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A Users Manual for the FORSS Sensitivity and Uncertainty Analysis Code System

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ABSTRACT

FORSS is a code system used to study relationships between nuclear reaction cross sections, integral experiments, reactor performance parameter predictions and associated uncertainties. This report describes the computing environment and the modules currently used to implement FORSS Sensitivity and Uncertainty Methodology.

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CHAPTER I

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I. INTRODUCTION

The purpose of this document is to provide guidance on the use of the computational methods that are germane to FORSS[1] Sensitivity and Uncertainty Methodology. In its totality FORSS is not a single code system but rather a collection of code systems and stand alone codes that contribute to the solution of a FORSS problem. FORSS includes multigroup cross section processing, uncertainty file processing, neutronics calculations, source calculations, sensitivity profile generation, uncertainty analysis, and estimation of accuracy requirements for nuclear data to meet pre-determined design constraints and error margins. A modular code system under driver control has been developed and is commonly called FORSS; however, it does not at present place all the FORSS methodology under the control of a single driver. This document will attempt to show the relationship of all the codes and code systems that contribute to the solution of a FORSS problem. Some of the major code systems used are well established and documented. Such documentation will not be duplicated here but will be referenced as required. The scope of this report assumes familiarity with the discussion of FORSS methodology found in reference 1.

A. Cross Section Processing

Multigroup cross sections must be prepared for the neutronics calculation selected to model the assembly being investigated. The MINX-SPHINX[2,3] and the AMPX[4] cross section processing systems are examples of cross section processors that provide this capability. The AXMIX[5] code is also useful in cross section preparation. However, in sensitivity and uncertainty analysis partial cross sections must be available. FORSS uses the proposed CCCC[6] file MATXS[7] as the data base for partial cross sections. The aforementioned cross section processors do not now produce a MATXS file although such capability is currently being tested. At present, the FORSS system includes three translators for producing MATXS from the more mature ISOTXS[6] AMPX master, or ANISN[6] formats.

B. ENDF/B Uncertainty File Processing

Uncertainty analysis within the FORSS system requires that multigroup covariance matrices be produced from ENDF/B[9] formatted uncertainty files. Covariance matrices are produced by the PUFF[10] code. The matrices are placed in a proposed CCCC file COVERX[11]. COVERX files must be available before uncertainty analysis can be initiated. If appropriate, available multigroup covariance matrices can be used directly thus bypassing the PUFF processing step.

C. Neutronics Calculations

The ANISN, DOT[12], and VENTURE[13] neutronics codes are used in the FORSS methodology. ANISN is a module in the FORSS driver controlled system and its interaction with the other modules in the system is somewhat automated. Comments about the use of DOT and VENTURE in FORSS will be made in Section E.

The number of neutronics calculations required for a study is a function of the number and type of responses under consideration. Sensitivity analysis for criticality requires a forward and adjoint neutronics calculation; reaction rate ratio analysis requires, in addition, the computation of a generalized adjoint. For worth sensitivity, four neutronics calculations are required; these being a forward and adjoint, and a generalized forward and adjoint. The JULIET module uses the fluxes produced by these neutronics calculations.

D. The JULIET Module

This module calculates sources, responses, normalization parameters and sensitivity coefficients. The JULIET algorithms for generalized sources, responses, and normalization parameters use FORSS ANISN (FANISN) produced angular fluxes. The sources calculated by JULIET are returned to FANISN as input to generalized neutronics calculations. A more detailed description of the FANISN and JULIET data interchange mechanism is available to Chapter IV.

The sensitivity coefficients calculated by JULIET are placed in a proposed CCCC file SENPRO[11].

JULIET is organized into execution paths, i.e., it has multiple entry points. A source calculation may be performed and execution terminated without generating sensitivity coefficients. When sufficient results are available from preliminary calculations, JULIET may be asked to generate sensitivity coefficients and bypass the source calculation.

E. Two-Dimensional Analysis With DOT or VENTURE Neutronics

With an understanding of how ANISN and JULIET interact to produce generalized fluxes, sources, and normalization parameters, the use of 2-D neutronics in FORSS can be clarified. Before sensitivity coefficients are generated, JULIET prepares a so-called $\langle \phi^* \phi \rangle$ file. This is symbolic since it could be $\langle \Gamma^* \phi \rangle$ or $\langle \phi^* \Gamma \rangle$ (brackets imply integration over spatial regions and angles). This file is used in the generation of sensitivity coefficients. When 2-D neutronics is used in FORSS, the selected 2-D code system, DOT or VENTURE, is used to produce the equivalent fluxes as produced by ANISN and the JULIET-SOURCE algorithms. The VIP[14] code is then used to prepare the $\langle \phi^* \phi \rangle$ file. The selected 2-D code system must also produce the normalization parameters required by the JULIET sensitivity profile calculation. With appropriate $\langle \phi^* \phi \rangle$ files and normalization parameters available, the JULIET-SENSE execution path is entered and the problem solution path is the same as when ANISN neutronics is used.

F. The SENPRO Service Module[15]

JULIET generates the SENPRO file containing sensitivity profiles. However, before using the file in uncertainty analysis, it may be desirable to examine the file(s) in detail. The SENPRO service module operates on the file providing a number of services including plotting and listing. A complete inventory of the modules capabilities is available in Chapter VIII.

G. Cross Section Difference Effects

When the calculation of sensitivity coefficients is complete and SENPRO file(s) are available, the effects of proposed cross section modifications may be investigated. The SENTINEL[16] module computes the percentage

(or fractional) change in the performance parameter of a given assembly due to specified percentage (or fractional) changes in designated reaction cross sections over a number of energy regions. An edited list of the most significant individual contributions to the response change is also provided.

H. COVERT[17]

The module COVERT copies a covariance file in COVERX format, and in the copying process changes the file representation from binary to card image form or vice versa. In addition, a complete listing or a partial listing of the file is printed to give the user information about the contents of a particular file.

I. The COVERX Service Module

As stated in Section B, COVERX files must be available before uncertainty analysis can be initiated with the CAVALIER or UNCOVER modules.

The COVERX service module operates on the file providing a number of services such as listing and merging. A complete inventory of the capabilities is available in Chapter XI.

J. Uncertainties Due Exclusively to Nuclear Data Uncertainties

When COVERX and SENPRO files are available, uncertainty analysis may be initiated. The CAVALIER[17] module folds sensitivity profiles (SENPRO) and covariance matrices (COVERX) to estimate reactor performance uncertainties which result from uncertainties in nuclear data.

K. Uncertainties With Integral Experiments Taken Into Account

The module UNCOVER[18] finds the adjustments of both integral and differential data which are most consistent (in a general least squares sense) with the data and with the calculational model as represented by the sensitivity coefficients. The input to UNCOVER includes data from SENPRO

sensitivity and COVERX (a priori) covariance files. The output includes a posteriori covariances for the adjusted data in addition to the adjustments themselves. The adjusted data and associated covariances can be applied to design models for improved predictions of performance parameter and of their uncertainties.

L. COVERS

COVERS is a convenience module whose sole function is to process data from a SENFRO file and a COVERX file into informal files acceptable as input to the UNCOVER module.

M. ADJUST

The ADJUST module modifies the cross sections on an AMPX master file by the percent changes calculated by the UNCOVER module. This creates an adjusted cross section library for dissemination via the AMPX system.

N. The Inverse Problem

The NUTCRCKR[19] module is a first attempt at solution of the "Inverse Problem" of reactor sensitivity. The objective is to provide quantitative guidance to data acquisition, data evaluation, and associated data processing code development programs by giving estimated accuracy requirements on various multigroup nuclear data to meet predetermined design constraints and error margins.

O. System Structure

The system is composed of modules which may be executed under DRIVER control or they may be executed as stand-alone programs. Under DRIVER control, a run is executed from a procedure which includes most of the IBM JCL needed. We are indebted to the AMPX project for the DRIVER and procedure technology.

Data interchange between modules is accomplished by well defined files which are located on external storage devices such as magnetic tape or disks. Proposed CCCC files are used for partial cross sections (MATXS), sensitivity coefficients (SENPRO), and covariance matrices (COVERX). In this version of the system, FORSS ANISN uses a traditional ANISN formatted tape which is discussed in Chapter V. The COVERS module prepares from SENPRO and COVERX files two other files which are suitably formatted for the flexible structure of the UNCOVER module. FORSS ANISN and JULIET interchange data via a repository which is implemented with the FMANG module. FMANG and the repository are discussed in Chapter IV.

FORSS is designed to permit multiple entry points into the system. A comprehensive calculation may be designed to generate fluxes, normalization parameters, sensitivity coefficients and perform an adjustment in a single computer run. Conversely, many computer runs may be used to obtain the same results. The latter approach requires that the appropriate files (Repository, SENPRO, COVERS files, etc.) must be saved on semi-permanent external storage devices. It is also good policy to do this for the comprehensive run unless the calculation is small enough to make little demand on computer resources. A correct calculational hierarchy must be defined and executed for either the comprehensive or the segmented solution. A correct hierarchy is determined by the prerequisites of the modules needed to solve the problem of interest. An example of a correct hierarchy is:

1. Processing of ENDF/B files into multigroup neutron cross sections. Resulting files may be an AMPX master, ISOTXS, or ANISN cross-section library.
2. Processing of ENDF/B uncertainty files resulting in a COVERX file. NOTE: The FORSS DRIVER controlled program does not include the modules needed to implement steps 1 and 2; these are external preparatory steps for FORSS.
3. Generating forward and adjoint fluxes on the repository with FANISN.
4. Translating AMPX, ISOTXS, or ANISN cross sections to the MATXS file with the appropriate translation module.

5. Generating normalization parameters and generalized sources on the repository with JULIET.
6. Generating generalized forward and adjoint fluxes on the repository with FANISN.
7. Calculating sensitivity coefficients and preparing a SENPRO file(s) with JULIET.
8. Operating on SENPRO files with the SENPRO SERVICE module.
9. Performing perturbation analysis with SENTINEL.
10. Operating on COVERX files with the COVERX SERVICE module.
11. Performing uncertainty analysis with CAVALIER.
12. Preparing input for UNCOVER WITH COVERS.
13. Performing uncertainty analysis and adjustment with UNCOVER.

The multiple entry feature of FORSS permits entry at the module level and in some situations at the submodule level. Some modules perform more than one task and some of these tasks may be selected for execution in a particular run and others excluded. This concept is referred to as execution paths.

FORSS has a very powerful and flexible free field data input scheme called Improved FIDO which is discussed in Chapter IV.

P. FORSS Input Preparation

Detailed input requirements for each module are included in the chapters describing the modules. The user creates an input stream by preparing = MODNAME cards and, where appropriate, execution path names. Immediately following the = MODNAME and execution path names place the required input cards.

Example:

=FMANG	— Repository manager (input data, see Chapter IV).
=ITOM	— ISOTXS to MATXS translator (no input data required).
=ANTMX	— ANISN to MATXS translator (input data, see Chapter III).
=AMPXM	— AMPX to MATXS translator (input data, see Chapter III).

=PMATXS — Lists a MATXS file (no input data required).

=FANISN — 1-D S_n transport calculation (input data, see Chapter V).

=FJULIE — JULIET for sources and sensitivity coefficients

MIX — execution path for operator definition (input data, see Chapter VII).

FLUX — execution path for flux preparation and $\phi^*\phi$ generation. (Input data, see Chapter VII).

SOURCE — execution path for response and source calculation (input data, see Chapter VII).

SENSE — execution path for generation of senstivity coefficients (Input data, see Chapter VII).

=SENPRO — Senpro service module.

LIST — execution path of a file list (input data, see Chapter VIII).

PLOT — execution path for plotting a file (input data, see Chapter VIII).

ADD — execution path for adding, deleting, or copying. (Input data, see Chapter VIII).

MERGE — execution path for merging two SENPRO files. (Input data, see Chapter VIII).

SEND — execution path for mode conversion unformatted to formatted and reverse. (Input data, see Chapter VIII).

SIZE — execution path for listing profile titles in descending order of the absolute magnitude of $A = \sum_{i=1}^{NG} C_i$, where C_i is the sensitivity coefficient for group i. (Input data, see Chapter VIII).

NORM — execution path for normalizing the sensitivity coefficients in a file. (Input data, see Chapter VIII).

FIX — execution path for modifying the MAT-MT control record. (Input data, see Chapter VIII).

GRID — execution path for placing the sensitivity coefficients in a file on a user supplied group structure. (Input data, see Chapter VIII).

EDIT	— execution path for selectively editing or copying a file. (Input data, see Chapter VIII).
SUM	— execution path for summing all profiles in a file and producing a new file. (Input data, see Chapter VIII).
=SENTINEL	— perturbation analysis. (Input data, see Chapter IX).
=COVERT	— format conversion of COVERX files. (Input data, see Chapter X).
=COVEPX	— Coverx Service Module.
LIST	— execution path for listing a file. (Input data, see Chapter XI).
ADD	— execution path for adding to a file. (Input data, see Chapter XI).
DELETE	— execution path for deleting from a file. (Input data, see Chapter XI).
MERGE	— execution path for merging two files. (Input data, see Chapter XI).
CONVERT	— execution path for format conversion. (Input data, see Chapter XI).
FIX	— execution path for record modification. (Input data, see Chapter XI).
EDIT	— execution path for selectively editing or copying a file. (Input data, see Chapter XI).
=CAVALIER	— Nuclear Data Uncertainty Analysis, differential data only. (Input data, see Chapter X).
=COVERS	— prepares input for UNCOVER. (Input data, see Chapter XIII).
=UNCOVER	— uncertainty analysis and least squares adjustment taking into account results from integral experiments. (Input data, see Chapter XII).
=ADJUST	— cross section modification (input data, see Chapter XIV).
=NUTCRCKR	— Nuclear data accuracy requirement determination. (Input data, see Chapter XV).

The modules are executed in the order the = MODNAME cards are encountered and the execution paths are executed in the order the path names are encountered.

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18. UNCOVER is a revision of the AMARA program permitting the solution of problems with a large number of energy groups. See also A. Gandini and M. Petilli, "AMARA: Code Using the Lagrange Multiplier Method for Nuclear Data Adjustment," private communication, M. Salvatores (1975), see Chapter XII.

19. See reference 1, p. 102.

CHAPTER II. THE IMPROVED FIDO INPUT SYSTEM

J. H. Marable

II. THE IMPROVED FIDO INPUT SYSTEM

The FIDO input method was devised for entering data into large arrays, using patterns of repetition and symmetry wherever possible. This method was designed by Ward Engle and Wayne Rhoades using the input method of the Los Alamos FLOCO coding system as a model. It was first applied to the DTF-II code, and since that time FIDO has been applied to other codes. For these a free-field option and other features were incorporated.

Recently extensive improvements were made by James Marable. These improvements include the reading of formatted or unformatted pieces of arrays from various I/O devices, reading hollerith characters, reading numbers to an arbitrary base (e.g., octal, binary, and hexidecimal), modifying (by multiplication, etc.) numbers already in storage, entering double precision arrays, and other changes. It is important to note that these improvements have been incorporated without changing the previous definitions. Old FIDO input decks will still be read correctly!

Each FIDO call for input allows data to be read into a "block" until a delimiter 'T' instruction operator appears in the input. Such a "block" is partitioned into consecutive arrays, each of which is numbered according to its order in the block. Input data is read into an array by first designating the array number and the data type - integer, floating point, or double precision. For each FIDO input call the order in which arrays are designated is of no importance, and an array can be designated an arbitrary number of times in a single FIDO input call.

For example, an array can be filled with zeroes using a special option, and then a few scattered locations can be changed by designating the array again and reading in a partial set of new data for that array. If no entries to the arrays in a block are needed, the 'T' delimiter alone satisfies the FIDO input call.

Three major types of FIDO input are available: fixed-field input,

free-field input, and user-format input. Only the free-field option is discussed here. Free-field FIDO reads data into an array by units called fields. To read data into an array, an array designator field must first appear. Data defined by successive fields are then entered until the required number of entries has been accounted for.

In entering data, it is convenient to think of an "index" or "pointer" which specifies the array location into which the next data entry is to go. The pointer is always positioned at array location #1 by entering the array designator field. The pointer subsequently moves through the array according to the data operators chosen.

Each field is broken up into three subfields. However, it is not always necessary that all three subfields appear explicitly in the input. Frequently only one or two subfields are given, and any missing subfield is implied or is simply not required.

The three subfields which make a field are N1, Op, and N3. The first subfield N1 is an integer and the second subfield Op is a character specifying a type of input operation. The third subfield N3 is an integer, a floating point number, a double precision number, or a string of hollerith characters according to the array type and the input operation. FIDO input fields must not extend beyond the first 72 characters of a card image, and all subfields of a field must be on the same card.

The first subfield is an integer N1 which has a preset default value of zero. (Operations denoted by Z and R are exceptions in that the default value of N1 is unity.) If the first subfield appears explicitly in an input field it must be followed immediately by the second subfield operation character without an intervening space. Negative integers are allowed for N1 for some of the operations defined by the second subfield.

The third subfield N3 may have one of the following five forms:

(1) An integer (positive, negative, or zero) of any magnitude allowed by the computer.

(2) A decimal number with an arbitrary number of digits. If no decimal is given explicitly it is assumed to follow the last digit.

(3) A floating point number which consists of a decimal number (as defined above) followed by an exponent indicator E, D,

+, or -. Any of these four exponent indicators may be followed by a single space before the exponent itself is given.

(4) A floating point number (with or without an exponent) to an arbitrary base b (2 through 36). For this purpose digits are chosen from 0, 1, 2, ... 9, A, B, C, ... Z as required. If the base b is greater than 12, the character D is no longer valid as an exponent indicator, and if the base b is greater than 13, E is no longer valid as an exponent indicator. Of course, + and - are still available as exponent indicators. The subfield entry consists of the base b (using the base 10) followed by the single character "X" and then the floating point number itself. No blank may appear, between the base b and the 'X', but any number of blanks may occur between the 'X' and the floating point entry. If an exponent appears, it is also to the base b and gives powers of the base b. Each subfield is assumed to be the base 10 unless the base is given explicitly in that subfield.

(5) A string of alphanumeric or hollerith characters. This is used only with the operation character 'H', and the first subfield N1 is the number of such characters.

The second subfield consists of a single character, except for the three array-designator characters $$, **, and ##, which when entered in pairs indicate that data is to be entered using the free-field input option.

The characters and the corresponding operation instructions are listed in Table 1. Operator characters with superscript 'a' denote operations which ignore the first subfield value N1. Operator characters with a superscript 'b' denote operations for which it is not possible to enter a third subfield (using free-field input). These characters terminate the field, and a new field starts immediately reagardless of whether there is a space or not. Except for these operations a field is terminated by a space following the third subfield.

In general, no space is allowed between the first and second subfields,

and spaces are allowed but are not required between the second ard third subfields. Setween fields spaces are allowed and one is required (except for above exceptions associated with superscript 'b').

Typical FIDO input is shown in Figure 1. The resulting contents of the arrays is given by the output shown in Figure 2.

Table 1. Characters and Their Corresponding Operation Instructions

Character	Operation Instruction
$^{b}	Designate array N1 to be an integer array and set the pointer to the first location in array N1. When interpolated, etc., numbers are always rounded off to the nearest integer value.
**^{b}	Designate array N1 to be a floating point array and set the pointer to the first location in array N1.
##^{b}	Designate array N1 to be a double precision array and set the pointer to the first location in array N1.
/^{a,b}	Skip to the next card ignoring all comments following the slash.
(blank)^a	Enter the third and only nonblank subfield into the location indicated by the pointer and then advance the pointer by 1.
Z^b	Enter 0 |N2| times and advance the pointer by |N1|. If zero or blank is entered for N1 it is replaced by 1.
R	Enter the third subfield |N1| times, and with alternating sign if N1 is negative. Increase the pointer by |N1|. If a zero or blank is entered from N1, it is replaced by 1.
I	Determine N1+2 numbers by linear interpolation starting with the third subfield of this field and ending with the third subfield of the next field. Enter the first N1+1 numbers.
T^{a,b}	Terminate this call for FIDO input and return to the calling program.

Table 1. (continued)

Character	Operation Instruction
L	Determine N1+2 numbers determined by logarithmic interpolation starting with the third subfield of this field and ending with the third subfield of the next field. Enter the first N1+1 numbers. (The logarithms of the numbers entered are uniformly spaced.)
W	Repeat the sequence of |N3| numbers immediately preceding the pointer |N1| more times, multiplying on each repetition each number of the sequence by 10 or 0.1 according as N3 is positive or negative. If N1 is negative the sign of the sequence changes on each repetition.
Q	Repeat the sequence of |N3| numbers immediately preceding the pointer |N1| more times. If N1 is negative change the sign of each number of the sequence on each repeat. If N3 is negative reverse the order of the sequence for each repetition. The pointer is finally advanced by |N1|*|N3|.
N	This is equivalent to the operation Q with a first subfield N1 and a third subfield -|N3|.
M	This is equivalent to the operation Q with a first subfield -|N1| and a third subfield N3.
$C^{a,b}$	Print the pointer value of the last array item entered. This is one less than the pointer position.
O^{b}	If N1>0 the print trigger is turned on. If N1=0 the print trigger if flipped. If N1<0 the print trigger if turned off. When the print trigger is on, each card image is printed as it is read.

Table 1. (continued)

Character	Operation Instruction
S^b	Add N1 to the pointer value. N1 may be negative thereby desc easing the pointer value.
A^a	Place the pointer at N3.
F	Fill the remaining locations of the array with the third subfield entry. If N1 is negative the entries alternate in sign. Set the pointer after the last location.
$E^{a,b}$	Skip over the remainder of the array by placing the pointer after the last location.
H	Enter the N1 hollerith characters which are in the third subfield. Advance the pointer by the number of words required to store these N1 characters. (number of words = (N1+NCPW-1)/NCPW where NCPW is the number of characters per word).
G	Read N3 words from I/O device with data set reference number N1 according to the format to be specified in the next field which is hollerith. If the next field is 0 or hollerith blank the field is unformatted. Advance the pointer by N3.
Y	If N1 is positive, change the input unit so as to read the succeeding card images from unit N1 until a delimiting T operation appears (or until a similar Y instruction appears). If N3>0 change all FIDO edit to unit N3. If N3<0 change card image listing (see 'O' operation) only to unit |N1|. After a delimiter T appears the next call to FIDO resets the input and output unit numbers to the original value.
$@^b$	Ordinarily FIDO enters data - interpolated, sequence repeat, etc. - by entering each "raw entry" into the proper location obliterating the previous "old number"

Table 1. (continued)

Character	Operation Instruction

in that location. By means of the operation denoted by character '@' FIDO changes its mode of entering data according to the value of the first subfield N1 preceding the operation character '@'. The various manipulations are performed on the "old number" in storage and the "raw entry" in order to obtain the final number which is stored. Let A be the "old number" previously stored, let B be the "raw value" determined by the usual FIDO entry. We have the following possibilities for the number finally stored according to the value of N1.

N1	Number Entered
0	B (the default mode)
1	A+B
2	A-B
3	A*B
4	A/B
5	B/A
6	B*EXP(A)
7	B*LN(A)
8	EXP(B)
9	LN(B)

Each time an array is designated by an array designator field the default mode (N1=0) is reactivated causing raw data to be entered directly into array storage.

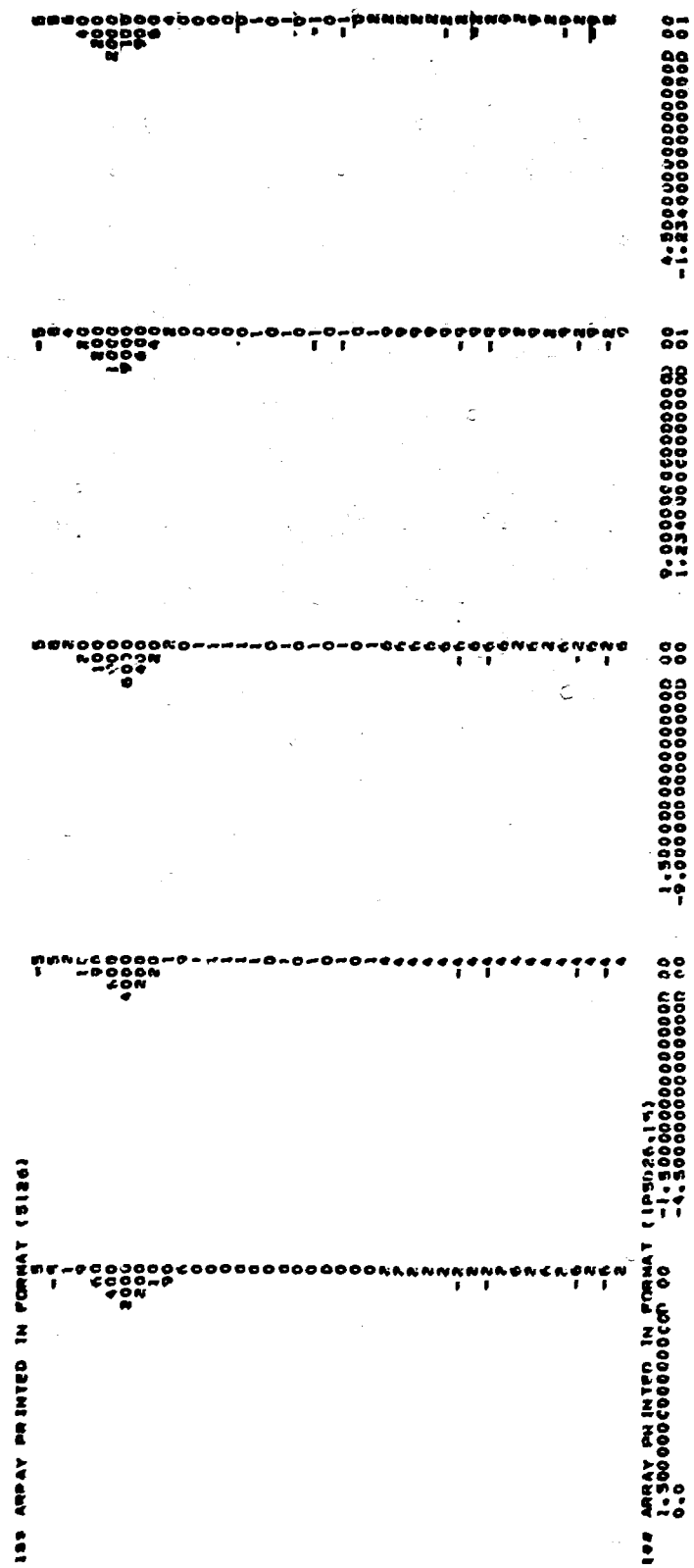
Figure 1. Data for Three Calls for FIDO Input on Unit 5

```
//GO.FT13F001 DD *
 1 2 & 816329999999999999
6499996971111111111111111111
/*
//GO.FT05F001 DD *
 /THIS IS THE FIRST CARD READ IN THE FIRST CALL FOR FIDO INPUT
      0  / THIS FLIPS THE PRINT TRIGGER.
     0    -10     /   THIS EVENTUALLY TURNS THE TRIGGER OFF.
   0   / THIS CARD WON'T PRINT
0  0  10   /    BUT THIS ONE WILL, AND THE TRIGGER IS TURNED ON.
 2$$   2127  219X20  21-9   18 / INTEGER INTERPOLATION COMING AND GOING.
10* F10.0
1**10100 201000 300.0001 4811111. 701.0 -15501.0 602.0 801. 902. E
 3** 11H THIS IS IT        20H THANK GOODNESS        E / HOLLERITH
 5**  10G10     9H( 6L12.5) / READ FORMATTED FROM FILE 10
 4$$ 11H THIS IS IT        20H THANK GOODNESS        E/ HOLLERITH
 6**    136.0    6H(6I2)    E /READ (FORMATTED) INTEGERS INTO F.P. ARRAY!
7** 25H THIS IS A USEFUL PACKAGE    E/ AT LEAST WE HOPE SO.
 12##   16XF.7FFFFABCDEF 7116XABCD-2 16X-A8.C-1/ DOUBLE PRECISION HEX
 13## 1.0990 2  1668 8H(8D10.4)    1.0990D3 /MIXED ENTRIES IN D.P. ARRAY.
 14##  48H THIS IS WRITTEN ONTO A DOUBLE PRECISION ARRAY        E / YES
8**     16X7FFFF.F-A     7.312547982176432179BD 01   -40-2 / 'O'
9$$     16X7FFFFFFF       8X-17777777777 4B-2/ '-' APPLIED TO LARGE INTEGERS
10$$    1.3    2.7    562      8H(5E12.4) 1 7 E T / A GOOD EXAMPLE
  14.0          13.0
 /DATA ON THE PREVIOUS CARD WERE READ INTO POSITIONS 3& 4 OF THE 10$* ARRAY
 /THIS IS THE SECOND CARD READ IN THE SECOND CALL FOR FIDO INPUT
 11## -3R1.5   12Y0   319. -9.        / A DOUBLE PRECISION ARRAY.
 /THIS IS THE FIRST CARD READ IN THE THIRD CALL FOR FIDO INPUT
 1**   999.9 9123.9 12349. / A FEW SIMPLE F.P. NUMBERS.
2147483.647123456789  2147483.648811111;11/ AND SOME LONG ONES.
  0.9990E 2   / AND ONE WITH A SPACED EXPONENT.
  16XF.7FFFFFF   16XABCDEFD-A/ THESE ARE SOME HEX NUMBERS.
2X1011.0110011   F2X1001.10E-1001/ SOME BINARY NUMBERS.
2## -7R5.5 3R7.7 4L1 9 3W6 4W-6 405 4P5 4N5 4M5 4L1 9 405 -405 40-5
3** -7R5.5 3R7.7 4L1 9 3W6 4W-6 405 4P5 4N5 4M5 4L1 9 405 -405 40-5
 4$$    2127   219X20   21-9          0
 5$$         95 99 8388607 8388608 2147483647 2147483648
   11 16XFFE0    16XFFE8    F 2X110101
9$$ 61 16X7FFFFFFF       8X 23777777776 F2X11011 E
    T
/*
//GO.FT10F001 DD *
  1.1           1.3         4.5         7.8           9.55          8.88
  1.1           1.3         4.5         7.8
/*
//GO.FT16F001 DD *
123.5D  0  125   D2  123.5      5555.66 555.66D01   12390D3  456.D-05  123E.7D0
/*
//GO.FT12F001 DD *
                        -1F12.3#/ A DOUBLE PRECISION ARRAY.
1$$ -7R5.5 3R7.7 4L1 9 3W6 4W-6 405 4P5 4N5 4M5 4L1 9 405 -405 40-5
  -40-5    E  T
/*
```

Figure 2. The Array Contents in Core Which Result from the FIDO Commands Shown in Figure 1.

```
100 ARRAY PRINTED IN FORMAT (1P5E26.6)
       1.10    0E 02      -9.900000E 02        9.999997E-04        9.000087E-04        4.342948E-01
       4.40    9E 04       2.718282E 00        6.931471E-01        9.999999E 00        9.999999E 00

255 ARRAY PRINTED IN FORMAT (5I26)
              27                 24                  21                  18                   9
               0                 -9                   0                   9                  18

300 ARRAY PRINTED IN FORMAT (32A4)
THIS IS IT  THANK GOODNESS

457 ARRAY PRINTED IN FORMAT (32A4)
THIS IS IT  THANK GOODNESS

500 ARRAY PRINTED IN FORMAT (1P5F26.6)
       1.099999E 00        1.299999E 00        4.500000E 00        7.799999E 00        9.849999E 00
       8.879999E 00        1.099999E 00        1.299999E 00        4.500000E 00        7.799999E 00

600 ARRAY PRINTED IN FORMAT (5I26)
               1                  2                   3                   8                  15
              32                 64                  99                  98                  97

700 ARRAY PRINTED IN FORMAT (32A4)
THIS IS A USEFUL PACKAGE

800 ARRAY PRINTED IN FORMAT (1P5F26.6)
       4.768371E-07        7.312547E 01       -7.312547E 01       -4.768371E-07        4.768371E-07
       7.312547E 01       -7.312547E 01       -4.768371E-07        4.768371E-07        7.312547E 01

955 ARRAY PRINTED IN FORMAT (5I26)
      2147483647        -2147483647           214748368          -214748368            21474837
       -21474837            2147484            -2147484              214748             -214748

1055 ARRAY PRINTED IN FORMAT (2I26,1P2E26.6,2I26)
               1                  3        1.400000E 01        1.300000E 01                   1
               7

1200 ARRAY PRINTED IN FORMAT (1P5D26.15)
  1.549999568634705D 01  1.718007812500000D 02  1.489838867187500D 02  1.261669921875000D 02  1.033500976562500D 02
  8.053320312500000D 01  5.771630859375000D 01  3.489941406250000D 01  1.208251953125000D 01 -1.073437500000000D 01

1300 ARRAY PRINTED IN FORMAT (1P5D26.15)
  1.099000000000000D 02  1.235000000000000D 02  1.250000000000000D 03  1.235000000000000D 03  5.555600000000000D 03
  5.556599999999999D 03  1.239000000000000D 03  4.559999999999999D-03  1.234700000000000D 03  1.099000000000000D 03

1400 ARRAY PRINTED IN FORMAT (32A4)
THIS IS WRITTEN ONTO A DOUBLE PRECISION ARRAY
```

Figure 2. (continued)



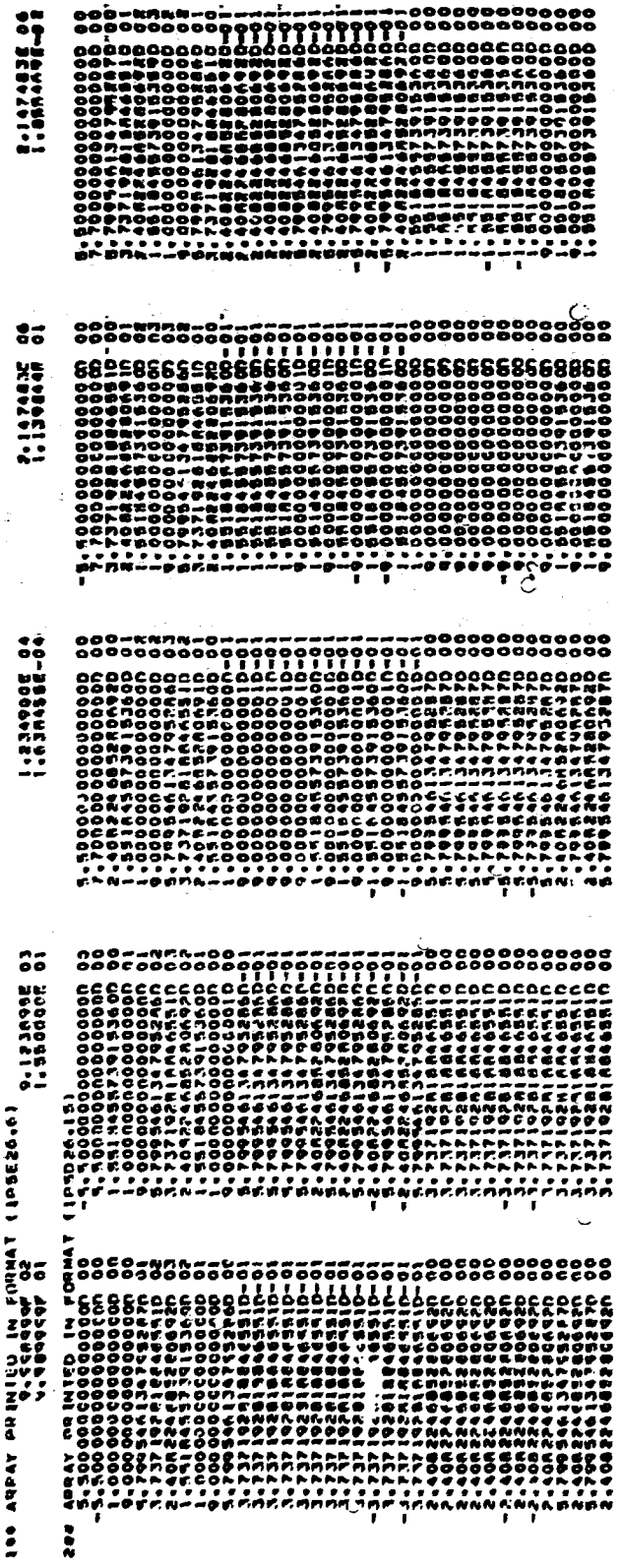
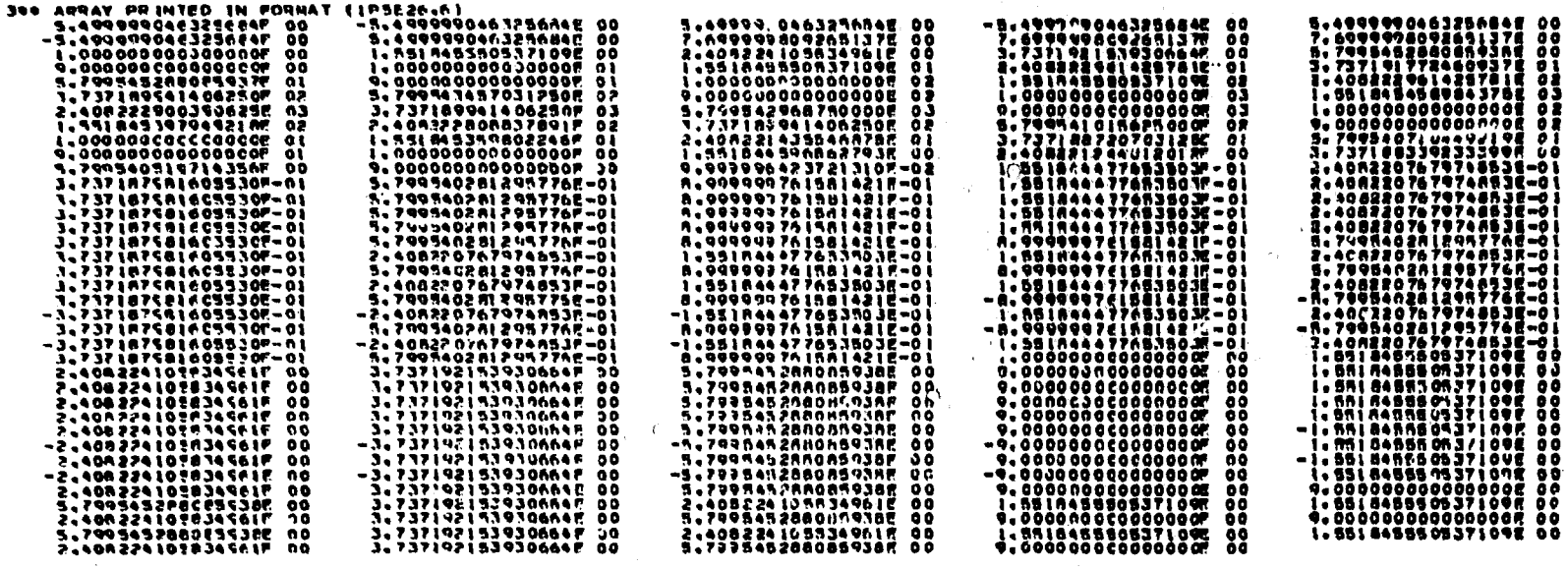


Figure 2. (continued)

Figure 2. (continued)



CHAPTER III. THE ANISN, AMPX, ISOTXS TO MATXS TRANSLATORS

J. L. Lucius

CHAPTER III

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A. Introduction

To calculate sensitivity coefficients the JULIET[1] module requires access to partial cross section sets. This is achieved with the proposed CCCC[2] file MATXS[3] which is specified in Section 10 of Chapter VII. However, many cross section sets of interest are available in other formats such as ANISN[4], AMPX[5], and ISOTXS[2]. The translation capabilities described in this chapter make these cross section sets available in the MATXS format.

B. ANISN to MATXS Cross Section Translator

Many problems do not require the translation of every material on the ANISN file to MATXS format. The translator includes a selective copy capability which produces a subset of the original ANISN file containing only the materials to be translated.

The ANISN cross section format uses numerical material identifiers and the reaction type is defined as a function of table position. The user must provide the translator enough information for materials and reaction types on the MATXS file to be identified by hollerith character strings (words). An input card is prepared for each material on the ANISN file containing the name to be assigned to the material on the MATXS file. The order in which these cards are input is crucial. Material 1 on the ANISN file goes on the MATXS file with the name found on the first material name card input to the translator, etc. This one-to-one correspondence must be correctly established or disaster is assured. Reaction type identification is built into the translator as a function of the ANISN table position (IHT) of the total cross section.

When IHT = 3, the translator assumes the following correspondence between table position and reaction type:

ANISN TABLE POSITION	REACTION	REACTION NAME ON MATXS
1	σ_a	ABSORP
2	$\nu\sigma_f$	NUFIS
3	σ_t	TOTAL

When IHT = 5, the following correspondence is assumed:

1	χ	CHI
2	σ_f	FIS
3	σ_a	ABSORP
4	$\nu\sigma_f$	NUFIS
5	σ_t	TOTAL

The translator calculates $\sigma_c = \sigma_a - \sigma_f$ only when IHT = 5 and identifies the reaction as MT101 on MATXS.

For those specialized cross section files for sensitivity analysis where a single reaction type has been placed in the ANISN format, the identification of the reaction type as a function of table position cannot be accomplished and the user must expand the material identification card to also identify the reaction type.

1) Input Description

1$$ Integer Parameters [11]

1. NNG - Number of groups
2. IHT - Position of σ_t in cross section table
3. ITL - Length of cross section table
4. IGG - Position of σ_{gg} (self scatter)
5. NL - Order of scatter, every material on the ANISN file must have the same order of scatter, enter 1 for Po, 4 for P_3, etc.

6. NMAT - Number of materials on ANISN file. Pn>0 are not counted as materials for this input. Set NMAT = -NMAT if ANISN cross sections are on cards. See description of 2$$ card.
7. IVERS - MATXS File version number. IVERS can be any number the user selects.
8. ISIG - Unit number of ANISN file (default = 4)
9. NN - Unit number of MATXS file (default = 8)
10. IOUT - Unit number of copy of ANISN file (default = 35)
11. LECT - Set to 0, reserved for future option

2$$ Integer Parameters [100]

NL
NU - ANISN material identifiers, any material identifier (ID) on the ANISN file satisfying the test NL≤ID≤NU will be copied from Unit ISIG to Unit IOUT. A maximum of 49 pairs of NL,NU may be entered. The 2$$ card may be omitted if no copy is desired. If a copy is made, NMAT, see 1$$ card item 6, must be equal to the number of materials copied to Unit IOUT.

F0

T

4** Group Boundaries [NNG + 1]. Enter the energy group boundaries, high energy to low energy, in units of eV.

T

NMAT - Fixed field cards follow, one for each of the NMAT materials.
Columns 1-6, Hollerith identification to be assigned to each material on the ANISN file. NOTE: Pn>0 not counted as a material for this input.
Columns 7-10, blank
Columns 11-16, if a specialized file is being processed, enter a word that identifies the reaction type, otherwise leave blank

If (NMAT<0), i.e., cross sections on cards, prepare 5** arrays.

5** [ITL*NNG]

ANISN cross section cards

Repeat 5** data for each scattering order

Repeat 5** sequence for each material to be translated

End each 5** array with a T.

2) Sample Input For ANISN to MATXS Translator

```
=ANTMX
1$$      100      5      105      6      4      7      F0
2$$        9     36       F0      T
4**
                  (Group boundaries, 101 entries)
T
PU240
PU241
U235C
U235B
U238C
U238B
PU239
```

The sample input takes seven, P_3 materials with material identifiers 9-36 from an ANISN file on Unit 4 and writes a new file on Unit 35 containing only the seven materials of interest. The seven materials are then translated from the ANISN format (Unit 35) to the MATXS format (Unit 8). Resource requirements are 270K bytes of core storage, 1900 I/O operations, and eight seconds of execution time on an IBM 360/91.

C. AMPX to MATXS Translator

This module will translate AMPXS master files containing neutron data. Other arrangements must be made for AMPX master files containing both neutron and gamma cross sections. An established option is NITAWL to ANISN then to MATXS. AMPX uses the ENDF/B numerical material (MAT) reaction type (MT) identification scheme. MATXS uses Hollerith character

(word) identification schemes. The translator requires user input to establish a correspondence. Every material on the AMPX master is translated to MATXS. An input card is prepared for each material on the AMPX master containing the name to be assigned to the material on the MATXS file. The input order of these cards is crucial. A one-to-one correspondence between the name cards and the materials on the AMPX master must be correctly established. The translator establishes the following reaction type correspondence:

ENDF/B (MT)	MATXS
1	TOTAL
2	ELSCAT
3	NONELS
4	INSTOT
16	N2N
17	N3N
18	FIS
19	FCFIS
20	SCFIS
21	TCFIS
51	INEL01
⋮	⋮
90	INEL40
91	CTNUUM
102	CAPT
452	NUBAR
1452	NUFIS

For other ENDF/B MT numbers the translator forms a MATXS six character string as follows. If the MT = 1234 the MATXS identifier will be MT1234.

1) Input Description for the AMPX to MATXS Translator. Formatted input is required rather than FIDO input.

Card 1: FORMAT (2I5)

NMW - Number of materials on AMPX file to be translated

NLD - Maximum order of scatter, enter 0 for Po, etc.

Cards 2 through NMW+1 FORMAT(A6,4X,I6)

HMATI - MATXS material description, ≤6 Hollerith characters (left adjusted)

MATW - AMPX material identification number (right adjusted)

2) Sample Input for AMPX to MATXS Translator.

Column	1	5	10	12
		2	3	
	016-C			12761
	016-B			12762

The sample input translates two, P_3, AMPX materials from an AMPX master on Unit 3 to a MATXS master on Unit 8. Resource requirements are 270K bytes of core storage, 6300 I/O operations, and 40 seconds of execution time on an IBM 360/91.

