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SENSIT: A Cross-Section and Design Sensitivity and Uncertainty Analysis Code

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SENSIT: A Cross-Section and Design Sensitivity and Uncertainty Analysis Code

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SENSIT: A CROSS-SECTION AND DESIGN SENSITIVITY AND UNCERTAINTY ANALYSIS CODE

by

S. A. W. Gerstl

ABSTRACT

SENSIT computes the sensitivity and uncertainty of a calculated integral response (such as a dose rate) due to input cross sections and their uncertainties. Sensitivity profiles are computed for neutron and gamma-ray reaction cross sections (of standard multigroup cross-section sets) and for secondary energy distributions (SED's) of multigroup scattering matrices. In the design sensitivity mode, SENSIT computes changes in an integral response due to design changes and gives the appropriate sensitivity coefficients. Cross-section uncertainty analyses are performed for three types of input data uncertainties: (a) cross-section covariance matrices for pairs of multigroup reaction cross sections, (b) spectral shape uncertainty parameters for secondary energy distributions (integral SED uncertainties), and (c) covariance matrices for energy-dependent response functions. For all three types of data uncertainties, SENSIT computes the resulting variance and expected standard deviation in an integral response of interest, based on generalized perturbation theory. SENSIT uses angular-flux files from one-dimensional discrete-ordinates codes like ONETRAN, ANISN and DTF and reads multigroup cross-section sets in three different formats. This report gives detailed input specifications; precise definitions of all input and output arrays; a discussion of the underlying theory; and details of program flow, data management, and storage requirements. Eight sample problems are described in detail for which complete input files and selected output prints are listed.

I. INTRODUCTION

Sensitivity analysis in radiation transport theory attempts to determine quantitatively how sensitive a calculated integral response is to the input data for the transport calculation. Such input data may concern either cross-section data, geometry specifications (design data), methods approximations, or any other input required to perform a transport calculation. In an uncertainty analysis, the sensitivity information is used, together with additional data about the uncertainty of the input data, to calculate or estimate the uncertainty of a calculated integral response which results from these input data uncertainties. In a cross-section uncertainty analysis the data uncertainties may be quantified in cross-section covariance matrices and in spectral shape uncertainty parameters for secondary energy distributions (SED's), while the resulting response uncertainty is best quantified by a variance or relative standard deviation. In a design sensitivity analysis, usually a specific design change (e.g., a material replacement or a geometry modification) and its effect on a calculated integral response is of concern. Therefore, in such cases a resulting response change is calculated based on generalized perturbation theory.

The SENSIT code is in some respects more comprehensive than earlier sensitivity codes presently in use[1]. Specifically, SENSIT includes the calculation of sensitivity profiles for secondary energy distributions (SED's) and performs also an SED uncertainty analysis. In addition, SENSIT also allows design sensitivity analyses and detector response uncertainty analyses to be performed in addition to the standard cross-section sensitivity and uncertainty analysis.

II. SENSIT INPUT SPECIFICATIONS

The following pages describe the input data to SENSIT in the order in which they must be entered into the code. In addition to the title card, which is always first, all input data may be categorized as control integers on cards 2 and 3, and problem dependent data starting with card 4. Many of the problem dependent data are required only conditionally, depending on the value of certain control integers, as indicated. Therefore, mainly depending upon values for ITYP, the sequence of problem-dependent input data may be different from case to case.

Card 1: Format (8A10)

80-column title card for job description

Card 2: Format (12I6), control parameters

Integer No.	Variable Name	Description and Options
1	ITYP	Type of sensitivity/uncertainty analysis: 0 - standard cross-section sensitivity analysis 1 - design sensitivity analysis 2 - vector cross-section sensitivity and uncertainity analysis, 3 - SED sensitivity and uncertainty analysis.
2	IGE	Geometrical model: 1 - slab or plane geometry, 2 - one-dimensional cylindrical geometry, 3 - spherical geometry, 4 - two-angle slab geometry.
3	ISN	Order of S_N angular quadrature; must be even integer.
4	IM	Total number of spatial mesh intervals.
5	IGM	Total number of energy groups.
6	NCOUPL	Number of neutron groups in case of coupled neutron/gamma-ray calculations, Zero if pure neutron or pure gamma-ray calculation is performed.
7	LMAX	P_ℓ-order of cross-sections.
8	ITAPE	Type of angular fluxes to be read from TAPE1 (PHI) and TAPE2 (PHISTAR) (see. Sec. V.C): 0 - reads flux tapes generated by DTF or ANISN, 1 - reads flux tapes in CCCC-format; e.g., as generated by ONEDANT or ONETRAN.

Integer Variable (Card 2 continued)

No.	Name	Description and Options
9	IXSTAPE	Source of multigroup cross-section input (see Sec. V.A,B): 0 - expects cross sections from cards (i.e., in input stream of problem-dependent data), if ITYP = 0,1,3, 1 - expects cross sections from TAPE4, if ITYP = 0,1,3, 2 - expects vector cross sections and covariance data from TAPE10, only if ITYP = 2.
10	NPERXS	Number of successive cases to be run for the same PHI/PHISTAR, and the same perturbed zone identifications: - if ITYP = 0,1,3: number of perturbed cross-section sets to be read from TAPE4, or from cards - if ITYP = 2: number of vector cross-section pairs with covariance matrices to be read from TAPE10.
11	IDESIGN	Type of design sensitivity analysis (zero if ITYP = 0,2,3): 0 - for ITYP = 1 when 2 cross-section sets (perturbed and unperturbed) must be read per case, 1 - for ITYP = 1 when only 1 cross-section set (Σ) is read per case, and the special design perturbation of a 1% density increase is assumed ($\Delta\Sigma = 0.01\ \Sigma$) in all perturbed zones.

Card 3: Format (12I6), control parameters

Integer Variable

No.	Name	Description and options
1	KSRS	Number of source zones.
2	KDET	Number of detector zones.
3	KPER	Number of perturbed zones.

Integer No.	Variable Name	(Card 3 continued) Description and options
4	KXS	Format of input cross sections if ITYP = 0,1,3, cf. Sec.V.A.: 0 - if ITYP = 2 (KXS is not needed), 1 - LASL format: 6E12.5, 2 - ORNL format: limited fixed field FIDO format as read by ANISN (see Sec. V.A.1e).
5	IHT	Position (row) of total cross section in multigroup cross-section tables (typically 3), 0 - if ITYP = 2.
6	IHA	Position (row) of absorption cross section in multigroup cross-section tables (typically 1), 0 - if ITYP = 2.
7	DETCOV	0 - if no covariance matrix for the detector response function is provided, 1 - read covariance matrix for R(g) and perform relevant uncertainty analysis.
8	NSED	0 - for ITYP = 0,1,2, and for ITYP = 3 if no SED uncertainties are provided, 1 - read integral SED uncertainties if ITYP = 3.
9	IOUTPUT	0 - print sensitivity and uncertainty output only for the sum over all perturbed zones (in case KPER >> 1), 1 - print all sensitivity and uncertainty output for each individual perturbed zone and for the sum over all perturbed zones.
10	NSUMCOV	0 - if ITYP = 0,1,3, N - number of partial sums desired of individual response variances computed for ITYP = 2.

Integer Variable No.	Name	(Card 3 continued) Description and options
11	ITEST	Flag to output specific test prints (which may be very voluminous): 0 - no test printout, 1 - provide test printout including cross sections but no angular fluxes, 2 - provide test printout with angular fluxes but no cross sections. 3 - provide test printout with vector cross sections and covariance matrices if ITYP = 2.
12	IPRINT	Flag to provide test printouts of pointers, traces, and dumps as edited from the dynamic data management module BPOINTR: 0 - no test printout, 1 - print dumps only, 2 - print traces only, 3 - print dumps and traces.

Card 4 and all successive cards: Problem-dependent input data

Input Array Name	Number of Entries	Input Format	Required only if	Description and conditions
$E_n(g)$	IGM+1 (if NCOUPL=0) NCOUPL+1 (if NCOUPL≠0)	6E12.5	always	Energy group boundaries for neutron groups in eV, starting with highest energy (i.e., group 1). Zero is not allowed as group boundary.
$E_\gamma(g)$	IGM+1 -NCOUPL	6E12.5	NCOUPL≠0	Gamma-ray energy group boundaries in eV, starting with highest gamma-ray energy (i.e., group NCOUPL+1). Zero is not allowed as group boundary.

Input Array Name	Number of Entries	Input Format	Required only if	Description and conditions
W(m)	MM*	6E12.5	always	S_N quadrature weights consistent with those used in flux calculations for PHI and PHISTAR (level weights excluding starting weight).
MUE(m)	MM*	6E12.5	always	S_N quadrature direction cosines (level cosines excluding starting directions).
Z(i)	IM+1	6E12.5	always	Spatial mesh boundaries for the entire system in cm.
ISFIR(k), ISLAS(k)	2	2I6	always	Interval number of first and last interval of k-th source zone. 1 card with two numbers must be entered for each of the KSRS source zones!
IDFIR(k), IDLAS(k)	2	2I6	always	KDET cards describing all detector zones (like above)
IPFIR(k), IPLAS(k)	2	2I6	always	KPER cards describing all perturbed zones (like above).
RHO(g)	IGM	6E12.5	always	Energy distribution of detector response function R(g,i) by group, starting with g = 1 (see Sec. V.D).
RHO(j)	IDET	6E12.5	always	Spatial distribution of detector response function R(g,j), per detector

*)MM = ISN for slab and spherical geometry (IGE=1 or 3)
MM = ISN*(ISN+2)/4 for cylindrical geometry (IGE=2)
MM = ISN*(ISN+2) for two-angle slab geometry (IGE=4)
} see Sec. V.C.

Input Array Name	Number of Entries	Input Format	Required only if	Description and conditions
				interval j = 1,..., IDET, starting with first interval of first detector zone (see Sec. V.D).
COVR(g, gp)	IGM*IGM	6E12.5	ITYP=0 and DETCOV=1	Relative covariance matrix for detector response function starting with 1 title card.
QUE(g)	IGM	6E12.5	always	Energy distribution of source distribution functions Q(g,j) by group, starting with g = 1 (see Sec. V. D).
QUE(j)	ISRS	6E12.5	always	Spatial distribution of source distribution function Q(g,j), per source interval j = 1,...,ISRS, starting with first interval of first source zone (see Sec. V. D).
ID, DEN1, DEN2	3	(I6,6X, 2E12.5)	ITYP=2	Identification number and 2 number densities (in atoms/barn cm) for pair of vector cross sections read from tape 10. ‖1 card must be entered for each of the NPERXS vector cross-section pairs!‖
SUMSTRT, SUMEND	2	2I6	ITYP=2 and NSUMCOV≠0	SUMSTRT identifies the first (SUMEND the last) vector cross-section pair from the string of NPERXS cases, for which the response uncertainties are added and edited as partial sums of variances. ‖1 card must be entered for each of the NSUMCOV partial sums desired!‖

Input Array Name	Number of Entries	Input Format	Required only if	Description and conditions
GMED(g)	IGM1[+]	12I6	ITYP=3 and NSED=1	Array of energy-group numbers which identifies the median energy group for each SED associated with the initial energy group g. Use zero if no SED is identified for a given initial energy group g.
FSED(g)	IGM1[+]	6E12.5	ITYP=3 and NSED=1	Integral SED uncertainty associated with initial energy group g, corresponding to GMED(g).
ID, NUMDEN, XSNAME	3	I6,6X, E12.5, 2X,A10	IXSTAPE=1 and ITYP=0 or ITYP=3	ID identifies the cross-section set for the specific material for which a standard cross-section sensitivity analysis or an SED sensitivity/uncertainty analysis is to be performed. ID is the sequence number of the string of material cross sections on TAPE4, e.g., for the third XS-set on TAPE4: ID=3. NUMDEN is the number density for the material. XSNAME is an optional 10-column name designation which will reappear in the output. Note: If an SED sensitivity/uncertainty analysis is desired for more than 1 material per SENSIT run

+) IGM1 = Number of neutron groups in the problem:
IGM1 = IGM if pure neutron calculation is performed (NCOUPL = 0),
IGM1 = NCOUPL if coupled neutron/gamma-ray calculation is performed.

Input Array Name	Number of Entries	Input Format	Required only if	Description and conditions
				(NPERXS > 1), then the last three arrays GMED(g), FSED(g), and (ID, NUMDEN, XSNAME) must be provided for each material successively to make a total of NPERXS sets of these 3 arrays.
XS(g, gp,ℓ)	depends on control parameters		IXSTAPE = 0	Perturbed cross-section set with title card and number density card (see Sec. V. A).
XSBAR(g, gp,ℓ)	depends on control parameters		IXSTAPE =0 and ITYP=1 and IDESIGN =0	Reference or unperturbed cross-section set with title card and number density card (see Sec. V. A).

III. UNDERLYING THEORY

The basic theory upon which the present sensitivity and uncertainty analysis methods are based has developed over the past several years. We refer to only a few selected references here which can provide the user an overview of the field, Refs. (2) through (6). More mathematical detail is given in Ref. (7), with special emphasis on discrete-ordinates formulations. The description of the underlying theory in this section will be restricted to as much detail as is required to understand input and output of the SENSIT code, while a general knowledge of the field is assumed.

A. Standard Cross-Section Sensitivity Analysis (ITYP = 0)

Conventional sensitivity profiles P_Σ may be derived from the expression for the forward difference approximation, Eq. (36) in Ref. 7, or Eq. (17) in Ref. 3, or Eq. (26) in Ref. 4. The analytical definition of a cross-section sensitivity function F_Σ (E) expresses the sensitivity of a calculated integral response I to a particular cross section Σ_x at energy E and may be expressed as

$$F_{\Sigma_x}(E) = (1/I)\int d\underline{r}\int d\underline{\Omega}\ \Big\{ -\ \phi(\underline{r},\underline{\Omega},E)\ \Sigma_{x,T}(\underline{r},E)\ \phi^*(\underline{r},\underline{\Omega},E) + \int d\underline{\Omega}'\int dE'\ \phi(\underline{r},\underline{\Omega},E)\ \Sigma_{x,S}\ (\underline{r},\underline{\Omega}\rightarrow\underline{\Omega}',E\rightarrow E')\ \phi^*(\underline{r},\underline{\Omega}',E')\Big\} \quad . \tag{1}$$

In a multigroup formulation one usually prefers to identify and work with a sensitivity profile P^g_Σ , which is related to the above sensitivity function through the scaling factor Δu^g by $P^g_\Sigma = \bar{F}_\Sigma\ (E_g)/\Delta u^g$ and refers to a group-averaged sensitivity. Δu^g is the lethargy width of energy group g. The exact numerical definition of a multigroup cross-section sensitivity profile for the macroscopic cross section Σ^g_x is:

$$P^g_{\Sigma_x} = \left\{ -\ \Sigma^g_{x,T}\cdot\chi^g + \sum_{\ell = o}^{LMAX}\ \sum_{g' = g}^{GMAX} \Sigma^{g\rightarrow g'}_{s,\ell}\cdot\psi^{gg'}_\ell \right\} \Big/ I_\phi\cdot\Delta u^g \quad , \tag{2}$$

where $\Sigma^{g}_{x,T}$ = total macroscopic cross section for reaction type x,

$\Sigma^{g\to g'}_{s,\ell}$ = ℓ'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,

$$\chi^{g} = \sum_{i=1}^{IPERT} V_i \cdot \sum_{m=1}^{MM} \phi^{g}_{m}(i)\cdot\phi^{*g}_{m}(i)\cdot w_m \quad ,$$

= numerical integral of the product of forward and adjoint angular fluxes over all angles and all spatial intervals described by i = 1,...,IPERT.

$$\psi_{\ell}{}^{gg'} = \sum_{i=1}^{IPERT} V_i X^{g}_{\ell}(i)\cdot Y^{g'}_{\ell}(i) \quad ,$$

= spatial integral of the product of Legendre coefficients of forward and adjoint angular fluxes.

$$X^{g}_{\ell}(i) = \sum_{m=1}^{MM} \phi^{g}_{m}(i)\cdot P_{\ell}(\mu_m)\cdot w_m$$

$$Y^{g'}_{\ell}(i) = \sum_{m=1}^{MM} \phi^{*g'}_{m}(i)\cdot P_{\ell}(\mu_m)\cdot w_m$$

$\phi^{g}_{m}(i),\phi^{*g}_{m}(i)$ = discrete-ordinates representations of forward and adjoint angular fluxes for group g, spatial mesh point i and discrete direction m.

$P_{\ell}(\mu_m)$ = Legendre polynomial of order ℓ at direction cosine μ_m.

$\{\mu_m, w_m\}$ = discrete-ordinates quadrature direction cosines μ_m and associated quadrature weights w_m.

V_i = volume of spatial mesh interval i.

Δu^g = lethargy width of energy group g,
= $\ln (E^g/E^{g+1})$, where E^g and E^{g+1} are upper and lower energy group boundaries.

I_ϕ = integral response as calculated from forward fluxes only,

$$= \sum_{i=1}^{IDET} \sum_{g=1}^{IGM} \sum_{m=1}^{MM} V_i R_i^g \cdot \phi_m^g(i) \cdot w_m$$

R_i^g = spatially and group-dependent detector response function.

The basic Eq. (2), as well as its corresponding Eq. (1), consist of two terms on the right-hand side. The first term, which is always negative, is called the "loss term"(3,7) and involves always the total (collision) cross section for a certain reaction type. The second term involves only the differential scattering cross section and is always positive; it is called the "gain term"(3,7). Loss term and gain term, respectively, indicate a loss or a gain in (positive) sensitivity in the sense that the total cross section always indicates a neutron interaction which removes the neutron from the considered phase-space volume $\{\Delta \underline{r}_i, \Delta \underline{\Omega}_m, \Delta E_g\}$ represented by {i,m,g}, while scattering interactions can transfer neutrons from other phase-space regions into the specific phase-space volume under consideration.

In order to avoid ambiguities in the interpretation of sensitivity profiles, careful consideration must be given to cases when the reaction cross section Σ_x is a composite cross section. Ideally, Σ_x should always be chosen as a partial reaction cross section of one exclusive type, like (n,α), (n,2n), (n,n')-elastic, etc. However, in practice, complete cross-section sets, including full scattering matrices, are seldom available for all desired partials. In such cases, composite cross sections must be used, such as total absorption, total inelastic or even total scattering cross sections, which complicates the interpretation of the resulting sensitivity profiles. If, for example, the (n,2n) cross section is treated as a negative portion of the total absorption cross section, which is the case in some standard transport cross-section sets, then it is possible that the loss term for the absorption cross section is positive for those groups where the (n,2n)-reaction dominates.

In order to facilitate the interpretation of sensitivity results, SENSIT prints loss and gain terms in addition to the net sensitivity profiles. In the following we give the discrete-ordinates equations which are the exact equivalents to the algorithms coded in SENSIT to produce the standard sensitivity profile output. A verbal synopsis of Eqs. (3) through (13) is printed with the SENSIT output if ITYP=0 or 3.

1. Pure Loss Terms. For the neutron sensitivity profiles 4 loss terms are printed but only 3 for the gamma-ray profiles:

$$AXS = P^g_{\Sigma_{abs,Loss}} = -\Sigma^g_{abs} \cdot \chi^g / I_\phi \cdot \Delta u^g \quad , \tag{3}$$

where Σ^g_{abs} is the absorption cross section in group g as taken from position IHA in the input cross-section tables (see Sec.V.A).

$$NU\text{-}FISS = P_{\nu\Sigma_{fiss,Loss}} = -\nu\Sigma^g_f \cdot \chi^g / I_\phi \cdot \Delta u^g \quad , \tag{4}$$

where $\nu\Sigma^g_f$ is the standard group-averaged product of fission cross section and number of fission neutrons per incident neutron. This "cross section" is taken from position IHA+1 of the input cross-section tables. One may note here, that if no absorption or fission cross-section profiles are desired, the data in cross-section table positions IHA and IHA+1 may be replaced with any other multigroup cross section to produce the loss-terms of sensitivity profiles for such substitute cross sections.

$$SXS = P^g_{\Sigma_{s,loss}} = -\Sigma^g_{s,loss}\ \chi^g / I_\phi \cdot \Delta u^g \quad , \tag{5}$$

where $\Sigma^g_{s,loss}$ is the total scattering cross section for all group transfers within group g and out of group g:

$$\Sigma^{g}_{s,loss} = \sum_{g'=g}^{GMAX} \Sigma^{g \to g'}_{s,o} \quad . \tag{6}$$

Equation (6) is evaluated in SENSIT by summing the P_o component of the scattering matrix along the appropriate diagonal, where GMAX denotes either the total number of neutron groups or the total number of gamma-ray groups for neutron or gamma-ray profiles, respectively.

$$\text{TXS} = P^{g}_{\Sigma_{T,loss}} = -\Sigma^{g}_{T} \ \chi^{g}/I_{\phi} \cdot \Delta u^{g} \quad , \tag{7}$$

where Σ^g_T is the total interaction cross section for group g as taken from position IHT in the input cross-section tables.

2. Pure Gain Terms. SENSIT prints 3 gain terms for the neutron profiles, but only one for gamma rays. The two additional gain terms for neutrons refer to (n,γ)-reactions and neutron secondary energy distributions as explained below.

$$\text{N-GAIN or G-GAIN} = P^{g}_{\Sigma_{s,gain}}$$

$$= \left\{ \sum_{\ell=0}^{LMAX} \sum_{g'=g}^{GMAX} \Sigma^{g \to g'}_{s,\ell} \ \psi^{gg'}_{\ell} \right\} \Big/ I_{\phi} \cdot \Delta u^{g} \quad . \tag{8}$$

The inner summation in Eq. (8) indicates that all sensitivity gains are counted which relate to scattering transfers within and out of group g into all other groups g'. For the neutron profile (N-GAIN) the upper limit of the group summation, GMAX, is the total number of neutron groups, while for the gamma-ray profile (G-GAIN), GMAX is chosen as the total number of gamma-ray groups.

$$\text{N-GAIN(SED)} = \tilde{P}^{g}_{\Sigma_{s,gain}} = \left\{ \sum_{\ell=0}^{LMAX} \sum_{g'=1}^{g} \Sigma_{s,\ell}^{g'\to g} \psi_{\ell}^{g'g} \right\} \Big/ I_{\phi}\cdot\Delta u^{g} . \qquad (9)$$

This partial profile is only printed for neutron groups and differs from N-GAIN of Eq. (8) by re-arranging g and g' and the group summation. N-GAIN(SED) therefore counts all sensitivity gains due to scattering transfers from all (higher) energy groups g' into group g. Hence, this profile may be considered as an adjoint to N-GAIN; its physical interpretation relates to the importance of neutron secondary energy distributions, as described in Section D.

$$\text{NG-GAIN} = P^{g}_{\Sigma_{(n,\gamma),gain}}$$

$$= \left\{ \sum_{\ell=0}^{LMAX} \sum_{g'=NCOUPL+1}^{IGM} \Sigma_{(n,\gamma),\ell}^{g\to g'} \psi_{\ell}^{gg'} \right\} \Big/ I_{\phi}\cdot\Delta u^{g} , \qquad (10)$$

where $\Sigma_{(n,\gamma),\ell}^{g\to g'}$ is the ℓ'th Legendre coefficient of the gamma-ray production cross section for neutron group g as taken from the input scattering matrix. The group summation in Eq. (10) indicates that all sensitivity gains are counted, which are due to transfers from neutron group g into all gamma-ray groups g'.

3. Net Sensitivity Profiles. SENSIT prints for both, the neutron as well as the gamma-ray profiles, two net (or total) sensitivity profiles which are obtained by summing the appropriate loss and gain terms according to Eq. (2).

$$\text{SEN} = P^{g}_{\Sigma_{s,net}} = P^{g}_{\Sigma_{s,loss}} + P^{g}_{\Sigma_{s,gain}} , \qquad (11)$$

where simply the partial profiles defined in Eqs. (5) and (8) are added for each group.

$$SENT = P^g_{\Sigma_{T,net}} = P^g_{\Sigma_{T,loss}} + P^g_{\Sigma_{s,gain}} \quad , \tag{12}$$

where the partial profiles of Eqs. (7) and (8) are added.

It may be noted here that Eqs. (11) and (12) differ only with respect to which loss term is chosen. The loss term of Eq. (12) may include the effects of many more reaction types than that of Eq. (11), depending on the contents of position IHT in the input cross-section tables. In contrast, however, the net sensitivity profile of Eq. (11) may be considered self-consistent because it utilizes only the information contained in the input transfer matrix, independent of the values for Σ^g_T in cross-section table position IHT.

4. Integral Sensitivities. All sensitivity profiles printed by SENSIT are also integrated over neutron energies and gamma-ray energies separately, i.e.

$$\text{Integral} = \sum_g SEN^g \cdot \Delta u^g \quad , \tag{13}$$

where the group summation extends form g = 1 through g = NCOUPL for neutron profiles and from g = NCOUPL+1 through g = IGM for gamma-ray profiles. As a test for the consistency of the calculation one might note that the integrals over Eqs. (8) and (9) must be identical and equal to the total neutron-scattering gain term. If any n-gamma gain terms (NG-GAIN) are calculated, they will be offset again in the net total neutron profile (SENT), because Σ_T includes a component due to (n,γ)-reactions which is counted in TXS as a neutron loss mechanism.

5. Source and Detector Sensitivity Profiles. All SENSIT runs (for any value of ITYP) print sensitivity profiles for the source and detector distribution functions Q(E) and R(E) even before any cross sections are read. These sensitivity profiles are based on the dualism[4] that the integral response I may be calculated independently either from the forward flux alone:

$$I_\phi = \int d\underline{r} \int d\underline{\Omega} \int dE \; R(\underline{r},E) \; \phi(\underline{r},\underline{\Omega},E)$$

$$= \sum_{i=1}^{IDET} \sum_{m=1}^{MM} \sum_{g=1}^{IGM} V_i \cdot R_i^g \cdot \phi_m^g(i) \cdot w_m \quad , \tag{14}$$

or from the adjoint flux alone:

$$I_{\phi^*} = \int d\underline{r} \int d\underline{\Omega} \int dE \; Q(\underline{r},E) \; \phi^*(\underline{r},\underline{\Omega},E)$$

$$= \sum_{i=1}^{ISRS} \sum_{m=1}^{MM} \sum_{g=1}^{IGM} V_i \cdot Q_i^g \cdot \phi_m^{*g}(i) \cdot w_m \quad , \tag{15}$$

where R_i^g and Q_i^g are the spatially and group dependent detector response function and neutron source distribution, respectively. If it is desired to determine how sensitive the integral response I is to the energy distribution of either R_i^g or Q_i^g, Eqs. (14) and (15) can be used to define a detector and source sensitivity profile, which may then be interpreted in exact analogy to the standard cross-section sensitivity profiles:

$$P_R^g = \sum_{i=1}^{IDET} \sum_{m=1}^{MM} V_i R_i^g \phi_m^g(i) \; w_m / I_\phi \cdot \Delta u^g \quad , \tag{16}$$

$$P_Q^g = \sum_{i=1}^{ISRS} \sum_{m=1}^{MM} V_i Q_i^g \phi_m^{*g}(i) w_m / I_{\phi^*} \cdot \Delta u^g \quad . \tag{17}$$

For internal consistency, the detector sensitivity profile P_R^g is normalized to I_ϕ from Eq. (14), while the source sensitivity profile P_Q^g is normalized to I_{ϕ^*} from Eq. (15). Ideally, of course, $I_\phi = I_{\phi^*}$. The integrals over Eqs. (16) and (17), according to Eq. (13), must be 1.0 if the spatial integrations are carried out over <u>all</u> source and detector zones. However, if the control parameter IOUTPUT is set to 1, then SENSIT prints P_R^g and P_Q^g and their integrals for each individual source and detector zone as well. These zone-wise integral sensitivities allow a quantitative interpretation of the relative importance of the various source and detector zones to the total integral response I.

B. Design Sensitivity Analysis (ITYP = 1)

The objective in a design-sensitivity analysis is to estimate the change of an integral response I due to a given design change without repeating the transport calculation for the altered design. Methods, based on generalized perturbation theory, have been developed which allow such estimates to be made with second-order accuracy in respect to the associated flux changes[4,7]. These perturbation methods require only the forward and adjoint flux solutions to a reference case and the specification of a perturbation to this reference design, which is equivalent to a postulated design change. All such design changes can be described then by a perturbation, ΔL, in the linear Boltzmann operator L.

Due to the dualism of forward and adjoint formulations for radiation transport calculations, two different but equivalent expressions can be derived for the estimated integral response in the perturbed system[4,7]. These expressions are both second-order with respect to flux changes but first-order with respect to the perturbation and are denoted as the adjoint difference (AD) and the forward difference (FD) formulation. Using the convenient operator notation of Refs. 4 and 7, we obtain for the integral response in the perturbed system the two expressions

$$I_{AD}^{(2)} = \langle R,\phi \rangle - \langle \phi^*,\Delta L\phi \rangle \equiv I_\phi^{(1)} - \Delta I_{AD}^{(2)} \quad , \tag{18}$$

$$I_{FD}^{(2)} = \langle Q,\phi^* \rangle - \langle \phi,\Delta L^*\phi^* \rangle \equiv I_{\phi^*}^{(1)} - \Delta I_{FD}^{(2)} \quad , \tag{19}$$

where <, > indicates integrations over all independent variables, and ϕ, ϕ^* are the forward and adjoint angular fluxes for the reference design. It may be noted that the first-order terms on the right sides of Eqs. (18) and (19) are computationally identical to I_ϕ and I_{ϕ^*} as defined in Eqs. (14) and (15). In addition, if the operators ΔL and ΔL* are written down explicitly[7], it is noted that the second-order term in Eq. (19) is equivalent to the negative of the numerator of Eq. (2) when the cross sections Σ_x are replaced by cross-section changes $\Delta\Sigma$, and when an additional integration over all energies E, namely, a summation over all groups g, is performed:

$$\Delta I_{FD}^{(2)} = \sum_{g=1}^{IGM} \left\{ \Delta\Sigma_T^g \cdot \chi^g - \sum_{\ell=0}^{LMAX} \sum_{g'=g}^{IGM} \Delta\Sigma_{s,\ell}^{g\to g'} \cdot \psi_\ell^{gg'} \right\} . \tag{20}$$

The analogous expression for the seond-order term in Eq. (18) becomes

$$\Delta I_{AD}^{(2)} = \sum_{g=1}^{IGM} \left\{ \Delta\Sigma_T^g \cdot \chi^g - \sum_{\ell=0}^{LMAX} \sum_{g'=1}^{g} \Delta\Sigma_{s,\ell}^{g'\to g} \cdot \psi_\ell^{g'g} \right\} . \tag{21}$$

The perturbation, as expressed by macroscopic cross-section changes in Eqs. (20) and (21) is calculated in SENSIT from two sets of input cross-section tables, the unperturbed or reference cross-section set $\{\bar{\Sigma}\}$ and the perturbed cross-section set $\{\Sigma\}$:

$$\Delta\Sigma_T^g = \Sigma_T^g - \bar{\Sigma}_T^g , \tag{22}$$

$$\Delta\Sigma_{s,\ell}^{g\to g'} = \Sigma_{s,\ell}^{g\to g'} - \bar{\Sigma}_{s,\ell}^{g\to g'} \tag{23}$$

$$\Delta\Sigma_{s,\ell}^{g'\to g} = \Sigma_{s,\ell}^{g'\to g} - \bar{\Sigma}_{s,\ell}^{g'\to g} . \tag{24}$$

A design sensitivity coefficient X may be defined for both (AD and FD) formulations according to

$$X_{AD} = I_{AD}^{(2)}/I_\phi^{(1)} = 1 - \Delta I_{AD}^{(2)}/I_\phi^{(1)} , \tag{25}$$

$$X_{FD} = I_{FD}^{(2)}/I_{\phi*}^{(1)} = 1 - \Delta I_{FD}^{(2)}/I_{\phi*}^{(1)} \quad , \qquad (26)$$

from which the estimated fractional change of the integral response I due to the introduction of the perturbation can be easily determined.

It has been demonstrated in Refs. 4 and 7 that the AD-formulation is more appropriate for cases where the perturbation is geometrically closer to the detector than to the source, while the FD-fomulation is better suited for cases where the perturbation is geometrically closer to the source than to the detector. However, if both reference fluxes, ϕ and $\phi*$, are completely converged, then both formulations will give identical results.

SENSIT prints all design sensitivity information, as defined in Eqs. (18) through (26), separately for neutrons and gamma rays; also, if IOUTPUT = 1, it prints the same information for each perturbed zone as well as integrated over all perturbed zones. If the control parameter ITYP is set to 1, the SENSIT output will also contain a synopsis defining the variable names used to edit the design sensitivity information.

If the control parameter IDESIGN is set equal to 1, then the special case of a design perturbation is assumed, which is equivalent to a 1% increase in all cross sections in all perturbed zones, i.e., Eqs. (22) through (24) are replaced by $\Delta\Sigma = 0.01\Sigma$. Such a perturbation may also be interpreted as if the material density in the perturbed zones were increased by 1%. In this mode only one cross-section set $\{\Sigma\}$ needs to be read into SENSIT per case.

C. Vector Cross-Section Sensitivity and Uncertainty Analysis (ITYP = 2)

The term "vector cross-section" has been chosen to identify a multigroup cross-section set which consists of a linear string of numbers with one group-averaged reaction cross section per group, but no scattering matrix. Such a cross-section set can be described by a vector, or one-dimensional array, with IGM elements, in contrast to the two-dimensional cross-section tables, which include transfer matrices. All reaction cross sections which do not need to describe the production of secondary neutrons or gamma rays, such as (n,α), (n,abs.), Σ_T, etc., are completely described by a vector cross section. Obviously, by definition, such vector cross-sections can only generate a loss term in a sensitivity analysis. However, existing correlations between two individual vector cross sections are easily described by a simple two-dimensional correlation matrix. As a consequence, therefore, it is also straightforward to describe correlated cross-section uncertainties of pairs of vector cross sections by a two-dimensional covariance matrix[5]. For ITYP = 2, SENSIT performs a complete sensitivity and response uncertainty analysis for given sets of vector cross-section pairs $\{\Sigma_1^g\}$ and $\{\Sigma_2^g\}$ with an associated covariance matrix $Cov(\Sigma_1^g,\Sigma_2^{g'})$ attached to each pair. These pairs of vector cross sections with their covariance matrix are read from TAPE10 by identification numbers as specified in the input stream. In coupled (n,γ)-calculations, this analysis is treating only the neutron groups.

As a first step SENSIT calculates the sensitivity profiles P_1^g and P_2^g for each individual vector cross section according to an equation equivalent to Eq. (3), i.e., a pure loss term. Then the covariance matrix $Cov(\Sigma_1^g,\Sigma_2^{g'})$ is used to compute the resulting integral response uncertainty due to the correlated cross-section uncertainties of this pair of vector cross sections according to[5]

$$Var(I_\phi) = \sum_{g=1}^{IGM1} \sum_{g'=1}^{IGM1} P_1^g \cdot P_2^{g'} \cdot Cov\, \Sigma_1^g,\Sigma_2^{g'} \quad . \tag{27}$$

The upper limit of the double sum, IGM1, is the number of neutron groups (IGM1 = NCOUPL in a coupled (n,γ)-problem). Both, the variance $Var(I_\phi)$ as well as the relative standard deviation

$$\frac{\delta I}{I} = \sqrt{Var(I_\phi)} \quad , \tag{28}$$

are printed by SENSIT for each vector cross-section pair. Since all cross-section uncertainties pertaining to one material may be described by a sum of several vector cross-section covariance matrices, SENSIT also prints specified sums of response variances

$$Var(I_\phi)_{MAT} = \sum_{n=1}^{NSUMCOV} Var_n(I_\phi) \quad , \tag{29}$$

and the resulting standard deviation $(\delta I/I)_{MAT}$, assuming that NSUMCOV vector cross-section pairs describe the cross sections for one material sufficiently.

D. SED Sensitivity and Uncertainty Analysis (ITYP = 3)

It has only recently been recognized[8] that sensitivity profiles for secondary energy and angular distributions are obtained as adjoints of the standard sensitivity profiles, i.e., from the differential form of the adjoint difference (AD) formulation. For ITYP = 3, SENSIT computes and prints the double-differential and single-differential sensitivity profiles for secondary energy distributions (SED's) and performs also an SED uncertainty analysis based on the hot/cold concept of integral SED uncertainties[9]. A sensitivity or uncertainty analysis for secondary angular distributions is not implemented in this version of SENSIT. Also, the SED sensitivity and uncertainty analysis is not performed for secondary gamma rays in the case of a coupled (n,γ)-calculation.

As shown in Ref. (8), a double-differential SED sensitivity profile is described by the differential form of the gain term in the AD-formulation; cf. Eq. (21) and Eq. (9):

$$P_{SED}^{g',g} \equiv \mathrm{PSED(g\text{-}in,g\text{-}out)}$$

$$= \left\{ \sum_{\ell=0}^{LMAX} \Sigma_{s,\ell}^{g'\to g} \cdot \psi_{\ell}^{g'g} \right\} \Bigg/ I_{\phi} \cdot \Delta u^{g'} \cdot \Delta u^{g} \quad . \tag{30}$$

This double-differential SED sensitivity profile quantifies the sensitivity of the integral response I_{ϕ} to the scattering matrix element $\Sigma_s^{g'\to g}$. Therefore, $P_{SED}^{g',g}$ is a pure gain term for the sensitivity gain due to the transfer of neutrons from the incident energy group g' to the final energy group g. $P_{SED}^{g',g}$ is double differential because it is scaled to the product of both lethargy widths, $\Delta u^{g'}$ and Δu^{g}, of the incident and the final energy groups.

From Eq. (30), two single-differential SED sensitivity profiles may be obtained, depending upon which of the two group indices an integration is performed:

$$P^{g}_{SED} \equiv PSED(g\text{-}out) = \sum_{g'=1}^{g} P^{g',g}_{SED} \cdot \Delta u^{g'} \quad , \tag{31}$$

and

$$P^{g'}_{SED} \equiv PSED(g\text{-}in) = \sum_{g=g'}^{g} P^{g',g}_{SED} \cdot \Delta u^{g} \quad . \tag{32}$$

Equation (31) describes the sensitivity of I_ϕ to the sum of all scattering transfer cross sections which transfer neutrons from any incident energy group g' into the specific final energy group g. $P^{g}_{SED} \equiv$ PSED(g-out) is identical to N-GAIN(SED), as defined earlier in Eq. (9). In complete analogy, Eq. (32) adds up all sensitivity gains due to neutron transfers originating in group g' and transferring into any final energy group $g \geq g'$. $P^{g'}_{SED} \equiv$ PSED(g-in), when given as a function of g' is, therefore, identical to the standard sensitivity gain term N-GAIN(g), as defined in Eq. (8), where the nomenclature for g and g' is reversed.

