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Windows—A Program for the Analysis of Spectral Data Foil Activation Measurements

F. W. Stallmann
J. F. Eastham
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WINDOWS - A PROGRAM FOR THE ANALYSIS OF SPECTRAL DATA
FOIL ACTIVATION MEASUREMENTS

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WINDOWS
A PROGRAM FOR THE ANALYSIS OF SPECTRAL DATA
FOIL ACTIVATION MEASUREMENTS

F. W. Stallmann, J. F. Eastham, and F. B. K. Kam

INTRODUCTION

For a long time the standard procedure for neutron spectra dosimetry in a reactor environment has been the foil activation method. This method is robust, easily reproducible, efficient, and in many cases the only feasible method for determining the neutron flux (neutron density as a function of energy).

Nevertheless, there are serious theoretical difficulties connected with this method. The conversion of the measured activities to neutron fluxes requires the inversion of a set of integral equations, a mathematical procedure referred to as unfolding of the neutron spectrum. The underlying mathematical problem has no unique solution, and it is possible to obtain a variety of different unfolded spectra which are all consistent with the original measurements.

Usually an unfolded spectrum is selected which is in some way nearest to an a priori guess (trial spectrum) based on certain physical considerations. A review of currently used unfolding methods can be found in the report by Zijp (1975).¹

In some energy regions the unfolded spectrum appears to change only slightly when the trial spectrum is varied. This suggests that the activation data almost uniquely determines the spectrum there.

It is important to identify these regions and, if possible, to give bounds on the unfolded spectrum which are independent of the trial spectrum.

Early attempts at this used sensitivity or Monte Carlo studies in which the trial spectrum and sometimes the input data were varied within the limits imposed by physical constraints. The resulting variation in output then gave an indication of the reliability of the unfolding procedure as applied to the given set of input data. Such studies require a large amount of computation, and the outcome is still far from definite since only a small sample of the possible variations can be tried. Recently a more precise method of sensitivity analysis has been proposed by F. G. Perey.² However, this method requires the variance-covariance matrix for both the trial spectrum and the cross sections, which are not readily available.

The use of the trial spectrum can be avoided by a different approach which is at the same time mathematically well-defined and computationally simple. This is the linear programming technique which was first proposed by Burrus and Rust.³ These techniques do not apply directly to the differential flux, but rather to integral responses, i.e. integrals of weighting functions against the neutron flux.

An example of such an integral response is the level of activity in a foil resulting from a period of irradiation in the reactor. Here the weighting function is the activation cross section which describes the rate of activation at different energy levels. Other examples of integral responses are group fluxes, which give the total neutron energy within a given energy interval, and damage integrals, which describe the total damage done to certain reactor materials by a given neutron flux distribution.

An often used interpretation of the integral responses is that of the neutron spectrum seen through a "window" which emphasizes certain parts and cuts others out. The weighting functions in the integral responses will be called window functions for this reason.

The restriction to integral responses is not a serious drawback since all important properties of the neutron spectrum can be expressed

in terms of these spectral parameters. The advantage is that it is now possible to obtain definite and often realistic upper and lower bounds for the integral responses which are independent of a trial spectrum. These bounds are gotten by approximating the given weighting function (ideal window) with linear combinations of those weighting functions whose integral responses are known, namely the detector cross sections of the foils whose activities have been measured.

If the linear combination of detector cross sections is chosen so as to be uniformly larger or smaller than the ideal window (called an upper or lower window, respectively), then the corresponding linear combination of measured activities will be an upper or lower bound for the integral response to the ideal window. Obviously the closer upper and lower bounds are to each other, the more reliably the integral response can be determined from the activation measurements.

Another part of the program chooses a linear combination of detector cross sections to make a least squares approximation of the ideal window (called the estimated window). The goodness of fit in this approximation gives another indication of the reliability of the corresponding integral response. This additional measure of reliability is particularly important when the approximations in the upper or lower windows are poor because of the rigid requirements imposed on them.

An approximation of the ideal window by linear combinations of cross sections is inherent in those unfolding procedures which are based on linear estimation, which includes all but one of the known methods. The resulting estimated window applied to the (unknown) real spectrum then gives the same value as the ideal window applied to the unfolded spectrum. Thus, again, the better the fit in this approximation, the more reliable the integral response, even if no realistic bounds for it can be given.

The coefficients of the linear combinations determine which detectors contribute substantially to the approximation (and thus to the

integral response) and which are superfluous. The goodness of fit depends primarily on the ideal window and the set of approximating cross sections and is relatively insensitive to changes in the spectrum. It is therefore feasible to determine the optimal detector sets and the reliability of integral response measurements in advance of any real experiment using only a crude estimate of the spectrum.

Recent advances in neutron transport calculations now make it possible to predict with some confidence the total flux in selected energy intervals (group fluxes). These group flux computations can be incorporated into this program to improve the reliability of the results or detect inconsistencies between measured and calculated spectral parameters. This is accomplished by introducing the group fluxes as an additional set of detectors.

The program WINDOWS provides the facilities to carry out the computations mentioned above. In particular, the following procedures are available and may be applied either separately or in combination:

1. Unfolding of the neutron differential spectrum - A simplified and slightly faster version of the CRYSTAL BALL program is used. A graph of the unfolded spectrum together with a normalized trial spectrum is provided as an option.
2. Estimated windows and detector contributions - These will be computed from the unfolding by CRYSTAL BALL and plotted, if desired. These results can be obtained without actual activity measurements; in this case the computations will be based on the trial spectrum.
3. Upper and lower bounds for an integral response - The corresponding window functions as well as a list of contributions of the detector cross sections to the windows will be provided including plots, if desired. The results may also be based solely on the trial spectrum.
4. Group fluxes obtained from neutron transport calculations - These will be incorporated in 1. and 3., if requested. Estimated windows will not be provided in this case, because the combination of detector cross sections and energy groups can no longer be interpreted in a meaningful way.

MATHEMATICAL ANALYSIS

The unfolding of foil activation measurements is based on the formula:

$$\alpha_i = C \int_0^{\infty} [\sigma_i(E) + \tau_i(E)] \phi(E) dE + \eta_i, \quad (i = 1, 2, \dots, n) \quad (1)$$

where

- α_i = the activity measurement of the i^{th} foil,
- $\phi(E)$ = the neutron differential spectrum at energy E ,
- $\sigma_i(E)$ = the measured cross section of the i^{th} foil,
- $\tau_i(E)$ = errors in measuring $\sigma_i(E)$,
- η_i = error in measuring α_i ,
- C = a scaling constant relating units of α_i , σ_i , and ϕ .

In addition to these quantities we will consider integrals of $\phi(E)$ with given "window functions" $W(E)$:

$$I_w = \int_0^{\infty} W(E) \phi(E) dE, \quad (2)$$

which will be called the integral responses to the window function $W(E)$. All information about the spectrum $\phi(E)$ can be obtained from integral responses I_w for suitably chosen window functions $W(E)$. In particular, $I_w = \phi(E_0)$ at a specific energy E_0 if $W(E) = \delta(E - E_0)$, i.e. Dirac's delta function.

Thus the heart of the unfolding problem is to find reliable estimates $\hat{I}_w$ for the unknown integral responses I_w from the known measurements α_i and, if possible, to give the bounds to these estimates. In this program linear estimates are used, i.e. $\hat{I}_w$ is computed as a linear

combination of the α_i with suitable coefficients c_i :

$$\hat{I}_w = \sum_{i=1}^n c_i \alpha_i. \quad (3)$$

One may view this process as replacing the "ideal" window function $W(E)$ with an approximation $\hat{W}(E)$:

$$\hat{W}(E) = C \sum_{i=1}^n c_i [\sigma_i(E) + \tau_i(E)], \quad (4)$$

so that:

$$\hat{I}_w = \int_0^{\infty} \hat{W}(E) \Phi(E) dE + \sum_{i=1}^n c_i \eta_i. \quad (5)$$

Thus $\hat{I}_w$ is the measurement - with measuring errors - of an integral response to the window function $\hat{W}(E)$. In order for $\hat{I}_w$ to be a reliable estimate of I_w , the c_i must be chosen to make $\hat{W}(E)$ in some sense the best possible approximation to $W(E)$.

One part of the program - subroutine GTPSI - computes a form of least squares approximation. Another part - subroutine GTBD - chooses an approximation $\hat{W}(E)$ which is either consistently larger or consistently smaller than $W(E)$. This is done by linear programming techniques and leads to upper and lower bounds for the integral response I_w . These methods have been described earlier in the literature. We will give a brief description here concentrating on computational details.

The least squares approximation is essentially the same as the one used in the earlier CRYSTAL BALL program.⁴ Let $\hat{\phi}(E)$ be an estimate of

the spectrum and consider the equations:

$$\alpha_i = C \int_0^{\infty} \hat{\Phi}(E) \sigma_i(E) dE + \hat{\epsilon}_i, \quad (i = 1, 2, \dots, n). \quad (6)$$

The terms $\hat{\epsilon}_i$ may be considered residuals in a system (δ) of linear equations which determine $\hat{\Phi}(E)$. These terms should be commensurate with the combined error terms ϵ_i in the equations for the actual spectrum $\Phi(E)$:

$$\alpha_i = C \int_0^{\infty} \Phi(E) \sigma_i(E) dE + \epsilon_i, \quad (i = 1, 2, \dots, n), \quad (7)$$

with

$$\epsilon_i = \eta_i + C \int_0^{\infty} \Phi(E) \tau_i(E) dE. * \quad (8)$$

It is a peculiarity of least squares problems that the solution of one problem is equivalent to the solution of several others. For the sake of exposition, it is convenient to consider the following two quantities:

$$f^2 = \frac{1}{n} \sum_{i=1}^n \left(\frac{\hat{\epsilon}_i}{v_i \alpha_i} \right)^2 \quad (9)$$

and

$$S^2 = \int_0^{\infty} \left[\frac{d}{d\omega(E)} \left(\frac{\hat{\Phi}(E)}{\psi(E)} \right) \right]^2 d\omega(E). \quad (10)$$

*For a discussion of the role of cross section errors, see Appendix A.

Quantity (9) represents a measure for the residuals $\hat{\epsilon}_i$ in the equations (6) relative to the expected measuring errors $v_i \alpha_i$ where v_i is the relative accuracy of α_i (including cross section errors). It is assumed that the errors ϵ_i are uncorrelated. Correlated errors and the resulting change in the definition of f^2 could be implemented by a slight change in the algorithm.

Quantity (10) is a measure of the difference in shape between the estimated spectrum $\hat{\phi}(E)$ and a given trial spectrum $\psi(E)$. The function $\omega(E)$ represents essentially a transformation of the linear energy scale to a more appropriate representation of the spectrum, e.g. $\omega(E)$ may be the lethargy. This function can be used to modify the term (10) and thus to either facilitate or prevent modification of the input spectrum in certain energy regions. For convenience, $\omega(E)$ is chosen to make the integral in (10) a straight summation in the given energy grid structure.

The unfolding procedure is iterative. In each step, starting with a given trial spectrum $\psi(E)$, an estimated spectrum $\hat{\phi}(E)$ is computed so as to minimize the term:

$$f^2 + \gamma^2 s^2 \quad (11)$$

where γ is a suitably chosen positive parameter. This term mediates between the two goals of unfolding, namely to make both s and f as small as possible. If γ is small, then the residuals will be small, but the estimated spectrum $\hat{\phi}(E)$ will no longer be close to the trial spectrum and may contain negative values, which are not feasible. If γ is large, then the estimate $\hat{\phi}(E)$ will be similar to the trial spectrum, but the

residuals may be unduly large. In practice the program starts with a large γ which is reduced after each step until negative values of $\hat{\phi}(E)$ are encountered. Also after each step the trial spectrum $\psi(E)$ is replaced by the newly computed estimate $\hat{\phi}(E)$, which serves as a trial spectrum for the next step. This process is continued until f becomes small enough.

The minimizing algorithm proceeds as follows:

Let

$$s_i = \int_0^{\infty} \sigma_i(E) \psi(E) dE, \quad (i = 1, 2, \dots, n) \quad (12a)$$

$$S_i(E) = \frac{1}{s_i} \int_0^E \sigma_i(E) \psi(E) dE, \quad (i = 1, 2, \dots, n) \quad (12b)$$

$$K_i(E) = S_{i+1}(E) - S_i(E), \quad (i = 1, 2, \dots, n-1) \quad (12c)$$

$$\beta_i = \frac{\alpha_{i+1}}{s_{i+1}} - \frac{\alpha_i}{s_i}, \quad (i = 1, 2, \dots, n-1). \quad (12d)$$

The estimated spectrum $\hat{\phi}(E)$ will be computed for a number of given energy grid points E_j , $j = 1, 2, \dots, m$; $\hat{\phi}(E_j) = \hat{\phi}_j$. Since each of these is a special case of formula (3), $\hat{\phi}$ is a linear combination of the α_i 's. We set:

$$\hat{\phi}_j = \psi(E_j) \left(\frac{\alpha_1}{s_1} + \sum_{i=1}^{n-1} c_{ij} \beta_i \right). \quad (13)$$

Using the function:

$$\begin{aligned} H(x) &= 0 \text{ for } x < 0, \\ &= 1 \text{ for } x \geq 0, \end{aligned} \quad (14)$$

we define:

$$D_j(E) = H(E - E_j) - S_1(E), \quad (j = 1, 2, \dots, m). \quad (15)$$

Integration by parts yields:

$$\beta_i = -\int_0^\infty K_i(E) d\left(\frac{\phi(E)}{\psi(E)}\right) + \frac{\varepsilon_{i+1}}{s_{i+1}} - \frac{\varepsilon_i}{s_i} \quad (16a)$$

and

$$\phi(E_j) = -\psi(E_j) \left[\int_0^\infty D_j(E) d\left(\frac{\phi(E)}{\psi(E)}\right) - \frac{\alpha_1}{s_1} + \frac{\varepsilon_1}{s_1} \right]. \quad (16b)$$

Thus the difference between the true spectrum $\phi(E_j)$ and the estimate $\hat{\phi}_j$ can be expressed by the equation:

$$\begin{aligned} \frac{\phi(E_j) - \hat{\phi}_j}{\psi(E_j)} &= -\int_0^\infty \left[D_j(E) - \sum_{i=1}^{n-1} c_{ij} K_i(E) \right] d\left(\frac{\phi(E)}{\psi(E)}\right) \\ &\quad - \frac{\varepsilon_1}{s_1} - \sum_{i=1}^{n-1} c_{ij} \left(\frac{\varepsilon_{i+1}}{s_{i+1}} + \frac{\varepsilon_i}{s_i} \right) \end{aligned} \quad (17)$$

which is a linear functional in terms of the differential $d\left(\frac{\phi(E)}{\psi(E)}\right)$ and the error terms ε_i . The coefficients c_{ij} will be chosen to minimize the norm of this functional in a suitable Hilbert space. This is equivalent

to minimizing (11) with $\hat{\phi}(E)$ defined as in (13).^{*} To obtain the normal equations for this least squares problem, we compute the expressions:

$$A_{ij} = \int_0^{\infty} K_i(E) K_j(E) d\omega(E) + (\gamma_{i+1} + \gamma_i) \delta_{i,j} - \gamma_{i+1} \delta_{i+1,j} - \gamma_i \delta_{i,j+1},$$

$$(i, j = 1, 2, \dots, n-1), \quad (18a)$$

and

$$B_{ij} = \int_0^{\infty} K_i(E) D_j(E) d\omega(E) + \gamma_1 \delta_{1,i}, \quad (i = 1, 2, \dots, n-1),$$

$$(j = 1, 2, \dots, m), \quad (18b)$$

where $\omega(E)$ is the same function as in formula (10), so that these integrals are replaced by summation over the energy grid.

The terms γ_i are defined as:

$$\gamma_i = \gamma_0 \left(\frac{\alpha_i v_i}{s_i} \right)^2 \quad (19)$$

where γ_0 is proportional (but not identical) to the term γ^2 in (11). The symbol $\delta_{i,j}$ is defined as:

$$\delta_{i,j} = 1, \text{ if } i = j,$$

$$= 0, \text{ if } i \neq j. \quad (20)$$

^{*}For another interpretation of the method, see Appendix B.

The normal equations may now be written in matrix form as:

$$(A_{ik}) (c_{kj}) = (B_{ij}). \quad (21)$$

Since the primary purpose of this program is the computation of $\hat{\phi}(E)$, we rewrite equation (13) in matrix form:

$$(F_j)^T = (a)^T + (\beta_i)^T (c_{ij}) \quad (22)$$

with $F_j = \hat{\phi}_j / \psi(E_j)$ and $(a)^T$ an m -row vector with identical elements α_1 / s_1 . The normal equations can then be written in augmented form:

$$\left(\begin{array}{c|c} A & 0 \\ \hline -\beta^T & +1 \end{array} \right) \begin{pmatrix} C \\ F^T \end{pmatrix} = \begin{pmatrix} B \\ a^T \end{pmatrix}. \quad (23)$$

If the left-hand matrix in (23) is nonsingular, the solution of this equation becomes:

$$(F)^T = (0|1) \left(\begin{array}{c|c} A & 0 \\ \hline -\beta^T & +1 \end{array} \right)^{-1} \begin{pmatrix} B \\ a^T \end{pmatrix}. \quad (24)$$

Therefore, only the last row of the inverse matrix needs to be computed. This row can be obtained by a straight Gaussian elimination process without need for back-substitution. The same process works for singular matrices (A), too, if symmetric pivoting is used. This process is very economical in computer time and memory. It is carried out by the subroutine NORMAL.

From (24) one can compute estimates of integral responses:

$$\hat{I}_W = \int_0^{\infty} W(E) \hat{\Phi}(E) dE \quad (25)$$

by approximating the integral in the usual manner with suitable weights W_j :

$$\hat{I}_W = \sum_{j=1}^m W_j \hat{\Phi}_j. \quad (26)$$

This formula, combined with formulas (12) and (13), leads to a representation of $\hat{I}_W$ in the form (3). The coefficients c_i in (3), which give the estimated window (4), are computed in the following manner: after the last iteration, the normal equations are solved again for n different sets $(\alpha_i)_k$, $k = 1, 2, \dots, n$, with $\alpha_i = \delta_{i,k}$ [see (20)]. The resulting ϕ_j 's are substituted in the right hand side of (26). This is equivalent to substituting the set $(\alpha_i)_k$ into formula (3) and thus gives the desired coefficient c_k . The first part of this computation is done in the subroutine GTPSI, which stores the last rows of the inverse matrix in (24) for each set $(\alpha_i)_k$. Later, these values are used in the subroutine GTWD to compute the coefficients c_k and the estimated window $W(E)$ for any given window function $W(E)$. The terms $\tau_i(E)$ are disregarded in this computation.

To find upper and lower bounds for the integral responses, consider the difference between I_W and $\hat{I}_W$ as defined in equations (1)–(5):

$$I_W - \hat{I}_W = \int_0^{\infty} \Phi(E) \left[W(E) - C \sum_{i=1}^n c_i (\sigma_i(E) + \tau_i(E)) \right] dE - \sum_{i=1}^n c_i \eta_i \quad (27)$$

The estimate $\hat{I}_w$ is an upper or lower bound if the right hand side of (27) is nonpositive or nonnegative, respectively, for any choice of a nonnegative spectrum $\Phi(E)$ and errors $\tau_i(E)$ and η_i which are within certain given bounds:

$$|\eta_i| \leq \alpha_i \nu_i, \quad |\tau_i(E)| \leq \mu \sigma_i(E), \quad (28)$$

where ν_i and μ are constants representing relative error bounds. The goal of the computation is to find a system of coefficients c_i which give the smallest upper and largest lower bound consistent with these conditions.

In order to split the set of coefficients into positive and negative ones, we define:

$$c_i = c_i^+ - c_i^-, \quad c_i^+ \geq 0, \quad c_i^- \geq 0. \quad (29)$$

Furthermore, let:

$$\alpha_i^+ = \alpha_i(1 + \nu_i), \quad (30a)$$

$$\alpha_i^- = \alpha_i(1 - \nu_i), \quad (30b)$$

$$\sigma_i^+(E) = \sigma_i(E) (1 + \mu), \quad (30c)$$

$$\sigma_i^-(E) = \sigma_i(E) (1 - \mu). \quad (30d)$$

With these definitions and the assumptions (28) and (29) we can formulate the following linear programming problem for finding a least upper bound $\bar{I}_w$ for the integral response I_w .

With:

$$\sum_{i=1}^n \left[c_i^+ \sigma_i^-(E) - c_i^- \sigma_i^+(E) \right] \geq W(E), \text{ for all } E, \quad (31)$$

choose the coefficients c_i^+ , c_i^- , to minimize:

$$C \cdot \bar{I}_W = \sum_{i=1}^n \left(c_i^+ \alpha_i^+ - c_i^- \alpha_i^- \right). \quad (32)$$

A similar problem can be formulated to find the greatest lower bound for I_W .

The system (31) contains infinitely many inequalities. But there will be little loss of accuracy if it is replaced by a sufficiently large finite system. As it is customarily done, the total energy range is subdivided into a set of energy groups (E_{k-1}, E_k) , $k = 1, 2, \dots, m$, which may be the same groups which were used in the calculation of the trial spectrum or some other appropriate grouping. To keep computation time and accuracy at a manageable level, not more than about 200 groups should be used. Fewer groups give better results if the group averaged cross sections can be determined with sufficient confidence. These are defined as usual:

$$\bar{\sigma}_{ik} = \frac{\int_{E_{k-1}}^{E_k} \sigma_i(E) \psi(E) dE}{\int_{E_{k-1}}^{E_k} \psi(E) dE} \quad (33)$$

where $\psi(E)$ is a reasonable estimate of the true spectrum $\phi(E)$. These

group averaged cross sections $\bar{\sigma}_{ik}$ replace the point cross sections $\sigma_i(E)$ in formula (31). The window function $\bar{W}(E)$ is similarly replaced by its group average $\bar{W}_k$. Thus we obtain the finite linear programming tableaux:

$$\sum_{i=1}^n c_i^+ \bar{\sigma}_{ik}^+ - c_i^- \bar{\sigma}_{ik}^- \geq \bar{W}_k, \quad (k = 1, 2, \dots, m)$$

with $\bar{\sigma}_{ik}^+ = \bar{\sigma}_{ik} (1 + \mu)$, etc. (35)

This, together with formula (32), represents a standard linear programming problem. It may be unfeasible, usually if all the $\sigma_i(E)$ are zero below some energy, but $W(E)$ is positive there. In this case, no upper bound can be computed. If the α_i 's are inconsistent because of gross measuring errors, then the coefficients become unbounded. This will be indicated in the program. The coefficients c_i indicate the importance of the i^{th} detector for determining the bound. These and the upper or lower window functions computed according to (4) will be part of the output.

INPUT DATA PREPARATION

Data are transmitted to the program from cards and tapes. Two kinds of data are stored on tapes: the reaction cross sections (LOG 15) and the trial spectra (LOG 16). These tapes are the same as the ones used for the CRYSTAL BALL program.

There are five data sets which are transmitted by cards. In effect, a processing cycle consists of at most one each of these five data sets, followed by a command card which initiates the processing. On the first cycle, at least the first four data sets must be read. Thereafter, a missing data set will cause the program to reuse the corresponding previous data set (if possible).

All data sets must be read in the sequence given below. Missing data sets or cards read out of sequence may result in an error message. After the first processing cycle, some or all of the data sets may be changed and a new processing initiated. This continues until all input cards are exhausted.

Each data set is preceded by an identification card. The first four columns are used to identify the particular data set, and the remaining columns may be used for comments. For each data set, there are three options. In the first option, the identification field (column 1-4) is printed together with the remaining columns. In the other two options, the identification field is skipped and only the remaining columns are printed.

For example, the identification field for reaction rate data may be 'ACTI' or 'A _ _ _ ' or ' _ _ _ 1'. Thus, the id-card may be 'ACTIVITIES MEASURED IN EXPERIMENT 10' printed as is, or ' _ _ _ 1 DETECTOR SET LOCATED 30 CM FROM CORE' printed as 'DETECTOR SET LOCATED 30 CM FROM CORE', etc.