Unit numbers 3 and 8 are defined in the code. A more efficient and flexible AMPX to MATXS translator is under development.

D. ITOM[3] and PMATXS[3]

ITOM translates an ISOTXS file to MATXS. PMATXS lists a MATXS file. No input data are required for either module.

REFERENCES

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4. W. W. Engle, Jr., "A Users Manual for ANISN, A One-Dimensional Discrete Ordinates Transport Code with Anisotropic Scattering," K-1693, Computing Technology Center, Oak Ridge Gaseous Diffusion Plant (1967).

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CHAPTER IV. THE FORSS DATA REPOSITORY

J. L. Lucius

CHAPTER IV

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A. Data Interchange Between FANISN and JULIET

The solution of a FORSS problem requires a significant interchange of information between FANISN and JULIET. Under DRIVER control this process has been somewhat automated. The following types of data have been assigned a numerical identification and placed on a sequential I/O device which is referred to as a repository:

ID

1 FANISN forward angular flux

3 FANISN calculated multiplication factor

4 Fission term in FANISN forward equation. Results labeled as FISSION DENSITY on FANISN output

5 FANISN adjoint angular flux

6 Fission term in FANISN adjoint equation. Results labeled as FISSION DENSITY on FANISN output

7 An eight word record containing responses and normalization parameters

IS, W1, W2, W3, W4, W5, W6, 7

IS is a signal. If IS = 1, the data on the record are for a bilinear response (see Chapter VII, Equations 19-23). If IS = 0, the data on the record are for a linear response (see Chapter VII, Equations 28-30).

When IS = 1

$W1 = \frac{\langle \phi^* H_1 \phi \rangle}{\lambda \langle \phi^* H_2 \phi \rangle}$ (see Chapter VII, Equation 19). W1 is used as a normalization parameter in the calculation of a worth sensitivity profile

W2 = $\frac{\langle \emptyset^* H_1 \emptyset \rangle}{\langle \emptyset^* H_2 \emptyset \rangle}$ (see Chapter VII, Equation 19). W2 is the bilinear response.

W3 = $\langle \emptyset^* H_1 \emptyset \rangle$ numerator of bilinear response, used as a normalization parameter in worth sensitivity (see Chapter VII, Equation 39).

W4 = $\langle \emptyset^* H_2 \emptyset \rangle$ denominator of bilinear response, used as a normalization parameter in worth sensitivity (see Chapter VII, Equation 40).

W5 = $\frac{\langle \emptyset^* H_1 \emptyset \rangle}{\langle \emptyset^* H_2 \emptyset \rangle} \left[\frac{.6023}{N}\right]$. differential worth

where N is the number density (atoms/bn-cm) of the material of interest.

W6 = $\lambda \langle \emptyset^* H_2 \emptyset \rangle$, the normalization parameter for k sensitivity.

W7 = FANISN calculated multiplication factor.

When IS = 0

W1 = $\frac{\langle H_1 \emptyset \rangle}{\langle H_2 \emptyset \rangle}$ the linear response (see Chapter VII, Equation 28).

W2 = $\langle H_1 \emptyset \rangle$ numerator of linear response, used as a normalization parameter in the calculation of a reaction rate ratio sensitivity (see Chapter VII, Equation 35).

W3 = $\langle H_2 \emptyset \rangle$ denominator of linear response, used as a normalization parameter in the calculation of a reaction ratio sensitivity (see Chapter VII, Equation 36).

W4
W5
W6
W7 } 0

9 Generalized adjoint source calculated by JULIET. For bilinear source see Equation 25, for linear source see Equation 31 JULIET Users Guide Chapter VII.

11 Generalized source normalization calculated by FANISN = $\langle V(j)\ S(j,g) \rangle$ (brackets imply integration over space and energy of 0th moment source).

12 Generalized forward source calculated by JULIET. See Equation 24 JULIET Users Guide Chapter VII.

The repository has been designated by default as unit 2. This designation can be changed by user input to the FMANG module (see p. 6).

FMANG is a module that manages the data interchange between ANISN and JULIET. The execution of FMANG is a prerequisite to the execution of either FANISN or JULIET. FMANG scans the repository which contains the numerically identified data described above, and sets up a directory of the data on the repository. The directory is updated in FANISN and JULIET when any action involving the data is taken. Both modules know the position of the repository at all times to permit access to a particular data type with reasonable efficiency. Since the repository is a sequential device, it is structured to accommodate the typical problem with a minimum of device scanning.

A labeled common /D3MGT/ and unit 2 are used to make the directory available to points of interest throughout the system.

The directory includes a 10-word record for each type of data that has been written on unit 2. Currently six of these words have an assigned function and four left open for expansion.

Word	Function
1	Assembly identification number
2	Response related identification number
3	Data type identification number
4	Block number
5	Number of records
6	Record length

7	0
8	0
9	0
10	0

Each data block on the repository is immediately preceded by its descriptive 10-word record.

The user must supply the assembly identification number and the response related identification number (IRESP). The IRESP is used throughout ANISN and JULIET to achieve correct identification and retrieval of information.

1) Initial FANISN Runs

The initial FANISN forward and adjoint runs generate fluxes, fission densities and k (if calculated). This data is stored in the repository for use by subsequent ANISN and JULIET runs. This data must be identified by setting IRESP = 1. This identification is accomplished with the FMANG module which must be executed prior to each FANISN run. FMANG input is described in detail on pp. 6-9.

2) JULIET Generalized Source Runs

Generalized sources may be generated for several responses with a single pass through the JULIET-SOURCE execution path. Each source must be uniquely identified for correct deposit in and withdrawal from the repository. A detailed description of the JULIET-SOURCE input required to accomplish unique identification is found in Chapter VII, Section B, Block 4, the 74$$ card, parameters IDA and IDF.

The user via input to the FMANG module identifies the generalized source input to be used in the FANISN generalized flux calculation. The generalized flux set, Γ or Γ^*, calculated by FANISN is identified by the same number used to identify the generalized source which was input to the ANISN calculation. The user must insure consistency between the response related identification numbers input to FANISN via FMANG (see p. 6) and the identification numbers assigned to the generalized sources via JULIET-SOURCE input (see Chapter VII, Section B, Block 4, the 74$$ card, parameters

IDA and IDF).

3) Flux Preparation for Sensitivity Calculations

Any FORSS sensitivity calculation requires the preparation of at least one of the following files.

1. $\langle \phi^* \phi \rangle$ for k sensitivity
2. $\langle r^* \phi \rangle$ for reaction rate ratio sensitivity
3. $\langle r \phi^* \rangle$ and 1 and 2 for worth sensitivity

The files are prepared by the JULIET-FLUXP execution path. The user must identify the component fluxes for the sensitivity calculation. The identification of ϕ with IRESF=1 is assumed by the FORSS system. Any tampering with the identification of ϕ will destroy the calculation. Since ϕ is identified by default, for flux folds involving ϕ, only the adjoint flux must be identified. This can be adequately accomplished with FMANG input (Section 2.A). The generation of $\langle r \phi^* \rangle$ is more complex and correct identification requires the use of input parameters to the JULIET-FLUXP execution path. A detailed description of the input required may be found in Chapter VII, Section B, Block 3, the 60$$ card, parameters IRF and IRA.

4) Normalization and Response Parameters for JULIET Sensitivity Calcs.

See p. 1, data type 7, for a review of normalization and response parameters. These parameters are used in the calculation of a sensitivity profile (see Chapter VII, Equations 32-37). The parameters were calculated by the JULIET-SOURCE module and placed in the repository identified with same number used to identify the adjoint generalized source (see Chapter VII, Section B, Block 4, the 74$$ card, the IDA parameter). Identification of these parameters to the JULIET-SENSE execution path may be accomplished with input to the FMANG module (see p. 6) which is executed immediately preceding JULIET. The identification provided by FMANG may be superseded by input to the JULIET-SENSE execution path (see Chapter VII, Section B, Block 5, 83$$ card, IRESP parameter).

B. FORSS Manager (FMANG)

1) FANISN-JULIET Data Transfer

FMANG manages the data transfer between FANISN and JULIET. An I/O unit (Default = 2) is used as a repository for such data. The data are categorized by three integers, assembly, response related, and type identification numbers. Normal input to FMANG is one free form card.

1$$ Integer Parameters [10]

1.	IASB	— Assembly identification number
2.	IRESP	— Response related identification number
3.	ISIG	— Status signal 0 - no useful data in repository 1 - useful data in repository
4.	IAC	— Unit number of FANISN cross section file (Default = 4)
5.	ITH	— Enter 1 if FANISN case is adjoint
6.	IQM	— Number of source moments
7.	0	
8.	0	
9.	IR2	— Unit number of the repository (Default = 2)
10.	0	

T

If a zero is encountered on the 1$$ card for a parameter that has a default value, the default value is used. Parameters 5 and 6 ITH and IQM are used in the revision of FANISN input. When zeroes are encountered on the 1$$ card for these parameters no data revision occurs. See the discussion of input for FANISN generalized cases in Chapter VI for more detail about ITH and IQM. When FMANG is signaled that useful data are in the repository, it scans the unit and constructs a directory of contents. This directory is used throughout FANISN and JULIET. A FMANG execution must immediately precede each FANISN and JULIET calculation in the job stream.

2) Error Recovery

If an error is discovered which invalidates any type of data in the repository, the erroneous data must be removed. FMANG provides two options for describing the data to be removed.

Option 1 permits data description by assembly, response related, and type identification numbers.

Input

1$$ Integer Parameters [10]

- NIS, the number of data types to be removed (entered as a negative number)
  FO - Fill 0 option

T

2$$ Integer Parameters [3*|NIS|]

IASB - Assembly ID
IRESP - Response related ID
ITYP - Data type ID

.
.
.

The 3 integer sequence is repeated |NIS| times.

T

Option 2 permits data description by block number. This option is useful if 2 or more sets of data are on the repository with identical IASB, IRESP, and ITYP identification numbers.

Input

1$$ Integer Parameters [10]

- NIB, the number of data blocks to be removed (entered as a negative number).
  0
  0
  -1
  FO

T

2$$ Integer Parameters [|NIB|]

IBN . . . , the block numbers to be removed

T

The following is input if an ANISN or JULIET run is to be made after the data removal.

3$$ Integer Parameters [10]

IASB - Assembly identification

IRESP - Response related identification

1 - Indicates useful data in repository

F0 - Fill 0 option

T

3) Repository Copy

There are occasions when it is useful to copy the repository.

Input

1$$ Integer Parameter [10]

8Z

IOUT - Unit number of new repository (default = 31)

IN - Unit number of existing repository (default = 2)

T

The repcsitory is copied without modification from unit IN to unit IOUT.

4) Repository List

A complete listing of the repository may be obtained or a selected list is available with the data identified by IASB, IRESP, ITYP.

Input for complete list

1$$ - 1100 1 F0 T

Input for Selective List

1$$ Integer Parameters [10]

- NTS, the number of data types to be listed (entered as a negative number)

1

F0

T

```
255  Integer Parameters [3*|NTS|]
     IASB
     IAESP
     ITYP
     .
     .
     The sequence is repeated |NIS| times.
     T
```

CHAPTER V. INPUT INSTRUCTIONS FOR ANISN AND AXMIX

W. W. Engle Jr.
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CHAPTER V

Table of Contents

INPUT INSTRUCTIONS FOR CCC-254/ANISN-ORNL

W. W. Engle, Jr.

A. Data Description

This section is intended to be used as a guide in preparing problems for ANISN. The following section presents a more detailed description of the data. The quantity in brackets is the array dimension and the expression in braces is the condition requiring that array or set of arrays. Arrays or sets of arrays which are not required should not be entered. If no condition is specified the array is required. Note that a T must follow each of the five sets of arrays if that set is entered. (Old A definition of LIM1 no longer valid)

The title card may contain only 48 characters. Columns 61-72 of the title card are used to enter a maximum execution time (ignored if zero). FORMAT (12A4, 12X, I12)

Parameters

15$ Integer parameters [36]

1. ID — problem ID number: if greater than 1,000,000, disadvantage factors will be computed by group for each material which appears in the calculation
2. ITH — 0 - forward solution; 1 - adjoint solution
3. ISCT — maximum order of scatter found in any zone (P value)
4. ISN — order of angular quadrature (S value)
5. IGE — 1 - slab; 2 - cylinder; 3 - sphere
6. BL — left boundary condition
   0 - vacuum (no reflection)
   1 - reflection
   2 - periodic
   3 - white/albedo

7. IBR right boundary condition, same options as IBL
8. IZM number of zones or regions (same material)
9. IM number of mesh intervals
10. IEVT eigenvalue type
    0 - fixed source
    1 - k calculation
    2 - α calculation
    3 - concentration search
    4 - zone width search
    5 - outer radius search
    6 - buckling search
11. IGM number of energy groups
12. IHT position of σ_{total} in cross section table
13. IHS position of σ_{gg} (self-scatter) in cross section table
14. IHM length of cross section table
15. MS cross section mixing table length (10$, 11$, 12*)
16. MCR number of cross section sets to be read from cards (14*)
17. MTP number of cross section sets to be read from tape (13$)
18. MT total number of cross section sets (elements + mixtures)
19. IDFM 0 - density factors (21*) not used
    1 - density factors used
20. IPVT 0 - no effect
    1 - enter k_0 as PV (16*)
    2 - enter α_0 as PV
21. IQM 0 - no effect
    1 - enter distributed source (17*)
22. IPM 0 - no effect
    1 - enter shell source by group and angle (18*)
    IM - enter shell source by interval, group, and angle
23. IPP interval number which contains shell source if IPM = 1; 0 otherwise
24. IIM inner iteration maximum

25. ID1
0 - no effect
1 - print angular flux
2 - punch scalar flux
3 - both 1 and 2

26. ID2
0 - no effect
1 - use specially prepared group independent cross section tape (contains MTP materials)

27. ID3
0 - no effect
N - compute N activities by zone where N is any positive integer

28. ID4
0 - no effect
1 - compute N activities by interval where N refers to ID3

29. ICM
outer iteration maximum

30. IDAT1
0 - all data in core
1 - cross sections and fixed sources stored on tape
2 - fluxes and currents on tape also

✓ 31. IDAT2
0 - no effect
If IDAT2 is greater than zero, the first IDAT 2 outer iterations will be executed according to the specifications in the 24$ array. In the 24$ array 0 indicates an S_n calculation, 1 indicates a diffusion calculation and 2 indicates an infinite homogeneous medium calculation. If convergence is not obtained after IDAT2 iterations, the problem continues using the S_n calculation for all groups until convergence is obtained or ICM is reached.

✓ 32. IFG
0 - no effect
1 - execute cross section weighting
2 - read cross sections weighted in previous ANISN cases
3 - write weighted cross sections on tape/disk/etc. at completion of ANISN case, or
4 - both 2 and 3

✓ Updated 1973

✓ 33.	IFLU	0 - step model used when linear extrapolation yields negative flux (mixed mode) 1 - use linear model only 2 - use step model only 3 - weighted difference model 4 - weighted model used as negative flux fixup for linear model
34.	IFN	0 - enter fission guess (2*) 1 - enter flux guess (3*) 2 - use fluxes from previous case
35.	IPRT	0 - print cross sections 1 - do not print cross sections
✓ 36.	IXTR	0 - enter zero; not used

16* Floating point parameters [14]

1.	EV	first guess for eigenvalue (usually 0.0)
2.	EVM	eigenvalue modifier
3.	EPS	epsilon - accuracy desired
4.	BF	buckling factor, normally 1.420892
5.	DY	cylinder or plane height for buckling correction
6.	DZ	plane depth for buckling correction
7.	DFM1	transverse dimension for void streaming correction
8.	XNF	normalization factor (usually 1)
9.	PV	0.0, k_0, or α_0 according to IPVT = 0, 1, or 2
10.	RYF	λ_2 relaxation factor, normally 0.5
11.	XLAL	point flux convergence criterion if entered greater than zero
12.	XLAH	upper limit for $\lvert 1.0 - \lambda_1 \rvert$ used in linear search
13.	EQL	eigenvalue change epsilon
14.	XNPM	new parameter modifier

NOTE: The above data are followed by a T.

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Cross Sections (ID2 = 0)

13$ Library ID numbers [MTP] (MTP > 0) (Omit if using cards)

14* Cross sections [MCR x IGM x IHM] (MCR > 0)
NOTE: If entered, the above data are followed by a T.

Fixed Source (IEVT = 0 and ID2 < 2)

17* Distributed source [IGM x IM] (IQM = 1)

18* Shell source [IGM x IPM x NM] (IPM > 0)
NOTE: If entered, the above data are followed by a T.

Flux or Fission Guess (IFN < 2)

2* Fission density [IM] (IFN = 0)

3* Flux guess [IGM x IM] (IFN = 1)
NOTE: If entered, the above data are followed by a T.

Remainder of Data

1* Fission spectrum [IGM]
4* Radii by interval boundary [IM + 1]
5* Velocities [IGM]
6* Angular quadrature weights [MM][3]
7* Angular quadrature cosines [MM]
8* Zone numbers by interval [IM]
9$ Material numbers by zone [IZM]
10$ Mixture numbers in mixing table [MS] (MS > 0)
11$ Component numbers in mixing table [MS] (MS > 0)
12* Number densities in mixing table [MS] (MS > 0)
19$ Order of scatter by zone [IZM] (ISCT > 0)
20* Radius modifiers by zone [IZM] (IEVT = 4)
21* Density factors by interval [IM] (IDFM = 1)
22$ Material numbers for activities [ID3] (ID3 > 0)
23$ Cross section table position for activities [ID3] (ID3 > 0)

---

[3] MM = ISN + 1 for plane or sphere
MM = (ISN x (ISN + 4))/4 for cylinder

24$ Calculation type markers [IGM] (IDAT2 = 1)

25* Albedo by group - right boundary [IBM] (IBR = 3)

26* Albedo by group = left boundary [IGM] (IBL = 3)

27$ Few group parameters [5] (IFG = 1)

1. ICON — 0 - no effect
   1 - micro cross sections desired
   2 - macro cross sections desired (minus implies cell weighting)
2. IHTF — position of σ_{total} in weighted cross sections
3. IHSF — position of $\sigma_{g \to g}$ in weighted cross sections (minus implies upscatter removal)
4. IHMF — table length of weighted cross sections
5. IPUN — 0 - no effect
   1 - punch weighted cross sections

28$ Few group number for each multigroup [IGM] (IFG = 1)

NOTE: The above data are followed by a T.

"Double T"

Each ANISN/360 case must be followed by one extra card. This card may be blank or may contain the "double T" if desired. If a case terminates normally, this extra card is read and ignored. If a case is terminated by an error, the "double T" is searched for, and, if found, ANISN expects a title card and associated data to follow

SPECIAL NOTE: You should always put in a fission spectrum (1*) and a velocity (5*) array, even if they are just filled with zeros.

ANISN should always be run in a model which ignores floating point divide, overflow and underflow checks, and integer divide and overflow checks.

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B. Detailed Data Notes

This section presents a more detailed definition of selected parameters and arrays. Some comments derived from experience are also included.

Boundary conditions - IBL, IBR, 25*, 26*

The white boundary condition causes the entering flux at the specified boundary to be isotropic. This is accomplished by summing the flux leaving the system and returning an average flux in all directions. The albedo for each group specifies the fraction of the flux leaving to be returned. If the albedo is not specified it is assumed to be 1.0. The white boundary is recommended for the outer boundary of spherical and cylindrical cells.

Cross section mixing table - MS, 10$, 11$, 12*

The cross section mixing table is used to combine elements into macroscopic mixtures and to specify the method of the concentation search. Experience will reveal that only the imagination limits its flexibility. The following table illustrates the three types of operations performed by the mixing table.

	10$	11$	12*
1.	M	0	X
2.	M	N	X
3.	M	M	0.0

1. Multiply all cross sections in material M by X.
2. Multiply all cross sections in material N by X and add to corresponding cross sections in material M.
3. Multiply all cross sections in material M by EV, the eigenvalue. (concentration search)

Cross sections - 13$, 14*

ANISN expects a table of cross sections for each group, g, of each material in the following format:

Position	Cross section type
1	activity
.	"
.	"
.	"
IHT-2	absorption
IHT-1	nu x fission
IHT	total
IHT+1	$\sigma_{g+NUS \to g}$
.	.
.	. upscatter[5]
.	.
IHS-1	$\sigma_{g+1 \to g}$
IHS	$\sigma_{g \to g}$
IHS+1	$\sigma_{g-1 \to g}$
.	.
.	. downscatter[5]
.	.
IHM	$\sigma_{g-NDS \to g}$

Thus, the parameters IHT, IHS, and IHM completely describe the format of the cross sections. If there are no activity cross sections, IHT = 3. If there is no upscatter IHS = IHT + 1. If there is no downscatter IHM = IHS (i.e., a one group problem). If there is upscatter ANISN will compute a total upscatter cross section for each group of each material and place that cross section in position IHM + 1. The activity cross sections are used only for activities (22$, 23$).

The P_L cross section tables must correspond in format to the P_0 tables even though the transfer coefficients are the only numbers used. Note that the P_L cross sections must contain a (2L + 1) term. Previous S_n codes supplied this term internally (e.g., DTF-II multiplied by the

[5] NUS is the number of groups of upscatter
NDS is the number of groups of downscatter

P_1 cross sections by 3.0). This factor may be included externally or internally via the mixing table.

Material numbers - 10$, 11$, 9$, 22$

All cross section sets, whether elements or mixtures, are referred to by a continuous set of material numbers. In particular, the materials supplied in card form (14*) become materials 1 through MCR, the materials read from a library tape become MCR + 1 through MCR + MTP, and any number greater than MCR + MTP but less than or equal to MT refers to a mixture.

When the order of scatter for any zone (19$) is greater than zero, ANISN expects the P_1 cross sections to be material M + 1, the P_2 cross sections to be M + 2, etc. where M is the P_0 material number specified in the 9$ array.

Density factors - IDFM, 21*

All cross sections appropriate to an interval are multiplied by the density factor for that interval. Thus, one may easily and efficiently describe a void or a density variation by interval.

IPVT and PV - used in search

If IPVT = 1, ANISN will search for the parameter which results in a multiplication factor of PV. If IPVT = 2, ANISN will search for the parameter which results in a multiplication factor of 1.0 when α = PV. If IPVT = 0, ANISN will search for a multiplication factor of 1.0 with α = 0.0.

Distributed source = IQM, 17*

The distributed source is entered by group and interval as follows: group 1, interval 1 through IM; group 2, etc.

Shell source - IPM, IPP, 18*

If IPM = 1, the shell source is entered by group and angle for interval IPP as follows: group 1, angle 1 through angle MM; group 2, etc.

If IPM = IM, the shell source is entered by group, interval and angle as follows: group 1, interval 1, angle 1 through angle NM; interval 2, etc.

Special cross section tape - ID2 = 1

A special purpose program is available which will prepare a group independent cross section tape for ANISN. This tape is required if the complete input cross section matrix [(MCR + MTP) x IGM x IHM] is larger than the number of data locations available.

Activities - ID3, ID4, 22$, 23$

Activities may be computed by zone and interval as specified in ID3 and ID4. The zone activity is a total reaction rate and the interval activity is per unit volume. The following table illustrates the use of activity specifications.

	22$	23$
1.	1	3
2.	-5	1
3.	7	-1
4.	-3	-1

1. Compute activity for material 1, cross section position 3 in the intervals and/or zones in which material 1 appears.

2. Compute activity for material 5, cross section position 1 in all intervals and/or zones.

3. Compute activity for material 7, position 1 in appropriate intervals and/or zones and multiply interval activities by 1.0, $2\pi r$, or $4\pi r^2$ for slab, cylinder, or sphere respectively.

4. Compute activity for material 3, position 1 in all intervals and/or zones and multiply interval activities by geometry factor.

Auxiliary tape storage - IDAT1

If IDAT1 is specified as zero, ANISN will use the most efficient tape storage possible and modify IDAT1 accordingly. IDAT1 may be specified as 1 or 2 if cross section and/or flux tapes are available from a previous problem or if ID2 = 1.

Diffusion theory solution or infinite homogeneous medium solution

IDAT2, 24$

If IDAT2 = 1 the 24$ array must be entered. A zero implies a transport solution, a one implies a diffusion solution, and a two implies an infinite medium solution for the corresponding group. If IFN = 0, ANISN will use diffusion theory on the first outer iteration.

Weighted cross sections - IFG, 27$, 28$ *(see bottom of page)

When microscopic weighted cross sections are requested (ICON = 1), a set of cross sections is produced for each component of each material in each zone. When macroscopic cross sections are requested (ICON = 2), a set of cross sections is produced for each material in each zone. The cross sections are weighted by the flux or current in the zone in which the material appears. Since the mixing table is used to determine the components of a material, MS should not be zero when ICON = 1.

If the cross section structure specified for the weighted cross sections will not accommodate the complete multigroup scattering matrix, the "extra" transfer coefficients are placed such that they transfer as far down (or up) as possible.

If complete removal of the upscatter is desired, IHSF should be minus. |IHSF| should be the position of the self scatter cross section before the upscatter is removed. IHMF should be the final table length. After the upscatter is removed, IHSF will be IHTF + 1. The upscatter is removed by subtracting the reaction rate due to $\sigma_{j\to i}$ from the reaction rate due to $\sigma_{i\to j}$ where $j > i$. Thus, the net transfer rate between groups j and i is preserved.

---

*When IFG is 1, 3, or 4 the 27$ and 28$ arrays must be entered. When IFG is 2 or 4, cross section order is as follows: materials 1 through M - weighted by previous case; materials M+1 through MCR - read from cards; materials MCR+1 through MTP+MCR - read from library; materials MCR+MTP+1 through MT - mixtures.

Starting guess - IFN, 2*, 3*

If IFN is specified as zero, ANISN will execute a diffusion solution for the first outer iteration. Since this is undesirable for fixed source calculations where one normally desires a zero flux guess one may set IFN = 1 and enter no guess. Simply enter a card with a T in column three for that section of data.

EV and EVM guesses

IEVT	EV	EVM
0	0.0	0.0
1	0.0	0.0
2	best guess for α[6]	0.0
3	1.0	-0.1
4	0.0	-0.1
5	outer radius	-(10% of outer radius)
6	1.0	-0.1

When IEVT = 0 there is no eigenvalue (EV).

When IEVT = 1 the multiplication factor (k) is the eigenvalue.

When IEVT = 2 α is the eigenvalue.

When IEVT = 3 the eigenvalue is defined by its use in the mixing table.

When IEVT = 4 the eigenvalue is used as follows:

$\Delta R_I = \Delta R_I^\circ$ (1.0 + EV x RM_Z)

where ΔR_I° is the initial ΔR

RM_Z is the radius modifier (20*)

When IEVT = 5 the outer radius is the eigenvalue.

When IEVT = 6, EV = DY/DY° = DZ/DZ°

where DY° and DZ° are input.

Convergence - EPS, XLAL, RYF

The inner or flux iterations are considered converged when both

[6]Zero is the best guess unless one is reasonably sure that his guess is close to the answer.

the integral self-scatter error and the integral removal error are less than EPG or when the maximum flux deviation is less than EPS. EPG is related to EPS by a normalization factor, the total source divided by IGM. Since the integral tests are sometimes easily satisfied, a point flux convergence may be specified. If XLAL is greater than zero, the inner iterations are not considered converged until the maximum flux deviation is less than XLAL.

The outer or power iteration is considered converged when the total source ratio between successive iterations differs from 1.0 by less than EPS, the total scatter ratio differs from 1.0 by less than EPS/RYF and the upscatter ratio differs from 1.0 by less than EPS/RYF.

Buckling correction - BF, DY, DZ

ANISN computes a correction factor of the DB^2 form for finite transverse dimensions. The correction is applicable only with "transport corrected" P_0 cross sections where position IHT is occupied by the transport cross section.

Void streaming correction - DFM1

Since the DB^2 term is not applicable to a void region, ANISN computes a simple correction[7] which effectively removes the transverse component of each angular flux in the void region. This correction term is not included in the calculation of the absorption reaction rate as are the DB^2 losses. This omission causes the neutron balance to differ from 1.0. If DFM1 is zero, no correction is computed for the void regions.

Normalization

When IEVT is greater than zero the total fission source is normalized to XNF. When IEVT is equal to zero the total fixed source is normalized to XNF and the fission source, if any, is unnormalized. If XNF = 0.0 there is no normalization.

---

[7] Olsen, T., "Void Streaming in S_n Calculations," Nucl. Sci. Eng. 21 271 (1965).

Searches - XLAH, EQL, XNPM

When the absolute value of the difference between two successive lambdas (λ_1) is less than EQL, the eigenvalue, EV, is changed. The first EV change is the result of adding or subtracting the eigenvalue modifier, EVM. The second EV change is the result of a linear extrapolation. To prevent large changes early in the calculation, the absolute value of the difference between 1.0 and λ_1 is not allowed to exceed XLAH. To prevent oscillations when using the linear search, the extrapolation is limited by XNPM. The third EV change is the result of the quadratic search. The quadratic search is used until the absolute value of $1.0 - \lambda_1$ is less than EQL. At this point, the linear search is used to complete the problem. XLAH is normally 0.05 and XNPM is normally 0.75. EQL should be the larger of 0.001 and three times EPS. In cases where EPS is quite small, EQL may be less.

Multiple cases

The ANISN data arrays are stored in core in the order in which they are numbered. For example the fission density (2*) follows the fission spectrum (1*). No data are destroyed between cases. If problem dimensions change, the repositioned arrays are simply read into core over the previous data. The result is that all arrays following and including the first array to be repositioned must be respecified. It should be noted that the 15$ and 16* parameter arrays are exceptions to the above discussion and are never destroyed. Multiple cases in which IDAT1 changes will not retain data properly. If IDAT1 = 1, multiple cases will retain data properly only if ID2 = 2 in all cases following case 1. If IDAT1 = 2, multiple cases will retain data properly only if ID2 = 2 and IFN = 2 in all cases following case 1. If there is upscatter, multiple cases will retain data properly only if ID2 = 2 or if the complete cross section matrix is read in all cases.

In cases where the data in a particular section remains the same in multiple cases, one may enter a card containing only a T in any of the six appropriate columns for that section of data (e.g., the 15$, 16* section).

If any case is preceded by an adjoint solution, the following arrays must be respecified if they are required for the next case: 14*, 17*, 18*, 3*, 1*, 5*, 24$, 25*, 26*.

If multiple cases are completely independent of each other (i.e., all data are specified in each case) the data of each case may be terminated with a T in the third column of two successive fields on the same card. This "double T" is used in lieu of the normal single T. If ANISN terminates a case for any reason, the code will search for the "double T" and attempt to execute the following problem. This option may also be used for independent sets of multiple cases.

C. Problem Size

(24)	[240]	(1M)(IDFM)	[0]
(IGM+1)(2)	[8]	(IM)(IGM) if IDAT1 < 2	[105]
(IGM)(5)	[15]	(IM) if IDAT1 = 2	[0]
(IM)(11)	[385]	(IHP)(IGM)(MT)[8] if IDAT1 = 0	[216]
(IM+1)(4)	[144]	(IHP)(MT) if IDAT1 > 0	[0]
(MM)(5)	[25]	(IM)(IGM)(IQM) if IDAT1 = 0	[0]
(IZM)(3)	[9]	(IM)(IQM) if IDAT1 > 0	[0]
(MS)(3)	[36]	(IPM)(MM)(IGM) if IDAT1 = 0	[0]
(MTP)	[0]	(IPM)(MM) if IDAT1 > 0	[0]
(ID3)(2)	[12]	(IGM) if IBR = 3	[0]
(IFG)(5)	[5]	(IGM) if IBL = 3	[0]
(IFG)(IGM)	[3]	(MM)(JT) if ISCT > 0	[15]
(IM)(ISCT)	[105]	(IM)(JT)(IGM) if ISCT > 0 and IDAT1 < 2	[315]
(IM)(MM) (1973)			
(IM+1)(NM)(5)	[900]	(IM)(JT) if ISCT > 0 and IDAT1 = 2	[0]
(IM)(JT)(2)	[210]	(MM)(IGM) if IDAT1 < 2	[15]
(IM)(JT) + 1	[106]	(MM) if IDAT1 = 2	[0]
(IGM)(IDAT2)	[0]	TOTAL	[2869]

To determine the number of data locations required for a given problem, each of the above expressions should be evaluated and summed. The numbers in the brackets apply to the sample problem.

[8] IHP = IHM if there is no upscatter
IHP = IHM + 1 if there is upscatter

INPUT INSTRUCTIONS FOR PSR-75/AXMIX

G. C. Haynes

TITLE CARD -- First card of a problem, Format (20A4), identifying the problem and/or the output data set.

AXMIX Control Parameters (Array Block 1)

1$ Array -- Primary Control Parameters (12 entries)

1.	IGM	Number of energy groups for this problem
2.	ITLI	Input x-sect table length
3.	ITLØ	Output x-sect table length. If ITLØ≠ITLI, the difference is either truncated or padded with zeros. (At the end of the table if ITLØ is positive, or at the beginning if ITLØ is negative).
4.	MCR	Number of materials input from cards (30*). A "material" is one IGM*ITLI cross-section set.
5.	MTP	Number of materials input from nuclide libraries (13$).
6.	MGIP	Number of materials input from GIP data sets (15$). +M means entire GIP input is on KU1. -M means GIP input is specified in 15$ array.
7.	NDS13	Number of nuclide libraries specified by logical unit number (negative entry) in the 13$ array. If NDS13=0, MTP materials are input from unit KU3.
8.	NDS15	Number of GIP data sets specified by logical unit number (negative entry) in the 15$ array. If NDS15+0, MGIP materials are input from unit KU1.
9.	MS	X-sect mixing table length (10$, 11$, 12*).
10.	MT	Total number of materials processed in this problem. MT=MCR+MTP+MGIP+mixtures. All materials are numbered consecutively from 1 through MT, and are defined in the order of the terms of the equation above.

11. ITPOUT — Output nuclide library control (16$), such that:
0 means no output library, omit 16$ array.
1 means output materials according to 16$ array onto unit KU4.
2 or N means combine materials according to 16$ with materials on unit KCMB and write all onto unit KU4. N=(table length)*(no. of groups) for largest material on KCMB if greater than IGM*ITLØ.
(Check IDLST (3$ array) when using this option)

12. IDUP4 — 0 means no effect.
K means make extra copy of KU4 onto unit K.
-K means same as K, but prevents rewind at completion of this problem.
7 means copy KU4 onto unit 7 in fixed FIDO card image format.
-7 means copy KU4 onto unit 7 in free FIDO card image format.
When using unit 7 in this option be sure to specify PARM.GO='CK=-7' because unit 7 will be rewound at problem completion.

2$ Array -- Control for GIP data sets, P_n Adjustment

1. IGIPØ — Output GIP data set control (17$) such that:
0 means no output GIP data set, omit 17$ array.
1 means write materials as specified in the 17$ array onto GIP unit KU2.
-1 means same as 1 except output GIP data set is adjoint. (If this option is used, no input GIP data set is allowed, and all output will be adjoint.)

Note: If a GIP tape is to be output, cross sections may not contain upscatter. This limitation does not apply to input GIP data sets. (See special section on upscatter)

2. IPNC

0 means no P_n adjustment, omit 21$ through 24$ arrays.

J means do P_n adjustments on J elements or mixtures as specified in the 21$, 22$, 23$, and 24$ arrays. (In these arrays refer to only the P_0 component of each element or material to be adjusted.)

3. IHT

Table position of total cross section.
(Not used if IGIPØ=IPNC=ITRC=0)

4. IHS

Table position of within-group scattering cross section.
(Not used if IGIPØ=IPNC=ITRC=0)

Note: If IHS > IHT+1, upscattering is implied and any output GIP libary requested will be aborted.

5. ITRC

Output logical unit for a transport-corrected cross section library to be written according to the 25$ ID array. Negative entry prevents rewind at problem completion.

6. IHTSAV

Cross section table position to save sigma total in the transport library if ITRC≠0, (zero means no effect)

7. IADI

Upscatter GIP data set input type.
0 means input data sets contain no upscatter (be sure IHS=IHT+1).
1 means input data sets were for ANISN, and the total upscatter coefficients are in table position ITLI+1.

2 means input data sets were for DOT, and the total upscatter coefficients are in table position IHT+1.

Note: GIP data sets contain one extra table position for total upscatter coefficient. Disregard this extension of the table length when specifying ITLI.

8. LADØ — Not presently used. Enter zero.

This array defaults to all zero values if not entered as input.

3$ Array -- Input/Output Logical Units (8 entries, default values in parenthesis)

1. KU1 — (1) GIP tape input logical unit number. This number is used if the 15$ array is not entered, or if the first entry in the 15$ array is positive. Negative entry prevents rewind at input completion.
2. KU2 — (2) GIP tape output logical unit number. Negative entry prevents rewind at problem completion.
3. KU3 — (3) ANISN/DOT nuclide library input logical unit number. This number is used if the first entry in the 13$ array is positive.
4. KU4 — (4) ANISN/DOT nuclide library output logical unit number. Negative entry prevents rewind at problem completion.
5. KU5 — (5) Card input logical unit number.
6. KU6 — (6) Printed output logical unit number.
7. KCMB — (8) Logical unit number for old ANISN/DOT nuclide library to be combined with new library. The resulting library is written on unit KU4 and the library on KCMB is unaltered if KCMB≠KU4

8. IDLST
   0 = (if ITPØUT<2) No effect.
   0 = (if ITPØUT=2) Merge output with KCMB, ID numbers in ascending order (KCMB and KU4 must be different); KCMB is not altered.
   -I = Same as above, but drop I materials (14$) from library on KCMB when transferring to KU4.
   ID = Add output to KU4 following this ID on KCMB (KCMB may equal KU4).

This array is not required if the default values enclosed in parentheses are satisfactory. Any units not required by a problem are irrelevant, no DD cards are required for them, and any integer will suffice for them. Punched output, if any, must be output to logical unit number 7.

Note: The 1$, 2$, and 3$ arrays are the first array block for a problem, and the block is terminated with a "T".

AXMIX Input Arrays (Array Block 2)

10$ Mixture numbers in mixing table. [MS entries]
Negative entry causes division (10$/(11$·12*))

11$ Component numbers in mixing table [MS entries]
Negative entry causes multiplication (10$·11$·12*)

12* Number densities in mixing table [MS entries]

13$ Input ANISN/DOT nuclide library ID numbers, and logical unit numbers if NDS13>0. Data set logical unit numbers, if any are negative entries which are followed by the ID numbers of materials required from that data set. Duplicate ID's are permitted if they appear on different data sets. Entries may be up to 8 digits long. If the first entry is positive, it is assumed that KU3 is the data set logical unit number for all ID's before the first negative entry. [MTP+NDS13 entries]

14$ List of ID numbers of materials to be dropped from library on KCMB when merging output with KCMB and writing on KU4. [-IDLST entries] {omit if IDLST≥0}

15$ Input GIP tape control array. Data set logical unit numbers, if any, are negative entries which are followed by the position

numbers of materials required from each data set. Duplicate position numbers are permitted if they occur on different data sets. If the first entry is positive, it is assumed that IUl is the data set logical unit number for all entries before the first negative entry. Poisition numbers need not satisfy any fixed order.

[-MGIP+NDS15 entries]
{omit if MGIP≥0}

16$ Output ANISN/DOT nuclide library ID numbers. These may be up to 8 digits long (6 digit limit is recommended), and need not be arranged in order. One entry is required for each material of the problem, and a zero means that material is not output. If this library is being merged with one on KCMB, a new material may be substituted for one on KCMB by using the same ID number. Regardless of the array order here, all resulting output is written in order of ascending ID number. [MT entries]
{omit if ITPØUT=0}

17$ Output GIP tape control array. One entry is required for each material of the problem. A zero entry means that material is not output. Any nonzero entry (usually a 1) means that material is output. [MT entries]
{omit if IGIPØ=0}

18$ Output cross-section title control array, one entry for each material.
A zero entry means no title is to be assigned to that material.
Any positive entry means keep old title if one exists (from an ANISN/DOT nuclide library, KU3, not KCMB).
Any negative entry means a new title is to be read from a title card following the last data block of that problem.
[MT entries]
{omit it all pos}

19$ Output cross-section print control array, one entry for each material.
A zero entry means do not print that material.

Any nonzero entry means print that material.

[MT entries]
{omit if all zero}

20$ Output cross-section punch control array, one entry for each material.
A zero entry means do not punch that material.
A positive entry means punch in fixed FIDO format.
A negative entry means punch in free-form FIDO format.

21$ Material numbers of the P_0 scattering components of elements or mixtures to be "P_n adjusted". [IPNC entries]

22$ Material number of P_0 component to be used for the P_n adjustment. [IPNC entries]

23$ New (adjusted) scattering order of elements or mixtures identified in the 21$ array. [IPNC entries]

24$ Energy groups to which the P_n adjustment is to be applied, one entry for each group.
A zero menas that group is not affected.
Any nonzero entry means that group is affected.

[IGM entries]
{omit if IPNC=0}

25$$ Output ID numbers for P_0 materials to be "transport corrected". Zero entry for all other materials. Be sure the P_1 material follows the P_0 material referenced here.

[MT entries]
{omit if ITRC=0}

NOTE: End of array block 2, terminate with "T"

Card Input Cross-Sections (Array Block 3)

30* and/or 30** and/or any number from 01 through 99

All cross sections to be input from cards go here, one material immediately following another. They may be fixed FIDO format and/or free FIDO format. If the format changes, however, a new 30* or 30** must be entered to indicate the format of the data following it. [MCR*(IGM*ITLI) entries]

NOTE: This is the final array block, and it must be terminated with a "T".

(Caution: The "T" must not be immediately preceded by a "F" Option) Omit entire block, including the "T" if MCR=0

Cross-Section Title Cards

A title card must be entered, following the last array block, for each negative entry in the 18$ array. Any desired title is punched in Columns 25-72 of each card, and all other columns are irrelevant.

Multiple Problems

Multiple problems may be run consecutively by following the input to a previous problem with a new problem title card and new input data. Data from the previous problem is not automatically saved, and all default options apply independently to each problem. Output data sets from a previous problem, however, may be referenced as input to a problem if they were rewound. Data sets from previous problems may be added onto if they were not rewound.

Job Termination

A job may be terminated by any of the following ways:

1. End of data set on unit 5.
2. "STOP" command by entering a final card with STOP in Columns 1 - 4.
3. Call to "EXIT" by entering a final card with EXIT in Columns 1 - 4.

CHAPTER VI. INPUT INSTRUCTIONS FOR GENERALIZED CALCULATIONS WITH FORSS ANISN

J. L. Lucius

CHAPTER VI

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FORSS ANISN (FANISN) GENERALIZED FLUX

The theoretical development for FANISN generalized flux calculations may be found in ORNL/TM-4437 by E. M. Oblow. The calculation of sensitivity coefficients for linear responses such as reaction rate ratios and bilinear responses such as worth require the use of generalized fluxes. The linear response uses a generalized adjoint flux Γ^* and the bilinear response uses Γ^* and in addition a generalized forward flux Γ. These generalized fluxes are calculated by FANISN as a function of generalized sources which are calculated by the JULIET module (see Chapter VII). This dictates the following hierarchy of events which must precede the calculation of generalized fluxes.

1. The preparation of ANISN multigroup cross sections.
2. The calculation of ANISN forward flux, ϕ.
3. The calculation of ANISN adjoint flux, ϕ^*.
4. For linear responses, the calculation of a linear source for each response.
5. For bilinear responses, the calculation of a bilinear forward and adjoint source for each response.

The results of the calculations performed in steps 2 through 5 are placed in the repository (see Chapter IV) and the calculation of generalized fluxes can now proceed. As demonstrated by steps 4 and 5, generalized fluxes are response dependent and the necessary care must be taken to insure that a generalized flux calculated for a particular response is not used in subsequent calculations for any other response. The definition of the IRESP parameter in the FMANG input (see Chapter IV) deserves careful attention. The system cannot detect response identification errors and if such errors are made disaster is certain and often subtle.

The following modifications to the input data for the FANISN forward calculation which generated ϕ results in the input required for an FANISN generalized calculation.

FANISN INPUT FOR GENERALIZED CALCULATIONS

The input for the initial ANISN forward k calculation is defined as the reference case.

= FMANG

1$$ IASB IRESP 1 FO T

IASB - Assembly identification number

IRESP - Is the response related identification number. It must be set to the appropriate source identification number specified in JULIET.

Changes to the 15$$ card of the reference ANISN case.

Parameter 2 ITH = 1 if adjoint

Parameter 10 IEVT = 0

Parameter 20 IPVT = 1

Parameter 21 IQM = 1 for linear source

IQM = number of moments of P_ℓ source

Parameter 33 IFLU = 1

Parameter 34 IFN = 1

Changes to the 16** card of the reference ANISN case.

Parameter 1 EV = 0.0

Parameter 2 EVM = 0.0

Parameter 9 PV = k_{eff}

Remove the 2** fission density data, replace with 3** FO.0 T.

FMANG (see Chapter IV) and FANISN can revise the input for a preceding FANISN forward case and automatically generate the input required for a generalized FANISN case. This is demonstrated in a comprehensive sample case at the end of Chapter VII.

