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Computational Work with Response Functions: The RESTRAW Program System[1]

by

Manfred Matzke*

*Present Address: Haberweg 5
D-38116 Braunschweig, Germany

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[1] A diskette with the files described can be obtained from the author.

Abstract

Computer programs for operating and handling detector response functions and other relevant data in the framework of the so-called “few-channel measurements” are described.

After the outline of the mathematical background with introduction of the group-averaged response functions and the interpolation and integration formulas, the use of the computer programs and the plotting software is explained.

It is shown how the output response function library can be created and in which way new data of detector responses or spectral fluence values can be transferred to the library. Tables with (integral) dose equivalent values are presented obtained by folding the spectral fluence data of the data bank with the conversion functions.

Finally, an example is presented in which it is explained how new data with arbitrary energy structure can be treated and can be included into the library. It is shown how to operate within the library and how to estimate the reading of a (new) detector in a (new) spectral neutron field.

Zusammenfassung

Es werden Computerprogramme beschrieben, die geeignet sind, Response-Funktionen und andere wichtige Daten im Rahmen von sogenannten “Wenig-Kanal-Messungen” zu bearbeiten.

Nach einem kurzen Überblick über den mathematischen Hintergrund und der Einführung von gruppen-gemittelten Response-Funktionen werden die verwendeten Interpolations- und Integrationsformeln beschrieben. Danach wird die Benutzung der Computer-Programme und der Grafik-Software (Plot-Software) erklärt.

Es wird gezeigt, wie eine Bibliothek von Response-Funktionen erzeugt werden kann, und auf welche Weise neue Daten von Detektor-Response-Funktionen oder spektrale Fluenzwerte der Bibliothek zugefügt werden können. Tabellen mit (integralen) Äquivalentdosiswerten sind dargestellt, die mit Hilfe der Programme aus der Datenbank durch Faltung der spektralen Fluenzwerte mit den entsprechenden Konversionsfunktionen erhalten wurden.

Zum Schluss wird anhand eines Beispiels vorgestellt, wie neue Daten mit beliebiger Energiestruktur behandelt werden können. Es werden Datenoperationen innerhalb der Bibliothek beschrieben und es wird gezeigt, wie die Anzeige eines (neuen) Detektors in einem (neuen) Neutronenfeld berechnet werden kann.

The following Fortran computer programs are described:

RESTRAW

------ to create a response function library for “few” channel unfolding,

------ to add data or response functions or fluence-to-dose conversion functions to an existing response function library,

------ to change the energy structure of an existing response function library.

SELECTDF

------ to calculate integral responses and calibration factors for detectors irradiated in a certain neutron spectrum.

FLUTRANS

------ to transform a certain file of data represented as point or group values as a function of energy from one energy grid to another. (e. g. changing the bin structure of the energy data in an existing fluence file).

PLOFW

------ to plot data files or parts of the response function library on the screen, or to create an HPGL file for subsequent plotting. The plot program may be used for a variety of data formats of the files, including the ENDF format.

PLOTAW

------ to plot control data from a plot file created while one of the codes is running.

FLUDO

------ to calculate (integral) dose equivalent values for an input neutron spectrum using files which contain the corresponding conversion function (multiplication of two energy dependent functions followed by integration).

DOSRESP

------ to transform a fluence response library to a dose equivalent response library by dividing the fluence responses through the dose equivalent conversion function.

UMSFAC

------ to transform the data of a response function library to a new library after multiplying the responses by calibration factors.

CONTENTS

1. Introduction

The evaluation of the spectral particle fluence $\Phi_E(E)$ from integrating measurements involves solving the basic system of linear integral equations [1]

$$z_{0i} = \int \mathrm{d}E\ R_i(E)\ \Phi_E(E) \qquad (i = 1,...,M) \qquad (1.1)$$

which represent the model of the measurement. The vector $\boldsymbol{z}_0^{\mathrm{T}}=(z_{01},\ldots z_{0i},\ldots z_{0M})$ denotes the (measured) readings of the detector system, more exactly: the expectation values, the real readings being $\mathbf{z}'_0 = \mathbf{z}_0 + \boldsymbol{\varepsilon}$ with the statistically fluctuating quantity $\boldsymbol{\varepsilon}$ ($^{\mathrm{T}}$ meaning transposition). The kernels $R_i(E)$ are the **response functions** for the energy E of the M detector channels of the measuring system.

In the following, computational work with the response functions of so-called “few-channel measurements” is described, the number M of eq. (1.1) being of the order of 10 or less. The aim is to have a computer program allowing response data to be easily transferred to a response function library, with which response functions can be plotted in a fast way, and with which integral values (prediction of readings) can be compiled.

A similar code called SPKTBIB [2] is already available unfortunately, the output results of SPKTBIB cannot be directly linked to programs of the HEPRO [3] unfolding package.

The response functions considered here relate to Bonner sphere spectrometers as well as to activation or fission cross sections of sets of activation or fission foils. The format of the library which can be created by the RESTRAW program is similar to the SAND-II library which was used among others, from 1980 to 1984 in the so-called REAL exercises [4] in reactor dosimetry.

In addition to response functions of various detectors (like area dosemeters (remcounters) and other dosimeters) the fluence-to-dose equivalent conversion functions can be handled in the program package and folded integral values according to eq. (1.1) can be evaluated.

The program package is completed by a number of batch files dealing with some practical examples. The output tables of calibration factors for a number of detectors and a number of calibration fields, which are presented in chapter 13, may be helpful in understanding, for instance, the reading of area dosemeters (remcounters) in different spectra.

2. Differential Quantities and Response Functions.

The response function as defined in eq. (1.1) has the properties of a so-called transmission (or transfer) function, by which the “input” quantity “fluence” is linked with the “output” quantity “detector reading” via a linear relationship. In physics, within the framework of the “linear response theory,” the left-hand side of eq. (1.1) is generally called “response,” which should not be mixed with the re presentation given here. In “linear response theory,” the kernel of the right-hand side of eq. (1.1) (here called response function) is written as a functional derivative of the detector reading, which is repeated in the following.

As is documented in a separate paper [5] the particle fluence below a certain energy E can be defined as an integral over the spectral fluence:

$$\Phi(E) = \int_0^E \mathrm{d}E'\, \Phi_E(E'), \tag{2.1}$$

where the fluence in the entire energy range is $\Phi = \Phi(\infty) = \int_0^\infty \mathrm{d}E'\, \Phi_E(E')$. Thus, the spectral fluence is the differential-quotient $\Phi_E(E) = \frac{\mathrm{d}\Phi}{\mathrm{d}E}$.

In a similar way, the reading of a detector z_0 can be written as a linear relationship to the spectral fluence:

$$z_0 = \int_0^\infty \mathrm{d}E\; R(E)\Phi_E(E) \tag{2.2}.$$

From this equation it can be seen that the reading is a linear functional of the spectral fluence. The functional derivative of z_0 can be defined by

$$\frac{\delta z_0}{\delta \Phi_E(E)} = R(E) \tag{2.3}.$$

The response function $R(E)$, therefore, is the first functional derivative of the reading differentiated with respect to the spectral fluence. This relationship could be taken into account for the notation by replacement of $R(E)$ by the identity:

$$R(E) = \frac{\delta z_0}{\delta \Phi_E(E)} = z_{0,\Phi}(E) \tag{2.4}$$

As a consequence of the linear functional relationship, the fluence-to-dose equivalent conversion coefficient can be defined as the first functional derivative of the dose equivalent differentiated with respect to fluence:

$$H^*_\Phi(E) = \frac{\delta H^*}{\delta \Phi_E(E)} \tag{2.5}$$

In the literature the index Φ is correctly used to indicate the functional derivative of the dose-equivalent, but unfortunately the notation $h^*_\Phi(E)$ is used instead of $H^*_\Phi(E)$.

3. Group-averaged Response Functions

For numerical work, eq. (1.1) has to be transformed at least approximately into the discretized linear matrix equation

$$\mathbf{z}_0 = \mathbf{R}\ \mathbf{\Phi} \tag{3.1}$$

with the group fluence vector $\mathbf{\Phi}^T = (\Phi_1,...,\Phi_\nu,...,\Phi_N)$.

Discretization can be performed in different ways by application of approximations to the quadrature formula eq. (1.1) (see e.g. [6]). For instance, the simpson rule or the gaussian quadrature formula, would lead to expressions like

$$z_{0i} = \sum_{\nu=1}^{N} g_\nu\, R_i(E_\nu)\, \Phi_E(E_\nu) \tag{3.2}$$

with weights g_ν defined and determined by the approximation method and where the response functions and the fluence values are taken at energy points E_ν (their choice also being part of the approximation method).

Previously another method was used in reactor dosimetry introducing group-averaged cross sections or group-averaged response functions. This method is favoured here since it allows uncertainty propagation without further correlations being added. In this method a mesh of energy points is considered defining N energy intervals with N+1 energy points. The integral, eq. (1.1), is re-written as a sum of N integrals by

$$z_{0i} = \sum_{\nu=1}^{N} \int_{E_\nu}^{E_{\nu+1}} R_i(E)\, \Phi_E(E)\ \mathrm{d}E\ , \tag{3.3}$$

and the approximation is performed for the integrals in the individual groups. Eq. (3.3) is expanded to

$$z_{0i} = \sum_{\nu=1}^{N} \frac{\int_{E_\nu}^{E_{\nu+1}} R_i(E)\Phi_E(E)\,\mathrm{d}E}{\int_{E_\nu}^{E_{\nu+1}} \Phi_E(E)\,\mathrm{d}E} \cdot \int_{E_\nu}^{E_{\nu+1}} \Phi_E(E)\,\mathrm{d}E\,, \tag{3.4}$$

which is still identical to eq. (1.1). For eq. (3.4) two abbreviations are usually used:

$$R_{i\nu} = \frac{\int_{E_\nu}^{E_{\nu+1}} R_i(E)\Phi_E(E)\,\mathrm{d}E}{\int_{E_\nu}^{E_{\nu+1}} \Phi_E(E)\,\mathrm{d}E} \tag{3.5}$$

as **group-averaged response function values** of detector *i*, and

$$\Phi_\nu = \int_{E_\nu}^{E_{\nu+1}} \Phi_E(E)\,\mathrm{d}E \tag{3.6}$$

as **group fluence** values.

Eq. (3.4) is exact; the approximation begins with the introduction of constant or estimated functions for the fluence to calculate the group response functions. In practice, the interval between E_ν and $E_{\nu+1}$ should be selected so small that constant fluence can be assumed for calculating the integrals introduced above, thus leading to

$$R_{i\nu} = \frac{\int_{E_\nu}^{E_{\nu+1}} R_i(E)\,\mathrm{d}E}{E_{\nu+1} - E_\nu} \tag{3.7}$$

The introduction of approximated group-averaged response functions for the representation of the integral in each group has the advantage that no additional correlations between adjacent groups are artificially created as, for instance, with the Simpson rule. Two other important points have to be mentioned: (1): Resonant behaviour of the response function (as, for instance, for activation detectors where strong fluctuations in the single intervals may occur) can be correctly taken into account, since the average of the response function in the interval is used. (2): The group-averaged response functions can be calculated iteratively. If, for instance, after use of eq. (3.7), the spectral fluence is determined by unfolding, a second iteration can be performed using this spectral fluence together with eq. (3.5) for a second iteration step in unfolding, where eq. (3.5) now may used without the assumption of constant fluence within the interval.

4. Interpolation and Integration

A complete description of a continuous function $y = f(x)$ can be obtained from N tabulated points given by pairs (x_i , y_i) $(I = 1,\ldots,N)$ when an interpolation formula is known. In the ENDF-B tapes [7] five essential two-point interpolation formulas are considered, which are characterized by an integer INT determining the interpolation rule in an interval. Throughout this work the same nomenclature as for the ENDF tapes is used for the interpolation parameter:

INT=1 : y is constant in x (histogram)
INT=2 : y is linear in x (lin-lin)
INT=3 : y is linear in ln(x) (lin-log)
INT=4 : ln(y) is linear in x (log-lin)
INT=5 : ln(y) is linear in ln(x) (log-log)

In addition, INT=6 is used in ENDF-B for the interpolation of charged particle cross sections. The interpolation scheme defines the function $y = f(x)$ in an interval (x_i , x_{i+1}) in a unique representation. For INT=2, for instance, the interpolation formula reads:

$$y(x) = \frac{1}{(x_2 - x_1)} \cdot (-y_1 \cdot (x - x_2) + y_2 \cdot (x - x_1)) \tag{4.1}$$

For logarithmic interpolation formulas the natural logarithms of the variables have to be used instead (see below).

In the ENDF-B tapes higher-order interpolation formulas are avoided which would add additional correlations created by interpolation. Only in the radiation protection literature (e.g. [8]) are four-point interpolation formulas proposed, for instance, the Lagrange four-point formula for interpolation in the interval between x_2 and x_3:

$$\begin{aligned} y(x) = {} & y_1 \cdot \frac{(x - x_2) \cdot (x - x_3) \cdot (x - x_4)}{(x_1 - x_2) \cdot (x_1 - x_3) \cdot (x_1 - x_4)} \\ & + y_2 \cdot \frac{(x - x_1) \cdot (x - x_3) \cdot (x - x_4)}{(x_2 - x_1) \cdot (x_2 - x_3) \cdot (x_2 - x_4)} \\ & + y_3 \cdot \frac{(x - x_1) \cdot (x - x_2) \cdot (x - x_4)}{(x_3 - x_1) \cdot (x_3 - x_2) \cdot (x_3 - x_4)} \\ & + y_4 \cdot \frac{(x - x_1) \cdot (x - x_2) \cdot (x - x_3)}{(x_4 - x_1) \cdot (x_4 - x_2) \cdot (x_4 - x_3)} \end{aligned} \tag{4.2}$$

where also sometimes logarithms instead of the linear expressions are used.

For the determination of group cross sections or group response function values according to eq. (3.5) or eq. (3.7) integrals over $y(x)$ have to be taken. The corresponding formulas are given in the following:

INT=2: Introducing $\beta = \frac{y_2 - y_1}{x_2 - x_1}$ and $\alpha = y_2 - \beta x_2$, the interpolation formula in the interval between x_1 and x_2 can be abridged to $y(x) = \beta x + \alpha$ and the integral over an interval between a and b is:

$$\frac{1}{b-a}\int_a^b y(x)\,\mathrm{d}x = \frac{\beta}{2}(b+a) + \alpha \tag{4.3}$$

INT=3: Introducing $\beta = \frac{y_2 - y_1}{\ln(x_2) - \ln(x_1)}$ and $\alpha = y_2 - \beta \ln(x_2)$, the interpolation formula in the interval between x_1 and x_2 can be abridged to $y(x) = \beta \ln(x) + \alpha$ and the integral over an interval between a and b is:

$\frac{1}{b-a}\int_a^b y(x)\,\mathrm{d}x = \frac{1}{b-a}\int_a^b (\beta \ln(x) + \alpha)\,\mathrm{d}x = -\beta + \frac{\beta}{b-a}(b \cdot \ln(b) - a \cdot \ln(a)) + \alpha$, where the integration formula $\int \ln(x)\,\mathrm{d}x = x \cdot \ln(x) - x$ was used.

