensitivity and uncertainty analysis may involve several SENSIT (or SENSIT-2D) runs. Thus an option which allows one to save the ψ 's has been built into SENSIT-2D. It is obvious that the computing time required in SENSIT-2D is negligible compared to the computing time required for the forward and adjoint TRIDENT-CTR calculations.

The partial and the net sensitivity profiles calculated by SENSIT and SENSIT-2D are reproduced in TABLES VIII a and VIII b. It can be concluded that the SENSIT-2D results are in good agreement with those obtained by SENSIT. Note that the absorption cross section is negative for groups 2 and 3. A negative absorption cross section does not necessarily indicate that errors were made during the cross section processing. There are various ways to define an absorption cross section, and a controversy about a commonly agreed on definition is currently in progress. What is called an absorption cross section in a transport code is not truly an absorption cross section but the difference between the transport cross section and the outscattering ($\sigma_a^g = \sigma_a^g - \Sigma \sigma_a^{g+g'}$). Note that groups 2 and 3 are the main contributors to the integral sensitivity.

It was mentioned earlier that the χ 's can be calculated based on flux moments or based on angular fluxes according to

TABLE VIIIa: PARTIAL AND NET SENSITIVITY PROFILES FOR THE ONE-DIMENSIONAL ANALYSIS (Part 1)

		DEFINITIONS OF SENGIT SENSITIVITY PROFILE NOMENCLATURE
BAXS	•	SENSITIVITY PROFILE PER DELTA-U FOR THE ADSORPIIUM CROSS-SECTION (TAMÉN FROM POSITION IMA IN INPUT ERUSS-SECTION TABLES), PURE LUSS TERM
NU-F155	•	SENSITIVITY PROFILE PER DELTA-U FOR THE CROSS SECTION IN POSITION INAHI IN INPUT XS-TABLES. WHICH IS USUALLY NU-TIMES THE FISSION CROSS SECTION. PURE LOSS TERM
5X5	•	PARTIAL SENSITIVITY PROFILE PER DELTA-U FOR THE SCATTELING CRUSS-SECTION (COMPUTED FOR EACH ENERGY GROUP AS A DIAGONAL SUM FROM INPUT XS-TABLES), LOSS IENN ONLY
TXS	•	SENSITIVITY PROFILE PER DELTA-U FOR THE TOTAL CLOSS SECTION (AS GIVEN IN POSITION INT IN INPUT CROSS-SECTION TABLES), PURE LOSS TERM
H-GA1H	•	PARTIAL SENSITIVITY PROFILE PER DELTA-U FOR THE HEUTION SCATTERING CROSS-SECTION. GAIN TERM FOR SENSITIVITY GAINS DUE TO SERTICINING UNI OF EMERGY GROUP G INTO ALL LOWER MEUTION
		EVED TO THE FORM FOR SOLVER DIFFERENCE FORME OF AN
		ENERGY GROUPS, COIPUIED FROM FURGIND DIFFERENCE FURFOLMIION.
6-691N	•	PARTIAL SENSITIVITY PROFILE PER DELTA-U FOR THE GARDA SCATTERING CROSS-SECTION. GAIN TERM FOR SENSITIVITY GAINS DUE TO SCATTERING OUT OF GARDA ENERGY GROUP G INTO ALL LOWER GARDA ENERGY COMPUTED FROM FORWARD DIFFERENCE FURMULATION.
N-GAIN(SED)	•	RE-OPDERED PARTIAL SENSITIVITY PROFILE PED DELTA-U FOR SCATTURING CRUSS-SECTION. GAIN TERM FOR SENSITIVITY GAINS DUE TO SCATTERING INTO GROUP G FROM ALL'HIGHER NEUMONI ENERGY GROUPS. CONFUTED FROM ADJOINT DIFFERING FURINGTION. CONFERENCES IN SINGLE-DIFFERINGING SED REGITIVITY PROFILE, PSED(G-OUT) PER DELU-OUT. INTEGRATED OVER ALL INCIDENT ENERGY GROUPS.
NG-GA1N	•	PARTIAL SENSITIVITY PROFILE FOR DELIA-U FOR THE GRAFH PRODUCTION CROSS-SECTION At Heutron Eilingy Croup G. Puis Gain Term for Schjitivity Gains due to Transfer From Neutron Group G Into All Gaith Groups.
SEN		NET SENSITIVITY PROFILE PER DELTA-U FUR THE SCATTERING CRUDS-SECTION (SEN-555+66AIN)
SENT		NET SENSITIVITY PROFILE PER DELTA-U FOR THE THITAL CODSI-SECTION (SENT-TXSUMGATU)
CEMP		
	-	SCHOATAVATT ENDER EEN DELEMEU FUR THE DETECTUS: GEDFUNDE FURGIDUS (SUD
SENO	•	SENSITIVITY PROFILE PER DELTA-U FOR THE SOURCE DISTRIBUTION FUNCTION ORGO

TABLE VIIIa: PARTIAL AND NET SENSITIVITY PROFILES FOR THE ONE-DIMENSIONAL ANALYSIS (Part 2)

1.011.114	EUTRON INTERA	CTION CROSS	SECTIONS: (N	-H) AND CH-G	41614)		- 2.10415		
						.			
GOOUP	UPPER-E(EV)	DELTA-U	AXS	KU-FISS	S TERMI SXS	TXS	H-COIN	TE CONTRACEDO 11-GONKOSEDO	NG-GA10
1	1.7002+97	1.255-01	8. 2.4476+00	Ø. 0	0.	8.	0.	ίι.	0.
3	1.7505+07	1.182-01	2.440ET00	о. А.	-1 2015401	-1.7050/04	0.3246+00	4.772E+08	0.
4	1.2005+07	1.822-01	-1.995E-02	0.	-2.99 F-01	-3.1010-01	1.7102-01	2 80.00-01	0.
S	1.0057+07	2.55E-01	-1.3936-02	ü.	-3.4516-01	-3.5726-01	1.03/2-01	5.1600-01	0. n
6	7.7905+06	2.47E-01	-S.715E-03	ō.	-2.GU:E-01	-2.74GE-01	1.644L-01	21502-61	9.
?	6.DTGE+35	5.00E-01	-1.795E-03	0.	-2.4475-01	-2.4972-01	1.7430-01	2.32.12-01	ō.
6	3.6655+06	2.50E-01	-9.G2CE-04	0 .	-2.0075-01	-2.8376-01	2.3472-01	2.000E-R1	ō.
.9	2.0%55+06	2.500-01	-5.937E-04	Ð.	-3.6278-01	-3.629E-01	3.1502-01	3.715E-01	0.
11	1 7335105	2.305-01	-3.097E-04	U .	-3.501E-01	-3.512E-DI	3.193E-01	3.7095-01	0_
12	1.3550406	4.97E-01	-5.98CE-04	บ. ค.	-4.6305-01	-3.7430-01	3.3.0E-01 A 767E-01	4.0156-01	ย.
13	0.2365+05	4.98E-01	-1.534E-03	Ð.	-7.89.12-01	-7.1105-01	6.9000-01	7 63:5-01	0.
14	5.2305-05	5.012-01	-1.057E-03	8.	-7.707E-01	-7.797E-D1	7.7105-01	C. 254E-01	D.
15	3.620E+65	4.99E-DI	-3.822E-04	0.	-1.957E-01	-2.0C1E-01	1.9546-01	2.0715-01	ë.
16	1.0435+05	1.081+00	-7.039E-04	0.	-3.019E-01	-3.02GE-01	2.9255-01	3.13GE-01	0.
17	6.768±+04	1.06E+00	-4.683E-84	8.	-3.49CE-01	-3.502E-01	3.4028-01	3.521E-01	Ð.
10	2.403E+84	1.895+60	-5.532E-05	Ð.	-2.052E-02	-2.0501-02	1.9345-02	2.0340-82	D.
19	9,1202453	1.C.E+1.0	-7.329L-05	0.	-4.0075-02	-4.844E-02	4.00012-02	-1.0421-02	0.
23	3.35%2+53	9.902-01	-1.037E-05	0.	-2.1162-02	-2.412FCL	2.375-62	20-02	Ω.
21	1.2352+03	1.000+00	-2.631E-04	0.	-1.10/0-02	-1.5500-02	1.5052-62	1.570E-02	0.
22	4.5156452	1.005400	-3.80/12-03	ບ.	-1.0016-02	-1.5090-02	1.67.2-02	1.63662	0.
24	6.1/55+01	9.995-01	-5.910E-05	0.	-1.0.00-02	-1.0301-02	1.0	1.00000-02	0.
25	2.26CE+01	9.9°E-01	-6.C16E-U5	õ.	-7.0100-03	-7.03CE-03	6.93-0-03	7.0000-03	ü.
26	8.32CE+60	1.6JE+60	-7.8C5E-05	0.	-4.3051-03	-4.4555-03	4.57CE-03	4.441-6-00	0_
27	3.0652+00	9.965-01	-6.675E-0S	ຍ.	-2.5UCL-03	-2.5735-03	2.100-03	2.:.CCE-03	0.
29	1.130E+08	1.002+69	-5.720E-05	o.	-1.38CE-03	-1.3630-03	1.716-03	1.5510-03	0.
29	4.1424-61	1.05=+90	-4,4346-05	U. A	-6.110L-04	-0.5021-04	6.1789-04	6-5751-04	ຍ.
50	1.5202-01	1.112+00			-1.0362-05	-1.2,800-03		1.23.6-03	0.
INTEG	RAL		2.4\$5E-01	ຍ.	-5.0925+60	-4.04TE+00	3.3450+03	3.343E+00	0.
			NOT PR	OFILES #HAR					
CDC:0	INDER FILL		C						
SUC:05	UPPER-F(EV)	DELTA-U	SEN	SENT					
2 2 2	UPPER-E(EV) 1.70°E+07	DELTA-U 1.25E-01	SEN 8. -1.356F+01	SENT 0. -1.1:2F+81					
2860P 1 2 3	UPPER-E(EV) 1.705E+07 1.5555E+07 1.2555E+07	DELTA-U 1.2SE-D1 1.07E-81 1.1CE-D1	SEN 0. -1.356E+01 -1.059E+00	SENT 0. -1.1:2E+01 -1.021E+00					
2 2 3 4	UPPER-E(EV) 1.765E+07 1.5555E+07 1.2555E+07 1.201E+07	DELTA-U 1.25E-01 1.07E-01 1.1CE-01 1.82E-01	SEN 0. -1.35GE+01 -1.039E+00 -1.594L-01	SENT 0. -1.1:2E+81 -1.021E+0U -1.793E-01					
2 2 3 4 5	UPPER-E(EV) 1.765E+67 1.5755E+07 1.2555E+07 1.205E+07 1.050E+07	DELTA-U 1.2SE-01 1.07E-81 1.1CE-01 1.82E-01 2.59E-01	SEN 0. -1.356E+01 -1.039E+00 -1.594L-01 -1.594E-01	SENT 0. -1.1:2E+81 -1.021E+0U -1.793E-01 -1.7305-01					
1 2 3 4 5 6	UPPER-E(EV) 1.70/E+07 1.57/E+07 1.25//E+07 1.20/E407 1.02/02+07 7.70/E+05	DELTA-U 1.25E-01 1.07E-81 1.1CE-01 1.82E-01 2.55E-01 2.45E-01	SEN 0. -1.356E+01 -1.039E+00 -1.594L-01 -1.594E-01 -1.045E-01	SENT 0. -1.1:25+81 -1.021E+0U -1.793E-01 -1.7305-01 -1.102E-01 -1.102E-01					
1 2 3 4 5 6 7	UPPER-F(EV) 1.70/E+07 1.57/E+07 1.21/E+07 1.20/E407 1.02/02+07 7.70/E407 6.67/E4P6 7.70/E402	DELTA-U 1.2SE-01 1.07E-01 1.1CE-01 1.82E-01 2.59E-01 2.49E-01 S.862-01 3.662-01	SEN 0. -1.350E+01 -1.039E+00 -1.594E-01 -1.594E-01 -1.045E-01 -7.045E-02 -5.7045-02	SENT 0. -1.1:2E+01 -1.621E+0U -1.793E-01 -1.730E-01 -1.102E-01 -7.244E-02 -5.426E-03					
29.00 2 3 4 5 6 7 8 9	UPPER-E(EV) 1.70/E+07 1.51/E+07 1.25/E+07 1.25/E+07 1.20/E+07 7.70/E+C5 6.670/E+06 3.035/E+06 2.665/E+06	DELTA-U 1.2SE-01 1.07E-01 1.02E-01 1.82E-01 2.59E-01 2.45E-01 5.062-01 2.50E-01 2.50E-01	SEN 0. -1.35GE+01 -1.594E-01 -1.594E-01 -1.945E-01 -7.045E-02 -5.306E-02 -4.736E-02	SENT 0. -1.1:2E+81 -1.0:1E+0U -1.793E-01 -1.730E-01 -1.102E-01 -7.244E-02 -5.446E-02 -4.705E-02					
2 2 3 4 5 6 7 8 9 10	UPPER-E(EV) 1.70/E+07 1.57/E+07 1.20/E+07 1.20/E+07 1.00/01+07 7.70/E+07 6.67/E146 3.09/E+06 2.05/E+06 2.25/E+06 2.25/E+06	DELTA-U 1.2SE-01 1.07E-01 1.1E-01 1.82E-01 2.59E-01 2.59E-01 2.50E-01 2.50E-01 2.50E-01 2.50E-01	SEN 0. -1.356[+0] -1.594L-01 -1.594L-01 -1.594L-01 -1.542-01 -7.025L-02 -5.320E-62 -4.736C-62 -3.162E-02	SENT 0. -1.1:2E+81 -1.021E+0U -1.733E-01 -1.730E-01 -7.244E-02 -5.476E-02 -3.134E-02					
2 2 3 4 5 6 7 8 9 10 11	UPPER-F(EV) 1.76°CE407 1.57°.5+07 1.25°.5+07 1.20°.25+07 1.0°.35+07 7.7005+07 6.67°.5+06 3.6365+06 2.253°.456 2.253°.456 1.73.25+06	DELTA-U 1.2SE-01 1.07E-01 1.1CE-01 1.82E-01 2.5SE-01 2.4SE-01 2.50E-01 2.50E-01 2.S7E-01 2.S7E-01 2.S7E-01	SEN 0. -1.256E+01 -1.059E+00 -1.594E-01 -1.994E-01 -1.994E-01 -1.945E-01 -7.045E-02 -5.204E-02 -4.736E-02 -1.664E-02	SENT 0. -1.1:2E+01 -1.621E+0U -1.730E-01 -1.730E-01 -7.2446-02 -5.476E-02 -3.134E-02 -3.134E-02 -1.691E-02					
2000 1 2 3 4 5 6 7 8 9 10 11 12	UPPER-F(EV) 1.76/E+07 1.57/5+07 1.252/5+07 1.2024+07 7.7004+07 7.7004+06 6.67024+06 2.6552+06 2.2327.456 1.7324+06 1.3535+05	DELTA-U 1.2SE-01 1.07E-01 1.82E-01 2.59E-01 2.45E-01 2.50E-01 2.50E-01 2.50E-01 2.57E-01 2.57E-01 4.97E-01	SEN 0. -1.25GC+01 -1.594L-01 -1.594L-01 -1.594L-01 -1.594L-01 -7.045L-02 -5.320LE-02 -4.73CC-02 -4.73CC-02 -3.1652-02 -2.718E-02	SENT 0. -1.1:2E+81 -1.621E+0U -1.793E-01 -1.705-01 -7.244E-02 -5.476E-02 -4.705E-02 -5.134E-02 -1.691E-82 -2.7705-02					
2000 1 2 3 4 5 6 7 8 9 10 11 12 13	UPPER-F(EV) 1.76°CE407 1.57°5407 1.20°2407 1.20°2407 1.0°2407 3.6°52406 3.6°52406 2.23°2456 1.35°2465 8.23°2456 1.35°2465 8.23°2456 8.23°2457 8.23°2457 8.23°2457 8.23°2457 8.23°2457 8.23°2457 8.23°2457 8.23°247 8	DELTA-U 1.25E-01 1.07E-01 1.02E-01 1.02E-01 2.59E-01 2.59E-01 2.59E-01 2.59E-01 2.59E-01 2.59E-01 2.59E-01 4.97E-01 4.97E-01	SEN 0. -1.25GE+01 -1.059E+00 -1.594E-01 -1.042E-01 -7.045E-02 -5.200E-02 -3.102E-02 -1.046E-02 -2.710E-02 -1.253E-02 -1.254E-01 -1.254E-01 -1.254E-01 -1.254E-01 -1.254E-01 -1.254E-01 -1.254E-01 -1.254E-01 -1.254E-01 -1.254E-01 -1.254E-01 -1.254E-01 -1.254E-01 -1.254E-02 -1.254E-0	SENT 0. -1.1:2E+81 -1.4C1E+0U -1.793E-01 -1.730E-01 -7.244E-02 -5.476E-02 -3.134E-02 -1.691E-02 -2.770E-02 -1.497E-					
GRUUP 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15	UPPER-F(EV) 1.767:E+07 1.357:E+07 1.257:467 1.2022:407 1.0202:407 7.7005:405 3.6362:406 2.657:476 3.6362:406 2.237:476 1.73:E+06 1.73:25:405 1.73:405 1.73:40	DELTA-U 1.25E-01 1.07E-01 1.87E-01 2.56E-01 2.56E-01 2.56E-01 2.50E-01 2.50E-01 2.57E-01 2.57E-01 2.57E-01 2.57E-01 2.57E-01 3.57E-0	SEN 0. 1.25GC+01 -1.35GC+01 -1.594C+01 -1.594C+01 -1.954C+01 -7.045C+01 -7.045C+02 -5.30GE+02 -3.105C+02 -1.664C+02 -2.710E+02 -2.700E+02	SENT 0. -1.1:22:401 -1.021E+0U -1.7305-01 -1.7305-01 -1.102E-01 -7.244E-02 -5.476E-02 -4.7705-02 -1.691E-02 -1.691E-02 -1.691E-02 -1.691E-02 -1.697E-02 -7.904L-03					
GROUP 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16	UPPER-F(EV) 1.780/E407 1.255/E407 1.255/E407 1.2052407 1.2052407 1.0052407 6.6762406 3.056486 2.257246 2.257246 1.355405 8.2302405 8.2302405 3.005445 3.005445	DELTA-U 1.25E-01 1.07E-01 1.07E-01 1.02E-01 2.55E-01 2.55E-01 2.50E-01 2.50E-01 2.50E-01 2.57E-01 2.57E-01 2.57E-01 4.97E-01 4.97E-01 4.97E-01 4.97E-01 4.97E-01 4.97E-01	SEN 0. -1.256E+01 -1.039E+00 -1.594E-01 -1.994E-01 -1.994E-01 -7.045E-01 -7.045E-02 -5.264E-02 -4.736E-02 -2.716E-02 -2.716E-02 -6.920E-03 -4.34CE-05 -2.35%E-03	SENT 0. -1.1:2E+01 -1.621E+0U -1.730E-01 -1.730E-01 -1.730E-01 -1.102E-01 -7.244E-02 -3.476E-02 -4.70SE-02 -4.70SE-02 -1.631E-02 -1.631E-02 -1.631E-02 -1.631E-02 -1.631E-02 -1.631E-02 -1.631E-02 -1.631E-02 -2.7702-02 -1.631E-02 -3.65E-03 -4.727E-04 -3.65E-03 -4.727E-04 -3.65E-03 -4.727E-04 -3.65E-03 -4.727E-04 -3.65E-03 -4.727E-04 -3.65E-03 -4.727E-04 -5.65E-03 -4.727E-04 -5.65E-03 -5.65E-03 -5.65E-03 -5.65E-03 -5.65E-03 -5.65E-03 -5.65E-03 -5.65E-03 -5.65E-03 -5.65E-03 -5.65E-03 -5.65E-03 -5.65E-03 -5.65E-03 -5.65E-03 -5.770E-02 -5.770E-02 -7.904L-03 -4.725E-03 -4.725E-03 -4.725E-04 -5.65E-03 -5.770E-02 -7.904L-03 -4.725E-03 -4.725E-03 -4.725E-04 -7.55E-02 -7.55E-02 -7.55E-03 -7.55E-					
CRCUP 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 17	UPPER-F(EV) 1.70°CE407 1.557:5407 1.2025407 1.2025407 1.2025407 1.2025407 2.2596405 6.6765406 2.257:456 2.257:456 1.355405 8.2502405 5.0002405 1.0192405 1.0192405	DELTA-U 1.25E-01 1.07E-81 1.10E-01 2.59E-01 2.59E-01 2.59E-01 2.59E-01 2.50E-01 2.50E-01 2.57E-01 2.57E-01 4.97E-01 4.97E-01 3.01E-81 4.92E-01 1.68E+60	SEN 0. 1.356E+01 -1.039E+00 -1.594E+00 -1.594E+00 -1.594E+00 -1.594E+01 -7.055E+02 -3.105E+02 -3.105E+02 -1.664E+02 -2.710E+02 -1.253E+02 -1.253E+02 -2.352E+03 -2.352E+03 -5.292E+04	SENT 0. -1.1:2E+81 -1.021E+0U -1.793E-01 -1.730E-01 -1.102E-01 -7.244E-02 -5.476E-02 -3.134E-02 -4.705E-02 -3.134E-02 -2.7702-02 -1.497E-02 -2.7702-02 -1.497E-03 -3.065C-02 -9.977E-04					
SPCUP 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18	UPPER-F(EV) 1.76°CE407 1.57°5407 1.25°5407 1.20°5407 1.20°5407 1.20°5407 3.03°5405 3.03°5405 2.65°5405 2.25°5405 1.35°5405 8.230°405 3.03°5405 3.03°5405 3.03°5405 3.03°5405 3.03°4404	DELTA-U 1.25E-01 1.07E-01 1.07E-01 1.02E-01 2.56E-01 2.50E-01 2.50E-01 2.50E-01 2.50E-01 2.50E-01 2.57E-01 4.97E-01 4.97E-01 4.97E-01 1.67E-01 1.67E+00 1.67E+00 1.67E+00	SEN 0. 1.256E+01 -1.039E+00 -1.594E-01 -1.047E-01 -1.047E-01 -7.055E-02 -5.300E-02 -3.167E-02 -1.267E-02 -1.253E-02 -6.920E-03 -4.340E-03 -2.355E-03 -5.290CE-04 -5.010E-04	SENT 0. -1.1:2E+81 -1.021E+0U -1.793E-01 -1.730E-01 -7.244E-02 -5.476E-02 -4.795E-02 -3.134E-02 -1.031E-82 -2.770E-02 -1.497E-02 -7.994L-02 -7.994L-02 -3.665C-02 -9.977E-04					
SPCUP 1 2 3 4 5 6 7 8 9 0 11 12 3 4 5 6 7 8 9 0 11 12 3 4 5 6 7 8 9 0 11 12 3 4 5 6 7 8 9 0 11 12 3 4 5 6 7 8 9 0 11 12 3 4 5 6 7 8 9 11 12 3 4 5 6 7 8 9 11 12 3 4 5 6 7 8 9 11 12 3 4 5 6 7 8 9 11 12 3 4 5 6 7 8 9 11 11 11 11 11 11 11 11 11 11 11 11 1	UPPER-F(EV) 1.767:E+07 1.357:E+07 1.257:467 1.002407 7.7005407 6.675476 3.6365406 2.2527:456 1.732E+06 1.3534:65 8.2302+03 5.002E+05 3.0454:85 1.0454:85 6.7692404 9.1205403	DELTA-U 1.25E-01 1.07E-01 1.87E-01 2.56E-01 2.56E-01 2.56E-01 2.50E-01 2.50E-01 2.57E-0	SEN 0. 1.35GC+01 -1.35GC+01 -1.95G+00 -1.55GC+01 -1.045C+01 -7.0.55C-02 -5.3CGC+02 -3.1G5C+02 -3.1G5C+02 -1.CG4C+02 -2.71GC-02 -6.920C+03 -4.34GE+03 -5.29GC+04 -5.01CE+04 -2.090C+04	SENT 0. -1.1:22:401 -1.021E+0U -1.730E-01 -1.730E-01 -1.102E-01 -7.244-02 -5.134E-02 -3.476E-02 -1.631E-02 -1.631E-02 -1.631E-02 -1.631E-02 -1.631E-02 -1.631E-02 -3.655E-03 -9.976E-04 -3.632E-04					
Secur 1 2 3 4 5 6 7 8 9 11 12 13 14 15 16 17 18 19 20 	UPPER-F(EV) 1.760CE407 1.355C+87 1.2052+87 1.2052+87 1.2052+87 1.2052+87 1.2052+87 2.2552+86 2.2552+66 2.2552+66 1.3532+86 8.2302+83 3.67632+84 2.4032+84 9.1205+03 3.5502+03	DELTA-U 1.25E-01 1.07E-81 1.07E-81 1.02E-01 2.59E-01 2.59E-01 2.50E-01 2.50E-01 2.50E-01 2.50E-01 2.57E-01 2.57E-01 4.97E-01 4.97E-01 4.97E-01 4.97E-01 1.06E+00 1.06E+00 2.59E-01	SEN 0. 1.356C+01 -1.039C+001 -1.594L-01 -1.594L-01 -1.594L-01 -1.045C-01 -7.045C+02 -3.165C+02 -3.165C+02 -3.165C+02 -2.716C+02 -1.253E+02 -2.355E+00 -4.346E+05 -2.355E+05 -5.296C+04 -5.016E+04 -2.090C+04 -3.022E+04	SENT 0. -1.1:2E+81 -1.0:2E+01 -1.732E-01 -1.732E-01 -1.1:02E-01 -7.244E-02 -5.476E-02 -5.476E-02 -5.13:4E-02 -4.735E-02 -3.13:4E-02 -2.7705-02 -1.631E-02 -2.7705-02 -1.407E-03 -4.727E-03 -4.727E-03 -4.727E-03 -4.727E-03 -4.727E-04 -5.370E-04 -5.37					
SRCUP 1 2 3 4 5 6 7 8 9 10 11 12 3 4 5 6 7 8 9 10 11 2 3 4 5 6 7 8 9 10 11 2 3 4 5 6 7 8 9 10 11 2 3 4 5 6 7 8 9 10 11 2 3 4 5 6 7 8 9 10 12 3 4 5 6 7 8 9 10 12 3 4 5 6 7 8 9 10 12 3 4 5 6 7 8 9 10 12 3 4 5 6 7 8 9 10 11 2 3 4 5 6 7 8 9 10 11 2 3 4 5 6 7 8 9 10 11 2 3 4 5 6 7 8 9 10 11 2 3 4 5 6 7 8 9 10 11 2 3 4 5 6 7 8 9 10 11 2 3 4 5 10 10 11 2 3 4 5 10 10 10 10 10 10 10 10 10 10 10 10 10	UPPER-F(EV) 1.760-E407 1.557:507 1.257:407 1.202:407 1.202:407 1.202:407 2.252:476 2.252:466 1.355:465 8.230:405 1.252:40	DELTA-U 1.25E-01 1.07E-01 1.07E-01 2.59E-01 2.59E-01 2.59E-01 2.59E-01 2.59E-01 2.59E-01 2.59E-01 2.59E-01 2.57E-01 4.97E-01 4.97E-01 4.97E-01 4.97E-01 1.0E+00 1.0E+	SEN 0. 1.356E+01 -1.0359(±-01) -1.59(±-01) -1.0475E-01 -7.055L-02 -5.300E-02 -3.107E-02 -1.253E-02 -1.253E-02 -1.253E-02 -1.253E-02 -3.307E-03 -2.355E-03 -2.355E-03 -5.296E-04 -5.307E-04 -5.30	SENT 0. -1.1:2E+01 -1.793E-01 -1.739E-01 -1.739E-01 -1.102C-01 -7.244E-02 -5.476E-02 -4.705E-02 -3.134E-02 -1.697E-02 -1.697E-02 -7.904L-03 -4.727E-N3 -3.665C-03 -9.9767E-04 -6.370C-04 -3.632E-084 -3.52E-084					
SPC 1 2 3 4 5 6 7 8 9 10 12 13 4 5 6 7 8 9 10 12 13 4 5 6 7 8 9 10 12 12 3 4 5 6 7 8 9 10 12 12 3 4 5 6 7 8 9 10 12 12 3 4 5 6 7 8 9 10 12 12 3 4 5 6 7 8 9 10 11 12 3 4 5 6 7 8 9 10 11 12 3 4 5 6 7 8 9 10 11 12 13 4 5 6 7 8 9 10 11 12 13 14 5 10 11 11 11 11 11 11 11 11 11 11 11 11	UPPER-F(EV) 1.76°CE407 1.57°CE407 1.25°CE407 1.25°CE407 1.20°CE407 1.20°CE407 1.20°CE407 3.05°CE406 2.65°CE406 2.25°CE406 1.35°E405 1.35°E405 1.35°E405 3.0°CE405	DELTA-U 1.25E-01 1.07E-01 1.07E-01 1.82E-01 2.59E-01 2.59E-01 2.59E-01 2.59E-01 2.59E-01 2.59E-01 2.57E-01 4.97E-01 4.97E-01 4.97E-01 1.60E+00 1.60E+00 1.66E+00 1.66E+00 1.65E+01 1.66E+00 1.65E+01 1.66E+00 1.65E+01 1.65E+0	SEN 0. 1.256C+01 -1.039C+00 -1.594C+01 -1.594C+01 -1.594C+01 -1.047E+01 -7.055C+02 -3.167E+02 -3.167E+02 -1.253E+02 -6.920E+03 -2.355E+03 -5.294CE+04 -5.017E+04 -5.017E+04 -5.05E+05 -8.4706-05	SENT 0. -1.1:2E+81 -1.021E+0U -1.793E-01 -1.730E-01 -7.244E-02 -5.476E-02 -4.795E-02 -3.134E-02 -1.031E-82 -2.770E-02 -7.904L-02 -7.904L-02 -7.904L-02 -7.904L-02 -3.6656-02 -9.97/E-04 -3.632E-84 -3.632E-					
SP(J) 1 2 3 4 5 6 7 8 9 10 12 13 4 5 6 7 8 9 10 12 12 12 3 4 5 6 7 8 9 10 12 12 12 12 3 4 5 6 7 8 9 10 12 12 12 12 12 12 12 12 12 12	UPPER-F(EV) 1.760°E407 1.2005407 1.2005407 1.2005407 1.2005407 1.2005407 2.5076406 3.6365406 2.257456 1.353405 8.2307405 3.6576405 1.055405 3.6576404 1.055405 3.556403 3.556403 3.556403 3.556403 1.2354405 1.255405 3.556403 3.556403 1.255405	DELTA-U 1.25E-01 1.07E-01 1.87E-01 2.56E-01 2.56E-01 2.50E-01 2.50E-01 2.57E-01 2.57E-01 2.57E-01 2.57E-01 2.57E-01 2.57E-01 2.57E-01 3.50E-01 1.67E+00 1.66E+00 1.65E+0	SEN 0. 1.35GC+01 -1.35GC+01 -1.95G+00 -1.55GC+01 -1.95G+00 -3.05G+02 -5.30GE+02 -3.165C+02 -3.165C+02 -1.664G+02 -2.716E-02 -6.920E+03 -5.29GC+04 -5.920E+03 -5.29GC+04 -3.05E+05 -8.470L+05 -7.653U+05 -7.654U+05 -7.654U+05 -7.654U+05 -7.654U+05 -7.654U+05 -7.654U+05 -7	SENT 0. -1.1:2E+81 -1.602E+01 -1.733E-01 -1.733E-01 -7.244E-02 -5.4^6E-02 -5.4^6E-02 -5.134E-02 -4.705E-02 -3.134E-02 -2.7705-02 -1.631E-02 -2.7705-02 -1.631E-02 -2.7705-02 -1.631E-02 -3.6656-02 -9.977E-04 -6.370E-04 -3.6656-02 -9.977E-04 -3.632E-04 -1.2235E-04 -1.2					
SPC 12 3 4 5 6 7 8 9 0 11 12 3 4 5 6 7 8 9 0 11 12 3 14 5 6 7 8 9 0 11 12 3 14 15 6 7 8 9 0 12 22 22 22 22 22 22 22 22 22 22 22 22	UPPER-F(EV) 1.760°E407 1.557°E407 1.2025407 1.2025407 1.2025407 1.2025407 2.258°46 2.258°46 2.258°46 2.258°46 1.3554+05 8.2305405 8.2554+05 1.2554+05 1.2554+05 1.2554+05 1.2554+05 1.2554+03 1.2556+03 1.2566+0366+0366+0366+0366+0366+0566+0566+0	DELTA-U 1.25E-01 1.07E-81 1.1CE-01 2.59E-01 2.59E-01 2.59E-01 2.59E-01 2.50E-01 2.50E-01 2.50E-01 2.57E-01 2.57E-01 4.97E-01 4.97E-01 4.97E-01 1.67E+00 1.67E+0	SEN 0. 1.359(±+01) 1.59(±+01) 1.59(±+01) 1.59(±+01) 1.04(5)=01 7.0(5)(±-02) -3.10(5)=02 -3.10(5)=02 -4.73(6)=02 -1.66(4)=02 -2.710(±-02) -1.65(4)=02 -2.710(±-02) -2.35(2)=02 -3.35(2)=03 -2.35(2)=03 -3.35(2)=03 -3.35(2)=03 -3.42(2)=0	SENT 0. -1.1:2E+81 -1.021E+0U -1.793E-01 -1.730E-01 -1.102E-01 -7.244E-02 -5.476E-02 -4.705E-02 -3.134E-02 -4.705E-02 -2.7702-02 -1.407E-02 -2.7702-02 -1.407E-03 -3.665C-02 -4.727E-03 -3.665C-02 -9.97%E-04 -3.632E-04 -1.2255E-04 -1.025C-04 -1.025C-04					
SRUE 12345678901112314 112345678901112314 1123141567890112224 2245 226	UPPER-F(EV) 1.76°CE407 1.57°C5407 1.20°C2407 1.20°C2407 1.20°C2407 1.20°C2407 1.20°C2407 2.25°C406 2.25°C406 2.25°C406 2.25°C406 1.35°5405 8.25°C405 1.2°C405 1.2°C405 1.2°C405 1.25°	DELTA-U 1.25E-01 1.07E-01 1.07E-01 2.59E-01 2.59E-01 2.59E-01 2.59E-01 2.59E-01 2.59E-01 2.59E-01 2.57E-01 4.97E-01 4.97E-01 4.97E-01 1.08E+00 1.08E+00 1.66E+00 1.66E+00 1.62E+00 9.53E-01 1.05E+0	SEN 0. 1.35GE+01 -1.039E+00 -1.594E+01 -1.042E+01 -1.042E+01 -7.052E+02 -5.300E+02 -3.102E+02 -3.102E+02 -2.710E+02 -2.710E+02 -2.710E+02 -2.710E+02 -2.352E+03 -4.34CE+05 -2.352E+04 -3.05E+05 -3.452E+05	SENT 0. -1.1:2E+81 -1.4021E+0U -1.793E-01 -1.730E-01 -7.244E-02 -5.476E-02 -4.705E-02 -4.705E-02 -1.691E-02 -7.904C-03 -3.065C-03 -9.977C-04 -3.065C-03 -9.97C-04 -3.032E-04 -3.032E-04 -1.223E-04 -1.223E-04 -1.205C-					
50 12345678901123456789011234567 1111145167890017124567	UPPER-F(EV) 1.780°E407 1.2052+87 1.2052+87 1.2052+87 1.2052+87 1.2052+87 2.6552+06 2.2572+06 2.2572+06 1.3534+05 3.6752+86 2.2572+06 1.3534+05 3.6752+84 2.4752+84 2.4752+83 3.550E+03 1.2552+03 1.2552+03 1.2562+03 1.2562+03 3.5762+80 3.5762+8	DELTA-U 1.25E-01 1.07E-01 1.07E-01 1.25E-01 2.59E-01 2.59E-01 2.59E-01 2.59E-01 2.59E-01 2.57E-01 4.97E-01 4.97E-01 4.97E-01 4.97E-01 1.60E+00 1.60E+00 1.56E+00 1.56E+00 1.62E+0	SEN 0. 1.35GE+01 -1.039E+00 -1.59GE+01 -1.95GE+01 -1.95GE+01 -7.05SE-02 -5.30GE-02 -3.165E-02 -1.253E-02 -1.253E-02 -6.920E-03 -5.30GE-03 -5.30GE-03 -5.30GE-04 -5.016E-04 -5.05E-05 -6.470G-05 -7.639L-03 -5.942E-65 -3.427C-05 -0.652E-06 -3.427C-05 -0.652E-06 -3.427C-05	SENT 0. -1.1:2E+81 -1.021E+0U -1.793E-01 -1.730E-01 -7.244E-02 -5.476E-02 -4.795E-02 -3.134E-02 -1.031E-82 -2.770E-02 -7.9904_03 -3.6656-03 -9.977E-04 -3.6656-03 -9.977E-04 -3.632E-84 -3.632E-84 -2.097C-94 -1.223E-84 -1.225E-64 -1.024E-04 -1.024E-04 -1.024E-04 -2.9374E-05					
50 1 2 3 4 5 6 7 8 9 10 1 2 3 4 4 5 6 7 8 9 10 1 2 3 4 4 5 6 7 8 9 10 1 2 3 4 5 6 7 8 10 1 2 3 4 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	UPPER-F(EV) 1.760CE407 1.357C407 1.202407	DELTA-U 1.25E-01 1.07E-81 1.07E-81 1.07E-81 1.02E-01 2.59E-01 2.59E-01 2.59E-01 2.50E-01 2.50E-01 2.57E-01 2.57E-01 2.57E-01 2.57E-01 2.57E-01 2.57E-01 2.57E-01 1.02E+00 1.02E+00 1.02E+00 1.02E+00 1.02E+01 1.02E+0	SEN 0. 1.356E+01 -1.039E+001 -1.594E+01 -1.594E+01 -1.045E+01 -7.045E+02 -3.165E+02 -3.165E+02 -3.165E+02 -1.253E+02 -2.718E+02 -1.253E+02 -2.355E+02 -2.355E+02 -2.355E+02 -3.45E+05 -3.45E+05 -3.457E+05 -3.477E+05 -0.655E+05 -3.477E+05 -0.655E+05 -3.477E+05 -0.655E+05 -3.477E+05 -0.655E+05 -3.477E+05 -0.655E+05 -3.477E+05 -0.655E+05 -3.477E+05 -0.655E+05 -3.477E+05 -0.655E+05 -3.477E+05 -0.655E+05 -3.477E+05 -0.655E+05 -3.477E+05 -0.655E+05 -0.55E+0	SENT 0. -1.1:2E+81 -1.0:2E+801 -1.732E-01 -1.732E-01 -1.732E-01 -1.102E-01 -7.244E-02 -5.476E-02 -5.134E-02 -4.735E-02 -4.735E-02 -3.134E-02 -2.7705-02 -1.631E-02 -2.7705-02 -1.631E-02 -2.7705-02 -1.631E-02 -2.7705-02 -1.631E-02 -3.665E-03 -4.727E-03 -4.727E-03 -4.727E-03 -4.727E-03 -4.727E-03 -4.727E-04 -3.632E-04 -1.2352=04 -1.2352					
50 1 2 3 4 5 6 7 8 9 0 1 1 1 2 3 4 5 6 7 8 9 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	UPPER-F(EV) 1.760-E407 1.557:5407 1.2025407 1.2025407 1.2025407 1.2025407 2.257:476 2.257:477 2.257:4	DELTA-U 1.25E-01 1.07E-81 1.1CE-01 2.59E-01 2.59E-01 2.59E-01 2.59E-01 2.59E-01 2.59E-01 2.59E-01 2.59E-01 2.59E-01 2.57E-01 4.97E-01 4.97E-01 4.97E-01 4.97E-01 1.60E+00 1.66E+00 1.66E+00 1.66E+00 1.66E+00 1.66E+00 1.65E+00 1.55E+0	SEN 0. 1.359C+01 1.0359C+001 1.594C+01 1.045E+01 1.045E+01 1.045E+02 -3.105E+02 -3.105E+02 -3.105E+02 -1.664C+02 -2.710E+02 -1.253E+02 -2.355E+03 -5.320E+04 -3.025E+04 -3.025E+04 -3.025E+04 -3.025E+04 -3.025E+04 -3.025E+04 -3.025E+05 -3.427E+05 -3.457E+05 -	SENT 0. -1.1:2E+81 -1.021E+0U -1.793E-01 -1.730E-01 -7.244E-02 -5.476E-02 -3.134E-02 -4.735E-02 -3.134E-02 -1.691E-02 -2.770E-02 -1.497E-02 -2.770E-04 -3.665E-02 -9.977E-04 -3.665E-02 -9.977E-04 -3.632E-04 -1.225E-04 -1.025E-04 -1.025E-04 -1.025E-04 -3.215E-05 -3.215E-05 -3.215E-05 -1.039E-05 -2.039E-05 -2.039E-05 -3.215E-05 -1.039E-05 -2.039E-05 -1.039E-					
50 123456789811123456789011234567890 11123456789011234567890 111234567890 1123457890 1123457890 1123457890 1123457890 112345780 1123457890 112345780 1123457890 112345780 1123780 112345780 112345780 112345780 112345780 112345780 112345780 112345780 112345780 112345780 112345780 112345780 112345780 112345780 112345780 112345780 112345780 112345780 11235780 1125780 1125780 1125780 1125780 1125780 1125780 1125780 1125780 112578000000000000000000000000000000000000	UPPER-F(EV) 1.760-E407 1.557:5407 1.2557:407 1.2052:407 1.2052:407 1.2052:407 2.257:456 2.257:456 1.3557:456 8.2302:405 1.3557:456 8.2302:405 1.252:405 1.252:405 1.252:405 1.252:403 3.5502:403 3.5502:403 1.252:403 4.5402:401 2.252:403 1.252:4	DELTA-U 1.25E-01 1.07E-01 1.07E-01 1.42E-01 2.59E-01 2.59E-01 2.59E-01 2.59E-01 2.59E-01 2.59E-01 2.57E-01 4.97E-01 4.97E-01 4.97E-01 1.08E+00 1.68E+00 1.66E+00 1.65E+00 1.65E+01 1.65E+01 1.65E+01 1.65E+01 1.65E+00 1.65E+0	SEN 0. 1.35GE+01 -1.035E-01 -1.594E-01 -1.594E-01 -1.042E-01 -7.05SE-02 -5.300E-02 -3.102E-02 -1.253E-02 -1.253E-02 -2.710E-02 -1.253E-02 -2.352E-03 -4.34CE-05 -2.352E-04 -5.305E-05 -3.427E-05 -3.427E-05 -3.427E-05 -3.427E-05 -3.427E-05 -3.427E-05 -3.55E-05 1.037E-04	SENT 0. -1.1:2E+81 -1.021E+0U -1.739E-01 -1.739E-01 -1.102C-01 -7.244E-02 -5.476E-02 -4.705E-02 -3.134E-02 -1.691E-02 -2.770E-02 -1.497E-02 -7.904L-03 -4.727E-N3 -3.665C-03 -9.9747E-04 -3.632E-04 -1.223E-04 -1.223E-04 -1.024E-05 -3.215E-05 -1.039C-05 -2.032E-05 -2.052E-05 -2.052E-05 -2.052E-05 -2.052E-05 -2.052E					

CARTIAL AND HET SENSITIVITY PLOFILES PLR DLIA-U, HUC'SLIZED TO 11PH1 = (R,PH1) = 2.1047JE+U7 FOR NEUTRON INTERACTION COSS SECTIONS: (N-10) AND (N-GATAR)