In order to perform an SED uncertainty analysis based on the hot/cold concept introducted in Ref. 9, it is required to specify the median energy group of the SED for each incident neutron energy group, GMED(g'), as well as the associated integral SED uncertainty (spectral shape uncertainty parameter), $F_{SED}(g')$, for each SED with incident energy group g'. GMED(g') and $F_{SED}(g')$ are expected input arrays in SENSIT if ITYP = 3 and NSED = 1. Hot and cold integral SED sensitivity coefficients, $S_{HOT}(g')$ and $S_{COLD}(g')$, are then computed by SENSIT according to[9].

$$S_{HOT}(g') = \Delta u^{g'} \cdot \sum_{g=g'}^{GMED(g')} P^{g',g}_{SED} \cdot \Delta u^{g} \quad , \tag{33}$$

$$S_{COLD}(g') = \Delta u^{g'} \cdot \sum_{g=GMED+1}^{IGM1} P^{g',g}_{SED} \cdot \Delta u^{g} \quad . \tag{34}$$

From these two components of an integral SED sensitivity, SENSIT obtains the net integral SED sensitivity cofficient

$$S(g') = S_{HOT}(g') - S_{COLD}(g') \quad , \tag{35}$$

which quantifies how much more sensitive the integral response I_ϕ is to the hot component of the SED at incident energy group g' than to its cold component. The simplest possible response uncertainty estimate due to estimated SED uncertainties is then obtained from[9]

$$\left.\frac{\delta I}{I}\right|_{SED} = \sum_{g'=1}^{IGM1} \left|S(g')\right| \cdot F_{SED}(g') \quad . \tag{36}$$

Values for all SED sensitivity profiles, as defined in Eqs. (30) through (32), all integral SED sensitivity coefficients, Eqs. (33) through (35), and the estimated response uncertainty due to all integral SED uncertainties according to Eq. (36), are printed by SENSIT for each set of material cross sections and associated integral SED uncertainties.

IV. COMPUTATIONAL OUTLINE

Basically the SENSIT code reads angular-flux data and differential cross-section data and then performs the arithmetic calculations defined in the previous section. Therefore, no intrinsically complex computational algorithms are of concern, but an efficient management of large arrays of data is of prime importance. The code therefore employs variable dimensioned arrays throughout and uses for economical storage allocations a separate data management package (BPOINTR) subroutines. This software package has been developed by Argonne National Laboratory and is also a part of most ANL originated codes such as MC^2-2 (ANL-8144) or FX2-TH (ANL-78-97). Our version of BPOINTR is described in Ref. 10; a later, more comprehensive version of this data management package has recently been issued and its documentation is in print[11].

A. Overall Program Flow

The entire SENSIT code consists of four functionally different parts:

1. The main program which operates as a driver routine to allocate core space through BPOINTR subroutine calls.
2. Computational subroutines which evaluate the expressions defined in the previous section.
3. Data management subroutines from the BPOINTR package and standard FORTRAN functions from systems libraries.
4. Text editing routines which output the computed results.

In the following we describe the functions of all relevant subroutines in as much detail as may be required to understand the flow of computations performed in SENSIT.

B. Data Management and Storage Requirements

SENSIT uses one-, two-, and three-dimensional arrays to manage the large amount of numerical data involved in its execution. Core storage is reserved for a particular dimensioned array only during the time the corresponding data are required to be in-core; at other times, the space is made available for the storage of other data. In order to alleviate bookkeeping chores associated with such dynamic storage allocation techniques, Argonne National Laboratory developed a collection of subroutines, called the BPOINTR package[10,11], which is incorporated in SENSIT. The user needs to know nothing about the BPOINTR routines themselves, only that they require two large blocks of workspace called "containers" for data storage during execution of a job. The container sizes are set in the main program by four FORTRAN statements as explained below, and the choice of sizes is problem dependent. The first container, the FCM (fast-core memory) or SCM (small-core memory) container, is in the CDC-7600's fast memory. The second, the ECM (extended-core memory) or LCM (large-core memory) container, is in the slower memory banks of the CDC-7600. On IBM machines, both containers are in fast memory[10,11].

In SENSIT, the main program is the control routine which defines the two container arrays and makes appropriate calls to BPOINTR subroutines to control the dynamic allocation of space within these containers. Calls to calculational subroutines transmit pointers corresponding to array locations through the calling sequences. Detailed program documentation for the BPOINTR package, including flow charts, common block information and subroutine descriptions, is available in Ref. 11. A shorter, functional write-up is provided in Ref. 10, which gives calling sequences for the BPOINTR routines.

The SCM container is a blank common block BLK and is assigned in the main program by the two FORTRAN statements

```
COMMON BLK(24000)
MAXSIZ = 24000   .                                    (37)
```

The container size of 24 000 words is chosen so that the SENSIT code uses all of the available small (fast) core memory on the CDC-7600 at execution, after the code itself is stored there. Only the relatively small data arrays and arrays which are being used repeatedly during execution are allocated to this SCM container. On the CDC-7600 the full SCM is always available for any job, therefore, no operational advantage is achieved by reducing this pre-programmed container size to a smaller SCM allocation.

The LCM container is a named common block, ARRAY2, and is assigned in the main program by the two FORTRAN statements

```
COMMON /ARRAY2/ BLKECS(80000)   ,
CALL BULK(80000)   .                                  (38)
```

The container size (in this case 80 000 words) is completely problem dependent and should be chosen before execution according to the specific problem or machine size. An advantage at execution (quicker access to the machine, shorter job turn-around time, less computer costs if the charging algorithm counts the required LCM size) is realized when BLKECS is chosen as small as possible. To achieve this, the LCM container size in the two statements, given in (38), at the beginning of the main program must be changed simultaneously. The optimal size of BLKECS is probably best obtained by trial and error.

All large data arrays (two- and three-dimensional arrays) are stored in the LCM container BLKECS at the time when they are needed for execution in one of the computational subroutines. At one specific time there are never all LCM arrays stored in BLKECS, because the BPOINTR package allows to take out unneeded arrays and re-use that space to put in new arrays. Therefore, it is very difficult to predict the minimum size required for BLKECS just on the basis of input array sizes. However, if even the maximum available LCM on a specific computer may not be large enough to accomodate the minimum required BLKECS for a specific problem, the knowledge of which arrays are stored in LCM can help to indicate how or on which input arrays the problem might be trimmed down to fit the maximum available core space.

The major input arrays assigned to BLKECS are the angular flux arrays for ϕ and ϕ^* in the detector, source and perturbed zones, and the cross section arrays, as listed in Table I. The lengths of these arrays are also given in Table I as a function of input control parameters. This table allows the user to identify the largest arrays, which must be stored for a specific problem. If a problem must be trimmed in size to fit into LCM, it is then recommended to attempt to first cut down on the largest arrays. For example, if the cross-section arrays are dominating the LCM container space, a reduction in array size is easily achieved by choosing a lower order of cross section anisotropy; i.e., a smaller LMAX. Or, if the angular flux arrays are overwhelming the LCM container, one can simply reduce IPER, ISRS or IDET by including only a part of all perturbed, source, or detector zones in one SENSIT run. In this case the full problem is solved by a series of smaller size SENSIT runs.

C. Summary of Subroutine Functions

Basically, all subroutines are called from the main program with a few exceptions where subroutines are called from other subroutines. Comment cards are inserted generously at the subroutine calls as well as in between executable statements in the main program and in all subroutines. Here we summarize only the general functions carried out by each computational subroutine. We use the nomenclature defined in previous sections.

Since data management, as opposed to computational complexity, is of prime concern in SENSIT, as explained above, most subroutine calls refer to the dynamic

TABLE I

ARRAYS ALLOCATED TO THE LCM CONTAINER ARRAY BLKECS

Array Name	Length of array (words)	Subroutine in which array is first used	Array only used if
PHI	(IM+1)*MM	SUB2A	always
PHID	IGM*IDET*MM	SUB2A	always
COVR	IGM*IGM	SUB2A	DETCOV = 1
FISTAR	(IM+1)*MM	SUB2B	always
FISTAS	IGM*ISRS*MM	SUB2B	always
FISS	IGM*ISRS*MM	SUB2B	always
PHIP	IGM*IPER*MM	SUB3	always
FISP	IGM*IPER*MM	SUB3	always
FISTAP	IGM*IPER*MM	SUB3	always
XS	(IGM+IHT)* *IGM*(LMAX+1)	SUB5	ITYP = 0,1,3
XSBAR	(IGM+IHT)* *IGM*(LMAX+1)	SUB5	ITYP = 0,1,3
DSL	IGM*IGM* *NMOM (+)	SUB6	ITYP = 0,1,3
DSLFD	IGM*IGM* *NMOM (+)	SUB6	ITYP = 0,1,3
PSI	IGM*IGM *NMOM	SUB4	ITYP = 0,1,3
PSED	IGM1*IGM1	SUB11	ITYP = 3
COV	IGM1*IGM1	SUB5V	ITYP = 2

(+)NMOM = LMAX+1 for IGE = 1,3

= $(LMAX+2)^2/4$ for IGE = 2

= $(LMAX+1)^2$ for IGE = 4

storage allocation scheme provided by the BPOINTR package. Since these routines are described in detail elsewhere[10,11], we just summarize here the subroutine names which belong and refer to the BPOINTR package.

1. BPOINTR Package. Subroutines from the BPOINTR package which perform all dynamic storage allocation functions within SENSIT are:

POINTR	IPTERR	PRTI1E	ALLOC1
PUTPNT	PUTM	PRTI2E	ALLOC2
BULK	REDEF	PRTI2	IPT2
FREE	REDEFM	PRTR1E	ILAST
WIPOUT	PURGE	PRTR2	MEMGET
GETPNT	STATUS	PRTR2E	MEMGET1
IGET	PRTI1	FREE1	SQUEEZE
			SQUEEZEX

These subroutines are attached to SENSIT after the computational subroutines.

2. Subroutine SUB1. This routine reads, from input cards, the neutron and gamma-ray group structures $E_n(g)$ and $E_\gamma(g)$, the S_N quadrature weights w(m) and level cosines MUE(m), all geometry information such as spatial mesh boundaries z(i), and the interval numbers which identify source, detector and perturbed zones in the problem. SUB1 calculates the lethargy widths per group, Δu^g, and spatial mesh cell volumes V_i. The numbering sequence of the spatial mesh cells is reordered for the source, detector, and perturbed zones as described in Sec. V.C. This renumbering is achieved by three calls to subroutine MAP as described later. A somewhat elaborate editing algorithm is also built into SUB1 which prints the geometry information in one summary table that allows for easy debugging of input errors.

3. Subroutine SNCON. This routine is borrowed from the ONETRAN discrete-ordinates transport code[12] and generates point directions and point weights for the input S_N quadrature set $\{w_m, \mu_m\}$. It also computes the Legendre polynomials $P_\ell(\mu_m)$ and the more general spherical harmonic functions required for cylindrical and two-angle slab geometries.

4. Subroutine SUB2A. The main function of this routine is to calculate I_ϕ or $I_\phi^{(1)}$, the integral response for the unperturbed reference case, computed only from forward fluxes from Eq. (14). For this purpose the energy and spatial distribution functions for the detector response, RHO(g) and RHO(j), are read from input cards. The forward angular flux in the detector zones is read from TAPE1. As a by-product of the calculation of I_ϕ according to Eq. (14), the detector sensitivity profile P_R^g, Eq. (16), is also obtained and edited. If DETCOV = 1 and a covariance matrix COVR(g,g') is provided in the input, then subroutine SUB9 is called to perform a detector response uncertainty analysis.

5. Subroutine SUB2B. This routine performs functions analogous to SUB2A, except for the adjoint fluxes. First the energy and spatial distribution functions for the source distribution, QUE(g) and QUE(j), are read from input cards. Then, the adjoint angular flux in the source zones is read from TAPE2 and its group and directional order reversed to confirm to the same ordering as used for the forward flux. The integral response I_{ϕ^*}, obtained from the adjoint flux distribution alone, is calculated via Eq. (15), together with the source sensitivity profile P_Q^g via Eq. (17).

6. Subroutine SUB3. The main function of this routine is to read forward and adjoint angular fluxes from TAPE1 and TAPE2 for all perturbed zones. The adjoint angular fluxes are also reordered with respect to their group and angular variables to confirm with the ordering principle of the forward fluxes.

7. Subroutine MAP. MAP is a special utility routine which is called from subroutine SUB1 to renumber spatial mesh cells for given zones . Specifically, MAP generates an integer map for all spatial mesh boundaries, such that those mesh boundaries within specified (disjoint) zones are numbered consecutively, while those outside these zones are set to zero (Sec. V. C).

8. Subroutine SUB4. Using the forward and adjoint angular fluxes, $\phi_m^g(i)$ and $\phi_m^{*g}(i)$, for spatial intervals within perturbed zones, SUB4 calculates the arrays χ^g and $\psi_\ell^{gg'}$ required for the evaluation of sensitivity loss and gain terms, respectively. Two intermediate arrays, $X_\ell^g(i)$ and $Y_\ell^{g'}(i)$, are used to finally compute $\psi_\ell^{gg'}$ as defined in Sec. II. A.

9. Subroutine SUB4V. For vector cross-section sensitivity analyses (ITYP = 2) only sensitivity loss terms are computed. Therefore only the array χ^g is needed, but not $\psi_\ell^{gg'}$. Hence, if ITYP = 2, subroutine SUB4V is called instead of SUB4 to calculate χ^g as a spatial integral over all perturbed zones.

10. Subroutine SUB5. The general function of this routine is to read into SENSIT the needed differential cross sections, either from input cards or from TAPE4. SUB5 is only called for ITYP = 0, 1, 3, but not for ITYP = 2 because the vector cross-section sensitivity analysis requires a special cross-section tape, TAPE10, which is differently formatted than TAPE4. SUB5 is written in 3 different sections to read cross sections (a) in LASL format from cards, (b) in LASL format from TAPE4, and (c) in limited FIDO (ORNL) format from cards. For detailed format specifications we refer to Sec. V.A. SUB5 reads a complete cross-section table for each material, which includes LMAX Legendre components with IGM energy groups and a table length of IGM+IHT. After the (assumed) microscopic cross sections are read, SUB5 converts them immediately to macroscopic cross-sections using the input number densities.

11. Subroutine SUB5V. For the case of a vector cross-section sensitivity and uncertainty analysis (if ITYP = 2) SUB5V is called instead of SUB5 to read cross sections into SENSIT. SUB5V first reads, from input cards, the identification number and two number densities for the pair of vector cross sections to be read from TAPE10. Then subroutine COVARD is called from SUB5V, which actually reads the microscopic cross-section pair, Σ_1^g and Σ_2^g, together with the relative covariance matrix $\mathrm{Cov}(\Sigma_1^g,\Sigma_2^{g'})$. This information is printed if ITEST = 3. Finally, SUB5V generates macroscopic cross sections using the number densities read from input cards.

12. Subroutine SUB6. This routine extracts from the full cross-section tables the vector cross-sections Σ_{abs}^g, $\nu\Sigma_f^g$, $\Sigma_{s,loss}^g$, Σ_T^g, and the down-scattering matrix $\Sigma_{s,\ell}^{g\to g'}$. For design sensitivity analyses (ITYP = 1) these cross-section data are prepared for both the perturbed (Σ) as well as the unperturbed ($\bar{\Sigma}$) cross sections in order to then calculate the net cross-section perturbations, according to Eqs. (22) through (24). In addition, the total macroscopic scattering cross section per group is calculated directly from the scattering matrix, according to Eq. (6), by summing $\Sigma_{s,o}^{g\to g'}$ along diagonals. In coupled neutron/

gamma-ray calculations (if NCOUPL > 0) the total gamma-ray production cross section per neutron group is also evaluated. If ITEST = 1 is chosen, SUB6 will print all of the above calculated cross sections for all groups.

13. Subroutines TEXT and TEXTA. These two routines have the exclusive function to print definitions of variable names which are used when the computational results are edited. TEXT prints a list of definitions pertaining to the standard cross-section sensitivity analysis when ITYP is chosen as 0 or 3. TEXTA prints another list of definitions used for design sensitivity output (if ITYP=1).

14. Subroutine SUB8. This routine calculates and edits the final results of the sensitivity analyses for the standard (ITYP = 0) and design sensitivity (ITYP = 1) cases. SUB8 uses the previously prepared cross-section arrays from SUB6 and the arrays χ^g and $\psi_\ell^{gg'}$ from SUB4 to evaluate Eqs. (3) through (5), Eqs. (8) through (15), Eqs. (18) through (21) and Eqs. (25) and (26). If IOUTPUT = 1, all sensitivity results are printed for each individual perturbed zone and for the sum over all perturbed zones, while for IOUTPUT = 0 a considerably shorter printout is provided by editing only the sensitivity results integrated over all perturbed zones.

15. Subroutine SUB8V. In the case of a vector cross-section sensitivity and uncertainty analysis (ITYP = 2) all editing is provided by SUB8V instead of SUB8. First the sensitivity profiles, P_1^g and P_2^g, for the pair of vector cross sections read from TAPE10 via SUB5V are evaluated and edited. Then the uncertainty analysis, according to Eqs. (27) and (28), for this cross-section pair is performed using the relative covariance matrix $\mathrm{Cov}(\Sigma_1^g,\Sigma_2^{g'})$, which has also been read from TAPE10 via subroutine SUB5V.

16. Subroutine SUB9. Should a covariance matrix be provided for the detector response function R(g), i.e., if DETCOV = 1, then SUB9 is called to read these data and perform the relevant uncertainty analysis. Response variances are also calculated for the special cases of assumed full correlation (+1) and the completely uncorrelated case.

17. Subroutine SUB9V. This routine is called only if ITYP = 2 and NSUMCOV > 0, i.e., when partial sums are required of individual response vari-

ances. SUB9V first reads the integers SUMSTRT and SUMEND which define the variances to be summed. Assuming no correlations between the individual vector cross-section errors specified in any or all of the NCOV covariance matrices, SUB9 then computes the total variance and relative standard deviation.

18. Subroutine COVARD. For vector cross-section uncertainty analyses (ITYP = 2), the routine COVARD is called to read into SENSIT, from TAPE10, the pair of vector cross sections with their respective covariance matrix for each specified identification number. The input ID number is correlated with ENDF/B specifications through a call to subroutine SETID. It is important to note that all arrays in subroutine COVARD are fixed-dimensioned, i.e., their field length is not dynamically allocated as is the case for all other arrays in SENSIT. In the present version of SENSIT, the 2 arrays describing the covariance matrices are restricted to a maximum size of 50 x 50 each. This is not a serious restriction of the code and may be changed at any time. The choice of 50 x 50 was rather arbitrary, considering our specially prepared TAPE10 which uses only 30 neutron groups.

19. Subroutine SETID. This routine is called only from COVARD and has the sole function to translate the input ID numbers for vector cross-section pairs into ENDF/B nomenclature. It is these latter identifiers which are required to read data from TAPE10.

V. DETAILS OF PROGRAM OPTIONS

In this section we describe special details which are helpful in preparing input to SENSIT or may prove valuable if modifications of the FORTRAN coding are considered.

A. Cross-Section Input Options

If ITYP = 0, 1, 3, complete transport cross-section tables are read into SENSIT by subroutine SUB5; if ITYP = 2, a specially formatted vector cross-section file is read from TAPE10 as described later.

1. Transport Cross-Section Tables. Three options are built into subroutine SUB5 to read standard neutron (or coupled neutron/gamma-ray) cross-section sets: first, LASL format cross sections from cards; second, LASL format cross sections from TAPE4; and third, limited FIDO (ORNL) format cross sections from cards. The general structure of all transport cross-section tables is as described in the transport code literature; e.g, the ONETRAN[12] or ANISN manual[13]. Each nuclide is described by a cross-section table of IGM columns and length ITL = IGM + IHT. The position of a certain cross section in each of the IGM columns is specified relative to the total cross-section (pos. IHT). The following ordering is assumed in the column for group g:

general XS-position	XS type	XS-position in typical standard XS set
.	.	
.	.	
.	.	
IHT-4	$\sigma_{n,2n}$	–
IHT-3	$\sigma_{transport}$	–
IHT-2 = IHA	σ_{abs}	1
IHT-1	$\nu\sigma_f$	2
IHT	σ_T	3
IHS = IHT + 1	$\sigma_s^{g\rightarrow g}$	4
IHS + 1	$\sigma_s^{g-1\rightarrow g}$	5
.	.	.
.	.	.
.	.	.
IHT+IGM = ITL	$\sigma_s^{g-IGM+1\rightarrow g}$	IGM + 3

The requirements that IHS = IHT + 1 and ITL = IHT + IGM restricts these cross-section tables to include only downscattering but no upscattering. The test printout in sample problem 1 contains an example of a coupled 6-group cross-section set with 3 neutron and 3 (identical) gamma-ray groups. Since this printout is generated line-by-line, the sequence of data along lines corresponds to the ordering along columns as discussed above.

If anisotropic scattering is considered, then the complete cross-section set for an isotope or reaction is expected to consist of LMAX+1 cross-section tables representing Legendre exapansion coefficients. Note, however, that two different conventions are presently being used for such expansions. Omitting the energy dependence and abbreviating $\mu_o = \underline{\Omega}\cdot\underline{\Omega}'$ we have:

a. LASL (ONETRAN, etc.) convention:

$$\Sigma_s(\mu_o) = \sum_{\ell=0}^{LMAX} \frac{2\ell+1}{4\pi} \cdot \Sigma_{s,\ell}^{LASL} \cdot P_\ell(\mu_o) \quad , \tag{39}$$

so that

$$\Sigma_{s,\ell}^{LASL} = 2\pi \int_{-1}^{+1} \Sigma_s(\mu_o)\, P_\ell(\mu_o)\, d\mu_o \quad . \tag{40}$$

b. ORNL (ANISN, etc.) convention:

$$\Sigma_s(\mu_0) = \sum_{\ell=0}^{LMAX} \frac{1}{4\pi} \cdot \Sigma_{s,\ell}^{ORNL} \cdot P_\ell(\mu_0) \quad , \tag{41}$$

so that

$$\Sigma_{s,\ell}^{ORNL} = 2\pi\ (2\ell + 1) \int_{-1}^{+1} \Sigma_s(\mu)\, P_\ell(\mu_0)\, d\mu_0 \quad . \tag{42}$$

Due to these different conventions the higher-order components of the scattering tables differ by a factor of $(2\ell + 1)$:

$$\Sigma_{s,\ell}^{ORNL} = (2\ell + 1)\,\Sigma_{s,\ell}^{LASL} , \tag{43}$$

which is compensated for in SENSIT subroutines SUB8 and SUB11 according to KXS = 1 or 2.

The actual formats in which the cross sections are read into SENSIT differ also according to KXS = 1 or 2, and IXSTAPE = 0 or 1:

c. LASL-Formatted Transport Cross Sections From Cards (KXS = 1 and IXSTAPE = 0): The standard LASL cross-section format expects a string of data which corresponds to reading the above-mentioned cross-section table columnwise in ascending group order. The format for the numerical data is a 6E12.5 data field which expects 6 numbers per card. The only difference between cross sections read from cards or from tape lies in the title cards and the number density specifications. If KXS = 1 and IXSTAPE = 0, the format for one complete cross-section set is:

Input Array Name	Number of Entries	Input Format	Required only if	Description
TITLE	1 card	20A4	always	XS title card for this material
NUMDEN, JCOVAR	2 words	12X,E12.6, 11X,I1	always	NUMDEN = number density of cross section. JCOVAR = indicator if the last P_ℓ-XS set is followed by a covariance matrix, 0/1 = no/yes.
PLTITL	1 card	20A4	always	title card for P_0-component.
XS(g,g',0)	IGM*ITL	6E12.5	always	microscopic cross-section set for P_0-component.
PLTITL	1 card	20A4	LMAX > 0	title card for P_ℓ-component
XS(g,g',ℓ)	IGM*ITL	6E12.5	LMAX > 0	microscopic cross-section set for P_ℓ-component.

Input Array Name	Number of Entries	Input Format	Required only if	Description
				Note: For each P_L-component a set of {PLTITL,XS} must be input, until L = LMAX is reached.
CTITL	1 card	8A10	JCOVAR = 1	title card for covariance matrix.
COV(g,g')	IGM*IGM	6E12.5	JCOVAR = 1 and ITYP = 0	covariance matrix for cross-section set XS(g,g',ℓ)

If a design sensitivity is required (ITYP = 1) with an independent reference cross-section $\bar{\Sigma}$ (IDESIGN = 0), then a second complete cross-section set XSBAR(g,g',ℓ), starting with a material title card, is expected.

If JCOVAR on the number density card is 1 and a relative covariance matrix is entered, then SENSIT performs a cross-section uncertainty analysis analogous to the vector cross-section uncertainty analysis, where Eqs. (27) and (28) are evaluated for the net sensitivity profile as defined in Eq. (11), i.e., $P_1 = P_2 =$ SEN.

d. LASL-Formatted Transport Cross Sections From TAPE4 (KXS = 1 and IXSTAPE = 1):

In this case the cross-section data are read from a card-image tape according to their material sequence number. It is assumed that, for ITYP = 0 or 3, a tape has been prepared which contains complete cross-section sets for an arbitrary number, say MAXMAT, of materials. Then each cross-section set per material is identified by its sequence number between 1 and MAXMAT, which is then the material's ID number. The card input then must specify only this ID-number and the associated number density in order for SENSIT to read the desired cross-section set from TAPE4, as described in the detailed input specifications: 1 card with (ID, NUMDEN, XSNAME) is required for each of the NPERXS cases.

TAPE4 must then be formatted as follows:

1. record: title card (20A4) for material 1, P_0 component
2. record: P_0-XS data for ID = 1, IGMxITL words in (6E12.5)-format

3. record: title card for ID = 1, P_1 component

4. record: P_1-XS data for ID = 1,

⋮

n-th. rec.: title card for ID = 2, P_0 component

(n+1)st. rec.: P_0-XS data for ID = 2

(n+2)nd. rec.: title card for ID = 2, P_1 component

⋮

m-th. rec.: P_{LMAX}-XS data for last material (ID = MAXMAT).

e. FIDO (ORNL)-Formatted Cross Sections From Cards (KXS = 2 and IXSTAPE = 0): This option has been incorporated for convenience in cases when ANISN angular fluxes are used. We transferred the cross-section input algorithm from our (rather old) version of ANISN into SUB5 of SENSIT, which allows SENSIT to read the same cross sections as ANISN when KXS is set to 2. However, we caution the use of this option because there are a great many different versions of ANISN and FIDO routines in existence and compatibility among these different versions is not guaranteed. Moreover, we are unable to precisely date our version of ANISN from which this cross-section input algorithm was taken.

A total of LMAX+1 P_ℓ cross-section tables, based on definitions given in Eqs. (41) and (42), define a complete material cross-section set, where again each P_ℓ-table is preceded by a title card. The actual cross-section data are expected in a fixed-field FIDO format which allows blank fields and the repeat option. For a detailed description of the FIDO format we refer to Ref. 13, but stress again the limitations of our version, as mentioned above. To eliminate any remaining ambiguity, we recommend the editing of any cross sections used with ANISN and then reformatting them into the simpler LASL-formatted TAPE4 as described in the previous paragraph.

2. Vector Cross-Section and Covariance Matrix Input. If ITYP = 2, SENSIT reads pairs of vector cross-sections with their associated covariance matrix from TAPE10 which, therefore, must be specially prepared as described below.

3. Multigroup Processing of ENDF/B Covariance Data to Generate TAPE10.*

The NJOY code[14] was used for processing the ENDF/B-V covariance data into the 30-energy group multigroup structure used in a separate study[15] for TAPE10. The module in NJOY that specifically does this processing is the ERRORR module. The multigroup output of the ERRORR module is in an ENDF-like format; a sample of this output is given in Table II.

The data in Table II are given in standard ENDF/B BCD records or "cards" consisting of 80 columns divided into 10 fields. The first 6 fields are 11 digits wide and are used for either floating point numbers or integers. The 7th, 8th, 9th, and 10th field are 4, 2, 3, and 5 digits wide, respectively, and are used for integers only. In these latter 4 fields, that is, fields 7, 8, 9, and 10, the digits in the field of 4 (field No. 7) represent the MAT or "material number" of the isotope or element processed; the next 2 digits (field No. 9) are the MT or "section number" that usually indicates the nuclear reaction processed; and the final 5 digits (field No. 10) are just the card sequence number. Sections are delimited by zeros in the MT fields, files by zeros in the MF fields, and materials by zeros in the MAT fields. The first card shown in Table II, with zeros in all of the last four fields, is the delimiter for the preceding material.

The next card shown in Table II is the first card for the material with MAT-1326, which is natural iron. Note that on this card the number 2.6×10^4 appears in the first field and 55.365 is in the second field. These are the "ZA" (1 000 x Z + A) and "AWR" (atomic weight ratio, i.e., atomic weight of the material divided by weight of the neutron) numbers as taken by the NJOY code directly from the ENDF/B file. The fact that 1 000 x Z is 26 000 and A=0 just means that the data is for the element Fe rather than for an isotope.

Also note that MF=1 and MT=451 on cards 1 to 8. This MF-MT combination is normally used in the ENDF/B formats for descriptive Hollerith information, but it is used here for the boundaries of the multigroup set used for the processed data to follow. On card No. 2, note the number 30 in field 3 and the number 31 in field 5, which indicates, respectively, the number of energy groups and the

* The author is indebted to R. J. Labauve of LASL (T-2) who provided this section and cooperated with the author in supplying needed data for many practical applications of the SENSIT code.

TABLE II

SAMPLE LISTING OF MULTIGROUP COVARIANCE DATA ON TAPE10

```
                                                                   1 0  0
 2.60000+ 4 5.53650+ 1          0          0          0          01326 1451
 0.00000+ 0 0.00000+ 0         30          0         31          01326 1451
 1.39000- 4 1.52000- 1 4.14000- 1 1.13000+ 0 3.06000+ 0 8.32000+ 01326 1451
 2.26000+ 1 6.14000+ 1 1.67000+ 2 4.54000+ 2 1.23500+ 3 3.35000+ 31326 1451
 9.12000+ 3 2.48000+ 4 6.76000+ 4 1.84000+ 5 3.03000+ 5 5.00000+ 51326 1451
 8.23000+ 5 1.35300+ 6 1.73800+ 6 2.23200+ 6 2.86500+ 6 3.68000+ 61326 1451
 6.07000+ 6 7.79000+ 6 1.00000+ 7 1.20000+ 7 1.35000+ 7 1.50000+ 71326 1451
 2.00000+ 7                                                       1326 1451
                                                                  1326 1  0
                                                                  1326 0  0
 0.00000+ 0 0.00000+ 0          0          0         30          01326 3  1
 1.35541+ 1 1.22016+ 1 1.18821+ 1 1.16911+ 1 1.15747+ 1 1.15004+ 11326 3  1
 1.14473+ 1 1.13890+ 1 1.08615+ 1 9.81159+ 0 7.48915+ 0 1.03051+ 11326 3  1
 2.37348+ 0 9.85481+ 0 4.41598+ 0 3.68858+ 0 3.78846+ 0 3.06211+ 01326 3  1
 2.67145+ 0 2.98232+ 0 3.06996+ 0 3.34555+ 0 3.40099+ 0 3.67215+ 01326 3  1
 3.58365+ 0 3.28614+ 0 2.98118+ 0 2.72494+ 0 2.57176+ 0 2.33063+ 01326 3  1
                                                                  1326 3  0
 0.00000+ 0 0.00000+ 0          0          0         30          01326 3  2
 1.15197+ 1 1.14101+ 1 1.14035+ 1 1.14006+ 1 1.13984+ 1 1.13946+ 11326 3  2
 1.13848+ 1 1.13521+ 1 1.08378+ 1 9.56700+ 0 7.48389+ 0 1.02890+ 11326 3  2
 2.36615+ 0 9.84028+ 0 4.40579+ 0 3.68150+ 0 3.78343+ 0 3.05551+ 01326 3  2
 2.35213+ 0 2.28275+ 0 2.22931+ 0 2.43413+ 0 2.20602+ 0 2.14129+ 01326 3  2
 2.04250+ 0 1.77500+ 0 1.49848+ 0 1.30110+ 0 1.17171+ 0 9.82526- 11326 3  2
                                                                  1326 3  0
 0.00000+ 0 0.00000+ 0          0          0         30          01326 3  3
 2.03435+ 0 7.91472- 1 4.78657- 1 2.90519- 1 1.76230- 1 1.05795- 11326 3  3
 6.25256- 2 3.69154- 2 2.37323- 2 2.44582- 1 5.26174- 3 1.60700- 21326 3  3
 7.32804- 3 1.45286- 2 1.01936- 2 7.08119- 3 5.03364- 3 6.59400- 31326 3  3
 3.19314- 1 6.99575- 1 8.40647- 1 9.11424- 1 1.19498+ 0 1.53086+ 01326 3  3
 1.54115+ 0 1.51114+ 0 1.48270+ 0 1.42384+ 0 1.40006+ 0 1.34810+ 01326 3  3
                                                                  1326 3  0
 0.00000+ 0 0.00000+ 0          0          0         30          01326 3  4
 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 01326 3  4
 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 01326 3  4
 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 01326 3  4
 3.16090- 1 6.97516- 1 8.37997- 1 9.06140- 1 1.18417+ 0 1.50336+ 01326 3  4
 1.47693+ 0 1.40533+ 0 1.32806+ 0 1.07065+ 0 7.06491- 1 3.81651- 11326 3  4
                                                                  1326 3  0
 0.00000+ 0 0.00000+ 0          0          0         30          01326 3 16
 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 01326 3 16
 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 01326 3 16
 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 01326 3 16
 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 01326 3 16
 0.00000+ 0 0.00000+ 0 2.89441- 3 1.65433- 1 4.65000- 1 6.24670- 11326 3 16
                                                                  1326 3  0
 0.00000+ 0 0.00000+ 0          0          0         30          01326 3 22
 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 01326 3 22
 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 01326 3 22
 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 01326 3 22
 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 01326 3 22
 0.00000+ 0 0.00000+ 0 2.00000- 6 1.27543- 4 4.08366- 3 4.22890- 21326 3 22
                                                                  1326 3  0
 0.00000+ 0 0.00000+ 0          0          0         30          01326 3 28
 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 01326 3 28
 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 01326 3 28
 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 01326 3 28
 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 01326 3 28
 0.00000+ 0 0.00000+ 0 3.32449- 3 1.02461- 2 4.34896- 2 1.55290- 11326 3 28
                                                                  1326 3  0
```

TABLE II (cont.)

SAMPLE LISTING OF MULTIGROUP COVARIANCE DATA ON TAPE10

```
0.00000+ 0 0.00000+ 0          0          0         30           01326 3102    60
2.03435+ 0 7.91472- 1 4.78657- 1 2.90519- 1 1.76230- 1 1.05795- 11326 3102    61
6.25256- 2 3.69154- 2 2.37323- 2 2.44582- 1 5.26174- 3 1.60700- 21326 3102    62
7.32804- 3 1.45286- 2 1.01936- 2 7.08119- 3 5.03364- 3 6.59077- 31326 3102    63
3.20207- 3 1.87146- 3 1.52351- 3 1.24692- 3 1.01854- 3 7.77897- 41326 3102    64
6.66572- 4 6.35742- 4 6.48990- 4 7.13011- 4 8.13104- 4 9.53248- 41326 3102    65
                                                                1326 3  0    66
0.00000+ 0 0.00000+ 0          0          0         30           01326 3103    67
0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 01326 3103    68
0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 01326 3103    69
0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 3.23000- 61326 3103    70
2.22100- 5 1.87870- 4 1.12710- 3 4.03744- 3 9.77153- 3 2.60238- 21326 3103    71
5.64685- 2 8.63289- 2 1.13654- 1 1.28663- 1 1.20209- 1 7.33574- 21326 3103    72
                                                                1326 3  0    73
0.00000+ 0 0.00000+ 0          0          0         30           01326 3104    74
0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 01326 3104    75
0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 01326 3104    76
0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 01326 3104    77
0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 01326 3104    78
0.00000+ 0 1.80996- 5 2.25000- 3 9.13333- 3 1.99333- 2 2.86600- 21326 3104    79
                                                                1326 3  0    80
0.00000+ 0 0.00000+ 0          0          0         30           01326 3105    81
0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 01326 3105    82
0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 01326 3105    83
0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 01326 3105    84
0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 01326 3105    85
0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 5.60000- 4 1.44000- 21326 3105    86
                                                                1326 3  0    87
0.00000+ 0 0.00000+ 0          0          0         30           01326 3106    88
0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 01326 3106    89
0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 01326 3106    90
0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 01326 3106    91
0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 01326 3106    92
0.00000+ 0 0.00000+ 0 0.00000+ 0 8.33334- 6 3.91667- 4 5.31000- 31326 3106    93
                                                                1326 3  0    94
0.00000+ 0 0.00000+ 0          0          0         30           01326 3107    95
0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 01326 3107    96
0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 01326 3107    97
0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 01326 3107    98
0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 1.98577- 5 6.90973- 41326 3107    99
7.08327- 3 1.88243- 2 3.18674- 2 3.88640- 2 3.90835- 2 2.15230- 21326 3107   100
                                                                1326 3  0   101
                                                                1326 0  0   102
2.60000+ 4 5.53650+ 1          0          0          0         13132633  1   103
0.00000+ 0 0.00000+ 0          0          1          0         30132633  1   104
0.00000+ 0 0.00000+ 0          8          1          8          1132633  1   105
1.81487- 3 1.99084- 3 2.04160- 3 2.07346- 3 2.09334- 3 2.10578- 3132633  1   106
2.11317- 3 2.11788- 3                                            132633  1   107
0.00000+ 0 0.00000+ 0          8          1          8          2132633  1   108
1.99084- 3 2.18787- 3 2.24470- 3 2.28039- 3 2.30263- 3 2.31657- 3132633  1   109
2.32507- 3 2.33026- 3                                            132633  1   110
0.00000+ 0 0.00000+ 0          8          1          8          3132633  1   111
2.04160- 3 2.24470- 3 2.30329- 3 2.34007- 3 2.36301- 3 2.37737- 3132633  1   112
2.38619- 3 2.39151- 3                                            132633  1   113
0.00000+ 0 0.00000+ 0          8          1          8          4132633  1   114
2.07346- 3 2.28039- 3 2.34007- 3 2.37754- 3 2.40091- 3 2.41554- 3132633  1   115
2.42456- 3 2.42997- 3                                            132633  1   116
0.00000+ 0 0.00000+ 0          8          1          8          5132633  1   117
2.09334- 3 2.30263- 3 2.36301- 3 2.40091- 3 2.42454- 3 2.43934- 3132633  1   118
2.44849- 3 2.45396- 3                                            132633  1   119
```

TABLE II (cont.)