SAMPLE INPUT FOR FANISN GENERALIZED CASE

```
=FMANG
1$$    12   42   1     16    F0     T
=FANISN
ZPR 6/7 GENERALIZED AJOINT RUN
15$$   1  1  3  4  3  1  0  2  60  0  100  5  6  105  2Z  8  8
  0   1   4   2Z   12   0   1   0   0   25   1  2Z  1  1  1  0
16**   2Z   1.0-5   4Z   1.0  .98543 0.5   1.0-5   3Z    T
3** Fu.0 T
1**
  9.0576E-05  1.3844E-03  6.5907E-03  2.0758E-02  4.5693E-02  7.6253E-02
  1.0287E-01  6.9859E-02  1.5946E-02  4.0382E-03  3.9943E-03  2.4139E-02
  4.8338E-02  4.7780E-02  4.6546E-02  4.4760E-02  4.2547E-02  4.0028E-02
  3.7313E-02  3.4494E-02  1.3545E-02  1.8112E-02  2.8861E-02  2.6157E-02
  2.3583E-02  2.1162E-02  1.8910E-02  1.6834E-02  1.4935E-02  1.3210E-02
  6.0110E-03  5.6418E-03  1.0254E-02  9.0035E-03  9.6982E-04  3.5574E-04
  7.4622E-04  2.0042E-03  3.8139E-03  6.9018E-03  3.1165E-03  2.9113E-03
  5.2570E-03  4.5789E-03  3.9836E-03  3.4621E-03  1.5562E-03  1.4497E-03
  2.6078E-03  2.2606E-03  4.4137E-03  6.7274E-04  4.9410E-04  1.1962E-03
  7.0904E-04  2.1322E-03  1.4767E-03  1.0209E-03  3.4368E-04  1.4894E-04
  9.1435E-05  1.2087E-04  5.7150E-05  5.5065E-05  3.7402E-04  3.3512E-04
  2.3082E-04  1.5891E-04  1.0936E-04  7.5240E-05  5.1753E-05  2.2930E-05
  1.2662E-05  1.0900E-05  9.3835E-06  4.1901E-06  3.8876E-06  6.9535E-06
  5.9857E-06  1.1568E-05  7.9526E-06  5.4668E-06  3.7578E-06  2.5830E-06
  1.7754E-06  1.2203E-06  8.3878E-07  9.7277E-07  4.5956E-07  2.1712E-07
  1.0258E-07  4.8472E-08  2.2909E-08  1.0831E-08  5.1238E-09  2.4262E-09
  1.1506E-09  5.4707E-10  2.6118E-10  2.5220E-10
4** 3910.0 19188.16 121.97
5** F1.
6** 0.0 .17392742 .32607257 .32607257 .17392742
7** -1. -.86113631 -.33998104 .33998104 .86113631
8$$ 40R1 20R2
9$$   1   5
19$$ F3
T
```

CHAPTER VII. A USER'S GUIDE FOR THE JULIET MODULE OF THE FORSS SENSITIVITY AND UNCERTAINTY ANALYSIS CODE SYSTEM*

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DEPARTMENT OF ENERGY

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A USER'S GUIDE FOR THE JULIET MODULE OF THE FORSS SENSITIVITY AND UNCERTAINTY ANALYSIS CODE SYSTEM

J. L. Lucius, E. M. Oblow, and G. W. Cunningham, III

ABSTRACT

JULIET is the FORSS module that calculates generalized sources, responses (e.g., criticality, reaction rate ratios, reactivity worths), normalization parameters and sensitivity coefficients. JULIET is organized into execution paths which are in effect submodules. This permits a problem to be segmented for solution at the user's discretion (i.e., multiple entry points). JULIET normally operates with fluxes generated by the FORSS version of ANISN; however, the execution path concept permits interaction with other neutronics codes such as DOT and VENTURE.

The proposed CCCC file MATXS is the cross-section data base for JULIET permitting the calculation of sensitivity coefficients with respect to partial cross sections. The sensitivity coefficients calculated by JULIET are placed in the proposed CCCC file SENPRO where they may be accessed by other modules in the FORSS system or transmitted to other installations.

I. INTRODUCTION

JULIET is the FORSS[1] module that calculates sources, responses (e.g., criticality, reaction rate ratios, reactivity worths), normalization parameters, and sensitivity coefficients. As a user's guide, this document presents the algorithms implemented in JULIET but does not include their theoretical development which is available in Ref. 2. JULIET optimizes and extends algorithms that were initially implemented in the SOURCE (see Ref. 2 for theoretical development) and SWANLAKE[3] codes.

JULIET is designed to execute as a module of the FORSS driver controlled system. It withdraws and deposits information in the FORSS repository which serves as an information exchange medium for FANISN[4] (the FORSS

version of ANISN) and JULIET. When FANISN has been selected as the neutronics code for a FORSS study, JULIET receives angular fluxes and computes generalized source data for subsequent steps in which FANISN is used to generate generalized[2] angular fluxes. JULIET is organized into execution paths which are in effect submodules. This permits a problem to be segmented for solution at the user's discretion (i.e., multiple points of entry into the system). The execution path concept also permits interaction with neutronics codes other than ANISN such as DOT[5] and VENTURE.[6] Additional information on this interaction is available in the FORSS user's guide.[7]

Sensitivity analysis requires access to partial cross sections. The proposed CCCC file MATXS[8] is the cross-section data base for JULIET. The preparation of a MATXS file is discussed in the FORSS user's guide.

The end product of JULIET is sensitivity coefficients (profiles). They are placed in a proposed CCCC[9] file, SENPRO.[10] A SENPRO Service Module[7] is available in the FORSS system which operates on a SENPRO file providing a number of functions such as listing, plotting, merging, etc. SENPRO files are input for sensitivity analysis modules such as SENTINEL,[11] CAVALIER,[12] and UNCOVER.[13]

II. EXECUTION PATHS

JULIET has four execution paths and the combination selected is problem-dependent.

A. Operator Definition

The path is selected by the word, MIX. This path prepares the cross-section operators required for the problem solution (these correspond to cross sections appearing in the response definition and/or cross sections in the terms of the Boltzmann equation). The MATXS cross-section file is the primary data base for operator definition. User input defines the operators required for the problem solution. An operator may be a single material-reaction type or it may be a mixture of many materials and include several reaction types.

B. Flux Preparation

The path is selected by the word FLUX. This path calculates moment fluxes from existing forward and adjoint angular fluxes for use in computing certain reactor parameters (e.g., worth). This path also prepares the $\langle \phi^* \phi \rangle$, $\langle \Gamma^* \phi \rangle$, or $\langle \Gamma \phi^* \rangle$ inner products needed for a sensitivity calculation.

C. Source Response Calculation

The path is selected by the word SOURCE. The path has the capability to calculate bilinear sources, linear sources, responses, and normalization parameters.

D. Sensitivity Coefficient Generation

The path is selected by the word SENSE. This path calculates sensitivity coefficients using the SWANLAKE algorithm expanded to include direct effects.

III. OPERATOR DEFINITION

The FORSS system is an attempt to provide a sensitivity analysis capability with respect to a response defined as:

for bilinear $R = \frac{\langle \phi^* H_1 \phi \rangle}{\langle \phi^* H_2 \phi \rangle}$, for linear $R = \frac{\langle H_1 \phi \rangle}{\langle H_2 \phi \rangle}$ with sensitivity coefficients defined as: $\frac{\partial R/R}{\partial \Sigma_x / \Sigma_x}$ where Σ_x is a cross section appearing in the Boltzmann equation or in the definition of H_1 or H_2. In the above equations ϕ and ϕ^* represent the forward and adjoint fluxes, the brackets denote integration over phase space, and the operators H_1 and H_2 can in general be arbitrary. However, the physical cases of most practical interest occur when either H_1 or H_2 is a macroscopic cross section, in which case R would represent a weighted reaction rate ratio. For example, the linear response $^{28}\delta$ would be defined as $R = \frac{\langle {}^{238}\Sigma_c \phi \rangle}{\langle {}^{235}\Sigma_f \phi \rangle}$; clearly H_1 is the ^{238}U capture reaction and H_2 is the ^{235}U fission reaction. Operators may also be linear combinations of any or all terms appearing in the Boltzmann equation. For example, the bilinear response for Na worth would be defined as:

$$R = \frac{-\left\langle \phi^* \left(\Sigma_T \phi - \sum_{g',\ell'} \Sigma_s^{\ell'} (g' \to g) \phi_\ell(g') \right) \right\rangle}{\left\langle \phi_0^* \left(\chi \sum \nu \Sigma_f \right) \phi_0 \right\rangle}$$

Here H_s is the Boltzmann operator for Na, and H_f is the fission operator for all fissionable materials in the system of interest.

IV. FLUX PREPARATION

A. Moment Fluxes

Angular fluxes are input to a JULIET calculation. Moment fluxes are prepared for use in source, response, and sensitivity calculations according to the following equation:

$$\phi(j,g,\ell') = \sum_{i=1}^{NOA} W_i Y_\ell^m(\mu_i)\phi(j,g,\mu_i) \qquad (1)$$

where

ISCT - order of scattering,

NMOM - maximum of (ISCT, ISN),

NOA - number of angles,

for slab and spherical geometry NOA = ISN + 1

for cylindrical geometry NOA = (ISN * (ISN + 4))/4

ISN - quadrature order,

LMOM - number of moments,

ℓ' - moment index which assumes values from 1 to LMOM. ℓ' is a function of m and ℓ. Equations 4, 6, and 7 illustrate the relationship of ℓ', ℓ, m as implemented in the code.

g - group index,

i - angle index,

W_i - quadrature weight (input, see Section VI, Block 1),

μ_i - discrete angle cosine (input, see Section VI, Block 1),

Y_ℓ^m - spherical harmonic,

$\phi(j,g,\mu_i)$ - angular flux calculated by FANISN,

$\phi(j,g,\ell')$ - angular flux moment calculated by FANISN.

B. $\langle\phi^*\phi\rangle$ Files

$\langle\phi^*\phi\rangle$ files are prepared for use in the sensitivity equations. $\langle\phi^*\phi\rangle$ is a symbolic term since the file may represent products of $\langle\Gamma^*\phi\rangle$ or $\langle\Gamma\phi^*\rangle$. A $\langle\phi^*\phi\rangle$ file is required for K and worth sensitivity analysis. A $\langle\Gamma^*\phi\rangle$ file is required for reaction rate ratio sensitivity analysis.

$\langle\phi^*\phi\rangle$ files are prepared in the ANISN cross-section format. For the 0th moment the total position of the $\langle\phi^*\phi\rangle$ file is calculated as:

$$PS(IHT,g,z,1) = -\sum_{j\epsilon z} V(j) \sum_{i} \phi(j,g;\mu_i)\phi^*(j,g,\mu_i)W(i) \qquad (2)$$

where

IHT - position of total cross section in ANISN cross-section table,

g - group index,

z - zone index,

R - the radii by interval boundary,

V(j) - volume of spatial interval j,

$= R(j+1) - R(j)$ for slab,

$= (R^2(J+1) - R^2(j))$ for cylinder,

$= \frac{4}{3}(R^3(j+1) - R^3(j))$ for sphere.

For slab and spherical geometry and the P_0 and P_1 scattering orders of cylindrical geometry the scattering positions are

$$PS(G,g,z,\ell) = \sum_{j\epsilon z} \phi(j,g',\ell')\phi^*(j,g,\ell')V(j) \qquad (3)$$

where

G = IHT + g'+1,

IHT is the total cross-section position,

ℓ = ℓ' assumes values of 1 and 2.

For cylindrical geometry and scattering order higher than P_1

$$PS(G,g,z,\ell) = \sum_{\ell'=LL(\ell-1)}^{LL(\ell)} \sum_{j\epsilon z} \phi(j,g',\ell')\phi^*(j,g,\ell')V(j) \qquad (4)$$

initially the code defines LL(2)=2 then $LL(\ell) = LL(\ell-1) + 1 + \frac{(2\ell-1)}{4}$

where

ℓ is the scattering order index and assumes values from 3 to ISCT

(order of scattering) ℓ' is the moment index.

V. SOURCE RESPONSE ALGORITHMS

A. The $[H_1\phi]$ and $[H_2\phi]$ Components of a Bilinear Response

The $[H_1\phi]$ function includes three terms, a total term, a scattering term, and a fission term.

1. Total

$$T_1(j,g,\ell') = -\Sigma_T(j,g)\phi(j,g,\ell')$$

where

j - spatial index,

g - group index,

ℓ' - moment index,

Σ_T - total cross section,

ϕ - forward moment flux.

2. Scattering for Slab and Spherical Geometrics

When $\ell' \leq$ ISCT, ISCT = order of scattering

$$T_2(j,g,\ell') = \sum_{g'} \Sigma_s (j,g' \rightarrow g,\ell')\phi(j,g',\ell') \tag{5}$$

where

Σ_s - scattering matrix.

3. Scattering for Cylindrical Geometry

For the P_0 and P_1 scattering orders Eq. (5) also applies for cylindrical geometry.

For scattering orders greater than P_1 Eq. (6) and Eq. (7) establish the correspondence between the cross-section scattering order (index ℓ) and the flux moment (index ℓ').

$$T(j,g,\ell') = \sum_{g'} \Sigma_s(j,g' \rightarrow g,\ell)\phi(j,g',\ell') \tag{6}$$

To define the values of ℓ and ℓ' in Eq. (6), initially the code defines ℓ=3 and the indexing control parameter LHI=4. Then as ℓ' assumes values from 3 to LMOM (number of moments) the values of ℓ' and LHI are compared. If $\ell' \leq$ LHI, the values of LHI and ℓ are unchanged. When $\ell' >$ LHI, $\ell=\ell+1$, and LHI is redefined by Eq. (7) as follows:

$$LHI = LHI + 1 + (2\ell+1)/4 \tag{7}$$

when $\ell >$ ISCT

$$T_2(j,g,\ell') = 0 \quad . \tag{8}$$

4. Fission

For $\ell' = 1$

$$T_3(j,g,\ell') = \lambda\chi(g)\sum_{g'}\nu\Sigma_f(j,g')\phi(j,g',\ell') \tag{9}$$

where

$\lambda = \frac{1}{k}$

χ = fission spectrum .

For $\ell' > 1$

$$T_3(j,g,\ell') = 0 \quad . \tag{10}$$

5. The $[H_1\phi]$ Term

$$[H_1\phi](j,g,\ell') = T_1(j,g,\ell') + T_2(j,g,\ell') + T_3(j,g,\ell') \quad . \tag{11}$$

6. $[H_2\phi]$ is a fission function with one term.

For $\ell' = 1$

$$[H_2\phi](j,g,\ell') = \chi(g)\sum_{g'}\nu\Sigma_f(j,g',\ell')\phi(j,g',\ell') \quad . \tag{12}$$

For $[H_2\phi]$, $\nu\Sigma_f$ is a mixture of all fissionable materials in the assembly.

For $\ell' > 1$

$$[H_2\phi](j,g,\ell') = 0 \quad . \tag{13}$$

B. The $[H_1^*\phi^*]$ and $[H_2^*\phi^*]$ Components of a Bilinear Response

The $[H_1^*\phi^*](j,g,\ell')$ function has the same form as the $[H_1\phi]$ function.

1. Total

$$T_1(j,g,\ell') = -\Sigma_T(j,g)\phi^*(j,g,\ell') \tag{14}$$

2. Scattering

$$T_2(j,g,\ell') = \sum_{g'} \Sigma_s(j,g\rightarrow g',\ell)\phi^*(j,g',\ell') \tag{15}$$

The discussion of geometry and moments for the $[H_1\phi]$ function applies for the $[H_1^*\phi^*]$ function.

3. Fission

$$T_3(j,g,\ell') = \nu\Sigma_f(j,g)\sum_{g'}\chi(g')\phi^*(j,g',\ell') \tag{16}$$

4. The $[H_1^*\phi^*]$ Term

$$[H_1^*\phi^*]\ (j,g,\ell') = T_1(j,g,\ell') + T_2(j,g,\ell') + T_3(j,g,\ell') \tag{17}$$

5. The $[H_2^*\phi^*]$ function is very similar to the $[H_2\phi]$ function.

$$[H_2^*\phi^*](j,g,\ell') = \nu\Sigma_f(j,g)\sum_{g'}\chi(g')\phi^*(j,g',\ell') \tag{18}$$

C. The Bilinear Response

A bilinear response is defined as:

$$R \equiv \frac{\langle\phi^* H_1\phi\rangle}{\langle\phi^* H_2\phi\rangle} \tag{19}$$

where

$$\langle\phi^* H_1\phi\rangle = \sum_{\ell'}\sum_{g}\sum_{j}\phi^*(j,g,\ell')[H_1\phi](j,g,\ell')V(j) \quad , \tag{20}$$

$$\langle\phi^* H_2\phi\rangle = \sum_{g}\sum_{j}\phi^*(j,g,1)[H_2\phi](j,g,1)V(j) \quad , \tag{21}$$

$$\langle\phi H_1{}^*\phi^*\rangle = \sum_{\ell'}\sum_{g}\sum_{j}\phi(j,g,\ell')[H_1^*\phi^*](j,g,\ell')V(j) \quad , \tag{22}$$

$$\langle\phi H_2{}^*\phi^*\rangle = \sum_{g}\sum_{j}\phi(j,g,1)[H_2^*\phi^*](j,g,1)V(j) \quad . \tag{23}$$

D. The Bilinear Forward Source

$$S(j,g,\ell') = R\left[\frac{[H_1\phi](j,g,\ell')}{\langle\phi^* H_1\phi\rangle} - \frac{[H_2\phi](j,g,\ell')}{\langle\phi^* H_2\phi\rangle}\right] \tag{24}$$

E. The Bilinear Adjoint Source

$$S^*(j,g,\ell') = R\left[\frac{[H_1^*\phi^*](j,g,\ell')}{\langle\phi^* H_1\phi\rangle} - \frac{[H_2^*\phi^*](j,g,\ell')}{\langle\phi^* H_2\phi\rangle}\right] \tag{25}$$

F. The Worth in an Interval

Reactivity worth, w, is defined as:

$$w(\text{per mole}) = R\left[\frac{.6023}{N\,V}\right] \tag{26}$$

R - the bilinear response.

V - volume of the interval.

N - density of the material.

$$w(\text{per kilogram}) = \frac{1000}{A}\ [w(\text{per mole})] \tag{27}$$

A - the atomic mass.

G. The Linear Response

A linear response, R, is defined as:

$$P \equiv \frac{\langle H_1\phi\rangle}{\langle H_2\phi\rangle} \tag{28}$$

where

$$\langle H_1\phi\rangle = \sum_g \sum_j H_1(j,g)\phi(j,g,1)V(j) \tag{29}$$

$$\langle H_2\phi\rangle = \sum_g \sum_j H_2(j,g)\phi(j,g,1)V(j) \qquad (30)$$

where

H_1 and H_2 are simply reaction cross sections or other response functions,

$\phi(j,g,1)$ - 0th moment flux,

g - group index,

j - spatial index.

H. The Linear Source

$$S^*(j,g) = R\left[\frac{H_1(j,g)}{\langle H_1\phi\rangle} - \frac{H_2(j,g)}{\langle H_2\phi\rangle}\right] \qquad (31)$$

VI. GENERATION OF SENSITIVITY COEFFICIENTS

JUL1ET implements the sensitivity equations discussed in Section III of ORNL/TM-5563.[14] The equation below is solved to yield the sensitivity of a response to a cross section as defined by an operator. A common form of the operator is a single material--reaction type. However, the operator can take the form of a cross-section mixture. In the equation, the cross-section operator of interest is designated by the subscript X.

A. General Representation of Terms in Sensitivity Coefficient Definitions

$$T_1(g,z) = -\Sigma_x(g,z)\sum_{j\in z} V(j)\sum_{k=1}^{NOA}\phi^*(j,g,k)\phi(j,g,k)w(k) \qquad (32)$$

$$T_2(g,z) = \frac{1}{k}\sum_{j\in z} V(j)[\nu(g,z)\Sigma_f(g,z)\phi(j,g,1)\sum_{g'=1}^{IGM}\phi^*(j,g',1)\chi(g',z) \qquad (33)$$

$$T_3(g,z) = \sum_{\ell=1}^{LMOM} \sum_{j \in z} V(j) \sum_{g'=1}^{IGM} \phi^*(j,g',\ell)\psi(j,g,\ell)\Sigma_x(g\to g',\ell) \qquad (34)$$

$$T_4(g,z) = \Sigma_x(g,d)\psi(d,g,1)/\langle H_1\phi\rangle \qquad (35)$$

$T_4(g,z) = 0$ unless Σ_x appears in the definition of H_1

$$T_5(g,z) = -\Sigma_x(g,d)\psi(d,g,1)/\langle H_2\psi\rangle \qquad (36)$$

$T_5(g,z) = 0$ unless Σ_x appears in the definition of H_2

The d indicates the space increment where the direct effect $\neq 0$ (i.e., where H_1 and H_2 are defined).

$T_4(g,z) = T_5(g,z) = 0$ if d is not within zone z.

$$P(g,z) = \frac{1}{R}\left[T_1(g,z) + T_2(g,z) + T_3(g,z)\right] + T_4(g,z) + T_5(g,z) \qquad (37)$$

where

g - group index,

g' - group index,

z - zone index,

j - spatial interval index,

k - angle index,

V(j) - volume of interval,

$\Sigma_x(g,z)$ - cross section operator,

$\phi^*(j,g,k)$ - adjoint angular flux,

$\psi(j,g,k)$ - forward angular flux,

w(k) - discrete ordinates weight,

$\nu(g,z)$ - neutrons per fission,

$\Sigma_f(g,z)$ - fission cross section,

$\phi(j,g,z)$ - forward moment flux,

$\phi^*(j,g,z)$ - adjoint moment flux,

$\chi(g',z)$ - fission spectrum,

$\Sigma_x(g'\to g,z)$ - scattering cross section.

All of the five terms in the equation do not appear in every sensitivity calculation. The terms included are a function of the response and the operator of interest.

B. K Sensitivity

1. Absorption Reactions, Nonfissionable, Nonscattering Reactions such as Capture

The equation reduces to $T_1(g,z)$ where $\Sigma_x(g,z)$ is the absorption cross section of the material of interest.

2. Fission Reactions

The fission reaction requires only $T_1(g,z)$ and $T_2(g,z)$. In T_1, $\Sigma_x(g,z)$ is the fission cross section of the material of interest.

3. ν Sensitivity

The ν reaction requires only $T_2(g,z)$.

4. Scattering Reactions

A scattering reaction such as elastic requires $T_1(g,z)$ and $T_3(g,z)$ where $\Sigma_x(g,z)$ in T_1 is the elastic scattering cross section. $\Sigma_x(g'\to g,z)$ in T_3 is the elastic group-to-group scattering matrix for moment j of the material of interest.

5. Total Reaction of a Fissionable Material

The total reaction of a fissionable material requires the $T_1(g,z)$, $T_2(g,z)$ and $T_3(g,z)$ terms. $\Sigma_x(g,z)$ in T_1 is the total cross section and $\Sigma_x(g' \rightarrow g,\ell)$ is the total group-to-group scattering matrix.

6. Total Reaction of a Nonfissionable Material

The total reaction of non-fissionable materials is the same as (5) except the $T_2(g,z)$ term is 0.

The T_4 and T_5 terms do not enter into a k sensitivity since they are direct-effect expressions for reaction rate ratio responses. For k sensitivity, the R in Eq. (37) is to be interpreted as $R = \frac{1}{k}\langle \psi^* H_2 \psi \rangle$.

C. Reaction Rate Ratios

When the response is a reaction rate ratio such as ^{238}U capture/^{235}U fission, the $^{28}c/^{25}f$, both indirect and direct effects must be considered. Direct effects occur only when the operator of interest is a material reaction type which is a constituent of the response definition. All operators have indirect effects.

1. Indirect Effect

The algorithm is identical to k sensitivity with ψ^* replacing ψ^* in Eqs. (32), (33) and (34), and the R appearing in Eq. (37) is to be interpreted as:

$$R = \frac{1}{S}\left[\frac{\langle H_1 \psi \rangle}{\langle H_2 \psi \rangle}\right] \qquad (38)$$

where $\frac{\langle H_1 \psi \rangle}{\langle H_2 \psi \rangle}$ is the response calculated by the source execution path and S is the source normalization from the ANISN generalized adjoint calculation.

2. H_1 Direct Effect

When the operator of interest is the material-reaction type which forms the numerator of the reaction rate ratio, the H_1 direct effect is calculated and summed with the indirect effect to complete the profile. The H_1 direct effect is calculated by the $T_4(g,z)$ term in Eq. (37). For the example, $\Sigma_x(g,z)$ in T_4 is the ^{238}U capture cross section. $\langle H_1\phi\rangle$ is available from the source execution path. The T_4 term and $\langle H_1\phi\rangle$ must be calculated over the same space; frequently this is the central interval. T_4 is zero in any zone that does not include the space increment used in the $\langle\phi H_1\rangle$ calculation.

3. H_2 Direct Effect

When the operator of interest is the material-reaction type which forms the denominator of the reaction rate ratio, an H_2 direct effect is calculated and summed with the indirect effect to complete the profile. The H_2 direct effect is calculated by the $T_5(g,z)$ term in Eq. (37). For the example, $\Sigma_x(g,z)$ in T_5 is the ^{235}U fission cross section. $\langle H_2\phi\rangle$ is available from the source execution path. The T_5 term and $\langle H_2\phi\rangle$ must be calculated over the same space; frequently this is the central interval. T_5 is zero in any zone that does not include the space increment used in the $\langle H_2\phi\rangle$ calculation.

D. Worth Sensitivities

The following is based on a definition of the worth R of a material μ in region ν of the form

$$R = \frac{N}{k^2}\frac{\partial k}{\partial N} \tag{39}$$

$$= -N\frac{\partial \lambda}{\partial N}$$

where the eigenvalue λ is equal to $1/k$ and N is the density of material μ in region ρ. On the basis of generalized perturbation theory, an equivalent expression for R is

$$R = \frac{(\phi^* H_1 \phi)}{(\phi^* H_2 \phi)} \tag{40}$$

where operators H_1 and H_2 are given by

$$H_1 = -A_N + \lambda B_N \tag{41}$$

and

$$H_2 = B \tag{42}$$

The Boltzmann operator L is of the form $A - \lambda B$ and Operator B is that part of the Boltzmann operator which depends on $\nu\Sigma_f$. B_N is that contribution to B from material μ in region ρ. A_N is the contribution to the operator A from material μ in region ρ and consists of total and scattering cross section terms. The "unperturbed" flux and adjoint flux are given by ϕ and ϕ^* respectively. Sensitivities of a worth response may be calculated with respect to any material-reaction type. Let this type be indicated by τ. If the material of type τ is the same as the material μ which defines the worth response, then these sensitivities have direct-effect contributions and indirect-effect contributions. In general, there are five contributions to a sensitivity: Two are direct-effect contributions, and three are indirect effects. The five contributions are:

1. H_1 direct effect
2. H_2 direct effect
3. Eigenvalue indirect effect
4. Forward flux indirect effect
5. Adjoint flux indirect effect

If material of type τ is different from material μ, then only indirect

effects are nonzero and contribute to the sensitivities. The H_2 direct effect is nonzero only for fissionable material-reaction types.

1. H_1 Direct Effect

   This effect is defined as $\frac{<\phi^* H_{1\alpha}\phi>}{<\phi^* H_1\phi>}$ where $H_{1\alpha}$ is that part of the H_1 operator which consists of the cross sections of the material-reaction type α in the region of interest. The sensitivity of every reaction type of the material μ appearing in the response definition will have an H_1 direct effect contribution.

2. H_2 Direct Effect

   This effect is defined as $-\frac{<\phi^* H_{2\alpha}\phi>}{<\phi^* H_2\phi>}$ where $H_{2\alpha}$ is that part of the H_2 operator which consists of the fission operator for the material-reaction type α with the spatial dependence of the material in the assembly. The sensitivities of the chi, nubar, and fission reactions of the material μ appearing in the response definition have an H_2 direct effect contribution.

3. Eigenvalue Indirect Effect

   This effect is defined as

$$\left[-\frac{1}{R}\frac{<\phi^* A_N\phi>}{<\phi^* H_2\phi>} - 1\right] S_a^k(g) \qquad (43)$$

   $S_a^k(g)$ is the group dependend k sensitivity of the material-reaction type of interest.

The sensitivity of every reaction type will have an eigenvalue direct effect contribution.

4. Forward Flux Effect

   This effect is defined as $\frac{<\Gamma^* L\alpha\phi>}{\frac{R}{S^*}}$ where $L\alpha$ is that part of the Boltzmann operator due to cross sections for the material-reaction type α to

which sensitivities are being calculated. $L\alpha$ is defined over all spatial regions in which the material of type α occurs in the system. S* is the source normalization calculated by FORSS ANISN for the case which generated Γ^*. Computationally JULIET solves the same equation used for k sensitivity with the adjoint flux ϕ^* replaced by the generalized adjoint flux Γ^* and $\lambda\langle\phi^* H_2 \phi\rangle$ replaced by R/S*.

5. Adjoint Flux Effect

This effect is defined as $\frac{\langle\phi^* L\alpha\, \Gamma\rangle}{\frac{R}{S}}$ where $L\alpha$ is, as above, that part of the Boltzmann operator due to cross sections for the material-reaction type α to which sensitivities are being calculated. $L\alpha$ is defined over all spatial regions in which the material occurs in the system. S is the source normalization calculated by FORSS ANISN for the case which generated Γ. Computationally JULIET solves the same equation used for k sensitivity with the forward flux ϕ replaced by the generalized forward flux Γ and $\lambda\langle\phi^* H_2 \phi\rangle$ replaced by R/S.

VII. JULIET INPUT PREPARATION

JULIET performs two major functions, source generation and the calculation of sensitivity coefficients. A single computer run may be set up to accomplish both functions or they may be done independently. Normally a source calculation must precede a sensitivity calculation since source generates normalization parameters used in the sensitivity calculation.

A. Execution Paths

JULIET is divided into four execution paths. Path selection is accomplished by the user to solve the problem of interest. The paths are:

1. Operator Definition, Selected by the Word, MIX

This path must always be executed because operators are required for any JULIET function. Operators are defined from cross sections. They may have the form of a single material reaction cross-section type, a mixture of a single reaction from several materials or other combinations of materials and reaction cross-section types. A common operator is a mixture or material which includes Σ_c, χ, Σ_f, Σ_a, $\nu\Sigma_f$, Σ_T and the total group-to-group scattering matrix. This is referred to as an automatic operator in JULIET. It is used to form both the H_1 and H_2 bilinear operators in a SOURCE calculation. When an automatic operator is referenced in a sensitivity calculation, sensitivity coefficients are calculated for the capture, fission, $\bar{\nu}$, χ, and total reactions.

2. Flux Preparation, Selected by the Word, FLUX

The path calculates moment fluxes from angular fluxes and also prepares the so-called $\phi^*\phi$ file used by the sensitivity calculation. Actually, the file may also be $\Gamma^*\phi$ or $\Gamma\phi^*$. The execution of this path is prerequisite to a SOURCE-RESPONSE calculation. The execution of the path may be omitted when going directly to the calculation of sensitivity coefficients and appropriate $\phi^*\phi$ files already exist.

3. Source Generation, Selected by the Word, SOURCE

This path is executed to calculate sources, responses and normalization parameters. The equations solved are outlined in Section IV. Do not execute this path in studies using two-dimensional sensitivity analysis.

4. Sensitivity Coefficient Generation, Selected by the Word, SENSE

This path implements the sensitivity coefficient generation algorithms outlined in Section V.

B. Input Blocks

Since JULIET input is a function of the execution paths selected, the input is divided into five distinct blocks. All of the blocks do not have to appear in a run.

1. Block 1 (always provided)

The content of Block 1 is a function of the execution paths selected. If FLUX is a member of the execution path, Block 1 input is:

15$$ Integer Parameters [36]

1. Any integer
2. ITH <100 only downscatter cross sections; >100 upscatter
3. ISCT - maximum order of scatter found in any zone
4. ISN - order of angular quadrature
5. IGE - 1 - slab; 2 - cylinder; 3 - sphere
6. Any integer
7. Any integer
8. IZM - number of zones
9. IM - number of mesh intervals
10. Any integer
11. IGM - number of energy groups
12. IHT - position of σ_{total} in $\phi^*\phi$ table
13. IHS - position of σ_{gg} (self-scatter) in $\phi^*\phi$ table
14. IHM - length of $\phi^*\phi$ table

15.
.
. Any integer
.
36.

T

T

1** Fission spectrum [IGM]

4** Radii by interval boundary [IM + 1]

5** Velocities [IGM], the array may be omitted

6** Angular quadrature weights [MM]

7** Angular quadrature cosines [MM]

8$$ Zone numbers by interval [IM]

T

Note that Block 1 input is ANISN input with deletions and minor modifications. The 8$$ card describes the spatial dependence in the sensitivity calculation except for reaction rate ratio direct effects. The 3$$ card does account for the spatial dependence of worth direct effects and the card used in the ANISN calculation usually must be modified. All entries on the 15$$ card are not used in JULIET, but the format is unchanged to permit the convenience of reproducing the card from existing ANISN input.

If FLUX is not a member of the execution path, Block 1 input simplifies to:

15$$ 0 ITH ISCT 4Z IZM 2Z IGM IHT IHS IHM F0

T

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where

ITH <100/>100, no upscatter/upscatter,

ISCT maximum order of scatter,

IZM number of zones,

IGM number of energy groups,

IHT position of σ_{total} in cross-section table,

IHS position of σ_{gg} (self-scatter) in cross-section table,

IHM length of cross-section table.

2. Block 2 (always provided) Operator Definition

This input defines the operators to be used in subsequent source and sensitivity calculations. All Block 2 input is in a fixed field format. Operators are defined as a function of cross sections and this input references the MATXS file.

MIX (columns 1-3) selects execution path.

Operator Definition Cards. Columns (1-5) (I5) Operator ID. This may be an arbitrary number assigned by the user. However, if applicable, an ENDF/B material identification number is suggested for this input.

Columns (11-16) (A6) MATXS particle identifier, NEUT is normal input.

Columns (21-26) (A6) MATXS type identifier, NSCAT is normal input.

Columns (31-36) (A6) MATXS material identifier.

Columns (41-46) (A6) MATXS reaction type identifier/blank/ALLINL/ELSCAT or other reaction type name.

Columns (51-60) (E10.4) Density.

Columns (61-65) (I5) Order of P_n (P_0-0).

Columns (66-70) (I5) If < 0, eliminates χ.

When all operators are defined, insert 1 blank card.

Mixing. Operators are frequently defined as cross-section mixtures. A set of two or more operator definition cards with identical operator identifiers define a mixture which may be referenced in source and sensitivity calculations.

Comments on the Operator ID (Columns 1-5). Sensitivity coefficients are placed in a proposed CCCC file SENPRO. Part of the identification of a set of coefficients in SENPRO is the ENDF/B material identification. The operator ID is passed to SENPRO and used as the ENDF/B material identification number. If the operator is a mixture or something else that cannot be properly identified with an ENDF/B MAT number, the user must take appropriate action to insure proper identification and use of the data. For some applications, JULIET sabotages the SENFRO ENDF/B material identification scheme. Two or more equal operator ID numbers define a mixture. This can cause difficulty when several operators are defined for the same material but with different reaction types. Future code development will eliminate this problem. In the interim the ENDF/B material identification scheme must sometimes be abandoned and arbitrary unique operator IDs assigned. The SENPRO service module provides a quick and easy method to redefine the number used as an ENDF/B material identification. This service may also aid the user with an operator that cannot be correctly identified in ENDF/B terminology.

Comments on MATXS Reaction Type Identifier (Columns 41-46). Please note this is a six-character string, a word not an integer. The MATXS files currently in use were obtained by translating either ANISN files or AMPX master files. In either case, the ENDF/B reaction type numbers (MT) influence the procedure. The translators establish the following relationship:

ENDF/B (MT)	MATXS (Columns 41-46 entry)
1	TOTAL
2	ELSCAT
3	NONELS
4	INSTOT
16	N2N
17	N3N
18	FIS
19	FCFIS
20	SCFIS
21	TCFIS
51	INEL01
⋮	⋮
90	INEL40
91	CTNUUM
102	CAPT
452	NUBAR
1452	NUFIS

For other ENDF/B MT numbers the translator forms a MATXS six-character string as follows: If the MT = 1234, the MATXS identifier will be MT1234.

If columns (41-46) are left blank, an automatic operator is generated.

If columns (41-46) are ALLINL, sensitivity coefficients will be generated for all inelastic levels and the continuum.

Comments on Columns (66-70). If the operator is an automatic mixture, this entry prevents a mixing operation on the fission spectrum.

3. Block 3 (Optional)

FLUX Preparation

FLUX (Columns 1-4) selects execution path.

60$$ Integer Parameters [11]

KCI - 0/1, prepare $\int \phi V$ for central interval/no effect. This parameter controls spatial dependence of the direct effect for reaction rate ratio calculations. Central interval direct effect is the normal calculation. If a 1 is entered, then the direct effect spatial dependence is defined by the 8$$ card in Block 1. If KCI<0, no $\phi^*\phi$ file will be made.

IRF - identification number for forward flux.

IRA - identification number for adjoint flux.

LPATH - If <0 no adjoint flux will be read from repository.

KERT - Unit number of $\phi^*\phi$ file, default = 9.

F0 - reserved.

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For both IRF and IRA, enter negative values when the adjoint flux component of a worth sensitivity is being calculated. This informs the code that the forward and adjoint fluxes are to be interchanged. When IRF=IRA=0, the adjoint flux used is identified by the FMANG identification number (second entry FMANG 1$$ card) and the forward flux is ϕ.

4. Block 4 (Optional)

SOURCE Generation

SOURCE (Columns 1-6) selects execution path.

70$$ Integer Parameter [1]

NRESP - number of responses.

71** Floating point parameters [2]

k - If k = 0 is entered, the value is retrieved from the repository.

F0.0

T

Repeat the following title, 72$$, 73$$, 74$$, 75**, T sequence of cards for each response

HOLLERITH TITLE of response (20 A4)

72$$ Integer parameters [2+IM] where IM is the number of mesh intervals.

1. ILBL - operator type identifier.

   0 - linear operator

   1 - bilinear operator

2. ISCT - scattering order (P_0=0).

3. H_1 operator identifier for each mesh interval. See Block 2 input for operator definition.

:

IM+2

73$$ Integer Parameters [2+IM]

1. 0

2. 0

3. H_2 operator identifier for each mesh interval.

:

IM+2

74$$ Integer Parameters [10]

1. LPRT - source print option.

   0 - no print

   1 - print

2. LSAVE - source save option in the repository.

   0 - no save

   1 - save

3. IDA - adjoint source identification number.

4. IDF - forward source identification number.

5.
: FO, reserved for future options.
10.

75** Omit if response is not a reactivity worth [2]

A - Atomic mass of material of interest.

B - Density of material of interest.

T

5. Block 5 (Optional)

Sensitivity Coefficient Calculation

SENSE (Columns 1-5) selects execution path.

80S$ Integer Parameters [2]

NRESP - number of responses.

ILNG - last neutron group.

T

81** Floating point parameters [ILNG+1]

Neutron group structure.

82** Floating point parameters [NGG+1] where NGG is the number of γ groups.

γ group structure.

T

Repeat the following sequence of cards ending with 9155 T for each response

HOLLERITH TITLE FOR ASSEMBLY (20A4)

HOLLERITH TITLE FOR RESPONSE (20A4)

When the response is a reaction rate for which direct effects will be calculated, extra care must be taken with the response description.

Columns (1-8) material identifier for the numerator, example U-238.

Columns (9-16) reaction rate identifier for the numerator, example CAPT.

Columns (17-24) material identifier for the denominator.

Columns (25-32) reaction rate identifier for the denominator.

NOTE: These material and reaction rate identifiers must be identical to their appearance in the operator definition cards, see data block 2 input. If the automatic operator was designated then the reaction type is blank on the operator definition cards and the identifiers used here must be identical to those assigned by the code, see page 24.

83SS Integer Parameters [13]

NE - number of operators to be processed.

IRESP - response identifier for data retrieval from repository.

IDS - response identifier placed on SENPRO.

NTRN - reaction rate ratio identifier placed on SENPRO.

KERT - unit number of [illegible] file, default = 9, default used when 0 is entered.

IPRO - unit number of SENPRO file. Default - 23, code will not allow a change under the response loop after the initial definition.

FO - reserved for future options.

T

86** Floating point parameters [6]

R - calculated value of response.

R1 - $\langle H_1\phi \rangle$, used only when direct effects are to be calculated; otherwise enter 0.

R2 - $\langle H_2\phi \rangle$, used only when direct effects are to be calculated; otherwise enter 0.

EK - k; if not applicable, enter 0.

EVR - measured value of response; if not applicable, enter 1.0.

FUT - enter 0; reserved for future option.

T

When R, R1, R2 and EK are all entered as 0, these parameters are retrieved from the repository.

*****Repeat following sequence for NE operators

HOLLERITH TITLE for material-reaction (20A4)

87$$ Integer Parameters [10]

1. LMAX1 - Order of P_n, enter 0 for P_0.

2. IFISS - Fission option.

0 - no fission

3 - total sensitivity of fissionable material

13 - sensitivity of fission cross section

23 - sensitivity of $\overline{\nu}$

3. IOP - Direct effect option.

0 - no direct effect

1 - material-reaction type in response numerator

2 - material-reaction type in response denominator

4. NZP - number of entries on 91$$ card.
5. JOPA(1)[a] - 0/1 do not save/save indirect effect.
6. JOPA(2)[a] - 0/1 do not save/save direct effect.
7. JOPA(3)[a] - 0/1 do not save/save indirect + direct effect.
8. INC - 0/1 do not include/include results in summation over all operators.
9. LCRW - 0.
10. LPRT - 0/1 normal output/limited output. Normal output lists a sensitivity matrix which includes sensitivities by group and group-to-group transfers. Limited output lists only total sensitivities by zone.

T

88$$ Integer Parameters [NZONE]

Operator identifiers by zone.

89** Floating point parameters [NZONE]

Zone densities.

90$$ 50 - reserved for future options.

91$$ Integer Parameters [NZP]

DO - loop limiters for zone summations.

---

[a] When processing responses that do not have direct effects, for example k, then JOPA(1)=1, JOPA(2)=JOPA(3)=0 is sufficient to save the sensitivity coefficients on a SENPRO file. This is also true when processing responses that have direct effects but the material-reaction type being processed does not appear in the response definition, i.e. the direct effect sensitivity is 0. In the above situations, avoid the conclusion that JOPA(1)= JOPA(2) 0, JOPA(3)=1 will sum the indirect effect and 0 and thus save the indirect effect sensitivities on a SENPRO file. It will not happen and the erergy dependent sensitivity coefficients will be lost.

Example: 91$$ 1 1 2 2 1 2 will produce three sets of coefficients: zone 1, zone 2, and a summation over zones 1 and 2.

T

****** End of sequence

VIII. RESOURCE UTILIZATION

The amount of computer core required is highly problem-dependent. The parameters affecting core size requirements are listed in the discussion of the container array. The most important parameters are the number of groups and the number of spatial mesh intervals. The number of moments and the scattering order have little impact on core requirements but are important factors in the amount of usage of external storage devices such as disks and tapes. Computer CPU usage by JULIET is trivial relative to cross-section preparation and neutronics calculations.

A. Container Array

Most data storage is in a single container array. The length of this array varies for each execution path. It is necessary to calculate the container array length for each execution path activated in a run. In the main program the length must be set to the maximum value calculated plus a common term IC. Parameters of interest in determining container array length:

IGM - number of groups.

IM - number of space intervals.

NOA - number of angles.

NZ - number of zones.

ITL - ANISN cross-section table length.

IDP - precision parameter.

IDP = 2 for double-word precision.

IDP = 1 for single-word precision.

MKNT - number of materials in the bilinear H_1 operator.

MLSA - length of the largest compressed scattering matrix in the problem.

ISCT - order of scattering.

MS - total number of reactions available for sensitivity analysis.

NH1 - number of materials in the linear H_1 operator.

NH2 - number of materials in the linear H_2 operator.

COMMON TERM

IC - 132 + 6*IGM + 3*IM + NZ

1. Operator Definition

ICO = MS*(2*ISCT + 14) + 2*IGM^2 + IGM*(6 + 2*ISCT) + MAXO(7500, IGM^2,75*IGM)

2. Flux Preparation

I1 = 2*(IM+1)*NOA + IGM * (IM + NZ)

I2 = IGM * (ITL + 2*NZ + ITL)

I3 = IGM * (ITL + 2*NZ + 2*IM)

ICF = MAXO(I1, I2, I3)

3. Source Response

Bilinear

I4 = IGM*(IM*IDP + MKNT + 1) + MKNT + MLSA + MS*(ISCT + 2)

I5 = IM*IGM*(2*IDP + 1)

IC1 = MAXO(I4, I5)

Linear

IC2 = 2*IGM*(NH1 + NH2) + MS + IM + IGM

ICR = 2*IM + 4 + MAXO(IC1, IC2)

4. Sensitivities

ICS = 2*MSOP + MS*(ISCT + 3) + 3*(ITL*IGM) + 2*IGM*(NZ + ISCT) + ISCT*NZ; MSOP is the total number of operator definition cards required (see p. 22).

Container Array Size

KS = IC + MAXO(ICO, ICF, ICR, ICS)

B. Overlay Structure

JULIET uses a simple overlay structure which could be made more detailed if required. Basically each execution path is contained in an overlay segment. The sensitivity path uses three overlay segments. The overlay structure is shown in Fig. 1.