INT=4: Introducing $\beta = \frac{\ln(y_2) - \ln(y_1)}{x_2 - x_1}$ and $\alpha = \ln(y_2) - \beta\, x_2$, the interpolation formula in the interval between x_1 and x_2 can be abridged to $\ln(y(x)) = \beta x + \alpha$ or $y(x) = \exp(\beta x + \alpha)$ and the integral over an interval between a and b is:

$$\frac{1}{b-a}\int_a^b y(x)\,\mathrm{d}x = \frac{1}{b-a}\int_a^b \exp(\beta x + \alpha)\,\mathrm{d}x = \frac{1}{b-a} \cdot \frac{1}{\beta}(\exp(\beta b + \alpha) - \exp(\beta a + \alpha)). \tag{4.4}$$

INT=5: Introducing $\beta = \frac{\ln(y_2) - \ln(y_1)}{\ln(x_2) - \ln(x_1)}$ and $\alpha = \ln(y_2) - \beta \ln(x_2)$, the interpolation formula in the interval between x_1 and x_2 can be abridged to $\ln(y(x)) = \beta \ln(x) + \alpha$ or $y(x) = \exp(\beta \ln(x) + \alpha)$ and the integral over an interval between a and b is:

$$\frac{1}{b-a}\int_a^b y(x)\,\mathrm{d}x = \frac{1}{b-a}\int_a^b \exp(\beta \ln(x) + \alpha)\,\mathrm{d}x = \frac{\exp(\alpha)}{b-a}\int_a^b x^{\beta}\,\mathrm{d}x = \frac{\exp(\alpha)}{b-a}\frac{1}{\beta+1}(b^{\beta+1} - a^{\beta+1}) \tag{4.5}$$

For small values of b-a, the numerical differences in the integral formulas have to be carefully evaluated.

5. Scaled or Normalized Response Functions, Numerical Calibration

Eq. (2.2) reads: $$z_0 = \int_0^\infty \mathrm{d}E\ R(E)\Phi_E(E)\,, \tag{5.1}$$

where the detector reading z_0 may be given as scaled to a physical quantity, for instance, a dose-equivalent for an area dosimeter or a pulse rate for a counting device (in literature the letter M is sometimes used instead of z_0). In the following, the unit in which the detector reading is scaled, is termed “detector unit”, abbreviated to du. The dimension of the response function $R(E)$ is therefore du cm^2, and $R(E)$ is defined as the fluence response of the detector. The scaling of the detector reading to the quantity of interest is performed with a so-called calibration factor denoted as N. For instance, to calibrate the detector in units of the dose-equivalent H^*, the calibration factor $N=H^*/z_0$ may be introduced which might have the unit pSv/du and which in practice has to be multiplied by the readings to obtain the measured quantity (measurand) of interest.

When the detector has already been calibrated in units of the quantity of interest (e.g. p Sv), the response functions must be used in such a way that they relate to the same units (e.g. pSv cm^2). Calibration means scaling of the quantities involved in the definition equation (5.1), i. e. multiplication by a factor.

Most neutron instruments used in radiation protection for determining, for instance, ambient dose-equivalent have a fluence response as a function of energy differring from the energy-dependent fluence-to-dose-equivalent conversion function. When calibration is performed in a certain reference field, the instrument would indicate the correct value (for instance, ambient dose-equivalent) only under reference conditions. In practice, for the use of such instruments, several steps involving integral quantities have to be performed:

--- When the fluence response of a detector (denoted now by $\hat{R}(E)$) is considered to be arbitrarily scaled, the reading of the detector in the reference (calibration) field is given by:

$$\hat{z}_0 = \int_0^\infty \mathrm{d}E\ \hat{R}(E)\Phi_E^{\mathrm{ref}}(E) \tag{5.2}$$

For instance, the reading $\hat{z}_0$ may be given in the unit du and the response $\hat{R}(E)$ in the unit du cm^2.

--- Consider now the quantity of interest in the reference (calibration) field, for instance, the ambient dose-equivalent *H**

$$H^* = \int \mathrm{d}E \; h^*_{\Phi}(E)\,\Phi_E^{\mathrm{ref}}(E) \tag{5.3}$$

with the fluence-to-dose-equivalent conversion function $h^*_{\Phi}(E)$.

--- The dose-equivalent calibration factor by definition (see [24]) is given by the ratio

$$N = \frac{H^*}{\hat{z}_0} = \frac{\int \mathrm{d}E \;\; \mathrm{h}^*_{\Phi}(E)\,\Phi_E^{\mathrm{ref}}(E)}{\int_0^{\infty} \mathrm{d}E \;\; \hat{R}(E)\Phi_E^{\mathrm{ref}}(E)}. \tag{5.4}$$

When the detector is used in a field with spectral properties of $\Phi_E^{\mathrm{ref}}(E)$, the recalibrated reading $z_0 = \hat{z}_0\, N$ would yield the exact value of *H**. Within the RESTRAW program, the calibration factors *N* for all the detectors of the *.FMT library and for the spectrum under investigation are calculated and written both into the protocol file and into the output *.FMT file (see chapter 11).

--- Instead of recalibrating the reading, the response function may be recalibrated by multiplying $\hat{R}(E)$ by the calibration factor:

$$R(E) = \hat{R}(E)\, N = \hat{R}(E)\,\frac{\int \mathrm{d}E \;\; h^*_{\Phi}(E)\Phi_E^{\mathrm{ref}}E)}{\int \mathrm{d}E \;\; \hat{R}(E)\Phi_E^{\mathrm{ref}}(E)} = \hat{R}(E)\,\frac{H^*}{\hat{z}_0} \tag{5.5}$$

With the recalibrated (numerically calibrated) response function the instrument indicates the correct dose-equivalent *H** when used in a neutron field with the spectral fluence proportional to $\Phi_E^{\mathrm{ref}}(E)$. For other neutron fields a correction factor must be applied. For instance, for an arbitrary neutron field with known spectrum, as indicated by the index $_{\mathrm{un}}$, the reading of the detector already recalibrated for the reference field can be written as:

$$z_0^{\mathrm{un}} = \int \mathrm{d}E \;\; R(E)\,\Phi_E^{\mathrm{un}} = H^*_{un}\,\frac{\int \mathrm{d}E \;\; R(E)\,\Phi_E^{\mathrm{un}}(E)}{\int \mathrm{d}E \;\; h^*_{\Phi}(E)\,\Phi_E^{\mathrm{un}}(E)} = H^*_{un}\cdot k \tag{5.6}$$

with the correction factor:

$$k = \frac{\int \mathrm{d}E \;\; R(E)\,\Phi_E^{\mathrm{un}}(E)}{\int \mathrm{d}E \;\; h^*_{\Phi}(E)\,\Phi_E^{\mathrm{un}}(E)}. \tag{5.7}$$

It should be noted that eqs. (5.6) and (5.7) are more complicated when it is not

the recalibrated response function R(E) but the original response function $\hat{R}(E)$ which is used. According to eq. (5.5) the correction factor then reads

$$k = \frac{\int \mathrm{d}E \;\; \hat{R}(E)\, \Phi_E^{\mathrm{un}}(E)}{\int \mathrm{d}E \;\; h_{\Phi}^{*}(E)\, \Phi_E^{\mathrm{un}}(E)} \;\; \frac{\int \mathrm{d}E \;\; h_{\Phi}^{*}(E) \Phi_E^{\mathrm{ref}} E)}{\int \mathrm{d}E \;\; \hat{R}(E) \Phi_E^{\mathrm{ref}}(E)} \tag{5.8}$$

In general, the calibration factor N and the correction factor k should be separately determined. The SELECTDF program in the package allows the correction factors for all the detectors of a library (*.FMT file) and a special spectrum to be calculated (see chapter 12).

6. General Purpose of the RESTRAW program

The main task of the RESTRAW program is the transfer of detector response functions of various origin to the library for later use in unfolding programs. In addition, integral quantities like dose-equivalent or calibration factors can be calculated. All the files are expected to be, and written, in the HEPRO format (point structure or group structure, HEPRO version of December 2000). The essential point is that before the RESTRAW program is used, interpolation and extrapolation rules for the fluence and for the response function data must be known.

It is to be stated (as a part of quality management) that the use of tables defining functions is unambiguous when an interpolation and extrapolation formula is assigned together with the values point-wise given. In addition, for tables containing experimental results, an uncertainty description with a covariance matrix should be given. At present, this covariance matrix (for instance, for detector responses) can only be taken into account for reactor dosimetry problems (for which ENDF reaction cross sections are considered as responses).

For the ENDF data a well-established description is used together with an extended covariance formulation. It is recommended that the data format applied there should generally be used for response functions in order that a common software might be used. The data format of the covariance files of ENDF may be a good purpose for establishing the uncertainty matrix of the Bonner sphere response function.

In the following a brief description of the formats used at present in the HEPRO package [3] is given. Unfortunately it was originally not intended to introduce into the HEPRO files parameters defining interpolation and extrapolation rules or parameters describing the method by which the covariance information was determined. The next version of HEPRO has to allow for this possibility. At present, such parameters must be included in the program work by switches in the input files, these switches being certain numbers characterizing the method of interpolation or extrapolation or uncertainty propagation.

7. Structure of Data Files and Libraries

7.1 Data Files: Fluence Files, Single Response Functions

All files containing functions (i.e. tabulated x-y-values) within the HEPRO package or in the programs described have the same structure. The fluence files, the multichannel files, the single response functions and the various fluence-to-dose conversion functions consist of a number *KG* of triples $(E(i), F(i), \sigma(i), i = 1,...,KG)$, where *E(i)* is the energy, *F(i)* the value of the function considered and $\sigma(i)$ its standard deviation. The energy scale is thought to be in MeV, but some of the programs considered are able to convert this scale (see below).

The structure of a data file is as follows:

Line 1: arbitrary text characterizing the set,
FORMAT 80A1 (80 or less characters)

Line 2: *MODE, MEV* FORMAT *, i.e. format-free,
MODE = 0:
Point values follow, i.e. *F(i) = F(E(i))*, the function is taken at energy values *E(i)*

MODE = 1:

Average values of *F(i)* and $\sigma(i)$ in the interval $E(i) \le E < E(i+1)$ follow, with

$F(i) = \frac{\int_{E(i)}^{E(i+1)} F_E(E)dE}{E(i+1) - E(i)}$, which means that group-averaged values follow.

MODE = 2:

Group values of *F(i)* and $\sigma(i)$ follow (e.g. multichannel values or MCNP [9] result), with $F(i) = \int_{E(i)}^{E(i+1)} F_E(E)dE$, which means that group integrals follow.

MODE = 3:

Group values of *F(i)* and $\sigma(i)$ per "unit lethargy" follow.

For the interpretation of these values it is assumed that $F(i) = \int_{E(i)}^{E(i+1)} F_E(E)dE$ has been calculated or measured, and that $\frac{F(i)}{log(E(i+1)/E(i))}$ is contained in the file, which is sometimes called "fluence per unit lethargy". The interpretation of this terminus is sometimes misleading. Sometimes it is assumed that "lethargy representation" means that the expression $\frac{F(i) \cdot \overline{E}}{E(i+1) - E(i)}$ is contained in the file, with either $\overline{E} = \sqrt{E(i+1) \cdot E(i)}$ (logarithmic average of energy) or $\overline{E} = \frac{1}{2}(E(i+1) + E(i))$ (linear average of energy). These expressions are only approximately equal, $\frac{1}{log(E(2)/E(1))} \approx \frac{\overline{E}}{E(2) - E(1)}$.

The difficulties in the interpretation of "lethargy units" can often be seen in graphical representations where in most cases the values $\frac{F(i)}{log(E(i+1)/E(i))}$ are plotted in the form of a histogram with horizontal bars in the intervals in a log-x and lin-y representation but the abscissa is denoted as *E* and the ordinate as *F(E)*E* .

MEV = 0: energies *E(i)* in eV

MEV = 1: energies *E(i)* in MeV (recommended for HEPRO and RESTRAW)

MEV = 2: energies *E(i)* in keV.

It should be mentioned that some of the programs of the HEPRO package are able to use an additional parameter *IUN* in this second line with:

IUN=0 --------- no uncertainties in the following columns

IUN=1---------- standard uncertainties (standard deviations) follow,

IUN=2---------- standard variances follow

IUN=2---------- relative standard uncertainties (in %) follow.

In the present version not all the codes understand the *IUN* parameter, therefore it is recommended to use only standard deviations.

Line 3:

IL, *IH*,*KG*, *E(KG*+1*)* FORMAT *, i.e. format-free

IL=1, *IH=KG*, are used here as fixed values not yet explicitly needed by the codes. These parameters may be used in later versions of the programs for additional information.

KG is the number of points or groups which follow.

E(KG+1) is the last (right) energy boundary.

The programs need a (dummy) value, even in the case of point values (*MODE*=0).

Line 4 to line *KG*+3: *E*(*i*), *F*(*i*), $\sigma(i)$ FORMAT*, i.e. format-free

The meaning of the values of *E*(*i*) depend on the *MODE* parameter; for *MODE*=0 the following *E*(*i*), *F*(*i*) values are point values and *KG* values are needed; for *MODE* > 0 the *E(i)* are **left** boundaries of the interval ranging from *E(i*) to *E*(*i*+1) and *KG*+1 values of *E*(*i*) are needed, the last right boundary is found in line 3.

Note: In MCNP [9] data files the right boundaries of energy intervals are used. The values of *F(i)* have been explained above. $\sigma(i)$ is the standard deviation of *F*(*i*), (for Poisson statistics sometimes taken as $\sigma(i) = \sqrt{F(i)}$).

If $\sigma(i)$ is not available, a dummy column (by duplicating column 2) should be included since some of the HEPRO programs crash when this column is lacking.

Note: For the plot program PLOF or PLOFW, other data representations are possible (see description of the PLOT program).

Note: For input pulse-height spectra, MODE=2 is required in HEPRO.

7.2 Response Matrix Files in the "Few Channel" Case., *.FMT Files.

Response matrix files can be created by the RESTRAW program as output files but they can also be used as input library files in case the energy structure is to be changed or for the combination of library files.

The response matrix file has a similar format as the library files in the SAND-II format [10] of the REAL exercises [4,11]. It must again be mentioned that the method of group-averaged response functions is used here, i. e. the RESTRAW program has to perform the integration over the individual energy intervals, and the resulting response function library contains only group-averaged functions.

The structure of the library is as follows:

Line No 1:

80 arbitrary text characters to characterize the file; it is recommended to state the actual time of the creation of the file, for instance:

```
OCTOBER-23-2000                          TIME: 13:20:24
```

Line No 2:

80 arbitrary text characters, for instance:

```
RESTRAW FLUENCE RESP.,UNITS in cm**-2 and pSv and pSv cm**2
```

Line No 3:

KG+1, number of energy boundaries, format-free

Next lines:

KG+1 energy boundaries (one more than energy groups), FORMAT 1P,8E10.3

Note: For the few channel unfolding considered here, the energies should be in MeV.

Next line: *NC*, number of covers (for shielding calculation).

In the original SAND-II library the cross sections of cover materials like Cd and Gd were stored for use in the unfolding codes. Here a value of **NC=0** is recommended. (no shielding calculation possible)

Next line: *NL*, number of detectors in the library.

This is the number of all detectors including e.g. response functions of Bonner spheres, of survey meters (remcounters) as well as fluence-to-dose conversion functions.

NL packages follow, each package containing:

Line 1 of package No. i:

bk1(i),bk2(I),textall(i), where

bk1(i) is an 8-character short name for the reaction or the detector,

bk2(i) is a 16-character long name for the reaction or the detector,.

textall(i) is a 40-character comment characterizing the detector.

Example:

```
READ (15,'(a8,2x,a16,4x,a40)') bk1(i),bk2(I),textall(i)
```

For later use in the unfolding codes, the 8-character short name is important.

Line 2 of package No. i:

CLAM, CN1(i),CN2(i), MAT(i),MT(i), ILOG(i),IEXPL(i),IEXPR(i),IUNS(i), where *CLAM* is a factor for later multiplication by the following response function. Here e.g. the calibration factor can be given for later use by the UMSFAC program; in the original SAND-II library for *CLAM* a decay constant was given.

CN1(i) and *CN2(i)* are character arrays for names of reactions in the original SAND-II library. In the present version they may be used as blank variables.

MAT(i), MT(i) are the *MAT* and *MT* numbers of the reactions according to ENDF nomenclature in the original SAND-II library, here used as blanks.

The interpolation and extrapolation codes follow which were used in the creation of the data by the RESTRAW program.

ILOG(i) is the interpolation code No. for the response function which follows.