Data Set 1: Reaction Rate Data

id-card (18A4)

col. 1-4 : 'ACTI' or 'A _ _ _ ' or ' _ _ _ 1'

col. 5-72 : may be used for comments _ _ _

The purpose of this data set is to identify which foils were used (with what cover) and give the corresponding reaction rates. As long as the list of foils (with covers) remains the same, the reaction rates may be changed without the need for a new cross section reading.

data card 1 (I4)

col. 1-4 : NFØILS = number of foils

data card(s) 2 (2A4, 2E8.3, 4X, A4, E8.3) - there are NFØILS such cards:

col. 1-8 : REAC = foil identification (must match tape LOG 15)
 col. 9-16 : ALPHA = reaction rate for this foil (dps/target atom)
 col. 17-24 : GAMX = relative error in reaction rate
 col. 25-28 : not used
 col. 29-32 : CØVR = cover identification (must match tape LOG 15)
 col. 33-40 : THICK = cover thickness (1/barn)

Data Set 2: Procedural Data

id-card (18A4)

col. 1-4 : 'PRØC' or 'P _ _ _' or ' _ _ _ 2'
 col. 5-72 : may be used for comments _ _ _

This data set indicates which procedures are to be performed, how the input is to be formatted, and what values certain computing parameters will take (optional).

data card 1 (5I4)

col. 1-4 : IA = switch for type of computation
 col. 5-8 : IB = output parameter for unfolding
 col. 9-12 : IC = output parameter for windows
 col. 13-16 : ID = switch for additional data
 col. 17-20 : IPAR(11) = switch for printing contributions of foils to upper, lower, and estimated windows

Table 1. Procedural Switches

Switch	Sign	Interpretation
IA	+	compute bounds (and windows) only
	0	unfold spectrum and compute bounds
	-	unfold spectrum only (see remark)
IB ^a	+	plot
	0	no output
	-	print
IC	+, 0, -	SAME OPTIONS AS FOR IB ABOVE
ID	+, -	additional data are read (data card 4)
	0	additional data remain as previously set
IPAR (11)	+	print contributions of foils to windows
	0, -	omit contributions of foils to windows

^a|IB| = n means: every nth point is included in output.

data card 2 (18A4) - omit if IA >0 or IB <0 -
col. 1-72 : title for plot of the unfolded spectrum

data card 3 (18A4) - omit if IA < 0 or IC < 0 -
col. 1-72 : title for plot of the window functions

Data card 4 is optional as these quantities have default values assigned within the program. IPAR(28), which determines the weighting function W of formula (10), defaults to 0 at the beginning of each reading of procedural data (this data set). IPAR(3), which permits consideration of group fluxes as ideal detectors, is set to 0 in MAIN. Also, if window function data (data set 5) is read, IPAR(3) will be set to IC of that data set. [Thus, the value of IPAR(3) assigned here may be used as a switch for inclusion of group fluxes in unfolding (and estimated windows; see remark) when IA = -1 (so that data set 5 is not read).] GAM(1) serves both as a switch for computation of the estimated window matrix and, if unfolding does not take place, as a value for the smoothing parameter GAMMA0. If unfolding does take place, GAMMA0 is found by iteration, so then GAM(1) acts only as a switch. GAM(1) and GAM(7) are set to 1.0 in MAIN. CONST is reset to 10^{-24} at the beginning of each reading of procedural data (this data set), which corresponds to the use of dps/atom as units for reaction rate data since the cross sections on tape LØG 15 are given in barns. Except as noted above, the values of these quantities are preserved from one processing cycle to the next until changed by a reading of data card 4 of this data set.

```
data card 4 (2I4, 3E8.3) - omit if ID = 0 -
col. 1-4 : IPAR(28) = switch for energy emphasis
col. 5-8 : IPAR(3) = switch for including group fluxes
col. 9-16 : GAM(1) = smoothing parameter and switch for computation
               of estimated window matrix
col. 17-24 : GAM(7) = accuracy limit for unfolding
col. 25-32 : C0NST = scale factor to adjust for nonconforming units
               of activity measurements
```

Table 2. Additional Data (Optional)

Switch	Sign	Interpretation
IPAR (28)	+	high energy accuracy assumed, $\omega = 1/\Delta(E)$
	o	uniform accuracy assumed, $\omega = 1$
	-	low energy accuracy assumed, $\omega = \Delta(E)$
IPAR (3) ^a	+	group fluxes included
	o, -	group fluxes ignored
GAM (1)	+, o	estimated window matrix computed (see remark)
	-	estimated window matrix omitted
CØNST	+	use this scale factor
	o, -	use default value

^aWill be overridden by IC in data sets.

Remark: IA = -1 (unfolding only) may include the computation of estimated windows (with contributions of foils) if:

IPAR(11) >0 (contributions printed),
 GAM (1) >0 (computation of e.w. matrix), and
 IEW >0 (a previous window function).

GAM (1) >0 insures computation of the matrix for estimated windows regardless of whether it is used or not. Thus, it can be used in later runs once the other parameters are changed.

Data Set 3: Cross Section Data

id-card (18A4)

col. 1-4 : 'CRØS' or 'C _ _ _' or ' _ _ _ 3'

col. 5-72 : may be used for comments

data card 1 (I4, 4X, E8.3)

col. 1-4 : INT = n means every nth point of the basic energy grid is printed with the cross sections at this point of all detectors used

col. 5-8 : not used

col. 9-16 : GAM (5) = relative accuracy of the cross section values

After this data card is read, subroutine SIGS is called to read the cross section tape LOG 15 and compare it with the list of foils from data set 1. This tape provides the basic energy grid essential to all further computations, including the formation of data from data sets 4 and 5.*

Data Set 4: Trial Spectrum Data

id-card (18A4)

col. 1-4 : 'SPEC' or 'S _ _ _' or ' _ _ _ 4'
col. 5-72 : may be used for comments _ _ _

At the end of each processing cycle (and hence at the beginning of each cycle after the first) the program stores two spectra, one in array PSI and one in array EL. When unfolding takes place, the spectrum in PSI is used as the trial spectrum and then is replaced by the unfolded spectrum. This in turn becomes the trial spectrum for the next unfolding unless a new data set 4 (trial spectrum data) is read, which causes a new trial spectrum to be selected and stored in PSI. Normally, the trial spectrum is also stored in EL, where it remains unaffected by unfolding. [The trial spectrum data set 4/1/0 causes the contents of EL to be "restored" to PSI.] The exception is when the group fluxes are unfolded with the previous spectrum (old contents of PSI) to obtain a trial spectrum (new contents of PSI). In this case, a switch permits either the previous spectrum or the new trial spectrum to be "saved" in EL.

The purpose of this data set is to inform the program how the trial spectrum is to be determined. The first card gives the source and scaling procedure for the trial spectrum. The format of the subsequent cards depends upon the source given by the first card.

data card 1 (2I4, E8.3)

col. 1-4 : ISPEC = switch for trial spectrum source
col. 5-8 : IPAR(8) = switch for scaling procedure
col. 9-16 : SC = scale factor (see Table 3)

*See Appendix C.

If ISPEC >0, only one card is needed to complete this data set:

data card 2 (I4)

col. 1-4 : IDSPEC = identification number for spectrum on tape

Table 3. Switches for Trial Spectrum Source

Switch	Sign	Interpretation
ISPEC	+	trial spectrum taken from tape LOG 16
	o	trial spectrum taken from group fluxes on cards
	-	trial spectrum taken from point fluxes on cards
IPAR (8)	+	least squares fit to the activity measurements
	o	no separate scaling of the trial spectrum
	-	use scale factor SC from data card 1
IDSPEC	+	id number of spectrum on tape LOG 16
	o, -	restore previous trial spectrum

Remark: The program will keep a running average of scaling factors if on the consecutive cycles in which the scale factors are computed, IPAR(8) = 1, 2, 3, ..., etc. IPAR(8) = 1 causes the current scale factor (found by least squares fitting of the activity data) to be printed and used.

If ISPEC = 0, the trial spectrum will be found by unfolding group fluxes given in terms of lethargy on subsequent cards. [These values may also be used as additional activity and cross section data to improve the unfolding and calculation of bounds.] This itself requires a trial spectrum, which for clarity shall be called the intermediate trial spectrum as distinguished from the final trial spectrum.

The program will produce the intermediate trial spectrum in one of two ways, depending upon the setting of switches on the next card and upon the number of group fluxes given. Given one setting of the switches, the program tries to use the previous spectrum as the intermediate trial spectrum. If this fails, or if another setting of the switches is given, the program converts the group fluxes to point fluxes,

then interpolates and extrapolates to create the intermediate trial spectrum. If there are more than 40 group fluxes, not counting certain of the low energy groups which will be combined, then unfolding is unfeasible and the final trial spectrum will simply be the intermediate trial spectrum. Otherwise, the program will obtain the final trial spectrum by unfolding the group fluxes with the intermediate trial spectrum.

data card 2.1 (2I4, E8.3)

col. 1-4 : L $\emptyset$ = switches for selection of extrapolation to the low energies

col. 5-8 : LHI = switches for selection of extrapolation to the high energies

col. 9-16 : CT = temperature of moderator in degrees centigrade (needed only for Maxwellian extrapolation)

data card 2.2 (18A4)

col. 1-72 : FMT3 = format to read data cards 2.4 and 2.5

data card 2.3 (I4)

col. 1-4 : NIN = number of group fluxes to be read (max. 200)

data card(s) 2.4 (FMT3)

[ENER(I), I = 1, NIN] = lower lethargy boundaries ranked in increasing order (corresponds to decreasing order of energies)

data card(s) 2.5 (FMT3)

[FLUX(I), I = 1, NIN] = corresponding group fluxes

data card 2.6 (2E8.3)

col. 1-8 : UHI = highest lethargy value (lowest energy)

col. 9-16 : ERR = relative error estimate for group fluxes

Note the use of object time read format for the group fluxes and lethargy intervals.

Table 4. Intermediate Trial Spectrum Switches

Switch	Sign	Interpretation
LØ	>3	intermediate trial spectrum = previous spectrum
LHI	0	save previous spectrum
	+, -	save final trial spectrum
Intermediate trial spectrum found by interpolation/extrapolation		
	0	use default values for extrapolation
LØ	1	use E extrapolation at low energy
	2	use $\sqrt{E}$ extrapolation at low energy
	3	use Maxwellian scheme (default)
	0	use default high energy extrapolation
LHI	1	use fission scheme (default)
	2	use fusion scheme
CT	+	use this value as moderator temperature
	0, -	use default value = 20°
ERR	+	adjoin group fluxes to cross section file
	0, -	do not adjoin group fluxes

If ISPEC = -1, a point spectrum is read from cards and subroutine FAPT is called to interpolate and extrapolate the data to fit the basic energy grid. Energy instead of lethargy units are used, and the values given are point fluxes instead of integral fluxes. Data cards 2.1 through 2.5 are used in the same way as for ISPEC = 0 with obvious modifications. LØ = 4 will cause default values to be used for the extrapolation schemes without documentation in the output. Energy points should be read in increasing order. Data card 2.6 is not needed and must be omitted.

Data Set 5: Window Functions

id-card (18A4)

col. 1-4 : 'WIND' or 'W ___' or '___ 5'

col. 5-72 : may be used for comments

The purpose of this data set is to define "window functions." A window function is characterized by three pieces of information: a

group structure suitable for the linear programming procedure used to determine upper and lower bounds (max. 209 groups), a pair of limits of integration, and a response function defined over the whole basic energy grid. In effect, the window function equals the response function between the limits of integration and is zero elsewhere. Only one response function and one group structure for bounds can be considered in one processing cycle, but there may be up to 50 pairs of limits.

Remark: Since the response function is defined over the basic energy grid, it may be saved or changed independently of the group structure for bounds.

data card 1 (5I4)

col. 1-4 : ID = switch for group structure and limits
 col. 5-8 : IE = switch for response function
 col. 9-12 : IA = switch for bounds to be computed
 col. 13-16 : IB = switch for computational base
 col. 17-20 : IC = switch for inclusion of group fluxes

Table 5. Window Function Switches

Switch	Sign	Interpretation
ID	>1	previous group structure with new limits
	1	new group structure and limits to be given
	0, -	previous group structure with old limits
IE	5	response function found by interpolation
	4	response function = $1/\sqrt{E}$
	3	response function = $\sigma(E)$ of last foil
	2	response function = E
	1	response function = 1 (default)
	0, -	use previous response function
IA	>1	upper bounds only computed
	1	lower bounds only computed
	0	upper and lower bounds computed
	-	estimated integral response without bounds
IB	+	based on computed activities
	0, -	based on measured activities
IC	+	group fluxes used in all computations
	0, -	group fluxes ignored.

Remark: IA = -1 asks only for the estimated response. This eliminates the sometimes unnecessary and wasteful computation of bounds. Utilization of this option requires IA = 0 or 1 in data set 2, although bounds are not actually computed. The trial spectrum is scaled to give a least squares fit of the activity data, even if no unfolding takes place, in GTBD. The estimated response may be computed by GTBD from the activity measurements without unfolding, since what is done is to approximate the window function by a linear combination of cross sections.

If ID $\leq$ 0 and IE $\neq$ 5, this data set is complete.* If ID = 1, then the following cards are required to define a new group structure for bounds. Two options are provided: uniform broadening of the basic energy grid, or explicit input of a new energy grid.

data card 2.1 (I4)
col. 1-4 : IPAR(5) = switch for source of group structure

If IPAR(5) > 0, the group structure for bounds will be formed by combining IPAR(5) points of the basic energy grid into a single group. [If 0 < IPAR(5) < 3, it is first replaced by the default value, IPAR(5) = 20.] In this case, no further cards are needed to define the group structure for bounds. If IPAR(5) $\leq$ 0, the following cards are required:

data card 2.2 (3I4)
col. 1-4 : M = number of energy points to be read
col. 5-8 : IDIF = in absolute value, the number of points of the original input to be combined on one group
col. 9-12 : IP = switch for energy vs. lethargy units

data card 2.3 (18A4)
col. 1-72 : FMT3 = format specification of data card(s) 2.4

data card(2) 2.4 (FMT3)
[W(I), I = 1, M] = boundaries of the input group structure

*If ID = 0 in the first data set, the default values IPAR(5) = 20, PAR(1) = 1.0, PAR(51) = 20.0 are assumed (i.e. the flux above 1.0 MeV is computed).

Table 6. Switches for Group Structure for Bounds

Switch	Sign	Interpretation
IPAR (5)	+ 0, -	uniform broadening of basic energy grid explicitly read group structure
IDIF on [2.2]	+ -	input begins with lowest energy input begins with highest energy
IP on [2.2]	+ 0, -	input given in terms of lethargy input given in terms of energy

If $ID > 0$, the following cards are required to determine new pairs of limits, specified in terms of energy (MeV):

data card 3.1 (2I4)

col. 1-4 : M = number of different pairs of limits

col. 5-8 : IP = switch for procedure by which limits are determined

The format of the next card(s) depends on the value of IP specified above. If $IP > 0$, then the first and last pairs of limits are given, and the interval between the given upper (resp. lower) limits is logarithmically subdivided to obtain M pairs of limits:

data card 3.2 (4E8.3) - used only if $IP > 0$ -

col. 1-8 : $EMIN$	} first pair of limits
col. 9-16 : $EMAX$	
col. 17-24 : $EMIN1$	} last pair of limits
col. 25-32 : $EMAX1$	

If $IP = 0$, then the pairs of limits are read directly:

data card(s) 3.2 (9E8.3) - used only if $IP = 0$ -

$[PAR(I), PAR(I + 50), I = 1, M] = M$ pairs of limits

If $IP < 0$, then the first pair of limits are given, together with two constants. Succeeding pairs of limits are determined by fixing the ratio between consecutive upper (resp. lower) limits:

data card 3.2 (4E8.3) - used only if $IP < 0$ -

col. 1-8 : $EMIN$	} first pair of limits
col. 9-16 : $EMAX$	
col. 17-24 : $DFAC$	= ratio between consecutive lower limits
col. 25-32 : $UFAC$	= ratio between consecutive upper limits

If IE = 5, the following set of input cards is used by subroutine WW to determine the response function:

data card 4.1 (4I5, E10.2)

col. 1-5 : IW = number of input values (max. 1500)
 col. 6-10 : IDIF = switch for order of energies
 col. 11-15 : IP = switch for type of interpolation
 col. 16-20 : IPR = switch for printing the response function
 col. 21-30 : FAC = scale factor to convert energies to MeV

data card 4.2 (18A4)

col. 1-72 : FMT = format for subsequent input

data card(s) 4.3 (FMT)

[ERG(I), I = 1, IW] = energies where response is being given

data card(s) 4.4 (FMT)

[WERG(I), I = 1, IW] = corresponding values of response function

Table 7. Switches for Limits and Response Function

Switch	Sign	Interpretation
IP on [3.1]	+	limits found by logarithmic subdivision
	0	limits found by reading pairs directly
	-	limits found by multiplying by constants
IDIF on [4.1]	+1	energies given in increasing order
	-1	energies given in decreasing order
IP on [4.1]	0	log - log interpolation if possible
	+, -	linear interpolation
IPR	+	print response (every IPR th pt. of basic energy grid)
	0, -	no printing

Remark: An adjustment is made in subroutine STEP if limits do not coincide with boundary points of the group structure for bounds. If the group structure is read directly from cards in subroutine GTDATA, then the limits will be changed to boundary points so as to minimally cover the original interval. If the group structure is generated (by STEP) by uniformly broadening the basic energy grid, then the limits are used as boundary points. [EMIN is used in place of the next higher point of the basic energy grid; EMAX, in place of the next lower point.]

Command Card

id-card (18A4)

col. 1-4 : 'STAR' or 'GO _ _ ' or ' _ _ 6'

col. 5-72 : may be used for comments _ _ _

This card, to be read after all data sets are input or changed, causes the program to check whether the data sets have been properly given. Then, the computational part of the program starts.

PROGRAM ORGANIZATION

WINDOWS consists of four essentially independent modules. These are:

1. The data acquisition module consisting of the subroutine GTDATA and the auxiliary subroutines SIGS, FAPT, PSIGEN, GENER, STEP, WW, and SIGPR. Subroutine GTDATA is called from the MAIN program and in turn calls these auxiliary routines.
2. The unfolding module consisting of the subroutines GTPSI and GTWD and the auxiliary subroutine NORMAL. With the help of NORMAL, subroutine GTPSI computes the unfolded differential spectrum and prepares the results for plotting if desired. Using the results from GTPSI, the subroutine GTWD finds the estimated windows for any given ideal window function and computes the contributions of detector cross sections to the estimates from the subroutine GTBD.
3. The bound module consisting of the subroutine GTBD and the auxiliary subroutines TALAKO and RESTOR. The primary purpose of the subroutine GTBD is the determination of bounds for given integral responses and to compute the corresponding upper and lower windows and the contributions of detector cross sections to the bounds. It also prepares the results for plotting, if desired, and calls the unfolding module at the appropriate time. The solution of the linear programming problem arising from the determination of bounds is performed by standard algorithm in the subroutines TALAKO and RESTOR. The subroutine GTBD is called from the MAIN program.
4. The plotting module consisting of the subroutines GTGRAF (used in GTPSI) and GTPLOT (used in GTBD), the auxiliary subroutine MAXMIN, and the plot package INTRIGUE-II. Three subroutines of INTRIGUE-II (GRID, XTENS, and TENS) have been modified.

Description of the Subroutines

The MAIN program

The program starts by setting default values for the parameters and switches NFOILS, IFRST, IEW, GAM(1), GAM(5), GAM(7), CONST, SCAL, and G(I = 1, 621). The functions of these parameters are given in the list of COMMON variables. After this, the program calls in alternating fashion the input routine GTDATA and the processing routine GTBD until all input data are exhausted.

The input subroutine GTDATA

This part of the program reads input data from cards and tapes and prepares it for subsequent processing. Tests are performed to ensure that the proper sequence of input data has been observed. Certain key parameters which are used for these tests carry not only numerical information, but also serve as switches which guide the flow of processing. A detailed description of these parameters is found in the list of COMMON variables.

The program is structured into several independent sections, each being assigned to a specific set of input information. A brief description of each section and its function will be given below. A detailed account of the format and sequence of the input cards and tapes is given in the chapter on input data preparation.

Section 1: identification test - In this section, the identification card is compared with stored templates and the program proceeds from there to the proper input section. If the identification card does not conform to any template, an error message is given.

Section 2: reaction rate data - A list of detector names and activation rates is read and printed. The reading of the corresponding cross sections is requested by setting IDSPEC = -1. The first reading

of a detector list is confirmed by a positive value of the parameter NFOILS. A check is made to determine whether the same set of detectors has been used in the previous run. If so, no new cross section data need to be read.

Section 3: procedural data - The procedural data are read in accordance with the prescription given in the chapter on input data preparation. This information is then converted to appropriate values of the parameter sets GAM, IPAR, and CONST (see list of COMMON variables). The first reading of procedural data is confirmed by a positive value of the parameter CONST.

Section 4: cross section data - The program first checks the parameter NFOILS to determine whether a list of detectors has been read and, if so, confirms the reading of the corresponding cross sections by setting IDSPEC = 0. It also resets the values of IPAR(21) and IPAR(22) if these values have been altered by the unfolding routine GTPSI. It then reads the printing parameter INT and the cross section accuracy GAM(5). A nonnegative value of this last parameter confirms the first reading of the cross section tape LOG 15, and in particular, the reading of the basic energy grid contained on this tape, which is needed for the subsequent input operations. After reading in these two parameters, the cross sections are read and modified, if necessary, by attenuation factors for the covers on the detectors. This is done in the subroutine SIGS. Next, spurious values are removed from the cross sections to prevent underflow conditions in the linear programming routine. Finally, a list of cross sections is printed using the subroutine SIGPR if so requested by the input parameter INT.

Section 5: trial spectrum - The program first checks the parameter GAM(5) to see whether the basic energy grid has been read. It then resets the values of IPAR(21) and IPAR(22) if these values have been altered by the unfolding routine GTPSI. Then the first card, containing the parameters ISPEC and IFRST, is read. A nonnegative value of IFRST confirms the first reading of a trial spectrum.

The program now proceeds with the determination of the trial spectrum according to the value of the parameter ISPEC. If ISPEC = -1, differential flux data are read from cards and converted to flux data in the basic energy grid by the subroutine FAPT. If ISPEC = 0, lethargy values and group fluxes are read from cards and converted to differential fluxes in the basic energy grid by the subroutine PSIGEN. [These group fluxes are usually obtained from neutron transport calculations and the information contained in them may be used to improve computation of the unfolded spectrum and bounds. This is done by considering the group flux information as the activation data of an additional set of detectors. This addition to the original detector list is requested by a positive value of the parameter ERR, which also serves as an estimate of the relative accuracy of the group flux values. The cross section file is enlarged to record for each group flux a cross section whose value is one on the corresponding energy interval and zero elsewhere. The group flux values are multiplied by the parameter CONST before placing them in the reaction rate file so that they will conform to the definition of reaction rate for "real" detectors as given in formula (1). This procedure can be carried out only if the reaction rates and cross sections of the "real" detectors have been read first. This is tested by IDSPEC = 0. The group fluxes are converted into a point spectrum with the aid of the interpolation - extrapolation routine FAPT. This process is applied repeatedly, if necessary, to make the point spectrum conform with the given integral fluxes. If this fails and there are not more than 40 groups, the unfolding routine in GTPSI is used to construct the point spectrum, with the output of FAPT as a trial spectrum. Other trial spectra, e.g. from many group calculations, may also be used as input spectrum, as described in the chapter on input data preparation.

If ISPEC = +1, the trial spectrum is read directly from tape LØG 16 (if IDSPEC > 0) or the previous trial spectrum is restored after having been altered by the unfolding routine GTPSI. To make this possible, the trial spectrum is not only placed in the working storage PSI(I) but also into a permanent storage EL(I).

Section 6: window functions - The program first checks the parameter GAM(5) to determine whether the basic energy grid has been read. The subsequent data cards then determine the width and shape of the window functions, which bounds are to be compared, whether the measured or calculated activities are to be used, and whether group fluxes are to be included. Details are again to be found in the chapter on input data preparation.

Successful computation of the window function is confirmed by a positive value of the parameter IEW. An unsuccessful attempt to compute the window function is signalled by IEW = 0. This value may also be assigned to IEW in the procedural data section if the computation of bounds is omitted, and thus the computation of a window function is not required. In either event, the computation of bounds in GTBD is omitted until the introduction of a valid window function.

Section 7: call for processing - When the identification card calls for the start of processing, several parameters are tested to determine whether all required data have been properly read in. These parameters are IDSPEC (for reaction rate and cross section data), IFRST (for trial spectrum), CONST (for procedural data), and IEW (for the window function). If this test fails, an error message is given and the program stops. The same happens if one of the data sets cannot be properly read because supporting data are missing. If the data are complete, the program transfers control back to the MAIN program for subsequent processing.