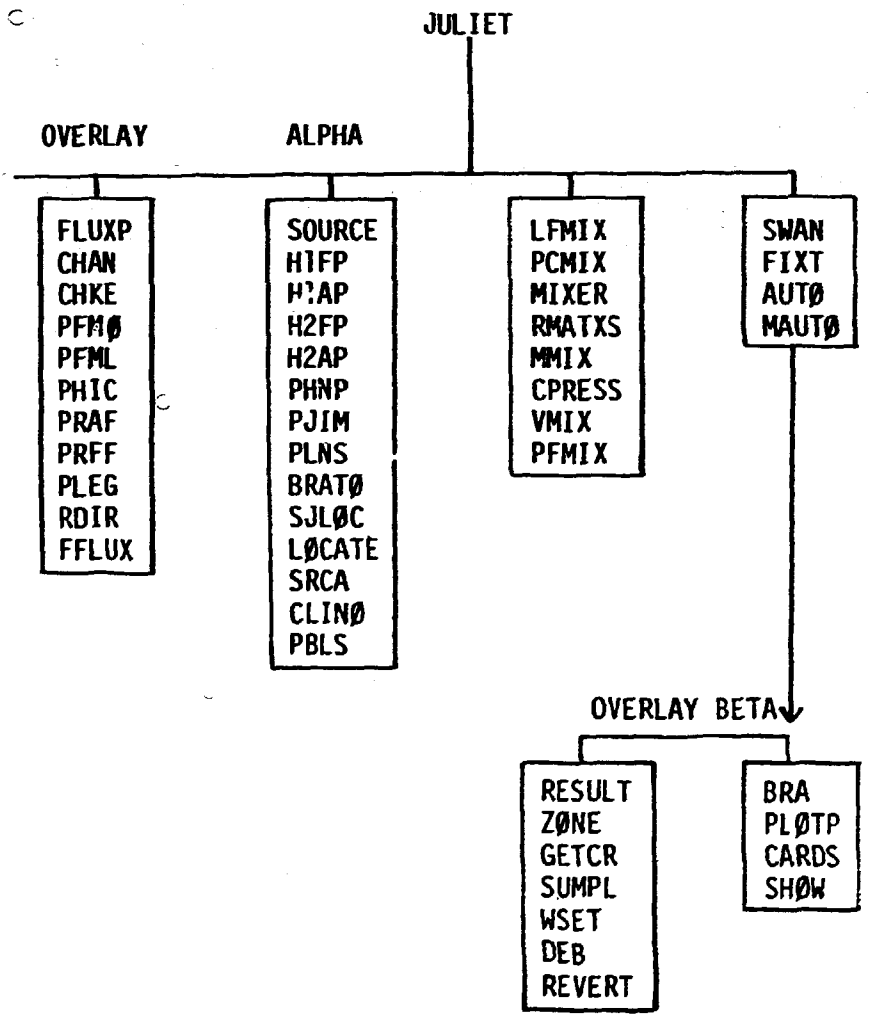

Fig. 1. Overlay Structure

C. I/O Units

Unit	Use	Record Length	Number of Records
1	PMANG Record	623	1
2	Repository	a	
5	Input		
6	Output		
8	MATXS Interface	b	
9	$\phi^*\phi$ File	ITL*IGM	1+NZ*ISCT
10	DA, Angular	(NOA+1)(IM)	2*IGM
11	DA, Moment	(IGM*IM)	2*LMOM1
12	DA, Bilinear Sources	IM	IGM*LMON1
13	DA, $\phi^*\phi$ Preparation	ITL*IGM	NZ*LMOM1
14	Scattering Blocks	c	NSR*ISCT
15	ID Cross Sections	IGM	NID
23	SENPRO Interface	IGM	NP
	In Source Execution Path		
31	Scratch (Unformatted)	2*IM*IGM	LMOM1
32	Scratch (Unformatted)	2*IM*IGM	LMOM1
33	Scratch (Unformatted)	2*IM*IGM	LMOM1
34	Scratch (Unformatted)	2*IM*IGM	LMOM1
35	Scratch (Unformatted)	2*IM*IGM	2*LMOM1
	In Sensitivity Execution Path		
31	Scratch (Unformatted)	ITL*IGM	ISCT
32	Scratch (Unformatted)	ITL*IGM	ISCT
33	Scratch (Unformatted)	ITL*IGM	ISCT
34	Scratch (Unformatted)	ITL*IGM	ISCT

Unit	Use	Record Length	Number of Records
35	Scratch (Unformatted)	ITL*IGM	ISCT
41	Scratch (Formatted)	80	NR
42	Scratch (Formatted)	80	NR

a. Problem-Dependent,

Angular flux record length = (NOA+1)(IM+1),

Number of records = IGM,

Source record length = IM*LMOM1,

Number of records = IGM.

There will be fluxes and sources for each response in the study.

b. Use a tape; if it is desirable to set up disk space, study the problem and the MATXS format and estimate space requirements.

c. For upscatter problems, the length of a scattering block is IGM^2.

For downscatter only problems, length = $\frac{IGM^2}{2} + IGM$.

NOA - number of angles. NSR - number of scattering reactions.

NZ - number of zones. NID - number of ID reactions.

LMOM1 - number of moments + 1. IM - number of space points.

IGM - number of groups. ISCT - scattering order + 1.

ITL - cross-section table length. NP - total number of profiles.

DD Card Preparation for Direct Access (DA) Units

DD cards for direct access units require the entry of a block length and the number of blocks. These should be calculated with care since inadequate space will kill the run. Large block lengths use core storage; small block lengths increase I/O's. The procedure is illustrated by example.

Rule 1

Length < 32000 bytes.

Rule 2

Length must be an even multiple of 16.

Example

Determine record length and number of records for unit 13 when ITL = 131, IGM = 126, NZ = 3, LMOM1 = 4.

L = 131 * 126 = 16506 words

L = 66024 bytes

Rule 1 is violated since 66024 > 32000.

Therefore,

L1 = L/N where N is large enough for L1 < 32000.

Let N = 6, then L1 = 66024/6 = 11004.

Now for rule 2, 11004 is not an even multiple of 16 so set L1 = 11008. L1 = 11008 satisfies both rules 1 and 2. If N could have been 1, then the number of records would = NZ*LMOM1 = 3*4 = 12. Since N = 6, number of records = 12*6 = 72. Increase number of records by ≈10% and on the DD card for unit 13 enter 11008 for the block size and 82 for the number of blocks.

```
//GO.FT13F001 DD UNIT=SYSDA,
//    SPACE=(11008, (082),,CONTIG,ROUND),
//    DCB=(RECFM=FT,BUFNO=1)
```

IX. JULIET ERROR STOPS

Several error stops are built into JULIET which abort the calculation when a condition is detected that will invalidate the results. In addition to numbered and unnumbered stop statements, the code also includes two error detecting subroutines (ERRA and CRASH). The unnumbered STOP statements always follow a printed statement indicating the nature of the difficulty.

A. The Unnumbered STOP Statements

Location: Subroutine RMATXS, format statement 93

Message: RMATXS is dimensioned for 1500 materials, this problem has, IIIIIIII

Action: The fixed dimension of MATNM(1500) in RMATXS must be increased or the problem size reduced. The latter is recommended.

Location: Subroutine RMATXS, format statement 23

Message: Dimensioning problem in RMATXS with variables associated with N2DB, take action in RMATXS, MIXER, PCMIX, N2DB = IIIII, MSCAT = JJJJJ.

Action: A material has been read from the MATXS file with a higher scattering order than anticipated by the program writer. If the scattering order for the problem is less than P_{21}, check MATXS for errors; if a scattering order greater than P_{20} is desired, program changes will be required in the routines cited in the message.

Location: Subroutine RMATXS, format statement 76

Message: See RMATXS, increase dimensions of variables associated with NIDR from 100 to IIIII.

Action: Check MATXS for an error; if none, take the action indicated in the message.

Location: Subroutine RMATXS, format statement 78

Message: Dimension of D exceeded in RMATXS; available space IIIIIIII, required space JJJJJJJJ.

Action: Increase the container array as indicated in the message or reduce problem size.

B. The Numbered STOP Statements

Statement: STOP 11

Location: Subroutine LOCATE

Action: An undefined cross-section operator was requested in either a 72$$ or 73$$ card. Insure that operator definition input (see Section VI, Block 2) is compatible with SOURCE input (see Section VI, Block 4).

Statement: STOP 67, STOP 74, STOP 75, STOP 76, STOP 78

Location: Subroutine SOURCE

Action: Increase container array size; for guidance see Section VII, A.(3).

Statement: STOP 111

Location: Subroutine ERRA

Action: See following discussion of ERRA.

C. Subroutine ERRA

Certain types of errors trigger a call to subroutine ERRA which prints a message containing an error STOP number and the subroutine name from which the call to ERRA originated. ERRA is misleading in that, when reference is made to subroutine MAIN, it should read subroutine SOURCE. Subroutine ERRA terminates with a STOP 111 statement.

Message:	Error stop 2 in subroutine MAIN
Called from:	Subroutine SOURCE
Action:	The scattering order requested for the H_1 operator of a bilinear function exceeds the maximum scattering order allowed for the problem. Check the third entry on the 15$$ card (see Section VI, B, Block 1) and the second entry of a 72$$ card (see Section VI, B, Block 4). The entry on a 72$$ card cannot exceed the entry on the 15$$ card.

Message:	Error stop 4 in subroutine MAIN
Called from:	Subroutine SOURCE
Action:	A non-zero scattering order was requested for the H_2 operator of a bilinear function. Correct the third entry of any 73$$ cards (see Section VI, B, Block 4) found in error.

Message:	Error stop 6 in subroutine MAIN
Called from:	Subroutine SOURCE
Action:	A non-zero scattering order was requested for the numerator of a linear response. Locate and correct the 72$$ cards in error.

Message:	Error stop 8 in subroutine MAIN
Called from:	Subroutine SOURCE
Action:	A non-zero scattering order was requested for the denominator of a linear response. Locate and correct the 73$$ cards in error.

Message:	Error stop 1 in subroutine PLEG
Called from:	Subroutine PLEG
Action:	Check 15$$ card for input errors relating to the geometry and quadrature order.

Message:	Error stop 1 in subroutine RDIR
Called from:	Subroutine RDIR
Action:	Check input weights and cosines (see Section VI, B., Block 1).

Message:	Error stop 2 in subroutine RDIR
Called from:	Subroutine RDIR
Action:	Check input weights and cosines (see Section VI, B., Block 1).

Message:	Error stop 3 in subroutine RDIR
Called from:	Subroutine RDIR
Action:	Check all input relating to the S_n quadrature.

D. Subroutine CRASH

This routine is called several times throughout the code to insure that the size of the container array is adequate. When an insufficient size is detected, a self-explanatory message is printed stating:

***CRASH IN HHHHHHHH, Required IIIIIII, Available JJJJJJJ

where

H...H is the subroutine name,

I...I is the required container array size,

J...J is the available container array size.

X. THE MATXS CROSS-SECTION FILE

```
C*************************************************************************
C                     REVISED 08/24/76                                    -
C                                                                         -
CF                    MATXS                                               -
CE                    COMPREHENSIVE CROSS SECTION FILE                    -
C                                                                         -
CN                          THIS FILES CONTAINS MACROSCOPIC AND           -
CN                          MICROSCOPIC CROSS SECTIONS, YIELDS AND        -
CN                          F-FACTORS FOR ALL PARTICLES, MATERIALS        -
CN                          AND REACTION TYPES                            -
C                                                                         -
C                           R J BARRETT, R E MACFARLANE                   -
C                                                                         -
C*************************************************************************


C-------------------------------------------------------------------------
CS                    FILE STRUCTURE                                      -
CS                                                                        -
CS                    RECORD TYPE                                         -
CS                    ========================== ==============           -
CS                    FILE IDENTIFICATION        ALWAYS                   -
CS                    FILE CONTROL               ALWAYS                   -
CS                    SET HOLLERITH IDENTIFICATN ALWAYS                   -
CS                    FILE DATA                  ALWAYS                   -
CS                                                                        -
CS    ************(REPEAT FOR ALL PARTICLES)                              -
CS    *               GROUP STRUCTURES           ALWAYS                   -
CS    *************                                                       -
CS                                                                        -
CS    *************(REPEAT FOR ALL DATA TYPES)                            -
CS    *               DATA TYPE CONTROL ALWAYS                            -
CS    *                                                                   -
CS    * ***********(REPEAT FOR ALL MATERIALS                             -
CS    * *             MATERIAL CONTROL           ALWAYS                   -
CS    * *             VECTOR CONTROL             NIDB.GT.0                -
CS    * *                                                                 -
CS    * * ********(REPEAT FOR ALL VECTOR PARTIAL                          -
CS    * * *             BLOCKS)                                           -
CS    * * *           VECTOR PARTIAL BLOCK       NIDB.GT.0                -
CS    * * ********                                                        -
CS    * *                                                                 -
CS    * *             SCATTERING MATRIX CONTROL  N2DB.GT.0                -
CS    * *                                                                 -
CS    * * ********(REPEAT FOR ALL SCATTERING                             -
CS    * * *             SUB BLOCKS)                                       -
CS    * * *           SCATTERING SUB-BLOCK       N2DB.GT.0                -
CS    ************                                                        -
C                                                                         -
C-------------------------------------------------------------------------


C-------------------------------------------------------------------------
CP                    FILE IDENTIFICATION                                 -
C                                                                         -
CL    HNAME,(HUSE(I),I=1,2),IVERS                                         -
C                                                                         -
CW    1+2*MULT                                                            -
C                                                                         -
CB    FORMAT(4H(1V ,A6,1H*,12A6,1H*,I6)                                   -
C                                                                         -
CD    HNAME           HOLLERITH FILE NAME - MATXS - (A6)                  -
CD    HUSE            HOLLERITH USER IDENTIFIATION (6A)                   -
CD    IVERS           FIELD VERSION NUMBER                                -
CD    MULT            DOUBLE PRECISION PARAMETER                          -
CD                          1 - A6 WORD IS SINGLE WORD                    -
CD                          2 - A6 WORD IS DOUBLE PRECISION WORD          -
C                                                                         -
C-------------------------------------------------------------------------
```

```
C-----------------------------------------------------------------------
CR                    FILE CONTROL                                     -
C                                                                      -
CL     NPART,NTYPE,NHOLL                                               -
C                                                                      -
CW     2                                                               -
C                                                                      -
CB     FORMAT(4H 1D ,3I6)                                              -
C                                                                      -
CD     NPART          NUMBER OF PARTICLES FOR WHICH GROUP              -
CD                    STRUCTURES ARE GIVEN                             -
CD     NTYPE          NUMBER OF DATA TYPES PRESENT IN SET              -
CD     NHOLL          NUMBER OF WORDS IN SET HOLLERITH                 -
CD                    IDENTIFICATION RECORD                            -
C                                                                      -
C-----------------------------------------------------------------------


C-----------------------------------------------------------------------
CR                    SET HOLLERITH IDENTIFICATION                     -
C                                                                      -
CL     (HSETID(I),I=1,NHOLL)                                           -
C                                                                      -
CW     NHOLL*MULT                                                      -
C                                                                      -
CB     FORMAT(4H 2D ,1146/(12A6))                                      -
C                                                                      -
CD     HSETID         HOLLERITH IDENTIFICATION OF SET (A5)             -
CD                     (TO BE EDITED OUT 72 CHARACTERS PER LINE)       -
C                                                                      -
C-----------------------------------------------------------------------


C-----------------------------------------------------------------------
CR                    FILE DATA                                        -
C                                                                      -
CL     (HPRT(J),J=1,NPART),(HTYPE(K),K=1,NTYPE),(NMAT(K),K=1,NTYPE),   -
CL    1(NINP(K),K=1,NTYPE),(NING(K),K=1,NTYPE),(NOUTP(K),K=1,NTYPE),   -
CL    2(NOUTG(K),K=1,NTYPE),(LOCT(K),K=1,NTYPE),(NGRP(J),J=1,NPART);   -
C                                                                      -
CW     (NPART+NTYPE)*MULT+6*NTYPE+NPART                                -
C                                                                      -
CB     FORMAT(4H 3D ,11A6/(12A6))      HPRT,HTYPE                      -
CB     FORMAT(12I6)                    NMAT,NINP,NING,NOUTP,NOUTG,     -
CB                                     LOCT,NGRP                       -
C                                                                      -
CD     HPRT(J)        HOLLERITH IDENTIFICATION FOR PARTICLE J          -
CD                              NEUT NEUTRON                           -
CD                              GAMA PHOTON                            -
CD                              BETA ELECTRON                          -
CD                              .    .                                 -
CD                              .    .                                 -
CD                              .    .                                 -
CD     HTYPE(K)       HOLLERITH IDENTIFICATION FOR DATA TYPE K          -
CD                              NSCAT NEUTRON SCATTERING               -
CD                              NGAMA NEUTRON INDUCED GAMMA PRODUCTION -
CD                              NGCUP NEUTRON-GAMMA COUPLED SET        -
CD                              GSCAT GAMMA SCATTERING                 -
CD                              NNFF  NEUTRON F-FACTORS                -
CD                              .    .                                 -
CD                              .    .                                 -
CD                              .    .                                 -
CD     NMAT(K)        NUMBER OF MATERIALS IN SET FOR DATA TYPE K       -
CD     NINP(K)        NUMBER OF INCIDENT PARTICLES ASSOCIATED WITH     -
CD                    DATA TYPE K                                      -
CD     NING(K)        NUMBER OF INCIDENT GROUPS ASSOCIATED WITH        -
CD                    DATA TYPE K                                      -
CD     NOUTP(K)       NUMBER OF OUTGOING PARTICLES ASSOCIATED WITH     -
CD                    DATA TYPE K                                      -
CD     NOUTG(K)       NUMBER OF OUTGOING GROUPS ASSOCIATED WITH        -
CD                    DATA TYPE K                                      -
CD     LOCT(K)        NUMBER OF RECORDS TO BE SKIPPED TO READ DATA FOR -
CD                    DATA TYPE K LOCT(1)=0                            -
CD     NGRP(J)        NUMBER OF ENERGY GROUPS FOR PARTICLE J           -
C                                                                      -
C-----------------------------------------------------------------------


C-----------------------------------------------------------------------
CR                    GROUP STRUCTURE                                  -
C                                                                      -
CL     (GPB(I),I=1,NGRP(J)),EMIN                                       -
C                                                                      -
CW     NGRP(J)+1                                                       -
C                                                                      -
CB     FORMAT(4H 4D ,(P5E12.5/(6E12.5))                                -
C                                                                      -
CD     GPB(I)         MAXIMUM ENERGY BOUND FOR GROUP I FOR PARTICLE J  -
CD     EMIN           MINIMUM ENERGY BOUND FOR PARTICLE J              -
C                                                                      -
C-----------------------------------------------------------------------
```

```
C-----------------------------------------------------------------------
CR                    DATA TYPE CONTROL                                -
C                                                                      -
CL     (HMATNM(I),I=1,NMAT),(TEMP(I),I=1,NMAT),(SIGZ(I),I=1,NMAT),    -
CL    1(LOCA(I),I=1,NMAT),((INP(J),J=1,NINP),(IOUTP(J),J=1,NOUTP),    -
CL    2NSBLK                                                           -
C                                                                      -
CC     NMAT =NMAT(K)                                                   -
CC     NINP =NINP(K)                                                   -
CC     NOUTP=NOUTP(K)                                                  -
C                                                                      -
CW     (3+MULT)*NMAT+NINP+NOUTP+1                                      -
C                                                                      -
CB     FORMAT(4H 5D ,11A6/(12A6))          HMATNM                      -
CB     FORMAT(1P6E12.5)                    TEMP,SIGZ                   -
CB     FORMAT(12I6)                        LOCA,IINP,IOUTP,NSBLK       -
C                                                                      -
CD     HMATNM(I)      HOLLERITH IDENTIFICATION FOR MATERIAL I          -
CD     TEMP(I)        AMBIENT TEMPERATURE(DEGREES KELVIN)              -
CD     SIGZ(I)        MATERIAL DILUTION FACTOR                         -
CD     LOCA(I)        NUMBER OF RECORDS TO BE SKIPPED TO READ DATA FOR -
CD                    MATERIAL I LOCA(I)=0                             -
CD     IINP(J)        NUMBER OF THE PARTICLE TYPE CORRESPONDING        -
CD                    TO INCIDENT PARTICLE I FOR DATA TYPE K           -
CD     IOUTP(J)       NUMBER OF THE PARTICLE TYPE CORRESPONDING        -
CD                    TO OUTGOING PARTICLE I FOR DATA TYPE K           -
CD     NSBLK          SUB-BLOCKING PARAMETER                           -
C                                                                      -
C-----------------------------------------------------------------------
```

```
C-----------------------------------------------------------------------
CR                    MATERIAL CONTROL                                 -
C                                                                      -
CL     HMAT,AMASS,IMAC,NIDR,NIDB,N2DB                                  -
C                                                                      -
CW     MULT+5                                                          -
C                                                                      -
CR     FORMAT(4H 6D ,A6,1H*,E12.5,4I6)                                 -
C                                                                      -
CD     HMAT           HOLLERITH MATERIAL IDENTIFIER                   -
CD     AMASS          GRAM ATOMIC MASS                                -
CD     IMAC           1/2 MEANS MICROSCOPIC/MACROSCOPIC CROSS SECTIONS -
CD     NIDR           NUMBER OF VECTOR PARTIALS                       -
CD     NIDB           NUMBER OF VECTOR PARTIAL BLOCKS                 -
CD     N2DR           NUMBER OF SCATTERING BLOCKS                     -
C                                                                      -
C-----------------------------------------------------------------------
```

```
C-----------------------------------------------------------------------
CR                    VECTOR CONTROL                                   -
C                                                                      -
CL     (HVSP(I),I=1,NIDR),(IBLK(I),I=1,NIDR),(NFG(I),I=1,NIDR),        -
CL    1(NLG(I),I=1,NIDR)                                               -
C                                                                      -
CW     (3+MULT)*NIDR                                                   -
C                                                                      -
CR     FORMAT(4H 7D ,11I6/(12I6))                                      -
C                                                                      -
CD     HVPS(I)        HOLLERITH IDENTIFIER OF PARTIAL(I)               -
CD                           SNGAM NEUTRON CAPTURE                     -
CD                           SFIS FISSION                              -
CD                           SAHE HELIUM PRODUCTION                    -
CD                           *     *                                   -
CD                           *     *                                   -
CD                           *     *                                   -
CD     IBLK(I)        NUMBER OF BLOCK IN WHICH PARTIAL(I) IS LOCATED   -
CD     NFG(I)         NUMBER OF FIRST NON-ZERO GROUP FOR PARTIAL(I)    -
CD     NLG(I)         NUMBER OF LAST NON-ZERO GROUP FOR PARTIAL(I)     -
C                                                                      -
C-----------------------------------------------------------------------
```

```
C-----------------------------------------------------------------------
CR                    VECTOR PARTIAL BLOCK                             -
C                                                                      -
CL     (VPS(I),I=1,KMAX)                                               -
C                                                                      -
CC     KMAX=SUM OVER PARTIALS IN BLOCK J OF NON-ZERO GROUPS            -
C                                                                      -
CW     KMAX                                                            -
C                                                                      -
CR     FORMAT(4H 8D ,1P5E12.5/(6E12.5))                                -
C                                                                      -
CD     VPS(I)         VECTOR DATA FOR ALL NON-ZERO GROUPS FOR ALL      -
CD                    PARTIALS WITH IBLK(I)=J                          -
C                                                                      -
C-----------------------------------------------------------------------
```

```
C-----------------------------------------------------------------------
CR                    SCATTERING MATRIX CONTROL                        -
C                                                                      -
CL     (HMTX(N),N=1,2D8),(LONE(N),N=1,N2D8),(LORD(N),N=1,N2D8),        -
CL    1((JBAND(L,N),L=1,NOUTG(K)),N=1,N2D8)                            -
CL    2((IJJ(L,N),L=1,NOJTG(K)),N=1,N2D8)                              -
C                                                                      -
CW     (MULT+2+2*NOUTG(K))*N2D8                                        -
C                                                                      -
CB     FORMAT(4H 9D ,11A6/(12A6))        HMTX                          -
CB     FORMAT(12I6)                      LONE,LORD,JBAND,IJJ           -
C                                                                      -
CD     HMTX(N)        HOLLERITH IDENTIFICATION FC BLOCK N              -
CD     LONE(N)        LOWEST LEGENDRE ORDER PRESENT IN BLOCK N         -
CD     LORD(N)        NUMBER OF SCATTERING ORDERS PRESENT IN BLOCK N    -
CD     JBAND(L,N)     SCATTERING BANDWIDTH FOR GROUP L,SCATTERING      -
CD                    BLOCK N                                          -
CD     IJJ(L,N)       LOWEST ENERGY GROUP OF BAND JBAND                -
C                                                                      -
C-----------------------------------------------------------------------


C-----------------------------------------------------------------------
CR                    SCATTERING SUB-BLOCK                             -
C                                                                      -
CL     ((SCAT(K,L),K=1,KMAX),L=1,LORD(N))                              -
C                                                                      -
CC     KMAX=SUM OVER I OF ALL JBAND(I,N) IN THE I RANGE OF SUB-BLOCK N  -
C                                                                      -
CW     KMAX*LORD(N)                                                    -
C                                                                      -
CD     SCAT(K,L) MATRIX DATA FOR GROUP TO GROUP TRANSFER OF PARTICLES   -
C                                                                      -
C-----------------------------------------------------------------------
```

XI. SAMPLE PROBLEM

This sample problem demonstrates the interaction of the FMANG, FANISN, ANTMX, and JULIET modules in calculating sensitivity coefficients for the k and 28C/25F responses of the ZPR 6/7 assembly. It also demonstrates the calculation of generalized sources for a worth response. Cross section requirements, identification schemes, and unit assignments are discussed in the following comments.

1. A shielded, microscopic, ANISN, cross section file is available on unit 4.
2. A shielded, macroscopic, forward, ANISN, cross section file generated by AXMIX is available on unit 16.
3. A shielded, macroscopic, adjoint, ANISN cross section file generated by AXMIX is available on unit 17.

4. The input for a forward FANISN core model of ZPR6/7 has been prepared and the card images placed on unit 38.
5. The following identifiers have been assigned:

   IASB = 12, assembly identifier on the Repository and the SENPRO file for ZPR 6/7.

   IRESP = 21, response related identifier on the repository for the bilinear, generalized, adjoint, ^{239}Pu worth, source and flux.

   IRESP = 22, response related identifier on the Repository for the bilinear, generalized, forward, ^{239}Pu worth, source and flux.

   IRESP = 31, response related identifier on the Reporitory for the linear, generalized, adjoint 28C/25F ratio, source, flux, and normalization parameters.

   IDS = 4, response identifier on the SENPRO file for 28C/25F sensitivity profile.

   NTRN = 3, reaction rate ratio identifier on the SENPRO file for the 28C/25F sensitivity profile.

   OPID = 1, the automatic operator identifier for the mixture of fissionable materials in the ZPR 6/7 core.

   OPID = 2, the automatic operator identifier for

6. The $\phi^*\phi$ file for k sensitivity will be placed on unit 9.
7. The k sensitivity profile will be placed on unit 23.
8. The $\Gamma^*\phi$ file 28C/25F sensitivity will be placed on unit 28.
9. The 28C/25F sensitivity profile will be placed on unit 24.

10. In the ANISN to MATXS input, note that the group boundaries are all one, 4** F1.0 T. It is not essential for this problem that the MATXS file contain a realistic group structure since the MATXS file is not being retained as a file of record.

11. In the input to calculate sensitivity profiles for 28C/25F, note that the group boundaries are all one, 81** F1.0 T. However, the group boundaries are specified for the k sensitivity calculation with the 81U (6E11.4) and following cards ending with the T. It is anticipated that the k profiles (unit 23) and the 28C/25F profiles (unit 24) will be merged to create a single SENPRO file. The group boundaries from unit 23 will be placed on this new SENPRO file. Therefore, a repetition of the group boundaries is unnecessary.

```
***  CONTENTS OF UNIT 36 FOLLOWS(CARD IMAGES)
15$$    1   0   3   4   3   1   C   2   60   1   100   5   6   105   2Z   6    8
   0    0   0    2Z    12    0    1    0    0    25    1   3Z   1   1   0
16**    2Z    1.0-5    4Z    1.0 0.0      0.5    1.0-5    3Z     T
3** F1.0 T
1**
  9.0576E-05   1.3844E-03   6.5907E-03   2.0758E-02   4.5693E-02   7.6253E-02
  1.0287E-01   6.9659E-02   1.5946E-02   4.0382E-03   3.9943E-03   2.4139E-02
  4.8338E-02   4.7780E-02   4.6546E-02   4.4760E-02   4.2547E-02   4.0028E-02
  3.7313E-02   3.4494E-02   1.3545E-02   1.8112E-02   2.8861E-02   2.6157E-02
  2.3583E-02   2.1162E-02   1.8910E-02   1.6834E-02   1.4935E-02   1.3210E-02
  6.0110E-03   5.6418E-03   1.0254E-02   9.0035E-03   9.6982E-04   3.5574E-04
  7.4622E-04   2.0042E-03   3.8139E-03   6.9018E-03   3.1165E-03   2.9113E-03
  5.2570E-03   4.5789E-03   3.9836E-03   3.4621E-03   1.5562E-03   1.4497E-03
  2.6076E-03   2.2606E-03   4.4137E-03   6.7274E-04   4.9410E-04   1.1962E-03
  7.0904E-04   2.1322E-03   1.4767E-03   1.0209E-03   3.4368E-04   1.4894E-04
  9.1435E-05   1.2087E-04   5.7150E-05   5.5065E-05   3.7402E-04   3.3512E-04
  2.3062E-04   1.5691E-04   1.0936E-04   7.5240E-05   5.1753E-05   2.2930E-05
  1.2662E-05   1.0900E-05   9.3835E-06   4.1901E-06   3.8876E-06   6.9535E-06
  5.9857E-06   1.1568E-05   7.9526E-06   5.4668E-06   3.7578E-06   2.5830E-06
  1.7754E-06   1.2203E-06   8.3878E-07   9.7277E-07   4.5956E-07   2.1712E-07
  1.0253E-07   4.8472E-08   2.2909E-08   1.0831E-08   5.1236E-09   2.4262E-09
  1.1506E-09   5.4707E-10   2.6118E-10   2.5220E-10
4** 3910.0 19188.16 121.97
5** F1.
6** 0.0 .17392742 .32607257 .32607257 .17392742
7** -1. -.86113631 -.33998104 .33998104 .86113631
8$$ 40R1 20R2
9$$    1    5
19$$ F3
   T
***  END OF CARD IMAGE INPUT ON UNIT 36
```

FORSS INPUT

```
=FMANG
1$$   12   1   0   16   FC   T
=FANISN
ZPR 6/7 FANISN FORWARD RUN
38Y0
38Y0
38Y0
=FMANG
1$$   12   1   1   17   1   F0   T
ZPR 6/7 FANISN ADJOINT RUN
38Y0
38Y0
38Y0
=ANTMX
1$$      100      5      105      6   4 7    F0
2$$   9   36   F0                    T
4**    F1.0       T
PU240
PU241
U235C
U235B
U238C
U238B
PU239
=FMANG
1$$   12   1   1   F0   T
=FJULIE
38Y0
38Y0
38Y0
MIX
```

```
    1       NEUT        NSCAT       U235C                    1.26    -5     3
    1       NEUT        NSCAT       U238C                    5.78036-3      3
    1       NEUT        NSCAT       PU239                    8.8672  -4     3
    1       NEUT        NSCAT       PU240                    1.1944  -4     3
    1       NEUT        NSCAT       PU241                    1.33    -5     3
    2       NEUT        NSCAT       U235B                    8.56    -5     3
    2       NEUT        NSCAT       U238B                    3.96179-2      3
  102       NEUT        NSCAT       U238C       CAPT         5.78036-3      0
   18       NEUT        NSCAT       U235C       FIS          1.26    -5     0
 1399       NEUT        NSCAT       PU239                    8.8672  -4     3
 (BLANK CARD)
FLUX
00$$  0  1  1  F0   T
SOURCE
70$$  2
71**  F0.0     T
PU239 C.I. NORTH
72$$  1  3  1399  F0
73$$  0   0  40R1  20R2
74$$  0   1   21  22  F0
75**  94.0  8.8672E-4    T
LINEAR RESPONSE C. I. REACTION RATE RATIO 28C/25F
72$$  0  0  102   F0
73$$  0  0  18  F0
74$$  0  1  31  F0   T
=FMANG
1$$  12  1  1  17  1  1  F0  T
ZPR 6/7 GENERALIZED FANISN ADJOINT RUN
36Y0
36Y0
36Y0
=FMANG
1$$  12  1  1  F0   T
=FJULIE
36Y0
36Y0
36Y0
MIX
 1398      NEUT        NSCAT       U238C                    5.78036-3      3
   98      NEUT        NSCAT       U238B                    3.96179-2      3
 1399      NEUT        NSCAT       PU239                    8.8672  -4     3
 (BLANK CARD)
SENSE
60$$  1   100   T
61U
(6E11.4)
  1.9640E+7  1.3499E+7  1.0000E+7  7.7880E+6  6.0653E+6  4.7237E+6
  3.6788E+6  2.8650E+6  2.4660E+6  2.3852E+6  2.3653E+6  2.3457E+6
  2.2313E+6  2.0190E+6  1.8268E+6  1.6530E+6  1.4957E+6  1.3534E+6
  1.2246E+6  1.1080E+6  1.0026E+6  9.0164E+5  9.0718E+5  8.2085E+5
  7.4274E+5  6.7206E+5  6.0810E+5  5.5023E+5  4.9787E+5  4.5049E+5
  4.0762E+5  3.6774E+5  3.6883E+5  3.3373E+5  3.0197E+5  2.9850E+5
  2.9720E+5  2.9452E+5  2.6725E+5  2.7324E+5  2.4724E+5  2.3518E+5
  2.2371E+5  2.0242E+5  1.8316E+5  1.6573E+5  1.4996E+5  1.4264E+5
  1.3569E+5  1.2277E+5  1.1109E+5  8.6517E+4  8.2500E+4  7.9500E+4
  7.2000E+4  6.7379E+4  5.2475E+4  4.0868E+4  3.1828E+4  2.8500E+4
  2.7000E+4  2.6056E+4  2.4788E+4  2.4176E+4  2.3579E+4  1.9305E+4
  1.5034E+4  1.1709E+4  9.1188E+3  7.1017E+3  5.5308E+3  4.3074E+3
  3.7074E+3  3.3546E+3  3.0354E+3  2.7465E+3  2.6126E+3  2.4652E+3
  2.2487E+3  2.0347E+3  1.5846E+3  1.2341E+3  9.6112E+2  7.4652E+2
  5.8095E+2  4.5400E+2  3.5358E+2  2.7536E+2  1.6702E+2  1.0130E+2
  6.1442E+1  3.7267E+1  2.2603E+1  1.3710E+1  8.3153E+0  5.0435E+0
  3.0590E+0  1.8554E+0  1.1254E+0  6.8256E-1  1.0000E-5
T
ZPR 6/7
K
83$$  2  1  1  0   F0   T
86**  42  1.0   F0   T
```

```
PU239
87$$  3  3  0  2  1  0  0  0  0  1  T
88$$  F1399
89**  1.0  0.0
91$$  1  2  T
U235
87$$  3  3  0  2  1  0  0  0  0  1  T
88$$  1398  98
89**  F1.0
91$$  1  2  T
FLUX
60$$  0  1  31  0  28  F0  T
SENSE
60$$  1  100  T
81**  F1.0  T
ZPR 6/7
U238C  CAPT  U235C  FIS
83$$  2  31  4  3  28  24  F0  T
86**  4Z  1.0  F0.0  T
PU239
87$$  3  3  0  2  1  0  0  0  0  1  T
88$$  F1399
89**  1.0  0.0
91$$  1  2  T
U238
87$$  3  3  1  0  1  1  1  0  0  1  T
88$$  1398  98
89**  F1.0
91$$  1  2  T
```

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CHAPTER VIII. THE SENPRO SERVICE MODULE OF THE FORSS SYSTEM

J. L. Lucius

CHAPTER VIII

Table of Contents

ABSTRACT

The SENPRO Service Module includes twelve execution paths to aid in understanding and using the group-dependent sensitivity coefficients contained in the standard interface file SENPRO. The execution paths provide the following operations on SENPRO file(s).

1. Lists the contents of a SENPRO file.
2. Plots a SENPRO file.
3. Operates on a SENPRO file by adding or deleting sets of sensitivity coefficients.
4. Merges two SENPRO files and creates a new file.
5. Changes the mode of a file. Unformatted to formatted and conversely.
6. Lists in order of descending absolute magnitude of the total sensitivity, the title and total sensitivity for each profile in the SENPRO file.
7. Renormalizes sensitivity coefficients.
8. Redefines any entry in the 12-word MAT-MT control record.
9. Places the sensitivity coefficients on a user-supplied group structure.
10. Selectively edits or copies a file.
11. Sums all profiles in a file and produces a new profile.
12. Replaces or modifies the group structure on a SENPRO file.

INTRODUCTION

Sets of sensitivity coefficients are calculated by the JULIET[1] module of the FORSS[2] system and placed on a proposed CCCC[3] file, SENPRO.[4] Each set is identified by an assembly number, a response number, a material number, a reaction type number, and, if applicable, a reaction rate response number. These sets of coefficients are referred to as sensitivity profiles. If the configuration of interest is a CSWEG[5] fast reactor benchmark, the CSWEG assigned assembly number is used throughout FORSS analysis. If the configuration is not a CSWEG fast reactor benchmark, the assignment of the assembly number, and the identification must be consistent throughout FORSS analysis. The response and reaction rate ratio identification numbers currently used are listed in the MAT-MT control record description of the SENPRO file. These will be augmented as required. The material and reaction type identification numbers are the MAT and MT numbers used in the ENDF/B[6] files. A complete description of the SENPRO file is in Appendix A.

When the generation of the SENPRO file(s) is complete for a study, a careful review is recommended before it is used. The SENPRO service module is available to aid in this review. If identification or normalization problems are detected, they can often be quickly corrected by the SENPRO service module. At present, the module has twelve execution paths which perform the following tasks.

1. Lists the contents of a SENPRO file.
2. Plots a SENPRO file.
3. Operates on a SENPRO file by adding or deleting sets of sensitivity coefficients.
4. Merges two SENPRO files and creates a new file.
5. Changes the mode of a file. Unformatted to formatted and conversely.
6. Lists in order of descending absolute magnitude of the total sensitivity, the title and total sensitivity for each profile in the SENPRO file.

7. Renormalizes sensitivity coefficients.
8. Redefines any entry in the 12-word MAT-MT control record.
9. Places the sensitivity coefficients on a user-supplied group structure.
10. Selectively edits or copies a file.
11. Sums all profiles in a file and produces a new profile.
12. Replaces or modifies the group structure on a SENPRO file.

The user selects the desired execution path by entering one of the following words on a card beginning in column 1: LIST, PLOT, ADD, MERGE, DELETE, SEND, SIZE, NORM, FIX, GRID, EDIT, SUM, GROUP. The control words ADD and DELETE access the same programming. Additional input requirements are described for each execution path.

SENPRO FILE LIST

LIST

1$$ Integer Parameter [1]

NBIN unit number of the SENPRO file, if NBIN < 0, only the profile titles will be listed

T

GRAPHIC DISPLAY

The INTRIGUE-II-C IBM-360[7] subroutine package is implemented to provide graphs of sensitivity profiles. Graphs of sensitivity coefficients per unit lethargy vs. energy in MeV are available with the following default characteristics.

1. Logarithmic on both axes.
2. Calcomp pen and ink graphs.

3. Height - 8".
4. Width - 8".
5. ITOPY - 10^{ITOPY} is maximum ordinate value, calculated by code.
6. NCY=4 - number of cycles on ordinate.
7. ITOPX=2 - 10^{ITOPX} is maximum absicissa value.
8. NCX=5 - number of cycles on abscissa.
9. CUT=0.005, if $\sum_{i=1}^{NG}|S(i)| \leq$ CUT, a graph is not produced.

Complete File Plotting

Every set of coefficients on the file where $\sum_{i=1}^{NG}|S(i)| >$ CUT will be plotted.

Input Data

PLOT

1$$ Integer Parameters [2]
IPRO - unit number of file
N - 0 complete file plotting
> 0 number of coefficients selected for plotting

2** CUT
3$$ NCY NCX
4$$ ITOPY ITOPX
5** WIDTH† HEIGHT
T

} All of these cards change default characteristics, if the default is acceptable, omit the card.

Selective Plotting

The user may select the profiles for plotting. If N > 0, prepare 6$$ card. The 6$$ entries identify the profiles with information from the MAT-MT control record.

†Reducing the plot width will result in a disaster.

6$$ Integer Parameters [5*N]

IASB - assembly identification

IRESP - response identification

MATID - material identification

MT - reaction type identification

NTRN - reaction rate ratio identification, enter 0 if not applicable

.

.

.

Sequence is repeated for each graph requested

T

SENPRO FILE ADD/DELETE

This execution path performs three functions. Profiles may be added to the file from card input. Profiles may be deleted from the file. If no profiles are added or deleted, the file is copied without change.

ADD

1$$ Integer Parameters [4]

NOLD - unit number of existing SENPRO file

NEW - unit number of new SENPRO file

NADD - the number of profiles to be added (may be 0)

NDL - the number of profiles to be deleted (may be 0)

T

ADD Option

If NADD > 0, enter the 2$$ array

2$$ Integer Parameters [12]. The MAT-MT control record of the SENPRO file

```
C-------------------------------------------------------------------------
CR        MAT - MT Control                                               -
C                                                                        -
CL    IASB,IRESP,MATID,MT,NZONE,ISTC,NPART,NWRD,NZDEN,MATRIX,NTRN,NTRD   -
CW    12                                                                 -
C                                                                        -
CB    FORMAT(4H 4D  11I6/I6)                                             -
C                                                                        -
CD    IASB        Assembly Identification                                -
CD                    Reference BNL 19302 (ENDF-202) F-1                 -
CD    IRESP       Response Identification                                -
CD                    1 - K                                              -
CD                    2 - Breeding Ratio                                 -
CD                    3 - Worth                                          -
CD                    4 - Reaction Rate Ratio                            -
CD                    5 - Other                                          -
CD    MATID       Material Identification                                -
CD    MT          Reaction Type Identification                           -
CD    NZONE       Number of Zones                                        -
CD    ISTC        Scattering Order for Total Coefficients                -
CD    NPART       Number of Partial Sets                                 -
CD    NWRD        Number of Hollerith (A6) Words Used to Describe the Response-
CD    NZDEN       Zone Density Option                                    -
CD                    0 - Zone Densities are Omitted                     -
CD                    1 - Zone Densities are Present                     -
CD    MATRIX      Reserved                                               -
CD    NTRN        Reaction Rate Ratio Identification                     -
CD                    1 - 28C/49F                                        -
CD                    2 - 28F/49F                                        -
CD                    3 - 28C/25F                                        -
CD                    4 - 28F/25F                                        -
CD                    5 - 49F/25F                                        -
CD                    6 - 28C/28F                                        -
CD    NTRD        Reserved                                               -
C-------------------------------------------------------------------------

T
```

Hollerith response description, FORMAT (11A6)
Input the number of cards needed to define NWRD (A6) words
Hollerith title, 1 card, FORMAT (11A6)

SENSITIVITY COEFFICIENTS, FORMAT (6E12.4)

Repeat the sequence until NADD profiles are described.

DELETE Option
If NDL > 0, enter the 3$$ array
3$$ Integer Parameters [5*NDL]
- IASB - assembly identification
- IRESP - response identification
- MATID - material identification
- MT - reaction type identification
- NTRN - reaction rate ratio identification

.
.
.

Sequence is repeated for each profile to be deleted.

T
If NADD = 0 and NDL = 0, the SENPRO file on unit NOLD is copied without change to unit NEW.

SENPRO FILE MERGE

This execution path merges two existing SENPRO files and creates a third file containing all of the profiles on the original files. The files to be merged must have identical group structures.

MERGE
1$$ Integer parameters [3]
- N1 unit number of a SENPRO file
- N2 unit number of a SENPRO file to be merged
- N3 unit number of new SENPRO file

T

SENDIN[8] - FORMAT CONVERSION

This execution path implements the SENDIN code which converts the SENPRO file from unformatted (binary) to formatted card images and conversely. SENDIN also lists a SENPRO file.

```
SEND
1$$ Integer Parameters [4]
    NBE Select conversion mode
        = 0 unformatted to formatted
        ≠ 0 formatted to unformatted
    NIN unit number of existing SENPRO file (DEFAULT = 23)
    NOUT unit number of SENPRO file to be prepared by SENDIN (DEFAULT = 24)
    NO6 Print option
        ≤ 0 File is printed
        > 0 No print
T
```

SENPRO FILE SIZE

The total sensitivity of each profile on the file is determined. The profile titles are then listed in descending order as a function of the absolute magnitude of the total sensitivity.

```
SIZE
1$$ Integer Parameter
    NBIN unit number of SENPRO file
T
```

SENPRO FILE NORMALIZATION

This execution path permits the modification of sensitivity coefficients in a SENPRO file. The following two options are available:

1. Renormalize all coefficients by a constant defined as R1/R2, see 2** card. This is useful for salvaging sets of coefficients with an incorrect R.
2. Apply a group-dependent multiplication factor. This is useful

for applying disadvantage factors. If a profile title card has no total sensitivity (A) or an incorrect A, 3** F1.0 input will correct the condition.

NORM

1$$ Integer Parameters [2]
NOLD unit number of old SENPRO file
NEW unit number of new SENPRO file

2** Floating Point Parameters [2]
R1 old normalization
R2 new normalization

T

End of input for option 1
If R1 = R2 = 0, then option 2 is executed

3** Floating Point Parameters [IGM]
Group-dependent multiplication factors

T

SENPRO FILE MAT-MT CONTROL RECORD FIX

This execution path allows any word in the 12-word MAT-MT control record to be redefined.

FIX

1$$ Integer Parameters [3]
N1 - old unit number
N2 - new unit number
NFIX - the number of redefinitions to be made

T

2$$ Integer Parameters [3*NFIX]
IP - position in MATMT record to be redefined
NCV - current value of MATMT(IP) on the file. If NCV < -10000, the current value is not considered and MATMT(IP) = NDV
NDV - desired value of MATMT(IP)

.
.
.

The 3 parameter sequence is repeated until 3*NFIX entries are complete.

T

SENPRO NEW GRID

This execution path places each profile in a file in a user designated group structure. The group structure may be input from cards or retrieved from another SENPRO file. The redistribution of the sensitivity coefficients on the new grid is done linearly in lethargy.