ILOG= 1 : *Y* is CONSTANT IN *X* Y = const

ILOG= 2 : *Y* is LINEAR IN *X* $Y = a\,X+b$

ILOG= 3 : *Y* is LINEAR IN LOG(*X*) $Y = a \log(X)+b$

ILOG= 4 : LOG(*Y*) is LINEAR IN *X* $\log(Y) = a X+b$

ILOG= 5 : LOG(*Y*) LINEAR IN LOG(*X*) $\log(Y) = a \log(X)+b$

ILOG=12 or 13,14,15 means the same as 2 or 3,4,5 but now a 4-point cubic Lagrange formula is used for interpolation (see chapter 4).

IEXPL(i): left-hand extrapolation mode, *IEXPR(i):* right-hand extrapolation mode for energy values outside the original interval,
value=1 means linear extrapolation of the present *ILOG* interpolation,
value=0 means values outside the original energy interval are set to zero.

IUNS=0 means no uncertainty file exists for this reaction,
IUNS=1 means an uncertainty file for this reaction is available.
In the present version only *IUNS*=0 can be used.
Example:

```
READ (15,'(e10.3,2a4,2x,2i10,4I5)')
1 CLAM,cn1(i),cn2(i),mat(I),mt(I),ilog(I),iexpl(I),iexpr(I),iuns(I)
```

Next lines the package No. i:

KG values of the response function

Example: `READ (15,'(1p,8e10.3)') (resp(i),i=1,kg)`

8. The Plot PLOFW Program

In the HEPRO package two plot codes are included: PLOF and PLOTA. These programs were originally compiled for running in the DOS box. In the present version two Quick-WIN compilations named PLOFW and PLOTAW are available. In every run of the programs a plot file is created, which can be seen by using the PLOTAW program. A description and an example are given further below.

The PLOFW program at the beginning just asks for the name (including the complete path) of the file to be plotted:

```
PROGRAM PLOF BY MANFRED MATZKE
```

```
 PLOTTING SPECTRUM FILES OR CROSS SECTION FILES OF SPECIAL
 FORMAT. >>>>>>>>VERSION JULY 25, 2000<<<<<<<<
 YOU ARE PROMPTED BY THE PROGRAM TO TYPE THE PARAMETERS
 *******************************************************
 typing # leads to a DOS window
 leave this screen by closing it (typing EXIT)
 *******************************************************
 give now either #
           or the name of the file containing the data
```

The next question is for the plotting mode, requiring *IFEE* and *LAY*:

```
-----------------------------------------------
 ifee=0 : F(E)   is plotted
 ifee=1 : F(E)*E is plotted
          (F(E)*E means function per unit lethargy)
 lay-parameter for axis scaling:
 lay=1: x-linear,      y-linear
 lay=2: x-logarithm,   y-linear
 lay=3: x-linear,      y-logarithm
 lay=4: x-logarithm,   y-logarithm
 give ifee, lay
-----------------------------------------------
```

The values of the parameters have to be chosen according to the list above.

The next parameters *iun, fakt* relate to uncertainties or are used for scaling:

```
-------------------------------------------------

 iun=0       : no uncertainties to plot
 if iun = 1  : standard deviations are expected in the file
 if iun = 2  : variances are expected in the file
 if iun = 3  : relative stand. deviations are expected in the file
 if iun = 300: relative stand. deviations are expected in the file
               given in %
 if iun =-1  : the square roots of the y-values are taken
 fakt     : all y-values are multiplied by fakt
 fakt=0.0 : normalization of this curve to max. of the first
            curve. (for the first curve use fakt=1.0 !!)
 fakt should normally be chosen at fakt=1.0
 give iun,fakt
```

As mentioned above, for *IUN*, a value of 1 should normally be used, however, PLOFW also understands the other parameter values.

A lot of different formats including the ENDF format can be handled by the PLOFW program. It is recommended to try the ENDF format; the user is prompted to MAT, MT values of an ENDF file. A parameter *IFMT* is used to distinguish the formats.

```
ifmt=1: special file format of the MIEKE and HEPRO packages
     =2: multichannel file, i. e. a few comment lines,
         (you are prompted to the number to skip)
         followed by lines of x,y, or x,y,sig values,
         sig-values are read in if iun > 0
    =22: multichannel file, i. e. a few comment lines,
         (you are prompted to the number to skip)
         followed by lines of y, or y, sig values,
```

```
       sig-values are read in if iun > 0
  =222: standard multichannel file (lines with ! in 1st column ignored)
   =3 : endf format, you are prompted to mat, mt values
   =4 : special format (KNAUF,PTB), you are prompted
   =5 : DOSCROSS (SAND-II) FORMATTED OR UNFORMATTED CROSS
        SECTION LIBRARY of the IAEA NMF package
        you are prompted to the name of a reaction
   =55: SAND-II new format (e.g.RESTRANS-LIBRARY)
   =6 : format of the GRAF-FILES of the PTB
        (can also be used for plotting up to 15 columns)
   =7 : special format of response functions (HEPRO package)
   =8 : Techplot-files x,y values between BEGIN and END
   =9 : MCNP, 3 comment lines, group fluence values, unit MeV
*************** give ifmt*************
```

After this input a screen is shown containing the desired plot. There are a number of possibilities of changing the outfit. The user should type either **CH** to change the outfit, (this input is identical with pressing ENTER), or **HP** to output the plot as a file in the HPGL language. The user is asked for the name of the HPGL file. **END** is to be used to finish the program, **OK** to continue with another file.

After giving **CH** has been entered the following screen appears:

```
PLOF-PLOTA VERSION JULY 25, 2000: change switches:
  1 : lay   (lin-log scaling of the axes)
  3 : modpl (plotting mode: POINTS or LINE or HISTOGRAM
      or special symbol, 38 symbols are available)
  4 : fakt  (multiply x-y-values by factor+offset)
      use fakty=0.0 to scale to maximum values
  5 : text  (new text for curve characterization)
  6 : com   (new comment line for all plots)
  7 : xmin,xmax (x-axis: new values for next plot)
  8 : ymin,ymax (y-axis: new values for next plot)
  9 : iun   (change plotting uncertainties)
 10 : ifee  (change plotting mode: y(X) or y(X)*X)
      ifee=1 means Y(X)*X  i.e. fluence per unit lethargy
 11 : xtext (new text on x-axis)
 12 : ytext (new text on y-axis)
 13 : integral over a certain x-range, or normalize curves
 14 : change LINETYP, PENWIDTH, PATTERN length for LASERJET
 15 : change colour or tick-length of the graph for plotting
 16 : DOS SCREEN (goto DOS level) leave this screen by EXIT
 17 : change background colour from white to black or from black to white
 18 : save as bitmap file (e.g. for later use under Windows)
 ---> give one number between 1 and 18
 ++ or press ENTER to see the graph again
```

After typing of one of the numbers, a second window is opened explaining what to do. As in the present version the LASERJET output works only with HP LASERJET 4, the user should choose the HP-Graphic language output and may edit this file, for instance, before transferring the graphic to a text program

such as WINWORD. In the QUICK-WIN application PLOFW, the user may mark graphic or text areas on the screen for copying.
The user should try the 38 special symbols available by changing MODPL (No. 3).

The PLOF or PLOFW program can be used with the first 4 parameters as command-line arguments. For instance, the call
PLOFW XXXXX 1 2 0 1.0 1
means a run of PLOFW with
file name=XXXXX
IFEE=1
LAY=2
IUN=0
FAKT=1.0
IFMT=1
The plot programs require a file called FARBDAT and search this file in the current directory or in the directory c:\fonts\ or d:\fonts\. The user may look at the contents of this file for editing and changing default color and pen width parameters.
It is recommended to place the .EXE versions of the PLOTAW and PLOFW plot programs in one of the automatically investigated (global) path directories.

9. Organization and Contents of the Directories

The directories in the database are organized as shown in fig. 9.1.

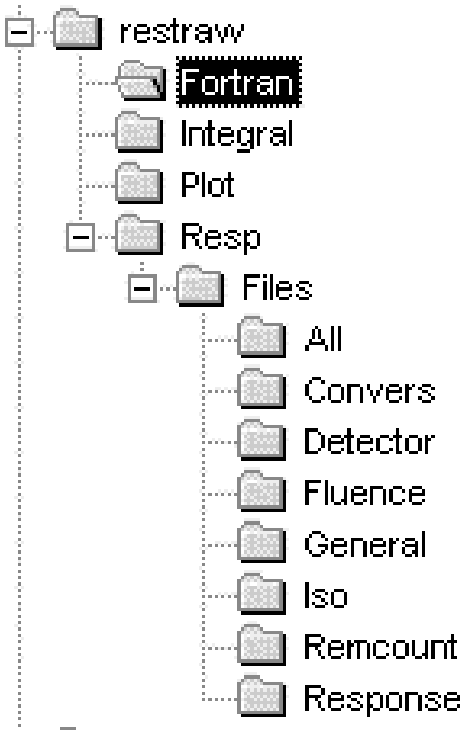

Fig. 9.1 Organization of directories

There is a main directory **\restraw** which may be placed everywhere (as a subdirectory) in the computer and may be renamed. It is strongly recommended to use the names and the organization of the subdirectories described in the following, for the programs used in the examples to run properly.

General-purpose directories are **\Fortran** with several utility programs (see below) and **\Plot** with the programs for plotting. The other names are self-explaining and will be described in more detail in the following.

The **\Resp** and **\Integral** directories contain batch files (BATCHNEU.BAT and BATCH.BAT) which the user may run with example input files which are also contained in those directories. After the run of the examples the **\All** directory contains all the response function files and conversion functions of the library in a newly chosen group structure. After the run of the examples the **\Integral** directory contains some of the integral tables, as for instance, the dose-equivalent or the integral fluence response.

It is intended that the user may introduce his own response functions and fluence files to run the programs for evaluating integral responses and spectrum averaged fluence-to-dose conversion factors.

9.1 Convers

Some of the fluence-to-dose conversion functions are tabulated in the **Convers** directory using the HEPRO format.

Hmade.665 and **H21_a**

Fluence-to-ambient dose conversion function according to ICRP-21 [12]. The file Hmade.665 was compiled using a program by Siebert from the SPKTBIB program package [2]. The file H21_a (see fig. 9.2) was obtained by A. Alevra [16], who developed a reasonable extension to high energies (see fig. 9.2).

H-wagner and H39_a

Fluence-to-ambient dose conversion function according to ICRU-39 [13, 14]. The file H-wagner was compiled using a program by Siebert from the SPKTBIB program package [2]. Above 20 MeV neutron energy the data are set to zero, the file H39_a (see fig. 9.2) was obtained by A. Alevra [16], who applied constant extrapolation to high energies.

ICRP74.665, ICRP74_a, ICRP74_I and **ICRP74n**

Fluence-to-ambient dose conversion function according to ICRP-74 [15]. The file ICRP74.665 was compiled using a program by Siebert from the SPKTBIB program package [2]. There are 665 points below 100 MeV neutron energy. The files ICRP74_i and ICRP74n are the same but different in energy binning. Above 200 MeV neutron energy the data are set to constant. File ICRP74_a was obtained by A. Alevra [16], who developed reasonable extension to high energies (see fig. 9.2).

HP10.665, HP10_00, HP10_15, HP10_30, HP10_45, HP10_60, HP10_75

These files contain the fluence-to-personal dose conversion functions [15] with different angles of neutron incidence (0° , 15° , 30° , 45° , 60° , 75°). Conversion functions for other angles are not yet available. The data were taken from reference [2]. HP10.665 is equal to HP10_00 with a different group structure (see fig. 9.3).

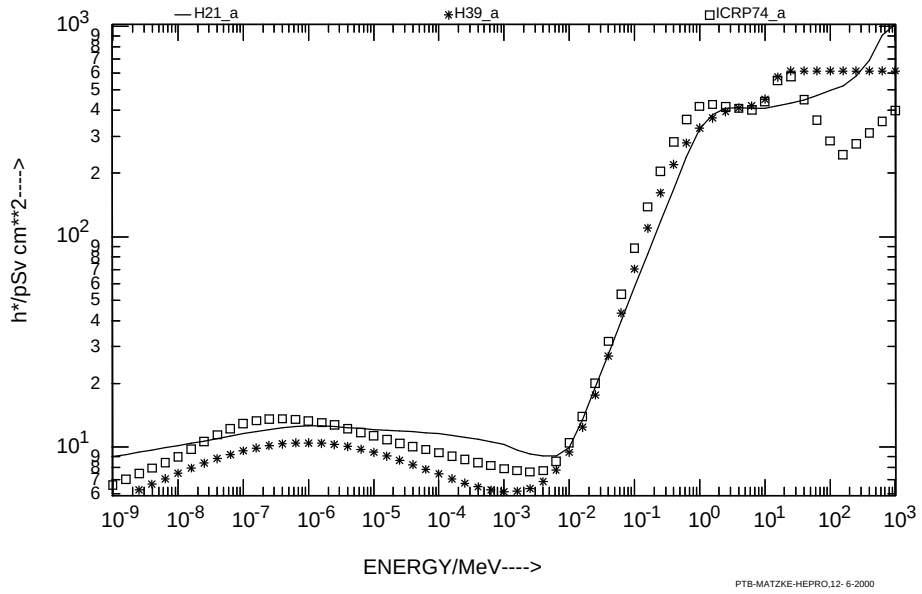

Fig. 9.2 : Fluence-to-ambient dose conversion functions of H21_a, H39_a and ICRP74_a, extrapolated according to Alevra [16] (the figure was plotted using the PLOFW program of the package, see text)

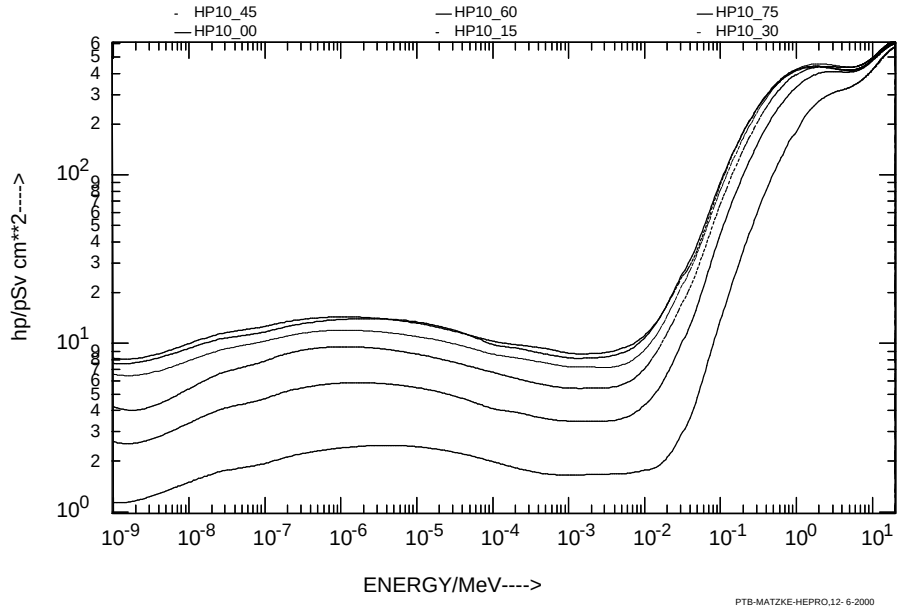

Fig. 9.3 : Fluence-to-personal dose conversion functions according to ICRP74. The numbers were taken from the SPKTBIB data library [2]. The figure was plotted using the PLOFW program of the package (see text). Note: There are increasing degrees for the curves from top to bottom (0° for the upper curve, 75° for the lowest one).

9.2 Detector

This directory contains some standard detector cross sections and responses, which might be helpful in predicting counting rates and readings in several neutron fields.

There are the cross section files **AU197G** (ENDF-B/V), **HE3NP.BVI** and **CD.BVI** in the 640 group structure of neutron energies. There are also responses and Cd-transmission functions for a 3-He sphere 1.6 cm in radius and a gold foil 0.5 cm in radius and 20.0 μm in thickness. Details of the calculation may be found in ref. [5]. The file names in the directory are self-explaining. Details of the parameters used may be found in the head of each ASCI-HEPRO file.