The processing subroutine GTBD

The program starts by computing several auxiliary variables which will be needed later. These initial computations depend on the type of processing required, i.e. whether computations are based on measured reaction rates or simulated ones based on the trial spectrum, whether

group fluxes are to be considered or not, and what types of bounds and window functions are requested (upper, lower, or both). Some of the original variables are placed into temporary storage since they are altered during processing and need to be restored later on.

If requested by a positive value of IPAR(21), unfolding subroutine GTPSI is called. This routine replaces the original trial spectrum with the unfolded differential spectrum for further computations. If the computations are to be based on the trial spectrum, no unfolding of the differential spectrum is performed. But the normal equations are solved and the results stored to obtain values for the estimated windows through subroutine GTWD (provided a positive smoothing parameter GAM(1) was given).

Next, the effective energy grid EW(I) and ideal window function WIND(I) is established in order to generate the linear programming tableaux of formula (35). These values are generated in the subroutine STEP each time a new window is considered.

Also, the ideal window function is converted to the basic energy grid and stored in the array SFLUX(I). This information is needed for printing and plotting, and also for the computation of the estimated window by subroutine GTWD. The storage locations SAVEIN(I), SAVEPS(I), and SPSI(I) are cleared, eventually to receive the upper, lower, and estimated windows.

Next, the linear programming tableaux (35) is set up. At this point the values $\sigma_{i,k}^+$ and $\sigma_{i,k}^-$ in array A(I), the values w_k in array B(I), and the values $a_{i,k}^+$, $a_{i,k}^-$ in array C(I) are computed. Array A(I) is handled internally as a one-dimensional array $A(I, k) = A(I * MR + k)$ where $MR = 6880/(2 * NF0ILS)$ is the largest numbers of rows the available space can accommodate. If the actual number of rows [= ℓ in formula (35)] exceeds this value, an error message is given.

Simulated reaction rates based on the trial spectrum and the given cross sections are found as a by-product of these computations. These simulated activities are compared with the measured activities (if these are to be used) and a scale factor is determined which minimizes the sum of the squares of the relative differences between measured and computed activities. Multiplying the trial spectrum with this scale factor gives a first order estimate of the true spectrum. The same procedure is used for scaling the trial spectrum and group fluxes at the beginning of the program, if requested. This estimate is used to calculate the estimated integral responses which are printed in the output. They are obtained in the variable ERW as another by-product of the computations for the linear programming tableaux. By calling the linear programming routines TALAKO and RESTOR, the bounds I_W and coefficients c_i^+ , c_i^- [see formula (32)] are obtained. These coefficients provide the information for the relative contributions of detector cross sections to the bounds of integral responses. They are also needed to compute the upper or lower window functions. The corresponding coefficients and window function for the estimated window are obtained from the subroutine GTWD, which will be called at this point if requested. If the linear programming routine is unsuccessful, a message is printed giving a likely explanation for the failure.

After all the requested computations have been performed, the program restores the original variables, and control is transferred back to the MAIN program for further data acquisition.

The unfolding subroutine GTPSI

This program generates and solves the normal equations in formula (23) with the help of the subroutine NORMAL. It also guides the iteration (described in the mathematical analysis) which obtains an estimate of the differential flux (unfolded spectrum) which is consistent with the measured activities. If no acceptable solution is found after 50 iterations, an error message is given and the program returns.

The start of the computation is confirmed by setting $GAM(9) = 0.0$. The parameter $GAM(2)$ is checked to tell whether the primary objective is unfolding of the differential spectrum or the computation of estimated windows. The initial values for the parameter $GAMMA0$ [corresponding to γ_0 in formula (19)] and associated parameters are then established, and the program enters the primary computation.

The quantities $SMALLS(I)$ [= s_i in formula (12)] are computed first, followed by computation of the array $A(I, J)$ [= A_{ij} in formula (18)]. To save space, the integrations of formulas (12) and (18) are carried out simultaneously, without using the intermediate variables $S_i(E)$ and $K_i(E)$. Auxiliary variables $SUMB(I)$, which are needed for efficient computation of the variables B_{ij} in formula (18), are also computed.

The array (β_i) [see formula (12) and (22)] is placed into location $C(1, I)$. If estimated windows are to be computed, the array $C(K, I)$ is expanded to a two-dimensional array of $NFOILS$ rows where the K^{th} row corresponds to an array (β_i) generated from a set α_i where $\alpha_i = 1$ for $i = k$, and $\alpha_i = 0$ otherwise (see page 13 of the mathematical analysis). The array $B(I, J)$ is loaded with the unit matrix to obtain the inverse matrix in formula (24). The generation of the normal equations is completed by adding the modifications through the parameters $GAMMA(I)$ [= γ_i in formula (18)] to the array A . These parameters are computed from the current value of $GAMMA0$, and certain limits are placed on them to avoid poor convergence or instabilities.

The program then calls the subroutine `NORMAL`, which returns the last row [or $NFOILS$ such rows, corresponding to each row of the array $C(K, I)$] of the inverse matrix in formula (24). These arrays appear in location $R(1, I)$ or $R(K, I)$, respectively.

For the computation of estimated windows, the array $R(K, I)$ is saved for later use by the subroutine `GTWD`, and the program returns. For the unfolding of the differential spectrum, the matrix multiplication on the right side of equation (24) is performed in combination

with the integrations needed for the calculation of the $\beta_{\chi j}$ in formula (18). Here again we avoid as much as possible the computation of intermediate variables by reversing matrix multiplication and integration, and by extensive use of the quantities SUMB(I), which correspond to the integrals $\int_0 S_1(E)K_{\chi}(E)d(E)$. The results of this computation are stored in array D(I), which then represents the current attempt to obtain an unfolded differential spectrum.

If D(I) contains negative values, the computation is repeated with the same trial spectrum but larger values of the smoothing parameter GAMMA0 (larger by a factor GAMX = 10). This may be repeated up to 10 times, after which the computation quits and an error message is printed.

If all D(I)'s are non-negative, the residuals f^2 of formula (9) are computed and tested. If f^2 is small enough, the iteration stops and the newly unfolded spectrum in D(I) is printed and plotted, together with a normalized original trial spectrum. After that the computation is repeated once more for the computation of estimated windows.

If the residuals are too large, the current unfolded spectrum is used as a new trial spectrum, and the value of GAMMA0 is decreased by a factor GAMMAY, which starts out to be 0.1, but is increased by taking the square root of it if negative values in the unfolded spectrum occur too often. This procedure may be repeated up to 50 times, after which the program returns with the current trial spectrum as the working spectrum for future computations. The same subroutine may be used to convert group fluxes into a point spectrum. This procedure is requested with a negative value of EL(1). Other parts of the EL array contain the group boundaries and integral fluxes. From this information, the program generates the cross section which corresponds to the group fluxes and proceeds otherwise in the same manner as before.

The subroutine GTWD

This program computes the coefficients c_i in formula (3) using the array $R(K, I)$, which corresponds to the inverse matrix in formula (24) and is gotten by the subroutine GTPSI. As in GTPSI, the matrix multiplication of formula (24) is carried out in combination with the integration in (25). This actually simplifies the computation since it reduces the matrix B to just one column. However, the matrix multiplication must be performed for each row of the matrix $R(K, I)$, one for each coefficient c_i in formula (3).

After the c_i 's are computed, the relative contributions of detector cross sections to the integral response is computed and printed. The estimated window function is also computed from these coefficients.

The subroutine NORMAL

This subroutine solves the special least squares problem described in the section on mathematical analysis and given in the particular form of formula (23). A straight forward Gaussian elimination algorithm is applied to an augmented matrix of the form $\left[\begin{array}{c|c} A & B \\ \hline C & D \end{array} \right]$. Let $A = (a_{ij})$, $i = 1, N$, $j = 1, N$; $B = (b_{ik})$, $i = 1, N$, $k = 1, K$; $C = (c_{lj})$, $l = 1, L$, $j = 1, N$; $D = (d_{lk})$, $l = 1, L$, $k = 1, K$. (The upper case characters are the ones actually used in the program.) The matrix A is assumed to be symmetric and non-negative semidefinite. Only the upper triangular part is actually used in computations.

The algorithm performed at the n^{th} elimination step can be described as follows:

$$a_{ij} \rightarrow a_{ij} - \frac{a_{in}a_{jn}}{a_{nn}}, \quad i = n+1, N, \quad j = i, N \quad (101a)$$

$$b_{ik} \rightarrow b_{ik} - \frac{a_{in}b_{nk}}{a_{nn}}, \quad i = n+1, N, \quad k = 1, K \quad (101b)$$

$$c_{\ell j} \rightarrow c_{\ell j} - \frac{c_{\ell n} a_{jn}}{a_{nn}}, \ell = 1, L, j = n + 1, N \quad (101c)$$

$$d_{\ell k} \rightarrow d_{\ell k} - \frac{c_{\ell n} b_{nk}}{a_{nn}}, \ell = 1, L, k = 1, K. \quad (101d)$$

This step can be performed whenever $a_{nn} \neq 0$, which may be assumed if A is positive definite. After N elimination steps the submatrix D is transformed into $-CX + Y$, where X and Y make up the solution to the matrix equation:

$$\begin{pmatrix} A & 0 \\ -C & I \end{pmatrix} \begin{pmatrix} X \\ Y \end{pmatrix} = \begin{pmatrix} B \\ D \end{pmatrix}, \quad (102)$$

where 0 is the $N \times L$ zero matrix, and I is the $L \times L$ unit matrix. As is always the case with normal equations, a solution consistent with (102) can be obtained even if A is singular. By proper pivoting, the elimination need continue only as long as there are non-zero diagonal elements remaining in A .

In practice, the largest remaining diagonal element is always placed in the n^{th} row and column by exchanging both rows and columns in the augmented matrix. This also provides stability for the elimination process. If all the remaining diagonal elements in A are less than a given tolerance, the remaining rows are assumed to be zero, and the program returns the results in matrix D for further processing. [If B is a unit matrix, as in this program, the last row of a pseudo-inverse of the matrix in formula (24) is returned.]

Subroutines STEP and WW

These two subroutines convert the input data into the actual window functions. STEP determines the width of the window. It establishes first the energy groups which are used for the linear programming tableaux and then sets the array $W(I) = TWP = 1.0$ if the I^{th} group is within the window and $W(I) = \text{BASE} = 0.0$ otherwise. The group structure is

either determined by the number of intervals from the basic energy grid contained in the window grid or by giving the groups directly. In the first case, the window groups are adjusted to coincide with the two boundaries of the window EMIN, EMAX. In the second case, the window boundaries are enlarged to coincide with the energy group boundaries.

The subroutine WW converts the input data through interpolation into a function over the basic energy grid which determines the shape of the window function.

The subroutine SIGS*

This subroutine reads the cross section tape LØG 15, which contains the basic energy grid and the cross sections of all foils to be used. The format and generation of this tape is described in detail in the report for the program CRYSTAL BALL⁵. The cross sections are selected according to a list of detectors which is read with the reaction rate information in GTDATA. These cross sections are modified by an attenuation factor corresponding to the cover specified in the list of foils. The results are placed in the cross section file SIG(I, J). The basic energy grid E(I) and the energy steps EDEL(I) = E(I) - E(I - 1) are also stored in their respective locations.

The trial spectrum subroutines FAPT, PSIGEN, and GENER

The subroutines FAPT and GENER are, like SIGS, exact copies of the same subroutines in CRYSTAL BALL. The subroutine FAPT essentially interpolates and extrapolates the given differential flux values to the basic energy grid. The interpolation is based on a log - log representation. Unless the flux values are given for the whole range of the basic energy grid, the values are extrapolated the low and high energy ends according to certain specifications. At the low energy end, there is a choice between linear, square root, and Maxwellian extrapolation. At the high end, either fission or fusion type of flux distribution may be chosen.

*See Appendix C.

The subroutine GENER reads the trial spectrum file on tape LØG 16. Each trial spectrum on this tape consists of two records. The first one is a twenty-character identification; the second record contains the 621 flux values at the basic energy grid. The parameter IDSPEC indicates the location of the desired spectrum on the tape.

The subroutine PSIGEN converts a given integral flux spectrum given in terms of lethargy into a point spectrum in the basic energy grid. This is accomplished by converting the integral fluxes into average differential fluxes and then using subroutine FAPT to interpolate the value thus obtained. A check is made whether the point fluxes are consistent with the original integral fluxes and, if necessary, the average fluxes are adjusted and FAPT is applied again. This procedure is repeated until point and integral spectra are consistent within reasonable bounds.

The unfolding procedure in GTPSI may also be used to generate consistent point fluxes. The detector cross sections are then replaced by step functions within the group boundaries. The trial spectrum may be described from outside or taken from unsuccessful output of FAPT. This procedure is restricted to integral spectra of not more than 40 groups.

The subroutine PSIGEN can also generate the step functions, which represent the group fluxes in the cross section file XSEC, if group fluxes are to be included in the procedures for unfolding and bounds. The corresponding integral fluxes are then placed in the activation rate file. Scaling may be done, if desired, as indicated in the chapter on input data preparation.

The plotting subroutines GTGRAF and GTPLOT with auxiliary routines

These subroutines generate plots of the output using the plot package INTRIGUE-II,⁶ the Calcomp plotter subroutines, and a subroutine MAXMIN, which determines the range of the variables contained in the plot. Subroutines GRID, XTENS, and TENS are slight modifications of subroutines with the same name in INTRIGUE-II. Subroutine MAXMIN is a modification

of the same routine in CRYSTAL BALL. In the present version, the program is applied sequentially, going through the data sets one at a time, each time enlarging the established grid size if necessary.

All plots are in the log - log mode, which prevents the representation of zero or negative values. Such may occur as values of window functions, but usually they are not significant and may be disregarded. In this way uniformity is achieved in the plots for spectra and window functions.

The subroutine GTGRAF generates a plot of the unfolded spectrum gotten in GTPSI together with the original trial spectrum. This is normalized to have the same total energy as the unfolded spectrum to minimize the range necessary to accommodate both variables in one plot. Every $M3^{\text{th}}$ point [$M3 = \text{GAM}(4)$] of the basic energy grid is plotted.

The subroutine GTPLOT gives plots of the ideal, upper, lower, and estimated windows whenever they are computed in GTBD. Every $M3^{\text{th}}$ point [$M3 = \text{GAM}(6)$] of the basic energy grid is plotted. The plotted values of the upper, lower, and estimated windows are smoothed by averaging the original values over each plotting interval.

The linear programming routines TALAKO and RESTOR and auxiliary routines

The subroutine TALAKO as used in this program and to some extent the subroutine RESTOR are modifications of the program TALAKO by Schneeberger, Burrus, and Rust.⁷

As in any standard linear programming algorithm, a given tableaux is transformed iteratively until it meets certain specifications. The tableaux consists of an $NR \times NC$ matrix $A = (a_{ij})$, and NR -column vector $B = (b_i)$, and an NR -row vector $C = (c_j)$. [These are the variable names used in the program.] The linear programming problem can be stated as follows:

Find a system of variables $x_j \geq 0$, $j = 1, NC$, such that:

$$\sum_{j=1}^{NC} a_{ij} x_j \leq b_i \quad (i = 1, NR) \quad (201)$$

$$\sum_{j=1}^{NC} c_j x_j = E = \text{maximum for all possible nonnegative } x_j.$$

Using "slack" variables y_i , $i = 1, NR$, $y_i \geq 0$, the problem can be reformulated as:

$$y_i = b_i - \sum_{j=1}^{nc} a_{ij} x_j, \quad (i = 1, NR), \quad (202a)$$

$$E = d + \sum_{j=1}^{nc} c_j x_j \quad (d = 0 \text{ initially}). \quad (202b)$$

with $x_j \geq 0$, $j = 1, NC$, $y_i \geq 0$, $i = 1, NR$, $E = \text{maximum}$.

If all $b_i \geq 0$ and all $c_j \leq 0$, then the problem has the obvious solution $x_j = 0$, $j=1, NC$, and $E = d$ is the external value. The goal of the linear programming algorithm is to transform the tableaux by exchanging the "primal" variables x_j with the slack variables y_i in such a manner that this state is reached.

Assuming that the coefficient $a_{mn} \neq 0$, the m^{th} equation in (202) can be rewritten:

$$x_n = \frac{b_m}{a_{mn}} - \sum_{\substack{j=1 \\ j \neq n}}^{NC} \frac{a_{mj}}{a_{mn}} x_j - \frac{1}{a_{mn}} y_m. \quad (203)$$

Substituting this value of x_n in the other equations of (202) and placing the coefficients for y_m in the now free n^{th} column of the tableaux, we obtain the following exchange algorithm:

$$a_{ij} \rightarrow a_{ij} - \frac{a_{mj}a_{in}}{a_{mn}}, \quad (i \neq m, j \neq n), \quad (204)$$

$$a_{mj} \rightarrow \frac{a_{mj}}{a_{mn}}, \quad (j \neq n),$$

$$a_{in} \rightarrow -\frac{a_{in}}{a_{mn}}, \quad (i \neq m),$$

$$a_{mn} \rightarrow \frac{1}{a_{mn}},$$

$$b_i \rightarrow b_i - \frac{b_m a_{in}}{a_{mn}}, \quad (i \neq m),$$

$$b_m \rightarrow \frac{b_m}{a_{mn}},$$

$$c_j \rightarrow c_j - \frac{a_{mj}c_n}{a_{mn}}, \quad (j \neq n),$$

$$c_n \rightarrow -\frac{c_n}{a_{mn}},$$

$$d \rightarrow d + \frac{b_m c_n}{a_{mn}}.$$

This exchange algorithm is applied repeatedly to eliminate positive values of c_j and negative values of b_i . It is well known that this exchange algorithm converges to an acceptable tableaux if certain rules are observed in the choice of variables to be exchanged. The algorithm halts when all b_i 's are nonnegative and all c_j 's are nonpositive.

It may also happen that some b_i 's remain negative regardless what exchanges are made. In this case the problem is unfeasible, i.e. the inequalities in (201) cannot be satisfied with nonnegative x_j 's. It can also happen that some c_j 's remain positive. Then the problem is unbounded, that is the inequalities in (201) can be satisfied with arbitrarily large values of some of the x_j 's, making E arbitrarily large.

In the normal exit, some of the primal variables x_j will occupy the place of slack variables in equation (202). The value of these variables will then be the corresponding value of b_i . The subroutine XS can find these values using the arrays IID and JID, which keep track of the exchanges.

The large matrix A (up to 6,800 entries) and a possibly large number of exchanges make it necessary to pay close attention to accuracy and stability of the procedure. Double precision is used for all computations. In addition, the exchange strategy is arranged to select among possible exchanges the one likely to cause the least loss of accuracy, even if this may lead to a larger number of iterations. If the computation of a matrix element becomes unreliable as the difference of two almost equal numbers, that element is set to zero. The exchange strategy also contains features which prevent cycling, i.e. the infinite repetition of the same sequence of exchanges.

To further reduce the inaccuracies caused by a large number of iterations, the linear programming tableaux is recomputed after leaving the subroutine TALAKO, this time going by the shortest possible route, avoiding all intermediate exchanges. This requires only as many exchanges as there are primal variables in the place of slack variables

and vice versa in the final tableaux. That is not more than either NR or NC. This direct exchange is performed in the subroutine RESTOR using the algorithm (204) and the information about the exchanges contained in the arrays IID and JID. After the direct exchange in RESTOR, the subroutine TALAKO is reentered to perform additional exchange steps if necessary. This process is repeated up to five times unless the tableaux obtained by direct exchange cannot be further altered. Also, the computations in TALAKO are terminated after 500 iterations, after which the subroutine RESTOR is entered in the same manner as after a regular exit.

COMMON BLOCK SNGLS ("singles")

NFOILS is the number of foils to be read in data set 1. If group fluxes are adjoined to the cross section file, NFOILS is increased so as to reflect the number of detectors, real or ideal, to be used in computation.

MPL1 is the number of points in the basic energy grid taken from the cross section tape. Although current usage is 621 points, fewer points may be used without changes to the program.

LOEX is the switch for the low energy extrapolation scheme to be used in generating a trial spectrum from point fluxes.

LHIX is the switch for the high energy extrapolation scheme.

CTEMP is the moderator temperature in degrees centigrade. This datum is needed only for Maxwellian extrapolation at low energies.

NIN is the number of group or point fluxes from which the trial spectrum is to be generated.

SCAL is the factor used to make the group fluxes commensurate with the measured activities.

IFRST is an internal switch used to indicate when a trial spectrum has been read (≥ 0) and when a least squares fit of the activity measurements should be done to determine the scale factor for the group fluxes (> 0).

IDSPEC is used both as an input parameter for the trial spectrum source and as an internal counter of the number of group fluxes added to the cross section file. It also indicates reading of cross sections.

M20 is MPL1-1 (useful as DO-loop index).

CONST is 0.5 times the factor used to adjust for non-conforming units in activity data, cross sections and trial spectra.

HALF is 0.5.

COMMON BLOCK PLRLS ("plurals")

REAC stores the reaction identification for each foil.

ALPHA stores the activity measurements.

GAMX stores the relative errors of the activity measurements.

COVR stores the cover identification for each foil.

THICK stores the cover thickness (1/barn).

E stores the basic energy grid.

EDEL stores the increments of the basic energy grid.

FLUX is the input array for the point/group fluxes used to generate the trial spectrum. It is also used to hold the trial spectrum during unfolding.

PSI stores the trial spectrum, which is replaced by the unfolded spectrum after unfolding.

SFLUX is the input array for energy/lethargy values corresponding to the point/group fluxes used to generate the trial spectrum. It is also used to preserve the previous trial spectrum during unfolding of the group fluxes only, and to store the 'ideal' window for output.

EL is used to preserve the trial spectrum during normal unfolding. It is also used to transfer fluxes and other data during unfolding of group fluxes only.

GAM stores computational parameters. At present, only three fields are used:

GAM(1) = smoothing parameter
 GAM(5) = relative accuracy of cross section values
 GAM(7) = limit of accuracy for unfolding.

TITL1 stores the title for plots of window functions.

TITL2 stores the title for plots of unfolded spectra.

TITL stores the id-card for the current data set.

SPSI is the output array for the upper window as well as an intermediate accumulator for the lower window.

SAVEIN is the output array for the lower window.

SAVEPS is the output array for the estimated window.

COMMON BLOCK XSEC ("cross sections")

SIG stores cross sections for up to 40 real or ideal detectors, discretized to the basic energy grid. This is the "cross section file."

COMMON BLOCK GT ("get")

GAMMA accumulates the quantities derived from the smoothing parameter used to modify the matrix of coefficients of the normal equations.

SUMB is used to accumulate certain numerical integrations.

SMALLS is used to compute the s_{λ} of formula (12), namely, the computed activities, based on trial spectrum.

S is used, among other things, to transfer the calculated group fluxes, based on the spectrum obtained by unfolding group fluxes only.

COMMON BLOCK WINDOW

IPAR is an array of switches and flags.

IPAR

1	IEW, number of points in group structure for bounds
2	JIND, combined switch for computational procedures
3	switch for inclusion of group fluxes
4	number of window functions (pairs of limits)
5	number of grid points in an energy group for bounds
6	current value of JIND
7	switch for entering linear programming
8	switch for trial spectrum scaling
9	not used at present
10	stores the number of group fluxes
11	print switch for estimated values
12-20	not used at present
21	flag which indicates unfolding has been done
22	flag which indicates matrix for estimated windows
23	switch for computation of bounds
24	print parameter for unfolded spectrum
25	not used at present
26	print parameter for bounds
27	not used
28	switch for energy weighting functions
29	switch for unfolding procedure
30-50	not used at present

PAR contains the pairs of limits of integration.

EW contains the energy grid for bounds.

W contains the 0's and 1's which determine the "support" of a window function, i.e. the region between the limits of integration, discretized to the energy grid for bounds. Denoted WIND in places.

G contains the response function, discretized to the basic energy grid.

COEF contains the absolute contributions of foils to bounds, i.e. the linear combinations. It is also used to accumulate the activities computed from the trial spectrum.

COMMON BLOCK NRML ("normal")

This is a large (8650 fields) double-precision working storage shared by the least squares and linear programming routines. Note that the way this region is partitioned varies from one subroutine to another.

In GTBD:

A is used to store the linear programming tableaux, which is transferred to RESTOR and TALAKO as an entry in the call.

B is the constant vector for the linear programming procedure.

C is the cost vector for the linear programming procedure.

R is not used.

In GTPSI and GTWD:

A is the matrix of normal equations.

B is initially a unit matrix.

C is one or NFOILS additional rows adjoined to A, for unfolding or estimated window, respectively.