GRID

1$$ Integer Parameters [3]

N1 - unit number of old SENPRO file

N2 - unit number of new SENPRO file

NG - selection option

When NG > 0, NG is the number of groups in the new group structure to be defined on input cards. When NG < 0, |NG| is the unit number of a SENPRO file containing the new group structure.

T

2** Group Boundaries [NG+1]

(The 2** card is included when NG > 0). Enter values from high energy to low energy in units of eV.

T

SENPRO FILE EDIT/COPY

This execution path permits selective listing and copying of a SENPRO file. Each profile on a SENPRO file has five identification numbers, assembly, response, material, reaction type and reaction rate ratio. The five identification numbers are located in the following positions of the MATMT record of the SENPRO file.

Identifier	MATMT Position
Assembly	1
Response	2
Material	3
Reaction type	4
Reaction rate ratio	11

The five identifiers and their positions in the MATMT record are used to provide a general edit/copy capability. An edit command consists of the identifiers ordered by assembly, response, material, reaction type, and reaction rate response. Any identifier may be entered as zero which indicates any value encountered for that identifier qualifies for the EDIT/COPY operation. To complete input requirements, a hierarchy must be defined establishing the order in which the identifiers in the EDIT command will be tested. The hierarchy is defined as a function of the identifiers position in the MATMT record. A default hierarchy of 1, 2, 3, 4, 11 is established by the coding. This default hierarchy may be replaced by data input on the 2$$ card.

As each profile is read from the SENPRO file, its five identifiers are compared with the corresponding identifiers in each edit command. The order in which the identifiers are compared is controlled by the established hierarchy. If equality is found between all of the nonzero identifiers in an edit command and the corresponding identifiers from the MATMT record of the profile, the profile qualifies for the edit/copy operation.

Input Data

EDIT

1$$ Integer Parameters [5]

- |NI| - unit number of existing SENPRO file, if NI < 0 the edited profiles will be copied with listing omitted
- NC - number of edit commands
- NEW - copy option
  - >0, the unit number of a SENPRO file to be written containing only those profiles edited.
  - =0, file not written
- NSS - unit number of a scratch device, default = 31
- NHI - hierarchy definition option
  - =0, use default definition
  - >0, prepare 2$$ card

T

2$$ Integer Parameters [5] (Omit if NHI = 0)
Input the MAT-MT positions 1 2 3 4 11 in the order required to define an appropriate hierarchy.

T

3$$ Integer Parameters [5*NC]
Assembly ID
Response ID
Material ID
Reaction type ID*
Reaction rate ratio ID
.
.
.
Complete NC edit commands

T

SENPRO FILE SUM

This execution path prepares one sensitivity profile by summing every profile contained in a SENPRO file. Practical application usually involves executing the EDIT/COPY, SUM, and MERGE paths in sequence.

Input Data

SUM

1$$ Integer Parameters [2]
N1 - old unit number
N2 - new number

T

2$$ Integer Parameters [12]
define the MATMT record for the new profile

T

---

*MT=5191 is a special reaction type identifier which permits any inelastic level and the continuum to be eligible for EDIT/COPY.

Response title card for new profile (FORMAT 11A6)
Profile title card for new profile (FORMAT 8A6)

The program supplies the last 3A6 words of a profile title.

SENPRO FILE GROUP

This execution path replaces or modifies the group structure on a SENPRO file.

Input Data

GROUP
1$$ Integer Parameters [2]
NOLD - unit number of existing SENPRO file
NEW - unit number of new SENPRO file
T

2** Group Boundaries or Modifiers [Number of groups + 1]
T

Comments

If the first and last entries in the 2** array are equal, the contents of the 2** array are used to modify the group boundaries on the SENPRO file.

$$GB_i = GB^*_i * GBM_i$$

where

GB* - group boundaries on SENPRO
GBM - modifiers read in 2** arra

The intent of this is to provide a capability to change the units of the group boundaries on a SENPRO file. For example, 2** F1.0E+6 T would change the units from MeV to EV.

If the first and last entries in the 2** array are not equal, the contents of the 2** array replaces the group boundaries on the SENPRO file.

The group boundaries entered in the 2** array may be in either ascending or descending order. GROUP will insure that the boundaries placed on the new SENPRO are in descending order.

GROUP assumes the number of entries in the 2** array are equal to the number of group boundaries on the SENPRO file. Since all information

about the number of boundaries is taken from the SENPRO file, any indication of an error in the number of entries read in the 2** array is disasterous and the input should be carefully checked.

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3. B. M. Carmichael, *Standard Interface Files and Procedures for Reactor Physics Codes, Version III*, LA-5486-MS (February 1974).

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APPENDIX A

The Format for Standard Interface File SENPRO for Group-Dependent Sensitivity Coefficients

```
C*****************************************************************
C                      REVISED 05/12/76                          -
C                                                                -
CF          SENPRO                                               -
CF          THIS FILE CONTAINS SENSITIVITY                       -
CF          COEFFICIENTS BY GROUP AS A FUNCTION OF               -
CF          MATERIAL - REACTION TYPE, ASSEMBLY, AND RESPONSE     -
C                                                                -
CF                DIVISION BY GROUP LETHARGY WIDTHS MAY BE       -
CF                NECESSARY FOR MEANINGFUL GRAPHIC DISPLAY.      -
CF                INCLUDED ARE, TOTAL SENSITIVITY COEFFICIENTS   -
CF                BY GROUP SUMMED OVER EFFECT TYPES, ZONES, AND
CF                SCATTERING ORDERS. ON OPTION, PARTIAL          -
CF                COEFFICIENTS MAY ALSO BE REPRESENTED AS VARIOUS -
CF                COMBINATIONS OF DIRECT AND INDIRECT EFFECT,    -
CF                ZONE, AND SCATTERING ORDER                     -
C                                                                -
CF             A FILE SUCH AS THIS IS NEEDED BY ORNL - FORSS     -
C                                                                -
C                                                  J. L. LUCIUS  -
C                                                                -
C                                                                -
C*****************************************************************


C-----------------------------------------------------------------
CS          FILE STRUCTURE                                       -
CS                                                               -
CS             RECORD TYPE                          PRESENT IF   -
CS             ****************************         **********   -
CS             FILE IDENTIFICATION                  ALWAYS       -
CS             FILE CONTROL                         ALWAYS       -
CS             NEUTRON GROUP BOUNDARIES             NNGROP.GT.0  -
CS             GAMMA GROUP BOUNDARIES               NGGROP.GT.0  -
CS   ************(REPEAT FOR ALL MATERIAL -                     -
CS   *             REACTION PAIRS, MAT - MT)                   -
CS   *         MAT - MT CONTROL                     ALWAYS       -
CS   *         RESPONSE DESCRIPTION                 NRRO.GT.0    -
CS   *         ZONE DENSITIES                       NZDEN.GT.0   -
CS   *         HOLLERITH DESCRIPTION OF TOTAL       ALWAYS       -
CS   *         SENSITIVITY COEFFICIENTS                          -
CS   *         TOTAL SENSITIVITY COEFFICIENTS       ALWAYS       -
CS   *         BY GROUP SUMMED OVER, TYPE, ZONE,                 -
CS   *         AND SCATTERING ORDER                              -
CS   *         PARTIAL CONTROL                      NPART.GT.0   -
CS   *  ***********(REPEAT FOR ALL PARTIAL                       -
CS   *  *            COEFFICIENT SETS)                          -
CS   *  *       HOLLERITH DESCRIPTION OF           NPART.GT.0   -
CS   *  *       PARTIAL SET                                     -
CS   *  *       PARTIAL COEFFICIENTS BY GROUP      NPARL.GT.0   -
CS   ************                                               -
C                                                                -
C-----------------------------------------------------------------


C-----------------------------------------------------------------
CF          FILE IDENTIFICATION                                  -
C                                                                -
CF     HNAME,(HUSE(I),I=1,2),ITERS                               -
CF     1,3*HOLT                                                  -
C                                                                -
CF     FORMAT(11H SENPRO , A6, 1H*, 2A6, 1H*, I6)                -
CD     HNAME          HOLLERITH FILE NAME-SENPRO- (A6)          -
CD     HUSE           HOLLERITH USER IDENTIFICATION (A6)        -
CD     ITERS          FILE VERSION NUMBER                       -
CD     HOLT           1 - A6 IS SINGLE PRECISION WORD           -
CD                    2 - A6 IS DOUBLE PRECISION WORD           -
C-----------------------------------------------------------------
```

```
C-----------------------------------------------------------------------
CA          FILE CONTROL                                               -
C                                                                      -
CL    NGROUP,NNGRP,NGGRP,NMAT,MAXORD,NZONE                             -
C                                                                      -
CM    6                                                                -
C                                                                      -
CB    FORMAT(4H ID ,6I5)                                               -
CD    NGROUP      NUMBER OF ENERGY GROUPS                              -
CD    NNGRP       NUMBER OF NEUTRON GROUPS                             -
CD    NGGRP       NUMBER OF GAMMA GROUPS                               -
CD    NMAT        NUMBER OF MAT- MT PAIRS                              -
CD    MAXORD      MAXIMUM SCATTERING ORDER                             -
CD    NZONE       MAXIMUM NUMBER OF ZONES                              -
C-----------------------------------------------------------------------


C-----------------------------------------------------------------------
CA          NEUTRON GROUP BOUNDARIES                                   -
C                                                                      -
CL    (GPBN(J),J=1,NNGRP),ENMIN                                        -
C                                                                      -
CC          PRESENT IF NNGRP.GT.0                                      -
CM    NNGRP+1                                                          -
C                                                                      -
CB    FORMAT(4H 2D ,5E12.4/(5E12.4))                                   -
CD    GPBN(J)     MAXIMUM ENERGY BOUND OF NEUTRON GROUP(J) (E7)        -
CD    ENMIN       MINIMUM ENERGY OF NEUTRON ENERGY RANGE               -
C-----------------------------------------------------------------------


C-----------------------------------------------------------------------
CA          GAMMA GROUP BOUNDARIES                                     -
C                                                                      -
CL    (GPBG(J),J=1,NGGRP),EGMIN                                        -
C                                                                      -
CC          PRESENT IF NGGRP.GT.0                                      -
CM    NGGRP+1                                                          -
C                                                                      -
CB    FORMAT(4H 3D ,5E12.4/(5E12.4))                                   -
CD    GPBG(J)     MAXIMUM ENERGY BOUND OF GAMMA GROUP(J)  (E7)         -
CD    EGMIN       MINIMUM ENERGY OF GAMMA ENERGY RANGE                 -
C-----------------------------------------------------------------------


C-----------------------------------------------------------------------
CA          MAT - MT CONTROL                                           -
C                                                                      -
CL    IASB,IRESP,MATID,MT,NZONE,ISTC,NPART,NWRD,NZDEN,MATRIX,NTRM,NTRD -
CM    12                                                               -
C                                                                      -
CB    FORMAT(4H 4D ,11I6/I6)                                           -
C                                                                      -
CD    IASB        ASSEMBLY IDENTIFICATION                            -
CD                     REFERENCE BNL 19302(ENDF-201)                   -
CD    IRESP       RESPONSE IDENTIFICATION                            -
CD                     1 - K                                           -
CD                     2 - BREEDING RATIO                              -
CD                     3 - WORTH                                       -
CD                     4 - REACTION RATE RATIO                         -
CD                     5 - OTHER                                       -
CD    MATID       MATERIAL IDENTIFICATION                            -
CD    MT          REACTION TYPE IDENTIFICATION                       -
CD    NZONE       NUMBER OF ZONES                                    -
CD    ISTC        SCATTERING ORDER FOR TOTAL CROSS SECTION           -
CD    NPART       NUMBER OF PARTIAL SETS                             -
CD    NWRD        NUMBER OF HOLLERITH(A6) WORDS USED TO DESCRIBE     -
CD                THE RESPONSE                                       -
CD    NZDEN       ZONE DENSITY OPTION                                -
CD                     0 - ZONE DENSITIES ARE OMITTED                -
CD                     1 - ZONE DENSITIES ARE PRESENT                -
CD    MATRIX      RESERVED                                           -
CD    NTRM        RESERVED                                           -
CD    NTRD        RESERVED                                           -
C-----------------------------------------------------------------------
```

```
C-----------------------------------------------------------------------
CR          RESPONSE DESCRIPTION                                       -
C                                                                      -
CL    (RDES(I),I=1,NWRD)                                               -
C                                                                      -
CC          PRESENT IF NWRD.GT.0                                       -
C                                                                      -
CW    NWRD*HOLT                                                        -
C                                                                      -
CB    FORMAT(4H 5D ,1H*,11A6/(11A6))                                   -
C                                                                      -
CD    RDES(I)       ARRAY CONTAINING HOLLERITH DESCRIPTION OF          -
CD                  RESPONSE                                           -
C-----------------------------------------------------------------------

C-----------------------------------------------------------------------
CR          ZONE DENSITIES                                             -
C                                                                      -
CL    (ZDEN(J),J=1,NZONE)                                              -
C                                                                      -
CC          PRESENT IF NZDEN.EQ.1                                      -
C                                                                      -
CW    NZONE                                                            -
C                                                                      -
CB    FORMAT(4H 6D ,5E12.4/(6E12.4))                                   -
C                                                                      -
CD    ZDEN          ZONE DENSITIES                                     -
C-----------------------------------------------------------------------

C-----------------------------------------------------------------------
CR          HOLLERITH DESCRIPTION OF TOTAL SENSITIVITY COEFFICIENTS    -
C                                                                      -
CL    (HOL(I),I=1,11)                                                  -
C                                                                      -
CW    11*HOLT                                                          -
C                                                                      -
CF    FORMAT(4H 7D ,1H*,11A6,1H*)                                      -
C-----------------------------------------------------------------------

C-----------------------------------------------------------------------
CR          TOTAL SENSITIVITY COEFFICIENTS BY GROUP                    -
C                                                                      -
CL    (TOTS(J),J=1,NGROUP)                                             -
C                                                                      -
CW    NGROUP                                                           -
C                                                                      -
CB    FORMAT(4H 8D ,5E12.4/(5E12.4))                                   -
C                                                                      -
CD    TOTS          SENSITIVITY COEFFICIENTS                           -
C-----------------------------------------------------------------------
```

```
C-----------------------------------------------------------------------
CR          PARTIAL CONTROL                                           -
C                                                                     -
CL    (ITYPE(I),IZONE1(I),IZONE2(I),ISCAT(I),I=1,NPART)               -
C                                                                     -
CC          PRESENT IF NPART.GT.0                                     -
C                                                                     -
CW    4*NPART                                                         -
C                                                                     -
CD    FORMAT(4X 9D  4I6/(4I6))                                        -
C                                                                     -
CD  / ITYPE(I)      TYPE IDENTIFICATION                               -
CD                        1 - H1 DIRECT EFFECT(H1DE)                  -
CD                        2 - H2 DIRECT EFFECT(H2DE)                  -
CD                        3 - FORWARD FLUX PERTURBATIONS(FFP)         -
CD                        4 - ADJOINT FLUX PERTURBATIONS(AFP)         -
CD                        5 - H1DE+H2DE+FFP                           -
CD                        6 - H1DE+H2DE+FFP+AFP                       -
CD  / IZONE1(I)     LOWER DO LIMITER FOR ZONE SUMMATIONS              -
CD    IZONE2(I)     UPPER DO LIMITER FOR ZONE SUMMATIONS              -
CD  / ISCAT(I)      SCATTERING ORDER SPECIFICATION                    -
CD                        LE.ISTC   - SCATTERING ORDER                -
CD                        GT.ISTC   - SUM OVER ALL SCATTERING ORDERS  -
C-----------------------------------------------------------------------
```

```
C-----------------------------------------------------------------------
CR          HOLLERITH DESCRIPTION OF PARTIAL SET                      -
C                                                                     -
CL    (HOLP(I),I=1,11)                                                -
C                                                                     -
CC          PRESENT IF NPART.GT.0                                     -
C                                                                     -
CW    11*HOLT                                                         -
C                                                                     -
CD    FORMAT(4H10D  ,1H*,11A6,1H*)                                    -
C-----------------------------------------------------------------------
```

```
C-----------------------------------------------------------------------
CR          PARTIAL SENSITIVITY COEFFICIENTS BY GROUP                 -
C                                                                     -
CL    (PARTS(J),J=1,NGROUP)                                           -
C                                                                     -
CC          PRESENT IF NPART.GT.0                                     -
C                                                                     -
CW    NGROUP                                                          -
C                                                                     -
CD    FORMAT(4H11D  ,5E12.6/(6E12.6))                                 -
C                                                                     -
CD    PARTS         SENSITIVITY COEFFICIENTS                          -
C-----------------------------------------------------------------------
```

CHAPTER IX. SENDIN AND SENTINEL: TWO COMPUTER CODES TO ASSESS THE EFFECTS OF NUCLEAR DATA CHANGES*

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C. R. Weisbin

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SENDIN AND SENTINEL: TWO COMPUTER CODES TO ASSESS THE EFFECTS OF NUCLEAR DATA CHANGES

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ABSTRACT

A description is given of the computer code SENTINEL, which provides a simple means for finding the effects on calculated reactor and shielding performance parameters due to proposed changes in the cross section data base. This code uses predetermined detailed sensitivity coefficients in SENPRO format, which is described in Appendix A. Knowledge of details of the particular reactor and/or shielding assemblies is not required of the user. Also described is the computer code SENDIN, which converts unformatted (binary) sensitivity files to card image form and vice versa. This is useful for transferring sensitivity files from one installation to another.

INTRODUCTION

Sensitivity coefficients for performance parameters of reactor and shielding systems,[1] especially benchmarks, have been collected in an interface file[2] using the SENPRO format. This format was developed according to the standards established by the Committee on Computer Codes Coordination (CCCC).[3] The description of the SENPRO format is given in Appendix A.

In order to use the sensitivity data on a file, it is necessary to have codes which can read such files as well as to perform the required computational manipulations. Such files are ordinarily unformatted (binary) for computational efficiency, but are not easily read on a different type of computer. To facilitate the transfer of data from one installation to another, the data are converted to card image form. This requires a code which can translate a binary file to card image form and vice versa.

This report documents two codes. The first, SENDIN, is useful for converting a sensitivity file from binary to card image, for converting from card image to binary, and for obtaining a printed listing of a sensitivity file. The second, SENTINEL, calculates the percent change in a specified response due to given percent changes in specified reaction cross sections over specified energy regions. An edited list of the most significant individual contributions to the response change is also given.

SENDIN

The program SENDIN copies a sensitivity file in SENPRO format, and in the copying process changes the file representation from binary to card image form or vice versa. In addition, a complete listing or a partial listing of the file is printed to give the user accurate information about the contents of a particular file.

There are two (2) input files:

(1) The SENPRO sensitivity file to be converted and which is specified by the FORTRAN data-set reference number NIN (default value 20).

(2) The control file which consists of a single card (card image) and which is specified by FORTRAN data-set reference number 5. This card consists of four integers in (4I5) format: NBE, NIN, NØUT, NØ6.

NBE = 0 conversion is binary to card image.

≠ 0 conversion is card image to binary.

NIN = FORTRAN data-set reference number of the input sensitivity file to be converted (a zero or negative value is replaced by the default value of 20).

NØUT = FORTRAN data-set reference number of the converted output file of sensitivities (a zero or negative value is replaced by a default value of 21).

NØ6 specifies the printer output FORTRAN data-set reference number and the type of edit – complete or reduced (a zero value of NØ6 is replaced by the default value of -6).

NØ6 > 0 an edit of the entire file is formed on the unit with FORTRAN data-set reference number NØ6.

NØ6 < 0 a reduced edit of the file is formed on the unit with FORTRAN data-set reference number -NØ6.

There are two output files (both referred to above):

(1) The converted sensitivity file with data-set reference number NØUT (default value 21).

(2) The file of printer output with data-set reference number specified by NØ6 (default value 6).

Sample Problem for SENDIN:

The input on unit 5 consists of a single blank card. Unit 20 contains the binary SENPRO file. On unit 21 is a dummy file.

```
//GØ.FT20F001 DD DSN= etc., UNIT= etc.
//GØ.FT21F001 DD DUMMY
//GØ.FT05F001 DD *
     (1 blank card)
/*
```

The blank card could be replaced by the following:

```
     0   20   21   -6
```

with the same result.

The printer output on unit 6 produces a reduced edit of the SENPRO file on unit 20.

SENTINEL

The program SENTINEL computes the percentage (or fractional) change in the performance parameter of a given assembly due to specified percentage (or fractional) changes in designated reaction cross sections over a number of energy regions.

The input data consists of:

(1) Parameters defining the performance parameter, the reactor or assembly, the number N of such sensitivities to be included, and the identification for these so that they may be selected from the sensitivity file which is in SENPRO format.

(2) The number of energy regions KMAX and the energy bounds for each such region.

(3) The percentage (or fractional) change in nuclear data for each of the N reactions for which a sensitivity is specified by (1) above, and over each of the KMAX energy regions specified in (2).

(4) Certain information specifying the printer output data-set reference number (default value 6), and the SENPRO sensitivity file data-set reference number (default value 10).

(5) Information limiting the printout of the most important individual contributions to the resulting change in the performance parameter.

(6) The binary sensitivity file in SENPRO format.

The output consists of:

(1) The input information.

(2) Information selected from the sensitivity file.

(3) The resulting value of the percentage (or fractional) change in the performance parameter.

(4) An ordered list of the most important individual contributions to the change.

Specifically, the input to SENTINEL for one case consists of one card of six numbers and three arrays entered in FIDO system format. The FIDO system is described in Appendix B. Several stacked cases can be calculated in one run. The following input is required for each case:

one card (format 2I5, F10, 3I5):	N,KMAX,PERCNT,NUMB,LUNIT,IØUT
array of energy regions:	1** ((EHI(K),ELØ(K)),K=1,KMAX)
percent changes:	3** ((PRCENT(K,N1),K=1,KMAX),N1=1,N)
sensitivity identifiers:	5$$ ((INFØ(I,N1),I=1,9),N1=1,N)
FIDØ terminator:	T

N = the number of sensitivity profiles to be included.

KMAX = the number of energy regions to be included.

PERCNT = the minimum magnitude (in percent of the total contribution) of a single (one energy region and one reaction) contribution to be included in a printout of the most important individual contributions.

NUMB = the maximum number of most important contributions to be printed out individually.

LUNIT = the data set reference number of the sensitivity file in SENPRO format (default value = 10).

IØUT = printer output data-set reference number (default value = 6).

EHI(K) = an energy bound in eV for energy region K (the regions should appear in order of decreasing energy).

ELØ(K) = the other bound for region K.

PRCENT(K,N1) = the percent change in nuclear data associated with sensitivity N1 in energy region K.

INFØ (I,N1) I=1,9 consists of nine identifiers for the sensitivity profile N1. The nine identifiers in order are:

IASB = the assembly identifier as it appears in the file, or, if the first IASB (=INFØ(1,1)) is negative, cases are made to include every assembly in the file.

IRESP = 1,2,3,4,5 according as the response is multiplication factor k, breeding ratio, worth, reaction rate ratio, or some other type of response, respectively; or, if the first IRESP (=INFØ(2,1)) is negative, cases are made to include all responses.

MATID = nuclide identification using ENDF assignments.

MT = reaction identification using ENDF assignments.

NTRN = 1,2,3,... an arbitrary identification number chosen by the file creator to distinguish different reaction rate or worth responses (0 for IRESP=1).

ITYPE, IZØN1, IZØN2, ISCAT refer to partial sensitivities and are set to zero since no partial sensitivities are presently used.

Sample Problem for SENTINEL:

This problem determines the effect of proposed changes in the fission cross section (MT number 18) of ^{235}U, ^{238}U, and ^{239}Pu (MAT numbers 1261, 1262, and 1264 respectively) on the multiplication factor (IRESP=1 and NTRN=0) of each assembly in the file (five), and on the central reaction rate ratio $^{28}c/^{49}f$ (IRESP=4 and NTRN=1), and on the central reaction rate ratio $^{28}f/^{49}f$ (IRESP=4 and NTRN=2) of the ZPR-6/7 assembly. (IASB=5 is the number assigned this assembly in the SENPRO file reported in Ref. 2.) The proposed changes represent approximate changes in going from ENDF/B-IV to ENDF/B-V. These changes are given in five groups as follows:

Energy Range (MeV)	Change in σ_f^{25} (percent)	Change in σ_f^{28} (percent)	Change in σ_f^{49} (percent
3.679-10.000	1.44	-2.50	-1.07
1.353-3.679	-0.24	-3.50	0.83
.498-1.353	-2.57	12.00	1.02
.183- .498	-3.32	0.00	-0.30
.067- .183	-2.13	0.00	-2.13

This sample problem uses the fast benchmarks for which sensitivities are reported in reference 2. We assume these sensitivities are available in binary SENPRO format on a unit with data-set reference number 10.

The input can be stacked as three cases. The first searches through all the assemblies in the file (since INFO(1,1) is negative) and manufactures a case for each assembly found. For these we limit to ten (NUMB = 10) the number of individual largest contributions to be printed out, regardless of magnitude.

The second of the three input cases finds the change in the central reaction-rate ratio $^{28}c/^{49}f$ in ZPR-6/7 and prints out the largest individual contributions, each of which is not less than one percent (PERCNT = 1.0) of the total calculated change. Not more than five such contributions will be printed out.

The third input case calculates the resulting change in the $^{28}c/^{49}f$ ratio in ZPR-6/7 and prints out (not more than six) individual contributions greater than four percent of the total.

The input data files are as follows:

```
//GØ.FT10F001 DD DSN=etc.,UNIT=VØL= etc.
//GØ.FT05F001 DD *
    3    5       0.0   10
1** 3.679E6 10.0E6 1.353E6 3.679E6 0.498E6 1.353E6
    0.498E6 2RO.183E6 0.067E6
3** 1.44 -.24 -2.57 -3.32 -2.13
    -2.50 -3.50 12.00 2Z
    -1.07 0.83 1.02 -0.0 -2.13
5$$ -12 1 1261 18 5RO 12 1 1262 18 5RO 12 1 1264
    18 5RO T
    3    5     1.0      5
5$$ 12 4 1261 18 1 4RO 12 4 1262 18 1 4RO
    12 4 1264 18 1 4RO T
    3    5     4.0      6
5$$ 12 4 1261 18 2 4TO 12 4 1262 18 2 4Z
    12 4 1264 18 2 4RO T
```

The output prints a warning message to note whenever a sensitivity is missing in the file and, hence, is not included in the calculation. Note that since the dimensions N and KMAX are constant the order of the reactions (MAT-MT pairs) remains fixed and that the energy regions (1** array) and the assigned percentages (3** array) remain fixed in storage location as well as in value. Therefore, the FIDO 1** and 3** arrays need not be read in again after the first case.

REFERENCES

1. C. R. Weisbin, J. H. Marable, J. L. Lucius, E. M. Oblow, F. R. Mynatt, R. W. Peelle, and F. G. Perey, "Application of FORSS Sensitivity and Uncertainty Methodology to Fast Reactor Benchmark Analysis," ORNL/TM-5563 (1976).

2. J. H. Marable, J. L. Lucius, and C. R. Weisbin, "Compilation of Sensitivity Profiles for Several CSEWG Fast Reactor Benchmarks," Oak Ridge National Laboratory report ORNL-5262 (ENDF-234) (March 1977).

3. B. M. Carmichael, "Standard Interface Files and Procedures for Reactor Physics Codes, Version III," Los Alamos Scientific Laboratory report LA-5486-MS (February 1974).

APPENDIX A

The Format for Standard Interface File SENPRO for Group-Dependent Sensitivity Coefficients

```
C*************************************************************************
C                        REVISED 05/12/76                                 -
C                                                                         -
CP          SENPRO                                                        -
CE          THIS FILE CONTAINS SENSITIVITY                                -
CE          COEFFICIENTS BY GROUP AS A FUNCTION OF                        -
CE          MATERIAL - REACTION TYPE, ASSEMBLY, AND RESPONSE              -
C                                                                         -
CM                 DIVISION BY GROUP LETHARGY WIDTHS MAY BE               -
CM                 NECESSARY FOR MEANINGFUL GRAPHIC DISPLAY.              -
CE                 INCLUDED ARE, TOTAL SENSITIVITY COEFFICIENTS           -
CM                 BY GROUP SUMMED OVER EFFECT TYPES, ZONES, AND          -
CM                 SCATTERING ORDERS. ON OPTION, PARTIAL                  -
CM                 COEFFICIENTS MAY ALSO BE REPRESENTED AS VARIOUS        -
CM                 COMBINATIONS OF DIRECT AND INDIRECT EFFECT,            -
CM                 ZONE, AND SCATTERING ORDER                             -
C                                                                         -
CE              A FILE SUCH AS THIS IS NEEDED BY ORNL - FORSS             -
C                                                                         -
C                                                  J. L. LUCIUS           -
C                                                                         -
C                                                                         -
C*************************************************************************


C-------------------------------------------------------------------------
CS          FILE STRUCTURE                                                -
CS                                                                        -
CS             RECORD TYPE                          PRESENT IF            -
CS             ===========                          ==========            -
CS             FILE IDENTIFICATION                  ALWAYS                -
CS             FILE CONTROL                         ALWAYS                -
CS             NEUTRON GROUP BOUNDARIES             NNGRUP.GT.0           -
CS             GAMMA GROUP BOUNDARIES               NGGRUP.GT.0           -
CS   **********(REPEAT FOR ALL MATERIAL -                                 -
CS   *             REACTION PAIRS, MAT - MT)                              -
CS   *         MAT - MT CONTROL                     ALWAYS                -
CS   *         RESPONSE DESCRIPTION                 NWRD.GT.0             -
CS   *         ZONE DENSITIES                       NZDEN.GT.0            -
CS   *         HOLLERITH DESCRIPTION OF TOTAL       ALWAYS                -
CS   *         SENSITIVITY COEFFICIENTS                                   -
CS   *         TOTAL SENSITIVITY COEFFICIENTS       ALWAYS                -
CS   *         BY GROUP SUMMED OVER, TYPE, ZONE,                          -
CS   *         AND SCATTERING ORDER                                       -
CS   *         PARTIAL CONTROL                      NPART.GT.0            -
CS   *  *******(REPEAT FOR ALL PARTIAL                                    -
CS   *  *          COEFFICIENT SETS)                                       -
CS   *  *      HOLLERITH DESCRIPTION OF             NPART.GT.0            -
CS   *  *      PARTIAL SET                                                -
CS   *  *      PARTIAL COEFFICIENTS BY GROUP        NPART.GT.0            -
CS   **************                                                       -
C                                                                         -
C-------------------------------------------------------------------------


C-------------------------------------------------------------------------
CR          FILE IDENTIFICATION                                           -
C                                                                         -
CL     HNAME,(HUSE(I),I=1,2),IVERS                                        -
CM     1+3*NOLT                                                           -
C                                                                         -
C8     FORMAT(11H OF SENPRO ,A6,1H*,2A6,1H*,I6)                           -
CD     HNAME          HOLLERITH FILE NAME-SENPRO- (A6)                    -
CD     HUSE           HOLLERITH USER IDENTIFICATION (A6)                  -
CD     IVERS          FILE VERSION NUMBER                                 -
CD     NOLT           1 - A6 IS SINGLE PRECISION WORD                     -
CD                    2 - A6 IS DOUBLE PRECISION WORD                     -
C-------------------------------------------------------------------------
```

```
C-----------------------------------------------------------------------
CR          FILE CONTROL                                               -
C                                                                      -
CL    NGROUP,NNGRP,NGGRP,NMAT,MAXORD,NZONE                             -
C                                                                      -
CW    6                                                                -
C                                                                      -
CB    FORMAT(6I 10 ,6I6)                                               -
CD    NGROUP        NUMBER OF ENERGY GROUPS                            -
CD    NNGRP         NUMBER OF NEUTRON GROUPS                           -
CD    NGGRP         NUMBER OF GAMMA GROUPS                             -
CD    NMAT          NUMBER OF MAT- MT PAIRS                            -
CD    MAXORD        MAXIMUM SCATTERING ORDER                           -
CD    NZONE         MAXIMUM NUMBER OF ZONES                            -
C-----------------------------------------------------------------------

C-----------------------------------------------------------------------
CR          NEUTRON GROUP BOUNDARIES                                   -
C                                                                      -
CL    (UPBN(J),J=1,NNGRP),ENMIN                                        -
C                                                                      -
CC          PRESENT IF NNGRP.GT.0                                      -
CW    NNGRP+1                                                          -
C                                                                      -
CB    FORMAT(6H 2D ,5E12.8/(6E12.8))                                   -
CD    UPBN(J)       MAXIMUM ENERGY BOUND OF NEUTRON GROUP(J) (EV)      -
CD    ENMIN         MINIMUM ENERGY OF NEUTRON ENERGY RANGE             -
C-----------------------------------------------------------------------

C-----------------------------------------------------------------------
CR          GAMMA GROUP BOUNDARIES                                     -
C                                                                      -
CL    (GPBG(J),J=1,NGGRP),EGMIN                                        -
C                                                                      -
CC          PRESENT IF NGGRP.GT.0                                      -
CW    NGGRP+1                                                          -
C                                                                      -
CB    FORMAT(6H 3D ,5E12.8/(6E12.8))                                   -
CD    GPBG(J)       MAXIMUM ENERGY BOUND OF GAMMA GROUP(J) (EV)        -
CD    EGMIN         MINIMUM ENERGY OF GAMMA ENERGY RANGE               -
C-----------------------------------------------------------------------

C-----------------------------------------------------------------------
CR          MAT - MT CONTROL                                           -
C                                                                      -
CL    IASB,IRESP,MATID,MT,NZONE,ISTC,NPART,NWRD,NZDEN,MATRIX,NTRM,NTRD -
CW    12                                                               -
C                                                                      -
CB    FORMAT(6H 4D ,11I6/I6)                                           -
C                                                                      -
CD    IASB          ASSEMBLY IDENTIFICATION                            -
CD                        REFERENCE BNL 19302(ENDF-202) P-1            -
CD    IRESP         RESPONSE IDENTIFICATION                            -
CD                        1 - K                                        -
CD                        2 - BREEDING RATIO                           -
CD                        3 - WORTH                                    -
CD                        4 - REACTION RATE RATIO                      -
CD                        5 - OTHER                                    -
CD    MATID         MATERIAL IDENTIFICATION                            -
CD    MT            REACTION TYPE IDENTIFICATION                       -
CD    NZONE         NUMBER OF ZONES                                    -
CD    ISTC          SCATTERING ORDER FOR TOTAL COEFFICIENTS            -
CD    NPART         NUMBER OF PARTIAL SETS                             -
CD    NWRD          NUMBER OF HOLLERITH(A6) WORDS USED TO DESCRIBE     -
CD                  THE RESPONSE                                       -
CD    NZDEN         ZONE DENSITY OPTION                                -
CD                        0 - ZONE DENSITIES ARE OMITTED               -
CD                        1 - ZONE DENSITIES ARE PRESENT               -
CD    MATRIX        RESERVED                                           -
CD    NTRM          RESERVED                                           -
CD    NTRD          RESERVED                                           -
C-----------------------------------------------------------------------
```

```
C-----------------------------------------------------------------------
CB          RESPONSE DESCRIPTION                                      -
C                                                                     -
CL    (RDES(I),I=1,NRRD)                                              -
C                                                                     -
CC          PRESENT IF NRRD.GT.0                                      -
C                                                                     -
CW    NRRD*NWLT                                                       -
C                                                                     -
CB    FORMAT(8H 5D ,1H',11A6/(11A6))                                  -
C                                                                     -
CD    RDES(I)       ARRAY CONTAINING HOLLERITH DESCRIPTION OF         -
CD                  RESPONSE                                          -
C-----------------------------------------------------------------------

C-----------------------------------------------------------------------
CB          ZONE DENSITIES                                            -
C                                                                     -
CL    (ZDEN(J),J=1,NZONE)                                             -
C                                                                     -
CC          PRESENT IF NZDEN.EQ.1                                     -
C                                                                     -
CW    NZONE                                                           -
C                                                                     -
CB    FORMAT(8H 6D ,5E12.4/(6E12.4))                                  -
C                                                                     -
CD    ZDEN          ZONE DENSITIES                                    -
C-----------------------------------------------------------------------

C-----------------------------------------------------------------------
CB          HOLLERITH DESCRIPTION OF TOTAL SENSITIVITY COEFFICIENTS   -
C                                                                     -
CL    (HOL(I),I=1,11)                                                 -
C                                                                     -
CW    11*NWLT                                                         -
C                                                                     -
CB    FORMAT(8H 7D ,1H',11A6,1H')                                     -
C-----------------------------------------------------------------------

C-----------------------------------------------------------------------
CB          TOTAL SENSITIVITY COEFFICIENTS BY GROUP                   -
C                                                                     -
CL    (TOTS(J),J=1,NGROUP)                                            -
C                                                                     -
CW    NGROUP                                                          -
C                                                                     -
CB    FORMAT(8H 9D ,5E12.4/(6E12.4))                                  -
C                                                                     -
CD    TOTS          SENSITIVITY COEFFICIENTS                          -
C-----------------------------------------------------------------------
```

```
C-----------------------------------------------------------------------
CR          PARTIAL CONTROL                                            -
C                                                                      -
CL    (ITYPE(I),IZON1(I),IZON2(I),ISCAT(I),I=1,NPART)                  -
C                                                                      -
CC          PRESENT IF NPART.GT.0                                      -
C                                                                      -
CW    4*NPART                                                          -
C                                                                      -
CB    FORMAT(8H 9D ,8I6/(8I6))                                         -
C                                                                      -
CD    ITYPE(I)      TYPE IDENTIFICATION                                -
CD                        1 - N1 DIRECT EFFECT(N1DE)                   -
CD                        2 - N2 DIRECT EFFECT(N2DE)                   -
CD                        3 - FORWARD FLUX PERTURBATION(FPP)           -
CD                        4 - ADJOINT FLUX PERTURBATION(APP)           -
CD                        5 - N1DE+N2DE+FPP                            -
CD                        6 - N1DE+N2DE+FPP+APP                        -
CD    IZON1(I)      LOWER DO LIMITER FOR ZONE SUMMATION                -
CD    IZON2(I)      UPPER DO LIMITER FOR ZONE SUMMATION                -
CD    ISCAT(I)      SCATTERING ORDER SPECIFICATION                     -
CD                        LE.ISTC   - SCATTERING ORDER                 -
CD                        GT.ISTC   - SUM OVER ALL SCATTERING ORDERS   -
C-----------------------------------------------------------------------


C-----------------------------------------------------------------------
CR          HOLLERITH DESCRIPTION OF PARTIAL SET                       -
C                                                                      -
CL    (HOLP(I),I=1,11)                                                 -
C                                                                      -
CC          PRESENT IF NPART.GT.0                                      -
C                                                                      -
CW    11*HOLT                                                          -
C                                                                      -
CB    FORMAT(8H10D ,1H*,11A6,1H*)                                      -
C-----------------------------------------------------------------------


C-----------------------------------------------------------------------
CR          PARTIAL SENSITIVITY COEFFICIENTS BY GROUP                  -
C                                                                      -
CL    (PARTS(J),J=1,NGROUP)                                            -
C                                                                      -
CC          PRESENT IF NPART.GT.0                                      -
C                                                                      -
CB    NGROUP                                                           -
C                                                                      -
CB    FORMAT(8H11D ,5E12.4/(6E12.4))                                   -
C                                                                      -
CD    PARTS         SENSITIVITY COEFFICIENTS                           -
C-----------------------------------------------------------------------
```

Blank

APPENDIX B

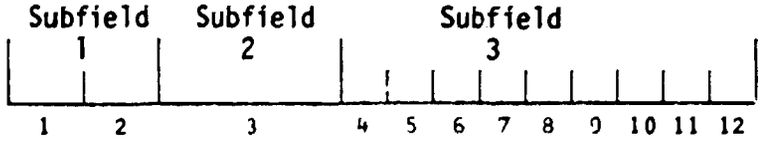
The FIDO Input System

The FIDO input method is especially devised to allow the entering or modifying of large data arrays with minimum effort. Special advantage is taken of patterns of repetition or symmetry wherever possible. The FIDO system was patterned by Ward Engle and Wayne Rhoades after the input method used with the FLOCO coding system at Los Alamos, and was first applied to the DTF-II code. Since that time, numerous features requested by users have been added, a free-field option has been developed, and the application of FIDO has spread to innumerable codes.

The data are entered in units called "arrays." An array comprises a group of contiguous storage locations which are to be filled with data at one time. These arrays usually correspond on a one-to-one basis with FORTRAN arrays used in the program. A group of one or more arrays read with a single call to the FIDO package forms a "block," and a special delimiter is required to signify the end of each block. Arrays within a block may be read in any order with respect to each other, but an array belonging to one block must not be shifted to another. The same array can be entered repeatedly within the same block. For example, an array could be filled with "0" using a special option, and then a few scattered locations could be changed by reading in a new set of data for that array. If no entries to the arrays in a block are required but the condition requiring the block is met, the delimiter alone satisfies the input requirement.

Three major types of input are available: fixed-field input, free-field input, and user-field input.

Fixed Field Input - Each card is divided into six 12-column data fields, each of which is divided into three subfields. The following sketch illustrates a typical data field. The three subfields always comprise 2, 1, and 9 columns, respectively.



To begin the first array of a block, an array originator field is placed in any field on a card:

Subfield 1: An integer array identifier < 100 specifying the data array to read

Subfield 2: An array-type indicator -
"$" if the array is integer data
"*" if the array is real data

Subfield 3: Blank

Data are then place in successive fields until the required number of entries has been accounted for. A sample data sheet shown on page 19 illustrates this input.

In entering data, it is convenient to think of an "index" or "pointer" which is under control of the user, and which specifies the position in the array into which the next data entry is to go. The pointer is always positioned at array location #1 by entering the array originator field. The pointer subsequently moves according to the data operator chosen. Blank fields are a special case, in that they do not cause any data modification and do not move the pointer.

A data field has the following form:

Subfield 1: The data numerator, an integer < 100. We refer to this entry as N_1 in the following discussion.

Subfield 2: One of the special data operators listed below.

Subfield 3: A nine-character data entry, to be read in F9.0 format. It will be converted to an integer if the array is a "$" array or if a special array operator such as "Q" is being used. Note that an exponent is permissible but not required. Likewise, a decimal is permissible but not required. If no decimal is supplied it is assumed to be immediately to the left of the exponent, if any; and otherwise to the right of the last column. This entry is referred to as N_3 in the following discussion.

Name General Example of Fido Input Charge Date Page

		IDENTIFICATION	REMARKS (DO NOT PUNCH)
1 1 $			Begin the 1$ array, fixed-field, integral
	1		Enter 1.
F	2		Fill array with 2.
2 *			Begin the 2* array, fixed-field, real.
	1.234	73 80	Enter 1.234.
	12.34 -1	10	" "
5 -	1234 +02		" "
3 -	1234		" "
	.7		" 7.0
			A blank field is always ignored.
T		73 80	Terminate this block.
		20	No entries may follow T on a card.
3 *			Begin 3* array, fixed-field real.
9 I	0		Enter 0,1,2,3,4,5,6,7,8,9,10,10,10.
3 R	10		as real numbers.
3 * *	10S10		Repeat 3* in free-field, skip
11 1	12	73 80	to 11th entry, correct sequence to
		30	----9,10,11,12.
4 * *	1I14.0		Begin 4* array, free-field, real.
2 Q 4			Enter 1,2,3,4, 1,2,3,4, 1,2,3,4.
	E		End reading this array; remainder of array unchanged.
	T		Terminate this block.
		73 80	
		40	

R - REPEAT I - INTERPOLATE S - SKIP T - TERMINATE

A list of data operators and their effect on the array being input follows:

"Blank" indicates a single entry of data. The data entry in the third subfield is entered in the location indicated by the pointer, and the pointer is advanced by one. However, an entirely blank field is ignored.

"+" or "-" indicates exponentiation. The data entry in the third field is entered and multiplied by $10^{\pm N_1}$, where N_1 is the data numerator in the first subfield, given the sign indicated by the data operator itself. The pointer is advanced by one. In cases where an exponent is needed, this option allows the entering of more significant figures than the blank option.

"&" has the same effect as "+".

"R" indicates that the data entry is to be repeated N_1 times. The pointer is advanced by N_1.

"I" indicates linear interpolation. The data numerator, N_1, indicates the number of interpolated points to be supplied. The data entry in the third subfield is entered, followed by N_1 interpolated entries equally spaced between that value and the data entry found in the third subfield of the next non-blank field. The pointer is advanced by $N_1 + 1$. The field following an "I" field is then processed normally, according to its own data operator. The "I" entry is especially valuable for specifying a spatial mesh. In "$" arrays, interpolated values will be rounded to the nearest integer.

"L" indicates logarithmic interpolation. The effect is the same as that of "I" except that the resulting data are evenly separated in log-space. This is especially convenient for specifying an energy mesh.

"Q" is used to repeat sequences of numbers. The length of the sequence is given by the third subfield, N_3. The sequence of N_3

entries is to be repeated N_1 times. The pointer is advanced by N_1*N_3. If either N_1 or N_3 is 0, then a sequence of $N_1 + N_3$ is repeated one time only, and the pointer is advanced by $N_1 + N_3$. This feature is especially valuable for geometry specification.

The "N" option has the same effect as "Q", except that the order of the sequence is reversed each time it is entered. This is valuable for the type of symmetry possessed by quadrature coefficients.

"M" has the same effect as "N" except that the sign of each entry in the sequence is reversed each time the sequence is entered. For example, the entries:

```
1 2 3 2M2
```

would be equivalent to:

```
1 2 3 -3 -2 2 3
```

This option is also useful in entering quadrature coefficients.

"Z" causes $N_1 + N_3$ locations to be set to 0. The pointer is advanced by $N_1 + N_3$.

"C" causes the position of the last array item entered to be printed. This is the position of the pointer, less 1. The pointer is not moved.

"O" causes the print trigger to be changed. The trigger is originally off. Successive "O" fields turn it on and off alternately. When the trigger is on, each card image is listed as it is read.