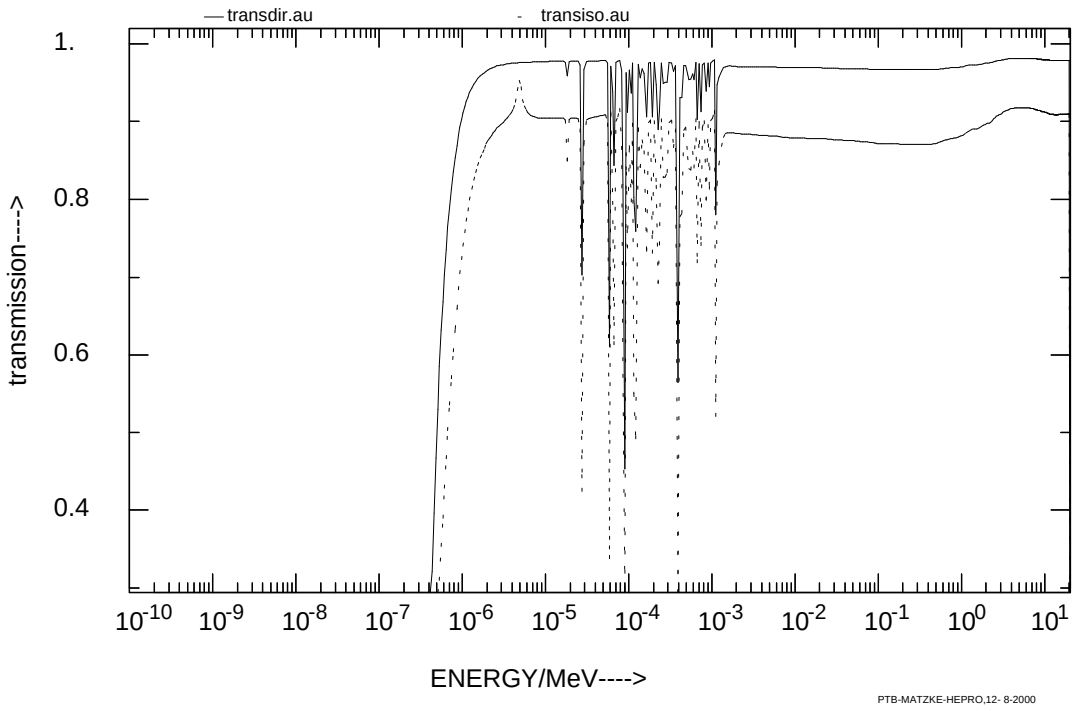

Fig. 9.4 : Transmission function of a 20 μm thick Au foil 0.5 cm in radius. The transmission function is the ratio of the absorption rates of the foil with and without a cadmium cover 0.1 cm in thickness. The difference in transmission for directed and isotropic incidence is clearly seen.

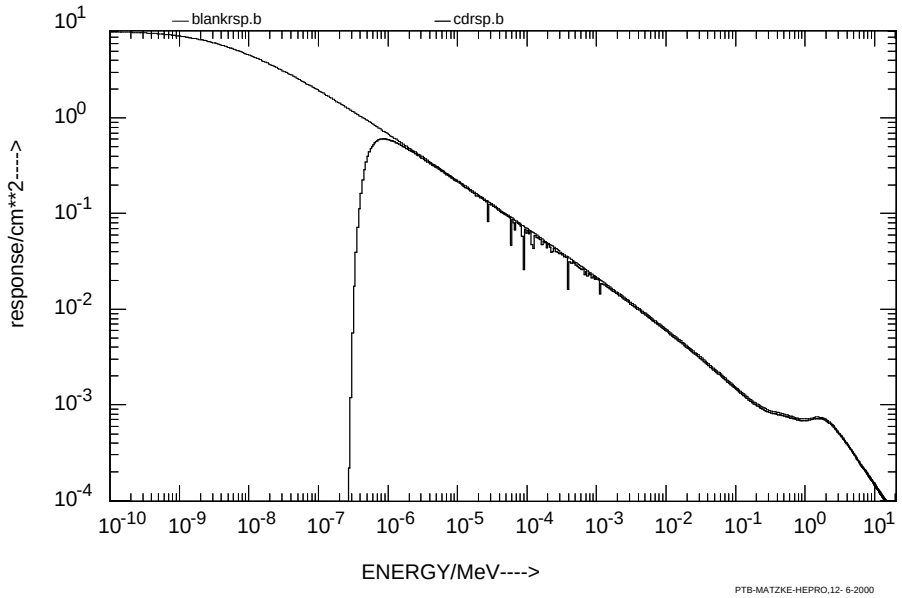

Fig. 9.5: Response function for a ^{3}He sphere, 1.6 cm in radius compared to the response function of a Cd-covered sphere (0.1 cm of Cd, scattering in Cd neglected). This is the response function of an ideal SP9 counter neglecting wall effects and scattering. For small neutron energies, the self-shielding effect (deviation from the $\frac{1}{\sqrt{E}}$ shape) can be seen.

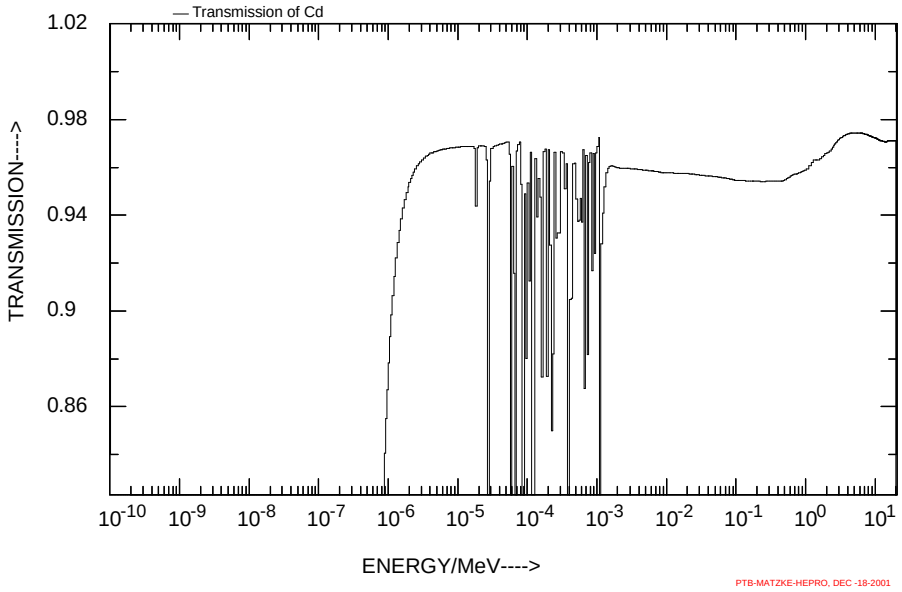

Fig. 9.6: Transmission function for 0.1 cm Cd around a SP9 counter. (only total cross section taken into account. (file TRANSMIS.B)

Apart from the cross section files, the following files can be found in the directory **detector**:

BLANKRSP.B	response function for a blank ^{3}He-sphere 1.6 cm in radius and with a number of particles of 4.92 10^{19} cm^{-3}.
CDRSP.B	response function for the same sphere but cadmium-covered with 0.1 cm cadmium.
TRANSMIS.B	transmission function for the same sphere (ratio of the values with and without Cd cover).
BLANKDIR.AU	response function (macroscopic absorption cross section) of a blank Au foil of 20 μm thickness and 0.5 cm radius. Number of particles: 5.907 10^{22} cm^{-3}. Self-shielding is taken into account. The incidence of neutrons is assumed perpendicular to the foil.
BLANKISO.AU	response function for the same foil but isotropic incidence of neutrons
CDDIR.AU	response function for the same foil but cadmium-covered with directed incidence of neutrons
CDISO.AU	response function for the same foil but cadmium-covered with isotropic incidence of neutrons.

There are another 2 transmission files, **TRANSDIR.AU** and **TRANSISO.AU**, which contain the ratios of the file data described above, i. e. the ratio of the response function with and without Cd cover. Finally, the files **SELFISO.AU** and **SELFDIR.AU** contain the self-shielding factors for the gold foil considered for isotropic and directed incidence of neutrons.

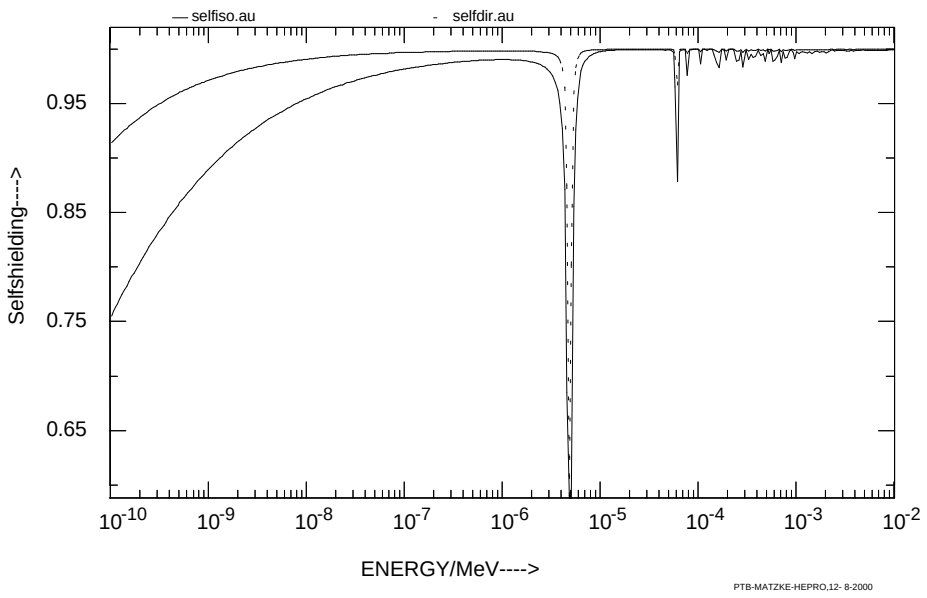

Fig. 9.7 Comparison of the self-shielding factor of a gold foil of 20 μm thickness for isotropic and directed incidence of neutrons. The great difference in resonance self-shielding can clearly be seen.

9.3 Fluence

Some standard fluence spectra are stored in the directory **FLUENCE**, which may be used for predicting the counting rates of detectors or the integral fluence-to-dose equivalent conversion factor. The files contain the results obtained from unfolding the results of Bonner sphere measurements carried out in the bunker room of the PTB [17]. The unfolding program used was MINCHI which is a STAY'SL-like code and allows consistent uncertainty propagation. In the files the 3rd column contains the standard uncertainty. The files contain spectral flux density values per source neutron.

In the following table the extension **.TOT** means total fluence in the bunker room of the PTB, i. e. fluence including wall scattering. The data are given for a distance of 170 cm from the source.

Comment	Name of the fluence file
Cf-source with moderator with Cd shell, Bonner sphere result, unfolding program: MINCHI 1995	MS_MMQFL.TOT
Cf-source with moderator with Cd shell, Bonner sphere result, unfolding program: MINCHI 1995	MS_MMQFL.INS
Cf-source with moderator without Cd shell, Bonner sphere result, unfolding program: MINCHI 1995	MS_MOQFL.TOT
Cf-source with moderator without Cd shell, Bonner sphere result, unfolding program: MINCHI 1995	MS_MOQFL.INS
blank Am-Be-source, Bonner sphere result, unfolding program: MINCHI 1995	MS_AMQFL.TOT
blank Am-Be-source, Bonner sphere result, unfolding program: MINCHI 1995	MS_AMQFL.INS
blank Cf-source, Bonner sphere result,unfolding program: MINCHI 1995	MS_CFQFL.TOT
blank Cf-source, Bonner sphere result, unfolding program: MINCHI 1995	MS_CFQFL.INS

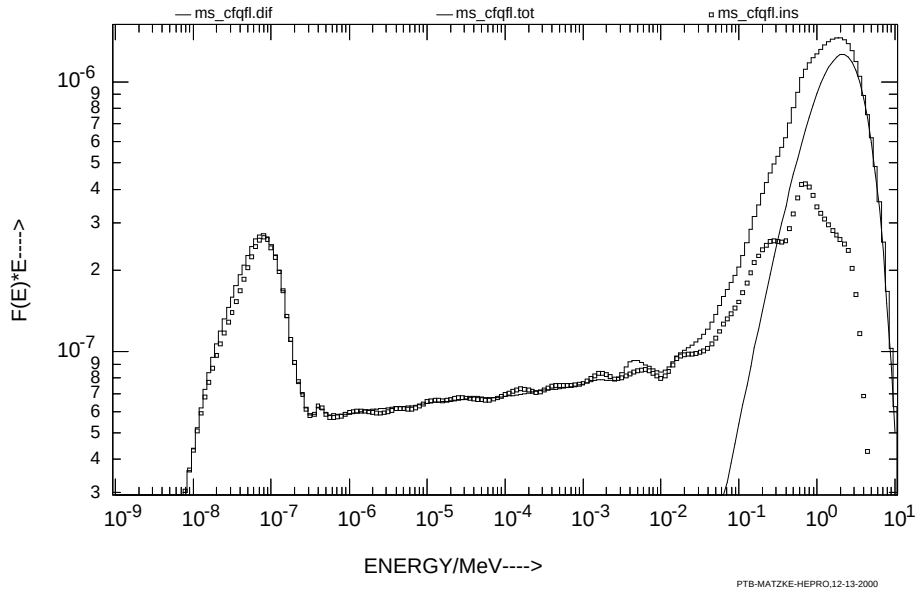

Fig. 9.8: Blank Cf-source: Spectral flux density times energy per source neutron obtained from unfolding results of Bonner sphere measurements in the bunker room of the PTB. Histogram: total fluence, □ □ □ □ : scattering contribution, line representation: difference spectrum (blank Cf-source).

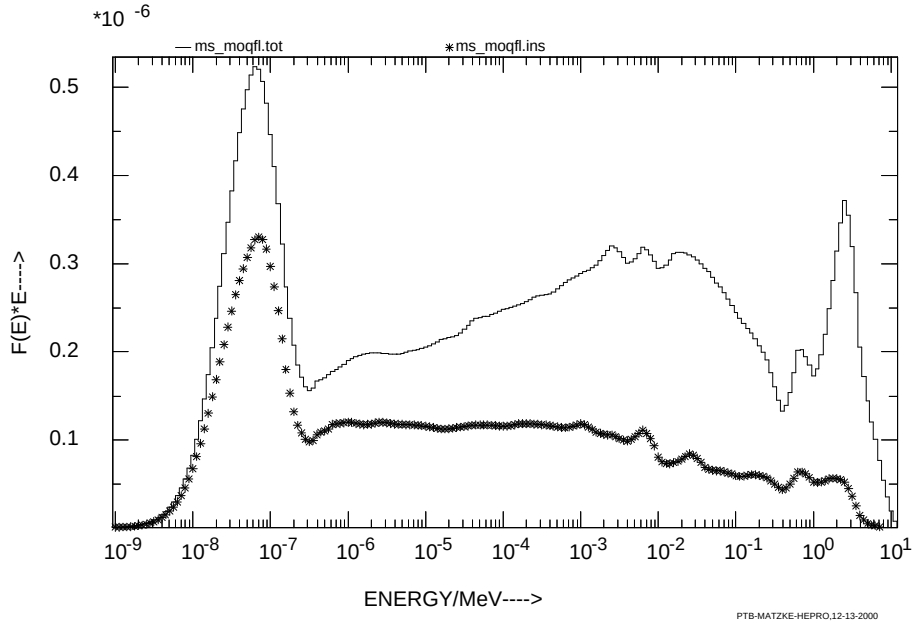

Fig. 9.9: Moderated Cf-source without Cd shell: Spectral flux density times energy per source neutron obtained from unfolding results of Bonner sphere measurements in the bunker room of the PTB. Histogram: total fluence, ********** : scattering contribution.