SAMPLE LISTING OF MULTIGROUP COVARIANCE DATA ON TAPE10

```
 0.00000+ 0 0.00000+ 0          6         25          6         30132633  4  900
-9.59302+11-5.00000+13-6.55048- 1-1.02718- 2-6.21454- 4-2.09329- 3132633  4  901
 0.00000+ 0 0.00000+ 0          0         28          0         30132633  4  902
 0.00000+ 0 0.00000+ 0          4         27          4         27132633  4  903
-6.98955- 4-2.38988- 4-5.63052- 5-1.57685- 5                      132633  4  904
 0.00000+ 0 0.00000+ 0          4         27          4         28132633  4  905
-9.13648- 4-7.47432- 4-1.53677- 4-2.40586- 5                      132633  4  906
 0.00000+ 0 0.00000+ 0          4         27          4         29132633  4  907
-1.38458- 3-9.88501- 4-1.87498- 3-2.79440- 4                      132633  4  908
 0.00000+ 0 0.00000+ 0          4         27          4         30132633  4  909
-2.56306- 3-1.02291- 3-1.84709- 3-6.80334- 3                      132633  4  910
 0.00000+ 0 0.00000+ 0          0        102          0         30132633  4  911
 0.00000+ 0 0.00000+ 0          5         17          5         19132633  4  912
-1.63835- 5-3.27826- 5-1.22710- 4-2.07985- 4-1.15466- 4           132633  4  913
 0.00000+ 0 0.00000+ 0          3         19          3         20132633  4  914
-5.50655- 5-1.07321- 4-5.95814- 5                                 132633  4  915
 0.00000+ 0 0.00000+ 0         12         19         12         21132633  4  916
-2.07223- 5-4.03725- 5-4.37136- 5-5.03268- 5-5.43578- 5-6.11663- 5132633  4  917
-6.59791- 5-6.76100- 5-6.68902- 5-6.37887- 5-5.99185- 5-5.58653- 5132633  4  918
 0.00000+ 0 0.00000+ 0         10         21         10         22132633  4  919
-3.80925- 5-9.04449- 5-9.83828- 5-1.11790- 4-1.21267- 4-1.24479- 4132633  4  920
-1.23061- 4-1.16954- 4-1.09333- 4-1.01351- 4                      132633  4  921
 0.00000+ 0 0.00000+ 0         10         21         10         23132633  4  922
-2.57173- 5-6.14953- 5-6.75694- 5-7.78287- 5-8.50809- 5-8.75384- 5132633  4  923
-8.64538- 5-8.17804- 5-7.59485- 5-6.98409- 5                      132633  4  924
 0.00000+ 0 0.00000+ 0         10         21         10         24132633  4  925
-1.74088- 5-4.20357- 5-4.68202- 5-5.49012- 5-6.06136- 5-6.25493- 5132633  4  926
-6.16950- 5-5.80138- 5-5.34202- 5-4.86094- 5                      132633  4  927
 0.00000+ 0 0.00000+ 0         10         21         10         25132633  4  928
-1.63792- 5-3.97730- 5-4.46431- 5-5.28688- 5-5.86834- 5-6.06538- 5132633  4  929
-5.97842- 5-5.60371- 5-5.13613- 5-4.64644- 5                      132633  4  930
 0.00000+ 0 0.00000+ 0         10         21         10         26132633  4  931
-1.68233- 5-4.09220- 5-4.60402- 5-5.46850- 5-6.07958- 5-6.28666- 5132633  4  932
-6.19527- 5-5.80147- 5-5.31006- 5-4.79542- 5                      132633  4  933
 0.00000+ 0 0.00000+ 0         10         21         10         27132633  4  934
-1.79797- 5-4.37020- 5-4.91180- 5-5.82658- 5-6.47322- 5-6.69235- 5132633  4  935
-6.59564- 5-6.17893- 5-5.65893- 5-5.11434- 5                      132633  4  936
 0.00000+ 0 0.00000+ 0         10         21         10         28132633  4  937
-2.33664- 5-5.66009- 5-6.33190- 5-7.46662- 5-8.26873- 5-8.54054- 5132633  4  938
-8.42057- 5-7.90368- 5-7.25866- 5-6.58314- 5                      132633  4  939
 0.00000+ 0 0.00000+ 0         10         21         10         29132633  4  940
-3.79314- 5-9.14425- 5-1.01624- 4-1.18819- 4-1.30975- 4-1.35094- 4132633  4  941
-1.33276- 4-1.25443- 4-1.15668- 4-1.05431- 4                      132633  4  942
 0.00000+ 0 0.00000+ 0         10         21         10         30132633  4  943
-7.67502- 5-1.83961- 4-2.02808- 4-2.34640- 4-2.57142- 4-2.64767- 4132633  4  944
-2.61401- 4-2.46901- 4-2.28806- 4-2.09856- 4                      132633  4  945
 0.00000+ 0 0.00000+ 0          0        103          0         30132633  4  946
 0.00000+ 0 0.00000+ 0          7         18          7         19132633  4  947
-1.71773- 7-1.71773- 7-1.71773- 7-1.71773- 7-1.71773- 7-1.71773- 7132633  4  948
-1.31582- 8                                                       132633  4  949
 0.00000+ 0 0.00000+ 0          7         18          7         20132633  4  950
-6.73354- 7-6.73354- 7-6.73354- 7-6.73354- 7-6.73354- 7-6.73354- 7132633  4  951
-5.15804- 8                                                       132633  4  952
 0.00000+ 0 0.00000+ 0         13         18         13         21132633  4  953
-3.36247- 6-3.36247- 6-3.36247- 6-1.17786- 4-7.13781- 5-3.14654- 5132633  4  954
-1.08098- 5-4.86305- 6-3.18096- 6-2.41618- 6-2.13432- 6-2.28442- 6132633  4  955
-3.74344- 6                                                       132633  4  956
 0.00000+ 0 0.00000+ 0         13         18         13         22132633  4  957
-1.11391- 5-1.11391- 5-1.11391- 5-2.36460- 4-1.45074- 4-6.64790- 5132633  4  958
-2.16325- 5-9.57623- 6-6.26389- 6-4.75790- 6-4.20287- 6-4.49844- 6132633  4  959
```

number of energy-group boundaries in the multigroup set. The values of the group boundaries, given in eV from low to high energy, follow on cards 3 through 8. Cards 9 and 10 are MT and MF delimiters, respectively.

Multigroup cross-section data are given in cards 11 through 102. This file, denoted by MF=3, corresponds to the smooth cross-section file in ENDF/B. The MT numbers used here are exactly those defined for ENDF/B, namely:

MT=1 - total cross section
MT=2 - inelastic scattering cross section
MT=3 - non-elastic cross section
MT=4 - total inelastic scattering cross section
MT=22 - (n,n'α) cross section
MT=28 - (n,n'p) cross section
MT=102 - (n,γ) radiative capture cross section
MT=103 - (n,p) cross section
MT=104 - (n,d) cross section
MT=105 - (n,t) cross section
MT=106 - (n,^{3}He) cross section
MT=107 - (n,α) cross section

Note that cross sections for these 13 reactions are given in barns.

The multigroup covariance data for MAT=1326 (Fe) begin with card No. 103. This card repeats the ZA and AWR numbers in fields 1 and 2, and indicates in field 6 that data for 13 reactions are to follow. The designation of MF=33 for this file is the same as that for analogous covariance data in ENDF/B. Note that the number "1" in the MT field indicates that the first set of data is for MT=1. Card 104 contains the number "1" in field No. 4, which indicates that the data to follow is the covariance of MT=1 with MT=1, or just the variance of the iron total cross sections. Note also that the number "30" appears in field No. 6, which is a repeat of the total number of energy groups in the multigroup structure.

Because of the large volume of data in the covariance files, zero values are suppressed in the output. Thus, flags must be set to indicate the positions of non-zero data in the output covariance matrix. On card No. 105, the numbers "8," "1," "8," and "1" occur in fields No. 3, 4, 5, and 6, respectively. The number "1" in field No. 6 indicates that the data to follow are for group No. 1 or row No. 1 in the covariance matrix. The number "8" in field No. 3 (or field No. 5) indicates that there are only 8 consecutive non-zero positions in this row, and, finally, the number "1" in field No. 4 means that the 8 consecutive non-zero numbers begin at row position No. 1. The 8 non-zero covariances then follow on cards 106 and 107.

This can be made somewhat clearer by taking another more general example farther down the data listing. In card No. 911, for MT=4, field No. 4 contains the number "102." This means that the data to follow are the covariances of the iron inelastic scattering reaction with the iron radiative capture reaction. The data for group No. 21 of MT=4, for example, are given on cards 916, 917, and 918. On card No. 916, the group number is identified in field No. 6. The number "12" in field No. 3 (or field No. 5) indicates that there are 12 consecutive groups for which covariances with MT=103 are non-zero, and the first non-zero value begins with group No. 19 for MT=103, as indicated by the number "19" in field No. 4. In referring to the entry in the 6th field of card 917, for example, one would say that "the relative covariance of the iron inelastic cross section (MT=4) in group 21 (1.738-2.232 MeV) with the iron radiative capture cross section (MT=102) in group No. 24 (3.68-6.07 MeV) is -6.11663×10^{-5}."

B. Geometry Input Options and Spatial Zone Descriptions

All computations in SENSIT are based on angular flux information as provided by angular-flux output tapes from the one-dimensional transport codes ONETRAN(12), DTF(16), or ANISN(13). Therefore, the geometry description in SENSIT must conform to some degree with that of the original transport problem. Particularly, the total number of spatial mesh cells, IM, must be the same in SENSIT as in the original transport problem, and it must be the same for forward and adjoint fluxes. (The same requirement holds for IGE, ISN, IGM, and NCOUPL). Also, source and detector zones should be chosen in SENSIT concurrent with those of the forward and adjoint transport calculations so that the total integral response, I_ϕ from Eq. (14) and $I_{\phi*}$ from Eq. (15), can be computed correctly and compared with the transport code's results. However, perturbed zones may be specified in SENSIT completely independent from the transport code's zone structure.

Specifically, SENSIT expects as an input array Z(i) the IM+1 spatial mesh boundaries for which forward and adjoint fluxes have been calculated. The angular flux values are then read from TAPE1 and TAPE2 selectively only for those spatial intervals which are identified to lie in either a source, detector, or perturbed zone. This way, the storage of the entire angular-flux arrays $\phi_m^g(i)$ and $\phi_m^{*g}(i)$ in core is avoided. Each of the angular-flux tapes is scanned three times: once to read values in source zones only, once to read values in detector zones only, and once for the perturbed zones only. The identification of source, detector, and perturbed zones follows the scheme shown in Fig. 1, which exemplifies the procedure for a total of KPER perturbed zones. The number of source, detector, and perturbed zones may be arbitrarily specified in the SENSIT input. The location of these zones on the entire spatial mesh is identified by pairs of input interval numbers, IFIR(k) and ILAS(k), which specify the first and last intervals for zone k. Subroutine MAP generates from this information an integer map IMAP(i) as shown in Fig. 1, which re-numbers the intervals so that all problem-irrelevant intervals carry an index zero. This map is used then to read angular fluxes selectively only for values with IMAP ≠ 0. All SENSIT printout edits this new numbering scheme for source, detector, and perturbed zone identification, which also allows an easy check of the geometry specification. The total number of intervals in all source zones, ISRS, in all detector zones, IDET, and in all perturbed zones, IPER, is computed internally by SENSIT.

C. Angular Flux Input Options, Quadrature Weights, and Direction Cosines

The input parameter ITAPE allows to read angular forward- and adjoint-flux tapes in two different formats. ITAPE = 1 is the preferred option because the standardized CCCC-flux format is defined precisely[17] and is recommended by the Committee on Computer Code Coordination as a code and computer independent standard interface format. (ONETRAN, e.g., generates a CCCC-formated angular flux tape on TAPE31 if both control integers IFO and IANG are set to 1.) If ITAPE = 0, SENSIT reads TAPE1 and TAPE2 as generated by ANISN or DTF.

As described in the previous section, angular fluxes are read selectively according to the integer map IMAP(i). However, in both options for ITAPE, values for angular fluxes are actually read at spatial mesh boundaries rather than at mesh centers. Therefore, after reading these mesh-boundary values, mesh center

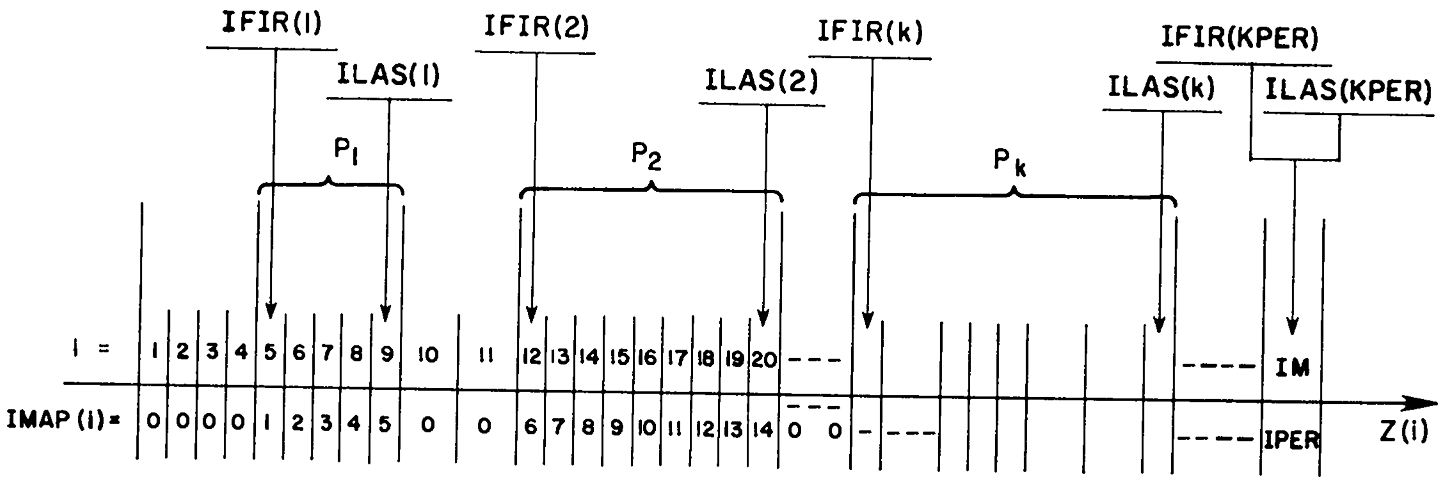

Fig. 1. Spatial zone identification in SENSIT.

averages are calculated by SENSIT, which are then used in all subsequent computational subroutines. These mesh-centered averages are also re-numbered according to the integer map IMAP(i); cf. Fig. 1.

The S_N angular quadrature set, $\{w(m),\mu(m)\}$, which must be read into SENSIT must conform with the quadrature set used in the transport calculations that generated the angular fluxes. If these sets were different, then the angular integrations in SENSIT will not be carried out correctly. Since tables of $\{w,\mu\}$ are standard printout in all transport codes, it is recommended that these values be copied for use in SENSIT. Only the level weights and level cosines must be entered into SENSIT, which then internally computes the proper point weights and point directions, for cylindrical geometry, for example. Starting weights and starting directions must be excluded from SENSIT input.

D. Source and Detector Distribution Functions

The descriptions of the source distribution function Q_i^g and the detector response function R_i^g are in complete analogy. Both functions can be specified with arbitrary spatial and group dependencies such that

$$Q_i^g = q^g \cdot q_i \text{ for } 1 \leq i \leq \text{ISRS} \quad , \tag{44}$$

and

$$R_i^g = \rho^g \cdot \rho_i \text{ for } 1 \leq i \leq \text{IDET} \quad , \tag{45}$$

where the spatial index i runs from 1 to ISRS in Eq. (44) and from 1 to IDET in Eq. (45). Only ISRS values for q_i are required to describe the spatial dependence of the source distribution on the source intervals; and IDET values for ρ_i.

Some freedom exists with respect to how the one-dimensional arrays q^g, q_i and ρ^g, ρ_i may be chosen. For consistency, however, at least two integral conditions must be satisfied:

<u>first</u>: Q_i^g and R_i^g must be chosen so that the total integral response must be the same if computed from forward or adjoint fluxes alone:

$$I_\phi = I_{\phi^*} \quad , \tag{46}$$

which, using Eqs. (14) and (15), becomes

$$\sum_{i=1}^{IDET} \sum_{g=1}^{IGM} V_i R_i^g \phi_0^g(i) = \sum_{i=1}^{ISRS} \sum_{g=1}^{IGM} V_i Q_i^g \phi_0^{*g}(i) \quad , \tag{47}$$

where we used the symbols ϕ_0 and ϕ_0^* for the scalar forward and adjoint fluxes.

<u>second</u>: If the source distribution Q_i^g is normalized to a total source strength

$$Q_{tot} = \sum_{i=1}^{ISRS} \sum_{g=1}^{IGM} V_i Q_i^g \quad , \tag{48}$$

then the detector distribution may remain unnormalized, and so will be ϕ_0^*.

For example, in all our coupled 3 + 3 group sample problems we chose to normalize the source distribution so that always 1 neutron plus 1 gamma ray are emitted per second from the source zone. Equation (48) yields then

$$Q_{tot} = 2 = \sum_{i=1}^{ISRS} V_i q_i \sum_{g=1}^{6} q^g \quad . \tag{49}$$

If we choose $q^g = \{1,0,0,1,0,0\}$, then $\sum_i V_i q_i = 1$ is required. The total volume of the source zone(s) is always $V_Q = \sum_i V_i$, and , therefore $q_i = 1/V_Q$ for all source mesh cells will guarantee $\sum_i V_i q_i = 1$. Since there is only one source zone with only one interval, it is easy to see that $q_1 = 1/V_1$ is required, so that $q_i = \{\frac{1}{V_1}\}$. In slab geometry, therefore, $V_1 = 1\ cm^3$ (compare sample cases 1,2, and 4), while in cylindrical geometry (sample 3) $V_1 = \pi\ (Z_2^2 - Z_1^2) = \pi\ cm^3$, which gives $q_1 = 1/\pi = 0.31831\ cm^{-3}$. As a response function for these sample cases we chose (arbitrarily) a flat energy distribution $\rho^g = \{100, 100, ..., 100\}$ which then leads to the spatial distribution function of $\rho_i = \{1/V_9, 1/V_{10}\}$. In general, it depends on how R_i^g was entered as the adjoint source when TAPE2 was generated, whether ρ_i must be divided by the mesh cell volume V_i or not.

In this context it might be convenient to list the analytic expressions for a mesh-cell volume V_i in the three different geometries treated in SENSIT. A spatial mesh cell with lower boundary Z_- and upper boundary Z_+ has the following volume:[12]

in slab geometry: $$V_i = Z_+ - Z_- \quad , \tag{50a}$$

in cylindrical geometry: $$V_i = \pi\ (Z_+^2 - Z_-^2) \quad , \tag{50b}$$

in spherical geometry: $$V_i = \frac{4\pi}{3}\ (Z_+^3 - Z_-^3) \quad . \tag{50c}$$

A dimensional consideration might assist in deciding whether q_i must be divided by V_i or not. From Eq. (47) the units in which R_i^g must be expressed may be derived. Assuming the dimensions

for $[V_i] = cm^3$,

$[Q_i^g] = neutrons/cm^3\ s$,

$[\phi_0^g] = neutrons/cm^2\ s$, and

$[\phi_0^{*g}] = response/neutron$,

it follows from Eq. (47) that

$$[R_i^g] = \frac{response}{neutron \cdot cm} ,$$

which is the unit of a macroscopic cross section. Often, however, response functions such as flux-to-dose-rate conversion factors, R_C, are given in units of response per flux unit, i.e.,

$$R_C = \frac{\text{response/s}}{\text{neutron/cm}^2\text{s}} .$$

It is clear in such cases, that R_C must be divided by a volume of units cm^3 so that the above derived dimensions for R_i^g are obtained.

VI. SAMPLE PROBLEMS

In this section we give a brief description of 8 sample problems, which demonstrate the capabilities built into SENSIT. In the Appendix, the complete input files and the relevant parts of the printed output files are reproduced for all 8 sample problems. The SENSIT code package contains all input and complete output files, together with all input angular flux and cross-section files (tape 1, tape 2, tape 4, and tape 10).

All 8 sample problems have been executed on LASL's and MFECC's* CDC-7600 computers, under the Livermore Time Sharing System (LTSS). Execution times for the first 6 sample cases are all under 1 second, sample 7 required 12.9 seconds CPU (central processor unit) time, and sample 8 executed in 62 seconds CPU time. The angular-flux tapes required to run SENSIT were obtained as output tapes from independent radiation transport calculations with the LASL code ONETRAN[12]. The CCCC-formatted angular-flux tape is assigned TAPE31 after completion of a ONETRAN run. This designation must be changed to either TAPE1 or TAPE2 before SENSIT is executed. The required cross-section tapes, TAPE4 or TAPE10, have also been prepared independently before SENSIT was run. For sample cases 7 and 8, the ENDF/B-V cross-section files were the basis for preparation of TAPE4

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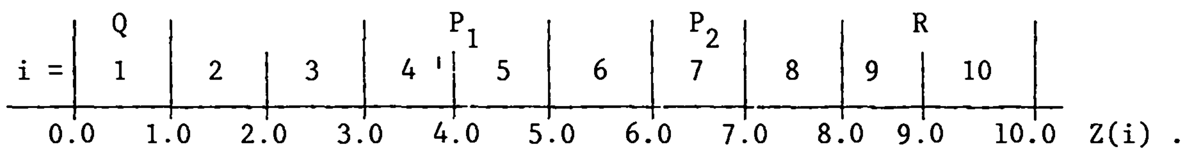
* Magnetic Fusion Energy Computer Center at Lawrence Livermore Laboratory (LLL) in Livermore, California.

and TAPE10 using the LASL cross section processing system NJOY(14) with the post processor TRANSX(18), which retrieves selected cross-section sets from the multigroup data base MATXS.

A. Problem Description for Samples 1 through 6

These samples are based on an artificial problem with artificial cross sections, which is ideally suited to demonstrate almost all SENSIT capabilities. The spatial mesh consists of 10 intervals of width 1 cm, subdivided into 4 zones, including two perturbed zones $P_{1,2}$ as shown below:



As an energy group structure we chose 6 groups. To allow coupled neutron/gamma-ray calculations, we designate groups 1, 2, 3 as neutron groups and groups 4,5,6 as gamma-ray groups. A coupled multigroup cross-section set has been invented which describes the above 10-cm long model as a scattering and absorbing medium of one mean free path (mfp) for groups 1 and 4, two mfp for groups 2 and 5, and three mfp for groups 3 and 6. The complete P_o transport cross-section table as used in SENSIT and the associated ONETRAN runs is given in Table III. Note that neutron and gamma-ray interaction cross sections were chosen to be identical. Because the gamma-ray production cross sections (framed portion in Table III) are set to zero, identical numerical results should be expected for neutrons and gamma rays. Symmetrical (with respect to neutrons or gamma rays) spectral distributions for source and detector were chosen as follows:

$$q^g = \{1,0,0,1,0,0\} \quad ,$$

$$\rho^g = 100 \times \{1,1,1,1,1,1\} \quad ,$$

and the total source strength was normalized to 2 as stated in Eq. (49). The spatial distributions q_i and ρ_i depend upon the geometry of the problem, as discussed in section V.D.

TABLE III

COUPLED 3+3 GROUP TRANSPORT CROSS-SECTION TABLE USED WITH SAMPLE PROBLEMS 1 THROUGH 6. FRAMED PORTION IS GAMMA PRODUCTION MATRIX

Table Pos.	XS type	n-groups g=1	g=2	g=3	γ-groups g=4	g=5	g=6
1=IHA	Σ_a^g	0.02	0.05	0.1	0.02	0.05	0.1
2	$\nu\Sigma_f^g$	0.0	0.0	0.0	0.0	0.0	0.0
3=IHT	Σ_T^g	0.1	0.2	0.3	0.1	0.2	0.3
4	$\Sigma_s^{g\to g}$	0.05	0.1	0.2	0.05	0.1	0.2
5	$\Sigma_s^{g-1\to g}$	0	0.02	0.05	0.0	0.02	0.05
6	$\Sigma_s^{g-2\to g}$	0	0	0.01	0.0	0.0	0.01
7	$\Sigma_s^{g-3\to g}$	0	0	0	0.0	0.0	0.0
8	$\Sigma_s^{g-4\to g}$	0	0	0	0	0.0	0.0
9=ITL	$\Sigma_s^{g-5\to g}$	0	0	0	0	0	0.0

An exact re-calculation with ONETRAN using $\Sigma_{pert.} = 0.9\ \bar{\Sigma}$ in the two perturbed zones gives

$$I_\phi^{exact} = < R,\phi_{pert.} > = 377.540 \quad .$$

All transport calculations to generate the angular-flux tapes were carried out with ONETRAN[12] and were converged to high accuracy, so that I_ϕ differed from I_{ϕ^*} by less than 0.1%.

1. Sample Problem 1. This is a standard design sensitivity problem with test printouts. Cross sections for the perturbed zones P_1 and P_2 were chosen such that

$$\left.\begin{array}{l} \Sigma_{perturbed} = 0.9\ \bar{\Sigma}\ , \\ \\ \Sigma_{unpert.} = 1.0\ \bar{\Sigma}\ , \end{array}\right\} \qquad \Delta\Sigma = \Sigma_p - \Sigma_u = -0.1\ \bar{\Sigma}\ .$$

After the input specifications are edited in the SENSIT output, the first computational result is $I_\phi = 365.487$ which is followed by the detector sensitivity profile integrated over both detector zones as well as for each detector zone individually. $I_{\phi^*} = 365.399$ is computed next and edited together with the source sensitivity profile per source zone. Note that the first-order responses I_ϕ and I_{ϕ^*} agree within 0.02% consistent with independent results from the ONETRAN calculations with Σ_{unpert}. Cross-section tables are edited next, together with test printouts for $\Delta\Sigma_T^g$ and $\Delta\Sigma_{s,\ell}^{g\to g'}$.

The actual design sensitivity results are preceded by a table of definitions for the acronyms used in the printout. The computed response perturbation is

$$\Delta I_{AD}^{(2)} = \Delta I_{FD}^{(2)} = -\ 11.9913\ ,$$

which results from two equal parts for neutrons and gamma rays each. The interpretation of this result is, of course, that the integral response $I = I^{(1)}$ is predicted by perturbation theory to change to $I^{(2)}$ when Σ_u is replaced by Σ_p in both perturbed zones:

$$I_{AD}^{(2)} = I_\phi^{(1)} - \Delta I_{AD}^{(2)} = 377.4783 \qquad\qquad I_{FD}^{(2)} = I_{FD}^{(1)} - \Delta I_{FD}^{(2)} = 377.3903$$

An exact recalculation with ONETRAN using $\Sigma_{pert.} = 0.9\ \bar{\Sigma}$ in the two perturbed zones give

$$I_{\phi}^{exact} = < R, \phi_{pert.} > = 377.540 \quad .$$

Comparing with the above perturbation theory results allows us to quantify the perturbation theory error in this case to

$$\Delta_{AD} = 100 \left(I_{\phi}^{exact} - I_{AD}^{(2)} \right) \Big/ I_{\phi}^{exact} \approx 0.02\% \quad ,$$

and $\Delta I_{FD} \approx 0.04\%$, which may be considered very small errors. Since IOUTPUT = 1 has been specified for this sample problem, the individual contributions to $\Delta I^{(2)}$ from each perturbed zone are also printed. Comparing the zone-wise sensitivity output $\Delta I_{k=1}^{(2)} = -7.994$ and $\Delta I_{k=2}^{(2)} = -3.997$ with the total response change $\Delta I^{(2)} = -11.9913$ shows that the total response is, in this case, exactly twice as sensitive to the zone-1-perturbation than to the zone-2-perturbation.

2. Sample Problem 2. This sample is a slightly modified version of sample problem 1 because we set IDESIGN = 1 and require, therefore, that only one cross section set is read into SENSIT. The design sensitivity results assume in this case that the perturbation consists of a 1% increase of these cross sections in all groups, which is equivalent to a 1% density increase in all perturbed zones. We chose $\bar{\Sigma}$ as the cross-section set in the perturbed zones, then

$$\Delta\Sigma = 0.01 \cdot \bar{\Sigma} \quad .$$

The results of the analysis show

$$\Delta I_{AD}^{(2)} = \Delta I_{FD}^{(2)} = +1.19913 \quad ,$$

which is in magnitude one tenth of the result in sample problem 1, but of opposite sign (as expected). The computational advantage of this option is that only one cross-section set needs to be stored in core during execution. It is quite possible, therefore, that a large design sensitivity problem can be executed with IDESIGN = 1 but may exceed available core storage for IDESIGN = 0. In the Appendix, only the first and the last page of the sample 2 printout are reproduced to avoid duplication.

3. Sample Problem 3. This sample is included to demonstrate how anisotropic cross sections are read into SENSIT from cards and how the S_N constants $\{w_m,\mu_m\}$ are specified in cylindrical geometry. For simplicity, we chose the P_1-component of the scattering cross-section tables to be identical to the P_0-component. This leads us, however, to a pathological case because only for a delta-function distribution are identical Legendre expansion coefficients for all orders obtained. Therefore, in order to obtain reasonable convergence of our transport calculations for ϕ and ϕ^*, we must choose a fairly high S_N-order of N = 16.

Again, only the first and last pages of the SENSIT printout are reproduced in the appendix. As final result for this sample case let's consider

$$\Delta I_{AD}^{(2)} = \Delta I_{FD}^{(2)} = -0.174833 \quad .$$

From an exact recalculation by running ONETRAN with $\Sigma = 0.9\ \bar{\bar{\Sigma}}$ we obtain

$$\Delta I_{\phi}^{exact} = -0.1747 \quad ,$$

which is in almost a perfect agreement with the perturbation theory estimate.

4. Sample Problem 4. The input specification for this sample case is based on the same problem as sample 1 and 2, except that now we perform a standard cross-section sensitivity analysis. Therefore, only one cross-section set needs to be entered as material specification in the perturbed zones. Only the first and the last 4 pages of the SENSIT printout are reproduced in the Appendix. The table of definitions, which is always printed for ITYP= 0, summarizes the information contained in Eqs. (2) through (17), and initiates the detailed sensitivity profile printout. Because we used identical neutron and gamma-ray cross sections, the resulting sensitivity coefficients are identical. The corresponding sensitivity profiles differ from each other, however, because of the different group structure assumed for neutrons and gamma rays.

The first two sensitivity profile prints (for neutrons and gamma-rays, respectively) are for the spatial integral over all perturbed zones. If IOUTPUT = 1, profiles are printed for the individual perturbed zones.

5. Sample Problem 5. This sample is based on the same problem as sample 4, but now we wish to perform an SED sensitivity analysis in addition to the standard cross-section sensitivity analysis. . We assume for this case that no SED uncertainties are available (NSED = 0), but we still wish to obtain the SED sensitivity profiles defined in Eqs. (30) through (32). As an additional feature we now read LASL-formatted cross sections from TAPE4. This cross-section tape has been prepared in advance and contains P_0 cross-section sets for 2 (identical) materials of which we read only the second set into SENSIT.

In the Appendix we reproduce only the output pertaining to the SED analysis. This is the page labeled "Double-Differential SED Sensitivity Profiles", which appears normally between the neutron and gamma-ray profiles summed over all perturbed zones. The appendix contains also a listing of the contents of TAPE4 for this sample case.

6. Sample Problem 6. This sample is a further extension of sample problem 5 to demonstrate how an SED uncertainty analysis may be added to the SED sensitivity analysis. NSED is set to 1 and the SED uncertainty information {GMED, FSED} must be added to the input cards.

B. Problem Description for Samples 7 and 8

These last two sample problems are taken from a comprehensive neutron cross section and secondary-energy-distribution uncertainty analysis for a fusion reactor, documented in detail in Ref. 15. The basic computational model consists of 137 spatial intervals with a 14 MeV neutron source covering the first 4 intervals and a detector zone at intervals 80 through 108 describing a superconducting toroidal field (TF) coil. Choosing an energy dependent KERMA factor as a response function in the TF coil zone identifies the integral response of interest as the total nuclear heating in this superconducting magnet. The question to be answered by this uncertainty analysis is: How uncertain is the calculated nuclear heating in the TF coil, due to all cross-section uncertainties in the model? In the comprehensive analysis as documented in Ref. 15, additional integral responses, and many more partial cross-section and SED uncertainties, were considered than in these two sample cases.

The neutron and gamma-ray cross sections employed for this study formed a coupled transport cross-section set with 30 neutron and 12 gamma-ray groups. The transport calculations to produce the angular-flux tapes were performed with P_2 anisotropic cross sections and an S_6 angular quadrature. The subsequent SENSIT calculations, however, employed only isotropic transport cross-section sets. The two sample cases described here identify 2 perturbed zones: P_1 is the TF-coil zone (intervals 80 through 108), and P_2 is another magnet coil (the E-coil) in intervals 111 through 125. Both coils are composed mostly of copper and a stainless steel structure. Therefore, the material cross sections to be considered in these two perturbed zones are those of Cr, Ni, Fe, and Cu. Sample problem 7 computes the integral response uncertainty due to the SED uncertainties in the neutron cross sections of these 4 materials in the TF and E-coils. Sample problem 8 performs an independent vector cross-section uncertainty analysis for all partial cross sections used in the generation of cross-section sets for Cr, Ni, Fe and Cu.

1. Sample Problem 7. The input file for this sample problem (as reproduced in the Appendix in its entirety) shows that a standard cross-section sensitivity analysis, together with an SED uncertainty analysis, is performed for 4 successive cases (NPERXS = 4) and the cross sections are entered from TAPE4 in LASL format (IXSTAPE = 1, KXS = 1). Therefore, at the end of the input file, four sets of SED uncertainty parameters and cross-section ID-cards are supplied. The identification numbers refer to the material sequence on TAPE4, which we chose to be C, O, Cr, Fe, Ni, Cu, and W.

Of the sample 7 printout, we reproduce in the Appendix only the first page and the last 10 pages which contain the relevant results for copper (material ID = 6). A response uncertainty of about 27%, due to the estimated SED uncertainties in the copper cross sections in both perturbed zones, is calculated. It is also noted that fairly large neutron sensitivity coefficients are calculated for both the SED and standard cross-section sensitivities. In contrast, the sensitivities to gamma-ray cross sections and to the gamma-ray production cross sections are much smaller.

At the end of the sample 7 printout we have attached two pages of a listing of the contents of tape 4 as used for this problem. Only the first page (beginning of carbon transport cross-section table) of the listing, and the last page (end of tungsten cross-section table) are reproduced to illustrate the TAPE4 format.

2. Sample Problem 8. This sample performs a vector cross-section sensitivity and uncertainty analysis for the fusion reactor design described earlier. The cross-section and covariance matrix input is from TAPE10 whose content and format are described in Sec. V.A.2. Sample 8 computes a total of 36 successive cases (NPERXS = 36) and expects in the input file, after QUE(j), 36 identification cards for vector cross-section pairs. In addition, these 36 vector cross-section pairs with their covariance matrices describe the partial cross sections with their estimated uncertainties for the 4 materials Cr, Ni, Fe, Cu, of which the two perturbed zones consist. We shall concentrate here, as in the previous sample case, only on the results for copper whose ID-numbers on TAPE10 are from 37 through 47. Therefore, again only the first page of the sample 8 printout together with the last 12 pages are reproduced in the appendix.

In order to interpret the results of this analysis correctly, it is necessary to know which pair of partial cross sections is identified by each ID number. Such a cross reference list is contained in subroutine COVARD of SENSIT and is also reproduced in Ref. 15. The SENSIT output for all Cu cross-section pairs identifies three contributions to the response uncertainty with relative standard deviations greater than 10 per cent:

ID = 37, Cov (Σ_T, Σ_T), $\delta I/I = 26.0$ %
ID = 38, Cov $(\Sigma_T, \Sigma_{elas})$, $\delta I/I = 25.8$ %
ID = 39, Cov $(\Sigma_{elas}, \Sigma_{elas})$, $\delta I/I = 25.7$ %

These two cross sections, Σ_T and Σ_{elas}, show also the largest sensitivity profiles compared to the other Cu vector cross-sections.

On the last page of the sample 8 printout a summary of all calculated response uncertainties is printed. According to the input parameter NSUMCOV = 4, four partial sums of individual response variances are provided where the last partial sum is over all Cu cross-section contributions (according to the input for SUMSTRT = 26 and SUMEND = 36). The total response variance due to all copper vector cross-section uncertainties is therefore computed to be 45.1 percent.

VII. RETRIEVING AND RUNNING SENSIT ON LASL'S AND MFECC'S CDC-7600 COMPUTERS

The current (March 1980) code package resides in a file named SENSIT10 and contains the FORTRAN code, the corresponding executable binary file, and all input and data files to execute sample problems 1 through 8. The contents of this code package are listed in Figs. 2 and 3, and spans a total of 27 files. The file names are self explanatory as far as possible:

SAMPLxIN and SAMPLxOUT are the input and output files, respectively, for sample problems x (for x = 1, 2, ..., 8) as described in Sec. VI;
TAPE1S3 is TAPE1 for sample 3;
TAPE2S7-8 is TAPE2 for sample 7 and sample 8;
SENS10 is the FORTRAN source program for the SENSIT code;
SENSIT is the executable binary file for the SENSIT code, which results from compiling SENS10 with the FTN compiler.

Figures 2 and 3 are copies of terminal listings generated from an actual retrieval and execution of a SENSIT sample problem on LTSS.

a. <u>On MFECC's CDC-7600 (see Fig.2)</u>:

To retrieve the code package from MFECC's file storage system, FILEM, the following command is required:

    FILEM READ 5013 SENSIT10 $END .

The file SENSIT10 which is then in the local file space is a LIX file whose contents will be listed by typing

    LIX SENSIT10 $LL SORT. .