TABLE VIIID: PARTIAL AND NET SENSITIVITY PROFILES FOR THE TWO-DIMENSIONAL ANALYSIS

The two second structure of the second structure for perturbed 20 K = 1 at the second structure for the second structure for perturbed to RR = (R.PH1) = 2.10592E+07 FOR REUTION INTERACTION CROSS SECTIONS: (N-N) AND (I-GAINA)

			sentation P II	PEIDS	с т ер м		Management 211	OF COIN TERMS	
COMP	HPPER-E(EV)	DEL TO-LI	AXS	100-F155	515	TAS	N-CAIN	N-GAIN(SFD)	NG-GOIN
1	1.7080487	1.25E-01	Ð.	0.	0.	e	8.	Ð.	ຄ.
ż	1.505E+87	1.01E-01	2.464E+00	ō.	-2.215E+01	-1.9CCE+01	8.452E+00	4.033E+00	ē.
3	1.350E+07	1.10E-01	1.797E-02	0.	-1.791E+08	-1.773E+60	7.523E-01	1.59JE+60	ō.
4	1.2065+07	1.02E-01	-1.977E-02	B.	-2.955E-01	-3.152E-01	1.365E-01	2.016E-01	0.
5	1.020E+07	2.SOE-01	-1.3C0E-02	0.	-3.399E-01	-3.537E-01	1.0020-01	3.1296-01	Ð.
6	7.799E+86	2.49E-81	-S.657E-03	0.	-2.662E-01	-2.7100-01	1.618E-01	2.4702-01	0.
7	6.8705+86	5.005-01	-1.77UE-03	Ð.	-2.4275-01	-2.445E-01	1.719E-01	2.3030-01	Ð.
8	3.6090+06	2.566-01	-9.5400-04	θ.	-2.8640-01	-2.8745-01	2.321E-01	2.055E-01	Ð.
9	2.CG5E+0G	2.\$CE-01	-S.809E-U4	в.	-3.594E-01	-3.600E-01	3.111E-01	3.68YE-01	Ð.
10	2.232E+€6	2.566-01	-3.073E-04	θ.	-3.401E-01	-3.404C-01	3.15%C-01	3.GG3E-01	0.
11	1.73CE+06	2.500-01	-2.624E-04	Ð.	-3.711E-01	-3.714E-01	3.511E-01	3.90CE-01	0.
12	1.3536.405	4.97E-81	-5.92-IE-U4	ย.	-4.508E-01	-4.59-IE-01	4.301L-01	4.9790-01	Ð.
13	8.2395405	4.986-01	-1.509E-03	ย.	-6.500L-01	-6.992E-01	5.03GE-01	7.5636-01	0.
14	3.100E-05	5.012-01	-1.0326-03	U.	-1.04/2-01	-1.0535-01	7.521E-01	0.0420-01	ย.
13	1 0415-05	4.9_0-01	-6.0515-04	υ. Α	-7.9400-01	-2.0202-01	1.00000-01	2.0196-01	U.
10	6 7605404	1.0000000	-0.0010-04	ρ.	-3 1966-01	-3 2005-01	3 1912-01	3.0202-01	0.
10	2 4000-004	1 656+09	-5 7996-65	ວ. ກ	-2 6030-02	-2 6000-07	1 9,152-62	2 0170-02	0.
19	9,1255:03	1.0. E+03	-7.097E-05		-4.6047-62	-4.0316-02	4.6525-02	4.6000-02	D .
20	3.500E+93	9,935-01	-1.022E-05	Ð.	-2.3966-62	-2.0926-02	2.360F-62	2.30 F-02	<u>я.</u>
21	1.2356:03	1.066+03	-2.503E-04	ũ.	-1.4%CE-62	-1.502E-02	1.4325-02	1.425E-02	Ð.
22	4.54/E+02	1.0CE+03	-3.72GE-05	Ð.	-1.6455-02	-1.6400-02	1.6370-02	1.64SE-02	0 .
23	1.6705.32	1.005+03	-4.G20E-05	Ð.	-1.350E-02	-1.362E-02	1.3516-02	1.3G1E-02	ō.
24	6.14GE 101	9.99E-01	-5.0102-05	υ.	-1.012E-02	-1.01CE-02	1.007E-02	1.01CE-02	0.
25	2.2CCE+01	9.925-01	-6.727E-05	Ð.	-6.927E-63	-6.904E-03	6.0052-63	6.907E-03	ė.
26	8.3205+03	1.005+00	-7.027E-US	Ð.	-4.3-00-03	-4.41CL-03	4.3-11E-63	4.412E-03	0.
27	3.8605+60	9.505-01	-6. 646E-05	Ð.	-2.496E-03	-2.5620-03	2.5096-03	2.95CE-03	Ð.
20	1.130E+DB	1.055400	-5.7202-05	0.	-1.30.12-03	-1.331E-03	1.320E-63	1.359E-03	θ.
29	4.140E-01	1.CCE+33	-4.45.IE-05	Ð.	-6.11CE-04	-6.SCIC-04	6.357C-04	6.SG1E-04	Ð.
30	1.520E-01	1.11E+00	-2.02ZE-04	θ.	-9.995E-04	-1.202E-03	1.16%E-03	1.181E-03	Ð.
INTER	DAI		2 4705-01		-5 9415 109	-4 7075+00	7 2765+60	7 2755400	
11120			2.4/92-01	0.	-2.0412100	-4.732700	3.2136700	3.2732400	0.
			REPORT NET PR	OFILES HONOR					
GROUP	UPPER-E(EV)	DEL TA~U	SEN	SENT					
GROUP 1	UPPER-E(EV) 1.700E+07	DEL TA-U 1.25E-01	NORT HET PR SEN B.	OFILES SOURT SENT B.					
GROUP 1	UPPER-E (EV) 1.700E+07	DEL TA-U 1.25E-01	SEN	SENT					
GROUP 1 2	UPPER-E(EY) 1.700E+07	DEL TA~U 1.25E-01 1.05E-01	BODE 1(ET PF SEN B. -1.3G9C+01	80F1LES #000# SENT 8. -1.123E+01					
GROUP 1 2 3	UPPER-E(EV) 1.700E+07 1.500E+07 1.355E+07	DELTA-U 1.25E-01 1.05E-01 1.102-01	#PAPF# I(ET PF SEN 8. -1.3G9E+01 -1.U72E+00	SENT 8. -1.123E+01 -1.021E+00					
GROUP 1 2 3 4	UPPER-E(EV) 1.700E+07 1.335E+07 1.2545-107	DEL TA-U 1.25E-01 1.05E-01 1.105-01 1.627-01	1.309C+01 -1.079C+01 -1.509C+01 -1.509C-01	CF1LES ***** SENT 6. -1.123E+01 -1.021E+00 -1.707E-01 -1.707E-01					
GROUP 1 2 3 4 5 6	UPPER-E(EV) 1.780E+07 1.335E+07 1.25*£+07 1.605E+07 2.790E+06	DELTA-U 1.25E-01 1.05E-01 1.025-01 1.625-01 2.56E-01	1.309C+01 -1.309C+01 -1.002C+00 -1.002C+00 -1.500E-01 -1.900E-01	CF1LES ***** SENT 6. -1.123E+01 -1.021E+00 -1.707E-01 -1.734E-01 -1.734E-01					
GROUP 1 2 3 4 5 6 7	UPPER-E (EV) 1.700E+07 1.500E+07 1.335E+07 1.25*A+07 1.6095+07 7.708E+06 6.021E+66	DELTA-U 1.25E-01 1.05E-01 1.105-01 1.827-01 2.56E-01 2.47E-01 2.60E-01	804022 HET PF SEN 8. -1.369C+01 -1.079C400 -1.509C-01 -1.506E-01 -1.04-IE-01 -2.6016-03	CF1LES ***** SENT 6. -1.123E+01 -1.021E+00 -1.707E-01 -1.7034E-01 -1.101E-01 -2.755E-02					
GROUP 1 2 3 4 5 6 7 0	UPPER-E (EV) 1.700E+07 1.500E+07 1.255:A107 1.255:A107 1.6035:407 7.706E+06 6.07(E+06 6.07(E+06	DELTA~U 1.25E-01 1.05E-01 1.027-01 1.527-01 2.5/E-01 2.47E-01 5.00E-01 2.50E-01	804021 HET PF SEN 8. -1.369C+01 -1.079C400 -1.509C-01 -1.509C-01 -1.044E-01 -7.601E-02 -5.601E-02	COFILES source SENT 8. -1.123E+001 -1.021E+00 -1.707C-01 -1.707K-01 -1.101E-01 -7.259E-02 -5.251E-02					
GROUP 1 2 3 4 5 6 7 0 9	UPPER-E(EV) 1.700E+07 1.355E+07 1.355E+07 1.25+6+07 1.6695E+07 1.6695E+07 7.710E+06 6.07(E+06 3.669:E+06	DEL TA~U 1.25E-01 1.05E-01 1.052:-01 1.627:-01 2.57E-01 2.47E-01 2.56E-01 2.56E-01	BRACE HET PR SEN 8. -1.369C+01 -1.079E460 -1.500E-01 -1.500E-01 -7.601E-02 -5.4332-02 -4.037E-02	80F1LES source SENT 8. -1.123E+01 -1.021E+00 -1.70TC-01 -1.7034E-01 -7.259E-02 -5.031E-02 -4.0916-02					
GROUP 1 2 3 4 5 6 7 9 18	UPPER-EKEY) 1.700E+07 1.355E+07 1.2545+07 1.2095+07 7.700E+06 6.070E+06 3.60%E+06 2.255E+06	DELTA-U 1.25E-01 1.05E-01 1.62E-01 1.62E-01 2.56E-01 2.56E-01 2.56E-01 2.56E-01 2.59E-01 2.59E-01	BOARCE HET PF SEN B. -1.369C+01 -1.UD2E460 -1.SUUE-01 -1.SUUE-01 -1.SUUE-01 -1.644E-01 -7.601E-02 -5.435E-02 -4.032E-62 -3.226E-02	80F1LES sched SENT 8. -1.123E+01 -1.021E+00 -1.707T-01 -1.707T-01 -1.707T-01 -1.707E-01 -2.559E-02 -3.551E-02 -3.257E-02					
GRDUP 1 2 3 4 5 6 7 8 9 16 11	UPPER-E(EY) 1.708E+07 1.500E+07 1.335E+07 1.6005+07 7.770E+06 6.070E+06 6.070E+06 2.055E+06 2.232E+05 1.733E+86	DELTA-U 1.25E-01 1.05E-01 1.102-01 1.627-01 2.56E-01 2.56E-01 2.50E-01 2.50E-01 2.59E-01	8000CF 11ET PF SEN 8. -1.369C+01 -1.079C+00 -1.50/2C-01 -1.04/IE-01 -7.601E-02 -5.433E-02 -4.032E-02 -3.220E-02 -2.007E-02	ROF1LES ROMAN SENT 8. -1.123E+01 -1.021E+00 -1.707E-01 -1.704E-01 -7.259E-02 -3.5531E-02 -3.257E-02 -2.034E-62					
GROUP 1 2 3 4 5 6 7 8 9 18 11 12	UPPER-E(EV) 1.700E+07 1.500E+07 1.350E+07 1.600E+07 1.600E+06 6.07(E+06 3.600E+06 2.050E+06 2.252E+06 1.733E+06	DELTA-U 1.25E-81 1.05E-81 1.10:2-61 1.527-61 2.57C-01 2.57C-01 2.59C-01 2.59C-01 2.59C-01 2.59C-01 2.59C-01 2.59C-01	BRACE HET PF SEN 8. -1.369C+01 -1.079C460 -1.5UJC-01 -1.5UJC-01 -1.5UGC-01 -2.601C-U2 -3.433U-02 -4.032C-02 -3.226E-02 -2.2007E-02	CF1LES #000# SENT 8. -1.021E+01 -1.754E-01 -1.707C-01 -1.707C-01 -1.101E-01 -7.259E-02 -5.531E-02 -3.257E-02 -2.034E-02 -2.927E-02					
GRDUP 1 2 3 4 5 6 7 8 9 16 11 12 13	UPPER-E(EY) 1.700E+07 1.335E+07 1.254:407 1.254:407 1.204:407 7.708E+06 6.071E+66 3.6016+66 2.252E+03 1.730E+06 1.730E+06 1.353E+06 0.226E+05	DELTA-U 1.25E-01 1.05E-01 1.025:-01 2.57(E-01 2.47E-01 5.06E-01 2.56E-01 2.50E-01 2.50E-01 4.97E-01	Energy HET PF SEN 6. -1.369C+01 -1.UD9E460 -1.SU9E-01 -1.SU9E-01 -7.601E-02 -5.433E-02 -4.032E-02 -3.226E-02 -2.U07E-02 -2.2007E-02 -2.2007E-02	SENT 8. -1.123E+01 -1.021E+01 -1.70TC-01 -1.70TC-01 -1.70TC-01 -1.70TE-02 -3.257E-02 -3.257E-02 -2.034E-02 -2.927E-02 -1.50EE-02					
GROUP 1 2 3 4 5 5 6 7 0 9 10 11 12 13 13 14	UPPER-E(EY) 1.700E+07 1.335E+07 1.254:407 1.6015+07 1.6015+07 7.770E+06 6.071E+06 3.601%+66 2.055E+06 2.252E+05 1.733E+86 1.353E+06 8.236E+05 5.6045+85	DELTA-U 1.25E-01 1.05E-01 1.027-01 2.57E-01 2.57E-01 2.56E-01 2.59E-01 2.59E-01 4.97E-01 4.97E-01 4.97E-01	EXAMPLE 11ET PR SEN 8. -1.369C+01 -1.079C460 -1.500E-01 -1.041E-01 -7.601E-02 -4.032E-02 -4.032E-02 -3.220E-02 -2.007E-02 -2.00E-02 -1.417E-02 -0.197E-03	CF1LES SCHOOL SENT 8. -1.123E+01 -1.021E+00 -1.707E-01 -1.707E-01 -1.704E-01 -7.259E-02 -3.257E-02 -2.034E-02 -2.927E-02 -1.560E-02 -9.224E-03					
GROUP 1 2 3 4 5 6 7 0 9 18 11 12 13 14 14 15	UPPER-E(EY) 1.700E+07 1.500E+07 1.2516+07 1.2516+07 1.0605E+07 1.0605E+07 1.0605E+06 3.05016+06 3.05016+06 2.252E+06 1.553E+06 0.236E+06 0.236E+05 5.007E+05	DELTA-U 1.25E-01 1.05E-01 1.10:2-01 1.627-01 2.57E-01 2.57E-01 2.59E-01 2.59E-01 2.59E-01 4.97E-01 5.01E-01	BRACE HET PF SEN 8. -1.369C+01 -1.0792460 -1.500E-01 -1.500E-02 -5.4330E-02 -4.032E-02 -3.226E-02 -2.007E-02 -2.006E-02 -1.417E-02 -0.197E-03 -4.5722E-03	CF1LES #000# SENT 8. -1.021E+00 -1.70TC-01 -1.70TC-01 -1.70TC-01 -1.101E-01 -7.259E-02 -5.531E-02 -3.257E-02 -2.927E-02 -1.560E-02 -9.224E-03					
GROUP 1 2 3 4 5 6 7 7 8 9 9 10 11 12 13 14 12 13 16	UPPER-E(EY) 1.700E+07 1.355E+07 1.25*£+07 1.25*£+07 1.25*£+07 1.20*2+07 1.20*2+07 1.20*2+07 2.252E+06 2.252E+06 1.73*2+86 1.73*2+86 1.553E+06 8.23*C+05 5.07*E+05 3.000E+05 1.0*7*E+05	DELTA-U 1.25E-01 1.05E-01 1.62E-01 2.57E-01 2.57E-01 2.57E-01 2.56E-01 2.59E-01 2.59E-01 4.97E-01 5.01E-01 1.0EE+00	BONCK HET PR SEN 0. 1.369C+01 -1.079E460 -1.509E-01 -1.509E-01 -1.04HE-01 -7.601E-02 -3.226E-02 -2.067E-02 -2.067E-02 -2.067E-02 -2.067E-02 -2.625E-03	CF1LES SCHOOL SENT 8. -1.123E+001 -1.021E+000 -1.707E-011 -1.707E-01 -1.707E-02 -3.257E-02 -2.034E-02 -2.034E-02 -1.500E-02 -3.214E-03 -4.944E-03 -3.314E-03					
GROUP 1 2 3 4 5 5 6 7 8 9 10 11 12 13 14 15 15 15 16 17	UPPER-E(EY) 1.700E+07 1.335E+07 1.254:407 1.254:407 1.2695+07 7.770E+06 6.071E+06 6.071E+06 2.055E+06 2.252E+06 2.252E+06 1.353E+06 8.253E+06 8.253E+06 8.253E+05 5.097E+05 3.055E+05 1.057E+05 3.055E+05	DELTA-U 1.25E-01 1.05E-01 1.027-01 2.57E-01 2.57E-01 2.56E-01 2.59E-01 4.97E-01 4.97E-01 4.97E-01 4.97E-01 1.0EE+00 1.0EE+00 1.0EE+00	BOARCE HET PR SEN 8. -1.369C+01 -1.079C460 -1.509C400 -1.509C400 -1.509C400 -1.499C400 -1.509C401 -7.601C-02 -1.601C-02 -3.220E-02 -2.007E-02 -2.007E-02 -1.417E-02 -4.572C-03 -2.625C-03 -5.4455-04	CF1LES SCHOOL SENT 8. -1.123E+001 -1.021E+000 -1.707E-01 -1.707E-01 -1.704E-01 -7.259E-02 -3.257E-02 -2.034E-02 -2.927E-02 -1.560E-02 -9.224E-03 -9.219E-03 -9.719E-04					
GROUP 1 2 3 4 5 6 7 9 10 11 12 13 14 15 16 17 18	UPPER-E(EY) 1.700E+07 1.500E+07 1.355E+07 1.251A+07 1.0005E+07 1.0005E+07 1.0005E+07 1.0005E+06 2.055E+06 2.055E+06 2.252E+06 1.553E+06 0.253E+06 0.253E+06 0.253E+06 0.253E+05 3.000E+05 1.0-7E+05 3.020E+05 1.0-7E+05 1.0005E+07 1.251A+07 1.252E+05 1.730E+05 1.553E+05 1.552E+05 1.55	DELTA-U 1.25E-81 1.05E-81 1.10:2-61 1.527-61 2.57E-81 2.57E-81 2.57E-81 2.59E-81 2.59E-81 2.59E-81 4.97E-81 4.97E-81 5.01E-01 1.00:E408 1.00:E408 1.00:E408 1.00:E408	BRACE HET PF SEN 8. -1.3692+01 -1.0792460 -1.5002-01 -1.5002-01 -1.5002-02 -3.43302-02 -3.2262-02 -3.2262-02 -2.0072-02 -2.0072-02 -1.4172-02 -0.1912-03 -4.5722-03 -5.6732-04	CF1LES CONT SENT 8. -1.021E+00 -1.70T-01 -1.734E-01 -1.70T-01 -1.101E-01 -7.259E-02 -5.531E-02 -3.257E-02 -3.257E-02 -2.927E-02 -3.257E-02 -1.560E-02 -9.224E-03 -3.314E-03 -3.719E-04 -6.21-1E-04					
GROUP 1 2 3 4 5 5 6 7 9 1 6 9 1 1 1 1 2 1 1 1 1 2 1 1 1 1 1 2 1 1 1 2 3 4 5 5 6 7 0 9 1 1 1 2 3 4 5 5 7 1 1 2 3 4 5 7 7 1 1 2 3 7 6 7 7 9 1 1 2 3 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7	UPPER-E(EY) 1.700E+07 1.355E+07 1.254:407 1.254:407 1.2052+07 7.708E+06 6.071E+06 6.071E+06 2.252E+06 1.732E+06 1.232E+06 1.242E+05	DELTA-U 1.25E-01 1.05E-01 1.62E-01 1.62E-01 2.57(E-01 2.57(E-01) 2.57(E-01) 2.57(E-01) 2.57(E-01) 2.59(E-01) 4.97(E-01) 4.97(E-01) 4.97(E-01) 4.92(E	BONCK HET PR SEN 6. -1.369C+01 -1.079E460 -1.509E-01 -1.404E-01 -7.601E-02 -5.435E-02 -4.032E-02 -2.067E-02 -2.067E-02 -2.067E-02 -3.226E-03 -4.572E-03 -5.4455-04 -5.6732E-04 -2.612E-04	ROF1LES RENT SENT 8. -1.123E+01 -1.021E+00 -1.707E-01 -1.707E-01 -7.754E-01 -1.101E-01 -7.259E-02 -3.531E-02 -3.531E-02 -2.034E-02 -2.034E-02 -3.314E-03 -4.0944E-03 -3.314E-03 -9.944E-03 -3.314E-03 -9.7192-04 -3.3252E-04					
GROUP 1 2 3 4 5 6 7 0 9 16 11 12 13 14 15 16 17 19 20 27 27 27 27 27 27 27 27 27 27	UPPER-E(EY) 1.700E+07 1.335E+07 1.254:407 1.254:407 1.2692+07 7.770E+06 6.071E+06 3.60%+66 2.252E+06 2.252E+06 2.252E+06 1.353E+06 8.236E+06 8.236E+05 3.055E+05 1.077E+03 3.335E+05 3.335E+05 3.355E+05 3.355E+05	DELTA-U 1.25E-01 1.05E-01 1.025-01 2.57E-01 2.57E-01 2.57E-01 2.57E-01 2.57E-01 4.97E-01 4.97E-01 4.97E-01 4.97E-01 1.0EE+00 1.05E+00 1.05E+00 1.05E+00 1.05E+00 9.97E-01	BOARCE HET PR SEN 8. -1.369C+01 -1.079C460 -1.509C400 -1.509C400 -1.509C400 -1.509C400 -1.509C400 -1.492C400 -2.601C-02 -2.007C402 -2.007C402 -2.007C402 -2.007C402 -2.007C402 -2.007C402 -2.007C402 -3.020C402 -3.417C+02 -3.54455C+04 -5.673E+04 -5.673E+04 -2.619E+04 -3.010E+04 -3.010E+04	CF1LES CONT SENT 8. -1.123E+01 -1.021E+00 -1.707E-01 -1.707E-01 -1.704E-01 -7.259E-02 -3.257E-02 -3.257E-02 -1.364E-02 -2.034E-02 -2.034E-02 -3.257E-02 -1.364E-03 -9.719E-04 -6.21.4E-04 -3.325C-04 -3.222E-04					
GROUP 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 21 21 21 21 22 23 24 25 25 25 25 25 25 25 25 25 25	UPPER-E(EY) 1.700E+07 1.500E+07 1.251A+07 1.251A+07 1.0005+07 1.0005+07 1.0005+07 1.0005+07 1.0005+07 1.0005+07 1.252E+06 2.252E+06 2.252E+06 2.252E+06 1.553E+06 8.250E+05 1.057E+05 3.050E+04 9.120E+04	DELTA-U 1.25E-01 1.05E-01 1.1027-01 2.57E-01 2.57E-01 2.59E-01 2.59E-01 2.59E-01 2.59E-01 4.97E-01 4.97E-01 4.97E-01 1.05E+00 1.65E+	BRACK HET PF SEN 8. -1.3692+01 -1.0792460 -1.5002-01 -1.5002-01 -1.5002-02 -3.4332-02 -4.0322-02 -3.2202-02 -2.007E-02 -2.2002-02 -1.417E-02 -3.2202-03 -2.6252-03 -2.6252-03 -2.6352-04 -3.0.002-04 -3.0.002-04 -3.0.002-04	SENT 8. -1.123E+01 -1.021E+00 -1.707C-01 -1.707C-01 -1.707E-01 -1.101E-01 -7.259E-02 -3.257E-02 -3.257E-02 -3.257E-02 -3.257E-02 -3.257E-02 -3.257E-02 -3.257E-02 -3.314E-03 -3.314E-03 -3.314E-03 -3.314E-03 -3.314E-03 -3.252E-04 -5.222E-04 -5.225E-04					
GROUP 1 2 3 4 5 6 7 8 9 16 6 7 11 12 13 14 15 16 17 18 19 20 21 22 22 23	UPPER-E(EY) 1.700E+07 1.355E+07 1.254:407 1.254:407 1.254:407 1.205:407 7.708E+06 6.071E+06 2.055E+06 1.733E+06 1.733E+06 0.232E+05 1.733E+06 0.232E+05 3.000E+05 3.000E+05 3.000E+05 3.000E+05 3.000E+05 3.000E+05 3.000E+05 3.000E+05 3.000E+05 3.000E+05 1.275E+03 3.575E+03 4.555E+02	DELTA-U 1.25E-01 1.25E-01 1.62E-01 1.62E-01 2.57(E-01 2.57(E-01) 2.57(E-01) 2.57(E-01) 2.57(E-01) 2.57(E-01) 2.57(E-01) 4.97(E	BONCK HET PR SEN 8. -1.369C+01 -1.0792460 -1.509E-01 -1.509E-01 -1.390E-01 -1.404E-01 -7.601E-02 -3.226E-02 -2.007E-02 -2.007E-02 -2.007E-02 -3.226E-03 -2.625E-03 -5.445E-04 -2.615E-04 -3.0:0E-04 -3.0:0E-04 -7.725E-05	CF1LES SCHOOL SENT 8. -1.123E+01 -1.021E+00 -1.707E-01 -1.707E-01 -1.707E-01 -7.259E-02 -3.257E-02 -3.257E-02 -3.257E-02 -3.257E-02 -3.257E-02 -3.224E-03 -4.091E-02 -3.224E-03 -4.944E-03 -3.224E-03 -3.214E-04 -3.252E-04					
GROUP 2 3 4 5 6 7 9 10 11 12 13 14 15 16 17 19 20 21 22 23 24	UPPER-E(EY) 1.700E+07 1.335E+07 1.254:407 1.254:407 1.254:407 1.254:407 1.254:407 1.254:407 1.254:407 2.055E+07 2.252E+05 2.252E+05 2.252E+05 1.353E+05 3.050E+05 1.077E+03 3.335E+03 1.255E+05	DELTA-U 1.25E-01 1.102-01 1.62E-01 2.57E-01 2.57E-01 2.57E-01 2.56E-01 2.56E-01 2.57E-01 4.97E-01 4.97E-01 4.97E-01 1.07E+00 1.69E+0	BOACH 11ET PF SEN SEN C C SEN C C SEN C SEN C SEN C C SEN SEN C SEN S	CF1LES CONT SENT 8. -1.123E+01 -1.021E+00 -1.707E-01 -1.707E-01 -1.704E-01 -7.259E-02 -3.257E-02 -3.257E-02 -2.034E-02 -3.257E-02 -1.364E-02 -3.257E-02 -1.364E-03 -9.719E-04 -6.21.4E-03 -9.719E-04 -3.325C-04 -3.222E-04 -1.163E-04 -1.163E-04 -1.163E-04					
GROUP 2 3 4 5 6 7 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 24 22 23 24 24 22 23 24 24 24 25 25 25 25 25 25 25 25 25 25	UPPER-E(EV) 1.700E+07 1.500E+07 1.251A+07 1.251A+07 1.6005+07 1.6005+07 1.6005+07 1.6005+07 2.252E+06 2.252E+06 2.252E+06 2.252E+06 1.533E+06 0.253E+06 0.253E+06 1.535E+05 1.057E+05 1.057E+03 1.275E+05	DELTA-U 1.25E-01 1.05E-01 1.62E-01 2.57E-01 2.57E-01 2.57E-01 2.57E-01 2.57E-01 2.57E-01 4.97E-01 4.97E-01 1.07E+00 1.07E+0	BOARCY HET PF SEN 8. -1.3692+01 -1.0792460 -1.5092-01 -1.5092-01 -1.3002-01 -1.041E-01 -7.601E-02 -4.032E-02 -2.067E-02 -2.067E-02 -1.417E-02 -3.252E-03 -2.6252-03 -2.635E-04 -3.050E-04 -3.050E-05 -7.725E-05 -7.005E-05 -7.005E-05 -3.1175-05	SENT 8. -1.123E+001 -1.021E+001 -1.707C-01 -1.707C-01 -1.707E-01 -1.101E-01 -7.259E-02 -3.257E-02 -3.257E-02 -3.257E-02 -3.257E-02 -2.9224E-03 -3.314E-03 -3.314E-03 -3.314E-03 -3.314E-03 -3.314E-04 -3.225C-04 -3.225C-04 -3.225C-04 -1.162E-04 -1.162E-04 -1.162E-04					
GROUP 1 2 3 4 5 6 7 0 9 16 6 7 0 9 16 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 25 25 25 25 25 25 25 25 25	UPPER-E(EY) 1.700E+07 1.355E+07 1.254.407 1.254.407 1.254.407 1.2052+07 7.708E+06 6.071E+06 2.055E+06 1.733E+06 0.232E+05 1.733E+06 0.232E+05 1.733E+06 0.232E+05 3.055E+03 3.575E+03 3.575E+03 4.545E+01 2.276E+01 2.276E+01 2.276E+01 2.276E+01 2.276E+01	DELTA-U 1.25E-81 1.102-61 1.622-81 2.57(-0) 2.57(-0) 2.57(-0) 2.57(-0) 2.57(-0) 2.57(-0) 2.57(-0) 2.57(-0) 2.57(-0) 2.57(-0) 2.57(-0) 2.57(-0) 4.97(-0) 4.97(-0) 4.97(-0) 4.97(-0) 4.97(-0) 4.97(-0) 4.97(-0) 4.97(-0) 4.97(-0) 4.97(-0) 4.97(-0) 4.97(-0) 4.97(-0) 4.97(-0) 4.97(-0) 4.97(-0) 4.97(-0) 1.012(-0) 1	BONCK HET PR SEN 8. -1.369C+01 -1.0792460 -1.509E-01 -1.509E-01 -1.404E-01 -7.601E-02 -3.226E-02 -2.007E-02 -2.007E-02 -2.007E-02 -3.226E-03 -2.625E-03 -5.445E-04 -5.673E-04 -5.673E-04 -5.673E-04 -5.673E-04 -5.445E-04 -5.673E-05 -7.725E-05 -7.725E-05 -3.114/E-05 -3.114/E-05	CF1LES SCHORT SENT 8. -1.123E+01 -1.021E+00 -1.707E-01 -1.707E-01 -1.707E-01 -7.34E-01 -1.101E-01 -7.359E-02 -3.531E-02 -3.531E-02 -3.531E-02 -3.257E-02 -3.314E-03 -9.24E-03 -3.314E-03 -9.719E-04 -3.325E-04 -3.325E-04 -3.255E-04 -3.255E-04 -3					
GROUP 1 2 3 4 5 6 7 9 10 11 12 13 14 15 16 17 18 20 21 22 23 24 25 26 27 27 27	UPPER-E(EV) 1.700E+07 1.500E+07 1.2012+07 1.2012+07 1.2012+07 1.2012+07 1.2012+07 1.2012+07 1.2012+07 2.0012+07 2.0012+07 2.0012+06 1.353E+06 0.2230E+06 0.230E+05 3.000E+05 1.0012+05 1.0012+05 1.2012+01 2.2012+01 0.1202+01 0.2012+05 0.2012+01 0.2012+00 0.2012+00 0.2012+00 0.2012+00 0.2012+00 0.2012+00 0.2012+0	DELTA-U 1.25E-01 1.25E-01 1.62E-01 2.57E-01 2.57E-01 2.57E-01 2.57E-01 2.57E-01 2.57E-01 4.97E-01 4.97E-01 4.97E-01 1.07E+00 1.69E+00 1.69E+00 1.69E+00 1.69E+03 9.96E-01 1.07E+03 9.92E-01 1.07E+03 1.07E+0	BOARCE HET PF SEN 8. -1.369C+01 -1.0792460 -1.509C+01 -1.509C+01 -1.509C+01 -1.404E-01 -7.601E-02 -4.032E-02 -2.007E-02 -2.007E-02 -1.417E-02 -3.220E-03 -5.455C-03 -5.455C-03 -5.455C-04 -5.005E-04 -5.005E-04 -5.005E-04 -5.005E-04 -5.005E-05 -7.725E-05 -7.005E-05 -3.114E-05 -6.5224E-05 -3.24456-04	CF1LES CONT SENT 8. -1.123E+01 -1.021E+00 -1.707E-01 -1.707E-01 -1.704E-01 -7.259E-02 -3.257E-02 -3.257E-02 -2.034E-02 -2.034E-02 -2.034E-02 -3.257E-02 -1.166E-02 -3.257E-02 -1.266E-02 -3.257E-02 -1.266E-02 -3.257E-02 -1.266E-02 -3.257E-02 -1.266E-02 -3.252E-04 -3.252E-04 -1.165E-04 -1.165E-04 -3.172E-04 -5.372E-05 -7.675E-05					
GROUP 1 2 3 4 5 6 7 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 26 27 20 27 20 20 20 20 20 20 20 20 20 20	UPPER-E(EV) 1.700E+07 1.500E+07 1.25%407 1.25%407 1.25%407 1.6005+07 1.6005+07 1.6005+07 1.6005+06 2.252E+06 0.252E+06 0.252E+06 0.252E+06 0.252E+06 0.252E+06 0.252E+06 0.252E+06 0.252E+06 0.252E+06 1.532E+06 1.500E+05 1.070E+03 1.2755+05 1.2755+05 1.2555+05 1	DELTA-U 1.25E-01 1.62E-01 1.62E-01 2.57E-01 2.57E-01 2.57E-01 2.57E-01 2.57E-01 2.57E-01 4.97E-01 4.97E-01 4.97E-01 1.07E+00 1.67E+0	BRACK HET PF SEN 8. -1.369C+01 -1.0792460 -1.509E-01 -1.509E-01 -7.601E-02 -7.601E-02 -3.220E-02 -3.220E-02 -2.067E-02 -2.067E-02 -2.067E-02 -3.220E-02 -1.417E-03 -2.635E-04 -5.673E-04 -5.673E-04 -5.673E-04 -5.673E-04 -3.00E-05 -7.725E-05 -7.725E-05 -7.005E-05 -3.115E-05 -3.115E-05 -3.215E-05 -5.455E-05 -5.455E-05 -5.255E-05 -5	SENT 8. -1.123E+001 -1.021E+00 -1.707E-01 -1.707E-01 -1.707E-01 -1.707E-01 -7.259E-02 -3.257E-02 -3.257E-02 -3.257E-02 -3.257E-02 -3.257E-02 -3.257E-02 -3.257E-02 -3.257E-02 -3.257E-02 -3.257E-02 -3.252E-04 -3.325E-04 -3.225E-04 -3					
GROUP 1 2 3 4 5 5 6 7 0 9 16 6 7 0 9 16 11 12 13 14 15 16 17 18 19 20 21 22 22 22 22 22 22 22 22 22	UPPER-E(EY) 1.700E+07 1.355E+07 1.254.407 1.254.407 1.254.407 1.2052+07 7.708E+06 6.071E+06 2.055E+06 1.733E+06 0.232E+05 1.733E+06 0.232E+05 1.733E+05 3.002E+05 3.002E+05 3.052E+03 3.3576E+03 3.3576E+01 2.276E+01 2.276E+01 3.654E+09 1.1274E+01	DELTA-U 1.25E-81 1.25E-81 1.102-61 1.622-81 2.57(-0) 2.57(-0) 2.57(-0) 2.57(-0) 2.57(-0) 2.57(-0) 2.57(-0) 2.57(-0) 2.57(-0) 2.57(-0) 4.97(-0) 4.97(-0) 4.97(-0) 4.97(-0) 4.97(-0) 4.97(-0) 4.97(-0) 4.97(-0) 4.97(-0) 4.97(-0) 4.97(-0) 4.97(-0) 4.97(-0) 4.97(-0) 4.97(-0) 4.97(-0) 4.97(-0) 1.07(-0) 1.07(-0) 9.95(-0) 1.07(-0	BONCK HET PF SEN 0. 1.369C+01 1.0792460 1.509E-01 1.396E-01 1.396E-01 1.404E-01 -7.601E-02 -3.226E-02 -2.007E-02 -2.007E-02 -2.007E-02 -1.417E-02 -4.572C-03 -5.445E-04 -5.673E-04 -5.673E-04 -5.673E-04 -5.725E-05 -7.725E-05 -8.132E-04 -7.725E-05 -7.725E-05 -8.132E-04 -1.142E-05 -1.142E-05 -1.142E-05 -1.142E-05 2.414E-05 2.414E-05	CF1LES SCHORT SENT 8. -1.123E+01 -1.021E+00 -1.707E-01 -1.707E-01 -1.707E-01 -7.34E-01 -1.101E-01 -7.359E-02 -3.531E-02 -3.531E-02 -3.531E-02 -3.531E-02 -3.531E-02 -3.531E-02 -3.531E-02 -3.531E-02 -3.531E-02 -3.532E-04 -3.25E-04 -3.25E-04 -3.25E-04 -3.25E-04 -1.176E-04 -1.176E-04 -1.176E-04 -7.672E-05 -7.672E-05 -3.327E-05 -3.327E-05 -3.327E-05					
GROUP 1 2 3 4 5 7 9 1 1 1 2 7 9 1 1 1 1 1 1 1 1 1 1 1 1 1	UPPER-E(EY) 1.700E+07 1.335E+07 1.335E+07 1.254:407 1.6015+07 1.6015+07 7.770E+06 6.070E+06 3.604:4+66 2.055E+06 2.252E+05 1.733E+06 1.355E+06 8.236E+05 3.050E+05 3.050E+03 3.3705+03 1.275E+03 3.3705+03 1.275E+03 3.3705+03 1.275E+04 1.275E+04 1.275E+04 1.275E+04 1.275E+04 1.275E+04 1.275E+04 1.275E+04 1.275E+04 1.275E+04 1.275E+04 1.275E+04 1.275E+04 1.275E+06 1.525E=01	DELTA-U 1.25E-01 1.25E-01 1.62E-01 2.57E-01 2.57E-01 2.57E-01 2.57E-01 2.57E-01 2.57E-01 2.57E-01 4.97E-01 4.97E-01 1.07E+00 1.07E+00 1.07E+00 1.05E+00 9.97E-01 1.07E+00 1.05E+00 9.97E-01 1.07E+00 9.97E-01 1.07E+00 9.97E-01 1.07E+00 9.97E-01 1.07E+00 9.97E-01 1.07E+00 9.97E-01 1.07E+00 1.07E+00 9.97E-01 1.07E+00 1.07E+0	BONCK HET PR SEN 8. -1.369C+01 -1.0792460 -1.509C+01 -1.509C+01 -1.509C+01 -1.902460 -1.902460 -1.902460 -1.902460 -1.902460 -1.902460 -1.902460 -1.902460 -1.902460 -1.902460 -1.902460 -1.902460 -2.002460 -2.002460 -2.002460 -2.002460 -3.00260 -3.415604 -5.6415604 -5.6415604 -5.6415604 -5.0026050 -7.7252605 -7.0026050 -3.112605 -6.5224505 -3.112605 -6.5224505 -1.324500 -1.324500 -1.324500 -1.324500 -1.324500 -1.324500 -1.324500 -1.324500 <	CF1LES SCHOOL SENT 8. -1.123E+01 -1.021E+00 -1.707E-01 -1.707E-01 -1.707E-01 -1.707E-01 -1.704E-01 -7.259E-02 -3.257E-02 -3.257E-02 -2.034E-02 -2.034E-02 -2.257E-02 -1.360E-02 -3.215E-04 -3.215E-04 -3.222E-04 -3.222E-04 -3.222E-04 -1.163E-04 -3.222E-04 -1.163E-04 -3.126E-04 -3.222E-05 -3.276E-05 -3.276E-05 -3.276E-05					
GROUP 1 2 3 4 5 6 7 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 20 20 21 20 21 20 20 20 20 20 20 20 20 20 20	UPPER-E(EY) 1.700E+07 1.500E+07 1.2016+07 1.2016+07 1.2016+07 1.2016+07 1.2016+07 1.2016+07 1.2016+07 1.2016+07 1.2016+07 1.2016+06 2.202E+06 0.2016+06 0.2016+06 0.2016+06 0.2016+06 0.2016+05 1.010E+03 1.2016+05 1.2016+05	DELTA-U 1.25E-01 1.25E-01 1.62E-01 2.57E-01 2.57E-01 2.57E-01 2.57E-01 2.57E-01 2.57E-01 2.57E-01 4.97E-01 4.97E-01 4.97E-01 4.97E-01 1.07E+00 1.67E+00 1.67E+00 1.67E+00 1.07E+00 9.97E-01 1.07E+00 9.97E-01 1.07E+00 9.97E-01 1.07E+00 9.97E-01 1.07E+00 9.97E-01 1.07E+00 9.97E-01 1.07E+00 9.97E-01 1.07E+00 1.07E+0	BRACK HET PF SEN 8. -1.369C+01 -1.0792460 -1.500E-01 -1.500E-01 -7.601E-02 -3.433E-02 -4.032E-02 -3.220E-02 -2.067E-02 -2.067E-02 -2.067E-02 -2.067E-02 -2.067E-02 -2.067E-02 -3.115E-03 -2.635E-04 -3.010E-04 S.502E-05 -7.725E-05 -7.006E-05 -5.435E-05 2.434E-05 2.44E-05 2.44E-05 2.454E-05 2.454E-05 2.454E-05 2.454E-05 2.454E-05 2.454E-05 2.454E-0	ROF1LES ROMAN SENT 8. -1.123E+001 -1.021E+00 -1.707E-01 -1.707E-01 -1.707E-01 -1.707E-01 -7.259E-02 -3.257E-02 -3.257E-02 -3.257E-02 -2.924E-03 -3.314E-03 -3.314E-03 -3.314E-03 -3.314E-03 -3.314E-03 -3.314E-03 -3.314E-04 -3.222E-05 -3.222E-05 -3.222E-05 -3.222E-05 -3.222E-05 -3.222E-05 -3.222E-05 -3.222E-05 -3.222E-05 -3.222E-05 -3.222E-05 -3.222E-05 -3.2240E-05 -3.240E-0					

$$\chi^{g} = \sum_{\substack{\ell=0 \\ \ell=0}}^{\text{LMAX}} \sum_{\substack{\ell=0 \\ \ell=0}}^{\ell} \psi^{kgg}_{\ell} = \sum_{\substack{\ell=0 \\ \ell=0}}^{\text{LMAX}} \psi^{gg}_{\ell}$$

Table IX provides a comparison between the χ 's calculated from angular fluxes and flux moments. There is a very good agreement. It was found that this relationship is also true in the one-dimensional analysis. For $\ell = 0$ and $\ell = 1$, the $\Psi_{\ell}^{k'}$ s calculated in SENSIT and SENSIT-2D are different. However, the Ψ_{ϱ} 's defined by

$$\Psi_{\mathcal{L}}^{gg} = \sum_{\underline{k}=0}^{\mathcal{L}} \Psi_{\mathcal{L}}^{kgg}$$
(123)

are in agreement.

5.1.3 Comparison between a two-dimensional and a one-dimensional crosssection sensitivity and uncertainty analysis

A cross-section sensitivity and uncertainty analysis was done for the heating in the copper region, using SENSIT and SENSIT-2D. In this analysis the effects of the uncertainties in the secondary energy distribution were included. Six separate SENSIT (or SENSIT-2D) runs were required:

	SENSIT-	ØD	SEVSIT	
Group	chi (ang. fluxes)	chi (flux moments)	chi (ang. fluxes)	chi (flux moments)
1	0.0	0.0	0.0	
2	2.5058+8	2.5053+8	2.4933+8	2.5003+9
3	2.4380+7	2.4362+7	2。山93+7	
հ	6.1304+6	6.1264+6	6.1829+6	
Ę	8.3365+6	8.3329+6	8.4135+6	
6	5.6569+6	5.6354+6	5.7424+6	
7	9.3953+6	9.39 <u>11</u> +6	9.1775+6	
8	5.6883+6	5.6991+6	5.7312+6	
9	7.1543+6	7.1543+6	7.2075+6	
10	7.3349+6	7.3349-6	7.3894+6	
n	7.5619+6	7.9619+6	7.9321+6	
12	2.1571+7	? . 1571+7	?.1793+6	8
13	2.8571+7	2.8571+7	2.9072+6	
1 4	2.5429+7	2.5429+7	2.6026+6	
15	6.3491+6	6.3491+6	6 . 5028+6	
16	1.5783+7	1.5783+7	1.6345.47	
17	6.5269+6	6.5269+6	7.1384+6	
18	1.7636+6	1.7636+6	1.8060+6	
19	1.2463+6	1.2463+6	1.2862+6	
20	7.6860+5	7.6860+5	7.7452+5	
21	3.7764+5	3.7764+5	3.8440+5	
27	3.7415+5	3.7415+5	3.9205+5	
23	2,9673+5	2.9673+5	3.0745+5	
21	2.2041+5	2.2041+5	2.2406+5	
25	1.5067+5	1.5067+5	1.5257+5	
26	9-րę3ր+ր	9-րę3ր+ր	9.5405+4	
27	5-1090+1	5.4091+4	5.4300+4	
28	2.8476+4	2.8176+1	2.8499+4	
29	1.332h+h	1.3325+4	1.3318+4	
30	?•3951+4	?.3951+4 ?.3949+4 ?.4910+4		

TABLE IX: COMPARISON BETWEEN THE CHI'S CALCULATED FROM ANGULAR FLUXES AND FROM FLUX MOMENTS

three runs for the vector cross-section sensitivity and uncertainty analysis (one for the cross sections of zone II, one for the cross sections of zone III, and one for the cross sections of zone IV),
 three runs for the SED sensitivity and uncertainty analysis.

Oxygen was not included in the vector cross-section sensitivity and uncertainty analysis, and hydrogen was ignored in the SED sensitivity and uncertainty analysis.

The procedure for an uncertainty analysis has been discussed by Gerstl. 45 The results from the one-dimensional analysis are reproduced in Table Xa, while those from the two-dimensional study are given in Table Xb. The studies are in good agreement. Sensit required a total of 89 seconds of computing time, while SENSIT-2D required 90 seconds on a CDC-7600 machine. The uncertainty of the heating rate due to all cross-section uncertainties is 30%. The iron in zone II is the largest contributor to that uncertainty. The contribution of the SED uncertainty is smaller than that from the vector cross sections. Gerst1 points out that the results obtained from the SED analysis might have been underestimated due to the simplicity of the "hot-cold" concept and due to the fact that the partial cross sections which contribute to the secondary energy distribution were not separated into individual partial cross sections. 45

TABLE Xa. PREDICTED RESPONSE UNCERTAINTIES DUE TO ESTIMATED CROSS SECTION AND SED UNCERTAINTIES IN A ONE-DIMENSIONAL ANALYSIS

CROSS SECTION	ZONE	RESPONSE UNCE TO SED UNCERT	CRTAINTIES DUE CAINTIES, IN %	RESPONSE UNCERTAINTIES DUE TO CROSS-SECTION UNCERTAIN- TIES, IN %			
		$\begin{bmatrix} \Delta R \\ R \\ zone \end{bmatrix}_{x-sect}$	$\begin{bmatrix} \Delta R \\ R \\ zone \end{bmatrix}$	$\begin{bmatrix} \Delta R \\ \overline{R} \\ zone \end{bmatrix}$	$\begin{bmatrix} \Delta R \\ R \end{bmatrix}^*$ zone		
Fo	TT	9 19	8 18	23.80	23 80		
<u></u>	11	0.10	0.10	25.80	25.80		
Fe	III	2.50		10.33			
0	III	0.78	2.61	_	10.52		
H	III	-		1.96			
Cu	IV	4.02	4.02	11.72	11.72		
A11*			9.48		28.54		

Overall uncertainty = $(9.48^2 + 28.54^2)^{\frac{1}{2}} = 30.0\%$

* quadratic sums

CROSS SECTION	ZONE	RESPONSE UNCER TO SED UNCERTA	TAINTIES DUE INTIES, IN %	RESPONSE UNCERTAINTIES DUE TO CROSS-SECTION UNCERTAIN- TIES, IN %		
1.7 <u>1.711.711</u>		$\begin{bmatrix} \Delta R \\ R \\ zone \end{bmatrix}$ element	$\left[\frac{\Delta R}{R}\right]_{zone}^{*}$	$\begin{bmatrix} \Delta R \\ R \end{bmatrix}$ element zone	$\begin{bmatrix} \Delta R \\ R \end{bmatrix}^{*}$ zone	
Fe	II	8.17	8.17	23.88	23.88	
Fe	III	2.50		10.27		
0		0.79	2.62	-	10.46	
H	III	-		1.96		
Cu	IV	4.02	4.02	11.68	11.68	
A11*			9.47		28.57	

TABLE XD. PREDICTED RESPONSE UNCERTAINTIES DUE TO ESTIMATED CROSS SECTION AND SED UNCERTAINTIES IN A TWO-DIMENSIONAL ANALYSIS

Overall uncertainty = $(9.47^2 + 28.57^2)^{\frac{1}{2}} = 30.1\%$

* quadratic sums

5.2 Sample Problem #2

A simple one-band problem will be analyzed to study the influence of the mesh spacing, quadrature order, convergence precision, and the c-factor (mean number of secondaries per collision) on the sensitivity profile. The band is 1-cm high and 20-cm wide. There are ten distinct zones, each 1-cm wide (Fig. 11), and all zones are made of the same material. A three-group artificial cross-section set with a third-order anisotropic scattering is used (Table XI). The P₁, P₂, and P₃ components of the scattering cross-section tables were chosen to be identical with the P₀ component. A volumetric source with a source density of 1 neutron/cm³ in group 1 is present in the first zone. A standard cross-section sensitivity analysis will be performed, in which the cross sections in zone IV are perturbed, and the detector response is calculated in zones IX and X for a response function of 100 cm⁻¹ in each group.