9.4 ISO

In the **ISO** directory spectra files corresponding to standard spectra recommended by ISO and IAEA are stored. File **AMBEISO** contains the data from the Report ISO 8529 [24], file **CFISOC** contains the fluence spectrum created according to the formula given in ISO 8529 [24], represented in 4000 energy groups, file **CF-FINE** contains the data of the IRDF recommended Cf-spectrum evaluated by Mannhart [25], including the uncertainties stated by Mannhart (see also ENDF B/VI).

9.5 REMCOUNT

Response functions for detectors measuring the ambient dose-equivalent (rem counters) from various sources are contained in the directory REMCOUNT; most of them have been taken from the SPKTBIB [2] data and some have been extrapolated by A. V. Alevra to higher neutron energies. The files contain the data as obtained from the references [18], [19], [20], [21], [22], [23] the calculation of calibration factors and the scaling of the responses are performed by the RESTRAW program. The user may add own new data (see e.g. [26], [27]).

Comment	remcounter response file
LB64 rem counter, data obtained from A. V. Alevra, see file 3h6s7r.e61 in the directory \GENERAL	LB64_A
LEAKE rem counter, data obtained from A. V. Alevra, see file 3h6s7r.e61 in the directory \GENERAL	LEAKE_A
LEAKE rem counter, data from SPKTBIB-IAEA Harrison data	LEAKIAEA
SNOOPY rem counter, data obtained from A. V. Alevra, see file 3h6s7r.e61 in the directory \GENERAL	SNOOPY_A
SNOOPY rem counter, data from SPKTBIB, Hankins data	SNOOPY1
HARWELL rem counter, data from SPKTBIB 0949	HARWELL
STUDSVIK rem counter 2202D, SPKTBIB, Nakamura	STUDSV1
EBERLINE rem counter, SPKTBIB, PNR-4, Hankins data	EBERL1
LINUS cylindrical rem counter, data from A. V. Alevra, see file 3h6s7r.e61 in the directory \GENERAL	CYLINU_A
LINUS spherical remcount., lateral incidence, data from M. Silari	LINUSLAT
LINUS spher. remcount., isotrop. incidence, data from M. Silari	LINUSISO
LINUS spherical rem counter, data obtained from A. V. Alevra,	LINUSALV
LINUS cylindr. rem counter, calculated by B. Wiegel (MCNP)	LINUSWGL
LINUS spherical rem counter, calculated by B. Wiegel (MCNP)	SPLINWGL
TEPC detector, data obtained from A. V. Alevra, file 3h6s7r.e61	TEPC_A
TEPC Juelich, data obtained from A. V. Alevra, file 3h6s7r.e61	JULICH_A

10. Database

Into the subdirectories existing in the directory **FILES** (see chapter 9) other files may be written when using the programs. For instance, the subdirectory **RESPONSE** contains all the *.FMT files created by the program RESTRAW and also some files possibly needed by the user.

11. Running the RESTRAW Program

All the programs of the HEPRO package and the programs described here can be used with an input file as command-line argument, e.g. typing

RESTRAW restraw.inp

means that the RESTRAW program is started and imports the input data from the file restraw.inp. When the name of the input file is not given in the command-line, the program asks for terminal input (interactive input).

Structure of the input file:

Line 1:

Name of the protocol file (control file), not more than 40 characters. For files not in the current directory the complete path according to DOS has to be given.

It is recommended to use the extension .LOG to enable fast editing within WINDOWS Explorer. When a file XXXXX.LOG is used, most of the HEPRO programs create a file XXXXX.PLO containing plotting information (see below).

It is further recommended to carefully read the protocol file.

Line 2:

MSAND format-free.

MSAND is a switch value for deciding on the energy structure of the new reponse matrix library.

MSAND=1 The original SAND-II energy structure is used with 640 energy groups below 20 MeV.

MSAND=2 The energy structure is taken from a HEPRO data file, the name of this file is asked for later.

MSAND=11 The energy structure is taken from the original response matrix file, whose name is asked for next.

MSAND=12 The energy structure is twice the number of energy points of the original response matrix file.

MSAND=13 The energy structure is three times the number of energy points of the original response matrix file.

MSAND=14 The energy structure is four times the number of energy points of the original response matrix file.

Line 3:

Name of input response matrix file (not more than 40 characters)

There are two possible formats for the input response matrix file:

1. A matrix given pointwise (see RESPSHOR.ALV of the examples) in a special format:
   line 1: comment line (80 characters)
   line 2: number of energy points *NP*
   from line 3 the following *NP* lines: one energy value per line in eV
   following line: number *NL* of detectors
   NL packages follow with
      short name of the detector (8 characters in one line)
      long name of the detector (16 characters in one line)
      in each package *NP* lines follow with the response function values.

2. A matrix with the format described in chapter 6.2.
   The program tries automatically to read a file in this format when the extension of the name of the input response matrix file in line 3 is FMT.

Line 4:

Name of the output new response matrix library file (not more than 40 characters).

The extension FMT must be used.

Line 5:

Name of an input fluence file (not more than 40 characters). The program needs this file for calculating integral responses for all the detectors of the library and to calculate average fluence-to-dose-conversion factors. The file must be in the HEPRO format (see chapter 6.1)

Line 6:

Name of output fluence file (not more than 40 characters).

The input fluence file is transformed into a file in the new energy structure according to line 2.

Line 7:

Name of a file with the new energy structure, **this line is required only for *MSAND*=2** (not more than 40 characters).

Next line :

Parameter *MEDE*, **this line is only required for *MSAND*=2.**

MEDE=0 (linear midpoints of each energy interval are taken for interpolation)

MEDE=1 (logarithmic midpoints of each energy interval are taken for interpolation)

Next line :

Highest neutron energy *EHIGH* in MeV to be transformed into the new response matrix file.

If this energy is chosen higher than the highest energy available in the input response function file, the latter is taken as *EHIGH*.

Next line :

Interpolation and extrapolation law for the input fluence file (see chapter 7.2), *ILOG, IEXPL, IEXPR*

ILOG is the interpolation code No. for the fluence file.

ILOG= 1 : *Y* is CONSTANT IN *X* $Y = \text{const}$

ILOG= 2 : *Y* is LINEAR IN *X* $Y = a\,X+b$

ILOG= 3 : *Y* is LINEAR IN LOG(*X*) $Y = a\,\log(X)+b$

ILOG= 4 : LOG(*Y*) is LINEAR IN *X* log*(Y) = a X+b*

ILOG= 5 : LOG(*Y*) LINEAR IN LOG(*X*) log*(Y) = a* log*(X)+b*

ILOG=12 or 13,14,15 means the same as 2 or 3,4,5 but now a 4-point cubic Lagrange formula is used for interpolation (see chapter 4).

IEXPL: left-hand extrapolation mode, *IEXPR:* right-hand extrapolation mode for energy values outside the original interval,

value=1 means linear extrapolation of the present *ILOG* interpolation

value=0 means values outside the original energy interval are set to zero.

Note: If the *MODE* parameter in the fluence input file is *MODE*=0, interpolation and integration according to chapter 3 will be performed; for *MODE* not equals to zero, only interpolation is performed.

Next line :

This line is needed only if the input response matrix is in the special format described above; **this line is not needed for *FMT input response matrices**.

A line of up to 40 characters is required as a comment line which is transferred to the output response matrix.

Next line :

This line, too, is needed only if the input response matrix is in the special format; **this line is not needed for *.FMT input response matrix files**.

It has to contain the interpolation and extrapolation rules for the input response matrix file. *ILOG, IEXPL, IEXPR* (see above).

Next line :

An additional *.FMT file can be combined with the input response matrix. The switch parameter is *IADDF*.

IADDF=1: An additional *.FMT file should be combined with the input response matrix.

IADDF=0: No additional *.FMT file should be combined with the input response matrix.

Next line :

Only required for *IADDF*=1: Name of the additional *.FMT file (not more than 40 characters).

Next line :

A number of additional files in the HEPRO format (detector responses, fluence-to-dose conversion functions) may be added to the new response function library. The number *IADD* of these files is needed.

Next (*IADD**5) **lines :**

A number of *IADD* packages follows, each package consisting of 5 lines:

Package line 1: Name of the HEPRO file with the data (including path, not more than 40 characters)

Package line 2: Short name of the detector (8 characters), this name is later used to identify the detector in the unfolding work.

Package line 3: Long name of the detector (16 characters) for more information on the detector.

Package line 4: Additional comment (up to 40 characters) identifying the detector.

This comment is transferred to the output.

Package line 5: . *ILOG, IEXPL, IEXPR, ICALIB, IUNS* (for the definition of *ILOG, IEXPL, IEXPR,* see above; these parameters define the interpolation and extrapolation modes of the detector data). If the *MODE* parameter of the HEPRO file under investigation is zero, interpolation **and integration** will be performed; otherwise, interpolation only.

For *ICALIB*=1, the calibration factor according to eq. (5.4) is calculated and written as the factor *CLAM* (see above) into the library

$$CLAM = \frac{\int \mathrm{d}E \;\; \mathrm{h}^{*}_{\Phi}(E)\, \Phi^{\mathrm{ref}}_{E}(E)}{\int \mathrm{d}E \;\; \widehat{R}(E)\, \Phi^{\mathrm{ref}}_{E}(E)} \qquad (11.1)$$

The parameter *IUNS* is introduced for later use as an uncertainty parameter. It is intended that the uncertainty information might be considered by *IUNS*=1. Up to now, only *IUNS*=0 can be used.

Next line :

Pseudo response functions can be created by the program which are defined as step functions for the fluence with response value of 1.0 in a certain energy interval E_1 to E_2 .

In this line the number *IPSEU* of these pseudo reactions has to be given.

Next (*IPSEU**5) **lines :**

IPSEU packages each containing 5 lines with

Package line 1: Energy interval E_1 to E_2 in MeV

Package line 2: Short name of this pseudo fluence respose (8 characters),

Package line 3: Long name of this pseudo fluence response (16 characters)

Dose-equivalent responses (fluence-to-dose-equivalent conversion factors) are established for the same energy interval as step functions, being zero outside.

Package line 4: Short name of the dose-equivalent response (8 characters)

Package line 5: Long name of the dose-equivalent response (16 characters)

Next line :

If the **energy** *E* itself is to be created as a pseudo response function, a value of 1 has to be given in this line, otherwise the value 0.

Next line :

Create the 1/v absortion cross section as an additional pseudo response function.

Value=1: The function $\frac{1}{v} = \frac{1}{\sqrt{E}}$ (which is proportional to the absorption cross section of many materials) is to be created as a pseudo response function, value=0: Otherwise.

Next line :

The short name of the response function used for the calculation of the pseudo dose-equivalent responses must be given in this line, e.g. ICRP74A.

12. Examples of RESTRAW

In the following some examples from the diskette are given.

1st Example

The response matrix file RESPSHOR.ALV (response matrix given pointwise, see chapter 11) is transferred to the new matrix RESTR-1.FMT; a finer group structure is chosen; a number of conversion functions and some pseudo response functions are added to the RESTR-1.FMT library.

Name of the input file: RESTR-1.INP; the contents are:

```
restr-1.log                                 name of protocol output file
14                                          E-structure four times the original
files\response\respshor.alv                 response matrix input file
files\response\RESTR-1.fmt                  formatted output
files\iso\ambeiso                           fluence file for Folding
files\fluence\ambeiso.flu                   fluence file in the new format
2000.0                                      highest neutron enrg. in MeV for use
15,1,1                                      interpol. law for fluence, extrapol.
response Matrix ALEVRA FILE: C-1_94.A61     commment line
3,1,1                                       interpol. law for responses, extrapol
0                                           0= no additional *.fmt, 1 = yes
7                                           number of following files
files\convers\ICRP74_A                      file name with path
ICRP74A                                     short name in the library
ICRP74 FROM ALEVRA                          long name in the library
values reasonably extrapolated by ALEVRA    long comment
15,1,1,0,0                                  interpol., 2X extrapol,icalib,iuns
files\convers\HP10_00                       file name with path
HP10_00                                     short name in the library
HP10 0 degree                               long name in the library
values obtained from the program SIEBERT    long comment
5,1,1,0,0                                   interpol., 2X extrapol,icalib,iuns
files\convers\HP10_15                       file name with path
HP10_15                                     short name in the library
HP10 15 degree                              long name in the library
values obtained from the program SIEBERT    long comment
5,1,1,0,0                                   interpol., 2X extrapol,icalib,iuns
files\convers\HP10_30                       file name with path
HP10_30                                     short name in the library
HP10 30 degree                              long name in the library
values obtained from the program SIEBERT    long comment
5,1,1,0,0                                   interpol., 2X extrapol,icalib,iuns
files\convers\HP10_45                       file name with path
HP10_45                                     short name in the library
HP10 45 degree                              long name in the library
values obtained from the program SIEBERT    long comment
5,1,1,0,0                                   interpol., 2X extrapol,icalib,iuns
files\convers\HP10_60                       file name with path
HP10_60                                     short name in the library
HP10 60 degree                              long name in the library
values obtained from the program SIEBERT    long comment
5,1,1,0,0                                   interpol., 2X extrapol,icalib,iuns
files\convers\HP10_75                       file name with path
HP10_75                                     short name in the library
HP10 75 degree                              long name in the library
values obtained from the program SIEBERT    long comment
5,1,1,0,0                                   interpol., 2X extrapol,icalib,iuns
```

```
6                                       6 energy range integrals
1.0e-13,1.0e12                          energy range
FPHI-TOT                                short name
PHI-TOTAL ******                        long name
DPHI-TOT                                short name dosis
PHI-TOTAL DOSE**                        long name dosis
1.0e-13,0.5e-6                          energy range
FTHERMAL                                short name
E < 0.5 eV F                            long name
DTHERMAL                                short name dosis
E < 0.5 eV D                            long name  dosis
0.5e-6,0.1                              energy range
F-INTER-                                short name
0.5eV -0.1 MeV F                        long name
D-INTER-                                short name  dosis
0.5eV -0.1 MeV D                        long name  dosis
0.1,1.0                                 energy range
F-FAST-1                                short name
0.1MeV-1.0 MeV F                        long name
D-FAST-1                                short name  dosis
0.1MeV-1.0 MeV D                        long name   dosis
1.0,10.0                                energy range
F-FAST-2                                short name
1.0MeV- 10 MeV F                        long name
D-FAST-2                                short name  dosis
1.0MeV- 10 MeV D                        long name   dosis
10.0,1.0e13                             energy range
F-FROM10                                short name
E > 10.0 MeV   F                        long name
D-FROM10                                short name  dosis
E > 10.0 MeV   D                        long name   dosis
1                                       energy as a response function, yes
1                                       1/v as a response function, yes
ICRP74A                                 for calculating calib. factor
```

2nd Example

A number of rem counter responses is added to the existing RESTR-1.fmt file. The new file is RESTR-2.fmt. The name of the input file is RESTR-2.INP.