In order to execute, for example, sample problem 3 we read from this LIX file the 4 files required:

```
FILEM READ 5013 SENSIT10 $END


1. READ SENSIT10
FILE IS ON TAPE.
MAKE ALL REQUESTS; THEN TYPE END TO GET FILES FROM TAPE.
REQUEST SENT TO FILE MANAGER
TAPE QUEUE POSITION IS 4.
1. READ SENSIT10
#DS

 ALL DONE

LIX SENSIT10$LL SORT.
   ADDRESS    LENGTH  NAME
     25705       542  SAMPL1IN
    503001      3675  SAMPL1OUT
     26447       403  SAMPL2IN
    506676      2761  SAMPL2OUT
       464      1042  SAMPL3IN
    511657      2411  SAMPL3OUT
      1526       402  SAMPL4IN
    514270      4207  SAMPL4OUT
      2130       253  SAMPL5IN
    520477      2707  SAMPL5OUT
      2403       273  SAMPL6IN
    523406      3140  SAMPL6OUT
     27052      1433  SAMPL7IN
    526546     34343  SAMPL7OUT
    307560      1473  SAMPL8IN
    447540     33241  SAMPL8OUT
    404222     43316  SENS10
    311253     72747  SENSIT
         0       232  TAPE1
    563111    306435  TAPE10S8
      3161     11252  TAPE1S3
     30505    104063  TAPE1S7-8
       232       232  TAPE2
     14433     11252  TAPE2S3
    134570    104063  TAPE2S7-8
      2676       263  TAPE4
    240653     46705  TAPE4SAMP7
  SPACE IS    205100
 BEGINS AT   1071546
INDEX SPACE       271 DECIMAL
DF. GR. SAMPL3IN TAPE1S3 TAPE2S3 SENSIT $ END

 ALL DONE
SWITCH SAMPL3IN INPUT

 ALL DONE
SWITCH TAPE1S3 TAPE1

 ALL DONE
SWITCH TAPE2S3 TAPE2

 ALL DONE

SENSIT / 1 2


 STOP FTN
SENSIT      LTSS TIME      2.076 SECONDS
CPU=     1.568        SYS=      .053        I/O=      .456

 ALL DONE
BANNER LSL OUTPUT COL1. BOX SIG OUT3
-ALLOUT-
-NETOUT-
 BANNERFNN : FILE-ID     OUT3          - RXLSL/KAAA

 ALL DONE
```

Fig. 2. Retrieval and execution of SENSIT on MFECC's CDC-7600 computer.

```
MASS
? GET /082190/SENSIT10
000 80/03/31 11:43:54.139  GET SENSIT10:/082190/SENSIT10
001 (1200000B WORDS) 80/03/13 14:50:06.121
? END

 ALL DONE
LIX SENSIT10!LL SORT.
   ADDRESS    LENGTH  NAME
     25705       542 SAMPL1IN
    503001      3675 SAMPL1OUT
     26447       403 SAMPL2IN
    506676      2761 SAMPL2OUT
       464      1042 SAMPL3IN
    511657      2411 SAMPL3OUT
      1526       402 SAMPL4IN
    514270      4207 SAMPL4OUT
      2130       253 SAMPL5IN
    520477      2707 SAMPL5OUT
      2403       273 SAMPL6IN
    523406      3140 SAMPL6OUT
     27052      1433 SAMPL7IN
    526546     34343 SAMPL7OUT
    307560      1473 SAMPL8IN
    447540     33241 SAMPL8OUT
    404222     43316 SENS10
    311253     72747 SENSIT
         0       232 TAPE1
    563111    306435 TAPE10S8
      3161     11252 TAPE1S3
     30505    104063 TAPE1S7-8
       232       232 TAPE2
     14433     11252 TAPE2S3
    134570    104063 TAPE2S7-8
      2676       263 TAPE4
    240653     46705 TAPE4SAMP7
  SPACE IS    105100
 BEGINS AT   1071546
INDEX SPACE      271 DECIMAL

 ALL DONE
LIX SENSIT10!GR. SAMPL2IN TAPE1 TAPE2 SENSIT

 ALL DONE
SWITCH SAMPL2IN INPUT

 ALL DONE
SENSIT / 1 2.5
 STOP FTN
SENSIT     LTSS TIME     1.936 SECONDS
CPU=    1.316       SYS=      .032        I/O=      .588

 ALL DONE
ALLOUT INPUT OUTPUT BOX T01MEB

 ALL DONE
```

Fig. 3. Retrieval and execution of SENSIT on LASL's CDC-7600 computer.

GR. SAMPL3IN TAPE1S3 TAPE2S3 SENSIT $END .

Since the executable binary file SENSIT expects the input file to be named INPUT, the forward-flux file to be named TAPE1, and the adjoint-flux file to be named TAPE2, we change these file names accordingly with the three commands:

```
SWITCH  SAMPL3IN  INPUT
SWITCH  TAPE1S3   TAPE1
SWITCH  TAPE2S3   TAPE2
```

To execute sample problem 3, all that is required is a call to the executable binary file by typing

SENSIT .

Completion of the run is indicated by the machine's response with "STOP FTN" and the LTSS time listing. SENSIT's printed output is now contained on a file named OUTPUT which may be listed with a number of systems routines, e.g., on LASL's DEC-10 printer by typing

BANNER LSL OUTPUT COL1. BOXID OUTPUT .

The option COL1. assures the proper line and page ejects to be recognized.

b. On LASL's CDC-7600 (see Fig. 3):

The SENSIT code package may be obtained from LASL's mass-storage system with the command

MASS GET /082190/SENSIT10 .

From the LIX file SENSIT10 we may then obtain, e.g., the files required to execute sample problem 1:

LIX SENSIT10!GR. SAMPL1IN TAPE1 TAPE2 SENSIT .

After changing the name of the input file to INPUT, by

SWITCH SAMPL1IN INPUT ,

we can then run SENSIT by typing

SENSIT

and obtain an OUTPUT file which may then be listed with

ALLOUT OUTPUT CC. BOXID .

c. Changing the FORTRAN source code (see Fig. 4):

If it is desired to change the FORTRAN code, for example, to execute SENSIT with another LCM container size as described in Sec. IV.B, we retrieve from the LIX file SENSIT10 the FORTRAN source program SENS10 and recompile. Figure 4

```
LIX SENSIT10 $GR. TAPE1 TAPE2 TAPE4 SAMPL5IN SENS10 $END

 ALL DONE


TRIX AC$O$SENS10$TP$BLKECS( 80000)
4520 LINES. (80A)
  14        COMMON /ARRAY2/ BLKECS( 80000)
.RP14$ 80000$120000$L
  14        COMMON /ARRAY2/ BLKECS(120000)
.TP$CALL BULK ( 80000)
 120        CALL BULK ( 80000)
.RP120$ 80000$120000$L
 120        CALL BULK (120000)
.END

 ALL DONE

SWITCH SAMPL5IN INPUT

 ALL DONE

LIX LASLFTN SKIPSUM $GR* ALL. $END

 ALL DONE

FTN (I=SENS10,LCM=I,GO)
* * * RUNNING FTN COMPILER * * *

1
* OFILE,SENS10/PA.
* DFILE,LISTFTN.
* CFILE,LISTFTN/PR.
* DFILE,ATMPBIN.
* CFILE,ATMPBIN/AB.
* DFILE,AOODZZI.
* LFC(A,I=SENS10,LCM=I,L=LISTFTN,B=ATMPBIN).
       4.810 CP SECONDS COMPILATION TIME
* GOTO,1.
* 1,EXIT.
$%CPU TIME        4.923 SEC
$%SYS TIME        0.431 SEC
$%I/O TIME        5.643 SEC
$%TOTAL  =        0.183 MINUTES
* * * FINISHED FTN COMPILER * * *
* * * LOD SUMMARY * * *
CODE BLOC      SENSIT WRITTEN
FILE SIZE=    0072747
FLD LGTH=     0605002   0151417
* * * EXECUTION * * *
 STOP FTN
SENSIT     LTSS TIME     1.684 SECONDS
CPU=    1.246       SYS=     .068       I/O=      .369

 ALL DONE
```

Fig. 4. Changing the SENSIT FORTRAN source code.

shows, for example, how the LCM container size is increased from 80 000 to 120 000 words and how sample problem 5 is executed.

First we read from LIX file SENSIT10 the input data files required to run sample 5, and the FORTRAN source code SENS10:

```
LIX SENSIT10 $GR. TAPE1 TAPE2 TAPE4 SAMPL5IN SENS10 $END
```

Next, we search the SENS10 file for the COMMON statement which assigns the LCM container array size according to Sec. IV.B, Eq. (38):

```
TRIX AC$O$SENS10$TP$BLKECS( 80000)
```

Then this line 14 is changed and listed again with the command

```
RP14$ 80000$120000$L
```

As explained in Sec. IV.B, we must also change simultaneously the card with CALL BULK (80000) in the main driver routine:

```
TP$CALL BULK ( 80000)
RP120$ 80000$120000$L
```

At this point, all necessary source code changes are accomplished and before executing sample problem 5 we must rename the input file

```
SWITCH SAMPL5IN INPUT
```

and generate a new executable binary file by recompiling the altered FORTRAN source code SENS10. But first, the FTN compiler package must be read into our local file space which, on the MFECC, is accomplished with

```
LIX LASLFTN SKIPSUM$GR* ALL.$END
```

The new SENS10 can now be compiled, loaded and executed with FTN by typing

```
FTN (I=SENS10,LCM=I,GO)
```

The parameter LCM=I is required because more than the default value of LCM storage is requested in this case. After completion, a new OUTPUT file will be written with the results for sample problem 5. The new executable binary file SENSIT may now be saved for later use.

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IX. APPENDIX

The following appendix contains 62 pages of selected computer printout as described in the previous section. Particularly, the complete input files for all 8 sample problems are reproduced exactly in the form in which they must be entered to execute SENSIT for these cases. Note, however, that these input listings are given with line numbers to the left of each input card, which, of course, are not a part of the actual SENSIT input.

```
SENSIT SAMPLE 1, *3+3 GP.*SLAB*S-2*P-0*DESIGN-SEN*WITH TEST PRINT
      1      1      2     10      6      3      0      1      0      1      0       CARD2
      1      2      2      1      3      1      0      0      1      0      1     0 CARD3
  10.0          5.0          1.0          0.5                                        EN(G)
   4.0          3.0          2.0          1.0                                        EG(G)
  0.5           0.5                                                                 W(M)
  -0.57735      +0.57735                                                            MUE(M)
   0.0           1.0          2.0          3.0          4.0          5.0            MESH1
   6.0           7.0          8.0          9.0          10.0                        MESH2
     1      1                                                                       KSRS
     9      9                                                                       KDET1
    10     10                                                                       KDET2
     4      5                                                                       KPER1
     7      7                                                                       KPER2
  100.0         100.0         100.0         100.0         100.0         100.0       R(G)
  1.0           1.0                                                                 RHO(J)
  1.0           0.0           0.0           1.0           0.0           0.0         Q(G)
  1.0                                                                               QUE(J)
CASE 1 PERTURBED XS-SET  (PERTURBED MATERIAL XS)                                     XS
NUMDEN =     0.9                                                                     XS
 PERT.XS-SET FOR SENSIT COUPLD-3+3-GP. TEST PROBLEM, XS=0.9*XSBAR, P-0               XS
          .02          0.0          0.1          .05          0.0          0.0 GP1
          0.0          0.0          0.0          0.05         0.0          0.2 GP1/2
          0.1          0.02         0.0          0.0          0.0          0.0 GP2
          0.1          0.0          0.3          0.2          .05          .01 GP3
          0.0          0.0          0.0          0.02         0.0          0.1 GP3/4
          0.05         0.0          0.0          0.0          0.0          0.0 GP4
          .05          0.0          0.2          0.1          .02          0.0 GP5
          0.0          0.0          0.0          0.1          0.0          0.3 GP5/6
          0.2          0.05         0.01         0.0          0.0          0.0 GP6
CASE 1 REFERENCE XS-SET  (REFERENCE MATERIAL XS)                                   XSBAR
NUMDEN =     1.0                                                                   XSBAR
 REFERENCE XS-SET FOR SENSIT COUPLD. 3+3-GP. TEST PROBLEM, P-0                     XSBAR
          .02          0.0          0.1          .05          0.0          0.0 GP1
          0.0          0.0          0.0          0.05         0.0          0.2 GP1/2
          0.1          0.02         0.0          0.0          0.0          0.0 GP2
          0.1          0.0          0.3          0.2          .05          .01 GP3
          0.0          0.0          0.0          0.02         0.0          0.1 GP3/4
          0.05         0.0          0.0          0.0          0.0          0.0 GP4
          .05          0.0          0.2          0.1          .02          0.0 GP5
          0.0          0.0          0.0          0.1          0.0          0.3 GP5/6
          0.2          0.05         0.01         0.0          0.0          0.0 GP6
```

SENSIT SAMPLE 1, *3+3 GP.*SLAB*S-2*P-0*DESIGN-SEN*WITH TEST PRINT

ITYP	= TYPE OF SENS.-UNCERT.-ANAL., 1-XS,2-DESIGN,3-VECTOR-XS,4-SED	= 1
IGE	= GEOMETRIC MODEL: 1-SLAB,2-CYLINDER,3-SPHERE	= 1
ISN	= ORDER OF S-N QUADRATURE	= 2
IM	= TOTAL NUMBER OF SPATIAL MESH INTERVALS	= 10
IGM	= TOTAL NUMBER OF ENERGY GROUPS	= 6
NCOUPL	= NUMBER OF NEUTRON GROUPS IN CPL. CALC., ZERO FOR NEUTRONS ONLY	= 3
LMAX	= MAX. P-L ORDER OF CROSS SECTIONS	= 0
ITAPE	= FORMAT OF ANG.FLX. TAPES 1 AND 2: 0-ANISN, 1-CCCC(ONETRAN)	= 1
IXSTAPE	= SOURCE OF INPUT CROSS-SECTIONS: 0-CARDS, 1-TAPE4, 2-TAPE10	= 0
NPERXS	= NUMBER OF SUCCESSIVE CASES, ALSO NO. OF INPUT XS-SETS TO BE READ	= 1
IDESIGN	= ASSUMED 1 PER CENT DENSITY INCREASE IN PERT. ZS. FOR DES.-SEN., 0/1=NO/YES	= 0
KSRS	= NUMBER OF SOURCE ZONES	= 1
KDET	= NUMBER OF DETECTOR ZONES	= 2
KPER	= NUMBER OF PERTURBED ZONES	= 2
KXS	= INPUT XS-FORMAT 0-IF ITYP=2, 1-LASL, 2-ORNL	= 1
IHT	= POSITION OF TOTAL CROSS-SECTION IN XS-TABLES	= 3
IHA	= POSITION OF ABSORPTION CROSS-SECTION IN XS-TABLES	= 1
DETCOV	= 0/1 = DO NOT/DO READ COVARIANCE MATRIX FOR R(G)	= 0
NSED	= 0/1 = DO NOT/DO READ INTEGRAL SED-UNCERTAINTIES	= 0
IOUTPUT	= OUTPUT PRINT DETAIL: 0-SUM OVER PERT.ZONES ONLY, 1-ALSO INDIV. PERT.ZS.	= 1
NSUMCOV	= NO. OF RESP.-VARIANCES SUMMED FOR ITYP=2, ZERO FOR ITYP=0,1,3	= 0
ITEST	= TEST PRINTOUT FLAG: 0-NONE, 1-XS, 2-ANG.FLXS., 3-VECTOR-XS	= 1
IPRINT	= TEST PRINTS FROM POINTR: 0-NONE,1-DUMPS, 2-TRACES, 3-ALL	= 0

4 NEUTRON ENERGY GROUP BOUNDARIES READ, IN EV
1.000E+01 5.000E+00 1.000E+00 5.000E-01

4 GAMMA ENERGY GROUP BOUNDARIES READ, IN EV
4.000E+00 3.000E+00 2.000E+00 1.000E+00

COMPUTED LETHARGY WIDTHS PER GROUP, DELU(G)
G = 1 DELU(G) = 6.931E-01
G = 2 DELU(G) = 1.609E+00
G = 3 DELU(G) = 6.931E-01
G = 4 DELU(G) = 2.877E-01
G = 5 DELU(G) = 4.055E-01
G = 6 DELU(G) = 6.931E-01

LEVEL WEIGHTS FOR DISCRETE ANGLES
.500000 .500000

DISCRETE ANGLES MUE FOR LEVEL WEIGHTS
-.577350 .577350

MESH BOUNDARIES READ
0. 1.000E+00 2.000E+00 3.000E+00 4.000E+00 5.000E+00 6.000E+00 7.000E+00 8.000E+00 9.000E+00
1.000E+01

ISMAP(BDY)	1	2	0	0	0	0	0	0	0	0	0
IDMAP(BDY)	0	0	0	0	0	0	0	0	1	2	3
IPMAP(BDY)	0	0	0	1	2	3	3	4	0	0	0

TEST PRINTOUT OF PAIRS OF DELZ-ZMID FOR RE-NUMBERED NON-ZERO MESH BOUNDARIES

********** GEOMETRY SPECIFICATIONS FOR SOURCE, DETECTOR, AND PERTURBED ZONES, BY ZONE AND INTERVAL NUMBERS **********

INTERVAL NO. I	LOWER BOUNDARY	INTERVAL MIDPOINT	SOURCE ZONE NO.	SOURCE INTERVAL NO.	DETECTOR ZONE NO.	DETECTOR INTERVAL NO.	PERTURBATION ZONE NO.	PERTURBATION INTERVAL NO.
1	0.	5.000E-01	1	1	0	0	0	0
2	1.000E+00	1.500E+00	0	0	0	0	0	0
3	2.000E+00	2.500E+00	0	0	0	0	0	0
4	3.000E+00	3.500E+00	0	0	0	0	1	1
5	4.000E+00	4.500E+00	0	0	0	0	1	2
6	5.000E+00	5.500E+00	0	0	0	0	0	0
7	6.000E+00	6.500E+00	0	0	0	0	2	3
8	7.000E+00	7.500E+00	0	0	0	0	0	0
9	8.000E+00	8.500E+00	0	0	1	1	0	0
10	9.000E+00	9.500E+00	0	0	2	2	0	0

```
TEST PRINT FOR MESH CELL VOLUMES DELZ(I)
I =   1  DELZ(I) =  1.00000E+00
I =   2  DELZ(I) =  1.00000E+00
I =   3  DELZ(I) =  1.00000E+00
I =   4  DELZ(I) =  1.00000E+00
I =   5  DELZ(I) =  1.00000E+00
I =   6  DELZ(I) =  1.00000E+00
I =   7  DELZ(I) =  1.00000E+00
I =   8  DELZ(I) =  1.00000E+00
I =   9  DELZ(I) =  1.00000E+00
I =  10  DELZ(I) =  1.00000E+00

TEST PRINT FOR POINT WEIGHTS WGT(M) AND POINT DIRECTIO COSINES U(M)
M =   1  WGT(M) =  5.00000E-01  U(M) = -5.77350E-01
M =   2  WGT(M) =  5.00000E-01  U(M) =  5.77350E-01

TEST PRINT FOR GENERAL SPHERICAL HARMONICS PN(N,M) FOR N=1,6 FROM SNCON
M =   1       1.00000E+00
M =   2       1.00000E+00

ENERGY DISTRIBUTION OF DETECTOR RESPONSE FUNCTION RHO(G) BY GROUP
G =   1     1.00000E+02
G =   2     1.00000E+02
G =   3     1.00000E+02
G =   4     1.00000E+02
G =   5     1.00000E+02
G =   6     1.00000E+02

SPATIAL DISTRIBUTION OF DETECTOR RESPONSE FUNCTION RHO(I) BY DETECTOR INTERVAL NUMBER
I =   1     1.00000E+00
I =   2     1.00000E+00

FIRST ORDER RESPONSE FROM FORWARD CALCULATION = I1PHI = (R,PHI) =  3.65487E+02
```

SENSIT SAMPLE 1. *3+3 GP.*SLAB*S-2*P-0*DESIGN-SEN*WITH TEST PRINT

****************************** SENSITIVITY PROFILE FOR DETECTOR RESPONSE FUNCTION R(G) ******************************
SENR(G) IS PER LETHARGY-WIDTH DELTA-U AND NORMALIZED TO THE TOTAL RESPONSE I1PHI = (R.PHI) = 3.65487E+02

FOR THE SUM OVER ALL DETECTOR ZONES

GROUP	UPPER-E(EV)	DELTA-U	SENR
1	1.000E+01	6.93E-01	5.508E-01
2	5.000E+00	1.61E+00	3.957E-02
3	1.000E+00	6.93E-01	7.866E-02
4	5.000E-01	2.88E-01	1.327E+00
5	4.000E+00	4.05E-01	1.571E-01
6	3.000E+00	6.93E-01	7.866E-02
INTEGRAL			1.000E+00

SENSIT SAMPLE 1. *3+3 GP.*SLAB*S-2*P-0*DESIGN-SEN*WITH TEST PRINT

****************************** SENSITIVITY PROFILE FOR DETECTOR RESPONSE FUNCTION R(G) ******************************
SENR(G) IS PER LETHARGY-WIDTH DELTA-U AND NORMALIZED TO THE TOTAL RESPONSE I1PHI = (R.PHI) = 3.65487E+02

FOR DETECTOR ZONE K = 1

GROUP	UPPER-E(EV)	DELTA-U	SENR
1	1.000E+01	6.93E-01	2.974E-01
2	5.000E+00	1.61E+00	2.222E-02
3	1.000E+00	6.93E-01	4.562E-02
4	5.000E-01	2.88E-01	7.166E-01
5	4.000E+00	4.05E-01	8.819E-02
6	3.000E+00	6.93E-01	4.562E-02
INTEGRAL			5.471E-01

SENSIT SAMPLE 1. *3+3 GP.*SLAB*S-2*P-0*DESIGN-SEN*WITH TEST PRINT

****************************** SENSITIVITY PROFILE FOR DETECTOR RESPONSE FUNCTION R(G) ******************************
SENR(G) IS PER LETHARGY-WIDTH DELTA-U AND NORMALIZED TO THE TOTAL RESPONSE I1PHI = (R.PHI) = 3.65487E+02

FOR DETECTOR ZONE K = 2

GROUP	UPPER-E(EV)	DELTA-U	SENR
1	1.000E+01	6.93E-01	2.534E-01
2	5.000E+00	1.61E+00	1.735E-02
3	1.000E+00	6.93E-01	3.304E-02
4	5.000E-01	2.88E-01	6.105E-01
5	4.000E+00	4.05E-01	6.889E-02
6	3.000E+00	6.93E-01	3.304E-02
INTEGRAL			4.529E-01

ENERGY DISTRIBUTION OF FORWARD SOURCE Q(G) BY GROUP

G =	1	1.00000E+00
G =	2	0.
G =	3	0.
G =	4	1.00000E+00
G =	5	0.
G =	6	0.

SPATIAL DISTRIBUTION OF FORWARD SOURCE QUE(I) BY SOURCE INTERVAL NUMBER

I = 1 1.00000E+00

FIRST ORDER RESPONSE FROM ADJOINT CALCULATION = I1FIS = (Q.FISTAR) = 3.65399E+02

SENSIT SAMPLE 1. *3+3 GP.*SLAB*S-2*P-0*DESIGN-SEN*WITH TEST PRINT

********************************** SENSITIVITY PROFILE FOR SOURCE DISTRIBUTION Q(G) **********************************
SENQ(G) IS PER LETHARGY-WIDTH DELTA-U AND NORMALIZED TO THE TOTAL RESPONSE I1FIS = (Q.FISTAR) = 3.65399E+02

FOR THE SUM OVER ALL SOURCE ZONES

GROUP	UPPER-E(EV)	DELTA-U	SENQ
1	1.000E+01	6.93E-01	7.213E-01
2	5.000E+00	1.61E+00	0.
3	1.000E+00	6.93E-01	0.
4	5.000E-01	2.88E-01	1.738E+00
5	4.000E+00	4.05E-01	0.
6	3.000E+00	6.93E-01	0.
INTEGRAL			1.000E+00

SENSIT SAMPLE 1. *3+3 GP.*SLAB*S-2*P-0*DESIGN-SEN*WITH TEST PRINT

********************************** SENSITIVITY PROFILE FOR SOURCE DISTRIBUTION Q(G) **********************************
SENQ(G) IS PER LETHARGY-WIDTH DELTA-U AND NORMALIZED TO THE TOTAL RESPONSE I1FIS = (Q.FISTAR) = 3.65399E+02

FOR SOURCE ZONE K = 1

GROUP	UPPER-E(EV)	DELTA-U	SENQ
1	1.000E+01	6.93E-01	7.213E-01
2	5.000E+00	1.61E+00	0.
3	1.000E+00	6.93E-01	0.
4	5.000E-01	2.88E-01	1.738E+00
5	4.000E+00	4.05E-01	0.
6	3.000E+00	6.93E-01	0.
INTEGRAL.			1.000E+00

CASE NUMBER 1 OF NPERXS = 1 SUCCESSIVE CASES

MICRO CROSS-SECTIONS AND NUMBER DENSITY READ IN LASL-FORMAT WITH FOLL. TITLE CARD
CASE 1 PERTURBED XS-SET (PERTURBED MATERIAL XS) XS
NUMBER DENSITY = .900000 , MAKES THE FOLLOWING MAKRO-CROSS SECTIONS, IN 1/CM

PERT.XS-SET FOR SENSIT COUPLD-3+3-GP. TEST PROBLEM, XS=0.9*XSBAR, P-0 XS

1.80000E-02	0.	9.00000E-02	4.50000E-02	0.	0.
0.	0.	0.	4.50000E-02	0.	1.80000E-01
9.00000E-02	1.80000E-02	0.	0.	0.	0.
9.00000E-02	0.	2.70000E-01	1.80000E-01	4.50000E-02	9.00000E-03
0.	0.	0.	1.80000E-02	0.	9.00000E-02
4.50000E-02	0.	0.	0.	0.	0.
4.50000E-02	0.	1.80000E-01	9.00000E-02	1.80000E-02	0.
0.	0.	0.	9.00000E-02	0.	2.70000E-01
1.80000E-01	4.50000E-02	9.00000E-03	0.	0.	0.

UNPERTURBED REFERENCE CROSS SECTION, XSBAR, FOR CASE NUMBER 1

MICRO CROSS-SECTIONS AND NUMBER DENSITY READ IN LASL-FORMAT WITH FOLL. TITLE CARD
CASE 1 REFERENCE XS-SET (REFERENCE MATERIAL XS) XSBAR
NUMBER DENSITY = 1.000000 , MAKES THE FOLLOWING MAKRO-CROSS SECTIONS, IN 1/CM

REFERENCE XS-SET FOR SENSIT COUPLD. 3+3-GP. TEST PROBLEM, P-0 XSBAR

2.00000E-02	0.	1.00000E-01	5.00000E-02	0.	0.
0.	0.	0.	5.00000E-02	0.	2.00000E-01
1.00000E-01	2.00000E-02	0.	0.	0.	0.
1.00000E-01	0.	3.00000E-01	2.00000E-01	5.00000E-02	1.00000E-02
0.	0.	0.	2.00000E-02	0.	1.00000E-01
5.00000E-02	0.	0.	0.	0.	0.
5.00000E-02	0.	2.00000E-01	1.00000E-01	2.00000E-02	0.
0.	0.	0.	1.00000E-01	0.	3.00000E-01
2.00000E-01	5.00000E-02	1.00000E-02	0.	0.	0.

TEST PROBLEM VALUES FOR DST(G)

-1.00000E-02	-2.00000E-02	-3.00000E-02	-1.00000E-02	-2.00000E-02	-3.00000E-02

TEST PRINTOUT FOR DSL(G.GP.L) FOR L= 1

WHEN G= 1	-5.00000E-03	-2.00000E-03	-1.00000E-03	0.	0.	0.
WHEN G= 2	0.	-1.00000E-02	-5.00000E-03	0.	0.	0.
WHEN G= 3	0.	0.	-2.00000E-02	0.	0.	0.
WHEN G= 4	0.	0.	0.	-5.00000E-03	-2.00000E-03	-1.00000E-03
WHEN G= 5	0.	0.	0.	0.	-1.00000E-02	-5.00000E-03
WHEN G= 6	0.	0.	0.	0.	0.	-2.00000E-02

TEST PRINTOUT FOR N-GAMMA MATRIX DSLFNG(G.GP.L) FOR L= 1

	G-G=1	G-G=2	G-G=3	G-G=4	G-G=5	G-G=6	G-G=7	G-G=8	G-G=9	G-G=10
N-G= 1	0.	-5.00E-03	-2.00E-03	-1.00E-03	0.	0.	0.			
N-G= 2	0.	0.	-1.00E-02	-5.00E-03	0.	0.	0.			
N-G= 3	0.	0.	0.	-2.00E-02	0.	0.	0.			

TEST PRINTOUT FOR TOTAL N-GAMMA MACROSCOPIC CROSS SECTION PER NEUTRON GROUP. IN 1/CM

G= 1 SXSNG-MACRO= 0. 1/CM
G= 2 SXSNG-MACRO= 0. 1/CM
G= 3 SXSNG-MACRO= 0. 1/CM

****

DEFINITIONS FOR SENSIT-1D DESIGN SENSITIVITY PRINTOUT

****

FOR THEORY AND DETAILED DERIVATIONS OF THESE EXPRESSIONS REFER TO
(1) S.A.W. GERSTL AND W.M. STACEY JR., NUCLEAR SCIENCE AND ENGINEERING. 51, 339(1973)
(2) S.A.W. GERSTL, ARGONNE NATIONAL LAB. TECHNICAL MEMORANDUM AP/CTR/TM-28 (1974) OR FRA-TM-67 (1974)

DUE TO THE DUALISM OF FORWARD AND ADJOINT FORMULATIONS FOR RADIATION TRANSPORT CALCULATIONS WE HAVE ALWAYS TWO DIFFERENT. BUT EQUIVALENT, FORMULATIONS FOR ANY RESPONSE CALCULATION. AND BOTH ARE IMPLEMENTED IN THIS CODE:

```
I1PHI   = (R.PHI)
        = FIRST-ORDER INTEGRAL RESPONSE FROM FORWARD CALCULATION
        = FORWARD INTEGRAL RESPONSE FOR THE UNPERTURBED REFERENCE CASE

I1FIS   = (Q.FISTAR)
        = FIRST-ORDER INTEGRAL RESPONSE FROM ADJOINT CALCULATION
        = ADJOINT INTEGRAL RESPONSE FOR THE UNPERTURBED REFERENCE CASE

DELI-AD = (FISTAR.DELTA-SIGMA*PHI)
        = SECOND-ORDER TERM (DELTA-I) FROM ADJOINT-DIFFERENCE FORMULATION

DELI-FD = (PHI.DELTA-SIGMASTAR*FISTAR)
        = SECOND-ORDER TERM (DELTA-I) FROM FORWARD DIFFERENCE FORMULATION

I2AD    = SECOND-ORDER INTEGRAL RESPONSE FROM ADJOINT-DIFFERENCE FORMULATION
        = APPROXIMATE INTEGRAL RESPONSE FOR PERTURBED CASE

I2FD    = SECOND-ORDER INTEGRAL RESPONSE FROM FORWARD-DIFFERENCE FORMULATION
        = APPROXIMATE INTEGRAL RESPONSE FOR PERTURBED CASE

XAD     = SENSITIVITY COEFFICIENT FROM ADJOINT-DIFFERENCE FORMULATION

XFD     = SENSITIVITY COEFFICIENT FROM FORWARD-DIFFERENCE FORMULATION
```

APPROXIMATE CALCULATIONS OF THE INTEGRAL RESPONSE FOR THE PERTURBED CASE FOLLOW DIRECTLY FROM THE AD- AND FD-FORMULATIONS (C.F. REFERENCES):

```
I2AD  =  I1PHI - DELI-AD
I2FD  =  I1FIS - DELI-FD
XAD   =  I2AD/I1PHI  =  1 - (DELI-AD)/I1PHI
XFD   =  I2FD/I1FIS  =  1 - (DELI-FD)/I1FIS
```

THE AD-FORMULATION (I2AD) IS MORE APPROPRIATE FOR CASES WHERE THE PERTURBATION IS GEOMETRICALLY CLOSER TO THE DETECTOR THAN TO THE SOURCE (C.F. THEORY).

THE FD-FORMULATION (I2FD) IS MORE APPROPRIATE FOR CASES WHERE THE PERTURBATION IS GEOMETRICALLY CLOSER TO THE SOURCE THAN TO THE DETECTOR (C.F. THEORY).

IF BOTH REFERENCE FLUXES. PHI AND FISTAR. ARE COMPLETELY CONVERGED (FOR THE SAME REFERENCE CASE). THEN BOTH FORMULATIONS WILL GIVE IDENTICAL RESULTS, I. E.

```
I1PHI    =  I1FIS
DELU-AD  =  DELU-FD
I2AD     =  I2FD
XAD      =  XFD
```

****

SENSIT SAMPLE 1. *3+3 GP.*SLAB*S-2*P-0*DESIGN-SEN*WITH TEST PRINT

DESIGN SENSITIVITY INFORMATION. INTEGRATED OVER ALL ENERGIES
FOR THE SUM OVER ALL PERTURBED ZONES

CONTRIBUTION FROM NEUTRON GROUPS ONLY:	DELI-AD(N)	= -5.99567E+00	DELI-FD(N)	= -5.99567E+00
TOTAL SECOND-ORDER TERM. FROM NEUTRON+GAMMA GROUPS:	DELI-AD	= -1.19913E+01	DELI-FD	= -1.19913E+01
INTEGRAL RESPONSE FOR UNPERTURBED REFERENCE CASE:	I1PHI	= 3.65487E+02	I1FIS	= 3.65399E+02
INTERGRAL RESPONSE FOR PERTURBED CASE:	I2AD	= 3.77478E+02	I2FD	= 3.77391E+02
SENSITIVITY COEFFICIENT FOR TOTAL PERTURBATION:	XAD	= 1.03281E+00	XFD	= 1.03282E+00

CONTRIBUTIONS TO DELI-AD AND DELI-FD FROM PERTURBED ZONE K = 1

FROM NEUTRON GROUPS ONLY:	DELI-AD(N)	= -3.99703E+00	DELI-FD(N)	= -3.99703E+00
FROM NEUTRON PLUS GAMMA GROUPS:	DELI-AD	= -7.99406E+00	DELI-FD	= -7.99406E+00