"S" indicates that the pointer is to skip N_1 positions leaving those array positions unchanged. If the third subfield is non-blank, that data entry is entered following the skip, and the pointer is advanced by $N_1 + 1$.

"A" moves the pointer to the position N_3, specified in the third subfield.

"F" fills the remainder of the array with the datum entered in the third subfield.

"E" skips over the remainder of the array. The array length criterion is always satisfied by an "E", no matter how many entries have been specified. No more entries to an array may be given following an "E", except that data entry may be restarted with an "A".

The reading of data to an array is terminated when a new array origin field is supplied, or when the block is terminated. If an incorrect number of positions has been filled, an error edit is given, and a flag is set which will later abort execution of the problem. FIDO then continues with the next array if an array origin was read. Otherwise, it returns control to the calling program.

A block termination consists of a field having "T" in the second sub-field. All entries following "T" on a card are ignored, and control is returned from FIDO to the calling program.

Comment cards can be entered within a block by placing an apostrophe (') in column 1. Then columns 2-80 will be listed, with column 2 being used for printer carriage control. Such cards have no effect on the data array or pointer.

Free-Field Input - With free-field input, data are written without fixed restrictions as to field and subfield size and positioning on the card. The options used with fixed-field input are available, although some are slightly restricted in form. In general, fewer data cards are required for a problem, the interpreting print is easier to read, a card listing is more intelligible, the cards are easier to keypunch, and certain common keypunch errors are tolerated without affecting the problem. Data arrays using fixed- and free-field input can be intermingled at will within a given block.

The concept of three subfields per field is still applicable to free-field input, but if no entry for a field is required, no space for it need be left. Only columns 1-72 may be used, as with fixed-field input.

The array originator field can begin in any position. The array identifiers and type indicators are used as in fixed-field input. The type indicator is entered twice, to designate free-field input (i.e., "$$" or "**"). The blank third subfield required in fixed-field input is not required. For example: 31** indicates that array 31, a real-data array, will follow in free-field format.

Data fields may follow the array origin field immediately. The data field entries are identical to the fixed-field entries with the following restrictions:

(1) Any number of blanks may separate fields, but at least one blank must follow a third subfield entry if one is used.
(2) If both first and second subfield entries are used, no blanks may separate them, i.e., 24S, but not 24 S.
(3) Numbers written with exponents must not have imbedded blanks, i.e., 1.0E+4, 1.0E4, 1.0+4, or even 1+4, but not 1.0 E4.
(4) In third-subfield data entries, only 9 digits, including the decimal but not including the exponent field, can be used, i.e., 123456.89E07, but not 123456.789E07.
(5) The Z entry must be of the form: 738Z, not Z738 or 738 Z.
(6) The + or - data operators are not needed and are not available.
(7) The Q, N, and M entries are restricted: 3Q4, 1N4, or M4, but not 4Q, 4N, or 4M.

User-Field Input - If the user follows the array identifier in the array originator field with the character "U" or "V", the input format is to be specified by the user. If "U" is specified, the FORTRAN FORMAT to be used must be supplied in columns 1-72 of the next card. The format must be enclosed by the usual parentheses. Then the data for the entire array must follow on successive cards. The rules of ordinary FORTRAN input as to exponents, blanks, etc., apply. If the array data do not fill the last card, the remainder must be left blank.

"V" has the same effect as "U" except that the format read in the last preceding "U" array is used.

CHAPTER X. COVER: AN
UNCERTAINTIES OF CALCU
STANDARD INTERFACE FILES-SE

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COVERT and CAVALIER: Two Computer Codes For Estimating Uncertainties of Calculated Neutronics Parameters Using Standard Interface Files SENPRO and COVERX

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ABSTRACT

A description is given of the computer code CAVALIER, which provides a simple means for estimating the uncertainties in calculated neutronics parameters that result from uncertainties in nuclear data. This code uses predetermined detailed multigroup sensitivity coefficients in SENPRO format for specific reactor and/or shielding assemblies and multigroup cross-section covariance uncertainties in COVERX format. Also described is the computer code COVERT, which converts unformatted (binary) covariance files to card image form and vice versa. This is useful for transferring covariance files from one installation to another. These two codes, along with extended compilations of sensitivity coefficients and covariance matrix libraries are currently available through the Radiation Shielding Information Center (RSIC) at Oak Ridge National Laboratory.

INTRODUCTION

The ORNL sensitivity and uncertainty analysis system (FORSS)[1] has been applied to several data-testing CSEWG benchmarks[2] in order to determine, for calculated performance parameters, the uncertainties which result from uncertainties in nuclear data. Interface files for multigroup sensitivity coefficients in SENPRO format[3] are used herein, as well as multigroup cross-section covariance interface files which use the COVERX format.[4] These formats were developed according to the standards established by the Committee on Computer Codes Coordination (CCCC).[5] The description of the COVERX format is given in Appendix A.

In order to use the covariance information from computerized data fi' 't is necessary to have codes which can read such files as well a to solve the pertinent algorithms. This report documents two su odes. The first, CAVALIER, is used to estimate the uncertainties in calculated neutronics parameters using sensitivity coefficients[6] in SENPRO format and covariance data in COVERX format. The second, COVERT, is useful for converting a covariance file from binary to card image (and vice versa), and for obtaining a printed edit of the nuclear data covariance file. This code is essential since COVERX unformatted (binary) data, for computational efficiency, are not easily read on different types of computers. To facilitate the transfer of data from one installation to another, COVERT can translate a binary file to card image form and vice versa.

CAVALIER

The program CAVALIER computes the relative standard deviations of calculated performance parameters of reactor systems. These standard deviations are assumed to result from specific nuclear data errors, the covariances of which are contained in a COVERX file. These nuclear data covariances are used with sensitivities in a SENPRO file to determine the standard deviation for response R by the following equation:

$$\left[(S.D.)^R\right]^2 = \sum_{\substack{i,j \\ g\ g'}} S^R_{g\,i}\ (cov)^{i,j}_{g\ g'}\ S^R_{g',j} \qquad (1)$$

where: S^R_{gi} is the relative sensitivity coefficient for response R to the cross section $\sigma_g{}^i$ of type i (denoting nuclide and reaction) in group g. This sensitivity is given by

$$S^R_{gi} = \frac{\sigma_g{}^i}{R}\ \frac{\partial R}{\partial \sigma_g{}^i} \qquad (2)$$

$(cov)^{i,j}_{g\ g'}$ is the relative covariance of cross sections $\sigma_g{}^i$ and $\sigma_{g'}{}^j$.

$(S.D.)^R$ is the standard deviation of response R resulting from the uncertainties included in the sum.

The input data consist of:

(1) Problem type specifications for labeling purposes.

(2) The number of parameter sets N. A set consists of nine identifiers describing a sensitivity profile and covariance matrix to be included in the calculation. Provisions are made for reporting results from searches on one or more of the above parameters as described below.

(3) The printer output data-set reference number (default value 6), the SENPRO sensitivity file data-set reference number (default value 10), and the COVERX covariance file data-set reference number (default value 11).

(4) The binary sensitivity file in SENPRO format.

(5) The binary covariance matrix file in COVERX format.

The output consists of:

(1) The input information.

(2) Problem type identification.

(3) Materials and reactions of interest which are selected from the covariance matrix file with associated warnings if a covariance is not found in the file.

(4) Assemblies and responses of interest which are selected from the sensitivity file with associated warnings if a sensitivity is not found in the file.

(5) The correlations included in the problem.

(6) The resulting relative standard deviation (%) for each of the calculated performance parameters of interest.

(7) The contributions from covariances in input cross section data to the output relative variance of the indicated response.

Specifically, the input to CAVALIER for one case consists of one card of 5 numbers and one array entered in FIDO system format. The FIDO system is described in Appendix B. Several stacked cases can be calculated in one run. The following input is required for each case:

one card (format 5I5):	NB, N, LUNIT, MUNIT, IOUT
sensitivity & covariance matrix identifiers:	5$$((INFO(I,J),I=1,9),J=1,N)
FIDO terminator:	T

NB = 1, 2, 3 according to problem type selection, fast reactor benchmark, shielding benchmark, or thermal reactor benchmark.

N = the number of parameter sets identifying the sensitivity profiles and the covariance matrices to be included.

LUNIT = the data-set reference number of the sensitivity file in SENPRO format (default value = 10).

MUNIT = the data set reference number of the covariance file in COVERX format (default value = 11).

IOUT = printer output data-set reference number (default value = 6).

INFO (I,J) I=1,9 J=1,N, consists of nine identifiers for the sensitivity profile J. The nine identifiers in order are:

IASB = the assembly identifier as it appears in the file or, if the first IASB (=INFO(1,1)) is negative, searches are made to include every assembly in the file. (Assembly identifiers were selected as reported in Ref. 2. Arbitrary numbers were chosen by the file creator in cases where assembly identification did not exist.)

IRESP = 1,2,3,4,5 according as the response is multiplication factor k, breeding ratio, worth, reaction rate ratio, or some other type of response. If the first IRESP (=INFO(2,1)) is negative, all responses are included by the search.

MATID = nuclide identification using ENDF assignments.

MT = reaction identification using ENDF assignments

NTRN = 1,2,3,... an identification number chosen by the file creator (presently arbitrary) to distinguish different reaction rate or worth responses (0 for IRESP=1).

ITYPE, IZON1, IZON2, ISCAT refer to partial sensitivities and are set to zero since no partial sensitivities are presently used.

Sample Problem for CAVALIER:

This problem determines the relative standard deviations in percent of the calculated response(s) due to estimated uncertainties in $^{238}U(n,f)$, $^{238}U(n,\gamma)$, $^{239}Pu(n,f)$, $^{239}Pu(n,\gamma)$, $^{239}Pu(\bar{\nu})$ including the correlation between $^{239}Pu(n,f)$ and the $^{239}Pu(n,\gamma)$ cross sections. The calculated responses for this sample are multiplication factor (IRESP=1 and NTRN=0), central reaction rate ratios $^{28}c/^{49}f$ (IRESP=4 and NTRN=1), and $^{28}f/^{49}f$ (IRESP=4 and NTRN=2) of the ZPR-6/7 assembly. (IASB=5 is the number assigned this assembly in the SENPRO file reported in Ref. 2.) The relative standard deviation for the three responses using CAVALIER are:

Assembly	Response	Standard Deviation (%)
ZPR-6/7	k	3.57
ZPR-6/7	$^{28}c/^{49}f$	8.86
ZPR-6/7	$^{28}f/^{49}f$	4.85

This sample problem uses the fast benchmarks for which sensitivities are reported in Ref. 3 and the covariance matrices from the LMFBR Core Physics Covariance Matrix Library.[4] We assume these sensitivities and covariances are available in binary SENPRO and COVERX formats and reside on units having data set reference numbers 10 and 11.

The input, as will be shown below, can be stacked as three cases. The first searches through all the responses in the SENPRO file (since INFO(2,1) is negative) and calculates a standard deviation for each response found. In this example the ZPR-6/7 assembly was specifically selected and five MAT-MT pairs were specifically identified.

The second of the three input cases finds the standard deviations for all assemblies (INFO(1,1) is negative) and all responses (INFO(2,1) is negative) in the file, but five nuclide and reaction types (MAT-MT pairs) were specifically identified.

The third input case calculates for all assemblies and responses in the SENPRO file, the standard deviations which result from errors in all nuclide reaction types residing in the COVERX file (N is negative).

The input data files are as follows:

```
//GO.FT10F001 DD DSN=etc.,UNIT=VOL=etc.
//GO.FT11F001 DD DSN=etc.,UNIT=VOL=etc.
    1    5
5$$
12 -1 1262 18 5R0 12 1 1262 102 5R0 12 1 1264 18 5R0
12 1 1264 102 5R0 12 1 1264 452 5R0 T
    1    5
5$$
-12 -1 1262 18 5R0 12 1 1262 102 5R0 12 1 1264 18 5R0
12 1 1264 102 5R0 12 1 1264 452 5R0 T
    1   -5
5$$
-12 -1 7R0 T
```

The output prints a warning message to note whenever a sensitivity or covariance is missing from the file, and these sensitivities and covariances are set to zero. Correlations, such as those between the $^{239}Pu(n,f)$ and the $^{239}Pu(n,\gamma)$ cross sections in the first example are automatically selected, included in the calculation, and flagged in the printer output.

COVERT

The program COVERT copies a covariance file in COVERX format, and in the copying process changes the file representation from binary to card image form or vice versa. In addition, a complete listing or a partial listing of the file is printed to give the user information about the contents of a particular file.

There are two (2) input files:

(1) The COVERX covariance file to be converted which is specified by the FORTRAN data-set reference number NIN (default value 20).

(2) The control file which consists of a single card (card image) which is specified by FORTRAN data-set reference number 5. This card consists of four integers in (4I5) format: NBE, NIN, NOUT, NO6.

NBE = 0 conversion is binary to card image.
≠ 0 conversion is card image to binary.

NIN = FORTRAN data-set reference number of the input covariance file to be converted (a zero or negative value is replaced by the default value of 20).

NOUT = FORTRAN data-set reference number of the converted output file of covariances (a zero or negative value is replaced by a default value of 21).

NO6 = specifies the printer output FORTRAN data-set reference number and the type of edit - complete or reduced (a zero value of NO6 is replaced by the default value of -6).

NO6 > 0 an edit of the entire file is formed on the unit with FORTRAN data-set reference number NO6.

NO6 < 0 a reduced edit of the file is formed on the unit with FORTRAN data-set reference number -NO6.

There are two output files (both referred to above):

(1) The converted covariance file with data-set reference number NOUT (default value 21).

(2) The file of printer output with data-set reference number specified by NO6 (default value 6).

Sample Problem for COVERT:

The input on unit 5 consists of a single blank card. Unit 20 contains the binary COVERX file. On unit 21 is a dummy file.

```
//GO.FT20F001 DD UNIT=3330,VOL=SER=ZX0000,DISP=SHR,
// DSN=JDD.COVERX.FICS.SPEC.V1.OCT2477
//GO.FT21F001 DD DUMMY
//GO.FT05F001 DD *
     (1 blank card)
 /*
```

The blank card could be replaced by the following:

```
0   20   21   -6
```

with the same result.

The printer output on unit 6 produces a reduced edit of the COVERX file on unit 20.

REFERENCES

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2. "Cross Section Evaluation Working Group Benchmark Specifications," BNL-19302 (ENDF-202) (November 1974).

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5. B. M. Carmichael, "Standard Interface Files and Procedures for Reactor Physics Codes, Version III," Los Alamos Scientific Laboratory report LA-5486-MS (February 1974).

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APPENDIX A

The Format for Standard Interface File COVERX for Multigroup Cross-Section Covariance Matrices

```
C*****************************************************************
C                        REVISED 11/01/77                        -
C                                                                -
CP          COVERX                                               -
CE          THIS FILE CONTAINS CROSS SECTIONS,                   -
CE          STANDARD DEVIATIONS, AND                             -
CE          BY DESIGNATION EITHER COVARIANCE,                    -
CE          RELATIVE COVARIANCE,                                 -
CE          OR CORRELATION MATRICES.                             -
C                                                                -
CE              A FILE SUCH AS THIS IS NEEDED BY ORNL - PORSS     -
C                                                                -
C                                                 J. L. LUCIUS   -
C                                                                -
C*****************************************************************


C----------------------------------------------------------------
CS          FILE STRUCTURE                                       -
CS                                                               -
CS             RECORD TYPE                      PRESENT IF       -
CS             ===========================      ==========       -
CS             FILE IDENTIFICATION              ALWAYS           -
CS             FILE CONTROL                     ALWAYS           -
CS             FILE DESCRIPTION                 NHOLL.GT.0       -
CS             NEUTRON GROUP BOUNDARIES         NNGRUP.GT.0      -
CS             GAMMA GROUP BOUNDARIES           NGGRUP.GT.0      -
CS             MAT - MT CONTROL                 ALWAYS           -
CS   **************(REPEAT FOR ALL MATERIAL-                     -
CS   *              REACTION TYPE PAIRS)                         -
CS   *          MAT-MT CROSS SECTION AND         ALWAYS          -
CS   *          STANDARD DEVIATIONS                              -
CS   **************                                              -
CS                                                               -
CS                                                               -
CS   **************(REPEAT FOR ALL MATRICES)                    -
CS   *          MATRIX CONTROL                   ALWAYS          -
CS   *          BLOCK CONTROL                    ALWAYS          -
CS   *  ************(REPEAT FOR ALL BLOCKS)                      -
CS   *  *       MATRIX DATA                      ALWAYS          -
CS   ****************                                           -
C--------- ------------------------------------------------------


C----------------------------------------------------------------
CR          FILE IDENTIFICATION                                  -
C                                                                -
CL    HNAME,(HUSE(I),I=1,2),IVERS                                -
CW    1+3*MULT                                                   -
C                                                                -
CB    FORMAT(11H OV COVERX ,A6,1H*,2A6,1H*,I6)                   -
CD    HNAME         HOLLERITH FILE NAME-COVERX  (A6)             -
CD    HUSE          HOLLERITH USER IDENTIFICATION (A6)           -
CD    IVERS         FILE VERSION NUMBER                          -
CD    MULT          1 - A6 IS SINGLE PRECISION WORD              -
CD                  2 - A6 IS DOUBLE PRECISION WORD              -
C----------------------------------------------------------------
```

```
C-----------------------------------------------------------------------
CR          FILE CONTROL                                               -
C                                                                      -
CL    NGROUP,NNGRUP,NGGRUP,NTYPE,NNMP,NMTRIX,NHOLL                     -
C                                                                      -
CW    7                                                                -
C                                                                      -
CB    FORMAT(8H 1D ,7I6)                                               -
C                                                                      -
CD    NGROUP        NUMBER OF ENERGY GROUPS                            -
CD    NNGRUP        NUMBER OF NEUTRON GROUPS                           -
CD    NGGRUP        NUMBER OF GAMMA GROUPS                             -
CD    NTYPE         TYPE OF DATA                                       -
CD                        1 - COVARIANCE MATRIX, STANDARD DEVIATION   -
CD                        2 - RELATIVE COVARIANCE MATRIX,             -
CD                            RELATIVE STANDARD DEVIATION             -
CD                        3 - CORRELATION MATRIX, STANDARD DEVIATION  -
CD    NNMP          NUMBER OF MAT - MT PAIRS                           -
CD    NMTRIX        NUMBER OF MATRICES                                 -
CD    NHOLL         NUMBER OF HOLLERITH WORDS IN DESCRIPTION           -
C-----------------------------------------------------------------------


C-----------------------------------------------------------------------
CR          FILE DESCRIPTION                                           -
C                                                                      -
CL    (WORDS(J),J=1,NHOLL)                                             -
CW    MULT*NHOLL                                                       -
C                                                                      -
CB    FORMAT(4H 2D ,1H*,11A6/(11A6))                                   -
C                                                                      -
CD    WORDS(J)      HOLLERITH DESCRIPTION OF FILE                      -
C-----------------------------------------------------------------------


C-----------------------------------------------------------------------
CR          NEUTRON GROUP BOUNDARIES                                   -
C                                                                      -
CL    (GPBN(J),J=1,NNGRUP),ENMIN                                       -
C                                                                      -
CC          PRESENT IF NNGRUP.GT.0                                     -
CW    NNGRUP+1                                                         -
C                                                                      -
CB    FORMAT(4H 3D ,5E12.4/(6E12.4))                                   -
CD    GPBN(J)       MAXIMUM ENERGY BOUND OF NEUTRON GROUP(J)  (EV)     -
CD    ENMIN         MINIMUM ENERGY OF NEUTRON ENERGY RANGE             -
C-----------------------------------------------------------------------


C-----------------------------------------------------------------------
CR          GAMMA GROUP BOUNDARIES                                     -
C                                                                      -
CL    (GPBG(J),J=1,NGGRUP),EGMIN                                       -
C                                                                      -
CC          PRESENT IF NGGRUP.GT.0                                     -
CW    NGGRUP + 1                                                       -
C                                                                      -
CB    FORMAT(4H 4D ,5E12.4/(6E12.4))                                   -
CD    GPBG(J)       MAXIMUM ENERGY BOUND OF GAMMA GROUP(J)  (EV)       -
CD    EGMIN         MINIMUM ENERGY OF GAMMA ENERGY RANGE               -
C-----------------------------------------------------------------------
```

```
C-----------------------------------------------------------------------
CB          MAT - MT CONTROL                                           -
C                                                                      -
CL    (MATID(I),MTID(I),MWGT(I),I=1,NMMP)                              -
C                                                                      -
CW    3*NMMP                                                           -
C                                                                      -
CB    FORMAT(4H 5D ,11I6/(12I6))                                       -
C                                                                      -
CD    MATID(I)      MATERIAL IDENTIFICATION NUMBER                     -
CD    MTID(I)       REACTION TYPE IDENTIFICATION NUMBER                -
CD    MWGT(I)       CROSS SECTION WEIGHTING OPTION                     -
CD                        1 - CONSTANT                                -
CD                        2 - 1/E                                     -
CD                        3 - THERMAL + 1/E + FISSION                 -
CD                        4 - ARBITRARY                               -
CD                        5 - COMBINED CTR CASE                       -
C-----------------------------------------------------------------------


C-----------------------------------------------------------------------
CB          MATERIAL - REACTION TYPE CROSS SECTIONS                    -
CB          AND ERROR FILES                                            -
CL    (CRS(J),J=1,NGROUP),(ERROR(J),J=1,NGROUP)                        -
CW    2*NGROUP                                                         -
C                                                                      -
CB    FORMAT(4H 6D ,5E12.4/(6E12.4))                                   -
C                                                                      -
CD    CRS           CROSS SECTION                                      -
CD    ERROR         STANDARD DEVIATION                                 -
C-----------------------------------------------------------------------


C-----------------------------------------------------------------------
CB          MATRIX CONTROL                                             -
CL    MAT1,MT1,MAT2,MT2,NBLOK                                          -
CW    5                                                                -
C                                                                      -
CB    FORMAT(4H 7D ,5I6)                                               -
C                                                                      -
CD    MAT1          MATERIAL 1 IDENTIFICATION NUMBER                   -
CD    MT1           REACTION TYPE 1 IDENTIFICATION NUMBER              -
CD    MAT2          MATERIAL 2 IDENTIFICATION NUMBER                   -
CD    MT2           REACTION TYPE 2 IDENTIFICATION NUMBER              -
CD    NBLOK         NUMBER OF BLOCKS INTO WHICH MATRIX IS SUBDIVIDED   -
C-----------------------------------------------------------------------


C-----------------------------------------------------------------------
CB          BLOCK CONTROL                                              -
CL    (JBAND(J),IJJ(J),J=1,NGROUP),(LGRP(N),N=1,NBLOK)                 -
C                                                                      -
CW    2*NGROUP +NBLOK                                                  -
C                                                                      -
CB    FORMAT(4H 8D ,11I6/(12I6))                                       -
C                                                                      -
CD    JBAND(J)      BANDWIDTH FOR GROUP J                              -
CD    IJJ(J)        POSITION OF DIAGONAL ELEMENT FOR GROUP J           -
CD    LGRP(N)       NUMBER OF GROUPS IN BLOCK(N)                       -
C-----------------------------------------------------------------------
```

```
C-----------------------------------------------------------------------
CR           MATRIX DATA                                              -
CL     (COV(K),K=1,KMAX)                                              -
C                                                                       -
CC     KMAX=SUM OVER JBAND(J) FOR ALL J IN BLOCK N                      -
CW     KMAX                                                           -
C                                                                       -
CB     FORMAT(4H 9D ,5E12.4/(6E12.4))                                 -
C                                                                       -
C                                                                       -
CD     COV           NTYPE MATRIX DATA                                -
C-----------------------------------------------------------------------
COEF
```

APPENDIX B

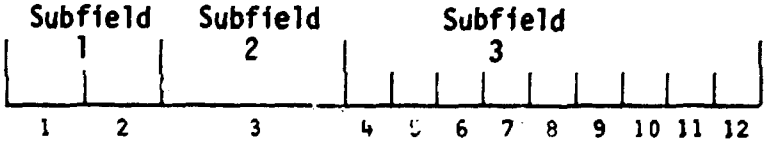
The FIDO Input System

The FIDO input method is especially devised to allow the entering or modifying of large data arrays with minimum effort. Special advantage is taken of patterns of repetition or symmetry wherever possible. The FIDO system was patterned by Ward Engle and Wayne Rhoades after the input method used with the FLOCO coding system at Los Alamos, and was first applied to the DTF-II code. Since that time, numerous features requested by users have been added, a free-field option has been developed, and the application of FIDO has spread to innumerable codes.

The data are entered in units called "arrays." An array comprises a group of contiguous storage locations which are to be filled with data at one time. These arrays usually correspond on a one-to-one basis with FORTRAN arrays used in the program. A group of one or more arrays read with a single call to the FIDO package forms a "block," and a special delimiter is required to signify the end of each block. Arrays within a block may be read in any order with respect to each other, but an array belonging to one block must not be shifted to another. The same array can be entered repeatedly within the same block. For example, an array could be filled with "0" using a special option, and then a few scattered locations could be changed by reading in a new set of data for that array. If no entries to the arrays in a block are required but the condition requiring the block is met, the delimiter alone satisfies the input requirement.

Three major types of input are available: fixed-field input, free-field input, and user-field input.

Fixed Field Input - Each card is divided into six 12-column data fields, each of which is divided into three subfields. The following sketch illustrates a typical data field. The three subfields always comprise 2, 1, and 9 columns, respectively.



To begin the first array of a block, an array originator field is placed in any field on a card:

Subfield 1: An integer array identifier < 100 specifying the data array to read

Subfield 2: An array-type indicator -
"$" if the array is integer data
"*" if the array is real data

Subfield 3: Blank

Data are then place in successive fields until the required number of entries has been accounted for. A sample data sheet shown on page 19 illustrates this input.

In entering data, it is convenient to think of an "index" or "pointer" which is under control of the user, and which specifies the position in the array into which the next data entry is to go. The pointer is always positioned at array location #1 by entering the array originator field. The pointer subsequently moves according to the data operator chosen. Blank fields are a special case, in that they do not cause any data modification and do not move the pointer.

A data field has the following form:

Subfield 1: The data numerator, an integer < 100. We refer to this entry as N_1 in the following discussion.

Subfield 2: One of the special data operators listed below.

Subfield 3: A nine-character data entry, to be read in F9.0 format. It will be converted to an integer if the array is a "$" array or if a special array operator such as "Q" is being used. Note that an exponent is permissible but not required. Likewise, a decimal is permissible but not required. If no decimal is supplied, it is assumed to be immediately to the left of the exponent, if any; and otherwise to the right of the last column. This entry is referred to as N_3 in the following discussion.

Name General Example of Fido Input Charge Date Page

		IDENTIFICATION	REMARKS (DO NOT PUNCH)
1 1,$			Begin the 1$ array, fixed-field, integral
15 1	1		Enter 1.
36 F	2		Fill array with 2.
37 2,*			Begin the 2* array, fixed-field, real.
40	1.234	73 80	Enter 1.234.
61	12.34 -1	10	" "
1 5,-	1234 +02		" "
15 3,-	1234		" "
36	7		" 7.0
37			A blank field is always ignored.
40 T		73 80	Terminate this block.
61		20	No entries may follow T on a card.
1 3,*			Begin 3* array, fixed-field real.
15 9,I	0		Enter 0,1,2,3,4,5,6,7,8,9,10,10,10.
30 3,R	10		as real numbers.
37 3,*,*	10S10		Repeat 3* in free-field, skip
40 1,1	12	73 80	to 11th entry, correct sequence to
61		30	----9,10,11,12.
1 4,*,*	2I1 4.0		Begin 4* array, free-field, real.
15 2,Q,4			Enter 1,2,3,4, 1,2,3,4, 1,2,3,4.
36	E		End reading this array; remainder of array unchanged.
37	T		Terminate this block.
40		73 80	
61		40	

R - REPEAT I - INTERPOLATE S - SKIP T - TERMINATE

A list of data operators and their effect on the array being input follows:

"Blank" indicates a single entry of data. The data entry in the third subfield is entered in the location indicated by the pointer, and the pointer is advanced by one. However, an entirely blank field is ignored.

"+" or "-" indicates exponentiation. The data entry in the third field is entered and multiplied by $10^{\pm N_1}$, where N_1 is the data numerator in the first subfield, given the sign indicated by the data operator itself. The pointer is advanced by one. In cases where an exponent is needed, this option allows the entering of more significant figures than the blank option.

"&" has the same effect as "+".

"R" indicates that the data entry is to be repeated N_1 times. The pointer is advanced by N_1.

"I" indicates linear interpolation. The data numerator, N_1, indicates the number of interpolated points to be supplied. The data entry in the third subfield is entered, followed by N_1 interpolated entries equally spaced between that value and the data entry found in the third subfield of the next non-blank field. The pointer is advanced by $N_1 + 1$. The field following an "I" field is then processed normally, according to its own data operator. The "I" entry is especially valuable for specifying a spatial mesh. In "$" arrays, interpolated values will be rounded to the nearest integer.

"L" indicates logarithmic interpolation. The effect is the same as that of "I" except that the resulting data are evenly separated in log-space. This is especially convenient for specifying an energy mesh.

"Q" is used to repeat sequences of numbers. The length of the sequence is given by the third subfield, N_3. The sequence of N_3

entries is to be repeated N_1 times. The pointer is advanced by N_1*N_3. If either N_1 or N_3 is 0, then a sequence of $N_1 + N_3$ is repeated one time only, and the pointer is advanced by $N_1 + N_3$. This feature is especially valuable for geometry specification.

The "N" option has the same effect as "Q", except that the order of the sequence is reversed each time it is entered. This is valuable for the type of symmetry possessed by quadrature coefficients.

"M" has the same effect as "N" except that the sign of each entry in the sequence is reversed each time the sequence is entered. For example, the entries:

```
1 2 3 2M2
```

would be equivalent to:

```
1 2 3 -3 -2 2 3
```

This option is also useful in entering quadrature coefficients.

"Z" causes $N_1 + N_3$ locations to be set to 0. The pointer is advanced by $N_1 + N_3$.

"C" causes the position of the last array item entered to be printed. This is the position of the pointer, less 1. The pointer is not moved.

"O" causes the print trigger to be changed. The trigger is originally off. Successive "O" fields turn it on and off alternately. When the trigger is on, each card image is listed as it is read.

"S" indicates that the pointer is to skip N_1 positions leaving those array positions unchanged. If the third subfield is non-blank, that data entry is entered following the skip, and the pointer is advanced by $N_1 + 1$.

"A" moves the pointer to the position N_3, specified in the third subfield.

"F" fills the remainder of the array with the datum entered in the third subfield.

"E" skips over the remainder of the array. The array length criterion is always satisfied by an "E", no matter how many entries have been specified. No more entries to an array may be given following an "E", except that data entry may be restarted with an "A".

The reading of data to an array is terminated when a new array origin field is supplied, or when the block is terminated. If an incorrect number of positions has been filled, an error edit is given, and a flag is set which will later abort execution of the problem. FIDO then continues with the next array if an array origin was read. Otherwise, it returns control to the calling program.

A block termination consists of a field having "T" in the second sub-field. All entries following "T" on a card are ignored, and control is returned from FIDO to the calling program.

Comment cards can be entered within a block by placing an apostrophe (') in column 1. Then columns 2-80 will be listed, with column 2 being used for printer carriage control. Such cards have no effect on the data array or pointer.

Free-Field Input - With free-field input, data are written without fixed restrictions as to field and subfield size and positioning on the card. The options used with fixed-field input are available, although some are slightly restricted in form. In general, fewer data cards are required for a problem, the interpreting print is easier to read, a card listing is more intelligible, the cards are easier to keypunch, and certain common keypunch errors are tolerated without affecting the problem. Data arrays using fixed- and free-field input can be intermingled at will within a given block.

The concept of three subfields per field is still applicable to free-field input, but if no entry for a field is required, no space for it need be left. Only columns 1-72 may be used, as with fixed-field input.

The array originator field can begin in any position. The array identifiers and type indicators are used as in fixed-field input. The type indicator is entered twice, to designate free-field input (i.e., "$$" or "**"). The blank third subfield required in fixed-field input is not required. For example: 31** indicates that array 31, a real-data array, will follow in free-field format.

Data fields may follow the array origin field immediately. The data field entries are identical to the fixed-field entries with the following restrictions:

(1) Any number of blanks may separate fields, but at least one blank must follow a third subfield entry if one is used.
(2) If both first and second subfield entries are used, no blanks may separate them, i.e., 24S, but not 24 S.
(3) Numbers written with exponents must not have imbedded blanks, i.e., .0E+4, 1.0E4, 1.0+4, or even 1+4, but not 1.0 E4.
(4) In third-subfield data entries, only 9 digits, including the decimal but not including the exponent field, can be used, i.e., 123456.89E07, but not 123456.789E07.
(5) The Z entry must be of the form: 738Z, not Z738 or 738 Z.
(6) The + or - data operators are not needed and are not available.
(7) The Q, N, and M entries are restricted: 3Q4, 1N4, or M4, but not 4Q, 4N, or 4M.

User-Field Input - If the user follows the array identifier in the array originator field with the character "U" or "V", the input format is to be specified by the user. If "U" is specified, the FORTRAN FORMAT to be used must be supplied in columns 1-72 of the next card. The format must be enclosed by the usual parentheses. Then the data for the entire array must follow on successive cards. The rules of ordinary FORTRAN input as to exponents, blanks, etc., apply. If the array data do not fill the last card, the remainder must be left blank.

"V" has the same effect as "U" except that the format read in the last preceding "U" array is used.

CHAPTER XI. THE COVERX SERVICE MODULE OF THE FORSS SYSTEM*

J. D. Drischler

*Originally published as ORNL/TM-7181.

CONTENTS

ABSTRACT

The COVERX Service Module includes seven execution paths to aid in understanding and using multigroup cross-section covariance matrices contained in the standard interface file COVERX. The execution paths provide the following operations on COVERX file(s):

1. List the contents of a COVERX file.

2. Allow adding new multigroup cross-section covariance matrices to an existing COVERX file.

3. Allow deletion of multigroup covariance matrices from an existing COVERX file.

4. Merge two COVERX files and creates a new file.

5. Change the mode of a file from unformatted to formatted and conversely.

6. Allow modification of the records contained in a COVERX file.

7. Selectively edits or copies a file.

I. INTRODUCTION

Multigroup cross-section covariance matrices are created using the PUFF covariance file processing code[1] and placed on a proposed CCCC[2] file, COVERX.[3] Each covariance matrix is identified by the matrix control record of the COVERX file. The material and reaction type identification numbers are the MAT and MT numbers used in the ENDF/B[4] files. Libraries[5] of multigroup matrices in COVERX format are currently available through the Engineering Physics Information Center (EPIC) at Oak Ridge National Laboratory and the National Nuclear Data Center (NNDC) at Brookhaven National Laboratory. The COVERX format is described in Appendix A. A sample problem utilizing the seven execution paths of the COVERX Service Module is described in Appendix B.

When the generation of a COVERX file(s) is complete for a study, a careful review is recommended before it is used. The COVERX service module is available to aid in this review. If identification problems or errors are detected, they can often be quickly corrected by the COVERX service module. At present, the module has seven execution paths which perform the following tasks:

1. Lists the contents of a COVERX file.
2. Allows additional multigroup cross-section covariance matrices to be added to an existing COVERX file.
3. Allows deletions of multigroup cross-section covariance matrices from an existing COVERX file.
4. Merges two COVERX files and creates a new file.
5. Changes the mode of a file from unformatted to formatted and conversely.

6. Allows modification of the records contained in the COVERX file.

7. Selectively edits or copies a file.

The user selects the desired execution path by entering one of the following words on a card beginning in column 1: LIST, ADD, DELETE, MERGE, CONVERT, FIX, EDIT. Additional FIDO[6] input requirements are described for each execution path.

II. COVERX FILE EXECUTION PATHS

A. List

Input Data

LIST

1$$ Integer Parameter [1]

NBIN - Unit number of the COVERX file, if NBIN < 0, only the matrix control records will be listed.

T

B. Add

This execution path allows multigroup cross-section covariance matrices to be added by creating a new file from the card input. The existing and newly created files are then merged producing a new COVERX file.

Input Data

ADD

1$$ Integer Parameters [4]

NOLD - Unit number of existing COVERX file

NADD - The number of coveriance matrices to be added

NEW - Unit number of new COVERX file

NSSS - Unit number of a scratch device (default = 31)

T

2$$ Integer Parameters [4]. The MATRIX CONTROL record of the COVERX file.

MAT1 - Material 1 ID

MT1 - Reaction type 1 ID

MAT2 - Material 2 ID

MT2 - Reaction type 2 ID

T

3** Floating Point Parameters [NG]. The MATERIAL REACTION TYPE CROSS SECTION AND STANDARD DEVIATIONS record of the COVERX file. NG is the number of groups of the existing COVERX file. The standard deviations are automatically calculated by the code.

(CRS(J),J=1,NG)

CRS - Cross sections (from E_{max} - E_{min})

T

[The 3** card is omitted if (MAT1.NE.MAT2.OR.MT1.NE.MT2)]

4$$ Integer Parameters [NG*2+1]. The BLOCK CONTROL record of the COVERX file.

Block control = (JBAND(J),IJJ(J),J=1,NG),(LGRP(N),N=1,NBLOK)

For simplicity in creating the block control record of a covariance matrix, let NG equal the number of groups of the existing COVERX file and let NBLOK=1. The current version of FORSS[7] requires that NBLOK=1.

Then: the 4$$ card for a three-group problem with NBLOK=1 would be:

4$$ 3 1 3 2 3 3 3

OR: using the improved FIDO

4$$ 0 1 [NG-1]Q2 A1 [NG] 1 1@ [NG-1]Q2 0@ [NG]

This is especially useful if matrices are large.

5** Floating Point Parameters [NG*NG]. The MATRIX DATA record of the COVERX FILE. If the preceding scheme for blocking is exercised, then the entire matrix can be input in one block.

COV - Matrix data (input by col.)

T

The 2$$, 3**, 4$$, and 5** sequence is repeated until NADD entries are complete.

C. Delete

This execution path allows multigroup cross-section covariance matrices to be deleted from a COVERX file.

Input Data

DELETE

1$$ Integer Parameters [3]

NBIN - Unit number of existing COVERX file

NEW - Unit number of new COVERX file

NDEL - The number of covariances to be deleted

T

2$$ Integer Parameters [4*NDEL]. The MATRIX CONTROL record of the COVERX FILE.

MAT1 - Material 1 ID

MT1 - Reaction type 1 ID

MAT2 - Material 2 ID

MT2 - Reaction type 2 ID

.

.

.

Sequence is repeated for each covariance to be deleted

T

D. Merge

This execution path merges two existing COVERX files and creates a third file.

Input Data

MERGE

1$$ Integer Parameters [3]

N1 - Unit number of original COVERX file

If identical matrix control records are encountered on both the original files (N1) and the file to be merged (N2), the matrix found on unit (N2) is written on unit (N3), and the matrix found on unit (N1) is skipped.

E. Format Conversion

This execution path implements features of the COVERT[8] code which converts the COVERX file from unformatted (binary) to formatted card images and conversely, and also lists a COVERX file.

CONVERT

1$$ Integer Parameters [4]

NBE - Select conversion mode

= 0, unformatted to formatted

≠ 0, formatted to unformatted

NIN - Unit number of existing COVERX file (DEFAULT = 23)

NOUT - Unit number of COVERX file to be prepared by COVERT (DEFAULT = 24)

NO6 - Print option

> 0, file is printed on unit NO6

≤ 0, reduced file edit on unit |NO6|

1

F. Record Modification

This execution path allows modification to the records contained in a COVERX file. FIX modifies only those covariances which have been selected by previously using EDIT and updates the existing COVERX file by using MERGE.

Input Data

FIX

1$$ Integer Parameter [5]

NOLD - Unit number of existing COVERX file

> 0, complete listing

< 0, reduced listing

NEW - Unit number of new COVERX file

NFIX - Number of covariance matrices to be reparied

NHOL - Modify file description record

= 0, file description record not modified

≠ 0, prepare 2## card

NSSS - Unit number of a scratch device (default = 31)

T

2## Doubled Precision Parameters [200(A6) words max.]. The FILE DESCRIPTION record of the COVERX file (omit if NHOL = 0).

NUNIT - Unit number where Hollerith description of file is input

NH - Number of (A6) words in Hollerith description

Then: using the improved FIDO

[NUNIT]G[NH] 6H(12A6) 6Hbbbbbb E T (b = blank)

would allow NH (A6) words to be input from unit NUNIT.

3$$ Integer Parameters [8]

NMAT1 - Material 1 ID

NMT1 - Reaction type 1 ID

NMAT2 - Material 2 ID

NMT2 - Reaction type 2 ID

NCRS - Modify cross sections

= 0, do not modify cross sections

≠ 0, prepare 4** card

NMT - Modify matrix control record

= 0, no modification

≠ 0, prepare 5$$ card

NBLK - Modify block control record

= , no modification

≠ 0, prepare 6$$ card

NCOV - Modify matrix data record

< 0, switch rows and columns

= 0, no modification

> 0, prepare 7** card

T

4** Floating Point Parameters [NG]. The MATERIAL-REACTION TYPE CROSS SECTIONS record of the COVERX file (omit if NCRS = 0). NG is the number of groups of the existing COVERX file. The standard deviations are automatically calculated by the code.

(CRS(J),J=1,NG)

CRS - Cross sections (from E_{max} - E_{min})

T

5$$ Integer Parame'ers [4]. The MATRIX CONTROL record of the COVERX file (omit if NMT = 0).

MAT1 - Material 1 ID

MT1 - Reaction type 1 ID

MAT2 - Material 2 ID

MT2 - Reaction type 2 ID

6$$ Integer Parameters [NG*2+1]. The BLOCK CONTROL record of the COVERX file (omit if NBLK = 0).

Block control = (JBAND(J),IJJ(J),J=1,NG),(LGRP(N),N=1,NBLOK)

JBAND(J) - Band for group (J)

IJJ(J) - Position of diagonal element for group (J)

LGRP(N) - Number of groups in block (N)

For simplicity in creating the block control record of a covariance matrix, let NG equal the number of groups of the existing COVERX file and let NBLOK = 1. The current version of FORSS requires that NBLOK = 1.

Then: the 6$$ card for a three-group problem with NBLOK = 1 would be:

6$$ 3 1 3 2 3 3 3

OR: using the improved FIDO

6$$ 0 1 [NG-1]Q2 A1 [NG] 1 1@ [NG-1]Q2 0@ [NG]

This is especially useful if matrices are large.

7** Floating Point Parameters [NG*NG]. The MATRIX DATA record of the COVERX file (omit if NCOV = 0). If the preceding scheme for blocking is exercised, then the entire matrix can be input in one block.

COV - Matrix data (input by col.)

T

The 3$$ through 7** sequence if repeated until NFIX entries are complete.

G. File Edit/Copy

This execution path permits selective listing and copying of a COVERX file. Each multigroup cross-section covariance matrix in a COVERX file is identified by the COVERX matrix control record. This record contains five

numbers: Material 1 (MAT1), reaction type 1 (MT1), Material 2 (MAT2), reaction type 2 (MT2), and the number of blocks into which matrix is subdivided (not used as input). Correlations between material-reaction types are extracted from the COVERX file using MAT1, MT1 as the first material-reaction type (column designation), and MAT2, MT2 the second material-reaction type (row designation).

As each covariance matrix is read from the COVERX file, its first four identifiers are compared with the corresponding identifiers in each edit command. If equality is found between all of the identifiers in an edit command and the corresponding identifiers from the matrix control record of the COVERX file, the multigroup cross-section covariance matrix qualifies for the edit/copy operation.

Input Data

EDIT

1$$ Integer Parameters [4]

NBIN - Unit number of existing COVERX file

> 0, complete listing

< 0, file identification

NC - Number of edit commands

NEW - Copy option

> 0, the unit number of a COVERX file to be written containing only those matrices edited

$\leq$ 0, file not written

NSS - Unit number of a scratch device (default = 31)

T

2$$ Integer Parameters [4*NC]

MAT1 - Material 1 ID

MT1 - Reaction type 1 ID

MAT2 - Material 2 ID

MT2 - Reaction type 2 ID

.
.
.
.

Complete MC edit commands

T

ACKNOWLEDGEMENTS

The author wishes to acknowledge and thank J. L. Lucius, J. H. Marable, and C. R. Weisbin for their useful suggestions and thorough review of this paper. Much of the important feedback, debugging, etc. was obtained through discussions with J. D. Smith. Finally, deep gratitude is given to Sandi Henry for her expert and patient typing of the several drafts of this report.