Contents:

```
restr-2.log                             name of protocol output file
11                                      E-structure four times the original
files\response\restr-1.fmt              response matrix input file
files\response\RESTR-2.fmt              formatted output
files\iso\ambeiso                       fluence file for Folding
files\fluence\ambeiso.flu               fluence file in the new format
2000.0                                  highest neutron enrg. in MeV for use
15,1,1                                  interpol. law for fluence, extrapol.
0                                       0= no additional *.fmt, 1 = yes
4                                       number of following files
files\remcount\LINUSISO                 file name with path
SPLINISO                                short name in the library
LINUS SIL. ISO                          long name in the library
LINUS ISO"Bonner sphere", LAGR INTERPOL.  long comment
3,1,1,0,0                               interpol., 2X extrapol,icalib,iuns
files\remcount\LINUSLAT                 file name with path
SPLINLAT                                short name in the library
LINUS SIL. LAT                          long name in the library
LINUS LAT"Bonner sphere", LAGR INTERPOL.  long comment
3,1,1,0,0                               interpol., 2X extrapol,icalib,iuns
files\remcount\LINUSALV                 file name with path
```

```
SPLINALV                                    short name in the library
LINUS SIL. ALV                              long name in the library
LINUS as "Bonner sphere", ext. by ALEVRA    long comment
3,1,1,0,0                                   interpol., 2X extrapol,icalib,iuns
files\remcount\LINUSWGL                     file name with path
SPLINWGL                                    short name in the library
LINUS MCNP WGL                              long name in the library
LINUS as "Bonner sphere", MCNP by WIEGEL    long comment
3,1,1,0,0                                   interpol., 2X extrapol,icalib,iuns
0                                           no energy range integrals
0                                           energy as a response function, yes
0                                           1/v as a response function, yes
ICRP74A                                     for calculating calib. factor
```

3rd Example

Calibration factors for Am-Be-neutron sources are created and the response functions of some added detector data are scaled and renamed. The input file is named RESTR_BE.INP, the response matrix output file is RESTR_BE.FMT. Note: some new names have been given to the rem counters, e.g. LEAKI_BE for the IAEA rem counter data, LEAKH_BE for the Harwell data and LEAKA_BE for the rem counter data obtained from A. V. Alevra, both calibrated with the Am-Be-spectrum.

Contents:

```
RESTR_be.log                                name of protocol output file
11                                          E-structure three times the
files\response\RESTR-2.FMT                  response matrix input file
files\response\RESTR_be.FMT                 formatted output
files\iso\ambeiso                           fluence file for Folding
files\fluence\ambeiso.flu                   fluence file in the new format
2000.0                                      highest neutron energy in MeV
3,1,1                                       interpol. law for fluence, extrap.
0                                           no additional *.fmt file
22                                          number of following files
files\remcount\LEAKE_A                      file name with path
LEAKA_be                                    short name in the library
LEAKE FROM ALEVRA                           long name in the library
LEAKE alevra 3h6s7r.61e (ambe-iso8529)      comment
3,1,1,1,0                                   interp. 2x exttrapol, icalib, iuns
files\remcount\LEAKIAEA                     file name with path
LEAKI_be                                    short name in the library
LEAKE spktbib                               long name in the library
LEAKE spktbib interp.assumed ambe-iso       comment
3,1,1,1,0                                   interpol.and extrapol.laws,calib.fac
files\remcount\HARWELL                      file name with path
LEAKH_be                                    short name in the library
HARWELL SPKTBIB                             long name in the library
HARWELL spktbib interp.assumed ambe-iso      comment
3,1,1,1,0                                   interpol.and extrapol.laws,calib.fac
files\remcount\JULICH_a                     file name with path
JULIC_be                                    short name in the library
JULIC FROM ALEVRA                           long name in the library
JULIC alevra 3h6s7r.61e (ambe-iso8529)      comment
3,1,1,1,0                                   interp. 2x exttrapol, icalib, iuns
files\remcount\LB64_A                       file name with path
LB64__be                                    short name in the library
```

```
LB64 from ALEVRA                              long name in the library
LB64 alevra 3h6s7r.61e  (ambe-iso8529)        comment
3,1,1,1,0                                     interp. 2x exttrapol, icalib, iuns
files\remcount\SNOOPY_A                       file name with path
SNOPA_be                                      short name in the library
SNOOPY from ALEVRA                            long name in the library
SNOOPY alevra 3h6s7r.61e (ambe-iso8529)       comment
3,1,1,1,0                                     interp. 2x exttrapol, icalib, iuns
files\remcount\SNOOPY1                        file name with path
SNOOP_be                                      short name in the library
SNOOPY Hankins,iaea318                        long name in the library
Hankins spktbib iaea318 (ambe-iso8529)        comment
3,1,1,1,0                                     interpol.2x extrap.,calib.fac,iuns
files\remcount\CYLINU_A                       file name with path
CYLIN_be                                      short name in the library
CYLINDRICAL LINUS NM5                         long name in the library
NM5 alevra 3h6s7r.61e (ambe-iso8529)          comment
3,1,1,1,0                                     interp. 2x exttrapol, icalib, iuns
files\remcount\LINUSISO                       file name with path
LINISObe                                      short name in the library
LIN-SIL-ISO-be                                LONG name
LINUS SILARI ISO (ambe-iso8529)               comment
3,1,1,1,0                                     interp. 2x exttrapol, icalib, iuns
files\remcount\LINUSLAT                       file name with path
LINLATbe                                      short name in the library
LIN-SIL-LAT-be                                LONG name
LINUS SILARI LAT (ambe-iso8529)               comment
3,1,1,1,0                                     interp. 2x exttrapol, icalib, iuns
files\remcount\LINUSALV                       file name with path
LINALVbe                                      short name in the library
LIN-SIL-ALV-be                                LONG name
LINUS alevra 3h6s7r.61e (ambe-iso8529)        comment
3,1,1,1,0                                     interp. 2x exttrapol, icalib, iuns
files\remcount\LINUSWGL                       file name with path
LINWGLbe                                      short name in the library
LIN-PTB-WGL-be                                LONG name
LINUS wiegel MCNP-calc. (ambe-iso8529)        comment
3,1,1,1,0                                     interp. 2x exttrapol, icalib, iuns
files\remcount\EBERL1                         file name with path
EBERL_be                                      short name in the library
EBERLINE                                      long name in the library
EBERLINE spktbib interp.assumed ambe-iso      comment
3,1,1,1,0                                     interpol.and extrapol.laws,calib.fac
files\remcount\STUDSV1                        file name with path
STUDS_be                                      short name in the library
STUDSVIK spktbib                              long name in the library
STUDSVIK spktbib interp.assumed ambe-iso      comment
3,1,1,1,0                                     interpol.and extrapol.laws,calib.fac
files\remcount\TEPC_A                         file name with path
TEPC__be                                      short name in the library
TEPC from ALEVRA                              long name in the library
TEPC from Alevra interp.assumed ambe-iso      comment
3,1,1,1,0                                     interpol.and extrapol.laws,calib.fac
files\detector\TLD-kr                         file name with path
TLDKR_be                                      short name in the library
TLD Karlsruhe (BAUER)                         long name in the library
TLD Karlsruhe (BAUER)  .assumed ambe-iso      comment
3,1,1,1,0                                     interpol.and extrapol.laws,calib.fac
files\detector\blankrsp.b                     file name with path
BLANKRSP                                      short name in the library
blankrsp-MAT225                               long name in the library
blank 3He-sphere PTB calculated MATZKE        comment
3,1,1,0,0                                     interpol.and extrapol.laws,calib
files\detector\cdrsp.b                        file name with path
CDRSPSH                                       short name in the library
CDRSPS-MAT225,CD                              long name in the library
cd-rsp round the PTB 0'' sphere (MATZKE)      comment
```

```
3,1,1,0,0                                   interpol.and extrapol.laws,calib
files\convers\icrp74n                       file name with path
ICRP74N                                     short name in the library
icrp74 (new run)                            long name in the library
data by program of B. Siebert (own run)     comment
15,1,1,0,0                                  interpol.and
files\convers\icrp74.665                    file name with path
ICRP665                                     short name in the library
icrp74.665                                  long name in the library
data by prog. of B. Siebert (665groups)     comment
15,1,1,0,0                                  interpol.and
files\convers\ICRP74_i                      file name with path
ICRP74I                                     short name in the library
spktbib data                                long name in the library
original ISO data as in SPKTBIB             comment
15,1,1,0,0                                  interpol.and
files\convers\H21_A                         file name with path
H21_A                                       short name in the library
H21 from ALEVRA                             long name in the library
data from alevra 3h6s7r.61e                 comment
15,1,1,0,0                                  interpol.and extrapol.laws,calib.
files\convers\H39_A                         file name with path
H39_A                                       short name in the library
H39 from ALEVRA                             long name in the library
data from alevra 3h6s7r.61e                 comment
15,1,1,0,0                                  interpol.and extrapol.laws,calib
0                                           no energy range integrals
0                                           energy as a response function:no
0                                           1/v as a response function: no
ICRP74A                                     for calculating calib. factor
```

Other input files are available (e.g. for californium spectra) for the creation of response functions calibrated in the ISO-Cf-spectrum or the ENDF(Mannhart) Cf-spectrum.

4th .Example

Running the program **UMSFAC** which multiplies the data values contained in an response matrix file *.FMT by the calibration factors *CLAM* (see chapter 7.2).
In the second line of the input file a global factor for all responses can be given.
File UMSFAC.INP:

```
umsfac.log                                  Protocol file
1.0                                         multiplication by factor
files\response\restr_ce.fmt                 input resp.file
files\response\resphig2.fmt                 output resp.file
```

13. The SELECTDF program

With the SELECTDF program single files in the HEPRO format can be extracted from a *.FMT file. In addition, calibration factors of a set of detectors for a given spectrum file are calculated.

An example may be discussed with the input file SELECTBE.INP:

```
   selectbe.log                              protocol file
   act                                       file with the readings of BONNER
spheres
   ..\resp\files\response\resphig3.fmt       ASCII response function file
   ..\resp\files\fluence\ambeiso.flu         Fluence file for the folding
   1                                         create single files
   ..\resp\files\all\                        path for the single files
```

In the second line a file name is required containing all the 8-character names of the library which should be considered (see directory \RESTRAW\integral), i.e. for the response functions corresponding to these names the calibration factors are calculated and (if required) extracted as a single file. The 5th line contains the name of the **fluence file** for which calibration factors have to be calculated by folding.

The user may use the BATCH.BAT file in the directory \RESTRAW\integral to evaluate the calibration factors for a number of different standard files. This batch file with the SELECDF run should be used after the creation of the various library files *.FMT, since some of the fluence files created there are used in the examples given here.

Note: Within the batch files, online plotting is possible; look at the contents of the batch files. (PLOTAW.EXE should be located in one of your path-directories).

14. Calibration Factors and Integral Fluence-to-dose Conversion Factors

The following table1 shows calibration factors and integral fluence-to-dose conversion factors obtained with the SELECTDF program using the input files of the directory \RESTRAW\integral. The table relates to fluence values normalized to 1.

The 1st column of the table gives the 8-character short name of the response function or the conversion function; the following 6 columns contain the integrals $Z_i = \int \mathrm{d}E\, R_i(E)\, \Phi_E(E)$ for

1. the ISO-spectral fluence of the Am-Be source,
2. the total spectral fluence for the Am-Be source,
3. the inscattered spectral fluence for the Am-Be source,
4. the ISO-spectral fluence of the Cf source,
5. the total spectral fluence for the Cf source,
6. the inscattered spectral fluence for the Cf source

The relationship between the names of table 1 and the names mentioned in chapter 9 can be found in table 3.

Table 1

Calibration factors and responses for a number of detectors and response functions in some calibration fields.

All fluence values are normalized to 1.0 (option in SELECTDF program)

	File AMBEISO. FLU	FILE BEQFL.TOT	FILE BEQFL.INS	FILE CFISOC. FLU	FILE CFQFL.TOT	FILE CFQFL.INS
ICRP74A	392.2	285.8	153.6	384.4	264.7	140.0
ICRP74N	391.8	285.4	153.4	384.0	264.4	139.8
ICRP665	391.8	285.4	153.4	384.0	264.4	139.8
ICRP74I	392.2	285.8	153.6	384.4	264.7	140.0
H21_A	374.2	262.8	128.7	337.6	225.2	109.5
H39_A	381.6	269.5	133.2	342.4	231.1	116.0
HP10_00	411.2	299.1	159.8	399.3	274.8	145.2
HP10_15	409.2	297.1	157.8	395.5	271.8	143.1
HP10_30	424.5	306.2	159.6	407.4	277.9	143.3
HP10_45	414.8	295.5	148.7	387.8	261.7	131.0
HP10_60	383.4	268.4	127.4	344.4	228.2	108.4
HP10_75	292.5	196.0	79.4	229.1	145.9	61.1
FPHI-TOT	**1.000E+00**	**1.000E+00**	**1.000E+00**	**1.000E+00**	**1.000E+00**	**1.000E+00**
DPHI-TOT	3.921E+02	2.857E+02	1.536E+02	3.844E+02	2.647E+02	1.400E+02
FTHERMAL	5.583E-08	9.787E-02	2.138E-01	1.580E-10	1.111E-01	2.213E-01
DTHERMAL	7.326E-07	1.168E+00	2.551E+00	2.118E-09	1.327E+00	2.652E+00
F-INTER-	1.459E-02	1.696E-01	3.659E-01	1.354E-02	1.877E-01	3.771E-01
D-INTER-	6.354E-01	3.022E+00	6.059E+00	6.930E-01	3.453E+00	6.407E+00
F-FAST-1	1.218E-01	1.661E-01	2.062E-01	2.837E-01	2.783E-01	2.595E-01
D-FAST-1	3.670E+01	4.738E+01	5.594E+01	9.091E+01	8.362E+01	7.138E+01
F-FAST-2	8.496E-01	5.500E-01	2.138E-01	6.997E-01	4.221E-01	1.419E-01
D-FAST-2	3.486E+02	2.266E+02	8.900E+01	2.914E+02	1.760E+02	5.954E+01
F-FROM10	1.389E-02	1.628E-02	1.003E-04	2.936E-03	7.068E-04	1.641E-05
D-FROM10	6.141E+00	7.573E+00	4.534E-02	1.376E+00	3.118E-01	7.242E-03
< E >---	4.150E+00	2.596E+00	6.854E-01	2.128E+00	1.279E+00	4.139E-01
<1/V>---	1.820E-08	1.230E-05	2.703E-05	2.398E-08	1.380E-05	2.730E-05

SPLINISO	0.494	0.362	0.202	0.504	0.345	0.181
SPLINLAT	0.491	0.359	0.199	0.497	0.340	0.178
SPLINALV	0.422	0.310	0.175	0.436	0.299	0.157
SPLINWGL	0.396	0.291	0.164	0.401	0.276	0.147
LEAKA_be	392.1	301.2	190.5	422.2	302.9	178.8
LEAKI_be	392.1	296.4	180.6	412.6	292.0	167.1
LEAKH_be	392.1	293.7	175.5	400.8	282.4	160.3
JULIC_be	392.2	264.9	112.2	314.4	202.2	87.8
LB64__be	392.1	277.8	143.1	369.9	248.1	122.9
SNOPA_be	392.0	288.5	164.5	403.0	277.1	147.3
SNOOP_be	392.1	283.3	153.6	381.7	261.1	136.5
CYLIN_be	392.1	284.3	154.0	384.6	262.1	136.0
LINISObe	392.1	287.4	160.7	400.5	274.1	143.7
LINLATbe	392.1	286.5	158.8	396.8	271.6	142.2
LINALVbe	392.1	288.5	163.0	405.5	277.8	146.1
LINWGLbe	392.2	288.0	162.9	397.5	273.5	145.8
EBERL_be	392.1	294.8	178.4	387.1	277.8	164.7
STUDS_be	392.1	273.3	132.9	348.0	230.7	110.7
TEPC__be	392.2	273.3	127.4	344.2	228.3	108.6
TLDKR_be	392.8	711.8	1098.3	567.7	850.5	1150.8
LEAKA_ci	357.0	274.2	173.4	384.4	275.8	162.8
LEAKI_ci	365.5	276.3	168.3	384.6	272.1	155.8
LEAKH_ci	376.2	281.8	168.4	384.4	270.9	153.7
JULIC_ci	479.4	323.8	137.2	384.4	247.2	107.3
lb64__ci	407.6	288.7	148.8	384.5	257.9	127.8
SNOPA_ci	374.1	275.4	156.9	384.6	264.4	140.6
SNOOP_ci	394.9	285.4	154.8	384.4	263.0	137.5
CYLIN_ci	392.1	284.3	154.0	384.6	262.1	136.0
LINISOci	376.4	275.8	154.2	384.5	263.1	138.0
LINLATci	379.9	277.5	153.8	384.4	263.1	137.8
LINALVci	371.7	273.5	154.5	384.4	263.3	138.5
LINWGLci	379.2	278.5	157.5	384.4	264.5	141.0
EBERL_ci	389.4	292.7	177.1	384.5	275.9	163.6
STUDS_ci	433.0	301.8	146.7	384.3	254.8	122.3
TEPC__ci	438.2	305.4	142.3	384.6	255.1	121.3
TLDKR_ci	266.0	482.0	743.7	384.4	575.9	779.3
LEAKA_ce	356.8	274.1	173.3	384.2	275.6	162.7
LEAKI_ce	364.9	275.9	168.1	384.0	271.7	155.5
LEAKH_ce	375.6	281.3	168.2	383.9	270.5	153.5
JULIC_ce	478.4	323.2	136.9	383.6	246.7	107.1
lb64__ce	406.5	287.9	148.3	383.4	257.2	127.4
SNOPA_ce	373.0	274.6	156.5	383.5	263.7	140.2
SNOOP_ce	394.3	284.9	154.5	383.8	262.5	137.3
CYLIN_ce	391.0	283.6	153.6	383.6	261.4	135.6
LINISOce	375.6	275.2	153.9	383.6	262.6	137.7
LINLATce	379.2	277.1	153.6	383.8	262.7	137.6
LINALVce	370.9	272.9	154.2	383.6	262.7	138.2
LINWGLce	378.4	277.9	157.2	383.6	264.0	140.7
EBERL_ce	389.1	292.5	177.0	384.2	275.7	163.4
STUDS_ce	431.7	301.0	146.3	383.2	254.0	121.9
TEPC__ce	437.8	305.1	142.2	384.2	254.8	121.2
TLDKR_ce	268.3	486.1	750.1	387.7	580.8	786.0