F is used to perform a numerical integration needed to obtain the linear combinations for the estimated window.

PIVAR, PIVAC, PIVB, and PIVC are not used.

D stores the linear combination needed for the estimated window.

R stores the rows of the inverse matrix needed to find the linear combinations for the estimated window.

In NORMAL: PIVAR, PIVAC, PIVB, and PIVC are used to perform the Gaussian elimination needed to solve the normal equations. The roles of D and R are reversed.

COMMON BLOCK GRAF ("graph")

ARRAY(7) stores parameters used by the graphics subroutines.

FOOTNOTES

¹W. L. Zijp, *Review of Activation Methods for the Determination of Neutron Flux Density Spectra*, Reactor Centrum Nederland, Petten, R.M.G. Note 75/19 (September 1975).

²F. G. Perey, *Least Squares Dosimetry Unfolding: The Program STAY'SL*, ORNL/TM-6062, ENDF-254 (October 1977).

³B. W. Rust and W. R. Burrus, *Mathematical Programming and the Numerical Solution of Linear Equations*, Elsevier, New York - London - Amsterdam (1972).

⁴F. B. K. Kam and F. W. Stallmann, *CRYSTAL BALL - A computer Program for Determining Neutron Spectra from Activation Measurements*, ORNL-TM-4601 (June 1974).

⁵Ibid.

⁶M. B. Emmett, *INTRIGUE-II - An IBM-369 Subroutine Package for Making Linear, Logarithmic and Semilogarithmic Graphs Using the Calcomp Plotter*, ORNL-4664 (March 1971).

⁷C. Schneeberger, W. R. Burrus, and B. Rust, *A Fortran Subroutine Package for Linear Programming*, ORNL-TM-1250 (July 18, 1967).

⁸R. Kinsey, *ENDF/B-V - Summary Documentation*, to be published by Brookhaven National Laboratory as a National Laboratory Report in 1979.

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APPENDIX A

The Role of Cross-Section Uncertainties

The component of the error ϵ_{χ} in formula (8), which is due to cross section errors is given by the integral

$$C \int_0^{\infty} \phi(E) \tau_{\chi}(E) dE . \quad (36)$$

The statistical distribution depends, therefore, not only on the - supposedly known - distribution of $\tau_{\chi}(E)$, but also on the unknown spectrum $\phi(E)$. This can be replaced by the trial spectrum $\psi(E)$ if its shape is not too different from that of the true spectrum. The absolute magnitude of the neutron fluxes is unimportant since only relative uncertainties are considered. If, on the other hand, the shape of the cross section σ_{χ} is supposed to be known exactly and only its absolute magnitude uncertain, then the uncertainty (36) would always be a certain fraction of α_{χ} independent of $\phi(E)$. This is the worst case in this particular context since one would normally expect some cancellation of errors $\tau_{\chi}(E)$. A more accurate estimate of cross section uncertainties will be made available in uncertainty cross section files for ENDF/B-V.⁸

A somewhat different problem arises in the determination of the term μ in formulas (30c) and (30d) from cross section uncertainties. The term μ not only includes the relative uncertainties of the cross section measurements, but also those which arise from replacing point cross sections with their group averages. This requires again the knowledge of the shape of the trial spectrum. Obviously, the uncertainty is less the smaller the energy groups are. Large groups, on the other hand, may introduce cancellation of individual uncertainties in $\tau_{\chi}(E)$. It may be noted that the uncertainties are different for different cross sections and also for different energy groups, but only one parameter is used to represent all of them. That is clearly a disadvantage, but to implement all individual uncertainties seems to be too difficult at present.

APPENDIX B

A Different Interpretation of the CRYSTAL BALL Procedure

Since any least squares procedure is the orthogonal projection from a full space into a subspace, the solution is always a linear combination from a fixed set of basis vectors. By identifying the basis vectors, a better understanding and interpretation of the results is possible. In the CRYSTAL BALL procedure, the basis vectors are given by the rows of the matrix B on page 12, together with the row vector $(a)^T$, all of which are to be multiplied with the current trial spectrum $\psi(E)$. In other words, the trial spectrum is modified through a combination of rows in B, where the entries in these rows correspond to the energy values in the basic energy grid.

Explicit expressions for the rows in B are given by formula (18b), where, for a fixed row i , the fixed function $K_i(E)$ is folded with the variable function $D_j(E)$. In the latter, the function $S_1(E)$ [formula (15)] contributes only a constant and may be disregarded. The essential contribution comes from the function $H(E - E_j)$ so that the part of B which causes the modification of the trial spectrum can be written in form of a "modifying function" $B_i(E)$ with

$$B_i(E_j) = B_{ij} + k_i = \int_{E_j}^{\infty} K_i(E) d\omega(E), \quad (37)$$

where k_i is a constant.

To illustrate the type of modification caused by $B_i(E)$, let us assume that the two cross sections σ_{i+1} and σ_i belong to two threshold foils with different threshold energies E_{i+1} and E_i , represented by two step functions (Figure 1). Integration according to formulas (12b) and (12c) converts the step functions to a triangular shape of $K_i(E)$ [Figure 2]. One more integration (36) leads to the smooth s-shape of $B_i(E)$

[Figure 3], which is composed of two parabolas. The effect of applying the correction $B_{\chi}(E)$ on the trial spectrum $\psi(E)$ is indicated schematically in Figure 4. Depending whether the correction $B_{\chi}(E)$ is added or subtracted, we have a smooth hole or hump superimposed to the original spectrum.

The situation is similar for nonthreshold spectra. The shape of $B_{\chi}(E)$ may be more complicated, but the repeated integration makes it very smooth, and in particular, eliminates resonance spikes which plague the SAND-II and SPECTRA methods. This does not necessarily mean that a CRYSTAL BALL unfolded spectrum is more realistic. The range of possible adjustments is very much restricted through the limited range of available foil cross sections, and the humps and holes in the unfolded spectrum are more an indication of the limited resolution of the foil dosimetry than of real properties of the measured spectrum. This fact has to be kept in mind when the unfolded spectrum is interpreted.

Figure 1. Simplified Cross Sections for Two Threshold Reactions

Figure 2. Integral (cumulative sum) of the Difference of the Normalized Cross Sections Corresponding to $K_i(E)$ in Formulas (12c) and (18a, 18b)

Figure 3. Illustration of the Modifying Function $B_i(E)$ Obtained by a Second Integration

Figure 4. Change in Spectral Shape Contributed by $B_i(E)$

APPENDIX C

Format and Generation of the Cross Section Tape

Subroutine SIGS inputs the basic energy grid and cross section data from logical unit 15 (tape) using unformatted READ statements. Thus, the user who wishes to alter or create a cross section tape should take care to employ unformatted WRITE statements. A program, XSTAPE, which generates cross section tapes from VIF (variable input format) is available through RSIC. See section 3 of the earlier CRYSTAL BALL documentation.

The cross section tape may be outlined in three sections. The first section contains records pertaining to the basic energy grid. The first record, MPL1, gives the number of points in the basic energy grid. The second record is the array of length MPL1 containing the energy points of the basic energy grid. Then comes the second section, a sequence of records dealing with attenuation cross sections for various covers. The first of these records, NCOV, gives the number of different covers. Then comes NCOV pairs of records, the first of each pair being a cover identification and a second being the corresponding attenuation cross section. Presently, the WINDOWS program requires that the first three pairs represent cadmium, boron, and gold (in that order). The last section of the tape contains records pertaining to the detector cross sections. The first of these, NLIB, gives the number of foils in the tape library. Then follow NLIB triples of records, the first record in each triple containing the reaction identification label and the third containing the array of associated cross section values. The second record in each triple has no function in WINDOWS.

The cross section tape supplied with the WINDOWS program is one generated from the ENDF/B-IV cross section files, using an energy structure similar to that of the SAND-II code.

EXAMPLES

The large number of options included in the WINDOWS-package allows the user to solve a large variety of problems. The few examples presented herein are fairly typical, but in no way exhaust the possibilities of these programs.

The first three examples, which are taken from HSST dosimetry experiments, demonstrate the primary goal of these programs: to find the unfolded spectrum and the flux above 1.0 MeV as the integral parameter. Input parameters in the first example are kept to a minimum, namely strings of zeros (or blank cards) for procedural data and window functions, and the necessary data for reaction rates, cross sections and trial spectrum, which is obtained from a neutron transport calculation. The spaces for comments are freely used for identification of the data sets and the procedures used. The output consists of the confirmation of input data, a summary of the CRYSTAL BALL unfolding, and estimated values and bounds for the flux above 1.0 MeV. This is the minimum output for these procedures.

The second example shows the maximum output available for the same type of problem, which can be obtained by suitable parameters in the Procedural Data Set. This includes prints and plots of the unfolded spectrum and the normalized trial spectrum, the contribution of foils to bounds and estimates as well as prints and plots of the actual upper, lower, and estimated window functions together with the ideal window. It can be seen that the largest contributions to the estimates and bounds come from ^{238}U and ^{237}Np fission foils and that the neutron-gamma reactions contribute only negligible amounts, as expected. The approximating window functions are fairly accurate to about 8 MeV, and are progressively worse above this limit. The total error is nevertheless reasonable since the neutron flux is relatively small at higher energies.

The third example has only three foils which are not sufficient to determine the true spectrum, even at high energies, since only one of the

three is a threshold reaction. The unfolding is, therefore, basically a scaling procedure and the computation of bounds and of all unnecessary output is suppressed.

To predict radiation damage, the integral over the total displacement cross section (dpa) instead of the flux above 1.0 MeV is recommended. The fourth example shows how the measure can be estimated by including the appropriate window function (values according to Doran and others).

The next example shows how a computed core leakage spectrum can be scaled to the actual power level using a set of foils which is placed at the core boundary. It is also of interest to determine how close the measured and calculated reaction rates are, assuming the calculated spectrum is scaled to obtain the best least squares fit, without unfolding the spectrum. This is accomplished in the next example, primarily through the choice of $IPAR(8) = 1$ in the Input Flux Data set. The other parameters are chosen to suppress all other computations, by excluding unfolding in Procedure Data and computation of bounds and estimates in Window Functions.

The last data set gives an example of calculating spectrum averaged group cross sections, which are defined by the formula (33). The two integrals in the formula are special curves of integral fluxes which are computed as a by-product in GTBD and given as Estimated Windows in the output. The groups can be given as energy bounds for a set of windows, and the response function is a constant for the denominator integral and the reaction cross section for the integral in the numerator. Both sets of integrals must be computed separately. The ratio can then be found by simply dividing the two.

INPUT DATA^a

ACTIVATION DATA FROM HSST DOSIMETRY EXPERIMENT. CAPSULE N-S-1

10

CO59GX	2.05E-11	.05	CADM	4.71E-3
FE54PX	2.61E-13	.05	CADM	4.71E-3
FE58GX	5.93E-13	.05	CADM	4.71E-3
U235FX	1.41E-10	.05	CADM	4.71E-3
U238FX	1.24E-12	.05	CADM	4.71E-3
NP237FX	9.26E-12	.05	CADM	4.71E-3
I1272X	3.86E-15	.05	CADM	4.71E-3
SC45GX	5.61E-12	.05	CADM	4.71E-3
TI46PX	3.03E-14	.05	CADM	4.71E-3
AL27AX	2.34E-15	.05	CADM	4.71E-3

PROCEDURE INCLUDES UNFOLDING AND BOUNDS FOR FLUX ABOVE 1 MEV

0 0 0 0 0

CROSS SECTION FILE IS ENDF/B-IV - CADMIUM COVER

0 0.05

S 3-D VENTURE CALCULATION, 15 ENERGY GROUPS, LOC. N-S-1

0

0 0 0.0

(9E8.3)

15

-0.4	0.0	.5	1.	1.5	2.0	2.5	3.0	3.5	
4.0	4.5	6.75	11.5	15.5	16.7159				
2.95E+096.23E+102.69E+116.68E+119.04E+119.50E+111.09E+128.59E+115.85E+11									N-S-1
5.37E+111.52E+122.11E+121.72E+124.30E+111.86E+12									
21.4164 -0.50									

W FLUX ABOVE 1 MEV REQUIRES NO ADDITIONAL DATA

0 0 0 0 0

START PROCESSING DATA SET 1

ACTIVATION DATA FROM HSST DOSIMETRY EXPERIMENT. CAPSULE N-S-2

10

CO59GX	2.04E-11	.05	CADM	4.71E-3
FE54PX	2.59E-13	.05	CADM	4.71E-3
FE58GX	5.94E-13	.05	CADM	4.71E-3
U235FX	1.47E-10	.05	CADM	4.71E-3
U238FX	1.31E-12	.05	CADM	4.71E-3
NP237FX	9.00E-12	.05	CADM	4.71E-3
I1272X	3.89E-15	.05	CADM	4.71E-3
SC45GX	5.79E-12	.05	CADM	4.71E-3
TI46PX	3.85E-14	.05	CADM	4.71E-3
AL27AX	2.35E-15	.05	CADM	4.71E-3

2 INCLUDE ALL GRAPHS AND PRINTS IN OUTPUT

0 10 10 0 1

HSST DOSIMETRY EXPERIMENT - SPECTRUM AT LOCATION N-S-2

HSST DOSIMETRY EXPERIMENT - UPPER AND LOWER WINDOWS AT N-S-2

S 3-D VENTURE CALCULATION, 15 ENERGY GROUPS, LOC. N-S-2

0

3 1 20.

(9E8.3)

15

-0.4	0.0	.5	1.	1.5	2.0	2.5	3.0	3.5	
4.0	4.5	6.75	11.5	15.5	16.7159				
2.75E+095.80E+102.50E+116.24E+118.51E+119.04E+111.04E+128.28E+115.65E+11									N-S-2
5.21E+111.47E+122.04E+121.66E+124.16E+111.76E+12									
21.4164 -0.50									

START PROCESSING N-S-2 (2 GRAPHS REQUESTED)

ACTIVATION DATA FROM HSST DOSIMETRY EXPERIMENT. CAPSULE N-N-1

3

CO59GX	2.10E-11	.05
FE54PX	4.92E-14	.05
FE58GX	5.46E-13	.05

2 BACK TO SIMPLIFIED PROCEDURE

0 0 0 0 0

^aEach line corresponds to one input card.

3 FOIL SET HAS NO CADMIUM COVER, NEW CROSS SECTION SET REQUIRED

.05

S 3-D VENTURE CALCULATION, 15 ENERGY GROUPS, LOC. N-N-1

0

3 1 20.

(9E8.3)

15

-0.4 0.0 .5 1. 1.5 2.0 2.5 3.0 3.5

4.0 4.5 6.75 11.5 15.5 16.7159

5.16E+089.35E+094.10E+101.34E+112.39E+113.75E+115.16E+114.18E+112.82E+11 N-N-1

2.71E+116.14E+116.45E+114.99E+111.28E+116.90E+11

21.4164 -0.50

5NOT ENOUGH FOILS TO COMPUTE REALISTIC BOUNDS

0 0 -1 0 0

GC

5 COMPUTE DAMAGE DISPLACEMENT RATE (DORAN)

2 5 -1 0 0

1 0

0.00E+002.00E+01

641 +1

1.00E+00

(6E12.3)

1.000E-10	1.050E-10	1.100E-10	1.150E-10	1.200E-10	1.275E-10	1
1.350E-10	1.425E-10	1.500E-10	1.600E-10	1.700E-10	1.800E-10	2
1.900E-10	2.000E-10	2.100E-10	2.200E-10	2.300E-10	2.400E-10	3
2.550E-10	2.700E-10	2.800E-10	3.000E-10	3.200E-10	3.400E-10	4
3.600E-10	3.800E-10	4.000E-10	4.250E-10	4.500E-10	4.750E-10	5
5.000E-10	5.250E-10	5.500E-10	5.750E-10	6.000E-10	6.300E-10	6
6.600E-10	6.900E-10	7.200E-10	7.600E-10	8.000E-10	8.400E-10	7
8.800E-10	9.200E-10	9.600E-10	1.000E-09	1.050E-09	1.100E-09	8
1.150E-09	1.200E-09	1.275E-09	1.350E-09	1.425E-09	1.500E-09	9
1.600E-09	1.700E-09	1.800E-09	1.900E-09	2.000E-09	2.100E-09	10
2.200E-09	2.300E-09	2.400E-09	2.550E-09	2.700E-09	2.800E-09	11
3.000E-09	3.200E-09	3.400E-09	3.600E-09	3.800E-09	4.000E-09	12
4.250E-09	4.500E-09	4.750E-09	5.000E-09	5.250E-09	5.500E-09	13
5.750E-09	6.000E-09	6.300E-09	6.600E-09	6.900E-09	7.200E-09	14
7.600E-09	8.000E-09	8.400E-09	8.800E-09	9.200E-09	9.600E-09	15
1.000E-08	1.050E-08	1.100E-08	1.150E-08	1.200E-08	1.275E-08	16
1.350E-08	1.425E-08	1.500E-08	1.600E-08	1.700E-08	1.800E-08	17
1.900E-08	2.000E-08	2.100E-08	2.200E-08	2.300E-08	2.400E-08	18
2.550E-08	2.700E-08	2.800E-08	3.000E-08	3.200E-08	3.400E-08	19
3.600E-08	3.800E-08	4.000E-08	4.250E-08	4.500E-08	4.750E-08	20
5.000E-08	5.250E-08	5.500E-08	5.750E-08	6.000E-08	6.300E-08	21
6.600E-08	6.900E-08	7.200E-08	7.600E-08	8.000E-08	8.400E-08	22
8.800E-08	9.200E-08	9.600E-08	1.000E-07	1.050E-07	1.100E-07	23
1.150E-07	1.200E-07	1.275E-07	1.350E-07	1.425E-07	1.500E-07	24
1.600E-07	1.700E-07	1.800E-07	1.900E-07	2.000E-07	2.100E-07	25
2.200E-07	2.300E-07	2.400E-07	2.550E-07	2.700E-07	2.800E-07	26
3.000E-07	3.200E-07	3.400E-07	3.600E-07	3.800E-07	4.000E-07	27
4.250E-07	4.500E-07	4.750E-07	5.000E-07	5.250E-07	5.500E-07	28
5.750E-07	6.000E-07	6.300E-07	6.600E-07	6.900E-07	7.200E-07	29
7.600E-07	8.000E-07	8.400E-07	8.800E-07	9.200E-07	9.600E-07	30
1.000E-06	1.050E-06	1.100E-06	1.150E-06	1.200E-06	1.275E-06	31
1.350E-06	1.425E-06	1.500E-06	1.600E-06	1.700E-06	1.800E-06	32
1.900E-06	2.000E-06	2.100E-06	2.200E-06	2.300E-06	2.400E-06	33
2.550E-06	2.700E-06	2.800E-06	3.000E-06	3.200E-06	3.400E-06	34
3.600E-06	3.800E-06	4.000E-06	4.250E-06	4.500E-06	4.750E-06	35
5.000E-06	5.250E-06	5.500E-06	5.750E-06	6.000E-06	6.300E-06	36
6.600E-06	6.900E-06	7.200E-06	7.600E-06	8.000E-06	8.400E-06	37
8.800E-06	9.200E-06	9.600E-06	1.000E-05	1.050E-05	1.100E-05	38
1.150E-05	1.200E-05	1.275E-05	1.350E-05	1.425E-05	1.500E-05	39
1.600E-05	1.700E-05	1.800E-05	1.900E-05	2.000E-05	2.100E-05	40
2.200E-05	2.300E-05	2.400E-05	2.550E-05	2.700E-05	2.800E-05	41
3.000E-05	3.200E-05	3.400E-05	3.600E-05	3.800E-05	4.000E-05	42

4.250E-05	4.500E-05	4.750E-05	5.000E-05	5.250E-05	5.500E-05	43
5.750E-05	6.000E-05	6.300E-05	6.600E-05	6.900E-05	7.200E-05	44
7.600E-05	8.000E-05	8.400E-05	8.800E-05	9.200E-05	9.600E-05	45
1.000E-04	1.050E-04	1.100E-04	1.150E-04	1.200E-04	1.275E-04	46
1.350E-04	1.425E-04	1.500E-04	1.600E-04	1.700E-04	1.800E-04	47
1.900E-04	2.000E-04	2.100E-04	2.200E-04	2.300E-04	2.400E-04	48
2.550E-04	2.700E-04	2.800E-04	3.000E-04	3.200E-04	3.400E-04	49
3.600E-04	3.800E-04	4.000E-04	4.250E-04	4.500E-04	4.750E-04	50
5.000E-04	5.250E-04	5.500E-04	5.750E-04	6.000E-04	6.300E-04	51
6.600E-04	6.900E-04	7.200E-04	7.600E-04	8.000E-04	8.400E-04	52
8.800E-04	9.200E-04	9.600E-04	1.000E-03	1.050E-03	1.100E-03	53
1.150E-03	1.200E-03	1.275E-03	1.350E-03	1.425E-03	1.500E-03	54
1.600E-03	1.700E-03	1.800E-03	1.900E-03	2.000E-03	2.100E-03	55
2.200E-03	2.300E-03	2.400E-03	2.550E-03	2.700E-03	2.800E-03	56
3.000E-03	3.200E-03	3.400E-03	3.600E-03	3.900E-03	4.000E-03	57
4.250E-03	4.500E-03	4.750E-03	5.000E-03	5.250E-03	5.500E-03	58
5.750E-03	6.000E-03	6.300E-03	6.600E-03	6.900E-03	7.200E-03	59
7.600E-03	8.000E-03	8.400E-03	8.800E-03	9.200E-03	9.600E-03	60
1.080E-02	1.050E-02	1.100E-02	1.150E-02	1.200E-02	1.275E-02	61
1.350E-02	1.425E-02	1.500E-02	1.600E-02	1.700E-02	1.800E-02	62
1.900E-02	2.000E-02	2.100E-02	2.200E-02	2.300E-02	2.400E-02	63
2.550E-02	2.700E-02	2.800E-02	3.000E-02	3.200E-02	3.400E-02	64
3.600E-02	3.800E-02	4.000E-02	4.250E-02	4.500E-02	4.750E-02	65
5.000E-02	5.250E-02	5.500E-02	5.750E-02	6.000E-02	6.300E-02	66
6.600E-02	6.900E-02	7.200E-02	7.600E-02	8.000E-02	8.400E-02	67
8.800E-02	9.200E-02	9.600E-02	1.000E-01	1.050E-01	1.100E-01	68
1.150E-01	1.200E-01	1.275E-01	1.350E-01	1.425E-01	1.500E-01	69
1.600E-01	1.700E-01	1.800E-01	1.900E-01	2.000E-01	2.100E-01	70
2.200E-01	2.300E-01	2.400E-01	2.550E-01	2.700E-01	2.800E-01	71
3.000E-01	3.200E-01	3.400E-01	3.600E-01	3.800E-01	4.000E-01	72
4.250E-01	4.500E-01	4.750E-01	5.000E-01	5.250E-01	5.500E-01	73
5.750E-01	6.000E-01	6.300E-01	6.600E-01	6.900E-01	7.200E-01	74
7.600E-01	8.000E-01	8.400E-01	8.800E-01	9.200E-01	9.600E-01	75
1.000E+00	1.100E+00	1.200E+00	1.300E+00	1.400E+00	1.500E+00	76
1.600E+00	1.700E+00	1.800E+00	1.900E+00	2.000E+00	2.100E+00	77
2.200E+00	2.300E+00	2.400E+00	2.500E+00	2.600E+00	2.700E+00	78
2.800E+00	2.900E+00	3.000E+00	3.100E+00	3.200E+00	3.300E+00	79
3.400E+00	3.500E+00	3.600E+00	3.700E+00	3.800E+00	3.900E+00	80
4.000E+00	4.100E+00	4.200E+00	4.300E+00	4.400E+00	4.500E+00	81
4.600E+00	4.700E+00	4.800E+00	4.900E+00	5.000E+00	5.100E+00	82
5.200E+00	5.300E+00	5.400E+00	5.500E+00	5.600E+00	5.700E+00	83
5.800E+00	5.900E+00	6.000E+00	6.100E+00	6.200E+00	6.300E+00	84
6.400E+00	6.500E+00	6.600E+00	6.700E+00	6.800E+00	6.900E+00	85
7.000E+00	7.100E+00	7.200E+00	7.300E+00	7.400E+00	7.500E+00	86
7.600E+00	7.700E+00	7.800E+00	7.900E+00	8.000E+00	8.100E+00	87
8.200E+00	8.300E+00	8.400E+00	8.500E+00	8.600E+00	8.700E+00	88
8.800E+00	8.900E+00	9.000E+00	9.100E+00	9.200E+00	9.300E+00	89
9.400E+00	9.500E+00	9.600E+00	9.700E+00	9.800E+00	9.900E+00	90
1.000E+01	1.010E+01	1.020E+01	1.030E+01	1.040E+01	1.050E+01	91
1.060E+01	1.070E+01	1.080E+01	1.090E+01	1.100E+01	1.110E+01	92
1.120E+01	1.130E+01	1.140E+01	1.150E+01	1.160E+01	1.170E+01	93
1.180E+01	1.190E+01	1.200E+01	1.210E+01	1.220E+01	1.230E+01	94
1.240E+01	1.250E+01	1.260E+01	1.270E+01	1.280E+01	1.290E+01	95
1.300E+01	1.310E+01	1.320E+01	1.330E+01	1.340E+01	1.350E+01	96
1.360E+01	1.370E+01	1.380E+01	1.390E+01	1.400E+01	1.410E+01	97
1.420E+01	1.430E+01	1.440E+01	1.450E+01	1.460E+01	1.470E+01	98
1.480E+01	1.490E+01	1.500E+01	1.510E+01	1.520E+01	1.530E+01	99
1.540E+01	1.550E+01	1.560E+01	1.570E+01	1.580E+01	1.590E+01	100
1.600E+01	1.610E+01	1.620E+01	1.630E+01	1.640E+01	1.650E+01	101
1.660E+01	1.670E+01	1.680E+01	1.690E+01	1.700E+01	1.710E+01	102
1.720E+01	1.730E+01	1.740E+01	1.750E+01	1.760E+01	1.770E+01	103
1.780E+01	1.790E+01	1.800E+01	1.810E+01	1.820E+01	1.830E+01	104
1.840E+01	1.850E+01	1.860E+01	1.870E+01	1.880E+01	1.890E+01	105