5.2.1 Influence of the quadrature order on the sensitivity profile

The detector response calculated by TRIDENT-CTR using EQ₆, EQ₁₂, and EQ₁₆ quadrature sets are compared in Table XII. For the first three cases, the pointwise convergence precision was set to 10^{-3} and each zone contained four triangles (using automatic meshes). Five additional cases are included in Table XII:



r-z geometry All zones contain identical materials 3 neutron groups Neutron source: 1 neutron / cm³ in zone I and group 1 Response function: 100 cm⁻¹ (all groups)

Figure 11. Two-dimensional model for sample problem #2

TABLE XI:	CROSS SE	CTION	TABLE	USED	IN SAM	IPLE	PROBLEM	#2
	(THE P ₀ ,	P ₁ , P	2, AND	P ₃ 1	TABLES	ARE	IDENTICA	L)

Cross Section	Group	g = 1	g = 2	g = 3
Σ ^g edit		-	-	_
Σ ^g a		0.02	0.05	0.1
Σ ^g f		0.0	0.0	0.0
Σg T		0.1	0.2	0.3
Σ ^{g→g} S		0.05	0.1	0.2
Σ ^{g-1→g} S		0.0	0.02	0.05
Σs ^{g-2→g}		0.0	0.0	0.01

Transport Code	Quadrature Set	Convergence Precision	# Triangles ¹	Forward Response	Adjoint Response
TRIDENT-CTR	EQ-6 ²	10 ⁻³	40	593.968	592.256
TRIDENT-CTR	EQ-12	10 ⁻³	40	592.826	591.659
TRIDENT-CTR	EQ-16	10 ⁻³	40	593.659	592.476
TRIDENT-CTR	EQ-12	10 ⁻⁴	40	593.659	593.148
TRIDENT-CTR	Eq-12	10 ⁻⁴	80	593.688	593.208
ONEDANT	S-12 ³	10 ⁻⁴	40	593.855	590.370
ONEDANT	S-32	10 ⁻⁴	40	591.814	590.883
ONEDANT	S-32	10 ⁻⁴	80	592.055	590.900

TABLE XII: INTEGRAL RESPONSE FOR SAMPLE PROBLEM #2

¹ # spatial intervals for ONEDANT.

-

_

² equal-weight quadrature sets.

³ Gaussian quadrature sets.

- 1. integral response using an EQ₁₂ quadrature set with convergence precision 10^{-4} ;
- integral response using an EQ₁₂ quadrature set with convergence precision 10⁻⁴ and eight triangles per zone;
- integral response calculated by ONEDANT using an S₁₂ quadrature set, four intervals per zone and a 10⁻⁴ convergence precision;,
- integral response calculated by ONEDANT, using an S₃₂ quadrature set, four intervals per zone and a 10⁻⁴ convergence precision;
- 5. integral response calculated by ONEDANT, using an S₃₂ quadrature set, eight intervals per zone and a 10⁻⁴ convergence precision.

The response functions in Table XII are in good agreement (maximum difference 0.6%). The standard cross-section sensitivity profiles for the EQ_6 , EQ_{12} , and EQ_{16} calculations are reproduced in Tables XIIIa, XIIIb, and XIIIc. The integral sensitivity for the EQ_6 case is 5% different from the EQ_{12} case for AXS (absorption cross-section sensitivity profile) and 5% different for N-GAIN (outscattering cross-section sensitivity profile). The results obtained from the EQ_{12} calculation are in good agreement with those obtained from the EQ_{16} calculation. The sensitivity profiles for the EQ_{12} case (10⁻⁴ convergence precision) and the EQ_{12} case (10⁻⁴ convergence precision, eight triangles per zone) are not shown. They are nearly identical with Table XIIIb.

TABLE IIIa:STANDARD CROSS-SECTION SENSITIVITY PROFILES
CALCULATED BY SENSIT-2D FOR THE EQ-6 CASE
(CONVERGENCE PRECISION 0.001, 4 TRIANGLES
PER ZONE) FOR SAMPLE PROBLEM #2

GROUP UPPER-E(EV) 1 1.0000E+01 2 5.000E+00 3 1.000E+00	DELTA-U 6.93E-01 1.61E+00 6.93E-01	AXS -4.632E-02 -4.532E-03 -1.142E-02	RELDS NU-F1SS 8. 8. 8. 8.	S T E R M SXS -1.853E-01 -1.359E-02 -2.284E-02	S #********* TXS -2.316E-01 -1.812E-02 -3.426E-02	HUCKELES PU N-GAIN 1.549E-01 1.186E-02 2.254E-02	RE GAIN TERMS N-GAIN(SED) 1.155E-01 2.196E-02 3.677E-02	NG-GAIN 0. 0. 0.
INTEGRAL		-4.732E-02	0.	-1.661E-01	-2.135E-01	1.423E-01	1.423E-01	0.
GROUP UPPER-E(EV) 1 1.000E+01 2 5.000E+00 3 1.000E+00	DELTA-U 6-93E-01 1.61E+00 6.93E-01	***** NET PR(5EN -3.039E-02 -1.731E-03 3.252E-06	DF1LES #000 SENT -7.671E-02 -6.263E-03 -1.142E-02					
INTEGRAL		-2,385E-02	-7.116E-02					

```
TABLE XIIID: STANDARD CROSS-SECTION SENSITIVITY PROFILES
CALCULATED BY SENSIT-2D FOR THE EQ-12 CASE
(CONVERGENCE PRECISION 0.001, 4 TRIANGLES
PER ZONE) FOR SAMPLE PROBLEM #2
```

GROUP 1 2 3	UPPER-E(EV) 1_000E+01 5_00CE+00 1.000E+00	DELTA-U 6_93E-01 1.61E+00 6_93E-01	AXS -4.329E-02 -4.366E-03 -1_103E-02	RELOS NU-F155 0. 0. 0.	S TERM SXS -1.731E-81 -1.310E-02 -2.206E-02	S TXS -2.164E-01 -1.746E-02 -3.310E-02	N-GAIN 1.458E-01 1.145E-02 2_207E-02	RE GAIN TERMS N-GAIN(SED) 1_07SE-01 2.12SE-02 3.76IE-32	HG-GAIN 0. 0. 0.
INTEG	RAL		-4.468E-02	0.	-1.564E-01	-2.811E-01	1.348E-01	1.3486-01	0.
GROUP 1 2 3	UPPEP-E(EV) 1.000E+01 5.0005+00 1.000E+00	DELTA-U 6,938-01 1.618+00 6.938-01	₩04404 HET PR SEN -2.731£-02 -1.668E-03 0.048E-07	0F1LES #04040 SENT -7.060E-02 -6.034E-03 -1.103E-02					
INTEG	RAL		-2.161E-02	-6_629E-02					

TABLE XIIIC:STANDARD CROSS-SECTION SENSITIVITY PROFILES
CALCULATED BY SENSIT-2D FOR THE EQ-16 CASE
(CONVERGENCE PRECISION 0.001, 4 TRIANGLES
PER ZONE) FOR SAMPLE PROBLEM #2

GROUP UPPER-E(EV) 1 1.0002+01 2 5.000E+00 3 1.000E+00 INTEGRAL	DELTA-U 6.93E-81 1.61E+00 6.93E-01	++++++++++++++++++++++++++++++++++++++	RELDS NU-FISS 0. 0. 0. 0. 0.	E TERM SXS -1.716E-01 -1.295E-02 -2.188E-02 -1.SS0E-01	S #200000000 TXS -2.145E-01 -1.732E-02 -3.281E-02 	N-GAIN N-GAIN 1.443E-01 1.133E-02 2.187E-02 1.334E-01	RE GAIN TERM N-GAIN(SED) 1.062E-01 2.109E-02 3.732E-02 1.334E-01	5 1000000000000000000000000000000000000
GROUP UPPEP-E(EV) 1 1.000E+01 2 5.000E+00 3 1.000E+00 1NTEGRAL	DELTA-U 6.93E-01 1.61E+00 6.93E-01	**************************************	DF1LES #DATA SENT -7.0245-02 -5.903E-03 -1.094E-02 -6.S91E-02					

Note that the net sensitivity profiles SEN (= SXS + N-GAIN) for group 3 are respectively 3.252×10^{-6} , 8.040×10^{-7} , and 1.484×10^{-6} for the EQ₆, the EQ₁₂, and the EQ₁₆ case. The large discrepancies here can be attributed to the fact that those quantities result from subtracting two numbers that are nearly equal in magnitude.

It can be concluded from Tables XII and XIII that even when the integral responses differ by less than 0.4%, the sensitivity profiles can differ by as much as 5% between an EQ₆ and an EQ₁₂ calculation. The close agreement between the results from the EQ₁₂ and the EQ₁₆ calculation suggest that this difference is probably due to the fact that the angular fluxes in the EQ₆ calculation are not yet fully converged.⁸¹ Indeed, choosing the higher-order anisotropic scattering cross sections equal to the isotropic components is unphysical. The convergence criteria used in ONEDANT and TRIDENT-CTR do guarantee convergence for the scalar fluxes, but not for the higher-order flux moments.

5.2.2 Comparison between the two-dimensional and one-dimensional analysys of sample problem #2

The cross-section sensitivity profiles resulting from a one-dimensional analysis (S_{12} quadrature set, 10^{-4} convergence precision and four intervals per zone; S_{32} quadrature set, 10^{-4} convergence precision and eight intervals per zone) are compared with those obtained from a two-dimensional analysis (EQ₁₂ quadrature set, 10^{-4} convergence precision and eight triangles per zone in Tables XIVa, .IVb, and XIVc.

TABLE XIVa: STANDARD CROSS-SECTION SENSITIVITY PROFILES CALCULATED BY SENSIT FOR THE S-12 CASE (CON-VERGENCE PRECISION 0.0001, 4 INTERVALS PER ZONE) FOR SAMPLE PROBLEM #2

								****** # (LDS	5 T 6	-	5 *****
***		****	••	PU	NE O	GAIN TERMS	: ++	******					
6=	aup	UPP	E=-	E U	EV)	DELTA-U		AXS	NU-	F155	\$	5	T = S
			IN		N-0	SAIN(SED)	N	S-GAIN					
	1	1.	ÛŬ	ÚE+	01	6.93E-01	ļ.	-4.284E-02	· 0.		-1.713	3m-Ú1	-2.142E
-01	1	. 351	E-1	01	9.	920E-02	0.						
	2	5.	00	DE+	00	1.61E+00)	-4.357E-03	3 0.		-1.307	'E-ÚZ	-1.743E
- 02	1	.140	E-1	62	2.	.039E-02	0.						
	з	1.	00	0e+	00	6.93E-01		-1.1016-02	2 0.		-2.202	E-02	-3.303m
- 02	2	. 234	E - I	20	з.	733E-02	0.						
IN	TEG							-4.433E-02	· 0.		-1.551	E-U1	-1.994E
-01	1	.274	E-	01	1	274E-01	٥.						
										5 ++++			
68	aup	UPP	EP	-E (EV)	DELTA-U		SEN	5	ENT			
	1	1.	ÛŬ	ÛE+	Ú1	6.93m-01		-3.6288-02	-7.5	128-02			
	2	5.	Ú O I	ÚE+	00	1.61E+00)	-1.671E-03	3 -6.0	268-03			
	з	1.	00	ŬE 🕈	ÚŬ	6.93E-01		3.232E-04	-1.0	969e-02			
IN	TEG							-2.762E-02	2 -7.1	95e-02			

TABLE XIVD: STANDARD CROSS-SECTION SENSITIVITY PROFILES CALCULATED BY SENSIT FOR THE S-32 CASE (CON-VERGENCE PRECISION 0.0001, 8 INTERVALS PER ZONE) FOR SAMPLE PROBLEM #2

GROUP 1 2 3	UPPER-E(EV) 1.0002+01 S-0002+00 1.000E+00	DELTA-U 6.93E-01 1.61E+00 6.93E-01	80000000 PU AXS -4.21SE-82 -4.277E-83 -1.881E-82	RELDS NU-FISS 0. 0. 0. 0.	S TERM SXS -1.686E-01 -1.283E-02 -2.161E-02	S #000 104000 TXS -2.107E-01 -1.711E-02 -3.242E-02	1.1295-01 2.221E-02	RE GAIN TERMS N-GAIN(SED) 9.517E-02 1.991E-02 3.689E-02	12.444 2.45 4.6 NG-GA ; 11 8. 8. 8.
1NTEG	RAL		-4.359E-02	0_	-1.525E-01	-1.961E-01	1.236E-01	1.236E-01	0.
CROUP	UPPER-E(EV)	DFL TA-U	NET PR	OFILES **** SENT					
1	1.000E+01	6.93E-01	-3.071E-02	-0.085E-02					
2	5.830c+90	1.61E+00	-1.551E-03	-5.829E+03					
3	1.0000 +00	6.93E-01	5.5898-04	-1.021E-02					
INTEG	RAL		-2.891E-02	-7.250E-02					

TABLE XIVC: STANDARD CROSS-SECTION SENSITIVITY PROFILES CALCU CALCULATED BY SENSIT-2D FOR THE EQ-12 CASE (CON-VERGENCE PRECISION 0.0001, 8 TRIANGLES PER ZONE) FOR SAMPLE PROBLEM #2

GROUP 1 2 3	UFPER-E(EV) 1.000E+01 5.000E+00 1.000E+00	DELTA-U 6.93E-01 1.61E+00 6.93E-01	400004404 P U AXS -4.324E-02 -4.362E-03 -1.162E-02	RELDS NU-F1SS D. 0. 0. 0.	S TERM SXS -1.730E-01 -1.309E-02 -2.203E-02	S #00000000000 TXS -2.162E-01 -1.745E-02 -3.305E-02	N-GAIN 1.457E-01 1.142E-02 2.203E-02	RE GAIN TERMS N-GAIN(SED) 1.074E-01 2.123E-02 3.755E-02	804004079-004 NG-EA1* 8. 8. 8.
INTEG	RAL		-4.463E•02	0.	-1.\$62E-01	-2.009E-01	1.346E-01	1.34GE-01	0.
			HORDER NET PR	OFILES ****					
GROUP	UPPER-E(EV)	DELTA-U	SEN	SENT					
1	1.8096+01	6.93E-01	-2.727E-02	-7.05IE-02					
2	S_000E+00	1.61E+00	-1_668E-Ø3	-C.038E-03					
3	1.000E+00	6.93E-01	7.918E-07	-1.1020-02					
INTEGR	RAL		-2_158E-02	-6.621E-02					

Note that the N-GAIN integral sensitivity differs by about 6% between Table XIV b and XIV c. The integral net sensitivity shows a 35% difference for SEN (= SXS + N-GAIN) and a 10% difference for SENT (= TXS + N-GAIN) between the one-dimensional and the two-dimensional analysis. The bulk part of this large difference for the integral net sensitivity results from the subtraction of two numbers that are nearly equal in magnitude. A comparison of N-GAIN (integral) in Tables XIV a, XIV b, and XIV c suggests that - even with an S_{32} quadrature set - the one-dimensional calculation is not yet fully converged.

$\frac{5.3.2 \text{ Comparison between the } \chi's \text{ calculated from angular fluxes and the}}{\chi's \text{ resulting from flux moments}}$

The χ 's (or the loss term of the cross-section sensitivity profile) can be evaluated based on flux moments (Eq. 58) or based on angular fluxes (Eq. 57). A calculation based on flux moments requires less computing time, less computer memory, and less data transfer. To have an idea of the order of expansion of the angular fluxes in flux moments necessary to reach a reasonable accuracy, the χ 's resulting from angular fluxes are compared with those obtained from a P-0, P-1, P-2, . . .,P-17 spherical harmonics expansion of the angular fluxes (Table XV). It is found that for any expansion of order greater than P-0, there is good agreement (less than 1% difference for $\Sigma \chi^{g}$). For very high spherical harmonics expansions (P-15 and higher) there is divergence. This divergence can be avoided by doing the computations in quadruple precision.

Order of Expansion of the Angular Flux	x ^{1^a}	x ²	x ³	$\left \begin{smallmatrix} \Sigma(\chi^g_{mom} - \chi^g_{ang}) \\ g \end{smallmatrix} \right $
angular fluxes	889.88	83.382	45.352	-
0	796.63	76.811	41.898	103.275
1	880.43	83.755	45.524	8.905
2	868.78	83.054	45.326	21.454
3	884.11	83.374	45.353	5.777
4	884.58	83.388	45.364	5.282
5	886.82	83.385	45.357	2.052
6	888.82	83.389	45.354	1.051
7	889.16	83.381	45.353	0.720
8	889.78	83.381	45.352	0.101
9	889.74	83.382	45.352	0.140
10	889.91	83.383	45.352	0.031
11	890.01	83.385	45.351	0.133
12	889.89	83.382	45.351	0.009
14	898.27	83.573	45.431	8.610
16	938.59	83.100	46.203	51.279
17	951.85	85.617	46.416	65.269

TABLE XV: COMPARISON BETWEEN THE CHI'S CALCULATED FROM ANGULAR FLUXES AND THE CHI'S CALCULATED FROM FLUX MOMENTS

^a χ^1 mean χ for group 1

The small differences in Table XV indicate that the loss term of the sensitivity profile can indeed be calculated based on a low-order spherical harmonics expansion of the angular fluxes.

$\frac{5.2.4}{10w} \frac{10}{c}$

The question whether the χ 's can be computed with adequate accuracy from Eq. (58) in the case of low c (mean number of secondaries per collision) was raised.⁸ Based on an analytical one-dimensional analysis of the half-space problem (one group) with a mono-directional boundary source, it was found that for c less than 0.8, a low-order spherical harmonics expansion of the angular flux would lead to erroneous results in the χ 's.

In order to confirm the analytical study, sample problem #2 was reexamined with a different cross-section table. The corresponding c's were 0.5 for the high-energy group, 0.4 for the second group, and 0.33 for the low-energy group. The χ 's calculated based on flux moments were still in agreement with those obtained from the angular fluxes (even for a P-1 expansion). An explanation for this paradoxical behavior is probably related to the use of a distributed volumetric source in sample problem #2, whereas the conclusions drawn in the analytical evaluation were based on the presence of a mono-directional boundary source.

5.3 Conclusions

The rigorous study of the two sample problems indicates that there is good agreement between the one- and two-dimensional analysis. Wherever discrepancies appear, a plausible explanation can be provided. Ultimately, the comparison between a one- and two-dimensional study proves to be a sound debugging procedure for SENSIT-2D as well as for the SENSIT code.

For the flux moments versus the angular fluxes comparison for the evaluation of the χ 's, there is a strong indication that the loss term can be calculated from lower-order flux moments (P-1) as well as from angular fluxes. By the same token, a P-1 sensitivity and uncertainty analysis seems to provide sufficient accuracy.

The study of the influence of the quadrature sets on the sensitivity profiles reveals the importance of the angular-flux convergence in ONEDANT and TRIDENT-CTR. Furthermore, some doubts about the meaningfulness and practicality of the net sensitivity profile (SEN) can be raised.

SENSITIVITY AND UNCERTAINTY ANALYSIS OF THE HEATING IN THE TF COIL FOR THE FED

In this part a secondary energy distribution and a vector crosssection sensitivity and uncertainty analysis will be performed for the heating of the TF coil in the inner shield of the FED. The results obtained from the two-dimensional analysis will be compared with selected results from a one-dimensional model. The blanket design for the FED is currently in development at the General Atomic Company.^{82,83}

6.1 Two-Dimensional Model for the FED

The two-dimensional model for the FED in r-z geometry is illustrated in Fig. 12, and is documented in more detail in reference 84. The material composition is shown in Table XVI. In the forward TRIDENT-CTR model, which was set up by W. T. Urban,⁸⁴ the standard Los Alamos 42 coupled neutron/gamma-ray group structure was used.⁸⁵ There are 30 neutron groups and 12 gamma-ray groups. The TRIDENT-CTR model⁸⁴ (Fig.

		MATERIAL										
Isotope	SS316	TFCOIL	SS304	CNAT	IHDLC	IHDLB	IHDLA	SS312				
H-1		3.79E-3			5.03E-2	1.34E-2	1.68E-3					
He~4		6.67E-3										
B-10		2.98E-5										
B-11		1.20E-4										
С		1.90E-3		8.03E-2								
0-16		2.17E-3			2.51E-2	6.70E-3	8.38E-4					
A1-27		1.81E-4										
Si		5.59E-4										
Ca		2.42E-4										
Cr	1.67E-2	5.97E-3	1.77E-2		4.18E-3	1.34E-2	1.63E-2	3.34E-3				
Mn-55	1.75E-3	6.27E-4	1.67E-3		4.38E-4	1.40E-3	1.71E-3	3.50E-4				
Fe	5.44E-2	1.95E-2	6.06E-2		1.36E-2	4.35E-2	5.30E-2	1.09E-2				
Ni	1.15E-2	4.12E-3	7.40E-3		2.88E-3	9.20E-3	1.12E-2	2.30E-3				
Cu		2.11E-2										
ND-93		2.44E-4										
Mo	1.51E-3	5.41E-4			3.78E-4	1.21E-3	1.47E-3	3.02E-4				

TABLE XVI. ATOM DENSITIES FOR THE ISOTOPES USED IN THE MATERIALS (atom/b cm)



Figure 12. Two-dimensional model for the FED⁸⁴ The numbers within each zone indicate the zone number.



Figure 13. The TRIDENT-CTR band and triangle structure for the FED

13) utilizes 2062 triangles, divided over 27 bands. The response functions for calculating the heating in the TF coil, were prepared by the TRANSXX code.⁷² Those response functions will be the sources for the adjoint calculation. It was noted earlier that negative sources can introduce instabilities in the sweeping algorithm for the adjoint TRIDENT-CTR calculation. The negative kerma factors are therefore set to zero. This will have a minor effect on the total heating calculated in the TF-coil (less than 1%).

EQ-2 and EQ-8 quadrature sets are used for groups 1 and 2 respectively, EQ-3 is used for groups 3, 4, and 5, while an EQ-4 quadrature set is utilized for the remaining groups. The convergence precision is specified to be 10^{-3} . The gamma-ray groups contribute most to the heating in the TF coil (93%). The total heating in the TF coil is 823 × 10^{-6} MW.

The heating calculated by the adjoint TRIDENT-CTR calculation is found to be 3% smaller than the heating resulting from the forward run. The forward calculation required about one hour of c.p.u. time on a CDC-7600 computer, while the adjoint run took about four hours. Groups 11 to 23 required significantly more inner iterations in the adjoint mode than the other groups. No explanation of this behavior could be found. Experience with other neutronics codes indicates that the adjoint mode for this type of calculation requires usually no more than 30% extra calculation time.

6.2 Two-Dimensional Sensitivity and Uncertainty Analysis for the Heating in the TF Coil due to SED and Cross-Section Uncertainties

A secondary energy distribution and vector cross-section uncertainty analysis was performed with SENSIT-2D using the forward and adjoint angular flux files created by TRDSEN. A separate SENSIT-2D run is required for each zone. Because separate runs are necessary for a crosssection and a SED analysis, a total of 22 SENSIT-2D cases were analyzed. A total of 15 minutes c.p.u. time was used by SENSIT-2D. The bulk of this time is consumed during input/output manipulations.

The median energies and fractional uncertainties for the SED uncertainty calculations were taken from Table II.⁴⁵ A special cross-section table was created - using TRANSX - for the SED analysis. COVFILS³³ data were used for generating the covariance matrices utilized in the crosssection uncertainty evaluation. Only O-16, C, Fe, Ni, Cr, and Cu were considered for the SED uncertainties, while H, Fe, Cr, Ni, B-10, C, and Cu were included for the cross-section uncertainties. With the exception of oxygen, no important materials were left out. It was found in an earlier study that the cross-section uncertainties for oxygen caused an 8% uncertainty in the heating.⁴⁵ The current version of SENSIT-2D does not include the option to extract the covariance data for oxygen from COVFILS.

The gamma-ray cross sections are generally better known than the neutron cross sections. Therefore, only the uncertainties resulting

from uncertainties in neutron cross sections are calculated. Throughout this analysis a third order of anisotropic scattering is used.

The predicted uncertainties in the heating of the TF-coil are summarized in Table XVII. It was assumed that the uncertainties for a particular element in the various SS316 zones (1, 3, 7, 11, and 12 in Fig. 12) are fully correlated, while all other uncertainties were assumed to be noncorrelated. This implies that the uncertainties for a particular element can be added over all SS313 zones, while all the other uncertainties are added quadratically. The approach of either assuming full correlation or assuming noncorrelation is rather simplistic. Translating the physics of this particular problem into a more sophisticated correlation scheme would be a major study by itself. The uncertainties resulting from the uncertainties in the cross sections for Cr, Fe, and Ni in the SS316 zones are reproduced in Table XVIII.

From Table XVII it can be concluded that the cross-section uncertainties (predicted to be 113%) tend to be more important than the SED uncertainties (20%). Even when the overal uncertainty seems to be relatively large (115%), the blanket designer is able to set an upper bound for the heating in the TF coil. The largest uncertainties are due to uncertainties in the Cr cross sections. A more detailed look at the computer listings generated by this analysis reveals that the largest uncertainties are produced by uncertainties in the total Cr and the elastic Cr scattering cross sections. The heating is less sensitive to Cr than to Fe. This indicates that the calculated uncertainty is largely due to the fact that Cr has very large covariances. A re-evaluation

TABLE XVII:PREDICTED UNCERTAINTIES (STANDARD DEVIATION) DUE TO
ESTIMATED SED AND CROSS-SECTION UNCERTAINTIES FOR
THE HEATING IN THE TF COIL (part 1)

Cross Section		SED Uncertai	nties in %	XS Uncertainties in %		
Materi	al Zone	$\begin{bmatrix} \Delta R \\ \overline{R} \end{bmatrix}_{Mat, regi}$	$ \begin{array}{c} \left[\Delta R \\ R \end{array} \right]_{Mat}^{*} $	$\left[\frac{\Delta R}{R}\right]_{Mat,region}$	$\left[\frac{\Delta R}{R}\right]_{Mat}^{*}$	
Cr	SS316 TFCOIL SS304 SS312 ISDLC ISDLB ISDLA	3.8 0.2 0.1 0.0 0.2 0.8 3.0	4.9	60.0 34.5 4.5 1.1 2.2 33.3 58.5	96.7	
Fe	SS316 TFCOIL SS304 SS312 ISDLC ISDLB ISDLA	14.8 0.1 0.0 0.2 0.5 2.7 10.8	18.4	18.9 10.4 2.2 0.7 4.4 23.6 34.5	47.3	
Ní	SS316 TFCOIL SS304 SS312 ISDLC ISDLB ISDLA	1.5 0.7 0.0 0.0 0.0 0.0 0.4 1.2	4.3	18.6 11.8 0.9 0.4 1.3 13.4 18.0	31.4	

* Quadratic Sums

TABLE XVII:PREDICTED UNCERTAINTIES (STANDARD DEVIATION) DUE TO
ESTIMATED SED AND CROSS-SECTION UNCERTAINTIES FOR
THE HEATING IN THE TF-COIL (part 2)

Cross S	ection	SED Uncertainti	les in %	XS Uncertainties in %			
Materia	l Zone	$\begin{bmatrix} \Delta \mathbf{R} \\ \mathbf{R} \end{bmatrix}$ Mat, region	$\left[\frac{\Delta R}{R}\right]^{*}_{Mat}$	$\begin{bmatrix} \Delta R \\ R \end{bmatrix}$ Mat, region	$\begin{bmatrix} \Delta R \\ R \end{bmatrix}_{Mat}^{*}$		
н	TFCOIL ISDLC ISDLB ISDLA	- - - -	-	1.7 6.0 3.7 0.5	7.2		
0	TFCOIL ISDLC ISDLB ISDLA	0.1 0.2 0.1 0.1	0.3		-		
С	TFCOIL C-region	0.0 0.3	0.3	0.1 3.2	3.2		
B	TFCOIL	-	-	0.0	0.0		
Cu	TFCOIL	2.9	2.9	10.1	10.1		
Total [*]			19.7		112.9		

Total uncertainty due to cross-section uncertainties and SEDs = 114.6%*

* Quadratic Sums

TABLE XVIII:PREDICTED SED AND CROSS-SECTION UNCERTAINTIES IN THE
TF COIL DUE TO UNCERTAINTIES IN THE SS316 ZONES

Cross Section		SED Uncertai	nties in %	XS Uncertain	XS Uncertainties in %		
Mater	ial Zone	$\begin{bmatrix} \Delta R \\ R \end{bmatrix}_{Mat, regi}$	$\frac{\Delta R}{R}_{Mat}$	$\left[\frac{\Delta R}{R}\right]_{Mat,regio}$	$n \begin{bmatrix} \Delta R \\ R \end{bmatrix}_{Mat}^{*}$		
Cr	1 3 7 11 12	0.1 0.7 0.0 3.0 0.0	3.8	12.0 45.5 0.8 4.3 0.4	60.0		
Fe	1 3 7 11 12	0.5 3.1 0.1 11.0 0.1	14.8	2.3 11.3 0.7 4.3 0.3	18.9		
Ni	1 3 7 11 12	0.0 0.3 0.0 1.2 0.0	1.5	3.6 12.8 0.3 1.8 1.1	18.6		

of the covariance data for Cr is highly recommended. If new covariance data would not reduce the predicted uncertainty, new experiments for measuring the Cr cross sections are suggested. The conclusions drawn here are consistent with an earlier study of a similar design.⁴⁵

The SED uncertainties, although less relevant to overall predicted uncertainty, tend to become more important in the outboard shield (region 11 in Table XVIII). An explanation for this behavior is related with the fact that the heating in the TF coil will be very sensitive to backscattering in this region. An SAD (secondary angular distribution) sensitivity and uncertainty analysis might lead to very interesting results.

The χ 's for the region near to the plasma in the outboard shield are calculated for each group based on angular fluxes and based on flux moments (Table XIX). Both methods lead generally to the same χ 's. The difference for the upper neutron groups might indicate that a thirdorder spherical harmonics expansion of the angular flux tends to become inadequate, due to the peaked shape of the angular flux close to the source region. In this particular study no serious error in the calculation of the uncertainties would have been introduced if the loss term of the sensitivity profile would have been calculated from flux moments. For a situation where the angular flux would have a pronounced peaked behavior, it would be highly desirable to evaluate the χ 's based on angular fluxes.

It is obvious from Table XIX that some fluxes in the lower gammaray groups (groups 41 and 42) are negative. Since only neutron sensitívity profiles are utilized to calculate uncertainties, this will not affect the results.

6.3 Comparison of the Two-Dimensional Model with a One-Dimensional Representation

The results obtained from the two-dimensional sensitivity and uncertainty analysis will be compared with those of a one-dimensional analysis in selected regions (Table XX). The uncertainties in the heating in the TF coil due to the uncertainties in the Cr, Ni, and Fe crosssections and secondary energy distributions will be calculated with ONEDANT and SENSIT in zone 1 and zone 3 (Fig. 12). The one-dimensional model for ONEDANT is straightforward. The total heating calculated in the TF-coil is 1043×10^{-6} MW (compared to 823×10^{-6} MW for the twodimensional model). In this comparison the uncertainties calculated by SENSIT will be normalized to the response calculated in the two-dimensional model.

It can be concluded from Table XII that the calculated uncertainties agree reasonably well for zone 3. There are substantial differences for the results in zone 1. The reason for those differences is probably related with the fact that the one-dimensional model is not adequate for calculating the overall heating in the TF coil (especially

TABLE XIX: COMPARISON BETWEEN THE χ 's CALCULATED FROM ANGULAR FLUXES (UPPER PART) AND THE χ 's RESULTING FROM FLUX MOMENTS (LOWER PART) FOR REGION 11 (SS316)^a

• • TEST PRINTOUT FOR THE CHI'S • • •									
0. 100	.13195E-05	.17957E-06	.67647E-07	.86778E-07	.79271E-07				
.21326E-06	.19166E-06	.32175E-06	.40693e-06	.48797E-06	.15589g-05				
.22361E-05	.14093E-05	.18633 e- U6	.37795e-06	.10788E-06	.17607E-07				
.86888E-08	.68189 e- 08	.28276E-U8	.17886E-08	.12639E-08	.54245E-09				
.49433E-09	.26407E-09	.12122E-UY	.48579e-10	.16319E-10	.47290E-11				
.24385E-10	.71906m-10	.12091E-09	.66533e-10	.49747E-10	.26669E-10				
.13096E-10	.22933E-11	.14850e-12	.22953E-16	51897E-23	28794E-48				

^a The X's are ordered by group (high neutron energy to low neutron energy; high gamma-ray energy to low gamma-ray energy)
TABLE XX	: PREDICTED	UNCERTAI	INTIES	(STANDARI	D DEV	IATION)	DUE	ΤO
	ESTIMATED	SED AND	CROSS-	SECTION	UNCER'	TAINTIES	S IN	
	ZONES 1 AN	ND 3 FOR	THE HE	CATING IN	THE 1	FF-COIL		

Cross Section		SED Uncertain	ties in %	XS Uncertainties in %		
Material	Zone	$\begin{bmatrix} \Delta R \\ R \end{bmatrix}_{Mat,zone} 1-D$	$ \begin{bmatrix} \Delta R \\ \overline{R} \end{bmatrix}_{Mat}^{*} $	$\begin{bmatrix} \Delta R \\ R \end{bmatrix}_{Mat,zone} 1-D$	$ \begin{bmatrix} \Delta R \\ R \end{bmatrix}_{Mat}^* $	
_						
Cr	1	0.1	0.1	29.3	12.0	
	2	0.6	0.7	44.8	42.5	
Fe	1	0.8	0.5	4.5	2.3	
	3	2.6	3.1	9.6	11.3	
Ni	1	0.0	0.0	8.3	3.6	
	3	0.2	0.3	13.1	12.8	

the source region is poorly simulated in the one-dimensional representation). A more relevant sensitivity analysis would be to consider the heating calculated at the hottest spot in the TF coil. The hottest spot is in the center plane of the toroid. We would expect that the onedimensional model would be an adequate representation in this case.

7. CONCLUSIONS AND RECOMMENDATIONS

Expressions for a two-dimensional SED (secondary energy distribution) and cross-section sensitivity and uncertainty analysis were developed. This theory was implemented by developing a two-dimensional sensitivity and uncertainty analysis code SENSIT-2D. SENSIT-2D has a design capability and has the option to calculate sensitivities and uncertainties with respect to the response function itself. A rigorous comparison between a one-dimensional and a two-dimensional analysis for a problem which is one-dimensional from the neutronics point of view, indicates that SENSIT-2D performs as intended. Algorithms for calculating the angular source distribution sensitivity and secondary angular distribution sensitivity and uncertainty are explained.

The analysis of the FED (fusion engineering device) inboard shield indicates that, although the calculated uncertainties in the 2-D model are of the same order of magnitude as those resulting from the 1-D model, there might be severe differences. This does not necessarily imply that the overall conclusions from a 1-D study would not be valuable. The more complex the geometry, the more compulsory a 2-D analysis becomes.

The most serious source of discrepancies between a 1-D and a 2-D study are related to the difficulty of describing a complex geometry adequately in a one-dimensional model. However, several neutronics related aspects might introduce differences. The use of different quadrature sets - especially when streaming might be involved - could lead to different results. When the angular fluxes have a pronounced peaked behavior, the angular flux option for calculating the loss term of the sensitivity profile will provide a better answer than the flux moment option. The different sweeping algorithms and code characteristics used by the 1-D and 2-D transport codes might be another cause of discrepancies in the results. Needless to say, a meaningful transport calculation is compulsory in order to obtain reliable results from a sensitivity and uncertainty analysis.

The results from the FED study suggest that the SED uncertainties tend to be smaller than those generated by cross-section uncertainties. It has been pointed out⁴⁵ that, because all secondary particle production processes for a particular element are presently treated as one single process, the simplicity of the hot-cold concept for SED sensitivity might mask several causes of a larger uncertainty than calculated by SENSIT or SENSIT-2D. A more elaborate algorithm for a SED analysis, as an alternative to the hot-cold concept, a separate treatment for the various particle production processes involved, or a combination of both, would eliminate this deficiency. Even with the hot-cold model, which might underestimate SED uncertainties, the SEDs might become the dominant cause of the calculated uncertainty in the case that the

response function is a threshold reaction or in the case that backscattering becomes important. In this latter situation, an SAD (secondary angular distribution) analysis might also contribute significantly to the overall uncertainty estimate. At present, the required crosssection data are not arranged in the proper format to do this type of study.

Sensitivity and uncertainty analysis estimates the uncertainty to a calculated response. It would be more meaningful to be able to implement those uncertainties with a confidence level. In order to do this, we have to know how reliable the covariance data are, what the effects of errors resulting from the transport calculations will be, and what the limits of first-order perturbation theory are. It was assumed in this study that the uncertainties, resulting from uncertainties in different regions, were either fully correlated or not correlated at all, depending on whether these regions have the same or a different material constituency. The evaluation of reliable correlation coefficients would be a major effort by itself.

The validity of an uncertainty analysis is often limited more due to the lack of the proper cross-section covariance data, than due to the lack of representative mathematical formalisms. Covariance data for several materials are still missing, or just guesstimates (e.g., Cu)³³. The fractional uncertainties required for an SED analysis are evaluated for just a few materials and are not available for the various individual particle production processes.

The current version of SENSIT-2D cannot yet access all the covariance data available in COVFILS,³³ but will be able to do so in the future. Even when SENSIT-2D does not require a lot of computing time, the extra amount of c.p.u. time required by the adjoint TRIDENT-CTR run makes a two-dimensional sensitivity and uncertainty analysis demanding when it comes to computer resources. The development and implementation of acceleration methods for TRIDENT-CTR are therefore desirable. A sensitivity analysis involves a tremendous amount of data management. A mechanization of the various steps required, by the development of an interactive systems code, would provide a more elegant procedure for sensitivity and uncertainty analysis.

The algorithms to perform a higher order sensitivity analysis have been developed, but are still too complicated to be built into a computer program for general applicability. The increasing number of transport equations to be solved prohibits the incorporation of present higher order sensitivity schemes in a two-dimensional code. An effort to develop simple algorithms for higher order sensitivity can certainly be justified, however.

It becomes obvious that several flaws can be found in the state of the art of sensitivity and uncertainty analysis. Removing any one of them would require a major commitment.

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APPENDIX A

SENSIT-2D SOURCE CODE LISTING

In this appendix a source listing of the SENSIT-2D code is reproduced. The source listing is documented by many comments.

A source listing of the SENSIT-2D code can also be obtained from the NMFECC by typing the command

FILEM\$READ 5043 .SENS2D SSSS\$END

```
Los Alamos Identification No. LP-1390.
          FROGRAM SENSES (ISIN TAFESESINI SENSOUTITAFESESOUTI
 1
                     TAPE10 TAPE1 TAPE2 TAPE4 TAPE7 TAPE8 TAPE3
 2
 3 с
 4 C THIS IS THE MAIN PART OF THE PROGRAM (SENSIT-20) + NOV. 1 VERSION
 5 c
 6
          LEVEL 2.LC
 7
          COMMON AC (22000)
8
          COMMON /PLOT/ TITLE (8)
 9
10
          COMMON/ITE/ITEST ITYP
          COMMON/COVARI/JCOVAR
11
12
          COMMON / XSFORM / KXSI INTI INA
          COMMON / VRS /LHAXP
13
          COMMON /LLC/ LC (40000)
14
15
         INTEGER 616P
16
17
18
          CALL ECZERD (LC)
19 C +++ START READING CONTROL PARAHETERS
20
          READ(5+1010) (TITLE(1)+1=1+8)
21
    1010 FORMAT (8A10)
          WRITE(6,1020) (TITLE(1),1=1,8)
22
23 1020 FORMAT (1N1+8A10)
          READ (5,1030) ITYPIMAXNED, HNPBIMNEL, IPREPIJTIJTHAX,
24
25
         1
                         IGHINCOUPLILHAXIITESTIJZHAX
26 1030 FORMAT (1216)
27
          READ(5+1030) INSTAPE+NPERNS+IDES+KD2+KR2+KXS+IHT+IHA+
         1
          1 DETCOVINSEDI IDUTPUTINSUNCOV
READ (5:1030) ICHIHOH: IDRT: ISTOP: IGED: IAP3
28
29
          HAITE (6+1040) ITTP+HALHAD+HNPP+HNEL+IPHER+JT+JTHAX+
30
         1
                         IGHINCOUPLILMAXIITESTIJZMAX
32 c
                 (1+ ++177 = TYPE DF SENS,-UNCERT.-AMAL.+ U-X5+1-DESIGN++
++2-VECTDR-X5+3-SED++ 16x+14+/
    1040 FORMAT(1H ++ITYP
33
34
         •
35
                 * MAXNED - MAXIMUM NUMBER OF NDEDS DN A FILE X 1000+,
         э
36
                 35x+1N=+14+/
         С
                 MARE # MAX. NUMBER FLUXES/BUADRANT+,48x,1M#,14,/
* MNEL # MAX. NUMBER DF ETA LEVELS+,50x,1M#,14,/
37
         D
38
         £
                 + IPREP = RREPARED FLUXTAPES REBUIRED? 0/1 ND/YES ++35x+
1MR+14+/
+ JT = NUMBER DF BANDS++60x+1NE+14+/
39
         F
40
         6
                 ♦ JT
ханть ♦
41
         ×
                            - MAXIMUM NUMBER OF TRIANGLES IN +
42
         L
                 +ANY DNE BAND+132x11H=1141/
43
         H

    IGH = TOTAL NUMBER DF ENERGY GROUPS++46x+1H±+14+/
    NCOUPL = NUMBER DF NEUTRON GROUPS IN CPL. CALC.+ ZERD++
    FDR NEUTRONS ONLT++13x+1H±+14+/

44
         N
45
         ٥
46
         .

    LHAX = HAX, P-L DRDER DF CROSS SECTIONS*+43x+14*+14+/
    ITEST = TEST PRINTOUT FLAGI 0-NDHE+1-X5+2-NDHE++

47
         48
49
                 ++3-VECTOR-X5++25X+1H=+14+/
         s
50
         Ŧ
                 + JZHAX - - HAX - DF ZDNES IN ANY DNE BAND++45x+1H=+14+/)
51 C
52
          HPITE (6,1050) IXSTAPE, HPERXS, IDES+KD2+KP2+KX5+IHT+IHA+
53
         1
                           DETCOVINSEDI IDUTPUTINSUNCOV
54 c
    1050 FORMAT(IM (*))JTAPE * SQURCE OF INPUT CROSS-SECTIONS: 0-CARDS(*)

A *1-TAPE4(2-TAPE1(*)152)1M=(14)/
55
56
57
                  * NPERXS , NUMBER OF SUCCESSIVE CASES! ALSO ND. OF INPUT .
         3
58
         с
                 * XS-SETS TO BE READ++11x+1H#+14+/
59
                 IDES
                            - ASSUMED 1 PER CENT DENSITY INCREASE IN PERT.**
         Ð
60
         E
                 + 25. FDR DES.-SEN. + U/1=ND/YES++01x+1H=+14/
                         * NUMBER OF DETECTOR ZONES*531x1H=14;/
* NUMBER OF REPUBLED ZONES*50x1H=14;/
                 • KDZ
61
         F
                 + KPZ
62
         6
63
                             - INPUT XS-FORMATI 0-IF ITTP=2: 1-LASL:2-OPHL+:
                  • KXS
         н
64
65
66
         1
                 32×,1+=,14,/
                              - POSITION OF TOTAL CROSS SECTION IN XS-TABLES*
         3
                  THT
                 31x+1H=+14+/
         ×
67
         L
                  + IHA
                              * POSITION OF ABSORPTION CROSS-SECTION IN X5-4;
                 +TABLES++26x+1++++14+/
68
         Ħ
69
70
         N
                 + DETCOV
                             = 0/1 = DD NDT/DD READ COVARIANCE MATRIX FDR+;
                 + #(6)++28x+1
         ۵
71
72
73
74
                             = 0/1 = DO NOT/DO READ INTEGRAL SED=UNCENTAIN+,
         •
                  + NSED
                  +TIES ++27x+1H=+14+/
         .

    IDUTPUT = DUTPUT PRINT DETAIL<sup>2</sup> O-SUM DVER PERT. 2DMES*;
    DNLY; 1- ALSD INDIV. PERT. 25.4;01x;1M=;14;/

         .
         5
75
                  + NSUMCOV = ND. OF MESP, -VARIANCES SUMMED FOR ITYPE2. +,
76
77 c
         υ
                  * ZERO FOR ITYP=():1:3+:14x:10=:14:/)
78
           WRITE (6,1055) ICHIMON IDPT, ISTOP, ISED : IMP3
20
    1055 FORMAT (IN FAICNINGH & CHI'S GENERATED FROM FLUX MOMENTSA)
```

```
81
                                            + ND/YES 0/681 ++28x+1H=+14+/
                         .
                                                                      = 0/1/2/3+PRINT ND/SN-SETS/RSI'S/PSI'S+SN-SETS++
   85
                                               IDPT
                         3
                                            31x+1+=+14+/
   83
                         с
   64
85
                                            + ISTOP - STOP AFTER PSI'S AND CHI'S ARE CALCULATED? +,
+0/1 ND/YES+;22x;1H=+14+/
                         Ð
                         E

    IGED = 0(1 #-2/x-Y GEOMETRT+,55x,1M#,14,/ -
    IAP3 = 0(1 USE EXISTING SEB. ANG. FLUX FILE? ND/YES+,

   86
                         F
   87
                         6
   88
                         н
                                           29x+1H=+14+/)
   89 C
90 C SET POINTERS FOR SUBROUTINE EBND
   91 C
   92
                           LE=1
   93
                           LDELUELE+16H+2
   94 C
   95
                          CALL EDND (AC (LDELU) + AC (LE) + IGH + NCOUPL)
   96 c
   97 c
   98 C SET POINTERS FOR SUBPOUTINE GEOM
   99 c
 100
                          LITZ = LDELU + IGH
 101
                          LIIT = LITZ + JT
102
                          LNTRZ = LIIT + JT
                          LNF2 = LNF2 + JT
LNF2 = LNF2 + JT
LND2 = LNF2 + KF2
LID2 = LN52 + KD2
LNFID2 = LID2 + JT
LNFID2 = LNFID2 + JT
LNF2 = LNF2 = LNF1D2 + JT
LNF2 = LNF2 = LNF1D2 + JT
LNF2 = LNF2 = LNF1D2 + JT
LNF2 = LNF2 = LNF2 + KF2
LNF2 = LNF2 = LNF2 + KF2
LNF2 = LNF2 = LNF2 + KF2
LNF2 = LNF2 = LNF2 = LNF2 + JT
LNF2 = LNF
103
104
105
106
107
                          LIPEL2 = LNDID2 + JT+JZHAX
LIDEL2 = LIPEL2 + KRZ
108
109
110
                          LPT = LIDELÉ + KDZ
LDT = LPT + JT+KPZ
111
                         LDT = LAT + JT0KAZ

LKTB = LDT + JT0KDZ

LHTD = LKTP + JT0KDZ

LKELAI = LKTD + JT0KDZ

LKELAI = LKELAI + JT0KDZ

LKELDI = LKELAI + JT0KDZ

LKELDI = LKELDI + JT0KDZ

LKELDI = LKELDI + JT0KDZ
112
113
114
115
116
117
118
                           LCOVA = LKELD2 + JT+KD2
119
120
                           LAST = LCOVA + IGH+IGH
121
                          CALL SEDM (AC (LITZ) + AC (LIIT) + AC (LNTPZ) + AC (LNPZ) + AC (LNTZ) + AC (LITZ) +
122
                        1
                                                      AC (LNPIDZ) + AC (LNDIDZ) + AC (LIPELZ) + AC (LIDELZ) + AC (LAT) +
123
                                                         AC (LDT) +AC (LHTP) +AC (LHTD) +AC (LHELP]) +AC (LHELP2) +
                         2
124
                        3
                                                         AC (LHELD1) + AC (LKELD2) + JT+ KP2+ KD2+ ITSUH)
125 c
126 C CALCULATE AUXILARY VARIABLES 127 C
128
                           KPZP = KPZ+1
                          LMAXR = LMAX + 1
IGHP = IGH + 1
129
130
                          HAD = 0
131
132
                          DD 110 1=1+LMAX#
133
                           NH = NH + 1
134
               110 CONTINUE
135 c
136 C SET RDINTERS FOR SUBROUTINE SHOON AND SUBROUTINE TAPAS 137 C
138 c
139
                          HAFNAD=HAYNAD+1000
140
141
142
                          LKTAPPLAST
                          LHT = LHTAP + 16H+5 + 1
143
144
                          -----
                          LISN E LMH + IGH
LNPB E LISN + IGH
LNUP E LISN + IGH
LNUP E LNPB + 4
LAST E LNUP + MNEL+4
145
146
147
148
149
150
151
                          ICE = 1
ICM = ICE + 4+MNPB+I6M
152
                          ILAST = ICH + 4+HNP#+IGH
153
154
155
                          CALL SNCDN (LC (ICE) +LC (ICH) +AC (LHT) +AC (LNUP) +AC (LNPB) +
                        1
                                                        AC (LHH) + HNPD + HNEL + AC (LISH) + IGH + IDPT)
156
157
                           CALL TAPAS (AC (LKTAP) + AC (LHH) + NH+ ITSUH+ IGH+ HAXHAD
158
                        1
                                                      AC (LKTP) +AC (LKELP1) +AC (LKELP2) +KP2+JT)
159 c
```