BLANKRSP	4.994E-04	2.703E-01	5.911E-01	6.785E-04	3.037E-01	6.012E-01
CDRSPSH	4.821E-04	2.125E-02	4.634E-02	6.529E-04	2.148E-02	4.413E-02
0W0	4.950E-04	2.468E-01	5.393E-01	6.657E-04	2.773E-01	5.491E-01
0W0iso	5.022E-04	2.595E-01	5.672E-01	6.767E-04	2.916E-01	5.774E-01
0W0nd	5.089E-04	2.696E-01	5.893E-01	6.855E-04	3.029E-01	5.998E-01
C0W0	4.819E-04	2.127E-02	4.627E-02	6.478E-04	2.140E-02	4.395E-02
C0W0iso	5.065E-04	2.217E-02	4.837E-02	6.788E-04	2.240E-02	4.602E-02
C0W0nd	4.917E-04	2.240E-02	4.874E-02	6.617E-04	2.253E-02	4.630E-02
3W0	1.992E-01	6.514E-01	1.201E+00	3.279E-01	7.764E-01	1.251E+00
3W5	4.060E-01	8.795E-01	1.451E+00	6.503E-01	1.075E+00	1.525E+00

4W0	6.675E-01	1.113E+00	1.644E+00	1.035E+00	1.376E+00	1.735E+00
4W5	9.533E-01	1.328E+00	1.767E+00	1.428E+00	1.642E+00	1.866E+00
5W0	1.234E+00	1.508E+00	1.820E+00	1.782E+00	1.848E+00	1.915E+00
6W0	1.718E+00	1.750E+00	1.767E+00	2.298E+00	2.070E+00	1.830E+00
7W0	2.027E+00	1.830E+00	1.574E+00	2.505E+00	2.057E+00	1.588E+00
8W0	2.170E+00	1.795E+00	1.334E+00	2.472E+00	1.897E+00	1.301E+00
10W	2.081E+00	1.528E+00	8.745E-01	2.002E+00	1.398E+00	7.787E-01
12W	1.754E+00	1.193E+00	5.429E-01	1.423E+00	9.320E-01	4.323E-01
15W	1.209E+00	7.662E-01	2.585E-01	7.645E-01	4.693E-01	1.699E-01
18W	7.606E-01	4.645E-01	1.214E-01	3.829E-01	2.253E-01	6.511E-02
22W	1.327E+00	1.518E+00	1.728E+00	1.767E+00	1.787E+00	1.807E+00
23W	1.497E+00	1.339E+00	1.133E+00	1.830E+00	1.498E+00	1.150E+00
24W	1.786E+00	1.767E+00	1.720E+00	2.285E+00	2.036E+00	1.773E+00
25W	1.853E+00	1.784E+00	1.673E+00	2.277E+00	2.003E+00	1.716E+00
0C0	4.912E-04	2.631E-01	5.755E-01	6.651E-04	2.956E-01	5.852E-01
C0C0	4.911E-04	2.268E-02	4.948E-02	6.651E-04	2.286E-02	4.700E-02
3C0	2.000E-01	6.381E-01	1.170E+00	3.270E-01	7.612E-01	1.219E+00
3C5	4.102E-01	8.685E-01	1.421E+00	6.530E-01	1.062E+00	1.495E+00
4C0	6.814E-01	1.114E+00	1.631E+00	1.050E+00	1.378E+00	1.722E+00
4C5	9.829E-01	1.346E+00	1.771E+00	1.462E+00	1.662E+00	1.871E+00
5C0	1.259E+00	1.516E+00	1.808E+00	1.805E+00	1.854E+00	1.902E+00
6C0	1.757E+00	1.769E+00	1.761E+00	2.336E+00	2.086E+00	1.822E+00
7C0	2.090E+00	1.867E+00	1.580E+00	2.567E+00	2.090E+00	1.591E+00
8C0	2.232E+00	1.829E+00	1.335E+00	2.524E+00	1.922E+00	1.297E+00
10C	2.139E+00	1.559E+00	8.754E-01	2.042E+00	1.416E+00	7.734E-01
12C	1.828E+00	1.237E+00	5.523E-01	1.471E+00	9.569E-01	4.343E-01
15C	1.209E+00	7.635E-01	2.546E-01	7.600E-01	4.643E-01	1.647E-01
18C	7.991E-01	4.853E-01	1.270E-01	4.024E-01	2.362E-01	6.725E-02

Table 2 below shows the absolute values for the expected readings and the absolute integral fluence-to-dose conversion factors obtained by the SELECTDF program using the input files of the directory \RESTRAW\integral.

In the 1st column of the table the 8-character short name of the response function or the conversion function is given. The following 4 columns contain the integrals $Z_i = \int \mathrm{d}E\, R_i(E)\, \Phi_E(E)$ for the fluence predicted at 170 cm distance from the source.

1. total spectral fluence for the Am-Be source,
2. inscattered spectral fluence for the Am-Be source,
3. total spectral fluence for the Cf source,
4. inscattered spectral fluence for the Cf source

Table 2: Absolute readings per source neutron for a number of detectors, conversion functions and response functions in some calibration fields. All fluence values are per source neutron at a distance of 170 cm from the source.

	Am-Be total fluence file be1qfl.tot	Am-Be inscattered fluence file be1qfl.ins	Cf-252 total fluence file cf1qfl.tot	Cf-252 inscattered fluence file cf1qfl.ins
ICRP74A	1.3366E-03	3.1744E-04	1.3815E-03	3.4753E-04
ICRP74N	1.3350E-03	3.1702E-04	1.3797E-03	3.4691E-04
ICRP665	1.3350E-03	3.1703E-04	1.3797E-03	3.4693E-04
ICRP74I	1.3367E-03	3.1746E-04	1.3816E-03	3.4758E-04
H21_A	1.2291E-03	2.6602E-04	1.1754E-03	2.7192E-04
H39_A	1.2607E-03	2.7514E-04	1.2059E-03	2.8787E-04
HP10_00	1.3989E-03	3.3012E-04	1.4342E-03	3.6048E-04
HP10_15	1.3895E-03	3.2608E-04	1.4186E-03	3.5526E-04
HP10_30	1.4320E-03	3.2980E-04	1.4500E-03	3.5559E-04
HP10_45	1.3820E-03	3.0725E-04	1.3658E-03	3.2528E-04
HP10_60	1.2552E-03	2.6324E-04	1.1910E-03	2.6911E-04
HP10_75	9.1652E-04	1.6403E-04	7.6165E-04	1.5163E-04
FPHI-TOT	4.6774E-06	2.0665E-06	5.2189E-06	2.4824E-06
DPHI-TOT	1.3366E-03	3.1744E-04	1.3815E-03	3.4753E-04
FTHERMAL	4.5780E-07	4.4198E-07	5.8007E-07	5.4957E-07
DTHERMAL	5.4637E-06	5.2717E-06	6.9290E-06	6.5841E-06
F-INTER-	7.9344E-07	7.5625E-07	9.7973E-07	9.3624E-07
D-INTER-	1.4136E-05	1.2521E-05	1.8025E-05	1.5905E-05
F-FAST-1	7.7723E-07	4.2616E-07	1.4525E-06	6.4423E-07
D-FAST-1	2.2162E-04	1.1561E-04	4.3643E-04	1.7721E-04
F-FAST-2	2.5728E-06	4.4190E-07	2.2029E-06	3.5231E-07
D-FAST-2	1.0600E-03	1.8394E-04	9.1853E-04	1.4782E-04
F-FROM10	7.6178E-08	2.0727E-10	3.6889E-09	4.0746E-11
D-FROM10	3.5426E-05	9.3707E-08	1.6276E-06	1.7977E-08
< E >---	1.2143E-05	1.4165E-06	6.6748E-06	1.0277E-06
<1/V>---	5.7560E-11	5.5863E-11	7.2067E-11	6.7789E-11
SPLINISO	1.6921E-06	4.1807E-07	1.8012E-06	4.4922E-07
SPLINLAT	1.6790E-06	4.1108E-07	1.7760E-06	4.4236E-07
SPLINALV	1.4513E-06	3.6229E-07	1.5589E-06	3.8993E-07
SPLINWGL	1.3590E-06	3.3961E-07	1.4400E-06	3.6514E-07

LEAKA_be	1.4088E-03	3.9366E-04	1.5806E-03	4.4394E-04
LEAKI_be	1.3863E-03	3.7318E-04	1.5237E-03	4.1480E-04
LEAKH_be	1.3738E-03	3.6276E-04	1.4739E-03	3.9784E-04
JULIC_be	1.2392E-03	2.3188E-04	1.0553E-03	2.1790E-04
LB64__be	1.2992E-03	2.9572E-04	1.2948E-03	3.0516E-04
SNOPA_be	1.3496E-03	3.3984E-04	1.4460E-03	3.6570E-04
SNOOP_be	1.3253E-03	3.1750E-04	1.3626E-03	3.3885E-04
CYLIN_be	1.3298E-03	3.1832E-04	1.3678E-03	3.3747E-04
LINISObe	1.3441E-03	3.3208E-04	1.4307E-03	3.5682E-04
LINLATbe	1.3400E-03	3.2809E-04	1.4175E-03	3.5305E-04
LINALVbe	1.3496E-03	3.3690E-04	1.4496E-03	3.6260E-04
LINWGLbe	1.3472E-03	3.3665E-04	1.4275E-03	3.6195E-04
EBERL_be	1.3787E-03	3.6862E-04	1.4497E-03	4.0884E-04
STUDS_be	1.2785E-03	2.7458E-04	1.2042E-03	2.7485E-04
TEPC__be	1.2784E-03	2.6322E-04	1.1913E-03	2.6959E-04
TLDKR_be	3.3293E-03	2.2697E-03	4.4385E-03	2.8568E-03
LEAKA_ci	1.2827E-03	3.5842E-04	1.4392E-03	4.0420E-04
LEAKI_ci	1.2922E-03	3.4785E-04	1.4203E-03	3.8665E-04
LEAKH_ci	1.3179E-03	3.4799E-04	1.4139E-03	3.8165E-04
JULIC_ci	1.5147E-03	2.8344E-04	1.2899E-03	2.6634E-04
lb64__ci	1.3504E-03	3.0739E-04	1.3459E-03	3.1720E-04
SNOPA_ci	1.2879E-03	3.2431E-04	1.3799E-03	3.4899E-04
SNOOP_ci	1.3348E-03	3.1978E-04	1.3724E-03	3.4128E-04
CYLIN_ci	1.3298E-03	3.1832E-04	1.3678E-03	3.3747E-04
LINISOci	1.2901E-03	3.1874E-04	1.3732E-03	3.4249E-04
LINLATci	1.2982E-03	3.1785E-04	1.3732E-03	3.4204E-04
LINALVci	1.2794E-03	3.1936E-04	1.3742E-03	3.4372E-04
LINWGLci	1.3027E-03	3.2555E-04	1.3804E-03	3.5002E-04
EBERL_ci	1.3691E-03	3.6606E-04	1.4397E-03	4.0600E-04
STUDS_ci	1.4117E-03	3.0318E-04	1.3296E-03	3.0347E-04
TEPC__ci	1.4284E-03	2.9410E-04	1.3311E-03	3.0121E-04
TLDKR_ci	2.2544E-03	1.5369E-03	3.0054E-03	1.9344E-03
LEAKA_ce	1.2819E-03	3.5819E-04	1.4382E-03	4.0393E-04
LEAKI_ce	1.2903E-03	3.4734E-04	1.4182E-03	3.8608E-04
LEAKH_ce	1.3160E-03	3.4749E-04	1.4118E-03	3.8110E-04
JULIC_ce	1.5118E-03	2.8289E-04	1.2874E-03	2.6583E-04
lb64__ce	1.3468E-03	3.0655E-04	1.3423E-03	3.1634E-04
SNOPA_ce	1.2843E-03	3.2339E-04	1.3760E-03	3.4800E-04
SNOOP_ce	1.3326E-03	3.1924E-04	1.3701E-03	3.4071E-04
CYLIN_ce	1.3263E-03	3.1747E-04	1.3642E-03	3.3658E-04
LINISOce	1.2874E-03	3.1807E-04	1.3703E-03	3.4177E-04
LINLATce	1.2960E-03	3.1731E-04	1.3709E-03	3.4146E-04
LINALVce	1.2765E-03	3.1864E-04	1.3710E-03	3.4294E-04
LINWGLce	1.3000E-03	3.2487E-04	1.3775E-03	3.4930E-04
EBERL_ce	1.3681E-03	3.6580E-04	1.4386E-03	4.0572E-04
STUDS_ce	1.4077E-03	3.0232E-04	1.3258E-03	3.0260E-04
TEPC__ce	1.4271E-03	2.9382E-04	1.3298E-03	3.0091E-04
TLDKR_ce	2.2738E-03	1.5502E-03	3.0312E-03	1.9512E-03
BLANKRSP	1.2643E-06	1.2216E-06	1.5849E-06	1.4924E-06
CDRSPSH	9.9414E-08	9.5752E-08	1.1211E-07	1.0954E-07

0W0	1.1543E-06	1.1145E-06	1.4471E-06	1.3630E-06
0W0iso	1.2138E-06	1.1721E-06	1.5217E-06	1.4333E-06
0W0nd	1.2609E-06	1.2177E-06	1.5808E-06	1.4889E-06
C0W0	9.9475E-08	9.5617E-08	1.1166E-07	1.0911E-07
C0W0iso	1.0370E-07	9.9958E-08	1.1689E-07	1.1423E-07
C0W0nd	1.0475E-07	1.0073E-07	1.1758E-07	1.1494E-07
3W0	3.0470E-06	2.4809E-06	4.0519E-06	3.1059E-06
3W5	4.1136E-06	2.9979E-06	5.6117E-06	3.7855E-06
4W0	5.2043E-06	3.3966E-06	7.1805E-06	4.3079E-06
4W5	6.2118E-06	3.6524E-06	8.5680E-06	4.6330E-06
5W0	7.0535E-06	3.7613E-06	9.6433E-06	4.7546E-06
6W0	8.1864E-06	3.6516E-06	1.0805E-05	4.5431E-06
7W0	8.5598E-06	3.2532E-06	1.0734E-05	3.9429E-06
8W0	8.3956E-06	2.7575E-06	9.9000E-06	3.2291E-06
10W	7.1456E-06	1.8071E-06	7.2969E-06	1.9330E-06
12W	5.5813E-06	1.1219E-06	4.8637E-06	1.0730E-06
15W	3.5838E-06	5.3425E-07	2.4493E-06	4.2176E-07
18W	2.1727E-06	2.5094E-07	1.1759E-06	1.6164E-07
22W	7.0996E-06	3.5708E-06	9.3267E-06	4.4856E-06
23W	6.2645E-06	2.3406E-06	7.8177E-06	2.8536E-06
24W	8.2666E-06	3.5536E-06	1.0624E-05	4.4002E-06
25W	8.3430E-06	3.4579E-06	1.0455E-05	4.2586E-06
0C0	1.2307E-06	1.1892E-06	1.5426E-06	1.4526E-06
C0C0	1.0610E-07	1.0225E-07	1.1931E-07	1.1667E-07
3C0	2.9849E-06	2.4177E-06	3.9725E-06	3.0271E-06
3C5	4.0622E-06	2.9373E-06	5.5446E-06	3.7105E-06
4C0	5.2117E-06	3.3696E-06	7.1891E-06	4.2749E-06
4C5	6.2944E-06	3.6599E-06	8.6736E-06	4.6433E-06
5C0	7.0893E-06	3.7363E-06	9.6745E-06	4.7218E-06
6C0	8.2730E-06	3.6383E-06	1.0886E-05	4.5216E-06
7C0	8.7307E-06	3.2649E-06	1.0905E-05	3.9482E-06
8C0	8.5553E-06	2.7595E-06	1.0029E-05	3.2184E-06
10C	7.2934E-06	1.8091E-06	7.3879E-06	1.9199E-06
12C	5.7854E-06	1.1413E-06	4.9941E-06	1.0782E-06
15C	3.5714E-06	5.2616E-07	2.4230E-06	4.0878E-07
18C	2.2699E-06	2.6247E-07	1.2325E-06	1.6694E-07

The relationship between the names of table 2 and the names mentioned in chapter 9 can be found in table 3.