1.900E+01	1.910E+01	1.920E+01	1.930E+01	1.940E+01	1.950E+01	106
1.960E+01	1.970E+01	1.980E+01	1.990E+01	2.000E+01		107
1.727E+02	1.721E+02	1.714E+02	1.708E+02	1.699E+02	1.689E+02	1 *
1.680E+02	1.670E+02	1.658E+02	1.645E+02	1.632E+02	1.619E+02	2
1.606E+02	1.593E+02	1.579E+02	1.566E+02	1.553E+02	1.537E+02	3
1.517E+02	1.500E+02	1.481E+02	1.454E+02	1.428E+02	1.402E+02	4
1.376E+02	1.349E+02	1.320E+02	1.287E+02	1.254E+02	1.221E+02	5
1.188E+02	1.155E+02	1.122E+02	1.090E+02	1.053E+02	1.014E+02	6
9.746E+01	9.351E+01	8.891E+01	8.365E+01	7.839E+01	7.313E+01	7
6.787E+01	6.262E+01	5.736E+01	5.462E+01	5.442E+01	5.421E+01	8
5.400E+01	5.374E+01	5.343E+01	5.312E+01	5.280E+01	5.244E+01	9
5.202E+01	5.161E+01	5.119E+01	5.078E+01	5.036E+01	4.995E+01	10
4.953E+01	4.911E+01	4.859E+01	4.797E+01	4.745E+01	4.683E+01	11
4.600E+01	4.516E+01	4.433E+01	4.350E+01	4.267E+01	4.173E+01	12
4.069E+01	3.965E+01	3.862E+01	3.758E+01	3.654E+01	3.550E+01	13
3.446E+01	3.331E+01	3.207E+01	3.082E+01	2.957E+01	2.812E+01	14
2.645E+01	2.479E+01	2.313E+01	2.146E+01	1.980E+01	1.814E+01	15
1.720E+01	1.699E+01	1.678E+01	1.657E+01	1.631E+01	1.599E+01	16
1.568E+01	1.536E+01	1.500E+01	1.458E+01	1.416E+01	1.374E+01	17
1.332E+01	1.290E+01	1.248E+01	1.206E+01	1.164E+01	1.111E+01	18
1.076E+01	1.060E+01	1.041E+01	1.016E+01	9.901E+00	9.647E+00	19
9.392E+00	9.138E+00	8.852E+00	8.534E+00	8.216E+00	7.898E+00	20
7.683E+00	7.569E+00	7.456E+00	7.343E+00	7.218E+00	7.082E+00	21
6.946E+00	6.810E+00	6.651E+00	6.470E+00	6.289E+00	6.107E+00	22
5.926E+00	5.745E+00	5.563E+00	5.462E+00	5.442E+00	5.421E+00	23
5.400E+00	5.374E+00	5.343E+00	5.312E+00	5.280E+00	5.244E+00	24
5.202E+00	5.161E+00	5.119E+00	5.078E+00	5.036E+00	4.995E+00	25
4.953E+00	4.911E+00	4.859E+00	4.797E+00	4.745E+00	4.683E+00	26
4.600E+00	4.516E+00	4.433E+00	4.350E+00	4.267E+00	4.173E+00	27
4.069E+00	3.965E+00	3.862E+00	3.758E+00	3.654E+00	3.550E+00	28
3.446E+00	3.331E+00	3.207E+00	3.082E+00	2.957E+00	2.812E+00	29
2.645E+00	2.479E+00	2.313E+00	2.146E+00	1.980E+00	1.814E+00	30
1.727E+00	1.721E+00	1.714E+00	1.708E+00	1.699E+00	1.689E+00	31
1.680E+00	1.670E+00	1.658E+00	1.645E+00	1.632E+00	1.619E+00	32
1.606E+00	1.593E+00	1.579E+00	1.566E+00	1.553E+00	1.537E+00	33
1.517E+00	1.500E+00	1.481E+00	1.454E+00	1.428E+00	1.402E+00	34
1.376E+00	1.349E+00	1.320E+00	1.287E+00	1.254E+00	1.221E+00	35
1.188E+00	1.155E+00	1.122E+00	1.090E+00	1.053E+00	1.014E+00	36
9.746E-01	9.351E-01	8.891E-01	8.365E-01	7.839E-01	7.313E-01	37
6.787E-01	6.262E-01	5.736E-01	5.462E-01	5.442E-01	5.421E-01	38
5.400E-01	5.374E-01	5.343E-01	5.312E-01	5.280E-01	5.244E-01	39
5.202E-01	5.161E-01	5.119E-01	5.078E-01	5.036E-01	4.995E-01	40
4.953E-01	4.911E-01	4.859E-01	4.797E-01	4.745E-01	4.683E-01	41
4.600E-01	4.516E-01	4.433E-01	4.350E-01	4.267E-01	4.173E-01	42
4.069E-01	3.965E-01	3.862E-01	3.758E-01	3.654E-01	3.550E-01	43
3.446E-01	3.331E-01	3.207E-01	3.082E-01	2.957E-01	2.812E-01	44
2.645E-01	2.479E-01	2.313E-01	2.146E-01	1.980E-01	1.814E-01	45
1.721E-01	1.703E-01	1.685E-01	1.667E-01	1.644E-01	1.616E-01	46
1.589E-01	1.561E-01	1.529E-01	1.493E-01	1.456E-01	1.420E-01	47
1.383E-01	1.347E-01	1.310E-01	1.273E-01	1.237E-01	1.191E-01	48
1.136E-01	1.091E-01	1.036E-01	9.879E-02	9.654E-02	9.428E-02	49
9.203E-02	8.978E-02	8.725E-02	8.443E-02	8.162E-02	7.880E-02	50
7.622E-02	7.387E-02	7.136E-02	6.868E-02	6.594E-02	6.318E-02	51
3.474E-01	4.149E-01	5.030E-01	5.989E-01	6.942E-01	7.884E-01	52
8.768E-01	9.694E-01	1.050E+00	1.169E+00	1.334E+00	1.229E+01	53
1.238E+01	1.686E+00	1.821E+00	1.967E+00	2.110E+00	2.274E+00	54
2.585E+00	2.626E+00	2.792E+00	2.952E+00	3.107E+00	3.258E+00	55
3.405E+00	3.575E+00	3.715E+00	3.910E+00	4.068E+00	4.248E+00	56
4.487E+00	4.734E+00	4.986E+00	5.414E+00	7.472E+00	6.842E+00	57
6.121E+00	6.251E+00	6.502E+00	6.849E+00	7.359E+00	8.188E+00	58
1.039E+01	1.731E+01	1.548E+01	1.438E+01	1.826E+01	2.993E+01	59
4.576E+01	3.840E+01	2.580E+01	1.924E+01	1.614E+01	1.422E+01	60
1.308E+01	1.230E+01	1.191E+01	1.145E+01	1.114E+01	1.086E+01	61

*Note: The dpa-cross sections are given in barns. The output values must be multiplied by 10^{-24} to obtain true dpa values.

1.061E+01	1.038E+01	9.947E+00	9.448E+00	8.834E+00	8.124E+00	62
7.339E+00	6.538E+00	5.863E+00	5.008E+00	3.605E+00	3.919E+00	63
6.076E+01	4.356E+02	4.289E+02	1.579E+02	1.011E+02	8.107E+01	64
7.140E+01	6.620E+01	6.275E+01	6.052E+01	5.931E+01	5.932E+01	65
8.029E+01	8.424E+01	7.094E+01	6.826E+01	6.025E+01	5.230E+01	66
4.575E+01	4.135E+01	1.999E+02	7.815E+01	1.617E+02	2.784E+02	67
1.407E+02	1.141E+02	1.146E+02	1.052E+02	9.306E+01	9.024E+01	68
7.400E+01	7.067E+01	1.295E+02	2.200E+02	2.531E+02	1.306E+02	69
1.148E+02	1.475E+02	2.230E+02	3.249E+02	2.014E+02	1.124E+02	70
2.675E+02	1.540E+02	1.783E+02	1.339E+02	2.411E+02	1.921E+02	71
1.422E+02	2.977E+02	1.503E+02	2.917E+02	5.052E+02	5.088E+02	72
3.876E+02	3.023E+02	3.189E+02	3.643E+02	2.972E+02	2.686E+02	73
2.789E+02	1.931E+02	2.257E+02	4.492E+02	3.499E+02	6.007E+02	74
6.220E+02	4.099E+02	4.068E+02	3.191E+02	2.486E+02	4.607E+02	75
5.042E+02	4.377E+02	6.974E+02	6.512E+02	7.855E+02	9.153E+02	76
8.127E+02	7.757E+02	8.195E+02	9.886E+02	1.068E+03	1.028E+03	77
1.006E+03	1.096E+03	1.214E+03	1.373E+03	1.198E+03	1.259E+03	78
1.275E+03	1.265E+03	1.365E+03	1.389E+03	1.352E+03	1.342E+03	79
1.395E+03	1.330E+03	1.434E+03	1.457E+03	1.508E+03	1.490E+03	80
1.556E+03	1.595E+03	1.562E+03	1.615E+03	1.555E+03	1.663E+03	81
1.643E+03	1.676E+03	1.719E+03	1.705E+03	1.718E+03	1.747E+03	82
1.752E+03	1.785E+03	1.793E+03	1.792E+03	1.826E+03	1.825E+03	83
1.830E+03	1.851E+03	1.872E+03	1.862E+03	1.873E+03	1.928E+03	84
1.927E+03	1.948E+03	1.958E+03	1.964E+03	1.982E+03	1.980E+03	85
1.987E+03	2.010E+03	2.010E+03	2.040E+03	2.038E+03	2.062E+03	86
2.052E+03	2.068E+03	2.085E+03	2.089E+03	2.092E+03	2.095E+03	87
2.117E+03	2.150E+03	2.150E+03	2.146E+03	2.143E+03	2.143E+03	88
2.181E+03	2.194E+03	2.207E+03	2.220E+03	2.232E+03	2.245E+03	89
2.258E+03	2.269E+03	2.279E+03	2.289E+03	2.299E+03	2.308E+03	90
2.320E+03	2.332E+03	2.344E+03	2.356E+03	2.369E+03	2.381E+03	91
2.394E+03	2.407E+03	2.419E+03	2.432E+03	2.444E+03	2.455E+03	92
2.466E+03	2.479E+03	2.490E+03	2.503E+03	2.514E+03	2.524E+03	93
2.532E+03	2.540E+03	2.546E+03	2.551E+03	2.556E+03	2.567E+03	94
2.582E+03	2.592E+03	2.601E+03	2.615E+03	2.629E+03	2.642E+03	95
2.655E+03	2.668E+03	2.683E+03	2.697E+03	2.713E+03	2.730E+03	96
2.747E+03	2.767E+03	2.786E+03	2.806E+03	2.824E+03	2.840E+03	97
2.857E+03	2.874E+03	2.890E+03	2.905E+03	2.917E+03	2.929E+03	98
2.941E+03	2.954E+03	2.958E+03	2.955E+03	2.952E+03	2.948E+03	99
2.942E+03	2.938E+03	2.936E+03	2.932E+03	2.928E+03	2.924E+03	100
2.924E+03	2.928E+03	2.932E+03	2.936E+03	2.940E+03	2.944E+03	101
2.948E+03	2.951E+03	2.955E+03	2.958E+03	2.966E+03	2.978E+03	102
2.990E+03	3.003E+03	3.014E+03	3.026E+03	3.037E+03	3.049E+03	103
3.061E+03	3.073E+03	3.087E+03	3.102E+03	3.118E+03	3.133E+03	104
3.149E+03	3.164E+03	3.180E+03	3.195E+03	3.211E+03	3.226E+03	105
3.239E+03	3.249E+03	3.259E+03	3.269E+03	3.279E+03	3.289E+03	106
3.300E+03	3.310E+03	3.320E+03	3.331E+03	0.		107

GC

1FOILS PLACED BETWEEN WINDOW AND CORE

4

NI58PX 1.51E-11 .05

FE54PX 1.28E-11 .05

AL27AX 9.63E-14 .05

CO59GX 4.73E-09 .05

2SCALE CALCULATED LEAKAGE TO CONFORM WITH FOIL ACTIVITIES

1 0 0 0 0

3

0 0.05

SPECTRUM OBTAINED WITH ANISN CODE

1

(9E8.3)

15

-6.93E-14.410E-17.340E-11.204E001.446E001.998E002.501E002.997E003.411E00

4.200E004.605E006.645E001.131E011.550E011.672E01
 5.426E-39.648E-33.035E-22.556E-25.826E-24.768E-24.304E-22.539E-23.747E-2
 1.496E-25.257E-29.263E-27.881E-22.487E-23.009E-1
 2.763E01 -.05

WINDOW PARAMETERS CHOSEN TO SUPPRESS COMPUTATION OF INTEGRAL FLUXES

2 0 0 0 0

0

6

5PROCEDURE TO FIND GROUP AVERAGED CROSS SECTIONS

2 1 -1 1

15 0

15.0	20.0	10.0	15.0	6.00	10.0	3.50	6.00	2.30
3.50	1.40	2.30	1.00	1.40	.8	1.00	.5	.8
.3	.5	.2	.3	.1	.2	.01	.1	1.0E-5

1.0E-2 1.0E-9 1.0E-5

6THE GROUP FLUXES ARE COMPUTED FIRST

5NOW THE CROSS SECTION OF C059G IS THE NEW RESPONSE FUNCTION

0 3 -1 1 0

6GROUP RESPONSES OF C059G ARE FOUND, TO BE DIVIDED BY GROUP FLUXES

5NOW THE CROSS SECTION OF AL27A IS THE NEW RESPONSE FUNCTION

0 3 -1 1 0

6GROUP RESPONSES OF AL27A ARE FOUND, TO BE DIVIDED BY GROUP FLUXES

5NOW THE CROSS SECTION OF FE54P IS THE NEW RESPONSE FUNCTION

0 3 -1 1 0

6GROUP RESPONSES OF FE54P ARE FOUND, TO BE DIVIDED BY GROUP FLUXES

PRINTED OUTPUT

START OF A NEW SET OF DATA

REACTION RATE DATA

ACTIVATION DATA FROM HSST DOSIMETRY EXPERIMENT. CAPSULE N-S-1

FOIL NO	REACTION NAME	COVER NAME	COVER THICKNESS 1/EAEN	SATURATION ACTIVITY CPS/TARGET ATOM	REL. ERROR
1	CO59GX	CADM	4.710E-03	2.050E-11	0.0500
2	FE54PX	CADM	4.710E-03	2.610E-13	0.0500
3	FE58GX	CADM	4.710E-03	5.930E-13	0.0500
4	U235PX	CADM	4.710E-03	1.410E-10	0.0500
5	U238PX	CADM	4.710E-03	1.240E-12	0.0500
6	NP237PX	CADM	4.710E-03	9.260E-12	0.0500
7	I1272X	CADM	4.710E-03	3.860E-15	0.0500
8	SC45GX	CADM	4.710E-03	5.610E-12	0.0500
9	TI46PX	CADM	4.710E-03	3.030E-14	0.0500
10	AL27AX	CADM	4.710E-03	2.342E-15	0.0500

PROCEDURAL DATA

PROCEDURE INCLUDES UNFOLDING AND BOUNDS FOR FLUX ABOVE 1 MEV

UNFOLDED SPECTRUM AND BOUNDS COMPUTED

CROSS SECTION DATA SET

CROSS SECTION FILE IS ENDF/B-IV - CADMIUM COVER

CROSS SECTION ACCURACY 5.00 PERCENT

INPUT FLUX DATA

3-D VENTURE CALCULATION, 15 ENERGY GROUPS, LOC. N-S-1

LOW TEMPERATURE EXTRAPOLATION:
MAXWELLIAN EXTRAPOLATION

HIGH TEMPERATURE EXTRAPOLATION:
FISSION EXTRAPOLATION

MODERATOR TEMPERATURE = 20.00 CENTIGRADE

OBJECT TIME BEAD FORMAT FOR FLUX INPUT
(9E8.3)

I	ULO	UHI	PHI(U)*DU	ELO	EHI	EBAR	PHI(E)
1	-4.00E-01	0.0	2.95E 09	1.00E 01	1.49E 01	1.22E 01	6.00E 08
2	0.0	5.00E-01	6.23E 10	6.67E 00	1.00E 01	7.79E 00	1.58E 10
3	5.00E-01	1.00E 00	2.69E 11	3.68E 00	6.07E 00	4.72E 00	1.13E 11
4	1.00E 00	1.50E 00	6.68E 11	2.23E 00	3.68E 00	2.87E 00	4.61E 11
5	1.50E 00	2.00E 00	9.04E 11	1.35E 00	2.23E 00	1.74E 00	1.03E 12
6	2.00E 00	2.50E 00	9.50E 11	8.21E-01	1.35E 00	1.05E 00	1.78E 12
7	2.50E 00	3.00E 00	1.09E 12	4.98E-01	8.21E-01	6.39E-01	3.37E 12
8	3.00E 00	3.50E 00	8.59E 11	3.02E-01	4.98E-01	3.88E-01	4.38E 12
9	3.50E 00	4.00E 00	5.85E 11	1.83E-01	3.02E-01	2.35E-01	4.92E 12

10	4.00E 00	4.50E 00	5.37E 11	1.11E-01	1.83E-01	1.43E-01	7.45E 12
11	4.50E 00	6.75E 00	1.52E 12	1.17E-02	1.11E-01	3.61E-02	1.53E 13
12	6.75E 00	1.15E 01	2.11E 12	1.01E-04	1.17E-02	1.09E-03	1.82E 14
13	1.15E 01	1.55E 01	1.72E 12	1.86E-06	1.01E-04	1.37E-05	1.73E 16
14	1.55E 01	1.67E 01	4.30E 11	5.50E-07	1.86E-06	1.01E-06	3.29E 17
15	1.67E 01	2.14E 01	1.86E 12	5.00E-09	5.50E-07	5.24E-08	3.41E 18

GROUP FLUXES ARE NOT CONSIDERED IN THE COMPUTATION OF UNFOLDING AND BOUNDS

1-TH ITERATION, RELATIVE ERROR= 150.961 PERCENT

2-TH ITERATION, RELATIVE ERROR= 25.998 PERCENT

3-TH ITERATION, RELATIVE ERROR= 7.631 PERCENT

4-TH ITERATION, RELATIVE ERROR= 2.318 PERCENT

GROUP NO.	INPUT FLUX	COMPUTED FLUX
1	.295E 10	.296E 10
2	.623E 11	.621E 11
3	.269E 12	.270E 12
4	.668E 12	.667E 12
5	.904E 12	.903E 12
6	.950E 12	.952E 12
7	.109E 13	.109E 13
8	.859E 12	.859E 12
9	.585E 12	.586E 12
10	.537E 12	.536E 12
11	.152E 13	.153E 13
12	.211E 13	.210E 13
13	.172E 13	.170E 13
14	.430E 12	.433E 12
15	.186E 13	.182E 13

NEW WINDOW FUNCTION

PLUX ABOVE 1 MEV REQUIRES NO ADDITIONAL DATA

BOTH UPPER AND LOWER BOUNDS REQUESTED

BOUNDS ARE BASED ON MEASURED ACTIVITIES

START PROCESSING DATA SET 1

THE DIFFERENTIAL SPECTRUM IS BEING UNFOLDED BY THE CRYSTAL BALL METHOD

AVERAGE RELATIVE DEVIATION = 5.39E 00

ITERATION NO= 1 KGAM= 1 GAMMA0= 1.0000000E 02

AVERAGE RELATIVE DEVIATION = 2.65E 00

ITERATION NO= 2 KGAM= 1 GAMMA0= 9.9999962E 00

AVERAGE RELATIVE DEVIATION = 1.01E 00

ITERATION NO= 3 KGAM= 1 GAMMA0= 9.9999923E-01

AVERAGE RELATIVE DEVIATION = 2.95E-01

ACCURACY SPECIFICATION SATISFIED AFTER 3 ITERATIONS

FOIL NO	FOIL NAME	MEASURED ACTIVITY	CALCULATED ACTIVITY	MEASURED ERROR	CALCULATED ERROR
1	CO59GX	2.05E-11	2.07E-11	5.00E-02	-8.42E-03
2	PE54PX	2.61E-13	2.57E-13	5.00E-02	1.65E-02
3	PE58GX	5.93E-13	5.91E-13	5.00E-02	4.09E-03
4	U235FX	1.41E-10	1.39E-10	5.00E-02	1.44E-02
5	U238FX	1.24E-12	1.28E-12	5.00E-02	-3.47E-02
6	NP237P	9.26E-12	9.09E-12	5.00E-02	1.86E-02
7	I1272X	3.86E-15	3.86E-15	5.00E-02	-9.59E-04
8	SC45GX	5.61E-12	5.64E-12	5.00E-02	-4.96E-03
9	TI46PX	3.03E-14	3.04E-14	5.00E-02	-4.94E-03
10	AL27AX	2.34E-15	2.33E-15	5.00E-02	3.25E-03

SUMMARY OF COMPUTED BOUNDS AND ESTIMATES

CUTOFF ENERGY (MEV)		INTEGRAL RESPONSE			DIFFERENCE BETWEEN BOUND AND ESTIMATE	
LOW	HIGH	LOWER BOUND	ESTIMATED VALUE	UPPER BOUND	LOWER BOUND	UPPER BOUND (PERCENT)
1.00E 00	2.00E 01	2.79E 12	3.59E 12	4.08E 12	22.40	13.48

START OF A NEW SET OF DATA

REACTION RATE DATA

ACTIVATION DATA FROM HSST DOSIMETRY EXPERIMENT. CAPSULE N-S-2

FOIL NO	REACTION NAME	COVER NAME	COVER THICKNESS 1/BARN	SATURATION ACTIVITY DPS/TARGET ATOM	REL. ERROR
1	CO59GX	CADM	4.710E-03	2.040E-11	0.0500
2	PE54PX	CADM	4.710E-03	2.590E-13	0.0500
3	PE58GX	CADM	4.710E-03	5.940E-13	0.0500
4	U235PX	CADM	4.710E-03	1.470E-10	0.0500
5	U238PX	CADM	4.710E-03	1.310E-12	0.0500
6	NP237PX	CADM	4.710E-03	9.000E-12	0.0500
7	I1272X	CADM	4.710E-03	3.890E-15	0.0500
8	SC45GX	CADM	4.710E-03	5.790E-12	0.0500
9	TI46PX	CADM	4.710E-03	3.850E-14	0.0500
10	AL27AX	CADM	4.710E-03	2.350E-15	0.0500