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APPENDIX A

The Format for Standard Interface File COVERX for Multigroup Cross-Section Covariance Matrices

```
C*****************************************************************
C                        REVISED 11/01/77                        -
C                                                                -
CP          COVERX                                               -
CE          THIS FILE CONTAINS CROSS SECTIONS,                   -
CE          STANDARD DEVIATIONS, AND                             -
CE          BY DESIGNATION EITHER COVARIANCE,                    -
CE          RELATIVE COVARIANCE,                                 -
CE          OR CORRELATION MATRICES.                             -
C                                                                -
CE              A FILE SUCH AS THIS IS NEEDED BY ORNL - PORSS     -
C                                                                -
C                                                 J. L. LUCIUS   -
C                                                                -
C*****************************************************************


C-----------------------------------------------------------------
CS          FILE STRUCTURE                                       -
CS                                                               -
CS             RECORD TYPE                          PRESENT IF   -
CS             ============================         ==========   -
CS             FILE IDENTIFICATION                  ALWAYS       -
CS             FILE CONTROL                         ALWAYS       -
CS             FILE DESCRIPTION                     NHOLL.GT.0   -
CS             NEUTRON GROUP BOUNDARIES             NNGROUP.GT.0 -
CS             GAMMA GROUP BOUNDARIES               NGGROUP.GT.0 -
CS             MAT - MT CONTROL                     ALWAYS       -
CS   **********(REPEAT FOR ALL MATERIAL-                         -
CS   *             REACTION TYPE PAIRS)                        -
CS   *         MAT-MT CROSS SECTION AND             ALWAYS       -
CS   *         STANDARD DEVIATIONS                              -
CS   **********                                                  -
CS                                                               -
CS                                                               -
CS   **********(REPEAT FOR ALL MATRICES)                        -
CS   *         MATRIX CONTROL                       ALWAYS       -
CS   *         BLOCK CONTROL                        ALWAYS       -
CS   *  **********(REPEAT FOR ALL BLOCKS)                       -
CS   *  *      MATRIX DATA                          ALWAYS       -
CS   *****************                                           -
C-----------------------------------------------------------------


C-----------------------------------------------------------------
CB          FILE IDENTIFICATION                                  -
C                                                                -
CL    HNAME,(HUSE(I),I=1,2),IVERS                                -
CW    1+3*MULT                                                   -
C                                                                -
CB    FORMAT(11H 0V COVERX ,A6,1H*,2A6,1H*,I6)                   -
CD    HNAME        HOLLERITH FILE NAME-COVERX  (A6)              -
CD    HUSE         HOLLERITH USER IDENTIFICATION (A6)            -
CD    IVERS        FILE VERSION NUMBER                           -
CD    MULT         1 - A6 IS SINGLE PRECISION WORD               -
CD                 2 - A6 IS DOUBLE PRECISION WORD               -
C-----------------------------------------------------------------
```

```
C-----------------------------------------------------------------------
CR          FILE CONTROL                                               -
C                                                                      -
CL    NGROUP,NNGROUP,NGGROUP,NTYPE,NMAP,NMTRIX,NHOLL                   -
C                                                                      -
CW    7                                                                -
C                                                                      -
CB    FORMAT(4H 1D ,7I6)                                               -
C                                                                      -
CD    NGROUP        NUMBER OF ENERGY GROUPS                            -
CD    NNGROUP       NUMBER OF NEUTRON GROUPS                           -
CD    NGGROUP       NUMBER OF GAMMA GROUPS                             -
CD    NTYPE         TYPE OF DATA                                       -
CD                        1 - COVARIANCE MATRIX, STANDARD DEVIATION    -
CD                        2 - RELATIVE COVARIANCE MATRIX,              -
CD                            RELATIVE STANDARD DEVIATION              -
CD                        3 - CORRELATION MATRIX, STANDARD DEVIATION   -
CD    NMAP          NUMBER OF MAT - MT PAIRS                           -
CD    NMTRIX        NUMBER OF MATRICES                                 -
CD    NHOLL         NUMBER OF HOLLERITH WORDS IN DESCRIPTION           -
C-----------------------------------------------------------------------


C-----------------------------------------------------------------------
CR          FILE DESCRIPTION                                           -
C                                                                      -
CL    (WORDS(J),J=1,NHOLL)                                             -
CW    MULT*NHOLL                                                       -
C                                                                      -
CB    FORMAT(4H 2D ,1H*,11A6/(11A6))                                   -
C                                                                      -
CD    WORDS(J)      HOLLERITH DESCRIPTION OF FILE                      -
C-----------------------------------------------------------------------


C-----------------------------------------------------------------------
CR          NEUTRON GROUP BOUNDARIES                                   -
C                                                                      -
CL    (GPBN(J),J=1,NNGROUP),ENMIN                                      -
C                                                                      -
CC          PRESENT IF NNGROUP.GT.0                                    -
CW    NNGROUP+1                                                        -
C                                                                      -
CB    FORMAT(4H 3D ,5E12.4/(6E12.4))                                   -
CD    GPBN(J)       MAXIMUM ENERGY BOUND OF NEUTRON GROUP(J) (EV)      -
CD    ENMIN         MINIMUM ENERGY OF NEUTRON ENERGY RANGE             -
C-----------------------------------------------------------------------


C-----------------------------------------------------------------------
CR          GAMMA GROUP BOUNDARIES                                     -
C                                                                      -
CL    (GPBG(J),J=1,NGGROUP),EGMIN                                      -
C                                                                      -
CC          PRESENT IF NGGROUP.GT.0                                    -
CW    NGGROUP+1                                                        -
C                                                                      -
CB    FORMAT(4H 4D ,5E12.4/(6E12.4))                                   -
CD    GPBG(J)       MAXIMUM ENERGY BOUND OF GAMMA GROUP(J) (EV)        -
CD    EGMIN         MINIMUM ENERGY OF GAMMA ENERGY RANGE               -
C-----------------------------------------------------------------------
```

```
C-----------------------------------------------------------------------
CR          MAT - MT CONTROL                                           -
C                                                                      -
CL    (MATID(I),MTID(I),MWGT(I),I=1,NMMP)                              -
C                                                                      -
CW    3*NMMP                                                           -
C                                                                      -
CB    FORMAT(4H 5D ,11I6/(12I6))                                       -
C                                                                      -
CD    MATID(I)      MATERIAL IDENTIFICATION NUMBER                     -
CD    MTID(I)       REACTION TYPE IDENTIFICATION NUMBER                -
CD    MWGT(I)       CROSS SECTION WEIGHTING OPTION                     -
CD                        1 - CONSTANT                                -
CD                        2 - 1/E                                     -
CD                        3 - THERMAL + 1/E + FISSION                 -
CD                        4 - ARBITRARY                               -
CD                        5 - COMBINED CTR CBR                        -
C-----------------------------------------------------------------------


C-----------------------------------------------------------------------
CR          MATERIAL - REACTION TYPE CROSS SECTIONS                    -
CR          AND ERROR FILES                                            -
CL    (CRS(J),J=1,NGROUP),(ERROR(J),J=1,NGROUP)                        -
CW    2*NGROUP                                                         -
C                                                                      -
CB    FORMAT(4H 6D ,5E12.4/(6E12.4))                                   -
C                                                                      -
CD    CRS           CROSS SECTION                                      -
CD    ERROR         STANDARD DEVIATION                                 -
C-----------------------------------------------------------------------


C-----------------------------------------------------------------------
CR          MATRIX CONTROL                                             -
CL    MAT1,MT1,MAT2,MT2,NBLOK                                          -
CW    5                                                                -
C                                                                      -
CB    FORMAT(4H 7D ,5I6)                                               -
C                                                                      -
CD    MAT1          MATERIAL 1 IDENTIFICATION NUMBER                   -
CD    MT1           REACTION TYPE 1 IDENTIFICATION NUMBER              -
CD    MAT2          MATERIAL 2 IDENTIFICATION NUMBER                   -
CD    MT2           REACTION TYPE 2 IDENTIFICATION NUMBER              -
CD    NBLOK         NUMBER OF BLOCKS INTO WHICH MATRIX IS SUBDIVIDED   -
C-----------------------------------------------------------------------


C-----------------------------------------------------------------------
CR          BLOCK CONTROL                                              -
CL    (JBAND(J),IJJ(J),J=1,NGROUP),(LGRP(N),N=1,NBLOK)                 -
C                                                                      -
CW    2*NGROUP +NBLOK                                                  -
C                                                                      -
CB    FORMAT(4H 8D ,11I6/(12I6))                                       -
C                                                                      -
CD    JBAND(J)      BANDWIDTH FOR GROUP J                              -
CD    IJJ(J)        POSITION OF DIAGONAL ELEMENT FOR GROUP J           -
CD    LGRP(N)       NUMBER OF GROUPS IN BLOCK(N)                       -
C-----------------------------------------------------------------------
```

```
C-------------------------------------------------------------------------
CR          MATRIX DATA                                                  -
CL     (COV(K),K=1,KMAX)                                                 -
C                                                                        -
CC     KMAX=SUM OVER JBAND(J) FOR ALL J IN BLOCK N                       -
CN     KMAX                                                              -
C                                                                        -
CB     FORMAT(4H 9D ,5E12.4/(6E12.4))                                    -
C                                                                        -
C                                                                        -
CD     COV           NTYPE MATRIX DATA                                  -
C-------------------------------------------------------------------------
COEF
```

APPENDIX B.

Sample Problem

The following sample input and output problem utilizes the seven execution paths available in the COVERX Service Module. The user should be aware that although all the execution paths are utilized in the sample problem, the input parameters may vary depending on the user's requirements.

A description of the input to the sample problem follows:

1. CONVERT - The formatted card image COVERX file residing on unit 24 is converted to a binary file on unit 32, and the resulting file is listed using the reduced file edit option.
2. EDIT - The $^{235}U(n,f)$ covariance matrix is extracted from the binary COVERX file and copied to unit 33 creating a new COVERX file containing one covariance matrix. The output for EDIT gives a complete listing of the COVERX file.
3. FIX - The $^{235}U(n,f)$ covariance data residing on unit 33 is changed as follows:

   The Hollerith description of the file is modified (2##),

   The cross sections were modified (4**),

   The matrix control record was modified renaming the $^{235}U(n,f)$ covariance data (5$$),

   The block control record was modified (6$$), and

   The covariance data was modified (7**).

The output of FIX resides on unit 34, and a complete listing of the input plus all modifications is given.

4. EDIT - Three additional covariance matrices were extracted from unit 32 and copied to unit 35.

5. MERGE - The COVERX file residing on unit 35 and the one residing on unit 34 are merged to produce a single COVERX file on unit 33 containing four covariance matrices.

6. DELETE - The covariance matrix indicated in the 2$$ array is deleted from unit 33, and the remaining covariances are placed on unit 34.

7. ADD - A new covariance indicated in the 2$$ array was added to the COVERX file residing on unit 34 with inclusion of the Block control record (4$$) and covariance data (5**). This produced a new COVERX file on unit 33.

8. LIST - The entire COVERX file residing on unit 33 was listed.

APPENDIX B.1. Job Control Cards for Local Use and Sample Input for the COVERX Service Module

```
//JDDDDDD2 JCE (18075),'J DRISCHLER, 6025'
//*CLASS CPUS1=10S,1C=02.0,R=270K
//STEP1 EXEC FCRTHLG,PARM.LKED='NCMAP,NOLIST',REGION.GO=270K
//LKED.COVERX CD UNIT=3330,VCL=SER=ZX0000,DISP=SHR,
// DSN=JDD.JAN2180.CCVERX.SERVICE
//LKED.SYSIN CC *
 INCLUDE CCVERX
/*
//GO.FT24F001 CC UNIT=SYSDA,DISP=(SHR,CATLG),VCL=,
// DCB=(RECFM=FB,LRECL=80,BLKSIZE=3120),
// SPACE=(TRK,(20,20),RLSE),
// DSN=T.JDC18075.TEMP1.JAN1780
//GO.FT31F001 DD UNIT=SYSDA,SPACE=(TRK,(010,010)),
//   DCB=(RECFM=VBST,LRECL=X,BLKSIZE=3120)
//GO.FT32F001 CD UNIT=SYSDA,SPACE=(TRK,(010,010)),
//   DCB=(RECFM=VBST,LRECL=X,BLKSIZE=3120)
//GO.FT33F001 DD UNIT=SYSDA,SPACE=(TRK,(010,010)),
//   DCB=(RECFM=VBST,LRECL=X,BLKSIZE=3120)
//GO.FT34F001 CD UNIT=SYSDA,SPACE=(TRK,(010,010)),
//   DCB=(RECFM=VBST,LRECL=X,BLKSIZE=3120)
//GO.FT35F001 CD UNIT=SYSDA,SPACE=(TRK,(010,010)),
//   DCB=(RECFM=VBST,LRECL=X,BLKSIZE=3120)
//GO.FT41F001 CC UNIT=SYSDA,
// SPACE=(TRK,(05,05)),
//   DCB=(RECFM=FB,LRECL=80,BLKSIZE=3200)
//GO.FT42F001 CC UNIT=SYSDA,
// SPACE=(TRK,(05,05)),
//   DCB=(RECFM=FB,LRECL=90,BLKSIZE=3200)
//GO.FT05F001 CC *
CONVERT
0
1$$ 1 24 32 0
EDIT
1$$  32 1 33 0 T
2$$ 1261 18 1261 18 T
FIX
1$$  33 34 1 1 0 T
2**
SG4 6H(12A6) 6F        E T
THIS IS A SAMPLE PROBLEM
3$$ 1261 18 1261 18 1 1 1 1 T
4** F1.0 T
5$$ 1266 18 1266 18
6$$ 0 1 502 A1 6 1 18 SC2 08 6
7** 1Z 3S 3Z 3S 3Z 3S 3Z 3S 3Z 3S 3Z 3S 2Z T
EDIT
1$$  32 3 35 0 T
2$$
1262 18 1262 18
1264 18 1264 18
1262 18 1264 18
T
MERGE
1$$ 35 34 33 T
DELETE
1$$ 33 34 1 T
2$$ 1262 18 1264 18 T
ADD
1$$ 34 1 33 0 T
2$$ 1261 452 1266 452 T
4$$ 0 1 502 A1 6 1 18 502 08 6
5** F1.33225-5 T
LIST
1$$  33 T
/*
//

IHC0021I STCP      0
```

APPENDIX B.2. Sample Output for the COVERX Service Module

I. CONVERT OUTPUT

```
COVERX EXECUTION PATH SELECTED... CONV
                                                PRT CN      OC
                                                1T$ 1 24 12 0 T

    1$ ARRAY       4 ENTRIES READ


    OT
 IN FCONV. CORE AVAILABLE   25000 CORE NEEDED      127
A CROSS-SECTION COVARIANCE FILE IN COVERX FORMAT WILL BE READ IN  .BCDIC FROM UNIT 24
AND WILL BE WRITTEN IN BINARY ONTO UNIT 32

*****************************AN EDIT OF THE COVERX CROSS-SECTION COVARIANCE FILE IS PRINTED HERE*************************
FILE IDENTIFICATION RECORD................. 0V COVERX COVERX*ORNL - FOR55*   1
FILE CONTROL RECORD........................ 1D    6     6     0     2     13    32    11
FILE DESCRIPTION........................... 2D *FISSION SPECTRUM COVARIANCE MATRIX LIBRARY (GODIVA WEIGHTING).
                                            *
NEUTRON GROUP BOUNDARIES................... 3D   2.0000E 07  3.6720E 06  1.3530E 06  4.9790E 05  1.8320E 05
                                                4.0870E 04  1.0000E-05
MATRIX CONTROL RECORD..........NO.   1.. 7D   1261    18  1261    18     1
MATRIX CONTROL RECORD..........NO.   2.. 7D   1261   452  1261   452     1
MATRIX CONTROL RECORD..........NO.   3.. 7D   1261   102  1261   102     1
MATRIX CONTROL RECORD..........NO.   4.. 7D   1261    18  1262    18     1
MATRIX CONTROL RECORD..........NO.   5.. 7D   1261    18  1264    18     1
MATRIX CONTROL RECORD..........NO.   6.. 7D   1261   452  1262   452     1
MATRIX CONTROL RECORD..........NO.   7.. 7D   1261   452  1264   452     1
MATRIX CONTROL RECORD..........NO.   8.. 7D   1261   452  1265   452     1
MATRIX CONTROL RECORD..........NO.   9.. 7D   1261   452  1266   452     1
MATRIX CONTROL RECORD..........NO.  10.. 7D   1262    18  1262    18     1
MATRIX CONTROL RECORD..........NO.  11.. 7D   1262   452  1262   452     1
MATRIX CONTROL RECORD..........NO.  12.. 7D   1262    51  1262    51     1
MATRIX CONTROL RECORD..........NO.  13.. 7D   1262    52  1262    52     1
MATRIX CONTROL RECORD..........NO.  14.. 7D   1262    53  1262    53     1
MATRIX CONTROL RECORD..........NO.  15.. 7D   1262    54  1262    54     1
MATRIX CONTROL RECORD..........NO.  16.. 7D   1262   102  1262   102     1
MATRIX CONTROL RECORD..........NO.  17.. 7D   1262    18  1264    18     1
MATRIX CONTROL RECORD..........NO.  18.. 7D   1262   452  1264   452     1
MATRIX CONTROL RECORD..........NO.  19.. 7D   1262   452  1265   452     1
MATRIX CONTROL RECORD..........NO.  20.. 7D   1262   452  1266   452     1
MATRIX CONTROL RECORD..........NO.  21.. 7D   1264    18  1264    18     1
MATRIX CONTROL RECORD..........NO.  22.. 7D   1264   452  1264   452     1
MATRIX CONTROL RECORD..........NO.  23.. 7D   1264   102  1264   102     1
MATRIX CONTROL RECORD..........NO.  24.. 7D   1264    18  1264   102     1
MATRIX CONTROL RECORD..........NO.  25.. 7D   1264   452  1265   452     1
MATRIX CONTROL RECORD..........NO.  26.. 7D   1264   452  1266   452     1
MATRIX CONTROL RECORD..........NO.  27.. 7D   1265   452  1265   452     1
MATRIX CONTROL RECORD..........NO.  28.. 7D   1265   102  1265   102     1
MATRIX CONTROL RECORD..........NO.  29.. 7D   1265   452  1266   452     1
MATRIX CONTROL RECORD..........NO.  30.. 7D   1266    18  1266    18     1
MATRIX CONTROL RECORD..........NO.  31.. 7D   1266   452  1266   452     1
MATRIX CONTROL RECORD..........NO.  32.. 7D   1266   102  1266   102     1
****************************************END OF EDIT OF COVERX COVARIANCE MATRIX FILE**************************************

THE FILE HAS BEEN SUCCESSFULLY COPIED.
```

II. EDIT OUTPUT

```
COVFRX EXECUTION PATH SELECTED... EDIT                    199  32 1 33 0 1

    1S ARRAY       4 ENTRIES READ

    0T
 IN FEDIT, CORE AVAILABLE   25000 CORE NEEDED      149
                                                    299 1261 18 1261 18 T
    2S ARRAY       4 ENTRIES READ

    0T
 NMMP=        18  NMTRIX=       32  NC=        1
  1261     18  1261     18
 FILE ID.  COVFRXCRNL - FORSS        1

 FILE CONTROL        6     6     0     2    18    32    11

 FILE DESCRIPTION
  FISSION SPECTRUM COVARIANCE MATRIX LIBRARY (GODIVA WEIGHTING).

 GROUP BOUNDARIES
  2.0000E 07  3.6790E 06  1.3530E 06  4.9790E 05  1.8320E 05  4.0870E 04
  1.0800E-05

 MAT-MT CONTROL
  1261    18     4

 MAT - MT TYPE CROSS SECTIONS AND STANDARD DEVIATIONS
  1.22100E 00 1.25400E 00 1.18600E 00 1.25500E 00 1.56000E 00 2.23600E 00 3.08300E-02 2.34200E-02 2.67800E-02 2.81100E-02
  2.69500E-02 3.29000E-02

 MATRIX CONTROL
         1261          18         1261          18          1

 BLOCK CONTROL
            6          1          6          2          6          3          6          4          6          5
            6          6          6

 RELATIVE COVARIANCE MATRIX

  9.50400E-04 3.94100E-04 1.51900E-04 4.29900E-05 8.14000E-06 0.0
  3.94100E-04 5.48400E-04 3.24000E-04 1.59900E-04 4.56900E-05 0.0
  1.51900E-04 3.24000E-04 7.17300E-04 5.63900E-04 2.24700E-04 0.0
  4.29900E-05 1.59900E-04 5.63900E-04 7.90100E-04 3.90600E-04 2.60900E-04
  8.14000E-06 4.56900E-05 2.24700E-04 3.90600E-04 7.26200E-04 5.40300E-04
  0.0         0.0         0.0         2.60900E-04 5.40300E-04 1.08200E-03
```

III. FIX OUTPUT

```
COVERX EXECUTION PATH SELECTED... FIX

    1$ ARRAY        5 ENTRIES READ

    0T

    2$ ARRAY      200 ENTRIES READ

    0T
 IN FFIX, CORE AVAILABLE    25000 CORE NEEDED       123
 NMMP=         1  NMTRIX=         1  NC=         1
 FILE ID, COVERXCRNL - ECH99         2

    3$ ARRAY        8 ENTRIES READ

    0T

    4$ ARRAY        6 ENTRIES READ

    0T

    5$ ARRAY        4 ENTRIES READ

    6$ ARRAY       13 ENTRIES READ
    7$ ARRAY       36 ENTRIES READ
```

```
1$$  33 34 1 1 0 T

2**
8Z4 6H(1246) 6H        2 T

3$$ 1261 18 1261 18 1 1 1 1 T

4** F1.0 T

5$$ 1266 18 1266 18
6$$ 0 1 802 A1 6 1 18 502 0B 6

7** 12 35 12 35 32 35 32 35 32 35 32 35 32 T
```

III. FIX OUTPUT (cont'd.)

```
   OT

FILE CONTROL         6     6     0     2     1     1     4

FILE DESCRIPTION
 THIS IS A SAMPLE PROBLEM

GROUP BOUNDARIES
 2.0000E 07  3.6790E 06  1.3530E 06  4.9790E 05  1.8320E 05  4.3070E 04
 1.0000E-05

MAT-MT CONTROL
 1266    18     4

MAT - MT TYPE CROSS SECTIONS AND STANDARD DEVIATIONS
 1.00000E 00 1.00000E 00 1.00000E 00 1.00000E 00 1.00000E 00 1.00000E 00 0.0          2.34170E-02 2.67835E-02 2.61097E-02
 0.0         0.0

MATRIX CONTROL
        1266          18          1266          18          1

BLOCK CONTROL
           6          1           6           2           6           3           6           4           6           5
           6          6           6

RELATIVE COVARIANCE MATRIX
 0.0         0.0         0.0         0.0         0.0         0.0
 3.94100E-04 5.48400E-04 3.24000E-04 1.59900E-04 4.56100E-05 0.0
 1.51900E-04 3.24000E-04 7.17300E-04 5.63900E-04 2.24700E-04 0.0
 4.29900E-05 1.59900E-04 5.63900E-04 7.50100E-04 3.90600E-04 2.60900E-04
 0.0         0.0         0.0         0.0         0.0         0.0
 0.0         0.0         0.0         0.0         0.0         0.0
```

IV. EDIT OUTPUT

```
COVERX EXECUTION PATH SELECTED... EDIT
                                                    1$$  32 3 35 0 T

   1$ ARRAY        4 ENTRIES READ


   0T
 IN FEDIT, CORE AVAILABLE    25000 CORE NEEDED     181
                                                    2$$
                                                    1262  18  1262  18
                                                    1264  18  1264  18
                                                    1262  18  1264  18
                                                    T

   2$ ARRAY       12 ENTRIES READ


   0T
NMMP=        16  NMTRIX=       32  NC=        3
 1262     18   1262     18   1264     18   1264     18   1262     18   1264     18

FILE ID.  COVERXCRNL - FORSS          1

FILE CONTROL       6      6      0      2     18     32     11

FILE DESCRIPTION
 FISSION SPECTRUM COVARIANCE MATRIX LIBRARY (GODIVA WEIGHTING).

GROUP BOUNDARIES
 2.0000E 07  3.6790E 06  1.3530E 06  4.9790E 05  1.8320E 05  4.0870E 04
 1.0000E-05

MAT-MT CONTROL
 1262     18      4   1264     18      4

MAT - MT TYPE CROSS SECTIONS AND STANDARD DEVIATIONS
 6.43200E-01 4.70200E-01 1.53300E-02 1.04400E-04 4.43500E-05 7.01900E-05 3.12000E-02 2.45100E-02 2.59000E-02 3.14600E-02
 7.82000E-02 1.07100E 00
 1.82800E 00 1.90400E 00 1.69300E 00 1.52300E 00 1.75300E 00 1.69700E 00 3.09700E-02 2.37800E-02 2.73100E-02 2.84200E-02
 2.77300E-02 3.40000E-02

MATRIX CONTROL
        1262          18          1262          18           1

BLOCK CONTROL
        6          1          6          2          6          3          6          4          6          5
        6          6          6
```

RELATIVE COVARIANCE MATRIX

```
 9.73800E-04 4.14700E-04 2.19800E-04 5.19700E-05-5.91800E-06-3.34700E-07
 4.14700E-04 6.00900E-04 3.94100E-04 1.86000E-04 6.23000E-05 2.54700E-07
 2.19800E-04 3.94100E-04 6.70900E-04 2.87000E-04 8.17800E-05-6.07900E-07
 5.19700E-05 1.86000E-04 2.87000E-04 9.89500E-04 1.16800E-03 2.26700E-04
-5.91800E-06 6.23000E-05 8.17800E-05 1.16800E-03 6.11600E-03 6.46200E-04
-3.34700E-07 2.54700E-07-6.07900E-07 2.26700E-04 6.46200E-04 1.14600E 00
```

MATRIX CONTROL

```
      1262          18          1264          18           1
```

BLOCK CONTROL

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

RELATIVE COVARIANCE MATRIX

```
 9.50400E-04 3.94100E-04 1.51900E-04 4.29900E-05 8.14900E-06 0.0
 3.94100E-04 5.48400E-04 3.24000E-04 1.59900E-04 4.56500E-05 0.0
 1.51900E-04 3.24000E-04 7.17300E-04 5.63900E-04 2.24700E-04 0.0
 4.29600E-05 1.59900E-04 5.63900E-04 7.90100E-04 3.90600E-04 2.60900E-04
 8.14900E-06 4.56900E-05 2.24700E-04 3.90600E-04 7.26200E-04 3.40300E-04
 0.0         0.0         0.0         2.60900E-04 5.40300E-04 1.06200E-03
```

MATRIX CONTROL

```
      1264          18          1264          18           1
```

BLOCK CONTROL

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

RELATIVE COVARIANCE MATRIX

```
 9.59100E-04 4.00500E-04 1.55900E-04 4.46000E-05 7.99400E-06 2.28500E-07
 4.00500E-04 5.65700E-04 3.31700E-04 1.63800E-04 4.88000E-05-7.88800E-07
 1.55900E-04 3.31700E-04 7.45700E-04 5.80400E-04 2.34800E-04 8.08200E-07
 4.46000E-05 1.63800E-04 5.80400E-04 8.07400E-04 4.00900E-04 2.62200E-04
 7.99400E-06 4.88000E-05 2.34800E-04 4.00900E-04 7.68700E-04 5.37200E-04
 2.28500E-07-7.88800E-07 8.08200E-07 2.62200E-04 5.37200E-04 1.15600E-03
```

V. MERGE OUTPUT

```
COVERX EXECUTION PATH SELECTED... MERG                    1$$ 35 34 33 T

   1$ ARRAY      3 ENTRIES READ


   01
 IN FMERG, CORE AVAILABLE   25000 CORE NEEDED     190
 MERGE   35    34    33
 IFC      6     6     0     2     2     3    11
 JFC      6     6     0     2     1     1     4
      1262        18          4       1264        18          4       1266        18          4
```

VI. DELETE OUTPUT

```
COVERX EXECUTION PATH SELECTED... DELE                          195 33 34 1 T

    1* ARRAY       3 ENTRIES READ

    OT
 IN EDEL. CORE AVAILABLE   25000 CORE NEEDED      114
                                                 2** 1262 18 1264 18 T

    2$ ARRAY       4 ENTRIES READ

    OT
 NBIN=       33  NEW=       34  NC=        1
  1262     18  1264     18
***** DELETED *****   MATRIX CONTROL RECORD... NO.    2.  1262   18 1264   18
```

VII. ADD OUTPUT

```
COVERX EXECUTION PATH SELECTED... ADD
                                                    1$$ 34 1 33 0 T
    1* ARRAY      4 ENTRIES READ

    0T
 IN FADD, CORE AVAILABLE   25000 CORE NEEDED      84
                                                    2$$ 1261 452 1266 452 T
    2$ ARRAY      4 ENTRIES READ

    0T
                                                    4$$ 0 1 522 A1 6 1 13 302 03 6
                                                    5** F1.33325-5 T
    4$ ARRAY     13 ENTRIES READ
    5* ARRAY     36 ENTRIES READ

    0T
 IN FMERG, CORE AVAILABLE   25000 CORE NEEDED     190
 MERGE   34   31   33
 IFC      6     6     0     3     3     3     4
 JFC      6     6     0     2     0     1     4
     1262       18        4      1264      19       4      1266      19       4
```

VIII. LIST OUTPUT

```
COVERX EXECUTION PATH SELECTED... LIST
                                                      1?? ?? T
    1S ARRAY        1 ENTRIES READ


    OT

 IN FLIST, CORE AVAILABLE   25000 CORE NEEDED        96

******************************AN EDIT OF THE COVERX CROSS-SECTION COVARIANCE FILE IS PRINTED HERE*****************************
FILE IDENTIFICATION RECORD.............. 0V COVERX COVERX*CRNL - FORSS*     3
FILE CONTROL RECORD..................... 1D      6      6      0      2      1      4      4
FILE DESCRIPTION........................ 2D *THIS IS A SAMPLE PROBLEM*
NEUTRON GROUP BOUNDARIES................ 3D    2.0000E 07   3.6790E 06   1.3330E 06   4.0790E 05   1.8320E 05
                                             4.1870E 04   1.0000E-05
MAT-MT CONTROL RECORD................... 5D    1262      18      4    1264      11      4    1266      18      4
MAT - MT TYPE CROSS-SECTIONS E ......... 6D    6.4320E-01   4.7020E-01   1.5730E-02   1.0440E-34   4.4350E-05
STANDARD DEVIATIONS                          7.0150E-05   3.1200E-02   2.4510E-02   2.5530E-02   3.1460E-02   7.6200E-02
                                             1.0710E 00
MAT - MT TYPE CROSS-SECTIONS E ......... 6D    1.8280E 00   1.9040E 00   1.6033E 00   1.5230E 00   1.5530E 00
STANDARD DEVIATIONS                          1.6970E 00   3.0970E-02   2.3780E-02   2.7310E-02   3.0420E-02   2.7730E-02
                                             3.4000E-02
MAT - MT TYPE CROSS-SECTIONS E ......... 6D    1.0000E 00   1.0030E 00   1.0133E 00   1.0000E 00   1.0030E 00
STANDARD DEVIATIONS                          1.0000E 00   0.0                       2.3419E-02   2.6782E-02   2.0105E-02   0.0
                                             0.0
MATRIX CONTROL RECORD..........NO.    1.. 7D    1262      18    1262      18       1
BLOCK CONTROL RECORD.................... 8D      6       1       6       2       6       3       6       4       6       5       6
                                               6       6
MATRIX DATA RECORD...................... 9D    5.7380E-04   4.1470E-04   3.1930E-04   5.1970E-05  -5.5190E-06
                                            -3.3470E-07   4.1470E-04   6.0090E-04   3.3410E-04   1.3600E-04   6.2300E-05
                                             2.5470E-07   2.1980E-04   3.9410E-04   6.7050E-04   2.9700E-04   8.1790E-05
                                            -6.0750E-07   5.1970E-05   1.8600E-04   2.9730E-04   9.1550E-04   1.1600E-03
                                             2.2670E-04  -5.9180E-06   6.2300E-05   8.1730E-05   1.1680E-03   6.1160E-03
                                             6.4620E-04  -3.3470E-07   2.5470E-07  -6.0790E-07   2.2670E-04   6.4620E-04
                                             1.1460E 00
MATRIX CONTROL RECORD..........NO.    2.. 7D    1264      18    1264      18       1
BLOCK CONTROL RECORD.................... 8D      6       1       6       2       6       3       6       4       6       5       6
                                               6       6
MATRIX DATA RECORD...................... 9D    9.5910E-04   4.0030E-04   1.5300E-04   4.4600E-05   7.9940E-06
                                             2.2850E-07   4.0050E-04   5.6570E-04   3.3170E-04   1.6380E-04   4.4600E-05
                                            -7.8880E-07   1.5550E-04   3.3170E-04   7.4570E-04   5.1940E-04   2.3450E-04
                                             8.0820E-07   4.4600E-05   1.6380E-04   5.8040E-04   8.0740E-04   4.0090E-04
                                             2.6220E-04   7.9940E-06   4.8800E-05   2.3440E-04   4.0950E-04   7.6870E-04
                                             5.3720E-04   2.2650E-07  -7.8850E-07   8.0820E-07   2.6220E-04   5.3720E-04
                                             1.1960E-03
MATRIX CONTROL RECORD..........NO.    3.. 7D    1266      18    1266      18       1
BLOCK CONTROL RECORD.................... 8D      6       1       6       2       6       3       6       4       6       5       6
                                               6       6
MATRIX DATA RECORD...................... 9D    0.0                       3.5410E-04   1.5190E-04   4.2990E-05   0.0
                                             0.0          0.0                       5.4840E-04   3.2400E-04   1.5990E-04   0.0
                                             0.0          0.0                       3.2400E-04   7.1730E-04   5.6350E-04   0.0
                                             0.0          0.0                       1.5990E-04   5.6390E-04   7.0010E-04   0.0
                                             0.0          0.0                       4.5690E-05   2.2470E-04   3.7060E-04   0.0
                                             0.0          0.0                       0.0          0.0          2.6050E-04   0.0
                                             0.0
MATRIX CONTROL RECORD..........NO.    4.. 7D    1261     452    1266     452       1
BLOCK CONTROL RECORD.................... 8D      6       1       6       2       6       3       6       4       6       5       6
                                               6       6
MATRIX DATA RECORD...................... 9D    1.3322E-05   1.3322E-05   1.3322E-05   1.3322E-05   1.3322E-05
                                             1.3322E-05   1.3322E-05   1.3322E-05   1.3322E-05   1.3322E-05   1.3322E-05
                                             1.3322E-05   1.3322E-05   1.3322E-05   1.3322E-05   1.3322E-05   1.3322E-05
                                             1.3322E-05   1.3322E-05   1.3322E-05   1.3322E-05   1.3322E-05   1.3322E-05
                                             1.3322E-05   1.3322E-05   1.3322E-05   1.3322E-05   1.3322E-05   1.3322E-05
                                             1.3322E-05   1.3322E-05   1.3322E-05   1.3322E-05   1.3322E-05   1.3322E-05
                                             1.3322E-05

THE FILE HAS BEEN SUCCESSFULLY LISTED.
```

XII. THE UNCOVER MODULE OF THE FORSS SYSTEM

J. H. Marable
J. L. Lucius

CHAPTER XII

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THE UNCOVER MODULE

UNCOVER is the FORSS module that incorporates the data from integral experiments with the evaluated nuclear data based on differential cross-section measurements and prepares data files which are used to adjust (see Chapter XIV) the nuclear data base leading to improved performance parameter prediction. UNCOVER requires sensitivity coefficients and covariance matrices as input. This data may be input by a card input stream or via SENPRO and COVERX files. A convenience module COVERS (see Chapter XIII) is available to aid in UNCOVER input preparation when SENPRO and COVERX files are used.

GENERAL DEVELOPMENT

The least-squares adjustment formula gives the minimum variance estimates x' of experimentally determined quantities x^e with covariance B. It is assumed that the estimates x' are subject to linear constraints imposed by theory and expressed as

$$S(x'-x^c) = 0$$

where x^c is any set of values consistent with the theory. The representation of the constraints by a matrix S is not unique since any linear equation remains a valid linear equation when multiplied by an arbitrary nonzero constant

The least-squares values for x' are given by

$$x'-x^e = P_{\perp}(x^c-x^e)$$

where $P_{\perp}$ is a projection operator given by

$$P_{\perp} = BS^T(SBS^T)^{-1} S.$$

The super-T indicates the transpose.

The covariance associated with these adjusted values x' is given by

$$B' = (1-P_{\perp})\, B\, (1-P_{\perp})^T$$
$$= B - P_{\perp}B.$$

In application it is convenient to partition the matrices x^e, x^c, B, and S into submatrices; x', $P_{\perp}$, and B' are also partitioned accordingly.

$$x^{eT} = [x^e_\alpha\ x^e_\beta\ \ldots\ x^e_\gamma]$$

$$x^{cT} = [x^c_\alpha\ x^c_\beta\ \ldots\ x^c_\gamma]$$

$$S = [S_\alpha S_\beta \ldots\ S_\gamma]$$

$$B = \begin{Bmatrix} B_{\alpha\alpha} & B_{\alpha\beta} \cdots & B_{\alpha\gamma} \\ B_{\beta\alpha} & B_{\beta\beta} & \\ \vdots & & \\ B_{\gamma\alpha} & & B_{\gamma\gamma} \end{Bmatrix}.$$

The partitions and the form of S can be chosen so that S_α is the negative of a unit matrix. This form is assumed in the code UNCOVER, and accordingly S_α is not required in the input. The remaining $S_\beta \cdots S_\gamma$ are then ordinary sensitivity coefficients. The code also assumes submatrices $x^c_\beta \cdots x^c_\gamma$ are chosen to be equal to submatrices $x^e_\beta \cdots x^e_\gamma$. Accordingly the input only requires the first submatrix of its difference $(x^c_\alpha - x^e_\alpha)$ since the other partitioned submatrices have zero differences.

The chi-square of the adjustment is given by

$$\chi^2 = (x'-x^e)^T\, B^{-1}\, (x'-x^e)$$
$$= (x^c-x^e)^T\, S^T\, (SBS^T)^{-1}\, X(x^c-x^e)$$

and components of χ^2 are found from

$$\chi^2_{\alpha\beta} = [(x^c-x^e)^T S^T(SBS^T)^{-1} S]_\alpha B_{\alpha\beta}[S^T(SBS^T)^{-1} S(x^c-x^e)]_\alpha$$

These components sum to χ^2.

UNCOVER INPUT PREPARATION

The input data for code module UNCOVER is based on the partitioning of the extended covariance matrix into NPxNP submatrices and the partitioning of the sensitivity coefficient matrix into (NP-1)xNC submatrices. This partitioning is defined by two partitions; the first partition is defined by NP integer parameters and the second partition is defined by NC integer parameters. The present restrictions on these partitions are (1) that NP be greater than or equal to 2 and not greater than 50, (2) that NC be equal to 1, and (3) that the first integer parameter of each partition be the number of integral experiments NIE. Thus, the first partition is a set of NP integer parameters whose sum NIE + ... is equal to the order of the extended covariance matrix, and the second partition is one integer parameter NIE. Except for these restrictions partitions are arbitrary and are determined by the user for his own convenience according to input and storage requirements.

The sample problem referenced in this description of UNCOVER input has an extended covariance matrix partitioned as illustrated in Fig. 1 and has the integral experiment data as described in Table 1. For this discussion, the extended covariance matrix is defined as a covariance matrix for all integral and differential experiments combined. Note that the sample problem includes data from eight integral experiments and that the extended covariance matrix is partitioned into 23x23 submatrices. The basic objective of UNCOVER input is the definition of the extended covariance matrix partitions and guidance of the code in accordance with these partitions in the assimilation of the associated sensitivity coefficient and covariance submatrices.

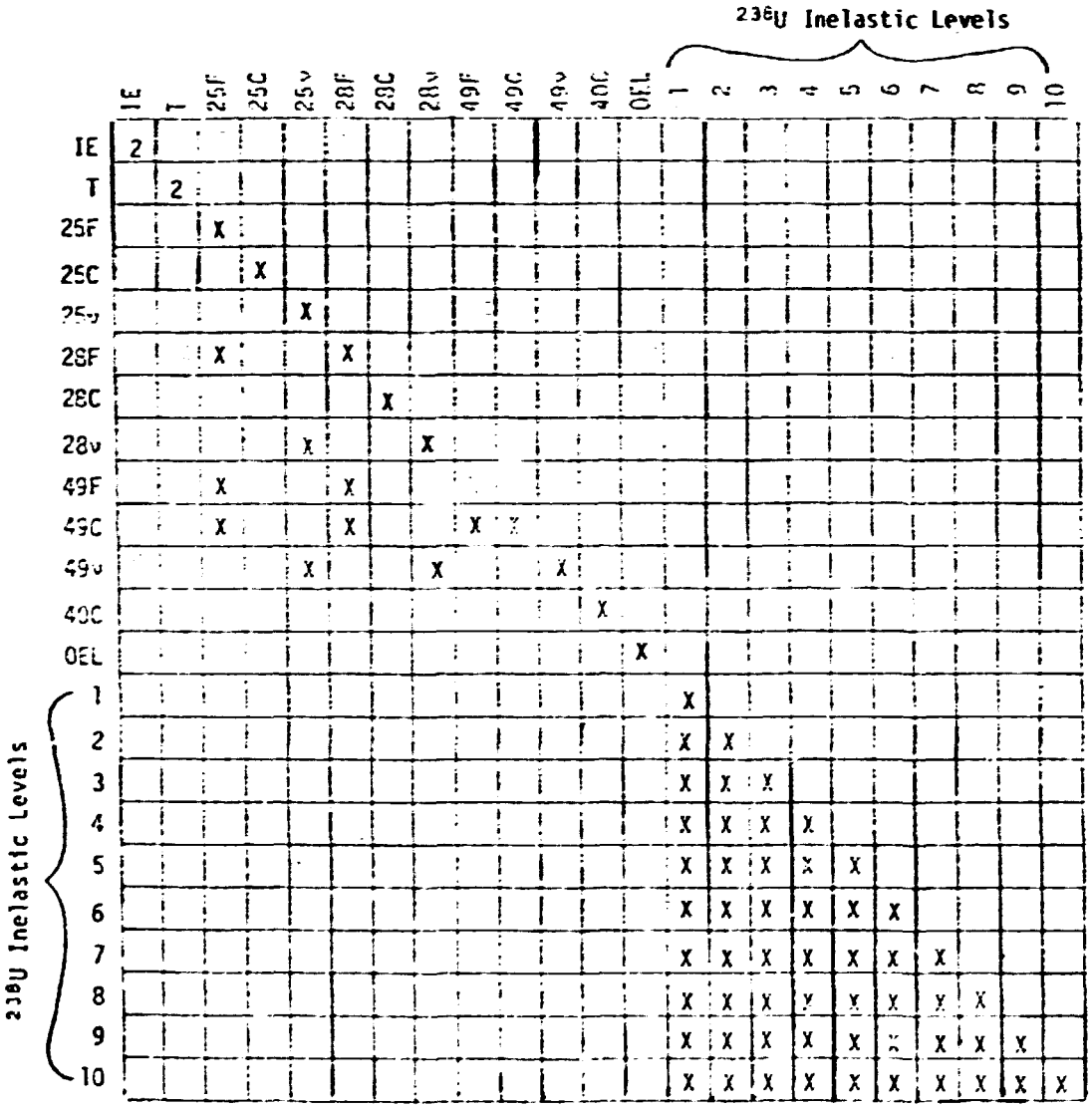

Fig. 1. Extended Covariance Matrix.

Table 1. Integral Experiment Data Used for Adjustment[a]

Assembly	Response	Exp.	Calc.	Y_{Exp}(%)[b]	Std. Dev. (%)
ZPR-6/7	k	1.000	0.9844	1.61	0.20
	$^{26}f/^{49}f$	0.02421	0.02344	3.32	1.78
	$^{28}c/^{49}f$	0.1406	0.1524	-7.57	2.56
ZPR-3/48	k	1.000	0.9911	0.915	0.20
ZPR-9/31	k	1.000	0.9885	1.18	0.15
	$^{25}f/^{49}f$	1.058	1.0140	4.37	1.32
	$^{28}f/^{49}f$	0.0300	0.0288	4.17	1.33
	$^{28}c/^{49}f$	0.1230	0.1311	-5.96	1.46

[a]This data was provided by ANL (R. McKnight and P. Collins).

[b]Y_{Exp} = (Exp − (Calc + Bias))/Calc where bias designates known corrections, e.g., homogeneous to heterogeneous, 1-D to 2-D, etc.

UNCOVER uses the container block concept for data storage: all data is stored in a single block and base addresses are provided which point to the starting locations of subsets or arrays of data within the container block. UNCOVER creates these base addresses and stores them in the O$$ array.

The improved FIDO routine is used to input data into the various arrays of the container block. The features of this routine, as described in Chapter II permit considerable flexibility in the preparation of input data. The @ feature, which allows modification of data already in memory, and the capability to direct the acquisition of data from external storage devices as well as from the card input stream are particularly useful.

The input of both the sensitivity matrix and the extended covariance matrix is by submatrix. The (NP-1)*NC submatrices of the sensitivity matrix

are entered through improved FIDO into the 22** array. UNCOVER provides several alternatives for entering the covariance submatrices. The first option (determined by IACSYM) is whether to enter all NPxNP submatrices of the symmetric covariance matrix or to apply symmetry and use the NP(NP+1)/2 submatrices of the upper or lower triangle. Obviously, space is conserved by using the symmetry. Another option (determined by MB) allows the (NPxNP or NP(NP+1)/2 according to the above option) submatrices of the extended covariance matrix to be stored all in memory or all on an external storage device (disk, tape, or drum). For these two alternatives the code calculates the base addresses and indicator of the 23$$ array correctly.

If however (1) one wishes to mix storage of the covariance submatrices so that some are in core and some are on external storage devices, and/or if (2) one wishes not to store zero or unit submatrices by the appropriate use of indicators in the 23$$ array, and/or if (3) one wishes to make use of the fact that one submatrix is identical to another submatrix, then the addresses and indicators of the 23$$ array must be entered by the user. Since in these circumstances the length of the core storage required in the 24** array for the extended covariance matrix is changed from that calculated by the code, the base address (in the 0$$ array) for the following 25$$ array must be calculated and entered by the user. For these purposes the user should note that the base address for the 24** extended covariance storage array is always calculated correctly by the code and this base address is stored in two locations: (1) in the 25'th word of the 0$$ base address array and (2) the first word of the 23$$ indicator array. The Q and @ input operations of improved FIDO can then be used to make the required address changes.

UNCOVER requires sensitivity coefficients and covariance matrices as input, and the SENPRO and COVERX files are the primary data bases for this information. However, rather than reading these files directly, UNCOVER reads compressed extracts from the files permitting more effective utilization of the improved FIDO input scheme. The COVERS module of the FORSS system reads SENPRO and COVERX files and prepares the extracts

acceptable to UNCOVER. A description of the COVERS module is available in Chapter XIII.