CONTRIBUTIONS TO DELI-AD AND DELI-FD FROM PERTURBED ZONE K = 2

FROM NEUTRON GROUPS ONLY:	DELI-AD(N)	= -1.99864E+00	DELI-FD(N)	= -1.99864E+00
FROM NEUTRON PLUS GAMMA GROUPS:	DELI-AD	= -3.99729E+00	DELI-FD	= -3.99729E+00

```
SENSIT SAMPLE 2, *3+3 GP.*SLAB*S-2*P-0*DESIGN-SEN*1 PER CENT PERTURBATION
       1       1       2      10       6       3       0       1       0       1       1          CARD2
       1       2       2       1       3       1       0       0       1       0       0       0  CARD3
   10.0            5.0             1.0             0.5                                            EN(G)
    4.0            3.0             2.0             1.0                                            EG(G)
   0.5             0.5                                                                           W(M)
   -0.57735        +0.57735                                                                      MUE(M)
    0.0             1.0             2.0             3.0             4.0             5.0          MESH1
    6.0             7.0             8.0             9.0            10.0                          MESH2
       1       1                                                                                 KSRS
       9       9                                                                                 KDET1
      10      10                                                                                 KDET2
       4       5                                                                                 KPER1
       7       7                                                                                 KPER2
   100.0           100.0           100.0           100.0           100.0           100.0         R(G)
   1.0             1.0                                                                           RHO(J)
   1.0             0.0             0.0             1.0             0.0             0.0           Q(G)
   1.0                                                                                           QUE(J)
CASE 1 PERTURBED XS-SET  (PERTURBED MATERIAL XS)                                                   XS
NUMDEN =     1.0                                                                                   XS
 STANDARD XS-SET FOR SENSIT COUPLD-3+3-GP. TEST PROBLEM, P-0                                       XS
           .02            0.0             0.1             .05             0.0             0.0 GP1
           0.0            0.0             0.0             0.05            0.0             0.2 GP1/2
           0.1            0.02            0.0             0.0             0.0             0.0 GP2
           0.1            0.0             0.3             0.2             .05             .01 GP3
           0.0            0.0             0.0             0.02            0.0             0.1 GP3/4
           0.05           0.0             0.0             0.0             0.0             0.0 GP4
           .05            0.0             0.2             0.1             .02             0.0 GP5
           0.0            0.0             0.0             0.1             0.0             0.3 GP5/6
           0.2            0.05            0.01            0.0             0.0             0.0 GP6
```

```
SENSIT SAMPLE 2, *3+3 GP.*SLAB*S-2*P-0*DESIGN-SEN*1 PER CENT PERTURBATION

ITYP     = TYPE OF SENS.-UNCERT.-ANAL., 1-XS,2-DESIGN,3-VECTOR-XS,4-SED                 =   1
IGE      = GEOMETRIC MODEL: 1-SLAB,2-CYLINDER,3-SPHERE                                  =   1
ISN      = ORDER OF S-N QUADRATURE                                                      =   2
IM       = TOTAL NUMBER OF SPATIAL MESH INTERVALS                                       =  10
IGM      = TOTAL NUMBER OF ENERGY GROUPS                                                =   6
NCOUPL   = NUMBER OF NEUTRON GROUPS IN CPL. CALC., ZERO FOR NEUTRONS ONLY               =   3
LMAX     = MAX. P-L ORDER OF CROSS SECTIONS                                             =   0
ITAPE    = FORMAT OF ANG.FLX. TAPES 1 AND 2: 0-ANISN, 1-CCCC(ONETRAN)                   =   1
IXSTAPE  = SOURCE OF INPUT CROSS-SECTIONS: 0-CARDS, 1-TAPE4, 2-TAPE10                   =   0
NPERXS   = NUMBER OF SUCCESSIVE CASES, ALSO NO. OF INPUT XS-SETS TO BE READ             =   1
IDESIGN  = ASSUMED 1 PER CENT DENSITY INCREASE IN PERT. ZS. FOR DES.-SEN., 0/1=NO/YES   =   1

KSRS     = NUMBER OF SOURCE ZONES                                                       =   1
KDET     = NUMBER OF DETECTOR ZONES                                                     =   2
KPER     = NUMBER OF PERTURBED ZONES                                                    =   2
KXS      = INPUT XS-FORMAT  0-IF ITYP=2, 1-LASL, 2-ORNL                                 =   1
IHT      = POSITION OF TOTAL CROSS-SECTION IN XS-TABLES                                 =   3
IHA      = POSITION OF ABSORPTION CROSS-SECTION IN XS-TABLES                            =   1
DETCOV   = 0/1 = DO NOT/DO READ COVARIANCE MATRIX FOR R(G)                              =   0
NSED     = 0/1 = DO NOT/DO READ INTEGRAL SED-UNCERTAINTIES                              =   0
IOUTPUT  = OUTPUT PRINT DETAIL: 0-SUM OVER PERT.ZONES ONLY, 1-ALSO INDIV. PERT.ZS.      =   1
NSUMCOV  = NO. OF RESP.-VARIANCES SUMMED FOR ITYP=2, ZERO FOR ITYP=0,1,3                =   0
ITEST    = TEST PRINTOUT FLAG: 0-NONE, 1-XS, 2-ANG.FLXS., 3-VECTOR-XS                   =   0
IPRINT   = TEST PRINTS FROM POINTR: 0-NONE,1-DUMPS, 2-TRACES, 3-ALL                     =   0



   4 NEUTRON ENERGY GROUP BOUNDARIES READ, IN EV
  1.000E+01  5.000E+00  1.000E+00  5.000E-01

   4 GAMMA ENERGY GROUP BOUNDARIES READ, IN EV
  4.000E+00  3.000E+00  2.000E+00  1.000E+00

LEVEL WEIGHTS FOR DISCRETE ANGLES
     .500000     .500000

DISCRETE ANGLES MUE FOR LEVEL WEIGHTS
    -.577350     .577350

MESH BOUNDARIES READ
  0.         1.000E+00  2.000E+00  3.000E+00  4.000E+00  5.000E+00  6.000E+00  7.000E+00  8.000E+00  9.000E+00
 1.000E+01
```

```
SENSIT SAMPLE 2. *3+3 GP.*SLAB*S-2*P-0*DESIGN-SEN*1 PER CENT PERTURBATION

******* RESULTS ARE FOR ASSUMED 1 PER CENT FLAT XS-INCREASE. OR 1 PER CENT DENSITY INCREASE IN PERT. ZONES *******

DESIGN SENSITIVITY INFORMATION. INTEGRATED OVER  ALL ENERGIES
FOR THE SUM OVER ALL PERTURBED ZONES

    CONTRIBUTION FROM NEUTRON GROUPS ONLY:                 DELI-AD(N) =  5.99567E-01     DELI-FD(N) =  5.99567E-01

    TOTAL SECOND-ORDER TERM. FROM NEUTRON+GAMMA GROUPS:    DELI-AD    =  1.19913E+00     DELI-FD    =  1.19913E+00

    INTEGRAL RESPONSE FOR UNPERTURBED REFERENCE CASE:      I1PHI      =  3.65487E+02     I1F1S      =  3.65399E+02

    INTERGRAL RESPONSE FOR PERTURBED CASE:                 I2AD       =  3.64288E+02     I2FD       =  3.64200E+02

    SENSITIVITY COEFFICIENT FOR TOTAL PERTURBATION:        XAD        =  9.96719E-01     XFD        =  9.96718E-01


******* RESULTS ARE FOR ASSUMED 1 PER CENT FLAT XS-INCREASE, OR I PER CENT DENSITY INCREASE IN PERT. ZONES *******

CONTRIBUTIONS TO DELI-AD AND DELI-FD FROM PERTURBED ZONE  K =  1

    FROM NEUTRON GROUPS ONLY:          DELI-AD(N) =  3.99703E-01     DELI-FD(N) =  3.99703E-01

    FROM NEUTRON PLUS GAMMA GROUPS:    DELI-AD    =  7.99406E-01     DELI-FD    =  7.99406E-01


******* RESULTS ARE FOR ASSUMED 1 PER CENT FLAT XS-INCREASE, OR 1 PER CENT DENSITY INCREASE IN PERT. ZONES *******

CONTRIBUTIONS TO DELI-AD AND DELI-FD FROM PERTURBED ZONE  K =  2

    FROM NEUTRON GROUPS ONLY:          DELI-AD(N) =  1.99864E-01     DELI-FD(N) =  1.99864E-01

    FROM NEUTRON PLUS GAMMA GROUPS:    DELI-AD    =  3.99729E-01     DELI-FD    =  3.99729E-01
```

```
SENSIT SAMPLE 3, *3+3 GP.*CYL.GEOM.*S-16*P-1*DESIGN SEN.*SHORT PRINT
       1       2     16      10       6       3       1       1       0       1       0         CARD2
       1       2      2       1       3       1       0       0       0       0       0       0 CARD3
   10.0          5.0           1.0           0.5                                                EN(G)
    4.0          3.0           2.0           1.0                                                EG(G)
   1.35762E-2  3.11267E-2  4.75792E-2  6.23144E-2  7.47979E-2  8.45782E-2 W(M)
   9.13017E-2  9.47253E-2  9.47253E-2  9.13017E-2  8.45782E-2  7.47979E-2 W(M)
   6.23144E-2  4.75792E-2  3.11267E-2  1.35762E-2                         W(M)
  -9.89400E-1 -9.44575E-1 -8.65631E-1 -7.55404E-1 -6.17876E-1 -4.58016E-1 MUE(M)
  -2.81603E-1 -9.50125E-2 +9.50125E-2 +2.81603E-1 +4.58016E-1 +6.17876E-1 MUE(M)
  +7.55404E-1 +8.65631E-1 +9.44575E-1 +9.89400E-1                         MUE(M)
   0.0           1.0           2.0           3.0           4.0           5.0        MESH1
   6.0           7.0           8.0           9.0          10.0                      MESH2
       1       1                                                                    KSRS
       9       9                                                                    KDET1
      10      10                                                                    KDET2
       4       5                                                                    KPER1
       7       7                                                                    KPER2
   200.0         200.0         200.0         200.0         200.0         200.0      R(G)
   1.87240E-2  1.67530E-2                                                           RHO(J)
   1.0           0.0           0.0           1.0           0.0           0.0        Q(G)
   0.31831                                                                          QUE(J)
CASE 1 PERTURBED XS-SET  (PERTURBED MATERIAL XS)                                     XS
NUMDEN =     0.9                                                                     XS
 PERT.XS-SET FOR SENSIT COUPLD-3+3-GP. TEST PROBLEM, XS=0.9*XSBAR, P-0              XS
            .02           0.0           0.1           .05           0.0         0.0 GP1
            0.0           0.0           0.0          0.05           0.0         0.2 GP1/2
            0.1          0.02           0.0           0.0           0.0         0.0 GP2
            0.1           0.0           0.3           0.2           .05         .01 GP3
            0.0           0.0           0.0          0.02           0.0         0.1 GP3/4
           0.05           0.0           0.0           0.0           0.0         0.0 GP4
            .05           0.0           0.2           0.1           .02         0.0 GP5
            0.0           0.0           0.0           0.1           0.0         0.3 GP5/6
            0.2          0.05          0.01           0.0           0.0         0.0 GP6
 PERT.XS-SET FOR SENSIT COUPLD-3+3-GP. TEST PROBLEM, XS=0.9*XSBAR, P-1              XS
            .02           0.0           0.1           .05           0.0         0.0 GP1
            0.0           0.0           0.0          0.05           0.0         0.2 GP1/2
            0.1          0.02           0.0           0.0           0.0         0.0 GP2
            0.1           0.0           0.3           0.2           .05         .01 GP3
            0.0           0.0           0.0          0.02           0.0         0.1 GP3/4
           0.05           0.0           0.0           0.0           0.0         0.0 GP4
            .05           0.0           0.2           0.1           .02         0.0 GP5
            0.0           0.0           0.0           0.1           0.0         0.3 GP5/6
            0.2          0.05          0.01           0.0           0.0         0.0 GP6
```

```
CASE 1 REFERENCE XS-SET  (REFERENCE MATERIAL XS)                                  XSBAR
NUMDEN =     1.0                                                                  XSBAR
 REFERENCE XS-SET FOR SENSIT COUPLD. 3+3-GP. TEST PROBLEM, P-0                    XSBAR
          .02        0.0        0.1        .05        0.0                     0.0 GP1
          0.0        0.0        0.0       0.05        0.0                     0.2 GP1/2
          0.1       0.02        0.0        0.0        0.0                     0.0 GP2
          0.1        0.0        0.3        0.2        .05                     .01 GP3
          0.0        0.0        0.0       0.02        0.0                     0.1 GP3/4
         0.05        0.0        0.0        0.0        0.0                     0.0 GP4
          .05        0.0        0.2        0.1        .02                     0.0 GP5
          0.0        0.0        0.0        0.1        0.0                     0.3 GP5/6
          0.2       0.05       0.01        0.0        0.0                     0.0 GP6
 REFERENCE XS-SET FOR SENSIT COUPLD. 3+3-GP. TEST PROBLEM, P-1                    XSBAR
          .02        0.0        0.1        .05        0.0                     0.0 GP1
          0.0        0.0        0.0       0.05        0.0                     0.2 GP1/2
          0.1       0.02        0.0        0.0        0.0                     0.0 GP2
          0.1        0.0        0.3        0.2        .05                     .01 GP3
          0.0        0.0        0.0       0.02        0.0                     0.1 GP3/4
         0.05        0.0        0.0        0.0        0.0                     0.0 GP4
          .05        0.0        0.2        0.1        .02                     0.0 GP5
          0.0        0.0        0.0        0.1        0.0                     0.3 GP5/6
          0.2       0.05       0.01        0.0        0.0                     0.0 GP6
```

```
SENSIT SAMPLE 3, *3+3 GP.*CYL.GEOM.*S-16*P-1*DESIGN SEN.*SHORT PRINT

ITYP     = TYPE OF SENS.-UNCERT.-ANAL., 1-XS,2-DESIGN,3-VECTOR-XS,4-SED                    =   1
IGE      = GEOMETRIC MODEL: 1-SLAB,2-CYLINDER,3-SPHERE                                     =   2
ISN      = ORDER OF S-N QUADRATURE                                                         =  16
IM       = TOTAL NUMBER OF SPATIAL MESH INTERVALS                                          =  10
IGM      = TOTAL NUMBER OF ENERGY GROUPS                                                   =   6
NCOUPL   = NUMBER OF NEUTRON GROUPS IN CPL. CALC., ZERO FOR NEUTRONS ONLY                  =   3
LMAX     = MAX. P-L ORDER OF CROSS SECTIONS                                                =   1
ITAPE    = FORMAT OF ANG.FLX. TAPES 1 AND 2: 0-ANISN, 1-CCCC(ONETRAN)                      =   1
IXSTAPE  = SOURCE OF INPUT CROSS-SECTIONS: 0-CARDS, 1-TAPE4, 2-TAPE10                      =   0
NPERXS   = NUMBER OF SUCCESSIVE CASES, ALSO NO. OF INPUT XS-SETS TO BE READ                =   1
IDESIGN  = ASSUMED 1 PER CENT DENSITY INCREASE IN PERT. ZS. FOR DES.-SEN., 0/1=NO/YES      =   0

KSRS     = NUMBER OF SOURCE ZONES                                                          =   1
KDET     = NUMBER OF DETECTOR ZONES                                                        =   2
KPER     = NUMBER OF PERTURBED ZONES                                                       =   2
KXS      = INPUT XS-FORMAT  0-IF ITYP=2, 1-LASL, 2-ORNL                                    =   1
IHT      = POSITION OF TOTAL CROSS-SECTION IN XS-TABLES                                    =   3
IHA      = POSITION OF ABSORPTION CROSS-SECTION IN XS-TABLES                               =   1
DETCOV   = 0/1 = DO NOT/DO READ COVARIANCE MATRIX FOR R(G)                                 =   0
NSED     = 0/1 = DO NOT/DO READ INTEGRAL SED-UNCERTAINTIES                                 =   0
IOUTPUT  = OUTPUT PRINT DETAIL: 0-SUM OVER PERT.ZONES ONLY, 1-ALSO INDIV. PERT.ZS.         =   0
NSUMCOV  = NO. OF RESP.-VARIANCES SUMMED FOR ITYP=2, ZERO FOR ITYP=0,1,3                   =   0
ITEST    = TEST PRINTOUT FLAG: 0-NONE, 1-XS, 2-ANG.FLXS., 3-VECTOR-XS                      =   0
IPRINT   = TEST PRINTS FROM POINTR: 0-NONE,1-DUMPS, 2-TRACES, 3-ALL                        =   0


   4 NEUTRON ENERGY GROUP BOUNDARIES READ, IN EV
  1.000E+01  5.000E+00  1.000E+00  5.000E-01

   4 GAMMA ENERGY GROUP BOUNDARIES READ, IN EV
  4.000E+00  3.000E+00  2.000E+00  1.000E+00

LEVEL WEIGHTS FOR DISCRETE ANGLES
     .013576     .031127     .047579     .062314     .074798     .084578     .091302     .094725     .094725     .09130

2     .084578

     .074798     .062314     .047579     .031127     .013576

DISCRETE ANGLES MUE FOR LEVEL WEIGHTS
    -.989400    -.944575    -.865631    -.755404    -.617876    -.458016    -.281603    -.095013     .095013     .28160

3     .458016

     .617876     .755404     .865631     .944575     .989400

MESH BOUNDARIES READ
  0.         1.000E+00  2.000E+00  3.000E+00  4.000E+00  5.000E+00  6.000E+00  7.000E+00  8.000E+00  9.000E+00
 1.000E+01
```

SENSIT SAMPLE 3, *3+3 GP.*CYL.GEOM.*S-16*P-1*DESIGN SEN.*SHORT PRINT

DESIGN SENSITIVITY INFORMATION. INTEGRATED OVER ALL ENERGIES
FOR THE SUM OVER ALL PERTURBED ZONES

CONTRIBUTION FROM NEUTRON GROUPS ONLY:	DELI-AD(N)	= -8.74164E-02	DELI-FD(N)	= -8.74164E-02
TOTAL SECOND-ORDER TERM, FROM NEUTRON+GAMMA GROUPS:	DELI-AD	= -1.74833E-01	DELI-FD	= -1.74833E-01
INTEGRAL RESPONSE FOR UNPERTURBED REFERENCE CASE:	I1PHI	= 1.44406E+01	I1FIS	= 1.43925E+01
INTERGRAL RESPONSE FOR PERTURBED CASE:	I2AD	= 1.46155E+01	I2FD	= 1.45674E+01
SENSITIVITY COEFFICIENT FOR TOTAL PERTURBATION:	XAD	= 1.01211E+00	XFD	= 1.01215E+00

```
SENSIT SAMPLE 4, *3+3 GP.*SLAB*S-2*P-0*SENS.-PROFILES*LONG PRINT
      0      1      2     10      6      3      0      1      0      1      0         CARD2
      1      2      2      1      3      1      0      0      1      0      0       0 CARD3
  10.0         5.0          1.0          0.5                                          EN(G)
   4.0         3.0          2.0          1.0                                          EG(G)
  0.5          0.5                                                                   W(M)
  -0.57735     +0.57735                                                              MUE(M)
   0.0          1.0          2.0          3.0          4.0          5.0             MESH1
   6.0          7.0          8.0          9.0         10.0                          MESH2
      1      1                                                                       KSRS
      9      9                                                                       KDET1
     10     10                                                                       KDET2
      4      5                                                                       KPER1
      7      7                                                                       KPER2
  100.0        100.0        100.0        100.0        100.0        100.0             R(G)
  1.0          1.0                                                                   RHO(J)
  1.0          0.0          0.0          1.0          0.0          0.0              Q(G)
  1.0                                                                                QUE(J)
CASE 1 PERTURBED ZONE XS-SET                                                          XS
NUMDEN =     0.9                                                                      XS
 PERT.XS-SET FOR SENSIT COUPLD-3+3-GP. TEST PROBLEM, XS=0.9*XSBAR, P-0               XS
            .02          0.0          0.1          .05          0.0          0.0 GP1
            0.0          0.0          0.0         0.05          0.0          0.2 GP1/2
            0.1         0.02          0.0          0.0          0.0          0.0 GP2
            0.1          0.0          0.3          0.2          .05          .01 GP3
            0.0          0.0          0.0         0.02          0.0          0.1 GP3/4
           0.05          0.0          0.0          0.0          0.0          0.0 GP4
            .05          0.0          0.2          0.1          .02          0.0 GP5
            0.0          0.0          0.0          0.1          0.0          0.3 GP5/6
            0.2         0.05         0.01          0.0          0.0          0.0 GP6
```

```
SENSIT SAMPLE 4, *3+3 GP.*SLAB*S-2*P-0*SENS.-PROFILES*LONG PRINT

ITYP     = TYPE OF SENS.-UNCERT.-ANAL., 1-XS,2-DESIGN,3-VECTOR-XS,4-SED                  =   0
IGE      = GEOMETRIC MODEL: 1-SLAB,2-CYLINDER,3-SPHERE                                   =   1
ISN      = ORDER OF S-N QUADRATURE                                                       =   2
IM       = TOTAL NUMBER OF SPATIAL MESH INTERVALS                                        =  10
IGM      = TOTAL NUMBER OF ENERGY GROUPS                                                 =   6
NCOUPL   = NUMBER OF NEUTRON GROUPS IN CPL. CALC., ZERO FOR NEUTRONS ONLY                =   3
LMAX     = MAX. P-L ORDER OF CROSS SECTIONS                                              =   0
ITAPE    = FORMAT OF ANG.FLX. TAPES 1 AND 2: 0-ANISN, 1-CCCC(ONETRAN)                    =   1
IXSTAPE  = SOURCE OF INPUT CROSS-SECTIONS: 0-CARDS, 1-TAPE4, 2-TAPE10                    =   0
NPERXS   = NUMBER OF SUCCESSIVE CASES, ALSO NO. OF INPUT XS-SETS TO BE READ              =   1
IDESIGN  = ASSUMED 1 PER CENT DENSITY INCREASE IN PERT. ZS. FOR DES.-SEN., 0/1=NO/YES    =   0

KSRS     = NUMBER OF SOURCE ZONES                                                        =   1
KDET     = NUMBER OF DETECTOR ZONES                                                      =   2
KPER     = NUMBER OF PERTURBED ZONES                                                     =   2
KXS      = INPUT XS-FORMAT  0-IF ITYP=2, 1-LASL, 2-ORNL                                  =   1
IHT      = POSITION OF TOTAL CROSS-SECTION IN XS-TABLES                                  =   3
IHA      = POSITION OF ABSORPTION CROSS-SECTION IN XS-TABLES                             =   1
DETCOV   = 0/1 = DO NOT/DO READ COVARIANCE MATRIX FOR R(G)                               =   0
NSED     = 0/1 = DO NOT/DO READ INTEGRAL SED-UNCERTAINTIES                               =   0
IOUTPUT  = OUTPUT PRINT DETAIL: 0-SUM OVER PERT.ZONES ONLY, 1-ALSO INDIV. PERT.ZS.       =   1
NSUMCOV  = NO. OF RESP.-VARIANCES SUMMED FOR ITYP=2, ZERO FOR ITYP=0,1,3                 =   0
ITEST    = TEST PRINTOUT FLAG: 0-NONE, 1-XS, 2-ANG.FLXS., 3-VECTOR-XS                    =   0
IPRINT   = TEST PRINTS FROM POINTR: 0-NONE,1-DUMPS, 2-TRACES, 3-ALL                      =   0


   4 NEUTRON ENERGY GROUP BOUNDARIES READ, IN EV
  1.000E+01  5.000E+00  1.000E+00  5.000E-01

   4 GAMMA ENERGY GROUP BOUNDARIES READ, IN EV
  4.000E+00  3.000E+00  2.000E+00  1.000E+00

LEVEL WEIGHTS FOR DISCRETE ANGLES
     .500000     .500000

DISCRETE ANGLES MUE FOR LEVEL WEIGHTS
    -.577350     .577350

MESH BOUNDARIES READ
  0.         1.000E+00  2.000E+00  3.000E+00  4.000E+00  5.000E+00  6.000E+00  7.000E+00  8.000E+00  9.000E+00
 1.000E+01
```

DEFINITIONS OF SENSIT SENSITIVITY PROFILE NOMENCLATURE

AXS = SENSITIVITY PROFILE PER DELTA-U FOR THE ABSORPTION CROSS-SECTION (TAKEN FROM POSITION IHA IN INPUT CROSS-SECTION TABLES). PURE LOSS TERM

NU-FISS = SENSITIVITY PROFILE PER DELTA-U FOR THE CROSS SECTION IN POSITION IHA+1 IN INPUT XS-TABLES. WHICH IS USUALLY NU-TIMES THE FISSION CROSS SECTION. PURE LOSS TERM

SXS = PARTIAL SENSITIVITY PROFILE PER DELTA-U FOR THE SCATTERING CROSS-SECTION (COMPUTED FOR EACH ENERGY GROUP AS A DIAGONAL SUM FROM INPUT XS-TABLES). LOSS TERM ONLY

TXS = SENSITIVITY PROFILE PER DELTA-U FOR THE TOTAL CROSS SECTION (AS GIVEN IN POSITION IHT IN INPUT CROSS-SECTION TABLES). PURE LOSS TERM

N-GAIN = PARTIAL SENSITIVITY PROFILE PER DELTA-U FOR THE NEUTRON SCATTERING CROSS-SECTION. GAIN TERM FOR SENSITIVITY GAINS DUE TO SCATTERING OUT OF ENERGY GROUP G INTO ALL LOWER NEUTRON ENERGY GROUPS. COMPUTED FROM FORWARD DIFFERENCE FORMULATION.

G-GAIN = PARTIAL SENSITIVITY PROFILE PER DELTA-U FOR THE GAMMA SCATTERING CROSS-SECTION. GAIN TERM FOR SENSITIVITY GAINS DUE TO SCATTERING OUT OF GAMMA ENERGY GROUP G INTO ALL LOWER GAMMA ENERGY GROUPS. COMPUTED FROM FORWARD DIFFERENCE FORMULATION.

N-GAIN(SED) = RE-ORDERED PARTIAL SENSITIVITY PROFILE PER DELTA-U FOR SCATTERING CROSS-SECTION. GAIN TERM FOR SENSITIVITY GAINS DUE TO SCATTERING INTO GROUP G FROM ALL HIGHER NEUTRON ENERGY GROUPS. COMPUTED FROM ADJOINT DIFFERNCE FORMULATION.
CORRESPONDS TO SINGLE-DIFFERENTIAL SED SENSITIVITY PROFILE. PSED(G-OUT) PER DELU-OUT. INTEGRATED OVER ALL INCIDENT ENERGY GROUPS.

NG-GAIN = PARTIAL SENSITIVITY PROFILE PER DELTA-U FOR THE GAMMA PRODUCTION CROSS-SECTION AT NEUTRON ENERGY GROUP G. PURE GAIN TERM FOR SENSITIVITY GAINS DUE TO TRANSFER FROM NEUTRON GROUP G INTO ALL GAMMA GROUPS.

SEN = NET SENSITIVITY PROFILE PER DELTA-U FOR THE SCATTERING CROSS-SECTION (SEN=SXS+NGAIN)

SENT = NET SENSITIVITY PROFILE PER DELTA-U FOR THE TOTAL CROSS-SECTION (SENT=TXS+NGAIN)

SENR = SENSITIVITY PROFILE PER DELTA-U FOR THE DETECTOR RESPONSE FUNCTION R(G)

SENQ = SENSITIVITY PROFILE PER DELTA-U FOR THE SOURCE DISTRIBUTION FUNCTION Q(G)

SENSIT SAMPLE 4. *3+3 GP.*SLAB*S-2*P-0*SENS.-PROFILES*LONG PRINT

************************************** NEUTRON CROSS SECTION SENSITIVITY PROFILES **
** SUMMED OVER ALL PERTURBED ZONES **
PARTIAL AND NET SENSITIVITY PROFILES PER DELTA-U. NORMALIZED TO I1PHI = (R.PHI) = 3.65487E+02
FOR NEUTRON INTERACTION CROSS SECTIONS: (N-N) AND (N-GAMMA)

			****** P U R E	L O S S	T E R M S	**********	********* PURE GAIN TERMS		**********
GROUP	UPPER-E(EV)	DELTA-U	AXS	NU-FISS	SXS	TXS	N-GAIN	N-GAIN(SED)	NG-GAIN
1	1.000E+01	6.93E-01	-6.932E-02	0.	-2.773E-01	-3.466E-01	1.875E-01	1.423E-01	0.
2	5.000E+00	1.61E+00	-7.395E-03	0.	-2.218E-02	-2.958E-02	1.707E-02	2.764E-02	0.
3	1.000E+00	6.93E-01	-2.048E-02	0.	-4.096E-02	-6.143E-02	3.659E-02	5.724E-02	0.
INTEGRAL			-7.414E-02	0.	-2.563E-01	-3.304E-01	1.828E-01	1.828E-01	0.

			**** NET PROFILES ****	
GROUP	UPPER-E(EV)	DELTA-U	SEN	SENT
1	1.000E+01	6.93E-01	-8.981E-02	-1.591E-01
2	5.000E+00	1.61E+00	-5.109E-03	-1.250E-02
3	1.000E+00	6.93E-01	-4.366E-03	-2.484E-02
INTEGRAL			-7.350E-02	-1.476E-01

******************************** GAMMA CROSS SECTION SENSITIVITY PROFILES *********************************
************************************* SUMMED OVER ALL PERTURBED ZONES ***************************************
PARTIAL AND NET SENSITIVITY PROFILES PER DELTA-U. NORMALIZED TO I1PHI = (R.PHI) = 3.65487E+02
FOR GAMMA INTERACTION CROSS SECTIONS: (GAMMA-GAMMA) ONLY

			**********PURE LOSS TERMS***********			*GAIN TERM*	*****NET PROFILES*****	
GROUP	UPPER-E(EV)	DELTA-U	AXS	SXS	TXS	G-GAIN	SEN	SENT
4	5.000E-01	2.88E-01	-1.670E-01	-6.680E-01	-8.351E-01	4.517E-01	-2.164E-01	-3.834E-01
5	4.000E+00	4.05E-01	-2.935E-02	-8.805E-02	-1.174E-01	6.778E-02	-2.028E-02	-4.963E-02
6	3.000E+00	6.93E-01	-2.048E-02	-4.096E-02	-6.143E-02	3.659E-02	-4.366E-03	-2.484E-02
INTEGRAL			-7.414E-02	-2.563E-01	-3.304E-01	1.828E-01	-7.350E-02	-1.476E-01

************************************ NEUTRON CROSS SECTION SENSITIVITY PROFILES ************************************
************************************ FOR PERTURBED ZONE K = 1 ************************************
PARTIAL AND NET SENSITIVITY PROFILES PER DELTA-U, NORMALIZED TO I1PHI = (R,PHI) = 3.65487E+02
FOR NEUTRON INTERACTION CROSS SECTIONS: (N-N) AND (N-GAMMA)

			****** P U R E L O S S		T E R M S ********		******** PURE GAIN TERMS ********		
GROUP	UPPER-E(EV)	DELTA-U	AXS	NU-FISS	SXS	TXS	N-GAIN	N-GAIN(SED)	NG-GAIN
1	1.000E+01	6.93E-01	-4.819E-02	0.	-1.928E-01	-2.410E-01	1.300E-01	1.013E-01	0.
2	5.000E+00	1.61E+00	-4.566E-03	0.	-1.370E-02	-1.826E-02	1.062E-02	1.781E-02	0.
3	1.000E+00	6.93E-01	-1.148E-02	0.	-2.295E-02	-3.443E-02	2.114E-02	3.315E-02	0.
			----------	----------	----------	----------	----------	----------	----------
INTEGRAL			-4.871E-02	0.	-1.716E-01	-2.203E-01	1.218E-01	1.218E-01	0.

			**** NET PROFILES ****	
GROUP	UPPER-E(EV)	DELTA-U	SEN	SENT
1	1.000E+01	6.93E-01	-6.277E-02	-1.110E-01
2	5.000E+00	1.61E+00	-3.080E-03	-7.646E-03
3	1.000E+00	6.93E-01	-1.812E-03	-1.329E-02
			----------	----------
INTEGRAL			-4.972E-02	-9.843E-02

************************************ GAMMA CROSS SECTION SENSITIVITY PROFILES ************************************
************************************ FOR PERTURBED ZONE K = 1 ************************************
PARTIAL AND NET SENSITIVITY PROFILES PER DELTA-U, NORMALIZED TO I1PHI = (R,PHI) = 3.65487E+02
FOR GAMMA INTERACTION CROSS SECTIONS: (GAMMA-GAMMA) ONLY

			*********PURE LOSS TERMS*********			*GAIN TERM*	*****NET PROFILES*****	
GROUP	UPPER-E(EV)	DELTA-U	AXS	SXS	TXS	G-GAIN	SEN	SENT
4	5.000E-01	2.88E-01	-1.161E-01	-4.644E-01	-5.806E-01	3.132E-01	-1.512E-01	-2.673E-01
5	4.000E+00	4.05E-01	-1.812E-02	-5.437E-02	-7.249E-02	4.214E-02	-1.223E-02	-3.035E-02
6	3.000E+00	6.93E-01	-1.148E-02	-2.295E-02	-3.443E-02	2.114E-02	-1.812E-03	-1.329E-02
			----------	----------	----------	----------	----------	----------
INTEGRAL			-4.871E-02	-1.716E-01	-2.203E-01	1.218E-01	-4.972E-02	-9.843E-02

************************************** NEUTRON CROSS SECTION SENSITIVITY PROFILES **
** FOR PERTURBED ZONE K = 2 **
PARTIAL AND NET SENSITIVITY PROFILES PER DELTA-U, NORMALIZED TO I1PHI = (R.PHI) = 3.65487E+02
FOR NEUTRON INTERACTION CROSS SECTIONS: (N-N) AND (N-GAMMA)

			****** P U R E	L O S S	T E R M S	**********	********* PURE GAIN TERMS	**********	
GROUP	UPPER-E(EV)	DELTA-U	AXS	NU-FISS	SXS	TXS	N-GAIN	N-GAIN(SED)	NG-GAIN
1	1.000E+01	6.93E-01	-2.113E-02	0.	-8.450E-02	-1.056E-01	5.746E-02	4.100E-02	0.
2	5.000E+00	1.61E+00	-2.829E-03	0.	-8.486E-03	-1.131E-02	6.458E-03	9.822E-03	0.
3	1.000E+00	6.93E-01	-9.001E-03	0.	-1.800E-02	-2.700E-02	1.545E-02	2.409E-02	0.
INTEGRAL			-2.543E-02	0.	-8.471E-02	-1.101E-01	6.093E-02	6.093E-02	0.

			**** NET PROFILES ****	
GROUP	UPPER-E(EV)	DELTA-U	SEN	SENT
1	1.000E+01	6.93E-01	-2.705E-02	-4.817E-02
2	5.000E+00	1.61E+00	-2.028E-03	-4.857E-03
3	1.000E+00	6.93E-01	-2.554E-03	-1.155E-02
INTEGRAL			-2.378E-02	-4.922E-02

*********************************** GAMMA CROSS SECTION SENSITIVITY PROFILES **********************************
** FOR PERTURBED ZONE K = 2 **
PARTIAL AND NET SENSITIVITY PROFILES PER DELTA-U. NORMALIZED TO I1PHI = (R.PHI) = 3.65487E+02
FOR GAMMA INTERACTION CROSS SECTIONS: (GAMMA-GAMMA) ONLY

			**********PURE LOSS TERMS***********			*GAIN TERM*	*****NET PROFILES*****	
GROUP	UPPER-E(EV)	DELTA-U	AXS	SXS	TXS	G-GAIN	SEN	SENT
4	5.000E-01	2.88E-01	-5.090E-02	-2.036E-01	-2.545E-01	1.384E-01	-6.516E-02	-1.161E-01
5	4.000E+00	4.05E-01	-1.123E-02	-3.368E-02	-4.491E-02	2.563E-02	-8.051E-03	-1.928E-02
6	3.000E+00	6.93E-01	-9.001E-03	-1.800E-02	-2.700E-02	1.545E-02	-2.554E-03	-1.155E-02
INTEGRAL			-2.543E-02	-8.471E-02	-1.101E-01	6.093E-02	-2.378E-02	-4.922E-02

```
SENSIT SAMPLE 5, *3+3 GP.*SLAB*S-2*P-0*XS FROM TAPE4*SED SEN*SHORT PRINT
     3       1       2      10       6       3       0       1       1       1       0          CARD2
     1       2       2       1       3       1       0       0       0       0       0        0 CARD3
  10.0            5.0            1.0            0.5                                              EN(G)
   4.0            3.0            2.0            1.0                                              EG(G)
  0.5             0.5                                                                            W(M)
  -0.57735       +0.57735                                                                        MUE(M)
   0.0             1.0            2.0            3.0            4.0            5.0               MESH1
   6.0             7.0            8.0            9.0            10.0                             MESH2
     1       1                                                                                   KSRS
     9       9                                                                                   KDET1
    10      10                                                                                   KDET2
     4       5                                                                                   KPER1
     7       7                                                                                   KPER2
  100.0           100.0          100.0          100.0          100.0          100.0              R(G)
  1.0             1.0                                                                            RHO(J)
  1.0             0.0            0.0            1.0            0.0            0.0                Q(G)
  1.0                                                                                            QUE(J)
     2          0.9              ID2 P-0 XS                                                      XS
```

```
SENSIT SAMPLE 5, *3+3 GP.*SLAB*S-2*P-0*XS FROM TAPE4*SED SEN*SHORT PRINT

ITYP     = TYPE OF SENS.-UNCERT.-ANAL., 1-XS,2-DESIGN.3-VECTOR-XS.4-SED                          =   3
IGE      = GEOMETRIC MODEL: 1-SLAB.2-CYLINDER.3-SPHERE                                           =   1
ISN      = ORDER OF S-N QUADRATURE                                                               =   2
IM       = TOTAL NUMBER OF SPATIAL MESH INTERVALS                                                =  10
IGM      = TOTAL NUMBER OF ENERGY GROUPS                                                         =   6
NCOUPL   = NUMBER OF NEUTRON GROUPS IN CPL. CALC., ZERO FOR NEUTRONS ONLY                        =   3
LMAX     = MAX. P-L ORDER OF CROSS SECTIONS                                                      =   0
ITAPE    = FORMAT OF ANG.FLX. TAPES 1 AND 2: 0-ANISN, 1-CCCC(ONETRAN)                            =   1
IXSTAPE  = SOURCE OF INPUT CROSS-SECTIONS: 0-CARDS. 1-TAPE4. 2-TAPE10                            =   1
NPERXS   = NUMBER OF SUCCESSIVE CASES, ALSO NO. OF INPUT XS-SETS TO BE READ                      =   1
IDESIGN  = ASSUMED 1 PER CENT DENSITY INCREASE IN PERT. ZS. FOR DES.-SEN., 0/1=NO/YES            =   0

KSRS     = NUMBER OF SOURCE ZONES                                                                =   1
KDET     = NUMBER OF DETECTOR ZONES                                                              =   2
KPER     = NUMBER OF PERTURBED ZONES                                                             =   2
KXS      = INPUT XS-FORMAT  0-IF ITYP=2, 1-LASL, 2-ORNL                                          =   1
IHT      = POSITION OF TOTAL CROSS-SECTION IN XS-TABLES                                          =   3
IHA      = POSITION OF ABSORPTION CROSS-SECTION IN XS-TABLES                                     =   1
DETCOV   = 0/1 = DO NOT/DO READ COVARIANCE MATRIX FOR R(G)                                       =   0
NSED     = 0/1 = DO NOT/DO READ INTEGRAL SED-UNCERTAINTIES                                       =   0
IOUTPUT  = OUTPUT PRINT DETAIL: 0-SUM OVER PERT.ZONES ONLY, 1-ALSO INDIV. PERT.ZS.               =   0
NSUMCOV  = NO. OF RESP.-VARIANCES SUMMED FOR ITYP=2, ZERO FOR ITYP=0,1,3                         =   0
ITEST    = TEST PRINTOUT FLAG: 0-NONE, 1-XS, 2-ANG.FLXS., 3-VECTOR-XS                            =   0
IPRINT   = TEST PRINTS FROM POINTR: 0-NONE,1-DUMPS, 2-TRACES, 3-ALL                              =   0


  4 NEUTRON ENERGY GROUP BOUNDARIES READ, IN EV
 1.000E+01  5.000E+00  1.000E+00  5.000E-01

  4 GAMMA ENERGY GROUP BOUNDARIES READ, IN EV
 4.000E+00  3.000E+00  2.000E+00  1.000E+00

LEVEL WEIGHTS FOR DISCRETE ANGLES
     .500000      .500000

DISCRETE ANGLES MUE FOR LEVEL WEIGHTS
    -.577350      .577350

MESH BOUNDARIES READ
  0.          1.000E+00  2.000E+00  3.000E+00  4.000E+00  5.000E+00  6.000E+00  7.000E+00  8.000E+00  9.000E+00
 1.000E+01
```

```
****************************************DOUBLE-DIFFERENTIAL SED SENSITIVITY PROFILES****************************************
****************************************FOR THE SUM OVER ALL SPECIFIED PERTURBED ZONES****************************************
DOUBLE-DIFFERENTIAL PROFILES PER DELTA-U-IN AND PER DELTA-U-OUT, NORMALIZED TO I1PHI=(R,PHI)=  3.65487E+02
FOR NEUTRON GROUPS ONLY
```

******************************PSED(G-IN,G-OUT) PER (DELU-IN)(DELU-OUT)I1PHI******************************

G-OUT	DELU-OUT	G-IN = 1	G-IN = 2	G-IN = 3	G-IN = 4	G-IN = 5	G-IN = 6	G-IN = 7	G-IN = 8	G-IN = 9	G-IN =10
1	.693147	2.05E-01	0.	0.							
2	1.609438	2.12E-02	8.02E-03	0.							
3	.693147	1.58E-02	6.01E-03	5.28E-02							

*** SINGLE-DIFFERENTIAL PROFILES, PSED ***

G-IN OR G-OUT	PSED(G-OUT) PER DELU-OUT	PSED(G-IN) PER DELU-IN
1	1.423E-01	1.875E-01
2	2.764E-02	1.707E-02
3	5.724E-02	3.659E-02
	-----------	-----------
TOTAL INTEGRAL	1.828E-01	1.828E-01

NO SED UNCERTAINTY ANALYSIS WAS PERFORMED FOR LACK OF INPUT DATA
NSED IS ZERO ON INPUT FILE

```
MATERIAL 1 *** MICROSCOPIC CROSS-SECTION SET *** P-0                       XS
             .02        0.0        0.1        .05        0.0        0.0 GP1
             0.0        0.0        0.0       0.05        0.0        0.2 GP1/2
             0.1       0.02        0.0        0.0        0.0        0.0 GP2
             0.1        0.0        0.3        0.2        .05        .01 GP3
             0.0        0.0        0.0       0.02        0.0        0.1 GP3/4
            0.05        0.0        0.0        0.0        0.0        0.0 GP4
             .05        0.0        0.2        0.1        .02        0.0 GP5
             0.0        0.0        0.0        0.1        0.0        0.3 GP5/6
             0.2       0.05       0.01        0.0        0.0        0.0 GP6
MATERIAL 2 *** MICROSCOPIC CROSS-SECTION SET *** P-0                       XS
             .02        0.0        0.1        .05        0.0        0.0 GP1
             0.0        0.0        0.0       0.05        0.0        0.2 GP1/2
             0.1       0.02        0.0        0.0        0.0        0.0 GP2
             0.1        0.0        0.3        0.2        .05        .01 GP3
             0.0        0.0        0.0       0.02        0.0        0.1 GP3/4
            0.05        0.0        0.0        0.0        0.0        0.0 GP4
             .05        0.0        0.2        0.1        .02        0.0 GP5
             0.0        0.0        0.0        0.1        0.0        0.3 GP5/6
             0.2       0.05       0.01        0.0        0.0        0.0 GP6
```

TAPE4 FOR SAMPLES 5 AND 6

```
SENSIT SAMPLE 6, *3+3 GP.*SLAB*S-2*P-0*XS FROM TAPE4*SED SEN.+UNCERT. ANALYSIS
      3       1       2      10       6       3       0       1       1       1       0         CARD2
      1       2       2       1       3       1       0       1       0       0       0       0 CARD3
  10.0            5.0             1.0             0.5                                            EN(G)
   4.0            3.0             2.0             1.0                                            EG(G)
  0.5             0.5                                                                           W(M)
  -0.57735        +0.57735                                                                      MUE(M)
   0.0             1.0             2.0             3.0             4.0             5.0          MESH1
   6.0             7.0             8.0             9.0            10.0                          MESH2
      1       1                                                                                 KSRS
      9       9                                                                                 KDET1
     10      10                                                                                 KDET2
      4       5                                                                                 KPER1
      7       7                                                                                 KPER2
  100.0           100.0           100.0           100.0           100.0           100.0         R(G)
  1.0             1.0                                                                           RHO(J)
  1.0             0.0             0.0             1.0             0.0             0.0           Q(G)
  1.0                                                                                           QUE(J)
      1       2       0                                                                          GMED
  1.0             0.5             0.0                                                            FSED
      2           0.9              ID2 P-0 XS                                                   XS
```

```
SENSIT SAMPLE 6. *3+3 GP.*SLAB*S-2*P-0*XS FROM TAPE4*SED SEN.+UNCERT. ANALYSIS

ITYP     = TYPE OF SENS.-UNCERT.-ANAL.. 1-XS.2-DESIGN.3-VECTOR-XS.4-SED                          =  3
IGE      = GEOMETRIC MODEL: 1-SLAB.2-CYLINDER.3-SPHERE                                           =  1
ISN      = ORDER OF S-N QUADRATURE                                                               =  2
IM       = TOTAL NUMBER OF SPATIAL MESH INTERVALS                                                = 10
IGM      = TOTAL NUMBER OF ENERGY GROUPS                                                         =  6
NCOUPL   = NUMBER OF NEUTRON GROUPS IN CPL. CALC.. ZERO FOR NEUTRONS ONLY                         =  3
LMAX     = MAX. P-L ORDER OF CROSS SECTIONS                                                      =  0
ITAPE    = FORMAT OF ANG.FLX. TAPES 1 AND 2: 0-ANISN. 1-CCCC(ONETRAN)                            =  1
IXSTAPE  = SOURCE OF INPUT CROSS-SECTIONS: 0-CARDS. 1-TAPE4. 2-TAPE10                            =  1
NPERXS   = NUMBER OF SUCCESSIVE CASES. ALSO NO. OF INPUT XS-SETS TO BE READ                      =  1
IDESIGN  = ASSUMED 1 PER CENT DENSITY INCREASE IN PERT. ZS. FOR DES.-SEN.. 0/1=NO/YES            =  0

KSRS     = NUMBER OF SOURCE ZONES                                                                =  1
KDET     = NUMBER OF DETECTOR ZONES                                                              =  2
KPER     = NUMBER OF PERTURBED ZONES                                                             =  2
KXS      = INPUT XS-FORMAT  0-IF ITYP=2. 1-LASL. 2-ORNL                                          =  1
IHT      = POSITION OF TOTAL CROSS-SECTION IN XS-TABLES                                          =  3
IHA      = POSITION OF ABSORPTION CROSS-SECTION IN XS-TABLES                                     =  1
DETCOV   = 0/1 = DO NOT/DO READ COVARIANCE MATRIX FOR R(G)                                       =  0
NSED     = 0/1 = DO NOT/DO READ INTEGRAL SED-UNCERTAINTIES                                       =  1
IOUTPUT  = OUTPUT PRINT DETAIL: 0-SUM OVER PERT.ZONES ONLY. 1-ALSO INDIV. PERT.ZS.               =  0
NSUMCOV  = NO. OF RESP.-VARIANCES SUMMED FOR ITYP=2. ZERO FOR ITYP=0.1.3                         =  0
ITEST    = TEST PRINTOUT FLAG: 0-NONE. 1-XS. 2-ANG.FLXS.. 3-VECTOR-XS                            =  0
IPRINT   = TEST PRINTS FROM POINTR: 0-NONE.1-DUMPS. 2-TRACES. 3-ALL                              =  0


   4 NEUTRON ENERGY GROUP BOUNDARIES READ. IN EV
  1.000E+01  5.000E+00  1.000E+00  5.000E-01

   4 GAMMA ENERGY GROUP BOUNDARIES READ. IN EV
  4.000E+00  3.000E+00  2.000E+00  1.000E+00

LEVEL WEIGHTS FOR DISCRETE ANGLES
     .500000     .500000

DISCRETE ANGLES MUE FOR LEVEL WEIGHTS
    -.577350     .577350

MESH BOUNDARIES READ
 0.          1.000E+00  2.000E+00  3.000E+00  4.000E+00  5.000E+00  6.000E+00  7.000E+00  8.000E+00  9.000E+00
 1.000E+01
```

SED MEDIAN ENERGY GROUPS (GMED) AND INTEGRAL UNCERTAINTIES (FSED) INPUT FOR SED UNCERT. ANALYSIS

G-IN	GMED	FSED
1	1	1.000E+00
2	2	5.000E-01
3	0	0.