160 C SET ROINTERS FOR SUBROUTINES RAGEN AND FLUXHOM

```
161 c
            LP - LNPB
162
            LR = LNPB
LR = LP + MNPD+LMAXP+LMAXR
LPMNI = LR + 4+MNPB+MH
LT = LPMHI + MNPB
LAST = LT + 2+LMAX + 1
163
164
165
166
167
168
            IFFLUX = ILAST
            IFLUX # IFFLUX + JTHAX+HMPB
IFUX # IFFLUX + JTHAX+HMPB
IFMDH # IFUX + MM+JT+JTHAX
169
170
171
            ILAST=IFHDH+JT+JTHAX
172
173
            IF (IPREP.EB.1) 60 TO 140
174
175
            Do 130 1=1+2
176
            1F (1.ER.2) HAD=1
177
            120 GP=1.16M
178
            ....
180
            CALL PAGEN (AC (LP) + AC (LR) + LC (ICH) + LC (ICE) + AC (LPHHI) + AC (LT) +
181
          1
                         AC (LHH) ILHAI I HNPBINHI LHAXPIGIKADIAC (LISN))
182
183
            CALL FLUXHON (AC (LIIT)+LC (IFFLUX)+LC (IFLUX)+LC (IFUX)+AC (LNT)+
                            AC LENHI FAC (LR) FAC (LETAP) FEFIGHFEPZENHEJTE
184
           1
           ž
                             HPITIMAIMPDIHADIAC (LHTP) AC (LHELP1) AC (LKELP2)
185
           ā
                             AC (LKTD) + AC (LHELD1) + AC (LHELD2) + LC (IFMDH) + HD2+ IAF3)
186
187
      120 CONTINUE
130 CONTINUE
186
189
190
      140 CONTINUE
191 c
192 C SET ROINTERS FOR SOUDROUTINE DETSEN
193 c
194
            LESUME - LNPE
195
            LPHIN = LFSUH# + 16H
196
            LR = LPHIV + JTHAY
L2DN = LR + K52+16H
            LSENP + LZON + KDZ
198
           LSENN = LZENN + IGH
LSIGHA = LSENN + IGH+KDZ
199
200
           LAST = LEIGHA + KDZ+IGH
201
202
203
            CALL DETSEN (AC (LHELDI) +AC (LHELDE) +AC (LHTD) +HDZ+ JT+AC (LIIT) +
                       IGHI IDUTPUTI DETCOUI PRIAC (LCOVPIIAC (LFSUMPIAC (LPHIV))
204
          1
205
           ž
                         AC (LR) + AC (LZDN) + AC (LSEND) + AC (LSSEND) + AC (LSIGHA) +
206
           з
                         AC (LDELU) + AC (LE) + NCDUPL + 16ED)
207 c
208 C SET POINTERS FOR CHI'S AND PSI'S
209 c
210
            LIPSI = LNPB
           LCHI = LIPSI + 16H4KP2P
LCCHI = LCHI + HP2P+16M
LASTI = LCCHI + 16H
211
212
213
214
215
            IF (ICHINDH.EB.1) 60 TO 145
216 C SET POINTERS FOR SUBROUTINE CHIS
217
218
            IFLUX = 1
            IAFFLUX EIFLUX + HNPB+JTHAX
IAFLUX E IAFFLUX +HNPB+JTHAX
ILAST E IAFLUX + HNPB+JTHAX
219
220
221
222
223 C CALCULATE THE CHI'S
224
225
            CALL CHIS (LC (IFLUX)+LC (IAFFLUX)+LC (IAFLUX)+AC (LHTAP)+AC (LCHI)+
226
                          AC (LKELP1) +AC (LHELP2) +AC (LHTP) +AC (LIIT) +AC (LHHI)
227
           2
                          AC (LISN/ +AC (LNT) +KPZ+JT+JTHAX+IGH+IDUTPUT+ITSUH+IGED)
228 c
229 C SET POINTERS FOR SUBROUTINE POINT43
230 c
231
      145 LIAMA = LAST1
           LILP = LIAPP + JT44PZ
LPSI = LILP + JT44PZ
232
233
            LEPSIELPSI + LMAXP+16H4WP2P
234
235
            LAST = LPPSI + LHAXP+IGH
236
237 C SET POINTERS FOR SUBPOUTINE PSIS
238
            CALL POINTAB (IGHIAC (LIPSI) + ISUHILHAXPI ILANTIKPZP)
239
240
            IFFLUX = ISUH + 1
```

```
241
           IFAFLUX # IFFLUX + ITSUH<sup>4</sup>nm
Ilast # Ifaflux + Itsuh<sup>4</sup>nm
242
243
244 C CALCULATE THE #SI'S AND STORE IN LCM
245 CALL #SIS(AC(LHTP)+AC(LIIT)+AC(LHELP1)+AC(LHELP2)+
246
          1
                        AC(LIPSI) +LC(IFFLUx) +LC(IFAFLUx) +
                        AC (LPSI) + AC (LPPSI) + NH+ JT+ PZ+ PZP+ IGH+ LHAXP+
247
          2
                        AC (LKTAP) + AC (LCHI) + IDFT + IPREP + ICHIMDH + IGED)
248
          з
249
250
           IF (ISTOP.EB.1) STOP
251
252 C CLEAR APPROPRIATE SCH AND LCH SPACE
           INELP1=ISUM+1
253
254
           NELPZEILAST
255
           DD 155 INELPEINELP1+INELP2
256
257
258
      155 LC (INEL#)=0.0
           IMELP1=LAST1
           IHELP2=LAST
259
           DO 157 INELPEINELP1 INELPE
      157 AC (IHELP)=0.0
260
261
           CALL SUBROUTINES TO READ IN AND/DR CALCULATE VALUES OF CROSS
262 C
           SECTIONS
263 с
264
           NXS = 0
265 C +++ DEPENDING ON THE TYPE OF CROSS SECTION OF ERRORFILE AVAILABLE!
266 C +++ THE CODE BRANCHES HERE INTO THO DIFFERENT EXECUTION MODES
           IF (ITYP.EB.2) 60 TO 290
26.7
268 c
269 C +++ IF A SED UNCERTAINTY ANALYSIS IS HANTED THEN I MUST READ IN THE
270 C +++ ARRAYS GHED AND FSED FOR ALL NEUTRON GROUPS
271
      150 CONTINUE
           IF (NSED.EB.0) SO TO 170
IF (NCDUPL.EB.0) ISHIFISH
IF (NCDUPL.NE.0) ISHIFNCDUPL
272
273
274
275 C SET POINTERS FOR GHED AND FSED
          LGMED = LAST1
LFSED = LGMED + 16M1
LAST1 = LFSED + 16M1
276
278
279
280
           READ(5+1060) (AC(LGHED-1+1)+1=1+16H1)
281 1060 FORMAT (1216)
           READ (5+1070) (AC (LESED-1+1)+1=1+16H1)
282
     1070 FORMAT (612.5)
283
           HPITE (6+1080)
284
     285
286
287
288
          DD 160 I=1.IGH1
289
           HRITE (6+1090) I+AC (LGHED-1+1)+AC (LESED-1+1)
290 1090 FORMAT (14 +2×+13+4×+13+6×+18E10.3)
291
      160 CONTINUE
292 C 444 END OF SED-UNCERTAINTY INPUT AND PRINT
293 c
294
      170 CONTINUE
295 C CALCULATE AUXILARY VARIABLES
         1TL = 16H + 1HT
296
           NHJ = ITLOIGHOLMAXP
NHL = IGHOITL
NNK = IGHOIGHOLMAXP
297
298
299
300 C SET POINTERS FOR DELFD AND DEL (LCH)
           155LFD = 150H + 1
301
           IDSL = IDSLED + NHK
302
303 C SET LCH-POINTERS FOR CROSS SECTIONS
           IXS = IDSL + NUK
IXS1 = IXS
IF(KXS.EB.2) IXS1 = IXS + NUJ
304
305
306
307
            ILAST = IXS1 + HHJ
           NXS1 = NXS + 1
308
            HRITE (6+1100) NXS1+NPERXS
309
    1100 FORMAT(1H ++ CASE NUMBER ++13++ DF NPERXS =++13++ SUCCESSIVE+

1 + CASES+)
310
311
           CALL SUB5 (LC (IXS) + IGH+ ITL+ NNL+ LHAX+ IXSTAPE+TITLE+LC (IXS1))
312
313 C SET POINTERS FOR SECOND CROSS SECTION SET
314 - 1x53MR = 1x5
           IF (ITYP.NE.1) 60 TO 180
IF (IDES.EB.1) 60 TO 180
315
316
           IXSBAR = IXS + HUJ
IXS1 = IXSBAR
317
318
           IF (HXS.EB.2) IXS1 = IXSBAR + HHJ
ILAST = IXS1 + HHJ
319
320
```

```
321
            HRITE (6+1110) NEST
     322
323
       1
            CALL SUB5 (LC (IXSBAR) + IGH+ ITL+ NHL+ LHAF+ IXSTAPE+TITLE+
324
      LC(IXSBAR
LC(IXSI))
180 CONTINUE
325
326
327 C SET SCH-POINTERS FOR DETIAXSIFIEXEISXESESSIE
           LDST = LAST1
LAXS = LDST + IGH
328
329
           LFISXS # LAXS + IGH
LSXS # LFISXS + IGH
330
331
332
           LEXENG = LEXE + IGH
333
            LAST = LEXENG + 16H
334 C CALL SUBROUTINE TO CALCULATE PERTURBATION OF CROSS SECTIONS
           CALL SUBS (AC (LDST) +LC (IDSL) +LC (IXS) +LC (IXSBAR) +
335
                     IGHI ITLIAC (LAXS) AC (LSXS) +LC (IDSLFD) AC (LSXSNG) +
336
          2
                       NCOUPLIAC (LEISXS) + IDES)
337
338 C 444 IN DRDER TO EDIT SED PROFILES AND COMPUTE SED UNCERTAINTIES
339 C 444 ME NEED ADDITIONAL ARRAYS AS FOLLONS
            IF (NCOUPL.ED. 0/IGH1=IGH
340
341
            IF (NCOUPL. HE. 0) IGHIENCOUPL
            NNSED = IGH1+IGH1
IPSED = IDSL + NHK
342
343
344
            ILAST = IPSED + NHSED
           LFFD = LFFD + 16M
LFFD = LFFD + 16M
LSEN = LFFD + 16M
345
346
347
           LSENT = LSEN + 16M
LFFDNG = LSENT + 16M
LPSGP = LFFDNG + 16M
346
349
350
351
           LPSG = LPSGP + IGH1
352
            LSSED = LPS6 + IGH1
           LSHOT = LSSED + 16H1
LSCOLD = LSHOT + 16H1
LDRSED = LSCOLD + 16H
353
354
355
                                 16H1
356
           LAST = LDRSED + 16H1
357 c
358 C 444 TO PRINT SENSITIVITY PROFILES RER ZONE WE IDENTIFY A ZONE-PARAMETE
359 C 444 ANI-LOOP THROUGH ALL DUTPUT ROUTINES
360 c
361
     1=1
ט=⊬ 190
362
363
     60 TD 210
200 ₩≅₩+1
364
365
       31=1
366
367
           HRITE (6+1120)
    1120 FORMAT (1H )
368
36.9
      210 CONTINUE
370
            1F (NYS.NE. 0) 60 TO 220
371
            IF ((J1.NE.1).DR. (M. GT. 0)) 60 TO 220
372 C +++ FOR XS-SENSITIVITY CALCULATIONS PRINT A LIST OF DEFINITIONS
373 C FOR PARTIAL AND NET SENSITIVITY PROFILES AS EDITED IN SUBU
374
375 c
376 C +++ FOR DESIGN-SENSITIVITY CALCULATIONS PRINT ANDTHER LIST OF
377 C DEFINITIONS OF EDITS FROM SUBB
378
            IF (ITYP.ED. U.DP. ITYP.ED. 3) CALL TEXT
379
380
            IF (ITYR.EB.1) CALL TEXTA
381 220 CONTINUE
362 C
383
            IF (J1.NE.1) 60 TO 230
384
            IF (NCOUPL.EB. 0) IGH1=IGH
385
            IF (NCOUPL.NE. 0) IGHI-NCOUPL
386
      230 CONTINUE
387
            CALL PDINTS (AC (LIPSI) + + 1PPSI + + P2P + 16H + AC (LCHI) + AC (LCCHI))
386
389
            CALL SUBB (AC (LF) +LC (IDSL) +LC (IPPSI) +AC (LDST) +AC (LCCHI) +DELI +
                       DELIFDIARILHAIPIIGHIAC (LAIS) IAC (LSEN) IAC (LSES)
390
          1
          23
391
                        AC (LE) +AC (LDELU) +LC (IDSLFD) +AC (LFFD) +AC (LFISXS) +
392
                        AC (LSENT) + J1+NCOUPL+ IGHI+AC (LFFDNG) + ++ IDES)
393
394
            IF (ITYP.NE.3) 60 TO 240
395 C *** FOR SED SENSITIVITY AND UNCERTAINTY ANALYSIS WE EDIT FROM SUB11:
396 C *** But only for the sum over all reaturded zones:
397 C +++ AND DHLY FOR NEUTRON GROUPS .
398
399
            IF ((J1.HE.1).DR. (K.ST. 0)) 60 TO 240
400
```

401 CALL SUB11 (LMAJPIJ1) IGH1 / IGHI PPINSEDILC (IPSED) AC (LPSEP) AC (LPSG) +AC +LSSED/ +AC +LSHOT) +AC (LSCOLD) +AC (LDRSED/ + 402 403 LC (IDSL/+LC (IPPSI) +AC (LDELU/+AC (LGHED/+AC (LFSED/) 404 405 C +++ END SED MUNLYSIS 406 C 407 240 IF (NCOUPL.ED. 0) 60 TO 250 408 IF (J1.NE.1) 60 TO 250 409 1GH1=16H 410 JI=NCOUPL+1 60 TO 220 411 250 CONTINUE 412 413 IF (IDUTPUT.EP. 0) 60 TO 260 414 IF (H.EB.KPZ) 60 TO 260 GD TD 200 260 IF (JCDVAR.EB.0) 60 TD 270 415 416 417 LENCOVEIGNOIGH 418 C SET POINTERS FOR COVARIANCE MATRIX ICOVR = ILAST ILAST = ICOVR + LENCOV 419 420 421 LESUN . LAST 422 LAST = LESUN + IGH 423 CALL SUBSILC (ICOVA) + AC (LSEN) + AC (LFSUH) + IGH+LC (LDELU)) 270 NJS = NXS + 1 424 425 IF (NXS.LT. NPERXS) 60 TO 150 426 427 428 280 STOP 429 430 c 431 290 CONTINUE 432 c 433 C 444 THIS SECTION PERFORMS A COMPLETE SENSITIVITY AND UNCERTAINTY ANA-434 C +++ LISIS OF THE VECTOR CROSS SECTIONS 435 C 444 THE CODE THEN RECTURES A COVARIANCE FILE TO BE GIVEN IN LASL EMBFI 435 C 444 Format which contains rairs of vector cross sections with their 437 C +++ RESPECTIVE COLARIANCE MATRIX. 438 C 439 NCOV - NPERXS 440 HPITE (6+1130) NCDV 441 1130 FORMAT (1H + / A VECTOR CROSS-SECTION UNCERTAINTY ANALYSIS HILL++ + 3E+, 1 442 443 ž + PERFORMED+1/+FOR A TOTAL OF NPERXS = +1131 444 3 . PAIRS OF VECTOR >S WITH COVARIANCES FROM TAPE10 +/) IF (NCDUPL.EB. 0) IGH1=IGH IF (NCDUPL.NE. 0) IGH1=NCDUPL 445 446 447 NNCOV = 16H1+16H1 448 C SET POINTERS FOR VECTOR CROSS SECTION UNCERTAINTT ANALYSIS 449 LVXS1 = LAST 450 LUX52 = LUX51 + 1641 451 LP1 = LVX52 + 16H1 LP2 = LP1 + 16H1 LDP = LP2 + 16H1 452 453 454 LAST = LDP + NCOV 455 ICOV # ILAST 456 ILAST E ICDU + NHCDU 457 C +++ START A LODP HERE DVER ALL XS-PAIRS 459 C PUT CHI'S IN APPROPRIATE SPACE IN SCH 460 c 461 CALL PDINTS (AC (LIPSI) + P2P+ IPPSI+ KP2P+ IGH+AC (LCHI) + AC (LCCHI)) 462 c 463 c 464 300 NXS = NXS + 1 465 CALL SUBSH (AC (LUXS1) + AC (LUXS2) + LC (ICDH) + IGH1+ ID+ DEN1+ DEN2) 466 C 444 THIS ROUTINE READS RAIRS OF VECTOR 35 AND THEIR COUNDIANCE HATRIS 467 C 444 FROM TAPE10 468 469 CALL SUBBU (AC (LVXS1) +AC (LVXS2) +LC (ICDV) +AC (LCCNI) +AC (LDELU) + 470 1 AC (LP1) FAC (LP2) FAC (LDR) FAC (LE) FIGHT IGH1 FKP2+ 471 è. AAIIDINSSIDEN1IDENC) 472 C 473 C +++ THIS ROUTINE COMPUTES AND EDITS SENSITIVITY PROFILES #1 AND #2 474 C +++ AND FOLDS THEM WITH THE COURDINNEE MATRIX DRIN 475 C 444 FOR THIS PARTICULAR PAIR OF VECTOR XS AND THEIR CORELATED ERRORS 476 c 477 IF (NYS.LT.NCOV) 60 TO 300 478 c 479 CALL SUBSY (AC (LDR) + NCDV + NSUMCDV) 480 C 444 THIS ROUTINE COMPUTES THE TOTAL VARIANCE DUE TO THE SUM OF ALL

```
481 C +++ CROSS-SECTION ERRORS: AND REPEDRES PARTIAL SUMS IF NSUMCOV.NE.U
482 c
483
484
            END
485 c
486 c
487
     с
488 C
489 C EBND READS IN NEUTRON AND GAMMA MAY STRUCTURE AND CALCULATES LETHARGY
490 c
              WIDTHS PER GROUP
491 c
492 c
493
           SUBROUTINE EBND (DELUSESIGHINCOUPL)
494 C
495 C + + + INPUT COMMENTS + + +
496 C
497 c
                E (J)
                          - ENERGY BOUNDARIES FOR HEUTRON AND/OR GAMMA GROUPS
498 c
499 C + + + DUTPUT COMMENTS + + +
500 c
               DELU(J) - LETHARGY NIDTHS
501 c
502
            INTEGER 6
503
            INENSION DELU(1) +E(1)
505 FIRENSIDE DECOMPLETATION DECOMPLETATION DECOMPLETATION DECOMPLETATION AND GANNA GROUP BOUNDARIES AND EDIT

505 IF (NCDUPL.EB.0) IGHP1 = IGH + 1

506 IF (NCDUPL.NE.0) IGHP1 = NCDUPL+1

507 READ (5:430) (E(I):I=1;IGHP1)

508 HRITE (6:420) IGHP1
509
            WFITE (6,410) (E (1), 1=1, 1600 1)
510
            IF (NCOUPL.ED. 0) 60 TO 110
            IGHP2 = IGH + 2
NCP2 = NCDUPL + 2
NGAMP1 = IGH - NCDUPL + 1
511
512
513
514
            READ (5+430) (E 12+1=NCP2+16HP2)
515
            HAITE (6+440) NEAHAI
516
            HPITE (6+450) (E (1)+1=NCP2+16HP2)
     110 CONTINUE
517
518 C CALCULATE LETHARGY INTERVALS FOR BOTH HEUTRON AND GAMMA GROUPS
519
           IF (NCOUPL.ER. 0) NHEUTEIGH
520
            IF (NCOUPL.NE. 0) HNEUTENCOUPL
521
            120 120 6=1+HNEUT
            EPUDZ= E(6)/E(6+1)
522
523
524
            DELU(6) = ALOG (EPUDZ)
     120 CONTINUE
525
            IF (NCOUPL.EB. 0) 60 TO 150
526
            DD 130 6=16HP1+16H
527
            EDUD2=E(6+1)/E(6+2)
528
            SELU(6) PALOS (EBUDZ)
529
      130 CONTINUE
530
            NRITE (6+460)
531
            DD 140 6=1+16H
            HRITE (6,470) 6, DELU (6)
532
533
      140 CONTINUE
534
       150 CONTINUE
535
       410 FORMAT(1H +10(1x+1PE10.3))
536
       420 FORMAT(1M +14) NEUTRON ENERGY GROUP BOUNDARIES READ: IN EVA:
430 FORMAT(6612.5)
440 FORMAT(1M +14) GAMMA ENERGY GROUP BOUNDARIES READ: IN EV +)
537
538
539
       450 FORMAT(1H +10(1x+1PE10.3))
<u>-</u>40
       460 FORMAT (1H +/++COMPUTED LETHARGY WIDTHS PER GROUP+ DELU(6/+)
541
       470 FORMAT(1H ++6 =++13+3+++DELU(6) =++1#E10.3)
542
543
           RETURN
            END
544 c
545 с
546 C SECH READS AND EDITS THE SECHETRY FOR PERTURDED AND DETECTOR ZONES
547 c
548
            SUBROUTINE GEOM (ITZ: IIT: NTPZ: NFZ: NDZ: IDZ: MPIDZ: NDIDZ: IPELZ:
549
           1
                                 IDEL2+PT+DT+HTP+HTD+HELP1+HELP2+KELD1+KELD2+
550
           2
                                 JT+KPZ+KDZ+ITSUH)
551 c
552
            INTEGER ATIOTINELAIINELASINELASINELAS
553 c
554
            DIMENSION ITZ(1)+IIT(1)+NTPZ(JT+1)+NPZ(1)+NDZ(1)+IDZ(JT+1)+
555
           1
                       NPIDZ (JT+1)+NDIDZ (JT+1)+IPEL2(1)+IDEL2(1)+PT (JT+1)
556
                        DT (3T+1)+KTP (3T+1)+KTD (3T+1)+KELP1 (3T+1)+KELP2 (3T+1)+
557
           3
                        RELDI (JT+1) +RELDZ (JT+1)
557 - -
558 c
559 c + + Dutput Comments + + +
560 c - NPIDZ(J+K) - IDENTIFIES PERTURBED ZOME = FOR BAND J
```

```
561 c
              NDIDZ (J+K) - IDENTIFIES DETECTOR ZONE - FOR BAND J
              IPEL2(K) - PERT, ZONE & SMONS UP IN IPEL2(H) BANDS
IDEL2(H) - DET, ZONE & SMONS UP IN IDEL2(H) BANDS
562 c
                          - PERT, ZONE & SHONS UP IN IPELS (F) INTO
- DET. ZONE & SHONS UP IN IDEL2(H) BANDS
- PERT, ZONE & SHONS UP IN THE BANDS PT(K+1) . . .
- DET. ZONE & SHONS UP IN THE BAND DT(H+1) . . .
- IS PERT, ZONE & PRESENT IN BAND J ? 0/1 NOVES
563 c
564 c
              PT (JJIH)
565 c
              DT (JJ+K)
566 c
              HTP (JIK)
                           - IS DET. ZONE & PRESENT IN BAND J ? U/1 ND/YES
567 c
              KTI (J+K)
              KELPI (J+K) - PERT, ZONE H IN DAND J STARTS WITH TRI, KELPI
568 c
              KELP2(J+K) - PERT, ZONE K IN DAND J ENDS WITH TRI. KELP2
569 c
              KELDE(J)K) - DET, ZONE K IN JAND J ENDS MINN INI, KELDE
Keldi(J)K) - DET, ZONE K IN JAND J ENDS MITH TRI, KELDE
570 c
571 c
572 c
573 C + + + INPUT COMMENTS + + +
574 c
             111(3)
              IIT(J) - 4 TRIANGLES IN BAND J
NTP2(J)12) - 4 NUMBER OF TRIANGLES IN ZOME 12 FOR BAND J
575 c
576 c
577 c
              IDZ(J) - ZONE IDENTIFICATION FOR THE IZ'TH ZONE IN BAND J
ITZ(J) - P ZONES IN BAND J
KPZ - P PERTURBED ZONES
578 c
                            - P DETECTOR ZONES
579 с
              KDZ
                            - PERTURDED ZONE IDENTIFICATION FOR KPZ'TH REPT. ZONE
580 c
              NP2 (MP2)
                           - DETECTOR ZONE IDENTIFICATION FOR KD2'TH DET. ZONE

- DETAILED DUTPUT DESIRED ? 0/6T.0 ND/YES
              NDZ (KDZ)
581 c
582 c
              ITEST
                            - C BANDS
583 c
              37
584 c
585 C READ IN " ZONES FOR EACH BAND 1721 " TRIANGLES FOR EACH BAND 117
586 C READ IN & TRIANGLES IN EACH ZONE NTRZ
587 C READ IN ZONE IDENTIFICATIONS IDZ
         ITSUM=0
588
            DD 110 J=1+JT
589
            READ (5:402) ITZ (3) + IIT (3)
ITSUM=ITSUM+IIT (3)
590
591
592
             12=172 (J)
593
             READ (5+403) (NTP2 (3+1)+1=1+12)
594
             READ (5+403) (102 (3+1)+1=1+12)
595 110 CONTINUE
596 C PEAD PERTURBED ZONE IDENTIFICATION 4 MPZ
597 C READ DETECTOR ZONE IDENTIFICATION & NDZ
598
             PEAD (5+403) (NP2 (12)+12=1+KP2)
599
             READ (5+403) (ND2 (12)+12=1+HD2)
600 C SET IDENTIFIERS FOR PERTURBED AND DETECTOR 20NES
            20 120 H=1+KPZ
601
             IPEL2(K)=0
602
            DO 120 J=1+JT
603
604
             KTP (3+K)=0
      120 CONTINUE
DO 125 K=1+KDZ
605
€06
607
             IDEL2(H)=0
608
      125 CONTINUE
609
             DD 210 J=1+JT
610
611
             33=172 (3)
             DD 130 12=1+33
             NF 112 (3+12)=0
612
613
      130 NDIDZ(J+12)=0
614
            DD 160 12=1+JJ
             DD 150 K=1+KPZ
615
616
             NRENPZ (K)
             IF (102 (3+12) .NE.NP) 60 TO 150
€17
             IF (HTP (J+H) . NE. 0) 60 TO 140
IFEL2 (H)=IPEL2 (H)+1
618
619
620
             PT (IPEL2 (K) +K)=J
621
       140 NPIDZ (3+12)=K
622
            KT# (3+K)=1
       150 CONTINUE
623
624
       160 CONTINUE
625
            DD 170 H=1+HD2
             KTD (J+K)=0
626
627
       170 CONTINUE
            DD 200 IZ=1+JJ
DD 190 K=1+KDZ
628
629
630
             NDENDZ (K)
631
             IF (102 (3+12) . NE. ND) 60 TO 190
             IF (KTD (J+K) .NE. 0) 60 TO 180
632
633
             IDEL2(K)=IDEL2(K)+1
634
             DT (IDEL2 (H) +H)=J
635
      180 NDIDZ (J. 12) =K
636
            KTD (J+K)=1
637
        190 CONTINUE
638
        200 CONTINUE
639
       210 CONTINUE
```

639 2100 640 c

```
641 C SET TRIANGLE IDENTIFICATION FOR PERTURBED AND DEVECTOR ZONES
642 C
643
                      DD 280 J=1.JT
                      DD 240 12=1+#P2
1F(#TP(J+12).EP.0) 60 TO 240
 644
645
 646
                      KELP1 (3+12)=1
647
                      HELP2 (3+12)=0
 648
                      HELP2=172 (J)
649
650
                      DD 220 1=1+HEL#2
                      HELPIENTPZ (J)
651
                       IF (NPIDZ (J+1).E8.12) 60 TO 230
652
                       HELP1 (J+12)=KELP1 (J+12)+HELP1
 653
            220 CONTINUE
654 230 HELP2(J)12) HHELP1(J)12/ HHELP2(J)12/ HELP2(J)12) HELP2(J)
658
659
            240 CONTINUE
                     DD 270 12=1++DZ
660
                      IF (MTD (3+12).EB. 0) 60 TO 270
661
                      KELD1 (3+12)=1
662
                      KELD2(J+12)=0
 663
                      HELP4=172 (J)
                      DD 250 1=1+HELP4
664
                      HELP 3=NTPZ (JII)
665
                      IF (NDIDZ (J+1). E8. 12) 60 TO 260
666
667
                      RELD1(J+12)=RELD1(J+12)+ HELPJ
            250 CONTINUE
668
260 HELD2 (3+12) =HELD1 (3+12) +HELP3-1
672 C END REMOVING
673 270 CONTINUE
673
674
            280 CONTINUE
675 c
676 C EDITING
677
678
679
                   WFITE (6+410)
                      WRITE (6+410)
                      12=172 (3)
680
681
                      HPITE (6+409) J
682
                      HPITE(6:408)
683
                      WEITE (6+405) (102 (3+1)+1=1+12)
                      HAITE (6+408)
684
685
                      HAITE (6+404) (NTAZ (3+1)+1=1+12)
686
                      WRITE (6+406) (NPIDZ (3+1)+1=1+12)
667
                      WRITE (6:407) (NDID2 (3+1)+1=1+12)
688
                       H#1TE +6+410>
             689
690
                      HPITE (6+410)
691
                      H#1TE (6+411)
692
                      DD 310 H=1+H=2
                      IPEL#IPEL2(K)
H#ITE(6+412) KHIPEL
693
694
695
                      WRITE (6+413) (PT (J+K)+J=1+1#EL)
 696
             310 CONTINUE
 697
                      WRITE (6+410)
698
                      HRITE (6+415)
699
                      DD 320 #=1+HDZ
 700
                       IDEL=IDEL2(K)
701
                       MRITE (6+414) KHIDEL
702
                       NAITE (6+413) (DT (J+K)+J=1+IDEL)
703
            320 CONTINUE
704 c
705 C PRAP REHOVE FOLLONING CARDS IN ACTUAL PROGRAM
706
                   MRITE (6+410)
MRITE (6+500)
DD 330 J=1+JT
708
709
                      HRITE (6+503) (KTP (3+K)+K=1+KR2)
710
             330 NRITE (6+504) (HTD (3+K) +H=1+KDZ)
711
             500 FORMAT (1H +40H4 + + TRIANGLE INFO FOR PERT ZONES + + +)
             501 FORMAT(1M +11x+9M JUNEDUT +21503M K=+13+4M JJ=+13)
502 FORMAT(1M +11x+9M JUNEDUT +2110+3M K=+13+4M JJ=+13)
712
 713
714
              503 FORMAT (14 +20×+3+++++2×+1216)
715
              504 FORMAT (14 +20x+344TD+2x+1216)
716 C RAPA END MEHOVING
717
              401 FORMAT (16)
 718
              402 FORMAT (216)
 719
              403 FORMAT (1216)
              404 FORMAT (1M +8x+11N= TRIANGLES+15(16+1x))
 720
```

```
721
       405 FORMAT(1H +10x+9H ZONE ID.+15(16+1H+))
722
723
       40; FORMAT(1H +8x+11HPERT. ZONE?+15(16+1x))
407 FORMAT(1H +9x+10NDET. ZONE?+15(16+1x))
       408 FORMAT (1M +20x+15(7+++++++) //)
724
725
       409 FORMAT (1H +12H+++ BAND = =+16+4H +++)
       410 FORMAT(IN $/$/)
411 FORMAT(IN $270400 PERTURBED ZONE INFO 000)
412 FORMAT(IN $10$)16HPERTURBED ZONE $120208 IS PRESENT IN THE FOLLOW
726
727
728
729
           IINGIIEIGH BANDS)
       413 FORMAT(14 +200+2014)
414 FORMAT(14 +10++15+DETECTOR ZONE =+12+28H IS PRESENT IN THE FOLLOWI
730
731
732
           INGI IZIGH BANDS)
733
       415 FORMAT (1M +26H+++ DETECTOR ZONE INFO +++)
734
            RETURN
735
736 c
            END
737 C SUBROUTINE DETSEN CALCULATES DETECTOR RESPONSES AND DETECTOR
738 C SENSITIVITY PROFILES. IF DETCOURT A DETECTOR UNCERTAINTY ANALYSIS
739 C IS PERFORMED
740 c
            SUBROUTINE DETSEN (RELD] + RELDZ + KTD+ KDZ+ JT+ 11T+ 16H+ 10UTPUT+ DETCOV+
741
742
           1
                                 RAICOVAIFSUNAIPHIVIRIZONISENAISSENAISIGHAIDELUIEI
743
           2
                                 NCOUPL + IGED)
744
745
746
            DIMENSION RELDI(JT+1)+RELDZ(JT+1)+RTD(JT+1)+IIT(1)+DELU(1)+E(1)+
          ź
                        PHIV(1)+#(+22+1)+SSEN#(+22+1)+20+(1)+COV#(16++1)+
747
                         SENR (1) +FSUMP (1) + SIGHA (HDZ+1) +EE (50)
748
           COMMON /PLOT/ TITLE (8)
749
            INTEGER GIDETCOV
750
751
752
           DATA CR1/6.283185308/
753
           IF(IGED.EB.1) CFI=1.0
754 c
755 C READ AND EDIT DETECTOR RESPONSE FUNCTIONS
756 DD 120 H=1+KDZ
757
            READ (5+410) (SIGHA (K+6)+6=1+16H)
758
759
           NRITE (6+420) K
            DD 110 G=1+16H
759 DD 110 BLITE

760 110 NRITE(6:430) 6:SIGHA(K:6)

761 120 CONTINUE

762 C

763 C INITIALIZE
      DD 130 6=1+16H
130 5ENR (6)=0.0
764
765
766
767
           DD 150 K=1+KD2
            ZON (#)=0.
768
            DD 140 6=1.16H
769
            # (x + 6)=0.
770
            771
772
       140 CONTINUE
       150 CONTINUE
773
            ee≖ú.
774 c
775 C CALCULATE GADUPHISE AND ZOMENISE RESPONSES A (#16)
776
777
778
           REHIND 1
DD 200 6=1,16H
DD 190 J=1,JT
779
            DD 180 H=1+HDZ
780
            IF (HTD (J+H).EB.0) 60 TO 180
781
            IZ=MELD2(J+K)-MELD1(J+K)+1
            menb(1)(PMIV(1)+1=1+12)
DD 170 1=1+12
P(K+6)=P(K+6)+PMIV(1)+516HA(K+6)
782
783
784
785
       170 CONTINUE
786
       180 CONTINUE
787
       190 CONTINUE
768
      200 CONTINUE
789 с
790 C CALCULATE TOTAL RESPONSE FUNCTION RR
         DD 220 6=1+16H
SENR(6)=0
791
792
793
            DD 210 #=1+KDZ
794
            795 210 CONTINUE
796 220 CONTINUE
797 C
798 C CALCULATE SENSITIVITY ANDFILES
799 MRITE(6,525)
800 DD 240 6=1;164
```

```
801
             DD 230 #=1+#DZ
802
             IF (SIGHA (H+6).E8.0.0) 60 TO 230
803
             # 1++G) ## (K+G) #C#I
             HATTE (6.530) KIELE (KIE)
804
805
             SSENA (K+G) == (H+G) / (HH+DELU (G))
806
             SENRIG) = SENRIG) + SSENRIKIG)
607
        230 CONTINUE
808
       240 CONTINUE
809 c
810 C SET UPPER-BOUNDARIES FOR GROUPS
             IF (NCOUPL.ED. 0) 60 TO 270
811
             DO 250 GETINCOUPL
812
813
             EE (6) *E (6)
        250 CONTINUE
814
815
             NCP1=NCDUPL + 1
             DD 260 ...........
816
817
             EE (G) =E (G+1)
618
        260 CONTINUE
       60 TO 290
270 DO 280 6=1, 16H
819
820
821
             EE (6) =E (6)
822
        280 CONTINUE
823 c
824 C EDIT SENSITIVITY PROFILES SUMMED DUER ALL DET. ZONES
825 290 MRITE(6:440) (TITLE(1):1=1:8)
826
             H#ITE (6+450)
827
             HRITE (6:460) AR
828
             HRITE (6+470)
             HRITE (6+490)
829
830
             DD 300 6=1+16H
             HAITE (6+500) 6+EE (6) +DELU (6) +SENA (6)
831
832
        300 CONTINUE
833
             MRITE (6+510)
             WRITE (6,520) 1.0
834
835 c
836 C DO UNCERTAINTY ANALYSIS IF DESIRED
837
             IF (DETCOV.NE. 1) 60 TO 310
838
             CALL SUBSICOURISENIFSUMPISONIDELU)
839 c
840 C EDIT SENSITIVITY PROFILES FOR INDIVIDUAL ZONES
        310 IF (IDUTPUT.EB. 0) 60 TO 360
841
             201 30 ( += 1, + 2)

20 30 ( += 1, + 2)

20 ( k) = 20 ( k) + SSENP ( + ; 6) + DELU ( 6)
842
643
844
845
        320 CONTINUE
330 CONTINUE
846
847
             DD 350 #=1+KDZ
648
             WRITE(6+440) (TITLE(1)+1=1+8)
849
             HPITE (6+450)
850
851
             HAITE (6+460) MR
             N#ITE(6+480) K
852
             HPITE (6+490)
853
             10 340 G=1+16M
854
             HPITE (6+500) 6+EE (6) + DELU (6) + SSENA (K+6)
855
856
        340 CONTINUE
             H#ITE (6:510)
857
858
        350 CONTINUE
859 C FORMATS
860
        410 FORMAT (6E12.5)
        420 FORMAT(IN +/+0ENERGY DISTRIBUTION OF DETECTOR RESPONSE FUNCTION

$SIGNA(H+G) BT GROUP FOR DETECTOR ZONE 5 4+16)

430 FORMAT(5H 6 = +13+3x+1PE12+5)
861
862
8£ 3
864
865
        440 FORMAT (14 1/18A101/)
        450 FORMAT(1H +24(1H+)++ SENSITIVITY PROFILE FOR THE DETECTOR RESPONS
SE FUNCTION R(6) ++25(1H+))
866
        SE FUNCTION #(6) *)20(14*))

460 FORMAT(1M +*SENR(6) IS PER LETMARGY-HIDTH DELTA-U AND NORMALIZED

STO THE TOTAL RESPONSE BR = (R+PHI) = ++1PE12.5+/)

470 FORMAT(1M +*FOR THE SUM DUER ALL DETECTOR ZONES*)

480 FORMAT(1M +*FOR DETECTOR ZONE K*++13+/)

490 FORMAT(1M +* GROUP UPPER-E(E/) DELTA-U*+8x+*SENR*)
867
866
869
870
871
872
        500 FORMAT (1N + 15+2x+ 1PE10.3+2x+ 1PEY.2+4x+ 1PE10.3)
873
874
        510 FORMAT (1H +32x++----+)
        520 FORMAT (14 + 1x++ INTEGRAL++23x+ 18810.3+/)
        525 FORMAT (46H + 4 + RESPONSE ) GEOUP AND DETECTOP ZONE + + +)
530 FORMAT (46H + 6 + RESPONSE FOR DETECTOR ZONE +13+10H AND GROUP+13+
675
876
877
878
879
            12×+=12.5>
        360 RETURN
             END
```

880 c

```
881 c
REC C SUBEDUTINE TAPAS ASSIGNS LOGICAL UNITS TO THE ANGULAR FLUXES AND THE
893 C FLUX MOMENTS
884 c
685
           SUBROUTINE TAPAS (KTAPINHINHIITSUHIIGHIHRXWPDIKTPI
886
                               KELP1+KELP2+KP2+JT)
          1
887
888 C + + + INPUT COMMENTS + + +
                        - MANIMUM NUMBER DF HORDS DN A LOGICAL UNIT
              MALHED
889 c
                          - NUMBER OF GROUPS
890 c
              IGH
              ITSUH
                         - TOTAL NUMBER OF TRIANGLES
891 C
892 C
              NH
                          - NUMBER OF MOMENTS
              A TO DUADEATURE SIRECTIONS BUASMANT FOR GROUP 6
893 c
894
895 C + + DUTPUT COMMENTS + + +
896 C KTAP(5)16M) = LOGICAL UNITS FOR FLUXES
896 C
897 C WHERE!
898 c
              WTAP (1.6) # LOGICAL UNITS FOR ANGULAR FLUXES
              HTAP (216) - LOGICAL UNIT FOR ADJOINT ANGULAR FLUXES FOR GROUP &
899 c
              HTAP (3:6) = LOGICAL UNITS FOR ADJOINT ANGULAR FLUXES-BANDON ACCESS
HTAP (4:6) = LOGICAL UNITS FOR FLUX HOMENTS FOR GROUP 6
HTAP (5:6) = LOGICAL UNIT FOR ADJOINT FLUX HOMENTS
900 c
901 C
902 c
903
           TIMENSION MTAP (5.1) + HH (1) + HTR (31+1) + HELP1 (31+1) + HELP2 (31+1)
904
905
906
           INTEGER 6166
907
800
           DD 200 1=1+2
      200 PEAD (5:410) (HTAP (1:6):6=1:16H)
LAST = HTAP (2:16H) + 1
909
910
           ISUH=0
911
912
           DE 230 6= 1,164
           66=16H-6+1
913
914
           ANGNOR-ITSUHAHH (66)
915
           IF (ANGHOR. GT. HAANRD) 60 TO 240
916
           ISUM - ISUM+ANGHDR
917
           IF (ISUH.LT. HAXWED) 60 TO 210
918
           ISUHEANGHOR
919
           HTAP (3+66)=LAST+1
920
           GD TD 220
921
      210 HTAP (3+66)=LAST
922
      220 LAST=+TAP (3+66)
923
      230 CONTINUE
924
           GD TD 250
925
      240 MRITE (6+420)
926
          STOP
      250 LASTERTAR (3,1) + 1
927
928
           DD 290 1=1+2
           IF (1.ED.2) LAST = HTAP (4+16H)+1
929
930
           1==3+1
931
           ISUH=0
932
           IPLOFEU
           DD 255 J=1+JT
DD 255 K=1+K#2
933
934
935
           IF (HTP (J+H).EB.0) 60 TO 255
936
           IPLOF=IPLOF+KELP2(J+K)-KELP1(J+K)+1
937
      255 CONTINUE
938
           HUHNDREIPLDEANH
939
           IF (HOHNOP. 61. HAXHAD) 60 TO 240
           DD 280 66=1+16H
940
941
           6=66
942
           1F(1.E0.2) 6=16H-66+1
943
           ISUM = ISUM + MOMMOR
944
945
           IF (ISUM. LT. MAXWED) 60 TO 260
           ISUMENDHUDE
946
           HTAP (IRIE) -LAST+1
947
           6D TD 270
948
       260 HTAP (IP+6)=LAST
949
950
       270 LAST HTAP (1P+6)
       280 CONTINUE
951
       290 CONTINUE
952
       410 FORMAT (1216)
953
954
       420 FORMAT(1H +50H + + + ERADA XXX - VALUE OF MAXHAD TOD SHALL + + +)
           RETURN
955
           END
956 c
957
    с
958 c
959 c
           SUBROUTINE SNCON (CEICHINTINUPINPBINNIMIPPINNELIISNIIGHI
95Ú
```