PROCEDURAL DATA

INCLUDE ALL GRAPHS AND PRINTS IN OUTPUT

UNFOLDED SPECTRUM AND BOUNDS COMPUTED

PLOTS REQUESTED
FOR UNFOLDED DIFFERENTIAL SPECTRUM
EVERY 10-TH POINT IS USED FOR PRINTING AND PLOTTING

PLOTS REQUESTED
FOR WINDOW FUNCTIONS
EVERY 10-TH POINT IS USED FOR PRINTING AND PLOTTING

INPUT FLUX DATA

3-D VENTURE CALCULATION, 15 ENERGY GROUPS, LOC. N-S-2

LOW TEMPERATURE EXTRAPOLATION:
MAXWELLIAN EXTRAPOLATION

HIGH TEMPERATURE EXTRAPOLATION:
FISSION EXTRAPOLATION

MODERATOR TEMPERATURE = 20.00 CENTIGRADE

OBJECT TIME READ FORMAT FOR FLUX INPUT
(9E8.3)

I	ULO	UHI	PHI(U)*DU	ELO	EHI	EBAR	PHI(E)
1	-4.00E-01	0.0	2.75E 09	1.00E 01	1.49E 01	1.22E 01	5.59E 08
2	0.0	5.00E-01	5.80E 10	6.07E 00	1.00E 01	7.79E 00	1.47E 10
3	5.00E-01	1.00E 00	2.50E 11	3.68E 00	6.07E 00	4.72E 00	1.05E 11
4	1.00E 00	1.50E 00	6.24E 11	2.23E 00	3.68E 00	2.87E 00	4.31E 11
5	1.50E 00	2.00E 00	8.51E 11	1.35E 00	2.23E 00	1.74E 00	9.69E 11
6	2.00E 00	2.50E 00	9.04E 11	8.21E-01	1.35E 00	1.05E 00	1.70E 12
7	2.50E 00	3.00E 00	1.04E 12	4.98E-01	8.21E-01	6.39E-01	3.22E 12
8	3.00E 00	3.50E 00	8.28E 11	3.02E-01	4.98E-01	3.88E-01	4.23E 12

9	3.50E 00	4.00E 00	5.65E 11	1.83E-01	3.02E-01	2.35E-01	4.76E 12
10	4.00E 00	4.50E 00	5.21E 11	1.11E-01	1.83E-01	1.43E-01	7.23E 12
11	4.50E 00	6.75E 00	1.47E 12	1.17E-02	1.11E-01	3.61E-02	1.48E 13
12	6.75E 00	1.15E 01	2.04E 12	1.01E-04	1.17E-02	1.09E-03	1.76E 14
13	1.15E 01	1.55E 01	1.66E 12	1.86E-06	1.01E-04	1.37E-05	1.67E 16
14	1.55E 01	1.67E 01	4.16E 11	5.50E-07	1.86E-06	1.01E-06	3.19E 17
15	1.67E 01	2.14E 01	1.76E 12	5.00E-09	5.50E-07	5.24E-08	3.23E 18

GROUP FLUXES ARE NOT CONSIDERED IN THE COMPUTATION OF UNFOLDING AND BOUNDS

1-TH ITERATION, RELATIVE ERROR= 149.212 PERCENT

2-TH ITERATION, RELATIVE ERROR= 25.889 PERCENT

3-TH ITERATION, RELATIVE ERROR= 7.659 PERCENT

4-TH ITERATION, RELATIVE ERROR= 2.342 PERCENT

GROUP NO.	INPUT FLUX	COMPUTED FLUX
1	.275E 10	.276E 10
2	.580E 11	.578E 11
3	.250E 12	.251E 12
4	.624E 12	.623E 12
5	.851E 12	.850E 12
6	.904E 12	.906E 12
7	.104E 13	.104E 13
8	.828E 12	.828E 12
9	.565E 12	.566E 12
10	.521E 12	.520E 12
11	.147E 13	.148E 13
12	.204E 13	.203E 13
13	.166E 13	.164E 13
14	.416E 12	.419E 12
15	.176E 13	.172E 13

START PROCESSING N-S-2 (2 GRAPHS REQUESTED)

THE DIFFERENTIAL SPECTRUM IS BEING UNFOLDED BY THE CRYSTAL BALL METHOD

AVERAGE RELATIVE DEVIATION = 6.33E 00

ITERATION NO= 1 KGAM= 1 GAMMA0= 1.0000000E 02

AVERAGE RELATIVE DEVIATION = 2.87E 00

ITERATION NO= 2 KGAM= 1 GAMMA0= 9.9999962E 00

AVERAGE RELATIVE DEVIATION = 1.33E 00

ITERATION NO= 3 KGAM= 1 GAMMA0= 9.9999923E-01

AVERAGE RELATIVE DEVIATION = 6.32E-01

ACCURACY SPECIFICATION SATISFIED AFTER 3 ITERATIONS

POIL NO	POIL NAME	MEASURED ACTIVITY	CALCULATED ACTIVITY	MEASURED ERRCR	CALCULATED ERROR		
1	CO59GX	2.04E-11	2.06E-11	5.00E-02	-1.21E-02		
2	PE54PX	2.59E-13	2.74E-13	5.00E-02	-5.62E-02		
3	PE58GX	5.94E-13	5.92E-13	5.00E-02	3.48E-03		
4	U235FX	1.47E-10	1.44E-10	5.00E-02	2.04E-02		
5	U238PX	1.31E-12	1.31E-12	5.00E-02	3.77E-03		
6	NP237P	9.00E-12	8.98E-12	5.00E-02	2.46E-03		
7	I1272X	3.89E-15	3.87E-15	5.00E-02	5.66E-03		
8	SC45GX	5.79E-12	5.84E-12	5.00E-02	-9.05E-03		
9	TI46PX	3.85E-14	3.57E-14	5.00E-02	7.29E-02		
10	AL27AX	2.35E-15	2.42E-15	5.00E-02	-2.79E-02		
PLOT CALL OUTSIDE LIMITS			X=0.0		Y=-.5000E 00	IPEN=	3

DIFFERENTIAL SPECTRUM - NORMALIZED TRIAL SPECTRUM

ENERGY	FLUX	ENERGY	FLUX	ENERGY	FLUX
9.9999994E-11	2.5165114E 17	1.6999999E-10	4.2662295E 17	2.7999980E-10	6.9961891E 17
5.0000004E-10	1.2384855E 18	8.0000007E-10	1.9581774E 18	1.2749994E-09	3.0627006E 18
2.1999993E-09	5.0946146E 18	3.7999968E-09	8.2596138E 18	6.2999952E-09	1.2403052E 19
9.9999973E-09	1.7004569E 19	1.6999991E-08	2.1910241E 19	2.7999985E-08	2.3345798E 19
4.9999986E-08	1.7447146E 19	7.9999950E-08	1.0079059E 19	1.2749990E-07	5.7973741E 18
2.1999989E-07	3.0346983E 18	3.7999979E-07	1.5866074E 18	6.2999970E-07	8.7086310E 17
9.9999943E-07	5.0332516E 17	1.6999984E-06	3.1304196E 17	2.7999968E-06	2.0085459E 17
4.9999971E-06	1.1993384E 17	7.9999954E-06	7.8961153E 16	1.2749995E-05	5.2167884E 16
2.1999993E-05	3.0086216E 16	3.7999984E-05	1.7160147E 16	6.2999985E-05	1.0208553E 16
9.9999990E-05	6.3507362E 15	1.6999996E-04	3.6819804E 15	2.7999980E-04	2.2052298E 15
4.9999985E-04	1.2155042E 15	7.9999981E-04	7.5000571E 14	1.2749995E-03	4.7544671E 14
2.1999995E-03	2.9395723E 14	3.7999989E-03	1.8158340E 14	6.2999986E-03	1.1629475E 14
9.9999979E-03	7.7393398E 13	1.6999993E-02	4.8482564E 13	2.7999986E-02	3.1230653E 13
4.9999990E-02	2.0745766E 13	7.9999983E-02	1.5876510E 13	1.2749988E-01	1.2177216E 13
2.1999985E-01	7.3832637E 12	3.7999976E-01	6.6445210E 12	6.2999970E-01	5.3075069E 12
9.9999964E-01	2.7423859E 12	1.9999943E 00	1.2421022E 12	2.9999886E 00	6.2215265E 11
3.9999828E 00	2.6426933E 11	4.9999771E 00	1.2937167E 11	5.9999714E 00	6.4024113E 10
6.9999657E 00	3.5322425E 10	7.9999599E 00	1.8898649E 10	8.9999542E 00	7.3976586E 09
9.9999485E 00	3.1968274E 09	1.0999943E 01	1.4965862E 09	1.1999937E 01	7.4847693E 08
1.2999931E 01	3.6451200E 08	1.3999926E 01	1.7409798E 08	1.4999920E 01	8.2940176E 07
1.5999914E 01	3.9424688E 07	1.6999817E 01	1.8704752E 07	1.7999725E 01	8.8589290E 06

DIFFERENTIAL SPECTRUM - UNFOLDED

ENERGY	FLUX	ENERGY	FLUX	ENERGY	FLUX
9.9999994E-11	2.5741931E 17	1.6999999E-10	4.3640173E 17	2.7999980E-10	7.1565521E 17
5.0000004E-10	1.2668727E 18	8.0000007E-10	2.0030606E 18	1.2749994E-09	3.1329001E 18
2.1999993E-09	5.2113893E 18	3.7999968E-09	8.4489365E 18	6.2999952E-09	1.2687348E 19
9.9999973E-09	1.7394339E 19	1.6999991E-08	2.2412445E 19	2.7999985E-08	2.3880882E 19
4.9999986E-08	1.7846977E 19	7.9999950E-08	1.0309952E 19	1.2749990E-07	5.9301247E 18
2.1999989E-07	3.1041599E 18	3.7999979E-07	1.6223690E 18	6.2999970E-07	8.8188172E 17
9.9999943E-07	5.0129862E 17	1.6999984E-06	3.0156168E 17	2.7999968E-06	1.9071778E 17
4.9999971E-06	1.1352121E 17	7.9999954E-06	7.4595542E 16	1.2749995E-05	4.6612859E 16
2.1999993E-05	2.4013184E 16	3.7999984E-05	1.1496442E 16	6.2999985E-05	5.3631257E 15
9.9999990E-05	2.4799308E 15	1.6999996E-04	1.3059154E 15	2.7999980E-04	9.7916369E 14
4.9999985E-04	6.2986071E 14	7.9999981E-04	4.3906484E 14	1.2749995E-03	3.0994363E 14
2.1999995E-03	2.1081100E 14	3.7999989E-03	1.4184193E 14	6.2999986E-03	9.8239861E 13
9.9999979E-03	7.0243032E 13	1.6999993E-02	4.7008384E 13	2.7999986E-02	3.2167829E 13
4.9999990E-02	2.2586310E 13	7.9999983E-02	1.8171419E 13	1.2749988E-01	1.4570426E 13
2.1999985E-01	9.1754647E 12	3.7999976E-01	8.5140712E 12	6.2999970E-01	6.8729816E 12
9.9999964E-01	3.3783619E 12	1.9999943E 00	1.2628934E 12	2.9999886E 00	4.7605370E 11
3.9999828E 00	2.2474975E 11	4.9999771E 00	1.4103013E 11	5.9999714E 00	7.5376951E 10
6.9999657E 00	3.7834154E 10	7.9999599E 00	1.7493922E 10	8.9999542E 00	6.3778570E 09
9.9999485E 00	2.8172462E 09	1.0999943E 01	1.3861353E 09	1.1999937E 01	7.1998592E 08
1.2999931E 01	3.5857946E 08	1.3999926E 01	1.7335549E 08	1.4999920E 01	8.3104736E 07
1.5999914E 01	3.9620560E 07	1.6999817E 01	1.8819808E 07	1.7999725E 01	8.9155630E 06

LOWER BOUND

BOUNDS COMPUTED FROM ACTIVITIES AND COEFFICIENTS
 MEAN VALUE= 3.403E 12, VARIANCE= 6.98 PERCENT

CONTRIBUTION OF FOILS TO BOUND

FOIL NO	REACTION NAME	ACTIVITY MEASURED	CONTRIBUTION ABSOLUTE	CONTRIBUTION RELATIVE
1	CO59GX	2.040E-11	6.151E-05	3.868E-04
2	FE54PX	2.590E-13	-4.875E 00	-4.302E-01
3	FE58GX	5.940E-13	2.369E-03	4.338E-04
4	U235FX	1.470E-10	-1.442E-04	-7.223E-03
5	U238FX	1.310E-12	3.485E 00	1.407E 00
6	NP237FX	9.000E-12	-1.267E-02	-3.886E-02
7	I1272X	3.890E-15	-1.195E 00	-1.584E-03
8	SC45GX	5.790E-12	9.949E-04	1.776E-03
9	TI46PX	3.850E-14	8.873E 00	1.053E-01
10	AL27AX	2.350E-15	-4.639E 01	-3.714E-02

UPPER BOUND

BOUNDS COMPUTED FROM ACTIVITIES AND COEFFICIENTS
 MEAN VALUE= 4.118E 12, VARIANCE= 5.94 PERCENT

CONTRIBUTION OF FOILS TO BOUND

FOIL NO	REACTION NAME	ACTIVITY MEASURED	CONTRIBUTION ABSOLUTE	CONTRIBUTION RELATIVE
1	CO59GX	2.040E-11	-5.252E-06	-2.314E-05
2	FE54PX	2.590E-13	-2.437E 00	-1.363E-01
3	FE58GX	5.940E-13	0.0	0.0
4	U235FX	1.470E-10	2.640E-05	9.267E-04
5	U238FX	1.310E-12	3.703E 00	1.158E 00
6	NP237FX	9.000E-12	-8.982E-03	-1.746E-02
7	I1272X	3.890E-15	1.201E-01	1.116E-04
8	SC45GX	5.790E-12	-1.644E-04	-2.056E-04

9	TI46PX	3.850E-14	0.0	0.0
10	AL27AX	2.350E-15	-1.076E 01	-5.460E-03

CONTRIBUTION OF FOILS TO ESTIMATED SPECTRUM

ESTIMATED VALUE OF THE INTEGRAL RESPONSEV 3.466D-12 ,VARIANCE= 3.76 PERCENT

FOIL NO	REACTION NAME	ACTIVITY MEASURED	CONTRIBUTION ABSOLUTE	CONTRIBUTION RELATIVE
1	CO59GX	2.040E-11	9.123E-04	5.369D-03
2	FE54PX	2.590E-13	-1.184D-02	-8.843D-04
3	FE58GX	5.940E-13	-8.295D-02	-1.421D-02
4	U235PX	1.470E-10	-3.785D-04	-1.605D-02
5	U238PX	1.310E-12	1.549D 00	5.855D-01
6	NP237PX	9.000E-12	1.812D-01	4.705D-01
7	I1272X	3.890E-15	1.122D 00	1.259D-03
8	SC45GX	5.790E-12	7.033E-03	1.175D-02
9	TI46PX	3.850E-14	-3.412D 00	-3.789D-02
10	AL27AX	2.350E-15	-7.959D 00	-5.396D-03

EXACTLY COMPUTED WINDOWFUNCTIONS

ENERGY	UPPER WINDOW	IDEAL WINDOW	LOWER WINDOW	ESTIMATED WINDOW
1.000E-10	0.0	0.0	0.0	0.0
1.700E-10	0.0	0.0	0.0	0.0
2.800E-10	0.0	0.0	0.0	0.0
5.000E-10	0.0	0.0	0.0	0.0
8.000E-10	0.0	0.0	0.0	0.0
1.275E-09	0.0	0.0	0.0	0.0
2.200E-09	2.447E-17	0.0	-1.285E-16	-9.889E-17
3.800E-09	7.835E-14	0.0	-3.912E-13	-7.327E-13
6.300E-09	2.311E-11	0.0	-1.163E-10	-2.173E-10
1.000E-08	1.311E-09	0.0	-6.529E-09	-1.216E-08
1.700E-08	1.642E-08	0.0	-8.151E-08	-1.501E-07
2.800E-08	6.782E-08	0.0	-3.351E-07	-6.074E-07
5.000E-08	7.551E-08	0.0	-3.695E-07	-6.452E-07
8.000E-08	7.901E-09	0.0	-3.814E-08	-6.333E-08
1.275E-07	4.696E-14	0.0	-2.231E-13	-3.475E-13
2.200E-07	2.244E-12	0.0	-1.081E-11	-1.830E-11
3.800E-07	3.478E-04	0.0	-1.673E-03	-2.633E-03
6.300E-07	5.675E-04	0.0	-2.263E-03	9.422E-05
1.000E-06	9.817E-04	0.0	-4.494E-03	-5.900E-03
1.700E-06	-1.741E-04	0.0	1.626E-03	9.303E-03
2.800E-06	-7.607E-05	0.0	9.926E-04	6.474E-03
5.000E-06	-6.810E-05	0.0	7.610E-04	4.839E-03
8.000E-06	-5.159E-05	0.0	5.643E-04	4.028E-03
1.275E-05	1.747E-03	0.0	-9.311E-03	-2.238E-02
2.200E-05	8.126E-04	0.0	-4.479E-03	-9.349E-03
3.800E-05	-4.612E-03	0.0	-1.138E-02	9.929E-02
6.300E-05	3.681E-04	0.0	-2.113E-03	-2.935E-03
1.000E-04	4.209E-04	0.0	-2.157E-03	3.561E-04
1.700E-04	-6.425E-04	0.0	-3.839E-03	1.951E-02
2.800E-04	3.057E-04	0.0	-2.941E-03	-3.253E-03
5.000E-04	2.971E-04	0.0	-2.145E-03	-3.756E-03
8.000E-04	-1.077E-05	0.0	-1.708E-03	1.695E-03
1.275E-03	2.666E-03	0.0	1.158E-03	3.992E-03
2.200E-03	1.184E-04	0.0	-7.530E-04	-1.602E-03
3.800E-03	8.570E-05	0.0	-6.087E-04	-7.679E-04
6.300E-03	-7.243E-05	0.0	2.743E-04	-1.392E-02
1.000E-02	2.728E-04	0.0	-7.278E-05	-4.601E-03
1.700E-02	2.882E-04	0.0	-1.526E-04	9.570E-04
2.800E-02	2.582E-04	0.0	-1.099E-05	1.933E-03
5.000E-02	7.788E-05	0.0	-2.026E-04	1.322E-03
8.000E-02	5.276E-05	0.0	-2.341E-04	1.882E-03
1.275E-01	3.075E-05	0.0	-2.629E-04	2.643E-03
2.200E-01	-3.256E-06	0.0	-3.074E-04	4.375E-03
3.800E-01	-1.067E-03	0.0	-1.886E-03	2.979E-02
6.300E-01	-3.156E-03	0.0	-6.737E-03	1.557E-01
1.000E 00	4.796E-02	0.0	3.889E-02	2.843E-01
2.000E 00	1.875E 00	1.000E 00	1.723E 00	1.098E 00
3.000E 00	1.641E 00	1.000E 00	1.210E 00	1.115E 00
4.000E 00	1.435E 00	1.000E 00	8.861E-01	1.062E 00
5.000E 00	1.039E 00	1.000E 00	5.476E-01	8.764E-01
6.000E 00	1.138E 00	1.000E 00	7.434E-01	0.714E-01
7.000E 00	1.820E 00	1.000E 00	1.093E 00	1.119E 00
8.000E 00	1.730E 00	1.000E 00	3.873E-01	9.077E-01
9.000E 00	1.448E 00	1.000E 00	-6.290E-01	5.995E-01
1.000E 01	1.243E 00	1.000E 00	-1.710E 00	6.696E-01
1.100E 01	1.241E 00	1.000E 00	-2.717E 00	1.066E 00
1.200E 01	1.285E 00	1.000E 00	-3.493E 00	1.384E 00
1.300E 01	1.550E 00	1.000E 00	-3.725E 00	1.691E 00
1.400E 01	2.125E 00	1.000E 00	-3.120E 00	2.054E 00
1.500E 01	2.864E 00	1.000E 00	-2.086E 00	2.502E 00
1.600E 01	3.382E 00	1.000E 00	-1.147E 00	2.872E 00
1.700E 01	3.750E 00	1.000E 00	-1.160E-01	3.016E 00
1.800E 01	3.871E 00	1.000E 00	9.148E-01	2.790E 00

SUMMARY OF COMPUTED BOUNDS AND ESTIMATES

CUTOFF ENERGY (MEV)		INTEGRAL RESPONSE			DIFFERENCE BETWEEN BOUND AND ESTIMATE	
LOW	HIGH	LOWER BOUND	ESTIMATED VALUE	UPPER BOUND	LOWER BOUND	UPPER BOUND (PERCENT)
1.00E 00	2.00E 01	3.08E 12	3.64E 12	4.40E 12	15.24	20.93

START OF A NEW SET OF DATA

REACTION RATE DATA

ACTIVATION DATA FROM HSST DOSIMETRY EXPERIMENT. CAPSULE N-N-1

FOIL NO	REACTION NAME	COVER NAME	COVER THICKNESS 1/EAFN	SATURATION ACTIVITY CPS/TARGET ATOM	REL. ERROR
1	CO59GX		0.0	2.100E-11	0.0500
2	FE54PX		0.0	4.920E-14	0.0500
3	FE58GX		0.0	5.460E-13	0.0500

PROCEDURAL DATA

BACK TO SIMPLIFIED PROCEDURE

UNFOLDED SPECTRUM AND BOUNDS COMPUTED

CROSS SECTION DATA SET

FOIL SET HAS NO CADMIUM COVER, NEW CROSS SECTION SET REQUIRED

CROSS SECTION ACCURACY 5.00 PERCENT

INPUT FLUX DATA

3-D VENTURE CALCULATION, 15 ENERGY GROUPS, LOC. N-N-1

LOW TEMPERATURE EXTRAPOLATION:

MAXWELLIAN EXTRAPOLATION

HIGH TEMPERATURE EXTRAPOLATION:

FISSION EXTRAPOLATION

MODERATOR TEMPERATURE = 20.00 CENTIGRADE

OBJECT TIME READ FORMAT FOR FLUX INPUT
(9E8.3)

I	ULO	UHI	PHI(U)*DU	ELO	EHI	EBAR	PHI(E)
1	-4.00E-01	0.0	5.16E 08	1.00E 01	1.49E 01	1.22E 01	1.05E 08
2	0.0	5.00E-01	9.35E 09	6.07E 00	1.00E 01	7.79E 00	2.38E 09
3	5.00E-01	1.00E 00	4.10E 10	3.68E 00	6.07E 00	4.72E 00	1.72E 10
4	1.00E 00	1.50E 00	1.34E 11	2.23E 00	3.68E 00	2.37E 00	9.26E 10
5	1.50E 00	2.00E 00	2.39E 11	1.35E 00	2.23E 00	1.74E 00	2.72E 11
6	2.00E 00	2.50E 00	3.75E 11	8.21E-01	1.35E 00	1.05E 00	7.04E 11
7	2.50E 00	3.00E 00	5.16E 11	4.98E-01	8.21E-01	6.39E-01	1.60E 12
8	3.00E 00	3.50E 00	4.18E 11	3.02E-01	4.98E-01	3.88E-01	2.13E 12
9	3.50E 00	4.00E 00	2.82E 11	1.83E-01	3.02E-01	2.35E-01	2.37E 12
10	4.00E 00	4.50E 00	2.71E 11	1.11E-01	1.83E-01	1.43E-01	3.76E 12
11	4.50E 00	6.75E 00	6.14E 11	1.17E-02	1.11E-01	3.61E-02	6.18E 12
12	6.75E 00	1.15E 01	6.45E 11	1.01E-04	1.17E-02	1.09E-03	5.56E 13
13	1.15E 01	1.55E 01	4.99E 11	1.86E-06	1.01E-04	1.37E-05	5.02E 15
14	1.55E 01	1.67E 01	1.28E 11	5.50E-07	1.86E-06	1.01E-06	9.81E 16
15	1.67E 01	2.14E 01	6.90E 11	5.00E-09	5.50E-07	5.24E-08	1.27E 18

GROUP FLUXES ARE NOT CONSIDERED IN THE COMPUTATION OF UNFOLDING AND BOUNDS

1-TH ITERATION, RELATIVE ERROR= 168.509 PERCENT
 2-TH ITERATION, RELATIVE ERROR= 26.744 PERCENT
 3-TH ITERATION, RELATIVE ERROR= 7.256 PERCENT
 4-TH ITERATION, RELATIVE ERROR= 2.080 PERCENT