CASE NUMBER 1 OF NPERXS = 1 SUCCESSIVE CASES

MATERIAL 2 *** MICROSCOPIC CROSS-SECTION SET *** P-0 XS
NUMBER DENSITY= 9.00000E-01 ID2 P-0 XS

*************DOUBLE-DIFFERENTIAL SED SENSITIVITY PROFILES*************
*************FOR THE SUM OVER ALL SPECIFIED PERTURBED ZONES*************
DOUBLE-DIFFERENTIAL PROFILES PER DELTA-U-IN AND PER DELTA-U-OUT, NORMALIZED TO I1PHI=(R.PHI)= 3.65487E+02
FOR NEUTRON GROUPS ONLY

*************PSED(G-IN,G-OUT) PER (DELU-IN)(DELU-OUT)I1PHI*************

G-OUT	DELU-OUT	G-IN = 1	G-IN = 2	G-IN = 3	G-IN = 4	G-IN = 5	G-IN = 6	G-IN = 7	G-IN = 8	G-IN = 9	G-IN =10
1	.693147	2.05E-01	0.	0.							
2	1.609438	2.12E-02	8.02E-03	0.							
3	.693147	1.58E-02	6.01E-03	5.28E-02							

*** SINGLE-DIFFERENTIAL PROFILES, PSED ***

G-IN OR G-OUT	PSED(G-OUT) PER DELU-OUT	PSED(G-IN) PER DELU-IN
1	1.423E-01	1.875E-01
2	2.764E-02	1.707E-02
3	5.724E-02	3.659E-02
	-----------	-----------
TOTAL INTEGRAL	1.828E-01	1.828E-01

SENSIT SAMPLE 6, *3+3 GP.*SLAB*S-2*P-0*XS FROM TAPE4*SED SEN.+UNCERT. ANALYSIS

************************ SED UNCERTAINTY ANALYSIS ************************

G-IN	MEDIAN G-OUT OF SED (FROM INPUT)	INTEGRAL SED-UNCERT. F (FROM INPUT)	HOT INTEGRAL SENS. COEFF. S-HOT	COLD INTEGRAL SENS. COEFF. S-COLD	NET INTEGRAL SED SENS.-COEFF. S (SHOT - SCOLD)	RESPONSE UNCERT. DR/R DUE TO SED-UNCERT. (F * S)
1	1	1.0000	9.862E-02	3.131E-02	6.731E-02	6.731E-02
2	2	.5000	2.078E-02	6.703E-03	1.408E-02	7.038E-03
3	0	0.0000	0.	0.	0.	0.
			----------	----------	----------	----------
TOTAL INTEGRAL			1.194E-01	3.801E-02	8.139E-02	7.435E-02 = 7.435 PER CENT

```
SENSIT SAMPL 7. *FUSION REACTOR*XS+SED SENS.*RUN 76SED: CR. NI. FE. CU
       3       1       6     137      42      30       0       1       1       4       0        CARD2
       1       1       2       1       3       1       0       1       0       0       0      0 CARD3
     1.700E+7        1.500E+7        1.350E+7        1.200E+7        1.000E+7        7.79 E+6 EN(G)
     6.070E+6        3.680E+6        2.865E+6        2.232E+6        1.738E+6        1.353E+6 EN(G)
     8.230E+5        5.000E+5        3.030E+5        1.840E+5        6.760E+4        2.480E+4 EN(G)
     9.120E+3        3.350E+3        1.235E+3        4.540E+2        1.670E+2        6.140E+1 EN(G)
     2.260E+1        8.320E+0        3.060E+0        1.130E+0        4.140E-1        1.520E-1 EN(G)
     5.000E-2                                                                                 EN(G)
     2.000E+7        9.000E+6        8.000E+6        7.000E+6        6.000E+6        5.000E+6 EG(G)
     4.000E+6        3.000E+6        2.000E+6        1.000E+6        5.000E+5        1.000E+5 EG(G)
     1.000E+4                                                                                 EG(G)
    0.0856623       0.1803808       0.2339570       0.2339570       0.1803808       0.0856623 W(M)
   -0.9324695      -0.6612094      -0.2386192       0.2386192       0.6612094       0.9324695 MUE(M)
    0.0             24.25           48.5            72.75           97.0            98.0      MESH
    99.0            100.0           101.0           102.0           104.5           107.0     MESH
    107.5           108.0           108.5           109.0           109.5           110.0     MESH
    110.5           111.0           111.5           112.0           113.0           114.0     MESH
    115.0           116.0           117.0           118.0           119.0           120.0     MESH
    121.0           122.0           122.5           123.0           123.5           124.0     MESH
    125.0           126.0           127.0           128.0           129.0           130.0     MESH
    131.0           132.0           133.0           134.0           135.0           136.0     MESH
    137.0           138.0           139.0           140.0           141.0           142.0     MESH
    143.0           144.0           145.0           146.0           147.0           148.0     MESH
    149.0           150.0           151.0           152.0           153.0           154.0     MESH
    155.0           156.0           157.0           158.0           159.0           160.0     MESH
    161.0           162.0           163.0           164.0           165.0           165.5     MESH
    166.0           168.0           171.0           174.0           177.0           180.0     MESH
    183.0           186.0           189.0           192.0           195.0           198.0     MESH
    201.0           204.0           207.0           210.0           213.0           216.0     MESH
    219.0           222.0           225.0           228.0           231.0           234.0     MESH
    237.0           240.0           243.0           246.0           249.0           252.0     MESH
    255.0           256.0           257.0           259.067         261.133         263.2     MESH
    265.267         267.333         269.400         271.357         273.533         275.6     MESH
    277.667         279.733         281.800         283.867         285.933         288.0     MESH
    290.0           291.0           294.0           296.0           298.0           300.0     MESH
    302.0           304.0           306.0           308.333         310.667         313.0     MESH
       1       4                                                                              SRS
      80     108                                                                              DET
      80     108                                                                             PER1
     111     125                                                                             PER2
      .184E+07        .200E+07        .197E+07        .222E+07        .159E+07        .106E+07 R3(G)
      .567E+06        .284E+06        .190E+06        .116E+06        .736E+05        .730E+05
      .640E+05        .485E+05        .340E+05        .216E+05        .167E+05        .118E+05
      .214E+05        .204E+05        .936E+05        .124E+05        .305E+04        .473E+04
      .875E+04        .200E+05        .334E+05        .562E+05        .102E+06        .289E+06
      .307E+08        .197E+08        .169E+08        .142E+08        .118E+08        .956E+07
      .737E+07        .539E+07        .357E+07        .207E+07        .130E+07        .692E+07
    1.0000          1.0000          1.0000          1.0000          1.0000          1.0000       RHO(J)
    1.0000          1.0000          1.0000          1.0000          1.0000          1.0000       RHO(J)
    1.0000          1.0000          1.0000          1.0000          1.0000          1.0000       RHO(J)
    1.0000          1.0000          1.0000          1.0000          1.0000          1.0000       RHO(J)
    1.0000          1.0000          1.0000          1.0000          1.0000                       RHO(J)
    0.0             1.00000         0.0             0.0             0.0             0.0          Q(G)
    0.0             0.0             0.0             0.0             0.0             0.0          Q(G)
    0.0             0.0             0.0             0.0             0.0             0.0          Q(G)
    0.0             0.0             0.0             0.0             0.0             0.0          Q(G)
    0.0             0.0             0.0             0.0             0.0             0.0          Q(G)
    0.0             0.0             0.0             0.0             0.0             0.0          Q(G)
    0.0             0.0             0.0             0.0             0.0             0.0          Q(G)
```

0.01031		0.01031		0.01031		0.01031						QUE(J)
8	5	4	4	5	6	7	8	9	10	11	12	GMED1
13	0	0	0	0	0	0	0	0	0	0	0	GMED2
0	0	0	0	0								GMED3
0.16		0.14		0.12		0.10		0.08		0.07		FSED1
0.06		0.06		0.05		0.04		0.03		0.02		FSED2
0.02		0.0		0.0		0.0		0.0		0.0		FSED3
0.0		0.0		0.0		0.0		0.0		0.0		FSED4
0.0		0.0		0.0		0.0		0.0		0.0		FSED5
3		0.00502		CR-MIC P0								MAT1
2	2	3	4	5	6	7	8	9	10	11	12	GMED1
0	0	0	0	0	0	0	0	0	0	0	0	GMED2
0	0	0	0	0	0							GMED3
0.12		0.10		0.10		0.09		0.08		0.08		FSED1
0.07		0.06		0.05		0.04		0.03		0.02		FSED2
0.0		0.0		0.0		0.0		0.0		0.0		FSED3
0.0		0.0		0.0		0.0		0.0		0.0		FSED4
0.0		0.0		0.0		0.0		0.0		0.0		FSED5
5		0.0032		NI-MIC P0								MAT2
7	7	4	4	5	6	7	8	9	10	11	12	GMED1
13	14	0	0	0	0	0	0	0	0	0	0	GMED2
0	0	0	0	0	0							GMED3
0.08		0.075		0.075		0.07		0.07		0.06		FSED1
0.06		0.05		0.05		0.05		0.04		0.03		FSED2
0.02		0.02		0.0		0.0		0.0		0.0		FSED3
0.0		0.0		0.0		0.0		0.0		0.0		FSED4
0.0		0.0		0.0		0.0		0.0		0.0		FSED5
4		0.0189		FE-MIC P0								MAT3
8	8	7	4	5	6	7	8	9	10	11	12	GMED1
13	14	15	16	0	0	0	0	0	0	0	0	GMED2
0	0	0	0	0								GMED3
0.09		0.072		0.07		0.07		0.07		0.06		FSED1
0.06		0.06		0.05		0.05		0.04		0.04		FSED2
0.02		0.02		0.02		0.02		0.0		0.0		FSED3
0.0		0.0		0.0		0.0		0.0		0.0		FSED4
0.0		0.0		0.0		0.0		0.0		0.0		FSED5
6		0.0407		CU-MIC P0								MAT4

```
SENSIT SAMPL 7, *FUSION REACTOR*XS+SED SENS.*RUN 76SED: CR, NI, FE, CU

ITYP     = TYPE OF SENS.-UNCERT.-ANAL., 1-XS,2-DESIGN,3-VECTOR-XS,4-SED             =   3
IGE      = GEOMETRIC MODEL: 1-SLAB,2-CYLINDER,3-SPHERE                              =   1
ISN      = ORDER OF S-N QUADRATURE                                                  =   6
IM       = TOTAL NUMBER OF SPATIAL MESH INTERVALS                                   = 137
IGM      = TOTAL NUMBER OF ENERGY GROUPS                                            =  42
NCOUPL   = NUMBER OF NEUTRON GROUPS IN CPL. CALC., ZERO FOR NEUTRONS ONLY           =  30
LMAX     = MAX. P-L ORDER OF CROSS SECTIONS                                         =   0
ITAPE    = FORMAT OF ANG.FLX. TAPES 1 AND 2: 0-ANISN, 1-CCCC(ONETRAN)               =   1
IXSTAPE  = SOURCE OF INPUT CROSS-SECTIONS: 0-CARDS, 1-TAPE4, 2-TAPE10               =   1
NPERXS   = NUMBER OF SUCCESSIVE CASES, ALSO NO. OF INPUT XS-SETS TO BE READ         =   4
IDESIGN  = ASSUMED 1 PER CENT DENSITY INCREASE IN PERT. ZS. FOR DES.-SEN., 0/1=NO/YES =   0

KSRS     = NUMBER OF SOURCE ZONES                                                   =   1
KDET     = NUMBER OF DETECTOR ZONES                                                 =   1
KPER     = NUMBER OF PERTURBED ZONES                                                =   2
KXS      = INPUT XS-FORMAT  0-IF ITYP=2, 1-LASL, 2-ORNL                             =   1
IHT      = POSITION OF TOTAL CROSS-SECTION IN XS-TABLES                             =   3
IHA      = POSITION OF ABSORPTION CROSS-SECTION IN XS-TABLES                        =   1
DETCOV   = 0/1 = DO NOT/DO READ COVARIANCE MATRIX FOR R(G)                          =   0
NSED     = 0/1 = DO NOT/DO READ INTEGRAL SED-UNCERTAINTIES                          =   1
IOUTPUT  = OUTPUT PRINT DETAIL: 0-SUM OVER PERT.ZONES ONLY, 1-ALSO INDIV. PERT.ZS.  =   0
NSUMCOV  = NO. OF RESP.-VARIANCES SUMMED FOR ITYP=2, ZERO FOR ITYP=0,1,3            =   0
ITEST    = TEST PRINTOUT FLAG: 0-NONE, 1-XS, 2-ANG.FLXS., 3-VECTOR-XS               =   0
IPRINT   = TEST PRINTS FROM POINTR: 0-NONE,1-DUMPS, 2-TRACES, 3-ALL                 =   0


 31 NEUTRON ENERGY GROUP BOUNDARIES READ, IN EV
 1.700E+07  1.500E+07  1.350E+07  1.200E+07  1.000E+07  7.790E+06  6.070E+06  3.680E+06  2.865E+06  2.232E+06
1.738E+06  1.353E+06  8.230E+05  5.000E+05  3.030E+05  1.840E+05  6.760E+04  2.480E+04  9.120E+03  3.350E+03
1.235E+03  4.540E+02  1.670E+02  6.140E+01  2.260E+01  8.320E+00  3.060E+00  1.130E+00  4.140E-01  1.520E-01
5.000E-02

 13 GAMMA ENERGY GROUP BOUNDARIES READ, IN EV
 2.000E+07  9.000E+06  8.000E+06  7.000E+06  6.000E+06  5.000E+06  4.000E+06  3.000E+06  2.000E+06  1.000E+06
5.000E+05  1.000E+05  1.000E+04

LEVEL WEIGHTS FOR DISCRETE ANGLES
    .085662     .180381     .233957     .233957     .180381     .085662

DISCRETE ANGLES MUE FOR LEVEL WEIGHTS
   -.932470    -.661209    -.238619     .238619     .661209     .932470

MESH BOUNDARIES READ
 0.          2.425E+01  4.850E+01  7.275E+01  9.700E+01  9.800E+01  9.900E+01  1.000E+02  1.010E+02  1.020E+02
 1.045E+02  1.070E+02  1.075E+02  1.080E+02  1.085E+02  1.090E+02  1.095E+02  1.100E+02  1.105E+02  1.110E+02
 1.115E+02  1.120E+02  1.130E+02  1.140E+02  1.150E+02  1.160E+02  1.170E+02  1.180E+02  1.190E+02  1.200E+02
 1.210E+02  1.220E+02  1.225E+02  1.230E+02  1.235E+02  1.240E+02  1.250E+02  1.260E+02  1.270E+02  1.280E+02
 1.290E+02  1.300E+02  1.310E+02  1.320E+02  1.330E+02  1.340E+02  1.350E+02  1.360E+02  1.370E+02  1.380E+02
 1.390E+02  1.400E+02  1.410E+02  1.420E+02  1.430E+02  1.440E+02  1.450E+02  1.460E+02  1.470E+02  1.480E+02
 1.490E+02  1.500E+02  1.510E+02  1.520E+02  1.530E+02  1.540E+02  1.550E+02  1.560E+02  1.570E+02  1.580E+02
 1.590E+02  1.600E+02  1.610E+02  1.620E+02  1.630E+02  1.640E+02  1.650E+02  1.655E+02  1.660E+02  1.680E+02
 1.710E+02  1.740E+02  1.770E+02  1.800E+02  1.830E+02  1.860E+02  1.890E+02  1.920E+02  1.950E+02  1.980E+02
 2.010E+02  2.040E+02  2.070E+02  2.100E+02  2.130E+02  2.160E+02  2.190E+02  2.220E+02  2.250E+02  2.280E+02
 2.310E+02  2.340E+02  2.370E+02  2.400E+02  2.430E+02  2.460E+02  2.490E+02  2.520E+02  2.550E+02  2.560E+02
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SED MEDIAN ENERGY GROUPS (GMED) AND INTEGRAL UNCERTAINTIES (FSED) INPUT FOR SED UNCERT. ANALYSIS

G-IN	GMED	FSED
1	8	9.000E-02
2	8	7.200E-02
3	7	7.000E-02
4	4	7.000E-02
5	5	7.000E-02
6	6	6.000E-02
7	7	6.000E-02
8	8	6.000E-02
9	9	5.000E-02
10	10	5.000E-02
11	11	4.000E-02
12	12	4.000E-02
13	13	2.000E-02
14	14	2.000E-02
15	15	2.000E-02
16	16	2.000E-02
17	0	0.
18	0	0.
19	0	0.
20	0	0.
21	0	0.
22	0	0.
23	0	0.
24	0	0.
25	0	0.
26	0	0.
27	0	0.
28	0	0.
29	0	0.
30	0	0.

CASE NUMBER 4 OF NPERXS = 4 SUCCESSIVE CASES

CU-MIC P0 45X42 TABLE
NUMBER DENSITY= 4.07000E-02 CU-MIC P0

DEFINITIONS OF SENSIT SENSITIVITY PROFILE NOMENCLATURE

AXS	=	SENSITIVITY PROFILE PER DELTA-U FOR THE ABSORPTION CROSS-SECTION (TAKEN FROM POSITION IHA IN INPUT CROSS-SECTION TABLES), PURE LOSS TERM
NU-FISS	=	SENSITIVITY PROFILE PER DELTA-U FOR THE CROSS SECTION IN POSITION IHA+I IN INPUT XS-TABLES, WHICH IS USUALLY NU-TIMES THE FISSION CROSS SECTION. PURE LOSS TERM
SXS	=	PARTIAL SENSITIVITY PROFILE PER DELTA-U FOR THE SCATTERING CROSS-SECTION (COMPUTED FOR EACH ENERGY GROUP AS A DIAGONAL SUM FROM INPUT XS-TABLES), LOSS TERM ONLY
TXS	=	SENSITIVITY PROFILE PER DELTA-U FOR THE TOTAL CROSS SECTION (AS GIVEN IN POSITION IHT IN INPUT CROSS-SECTION TABLES), PURE LOSS TERM
N-GAIN	=	PARTIAL SENSITIVITY PROFILE PER DELTA-U FOR THE NEUTRON SCATTERING CROSS-SECTION. GAIN TERM FOR SENSITIVITY GAINS DUE TO SCATTERING OUT OF ENERGY GROUP G INTO ALL LOWER NEUTRON ENERGY GROUPS. COMPUTED FROM FORWARD DIFFERENCE FORMULATION.
G-GAIN	=	PARTIAL SENSITIVITY PROFILE PER DELTA-U FOR THE GAMMA SCATTERING CROSS-SECTION. GAIN TERM FOR SENSITIVITY GAINS DUE TO SCATTERING OUT OF GAMMA ENERGY GROUP G INTO ALL LOWER GAMMA ENERGY GROUPS, COMPUTED FROM FORWARD DIFFERENCE FORMULATION.
N-GAIN(SED)	=	RE-ORDERED PARTIAL SENSITIVITY PROFILE PER DELTA-U FOR SCATTERING CROSS-SECTION. GAIN TERM FOR SENSITIVITY GAINS DUE TO SCATTERING INTO GROUP G FROM ALL HIGHER NEUTRON ENERGY GROUPS. COMPUTED FROM ADJOINT DIFFERNCE FORMULATION. CORRESPONDS TO SINGLE-DIFFERENTIAL SED SENSITIVITY PROFILE, PSED(G-OUT) PER DELU-OUT, INTEGRATED OVER ALL INCIDENT ENERGY GROUPS.
NG-GAIN	=	PARTIAL SENSITIVITY PROFILE PER DELTA-U FOR THE GAMMA PRODUCTION CROSS-SECTION AT NEUTRON ENERGY GROUP G. PURE GAIN TERM FOR SENSITIVITY GAINS DUE TO TRANSFER FROM NEUTRON GROUP G INTO ALL GAMMA GROUPS.
SEN	=	NET SENSITIVITY PROFILE PER DELTA-U FOR THE SCATTERING CROSS-SECTION (SEN=SXS+NGAIN)
SENT	=	NET SENSITIVITY PROFILE PER DELTA-U FOR THE TOTAL CROSS-SECTION (SENT=TXS+NGAIN)
SENR	=	SENSITIVITY PROFILE PER DELTA-U FOR THE DETECTOR RESPONSE FUNCTION R(G)
SENQ	=	SENSITIVITY PROFILE PER DELTA-U FOR THE SOURCE DISTRIBUTION FUNCTION Q(G)

SENSIT SAMPL 7. *FUSION REACTOR*XS+SED SENS.*RUN 76SED: CR. NI. FE CU

** NEUTRON CROSS SECTION SENSITIVITY PROFILES **

** SUMMED OVER ALL PERTURBED ZONES **

PARTIAL AND NET SENSITIVITY PROFILES PER DELTA-U. NORMALIZED TO I1PHI = (R.PHI) = 1.12278E+04

FOR NEUTRON INTERACTION CROSS SECTIONS: (N-N) AND (N-GAMMA)

			****** P U R E	L O S S	T E R M S	**********	********* PURE GAIN TERMS		**********
GROUP	UPPER-E(EV)	DELTA-U	AXS	NU-FISS	SXS	TXS	N-GAIN	N-GAIN(SED)	NG-GAIN
1	1.700E+07	1.25E-01	0.	0.	0.	0.	0.	0.	0.
2	1.500E+07	1.05E-01	7.432E+00	0.	-3.698E+00	-3.173E+00	1.987E+00	1.191E+00	5.850E-01
3	1.350E+07	1.18E-01	2.074E+00	0.	-1.146E+00	-1.052E+00	6.730E-01	5.178E-01	2.009E-01
4	1.200E+07	1.82E-01	6.011E-01	0.	-3.614E-01	-3.677E-01	2.271E-01	1.753E-01	7.446E-02
5	1.000E+07	2.50E-01	3.635E-01	0.	-2.589E-01	-2.666E-01	1.756E-01	1.367E-01	5.120E-02
6	7.790E+06	2.49E-01	2.661E-01	0.	-2.181E-01	-2.231E-01	1.557E-01	1.280E-01	3.816E-02
7	6.070E+06	5.00E-01	1.688E-01	0.	-1.733E-01	-1.762E-01	1.361E-01	1.289E-01	2.502E-02
8	3.680E+06	2.50E-01	1.857E-01	0.	-2.334E-01	-2.364E-01	1.944E-01	1.846E-01	2.724E-02
9	2.865E+06	2.50E-01	1.943E-01	0.	-3.053E-01	-3.081E-01	2.645E-01	2.404E-01	2.778E-02
10	2.232E+06	2.50E-01	1.921E-01	0.	-3.842E-01	-3.864E-01	3.434E-01	3.145E-01	2.616E-02
11	1.738E+06	2.50E-01	1.953E-01	0.	-5.293E-01	-5.315E-01	4.869E-01	4.501E-01	2.806E-02
12	1.353E+06	4.97E-01	1.196E-01	0.	-1.241E+00	-1.246E+00	1.197E+00	1.158E+00	2.057E-02
13	8.230E+05	4.98E-01	2.667E-02	0.	-3.164E+00	-3.173E+00	3.132E+00	3.097E+00	1.613E-02
14	5.000E+05	5.01E-01	1.760E-02	0.	-5.445E+00	-5.462E+00	5.436E+00	5.380E+00	2.327E-02
15	3.030E+05	4.99E-01	1.537E-02	0.	-4.536E+00	-4.551E+00	4.529E+00	4.628E+00	1.963E-02
16	1.840E+05	1.00E+00	2.587E-02	0.	-6.228E+00	-6.255E+00	6.235E+00	6.197E+00	3.194E-02
17	6.760E+04	1.00E+00	2.279E-02	0.	-4.494E+00	-4.517E+00	4.496E+00	4.446E+00	2.670E-02
18	2.480E+04	1.00E+00	3.488E-02	0.	-4.486E+00	-4.522E+00	4.486E+00	4.546E+00	4.009E-02
19	9.120E+03	1.00E+00	7.308E-02	0.	-5.339E+00	-5.415E+00	5.338E+00	5.457E+00	8.174E-02
20	3.350E+03	9.98E-01	7.857E-02	0.	-5.323E+00	-5.406E+00	5.321E+00	5.355E+00	8.721E-02
21	1.235E+03	1.00E+00	8.431E-02	0.	-5.820E-01	-6.703E-01	5.787E-01	6.147E-01	9.278E-02
22	4.540E+02	1.00E+00	8.781E-03	0.	-3.471E-01	-3.563E-01	3.461E-01	3.481E-01	1.062E-02
23	1.670E+02	1.00E+00	1.845E-03	0.	-3.511E-01	-3.530E-01	3.508E-01	3.504E-01	2.236E-03
24	6.140E+01	9.99E-01	2.339E-03	0.	-2.982E-01	-3.006E-01	2.984E-01	3.003E-01	2.682E-03
25	2.260E+01	9.99E-01	2.909E-03	0.	-2.061E-01	-2.092E-01	2.064E-01	2.087E-01	3.193E-03
26	8.320E+00	1.00E+00	3.826E-03	0.	-1.297E-01	-1.337E-01	1.299E-01	1.332E-01	4.069E-03
27	3.060E+00	9.96E-01	2.956E-03	0.	-6.019E-02	-6.329E-02	6.020E-02	6.243E-02	3.108E-03
28	1.130E+00	1.00E+00	1.754E-03	0.	-2.149E-02	-2.333E-02	2.145E-02	2.268E-02	1.828E-03
29	4.140E-01	1.00E+00	7.978E-04	0.	-5.918E-03	-6.754E-03	5.888E-03	6.384E-03	8.254E-04
30	1.520E-01	1.11E+00	4.086E-04	0.	-1.078E-03	-1.506E-03	1.061E-03	1.230E-03	4.127E-04
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INTEGRAL			2.005E+00	0.	-3.624E+01	-3.656E+01	3.584E+01	3.584E+01	5.904E-01

			**** NET PROFILES	****
GROUP	UPPER-E(EV)	DELTA-U	SEN	SENT
1	1.700E+07	1.25E-01	0.	0.
2	1.500E+07	1.05E-01	-1.710E+00	-1.186E+00
3	1.350E+07	1.18E-01	-4.732E-01	-3.786E-01
4	1.200E+07	1.82E-01	-1.343E-01	-1.405E-01
5	1.000E+07	2.50E-01	-8.337E-02	-9.105E-02
6	7.790E+06	2.49E-01	-6.233E-02	-6.739E-02
7	6.070E+06	5.00E-01	-3.714E-02	-4.004E-02
8	3.680E+06	2.50E-01	-3.902E-02	-4.203E-02
9	2.865E+06	2.50E-01	-4.077E-02	-4.359E-02
10	2.232E+06	2.50E-01	-4.072E-02	-4.298E-02
11	1.738E+06	2.50E-01	-4.240E-02	-4.458E-02
12	1.353E+06	4.97E-01	-4.461E-02	-4.889E-02
13	8.230E+05	4.98E-01	-3.152E-02	-4.071E-02
14	5.000E+05	5.01E-01	-9.411E-03	-2.611E-02
15	3.030E+05	4.99E-01	-6.458E-03	-2.146E-02

16	1.840E+05	1.00E+00	6.860E-03	-1.948E-02
17	6.760E+04	1.00E+00	2.593E-03	-2.105E-02
18	2.460E+04	1.00E+00	5.615E-04	-3.585E-02
19	9.120E+03	1.00E+00	-7.364E-04	-7.720E-02
20	3.350E+03	9.98E-01	-1.849E-03	-8.409E-02
21	1.235E+03	1.00E+00	-3.310E-03	-9.166E-02
22	4.540E+02	1.00E+00	-1.007E-03	-1.021E-02
23	1.670E+02	1.00E+00	-2.897E-04	-2.224E-03
24	6.140E+01	9.99E-01	1.727E-04	-2.279E-03
25	2.260E+01	9.99E-01	3.068E-04	-2.742E-03
26	8.320E+00	1.00E+00	1.599E-04	-3.850E-03
27	3.060E+00	9.96E-01	2.556E-06	-3.096E-03
28	1.130E+00	1.00E+00	-3.715E-05	-1.875E-03
29	4.140E-01	1.00E+00	-2.948E-05	-8.656E-04
30	1.520E-01	1.11E+00	-1.684E-05	-4.451E-04
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INTEGRAL			-3.985E-01	-7.235E-01

**************************************DOUBLE-DIFFERENTIAL SED SENSITIVITY PROFILES***************************************
**************************************FOR THE SUM OVER ALL SPECIFIED PERTURBED ZONES**************************************
DOUBLE-DIFFERENTIAL PROFILES PER DELTA-U-IN AND PER DELTA-U-OUT. NORMALIZED TO I1PHI=(R.PHI)= 1.12278E+04
FOR NEUTRON GROUPS ONLY

**********************************PSED(G-IN.G-OUT) PER (DELU-IN)(DELU-OUT)I1PHI*********************************

G-OUT	DELU-OUT	G-IN = 1	G-IN = 2	G-IN = 3	G-IN = 4	G-IN = 5	G-IN = 6	G-IN = 7	G-IN = 8	G-IN = 9	G-IN =10
1	.125163	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
2	.105361	0.	1.13E+01	0.	0.	0.	0.	0.	0.	0.	0.
3	.117783	0.	7.94E-01	3.69E+00	0.	0.	0.	0.	0.	0.	0.
4	.182322	0.	2.65E-02	1.22E-01	8.68E-01	0.	0.	0.	0.	0.	0.
5	.249744	0.	6.78E-02	2.44E-02	2.52E-02	4.89E-01	0.	0.	0.	0.	0.
6	.249482	0.	1.00E-01	3.53E-02	7.16E-03	2.45E-02	4.24E-01	0.	0.	0.	0.
7	.500446	0.	1.98E-01	5.92E-02	1.94E-02	1.34E-02	1.85E-02	1.79E-01	0.	0.	0.
8	.250344	0.	2.60E-01	8.53E-02	2.97E-02	2.35E-02	1.91E-02	2.65E-02	4.71E-01	0.	0.
9	.249670	0.	2.49E-01	8.37E-02	3.21E-02	2.67E-02	2.36E-02	2.13E-02	5.39E-02	6.48E-01	0.
10	.250163	0.	2.30E-01	7.36E-02	3.10E-02	2.60E-02	2.48E-02	2.07E-02	4.58E-02	8.02E-02	8.85E-01
11	.250411	0.	2.28E-01	6.62E-02	2.63E-02	2.29E-02	2.34E-02	2.28E-02	4.24E-02	6.39E-02	1.02E-01
12	.497123	0.	2.03E-01	5.48E-02	1.77E-02	1.63E-02	1.78E-02	2.14E-02	2.58E-02	6.58E-02	7.55E-02
13	.498348	0.	1.62E-01	4.67E-02	1.03E-02	8.30E-03	9.66E-03	1.33E-02	2.36E-02	1.88E-02	6.16E-02
14	.500875	0.	1.18E-01	3.58E-02	6.22E-03	4.12E-03	4.92E-03	7.26E-03	1.81E-02	2.82E-02	3.68E-02
15	.498797	0.	7.77E-02	2.50E-02	3.94E-03	1.98E-03	2.29E-03	3.51E-03	9.09E-03	1.26E-02	1.30E-02
16	1.001328	0.	2.88E-02	1.04E-02	1.61E-03	5.78E-04	6.18E-04	9.89E-04	2.62E-03	3.79E-03	2.88E-03
17	1.002764	0.	3.88E-03	2.21E-03	4.23E-04	4.47E-05	6.15E-06	5.40E-05	1.39E-04	2.16E-04	3.86E-04
18	1.000374	0.	1.48E-03	8.43E-04	1.61E-04	1.71E-05	2.37E-06	2.07E-05	5.35E-05	8.30E-05	6.32E-05
19	1.001509	0.	5.67E-04	3.24E-04	6.21E-05	6.57E-06	9.14E-07	7.99E-06	2.06E-05	3.19E-05	1.09E-05
20	.997889	0.	2.14E-04	1.22E-04	2.35E-05	2.48E-06	3.46E-07	3.02E-06	7.77E-06	1.20E-05	1.98E-06
21	1.000729	0.	8.24E-05	4.71E-05	9.04E-06	9.58E-07	1.33E-07	1.16E-06	2.98E-06	4.62E-06	3.92E-07
22	1.000103	0.	2.62E-05	1.50E-05	2.88E-06	3.05E-07	4.24E-08	3.71E-07	9.55E-07	1.48E-06	0.
23	1.000584	0.	9.47E-06	5.44E-06	1.04E-06	1.10E-07	1.53E-08	1.34E-07	3.46E-07	5.38E-07	0.
24	.999460	0.	3.68E-06	2.11E-06	4.05E-07	4.29E-08	5.96E-09	5.22E-08	1.34E-07	2.09E-07	0.
25	.999288	0.	1.42E-06	8.12E-07	1.38E-07	0.	0.	0.	0.	0.	0.
26	1.000247	0.	5.46E-07	3.13E-07	5.31E-08	0.	0.	0.	0.	0.	0.
27	.996197	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
28	1.004107	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
29	1.001985	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
30	1.111858	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

1	.125163	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
2	.105361	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
3	.117783	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
4	.182322	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
5	.249744	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
6	.249482	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
7	.500446	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
8	.250344	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
9	.249670	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
10	.250163	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
11	.250411	1.35E+00	0.	0.	0.	0.	0.	0.	0.	0.	0.
12	.497123	1.08E-01	2.09E+00	0.	0.	0.	0.	0.	0.	0.	0.
13	.498348	7.84E-02	1.56E-01	5.90E+00	0.	0.	0.	0.	0.	0.	0.
14	.500875	4.98E-02	5.72E-02	3.49E-01	1.02E+01	0.	0.	0.	0.	0.	0.
15	.498797	2.76E-02	5.48E-02	0.	6.32E-01	8.53E+00	0.	0.	0.	0.	0.
16	1.001328	1.24E-02	1.90E-02	1.16E-02	0.	2.75E-01	6.03E+00	0.	0.	0.	0.
17	1.002764	3.70E-03	4.15E-03	5.82E-03	0.	0.	2.01E-01	4.23E+00	0.	0.	0.

18	1.000374	6.68E-04	8.17E-04	1.23E-03	0.	0.	0.	2.58E-01	4.28E+00	0.	0.
19	1.001509	9.42E-05	1.46E-04	2.02E-04	0.	0.	0.	0.	2.01E-01	5.25E+00	0.
20	.997889	1.14E-05	2.57E-05	3.09E-05	0.	0.	0.	0.	0.	8.26E-02	5.28E+00
21	1.000729	1.65E-06	3.79E-06	3.36E-06	0.	0.	0.	0.	0.	0.	4.95E-02
22	1.000103	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
23	1.000584	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
24	.999460	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
25	.999288	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
26	1.000247	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
27	.996197	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
28	1.004107	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
29	1.001985	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
30	1.111858	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

1	.125163	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
2	.105361	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
3	.117783	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
4	.182322	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
5	.249744	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
6	.249482	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
7	.500446	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
8	.250344	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
9	.249670	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
10	.250163	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
11	.250411	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
12	.497123	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
13	.498348	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
14	.500875	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
15	.498797	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
16	1.001328	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
17	1.002764	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
18	1.000374	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
19	1.001509	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
20	.997889	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
21	1.000729	5.65E-01	0.	0.	0.	0.	0.	0.	0.	0.	0.
22	1.000103	1.34E-02	3.35E-01	0.	0.	0.	0.	0.	0.	0.	0.
23	1.000584	0.	1.13E-02	3.39E-01	0.	0.	0.	0.	0.	0.	0.
24	.999460	0.	0.	1.17E-02	2.89E-01	0.	0.	0.	0.	0.	0.
25	.999288	0.	0.	0.	9.75E-03	1.99E-01	0.	0.	0.	0.	0.
26	1.000247	0.	0.	0.	0.	7.43E-03	1.26E-01	0.	0.	0.	0.
27	.996197	0.	0.	0.	0.	0.	4.16E-03	5.85E-02	0.	0.	0.
28	1.004107	0.	0.	0.	0.	0.	0.	1.92E-03	2.07E-02	0.	0.
29	1.001985	0.	0.	0.	0.	0.	0.	0.	6.80E-04	5.69E-03	0.
30	1.111858	0.	0.	0.	0.	0.	0.	0.	0.	1.69E-04	9.54E-04

*** SINGLE-DIFFERENTIAL PROFILES, PSED ***

G-IN OR G-OUT	PSED(G-OUT) PER DELU-OUT	PSED(G-IN) PER DELU-IN
1	0.	0.
2	1.191E+00	1.987E+00
3	5.178E-01	6.730E-01
4	1.753E-01	2.271E-01
5	1.367E-01	1.756E-01
6	1.280E-01	1.557E-01
7	1.289E-01	1.361E-01
8	1.846E-01	1.944E-01
9	2.404E-01	2.645E-01

10	3.145E-01	3.434E-01
11	4.501E-01	4.869E-01
12	1.158E+00	1.197E+00
13	3.097E+00	3.132E+00
14	5.380E+00	5.436E+00
15	4.628E+00	4.529E+00
16	6.197E+00	6.235E+00
17	4.446E+00	4.496E+00
18	4.546E+00	4.486E+00
19	5.457E+00	5.338E+00
20	5.355E+00	5.321E+00
21	6.147E-01	5.787E-01
22	3.481E-01	3.461E-01
23	3.504E-01	3.508E-01
24	3.003E-01	2.984E-01
25	2.087E-01	2.064E-01
26	1.332E-01	1.299E-01
27	6.243E-02	6.020E-02
28	2.268E-02	2.145E-02
29	6.384E-03	5.888E-03
30	1.230E-03	1.061E-03
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TOTAL INTEGRAL	3.584E+01	3.584E+01

SENSIT SAMPL 7, *FUSION REACTOR*XS+SED SENS.*RUN 76SED: CR, NI, FE, CU

** SED UNCERTAINTY ANALYSIS **

G-IN	MEDIAN G-OUT OF SED (FROM INPUT)	INTEGRAL SED-UNCERT. F (FROM INPUT)	HOT INTEGRAL SENS. COEFF. S-HOT	COLD INTEGRAL SENS. COEFF. S-COLD	NET INTEGRAL SED SENS.-COEFF. S (SHOT - SCOLD)	RESPONSE UNCERT. DR/R DUE TO SED-UNCERT. (F * S)
1	8	.0900	0.	0.	0.	0.
2	8	.0720	1.576E-01	5.179E-02	1.058E-01	7.617E-03
3	7	.0700	5.899E-02	2.028E-02	3.871E-02	2.710E-03
4	4	.0700	2.884E-02	1.257E-02	1.628E-02	1.139E-03
5	5	.0700	3.048E-02	1.337E-02	1.711E-02	1.198E-03
6	6	.0600	2.641E-02	1.244E-02	1.398E-02	8.385E-04
7	7	.0600	4.481E-02	2.331E-02	2.150E-02	1.290E-03
8	8	.0600	2.950E-02	1.917E-02	1.033E-02	6.198E-04
9	9	.0500	4.038E-02	2.566E-02	1.472E-02	7.358E-04
10	10	.0500	5.538E-02	3.054E-02	2.484E-02	1.242E-03
11	11	.0400	8.475E-02	3.717E-02	4.758E-02	1.903E-03
12	12	.0400	5.164E-01	7.853E-02	4.378E-01	1.751E-02
13	13	.0200	1.464E+00	9.655E-02	1.368E+00	2.736E-02
14	14	.0200	2.565E+00	1.578E-01	2.407E+00	4.814E-02
15	15	.0200	2.122E+00	1.374E-01	1.984E+00	3.969E-02
16	16	.0200	6.042E+00	2.017E-01	5.840E+00	1.168E-01
17	0	0.0000	0.	0.	0.	0.
18	0	0.0000	0.	0.	0.	0.
19	0	0.0000	0.	0.	0.	0.
20	0	0.0000	0.	0.	0.	0.
21	0	0.0000	0.	0.	0.	0.
22	0	0.0000	0.	0.	0.	0.
23	0	0.0000	0.	0.	0.	0.
24	0	0.0000	0.	0.	0.	0.
25	0	0.0000	0.	0.	0.	0.
26	0	0.0000	0.	0.	0.	0.
27	0	0.0000	0.	0.	0.	0.
28	0	0.0000	0.	0.	0.	0.
29	0	0.0000	0.	0.	0.	0.
30	0	0.0000	0.	0.	0.	0.
TOTAL INTEGRAL			1.327E+01	9.183E-01	1.235E+01	2.688E-01 = 26.879 PER CENT

******************************* GAMMA CROSS SECTION SENSITIVITY PROFILES ********************************
************************************ SUMMED OVER ALL PERTURBED ZONES **
PARTIAL AND NET SENSITIVITY PROFILES PER DELTA-U. NORMALIZED TO I1PHI = (R.PHI) = 1.12278E+04
FOR GAMMA INTERACTION CROSS SECTIONS: (GAMMA-GAMMA) ONLY

			*********PURE LOSS TERMS***********			*GAIN TERM*	*****NET PROFILES*****	
GROUP	UPPER-E(EV)	DELTA-U	AXS	SXS	TXS	G-GAIN	SEN	SENT
31	5.000E-02	7.99E-01	1.610E-02	-2.512E-02	-9.025E-03	2.397E-03	-2.273E-02	-6.629E-03
32	2.000E+07	1.18E-01	1.542E-01	-2.618E-01	-1.076E-01	3.550E-02	-2.263E-01	-7.206E-02
33	9.000E+06	1.34E-01	1.787E+00	-3.182E+00	-1.395E+00	4.971E-01	-2.685E+00	-8.981E-01
34	8.000E+06	1.54E-01	4.208E-01	-7.989E-01	-3.782E-01	1.435E-01	-6.554E-01	-2.347E-01
35	7.000E+06	1.82E-01	2.356E-01	-4.887E-01	-2.532E-01	1.018E-01	-3.869E-01	-1.514E-01
36	6.000E+06	2.23E-01	1.626E-01	-3.893E-01	-2.267E-01	9.633E-02	-2.930E-01	-1.303E-01
37	5.000E+06	2.88E-01	9.694E-02	-3.040E-01	-2.071E-01	9.170E-02	-2.123E-01	-1.154E-01
38	4.000E+06	4.05E-01	4.036E-02	-2.333E-01	-1.930E-01	8.984E-02	-1.435E-01	-1.031E-01
39	3.000E+06	6.93E-01	4.484E-03	-2.011E-01	-1.966E-01	1.031E-01	-9.798E-02	-9.350E-02
40	2.000E+06	6.93E-01	-5.551E-03	-3.409E-01	-3.464E-01	2.163E-01	-1.245E-01	-1.301E-01
41	1.000E+06	1.61E+00	-5.247E-02	-1.632E-01	-2.156E-01	1.534E-01	-9.807E-03	-6.228E-02
42	5.000E+05	2.30E+00	-1.163E-03	-1.396E-04	-1.303E-03	1.395E-04	-1.175E-07	-1.164E-03
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INTEGRAL			3.701E-01	-1.596E+00	-1.225E+00	6.660E-01	-9.295E-01	-5.594E-01

START User SIG 5013 [77,5013] Job BANNER Seq. 3756 Date 15-Feb-80 15:35:54 Monitor LASL/CTR 603A(66)-BTS *START*