961 1 IDPT) 962 963 LEVEL ZICEICH 964 DIMENSION CH (HNPB+4+1)+CE (HNPB+4+1)+NT (1)+NUP (HNEL+1)+NEL (4)+ 965 112LS (8) + SN (4) + NPB (1) + ISN (1) + MH (1) 966 967 968 969 970 DIMENSION 04(3)+ 06(6)+ 08(10)+ 010(15)+ 012(21)+ 014(28)+ 016(36) INTEGER 6 971 972 973 974 DATA U2/.5773503/ DATA 04/.8688903.3500212.3500212/ DATA US .. 93206461.68136461.68136461.25614291.26634431.2561429/ 975 976 DATA US/ .9603506+.6065570+.8065570+.5512958+.5773503+.5512958+ 1.1971380+.2133981+.2133981+.1971380 / 977 978 979 DATA U10/ .9730212.8721024.8721024.6761286.7212773.6961286. 1.4567576.4897749.4897749.4567576.1631408.1755273.1755273. 2.1755273+.1631408 / 980 DATA U12/ .9810344..9080322..9080322..7827706..8030727..7827706. 1.6(40252+.6400755+.6400755+.6040252+.3911744+.4213515+.4249785+ 981 2.4213515+.3911744+.1370611+.149/456+.1497456+.1497456+.1497456+ 982 983 3.1370611 / DATA 014/ .9855865,.9314035,.9314035,.8362916,.8521252,.8362916, 1.7010923,.7324250,.7324250,.7010923,.5326134,,5691823,.5773503, 984 985 986 2.5691823+.5326134+.3399238+.3700559+.3736108+.3736108+.3700559+ 3.3399238+.1196230+.1301510+.1301510+.1301510+.1301510+.1301510+ 987 988 4.1196230 / Hitsesu /
Data u16/.9989102+.9464163+.9464163+.8727534+.8855877+.8727534+
1.7657351+.7925089+.7925089+.7657351+.6327389+.6666774+.6752671+
2.6666774+.6327369+.4743525+.510/319+.5215431+.5215431+.5107319+
3.4743525+.3016701+.3284315+.3332906+.3332906+.3332906+.3284315+ 989 990 991 992 4.3016701.1050159.1152880.1152880.1152860.1152860.1152860. 5.1152680.1050159 / 993 994 995 DATA SN/1.0+-1.0+-1.0+1.0/ 996 c 997 c 998 READ (5+440) (ISN (6)+6=1+16H) 999 DD 350 6=1+16M 1000 120 HEL=ISN (6) /2 GD TD (130+150+170+190+210+230+250+270)+ HEL 130 DD 140 L=1+4 1001 1002 1003 NPB(L)=1 1004 CE (1+L+6)=SN (L)+02 1005 NT (6)=0.25 1006 140 CONTINUE 60 TO 290 150 DO 160 L=1+4 1007 1008 1009 NPP(L)=3 1010 DD 160 H=1+3 1011 CE (H1L16)=SN (L)+U4 (H) HT (G)=0.06333333 1012 1013 160 CONTINUE 1014 60 TO 290 170 DD 180 L=1+4 1015 1016 NPD (L)=6 10 180 H=1+6 1018 CE (H+L+G)=SN (L)+U6 (H) 1019 HT (6)=0.04166667 1020 180 CONTINUE 1021 60 TO 290 1022 190 Do 200 L=1+4 NPD (L)=10 1023 1024 DD 200 H=1+10 1025 CE (H+L+6)=SN (L) +UB (H) 1026 HT (6) =. 025 1027 200 CONTINUE 60 TO 290 210 DO 220 L=1,4 1028 1029 1030 NPB (L)=15 1031 DD 220 H=1+15 1032 CE (H+L+6)=SN(L)+U10(H) 1033 HT (G)=0.01666667 1034 220 CONTINUE SD TD 290 230 DD 240 L=1+4 NP#(L)=21 1035 1036 1037 1038 DD 240 H=1+21 CE (H+L+6)=SN(L)+U12(H) NT (6)=0.01190476 1039 1040

```
1041
       240 CONTINUE
           60 TO 290
1042
       250 DE 260 L=1+4
1043
1044
            NPR(L)=28
            DD 260 H=1+28
1045
            CE (HILIG)=SN (L)+U14 (H)
1046
            HT (G)=0.008928571
1047
1048
       260 CONTINUE
       GD TD 290
270 DD 280 L=1+4
1049
1050
            NPD (L)=36
1051
            DD 280 H=1+36
1052
            CE (H+L+G/#SN(L)+016(H)
1053
            HT (G)=0. 006944444
1054
       280 CONTINUE
1056
       290 HH (6)=4+NPB (1)
1057
            DD 310 IL=1+MEL
            DD 300 L=1+4
1058
            NUP (IL+L) #IL
1059
1060
       300 CONTINUE
            IELS(IL)=(IL+(IL-1))/2
1061
1062
       310 CONTINUE
            20 320 L=1+4
1063
1064
            NEL (L) PHEL
       320 CONTINUE
1065
           DD 330 1L=1+MEL
1066
1067
            IL1=HEL-IL
1068
            20 330 HP=1+1L
1069
            HEIELS (IL) +HP
            HITTELS (IL 1+HP)+HP
1070
            CH (H14161=-CE (H11416)
1071
1072
            CH (H) 316/ =-CE (H11416)
1073
            MZ=IELS (IL) +IL-HP+1
1074
            CH 1H2+1+6)=CE (H1+4+6)
            CH (H2+2+6)=CE (H1+4+6)
       330 CONTINUE
1076
1077
1078 C EDIT SN-SETS BY GROUP IF IDPT EBURL TO 1 DR 3
1079
           IF (IDPT.NE.1.AND.IDPT.NE.3) 60 TO 350
           WRITE (6+410) 6+ ISN(6)
DD 340 L = 1+ 4
WRITE (6+420) L
1080
1021
1082
1083
            HPD = NPB(L)
1084
            DD 340 H = 1+ HPB
            HPITE (6+430) H+CH(H+L+6)+CE(H+L+6)+HT(6)
1085
       340 CONTINUE
1086
1067
       350 CONTINUE
       410 FORMAT (///1x+27H+ + + + # BUADRATURE GROUP +13+10H + + + + //
1068
       113++22HBUILT-IN CONSTRATS: 5-+12 )
420 FORMAT (//7+9HPUADRANT +11//26++2HHU+17+3HETA+14++6HHE16HT/)
1089
1090
1091
       430 FORMAT (5++13+3E20.8)
1092
       440 FORMAT (1216)
1093 c
1094
            RETURN
1095
            END
1096 C
1097 C SUBROUTINE PNGEN HAS BEEN COPIED AND HODIFIED FROM THE TRIDENT-CTR
1098 C CODE.
1099 C CHIS SUBBOUTINE GENERATES SPHERICAL MARMONICS POLYNOMIALS AND
1100 C STORES THEM IN THE PROPER DRDER; CORRESPONING NITH A DIRECT DR
1101 C ADJOINT FLUX-HOMENT CONSTRUCTION.
1102 c
            SUBBOUTINE ANGEN (PIRICHICEIPHNIITIMHILMAXIMNPBINHILMAXPIGIHADIISN)
1103
1104
1105
            LEVEL 21 CEICH
1106
            DIMENSION CH(HNP#+4+1)+CE(HNP#+4+1)+PHH1(1)+T(1)+P(HNP#+LMAXP+1)+
1107
1108
           1# (NH+1) + HH (1) + ISN (1)
1109
1110
            INTEGER 6
1111
            DATA CR1/3.1415926/
1112
1113
1114 C + + + INPUT COMMENTS + + +
               CHIMNPERATIONS BUADMATURE HU'S
1115 C
               CE (HNPD+4+IGH) BUADRATURE ETA'S
1116 c
               HH (G)
                                 S DUADRATURE DIRRECTIONS FOR GROUP 6
1117 c
                                 DRUES OF SCATTERING
1118 c
               LHAX
1119 c
               LHAXP
                                TOTAL HUNDER OF HOMENTS
1120 c
               NH
```

```
1121 c
                 6
Kad
                                   GROUP INDEX
1122 c
                                   IDENTIFIER ADJOINT OF DIRECT FLUXES
 1123
 1124 C + + + DUTPUT COMMENTS + + +
1125 c
1126 c
                R (NHI HH (6))
                                 SPHERICAL MARMONICS POLTNOMIALS REARDANGED IN
The Duadrant Seduence 3:2:4:1 IF Hai#ú
And in the Seduence 1:4:2:3 IF Hai#1
1127 c
1128
1129
             NELFISN (6)/2
             IF=2+LMAX+1
1130
1131 с
1132 c
             GENERATE FACTORIALS
 1133 c
1134
             τ(1)=1.0
1135
1136
             DD 100 J=2+1F
T(J)=(J-1)+T(J-1)
 1137
        100 CONTINUE
 1138
             MP=0
             DD 210 La=1.4
1139
1140
1141 c
             HP8=HH (6)/4
1142 c
             GENERATE PHHI
 1143 c
1144
             DD 110 H=1+HPB
1145
1146
             PHHI (H)=0.5+CPI
             IF (CE (HILBIG) .NE. 0. 0) PHHI (H) = ATAN (SPAT (1. 0-CH (HILBIG) ++2
 1147
            1-CE (H+LB+6) ++2) /A35 (CE (H+LB+6)))
1148
             IF (CE (H+LB+6).LT.0.0) #HHII (H) #PHHII (H) +C#I
        110 CONTINUE
1149
1150 c
1151 c
             ZERD DRDER ASSOCIATED LEGENDRE POLYNOMIALS
 1152 c
1153
1154
             DD 130 H=1, HPS
             C=CH(HILDIG)
1155
             # (H+1+1)=1.0
1156
             IF (LHA. . EB. 0) GD TD 130
1157
             # (H+2+1)=c
1158
             IF (LMAX.ED.1) 60 TO 130
             P(M+N+1+1)=C+(2.0-1.0/N)+P(M+N+1)-(1.0-1.0/N)+P(M+N-1+1)
1160
1161
        120 CONTINUE
1162
        130 CONTINUE
             IF (LMAX.ED. 0. AND. HAD.ED. 0) GD TO 180
IF (LMAX.ED. 0. AND.HAD.ED.1) GD TO 220
1163
1164
1165 c
1166 c
             HIGHER DRDER ASSOCIATED LEGENDRE ROLYHOMIALS
1167 c
1168
             DD 160 H=1.HP3
1169
             C=CH(H+LB+G)
1170
             10 160 J=2+LHAXP
1171
1172
1173
1174
1175
             DO 160 N=1+LMAX#
             IF (N-3/ 160+140+150
        140 # (H+N+3)=- (2+3-3)+SURT (1.0-C++2)+# (H+N-1+3-1)
        150 IF (N.EB.LMAZP) 60 TO 160

P(H1N+11-J)=((20N-1)000 (H1N+3)-(N+3-2)00 (H1N-11-3))/(N-3+1)
1176
1177 c
1178 c
1179 c
       160 CONTINUE
             HULTIPLY BT COS (PHHI) TERM AND FACTORIAL COEFFICIENT
1180
             DO 170 J=2+LHAXP
1181
             DD 170 NEJILMAXA
1182
             3=588T (2. 0+1 (N-3+1) /1 (N+3-1))
             DO 170 HE1. HPB
1183
1184
             CEPHHI (H)
1185
             AAP=CDS ((J-1)+C)
1186 c
             IF (G. ED. 1) NRITE (10:420) 318 (HINIJ) 1888
1167
             + (H+N+J/=3++ (H+N+J)+CDS ((J-1)+C)
       170 CONTINUE
1168
1189 c
1190 c
             REDUCE NUMBER OF INDICIES AND READANNEE
1191 c
1192
             IF (HAD.NE. 0) 60 TO 220
        1193
1194
1195
1196
             ×=1
1198
             DE 200 NEI+LMAXP
             DD 200 J=1+N
DD 190 M=1+MPB
1200
```

```
1201
           190 CONTINUE
1202
1203
           H=++1
       200 CONTINUE
1204
           GD TD 210
1205
       220 IF (LO.ED.1) HP=0
1206
          IF (LD.ED.2) MP=2+MPB
IF (LD.ED.3) MP=3+MPB
1207
1208
           IF (LB.ED.4) HPENPE
12:09
1210
           ĸ=1
1211
           10 240 N=1+LMAX#
           REVERSE COUNT ON EACH ETA LEVEL FOR ADJOINT HOMENTS
1212
          DD 240 J=1+N
1213 c
1214
1215
           INDEX1=1
1216
           DO235 IJ=1+NEL
           INDER1=INDEX1+IJ-1
1217
           DD 230 H1=1+13
1218
1219
           INDEX2=IJ-M1
           INDE#3=INDEX1+INDEX2
1220
           # (K+MP+INDEX3) =P (M+N+J)
1221
1222
           н=н+1
      230 CONTINUE
1223
      235 CONTINUE
1224
1225
          K = K + 1
       240 CONTINUE
1226
1227
      210 CONTINUE
           pp 500 1=1+10
1228
           IF (G.EB.1) WRITE (10+420) (#(1+3)+3=1+12)
1229 c
1230
      500 CONTINUE
1231
       420 FORMAT (6E12.5)
        RETURN
1232
1233
           END
1234 c
1235 C SUSPOUTINE FLUXMON GENERATES THE FLUX HOMENTS
1236 c
1237 c
           SUBROUTINE FLUXMON (IIT+FFLUX+FLUX+FUX+N+MM+R+FTAP+6+I6M)
1238
                               HEZINHIJTIKRITIMAINRDIKADIKTPIKELRIIKELPËI
1239
          1
1240
         2
                               KTDINELDIINELDŽIFHOMINDZIIAP3)
1241
1242 C + + + INPUT COMMENTS + + +
             FFLUX (ITSUMAMM (6) /4) ANGULAR FLUXES IN LCM
1243 c
              FLUX (ITSUNAMM (6) /4) ANGULAR FLUXES IN LCM
1244 c
1245 c
              H (16H)
                                BUASPATURE MEIGHTS
1246 c
              11T (JT)
                                  GTRIANGLES/BAND
1247 c
              нн (6)
                                  TOTAL - DUADMATURE DIRECTIONS
1248 c
              KTAP (IGH)
                                  IDENTIFIES FILES FOR ANGULAR FLUXES
1249 c
                                  GROUP INDEX
Total & Groups
              6
1250 c
              16H
                                  NUMBER OF HOMENTS
1251 c
              NM
                                  1252 c
              зт
1253 c
              KAD
                                  IDENTIFIER ADJOINT/DIRECT FLUXES
                                  PANDON ACCESS FILE ALDRESS INDICATOR
1254 c
              HRIT
1255 c
                                  SCALAR FLUXES IN DETECTOR REGION
              FHDH
1256
1257 C + + + DUTPUT COMMENTS + + +
1258 c
             DEPENDING UPON THE PARAMETER HADE DIRECT OR ADJOINT
1259 c
              FLUS HOMENTS ARE CALCULATED AND WRITTEN
              THE ZERD'TH HOMENTS OF THE DIRECT FLUX ARE SORTED OUT AND
1260 c
              HRITTEN ON TAPEL
1261 c
1262 C
1263 c
              FUX (NHIJTIIT (JT)) FLUX HOMENTS
1264
           LEVEL 2. FFLUXIFLUXIFUXIFHON
1265
1266
           DIMENSION FFLUX (1) + FLUX (1) + FUX (NH+ JT+1) + KTAP (5+1) + H (1)
1267
1268
           DIMENSION MM (1) +# (NM+1) + IIT (1) + IMOLTM (23) + J##### (10)
           DIMENSION HTP (JT+1)+KELP1 (JT+1)+KELP2 (JT+1)
1269
1270
           DIMENSION HTD (JT+1)+KELDI (JT+1)+KELD2 (JT+1)+FHOH (JT+1)
1271
1272
1273
           INTEGER GOUNIOUNZOUNS
1274
1275 C INITIALIZE
1276
1277
           16 = KAD + 1
           IF (HAD. HE. 0) 60 TO 130
1278
           HH2 = HH (6)/2
1279
1280
           UN1 = HTAP (16+6)
```

.

```
1281
            UN2 = +TAP (16+3+6/
             IF (+ TAP (16+6) .NE. KTAP (16+6-1)_DR.6.EB.1) 60 TO 100
1282
1283
             GD TD 110
1284
        100 CALL ASSIGN (UH1+0+-3)
            REAL(UN1) (INDLTH (HK)+H+=1+23)
HRITE (7+1000) (INDLTH (HK)+KH=1+23)
1285
1286 c
1287
      1000 FORMAT (2364)
            1288
1289 c
       1010 FORMAT (1216)
1290
1291
        110 IF (HTAP (16+3+6) .NE.KTAP (16+3+6-1).DP.6.EB.1) 60 TO 120
1295
            GD TD 190
       120 CALL ASSIEN (UN2: 0:-3)
CALL FANSIZ (UN2: MAXWED)
1293
1294
1295
            6D TD 190
1296
1297 C INITIALIZE FOR THE ADJOINT CASE
1298
       130 G=16H-6+1
            HH2=HH (6)/2
1299
1300
            UNI=HTAP (IGIG)
1301
            UN2=+TAP (16+3+6)
1302
            UNSENTAP (316)
            IF (HTAP (IG+G) . NE. KTAP (IG+G+1) . DR. G. ED. IGH) 60 TO 140
1303
1304
            са та 150
1305
       140 CALL ASSIGN (UN1+0+-3)
1306
            PEAD (UN1) (IMDLTH (KK) + + K=1+23)
PEAD (UN1) (JPPAN (KK) + + KF=1+10)
1307
1308
       150 IF (HTAP (16+3+6) .NE. HTAP (16+3+6+1) .DR. G. EB. 16H) 60 TO 160
            GD TD 170
1309
1310
       160 CALL ASSIGN (UN2: 0:-3)
1311
            CALL FAMSIZ (UN2+MAXWED)
       170 IF (HTAP (3+6). HE. KTAP (3+6+1). DP.6. ED. 164) 60 TO 180
1312
            GD TD 190
1313
1314
       180 CALL ASSIGN (UN3: 0: -3)
1315
            CALL FAMSIZ (UNJI MAXHAD)
1316
            KRIT=1
       190 CONTINUE
1317
1318
1319 C INITIALIZE FLUX HOMENTS
1320
1321
            DD 205 J=1+JT
            ITJ=IIT(J)
20 205 IT=1+ITJ
20 200 IN=1+NM
1322
1323
1324
1325
       200 FUX (1N+3+17)=0.
1726
1327
       205 FHOH (J) IT)=0
            JJT#2+JT
1328
1329
            DD 605 J=1+JJT
1330
1331 C READ ANGULAR FLUXES
1332
1333
            ICOUN1=1
1334
            33=3
            1F(3.6T.JT) J3=2+JT-J+1
1335
1336
            111J=111 (JJ) 4mmi /2
1337
            173=117 (33)
1338
            HHX=HH2/2
1339
            DD 210 HHI=1+HHX
1340
            1000N2=1000N1+173-1
1341
            PEAD (UN1) IK
READ (UN1) (FFLUX (IEDUN)+ICDUN=ICDUN1+ICDUN2)
1342
1343
             ICOUN1#ICOUN2+1
1344
       210 CONTINUE
1345 c
            IF (HAD.ED. 1) HRITE (7+420) (FFLUX (ICDUN) + ICDUN=ICDUN1+ICDUN2)
1346
            IF (HAD.NE. 1. DR. IAP3. ED. 1) GD TD 230
1347 c
            MPITE(10:430) KPIT
            CALL HDISH (UN3+FFLUX+IITJ+KRIT)
1348
1349
            1350
       230 ICOUN1=1
            DO 220 MHI=1, HH
1351
1352
1353
            ICOUNE=ICOUN1+ITJ-1
            READ (UN1) IK
READ (UN1) (FLUX (ICDUN), ICDUN#ICDUN1, ICDUN2)
1354
1355
1356
1357 c
             ICOUN1#ICOUN2+1
       220 CONTINUE
            IF (HAD.EB. 1) WHITE (7:420) (FLUX (ICDUN) + ICDUN=ICDUN1+ ICDUN2)
1358
            IF (MAD. NE. 1. DR. INP3. EB. 1) 60 TO 250
HRITE (10:430) KRIT
1359 c
1360
            CALL NEISH (UN3+FLUX+IITJ+KRIT)
```

```
KRITEKRIT+IITJ
1361
1362
1363 C CALCULATE FLUX HOMENTS IN PERTURBED ZOMES
1364 250 IF (J.GT.JT) 60 TO 320
1365 DO 315 H=1+KRZ
            IF (HTP (JJ+H).EB. 0) 60 TO 315
1366
            111=HEL#1(JJ+K)
1367
1368
            IT2=HELP2(JJ+K)
            HH1=HH2/2
1369
1370
            ICOUNT#0
1371
            ICDUN#IT1
            DD 280 1H=1,HH1
DD 270 1T=1T1,1T2
1372
1373
1374
            DD 260 IN=1+NH
1375
       260 FUX (IN+33+17) = FUX (IN+33+17) + W(6/+#(IN+1H)+FFLUX (ICDUN)
1376
            ICOUN#ICOUN+1
       270 CONTINUE
1377
1378
            ICOUNT#ICOUNT+ITJ
            ICOUN=ICOUNT+IT1
1379
       280 CONTINUE
1380
            ICOUNT=0
1381
1382
            ICOUN#IT1
1383
            нн1=нн2/2+1
            DD 310 IM=HH1+HH2
DD 300 IT=IT1+IT2
1384
1385
            DO 290 IN=1+NM
1386
       290 FUX (IN+33+17) = FUX (IN+33+17) + H (6) +R (IN+1H) +FLUX (ICDUN)
1387
1368
            ICOUN=ICOUN+1
       300 CONTINUE
1389
            ICOUNTEICOUNTEITJ
1390
1391
            ICOUN=ICOUNT+IT1
       310 CONTINUE
1392
1393
       315 CONTINUE
1394
           GD TD 390
1395
       320 20 385 H=1+HP2
            IF (HTR (JJ+K).EB. 0) 60 TO 385
1396
1397
            111=KE_#1(33+K)
            IT2=KEL#2 (JJ+K)
1398
1399
           ICOUNT=0
1400
            ICOUN#IT1
1401
            нн3=нн2+1
            HH4=3+HH2/2
            20 350 IM=HH3+HH4
1403
1404
            DD 340 1T=1T1+1T2
       DD 330 IN=1+N-
330 FUX(IN+JJ+IT) = FUX(IN+JJ+IT) + H(6)+F(IN+IH)+FFLUX(ICDUN+
1405
1406
            ICOUNFICOUN + 1
1407
1408
       340 CONTINUE
1409
            ICOUNTEICOUNT+ITJ
            ICDUN#ICDUNT+IT1
1410
1411
       350 CONTINUE
1412
           ICOUNT=0
1413
            ICOUNFIT1
1414
            mm4=mm4+1
            1415
1416
            10 380 IH=HH4+HH5
1417
1418
            DD 370 1T=1T1+1T2
       DD 360 IN=1+MM
360 FUX (IN+JJ+IT) = FUX (IN+JJ+IT) + M(6)+R(IN+IM)+FLUX (ICDUN)
1419
1420
            ICOUN#ICOUN+1
1421
       370 CONTINUE
1422
            ICOUNTEICOUNTEITJ
1423
            ICOUNFICOUNT+IT1
1424
       380 CONTINUE
1425
       385 CONTINUE
1426
       390 IF (HAD.HE. 0) 60 TO 605
1427
1428 c
1429 C CALCULATE SCALAR FLUXES IN DETECTOR REGION
1430 c
1431
            IF (J. 6T. JT) 60 TO 560
1432
            DD 550 #=1+HDZ
            IF (HTD (JJ+H) . EB. 0) 60 TO 550
1434
            ITI=HELDI (JJ+K)
1435
            IT2=HELD2 (JJ+K)
1436
            MH1=HH2/2
            ICOUNT=Ú
1438
            ICOUN#IT1
            DD 520 IM=1+HH1
DD 510 IT=IT1+IT2
1439
1440
```

1441		FHDH(JJ;IT) = FHDH(JJ;IT) + H(G)+FFLUx(ICDUN)
1442	E 1 /	ICOUN=ICOUN+1
1444	510	CONTINUE
1445		
1446	520	CONTINUE
1447		ICOUNTEO
1448		ICDUNFIT
1449		MM1=MM2/2+1
1451		50 JTEITINE
1452		FHDH(JJ)IT) FFHDH(JJ)IT) + H(G) +FLUX(ICDUN)
1453		ICOUN=ICOUN+1
1454	530	CONTINUE
1400		
1457	540	
1458	550	CONTINUE
1459		GD TD 605
1460	560	DD 600 K=1+KDZ
1461		IF (KTD (JJ)K).ED.U) 60 TO 600 TT THE ST (TTAK)
1463		ITZERELDZ (JJIK)
1464		ICDUNTED
1465		ICDUN=IT1
1466		mm3≈nm2+1
1467		nn4=3+nn2/2
1468		DD 570 IM#MM3; MM4
1470		
1471		TCDUMEICDUMEI
1472	565	CONTINUE
1473		ICOUNT#ICOUNT+ITJ
1474		ICOUNFICOUNT+IT1
1475	570	CONTINUE
1475		
1478		
1479		MM5=nm (6)
1480		DD 590 1=m=4,m=5
1481		zo 580 it=it1,it2
1482		FHDH(JJ)IT)=FHDH(JJ)IT) + H(G)+FLUx(ICDUN)
1423	560	ICDUN#ICDUN+1
1485	500	
1466		ICDUN=ICDUNT+IT]
1487	590	CONTINUE
1468	600	CONTINUE
1489	605	CONTINUE
1491 0		
1492 0		
1493		DD 620 J=1,JT
1494		DD 610 K=1+KPZ
1490		IF (MTP (J)M).EB.U) 60 TO 610
1497		121-FELF1(398) 1728-61
1498		NEITE(UN2)((FUX(IN)J)IT))INE1+NH/+ITEIZ1+IZ2)
1499	610	CONTINUE
1500	620	CONTINUE
1501		IF (MAD. HE. 0) 60 TO 650
1502		DD 640 J=1+JT
1503		DD 630 K#1+KDZ
1505		17 (KID(J)K).EW.U/ 00 10 030
1506		122=HELD2(J+H)
1507		HRITE (1) (FHDH (3+12)+12=121+122)
1508	630	CONTINUE
1509	640	CONTINUE
1510 0		RE TABES IE WEFERSERV
1512 0	 :	PL INTED OF MELEDDENT
1513	650	IF (MAD. ME. 0) 60 TO 400
1514		IF (FTAP (16+6) . NE. KTAP (16+6+1) . DP. 6. ED. 164) CALL CLOSE (UN1)
1715		IF (HTAP (16+3+6), NE. HTAP (16+3+6+1), DR. G. EB. 16H) CALL CLOSE (UND
1516	466	60 TO 410 TE (MTAR (16.6) NE NTAR (16.6-1) OR 6 ER 1) CALL CLOSE (10.1)
1518	400	17 YF YMF Y19767, NE.FTMF Y1979-17,07,07,0,87,17 CHEL CLUSE (UN17 17 (7767 (16+3), NE.FTMF (16+316-1),08,6.58,1) CALL CLUSE (UN17)
1519		IF (HTAP (3:6)_HE.KTAP (3:6-1).DR.6.ED.1) CALL CLOSE (UN3)
1520	410	CONTINUE

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```
1521
       420 FORMAT (6E12.5)
      430 FORMAT (1M + 6HHRIT =+16)
15ċ2
            RETURN
1523
1524
            END
1525 c
1526 C
1527 C SUBRDUTINE CHIS CALCULATES THE CHI'S
1528 c
1529
            SUBROUTINE CHIS (FLUX + AFFLUX + AFLUX + HTAP + CHI+KELP1 + HELP2 + HTP + IIT +
1530
1531
                               MM+ ISNIHIKFZ+ JT+ JTHA#+ IGH+ IDUTPUT+ ITSUM+ IGED)
          1
1532
1533 C + + + INPUT COMMENTS + + +
               FLU; (ITJ; HPB) - ANGULAR FLU;ES READ FROM UN1 (LCM)
AFFLU; (IITJ) - ADJDINT ANGULAR FLU;ES; READ FROM UN2 (LCM)
1534 c
1535 c
               AFLUX (ITJIHPE) - REARMANGED ADJOINT ANGULAR FLUXES (LCM)
1536 c
1537 c
               KTAP (5:16H)
                                - DISK INDEX
                                - PERT, ZONE K IN BAND J STARTS HITH TRI. HELP1
1538 c
               HELP1 (JIH)
               KEL#2 (J+K)
1539 c
                                - RERT. ZONE # IN BAND J ENDS HITH TRI.KELRE
                               - IS PERT. ZONE & PRESENT IN BAND J? U/1 ND/YES
540 c
               KTP (J+K)
               117 (3)
                               - TOTAL " TRIANGLES IN DAND J
1541 c
                                - TOTAL " HOHENTS FOR GROUP 6
1542 C
               -----
1543 c
               ISN (6)
                                - ED. - DUALPATURE SET INDICATOR FOR GROUP G
1544 c
               H (6)
                                - ED.-DUALPATURE HEIGHTS FOA GROUP 6
1545 c
               KPZ
                                - B PERTURNED ZONES
                                1546 c
               16H
                                - - -
1547 c
               37
1548 c
                                - HAX. " TRIANGLES/SAND
               JTHAX
                                - TOTAL NUMBER OF TRIANGLES
1549 c
               ITSUH
1550
1551 c + + + BUTPUT COMMENTS + + +
               CHI (16H+KP2P) - CHI'S
1552 c
1553
1554
           LEVEL 21FLUXIAFFLUXIAFLUX
1555
1556
           INTEGER GOUNTOUN2
1557
1558
            DIMENSION FLUX (JTHAX+1) + AFFLUX (1) + AFLUX (JTHAX+1) + KTAP (5+1) +
1559
          1 2
                       HELP1 (JT+1)+HELP2 (JT+1)+HTP (JT+1)+IIT (1)+HH (1)+
1560
                       N(1)+ISN(1)+CHI(IGH+1)+IHOLTH(23)+JPRAH(10)
1561
           DATA CP1/6.283185307/
1562
1563
            IF (IGED.EB.1) C#I=1.0
1564
1565
            HPITE (6+420)
1566
            DD 190 6=1,16H
1567 c
1568 C INITIALIZE
1569 c
1570
            DD 100 11=6+16H
1571
            1=16H+6-11
            HRITEHRIT+ITSUMONN(I)
1572
1573
      100 IF (NTAP (3:1) . NE. KTAP (3:1+1). DR. 1. EB. 164) KRITEITSUMMH (1)+1
1574
            NELTISN (6)/2
1575
            JJT=2+JT
1576
            HPD=HH (6)/4
1577
1578
            UNIENTAP (1.6)
            UN2=+TAP (316)
1579 c
1580 C DREN FILES IF NECESSARY
1581 c
            IF (KTAP (1+6) . HE. KTAP (1+6-1) . DR. 6. EB. 1) 60 TO 80
1582
            6D TD 90
1593
1564
        80 CALL ASSIGN (UN1+0+-3)
1585
            READ (UN1) (INOLTH (HH) + HH=1+23)
1586
            READ (UH1) (JPRAM(KH) + HH=1+10)
         90 IF (HTAP (3+6), HE, HTAP (3+6-1), DR. 6. EB. 1) CALL ASSIGN (UN2+0+-3)
1557
1588 c
1589 C READ ANGULAR FLUXES DNE BAND AND DNE BUADRANT AT A TIME
1590 c
1591
1592
1593
            DD 180 J=1+JJT
            23=2
            1# (J.6T.JT) JJ=2+JT-J+1
1594
            113=111(33)
1595
1596
            IITJ=ITJ+HPB
            DD 170 1=1+2
1597
            KRIT=MRIT-IITJ
1598
            10 95 IH=1+HP#
1599
            READ (UN1) IK
         95 READ (UN1) (FLUX (IT+ IH) + IT=1+ ITJ)
1600
```
```
CALL RDISK (UN2+AFFLUX+IITJ+KRIT)
1601
            IF (UNIT (UN2)) 96:96:96
HRITE (10:440) KRIT: UNIT (UN2)
1602
1603 c
            HEITE(8+440) KRIT
HRITE(8+450) (AFFLUX(10)+10=1+1173)
1604 c
1605 c
         96 ICDUN=1
1606
1607 c
1608 C REARMANCE ADJOINT ANGULAR FLUXES
1609 C
1610
             INDEX1=1
1611
            DD 130 13=1+HEL
             INDEX1#INDEX1+IJ-1
1612
            DD 120 M1=1+1J
INDEX2 = IJ-M1
INDEX3 = INDEX1 + INDEX2
1613
1614
1615
            DD 110 1T=1+1TJ
1616
            AFLUX (IT, INDEX3) #AFFLUX (ICDUN)
1617
            HPITE (9,460) ICOUNIINDEX3:ITIAFLUX (ITIINDEX3):
1618 C
1619 c
           INFFLUX (ICDUN)
1620
            ICOUN = ICOUN + 1
       110 CONTINUE
1621
      120 CONTINUE
130 CONTINUE
16.22
1623
1624 c
1625 C CALCULATE THE CHI'S
1626 C
1627 C Initialize and skip if necessary
1628
            DD 160 #=1+##Z
1629
            INDEX1=KELP1 (JJ+K)
1630
            INDEX2=HELAS(JJ+K)
1631
             IF (J.EB.1.AND.1.EB.1) CHI (6+K)=U.
1632
             IF (HTP (JJ;H).EB. 0) 60 TO 160
1633 C CALCULATE CHI'S
1634 DO 150 IZ=INDEX1+INDEX2
            10 140 IM=1+MPB
1635
1636
            CHI (G++)=CHI (G++)+FLUX (IZ+IH) +AFLUX (IZ+IH) +H(G)
1637 c
            WRITE (2+430) IZ+IM+CHI (6+#)+FLUx (IZ+IM)+
           1AFLUX (12+1H) +H (6)
1638 c
       140 CONTINUE
150 CONTINUE
1639
1640
1641
        160 CONTINUE
1642
       170 CONTINUE
1643 180 CONTINUE
1644 C
1645 C CLOSE TAPES IF NECESSARY
1646 c
1647
            IF (HTAP (1+6), NE, HTAP (1+6+1), DR. 6. EB. 16H) CALL CLOSE (UN1)
1648
            IF (KTAF (3) 6) . NE. KTAP (3) 6+1) . DR. G. EB. IGH) CALL CLOSE (UN2)
1649
       190 CONTINUE
1650 c
1651 C CALCULATE THE CNI'S FOR THE SUN DVER ALL PERTURBED ZONES
1652 C AND MULTIPLY THE CHI'S BT 24PI IN THE CASE OF R-2 GEDHETRY
1653 c
1654
            METRENET+1
1655
            DD 210 6=1+16M
1656
            CHI (G++PZP)=0.
1657
            DD 200 H=1+H#2
1658
            CNI (G++)=CPI+CHI (6++)
1659
            CHI (6+ #P2P) =CHI (6+ #P2P) +CHI (6+ K)
1660
       200 CONTINUE
1661
       210 CONTINUE
1662 c
1663 C HRITE DUT THE CHI'S
1664 C
1665
            DD 220 K=1+KP2#
            HPITE(6+470) K
HPITE(6+410) (CHI(6+K)+6=1+16H)
1666
1667
1668
       220 CONTINUE
1669
1670
        410 FORMAT (1H +6E12.5)
        420 FORMAT (14 + 2460 + + TEST PRINTOUT FOR THE CHI'S + +)
430 FORMAT (14 +216+4E12.5)
1671
1672
        440 FORMAT (1H + 6HHRIT =+ 18+16)
1673
1674
        450 FORMAT (6E12.5)
        460 FORMAT(14 +316+2812.5)
470 FORMAT(14 +64444 =+13,34444)
1675
1676
1677
            RETURN
             END.
1678 c
1679 c
1680 C SUBROUTINE POINTAD SETS THE APPROPRIATE POINTERS FOR THE FLUXITHE
```

```
1681 C ADJOINT FLUX AND THE ASI'S
1682 C
1683
            SUBROUTINE ROINT43 (IGH: IPSI: ISUH: LHAXP: ILPNT: HP28)
1684
1685
            INTEGER 6
1686
            DIMENSION IPSI (HP2P+1)
1687 c
1688 C + + + INPUT COMMENTS + + +
                              - NUMBER OF PERTURBED ZONES
1689 c
              KPZ
                              - NUMBER OF BANDS
1690 C
                JT
                              - NUMBER OF GROUPS
1691 c
               16H
                ILPNT
                              * LCH PDINTER FROM WHICH THE PSI'S ARE TO START (1)
1692 C
1693 C + + + DUTPUT COMMENTS + + +
                            - LCH PDINTERS FOR PSI'S
- Firt available space in LCH after RSI stopage
              1851 (K+6)
1694 c
1695 c
               TEUM
1696 C
1697
            IRSI(1+1) FILANT
1698
            DD 110 #=2+KP2P
            IPSI(H,1)=ILBNT + IGH+IGH+LMAXP+(K-1)
1699
1700
1701
       110 CONTINUE
            TO 130 H=1+H=2#
1702
            DD 120 6=2+16M
            IPSI(K+6)=IPSI(K+6-1) + IGH+LMAXP
1703
1704
       120 CONTINUE
1705
1706
       130 CONTINUE
           ISUN - ILANT + IGHAIGHALMAXPANPZR
1707
            RETURN
1708
            END
1709 c
1710 c
1711 C SUBROUTINE PSIS CALCULATES THE PSI'S
1712 c
1713
            SUBROUTINE ASIS (HTP+IIT+HELPI+HELPZ+IRSI+FFLU++FAFLU++
1714
                                #$1+ PP$1+ NM+ JT+ #P2+ #P2P+ IGH+ LMAXP+
           1
1715
           2
                                + TAP + CHI + IDPT + IPPEP + ICHIMON + IGED)
1716
1717 C + + INBUT COMMENTS + + +
           FFLUX(1)
1718 c
                         - FLUX HEMENTS FER A PARTICULAR GROUP (LCH)
- ADJEINT FLUX HEMENTS FER A PARTICULAR GROUP (LCH)
1719 c
            FAFLUX(1)
1720 c
             117(3)
                           - 4 TRIANGLES IN BAND J
                           - IS REAT. ZONE & PRESENT IN SAND J? 0/1 ND/YES
1721 c
             KTP (J+H)
1722 c
                           - PERT. ZONE # IN BAND J STARTS WITH THI. HELPI
             KEL#1(J+K)
1723 c
             HELPE (JIK) - PERT, ZONE H IN BAND J ENDS HITH TRIANGLE KELRE
                          - LCH POINTER FOR THE RSI'S (PERT, ZOME HIGHOUP G)

- DISH IDENTIFIERS FOR THE FLUX HOMENTS FOR GROUP G

- DISH IDENTIFIERS FOR THE ADJOINT HOMENTS FOR GROUP G
1724 c
             IPSI(H+6)
1725 c
             NTAR (4.E)
             KTAP (5+6)
1726 C
1727 c
                           - IF .GE. 1 CHI'S WILL BE CALCULATED FROM FLUE HOMENTS
             ICHIMDH
1728 c
             IPRER
                           - 0/1 CALCULATE PSI STREAD PREPARED PSI'S FROM TAPES
1729 c
             IDPT
                           - IF .GE. 2 PRINT DUT PSI'S
1730 c
1731 C + + + DUTRUT COMMENTS
1732 c
                           - ASI'S IN LCH
1732 C RPSI - RSI'S IN LCH
1733 C CHI(6+K) - CHI'S IF ICHIMDM .6E. 1
1734
1735
1736
            LEVEL SILCIFFLUXIFAFLUX
            COMMON /LLC/ LC (40000)
1737
            INTEGER ELECTION 11 UN2
1738
            DIMENSION HTP (JT+1)+IIT (1)+KELP1 (JT+1)+KELP2 (JT+1)+
1740
                        FFLUX (1) + FAFLUX (1) + 1PS1 (KPZP+1) +
           ż
1741
                        #SI (IGH+LHAX#+1)+PRSI (IGH+1)+KTAP (5+1)+CHI (IGH+1)
1742
1743
            DATA CP1/6.283185307/
1744
1745
            IF (IGED.E. 1) CPI=1.0
1746
            IF (IDPT. GE.2) WRITE (6:400)
1747 C INITIALIZE PSI'S
1748
            10 320 6=1, IGH
1749
            IF (IPREP.HE. 0) 60 TO 251
            140 GP=1+16M
1750
1751
            DD 130 L=1+LHAXP
1752
            120 120 K=1+K#2#
1753
1754
            PSI(GP+L+K)=0.
       120 CONTINUE
1755
       130 CONTINUE
1756
        140 CONTINUE
1757 C DPEN TAPE IF NECESSARY
          UN1=HTAP (4+6)
1758
            IF (HTAP (4+6) . HE. HTAP (4+6-1). DR. 6. EB. 1) CALL ASSIGN (UN1+0+-3)
1759
1760 C READ THE FLUX HOMENTS
```

ICOUN1 = 1 1761 1762 1763 DD 150 J=1+JT DD 145 H=1+HP2 1764 TELETE (JIE). ER. 0) ED TO 145 1765 ICOUNETICOUNI + (KELP2(J++)-HELP1(J++)+1)+1 + 1 1766 READ (UN1) (FFLUX (ICDUN) + ICDUN=ICDUN1+ ICDUN2) NRITE (8+420) (FFLUX (ICDUN) + ICDUN=ICDUN1+ICDUN2) 1767 c 1768 ICOUNTEICOUN2 + 1 145 CONTINUE 1769 1770 150 CONTINUE 1771 DD 220 G6P=6, 16H 1772 GP=16H-66P+6 1773 C DPEN FILE IF NECESSARY 1774 UN2=+TAP (5+6P) UNZERTAP (516P) 1775 IF (+TAP (5+6P) .NE. +TAP (5+6P+1), DP. 6P. EB. IGH) CALL ASSIGN (UN2+0+-3) 1776 C READ THE ADJOINT FLUX HOMENTS ICDUN1 = 1 1777 1778 1779 DD 160 J=1+JT DD 155 K#1+KPZ IF (HTP (J+H) .EB. 0) GD TD 155 1780 ICOUN2 = ICOUN1 + (KELP2(J+#)-KELP1(J+#)+1)++ - 1 1781 1782 READ (UN2) (FAFLUX (ICOUN) + ICOUN=ICOUN1+ ICOUN2) 1783 C HAITE (8+420) (FAFLUX (ICOUN/+ICOUN=ICOUN1+ICOUN2) ICDUN1 = ICDUN2 + 1 1784 155 CONTINUE 1785 160 CONTINUE 1786 1787 C CLOSE FILE IF NECESSARY 1788 IF (HTAP (5+6P) . NE. HTAP (5+6P-1) . DR. 6P. EB. 6) CALL CLOSE (UN2) 1789 C CALCULATE THE PSI'S 1790 INDEX1=1 1791 DO 210 J=1,JT 1792 DD 200 K=1+KPZ 1793 IF (FTP (J+K).EB. 0) 60 TO 200 1794 IT#=#ELP2(J+#)-#EL#1(J+#)+1 1795 DD 190 12=1+17# DD 180 L=1+LMAX# 1796 1797 1798 c HATTE (7+444) ASI (GP+L+K)+FFLUX (INDEX1)+FAFLUX (INDEX1)+L+6P+ 1799 c 1K+12+INDEX1 1800 PSI(GP+L+K)=PSI(GP+L+K)+FFLUX(INDEX1)+FAFLUX(INDEX1) 1801 INDEX1=INDEX1+1 170 CONTINUE 18.02 1803 180 CONTINUE 1804 190 CONTINUE 1805 200 CONTINUE 1806 210 CONTINUE 1807 220 CONTINUE 1808 C CALCULATE THE PSI'S FOR THE SUM DUER ALL PERTURBED ZONES 1809 C AND MULTIPLY BY 24P1 IF A-2 GEDHETRY 1810 10 250 L=1+LHAX# 1811 DD 240 6P=6+16H DD 230 #=1+##Z 1812 ASI (GP+L+H)=CPI+PSI (GP+L+H) 1613 1814 FSI (GP+L++PZP)=PSI (GP+L++RZP)+RSI (GP+L++) 1815 230 CONTINUE 1816 240 CONTINUE 250 CONTINUE 1818 C READ THE REL'S FROM PREVIDUELY PREPARED TAPES 251 IF (IPPEP.ED. 0) GD TD 254 DD 253 K=1;KP2P 1819 1820 DD 252 6P64:16H PEAD (3:410) 1A1:1A2:1A3 PEAD (3:420) (PS1 (GP+L+K)+L=1+LMAXP) 1821 1822 1823 252 CONTINUE 1824 1825 253 CONTINUE 1826 C CALCULATE CHI'S FROM FLUX MOMENTS IF CNIMON ED 1 1827 - 254 IF (ICHIMON.LT.1) 60 TO 259 DD 255 H=1+HP2P 1628 255 CHI (6++)=0.0 1829 1830 DD 256 L=1+LMAXP 1831 DD 256 H=1+HP2P 256 CHI (GIK) =CHI (GIH) +PSI (GILIK) + (2+L-1) 1832 1833 C MAITE ASI'S IF DESIMED 1634 259 IF (IPREP.EB.1. AND. IDPT.LT.2) 60 TO 280 1835 20 270 H=1+HP2P 1836 10 260 6P=6+16H 1837 IF (IPREP.EB. 0) WRITE (3:410) 6:69:K IF (IPREP.EB. 0) WRITE (3:420) (PSI(69:L:K):L=1:LMAXP) 1838 1839 IF (IDPT.6E.2) WHITE (6:410) 6:6P+M IF (IDPT.6E.2) WHITE (6:420) (PSI(SP+L+K)+L#1+LMAXP) 1640