GROUP NO.	INPUT FLUX	COMPUTED FLUX
1	.516E 09	.519E 09
2	.935E 10	.930E 10
3	.410E 11	.412E 11
4	.134E 12	.134E 12
5	.239E 12	.239E 12
6	.375E 12	.375E 12
7	.516E 12	.515E 12
8	.418E 12	.418E 12
9	.282E 12	.283E 12
10	.271E 12	.270E 12
11	.614E 12	.619E 12
12	.645E 12	.640E 12
13	.499E 12	.494E 12
14	.128E 12	.129E 12
15	.690E 12	.676E 12

NEW WINDOW FUNCTION

NOT ENOUGH FOILS TO COMPUTE REALISTIC BOUNDS

COMPUTATION OF BOUNDS OMITTED

BOUNDS ARE BASED ON MEASURED ACTIVITIES

THE DIFFERENTIAL SPECTRUM IS BEING UNFOLDED BY THE CRYSTAL BALL METHOD

AVERAGE RELATIVE DEVIATION = 6.56E 00

ITERATION NO= 1 KGAM= 1 GAMMA0= 1.0000000E 02

AVERAGE RELATIVE DEVIATION = 1.88E 00

ITERATION NO= 2 KGAM= 1 GAMMA0= 9.9999962E 00

AVERAGE RELATIVE DEVIATION = 5.34E-01

ACCURACY SPECIFICATION SATISFIED AFTER 2 ITERATIONS

POIL NO	POIL NAME	MEASURED ACTIVITY	CALCULATED ACTIVITY	MEASURED ERRCR	CALCULATED ERRCR
1	CO59GX	2.10E-11	2.03E-11	5.00E-02	3.17E-02
2	FE54PX	4.92E-14	4.89E-14	5.00E-02	5.43E-03
3	FE58GX	5.46E-13	5.64E-13	5.00E-02	-3.32E-02

SUMMARY OF COMPUTED BOUNDS AND ESTIMATES

CUTOFF ENERGY (MEV)		INTEGRAL RESPONSE			DIFFERENCE BETWEEN BOUND AND ESTIMATE	
LOW	HIGH	LOWER BOUND	ESTIMATED VALUE	UPPER BOUND	LOWER BOUND	UPPER BOUND (PERCENT)
1.00E 00	2.00E 01	0.0	8.49E 11	0.0	0.0	0.0

START OF A NEW SET OF DATA

NEW WINDOW FUNCTION

COMPUTE DAMAGE DISPLACEMENT RATE (DORAN)

COMPUTATION OF BOUNDS OMITTED

BOUNDS ARE BASED ON MEASURED ACTIVITIES

1 SUCCESSIVE WINDOWS ARE COMPUTED

NO LOW ENERGY HIGH ENERGY
1 0.0 2.00E 01

THE INTEGRAL RESPONSE FUNCTION R(E) IS
READ FROM CARDS

INPUT WINDOW FUNCTION		ENERGY WINDOW		ENERGY WINDOW		ENERGY WINDOW	
ENERGY	WINDOW	ENERGY	WINDOW	ENERGY	WINDOW	ENERGY	WINDOW
0.9999999E-10	0.1727000E 03	0.1C50000E-09	0.1721000E 03	0.1100000E-09	0.1714000E 03	0.1100000E-09	0.1714000E 03
0.1150000E-09	0.1708000E 03	0.1200000E-09	0.1699000E 03	0.1275000E-09	0.1689000E 03	0.1275000E-09	0.1689000E 03
0.1350000E-09	0.1680000E 03	0.1425000E-09	0.1670000E 03	0.1500000E-09	0.1658000E 03	0.1500000E-09	0.1658000E 03
0.1600000E-09	0.1645000E 03	0.1700000E-09	0.1632000E 03	0.1800000E-09	0.1619000E 03	0.1800000E-09	0.1619000E 03
0.1900000E-09	0.1606000E 03	0.2000000E-09	0.1593000E 03	0.2100000E-09	0.1579000E 03	0.2100000E-09	0.1579000E 03
0.2200000E-09	0.1566000E 03	0.2300000E-09	0.1553000E 03	0.2399998E-09	0.1537000E 03	0.2399998E-09	0.1537000E 03
0.2549998E-09	0.1517000E 03	0.2699998E-09	0.1500000E 03	0.2799998E-09	0.1481000E 03	0.2799998E-09	0.1481000E 03
0.2999998E-09	0.1454000E 03	0.3199998E-09	0.1428000E 03	0.3399998E-09	0.1402000E 03	0.3399998E-09	0.1402000E 03
0.3599998E-09	0.1376000E 03	0.3799998E-09	0.1349000E 03	0.3999998E-09	0.1320000E 03	0.3999998E-09	0.1320000E 03
0.4249998E-09	0.1287000E 03	0.4499998E-09	0.1254000E 03	0.4749998E-09	0.1221000E 03	0.4749998E-09	0.1221000E 03
0.4999998E-09	0.1188000E 03	0.5249998E-09	0.1155000E 03	0.5499998E-09	0.1122000E 03	0.5499998E-09	0.1122000E 03
0.5749998E-09	0.1090000E 03	0.5999998E-09	0.1053000E 03	0.6299998E-09	0.1014000E 03	0.6299998E-09	0.1014000E 03
0.6599998E-09	0.9745999E 02	0.6899998E-09	0.9350999E 02	0.7199998E-09	0.8890999E 02	0.7199998E-09	0.8890999E 02
0.7599998E-09	0.8364999E 02	0.7999998E-09	0.7839000E 02	0.8399998E-09	0.7312999E 02	0.8399998E-09	0.7312999E 02
0.8799999E-09	0.6787000E 02	0.9199999E-09	0.6262000E 02	0.9599999E-09	0.5243999E 02	0.9599999E-09	0.5243999E 02
0.9999999E-09	0.5462000E 02	0.1C50000E-08	0.5442000E 02	0.1100000E-08	0.542C999E 02	0.1100000E-08	0.542C999E 02
0.1150000E-08	0.5400000E 02	0.1200000E-08	0.5373999E 02	0.1275000E-08	0.5342999E 02	0.1275000E-08	0.5342999E 02
0.1350000E-08	0.5312000E 02	0.1425000E-08	0.5279999E 02	0.1500000E-08	0.5243999E 02	0.1500000E-08	0.5243999E 02
0.1600000E-08	0.5201999E 02	0.1700000E-08	0.5160999E 02	0.1800000E-08	0.5118999E 02	0.1800000E-08	0.5118999E 02
0.1900000E-08	0.5078000E 02	0.2000000E-08	0.5035999E 02	0.2100000E-08	0.4995000E 02	0.2100000E-08	0.4995000E 02
0.2200000E-08	0.4953000E 02	0.2300000E-08	0.4910999E 02	0.2400000E-08	0.4859000E 02	0.2400000E-08	0.4859000E 02
0.2550000E-08	0.4796999E 02	0.2700000E-08	0.4745000E 02	0.2800000E-08	0.4682999E 02	0.2800000E-08	0.4682999E 02
0.3000000E-08	0.4600000E 02	0.3200000E-08	0.4515999E 02	0.3400000E-08	0.4432999E 02	0.3400000E-08	0.4432999E 02
0.3600000E-08	0.4350000E 02	0.3799997E-08	0.4267000E 02	0.3999997E-08	0.4173000E 02	0.3999997E-08	0.4173000E 02
0.4249998E-08	0.4068999E 02	0.4499999E-08	0.3964999E 02	0.4750000E-08	0.3862000E 02	0.4750000E-08	0.3862000E 02
0.4999997E-08	0.3757999E 02	0.5249998E-08	0.3653999E 02	0.5499999E-08	0.3550000E 02	0.5499999E-08	0.3550000E 02
0.5750000E-08	0.3445999E 02	0.5999997E-08	0.3331000E 02	0.6299999E-08	0.3206999E 02	0.6299999E-08	0.3206999E 02
0.6599997E-08	0.3081999E 02	0.6899999E-08	0.2956999E 02	0.7199997E-08	0.2812000E 02	0.7199997E-08	0.2812000E 02
0.7599997E-08	0.2645000E 02	0.7999997E-08	0.2478999E 02	0.8399997E-08	0.2312999E 02	0.8399997E-08	0.2312999E 02
0.8799997E-08	0.2145999E 02	0.9199997E-08	0.1979999E 02	0.9599997E-08	0.1814000E 02	0.9599997E-08	0.1814000E 02
0.9999997E-08	0.1720000E 02	0.1050000E-07	0.1698999E 02	0.1100000E-07	0.1678000E 02	0.1100000E-07	0.1678000E 02
0.1150000E-07	0.1656999E 02	0.1200000E-07	0.1631000E 02	0.1275000E-07	0.1599000E 02	0.1275000E-07	0.1599000E 02
0.1350000E-07	0.1568000E 02	0.1425000E-07	0.1536000E 02	0.1500000E-07	0.1500000E 02	0.1500000E-07	0.1500000E 02
0.1600000E-07	0.1458000E 02	0.1700000E-07	0.1416000E 02	0.1800000E-07	0.1374000E 02	0.1800000E-07	0.1374000E 02
0.1900000E-07	0.1332000E 02	0.2000000E-07	0.1290000E 02	0.2100000E-07	0.1248000E 02	0.2100000E-07	0.1248000E 02
0.2200000E-07	0.1206000E 02	0.2300000E-07	0.1164000E 02	0.2400000E-07	0.1111000E 02	0.2400000E-07	0.1111000E 02
0.2550000E-07	0.1076000E 02	0.2700000E-07	0.1060000E 02	0.2800000E-07	0.1041000E 02	0.2800000E-07	0.1041000E 02
0.3000000E-07	0.1016000E 02	0.3200000E-07	0.9900999E 01	0.3400000E-07	0.9646999E 01	0.3400000E-07	0.9646999E 01
0.3600000E-07	0.9391999E 01	0.3800000E-07	0.9138000E 01	0.4000000E-07	0.8851999E 01	0.4000000E-07	0.8851999E 01
0.4250000E-07	0.8533999E 01	0.4500000E-07	0.8216000E 01	0.4750000E-07	0.7898000E 01	0.4750000E-07	0.7898000E 01
0.5000000E-07	0.7683000E 01	0.5250000E-07	0.7568999E 01	0.5500000E-07	0.7455999E 01	0.5500000E-07	0.7455999E 01
0.5750000E-07	0.7342999E 01	0.5999999E-07	0.7217999E 01	0.6299996E-07	0.7082000E 01	0.6299996E-07	0.7082000E 01

0.6599998E-07	0.6945999E 01	0.6899995E-07	0.6809999E 01	0.7199998E-07	0.6650999E 01
0.7599999E-07	0.6469999E 01	0.7599995E-07	0.6289000E 01	0.8399996E-07	0.6106999E 01
0.8799998E-07	0.5926000E 01	0.9199999E-07	0.5745000E 01	0.9599995E-07	0.5563000E 01
0.9999997E-07	0.5462000E 01	0.1050000E-06	0.5441999E 01	0.1100000E-06	0.5421000E 01
0.1150000E-06	0.5400000E 01	0.1200000E-06	0.5374000E 01	0.1275000E-06	0.5342999E 01
0.1350000E-06	0.5311999E 01	0.1425000E-06	0.5280000E 01	0.1499999E-06	0.5243999E 01
0.1600000E-06	0.5202000E 01	0.1700000E-06	0.5160999E 01	0.1800000E-06	0.5118999E 01
0.1900000E-06	0.5077999E 01	0.2000000E-06	0.5035999E 01	0.2100000E-06	0.4995000E 01
0.2199999E-06	0.4952999E 01	0.2300000E-06	0.4910999E 01	0.2400000E-06	0.4858999E 01
0.2550000E-06	0.4797000E 01	0.2700000E-06	0.4745000E 01	0.2800000E-06	0.4683000E 01
0.3000000E-06	0.4599999E 01	0.3200000E-06	0.4516000E 01	0.3400000E-06	0.4433000E 01
0.3599999E-06	0.4349999E 01	0.3800000E-06	0.4266999E 01	0.4000000E-06	0.4172999E 01
0.4250000E-06	0.4068999E 01	0.4500000E-06	0.3964999E 01	0.4750000E-06	0.3862000E 01
0.5000000E-06	0.3757999E 01	0.5250000E-06	0.3653999E 01	0.5500000E-06	0.3549999E 01
0.5749999E-06	0.3445999E 01	0.6000000E-06	0.3330999E 01	0.6300000E-06	0.3207000E 01
0.6600000E-06	0.3082000E 01	0.6900000E-06	0.2957000E 01	0.7199999E-06	0.2811999E 01
0.7600000E-06	0.2645000E 01	0.8000000E-06	0.2478999E 01	0.8400000E-06	0.2313000E 01
0.8800000E-06	0.2146000E 01	0.9200000E-06	0.1980000E 01	0.9599999E-06	0.1813999E 01
0.9999994E-06	0.1726999E 01	0.1050000E-05	0.1721000E 01	0.1099999E-05	0.1714000E 01
0.1150000E-05	0.1707999E 01	0.1199999E-05	0.1698999E 01	0.1275000E-05	0.1688999E 01
0.1349999E-05	0.1679999E 01	0.1425000E-05	0.1669999E 01	0.1500000E-05	0.1658000E 01
0.1599999E-05	0.1645000E 01	0.1699999E-05	0.1632000E 01	0.1799999E-05	0.1618999E 01
0.1900000E-05	0.1606000E 01	0.2000000E-05	0.1592999E 01	0.2100000E-05	0.1579000E 01
0.2199999E-05	0.1566000E 01	0.2299999E-05	0.1552999E 01	0.2399999E-05	0.1537000E 01
0.2549999E-05	0.1516999E 01	0.2700000E-05	0.1500000E 01	0.2799999E-05	0.1481000E 01
0.2999999E-05	0.1454000E 01	0.3200000E-05	0.1427999E 01	0.3400000E-05	0.1401999E 01
0.3599999E-05	0.1375999E 01	0.3800000E-05	0.1349000E 01	0.4000000E-05	0.1320000E 01
0.4250000E-05	0.1287000E 01	0.4500000E-05	0.1254000E 01	0.4750000E-05	0.1221000E 01
0.5000000E-05	0.1188000E 01	0.5250000E-05	0.1155000E 01	0.5499999E-05	0.1122000E 01
0.5749999E-05	0.1089999E 01	0.5999999E-05	0.1052999E 01	0.6300000E-05	0.1014000E 01
0.6599999E-05	0.9746000E 00	0.6900000E-05	0.9351000E 00	0.7199999E-05	0.8891000E 00
0.7600000E-05	0.8365000E 00	0.8000000E-05	0.7839000E 00	0.8399999E-05	0.7313000E 00
0.8800000E-05	0.6787000E 00	0.9199999E-05	0.6262000E 00	0.9599999E-05	0.5736000E 00
0.1000000E-04	0.5462000E 00	0.1050000E-04	0.5441999E 00	0.1100000E-04	0.5421000E 00
0.1150000E-04	0.5400000E 00	0.1200000E-04	0.5373999E 00	0.1275000E-04	0.5343000E 00
0.1350000E-04	0.5312000E 00	0.1425000E-04	0.5280000E 00	0.1500000E-04	0.5244000E 00
0.1599999E-04	0.5202000E 00	0.1700000E-04	0.5161000E 00	0.1799999E-04	0.5118999E 00
0.1900000E-04	0.5078000E 00	0.1999999E-04	0.5035999E 00	0.2100000E-04	0.4995000E 00
0.2199999E-04	0.4953000E 00	0.2299999E-04	0.4911000E 00	0.2399999E-04	0.4858999E 00
0.2549999E-04	0.4797000E 00	0.2699999E-04	0.4744999E 00	0.2799999E-04	0.4683000E 00
0.3000000E-04	0.4600000E 00	0.3200000E-04	0.4516000E 00	0.3400000E-04	0.4433000E 00
0.3600000E-04	0.4349999E 00	0.3800000E-04	0.4267000E 00	0.4000000E-04	0.4173000E 00
0.4249999E-04	0.4069000E 00	0.4499999E-04	0.3965000E 00	0.4750000E-04	0.3862000E 00
0.4999999E-04	0.3758000E 00	0.5249999E-04	0.3654000E 00	0.5500000E-04	0.3549999E 00
0.5749999E-04	0.3446000E 00	0.5999999E-04	0.3331000E 00	0.6300000E-04	0.3207000E 00
0.6599999E-04	0.3081999E 00	0.6899999E-04	0.2957000E 00	0.7199999E-04	0.2812000E 00
0.7600000E-04	0.2645000E 00	0.8000000E-04	0.2478999E 00	0.8400000E-04	0.2313000E 00
0.8799999E-04	0.2146000E 00	0.9199999E-04	0.1980000E 00	0.9599999E-04	0.1813999E 00
0.9999999E-04	0.1720999E 00	0.1050000E-03	0.1702999E 00	0.1100000E-03	0.1684999E 00
0.1150000E-03	0.1666999E 00	0.1200000E-03	0.1644000E 00	0.1275000E-03	0.1616000E 00
0.1350000E-03	0.1589000E 00	0.1425000E-03	0.1561000E 00	0.1500000E-03	0.1529000E 00
0.1600000E-03	0.1493000E 00	0.1700000E-03	0.1456000E 00	0.1800000E-03	0.1420000E 00
0.1900000E-03	0.1382999E 00	0.2000000E-03	0.1346999E 00	0.2100000E-03	0.1310000E 00
0.2200000E-03	0.1273000E 00	0.2300000E-03	0.1237000E 00	0.2400000E-03	0.1191000E 00
0.2549998E-03	0.1136000E 00	0.2700000E-03	0.1091000E 00	0.2799998E-03	0.1036000E 00
0.3000000E-03	0.9878999E-01	0.3199999E-03	0.9653997E-01	0.3399998E-03	0.9427994E-01
0.3599999E-03	0.9202999E-01	0.3799999E-03	0.8977997E-01	0.3999998E-03	0.8724999E-01
0.4250000E-03	0.8442998E-01	0.4499999E-03	0.8161998E-01	0.4749999E-03	0.7879996E-01
0.4999998E-03	0.7621998E-01	0.5249998E-03	0.7386994E-01	0.5500000E-03	0.6966999E-01
0.5750000E-03	0.1536000E 00	0.5999999E-03	0.2144000E 00	0.6299999E-03	0.2818000E 00
0.6599999E-03	0.3474000E 00	0.6899999E-03	0.4148999E 00	0.7199999E-03	0.5030000E 00
0.7600000E-03	0.5989000E 00	0.7999998E-03	0.6942000E 00	0.8399999E-03	0.7884000E 00
0.8799999E-03	0.8767999E 00	0.9199998E-03	0.9694000E 00	0.9599999E-03	0.1049999E 01
0.9999999E-03	0.1169000E 01	0.1050000E-02	0.1334000E 01	0.1100000E-02	0.1229000E 02
0.1150000E-02	0.1238000E 02	0.1200000E-02	0.1686000E 01	0.1275000E-02	0.1820999E 01
0.1350000E-02	0.1966999E 01	0.1425000E-02	0.2110000E 01	0.1500000E-02	0.2273999E 01

0.1600000E-02	0.2584999E 01	0.1700000E-02	0.2625999E 01	0.1800000E-02	0.2792000E 01
0.1900000E-02	0.2952000E 01	0.2000000E-02	0.3106999E 01	0.2100000E-02	0.3257999E 01
0.2200000E-02	0.3405000E 01	0.2300000E-02	0.3575000E 01	0.2400000E-02	0.3714999E 01
0.2550000E-02	0.3910000E 01	0.2700000E-02	0.4068000E 01	0.2800000E-02	0.4247999E 01
0.3000000E-02	0.4487000E 01	0.3200000E-02	0.4733999E 01	0.3400000E-02	0.4985999E 01
0.3600000E-02	0.5414000E 01	0.3800000E-02	0.7471999E 01	0.3999997E-02	0.6841999E 01
0.4249997E-02	0.6120999E 01	0.4499998E-02	0.6250999E 01	0.4749998E-02	0.6502000E 01
0.4999999E-02	0.6849000E 01	0.5249999E-02	0.7358999E 01	0.5500000E-02	0.8188000E 01
0.5749997E-02	0.1039000E 02	0.5999997E-02	0.1731000E 02	0.6299999E-02	0.1548000E 02
0.6600000E-02	0.1438000E 02	0.6899998E-02	0.1825999E 02	0.7199999E-02	0.2992999E 02
0.7599998E-02	0.4575999E 02	0.7999998E-02	0.3839999E 02	0.8399997E-02	0.2579999E 02
0.8800000E-02	0.1923999E 02	0.9199999E-02	0.1614000E 02	0.9599999E-02	0.1422000E 02
0.1080000E-01	0.1308000E 02	0.1C50000E-01	0.1230000E 02	0.1100000E-01	0.1191000E 02
0.1150000E-01	0.1145000E 02	0.1200000E-01	0.1114000E 02	0.1275000E-01	0.1086000E 02
0.1350000E-01	0.1061000E 02	0.1425000E-01	0.1038000E 02	0.1500000E-01	0.9947000E 01
0.1600000E-01	0.9448000E 01	0.1700000E-01	0.8834000E 01	0.1800000E-01	0.8124000E 01
0.1900000E-01	0.7339000E 01	0.2000000E-01	0.6537999E 01	0.2100000E-01	0.5863000E 01
0.2200000E-01	0.5007999E 01	0.2300000E-01	0.3605000E 01	0.2400000E-01	0.3919000E 01
0.2550000E-01	0.6075999E 02	0.2700000E-01	0.4355999E 03	0.2800000E-01	0.4288999E 03
0.3000000E-01	0.1579000E 03	0.3200000E-01	0.1011000E 03	0.3400000E-01	0.8106999E 02
0.3600000E-01	0.7139999E 02	0.3800000E-01	0.6620000E 02	0.4000000E-01	0.6275000E 02
0.4250000E-01	0.6051999E 02	0.4500000E-01	0.5931000E 02	0.4750000E-01	0.5931999E 02
0.5000000E-01	0.8028999E 02	0.5250000E-01	0.8423999E 02	0.5500000E-01	0.7093999E 02
0.5750000E-01	0.6825999E 02	0.6000000E-01	0.6025000E 02	0.6299996E-01	0.5229999E 02
0.6599998E-01	0.4575000E 02	0.6899995E-01	0.4134999E 02	0.7199997E-01	0.1995000E 03
0.7599998E-01	0.7814999E 02	0.7999998E-01	0.1617000E 03	0.8399999E-01	0.2783999E 03
0.8800000E-01	0.1407000E 03	0.9199995E-01	0.1141000E 03	0.9599996E-01	0.1146000E 03
0.9999996E-01	0.1052000E 03	0.1C50000E 00	0.9306000E 02	0.1100000E 00	0.9023999E 02
0.1149999E 00	0.7400000E 02	0.1199999E 00	0.7067000E 02	0.1275000E 00	0.1295000E 03
0.1350000E 00	0.2200000E 03	0.1425000E 00	0.2531000E 03	0.1500000E 00	0.1306000E 03
0.1600000E 00	0.1148000E 03	0.1700000E 00	0.1475000E 03	0.1799999E 00	0.2230000E 03
0.1900000E 00	0.3248999E 03	0.2000000E 00	0.2014000E 03	0.2100000E 00	0.1124000E 03
0.2200000E 00	0.2675000E 03	0.2300000E 00	0.1540000E 03	0.2399999E 00	0.1783000E 03
0.2550000E 00	0.1339000E 03	0.2700000E 00	0.2411000E 03	0.2800000E 00	0.1921000E 03
0.3000000E 00	0.1422000E 03	0.3200000E 00	0.2977000E 03	0.3400000E 00	0.1503000E 03
0.3600000E 00	0.2917000E 03	0.3800000E 00	0.5052000E 03	0.4000000E 00	0.5087998E 03
0.4250000E 00	0.3875999E 03	0.4500000E 00	0.3022998E 03	0.4750000E 00	0.3188999E 03
0.5000000E 00	0.3642998E 03	0.5250000E 00	0.2972000E 03	0.5500000E 00	0.2685999E 03
0.5750000E 00	0.2788999E 03	0.6000000E 00	0.1931000E 03	0.6300000E 00	0.2257000E 03
0.6600000E 00	0.4492000E 03	0.6900000E 00	0.3498999E 03	0.7200000E 00	0.6007000E 03
0.7600000E 00	0.6220000E 03	0.8000000E 00	0.4098999E 03	0.8400000E 00	0.4067998E 03
0.8800000E 00	0.3190999E 03	0.9200000E 00	0.2486000E 03	0.9600000E 00	0.4607000E 03
0.1000000E 01	0.5042000E 03	0.1099999E 01	0.4377000E 03	0.1200000E 01	0.6973999E 03
0.1299999E 01	0.6512000E 03	0.1400000E 01	0.7855000E 03	0.1500000E 01	0.9152998E 03
0.1599999E 01	0.8127000E 03	0.1700000E 01	0.7757000E 03	0.1799999E 01	0.8195000E 03
0.1900000E 01	0.9885999E 03	0.2000000E 01	0.1068000E 04	0.2099999E 01	0.1028000E 04
0.2200000E 01	0.1006000E 04	0.2299999E 01	0.1096000E 04	0.2400000E 01	0.1214000E 04
0.2500000E 01	0.1373000E 04	0.2599999E 01	0.1198000E 04	0.2700000E 01	0.1259000E 04
0.2799999E 01	0.1275000E 04	0.2900000E 01	0.1265000E 04	0.3000000E 01	0.1365000E 04
0.3099999E 01	0.1389000E 04	0.3200000E 01	0.1352000E 04	0.3299999E 01	0.1342000E 04
0.3400000E 01	0.1395000E 04	0.3500000E 01	0.1330000E 04	0.3599999E 01	0.1434000E 04
0.3700000E 01	0.1457000E 04	0.3799999E 01	0.1508000E 04	0.3900000E 01	0.1490000E 04
0.4000000E 01	0.1556000E 04	0.4099999E 01	0.1595000E 04	0.4200000E 01	0.1562000E 04
0.4299999E 01	0.1615000E 04	0.4400000E 01	0.1555000E 04	0.4500000E 01	0.1663000E 04
0.4599999E 01	0.1643000E 04	0.4700000E 01	0.1676000E 04	0.4799999E 01	0.1719000E 04
0.4900000E 01	0.1705000E 04	0.5000000E 01	0.1718000E 04	0.5099999E 01	0.1747000E 04
0.5200000E 01	0.1752000E 04	0.5299999E 01	0.1785000E 04	0.5400000E 01	0.1793000E 04
0.5500000E 01	0.1792000E 04	0.5599999E 01	0.1826000E 04	0.5700000E 01	0.1825000E 04
0.5799999E 01	0.1830000E 04	0.5900000E 01	0.1851000E 04	0.6000000E 01	0.1872000E 04
0.6099999E 01	0.1862000E 04	0.6200000E 01	0.1873000E 04	0.6299999E 01	0.1928000E 04
0.6400000E 01	0.1927000E 04	0.6500000E 01	0.1948000E 04	0.6599999E 01	0.1958000E 04
0.6700000E 01	0.1964000E 04	0.6799999E 01	0.1982000E 04	0.6900000E 01	0.1980000E 04
0.7000000E 01	0.1987000E 04	0.7099999E 01	0.2010000E 04	0.7200000E 01	0.2010000E 04
0.7299999E 01	0.2040000E 04	0.7400000E 01	0.2038000E 04	0.7500000E 01	0.2062000E 04
0.7599999E 01	0.2052000E 04	0.7700000E 01	0.2068000E 04	0.7799999E 01	0.2085000E 04
0.7900000E 01	0.2089000E 04	0.8000000E 01	0.2092000E 04	0.8099999E 01	0.2095000E 04