```
  SSSSS    IIIIII    GGGGG                                                      555555555   00000      1     333333333
 SSSSSSS   IIIIII   GGGGGGG                                                     555555555  0000000    11     33333333
SS     SS    II    GGG   GGG                                                    55        000   000  111           33
SS           II    GG                                                           5555555   00     00 1111          333
 SSSSSS      II    GG                                                           55555555  00     00 1  11       33333
  SSSSSS     II    GG  GGGGG                                                          555 00     00   11           333
       SS    II    GG  GGGGG                                                           55 00     00   11            33
SS     SS    II    GGG   GGG                                                    555    55 000   000   11     333   333
 SSSSSSS   IIIIII   GGGGGGGG                                                     5555555   0000000  111111    3333333
  SSSSS    IIIIII    GGGG GG                                                      55555     00000   111111     33333

TTTTTTTT   AAAAA   PPPPPPP  EEEEEEEEE        4    SSSSS     AAAAA   M       M PPPPPPP   LL          777777777
TTTTTTTT  AAAAAAA  PPPPPPPP EEEEEEEEE       44   SSSSSSS   AAAAAAA  MM     MM PPPPPPPP  LL          77777777
   TT    AAA   AAA PP    PP EE             444  SS     SS AAA   AAA MMM   MMM PP    PP  LL          77    77
   TT    AA     AA PP    PP EE            4444  SS        AA     AA MMMM MMMM PP    PP  LL               77
   TT    AA     AA PPPPPPPP EEEEEEE      44 44   SSSSSS   AA     AA MM MMM MM PPPPPPPP  LL              77
   TT    AAAAAAAAA PPPPPPP  EEEEEEE     44  44    SSSSSS  AAAAAAAAA MM  M  MM PPPPPPP   LL             77
   TT    AAAAAAAAA PP       EE         444444444       SS AAAAAAAAA MM     MM PP        LL             77
   TT    AA     AA PP       EE         444444444  SS     SS AA     AA MM     MM PP        LL             77
   TT    AA     AA PP       EEEEEEEEE       44   SSSSSSS  AA     AA MM     MM PP        LLLLLLLLL      77
   TT    AA     AA PP       EEEEEEEEE       44    SSSSS   AA     AA MM     MM PP        LLLLLLLLL      77

BBBBBBB    AAAAA   N      NN N      NN EEEEEEEEE RRRRRRR               PPPPPPP   RRRRRRR   TTTTTTTT
BBBBBBBB  AAAAAAA  NN     NN NN     NN EEEEEEEEE RRRRRRRR              PPPPPPPP  RRRRRRRR  TTTTTTTT
BB     BB AAA   AAA NNN    NN NNN    NN EE        RR     RR             PP    PP  RR     RR    TT
BB     BB AA     AA NNNN   NN NNNN   NN EE        RR     RR             PP    PP  RR     RR    TT
BBBBBBBB  AA     AA NN NN  NN NN NN  NN EEEEEEE   RRRRRRRR              PPPPPPPP  RRRRRRRR     TT
BBBBBBBB  AAAAAAAAA NN  NN NN NN  NN NN EEEEEEE   RRRRRRR               PPPPPPP   RRRRRRR      TT
BB     BB AAAAAAAAA NN   NNNN NN   NNNN EE        RR  RR                PP        RR  RR       TT
BB     BB AA     AA NN    NNN NN    NNN EE        RR   RR               PP        RR   RR      TT
BBBBBBBB  AA     AA NN     NN NN     NN EEEEEEEEE RR    RR      ::      PP        RR    RR     TT
BBBBBBB   AA     AA NN      N NN      N EEEEEEEEE RR     RR     ::      PP        RR     RR    TT
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LPTSPL Version 6(34420) Running on EPL010
START User SIG 5013 [77,5013] Job BANNER Seq. 3756 Date 15-Feb-80 15:35:54 Monitor LASL/CTR 603A(66)-BTS *START*
Request created: 15-Feb-80 15:35:22
File: DSK:BANNER.PRT[3,3] Created: 15-Feb-80 15:33:00 Printed: 15-Feb-80 15:36:03
QUEUE Switches: /PRINT:ARROW /FILE:ASCII /COPIES:1 /SPACING:1 /LIMIT:78 /FORMS:NORMAL
File will be deleted after printing

C-MICR P0 45X42 TABLE 0

-7.62694E-02	0.	1.37000E+00	4.45473E-01	0.	0.	1
0.	0.	0.	0.	0.	0.	2
0.	0.	0.	0.	0.	0.	3
0.	0.	0.	0.	0.	0.	4
0.	0.	0.	0.	0.	0.	5
0.	0.	0.	0.	0.	0.	6
0.	0.	0.	0.	0.	0.	7
0.	0.	0.	-1.36327E-01	0.	1.28262E+00	8
4.28130E-01	2.14476E-01	0.	0.	0.	0.	9
0.	0.	0.	0.	0.	0.	10
0.	0.	0.	0.	0.	0.	11
0.	0.	0.	0.	0.	0.	12
0.	0.	0.	0.	0.	0.	13
0.	0.	0.	0.	0.	0.	14
0.	0.	0.	0.	0.	0.	15
-1.86899E-01	0.	1.35622E+00	5.24605E-01	1.70995E-01	1.41896E-01	16
0.	0.	0.	0.	0.	0.	17
0.	0.	0.	0.	0.	0.	18
0.	0.	0.	0.	0.	0.	19
0.	0.	0.	0.	0.	0.	20
0.	0.	0.	0.	0.	0.	21
0.	0.	0.	0.	0.	0.	22
0.	0.	0.	-2.60497E-01	0.	1.29799E+00	23
5.39639E-01	2.21484E-01	1.51653E-01	1.17480E-01	0.	0.	24
0.	0.	0.	0.	0.	0.	25
0.	0.	0.	0.	0.	0.	26
0.	0.	0.	0.	0.	0.	27
0.	0.	0.	0.	0.	0.	28
0.	0.	0.	0.	0.	0.	29
0.	0.	0.	0.	0.	0.	30
-1.56935E-01	0.	1.37670E+00	5.32013E-01	2.07243E-01	1.44156E-01	31
1.37083E-01	6.27837E-02	0.	0.	0.	0.	32
0.	0.	0.	0.	0.	0.	33
0.	0.	0.	0.	0.	0.	34
0.	0.	0.	0.	0.	0.	35
0.	0.	0.	0.	0.	0.	36
0.	0.	0.	0.	0.	0.	37
0.	0.	0.	-2.33009E-01	0.	1.22144E+00	38
5.26689E-01	3.15502E-01	1.13325E-01	1.26088E-01	8.15561E-02	2.07403E-02	39
0.	0.	0.	0.	0.	0.	40
0.	0.	0.	0.	0.	0.	41
0.	0.	0.	0.	0.	0.	42
0.	0.	0.	0.	0.	0.	43
0.	0.	0.	0.	0.	0.	44
0.	0.	0.	0.	0.	0.	45
-3.17644E-02	0.	1.70150E+00	1.01383E+00	4.38871E-01	1.44221E-01	46
2.52084E-01	6.78060E-02	1.90679E-02	5.01360E-02	0.	0.	47
0.	0.	0.	0.	0.	0.	48
0.	0.	0.	0.	0.	0.	49
0.	0.	0.	0.	0.	0.	50
0.	0.	0.	0.	0.	0.	51
0.	0.	0.	0.	0.	0.	52
0.	0.	0.	-4.24503E-03	0.	2.20203E+00	53
8.71494E-01	5.26786E-01	5.39588E-03	1.17404E-01	4.07888E-03	1.43615E-02	54
2.74775E-02	4.15946E-02	0.	0.	0.	0.	55
0.	0.	0.	0.	0.	0.	56
0.	0.	0.	0.	0.	0.	57
0.	0.	0.	0.	0.	0.	58
0.	0.	0.	0.	0.	0.	59

4.64481E-01	6.31638E-01	4.66563E-01	3.68487E-01	3.04701E-01	2.05803E-01	264
2.74843E-01	9.52587E-02	5.58104E-02	3.12257E-02	1.64447E-02	8.43018E-03	265
3.43304E-03	1.42434E-01	8.79890E-01	2.10033E-01	1.44366E-01	5.29304E-02	266
2.66533E-02	1.73727E-02	1.41074E-02	8.69159E-03	8.40226E-03	1.07888E-02	267
1.56518E-02	1.54475E-02	1.42737E-02	1.28584E-02	1.07162E-02	8.47441E-02	268
3.63676E-01	3.37196E-01	1.27826E-01	9.98615E-02	1.73168E-01	2.63296E-01	269
0.	0.	0.	0.	0.	0.	270
-1.12692E+01	0.	1.21494E+01	7.55076E-01	9.48693E-01	6.65584E-01	271
5.11724E-01	4.16934E-01	3.53053E-01	2.47719E-01	5.61875E-01	1.94742E-01	272
1.14096E-01	6.38363E-02	3.36187E-02	1.78793E-02	1.07176E-02	4.04294E-01	273
2.70601E+00	6.98770E-01	4.76575E-01	1.70112E-01	8.26233E-02	5.32172E-02	274
4.19548E-02	2.44202E-02	2.21590E-02	2.62628E-02	3.52337E-02	3.36688E-02	275
3.08739E-02	2.75054E-02	6.40815E-02	4.70662E-01	9.26399E-01	7.65152E-01	276
2.56318E-01	3.34852E-01	5.70348E-01	6.74610E-01	0.	0.	277
0.	0.	0.	-5.77258E+00	0.	1.25590E+01	278
1.43890E+00	1.58675E+00	1.03835E+00	7.76226E-01	6.24206E-01	5.24999E-01	279
4.54865E-01	3.30348E-01	1.09612E+00	3.79909E-01	2.22582E-01	1.24534E-01	280
6.55844E-02	3.58378E-02	2.61397E-02	8.93251E-01	6.31534E+00	1.70592E+00	281
1.16166E+00	4.13932E-01	2.00175E-01	1.27512E-01	9.78414E-02	5.44093E-02	282
4.66967E-02	5.10617E-02	6.35154E-02	5.87495E-02	6.22055E-02	2.78120E-01	283
7.75134E-01	1.19430E+00	1.83694E+00	1.40737E+00	5.85522E-01	9.62993E-01	284
1.30881E+00	1.32013E+00	0.	0.	0.	0.	285
6.50739E-01	0.	1.54952E+01	3.79757E+00	3.22888E+00	1.94283E+00	286
1.42506E+00	1.14051E+00	9.56828E-01	8.27287E-01	7.30366E-01	5.44647E-01	287
1.17953E+00	4.08818E-01	2.39519E-01	1.34010E-01	7.05749E-02	4.08246E-02	288
4.09893E-02	1.33348E+00	9.81299E+00	2.79853E+00	1.91580E+00	6.82502E-01	289
3.29484E-01	2.08254E-01	1.56853E-01	8.48237E-02	7.02023E-02	7.23812E-02	290
1.22253E-01	5.36790E-01	1.14439E+00	1.60601E+00	1.98285E+00	2.19665E+00	291
2.88368E+00	2.15034E+00	1.62456E+00	2.14058E+00	2.43458E+00	2.26606E+00	292
0.	0.	0.	7.89355E+00	0.	2.71201E+01	293
7.71765E+00	6.32030E+00	1.09978E+01	1.72603E+01	2.26472E+01	2.69094E+01	294
3.03678E+01	3.37519E+01	3.70663E+01	4.59001E+01	4.74023E-01	1.64293E-01	295
9.62566E-02	5.38552E-02	2.83622E-02	1.75268E-02	2.31194E-02	7.85283E-01	296
5.69724E+00	1.59824E+00	1.09269E+00	3.89192E-01	1.87814E-01	1.18626E-01	297
8.92329E-02	4.82661E-02	3.39711E-02	4.12505E-02	4.29084E-01	1.27678E+00	298
1.62057E+00	1.79885E+00	1.79987E+00	1.85646E+00	2.15905E+00	1.79728E+00	299
1.77152E+00	1.88117E+00	1.81255E+00	1.64227E+00	0.	0.	300
1.74873E+02	0.	2.11916E+02	3.51564E+01	1.15089E+01	4.72659E+00	301
2.66604E+00	1.87360E+00	1.44586E+00	1.17749E+00	9.92931E-01	8.58633E-01	302
7.56580E-01	5.59530E-01	4.92237E-01	1.70606E-01	9.99551E-02	5.59245E-02	303
2.94520E-02	1.98966E-02	3.44014E-02	1.27229E+00	8.88958E+00	2.36966E+00	304
1.61214E+00	5.74122E-01	2.77219E-01	1.75850E-01	1.62891E-01	2.70373E-01	305
4.22657E-01	7.13155E-01	9.00363E-01	8.92412E-01	1.16971E+00	1.42649E+00	306
1.59919E+00	1.57040E+00	1.57187E+00	1.68881E+00	2.29546E+00	2.25455E+00	307
2.01919E+00	1.80105E+00	0.	2.25351E+03	0.	2.39146E+03	308
1.37954E+02	1.88648E+00	0.	0.	0.	0.	309
0.	0.	0.	0.	0.	0.	310
2.41627E-01	8.37464E-02	4.90656E-02	2.74520E-02	1.44573E-02	8.87725E-03	311
1.16225E-02	4.29530E-01	2.98159E+00	7.87313E-01	5.35117E-01	1.90558E-01	312
9.20222E-02	5.84285E-02	4.45142E-02	2.45598E-02	2.08765E-02	2.24803E-02	313
2.30116E-01	5.06148E-01	5.35248E-01	5.57606E-01	5.80526E-01	5.99734E-01	314
5.64223E-01	7.26072E-01	1.02183E+00	1.01115E+00	9.44940E-01	7.76900E-01	315