```
260 CONTINUE
1841
1842
        270 CONTINUE
1843 C BUT PSI'S IN APPROPRIATE PLACE IN LCM
1844 - 260 DD 310 HEINHER
1844
             DD 300 L=1+LMAXP
DD 290 GP=1+IGM
1845
1846
1847
             PPSI(GPIL)=PSI(GPILIK)
       290 CONTINUE
1848
1849
        300 CONTINUE
             CALL ECHR (RPSI+IRSI (K+6)+IGH+LHAXR)
1850
1851
        310 CONTINUE
1852 C CLOSE FILE IF NECESSARY
             IF (IPPEP.HE. 0) 60 TO 320
1853
             IF (#TAP (4+6) .NE. #TAP (4+6+1).DP.G.EB. IGH) CALL CLOSE (UN1)
1854
1855
       320 CONTINUE
1656 C MRITE CHI'S IF CALC, FROM MOMENTS AND LIST DESIMED
1857 IF (ICNIMOM.LT.1) 60 TO 340
1857
             NPITE (6+450)
1858
1859
             HRITE (6+440)
1860
             DD 330 H=1+H#2#
             HRITE (6+460) K
1861
      330 HRITE (6+430) (CHI (6+K)+6=1+16H)
340 CONTINUE
1862
1863
1864 C READ THE PSI'S IF PREPARED
           IF (IPPEP.HE.1) 60 TO 345
1865
             DD 344 K=1+K#2#
1866
             READ (3+420) (CHI (6+H)+6=1+16H)
1867
1868
      344 CONTINUE
1869 C HRITE DUT THE CHI'S
             DD 350 H=1+H=2#
1870
1871
        345 IF (IPREP. HE. 0) 60 TO 355
             HRITE (3+420) (CHI (6)+6=1+16H)
1872
1873
        350 CONTINUE
1874
        355 CONTINUE
        400 FORMAT (1H $/$40H + + TES' PRINTOUT FOR THE PSI'S + + +)
1675
        410 FORMAT (14 +346 =+13+54 6P =+13+44 4 =+13)
420 FORMAT (14 +6612.5)
1877
1878
        430 FORMAT (1H +6E12.5)
1879
        440 FORMAT (1H +40H + + TEST PRINTEUT FOR THE CHI'S + + +)
        444 FORMAT (IN 1412.5)6HL16P141315)
450 FORMAT (IN 1716.400000 CHI'S GENERATED FROM FLUX MOMENTS 400000)
460 FORMAT (IN 1640000 H =13330000)
1880
1681
1662
1663
             PETURN
1884
             END
1865 c
1886 C SUBROUTINE ROINTS SETS THE LCH ROINTER FOR THE RSI'S CORRESPONDING
1887 C MITH PERTURSED ZONE HI AND PUTS THE APPROPRIATE CHI'S IN VECTOR CCHI
1888 c
1889
             SUBROUTINE ROINTS (IRSINK+ IPPSI+ HP2P+ 16H+ CHI+ CCHI)
1890 c
1891 C + + + INPUT COMMENTS + + +
                 IRSI(H)]) - LCH RDINTER FOR THE RSI'S FOR PERTURBED ZOME H

(H)(6)K) - CHI'S FOR GROUP 6 AND PERTURBED ZOME H

K - PERTURBED ZOME IDENTIFIER
1892 c
1893 c
1894 c
1895 c
                             - D PERTURSED ZONES
                 KPZ
                            - IDENTIFIER FOR SUN OVER ALL PERTURSED ZONES
1896 c
                 KRZP
1897 c
                             - - -
                 1 G M
1898 c
1899 C + + + DUTRUT COMMENTS + + +
1900 C
                IPPSI
                            - LCH PDINTER FOR THE PSI'S FOR PERTURBED ZOHE H
- Chi Factor for Group 6 and Perturbed Zohe H
1901 c
                 CCHI(6)
1902
1903
             DIMENSION IPSI (KPZP+1)+CHI (IGH+1)+CCHI (1)
1904
1905
             INTEGER 6
1906
1907
             IF (K.NE. 0) 60 TO 120
             IPPS1 = IPS1(KP2P+1) + 1
NRITE(2+410) IPRS1+K
1906
1909 c
1910
             DD 110 6=1+16H
1911
             CCHI (6) = CHI (6+KPZP)
        110 CONTINUE
1912
1913
             €D TD 140
        120 IPPSI = IPSI(K+1) + 1
HRITE(2+410) IPPSI+K
1914
 1915 c
             DD 130 6=1+16H
CCN1(6) = CN1(6+K)
1916
1917
       130 CDNTINUE
410 FORMAT(1M +6M 18851+216)
140 RETURN
1918
1919
1920
```

1921 END 1922 c 1923 c 1924 c 1925 c 1926 c SUBROUTINE SUB5 (XN2+NCG+NCTL+NHL+ILMAX+IXSTAPE+XTITLE+XN1) 1927 HAROLDS ANISH SECTION POUTINE, SIMPLIFIED TO READ ANISIN CROSS SECT 1928 c TABLES FOR DALT 1 ISOTOPE DR MIX AT A TIME: BUT ALL P-L COMPONENTS Level 2: XH2:XN1 1929 c 1930 1931 DIMENSION XN2 (NCG+NCTL+1)+XN1 (NHL+1)+ 1932 IN (6) + + + (6) + + (6) + + (12) + NAME1 (10) + TITLE (20) 1933 ٠ +ITITLE (11) +TITLEY (20) 1934 EPUIVALENCE (IBLANH+XBLANK) 1935 COMMON/ITE/ITESTFITYP 1936 COMMON COMMIN JOURA 1937 COMMON-XSFORM-KXS+INT+INA 1938 COMMON/DENS/ NUMDEN NUMBEN 1939 PEAL 1940 INTEGER ALCOM 1941 DATA BUODHL/4HERP. / 13LANH/4H 1942 N5=5 1943 N6=6 1944 GRP= #000HL NC = 0 NC1 = 0 1945 1946 NT1 = 32767 1947 1948 LLMAX = ILMAX + 1 1949 IF (INSTAPE.EB.1. AND. KXS.EB. 1) GD TD 500 1950 IF (KX5.E0.2) GD TD 40 1951 c 1952 C +++ READ LASL-FORMAT CROSS SECTIONS FROM INPUT FILE (OR CARDS) 1953 1 CONTINUE READ (N5+2) (TITLE (1)+1=1+20) 2 FORMAT (2044) 1954 1955 READ (N5+3) NUMDEN+JCOVAR 3 FORMAT(12++12.6+11++11) 1956 1957 HAITE (6+303) 1958 1959 303 FORMAT (IN 14 MICRO CROSS-SECTIONS AND NUMBER DEMSITY READ IN LASL-1960 +FORMAT WITH FOLL. TITLE CARD +) WRITE(6+4) (TITLE(1)+1=1+20) 1961 1962 4 FURMAT (1H +2044) WRITE (615) NUMBEN 5 FORMAT (14 14 NUMBER DENSITY #41FY.614 1 MAKES THE FOLLOWING MARRO-1963 1964 1965 +CROSS SECTIONS: IN 1/CH+/) 1966 6 30 900 LL=1+LLMAX 1967 READ (N5+2) (TITLEX(1)+1=1+20) MRITE(6+4) (TITLE×(1)+1=1+20) READ(N5+301) ((XN2(1+3+LL)+3=1+NCTL)+1=1+NC6) 1968 1969 1970 301 FORMAT (6E12.5) 1971 10 DD 300 1=1+NCS DD 300 J=1+NCTL 1972 1973 XN2(1+J+LL) = NUMDEM+XN2(1+J+LL) 300 CONTINUE 1974 1975 IF (ITEST.ED.1) 60 70 304 1976 1977 1978 NRITE (6+305) 305 FORMAT(IN ; +XS PRINTED DNLY HHEN ITEST#1; DHITTED FOR THIS CASE+) GD TD 910 304 HRITE(6:302) ((XH2(1;j:LL);j#1:HCTL);1#1:HC6) 1979 1980 302 FORMAT (14 +6(2+)1+E12.5)) 1981 910 CONTINUE 900 CONTINUE 1982 1983 999 RETURN 1984 c 500 CONTINUE 1985 1986 RENIND 4 1987 COMM READ MICHOSCOPIC CROSS SECTIONS FROM LASL CARD IMAGE TAPE 1985 C++++ PROGRAM DETERMINES NUMBER OF RECORDS PER ISOTOPE 1989 HI= (NCG+NCTL)/6 1990 c+ IF MI IS NOT A MULTIPLE OF 61 THEN ADD 1 HORE RECORD 1991 IF ((6+H1).HE. (NC6+HCTL)) H1=H1+1 1992 c+ ADD DHE FOR TITLE RECORD 1993 H2=H1+1 1994 c+ MULTIPLY WITH NUMBER OF RE-COMPONENTS RER ISOTOPE HERDINGISUOD IDINUMDENIXSNAME 1995 1996 1997 5000 FORMAT (16:62:12:5:22:410) 1998 C444 PROGRAM DETERMINES THE NUMBER DF RECORDS TO BE SKIPPED 1999 ISCIPE(ID-1) 4H2 2000 IF READING FIRST MATERIAL DN TAPE SHIP ZERD RECORDS

```
IF (ID.ED.1) 60 TO 5007
2001
        DD 510 1=1+15CIP
510 8660(4+5001) (TITLEX(N)+N=1+20)
2002
2003
     5007 CONTINUE
2004
2005
             DO 502 LL=1+LLHAX
             READ TITLE OF MATERIAL DR P-L COMPONENT DESIRED FROM TAPE
REAL(4+5001)(TITLEX(1)+1=1+20)
2006 c++
2007
      5001 FORMAT (2084)
2008
2009
             HAITE (N6+5002) (TITLEX(1)+1=1+20)
2010 5002 FORMAT(1H +1x+20A4)
2011 MRITE(N6+5003) NUMDEN+X$NAME
2012 5003 FORMAT(1H +1x++NUMDER DENSITYE++1PE12.5+2x+A10)
2013 C++
            READ CROSS SECTIONS OF MATERIAL DESIRED
             READ (4+5004) ( (XN2 (1+3+LL)+3=1+NCTL)+1=1+NC6)
2014 2015
       5004 FORMAT (6E12.5)
2016 C++
            IF ITEST FLAGED DO NOT PRINT HICPOX'S
             IF (ITEST.HE.1) 60 TO 507
2017
2018
             LELL-1
            METTE (6+5005)L
2019
      5005 FORMAT (14 +1x++TEST PRINOUT FOR HICROSCOPIC CROSS SECTIONS FOR L
2020
2021
           1=+,13>
       мяіте(6+509)((xN2(1+J+LL)+J=1+NCTL)+J=1+NC6)
509 гранат(1N +6(2x+1PE12.5))
2022
2023
        HAFE THE HACHDSCOPIC CROSS SECTIONS
507 DD 505 I=1+NC6
DD 505 J=1+NCTL
2024 C++
2025
2026
2027
        505 XN2(1+J+LL)=NUMDEN+XN2(1+J+LL)
2028
        502 CONTINUE
2029
             GD TD 499
2030 c
2031 C +++ READ LIMITED-FIDD FORMAT XS
2032 c
2033
         40 DD 9999 LN=1+LLMAX
        50 1F (NC) 121+121+31
121 REAL (N5+11) NCC+PLCOMP+NAME1
2034
2035
         11 FORMAT (216+1044)
2036
2037
            NCID = PLCOMP + 1
NCI= NCID
2038
2039
            1# (NCC) 22+22+21
2040
         21 IF (NCC-2)24+22+24
2041
         22 3=0
2042
            NCOUNTRNC64NCTL
        622 READ (N5+8) (1) (1) +MK(1) +V(1) +1=1+6) + (M(1) +1=1+12)
6 FERMAT (6(12+A1+F9-0)+T1+6(4x+2A4))
2643
2044
2045
             DD 635 1=1+6
2046
             IF (KK (1)-13LANA) 700+810+700
2047 c
             ND PEPEATS
       810 IF (#(2+1-1). EB. XBLANH . AND. #(2+1). EB. XBLANK) 60 TO 800
2048
2049
             3=3+1
2050
             XN1 (J+LN/=v (1)
2051
             GD TD 800
2052 c
             REPEAT
2053
        700 L=IN(1)
            DD 809 H=1+L
2055
             3=3+1
2056
        809 ×N1 (J+LN)=V (1)
2057
        800 IF (J-NCOUNT) 635,24,24
2058
        635 CONTINUE
2059
             60 TD 622
         24 NC=1
2060
2061
             IF (NCC-7) 31+25+31
2062
         25 NC1=32767
2063
             1# (NC1-NT1) 31+26+31
2064
         26 PETURN
2065
         31 IF (NT1-NC1) 43+41+43
2066
         43 NC=0
2067
             H=0
2068
             DD 120 1=1.NC6
2069
             DO 120 J=1+NCTL
2070
             H=H+1
2071
        120 XN2 (1+3+LN)=XN1 (K+LN)
2072
             IF (ITEST. HE. 1) 60TO 51
2073
             MAITE (N6,201) NC6+HCTL+NCC+NCID+LN+NAME1
2074
        201 FORMAT(
                       5N1NDG=13+3++ 9HT.LENGTH=13+3++5HCDNTROL=13+3++19HNC1D=RH
            +ISN-HAT.ND.=14+3x+13HL-DRDER=PL+1=12+3x+10A4>
2076
         51 MM1=1
2077
             M12=8
2078
             TEST# FLOAT (NC6) /8.0 +.999
2079
             LHAFETEST
2080
             DD 145 L=1+LMAX
```

```
1F (NH2-HC6) 232+ 232+ 233
2081
        233 MH2= NCG
232 IF (ITEST.HE.1) GDTD 49
2082
2083
2084
             HEITE (NE: 245) (GRP : J : J=HN1 : HN2)
        245 FORMAT (7H-POS MT+8(6×14413))
2085
            10 241 1=1+NCTL
2086
2087
        241 HRITE (N6+202) IILN+ (XN2 (J+IILN)+ J=NN1+NN2)
        202 FORMAT (214, 1+8E13.5)
2088
2089
          49 NN1= NN2+1
2090
        145 MN2=NN1+7
2091
             1F (ITEST.NE.1) 60T0 9999
         HRITE (N6175)
75 FORMAT (140)
2092
2093
2094
      9999 CONTINUE
        41 во то 50
2095
2096 C
2097 499 PETURN
2098
             END
2099 c
2100 c
2101 c
2102
      с
2103 c
2104
             SUBROUTINE SUBG (DST+DSL+XS+XSBAR+IGH+ITL+AXS+SXS+DSLFD+SXSNG+
2105
                               NCOUPL + FISXS+ IDES)
2106 C +++ CALCULATES DET-+ DEL- AND ANE-ANDAYS+ AND DELED-ANNAY
2107
             LEVEL 21 DSLIXSIXSDARIDSLED
21 08
             DIMENSION AXS(1)+SXS(1)+DSLFD(IGH+IGH+1)+FISXS(1)
             DIMENSION DSL(IGH+IGH+1)+DST(1)+XS(IGH+ITL+1)+XSBAR(IGH+ITL+1)
2109
2110
             DIMENSION SYSNE(1)
2111
             COMMON'ITE'ITESTITYP
             COMMON/VRS/LL
2112
2113
             COMMON / DENS / NUMDEN
2114
             CONMON/XSEDPH/KXS+INT+IMA
2115
             REAL NUMBEN
2116
             INTEGER 616P
             DD 1 6=1+16M
2117
2118
2119
             DD 1 L=1+LL
             DSLFD(6+8++L)=0.0
2120
          1 DSL (G+ 6P+L)=0.0
2121
2122 C +++ CALCULATE DELTA SIGNAS DET AND DEL
            DD 40 6=1+16H
DST (6) = x5 (6+1HT+1)
2123
2124
           F ((1749.EB.1). MND. (1DES.EB.0))

◆ DST(6) = x5(G+1MT+1) = x53AB(G+1MT+1)
2125
2126
            IF ((ITYP.EB.1). AND. (IDES.EB.1))
2127
2128
            ٠
              DST(6) = 0.01+x5(6:1HT:1)
2129
             AXS(G) = XS(G+1HA+1)
             #15x5 (6)=x5 (6+1+A+1+1)
2130
2131
            DD 40 G#=1+6
2132
             DD 40 L =1+LL
2133
             DSL (8+1-6P+6+L) = XS (6+6P+1HT+L)
2134
             IF ((ITYP.EB.1) AND. (IDES.EB.U))
2135
           • DSL(6+1-6P+6+L) = XS(6+6P+1HT+L) - XSBAR(6+6P+1HT+L)
IF((1TYP.ED.1).AND.(1DES.ED.1))
2136
2137
            ٠
              ESL (G+1-6P+6+L) = 0.01+XS (6+6P+1HT+L)
2138
         40 CONTINUE
2139 C +++ NON THE DEL-ARRAT IS CONVENIENTLY DRDERED FOR THE AD-FORMULATION
2140 C +++ DSL (GP:GL) CAN DIRECTLY BE INTERPRETED AS SCATTERING FROM GROUP
2141 C +++ GP INTO GROUP 6: DRDERED SD THAT GP STARTS WITH 1 AND INCREASES
2142 C +++ TO GPEG; THE REST ARE ZEROS.
2143 c
2144 C +++ CALCULATE DELED FOR FD-FDRHULATION
2145
            DD 30 6=1.16M
2146
2147
             ##IMT+6P-6+1
2148
             20 30 L=1+LL
2149
             DSLFD(6+6+L) = XS(6++K+L)
            IF ((1779,EB,1), AND. (IDES.EB.0))

• DSLFD(G:GP:L) = x5(GP:K:L) - x53AA (GP:K:L)
2150
2151
            IF((ITYP.EB.1).MND.(IDES.EB.1))
2152
2153
                DSLFD(6+0++L) = 0.01+x5(0+++L)
            ٠
2154 - 30 CONTINUE
2155 C 444 NOH THE DELTARRAY IS CONVENIENTLY DRDERED FOR THE FD-FORMULATION
2156 c
2157 C +++ CALCULATE TOTAL HSCHOSCOPIC SCATTERING CROSS SECTION RER GROUP
2158 IF (ITYP.EB.1) 60 TO 203
             IF (ITYP.EB.1) 60 TO 203
DD 60 I=1,164
2159
2160
             s \times s (1) = 0.0
```

```
2161
           DD 50 6=1+16M
           GP = INT+6-1+1
2162
        50 $x$(1) = $x$(1) + x$(6+6+1)
2163
2164
        60 CONTINUE
            IF (NCDUPL.ED. 0) GD TD 202
2165
2166 C +++ CORRECT DIAGONAL SUNS FOR NEUTRON-SXS BY SUBTRACTION OF SXSNG
           DD 204 6=1+16H
2167
2168
       204 $X$NE(6)=0.0
            NG1=NCOUPL+1
2169
            DO 200 GEINCOUPL
2170
2171
            DD 201 6P=N61+16M
            1=1HT+6P-6+1
2172
      201 $X5NG (6)=$X5NG (6)+X5 (6+111)
2173
2174
            $x5 (6) =5x5 (6) -5x5N6 (6)
2175
       200 CONTINUE
       202 IF (ITEST.HE.1) 60 TO 26
2176
           HRITE (6+1050)
2178
2179
      1050 FORMAT (14 + TEST RRINT-DUT FOR TOTAL MACROSCOPIC SCATTERING CROSS-
           SECTION PER GROUPS IN 1/CH4/)
2180
            DD 70 G=1+16H
            MRITE (6+1051) 6+5×5(6)
2181
      1051 FORMAT (14 ++6 =++13++ SX5-MACRO = ++18E12.5++ 1/CH+)
2162
2183
        70 CONTINUE
2184
            HRITE (6+1052)
2185
      1052 FORMAT (14 14TEST PRINTOUT FOR TOTAL GAMMA PRODUCTION XS PER NEUTRO
2186
           +N GROUP+>
           DD 71 SELINCOUPL
2187
      итте (6:1053) с:$x$N6(6)
1053 горнат(1н :+6 =+:13:+ $x$N6-насво = +:1PE12.5:+ 1/сн+)
2188
2189
2190
        71 CONTINUE
      203 1F (ITEST.NE.1) 60 TO 26
2191
2192 C +++ TEST PRINTOUT OF DELTA SIGNAS
2193
           MPITE (6+7004)
2194
      7004 FORMAT (IN SATEST RECOLEN VALUES FOR DST (6)4/)
2195
            NRITE (6+1042) (DST (6)+6=1+16H)
2196
      1042 FORMAT(1H +9 (2x+1PE12.5))
IF(IGH.6T.9) 60 TO 805
2197
2198
            DD 41 L=1+LL
           WHITE (6+1040) L
2199
2200 1040 FORMAT (IN SATEST ARINTOUT FOR DEL(6,64) FOR LEASI3//)
           DD 41 6 =1+16H
2201
22 02
            HRITE (6+1016) 6
2203
     1016 FORMAT (1H ++WHEN 6=++13 )
        41 HRITE (6:1042) (DSL (6:6012):60=1:16H)
2204
22 05
       805 CONTINUE
            IF (NCOUPL.ED. 0) 60 TO 26
2206
22 07
            DD 800 L=1+LL
            NRITE (6+801) L
22.08
2209
       BOI FORMAT (IN SATEST ARINTOUT FOR N-GAMMA MATRIX DELFNG (6) 60 + L) FOR LE
2210
           ++,13 )
2211
           HRITE (6,807)
       607 FDMAT(1H +7x++6-6=1++5x++6-6=2++5x++6-6=3++5x++6-6=4++5x++6-6=5++
+5x++6-6=6++5x++6-6=2++5x++6-6=2++5x++6-6=10+ )
2212
2213
2214
            DO 810 GETINCOUPL
2215
       810 MPITE (6:1062) 6: (DSLFD (6:6P+L):6P=NG1:16H)
2216
      1062 FORMAT (1M ++N-G=++12+12(1x+1PEY.2))
2217
       BUU CONTINUE
2218
            MPITE (6+803)
       803 FORMAT (1H + TEST PRINTOUT FOR TOTAL N-SAMMA MACROSCOPIC CROSS
2219
           SECTION PER NEUTRON SHOUPS IN 1/CH+ >
2220
2221
            DO 802 GEIINCOUPL
2222
       802 MMITE (6,804) 6,5x5N6(6)
2223
       604 FORMAT (1H + +68++, 13+ $X$NG-MACHOR++ 1PE12.5+1×++1/CH+)
2224
        26 PETURN
2225
            END
2226 c
2227 c
2228 c
2229 c
2230 c
2231
            SUBPOUTINE TEXT
2232 C +++ THIS BOUTINE BRINTS A LIST OF DEFINITIONS FOR XS-PROFILES
2233 с
            EDITED IN SUB8
            HPITE (6+801)
2234
2235
       801 #D#HAT(1H +11x+87(+-+)+/)
       WHITE (6:802)
802 FORMAT (14 : 26X: + DEFINITIONS OF SENSIT SENSITIVITT PROFILE NOMENCLA
2236
2237
          1TURE + >
2238
2239
            HRITE (6+805)
      805 FDAMAT (1H +11x+87 (+-+)+/)
2240
```

HRITE (6+803) 2241 2242 803 FORMAT (1H + 48×5 * SENSITIVITY PROFILE PER DELTA-U FOR++ 2243 + THE ABSORPTION CROSS-SECTION (TAHEN FROM POSITION+1/ 2244 15x14 INA IN INPUT CROSS-SECTION TABLES); PURE LOSS TERM 4:// 2 2245 - SENSITIVITY PROFILE PER DELTA-U FOR THEM. 3 . ----2246 + CROSS SECTION IN POSITION IMA+1 IN INPUT XS-TABLES: 4/3 2247 15x10 WHICH IS USUALLY NUTTIMES THE FISSION CROSS SECTION. 0; + PURE LOSS TERM+ // + SXS * PAR 2248 2249 - PARTIAL SENSITIVITY PROFILE PER DELTA-UM 2250 + EDB THE SCATTERING CROSS-SECTION (COMPUTED FOR FACMAL) 8 2251 9 15x1+ ENERGY GROUP AS A DIAGONAL SUM FROM INPUT XS-TABLES) +++ 2252 + LOSS TERM DHLY+ //) . 2253 HPITE (6+604) 2254 804 FORMAT (1H ++TXS - SENSITIVITY PROFILE REP DELTA-U FORA 1 + THE TOTAL CROSS SECTION (AS GIVEN IN POSITION INT IN+)/ 2 15x++ INPUT CROSS-SECTION TABLES); RURE LOSS TERM+)// 2255 2256 2257 + N-GAIN - AARTIAL SENSITIVITY PROFILE PER DELTA-U++ + FOR THE NEUTRON SCATTERING CROSS-SECTION, GAIN TERM FOR41/ 2258 2259 5 15x++ SENSITIVITY GAINS DUE TO SCATTERING OUT OF EHERGY++ 226.0 . GROUP & INTO ALL LOWER NEUTHON + / 6 7 2261 15x1 + ENERGY GROUPS: COMPUTED FROM FORMARD DIFFERENCE. + FORHULATION. +1// 2262 3 - PARTIAL SENSITIVITY RADFILE REA DELTA-U++ 2263 + G-GAIN . + FOR THE GAMMA SCATTERING CROSS-SECTION. GAIN TERMAN 2264 L. 2265 15x1+ FOR SENSITIVITY GAINS DUE TO SCATTERING OUT OF GAMMA+1 2266 -+ ENERGY GROUP & INTO ALL LONER GAMMA EMERGT GROUPSI */ 2267 -15+++ COMPUTED FROM FORWARD DIFFERENCE FORMULATION.++// + N-GAIN (SED) = RE-DRIERED RAPTIAL SENSITIVITY PROFILE+ 2268 8 + PER DELTA-U FOR SCATTERING CROSS-SECTION. GAIN TERM FOR+1/ 2269 9 2270 15x1+ SENSITIVITY GAINS DUE TO SCATTERING INTO GROUP & FROM+1 • 2271 + ALL MIGHER NEUTRON ENERGY GROUPSI +1/ . C 15x14 COMPUTED FROM ADJOINT DIFFERNCE FORMULATION.41/ 2272 D 15414 CORRESPONDS TO SINGLE-DIFFERENTIAL SED SENSITIVITY41 2273 + FROFILE: PSED (G-DUT) RER DELU-DUT: +:/ 2274 . 15+++ INTEGRATED OVER ALL INCIDENT ENERGY GROUPS.++// > 2275 F. 2276 MRITE (6+806) 2277 806 FORMAT (1H + +NG-GAIN 2278 + DELTA-U FOR THE GAMMA PRODUCTION CROSS-SECTION+1/ 1 2 15x14 AT NEUTRON ENERGY GROUP G. PURE GAIN TERM FOR4; 3 4 SENSITIVITY GAINS DUE TO TRANSFER FROM NEUTRON4; 2279 2280 X 15X1+ GROUP & INTO ALL GANHA GROUPS. +1// 2281 NET SENSITIVITY ANDFILE ARA DELTA-U FORA 2282 + SEN + THE SCATTERING CROSS-SECTION (SEN=\$x\$+NGAIN)++// 2283 5 2284 + SENT - NET SENSITIVITY PROFILE PER DELTA-U FOR+ 2285 + THE TOTAL CROSS-SECTION (SENTETSS+NGAIN)+1// . SENR - SENSITIVITY PROFILE PER DELTA-U FOR THE* 2286 8 + DETECTOR RESPONSE FUNCTION R(6) +1// 2287 9 * SENSITIVITT PROFILE PER DELTA-U FOR THE* 2286 + SEND 2289 ♦ SOURCE DISTRIBUTION FUNCTION B(6) ♦+// > 2290 MRITE (6+805) 2291 HPITE (6+805) 2292 RETURN 2293 END 2294 c 2295 c 2296 c 2297 с 2298 c 2299 SUBBOUTINE TEXTO 2300 C +++ THIS ROUTINE PRINTS A LIST OF DEFINITIONS FOR TERMS EDITED IN 2301 C DESIGN SENSITIVITY MODE FROM SUDU HRITE (6+101) 2302 2303 101 FORMAT (1H1) 2304 HPITE (6+100) 2305 100 FORMAT (1H +10x+90(1H+)+/ > WRITE (6+110) 2306 110 FORMAT(1H +30x++DEFINITIONS FOR SENSIT-1D DESIGN SENSITIVITY ++ 2307 2308 1 *PRINTOUT + > WRITE (6+100) 2309 2310 NFITE (6+120) 120 FORMAT (IN + 12, OFDR THEORY AND DETAILED DERIVATIONS OF THESE ++ 2311 2312 1 2313 AND ENGINEERING, 51, 339(1973) \bullet , /; 2x; \bullet (2) S.A.W. GERSTL: ARGONNE NATIONAL LAB. TECHNICAL MEMO*, 2314 з 2315 4 *RANDUH AP/CTR/TH-28 (1974) DR FRA-TH-67 (1974) *) 2316 5 MEITE (6+130) 2317 2318 130 FORMAT (14 +2x+ +DUE TO THE DUBLISH OF FORMARD AND ADJOINT ++ 2319 FORMULATIONS FOR RADIATION TRANSPORT CALCULATIONS 4 2320 2

2321 THE DIFFERENT: BUT EBUIVALENT: FORMULATIONS FOR ANY +. 3 *RESPONSE CALCULATION, AND BOTH ARE IMPLEMENTED IN THIS *: 2322 2323 5 +cnbs1 +) HRITE (6+140) 2324 2325 140 FORMAT (1H + 3x++## = (#+PHI) ++ / 1 12x, +* FIRST-DADER INTEGRAL RESPONSE FROM FORMARD +; 2 + CALCULATION +: / 2326 2327 2328 2329 2330 2331 2332 2333 150 FORMAT (1M , 3x) + DELI-AD = (FISTAR, DELTA-SIGHA+, 1M+, +PNI) +, / 2334 1 12x++ SECOND-ORDER TERM (DELTA-1) FROM ADJOINT-DIFFERENCE + 2335 +FORHULATION ++ // 2336 3 4x++DELI-FD = (PHI+DELTA-SIGHASTAR+, 1++++FISTAR) ++ / 2337 2338 4 12x1+** SECOND-DRDER TERM (SELTA-1) FROM FORMARD DIFFERENCE +; 5 +FORMULATION +; // 2339 6 4x++12AD * SECOND-ORDER INTEGRAL RESPONSE FROM ADJOINT-+, 2340 +DIFFERENCE FORMULATION +1 / 2341 2342 8 12x+** APPROXIMATE INTEGRAL RESPONSE FOR PERTURBED CASE *+ > 2343 WRITE (6+160) 2344 160 FORMAT(1H +3×++12FD - SECOND-DRDER INTEGRAL RESPONSE FROM + +FORMARD-DIFFERENCE FORMULATION +; / 12x; += APPRDXIMATE INTEGRAL RESPONSE FOR PERTURBED CASE + //; 1 2345 2346 2347 3 4x++xAD * SENSITIVITY COEFFICIENT FROM ADJDINT-DIFFERENCE +, 2348 *FORHULATION +, // 5 4.x++xPD 2349 * SENSITIVITY COEFFICIENT FROM FORMARD-DIFFERENCE *; 6 OFDAHULATION 0, // 7 3x,0APPRDXIMATE CALCULATIONS OF THE INTEGRAL RESPONSE FOR 0, 2350 2351 2352 8 • THE PERTURBED CASE FOLLOW DIRECTLY FROM THE AD- AND FD-++/ 9 3_{++} +Formulations (C.F. References): • /) 2353 2354 2355 2356 2357 2358 2359 32x,**0mn = nn 0 /;** 33x,0<u>delu-AD</u> = Delu-FD 0; / 33x,012AD = 12FD 0; / 33x,0xAD = xFD 0) 180 FORMAT (14 + 32×++88 2360 2361 1 2362 2363 3 MPITE (6+100) 2364 2365 RETURN 2366 END 2367 c 2368 c 2369 c 2370 c 2371 c 2372 SUBROUTINE SUBBIFIDSLIPSIIDSTICHIIDELIIDELIFDINRILMAXPI IGMIA/SISENISISIEIDELUIDSLFDIFFDIFISXSI 2373 1 2374 SENTIJIINCOUPLIIGHIIFFDNGIKIIDES) Ê 2375 LEVEL 2, DSLIPSIIDSLED 2376 DIMENSION ANS(1)+SEN(1)+SES(1)+E(1)+DELU(1)+DELFD(IGH+IGH+1)+FFD(1 2377) #FISXS (1) #SENT (1) #FFDNG (1) #THOLH1 (50) #EE (50) ٠ 237R DIMENSION # (1)+DSL (164+164+1)+PS1 (164+LMA#P+1)+CH1 (1)+DST (1) 2379 COMMON/XSEDRM/HXS+INT+IMA 2380 COMMON / PLOT / TITLE (8) 2381 COMMON/ITE/ITESTITYP 2382 INTEGER 616P 2383 PEAL IZADIIZED DATA #1/3.141591/ 2384 2385 410 FORMAT (6E12.5) IF ((H. EB. 0) . MND. (J1.EB. 1)) MRITE (6+1014) (TITLE (1)+1=1+8) 2386 2387 1014 FORMAT(1H + 8A10+/> 2388 с 2389 C SET UPPER-BOUNDARIES FOR GROUPS 2390 IF (NCOUPL.EP. 0) 60 TO 250 DE 255 6=1+NCOUPL 2391 2392 EE (6) =E (6) 2393 255 CONTINUE 2394 NCP1=NCDUPL + 1 10 260 GENCP1+16H 2395 2396 EE (6) =E (6+1) 2397 260 CONTINUE 60 TO 205 250 DO 265 6=1, 164 2398 2399 2400 EE (6)=E (6)

```
265 CONTINUE
2401
2402 c
2403 C +++ CALCULATE SECOND DRDER EFFECT DF INTEREST FROM AD-FORMULATION
2404
         205 IF (J1.E8.1) DELI=0.0
2405
              ID 5 LEILHANP
              IF (K×5.EB.2) THOLH1(L)=1.0
IF (K×5.HE.2) THOLH1(L)=FLOAT(24L-1)
2406
2407
2408
            5 CONTINUE
2409 c
2410 C +++ USE A SIMPLE SUMMATION DVER L
2411 DD 99 G=J1+16H1
              # (G)=0.0
2412
2413
             DO 98 LEIILMAXA
2414
              20 99 GP=J1+6
          98 F (G) * THOLH1 (L) +DSL (6++6+L) +F1 (6+L+6+) + F(G)
2415
          99 DELI=DELI+ (DST (6) +CHI (6)) -F (6)
2416 2417
              IZAD = ## - DELI
2418
               XAD - ICAD/AR
2419 c
2420 C +++ CALCULATE SECOND DADER EFFECT OF INTEREST FROM FD-FORMULATION
2421 C
2422
               IF (J1.EP.1) DELIFD = 0.0
2423
             DD 89 6=J1+1641
FFD(6) = 0.0
2424
              DO 88 LEIILMAXP
2425
2426
              10 88 GP=6:16H1
2427
              FFD(G)=FFD(G)+THOLH1(L)+DSLFD(G+GP+L)+PSI(GP+L+G)
          68 HPITE(2:132) THULHI(L):DSLFD(6:6P+L):RSI(6P+L:6):FFD(6)
302 FORMAT(5M +4E12.5)
2428
      1302 FORMAT (5H
2429
         1902 FLEMENT (0) - FELIFD + DST(6)+CHI(6) - FFD(6)

BELIFD = DELIFD + DST(6)+CHI(6)+FFD(6)+DELIFD

69 MPITE(2)1303) DST(6)+CHI(6)+FFD(6)+DELIFD
2430
2431
      1303 FORMAT (14 +4612.5)
12FD = MA - DELIFD
2432
2433
              XFD = 12FD/MM
2434
              IF (ITYP.NE.1) 60 TO 100
2435
2436 c
2437 C +++ START EDITING DESIGN SENSITIVITY INFORMATION
2438
             IF (J1.NE.1) 60 TO 1110
2439 IF (IDES.ED.1) WRITE (6,1109)
2440 II09 FORMAT(IN + 06(1+0+)+ RESULTS ARE FOR ASSUMED 1 PER CENT FLAT XS-IN
2441 ICREASE: OR 1 PER CENT DENSITY INCREASE IN RERT. 2DNES +,07(1++))
2442 I110 IF (W.GT.O) GO TO 70
             IF (J1.NE.1) GD TD 71
NWITE (6+1100)
2443
2444
2445 1100 FORMAT (14 + DESIGN SENSITIVITY INFORMATION; INTEGRATED OVER +;
           1 + ALL ENERGIES + /
2 + FOR THE SUM OVER ALL PERTURBED ZONES + / )
2446
2447
      MRITE (6+1101) DELIF DELIFD
1101 FORMAT(5x)+CONTRIBUTION FROM NEUTRON GROUPS DNLYI ++15x+
2448
2449
           1
2450
                     +DELI-AD(N) = +, 1PE12.5, 5x, +DELI-FD(N) = +, 1PE12.5, / )
          SD TD 73
71 MRITE (6,1102) DELI, DELIFD
2451
2452 71 MRITE (6+1102) DELI+ DELIFD
2452 71 MRITE (6+1102) DELI+ DELIFD
2453 1102 FORMAT(5+)+TOTAL SECONL-ORDER TERM; FROM NEUTRON+GAMMA GROUPS:
2454 1 +DELI-AD = ++1PE12.5+5x++DELI-FD = ++1PE12.5+/ )
2455 MRITE (6+1103) PR
2455 MRITE (6+1103) PR
      1103 FORMAT (5x) + INTEGRAL RESPONSE FOR UNPERTURBED REFERENCE CASE:

1 + PR = + 1PE12.5// )

HRITE (6:1104) 12AD: 12FD
2456
2458
2459
      1104 FORMAT (SritINTERGAAL RESPONSE FOR PERTURBED CASE: 4114x1
      1 •12AD = •1PE12.5+5x++12FD = •1PE12.5+

MRITE (6+1105) XAD+ XFD

1105 FORMAT(5x++SENSITIVITT COEFFICIENT FOR TOTAL PERTURBATION:
          าโ
2460
                                                                       = ++1PE12.5+/ >
2461
2462
                                                                                               +, 4x,
2463
           1
                                     # ++1#E12.5+5x++xFD
                                                                         = +,1PE12.5,/// )
              1 +хнр
60 то 73
2464
2465
          70 1F (J1.NE.1) 60 TO 72
             MPITE (6+1106) K
2466
      1106 FORMAT (1H ++CONTRIBUTIONS TO DELI-AD AND DELI-FD FROM PERTURBED ++
2467
      2468
2469
2470
2471
2472
2473
2474
      1108 FORMAT (5x +FROM HEUTRON PLUS GAMMA GROUPSI ++4x
                                   = ++1PE12.5+5×++DEL1-FD
            1
                    +DELI-AD
                                                                         = ++1e=12.5+// )
2476
          73 CONTINUE
2477 C +++ END EDITING DESIGN SENSITIVITY INFORMATION
2478 c
2479 60 TO 900
2460 100 CONTINUE
```

2481 C +++ FOR SENSITIVITY CALCULATIONS IT FOLLOWS +F (G) - PR IS THE GAIN-TERM FROM SCATTERING MATRIX 2482 c -DST(G) CHI(G)/AR IS THE LOSS-TERM FROM SIGHA-TOTAL -AXS(G) CHI(G)/AR IS THE LOSS-TERM FROM SIGHA-ABSORPTION -SXS(G) CHI(G)/AR IS THE LOSS-TERM FROM SIGHA-SCATTERING(DUT) 2483 c 2484 c 2485 c SYS(G) IS FINALLY USED FOR THE SUM OF LOSS AND GAIN-TERMS FROM SC SEN(G) IS FINALLY USED FOR THE SUM OF LOSS AND GAIN-TERMS FROM SC SEN(G) IS FINALLY USED FOR THE SUM OF LOSS AND GAIN-TERMS IF (NCOUPL.EB.0) GO TO 942 2486 c 2487 c 2488 IF (J1.NE.1) 60 TO 941 2489 2490 2491 2492 2493 GD TD 942 2494 2495 941 CONTINUE HRITE (6+1751) 2496 2497 42H GAMMA CROSS SECTION SENSITIVITY PROFILES + 2498 2499 2500 942 CONTINUE IF ((H.EB.0).MND.(J1.EB.1)) HRITE(6;1080) IF ((K.EB.0).MND.(J1.HE.1)) HRITE(6;1082) 2501 2502 2503 IF ((K.GT.0). MND. (J1.EB.1)) WRITE (6+1081) H 2504 IF ((F. GT. 0) . AND. (J1. NE. 1)) NRITE (6:1083) # 1080 FORMAT(2N +40(1H4)+4 SUMMED DUER ALL PERTURBED ZONES 4+40(1H4) > 1082 FORMAT(2H +34(1H4)+4 SUMMED DUER ALL PERTURBED ZONES 4+34(1H4) > 2505 2506 1061 FORMAT (24 - +32 (1+4)+4 FOR REATURDED ZONE & #4+13+12+34 (1+4)) 1063 FORMAT (24 - +37 (1+4)+4 FOR REATURDED ZONE & #4+13+12+37 (1+4)) 2507 2508 2509 C 444 COMPUTE LOSS-TERMS, GAIN-TERMS, AND NET SENSITIVITY PROFILES 2510 C +++ FOR BOTH, PURE HEUTRON AND PURE GANNA INTERACTION XS 2511 C +++ (HNICH OF THE THO IS COMPUTED DEPENDS ON THE VALUES OF J1 AND 16H1 2512 SADS = 0.8 SF15 = 0.0 2513 2514 STOT = J.0 2515 SSCATE 0.0 2516 SFFD = 0.0 2517 2518 SFAD = 0.0SSEN = 0.0 2519 SSENT = 0.0 2520 DD 2 6=31+16H1 2521 = #(G)/(##+DELU(G)) F (G) 2522 FF5(6) = FF5(6)/(##+5ELU(6)) 2523 A+5(6) = -(A+5(6)+CH1(6))/(##+DELU(6)) 2524 FISYS(6) = - (FISYS(6) +CHI(6))/(##+bELU(6)) D21(0) = -(221(0)+CH1(0))/(m+DEFD(0)) 222(0) = -(222(0)+CH1(0))/(m+DEFD(0)) 2525 2526 2527 SEN(6) = SXS(6) + FFD(6) SENT(6) = DST(6) + FFD(6) 2528 SABS = SABS + AXS(6)+DELU(6) SFIS = SFIS + FISXS(6)+DELU(6) 2529 2530 2531 SSCATE SSCATE SES (6) +DELU (6) 2532 STOT = STOT + DST(6)+DELU(6) 2533 SFFD = SFFD + FFD(6)+DELU(6) 2534 SFAD = SFAD + F(G)+DELU(G) 2535 SSEN = SSEN + SEN(6)+DELU(6) 2536 SSENT = SSENT + SENT (6) +DELU (6) 2537 2 CONTINUE 2538 IF (NCOUPL.ER. 0) 60 TO 8000 2539 IF (J1.NE.1) 60 TO 2001 2540 C *** COMPUTE GAMMA ARODUCTION AROFILE FEDNG (GAIN-TERM DNLT) 2541 2542 NG1=NCOUPL+1 10 802 6=11.1em1 2543 FFDNG (6)=0.0 DD 802 L=1+LHAXP 2544 2545 DO BUZ SPENSIIISM 2546 802 FFDNG (6) = FFDNG (6) + TNDLH] (L) + DSLFD (6, 6, 1) + SI (6, 1) 2547 SFFDNG=0.0 2548 20 804 ##J1+1#H1 2549 FFDNG(G) FFFDNG(G) / (PR+DELU(G)) 2550 804 SFFDNGESFFDNG+FFDNG (6) +DELU(6) 8000 CONTINUE 2551 2552 C +++ PRINT NEUTRON PROFILES (INCL. N-SANNA) 2553 IF (J1.NE.1) 60 TO 2001 HPITE (6:11) 88 2554 THE DELTA-UP PRATIAL AND NET SENSITIVITY PROFILES PER DELTA-UP NOR MALIZED TO AN = (PTPHI) = 4119E12.57/ 2555 2556 2557 ** FOR NEUTRON INTERACTION CROSS SECTIONSI (N-N) AND (N-SAMMA)*//) 2558 HRITE (6+21) 2559 21 FORMAT (1H +32x+46H+***** R U R E L D S S T E R H S ******** *2x+34H******** PURE GRIN TERHS ******** 2560