Table 3: 8-character short names and their origin (see also text of the input files of the examples)

Conversion functions (see chapter 9.1)	
ICRP74A	ICRP74 acc. to A.V.Alevra (from file ICRP74_a)
ICRP74N	see chapter 9.1
ICRP665	see chapter 9.1 (ICRP74.665)
ICRP74I	see chapter 9.1(ICRP74_I)

H21_A	see chapter 9.1
H39_A	see chapter 9.1
HP10_00	see chapter 9.1
HP10_15	see chapter 9.1
HP10_30	see chapter 9.1
HP10_45	see chapter 9.1
HP10_60	see chapter 9.1
HP10_75	see chapter 9.1
	Pseudo response functions (step functions to calculate integrals over a certain energy range)
FPHI-TOT	total fluence
DPHI-TOT	total dose equivalent
FTHERMAL	thermal fluence (E < 0.5 eV)
DTHERMAL	thermal dose equivalent (E < 0.5 eV)
F-INTER-	intermediate fluence (range from 0.5 eV to 0.1 MeV)
D-INTER-	intermediate dose equivalent (range from 0.5 eV to 0.1 MeV)
F-FAST-1	fast fluence No. 1(range from 0.1 MeV to 1.0 MeV)
D-FAST-1	fast dose equivalent No. 1(range from 0.1 MeV to 1.0 MeV)
F-FAST-2	fast fluence No. 2(range from 1.0 MeV to 10.0 MeV)
D-FAST-2	fast dose equivalent No. 2(range from 1.0 MeV to 10.0 MeV)
F-FROM10	fluence above 10 MeV
D-FROM10	Dose equivalent above 10 MeV
< E >---	Neutron energy (Energy E as a pseudo response)
<1/V>---	1/v (1/SQRT(E) as a pseudo response)
	The LINUS rem counter as a fluence detector
SPLINISO	spherical LINUS isotropic incidence (see chapter 9.5)
SPLINLAT	spherical LINUS lateral incidence (see chapter 9.5)
SPLINALV	spherical LINUS evaluated by Alevra (see chapter 9.5)
SPLINWGL	spherical LINUS isotropic incidence (see chapter 9.5)
	Rem counters and other dose equivalent detectors
LEAKA_be	LEAKE acc. To Alevra (see chapter 9.5) Am-Be calibrated
LEAKI_be	LEAKE acc. To IAEA (Harrison)(see chapt. 9.5) Am-Be calibr.
LEAKH_be	LEAKE acc. To Harwell (see chapter 9.5) Am-Be calibrated
JULIC_be	TEPC Juelich acc. To Alevra (see chapter 9.5) Am-Be calibr.
LB64__be	LB64 from LB64_A (see chapter 9.5) Am-Be calibrated
SNOPA_be	SNOOPY from SNOOPY_A (see chapter 9.5) Am-Be calibrated
SNOOP_be	SNOOPY from SNOOP1 (Hankins)see chapter 9.5) Am-Be calibrated
CYLIN_be	Cylindr. LINUS from CYLINU_A (Chapter 9.5) Am-Be calibrated
LINISObe	Sperical LINUS from LINUSISO (Chapter 9.5) Am-Be calibrated
LINLATbe	Sperical LINUS from LINUSLAT (Chapter 9.5) Am-Be calibrated
LINALVbe	Sperical LINUS from LINUSALV (Chapter 9.5) Am-Be calibrated
LINWGLbe	Sperical LINUS from LINUSWGL (Chapter 9.5) Am-Be calibrated
EBERL_be	Eberle remcounter from EBERL1 (chapter 9.5) Am-Be calibrated
STUDS_be	Studsvik remcount.from STUDSV1 (chapter 9.5) Am-Be calibrated
TEPC__be	TEPC from TEPC_A (chapter 9.5) Am-Be calibrated
TLDKR_be	TLD response, Karlsruhe data (Bauer) Am-Be calibrated
LEAKA_ci	LEAKE acc. To Alevra (see chapter 9.5) Cf-ISO calibrated
LEAKI_ci	LEAKE acc. To IAEA (Harrison)(see chapt. 9.5) Cf-ISO calibr.
LEAKH_ci	LEAKE acc. To Harwell (see chapter 9.5) Cf-ISO calibrated
JULIC_ci	TEPC Juelich acc. To Alevra (see chapt. 9.5) Cf-ISO calibr.
Lb64__ci	LB64 from LB64_A (see chapter 9.5) Cf-ISO calibrated

SNOPA_ci	SNOOPY from SNOOPY_A (see chapter 9.5) Cf-ISO calibrated
SNOOP_ci	SNOOPY from SNOOP1 (Hankins)see chapt.9.5) Cf-ISO calibrated
CYLIN_ci	Cylindr. LINUS from CYLINU_A (Chapter 9.5) Cf-ISO calibrated
LINISOci	Sperical LINUS from LINUSISO (Chapter 9.5) Cf-ISO calibrated
LINLATci	Sperical LINUS from LINUSLAT (Chapter 9.5) Cf-ISO calibrated
LINALVci	Sperical LINUS from LINUSALV (Chapter 9.5) Cf-ISO calibrated
LINWGLci	Sperical LINUS from LINUSWGL (Chapter 9.5) Cf-ISO calibrated
EBERL_ci	Eberle remcounter from EBERL1 (chapter 9.5) Cf-ISO calibrated
STUDS_ci	Studsvik remcount.from STUDSV1 (chapt. 9.5) Cf-ISO calibrated
TEPC__ci	TEPC from TEPC_A (chapter 9.5) Cf-ISO calibrated
TLDKR_ci	TLD response, Karlsruhe data (Bauer) Cf-ISO calibrated
LEAKA_ce	LEAKE acc. to Alevra (see chapter 9.5) Cf-IAEA calibrated
LEAKI_ce	LEAKE acc. to IAEA (Harrison)(see chapt. 9.5) CF-IAEA calibr.
LEAKH_ce	LEAKE acc. to Harwell (see chapter 9.5) Cf-IAEA calibrated
JULIC_ce	TEPC Juelich acc. to Alevra (see chapt. 9.5) Cf-IAEA calibr.
lb64__ce	LB64 from LB64_A (see chapter 9.5) Cf-IAEA calibrated
SNOPA_ce	SNOOPY from SNOOPY_A (see chapter 9.5) Cf-IAEA calibrated
SNOOP_ce	SNOOPY from SNOOP1 (Hankins)see chapt.9.5) Cf-IAEA calibrated
CYLIN_ce	Cylindr. LINUS from CYLINU_A (Chapter 9.5) Cf-IAEA calibrated
LINISOce	Sperical LINUS from LINUSISO (Chapter 9.5) Cf-IAEA calibrated
LINLATce	Sperical LINUS from LINUSLAT (Chapter 9.5) Cf-IAEA calibrated
LINALVce	Sperical LINUS from LINUSALV (Chapter 9.5) Cf-IAEA calibrated
LINWGLce	Sperical LINUS from LINUSWGL (Chapter 9.5) Cf-IAEA calibrated
EBERL_ce	Eberle remcounter from EBERL1 (chapter 9.5) Cf-IAEA calibr.
STUDS_ce	Studsvik remcount.from STUDSV1 (chapt. 9.5) Cf-IAEA calibr.
TEPC__ce	TEPC from TEPC_A (chapter 9.5) Cf-IAEA calibrated
TLDKR_ce	TLD response, Karlsruhe data (Bauer) CF-IAEA calibrated
	Detectors and Bonner spheres
BLANKRSP	see chapter 9.2
CDRSPSH	see chapter 9.2
0W0	blank Bonner sphere calculated by B. Wiegel
0W0iso	isotropic incidence
0W0nd	directed incidence
C0W0	Cd covered Bonner sphere calculated by B. Wiegel
C0W0iso	isotropic incidence
C0W0nd	directed incidence
3W0	3 inch Bonner sphere calculated by B. Wiegel
3W5	3.5 inch Bonner sphere calculated by B. Wiegel
4W0	4 inch Bonner sphere calculated by B. Wiegel
4W5	4.5 inch Bonner sphere calculated by B. Wiegel
5W0	5 inch Bonner sphere calculated by B. Wiegel
6W0	6 inch Bonner sphere calculated by B. Wiegel
7W0	7 inch Bonner sphere calculated by B. Wiegel
8W0	8 inch Bonner sphere calculated by B. Wiegel
10W	10 inch Bonner sphere calculated by B. Wiegel
12W	12 inch Bonner sphere calculated by B. Wiegel
15W	15 inch Bonner sphere calculated by B. Wiegel
18W	18 inch Bonner sphere calculated by B. Wiegel
22W	modified Bonner sphere calculated by B. Wiegel
23W	modified Bonner sphere calculated by B. Wiegel
24W	modified Bonner sphere calculated by B. Wiegel
25W	modified Bonner sphere calculated by B. Wiegel

0C0	blank Bonner sphere, response from A. V. Alevra
C0C0	Cd covered Bonner sphere, response from A. V. Alevra
3C0	3 inch Bonner sphere response from A. V. Alevra
3C5	3.5 inch Bonner sphere response from A. V. Alevra
4C0	4 inch Bonner sphere response from A. V. Alevra
4C5	4.5 inch Bonner sphere response from A. V. Alevra
5C0	5 inch Bonner sphere response from A. V. Alevra
6C0	6 inch Bonner sphere response from A. V. Alevra
7C0	7 inch Bonner sphere response from A. V. Alevra
8C0	8 inch Bonner sphere response from A. V. Alevra
10C	10 inch Bonner sphere response from A. V. Alevra
12C	12 inch Bonner sphere response from A. V. Alevra
15C	15 inch Bonner sphere response from A. V. Alevra
18C	18 inch Bonner sphere response from A. V. Alevra

15. Running the FLUTRANS Program

By the FLUTRANS program the structure in the energy of a HEPRO file can be changed to a new structure (changing the energy binning).

Example of an input file, the new energy structure being taken from the response matrix file:

```
tracftot.log                              name of protocol output file
11                                        original group structure of resp file
..\resp\files\response\resphig3.fmt       response matrix input file
..\resp\files\fluence\ms_cfqfl.tot        fluence file for calculating
..\resp\files\fluence\cfqfl.tot           fluence file in the new format
1                                         norm of the new file is 1 (otherwise 0)
20.000                                    highest neutron energy in MeV for use
5,1,0                                     interpolation law for fluence
```

The new energy structure can also be taken from another HEPRO file. The mode used depends on the parameter in the second line. The user may try an interactive run to find out which modes are possible.

16. Example

In this section it is described how to proceed, when a new ASCI file of a spectrum is available and the response for a detector or a dosimeter has to be calculated. This example is part of the RESTRAW package, where the spectrum PWR of the SPEKTBIB [2] package is used together with data for the HARWELL remcounter (response data also taken from SPEKTBIB).

The following steps have to be performed:

-- Editing the file PWR from SPEKTBIB to complete the first three lines with HEPRO data (see section 7.1). The new file may be named PWR.HEP.
-- Transformation of the file PWR.HEP (which is in coarse energy structure) to the energy structure of the response matrix file RESPHIG3.fmt using the FLUTRANS program, the output fluence is named PWR.out.

FLUTRANS is used with the input file FLUTRANS.INP as command-line argument. The contents of FLUTRANS.INP are :

```
flutrans.log                              protocol file
11                                        new       energystructure       of
resphig3.fmt
..\resp\files\response\resphig3.fmt       file with structure of energy
pwr.hep                                   Fluence file to be transformed
pwr.out                                   output fluence file
1                                         pwr.out normalized to 1.0
20.0                                      upper last energy
15,0,0                                    interpol. and extrapol. parameter
```

The next steps are

-- Create a table of integral responses for a number of detectors (names of the detectors are read from the file ACT) by folding the detector responses in the RESPHIG3.fmt library with the PWR spectrum using the SELECTDF program.

SELECTDF is used with the input file SELECTDF.INP as command-line argument. The contents of SELECTDF.INP are:

```
selectdf.log                              protocol file
act                                       file with the names of the
reactions
..\resp\files\response\resphig3.fmt       ASCII response function file
pwr.out                                   Fluence file for the folding
0                                         create no single files
```

In the next step a remcounter response (file HARWELL) is transformed to the group structure of the response matrix file RESPHIG3.fmt and the result is included into a new RESPHIG4.fmt file. The reading for the HARWELL remcounter in the Am-Be-ISO spectrum is calculated.

The RESTRAW program is used with RESTRAW.INP as command-line argument. The contents of RESTRAW.INP are:

```
restraw.log                              name of protocol output file
11                                       E-structure from response matrix
..\resp\files\response\resphig3.fmt      response matrix input file
resphig4.fmt                             formatted output
..\resp\files\iso\ambeiso                fluence file for Folding
ambeiso.flu                              fluence file in the new format
20.0                                     highest neutron enrg. in MeV for
use
15,1,1                                   interpol. law for fluence,
extrapol.
0                                        0= no additional *.fmt, 1 = yes
1                                        number of following files
harwell                                  file name with path
harw-new                                 short name in the library
Harwell example                          long name in the library
example with a new file Harwell          long comment
3,1,1,1,0                                interpol., 2X extrapol,icalib,iuns
0                                        no energy range integrals
0                                        energy as a response function: no
0                                        1/v as a response function: no
ICRP74A                                  for calculating calib. factor
```

The UMSFAC program is used next to multiply the responses by the calibration factors. The contents of UMSFAC.INP are:

```
umsfac.log                               Protocol file
1.0                                      multiplication by factor
resphig4.fmt                             input resp-file
resphig5.fmt                             output resp.file,
```

Finally the calibration factors for all detectors in the library RESPHIG5.fmt for the fluence spectrum PWR.out are calculated using the SELECTDF program woth SELECTDF.in2 as input file.

The contents of SELECTDF.IN2 are:

```
selectdf.pr2                             protocol file
act2                                     file with the names of the
reactions
resphig5.fmt                             ASCII response function file
pwr.out                                  Fluence file for the folding
   0                                     create no single files
```

The protocol file SELECTDF.PR2 may be checked for the calibration factors.

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