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SENSIT SAMPLE 8. *FUSION REACTOR*VECTOR-XS.SEN+UNCERT.*RUN76: CR. NI. FE. CU
       2       1       6     137      42      30       0       1       2      36       0         CARD2
       1       1       2       0       0       0       0       0       0       4       0       0 CARD3
    1.700E+7        1.500E+7        1.350E+7        1.200E+7        1.000E+7        7.79 E+6 EN(G)
    6.070E+6        3.680E+6        2.865E+6        2.232E+6        1.730E+6        1.353E+6 EN(G)
    8.230E+5        5.000E+5        3.030E+5        1.840E+5        6.760E+4        2.480E+4 EN(G)
    9.120E+3        3.350E+3        1.235E+3        4.540E+2        1.670E+2        6.140E+1 EN(G)
    2.260E+1        8.320E+0        3.060E+0        1.130E+0        4.140E-1        1.520E-1 EN(G)
    5.000E-2                                                                                 EN(G)
    2.000E+7        9.000E+6        8.000E+6        7.000E+6        6.000E+6        5.000E+6 EG(G)
    4.000E+6        3.000E+6        2.000E+6        1.000E+6        5.000E+5        1.000E+5 EG(G)
    1.000E+4                                                                                 EG(G)
   0.0856623       0.1803808       0.2339570       0.2339570       0.1803808       0.0856623 W(M)
  -0.9324695      -0.6612094      -0.2386192       0.2386192       0.6612094       0.9324695 MUE(M)
  0.0             24.25           48.5            72.75           97.0            98.0       MESH
  99.0            100.0           101.0           102.0           104.5           107.0      MESH
  107.5           108.0           108.5           109.0           109.5           110.0      MESH
  110.5           110.0           111.5           112.0           113.0           114.0      MESH
  115.0           116.0           117.0           118.0           119.0           120.0      MESH
  121.0           122.0           122.5           123.0           123.5           124.0      MESH
  125.0           126.0           127.0           128.0           129.0           130.0      MESH
  131.0           132.0           133.0           134.0           135.0           136.0      MESH
  137.0           138.0           139.0           140.0           141.0           142.0      MESH
  143.0           144.0           145.0           146.0           147.0           148.0      MESH
  149.0           150.0           151.0           152.0           153.0           154.0      MESH
  155.0           156.0           157.0           158.0           159.0           160.0      MESH
  161.0           162.0           163.0           164.0           165.0           165.5      MESH
  166.0           168.0           171.0           174.0           177.0           180.0      MESH
  183.0           186.0           189.0           192.0           195.0           198.0      MESH
  201.0           204.0           207.0           210.0           213.0           216.0      MESH
  219.0           222.0           225.0           228.0           231.0           234.0      MESH
  237.0           240.0           243.0           246.0           249.0           252.0      MESH
  255.0           256.0           257.0           259.067         261.133         263.2      MESH
  265.267         267.333         269.400         271.357         273.533         275.6      MESH
  277.667         279.733         281.800         283.867         285.933         288.0      MESH
  290.0           291.0           294.0           296.0           298.0           300.0      MESH
  302.0           304.0           306.0           308.333         310.667         313.0      MESH
       1       4                                                                             SRS
      80     108                                                                             DET
      80     108                                                                            PER1
     111     125                                                                            PER2
    .184E+07        .200E+07        .197E+07        .222E+07        .159E+07        .106E+07 R3(G)
    .567E+06        .284E+06        .190E+06        .116E+06        .736E+05        .730E+05
    .640E+05        .485E+05        .340E+05        .216E+05        .167E+05        .118E+05
    .214E+05        .204E+05        .936E+05        .124E+05        .305E+04        .473E+04
    .875E+04        .200E+05        .334E+05        .562E+05        .102E+06        .289E+06
    .307E+08        .197E+08        .169E+08        .142E+08        .118E+08        .956E+07
    .737E+07        .539E+07        .357E+07        .207E+07        .130E+07        .692E+07
  1.0000          1.0000          1.0000          1.0000          1.0000          1.0000     RHO(J)
  1.0000          1.0000          1.0000          1.0000          1.0000          1.0000     RHO(J)
  1.0000          1.0000          1.0000          1.0000          1.0000          1.0000     RHO(J)
  1.0000          1.0000          1.0000          1.0000          1.0000          1.0000     RHO(J)
  1.0000          1.0000          1.0000          1.0000          1.0000                     RHO(J)
  0.0             1.00000         0.0             0.0             0.0             0.0        Q(G)
  0.0             0.0             0.0             0.0             0.0             0.0        Q(G)
  0.0             0.0             0.0             0.0             0.0             0.0        Q(G)
  0.0             0.0             0.0             0.0             0.0             0.0        Q(G)
  0.0             0.0             0.0             0.0             0.0             0.0        Q(G)
  0.0             0.0             0.0             0.0             0.0             0.0        Q(G)
  0.0             0.0             0.0             0.0             0.0             0.0        Q(G)
```

61	0.01031		0.01031	0.01031	0.01031	QUE(J)
62	12		0.00502	0.00502		ID1
63	13		0.00502	0.00502		ID2
64	14		0.00502	0.00502		ID3
65	15		0.00502	0.00502		ID4
66	16		0.00502	0.00502		ID5
67	17		0.00502	0.00502		ID6
68	18		0.00502	0.00502		ID7
69	32		0.0032	0.0032		ID8
70	33		0.0032	0.0032		ID9
71	34		0.0032	0.0032		ID10
72	35		0.0032	0.0032		ID11
73	36		0.0032	0.0032		ID12
74	19		0.0189	0.0189		ID13
75	20		0.0189	0.0189		ID14
76	21		0.0189	0.0189		ID15
77	22		0.0189	0.0189		ID16
78	23		0.0189	0.0189		ID17
79	24		0.0199	0.0189		ID18
80	25		0.0189	0.0189		ID19
81	26		0.0189	0.0189		ID20
82	27		0.0189	0.0189		ID21
83	28		0.0189	0.0189		ID22
84	29		0.0189	0.0189		ID23
85	30		0.0189	0.0189		ID24
86	31		0.0189	0.0189		ID25
87	37		0.0407	0.0407		ID26
88	38		0.0407	0.0407		ID27
89	39		0.0407	0.0407		ID28
90	40		0.0407	0.0407		ID29
91	41		0.0407	0.0407		ID30
92	42		0.0407	0.0407		ID31
93	43		0.0407	0.0407		ID32
94	44		0.0407	0.0407		ID33
95	45		0.0407	0.0407		ID34
96	46		0.0407	0.0407		ID35
97	47		0.0407	0.0407		ID36
98	1	7				SUM1
99	8	12				SUM2
100	13	25				SUM3
101	26	36				SUM4

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SENSIT SAMPLE B, *FUSION REACTOR*VECTOR-XS.SEN+UNCERT.*RUN76: CR, NI, FE, CU

ITYP     = TYPE OF SENS.-UNCERT.-ANAL., 1-XS,2-DESIGN,3-VECTOR-XS,4-SED              =   2
IGE      = GEOMETRIC MODEL: 1-SLAB,2-CYLINDER,3-SPHERE                               =   1
ISN      = ORDER OF S-N QUADRATURE                                                   =   6
IM       = TOTAL NUMBER OF SPATIAL MESH INTERVALS                                    = 137
IGM      = TOTAL NUMBER OF ENERGY GROUPS                                             =  42
NCOUPL   = NUMBER OF NEUTRON GROUPS IN CPL. CALC., ZERO FOR NEUTRONS ONLY            =  30
LMAX     = MAX. P-L ORDER OF CROSS SECTIONS                                          =   0
ITAPE    = FORMAT OF ANG.FLX. TAPES 1 AND 2: 0-ANISN, 1-CCCC(ONETRAN)                =   1
IXSTAPE  = SOURCE OF INPUT CROSS-SECTIONS: 0-CARDS, 1-TAPE4, 2-TAPE10                =   2
NPERXS   = NUMBER OF SUCCESSIVE CASES, ALSO NO. OF INPUT XS-SETS TO BE READ          =  36
IDESIGN  = ASSUMED 1 PER CENT DENSITY INCREASE IN PERT. ZS. FOR DES.-SEN., 0/1=NO/YES =   0

KSRS     = NUMBER OF SOURCE ZONES                                                    =   1
KDET     = NUMBER OF DETECTOR ZONES                                                  =   1
KPER     = NUMBER OF PERTURBED ZONES                                                 =   2
KXS      = INPUT XS-FORMAT  0-IF ITYP=2, 1-LASL, 2-ORNL                              =   0
IHT      = POSITION OF TOTAL CROSS-SECTION IN XS-TABLES                              =   0
IHA      = POSITION OF ABSORPTION CROSS-SECTION IN XS-TABLES                         =   0
DETCOV   = 0/1 = DO NOT/DO READ COVARIANCE MATRIX FOR R(G)                           =   0
NSED     = 0/1 = DO NOT/DO READ INTEGRAL SED-UNCERTAINTIES                           =   0
IOUTPUT  = OUTPUT PRINT DETAIL: 0-SUM OVER PERT.ZONES ONLY, 1-ALSO INDIV. PERT.ZS.    =   0
NSUMCOV  = NO. OF RESP.-VARIANCES SUMMED FOR ITYP=2, ZERO FOR ITYP=0,1,3             =   4
ITEST    = TEST PRINTOUT FLAG: 0-NONE, 1-XS, 2-ANG.FLXS., 3-VECTOR-XS                =   0
IPRINT   = TEST PRINTS FROM POINTR: 0-NONE,1-DUMPS, 2-TRACES, 3-ALL                  =   0


 31 NEUTRON ENERGY GROUP BOUNDARIES READ, IN EV
 1.700E+07  1.500E+07  1.350E+07  1.200E+07  1.000E+07  7.790E+06  6.070E+06  3.680E+06  2.865E+06  2.232E+06
 1.738E+06  1.353E+06  8.230E+05  5.000E+05  3.030E+05  1.840E+05  6.760E+04  2.480E+04  9.120E+03  3.350E+03
 1.235E+03  4.540E+02  1.670E+02  6.140E+01  2.260E+01  8.320E+00  3.060E+00  1.130E+00  4.140E-01  1.520E-01
 5.000E-02

 13 GAMMA ENERGY GROUP BOUNDARIES READ, IN EV
 2.000E+07  9.000E+06  8.000E+06  7.000E+06  6.000E+06  5.000E+06  4.000E+06  3.000E+06  2.000E+06  1.000E+06
 5.000E+05  1.000E+05  1.000E+04

LEVEL WEIGHTS FOR DISCRETE ANGLES
     .085662     .180381     .233957     .233957     .180381     .085662

DISCRETE ANGLES MUE FOR LEVEL WEIGHTS
    -.932470    -.661209    -.238619     .238619     .661209     .932470

MESH BOUNDARIES READ
 0.         2.425E+01  4.850E+01  7.275E+01  9.700E+01  9.800E+01  9.900E+01  1.000E+02  1.010E+02  1.020E+02
 1.045E+02  1.070E+02  1.075E+02  1.080E+02  1.085E+02  1.090E+02  1.095E+02  1.100E+02  1.105E+02  1.100E+02
 1.115E+02  1.120E+02  1.130E+02  1.140E+02  1.150E+02  1.160E+02  1.170E+02  1.180E+02  1.190E+02  1.200E+02
 1.210E+02  1.220E+02  1.225E+02  1.230E+02  1.235E+02  1.240E+02  1.250E+02  1.260E+02  1.270E+02  1.280E+02
 1.290E+02  1.300E+02  1.310E+02  1.320E+02  1.330E+02  1.340E+02  1.350E+02  1.360E+02  1.370E+02  1.300E+02
 1.390E+02  1.400E+02  1.410E+02  1.420E+02  1.430E+02  1.440E+02  1.450E+02  1.460E+02  1.470E+02  1.480E+02
 1.490E+02  1.500E+02  1.510E+02  1.520E+02  1.530E+02  1.540E+02  1.550E+02  1.560E+02  1.570E+02  1.580E+02
 1.590E+02  1.600E+02  1.610E+02  1.620E+02  1.630E+02  1.640E+02  1.650E+02  1.655E+02  1.660E+02  1.680E+02
 1.710E+02  1.740E+02  1.770E+02  1.800E+02  1.830E+02  1.860E+02  1.890E+02  1.920E+02  1.950E+02  1.980E+02
 2.010E+02  2.040E+02  2.070E+02  2.100E+02  2.130E+02  2.160E+02  2.190E+02  2.220E+02  2.250E+02  2.280E+02
 2.310E+02  2.340E+02  2.370E+02  2.400E+02  2.430E+02  2.460E+02  2.490E+02  2.520E+02  2.550E+02  2.560E+02
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SENSIT SAMPLE B, *FUSION REACTOR*VECTOR-XS.SEN+UNCERT.*RUN76: CR, NI, FE, CU

****************************** SENSITIVITY PROFILES FOR CROSS-SECTION PAIRS WITH ID = 37 ******************************
PI(G) AND P2(G) ARE PER LETHARGY WIDTH DELTA-U AND NORMALIZED TO THE RESPONSE I1PHI = (R,PHI) = 1.12278E+04
FOR THE SUM OVER ALL PERTURBED ZONES, WHERE BOTH CROSS SECTIONS WITH THIS ID ARE PRESENT IN THE MODEL
THE NUMBER DENSITIES FOR THIS XS-PAIR ARE NDEN1 = 4.07000E-02 AND NDEN2 = 4.07000E-02

GROUP	UPPER-E(EV)	DELTA-U	P1(G)	P2(G)
1	1.700E+07	1.25E-01	0.	0.
2	1.500E+07	1.05E-01	-3.156E+00	-3.156E+00
3	1.350E+07	1.10E-01	-1.060E+00	-1.060E+00
4	1.200E+07	1.82E-01	-3.690E-01	-3.690E-01
5	1.000E+07	2.50E-01	-2.651E-01	-2.651E-01
6	7.790E+06	2.49E-01	-2.220E-01	-2.220E-01
7	6.070E+06	5.00E-01	-1.781E-01	-1.781E-01
8	3.680E+06	2.50E-01	-2.379E-01	-2.379E-01
9	2.865E+06	2.50E-01	-3.094E-01	-3.094E-01
10	2.232E+06	2.50E-01	-3.870E-01	-3.870E-01
11	1.738E+06	2.50E-01	-5.172E-01	-5.172E-01
12	1.353E+06	4.97E-01	-1.172E+00	-1.172E+00
13	8.230E+05	4.98E-01	-2.950E+00	-2.950E+00
14	5.000E+05	5.01E-01	-5.073E+00	-5.073E+00
15	3.030E+05	4.99E-01	-3.998E+00	-3.998E+00
16	1.840E+05	1.00E+00	-6.075E+00	-6.075E+00
17	6.760E+04	1.00E+00	-4.462E+00	-4.462E+00
18	2.480E+04	1.00E+00	-5.170E+00	-5.170E+00
19	9.120E+03	1.00E+00	-6.729E+00	-6.729E+00
20	3.350E+03	9.98E-01	-5.895E+00	-5.895E+00
21	1.235E+03	1.00E+00	-7.186E-01	-7.186E-01
22	4.540E+02	1.00E+00	-3.826E-01	-3.826E-01
23	1.670E+02	1.00E+00	-4.038E-01	-4.038E-01
24	6.140E+01	9.99E-01	-3.549E-01	-3.549E-01
25	2.260E+01	9.99E-01	-2.423E-01	-2.423E-01
26	8.320E+00	1.00E+00	-1.335E-01	-1.335E-01
27	3.060E+00	9.96E-01	-6.314E-02	-6.314E-02
28	1.130E+00	1.00E+00	-2.324E-02	-2.324E-02
29	4.140E-01	1.00E+00	-6.719E-03	-6.719E-03
30	1.520E-01	1.11E+00	-1.452E-03	-1.452E-03
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INTEGRAL			-3.036E+01	-3.036E+01

************************ AN UNCERTAINTY ANALYSIS FOR THIS CROSS-SECTION PAIR YIELDS THE FOLLOWING ************************
FRACTIONAL RESPONSE UNCERTAINTY DUE TO XS-UNCERTAINTIES SPECIFIED IN THE COVARIANCE MATRIX FOR THIS ID:

VARIANCE, (DELTA-R OVER R)-SQUARE = (DR/R)SQ. = 6.769E-02
RELATIVE STANDARD DEVIATION = DR/R = 2.602E-01
= 2.602E+01 PER CENT

**************************** SENSITIVITY PROFILES FOR CROSS-SECTION PAIRS WITH ID = 38 ****************************
P1(G) AND P2(G) ARE PER LETHARGY WIDTH DELTA-U AND NORMALIZED TO THE RESPONSE I1PHI = (R,PHI) = 1.12278E+04
FOR THE SUM OVER ALL PERTURBED ZONES, WHERE BOTH CROSS SECTIONS WITH THIS ID ARE PRESENT IN THE MODEL
THE NUMBER DENSITIES FOR THIS XS-PAIR ARE NDEN1 = 4.07000E-02 AND NDEN2 = 4.07000E-02

GROUP	UPPER-E(EV)	DELTA-U	P1(G)	P2(G)
1	1.700E+07	1.25E-01	0.	0.
2	1.500E+07	1.05E-01	-3.156E+00	-1.478E+00
3	1.350E+07	1.18E-01	-1.060E+00	-5.142E-01
4	1.200E+07	1.82E-01	-3.690E-01	-1.861E-01
5	1.000E+07	2.50E-01	-2.651E-01	-1.439E-01
6	7.790E+06	2.49E-01	-2.220E-01	-1.261E-01
7	6.070E+06	5.00E-01	-1.781E-01	-1.019E-01
8	3.680E+06	2.50E-01	-2.379E-01	-1.385E-01
9	2.865E+06	2.50E-01	-3.094E-01	-1.905E-01
10	2.232E+06	2.50E-01	-3.870E-01	-2.596E-01
11	1.738E+06	2.50E-01	-5.172E-01	-3.849E-01
12	1.353E+06	4.97E-01	-1.172E+00	-1.062E+00
13	8.230E+05	4.98E-01	-2.950E+00	-2.923E+00
14	5.000E+05	5.01E-01	-5.073E+00	-5.056E+00
15	3.030E+05	4.99E-01	-3.998E+00	-3.983E+00
16	1.840E+05	1.00E+00	-6.075E+00	-6.050E+00
17	6.760E+04	1.00E+00	-4.462E+00	-4.439E+00
18	2.480E+04	1.00E+00	-5.170E+00	-5.129E+00
19	9.120E+03	1.00E+00	-6.729E+00	-6.629E+00
20	3.350E+03	9.98E-01	-5.885E+00	-5.773E+00
21	1.235E+03	1.00E+00	-7.186E-01	-6.102E-01
22	4.540E+02	1.00E+00	-3.826E-01	-3.704E-01
23	1.670E+02	1.00E+00	-4.038E-01	-4.012E-01
24	6.140E+01	9.99E-01	-3.549E-01	-3.513E-01
25	2.260E+01	9.99E-01	-2.423E-01	-2.392E-01
26	8.320E+00	1.00E+00	-1.335E-01	-1.296E-01
27	3.060E+00	9.96E-01	-6.314E-02	-6.017E-02
28	1.130E+00	1.00E+00	-2.324E-02	-2.148E-02
29	4.140E-01	1.00E+00	-6.719E-03	-5.916E-03
30	1.520E-01	1.11E+00	-1.452E-03	-1.079E-03
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INTEGRAL			-3.836E+01	-3.735E+01

************************ AN UNCERTAINTY ANALYSIS FOR THIS CROSS-SECTION PAIR YIELDS THE FOLLOWING ************************
FRACTIONAL RESPONSE UNCERTAINTY DUE TO XS-UNCERTAINTIES SPECIFIED IN THE COVARIANCE MATRIX FOR THIS ID:

VARIANCE, (DELTA-R OVER R)-SQUARE = (DR/R)SQ. = 6.682E-02
RELATIVE STANDARD DEVIATION = DR/R = 2.585E-01
= 2.585E+01 PER CENT

SENSIT SAMPLE 8. *FUSION REACTOR*VECTOR-XS.SEN+UNCEPT.*RUN76: CR. NI. FE. CU

****************************** SENSITIVITY PROFILES FOR CROSS-SECTION PAIRS WITH ID = 39 ******************************
P1(G) AND P2(G) ARE PER LETHARGY WIDTH DELTA-U AND NORMALIZED TO THE RESPONSE I1PHI = (R.PHI) = 1.12278E+04
FOR THE SUM OVER ALL PERTURBED ZONES. WHERE BOTH CROSS SECTIONS WITH THIS ID ARE PRESENT IN THE MODEL
THE NUMBER DENSITIES FOR THIS XS-PAIR ARE NDEN1 = 4.07000E-02 AND NDEN2 = 4.07000E-02

GROUP	UPPER-E(EV)	DELTA-U	P1(G)	P2(G)
1	1.700E+07	1.25E-01	0.	0.
2	1.500E+07	1.05E-01	-1.478E+00	-1.478E+00
3	1.350E+07	1.18E-01	-5.142E-01	-5.142E-01
4	1.200E+07	1.82E-01	-1.861E-01	-1.861E-01
5	1.000E+07	2.50E-01	-1.439E-01	-1.439E-01
6	7.790E+06	2.49E-01	-1.261E-01	-1.261E-01
7	6.070E+06	5.00E-01	-1.019E-01	-1.019E-01
8	3.680E+06	2.50E-01	-1.385E-01	-1.385E-01
9	2.865E+06	2.50E-01	-1.905E-01	-1.905E-01
10	2.232E+06	2.50E-01	-2.596E-01	-2.596E-01
11	1.738E+06	2.50E-01	-3.849E-01	-3.849E-01
12	1.353E+06	4.97E-01	-1.062E+00	-1.062E+00
13	8.230E+05	4.98E-01	-2.923E+00	-2.923E+00
14	5.000E+05	5.01E-01	-5.056E+00	-5.056E+00
15	3.030E+05	4.99E-01	-3.983E+00	-3.983E+00
16	1.840E+05	1.00E+00	-6.050E+00	-6.050E+00
17	6.760E+04	1.00E+00	-4.439E+00	-4.439E+00
18	2.480E+04	1.00E+00	-5.129E+00	-5.129E+00
19	9.120E+03	1.00E+00	-6.629E+00	-6.629E+00
20	3.350E+03	9.98E-01	-5.773E+00	-5.773E+00
21	1.235E+03	1.00E+00	-6.102E-01	-6.102E-01
22	4.540E+02	1.00E+00	-3.704E-01	-3.704E-01
23	1.670E+02	1.00E+00	-4.012E-01	-4.012E-01
24	6.140E+01	9.99E-01	-3.513E-01	-3.513E-01
25	2.260E+01	9.99E-01	-2.382E-01	-2.382E-01
26	8.320E+00	1.00E+00	-1.296E-01	-1.296E-01
27	3.060E+00	9.96E-01	-6.017E-02	-6.017E-02
28	1.130E+00	1.00E+00	-2.148E-02	-2.148E-02
29	4.140E-01	1.00E+00	-5.916E-03	-5.916E-03
30	1.520E-01	1.11E+00	-1.079E-03	-1.079E-03
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INTEGRAL			-3.735E+01	-3.735E+01

********************** AN UNCERTAINTY ANALYSIS FOR THIS CROSS-SECTION PAIR YIELDS THE FOLLOWING **********************
FRACTIONAL RESPONSE UNCERTAINTY DUE TO XS-UNCERTAINTIES SPECIFIED IN THE COVARIANCE MATRIX FOR THIS ID:

VARIANCE. (DELTA-R OVER R)-SQUARE = (DR/R)SQ. = 6.626E-02
RELATIVE STANDARD DEVIATION = DR/R = 2.574E-01
= 2.574E+01 PER CENT

SENSIT SAMPLE 8, *FUSION REACTOR*VECTOR-XS.SEN+UNCERT.*RUN76: CR, NI, FE, CU

************************* SENSITIVITY PROFILES FOR CROSS-SECTION PAIRS WITH ID = 40 *************************
P1(G) AND P2(G) ARE PER LETHARGY WIDTH DELTA-U AND NORMALIZED TO THE RESPONSE I1PHI = (R,PHI) = 1.12278E+04
FOR THE SUM OVER ALL PERTURBED ZONES. WHERE BOTH CROSS SECTIONS WITH THIS ID ARE PRESENT IN THE MODEL
THE NUMBER DENSITIES FOR THIS XS-PAIR ARE NDEN1 = 4.07000E-02 AND NDEN2 = 4.07000E-02

GROUP	UPPER-E(EV)	DELTA-U	P1(G)	P2(G)
1	1.700E+07	1.25E-01	0.	0.
2	1.500E+07	1.05E-01	-1.478E+00	-6.767E-01
3	1.350E+07	1.18E-01	-5.142E-01	-3.227E-01
4	1.200E+07	1.82E-01	-1.861E-01	-1.501E-01
5	1.000E+07	2.50E-01	-1.439E-01	-1.132E-01
6	7.790E+06	2.49E-01	-1.261E-01	-9.247E-02
7	6.070E+06	5.00E-01	-1.019E-01	-7.401E-02
8	3.680E+06	2.50E-01	-1.385E-01	-9.692E-02
9	2.865E+06	2.50E-01	-1.905E-01	-1.163E-01
10	2.232E+06	2.50E-01	-2.596E-01	-1.256E-01
11	1.738E+06	2.50E-01	-3.849E-01	-1.306E-01
12	1.353E+06	4.97E-01	-1.062E+00	-1.0[illegible]9E-01
13	8.230E+05	4.98E-01	-2.923E+00	-1.786E-02
14	5.000E+05	5.01E-01	-5.056E+00	0.
15	3.030E+05	4.99E-01	-3.983E+00	0.
16	1.840E+05	1.00E+00	-6.050E+00	0.
17	6.760E+04	1.00E+00	-4.439E+00	0.
18	2.480E+04	1.00E+00	-5.120E+00	0.
19	9.120E+03	1.00E+00	-6.620E+00	0.
20	3.350E+03	9.98E-01	-5.773E+00	0.
21	1.235E+03	1.00E+00	-6.102E-01	0.
22	4.540E+02	1.00E+00	-3.704E-01	0.
23	1.670E+02	1.00E+00	-4.012E-01	0.
24	6.140E+01	9.99E-01	-3.513E-01	0.
25	2.260E+01	9.99E-01	-2.382E-01	0.
26	8.320E+00	1.00E+00	-1.296E-01	0.
27	3.060E+00	9.96E-01	-6.017E-02	0.
28	1.130E+00	1.00E+00	-2.148E-02	0.
29	4.140E-01	1.00E+00	-5.916E-03	0.
30	1.520E-01	1.11E+00	-1.079E-03	0.
INTEGRAL			-3.735E+01	-4.040E-01

THE DOUBLE SUM FOR DR/R-SQUARE RESULTED IN A NEGATIVE NUMBER
DROVRSQ = -8.94919E-05
ANALYSIS TERMINATED FOR THIS ID-NUMBER
VARIANCE IS SET TO ZERO FOR LATER TOTAL VARIANCE CALCULATION

SENSIT SAMPLE B. *FUSION REACTOR*VECTOR-XS.SEN+UNCERT.*RUN76: CR, NI, FE, CU

************************** SENSITIVITY PROFILES FOR CROSS-SECTION PAIRS WITH ID = 41 **************************
P1(G) AND P2(G) ARE PER LETHARGY WIDTH DELTA-U AND NORMALIZED TO THE RESPONSE I1PHI = (R,PHI) = 1.12278E+04
FOR THE SUM OVER ALL PERTURBED ZONES, WHERE BOTH CROSS SECTIONS WITH THIS ID ARE PRESENT IN THE MODEL
THE NUMBER DENSITIES FOR THIS XS-PAIR ARE NDEN1 = 4.07000E-02 AND NDEN2 = 4.07000E-02

GROUP	UPPER-E(EV)	DELTA-U	P1(G)	P2(G)
1	1.700E+07	1.25E-01	0.	0.
2	1.500E+07	1.05E-01	-6.767E-01	-6.767E-01
3	1.350E+07	1.18E-01	-3.227E-01	-3.227E-01
4	1.200E+07	1.82E-01	-1.501E-01	-1.501E-01
5	1.000E+07	2.50E-01	-1.132E-01	-1.132E-01
6	7.790E+06	2.49E-01	-9.247E-02	-9.247E-02
7	6.070E+06	5.00E-01	-7.401E-02	-7.401E-02
8	3.680E+06	2.50E-01	-9.692E-02	-9.692E-02
9	2.865E+06	2.50E-01	-1.163E-01	-1.163E-01
10	2.232E+06	2.50E-01	-1.256E-01	-1.256E-01
11	1.738E+06	2.50E-01	-1.306E-01	-1.306E-01
12	1.353E+06	4.97E-01	-1.059E-01	-1.059E-01
13	8.230E+05	4.98E-01	-1.786E-02	-1.786E-02
14	5.000E+05	5.01E-01	0.	0.
15	3.030E+05	4.99E-01	0.	0.
16	1.840E+05	1.00E+00	0.	0.
17	6.760E+04	1.00E+00	0.	0.
18	2.480E+04	1.00E+00	0.	0.
19	9.120E+03	1.00E+00	0.	0.
20	3.350E+03	9.98E-01	0.	0.
21	1.235E+03	1.00E+00	0.	0.
22	4.540E+02	1.00E+00	0.	0.
23	1.670E+02	1.00E+00	0.	0.
24	6.140E+01	9.99E-01	0.	0.
25	2.260E+01	9.99E-01	0.	0.
26	8.320E+00	1.00E+00	0.	0.
27	3.060E+00	9.96E-01	0.	0.
28	1.130E+00	1.00E+00	0.	0.
29	4.140E-01	1.00E+00	0.	0.
30	1.520E-01	1.11E+00	0.	0.
			----------	----------
INTEGRAL			-4.040E-01	-4.040E-01

************************** AN UNCERTAINTY ANALYSIS FOR THIS CROSS-SECTION PAIR YIELDS THE FOLLOWING **************************
FRACTIONAL RESPONSE UNCERTAINTY DUE TO XS-UNCERTAINTIES SPECIFIED IN THE COVARIANCE MATRIX FOR THIS ID:

VARIANCE, (DELTA-R OVER R)-SQUARE = (DR/R)SQ. = 4.974E-04
RELATIVE STANDARD DEVIATION = DR/R = 2.230E-02
= 2.230E+00 PER CENT

****************************** SENSITIVITY PROFILES FOR CROSS-SECTION PAIRS WITH ID = 42 ******************************
P1(G) AND P2(G) ARE PER LETHARGY WIDTH DELTA-U AND NORMALIZED TO THE RESPONSE I1PHI = (R.PHI) = 1.1227BE-04
FOR THE SUM OVER ALL PERTURBED ZONES, WHERE BOTH CROSS SECTIONS WITH THIS ID ARE PRESENT IN THE MODEL
THE NUMBER DENSITIES FOR THIS XS-PAIR ARE NDEN1 = 4.07000E-02 AND NDEN2 = 4.07000E-02

GROUP	UPPER-E(EV)	DELTA-U	P1(G)	P2(G)
1	1.700E+07	1.25E-01	0.	0.
2	1.500E+07	1.05E-01	-6.767E-01	-2.464E-03
3	1.350E+07	1.18E-01	-3.227E-01	-8.154E-04
4	1.200E+07	1.82E-01	-1.501E-01	-2.788E-04
5	1.000E+07	2.50E-01	-1.132E-01	-2.022E-04
6	7.790E+06	2.49E-01	-9.247E-02	-1.798E-04
7	6.070E+06	5.00E-01	-7.401E-02	-1.727E-04
8	3.680E+06	2.50E-01	-9.692E-02	-3.194E-04
9	2.865E+06	2.50E-01	-1.163E-01	-5.220E-04
10	2.232E+06	2.50E-01	-1.256E-01	-8.115E-04
11	1.738E+06	2.50E-01	-1.306E-01	-1.397E-03
12	1.353E+06	4.97E-01	-1.059E-01	-3.834E-03
13	8.230E+05	4.98E-01	-1.786E-02	-9.181E-03
14	5.000E+05	5.01E-01	0.	-1.674E-02
15	3.030E+05	4.99E-01	0.	-1.498E-02
16	1.840E+05	1.00E+00	0.	-2.526E-02
17	6.760E+04	1.00E+00	0.	-2.296E-02
18	2.480E+04	1.00E+00	0.	-4.053E-02
19	9.120E+03	1.00E+00	0.	-9.979E-02
20	3.350E+03	9.98E-01	0.	-1.112E-01
21	1.235E+03	1.00E+00	0.	-1.084E-01
22	4.540E+02	1.00E+00	0.	-1.212E-02
23	1.670E+02	1.00E+00	0.	-2.591E-03
24	6.140E+01	9.99E-01	0.	-3.591E-03
25	2.260E+01	9.99E-01	0.	-4.093E-03
26	8.320E+00	1.00E+00	0.	-3.840E-03
27	3.060E+00	9.96E-01	0.	-2.973E-03
28	1.130E+00	1.00E+00	0.	-1.762E-03
29	4.140E-01	1.00E+00	0.	-9.030E-04
30	1.520E-01	1.11E+00	0.	-3.738E-04
INTEGRAL			-4.040E-01	-4.641E-01

************************ AN UNCERTAINTY ANALYSIS FOR THIS CROSS-SECTION PAIR YIELDS THE FOLLOWING ************************
FRACTIONAL RESPONSE UNCERTAINTY DUE TO XS-UNCERTAINTIES SPECIFIED IN THE COVARIANCE MATRIX FOR THIS ID:

VARIANCE. (DELTA-R OVER R)-SQUARE = (DR/R)SQ. = 1.804E-06
RELATIVE STANDARD DEVIATION = DR/R = 1.343E-03
= 1.343E-01 PER CENT

SENSIT SAMPLE 8. *FUSION REACTOR*VECTOR-XS.SEN+UNCERT.*RUN76: CR. NI. FE. CU

****************************** SENSITIVITY PROFILES FOR CROSS-SECTION PAIRS WITH ID = 43 ******************************
P1(G) AND P2(G) ARE PER LETHARGY WIDTH DELTA-U AND NORMALIZED TO THE RESPONSE I1PHI = (R.PHI) = 1.12278E+04
FOR THE SUM OVER ALL PERTURBED ZONES. WHERE BOTH CROSS SECTIONS WITH THIS ID ARE PRESENT IN THE MODEL
THE NUMBER DENSITIES FOR THIS XS-PAIR ARE NDEN1 = 4.07000E-02 AND NDEN2 = 4.07000E-02

GROUP	UPPER-E(EV)	DELTA-U	P1(G)	P2(G)
1	1.700E+07	1.25E-01	0.	0.
2	1.500E+07	1.05E-01	-6.767E-01	-2.897E-02
3	1.350E+07	1.18E-01	-3.227E-01	-1.232E-02
4	1.200E+07	1.82E-01	-1.501E-01	-5.231E-03
5	1.000E+07	2.50E-01	-1.132E-01	-3.845E-03
6	7.790E+06	2.49E-01	-9.247E-02	-2.878E-03
7	6.070E+06	5.00E-01	-7.401E-02	-1.956E-03
8	3.680E+06	2.50E-01	-9.692E-02	-2.115E-03
9	2.865E+06	2.50E-01	-1.163E-01	-2.034E-03
10	2.232E+06	2.50E-01	-1.256E-01	-9.537E-04
11	1.738E+06	2.50E-01	-1.306E-01	-2.470E-04
12	1.353E+06	4.97E-01	-1.059E-01	-1.185E-04
13	8.230E+05	4.98E-01	-1.786E-02	-7.011E-05
14	5.000E+05	5.01E-01	0.	-5.686E-05
15	3.030E+05	4.99E-01	0.	-2.431E-05
16	1.840E+05	1.00E+00	0.	-1.440E-05
17	6.760E+04	1.00E+00	0.	-2.604E-06
18	2.480E+04	1.00E+00	0.	-7.225E-07
19	9.120E+03	1.00E+00	0.	-3.303E-07
20	3.350E+03	9.98E-01	0.	-7.873E-08
21	1.235E+03	1.00E+00	0.	-7.554E-09
22	4.540E+02	1.00E+00	0.	-1.914E-09
23	1.670E+02	1.00E+00	0.	-6.579E-10
24	6.140E+01	9.99E-01	0.	-1.976E-10
25	2.260E+01	9.99E-01	0.	-4.816E-11
26	8.320E+00	1.00E+00	0.	-9.934E-12
27	3.060E+00	9.96E-01	0.	-1.691E-12
28	1.130E+00	1.00E+00	0.	-2.223E-13
29	4.140E-01	1.00E+00	0.	-2.248E-14
30	1.520E-01	1.11E+00	0.	-1.105E-15
			----------	----------
INTEGRAL			-4.040E-01	-9.604E-03

****************************** AN UNCERTAINTY ANALYSIS FOR THIS CROSS-SECTION PAIR YIELDS THE FOLLOWING ******************************
FRACTIONAL RESPONSE UNCERTAINTY DUE TO XS-UNCERTAINTIES SPECIFIED IN THE COVARIANCE MATRIX FOR THIS ID:

VARIANCE. (DELTA-R OVER R)-SQUARE = (DR/R)SQ. = 1.533E-06
RELATIVE STANDARD DEVIATION = DR/R = 1.238E-03
= 1.238E-01 PER CENT

SENSIT SAMPLE 8. *FUSION REACTOR*VECTOR-XS.SEN+UNCERT.*RUN76: CR, NI, FE, CU

****************************** SENSITIVITY PROFILES FOR CROSS-SECTION PAIRS WITH ID = 44 ******************************
P1(G) AND P2(G) ARE PER LETHARGY WIDTH DELTA-U AND NORMALIZED TO THE RESPONSE I1PHI = (R,PHI) = 1.12278E+04
FOR THE SUM OVER ALL PERTURBED ZONES, WHERE BOTH CROSS SECTIONS WITH THIS ID ARE PRESENT IN THE MODEL
THE NUMBER DENSITIES FOR THIS XS-PAIR ARE NDEN1 = 4.07000E-02 AND NDEN2 = 4.07000E-02

GROUP	UPPER-E(EV)	DELTA-U	P1(G)	P2(G)
1	1.700E+07	1.25E-01	0.	0.
2	1.500E+07	1.05E-01	-6.767E-01	-3.009E-02
3	1.350E+07	1.18E-01	-3.227E-01	-1.025E-02
4	1.200E+07	1.82E-01	-1.501E-01	-3.614E-03
5	1.000E+07	2.50E-01	-1.132E-01	-1.519E-03
6	7.790E+06	2.49E-01	-9.247E-02	-3.874E-04
7	6.070E+06	5.00E-01	-7.401E-02	-9.308E-06
8	3.680E+06	2.50E-01	-9.692E-02	-4.664E-08
9	2.865E+06	2.50E-01	-1.163E-01	-2.580E-08
10	2.232E+06	2.50E-01	-1.256E-01	-2.595E-08
11	1.738E+06	2.50E-01	-1.306E-01	-2.738E-08
12	1.353E+06	4.97E-01	-1.059E-01	-4.119E-08
13	8.230E+05	4.98E-01	-1.786E-02	-5.486E-08
14	5.000E+05	5.01E-01	0.	-5.087E-08
15	3.030E+05	4.99E-01	0.	-2.176E-08
16	1.840E+05	1.00E+00	0.	-1.288E-08
17	6.760E+04	1.00E+00	0.	-2.330E-09
18	2.480E+04	1.00E+00	0.	-6.464E-10
19	9.120E+03	1.00E+00	0.	-2.955E-10
20	3.350E+03	9.98E-01	0.	-7.009E-11
21	1.235E+03	1.00E+00	0.	-6.759E-12
22	4.540E+02	1.00E+00	0.	-1.713E-12
23	1.670E+02	1.00E+00	0.	-5.887E-13
24	6.140E+01	9.99E-01	0.	-1.768E-13
25	2.260E+01	9.99E-01	0.	-4.309E-14
26	8.320E+00	1.00E+00	0.	-8.889E-15
27	3.060E+00	9.96E-01	0.	-1.513E-15
28	1.130E+00	1.00E+00	0.	-1.989E-16
29	4.140E-01	1.00E+00	0.	-2.011E-17
30	1.520E-01	1.11E+00	0.	-9.885E-19
			----------	----------
INTEGRAL			-4.040E-01	-5.517E-03

************************ AN UNCERTAINTY ANALYSIS FOR THIS CROSS-SECTION PAIR YIELDS THE FOLLOWING ************************
FRACTIONAL RESPONSE UNCERTAINTY DUE TO XS-UNCERTAINTIES SPECIFIED IN THE COVARIANCE MATRIX FOR THIS ID:

VARIANCE, (DELTA-R OVER R)-SQUARE = (DR/R)SQ. = 9.404E-07
RELATIVE STANDARD DEVIATION = DR/R = 9.697E-04
= 9.697E-02 PER CENT

SENSIT SAMPLE 8, *FUSION REACTOR*VECTOR-XS.SEN+UNCERT.*RUN76: CR, NI, FE, CU

****************************** SENSITIVITY PROFILES FOR CROSS-SECTION PAIRS WITH ID = 45 ******************************
P1(G) AND P2(G) ARE PER LETHARGY WIDTH DELTA-U AND NORMALIZED TO THE RESPONSE I1PHI = (R,PHI) = 1.12278E+04
FOR THE SUM OVER ALL PERTURBED ZONES. WHERE BOTH CROSS SECTIONS WITH THIS ID ARE PRESENT IN THE MODEL
THE NUMBER DENSITIES FOR THIS XS-PAIR ARE NDEN1 = 4.07000E-02 AND NDEN2 = 4.07000E-02

GROUP	UPPER-E(EV)	DELTA-U	P1(G)	P2(G)
1	1.700E+07	1.25E-01	0.	0.
2	1.500E+07	1.05E-01	-2.464E-03	-2.464E-03
3	1.350E+07	1.18E-01	-8.154E-04	-8.154E-04
4	1.200E+07	1.82E-01	-2.780E-04	-2.780E-04
5	1.000E+07	2.50E-01	-2.022E-04	-2.022E-04
6	7.790E+06	2.49E-01	-1.798E-04	-1.798E-04
7	6.070E+06	5.00E-01	-1.727E-04	-1.727E-04
8	3.680E+06	2.50E-01	-3.194E-04	-3.194E-04
9	2.865E+06	2.50E-01	-5.220E-04	-5.220E-04
10	2.232E+06	2.50E-01	-8.115E-04	-8.115E-04
11	1.738E+06	2.50E-01	-1.397E-03	-1.397E-03
12	1.353E+06	4.97E-01	-3.834E-03	-3.834E-03
13	8.230E+05	4.98E-01	-9.181E-03	-9.181E-03
14	5.000E+05	5.01E-01	-1.674E-02	-1.674E-02
15	3.030E+05	4.99E-01	-1.498E-02	-1.498E-02
16	1.840E+05	1.00E+00	-2.526E-02	-2.526E-02
17	6.760E+04	1.00E+00	-2.296E-02	-2.296E-02
18	2.480E+04	1.00E+00	-4.053E-02	-4.053E-02
19	9.120E+03	1.00E+00	-9.979E-02	-9.979E-02
20	3.350E+03	9.90E-01	-1.112E-01	-1.112E-01
21	1.235E+03	1.00E+00	-1.084E-01	-1.084E-01
22	4.540E+02	1.00E+00	-1.212E-02	-1.212E-02
23	1.670E+02	1.00E+00	-2.591E-03	-2.591E-03
24	6.140E+01	9.99E-01	-3.591E-03	-3.591E-03
25	2.260E+01	9.99E-01	-4.093E-03	-4.093E-03
26	8.320E+00	1.00E+00	-3.840E-03	-3.840E-03
27	3.060E+00	9.96E-01	-2.973E-03	-2.973E-03
28	1.130E+00	1.00E+00	-1.762E-03	-1.762E-03
29	4.140E-01	1.00E+00	-8.030E-04	-8.030E-04
30	1.520E-01	1.11E+00	-3.738E-04	-3.738E-04
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INTEGRAL			-4.641E-01	-4.641E-01

************************* AN UNCERTAINTY ANALYSIS FOR THIS CROSS-SECTION PAIR YIELDS THE FOLLOWING *************************
FRACTIONAL RESPONSE UNCERTAINTY DUE TO XS-UNCERTAINTIES SPECIFIED IN THE COVARIANCE MATRIX FOR THIS ID:

VARIANCE, (DELTA-R OVER R)-SQUARE = (DR/R)SQ. = 1.869E-03
RELATIVE STANDARD DEVIATION = DR/R = 4.323E-02
= 4.323E+00 PER CENT

SENSIT SAMPLE 8. *FUSION REACTOR*VECTOR-XS.SEN+UNCERT.*RUN76: CR. NI. FE. CU

************************* SENSITIVITY PROFILES FOR CROSS-SECTION PAIRS WITH ID = 46 *************************
P1(G) AND P2(G) ARE PER LETHARGY WIDTH DELTA-U AND NORMALIZED TO THE RESPONSE I1PHI = (R.PHI) = 1.12278E+04
FOR THE SUM OVER ALL PERTURBED ZONES. WHERE BOTH CROSS SECTIONS WITH THIS ID ARE PRESENT IN THE MODEL
THE NUMBER DENSITIES FOR THIS XS-PAIR ARE NDEN1 = 4.07000E-02 AND NDEN2 = 4.07000E-02

GROUP	UPPER-E(EV)	DELTA-U	P1(G)	P2(G)
1	1.700E+07	1.25E-01	0.	0.
2	1.500E+07	1.05E-01	-2.897E-02	-2.897E-02
3	1.350E+07	1.18E-01	-1.232E-02	-1.232E-02
4	1.200E+07	1.82E-01	-5.231E-03	-5.231E-03
5	1.000E+07	2.50E-01	-3.845E-03	-3.845E-03
6	7.790E+06	2.49E-01	-2.878E-03	-2.878E-03
7	6.070E+06	5.00E-01	-1.956E-03	-1.956E-03
8	3.680E+06	2.50E-01	-2.115E-03	-2.115E-03
9	2.865E+06	2.50E-01	-2.034E-03	-2.034E-03
10	2.232E+06	2.50E-01	-9.537E-04	-9.537E-04
11	1.738E+06	2.50E-01	-2.470E-04	-2.470E-04
12	1.353E+06	4.97E-01	-1.185E-04	-1.185E-04
13	8.230E+05	4.99E-01	-7.011E-05	-7.011E-05
14	5.000E+05	5.01E-01	-5.686E-05	-5.686E-05
15	3.030E+05	4.99E-01	-2.431E-05	-2.431E-05
16	1.840E+05	1.00E+00	-1.440E-05	-1.440E-05
17	6.760E+04	1.00E+00	-2.604E-06	-2.604E-06
18	2.480E+04	1.00E+00	-7.225E-07	-7.225E-07
19	9.120E+03	1.00E+00	-3.303E-07	-3.303E-07
20	3.350E+03	9.98E-01	-7.833E-08	-7.833E-08
21	1.235E+03	1.00E+00	-7.554E-09	-7.554E-09
22	4.540E+02	1.00E+00	-1.914E-09	-1.914E-09
23	1.670E+02	1.00E+00	-6.579E-10	-6.579E-10
24	6.140E+01	9.99E-01	-1.976E-10	-1.976E-10
25	2.260E+01	9.99E-01	-4.816E-11	-4.816E-11
26	8.320E+00	1.00E+00	-9.934E-12	-9.934E-12
27	3.060E+00	9.96E-01	-1.691E-12	-1.691E-12
28	1.130E+00	1.00E+00	-2.223E-13	-2.223E-13
29	4.140E-01	1.00E+00	-2.248E-14	-2.248E-14
30	1.520E-01	1.11E+00	-1.105E-15	-1.105E-15
			----------	----------
INTEGRAL			-9.604E-03	-9.604E-03

************************* AN UNCERTAINTY ANALYSIS FOR THIS CROSS-SECTION PAIR YIELDS THE FOLLOWING *************************
FRACTIONAL RESPONSE UNCERTAINTY DUE TO XS-UNCERTAINTIES SPECIFIED IN THE COVARIANCE MATRIX FOR THIS ID:

VARIANCE. (DELTA-R OVER R)-SQUARE = (DR/R)SQ. = 8.049E-08
RELATIVE STANDARD DEVIATION = DR/R = 2.837E-04
= 2.837E-02 PER CENT

SENSIT SAMPLE 8. *FUSION REACTOR*VECTOR-XS.SEN+UNCERT.*RUN76: CR, NI, FE, CU

************************** SENSITIVITY PROFILES FOR CROSS-SECTION PAIRS WITH ID = 47 **************************
P1(G) AND P2(G) ARE PER LETHARGY WIDTH DELTA-U AND NORMALIZED TO THE RESPONSE I1PHI = (R.PHI) = 1.12278E+04
FOR THE SUM OVER ALL PERTURBED ZONES, WHERE BOTH CROSS SECTIONS WITH THIS ID ARE PRESENT IN THE MODEL
THE NUMBER DENSITIES FOR THIS XS-PAIR ARE NDEN1 = 4.07000E-02 AND NDEN2 = 4.07000E-02

GROUP	UPPER-E(EV)	DELTA-U	P1(G)	P2(G)
1	1.700E+07	1.25E-01	0.	0.
2	1.500E+07	1.05E-01	-3.009E-02	-3.009E-02
3	1.350E+07	1.18E-01	-1.025E-02	-1.025E-02
4	1.200E+07	1.82E-01	-3.614E-03	-3.614E-03
5	1.000E+07	2.50E-01	-1.519E-03	-1.519E-03
6	7.790E+06	2.49E-01	-3.874E-04	-3.874E-04
7	6.070E+06	5.00E-01	-9.308E-06	-9.308E-06
8	3.680E+06	2.50E-01	-4.664E-08	-4.664E-08
9	2.865E+06	2.50E-01	-2.580E-08	-2.580E-08
10	2.232E+06	2.50E-01	-2.595E-08	-2.595E-08
11	1.738E+06	2.50E-01	-2.738E-08	-2.738E-08
12	1.353E+06	4.97E-01	-4.119E-08	-4.119E-08
13	8.230E+05	4.98E-01	-5.486E-08	-5.486E-08
14	5.000E+05	5.01E-01	-5.087E-08	-5.087E-08
15	3.030E+05	4.99E-01	-2.176E-08	-2.176E-08
16	1.840E+05	1.00E+00	-1.288E-08	-1.288E-08
17	6.760E+04	1.00E+00	-2.330E-09	-2.330E-09
18	2.480E+04	1.00E+00	-6.464E-10	-6.464E-10
19	9.120E+03	1.00E+00	-2.955E-10	-2.955E-10
20	3.350E+03	9.98E-01	-7.009E-11	-7.009E-11
21	1.235E+03	1.00E+00	-6.759E-12	-6.759E-12
22	4.540E+02	1.00E+00	-1.713E-12	-1.713E-12
23	1.670E+02	1.00E+00	-5.887E-13	-5.887E-13
24	6.140E+01	9.99E-01	-1.768E-13	-1.768E-13
25	2.260E+01	9.99E-01	-4.309E-14	-4.309E-14
26	8.320E+00	1.00E+00	-8.899E-15	-8.899E-15
27	3.060E+00	9.96E-01	-1.513E-15	-1.513E-15
28	1.130E+00	1.00E+00	-1.989E-16	-1.989E-16
29	4.140E-01	1.00E+00	-2.011E-17	-2.011E-17
30	1.520E-01	1.11E+00	-9.885E-19	-9.805E-19
			----------	----------
INTEGRAL			-5.517E-03	-5.517E-03

************************** AN UNCERTAINTY ANALYSIS FOR THIS CROSS-SECTION PAIR YIELDS THE FOLLOWING **************************
FRACTIONAL RESPONSE UNCERTAINTY DUE TO XS-UNCERTAINTIES SPECIFIED IN THE COVARIANCE MATRIX FOR THIS ID:

VARIANCE, (DELTA-R OVER R)-SQUARE = (DR/R)SQ. = 4.145E-07
RELATIVE STANDARD DEVIATION = DR/R = 6.438E-04
= 6.438E-02 PER CENT

************************** THIS COMPLETES THE INDIVIDUAL VECTOR CROSS-SECTION UNCERTAINTY ANALYSIS **************************

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************************************************** PARTIAL SUMS OF RESPONSE UNCERTAINTIES **************************************************

ASSUMING NO CORRELATION AMONG THE STRING OF INPUT COVARIANCES,
THE RESPONSE UNCERTAINTIES DUE TO INPUT SEQUENCE NUMBERS  1 THROUGH  7 HAVE BEEN SUMMED AND YIELD
          PARTIAL SUM OF VARIANCES          =  9.648E-01
          RELATIVE STANDARD DEVIATION       =  9.822E-01  =  9.822E+01 PER CENT

ASSUMING NO CORRELATION AMONG THE STRING OF INPUT COVARIANCES,
THE RESPONSE UNCERTAINTIES DUE TO INPUT SEQUENCE NUMBERS  8 THROUGH 12 HAVE BEEN SUMMED AND YIELD
          PARTIAL SUM OF VARIANCES          =  6.151E-02
          RELATIVE STANDARD DEVIATION       =  2.480E-01  =  2.480E+01 PER CENT

ASSUMING NO CORRELATION AMONG THE STRING OF INPUT COVARIANCES,
THE RESPONSE UNCERTAINTIES DUE TO INPUT SEQUENCE NUMBERS 13 THROUGH 25 HAVE BEEN SUMMED AND YIELD
          PARTIAL SUM OF VARIANCES          =  2.475E-02
          RELATIVE STANDARD DEVIATION       =  1.573E-01  =  1.573E+01 PER CENT

ASSUMING NO CORRELATION AMONG THE STRING OF INPUT COVARIANCES,
THE RESPONSE UNCERTAINTIES DUE TO INPUT SEQUENCE NUMBERS 26 THROUGH 36 HAVE BEEN SUMMED AND YIELD
          PARTIAL SUM OF VARIANCES          =  2.032E-01
          RELATIVE STANDARD DEVIATION       =  4.507E-01  =  4.507E+01 PER CENT

************************ THIS COMPLETES THE INDIVIDUAL VECTOR CROSS-SECTION UNCERTAINTY ANALYSIS ************************

ASSUMING THAT ALL SPECIFIED XS-COVARIANCES ARE UNCORRELATED, WE OBTAIN THE FOLLOWING TOTAL RESPONSE UNCERTAINTY
DUE TO ALL XS-UNCERTAINTIES SPECIFIED IN ALL  36 COVARIANCE MATRICES

        TOTAL VARIANCE, (DELTA-R OVER R)-SQUARE =  1.254E+00
        TOTAL RELATIVE STANDARD DEVIATION       =  1.120E+00  =  1.120E+02 PER CENT

************************************************ END OF COMPUTATION - NO MORE COVARIANCE DATA ************************************************
*********************************************************************************************************************************************
```

START User SIG 5013 [77,5013] Job BANNER Seq. 450 Date 21-Feb-80 15:45:36 Monitor LASL/CTR G03A(67)-BTS *START*

SIG 5013

* GOOD LUCK *

BANNER.PRT ..

LPTSPL Version 6(34/20) Running on FPL010
START User SIG 5013 [77,5013] Job BANNER Seq. 450 Date 21-Feb-80 15:45:36 Monitor LASL/CTR G03A(67)-BTS *START*
Request created: 21-Feb-80 15:46:45
File: DSK:BANNER.PRT[3,3] Created: 21-Feb-80 15:44:08 Printed: 21-Feb-80 15:45:41
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