```
2561
                   WRITE (6+12)
2562
              2563
                 +7+++5+5++9++++5++8++++-GAIN++4++++-GAIN+5ED/++3++++6-GAIN+ )
2564
                   DD 13 G=J1+16H1
2565
                   HAITE (6:14) G. EE (6) + DELU(6) + AXS (6) + FISXS (6) + SXS (6) +
2566
                                        FFD (G) +F (G) +FFDNG (G)
2567
              14 FORMAT (14 + 15+2++ 1PE10.3+2++ 1PE7.2+2++7(2++1PE10.3))
2568 C +++ REVERSE NORMALIZATION FROM PRINTED PROFILES BACK TO
2569 C +++ DRIGINALLY STORED XS-VECTORS
                  IF (CHI (6).LT. (1. UE-15)) GD TD 13
2570
2571
                                 B -ALS (C) PROPRELU(C)/CHI (C)
                   AVELO
                   FISYS(G) = -FISHS(GI+MA+DELU(G)/CHI(G)
                   2573
2574 DST (6) = -IST (6) OPRODELL
2575 C +++ END REVERSE NORMALIZATION
2576
            13 CONTINUE
                   NRITE (6+201)
          201 FORMAT(14 + 30×+7(2×++----++))
MRITE(6+15) SABS+SF15+SSCAT+STOT+SFFD+SFAD+SFFDH6
2578
2579
2580
             15 FORMAT (14 +1x++INTEGRAL++21x+7(2x+1PE10,3)+/)
                   HPITE (6+22)
2581
              22 FORMAT (14 + 32×+ 22+++++ HET PROFILES +++++)
2582
2583
                   HETTE (6+16)
2584
              16 FORMAT (14 +* GROUP UPPER-E(EV) DELTA-U *+07x+*SEN*+(05++*SEN**)
                   10 17 G=31+16M1
2585
2586
                   MAITE (6+18) GHEE (6) + DELU (6) + SEN (6) + SENT (6)
2587
             18 FORMAT (1H +15+2x+1PE10.3+2x+1PEY.2+2+2(2x+1PE10.3))
2588
             17 CONTINUE
2589
                   HRITE (6,202)
2590
           202 FORMAT (1H + 30x+2 (2x++-----++))
                   HRITE (6+19) SSEN+ SSENT
2591
2592
             2593
                   GD TD 900
         2001 CONTINUE
2594
2595 C +++ PRINT SPECIFICATIONS FOR GAMMA RADFILES
2596
                   HEITE (6:20) MA
              20 FORMAT (1H ++ PARTIAL AND NET SENSITIVITY PROFILES PER DELTA-U+ NOR
2597
2598
                 MALIZED TO AR = (R.PHI) = 4, 19812.5,/
                 ** FOR GAMMA INTERACTION CROSS SECTIONS: (GAMMA-GAMMA) ONLY *//)
2599
2600
                   WRITE (6+23)
2601
              26.02
                 1+++++HET ABOFILES+++++)
2603
                   HPITE (6+312)
26.04
            312 FORMAT (1H ++ GROUP UPPER-E(EV) DELTA-U++8x++Ax5++9x++5x5++9+++7x5
2605
                 26 06
                 DD 313 6=31.16H1
2607
                   HRITE (6+14) 6+EE (6)+DELU (6)+A+S (6)+S+S (6)+DST (6)+FFD (6)+
2608
                 ٠
                                       SEN (G) + SENT (G)
2609 C +++ REVERSE NORMALIZATION FROM PRINTED PROFILES BACK TO
2610 C +++ DRIGINALLY STORED 35-VECTORS
2611 IF (CNI(G).LT. (1.0E-15)) 60 TO 313
2612
                   AIS(G) = -A-S(G) + PA+DELU(6)/CHI(6)
                   S#S (6) = -S#S (6)+##+DELU (6) /CHI (6)
2613
2614
                  DST(6) = -DST(G)+###DELU(6)/CHI(6)
2615 C +++ END REVERSE NORHALIZATION
2616
2617
          313 CONTINUE
                 HEITE (6+203)
          203 FORMAT (1M + 30x+6 (2x++-----+) )
2618
                  HRITE (6:15) SABSISSCATISTOTISFEDISSENISSENT
2619
2620 900
                   CONTINUE
2621
                   RETURN
2622
                   END
2623 c
2624 c
2625 c
2626 c
2627 c
2628
                   SUBROUTINE SUB11 (LMAXP, J1, IGH1, IGH+ MA-NSED)
2629
                                                  PSED + PSEDG+ + PSEDG + SSED + SHOT + SCOLD + DRSED +
2630
                 2
                                                   DSLIPSIIDELUIGHEDIFSED )
2631 c
2632
                   LEVEL 2. DSLIPSIIPSED
                   DIMENSION #SED (IGH1+1) +PSEDGP (1) +PSEDG (1) +SSED (1) + SHOT (1) +
2633
                                  SCOLD (1) + DRSED (1) + DSL (IGH+ IGH+ 1) + PSI (IGH+ LHAXP+ 1) +
2634
                                    DELU(1)+ GHED(1)+FSED(1)+THDLH1(50)
                 2
2635
2636
                   COMMON /VRS/ LL
                   COMMON /PLOT/ TITLE (8)
2637
2638
                   COMMON /XSFORM/ KXSIIMTIIMA
2639
                   INTECER 6, 6+ SHED - SHEDAN + SHEDP 1
2640
                   PEAL BR
```

```
2641 c
 2642 C +++ ZERD DUT THE NEN ARRAYS
               10 2 G=1.16M1
2643
                #SEDG# (6)= 0.0
2644
                #SED6(6) = 0.0
 2645
               SSED(6) = 0.0
SHOT(6) = 0.0
 2646
 2647
                SCOLD(6) = 0.0
 2648
               DRSED(6) = 0.0
 2649
 2650
                10 1 GP=1:16#1
 2651
             1 = sep(se_{1}s) = 0.0
2652
             2 CONTINUE
2653 c
2654 C +++ COMPUTE ALL ARRAYS TO DE EDITED
2655
              DO 5 LEI+LL
               DD 3 L-IIL
IF (KXS.E0.2) TWDLM1(L)#1.0
IF (KXS.NE.2) TWDLM1(L)#FLDAT(24L-1)
2656
2657
             5 CONTINUE
2658
               DD 33 GP=J1+16H1
2659
               DD 32 6 = 31, 1641
DD 31 L =1+LL
2660
 2661
 2662
           31 PSED(GP+6) = PSED(GP+6) + (THOLH1(L)+DSL(GP+6+L)+PS1(G+L+6P))
2663
              1
                                                    /(RR+DELU(G)+DELU(GP))
           32 CONTINUE
2664
           33 CONTINUE
2665
2666
               GD TD 50
2667 c
                ENT OF COMPUTATION OF BASIC PSED (6P+6)
2668 C +++ INTEGRATE PSED DUER ALL INCIDENT GROUPS GP; FOR ALL FINAL GROUPS G
2669 50 DD 52 S=1; IGH1
2670 DD 51 SP=1; S
2669
2671
           51 PSEDEP(6) = PSEDEP(6) + PSED(6P(6)+DELU(6P)
2672
           52 CONTINUE
2673 C 444 INTEGRATE RSED DVER ALL FINAL GROUPS 6; FOR ALL INCIDENT GROUPS GP 2674 DD 62 GP=1:16H1
              DD 62 6P=1+16H1
2675
               DD 62 6 =6P. 16H1
           61 PSEDG (GP) = PSEDG (GP) + PSED (GP+G)+DELU(G)
2676
2677
           62 CONTINUE
2678 C +++ INTEGRATE PSED DHLY DVER HOT FINAL GROUPS
2679
               IF (NSED.ED.0) 60 TO 93
DD 72 6P#1+1641
2680
                SHEDAN - SHED (SP)
2681
               IF (GHEDAN.EB.0) 60 TO 72
IF (GHEDAN.LT.SP) 60 TO 256
2682
2683
2684
               DO 71 GEGPIGHEDAN
           71 SHOT (GP) = SHOT (GP) + PSED (GP+G)+DELU(G)
SHOT (GP) = SHOT (GP)+DELU(GP)
2685
2686
           72 CONTINUE
2687
2688 C +++ INTEGRATE RED DALY OVER COLD FINAL GROUPS
               DD 82 GP=1+16H1
2689
               IF (GMED(GP).EB.0) 60 TO 82
IF (GMED(GP).EB.16H1) 60 TO 82
2690
2691
2692
               GHELP1 = GHEL(GP) + 1
2693
               DD 81 6=GHEDP1+IGH1
           SI SCOLD(GP) = SCOLD(GP) + PSED(GP+G)+DELU(G)
SCOLD(GP) = SCOLD(GP)+DELU(GP)
2694
2695
           82 CONTINUE
2696
2697 C +++ COMPUTE INTEGRAL SED SENSITIVITY COEFFICIENTS AND RESPONSE UNCERT.
2698 - TSSED = 0.0
2699
                TSHOT = 0.0
2700 2701
                TSCOLD= 0.0
               TD#SED# 0.0
               DD 91 6P=1:16H1
SEED (6P) = SHDT(6P) - SCDLD(6P)
DRSED(6P) = FSED(6P)*SSED(6P)
2702
2703
2704
2705
               DRSED(GP) = ABS(DRSED(GP))
2706 C +++ COMPUTE TOTAL INTEGRALS
2707 TSSED = TSSED + SSED(GP)
2708 TDRSED= TDRSED+ DRSED(GP)
           TSHOT = TSHOT + SHOT(6P)
91 TSCOLD= TSCOLD+ SCOLD(6P)
2709
2710
2710 91 TSCOLDE TECOLDE PEDER ()

2711 92 CONTINUE

2712 C 400 COMPUTE TOTAL INTEGRALS OF SINGLT DIFFERENTIAL PROFILES

2713 93 TPSGE = 0.0

2714 TPSG = 0.0

2715 DO 94 I=1:IGH1

2716 TPSGE TPSGE + PSEDG(I) + DELU(I)

2717 TPSG = TPSG + PSEDG(I) + DELU(I)

2717 OF SUME
2719 C
2720 C +++ NDH HE STORT EDITIME
```

2721 c PRINT RSED (GPIG) =PSED (6-INIG-DUT) AND INTEGRAL SENS, PROFILES 2722 c 2723 HRITE (6+200) -2724 200 FORMAT (IN 1/135 (IN+) ++ DOUBLE-DIFFERENTIAL SED SENSITIVITY+, 2725 + PROFILES++ ٠ 36 (1++) +/+1+ +34 (1++) ++FDR THE SUN DUER ALL SPECIFIED ++ 2726 1 +PERTURBED ZONES++35(1H+)+/ 2727 2 IN ++100BLE-DIFFERENTIAL PROFILES PER DELTA-U-IN AND PER +; 2728 з 2729 +DELTA-U-DUT: NORMALIZED TO ARE (ROPHI) = ++1PE12.5+/+ 1H POP NEUTRON GROUPS DNLY ++//) 2730 5 2731 HRITE (6+210) 2732 210 FORMAT (18x+27 (1H+)++PSED (6-IN+6-DUT) REP (DELU-IN) (DELU-DUT)++ 2733 *##*+27(1++>+/+ •###•#27(1##7)77 17x1• 5-1N # 1 5-1N # 2 5-1N # 3 5-1N # 4 5-1N # 5 +; • 5-1N # 6 5-1N # 7 5-1N # 8 5-1N # 9 5-1N #10+) 4 2735 5 HRITE (6+220) 2736 2737 220 FORMAT (1H +*6-DUT DELU-DUT+) 2738 12 = 0 221 11 = 12 + 1 2739 12 = MINO(12+10,16M1) 2740 2741 DD 230 6=1.16+1 HEITE (6:231) (G:DELU(G):(PSED(G+;6);6P=11;12)) 231 FORMAT(1N:13:3x;F8,6:1x:10(1x:1854.2)) 2742 2743 2744 230 CONTINUE 2745 IF (12.EP.10H1) 60 TO 232 2746 NRITE (6+233) 2747 233 FORMAT (1H +/) 2748 GD TD 221 2749 232 CONTINUE 2750 HPITE (6+240) 240 FORMAT(IN +16x+3(1M+)++ SINGLE-DIFFERENTIAL PROFILES, RSED + 1 3(1M+)+/+16x++ PSED(G-DUT) RSED(G-IN) ++/+ 2 1x++G-IN DR G-DUT RER DELU-DUT PER DELU-IN ++/+) 2751 2752 2753 1x++6-IN DR 6-DUT RER DELU-DUT DD 242 1=1+16H1 HRITE (6+241) 1+PSEDGP(1)+PSEDG(1) 2754 2755 2756 2757 241 FORMAT (1H +4x+13+10x+18E10.3+6x+18E10.3) 242 CONTINUE 2758 HRITE (6+243) 2759 2760 243 FORMAT (1H +16x+ +----++, 5x++----++) WRITE (6+244) TPSGRETRSG 2761 244 FORMAT(IN ; +TOTAL INTEGRAL 2762 C +++ END OF SED-PPROFILE RRINTS 244 FORMAT (1H ++TOTAL INTEGRAL +, 1PE10. 3, 6x, 1PE10. 3) 2763 15 (NSED.HE.0) 60 TO 249 2764 HPITE (6+245) DELETIONY ANALYSIS WAS PERFORMED FOR 41 4 ALACK OF INPUT DATA41/14 NSED IS ZERO ON INPUT FILE41/141) 50 TO 999 2765 245 FORMAT (1H 1//14ND SED UNCERTAINTY ANALYSIS WAS PERFORMED FOR 4 1 2766 2767 2768 C +++ EDIT SED UNCERTAINTY INFORMATION 276.9 249 MRITE (6:246) (TITLE(I):I=1:8) 248 FORMAT(14::8A10:/) 2770 2771 HRITE (6+250) HRITE (6:250) 250 FORMAT(|h| +44(|h|)+* sed uncertainty analysis ++44(|h|)+//, 1 15x+* Median ++3x+* integral ++3x+* mot integral ++3x+ 2 +Cold integral+3x+* met integral ++3x+* response uncert, +/, 3 15x+* g-dut ++3x+* sed-uncert, ++3x+* sens. Cdeff. ++3x+ 4 * sens. Cdeff. ++3x+*sed sens.-Cdeff. ++6x,* dr/r ++/ 5 15x+* df sed ++3x+* f ++7x+* s-mot ++3x+ 4 * sens. Cdeff. ++3x+* f ++7x+* s-mot ++3x+ 2772 2773 2774 2775 2776 5 15x1+ DF SED +13x1+ F +17x1+ S-HDT 6 - S-CDLD +19x1+ S +19x1+DUE TD SED-UNCERT.+/ 7 5x1+ G-IN+5x1+(FROM INPUT)+; 2777 2778 2779 8 3+++ (FROM INPUT)++38+++ (SHOT - SCOLD)++09++7H(F + 5)+/) 2780 2781 10 252 se=1.1se1 2782 NRITE (6:251) SPIGHED (SP) IFSED (SP) ISHOT (SP) ISCOLD (SP) I 2783 1 SSED(GP): DPSED(GP) 2784 251 FORMAT (1M .5x+13+09x+13+11x+F7.4+9x+1PE10.3+6x+1PE10.3+ 2785 8x+1PE10.3+9x+1PE10.3) 1 2786 252 CONTINUE HPITE (6+253) 2787 2788 253 FORMAT (1H +47x++----+++6x+1U(1H-)+8x+10(1H-)+9x+10(1H-)) N=ITE (6,254) TSHOT+TSCOLD+TSSED+TDRSED 254 FORMAT(IH ++TOTAL INTEGRAL++33x+1PE10.3+6x+1PE10.3+8x+1PE10.3+ 2790 1 9x+1PE10.3) PERCT = 100.0+TDRSED WRITE (6:255) PERCT 255 FORMAT(99x;+= +;F9.3;+ RER CENT+;/;1H1) 2792 2793 2794 2795 6D TD 999 2796 2797 2798 256 HEITE (6+257) 257 FORMAT (14 + +ND SED UNCERTAINTY ANALYSIS CAN BE PERFORMED+, /, 1 + BECAUSE THE INPUT ARMA' FOR GHED(G) CONTAINS AT LEAST+, /, 2 + DNE HEDIAN SED ENERGY GROUP NUMBER SPECIFIED TO BE +/, 2799 2800 + LESS THAN THE INCIDENT ENERGY BROUP. +/+ 3

• GHEI-(G) HUST ALNA'S BE GREATER DR EBUAL TO G \$+/+ • CORRECT INPUT DATA\$ • > 2801 5 2802 999 CONTINUE 28.03 RETURN 28.04 2805 END 2806 c 2807 С 2808 c 2609 c 2810 c SUBROUTINE SUBBY (VXS1+VXS2+COV+CHI+DELU+P1+P2+DR+E+IGH+IGH1+ 2811 IPERIARIIDINISIDEN1IDEN2) 2812 1 2813 c 2014 C +++ THIS BOUTINE COMPUTES AND EDITS SENSITIVITY PROFILES FOR VECTOR 2815 C +++ CROSS-SECTIONS IN PAIRS OF 21 2016 C +++ IT ALSO COMPUTES AND PRINTS DELTA-R DUER R FOR THIS XS-PAIR AND 2817 C +++ ITS COUMPIANCE MATRIX. 2618 c LEVEL 2+COV 2819 2820 DIMENSION VXS1(1)+VXS2(1)+COV(IGH1+1)+CH1(1)+DELU(1)+P1(1)+P2(1)+ 2821 1 D#(1)+E(1) COMMON /ITE/ ITEST / ITYP COMMON /PLOT/ TITLE (8) 2822 2823 INTEGER 616P 2824 2825 PEAL AR 2826 WRITE (6+1000) (TITLE(I)+I=1+8) 1000 FORMAT(1H +8410+/) 2827 WRITE (6:1100) ID 1100 FORMAT(IN::///:24(IN+):+ SENSITIVITY PROFILES FOR CROSS-SECTION +: 2828 2829 *PAIRS WITH ID = ++13+1x+25(1++)) 2830 1 MPITE (6,1200) MR 2831 1200 FORMAT (1H + + + 1 (6) AND P2(G) ARE PER LETHONGY WIDTH DELTA-U AND +, 2832 2833 2834 2835 2836 2837 2838 2839 MPITE (6+1400) 2840 1400 FORMAT(1H +* GROUP UPPER-E(EV) _ DELTA-U*+7X+*F1(6)*+7X+*F2(6)* > 2641 C 444 COMPUTE SENSITIVITY PROFILES AND INTEGRAL SENSITIVITIES sp1 = 0.0 sp2 = 0.0 2842 2843 2844 DD 1 6=1+16H1 2845 P1(G) = -(Vx51(G)+CH1(G))/(HR+DELU(G)) #2(G) = -(Vx52(G)+CH1(G))/(HR+DELU(G)) 2846 2847 sp1 = sp1 + p1(G)+DELU(G)
sp2 = sp2 + p2(G)+DELU(G) 2848 502 2849 1 CONTINUE 2850 C +++ PRINT PROFILES 2851 DD 2 6=1+16H1 2852 WRITE (6+1500) 6+E(6)+DELU(6)+P1(6)+P2(6) 2853 1500 FORMAT (1H +15+2x+1PE10.3+2x+1PE7.2+2x+2(2x+1PE10.3)) 2854 2 CONTINUE 2855 HRITE (6+1600) 1600 FORMAT (1H + 30x+2(2x++----+)) 2856 2857 HRITE (6+1700) \$P1+5P2 2058 1700 FORMAT (1H +1x++INTEGRAL++21x+2(2x+1#E10.3)+/) 2859 C +++ PERFORM UNCERTAINTY ANALYSIS FOR THIS XS-PAIR AND ITS COU 2860 C +++ First Reverse the Rer-Delta-U Normalization of the Profiles 10 3 6=1+16H1 2861 P1(6) = P1(6)+DELU(6) 2862 3 #2(6) = #2(6)+DELU(6) 2863 2864 C +++ CALCULATE DOUBLE SUN (USE ANNAY VXS2(6) AS INTERHEDIATE SINGLE-SUM 2865 - DROVASE = 0.0 2866 DD 4 6=1+16H1 Vx52(6) = 0.0 2867 2668 DD 5 6P=1+16H1 5 UXS2(6) = UXS2(6) + #2(6#)+CDU(6+6#) 4 DHDUMSB = DHDUMSB + UXS2(6)+#1(6) 1F(DHDUMSB.66.0.0) 6D TD 6 2869 2870 2871 2872 WRITE (6+1800) DROVRSE 2873 1800 FORMAT (1H ++ THE DOUBLE SUM FOR DR/R-SPUARE RESULTED IN A NEGA++ 2874 1 +TIVE NUMBER+1/1+ DROVESE = +1 1PE12.51/ 2875 * ANALYSIS TERMINATED FOR THIS ID-NUMBER +1/ 1 2876 . VARIANCE IS SET TO ZERO FOR LATER TOTAL VARIANCE CALS ٤ 2877 з +CULATION +/) 2678 DH(NXS) = 0.06 TO 99 6 DROVA = SERT (DROVASE) 2879 2880

```
2881
            PERCT = 100.0+300VR
2882 C +++ EDIT UNCERTAINTY INFORMATION
            2883
     1900 FORMAT (IN +20(1H+)++ AN UNCENTAINTY ANALYSIS FOR THIS CROSS-++
2884
                   SECTION PAIR VIELDS THE FOLLONING ++20(1H+)+/
2885
           1
                   • FRACTIONAL RESPONSE UNCERTAINTY DUE TO XS-UNCERTAINTIES+

• Specified in the Courrience matrix for this id:*///i(x)

• Uariance; (delta-r ouer r)-sbuare = (dr/r)sd, = +;1pe10.3;

• Relative standard deviation = dr/r = +;1pe10.3;
2886
           ž
2887
           3
2888
           4
           5/110x1+ RELATIVE STADARD DEVIATION = D
6 /155x1+ = +10E10.31+ PER CENT +1////)
                                                                          = ++1#E10.3+
2689
2892 DR (NXS) = DRDVRSB
2893 99 RETURN
2894
            EHD
2895 c
2896 c
2897 c
2898 c
2899 c
           SUBROUTINE SUB9 (COURISENIESUNIIGHIDELU)
2900
2901 C +++ READS COVARIANCE HATRIX AND PERFORMS DOUBLE-SUN TO CALCULATE
2902 c
           +DELTA-R DVER R
2903
            LEVEL 2+ COVR
            DIMENSION CTITL(8) + COVR(IGH+1)+SEN(1)+FSUH(1)+DELU(1)
2904
2905 cpc+
2906 CLCH LEXT
                   SBRT
2907 cbc+
2908
            INTEGER 616P
2909 PEAD (5:1001) (CTITL(1):1=1:8)
2910 1001 FORMAT(8A10)
2911
            WHITE (6+1002) (CTITL(1)+1=1+8)
2912
     1002 FORMAT (1H + 6410/)
2913
            READ (5+1000) ((CDVR(6+6P)+6P=1+16H)+6=1+16H)
2914 1000 FORMAT(6E12.5)
2915
            DD 10 GP=1+16M
HRITE (6+1003) (GP+(CDUR(6+GP)+6=1+16M))
2916
     1003 FORMAT (1H ++6P=+,13+20(1x+5.3)/)
2917
2918
       10 CONTINUE
2919
           DD 11 6=1+16H
2920 11 SEN(6) = SEN(6) + DELU(6)
2921 C +++ CALCULATE DOUBLE SUM
          1000 = 0.0
2922
            DD 99 6=1+16
2923
2924
            FSUH (6) = 0.0
        10 96 6P=1+16H
98 FSUN(6) = FSUN(6) + SEN(6P)+CDUR(6+6P)
2925
2926
        99 DROUR = DROUR + FSUH (6) +SEN (6)
2927
2928
            1F (DROVR. SE. 0. 0) 60 TO 1
2929
            WRITE (6+1004)
2930 1004 FORMAT(1H ++DR/R-SQUARE RESULTS AS NEGATIVE NUMBER FROM DOUBLE SUM
2931
          • •///>
2932
            60 TO 9999
          1 DROVE # SPRT (DROVE)
PERCT # 100.+DROVE
2933
2934
2935
            WRITE (6+1005) DROVR+RENCT
2936
     1005 FORMAT (IN SATHE CALCULATED FRACTIONAL UNCERTAINTY OF THE RESPONSE
           2937
2938
           PANCE MATRIX ISP/15x1+DR/R
2939
           ++ PERCENT+)
2940 C +++ CALCULATE TOTALLY CORRELATED (+1) AND TOTALLY UNCORRELATED CASES
2941
            CDRDR = 0.0
            UNCOR = 0.0
2942
2943
            DD 20 6=1+16H
2944
            CORDR = CORDR + SEN (6) + SERT (CDVR (616))
UNCOR = UNCOR + SEN (6) + SEN (6) + CDVR (616)
2945
2946
       20 CONTINUE
2947
            CORDREADS (CORDR)
2948
            UNCOR = SURT (UNCOR)
MRITE (6+1007) CORDR
2949
2950 1007 FORMAT (14 + ASSUMING FULL CORRELATION (+1) WE DETAIN 4/+5+++DR+R-COR
2951
           +# # +#F8.5/>
2952 HRITE (6,1008) UNCOM
2953 1008 FORMAT(IN ; #RSSUMING HD CORMELATION ME DETAIN#/;5x;#DR/R-UNCOMM =
2954
           +++=8.5/)
2955
           DD 5 6=1+16M
2956
            SEN(6) = SEN(6)/DELU(6)
2957
          5 CONTINUE
2958 9999 METURN
2959
           END
2960 c
```

```
2961 c
2962 c
2963 c
2964 c
2965
             SUBROUTINE SUBY (DRSB+ NCOV+ NSUNCOV)
2966 c
2967 C 444 THIS ROUTINE COMPUTES DR-DVER-R FOR THE SUM OF ALL XS-UNCERTEINTIE
2967 C 444 Assuming ND Coppelations between the individual XS emores specifie
2969 C +++ IN MAY AND ALL OF THE NEDU COURRIANCE MATRICES.
2970 c
2971
             TIMENSION DRSB(1)
             INTEGER SUMSTRY SUMEND
IF (NSUMCOV.EB. 0) GD TO 20
2972
2973
             WRITE (6+1400)
2974
2975
       1400 FORMAT (141) 36 (144) + PARTIAL SUNS OF RESPONSE UNCERTAINTIES +,
         1
2976
                  36 (1me)//)
2977
         NSUM = 0
30 NSUM = NSUM
2978
                            + 1
2979
             READ (5+1300) SUMSTRT+ SUMEND
2980
       1300 FORMAT (216)
2981
             UNCO-50 = 0.0
             10 40 JESUMSTRT, SUMEND
2992
2983
         40 UNCORSE = UNCORSE + DRSE(J)
             UNCOR = SPAT (UNCORSE)
REACT = 100.04UNCOR
2984
2985
2986
             MAITE (6+1500) SUMSTATISUMEND
2967
       1500 FORMAT (IN + MASSUMING NO CORRELATION AMONG THE STRING OF INPUT ++
           1 COURDIANCES: 4:4:4 THE RESPONSE UNCERTAINTIES DUE TO 4:

2 GINARIT CEDURATE ANALYSE THE RESPONSE UNCERTAINTIES DUE TO 4:
2968
                    +INPUT SEBUENCE NUMBERS +IZI+ THROUGH +IZI+ MAVE BEEN +
2989
            2
2990
            ā
                    +SUMMED AND YIELD ++/>
2991
             HRITE (6+1600) UNCORSE: UNCORFRENCT
2992
       1600 FORMAT (IN +11++ PARTIAL SUN OF VARIANCES
                         12x10RELATIVE SUM OF VARIANCES
12x10RELATIVE STANDARD DEVIATION
0,10E10.344 PP-
                                                                      = ++1PE10.3+/
          1
2993
            1 12×1+PRELATIVE STANDARD DEVI

2 • = +11PE10.31+ RER CENT + ///)

1F (NSUM.NE.NSUMCDV) 60 TO 30
                                                                      = +,1#E10.3+
2994
2995
2996 C +++ SUH DVER ALL VARIANCES
2997
        20 UNCORSE = 0.0
2998
            DD 10 J=1+NCDV
         10 UNCORSE # UNCORSE + DRSE(J)
2999
3000
         UNCOR = SORT (UNCORSE)
REACT = 100,04UNCOR
3001
3002 C +++ EDIT INFORMATION AT THE VERY END OF THE ENTIRE UNCERTAINTY ANALLY
3003
             HRITE (6+1000) NCDV
      1000 FORMAT (1H +20(1H+)++ THIS COMPLETES THE INDIVIDUAL VECTOR ++
3004
3005
         1
               +CROSS-SECTION UNCERTAINTY ANALYSIS + +20(1++)+//+
3006
                    + ASSUMING THAT ALL SPECIFIED XS-COVARIANCES ARE UNCORRELA-
            2
3007
                TEDI ME DETAIN THE FOLLONING TOTAL RESPONSE UNCERTAINTY 41/1
                 + DUE TO ALL XS-UNCERTAINTIES SPECIFIED IN ALL +131
3008
3009
            5
                    + COVARIANCE HATRICES + / )
3010
             HRITE (6+1100) UNCORSE+UNCOR+PERCT
      1100 FORMAT(14 +102 OFDITAL VARIANCE) (DELTA-R DVER R)-SBUARE E +,

1 IPE10.3:/11x:*TOTAL RELATIVE STANDARD DEVIATION

2 IPE10.3:* = +:IRE10.3:* PER CENT +/// )
3011
3012
                                                                                      .....
3013
3014
            HRITE (6+1200)
3015
      1200 FORMAT (1H +36(1H4)+4 END OF COMPUTATION - HO HORE COVARIANCE ++
          1
3016
                   +DATA ++36(1H+)+/+120(1H+) )
3017
            RETURN
3018
             END
3019
      С
3020 c
3021 c
3022
      с
3023 c
3024 c
3025
             SUBROUTINE SUB5/ (VXS1+VXS2+COV+16H1+10+ DEN1+ DEN2)
3026 c
3027 C +++ READS PAIRS OF VECTOR XS AND THEIR COVARIANCE MATRIX
3028 c
3029
             LEVEL 2. COV
3030
             DIMENSION COU (IGH1+1) + UXS1 (1) + UXS2 (1) + BLKECS (1)
3031
             COMMON - ENDE - MATINE + MTINDTI JE + MATI + MEI + MEZIMTI + MT2, MAT2, NOUTIND2
3032
             COMMON/MTR=/COM (50+50) + CE2 (50+50) + XS1 (200) +
3033
           1
                   X52(200) + 635 (200) + A (10) + NEP
3034
            COMMON/ITE/ITESTITTP
3035
             REAL DEN1 > DEN2
3036 c
3037
            NIN#5
3038
            NUUT=6
3039
            NDT=10
3040
            N22=10
```