0.8200000E 01	0.2117000E 04	0.8299999E 01	0.2150000E 04	0.8400000E 01	0.2150000E 04
0.8500000E 01	0.2146000E 04	0.8599999E 01	0.2143000E 04	0.8700000E 01	0.2163000E 04
0.8799999E 01	0.2181000E 04	0.8900000E 01	0.2194000E 04	0.9000000E 01	0.2207000E 04
0.9099999E 01	0.2220000E 04	0.9200000E 01	0.2232000E 04	0.9299999E 01	0.2245000E 04
0.9400000E 01	0.2258000E 04	0.9500000E 01	0.2269000E 04	0.9599999E 01	0.2279000E 04
0.9700000E 01	0.2289000E 04	0.9799999E 01	0.2299000E 04	0.9900000E 01	0.2308000E 04
0.1000000E 02	0.2320000E 04	0.1010000E 02	0.2332000E 04	0.1020000E 02	0.2344000E 04
0.1030000E 02	0.2356000E 04	0.1040000E 02	0.2369000E 04	0.1050000E 02	0.2381000E 04
0.1060000E 02	0.2394000E 04	0.1070000E 02	0.2407000E 04	0.1080000E 02	0.2419000E 04
0.1090000E 02	0.2432000E 04	0.1100000E 02	0.2444000E 04	0.1110000E 02	0.2455000E 04
0.1120000E 02	0.2466000E 04	0.1130000E 02	0.2479000E 04	0.1140000E 02	0.2490000E 04
0.1150000E 02	0.2503000E 04	0.1160000E 02	0.2514000E 04	0.1170000E 02	0.2524000E 04
0.1180000E 02	0.2532000E 04	0.1190000E 02	0.2540000E 04	0.1200000E 02	0.2546000E 04
0.1210000E 02	0.2551000E 04	0.1220000E 02	0.2556000E 04	0.1230000E 02	0.2567000E 04
0.1240000E 02	0.2582000E 04	0.1250000E 02	0.2592000E 04	0.1260000E 02	0.2601000E 04
0.1270000E 02	0.2615000E 04	0.1280000E 02	0.2629000E 04	0.1290000E 02	0.2642000E 04
0.1300000E 02	0.2655000E 04	0.1310000E 02	0.2668000E 04	0.1320000E 02	0.2683000E 04
0.1330000E 02	0.2697000E 04	0.1340000E 02	0.2713000E 04	0.1350000E 02	0.2730000E 04
0.1360000E 02	0.2747000E 04	0.1370000E 02	0.2767000E 04	0.1380000E 02	0.2786000E 04
0.1390000E 02	0.2806000E 04	0.1400000E 02	0.2824000E 04	0.1410000E 02	0.2840000E 04
0.1420000E 02	0.2857000E 04	0.1430000E 02	0.2874000E 04	0.1440000E 02	0.2890000E 04
0.1450000E 02	0.2905000E 04	0.1460000E 02	0.2917000E 04	0.1470000E 02	0.2929000E 04
0.1480000E 02	0.2941000E 04	0.1490000E 02	0.2954000E 04	0.1500000E 02	0.2958000E 04
0.1510000E 02	0.2955000E 04	0.1520000E 02	0.2952000E 04	0.1530000E 02	0.2948000E 04
0.1540000E 02	0.2942000E 04	0.1550000E 02	0.2938000E 04	0.1560000E 02	0.2936000E 04
0.1570000E 02	0.2932000E 04	0.1580000E 02	0.2928000E 04	0.1590000E 02	0.2924000E 04
0.1600000E 02	0.2924000E 04	0.1609999E 02	0.2928000E 04	0.1620000E 02	0.2932000E 04
0.1629999E 02	0.2936000E 04	0.1639999E 02	0.2940000E 04	0.1650000E 02	0.2944000E 04
0.1659999E 02	0.2948000E 04	0.1670000E 02	0.2951000E 04	0.1679999E 02	0.2955000E 04
0.1689999E 02	0.2958000E 04	0.1700000E 02	0.2966000E 04	0.1709999E 02	0.2978000E 04
0.1720000E 02	0.2990000E 04	0.1729999E 02	0.3003000E 04	0.1739999E 02	0.3014000E 04
0.1750000E 02	0.3026000E 04	0.1759999E 02	0.3037000E 04	0.1770000E 02	0.3049000E 04
0.1779999E 02	0.3061000E 04	0.1789999E 02	0.3073000E 04	0.1800000E 02	0.3087000E 04
0.1809999E 02	0.3102000E 04	0.1820000E 02	0.3118000E 04	0.1829999E 02	0.3133000E 04
0.1839999E 02	0.3149000E 04	0.1850000E 02	0.3164000E 04	0.1859999E 02	0.3180000E 04
0.1870000E 02	0.3195000E 04	0.1879999E 02	0.3211000E 04	0.1889999E 02	0.3226000E 04
0.1900000E 02	0.3239000E 04	0.1909999E 02	0.3249000E 04	0.1920000E 02	0.3259000E 04
0.1929999E 02	0.3269000E 04	0.1939999E 02	0.3279000E 04	0.1950000E 02	0.3289000E 04
0.1959999E 02	0.3300000E 04	0.1970000E 02	0.3310000E 04	0.1979999E 02	0.3320000E 04
0.1989999E 02	0.3331000E 04	0.2000000E 02	0.0		

SUMMARY OF COMPUTED BOUNDS AND ESTIMATES

CUTOFF ENERGY (MEV)		INTEGRAL RESPONSE			DIFFERENCE BETWEEN BOUND AND ESTIMATE	
LOW	HIGH	LOWER BOUND	ESTIMATED VALUE	UPPER BOUND	LOWER BOUND	UPPER BOUND (PERCENT)
0.0	2.00E 01	0.0	1.50E 15	0.0	0.0	0.0

START OF A NEW SET OF DATA

REACTION RATE DATA

FOILS PLACED BETWEEN WINDOW AND CORE

FOIL NO	REACTION NAME	COVER NAME	COVER THICKNESS 1/BAEN	SATURATION ACTIVITY DPS/TARGET ATOM	REL. ERROR
1	NI58PX		0.0	1.510E-11	0.0500
2	FE54PX		0.0	1.280E-11	0.0500
3	AL27AX		0.0	9.630E-14	0.0500
4	CO59GX		0.0	4.730E-09	0.0500

PROCEDURAL DATA

SCALE CALCULATED LEAKAGE TO CONFORM WITH FOIL ACTIVITIES

BOUNDS ONLY COMPUTED

CROSS SECTION DATA SET

CROSS SECTION ACCURACY 5.00 PERCENT

INPUT FLUX DATA

SPECTRUM OBTAINED WITH ANISN CCDE

LOW TEMPERATURE EXTRAPOLATION:
MAXWELLIAN EXTRAPOLATIONHIGH TEMPERATURE EXTRAPOLATION:
FISSION EXTRAPOLATION

MODERATOR TEMPERATURE = 20.00 CENTIGRADE

OBJECT TIME READ FORMAT FOR FLUX INPUT
(9E8.3)

I	ULC	UHI	PHI(U)*DU	ELO	EHI	EBAR	PHI(E)
1	-6.93E-01	4.41E-01	5.43E-03	6.43E 00	2.00E 01	1.13E 01	4.00E-04
2	4.41E-01	7.34E-01	9.65E-03	4.80E 00	6.43E 00	5.56E 00	5.90E-03
3	7.34E-01	1.20E 00	3.03E-02	3.00E 00	4.80E 00	3.79E 00	1.69E-02
4	1.20E 00	1.45E 00	2.56E-02	2.36E 00	3.00E 00	2.66E 00	3.96E-02
5	1.45E 00	2.00E 00	5.83E-02	1.36E 00	2.36E 00	1.79E 00	5.83E-02
6	2.00E 00	2.50E 00	4.77E-02	8.20E-01	1.36E 00	1.05E 00	8.89E-02
7	2.50E 00	3.00E 00	4.30E-02	4.99E-01	8.20E-01	6.40E-01	1.34E-01
8	3.00E 00	3.41E 00	2.54E-02	3.30E-01	4.99E-01	4.06E-01	1.50E-01
9	3.41E 00	4.20E 00	3.75E-02	1.50E-01	3.30E-01	2.22E-01	2.08E-01
10	4.20E 00	4.60E 00	1.50E-02	1.00E-01	1.50E-01	1.22E-01	3.00E-01
11	4.60E 00	6.64E 00	5.26E-02	1.30E-02	1.00E-01	3.61E-02	6.04E-01
12	6.64E 00	1.13E 01	9.26E-02	1.22E-04	1.30E-02	1.26E-03	7.19E 00
13	1.13E 01	1.55E 01	7.88E-02	1.86E-06	1.22E-04	1.51E-05	6.53E 02
14	1.55E 01	1.67E 01	2.49E-02	5.48E-07	1.86E-06	1.01E-06	1.90E 04
15	1.67E 01	2.76E 01	3.01E-01	1.00E-11	5.48E-07	2.34E-09	5.49E 05

GROUP FLUXES ARE NOT CONSIDERED IN THE COMPUTATION OF UNFOLDING AND BOUNDS

1-TH ITERATION, RELATIVE ERROR= 883.895 PERCENT

2-TH ITERATION, RELATIVE ERROR= 209.676 PERCENT

3-TH ITERATION, RELATIVE ERROR= 63.488 PERCENT

4-TH ITERATION, RELATIVE ERROR= 19.967 PERCENT

5-TH ITERATION, RELATIVE ERROR= 6.528 PERCENT

FIRST ATTEMPT TO DETERMINE DIFFERENTIAL FLUX FROM GROUP FLUXES HAS FAILED

CRYSTAL BALL IS APPLIED TO THE DETERMINATION OF DIFFERENTIAL SPECTRUM FROM GROUP FLUXES

ITERATION NO= 1 KGAM= 1 GAMMA= 1.0000000E 02

THE MAXIMUM ERROR BETWEEN GIVEN AND COMPUTED GROUP FLUXES IS 0.69 PERCENT

ACCURACY SPECIFICATION SATISFIED AFTER 1 ITERATIONS

GROUP NO.	INPUT FLUX	COMPUTED FLUX
1	.543E-02	.545E-02
2	.965E-02	.961E-02
3	.303E-01	.304E-01
4	.256E-01	.255E-01
5	.583E-01	.583E-01
6	.477E-01	.477E-01
7	.430E-01	.430E-01
8	.254E-01	.254E-01
9	.375E-01	.374E-01
10	.150E-01	.150E-01
11	.526E-01	.526E-01
12	.926E-01	.927E-01
13	.788E-01	.786E-01
14	.249E-01	.250E-01
15	.301E 00	.299E 00

NEW WINDOW FUNCTION

WINDOW PARAMETERS CHOSEN TO SUPPRESS COMPUTATION OF INTEGRAL FLUXES

BOTH UPPER AND LOWER BOUNDS REQUESTED

BOUNDS ARE BASED ON MEASURED ACTIVITIES

WRONG INPUT PARAMETER FOR WINDOW FUNCTION

COMPUTATION OF BOUNDS AND ESTIMATES DELETED

COMPARISON BETWEEN MEASURED AND COMPUTED ACTIVITIES

FOIL NO	REACTION NAME	ACTIVITY MEASURED	ACTIVITY COMPUTED	RELATIVE DIFFERENCE
1	NI58PX	1.510E-11	2.294E-26	5.284E-01
2	FE54PX	1.280E-11	1.753E-26	5.750E-01
3	AL27AX	9.630E-14	2.500E-28	1.941E-01
4	CO59GX	4.730E-09	2.208E-23	-4.487E-01

MEAN QUOTIENT BETWEEN MEASURED AND COMPUTED ACTIVITIES = 3.104E 14, VARIANCE= 4.607E-01

1-TH CALIBRATION OF GROUP FLUXES
 NEW SCALE FACTOR= 3.10E 14, OLD SCALE FACTOR= 1.00E 00

START OF A NEW SET OF DATA

NEW WINDOW FUNCTION

PROCEDURE TO FIND GROUP AVERAGED CROSS SECTIONS

COMPUTATION OF BOUNDS OMITTED

BOUNDS ARE BASED ON TRIAL SPECTRUM

15 SUCCESSIVE WINDOWS ARE COMPUTED

NO	LOW ENERGY	HIGH ENERGY
1	1.50E 01	2.00E 01
2	1.00E 01	1.50E 01
3	6.00E 00	1.00E 01
4	3.50E 00	6.00E 00
5	2.30E 00	3.50E 00
6	1.40E 00	2.30E 00
7	1.00E 00	1.40E 00
8	8.00E-01	1.00E 00
9	5.00E-01	8.00E-01
10	3.00E-01	5.00E-01
11	2.00E-01	3.00E-01
12	1.00E-01	2.00E-01
13	1.00E-02	1.00E-01
14	1.00E-05	1.00E-02
15	1.00E-09	1.00E-05

THE INTEGRAL RESPONSE FUNCTION $R(E)$ IS
A CONSTANT

THE GROUP FLUXES ARE COMPUTED FIRST

SUMMARY OF COMPUTED BOUNDS AND ESTIMATES

CUTOFF ENERGY (MEV)		INTEGRAL RESPONSE			DIFFERENCE BETWEEN BOUND AND ESTIMATE		
LOW	HIGH	LOWER BOUND	ESTIMATED VALUE	UPPER BOUND	LOWER BOUND	UPPER BOUND	(PERCENT)
1.50E 01	2.00E 01	0.0	2.06E-05	0.0	0.0	0.0	0.0
1.00E 01	1.50E 01	0.0	7.79E-04	0.0	0.0	0.0	0.0
6.00E 00	1.00E 01	0.0	6.28E-03	0.0	0.0	0.0	0.0
3.50E 00	6.00E 00	0.0	2.58E-02	0.0	0.0	0.0	0.0
2.30E 00	3.50E 00	0.0	4.07E-02	0.0	0.0	0.0	0.0
1.40E 00	2.30E 00	0.0	5.25E-02	0.0	0.0	0.0	0.0
1.00E 00	1.40E 00	0.0	3.25E-02	0.0	0.0	0.0	0.0
8.00E-01	1.00E 00	0.0	2.07E-02	0.0	0.0	0.0	0.0
5.00E-01	8.00E-01	0.0	4.06E-02	0.0	0.0	0.0	0.0
3.00E-01	5.00E-01	0.0	3.07E-02	0.0	0.0	0.0	0.0
2.00E-01	3.00E-01	0.0	2.00E-02	0.0	0.0	0.0	0.0
1.00E-01	2.00E-01	0.0	2.73E-02	0.0	0.0	0.0	0.0
1.00E-02	1.00E-01	0.0	5.84E-02	0.0	0.0	0.0	0.0
1.00E-05	1.00E-02	0.0	1.33E-01	0.0	0.0	0.0	0.0
1.00E-09	1.00E-05	0.0	3.48E-01	0.0	0.0	0.0	0.0

START OF A NEW SET OF DATA

NEW WINDOW FUNCTION

NOW THE CROSS SECTION OF C059G IS THE NEW RESPONSE FUNCTION

COMPUTATION OF BOUNDS OMITTED

BOUNDS ARE BASED ON TRIAL SPECTRUM

THE INTEGRAL RESPONSE FUNCTION $R(E)$ IS
THE CROSS SECTION OF THE LAST FOIL

GROUP RESPONSES OF C059G ARE FOUND, TO BE DIVIDED BY GROUP FLUXES

SUMMARY OF COMPUTED BOUNDS AND ESTIMATES

CUTOFF ENERGY (MEV)		INTEGRAL RESPONSE			DIFFERENCE BETWEEN BOUND AND ESTIMATE		
LOW	HIGH	LOWER BOUND	ESTIMATED VALUE	UPPER BOUND	LOWER BOUND	UPPER BOUND	(PERCENT)
1.50E 01	2.00E 01	0.0	3.03E-08	0.0	0.0	0.0	
1.00E 01	1.50E 01	0.0	1.27E-06	0.0	0.0	0.0	
6.00E 00	1.00E 01	0.0	1.20E-05	0.0	0.0	0.0	
3.50E 00	6.00E 00	0.0	6.23E-05	0.0	0.0	0.0	
2.30E 00	3.50E 00	0.0	1.28E-04	0.0	0.0	0.0	
1.40E 00	2.30E 00	0.0	2.55E-04	0.0	0.0	0.0	
1.00E 00	1.40E 00	0.0	2.43E-04	0.0	0.0	0.0	
8.00E-01	1.00E 00	0.0	1.73E-04	0.0	0.0	0.0	
5.00E-01	8.00E-01	0.0	3.36E-04	0.0	0.0	0.0	
3.00E-01	5.00E-01	0.0	3.32E-04	0.0	0.0	0.0	
2.00E-01	3.00E-01	0.0	2.76E-04	0.0	0.0	0.0	
1.00E-01	2.00E-01	0.0	5.14E-04	0.0	0.0	0.0	
1.00E-02	1.00E-01	0.0	1.65E-03	0.0	0.0	0.0	
1.00E-05	1.00E-02	0.0	1.18E 00	0.0	0.0	0.0	
1.00E-09	1.00E-05	0.0	1.89E 01	0.0	0.0	0.0	

START OF A NEW SET OF DATA

NEW WINDOW FUNCTION

NOW THE CROSS SECTION OF AL27A IS THE NEW RESPONSE FUNCTION

COMPUTATION OF BOUNDS OMITTED

BOUNDS ARE BASED ON TRIAL SPECTRUM

THE INTEGRAL RESPONSE FUNCTION $R(E)$ IS
THE CROSS SECTION OF THE LAST FOIL

GROUP RESPONSES OF AL27A ARE FOUND, TO BE DIVIDED BY GROUP FLUXES

SUMMARY OF COMPUTED BOUNDS AND ESTIMATES

CUTOFF ENERGY (MEV)		INTEGRAL RESPONSE			DIFFERENCE BETWEEN BOUND AND ESTIMATE		
LOW	HIGH	LOWER BOUND	ESTIMATED VALUE	UPPER BOUND	LOWER BOUND	UPPER BOUND	(PERCENT)
1.50E 01	2.00E 01	0.0	1.99E-06	0.0	0.0	0.0	
1.00E 01	1.50E 01	0.0	8.54E-05	0.0	0.0	0.0	
6.00E 00	1.00E 01	0.0	1.61E-04	0.0	0.0	0.0	
3.50E 00	6.00E 00	0.0	1.82E-06	0.0	0.0	0.0	
2.30E 00	3.50E 00	0.0	0.0	0.0	0.0	0.0	
1.40E 00	2.30E 00	0.0	0.0	0.0	0.0	0.0	
1.00E 00	1.40E 00	0.0	0.0	0.0	0.0	0.0	
8.00E-01	1.00E 00	0.0	0.0	0.0	0.0	0.0	
5.00E-01	8.00E-01	0.0	0.0	0.0	0.0	0.0	
3.00E-01	5.00E-01	0.0	0.0	0.0	0.0	0.0	
2.00E-01	3.00E-01	0.0	0.0	0.0	0.0	0.0	
1.00E-01	2.00E-01	0.0	0.0	0.0	0.0	0.0	
1.00E-02	1.00E-01	0.0	0.0	0.0	0.0	0.0	
1.00E-05	1.00E-02	0.0	0.0	0.0	0.0	0.0	
1.00E-09	1.00E-05	0.0	0.0	0.0	0.0	0.0	

START OF A NEW SET OF DATA

NEW WINDOW FUNCTION

NOW THE CROSS SECTION OF FE54P IS THE NEW RESPONSE FUNCTION

COMPUTATION OF BOUNDS OMITTED

BOUNDS ARE BASED ON TRIAL SPECTRUM

THE INTEGRAL RESPONSE FUNCTION $R(E)$ IS
THE CROSS SECTION OF THE LAST FOIL

GROUP RESPONSES OF PE54P ARE FOUND, TO BE DIVIDED BY GROUP FLUXES

SUMMARY OF COMPUTED BOUNDS AND ESTIMATES

CUTOFF ENERGY (MEV)		INTEGRAL RESPONSE			DIFFERENCE BETWEEN BOUND AND ESTIMATE	
LOW	HIGH	LOWER BOUND	ESTIMATED VALUE	UPPER BOUND	LOWER BOUND	UPPER BOUND (PERCENT)
1.50E 01	2.00E 01	0.0	4.91E-06	0.0	0.0	0.0
1.00E 01	1.50E 01	0.0	3.98E-04	0.0	0.0	0.0
6.00E 00	1.00E 01	0.0	3.55E-03	0.0	0.0	0.0
3.50E 00	6.00E 00	0.0	8.61E-03	0.0	0.0	0.0
2.30E 00	3.50E 00	0.0	4.42E-03	0.0	0.0	0.0
1.40E 00	2.30E 00	0.0	5.46E-04	0.0	0.0	0.0
1.00E 00	1.40E 00	0.0	8.22E-07	0.0	0.0	0.0
8.00E-01	1.00E 00	0.0	0.0	0.0	0.0	0.0
5.00E-01	8.00E-01	0.0	0.0	0.0	0.0	0.0
3.00E-01	5.00E-01	0.0	0.0	0.0	0.0	0.0
2.00E-01	3.00E-01	0.0	0.0	0.0	0.0	0.0
1.00E-01	2.00E-01	0.0	0.0	0.0	0.0	0.0
1.00E-02	1.00E-01	0.0	0.0	0.0	0.0	0.0
1.00E-05	1.00E-02	0.0	0.0	0.0	0.0	0.0
1.00E-09	1.00E-05	0.0	0.0	0.0	0.0	0.0

HSST DOSIMETRY EXPERIMENT - SPECTRUM AT LOCATION N-S-2

HSST DOSIMETRY EXPERIMENT - UPPER AND LOWER WINDOWS AT N-S-2

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