```
READ (NIN+10) ID: DEN1: DENZ
10 FORMAT(16:6x;2e12.5)
3041
3042
3043
            CALL COUARD (ID: 0: UXS1: UXS2: CDU: 1641)
IF (ITEST. NE. 3) GD TD 40
3044
3045
            MRITE (NOUT:20) NEP:MAT1
        20 FORMAT (1H ++ MULTIGROUP COVARIANCE DATA IN +13+
3046
3047
           1
                 + GROUPS FOR HAT1 = +14)
           MRITE (NOUT, 50) HT1
3048
3(49
        50 FORMAT(1H ++ MICROSCOPIC CROSS SECTIONS FOR MT1 = +13)
           HRITE (NOUT+30) (VXS1(N)+N=1+NGP)
HRITE (NOUT+60) HT2
3050
3051
3052
        60 FORMAT(IN ++ MICROSCOPIC CROSS SECTIONS FOR MT2 = +13)
            FORMAT(IM IF HICHOSCUPIC CHULL -
MRITE (NOUTI30) (UXS2(N)INFIINGP)
MRITE (NOUTI70) MATIINTIINT2
3053
3054
3055
        70 FORMAT (1H ++ RELATIVE COVARIANCE MATRIX - MAT1 = +14+
3056
                + HT1= +13++ HT2 = +13)
           1
3057
           HPITE (NOUT+30) ((COV(1+3)+3=1+NGP)+1=1+NGP)
3058
            MAITE (NOUT:80) MATI MTI MTZ
        3059
3060
3061
           WRITE (NOUT: 30) ( (CE2 (1: 3) : 3=1: NGP) : 1=1: NGP)
3062
3063
        30 FORMAT (1010212.3)
3064
        40 CONTINUE
3065 C +++ TRANSFORM HICRO XS INTO MACROSCOPIC XS
3066
           DD 90 N=1+16H1
           vxs1(n) = Den1 + vxs1(n)
vxs2(n) = Den2 + vxs2(n)
3067
3068
3069
        90 CONTINUE
3070
            RETURN
3071
            END
3072 c
3073 c
3074 c
3075
     с
3076 c
            SUBPOLITINE COVARD (HYXINDHIXSAIXSBICE1:IGH1)
3977
            ROUTINE READ COVARIANCE DATA IN ENDELIKE FORMAT OUTPUT BY
3078 c
            NJOY AND TRANSFORMS IT TO T-1 FORMAT.
3079 c
3080 c
            MPY = T-1 IDENTIFIER
3081 c
            NOH = ABS. COV. FLAG. = 0: YES =1:ND.
3082 c
3083
           LEVEL 2. CE1
3084
            DIMENSION XSA(1)+XSB(1)+CE1(IGM1+1)
3085
            COMMON/ENDE MATINEINTINDT, JAJIMATINE I MEZIMTINTE MATEMATEMOUTINDE
            COMMON MTRX/COM (50+50) + CE2 (50+50) + X81 (200) +
3086
3087
           1
                  x52(200) +635(200) +A(10) +NEP
3088 c
3089
            HRYPHXX
3090
            JEFENXX
3091
            CALL SETID
3092 c
3093 c
            SETID SETS UP INDEXES TO GET DESIRED MAX SET.
3094 c
3095 c
             TABLE FOR DEFINITION OF ID-NOS IN TERMS OF SPECIFICATION OF
3096 c
             CROSS SECTION COUNDIANCES. NOTE IN THIS VERSION HAT 1-HAT2
3097
     с
3098 c
                            HAT2 HT1
                                         HTZ CROSS SECTION COVARIANCE
            ID-ND
                   HAT1
3099 c
            ----
                    ----
                            ____
                                  ___
                                         ---
                                               ------
                                              BIU TOTAL HITH BIO TOTAL
3100 c
                     305
                             305
                                  1
                                         1
               1
                                              BIU TOTAL HITH BID ELASTIC
3101 c
                     305
                             305
               2
                                   1
                     305
                             305
                                              BIU TOTAL MITH BIO (H-ALAHA)
3102 c
               3
                                   1
                                        107
3103 c
               ä
                     305
                             305
                                   2
                                               BIU ELASTIC NITH BIO ELASTIC
                                          ź
3104 c
                            305 2
305 107
                                              BIU ELASTIC MITH BIO (NIALPHA)
BIO (NIALPHA) NITH BIO (NIALPHA)
               5
                     305
                                        1.07
3105 c
                     305
                                        107
               67
                                              C TOTAL HITH C TOTAL
C TOTAL NITH C ELASTIC
3106 c
                     306
                             306
                                  1
                                          1
3107 c
               8
                     386
                             306
                                          2
                                  ź
                                         ź
3108 c
               9
                     306
                             306
                                              C ELASTIC NITH C ELASTIC
3109 c
              10
                     306
                             306
                                   4
                                              C INELASTIC WITH C INELASTIC
                             306 107
3110 c
              11
                     306
                                        107
                                               C (NIALPHA) HITH C (NIALPHA)
                                  1
                                        1
              12
13
                                               CR TOTAL WITH CR TOTAL
CR TOTAL WITH CR ELASTIC
3111 c
                     324
                             324
                     324
                             324
3112 c
                                   1
                                          2
                                               CR ELASTIC WITH CR ELASTIC
CR ELASTIC WITH CR INELASTIC
3113 c
              14
15
                     324
                             324
                                  2
                                          Ë
3114 c
                     324
                             324
                                   2
                                          4
3115 c
              16
                     324
                             324
                                  4
                                          4
                                               CP INELASTIC WITH CR INELASTIC
3116 c
              17
                     324
                             324
                                   4
                                        100
                                               CR INELASTIC WITH CR CAPTURE
3117
                     324
                             324 102
              18
                                               CR CAPTURE WITH CR CAPTURE
    с
                                        100
                                         1
3118 c
              19
                     326
                             326
                                   1
                                               FE TOTAL HITH FE TOTAL
              20
                     326
                             326
                                               FE TOTAL NITH FE ELASTIC
3119 c
3120 c
              21
                     326
                             326
                                   1
                                        1 02
                                               FE TOTAL HITH FE CAPTURE
```

3121	с		22	326	326	2	ź	FE	ELASTIC NITH FE ELASTIC
3122	с		23	326	326	2	4	FE	ELASTIC HITH FE INELASTIC
3123	с		24	326	326	2	102	FE	ELASTIC HITH FE CAPTURE
3124	с		25	326	326	4	4	FE	INELASTIC MITH FE INELASTIC
3125	с		26	326	326	4	102	FE	INELASTIC WITH FE CAPTURE
3126	с		27	326	326	4	103	FE	INELASTIC WITH FE (N+P)
3127	с		28	326	326	4	107	FE	INELASTIC HITH FE (N-ALPHA)
3128	С		29	326	326	102	102	FE	CAPTURE HITH FE CAPTURE
3129	c		30	326	326	103	103	FE	(NIP) HITH FE (NIP)
3130	c		31	326	320	107	107	FE	(NIALPHA) MITH FE (NIALPHA)
3131	c		32	328	328	-	-	NI	TOTAL HITH NI TOTAL
3132	c		33	320	320	2	2 4		REMATIC WITH NI ELASTIC
3133	2		35	320	326	102	1 112		THELMSTIC WITH NI INELASTIC
3135	2		36	326	328	103	1 03	N 7	(NIP) MITH NI (NIP)
3136	2		37	329	329	1	1	- C-U	TOTAL MITH CU TOTAL
3137	č		38	329	329	ī	2	ου	TOTAL HITH CU ELASTIC
3138	ē		39	329	329	ž	Ē	cυ	ELASTIC NITH CU ELASTIC
3139	c		40	329	329	2	4	cυ	ELASTIC NITH CU INELASTIC
3140	с		41	329	329	4	4	cυ	INELASTIC WITH CU INELASTIC
3141	С		42	329	329	4	102	cυ	INELASTIC HITH CU CAPTURE
3142	С		43	329	329	4	103	cυ	INELASTIC WITH CU (N+P)
3143	С		44	329	329	4	107	cυ	INELASTIC HITH CU (NHALPHA)
3144	С		45	329	329	102	102	cυ	CAPTURE HITH CU CAPTURE
3145	С		46	329	329	103	103	cυ	(NIP) HITH CU (NIP)
3146	С		47	329	329	107	107	cυ	(NIALPHA) HITH CU (NIALPHA)
3147	С		48	382	382	1	1	~ >	TOTAL HITH PD TOTAL
3148	c		49	382	382	1	2	~ >	TOTAL HITH PD ELASTIC
3149	c		50	382	382	1	102	~>	TOTAL HITH PE CAPTURE
3150	c		51	382	382	Ę	e	#3	ELASTIC HITH PB ELASTIC
3151	C		52	382	302	5			ELASTIC HITH PB INELASTIC
3152	c		33	302	302		1.05	P 3	INELASTIC WITH PB INELASTIC
3103	c		04 8 8	302	305	102	102		INELASTIC NITH PE CAPTURE
3155	2		56	1301	1301	1 1	1 1		
3156	2		57	1301	1301	1	\$		
3157	2		58	1301	1301	è	2		. ACTIC NITH N ELACTIC
3158	è					_	_	_	
0150									
312A	ē		MF1=3.	HF2=33					
3127	c c		HF1=3,	H#2=33	51600	-1.8	12=41T N		a \$16ma-2.
3159 3160 3161	- - - - - -		м₹1=3, мт1=мт	M#2=33	51600	-1+H	12=MT N		DR 516HA-2.
3159 3160 3161 3162	с с с		нғ1=3; нт1=нт нға=1	NF2=33	51600	-1+M	72=#T N	10 FC	on siem-2.
3159 3160 3161 3162 3163	- - - - -		MF1=3, MT1=MT MFA=1 MTA=4	HF2=33 -ND FDR	SIGNA	-1+M'	12=MT N	10 FE	on si sm -2.
3159 3160 3161 3162 3163 3163	- - - - - -		HF 1=3; HT 1=HT HFA=1 HTA=45 REH INI	HF2=33 -ND FDR	51600	-1++*	72=MT N	ic fe	om \$16mm−2.
3169 3160 3161 3162 3163 3164 3165			HF1=3; HT1=HT HFA=1 HTA=45 REHINI REHINI	HF2=33	SIGNA	-1+M'	72=MT N	4D FE	DA 21640-2.
3159 3160 3161 3162 3163 3164 3165 3166	с с с с	10	MF1=3; MT1=MT MFA=1 MTA=4 PEAL G PEAL G	HF2=33 -ND FDR 51 ND2 HDUP STI (ND2+20)	51600 NUCTUR (A (1)	-1+++ • • 1=1;	7) IMAT	10 FE	DR 516HR-2.
3159 3160 3161 3162 3163 3164 3165 3166 3166		10 20	MF1=3; MT1=MT MFA=1 MFA=1 MEA1NI BEAL G PEAL G FDMAT	H#2=33 -ND FDR 51 >ND2 HDUP STI (ND2+20) r (6A10+	51600 NUCTUR (A (1) A6114	-1+M' +I=1(12+I)	7) + HAT	(C) (F) () (N) (F)	DR SIGM-2.
3159 3160 3161 3162 3163 3164 3165 3166 3166 3167 3168		10 20	MF1=3; MT1=MT MFA=1 MTA=45 BEA103 BEA103 FDPHAT 1F (HA	HE2=33 -ND FDR ND2 HDUP STI (ND2+20) r (6A10+ NT.6T.13	SIGNA (A(I) A6:I4: 01) HA	E +1=1 12+1 17=46	7) + MAT 3, 13) 1-1000	10 FC	DR 516HA-2.
3109 3160 3161 3162 3163 3164 3165 3166 3166 3167 3168 3169 3169	с с с	10 20	HF1=3; HT1=H1 HFA=1 HTA=4 FEH1NI FEAL G FEAL	01 0 ND2 01 0 ND2 0000 STI 0000	SIGNA (A(1) A6:14: 01) HA T1) GD	-1, M' ; 1=1; ; 12; 13; ; T=HO (72=47 5 7),447 3,15) 1-1000 30	10 FC	DA SIGHA-2.
3109 3160 3161 3162 3163 3164 3165 3166 3165 3166 3167 3168 3169 3170	с с с	10 20	HF1=3; HT1=HT HFA=1 HFA=4 HFA=		SIGNA (A(I) A6:I4: 01) HA T1) GD T1) GD	н=1+М' +I=1 12+I 12+I 12+I 12+I 12+I 12+I 12+I 12+	7) + MAT 3 + 15) 1 - 1000 30		DR 516HA-2.
3109 3160 3161 3162 3163 3164 3165 3166 3166 3166 3168 3169 3171 3172		10 20	HF1=3, HT1=H1 HFA=1 MTA=45 PEHINI PEAL G PEDHAT IF (HA IF (HA IF (HA IF (HA	- HE 2=33 - HE FDR - ND2 - ND2 - ND2 - ND2 - ND2 - ST - ST - ST - ST - ST - ST - ST - ST	SIGHA (A(I) R6;I4; 01) HA T1) GD T1) GD 0) HAT	-1+M +1=1 12+1 T=HA T TO (T TO (1+ND)	7) - HAT 3- 15) 1-1000 30 10 1. HAT	10 FE	DR 516HR-2.
3159 3160 3161 3162 3163 3164 3165 3166 3166 3167 3168 3169 3171 3172 3173	- c c c c	10 20 30	HF1=3, HT1=H1 HTA=45 HEH1NI HEAL G HEAL G FORMAT IF (HA IF		SIGNA (A(I) AG(I)	-1+M +1=1 12+1 T=MA T=T= T= 1+ND	7), MAT 3, 15) 7-1000 30 10 1, MAT	40 ₽C	DA SIGNA-2.
3159 3160 3161 3162 3163 3164 3165 3166 3165 3166 3167 3168 3169 3170 3171 3172 3173 3174	- C C C C	10 20 30	HF1=3, HT1=H1 HFA=1 HTA=42 PEAL (PEAL (PEAL (FORMA1 IF (HA IF (HA	0 MP2=33 - ND FDR 51 51 51 51 52 50 51 52 50 51 52 50 51 51 50 51 50 51 50 51 50 50 51 50 50 50 50 50 50 50 50 50 50	SIGNA (A(I) AG(I)	-1+H +1=1 12+1 12+1 12+1 12+1 12+1 12+1 12+1	7) + HAT 3 + 15) 7-1000 30 10 7 + HAT		A SIGHA-2.
3159 3160 3161 3162 3163 3164 3165 3166 3165 3166 3167 3168 3169 3170 3171 3172 3173 3174 3175	- c c c c	10 20 30 40	MF1=3; MT1=MT MTA=1 MTA=45 MEA10 MEA10 FEAD FORMAT IF (MA IF (MA IF (MA IF (MA IF COMTIN FORMAT		SIGNA (A(I) AG,I4, 01) HA T1) GD 0) HAT • SD HAT	E 12:11 12:12 12:12 10:10 10:10 10:0	72=417 N 77) + 447 3, 15) 7-1000 30 10 10 7 + 447 465 + 14		AR SIGHA-2. MT:NSED MT = 414,4 NDT DN TAPE 413;
3159 3160 3161 3162 3163 3164 3165 3166 3166 3167 3168 3169 3170 3171 3172 3173 3174 3175 3176		10 20 30 40	MF1=3, MT1=MT MFA=1 MTA=45 MEAINL PEAL G PEAL G FORMAT IF (MA IF		SIGNA (A(I) R6+I4+ 01) HA T1) GD D) HAT C1+C2	-1+H +1=1(12+13) T=HA TO (1+ND) (1+ND) (1+ND) (1+ND) (1+ND) (1+ND) (1+ND)	72=417 N 77) + 447 7-1000 30 10 7 + 447 meguest 445 + 14 29 - 13 + 14	(E.D. + () (4) MP	
3159 3160 3161 3162 3163 3164 3165 3166 3166 3166 3167 3168 3170 3171 3172 3173 3175 3175 3176 3177	- C C C	10 20 30 40	HF1=3, HF1=3, HF4=1 HF4=1 PE41N2 PE42 G F0P41 IF (H4 HF1TE ST0P C0H1A F0P41 F0P41 F0P41 F0P41		SIGNA (A (I) AG (I) AG (I) AG (I) AG (I) AG (I) AG (I) AG AG AG AG AG AG AG AG AG AG AG AG AG	-1+M +1=1 12+1 T=HA TO 1+ND (PR++) EAL +1+L +14+1	72-47 N 3:15) 7-1000 30 10 7:487 4:59 4:4 2:13:1 2:13:1	(C) FE (194F) (2) (2) (3)	DR 516HR-2. MTINSED MT = 414,4 NOT DN TAPE 413; MTINFINTINSED
3159 3160 3162 3163 3164 3165 3164 3165 3166 3167 3168 3167 3168 3171 3172 3173 3174 3175 3177 3178		10 20 30 40	HF1=3; HF1=3; HF41=1; HF421; HF42; HF43; HF43; HF43; HF43; HF43; HF43; HF43; HF43; HF43; HF	HE2=33 	SIGHA (A(I) (A(I) (A(I) (A(I) (A(I))	-1, H' ; 1 = 1 ; 2 = 1 ; 7 = 4 ; 7 = 4 ; 7 = 4 ; 7 = 1 ; 7 = 4 ; 7	72=++T + 77) + ++T 30 + 55) 7-1000 30 10 10 10 10 10 10 10 10 10 1		AT = +14++ NOT DN TAPE +13+
3159 3160 3162 3163 3164 3165 3164 3165 3166 3167 3168 3167 3170 3177 3176 3177 31778 31779		10 20 30 40	HF1=3; HT1=H1 HTA=1 HTA=42 PEAL G PEAL G PEAL G FOPHAT IF (HA IF	(HE2:50) (HE2:50) (HE2:20) (HE2:20) (HE2:20) (HE2:20) (HE2:5	SIGNA (A(I) AG(I)	-1, H + I=1 12+1 T=+H T=1 T=1 T=1 T=1 = 1+N = 1+N	72-417 N 77) + 447 30 15) 7-1000 30 10 10 10 10 10 10 10 10 10 1	(C) FC () (4) (4) (4) (4) (4) (4) (4) (4) (4) (TINTINSED
3159 3160 3162 3163 3164 3165 3166 3166 3166 3166 3167 3170 3171 3172 3173 3174 3175 3176 3177 3176 31778 3179 3179 3180	ссс с	10 20 30 40 50 60	MF1=3; MF1=M1 MFA=1 MFA=2 MFA=1 MFA=2 MFA=2 MFA=2 MFA=2 MFA=2 MFA=2 MFA=2 MF1FE MF1FE FDMMA1 IF MF1FE FDMMA1 IF MF1FE FDMMA1		SIGHA (A(I) AG:I4: 01) HA T1) GD T1) GD O1 HA T1) GD O1 HA C1:C2 4:4111) GD T O2 NDT SDPPY	-1, H ; 1=1; ; 12; 12; ; 12; 12; ; 12; 12; ; 12; 12; ; 14; 14; 12; ; 14; 14; 14; ; 14; 14; 14; 14; ; 14; 14; 14; 14; 14; ; 14; 14; 14; 14; 14; 14; 14; 14; 14; 14	72=417 N 77) + 447 7-1000 30 10 7 + 447 447 147 147 147 147 147 147	(D FC () (HF) () () () () () () () () () () () () ()	DR SIGHA-2. HTTINSED HAT = 41414 HDT DH TAPE 4131 ATIMFIMTINSED HEMED UP MFE4131 4 MTE414)
3159 3160 3161 3162 3163 3163 3165 3166 3166 3166 3167 3172 3177 3177 31778 31778 31778 31778 31778 3180 3181	ссс с	10 20 30 40 50 60	HF1=3, HF1=3, HF4=1 HF4=1 PE4102 PE420 FE0H112 FC0H112 FC0H112 FC0H112 FC0H112 FC0H112 FC0H112 FC0H112 FC0H112 FC0H112 FC0H12 IF (HF	HE2=33 	SIGHA RUCTUM (A(1)) RG+14+ 01) HA T1) GD 0) HAT C1+C2 4+4111 C1+C2 4+4111 C1+C2 4+4111 C1+C2 C	-1.M .I=1, I2.I3 T0.3 I.ND EAL .L .I4.1 D.70 	72-47 N 3:55 7-1000 30 10 7:40 10 7:40 12:13:1 12:13:1 47 E \$13.6	10 FC 110F1 120 + 110 130 + 1	DR 516HR-2. MT:NSED NAT = +14.+ NDT DN TAPE +13. AT:NF:NT:NSED NEWED UP NF=+13. + MT=+14)
3159 3160 3161 3162 3163 3165 3165 3165 3165 31667 31667 31667 31667 31667 31667 3167 31		10 20 40 50 60 70	HF1=3, HF1=3, HF1=1, HF4=1 PEALG PEALG PEALG PEALG FOPH11	Imm2=33 Imm2=33 Imm0 FDR	SIGHA (A(I) AG:I4, 01) HA T1) GD 0) HAT C1:C2 (AII1) C0 HAT C1:C2 AII1) C0 HAT C1:C2	-1.H	72=++T N 77)+++4T 30:15) 7-1000 30 10 10 10 10 10 10 10 10 10 1	ID FC () (0) FC () (0) (0) (0) (0) (0) (0) (0) (0) (0) (THE SIGNA-2.
31590 31601 31633 31643 31663 31665 31667 31667 31667 31667 31667 31773 31753 31773 31775 31776 31777 31779 31800 318123 318123 318123		10 20 40 50 60 70	HF1=3; HT1=H1 HTA=45 HTA=45 HEA10 HEA10 HEA10 HEA10 FOMMA1 IF (HA HF1F FOMMA1 IF (HA HF1F FOMMA1 IF (HA HF1F FOMMA1 IF (HA HF1F FOMMA1 IF (HA HF1F HF1F HF1F HF1F	(HE2:50) (HE2:5	SIGNA (A(I) AG(I)	-1. H -1. H -1	72=++T N 3,15) 7-1000 30 10 10 10 10 10 10 10 10 10 1	(C) FC () (MF) () () () () () () () () () () () () ()	DR 510HR-2. HTT:NSED HAT E 414,4 NDT DH TAPE 413; AT:HF:HT:NSED HEWED UP HFE413; 4 HTE414)
31590 31601 31603 31623 31634 31655 31667 31668 31669 31669 31670 31722 31734 31775 31776 31777 31778 31777 31780 31812 31883 31884 31883 31884		10 20 40 50 60 70	HF1=3, HF1=3, HF4=1 HF4=1 HE41N2 HE41N2 HE42C FD0H41 IF (H4 HF1TE FD0H41 IF (H4 HF1TE FD0H41 IF (H4 HF1TE FD0H41 STD0 IF (H4 HF1TE STD0 IF (H4 HF1TE STD0		SIGHA (A(I) AG:I4, 01) HA T1) GD T1) GD T1) GD T1) GD T1) GD T1) GD T1) GD T SDPPY) GD T 0) NDT	E	72=417 N 77) + 447 7-1000 30 10 7- 447 12 + 13 + 1 47 14 14 14 14 14 14 14 14 14 14	() FC () () () () () () () () () () () () () (DR 516HR-2. HTT:NSED HAT = +14.+ HDT DH TAPE +13. AT:HF:HT:NSED HEMED UP HFE+13. + HTE+14)
31601 33161 31662 31663 316667 316667 316667 316667 31772 31774 31775 31778 31881 31882 31884 31884 31884 31884		10 20 40 50 60 70 80	HF1=3, HF1=3, HF1=1 HF4=1 PE4102 PE420 FE0H102 FE0H11 F(H4 HF1TE FE0H11 IF(H4 HF1TE FE0H11 IF(H4 HF1TE FE0H11 STOP IF(H1 HF1TE STOP IF(H1 HF1TE STOP		SIGHA (A(1)) RG+14+ 01) HA T1) GD T1) GD 0) HAT C1+C2 4+4111 C1+C2 4+4111 C1+C2 4+4111 C1+C2 4+411 SDRFY 0) NDT	E 12:12 12:12 1:12	72=417 N 3015) 7-1000 30 10 7:407 41 E \$13,5 41 41 41	(D FE () () () () () () () () () () () () () (DR 516HR-2. MTTINSED NAT = +14++ NOT DN TAPE +13+ ATHFINTINSED NEWED UP HFE413+ + HTE414)
31601 33162 31662 316667 316667 316667 31667 31667 31723 31773 31775 31778 31775 31778 31778 31775 31778 31883 31883 31885 31885 31885	ссс с	10 20 40 50 60 70 80	HF1=3; HF1=3; HF1=3; HF1=3; HF1=42; MEALO G PEALO G	Imm2=33 Imm2=33 Imm2 Imm2 <td>SIGNA (A(I) AG:I4, 01) HA T1) GD T1) GD 0) HAT C1:C2 4:4I11 0 GD T 02 NDT SDRPY) GD T 0) NDT</td> <td>-1:H ;1=1; ;T=HA :TO :TO :TO : : : : : : : : : : : : : :</td> <td>72=++T N 77)+++4T 30,15) 7-1000 30 10 10 10 10 10 10 10 10 10 1</td> <td>ED + FE</td> <td></td>	SIGNA (A(I) AG:I4, 01) HA T1) GD T1) GD 0) HAT C1:C2 4:4I11 0 GD T 02 NDT SDRPY) GD T 0) NDT	-1:H ;1=1; ;T=HA :TO :TO :TO : : : : : : : : : : : : : :	72=++T N 77)+++4T 30,15) 7-1000 30 10 10 10 10 10 10 10 10 10 1	ED + FE	
31590 31661 31662 31663 31665 31667 31667 31667 31667 31772 31773 31775 31778 31882 31883 31885 318883 318867 318883 318867 318883 318867 318883 318843 318843 318883 318843 318843 318843 318843 318844 318844 3188444 3188444 31884444444444		10 20 40 50 60 70 80	HF1=3, HF1=3, HF1=1, HF1=42 PEALG PEALG PEALG PEALG FDH11 IF (HA HF1TE STDP CONTIN FDH11 F	(HE2:33 	SIGNA (A(I) AG:I4, 01) AG T1) GD 0) HAT C1:C2 4,4I11 0) AD SDRT 0) NDT SDRT 0) NDT	-1. H -1. H -1	72=++T N 77)+++47 30,15) 7-1000 30 10 7+++47 +147 +1 +1 +1 +1 +1 +1 +1 +1 +1 +1	ED + FE	DR 510HR-2. NAT E 414,4 NDT DN TAPE 413; AT:HF:HT:NSED NEWED UP HFE413; 4 HTE414)
31601 31601 31662 31663 31663 31665 31667 31667 31667 31772 31773 31775 31775 31775 31775 31780 31882 31884 31884 318867 31889 31889	ссс с с	10 20 40 50 60 70 80 90	HF1=3, HF1=3, HT1=H1 HTA=10 HEA10 HE	(HE2=33 -HD FDR -HD FDR -HD2	SIGNA (A(I) n6,I4, 01) HA T1) GD T1) GD T1 (GD T1) GD T1) GD T1 (GD T1) GD T1 (GD T1) GD T1 (GD T1) GD T1 (GD T1) GD T1 (GD T1) GD T1 (GD T1) GD T1 (GD T1) GD T1 (GD T1) (GD T1) (E 11 H 12 I 12 I 12 I 1 I 1 I 1 I 1 I 1 I 1 I 1 I 1	72=417 N 77) + 447 30 15) 7-1000 30 10 7. 447 447 447 447 45 413,4 47 47 47 47 47 47 47 47 47 4	(D FE () () () () () () () () () () () () () (Эж SIGHA-2. MT:NSED MAT = 014,0 NDT DN TAPE 013; AT:HF:HT:NSED NEWED UP NFE013; 0 HTE014)
31661 331662 316634 316667 31665 316667 316667 31772 31774 31775 31778 31882 31885 31885 31885 31885 318889 31885 318889 31885 318889 31885 318889 31885 318889 31885 318889 31885 318889 31885 318889 31885 318889 31885 318889 31885 318889 31885 318889 31889 31889 318889 31899 31999 31999 31999 31999 31999 31999 31999 31999 31999 31999 31999 31999		10 20 40 50 60 70 80 90	HF1=3, HF1=3, HF1=1 HF4=1 HE41N2 HE41	HE2=33 	SIGHA (A(1)) AG:14: 01) HA T1) GD 0) HAT C1:C2 4:4111 C0) NDT SDRAY) GD T 0) NDT (GBD(4) HT1 A	E 12:12:12 12:12:12 12:12:12 1:1:ND EAU A 1:1:ND 1:1:ND 1:1:12 0:10 1:1:12 1:1:12 1:1:12 1:1:12 1:1:12 1:1:12 1:1:12 1:1:12 1:12:	T2=HT N 7),HAT 3:5) T-1000 30 T:HAT HE DUEST HAT E 0:3,0 HT *1+NBD) T2	(C) FE	ож 516ни-2. Мат = +14,+ NDT DN TAPE +13; Ат.нг.нт.NSEB Мешер UP нг=+13; + Мт=+14)
31601 331623 31661 3316623 316634 316667 316653 316673 316673 316673 316673 316673 31773 31775 318823 318823 31885 31885 31885 31885 31885 31885 31885 31885 31885 318901		10 20 40 50 60 70 80 90	HF1=3, HF1=3, HF1=1 HF4=1 ME41NI ME41NI ME41NI ME41NI ME41NI F00H11 F00H	Imm2=33 Imm2=33 Imm2 Imm2 <td>SIGHA (A(I) AG:14, 01) HA T1) GD T1) GD T1) GD O) HAT A C1:C2 4:4II SDPPY) GD T 0) NDT (GBD(4) HT1 A (A(I)</td> <td>-1.H -1.H -1. -1. -1. -1. -1. -1. -1. -1.</td> <td>72=++T h 77) + ++4 30 5 10 10 10 10 10 10 10 10 10 10</td> <td>(C) FE () (A)</td> <td>>A \$1000-2. NAT = +14.+ NOT DN TAPE +13. NAT = +14.+ NOT DN TAPE +13. NAT.00F.017.NSEB NEWED UP 00FE+13. + 00TE+14.)</td>	SIGHA (A(I) AG:14, 01) HA T1) GD T1) GD T1) GD O) HAT A C1:C2 4:4II SDPPY) GD T 0) NDT (GBD(4) HT1 A (A(I)	-1.H -1.H -1. -1. -1. -1. -1. -1. -1. -1.	72=++T h 77) + ++4 30 5 10 10 10 10 10 10 10 10 10 10	(C) FE () (A)	>A \$1000-2. NAT = +14.+ NOT DN TAPE +13. NAT = +14.+ NOT DN TAPE +13. NAT.00F.017.NSEB NEWED UP 00FE+13. + 00TE+14.)
31601 33161 331623 31667 331667 331667 331667 331667 331773 331773 331773 331775 331883 331883 331885 331885 31883 31883 31883 31885 31885 31887 31917 31917 <td>ссс с с</td> <td>10 20 40 50 60 70 80 90</td> <td>HF1=3, HF1=3, HF1=1, HF1=42 PEALG PEALG PEALG FOMMAT IF (HA HF1TE STOP CONTIN FOMMAT FOMMAT FOMMAT STOP CONTIN FOMMAT FOM</td> <td>(HE2:33 </td> <td>SIGHA (A(I) AG:I4, 1) GD T1) GD T1) GD O) HAT C1:C2 4:4I11 0) HAT SDRFY 0) NDT (GDD(4) HT1 A (GDD) O C1 T</td> <td>-1. H -1. H -1</td> <td>72=++T N 77)+++AT 3+15) 7-1000 30 10 7+++AT -2+13+1 47 -2+13+2 47 -2+13+2 47 -2+13+2 47 -2+13+2 47 -2+13+2 47 -2+13+2</td> <td>(C) FE</td> <td>>> SIGNA-2. >> >> >> >></td>	ссс с с	10 20 40 50 60 70 80 90	HF1=3, HF1=3, HF1=1, HF1=42 PEALG PEALG PEALG FOMMAT IF (HA HF1TE STOP CONTIN FOMMAT FOMMAT FOMMAT STOP CONTIN FOMMAT FOM	(HE2:33 	SIGHA (A(I) AG:I4, 1) GD T1) GD T1) GD O) HAT C1:C2 4:4I11 0) HAT SDRFY 0) NDT (GDD(4) HT1 A (GDD) O C1 T	-1. H -1. H -1	72=++T N 77)+++AT 3+15) 7-1000 30 10 7+++AT -2+13+1 47 -2+13+2 47 -2+13+2 47 -2+13+2 47 -2+13+2 47 -2+13+2 47 -2+13+2	(C) FE	>> SIGNA-2. >> >>
31661 331662 31663 31665 31667 31667 31667 31667 31667 31772 31773 31775 31775 31775 31775 31882 31885 31885 318890 31923 31992 31992 31992 31992 31992 31992 31992 31992 31992 31992 31992 31992 31992 31992 31992 31992 31992 31925 319555 319555 319555 319555 319555 319555 319555 319555 3195555 3195555 3195555 3195555555555	ссс с с	10 20 40 50 60 70 80 90	HF1=3, HF1=3, HF1=1, HF4=1 HE41N2 HE41N2 HE42C FD0H41 IF (H4 HF1TE FD0H41 IF (H4 HF1TE FD0H41 IF (H4 HF1TE STDP IF (H4 HF1TE STDP IF (H4 HF1TE FD0H41 NDD=L2 HF1F HF1F HF1F HF1F HF1F HF1F HF1F HF1	(HE2=33 (-HD FDR)))))))))))))	SIGNA (A(I) AG(I)	-1. H -1. H -11. -111. -11. -11. -11. -11. -11. -1.	72=++T N 3, 15) 7-1000 30 10 10 10 10 10 10 10 10 10 1	(C) FE	>m \$1000-2. >mt; NSEB >mt; NSEB >mt; NF; NT; NSEB NEWED UP NFE013; * NTE014) >mt; NSEB
331661333166733333333333333333333333333		10 20 40 50 60 70 80 90	HF1=3, HF1=3, HF1=1 HF4=1 HE41N2 HE41	Imm2=33 Imm2=33 Imm0 Imm0 <td>SIGHA RUCTUM (A(1)) AG:14: (1) HA T1) GD HAT B C1:C1 C1:C2 4:4111 C1:C2 4:4111 C1:C2 4:411 C1:C2 4:411 (G3D(4) HT1 A (A(1)) CD T (C3D(1) C1:C2 (C3D(1) C1:C2 (C3D(1) C1:C2 (C3D(1) C1:C2 (C3D(1) C1:C2 (C3D(1) (C1:C2) (C1</td> <td>E 1 + H 12+1 12+1 12+1 12+1 12+1 10 10 10 10 10 11 10 10 10 1</td> <td>T2=HT N 3:5) T-1000 30 T:HAT HE DUEST HAT E 0:3:0 HT E 0:3:0 HT E 0:3:0 HT E 0:3:0 HT E 0:0 HT E 0:0 HT HT E 0:0 HT HT HT HT HT HT HT HT HT HT</td> <td>(C) FE</td> <td>>A SIGNA-2. NAT = +14++ NDT DN TAPE +13+ NAT = +12++ NDT DN TAPE +13+ NAT = +13++ NDT DN TAPE +13+ NAT = +12++ NDT</td>	SIGHA RUCTUM (A(1)) AG:14: (1) HA T1) GD HAT B C1:C1 C1:C2 4:4111 C1:C2 4:4111 C1:C2 4:411 C1:C2 4:411 (G3D(4) HT1 A (A(1)) CD T (C3D(1) C1:C2 (C3D(1) C1:C2 (C3D(1) C1:C2 (C3D(1) C1:C2 (C3D(1) C1:C2 (C3D(1) (C1:C2) (C1	E 1 + H 12+1 12+1 12+1 12+1 12+1 10 10 10 10 10 11 10 10 10 1	T2=HT N 3:5) T-1000 30 T:HAT HE DUEST HAT E 0:3:0 HT E 0:3:0 HT E 0:3:0 HT E 0:3:0 HT E 0:0 HT E 0:0 HT HT E 0:0 HT HT HT HT HT HT HT HT HT HT	(C) FE	>A SIGNA-2. NAT = +14++ NDT DN TAPE +13+ NAT = +12++ NDT DN TAPE +13+ NAT = +13++ NDT DN TAPE +13+ NAT = +12++ NDT
33366233333333333333333333333333333333		10 20 40 50 60 70 80 90 100	HF1=3, HF1=3, HF1=1 HF4=1 HF4=1 F50H41 IF (H4 IF (H4 IF (H4 IF (H4 HF1TE STOP IF (H7 HF1TE STOP CONTIN HF1TE STOP CONTIN HF1TE STOP CONTIN HF1TE STOP CONTIN HF1TE STOP	Imm2=33 Imm2=33 Imm2 Imm2 <td>SIGHA (A(I) AG:14, 01) HA T1) GD T1) GD T1) GD HAT A C1+C2 4+4I1 0) HAT SDAP (G3D(4) HT1 A (A(I)) GD T (A(I)) GD T 0) NDT</td> <td>-1. H -1. H -1</td> <td>72=++T N 77) + ++4 30 5 10 10 10 10 10 10 10 10 10 10</td> <td>(C) FE</td> <td>>A \$1000-2. NAT = +14.+ NOT DN TAPE +13. NAT = +14.+ NOT DN TAPE +13. NAT.00F.017.NSEB NEWED UP 00FE+13. + 00TE+14.) NAT.017.NSEB</td>	SIGHA (A(I) AG:14, 01) HA T1) GD T1) GD T1) GD HAT A C1+C2 4+4I1 0) HAT SDAP (G3D(4) HT1 A (A(I)) GD T (A(I)) GD T 0) NDT	-1. H -1. H -1	72=++T N 77) + ++4 30 5 10 10 10 10 10 10 10 10 10 10	(C) FE	>A \$1000-2. NAT = +14.+ NOT DN TAPE +13. NAT = +14.+ NOT DN TAPE +13. NAT.00F.017.NSEB NEWED UP 00FE+13. + 00TE+14.) NAT.017.NSEB
33661 331623 3316673 3316673 3316673 3316673 3316673 3317733 3317753 3318883 3318883 331933 331775 331883 331883 33188567 33188567 331990 331990 331995		10 20 40 50 60 70 80 90 100	HF1=3, HF1=3, HT1=H1 HFA=1 HFA=1 HFA=2 FEALG FEALG FEALG FEALG HF1F HF1F STOP CONTIN FEAL HF1F STOP CONTIN HF1F STOP CONTIN HF1F STOP CONTIN HF1F STOP CONTIN HF1F STOP CONTIN HF1F STOP CONTIN HF1F STOP CONTIN HF1F STOP CONTIN HF1F STOP CONTIN HF1F STOP CONTIN HF1F STOP CONTIN HF1F STOP CONTIN HF1F STOP CONTIN HF1F STOP CONTIN	Imm2=33 Imm2=33 Imm0 FDM	SIGHA (A(I) AG,I4, 01) HA T1) GD T1) GD 0) HA T C1:C2 4:4I11 0) GD T 0) ND T (GDD (4) HT1 A (A(I)) 0 GD T 0) ND T (GDD (4) HT1 A (A(I)) 0 GD T 0) ND T	-1+H' -12:1 TEHA -TO -TO -TO -TO -TO -1+ND	72=++T N 77)+++AT 3+15) 7-1000 30 10 7+++AT 	ED + E 	>> SIGNA-2. >> >>
3166133166789033177333186783318867890331995675318823318673331775677890133188453319934319956753177890133188455318901331993433199567531778901331884553188901331995675317789013318856789013319956753177890133188567889013319956753177890133188567889013319956753188567890133199567553199555555555555555555555555555555555	ссс с с	10 20 40 50 60 70 80 90 100	HF1=3, HF1=3, HF4=1 HF4=1 HF4=2 HE4102 HE4102 HF410 HF410 H	Imm2=33 Imm2=33 Imm2 Imm2 <td>SIGNA (A(I) AG(I)</td> <td>-1. H -1. H -1111111111.</td> <td>72=++T N 3,15) 7-1000 30 10 10 10 10 10 10 10 10 10 1</td> <td>(C) FE</td> <td>>> Signa-2. >> >> >> >></td>	SIGNA (A(I) AG(I)	-1. H -1. H -1111111111.	72=++T N 3,15) 7-1000 30 10 10 10 10 10 10 10 10 10 1	(C) FE	>> Signa-2. >> >>
J331662333333333333333333333333333333333		10 20 40 50 60 70 80 90 100	HF1=3, HF1=3, HF1=1, HF4=1 PEAL G PEAL G PEAL G PEAL G F0PH11 F0P	Imm2=33 Imm2=33 Imm0 Imm0 <td>SIGHA RUCTUM (A(1)) AG:14; 01) HA T1) GD HAT B C1:C1 GD HAT SD PA (G3D(4) HT1 A (G3D(4) HT1 A (G3D(1) GD T 0) NDT (G3D(1) GD T 0) NDT (G3D(1) GD T 0) NDT (G3D(1) (A(1))</td> <td>-1+H1 -2+1</td> <td>T2=HT N 3:5) T-1000 30 T:HAT HS 4:4 L2:13:1 HT E 4:3:4 HT F2 T2 T2 T2 T2 T2 T2 T2 T2 T2 T</td> <td>(C) FE</td> <td>>A SIGNA-2. NAT = +14++ NDT DN TAPE +13+ NAT = +12++ NDT DN TAPE +13+ NAT = +13++ NDT DN TAPE +13+</td>	SIGHA RUCTUM (A(1)) AG:14; 01) HA T1) GD HAT B C1:C1 GD HAT SD PA (G3D(4) HT1 A (G3D(4) HT1 A (G3D(1) GD T 0) NDT (G3D(1) GD T 0) NDT (G3D(1) GD T 0) NDT (G3D(1) (A(1))	-1+H1 -2+1	T2=HT N 3:5) T-1000 30 T:HAT HS 4:4 L2:13:1 HT E 4:3:4 HT F2 T2 T2 T2 T2 T2 T2 T2 T2 T2 T	(C) FE	>A SIGNA-2. NAT = +14++ NDT DN TAPE +13+ NAT = +12++ NDT DN TAPE +13+ NAT = +13++ NDT DN TAPE +13+
336612333333333333333333333333333333333	ссс с с	10 20 40 50 60 70 80 90 100	HF1=3, HF1=3, HF1=1 HFA=1 HFA=1 FEALG FEAL	Imm2=33 Imm2=33 Imm2 Imm2 <td>SIGHA (A(1) AG:14 (A(1) AG:14 (A(1) AG:14 (A(1) (A(1) (A(1) (A(1) (A(1) (A(1) (A(1) (A(1) (A(1) (A(1) (A(1) (A(1) (A(1)) (A(1) (A(1) (A(1)) (A(1) (A(1)) (A(1) (A(1)) (A(1</td> <td>-1.41 + 1111 TE 12 TE 12 TE 12 TT 1 TT 1</td> <td>72=++T N 77) + ++4 30 5 10 10 10 10 10 10 10 10 10 10</td> <td>(C) FE</td> <td>>A \$1000-2. NAT = +14.+ NOT DN TAPE +13. NAT = +14.+ NOT DN TAPE +14. NAT = +14.+ NOT DN TAPE +14. NAT = +14.+ NOT DN TAPE +14. NAT = +14.+ NOT DN TAPE +14.</td>	SIGHA (A(1) AG:14 (A(1) AG:14 (A(1) AG:14 (A(1) (A(1) (A(1) (A(1) (A(1) (A(1) (A(1) (A(1) (A(1) (A(1) (A(1) (A(1) (A(1)) (A(1) (A(1) (A(1)) (A(1) (A(1)) (A(1) (A(1)) (A(1	-1.41 + 1111 TE 12 TE 12 TE 12 TT 1 TT 1	72=++T N 77) + ++4 30 5 10 10 10 10 10 10 10 10 10 10	(C) FE	>A \$1000-2. NAT = +14.+ NOT DN TAPE +13. NAT = +14.+ NOT DN TAPE +14.

```
3201
         120 CONTINUE
              READ (ND2+90) (x51(1)+1=1+N6P)
3202
              IF (HT1.NE,HT2) 60 TO 130
DO 125 I=1:HEP
32.03
3204
3205
              xs2(1)=xs1(1)
3206
         125 CONTINUE
              бр тр 150
3207
        GD TD 150
130 меар (Np2+20) (А(1)+1=1+7)+нАт+нF+нT+НSEB
1F (HT.LT.HT2) GD TD 130
1F (HT.EB.HT2) GD TD 140
NRITE (NDUT+60) NDT+HF+HT
3208
3209
3210
3211
        140 CONTINUE
3212
3213
              READ (ND2,90) (x52(1),1=1,NGP)
3214
         150 CONTINUE
              DD 155 N=1+NGP
3215
3216
3217
              CDH (K+N)=0.
3218
              CE1 (K+N)=0.
              CE2 (K+N)=0.
3219
3220
        155 CONTINUE
3221 c
             READ COV. DATA.
        NEND CDV. DATH.

160 меад (NDT;20) (А(1);1=1;7);нат;нт;нт;нхев

IF (нг.LT.HF2) бо то 160

IF (нт.NE.HT1) бо то 160

IF (нг.EB.HF2) бо то 170
3222
3223
3224
3225
3226
              HRITE (NOUT: 60) NOT: HE: HT
3227
              STOP
        170 CONTINUE
3228
              MEAD (NDT:50) C1:C2:L1:L2:L3:L4:MAT:MF:MT:NSED
IF (HT.LT.HT1) 60 T0 160
IF (MT.EB.HT1) 60 T0 180
3229
3230
3231
3232
              MAITE (NOUT+60) NOT+HF+HT
3233
              STOP
        180 CONTINUE
3234
3235
              MTX=L2
              HGP=L4
3236
3237 c
              13NOV80///FOLLONING THREE LINES INSERTED AS RER ERNOR FOUND BY HUI
              SEE LETTER DATED 13NDV80 AND REFERENCE T-2-L-3845.
DD 250 N=1+NGP
DD 250 K=1+NGP
3238 c
3239
3240
3241
        250 CDM (#+N)=0.
3242
              DD 190 H=1+H6P
3243
              READ (NDT+50) C1+C2+L1+L2+L3+L4
3244
              LGP1=L2
3245
              L6#2=L2+L3-1
3246
              NGNDEL 4
3247
              KL=L4
3248
              AEAD (NDT+90) (CDH (KL+L)+L=L6P1+L6P2)
3249
              IF (NGND.GE.KEP) 60 TO 200
3250
3251
         190 CONTINUE
        200 JF (HTX.LT.HT2) 60 TO 170
JF (HTX.EB.HT2) 60 TO 210
HRITE (NDUT:60) NDT:HF:HT
3252
3253
3254
              STOP
        210 CONTINUE
3255
3256
3257
              DD 230 H=1+NGP
              **=NGP-++1
3258
              XSA (KH)=XS1 (H)
3259
              X53 (NK)=X52 (N)
3260
              DO 220 N=1+N6P
3261
              NN=NEP-N+1
3262
              CEI (KKINN/ SCON (KIN)
3263
         220 CONTINUE
3264
         230 CONTINUE
3265
              IF (NDH. ST. 0) HETURN
              DD 240 H=1+NEP
3266
3267
3268
              CE2 (+++) =CE1 (+++) ++SA (+) ++SB (+)
3269
        240 CONTINUE
3270
              RETURN
3271
3272 с
              END
3273 c
3274 c
3275 c
3676 c
3277
              SUBROUTINE SETID
3278 c
3279 c
              SUBROUTINE SETS CORRECT HATHEFHT SIVEN MRX
3280 c
```

3301		
3203 6		COMON/ENDP/MITTADITADITADITADITADITADITADITADITADITA
3202 C		
3264		
3285		TE (MAX.47.6) ED TO 20
3286		Mat 1=305
3287		1F (MP#.6T.3) 60 TO 10
3288		MT1=1 \$ MT2=1
3289		1F (HRX.EB.2) HT2=2
3290		IF (MRF.ED.3) MT2=107
3291		RETURN
3292	10	CONTINUE
3293		HT1=2 \$ HT2=2
3294		IF (MRX.GE.5) MT2=107
3295		IF (MRX.EQ.6) MT1#107
3296	_	RETURN
3297	20	CONTINUE
3298		1F (MRX,6T,11) 60 TO 40
3299		HAT 1=306
3300		
3301		MTIFI 3 MTEFI 1 (may an 0) MT2F2
3302		IF (HWALES, C/ HIE-E
3303	30	
3305	50	
33.06		TIE (MAX.ED.10) MT1=4
3307		1F (MB4.EB.10) MT2=4
3308		1F (MPS.ED.11) HT1=107
3309		1F (MAX.EB.11) MT2=107
3310		PETURN
3311	40	CONTINUE
3312		IF (MPX.5T.18) 50 TD 70
3313		MAT1=324
3314		1F (MP#.GT.13) 6D TD 50
3315		MT1=1 \$ MT2=1
3316		IF (MPX.ED.13) MT2=2
3317		PETURN
3318	50	CONTINUE
3319		IF (MPX.6T.15) 60 TO 60
3320		MT1=2 \$ MT2=2
3321		IF (MA#.EB.15) MT2=4
3322		RETURN
3323	60	CONTINUE
3324		HT154 & HT254
3323		IF $\langle MP_{A}, GE_{A}, I \rangle$ MT2=102
3320		IF (MRX.ED.16) HTI-IUC
3327	70	
3329		$r_{\rm e}$ (max, $r_{\rm e}$, $r_{\rm e}$) and $r_{\rm e}$ (10)
3330		
3331		IF (Hes. 67.21) 60 TO 80
3332		HT1=1 \$ HT2=1
3333		1F (MPX.EB.20) HT2=2
3334		IF (HPY, EB.21) HT2=102
3335		RETURN
3336	80	CONTINUE
3337		1F (MR).5T.24) 5D TD 90
3338		MT1=2 \$ MT2=2
3339		IF (MPJ.E0.23) MT2=4
3340		IF (MRX.EB.24) MT2=102
3341		PETURN
3342	90	CONTINUE
3343		1F (MPX.6T.28) 60 TO 100
3344		HT1=4 \$ HT2=4
3345		IF (MPJ,EB.26) MT2=102
3340		IF (MPJ.ED.C/) MTC=103
3347		IF (HFX.EB.CO) WIC-10/
3349	1.00	CONTINUE
3350		HT1=102 \$ HT2=102
3351		IF (MP. E. 30) MT1=103
3352		IF (MP ED. 30) MT2=103
3353		IF (MP>.EB.31) MT2=107
3354		IF (MPX.EB.31) HT1=107
3355		PETUPN
3356	110	CONTINUE
3357		IF (MRX.67.36) 60 TO 120
3358		MAT1=328
3359		MT1=1 \$ MT2=1
3360		IF (MM/.EB.33) HT1=2

3361		IF (MRX.ED.33) MT2=2
3362		15 (HRX.50.34) HT2=4
3363		IF (MRX.ED.34) MT1#4
3364		IF (MPJ.ED.35) MT1=102
3365		IF (MR+.EP.35) HT2=102
3366		1F (HRL. FR. 36) HT2=103
3367		15 (MAY.50.36) MT18103
3369		
3349	120	
3307	120	$r_{\rm current} = r_{\rm cr} (47)$ on the 160
3370		10 (000.01.41) 00 10 100
3371		m(1-32)
3372		IF (MMX, 61,307 60 10 130
3373		HT1=1 & HTE=1 HT1=1 & HTE=1
3374		IF (MPX.LB.JO) HTC-C
3375	100	RETURN
33/6	130	CONTINUE
3377		IF (MMX.6T.402 60 TO 140
3378		HTIEC & HTCEC
3379		IF (MAX.EM.4U) ATCH4
3380		RETURN
3381	140	CONTINUE
3382		IF (MPX.6T.44) 60 TO JOU
3383		HT1=4 \$ HT2=4
3384		IF (MRX.EB.42) MT2#102
3385		IF (MRX.ED.43) HT2=103
3386		1F (MPX.EB.44) HT2=107
3387		PETURN
3388	150	CONTINUE
3389		MT1=102 \$ MT2=102
3390		IF (HP>.EB.46) HT1=103
3391		IF (MR#.EB.46) MT2=103
3392		IF (HP+.ED.47) HT1=107
3393		IF (MRX.EB.47) MT2=107
3394		RETURN
3395	160	CONTINUE
3396		IF (MP×.61.55) 6D TO 190
3397		HAT1=382
3398		IF (MRX.6T.50) 6D TD 170
3399		HT1=1 \$ HT2=1
3400		IF (MRJ.E0.49) HT2=2
3401		IF (MRX.E8.50) MT2=102
34 02		RETURN
3403	170	CONTINUE
34 04		1F (MR).67.52) 60 TO 180
34.05		HT1=2 \$ HT2=2
3406		IF (MAX.ED.52) MT2=4
3407		RETURN
3408	180	CONTINUE
3409	-	MT1=4 \$ MT2=4
3410		IF (MEx.GE.54) MT2=102
3411		IF (MPX.E8.55) MT1=102
3412		RETURN
3413	190	CONTINUE
3414		IF (HR#.61.58) 60 TO 200
3415		HAT1=1301
3416		HT1=1 \$ HT2=1
3417		IF (MR#.6E.57) MT2=2
3418		IF (HRK.EB.58) HT1=2
3419		RETURN
3420	200	CONTINUE
3421	-	IF (MRX.6T.MRXHX) WRITE (NOUT+510) MRX+MRXHX
3422	510	FORMAT (1H + MEXE+13+ GREATER THAN HEXHX=+13)
3423		STOP
3424		END

APPENDIX B

TRDSEN

This appendix was provided by T. J. Seed and is a summary of the changes made in TRIDENT-CTR in order to obtain angular fluxes compatible with SENSIT-2D. In order to make a distinction between this version of TRIDENT-CTR and the normal version, it was renamed TRDSEN.

```
#1D SENSIT
     #1 SEEKTUD.2
C SENSIT
 200
 45
     COMMON /SENST/ FNSEN(20), 1HOLTH(23)
C SENSIT
     #D CD2.4
C SENS1T
 57
R
     #1 TR1D8D.26
C SENSIT
10
11
12
13
     C SENSIT
      #1 1NPUT11.04
```

First UPDATE

1

```
2LTDH. IPXS.LTC. IPCT.LTCT.LTXS. IPFSM. IPFSMR.LTFS. IPSEN,LTSEN
C SENSIT
                           DATA FNSEH/GHSHSTB1.6HSHSTB2.6HSHSTB3.6HSHSTB4.6HSHSTB5.6HSHSTB6.
1 6HSHST87.6HSHSTB8.6HSHSTD9.6HSHST10.6HSHST11.6HSHST17.6HSHST13.
2 6HSHST14.6HSHST15.6HSHST16.6HSHST17.6HSHST10.6HSHS(19.6HSHST20 /
#1 INPUT11.84
C SENSIT
EDUIVALENCE (IA(164).LSEN)
C SENSIT
#1-INPUT11.230
C SENSIT
IHOLTH(1) = 4HTRID
IHOLTH(2) = 4H-SEN
IHOLTH(3) = 4HSIT
IHOLTH(4) = 4HLINK
INOLTH(5) = 4H
C SENSIT
=1 INPUT11.242
C SENSIT
IF(K.NE.1) GO TD 15B
                            1F(K.HE.1) GO TO 158
DO 155 1 = 1. 10
1HOLTH(1+5) = 1DUSE(1)
             155 CONTINUE
             C SENSIT
            #D INPUTII.682
C SENSIT
LSEN = LFL + 3 # HM # 1TMRX
LTLM = LSEN + 3 # 1TMRX
C SENSIT
D INPUTII.017
C SENSIT
                            LTSEN = 3 * NTC * 1TH

IPSEN = IPFSMA + NGF58 * LTFS

LASTEC = IPSEN + LTSEN + 512

IF(ITH.EO.8) IPSEN = IPP1
            C SENSIT
*D INPUTI1.912. INPUTI1.913
C SENSIT
,98123456789812345678981234567898
             520 FORMAT(70H
IROCESSOR DH
                                                                 THIS CASE WAS PROCESSED BY THE TRIDENT-CTR SENSIT P
                                                                   .2X.A10>
             C SENSIT
            C SENSIT
C SENSIT
750 FORMAT(//1X.37NTRIDENT-CTR SENSIT PROCESSOR. DATE -
                                                                                                                                                                 . A16/2
            C SENSIT
             #1 GEOCON. 14
            C SENSIT
EQUIVALENCE (1A(1),1TH)
            EUUIVALETLE CARCATA
C SENSIT
#1 GEOCON.S9
C SENSIT
IF (ITH.ED.8) RETURN
           D 128 J = 1, JT
D0 128 J = 1, JT
CALL LREED(A(LIP).A(LIPG).P1.J.1,3.1PP1.JT)
IMAX = 1T(J)
D0 118 I = 1, IMAX
VI = P1(1,1) + P1(2,1) + P1(3,1)
D0 118 K = 1, 3
P1(K,1) = P1(K,1) / VI
118 CONTINUE
CALL LRITE(A(LIP).A(LIPG).P1.J.1,3.1PSEN.JT)
128 CONTINUE
C SENSIT - 5
D GRIND20.S25 GRIND20.73
C SENSIT
= 1 OUTER.19
C SENSIT
            C SENSIT
CALL INSTAL
```

```
*CALL SEEKTUD
C SENSIT
*1 OUTER.23
   81
82
   03
04
                  C SENSIT
                                   DIMENSION JPARM(18).ESEN(5)
   85
   86
87
                 C SENSIT
                   #1 OUTER.35
                C SENSIT
EQUIVALENCE (IA(63).NTC),(IA(165).NSNST),(IA(166),JSEN)
   08
   09
   90
91
92
                #1 DUTER.S1
C SENSIT
                DATA ESEN GHTDO MA.GHNY SEN.GHSIT DU.GHMP FIL.GHES
C SENSIT
   93
94
   95
                 DUTER.60.0UTER.78
   96
                                  SIT

IDCLD = 8

MLDS = NTC * MMP0

NGSD = MAXOMP / MLDS

IF(NGSD.LT.J) NGSD = 1

NLDS = NGSD * MLDS + 33 + 512

NSDK = (1GM - 1) / NGSD + 1

IF(NSDK.GT.20) CALL ERCOR(1.ESEN,5)

NGLD = IGM - (NDSK-1) * NGSD

NLDLD = NGLD * MLDS + 33 + 512
   97
98
99
180
181
162
103
104
185
106
                С
                                   JPARM(1) = 1TH
JPARM(2) = 1GM
JPARM(3) = JT
JPARM(4) = NTC
JPARM(5) = MNPO
JPARM(6) = N5DK
187
109
189
118
111
112
                                   JPARM(7) = NGSD
JPARM(8) = MLDS
113
              JPARM(0) = nump

C SENSIT

=1 OUTER.181

C SENSIT

1DSDK = (G - 1) / NGSD + 1

1F(1DSDK.E0.1DOLD) GO TO 130

1F(1DSDK.E0.1) GO TO 137

CALL FILLU(1.FNSEN(1DSDK-1).FNSEN(1DSDK-1).NLDS1)

CALL SRITE(NSNST, ITEMP.0.8.0.4.JSEN)

CALL SRITE(NSNST, ITEMP.0.8.0.4.JSEN)

CALL SRITE(NSNST, ITEMP.0.8.0.4.JSEN)
114
115
116
117
110
119
120
121
122
              CALL SEEK(FNSEN(IDSDK-1).IVERS,NSNST,4)

137 CDNTINUE

NUDSI = NUDS

IF(IDSDK.E0_NSDK) NUDSI = NUDLD

IVERS = IDSDK

JPARM(3) = NDSI

JPARM(3) = NDSI

JPARM(3) = NDSDK

CALL FillU(1,FNSEN(IDSDK),FNSEN(IDSDK),MUDSI)

CALL FillU(2,FNSEN(IDSDK),FNSEN(IDSDK),6)

CALL SEEK(FNSEN(IDSDK),IVERS,NSNST,1)

JSEN = 0

CALL SRITE(NSNST,IHOLTH.8,8,23,1,JSEN)

CALL SRITE(NSNST,IHOLTH.8,18,0,1,JSEN)

I30 CONTINUE

C SENSIT

*D OUTER.303,OUTER.321

C SENSIT
123
124
126
127
128
129
138
131
132
133
134
135
136
137
130
139
                D DUTER.324.DUTER.334
C SENSIT
D DUTER.337.DUTER.379
148
141
142
143
144
                C SENSIT
145
146
                C SENSIT
147
148
149
158
151
                C SENSIT
               L SENSIT
#D INNER.94
C SENSIT
#D INNER.97.1MMER.115
C SENSIT
               C SENSIT
JFS = 1
C SENSIT
=D INNER.201.1NNER.207
C SENSIT
=TANK NEURB.A050R0
=1 SIECP 70
152
153
154
155
156
157
158
               WYANK NEUAB, ABSOR0

#1 SUEEP.32

C SENSIT

EOUIVALENCE (1A(154).LSEN)

C SENSIT

C SENSIT

CALL URSNST(AF(1.2).AS.A(LSEN).17)

C SENSIT

#0 SUEEP.140

C SENSIT

C SENSIT

C SENSIT
159
168
161
163
165
166
167
                CALL URSHST(AF(1.2).RS.A(LSEN).1T)
C BEHS1T
```

```
#D SLEEP.249,SLEEP.254
C SENSIT
#1 SLEEP.259
SUBROUTINE LRSNST(AF.CF.SEN.1T)
169
170
171
172
173
174
175
176
177
170
181
182
183
184
185
186
187
180
          SUBRI
C VOLUT
C FILE
C FILE
C #CALL 01AA
C #CALL CD2
C D11FFN
                       VOLUME AVERAGES ANGULAR FLUXES AND URITES TO SEQUENTIAL
                      DIMENSION AF (3, 1), SEN (3.1).CF (1)
           C
                      EQUIVALENCE (1A(165),NSNST),(1A(166),JSEN)
           C
                     DO 18 1 = 1, 1T

CF(1) = 0.0

DO 18 K = 1, 3

CF(1) = CF(1) + AF(K,1) = SEN(K,1)

CONTINUE
           18
C
190
191
                      CALL SRITE (NSNST.CF, 1T.8.8.2, JSEN)
192
193
           С
          RETURN
END
C TRDCTR.SETEC1
194
195
```

Second UPDATE

```
1 +ID SENI
 2 *1 PEADDF.80
3 *1 READDF.84
 4 NLCH = 0
5 +1 INNER.55
 6 C SENSIT
            EDUIVALENCE (IA (164)+LSEN)
 8 C SENSIT
 9 41 INNER.131
10 C SENSIT
11
           CALL LREED (A (LIP) + A (LIPG) + A (LSEN) + J + 1 + 3 + IP SEN + J + )
12 C SENSIT
13 +D INNER.144
14 C SENSIT
15 41 INNER. 167
16 C SENSIT
17
           CALL LREED (A (LIP) + A (LIPS) + A (LSEN/+J+1+3+IPSEN+JT)
18 C SENSIT
19 4J INNER.180
20 C SENSIT
21 4D SNEEP.269
22 4C TRUSEN.SETBCI
```

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