UNCOVER INPUT

1$$ Integer parameters [10]

1. NP - Order of the first partition specifying the number of submatrices along a row (or column) of the extended covariance matrix
2. NC - Order of the second partition 1 for this version of the code
3. IACSYM - Options for defining extended covariance matrix
   - -1 input only lower triangle submatrices
   - +1 input only upper triangle submatrices
   - 0 input all submatrices
4. ICLROS - Options for ordering submatrices of the extended covariance matrix
   - +1 order submatrices by column
   - -1 order submatrices by row
5. MB - Storage options
   - 2 all submatrices of extended covariance matrix to be in core
   - >1000000 all submatrices are in I/O device MB/1000000
6. MBB - Storage options
   - 0 all submatrices of adjusted extended covariance matrix to be in core
   - >1000000 submatrices are to be on the I/O device MBB/1000000
7. LCOM - Edit option
   - 0 Normal output
   - 1 Hordes of intermediate results for trouble shooting

8. IBCHK - Option to check[a] input covariance matrix B
   - 0 No effect
   - 1 Check is made

9. IBBCHK - Option to check [a] output covariance matrix BB
   - 0 No effect
   - 1 Check is made

10. IESENS - Option to calculate from sensitivities
   - 0 No effect
   - >0 Integral experiment adjustments are calculated from sensitivities and cross section adjustments
   - |≥2| Covariance of adjusted integral experiments calculated from sensitivities and from the covariances of adjusted cross sections

2$$ First Partition Integer Parameters [NP]

1. NIE - The number of integral experiments.
2. The dimension associated with each type of differential experiment, typically the number of groups. In reference to a sensitivity partition, it is the length of the vector. In reference to the NP covariance matrix, it is the order of the square matrix.

3$$ Second Partition Integer Parameters [NC]

NIE - The number of integral experiments.

T

20** Integral Experiment Data [NIE]

For each integral experiment enter:

$$\frac{\text{Integral experiment value - calculated value}}{\text{Calculated Value}}$$

T

---

[a]The covariance matrix is checked for symmetry. Correlations are checked and a warning message is generated for each correlation with an absolute magnitude greater than one.

22** Relative Sensitivity Coefficients [SUM1*NIE], See COMMENTS ON THE 22** CARD for definition of SUM1.

T

0$$ Base Addresses [30]

Modify base address number 26 according to the memory required for covariance data. (Modify only if different from that calculated by the code).

24** Covariance Data

Relative Covariances of integral experiments and other relative covariance data which are not available on the external storage device(s) specified in the 23$$ array.

23$$ Addresses and Indicators of the Extended Covariance Matrix [2*NP*NP]

IADDR (I), I=1, NP

IND(I), I=1, NP (Enter only if the storage option provided by MB is to be overridden.)

Indicators are:

0 - Null submatrix

1 - Unit submatrix

-1 - Negative unit submatrix

2 - Submatrix stored in address specified

-2 - Transpose of submatrix stored in address specified

$>10^6$ - Read submatrix from unit and record designated and store in address specified

$<10^6$ - Read transpose from unit and record designated and store in address specified

unit number = $|IND|/10^6$

record number = $|IND| - (\text{unit number})*10^6$

T

27$$ NOMIT, (LIST(I), I=1, NOMIT)

NOMIT - The number of integral experiments to be omitted in adjustment. NOMIT is preset to 0.

LIST - A list of integral experiment numbers which are to be omitted from the adjustment (assuming the order consistent with arrays 20, 22, and 24).

Note: If no integral experiments are to be omitted from the adjustment, the 27$$ card is not included in the input stream.

T

COMMENTS ON THE 22** CARD

The first partition is made up of NP numbers, the first corresponds to the number of integral experiments and the rest give the dimensions of NP-1 types of differential experiments. A set of sensitivity coefficients or sensitivity submatrix is provided for each type of nuclear data, making NP-1 sensitivity submatrices. Each sensitivity submatrix contains sensitivity coefficients for every integral experiment response considered in the analysis. The sensitivity coefficients for a single response and for nuclear data of type I form a vector of length LV(I), where LV(I) is the (I+1)th integer (on the 2$$ card) which defines the first partition. The length of the I'th sensitivity submatrix for UNCOVER is LV(I)*NIE where NIE is the number of integral experiment responses. There are NP-1 such submatrices. The total number of sensitivity coefficients is NIE*SUM1 is the sum of the LV(I).

Note in the sample input the first card in the 22** array contains the fission spectrum temperature sensitivity coefficients for eight responses. This forms the first submatrix. (The fission spectrum temperature corresponds to a submatrix with dimension 1). The last three cards in the array direct that 21 submatrices be read from unit 31, each submatrix forming one record. Note there are twenty-one 31G208 0 commands. The 31 is the I/O unit number, the G is an improved FIDO read command, the 208 sensitivity coefficients reflect an LV(I) of 26 and an NIE of 8, and the 0 indicates that unit 31 is unformatted (i.e., binary). The value of SUM1 is 547(=1+21*26). Unit 31 was prepared by the COVERS module which is discussed in Chapter XIII.

COMMENTS ON THE O$$ ARRAY

The O$$ array contains the base address for the FIDO arrays used in UNCOVER. The code correctly calculates these base addresses under either of two assumptions: (1) all submatrices of the extended covariance matrix (hereafter referred to as the B array) are assigned storage in the memory (the 24** array), or (2) all submatrices are stored on an I/O device and are read into the core (24** array) one submatrix at a time. If any submatrices are declared to be zero or if some are in core and some on an I/O device, then the length required for B-array core storage changes. This invalidates the precalculated 25$$ array base address which in the O$$ array follows the 24** array base address. The user must insert the correct 25$$ array base address via input into the O$$ array.

Note that the base address of the 24** array is stored in position 25 of the O$$ array, and that the base address of the 25$$ array is stored in position 26. First, the base address of the 24** array is entered into position 26 of the O$$ array by FIDO command A26 1Q1. In the sample problem the correct 25$$ array base address is determined by using the improved FIDO command A26 1@741. This command causes the base address just put into position 26 to be incremented by 741, which is the length required for B-array storage in the sample problem according to the partitioning and storage allocation used. For the sample problem, the length is determined as $NIE^2+1+IGM^2=741$, where the number of integral experiments NIE is 8, and the number of groups IGM is 26. NIE^2 locations are reserved in memory for storage of the integral experiment covariances, one location is reserved in memory for the variance of the fission spectrum temperature. IGM^2 is the storage required to read from external storage the largest submatrix for the differential experiments. The operation of UNCOVER is such that it is unnecessary to correct any base address in the O$$ array beyond position 26.

COMMENTS ON THE 23$$ ARRAY

According to the partition chosen for our sample problem the extended covariance matrix is partitioned into 23x23 submatrices as shown in Fig. 1. We have chosen to place two of these submatrices, denoted by 2 in Fig. 1, into core storage. The first requires 8x8 (=64) locations and the second requires 1x1 (=1) location making a total of 65 locations required in core. The submatrices denoted by X in Fig. 1 will be placed on an external device and will be read into core one at a time as needed. The largest such submatrix (in this example these externally stored submatrices are the same size) requires 26x26 (=676) locations. The remaining submatrices, denoted by blanks in Fig. 1 are all zero. Each will have an indicator 0 and will not be stored, and any base address assigned to them will be ignored. The total memory required of the 24** array for storage and reading of the submatrices of the extended covariance matrix is 741 (=64+1+676).

Since the storage of the extended covariance matrix is mixed (some submatrices in internal memory and some on external storage devices) and also because not all submatrices are stored (some are simply indicated to be zero), UNCOVER cannot calculate the correct storage required for the 24** array. The user must input base addresses and indicators into the 23$$ array and also must modify a base address in the 0$$ array.

The 23$$ array is made up of two sets of numbers, each set consisting of NPxNP numbers. The first NPxNP numbers of the 23$$ array are the base addresses which specify where the submatrices of the extended covariance matrix B are stored or into where they will be read. The second NPxNP numbers are indicators, one for each submatrix of the extended covariance matrix. The base address of the first submatrix of the B matrix is always correctly calculated by UNCOVER and is the first number of the 23$$ array.

Our strategy is as follows: after the first address (which already correctly gives the location of the first submatrix) we set all 528 remaining addresses to the address into which externally-stored submatrices will be read. Since the addresses of zero submatrices are ignored, we

need to correct only one address, that for the internally stored fission spectrum variance, this address is one less than the address for reading in externally-stored submatrices.

Recall that the extended covariance matrix for the sample input is partitioned into 23x23 submatrices (NP=23). We now define the base address for reading in the externally stored submatrices. The FIDO command A2 1Q1 places the first address into the second location, to which the improved FIDO command 1@ A2 65 adds 65. (The addition of 65 provided space for the 8x8 integral experiment covariance matrix and the variance of the fission spectrum temperature.) The second address is now the correct base address for reading in the externally stored submatrices. The remaining 527 addresses are set to this same address by the 0@ 527Q1 command on the 23$$ card. At this point, the base address for the temperature variance (submatrix number 25) is yet undefined. However, it is one less than the base address for reading the externally-stored submatrices. This is indicated on the 23$$ input cards by the improved FIDO command 1@-1. The following command 0@ cancels the preceeding 1@ command. This completed the definitions of base addresses for the submatrices of the B matrix.

The indicators for the submatrices of the B-matrix must now be entered into the 23$$ array starting in location 530 (after the first 23x23 base addresses). The first submatrix, the covariances of the integral experiments, is stored in core - it was read by FIDO into the 24** array. Hence the indicator for the first submatrix is 2 as shown on the second card for the 23$$ array. The next 23 submatrices are zero matrices (see Fig. 1) with 0 indicators. These are entered by the 23Z following the 2. The next submatrix is the temperature variance and was read by FIDO into the 24** array and is in core storage. This is indicated by the next 2, and following this 23Z again indicates 0 covariances for the next 23 submatrices.

At this point the next submatrix is stored externally, and all successive submatrices are stored externally or are zero. The module COVERS prepared these nonzero submatrices on unit 32 and also prepared the input stream as listed in Fig. 2.

OUTPUT DISCUSSION

Following the printing of the two correlation matrices, results are listed for each partition in the extended covariance matrix. Some of the output labels are self-explanatory. Perhaps the following will clarify others.

Partition 1 - The Integral Experiment Partition

Column	Label on Output Listing		
1	(E/C-1) OLD(%)	=	$\frac{\text{experimental value}}{\text{calculated value}} - 1$
2	(E-A)/C NEW(%)	=	$\frac{\text{experimental value - adjusted value}}{\text{original calculated value}}$
3	ST.DEV. EXP.(%)	=	uncertainties reported by the experimentalist
4	ST.DEV. OLD CALC(%)	=	uncertainty in calculated response due to uncertainties in the nuclear data (cross sections)
5	ST.DEV. NEW ADJ.(%)	=	standard deviation associated with the adjusted values.

The results in output columns 6 - 9 are functions of the results in columns 1 - 5 as indicated below.

6	EXP. CHANGE (IN S.D.'S)	=	- 2 / 3
7	CALC. CHANGE (IN S.D.'S)	=	$\frac{1 - 2}{4}$
8	S.D. RATIO (ADJ./EXP)	=	5 / 3

```
0
1$$      23   1  -1   1    32000000    35000000  0  0  0  T
2$$       8   1
 21R 26
3$$       8  T
20**
          / INTEGRAL EXPERIMENT VALUES
1.61124-2   3.31611-2   -7.56895-2    9.15261-3    1.17856-2  4.36551-2
 4.16667-2   -5.96465-2
T
22**
       0.1315     2Z     2R0.1315      3Z
  31G208 0    31G206 0    31G206 0    31G208 0    31G208 0
  31G206 0    31G208 0    31G208 0    31G208 0    31G206 0
  31G208 0    31G208 0    31G208 0    31G208 0    31G208 0
  31G208 0    31G206 0    31G208 0    31G206 0    31G206 0
  31G206 0
T
6$$   A26   101   A26   1a    741  E
2***
             /   COVARIANCES OF INTEGRAL EXPERIMENTS
4.-6 6Z 3.17-4  1.46-4  2Z  3.99-5  5.45-5  2.86-5   0 1.46-4   /COV-2  1
6.55-4  2Z  4.06-5  3.75-5  4.88-5  3Z  4.-6  4Z  4Z  2.25-6  3Z   /COV-2   3
0  3.99-5  4.06-5  2Z  1.74-4  5.44-5  5.76-5  0  5.45-5  3.75-5  2Z  /COV-2  3
5.44-5  1.77-4  6.02-5  0 2.66-5 4.86-5 2Z 5.76-5  6.02-5  2.13-4  /COV-2  4
   4.0-4          /VAR FISS SPECT TEMP
    A1    3a       64R4.
F
23$$  A2  101  1a A2  65  0a  52701  A25  1a  -1  0a  A530
 ?    23Z   2     23Z
   ?2000001         2Z      32000002       2Z       32000003        32000004
  16Z      32000005    23Z      32000006      2Z      32000007
   2Z      32000008    14Z     -32000002      2Z      32000009
   2Z      32000010      32000011       19Z      32000012
  20Z     -32000007     2Z      32000013      2Z      32000014
  14Z     -32000003     2Z     -32000010      2Z      32000015
   32000016       15Z     -32000004      2Z     -32000011
   2Z     -32000016      32000017       17Z     -32000008
   2Z     -32000014     2Z      3200001A     23Z      32000019
  23Z      32000020    23Z      32000021      32000022         32000023
    32000024         32000025         32000026         32000027
    3200002.         32000029         32000030     13Z    -32000022
    32000031         32000032         32000033         32000034
    32000035         32000036         32000037         32000038
    32000039     13Z    -32000023      -32000032         32000040
    32000041         32000042         32000043         32000044
    32000045         32000046         32000047     13Z    -32000024
   -32000033        -32000041         32000048         32000049
    32000050         32000051         32000052         32000053

    32000054     13Z    -32000025      -32000034        -32000042
   -32000049         32000055         32000056         32000057
    32000058         32000059         32000060     13Z    -32000026
   -32000035        -32000043        -32000050        -32000056
    32000061         32000062         32000063         32000064
    32000065     13Z    -32000027      -32000036        -32000044
   -32000051        -32000057        -32000062         32000066
    32000067         32000068         32000069     13Z    -32000028
   -32000037        -32000045        -32000052        -32000058
   -32000063        -32000057         32000070         32000071
    32000072     13Z    -32000029      -32000038        -32000046
   -32000053        -32000059        -32000064        -32000068
   -32000071         32000073         32000074     13Z    -32000030
   -32000039        -32000047        -32000054        -32000060
   -32000065        -32000069        -32000072        -32000074
    32000075
T
T
```

Fig. 2. List of Sample Irput

9	S.D. RATIO (ADJ./CALC)	= 5 / 4

Partition 2 ... NP - The Nuclear Data Partitions

1	CHANGE (%)	= $\frac{\text{adjusted value - old value}}{\text{old value}}$ x 100
2	ST.DEV. OLD(%)	= standard deviation associated with nuclear data
3	ST.DEV. NEW(%)	= standard deviation associated with adjusted nuclear data

The results in output columns 4 and 5 are functions of the results in columns 1, 2, and 3 as indicated below.

4	CHANGE (IN S.D.'S)	= 1 / 2
5	S.D. RATIO (NEW/OLD)	= 3 / 2

UNCOVER ERROR STOPS

STOP 1 - Problem size exceeds container array size. A printed message precedes the STOP 1 which specifies the memory required and the memory available. The container array size must be increased or the problem requirements reduced by partitioning.

STOP - Statement in subroutine COPYIT, see the printed message on the output.

STOP - Statement in subroutine COPYIT, see the printed message on the output.

STOP 13579 - The statement is located in subroutine UNPART. The number of partitions in the extended covariance matrix exceeds 50. A programming change is required unless the problem can be reduced.

RESOURCE UTILIZATION

For the sample problem, the container block size was 20000 words, the program loaded and executed in 270 K bytes of core storage, execution time was 9 seconds on the IBM 360-91, 685 I/O requests were made in the GO step, and four external storage units were used (1 for sensitivity coefficients, 1 for covariance matrices, 1 for indicators, 1 for the adjusted extended covariance matrix). Not every problem requires external storage.

CHAPTER XIII. THE COVERS MODULE OF THE FORSS SYSTEM

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CHAPTER XIII

Table of Contents

I. INTRODUCTION

COVERS is a convenience module which prepares input data for UNCOVER. The input requirements of UNCOVER which are described in Chapter XII should be reviewed before attempting to use COVERS. If all sensitivity and covariance data is to be made available to UNCOVER via the card input stream, then COVERS is unnecessary and the user should prepare input data directly for UNCOVER. When all or part of the required sensitivity and covariance data is on a SENPRO and/or a COVERX file, COVERS can relieve some of the burden of input preparation. COVERS can prepare all of the input needed for an UNCOVER run. This consists of three data files: 1) an extract of the SENPRO file, 2) an extract of the COVERX file, and 3) a file containing all of the card images required to define an UNCOVER input case. However, there are cases when it is convenient to use the SENPRO and COVERX extract files, abandon the card image file, and prepare the card input stream directly in UNCOVER. There are other cases when it is efficient to use the COVERS prepared input stream but modify it with card input directly in UNCOVER.

II. INPUT PREPARATION FOR COVERS

Before attempting to prepare input for COVERS, it is suggested that an extended covariance matrix for the problem of interest be diagrammed similar to Fig. 1. This diagram illustrates the partitions in the extended covariance matrix, the cross correlations, and the source of data for each submatrix. Data as used in this context is to be interpreted as the sensitivity coefficients and covariances for each submatrix of the extended covariance matrix. Such data may be provided via the

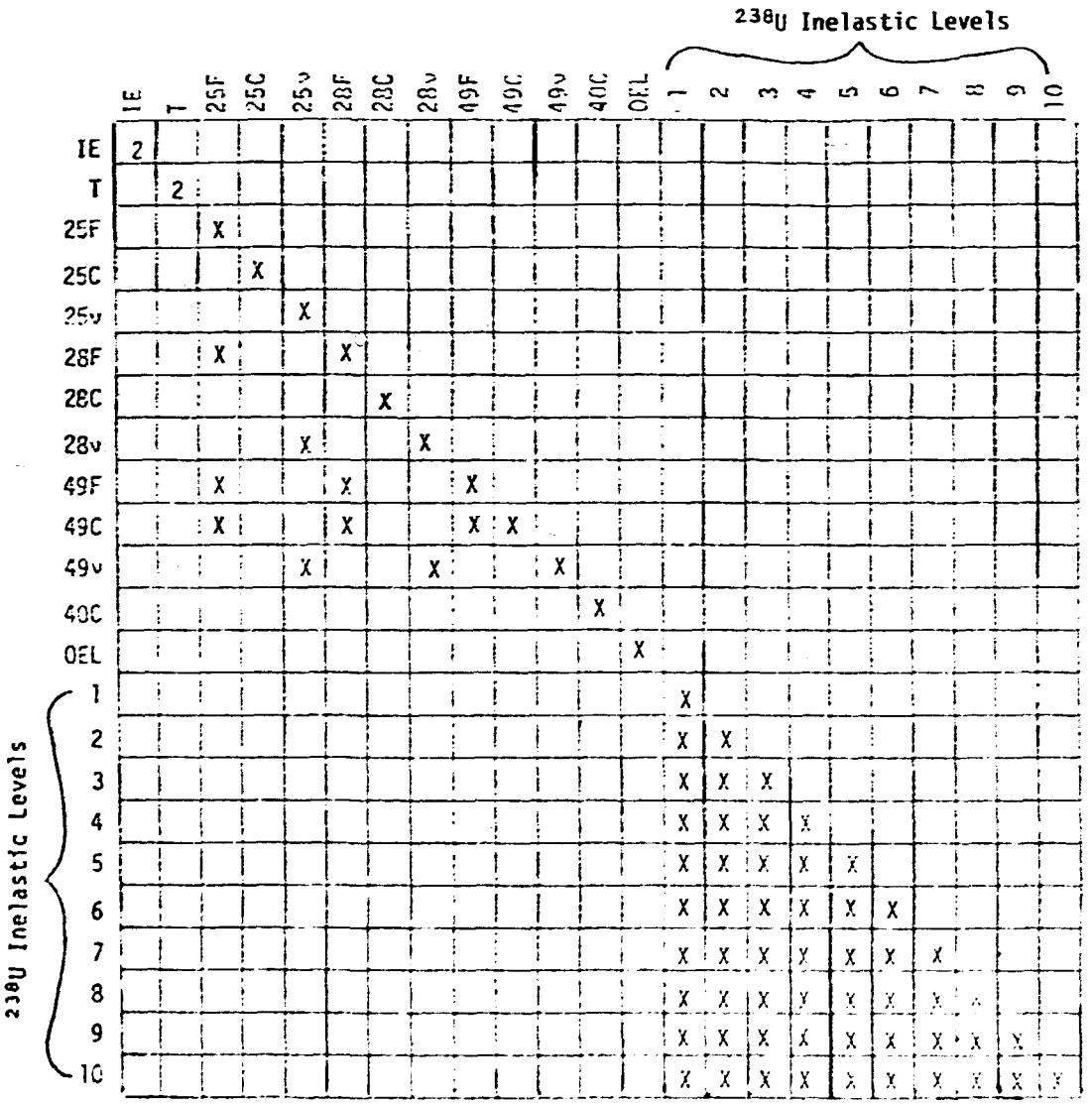

Fig. 1. Extended Covariance Matrix.

the card input stream and/or obtained from SENPRO and COVERX files. Realistic problems typically utilize data from both sources. COVERS input consists of Improved Fido Cards for the 1$$, 2$$, and 3$$ arrays which contain information used in COVERS computation and decision making. COVERS also reads three other types of data in the Hollerith format. This information is passed to UNCOVER witnout modification and defines the UNCOVER 20**, 22**, and 24** input arrays.

A. The COVERS 1$$ Card

This card contains administrative information, and the brief definitions of each parameter in the COVERS Input Data Description section should suffice with the exception of the ninth parameter, KRECT. KRECT is a modifier for input data contained on the 3$$ cards and its use will be described in the discussion of the 3$$ cards. KRECT is a very useful input parameter, but it is also very dangerous. If improperly used, disaster is certain. The most prudent use of KRECT is to initially set its value to zero and leave it unchanged until the need for a change is clearly demonstrated and understood.

B. The COVERS 2$$ Card

The information on this card is a list of the experiments included in the adjustment. SENPRO nomenclature is used; i.e., assembly identifier and response identifiers (see the discussion of the SENPRO file MAT-MT control record in Appendix A of Chapter VIII). This information, along with the material-reaction type identifiers provided on the 3$$ cards, identifies all of the sensitivity profiles located on a SENPRO file to be used in the adjustment.

C. The COVERS 3$$ Cards

The 3$$ cards provide a transcription of the diagram in Fig. 1 of the extended covariance matrix into functional numerical nomenclature. The 3$$ cards serve the following functions:

1. Delineate the partitions included in the extended covariance matrix.
2. Indicate the source of data for each submatrix of the extended covariance matrix. Recall that as used in this context, data is to be interpreted as sensitivity profiles and covariances. Two sources are available, the card input stream and the files (SENPRO, COVERX).
3. Identify the cross correlations needed between material-reaction type pairs. The correlation of a material-reaction type to itself is assumed.
4. Coupled with the 2$$ card, identify all sensitivity profiles to be used in the adjustment.
5. Identify all of the covariances needed in the adjustment.

In discussing preparation of the 3$$ cards, reference will be made to the sample input shown in Fig. 2. COVERS permits only the lower triangle of the extended covariance matrix to be described and then guarantees symmetry. The content of a 3$$ card is different depending upon whether the data is to come from the card input stream or from the files (SENPRO, COVERX). COVERS requires that all partitions requiring data from the card input stream be described before the partitions obtaining data from the files. If the sensitivity data is provided via the card input stream so must be the covariance data and conversely. Refer

```
0
1$$   23   24   31   32   33   23   6   F0   T
2$$   12   1   0   12   4   2   12   4   1   21   1   0
 29   1  0   22   4   7   22   4   2   29   4   1   T
3$$   F8   T
3$$   F1   T
3$$   1261   18   F0   T
3$$   1251   102   F0   T
3$$   1201   452   F0   T
3$$   1262   16   3   F0   T
3$$   1262   102   F0   T
3$$   1262   452   5   F0   T
3$$   1264   18   3   6   F0   T
3$$   1264   102   3   6   9   F0   T
3$$   1264   452   5   8   F0   T
3$$   1265   102   F0   T
3$$   1276   2   F0   T
3$$   398   51   F0   T
3$$   396   52   14   F0   T
3$$   396   53   14   15   F0   T
3$$   398   54   14   15   16   F0   T
3$$   398   55   21   14   17   F0   T
3$$   398   56   31   14   18   F0   T
3$$   398   57   41   14   19   F0   T
3$$   396   556   51   14   20   F0   T
3$$   396   559   61   14   21   F0   T
3$$   398   560   71   14   22   F0   T
     / INTEGRAL EXPERIMENT VALUES
1.61124-2   3.31611-2   -7.56895-2   9.15261-3   1.17856-2  4.36551-2
 4.16667-2   -5.96465-2
 (BLANK CARD)
      0.1315   2Z   2R0.1315   3Z
 (BLANK CARD)
          /   COVARIANCES OF INTEGRAL EXPERIMENTS
4.-6 6Z 3.17-4  1.46-4  2Z  3.99-5  5.45-5  2.86-5  0 1.46-4  /COV-2  1
6.55-4  2Z  4.06-5  3.75-5  4.88-5  3Z  4.-6  4Z  4Z  2.25-6  3Z  /COV-2  3
0  3.99-5  4.06-5  2Z  1.74-4  5.44-5  5.78-5  0  5.45-5  3.75-5  2Z  /COV-2  3
5.44-5  1.77-4  6.02-5  0 2.86-5 4.88-5 2Z 5.78-5  6.02-5  2.13-4  /COV-2  4
   4.0-4          /VAR FISS SPECT TEMP
    A1   3∅      64R4.
 (BLANK CARD)
```

Fig. 2. Sample Input for a COVERS Case.

to the diagram of the extended covariance matrix in Fig. 1; in reading down the diagonal from left to right, notice the two integers with a value of 2. These indicate that the data for these submatrices will be provided in the card input stream immediately following the 3$$ cards. The corresponding 3$$ cards contain information of a dimensional nature; i.e., how many numbers are to be read from cards. Note in Fig. 2, the content of the first 3$$ card is 3$$ F8 T. This card deals with the integral experiment partition which is unique in that no sensitivity coefficients are entered for the partition. UNCOVER generates the sensitivity coefficients for the integral experiment internally. However a covariance matrix must be input for the integral experiment partition and the 3$$ F8 T card directs that 64 numbers, an 8 × 8 covariance matrix, be entered in the covariance block. In Fig. 2, the

second 3$$ card content is 3$$ F1 T. This partition deals with the temperature associated with a fission spectrum. The first eight numbers in the sensitivity block of the card input are the sensitivity to the temperature of each of the eight integral experiments and the 65th entry in the covariance block is the variance of the temperature. Recall the first 64 words of the covariance block have been used for the 8×8 covariance matrix associated with the integral experimert partition. Data for the integral experiment partition must be entered first and immediately followed by all of the other partitions for which the data is entered from the card input stream. The order in which sensitivity and covariance data is entered in their respective blocks establishes the correspondence.

Now consider the content of the 3$$ cards that deal with the submatrices for which data is obtained from the files (SENPRO, COVERX). The objective is to identify all of the sensitivity profiles and all of the covariance matrices needed in the adjustment and to read this data from a SENPRO file and a COVERX file. Recall that a sensitivity profile on a SENPRO file has five identification numbers: 1) assembly, 2) response, 3) material, 4) reaction type, and 5) reaction rate ratio. Obviously items 2 and 5 are related and merely constitute a dual identification of a response. Identification of covariances is simpler. Covariance matrices are not assembly and response dependent. They are identified by four integers material-reaction type correlated to the same material-reaction type or cross correlated to another material-reaction type. Note that the third partition of the extended covariance matrix in Fig. 1 indicates a correlation of 25F to itself. In Fig. 2, note

that the third 3$$ card is completed as 3$$ 1261 18 FO T. The 1261 is the material identifier for ^{235}U on both the SENPRO and COVERX files and the 18 is the reaction type identifier for fission on both files. The actual numerical values of these identifiers are arbitrary, but they must be consistent on the 3$$ cards, the SENPRO file, and the COVERX file. The ENDF/B material-reaction type (MAT-MT) identifiers serve very effectively as identifiers in the adjustment process. With the assemblies and responses identified on the 2$$ cards and the material-reaction type identified on the 3$$ cards, COVERS can search a SENPRO file for the sensitivity profiles for all assemblies and all responses to ^{235}U fission. Also, COVERS can search a COVERX file for the covariance of ^{235}U fission correlated to itself. This process is now repeated for every partition of the extended covariance matrix. To further illustrate the preparation of 3$$ cards, consider the sixth partition of the extended covariance matrix. It is indicated that 28F is correlated to itself and cross correlated to 25F. Referring to the sixth 3$$ card in Fig. 2, the 1262 is the MAT number for ^{238}U and 18 is the MT number for fission. The 3 indicates the cross correlation to 25F since 25F has already been identified in the third partition of the extended covariance matrix, hence the 3 on the 3$$ card. It may also be convenient to note in Fig. 1 that the X indicating the cross correlation is in column 3 of the extended covariance matrix. Now suppose all input is prepared and it is decided that one additional partition with data in the card input stream should be added. Recall all card input partitions must precede the partitions with data from the files. The 3 in partition 6 used to indicate the cross correlation of 28F to 25F now should be 4 and every other cross

correlation indicator should be incremented by one. Before discarding all input and starting over, examine the 1$$ card, item 9, the parameter KRECT. When KRECT is nonzero, all cross correlation indicators are redefined as KN´ = KN + KRECT. Where KN is the input value but KN´ is the value actually used by the code to establish cross correlations.

III. THE HOLLERITH DATA BLOCKS

COVERS reads three Hollerith data blocks and passes the data directly to the UNCOVER card input stream to form the UNCOVER input arrays designated as 20**, 22**, and 24**. COVERS does not have a need to know any numerical values of this data and treats all of these cards as Hollerith information. However, the user must know how much and what information to prepare. A review of the UNCOVER input requirements in Chapter XII would be helpful, but all of the "how much" question is already answered in the preparation of the COVERS 1$$, 2$$, and 3$$ cards.

A. Block 1, The Integral Experiment Data

Enter one value (V) for each integral experiment: $V = \frac{VM - VC}{VC}$, where VM is the measured value of the experiment and VC is the calculated value of the experiment. Data must be entered in this block. End the block with a blank card.

B. Block 2, The Card Input Stream Sensitivity Coefficients

Excluding the 3$$ card for the integral experiment partition, examine all of the 3$$ cards relevant to partitions with sensitivity and covariance data being entered via the card input stream. In the

sample input shown in Fig. 2, this is one card 3$$ F1 T. From the seventh parameter on the 1$$ card it is known that the problem includes eight integral experiments; therefore, 1 × 8 is the number of sensitivities to be entered in Block 2. This completes the Block 2 data entry for the sample input, but assume following the 3$$ F1 T card there was another 3$$ card with the content 3$$ F4 T. In this hypothetical case, the total number of sensitivities to be entered would be calculated as (1 + 4) × 8. The first eight entries correspond to the 3$$ card (3$$ F1 T) and the following 32 entries would correspond to the hypothetical 3$$ card (3$$ F4 T). The 32 entries must be defined in the following order four sensitivities for the first integral experiment, four sensitivities for the second integral experiment, etc., until four sensitivities have been entered for each of the eight integral experiments. If all sensitivity and covariance data were to be obtained from the files (SENPRO, COVERX), Block 2 would be empty. One blank card is always used to end Block 2, designating either the empty condition or the end of card input stream sensitivity data.

C. Block 3, The Card Input Stream Covariances

A square covariance matrix must be entered for each partition for which the card input stream is the source of data. In Fig. 2, note the first two 3$$ cards: 3$$ F8 T, 3$$ F1 T. The number of values to be entered in Block 3 is calculated as $8^2 + 1^2$. If all sensitivity and covariance data were to be obtained from the files (SENPRO, COVERX), Block 3 would be empty. One blank card is always used to end Block 3, designating either the empty condition or the end of card input stream covariance data.

IV. COVERS INPUT DATA description

1$$ Inteyer parameters (12)

1. IPRO - unit numer of SENPRO file
2. ICOU - unit number of COVERX file
3. JAMS - unit number of data extracted from SENRPO
4. JAMC - unit number of data extracted from COVERX
5. JAMI - unit number of UNCOVER card image input stream
6. NP - number of partitions in extended covariance matrix
7. NRESP - number of responses (integral experiments)
8. LCOM - edit option
   0 - normal output
   >0 - full output for troubleshooting
9. KRECT - constant to be added to KN, see 3$$ card,
   KRECT may be negative
10. IBCHK - Option to check[a] input covariance matrix B
    0 - no check
    1 - check
11. IBBCHK - option to check[a] output covariance matrix BB
    0 - no check
    1 - check
12. IESENS - option to calculate from sensitivities
    0 - no effect

---

[a]The covariance matrix is checked for symmetry. Correlations are checked and a warning message is generated for each correlation with an absolute magnitude greater than one. These checks have the potential for generating thousands of lines of print.

>0 - integral experiment adjustments calculated from sensitivities and cross section adjustments

|≥2| - covariance of adjusted integral experiments calculated from sensitivities and from the covariances of adjusted cross sections

T

2$$ Integer parameters (3*NRESP) response description

IASB - assembly identification

IRESP - response identification

NTRN - reaction rate ratio identification

.

.

.

complete for all responses

T

The 3$$ card indicating data is to come from the card input stream and has the following form:

3$$ Integer parameters (100)

F ND T

The array is filled with the dimension (ND) associated with the experiment being described. On the first 3$$ card, ND is equal to the number of integral experiments. On succeeding 3$$ cards, the associated dimension is typically the number of groups. In reference to a sensitivity partition, it is the length of the vector. In reference to a covariance matrix, it is the order of the square matrix.

The 3$$ card indicating data is to come from SENRRO and COVERX files and has the following form:

3$$ Integer parameters (100)

MAT - material identification for the row

MT - reaction type identification for the row

KN - the partition column numbers of all nonzero covariance submatrices in the row and to the left of the diagonal element

FO - the FIDO fill with 0 option; this input is mandatory

T

The following three types of data are card images which COVERS uses to prepare the 20**, 22**, and 24** arrays for UNCOVER. Note each type of data is terminated with a blank card.

Block 1, Integral experiment data (NIE)

For each integral experiment enter:

$$\frac{\text{Integral experiment value} - \text{calculated value}}{\text{calculated value}}$$

End with a blank card.

Block 2, Sensitivity coefficients

Enter sensitivity coefficients for each differential experiment not retrieving coefficients from a SENRPO file. End with a blank card.

Block 3, Covariance data

Enter the covariances of integral experiments and other covariance data which are not available on a COVERX file. End with a blank card.

V. COVERS OUTPUT

If a sensitivity profile is needed for the problem and cannot be located on the SENPRO file, COVERS indicates the profile was not found

and proceeds as if the profile was found with all coefficients for that profile set to zero. COVERS also indicates what covariance matrices are required and those that are found. Any not found are set to zero.

Three files are prepared by COVERS: an extract of SENRPO, an extract of COVERX, and the card stream input for UNCOVER.

VI. COVERS ERROR STOPS

STOP 1	at least one 3$$ card did not end with 0, check 3$$ cards
STOP 2	all 3$$ cards were filled with 0, COVERS has nothing to do, check 3$$ cards
STOP 3, STOP 4, STOP 5	the container array is too small to accommodate the problem, reduce problem or increase the size of the container array

VII. COVERS RESOURCE UTILIZATION

For the sample problem the container block size was 20,000 words, the problem loaded and executed in 180K bytes of core storage, execution time was five seconds on the IBM 360-91, 386 I/O requests were made in the GO step. Two external storage units were required for the SENRPO and COVERX files, three external storage units were used for the SENRPO extracts, the COVERX extracts, and the UNCOVER card input stream.

CHAPTER XIV. THE ADJUST MODULE OF THE FORSS SYSTEM

J. L. Lucius
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CHAPTER XIV

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THE ADJUST MODULE

I. INTRODUCTION

The preparation of a functional, adjusted cross section set is a three step operation involving the UNCOVER module, the ADJUST module and the AMPX[1] modules, COMET, AJAX, DIAL AND RADE. The objective is to modify (adjust) an AMPX multigroup, infinitely dilute, master cross section file with the changes calculated by an UNCOVER adjustment run resulting in an adjusted cross section file in the AMPX master format. Extreme care must be exercised to insure that a consistent cross section set is produced. This involves application of the AMPX module COMET in a manner consistent with the type of adjustment made.

A. Correspondence Between UNCOVER and the AMPX Master File

A correspondence is established between each UNCOVER differential parameter (e.g., cross section) partition, and one or more material-reaction types on an AMPX master file. The multiple correspondence is especially useful in the adjustment of inelastic levels. UNCOVER produces a file containing one record for each differential partition in the UNCOVER run. Typically, each record contains the percent changes by energy group to be used in adjusting the corresponding material-reaction type(s) on the AMPX master. The AMPX master and the UNCOVER results must be in either identical group structures or the UNCOVER structure must be a subset of the group structure on the AMPX master. With both group structures available, ADJUST applies the UNCOVER percent changes over the appropriate energy ranges of the AMPX master.

B. Adjustment of Fission Spectrum Parameters

Unlike other reactions, the fission spectrum on the AMPX master is not mechanically adjusted by a multiplicative constant factor, but is rather replaced by recalculating group values based on modified parameters. UNCOVER produces percent changes to be applied to these parameters, which are passed to ADJUST which calculates a new fission spectrum and places it on the AMPX master. Both the Watt[2] and Maxwellian[2] definitions of a

fission spectrum are available (although ENDF/B-V allows for energy dependent parameters a and b, since in the AMPX master file there is only one fission spectrum, only one set of parameters per material is handled):

The Maxwellian fission spectrum

$$f(E \to E') = \frac{\sqrt{E'}}{I} e^{-E'/a}$$

I is the normalization constant,

$$I = a^{3/2} \left[\frac{\sqrt{\pi}}{2} \text{erf} \left(\sqrt{(E-U)/a} \right) - \sqrt{(E-U)/a}\, e^{-(E-U)/a} \right]$$

a is the adjusted parameter input from a 4** card.

U is a constant introduced to define the proper upper limit for the final neutron energy such that $0 \leq E' \leq E - U$.

The Watt fission spectrum

$$f(E \to E') = \frac{e^{-E'/a}}{I} \sinh (bE')$$

I is the normalization constant,

$$I = \frac{1}{2} \sqrt{\frac{\pi a^3 b}{4}} \exp \left(\frac{ab}{4} \right) \left[\text{erf} \left(\sqrt{\frac{E-U}{a}} - \sqrt{\frac{ab}{4}} \right) + \text{erf} \left(\sqrt{\frac{E-U}{a}} + \sqrt{\frac{ab}{4}} \right) \right] - a \exp \left(- \left(\frac{E-U}{a} \right) \sinh \left(\sqrt{b(E-U)} \right) \right)$$

a and b are adjusted parameters input from a 4** card

U is a constant introduced to define the proper upper for the final neutron energy such that $0 \leq E' \leq E - U$

To calculate a Watt Spectrum, the user must determine the values of the constants a and b at 1 MEV which were used to calculate the corresponding Watt spectrum on the AMPX master (see Appendix A). The UNCOVER results (percent change of a and b) must then be applied by hand

to calculate the adjusted values of a and b and be input to ADJUST (4** cards). The same procedure applies for a Maxwellian spectrum with the constant a interpreted as the Maxwellian θ and the constant b set to zero. The hand operations are required because values for a, b, and θ are currently not available on the AMPX master and the retrieval of these parameters from a basic ENDF/B-V file is beyond the scope of this version of ADJUST.

C. The ADJUST 2$$ and 3$$ Input Arrays

The ADJUST input to implement the correspondence between UNCOVER and the AMPX master file is provided in the 2$$ array and the 3$$ arrays. Typically there is a one-to-one correspondence between an UNCOVER partition and a 3$$ array. The correspondence is established by inspecting each UNCOVER partition and determining the applicable corresponding AMPX master material (MAT) and reaction type (MT) identifiers which are then entered in 3$$ arrays in the same order. A single UNCOVER partition may be designed to adjust parameters for more than one material-reaction type. For example, the parameters a and b may be adjusted for both ^{239}Pu and ^{240}Pu in the same UNCOVER partition. In this situation, a 3$$ array must be prepared to identify each material treated in the partition. The 2$$ array contains an indicator for each 3$$ array in the input stream. The indicator defines the relationship of the material-reaction type(s) specified in the 3$$ array with the corresponding UNCOVER partition. Also, a specific adjustment may be desired that does not require the results of every partition included in UNCOVER run. This condition can be indicated in the 2$$ array.

D. Preparation of a Consistent Cross Section Set With AMPX-COMET

Before an adjusted AMPX master can be used in calculations, AMPX-COMET must be used to calculate the following:

1. The neutron disappearance cross section (MT = 101) is the sum of all partial disappearance cross sections (i.e. (n,γ), (n,p), (n,α),...) (MT = 100 + i, i = 2, ..., 14)

2. The absorption cross section (MT = 27) is the sum of the disappearance (MT = 101) and fission (MT = 18) cross sections.
3. The total cross section as a sum of partials
4. For materials where the inelastic total cross section has been adjusted, the inelastic level cross sections must be normalized to sum to the adjusted inelastic total. For materials where the inelastic level cross sections have been adjusted, the inelastic total must be calculated as a sum of the adjusted levels.

AMPX-RADE may used to check the internal consistency of the cross section set. AMPX-AJAX is very useful in isolating materials requiring the specific treatments discussed in step 4 and then recombining all of the materials onto a single AMPX master. AMPX-DIAL may be used to edit the cross sections residing on an AMPX master file.

II. ADJUST INPUT

1$$ Integer Parameters [6]

1. NR - The number of differential parameter sets in the UNCOVER case. NR is also the number of 3$$ cards to be prepared.
2. NOMT - The maximum number of reaction types to be adjusted by the same factor. NOMT will be equal to the maximum number of reaction types identified on a single 3$$ card (default = 1), NOMT > 1 is useful for adjusting inelastic levels when several levels are to receive the same adjustment.
3. N61 - The unit number of the file containing the UNCOVER results. (percent changes) (default = 61).
4. NMG - The unit number of the AMPX master file to be adjusted (default = 45).
5. NAD - The unit number of the adjusted AMPX master file (default = 46).
6. ISU - The unit number of a SENPRO file containing the group boundaries and sensitivity coefficients used in the UNCOVER run (default = 23).

T

2$$ Integer Parameters [NR]

These parameters describing the requested operation for each 3$$ card assume one of the following values for each 3$$ card.

-1 - This indicates a fission spectrum is to be calculated from the adjusted parameters a and b which will be input on a 4** card. A record on unit N61 is read but the contents are discarded.

-25 - This indicates the same action as -1 above with one important exception; no corresponding record exists on unit N61 and no attempt is made to read such a record.

0 - This indicates that a record exists on unit N61 but that the information is not useful in this particular adjustment. The record is read and the contents discarded, i.e., the record skipped.

+1 - This indicates a record is read from unit N61 and the contents are used in the adjustment.

T

Prepare a 3$$ card[†] for each differential experiment (partition) in the UNCOVER run, i.e., prepare NR (see 1$$ card) 3$$ cards

3$$ Integer Parameters [NOMT + 1]

MAT - The material identifiers on the AMPX master of the material to be adjusted by the percent changes calculated in the corresponding UNCOVER partition.

MT - The reaction type identifier on the AMPX master of the reaction to be adjusted by the percent changes calculated in the corresponding UNCOVER partition. A maximum of NOMT (see 1$$ card) reaction types may be adjusted by the same percent changes. This is useful for inelastic levels.

F 0

T

[†]For records to be skipped, the 3$$ card should be filled with zeros (3$$ F0 T).

4** Adjusted Fission Spectrum Parameters [2]

a - This parameter is interpreted as the adjusted value of the constant a used in the definition of a Watt Spectrum. For a Maxwellian spectrum, this parameter is interpreted as the constant θ.

b - For a Watt spectrum, this parameter is the adjusted value of the constant b. Enter a value of zero for this parameter to calculate a Maxwellian spectrum.

T

Enter one 4** card for each fission spectrum identified by a 3$$ card in the same order as the 3$$ fission spectrum identifiers are encountered.

AMPX Input

Relevant sections of reference 1 have been reproduced and inserted in APPENDIX B for convenience.

REFERENCES

1. N. M. Greene, J. L. Lucius, L. M. Petrie, W. E. Ford III, J. E. White R. Q. Wright, "AMPX: A Modular Code System for Generating Coupled Multigroup Neutron-Gamma Libraries from ENDF/B," ORNL/TM-3706 (March 1976). See also RSIC PSR-63/AMPX-II Code Package Material (1978).

2. R. Kinsey, "Data Formats and Procedures for the Evaluated Nuclear Data File, ENDF," BNL-NCS-50496 (ENDF 102), 2nd Edition (ENDF/B-V) (1979).

Figure 1: Sample Input for ADJUST and AMPX (AJAX, COMET, RADE)

```
//CC#SA JOB (19738),'C C WEBSTER 6025'
/*JOBPARM LINECT=63
//*CLASS CPU91=03M,IO=010,REGION=0540K,LINES=050
// EXEC FORTHCLG,PARM.FORT='XREF ',REGION.GO=270K,
// PARM.GO='ID=-1,IO=-1,FD=-1,EG=-1,EJ=-1 '
//FORT.SYSIN DD *
//LKED.ADJUST DD VOL=SER=ZX0000,DISP=SHR,UNIT=3330-1,
//    DSN=JLL.FORSS.ADJUST.HEX
//LKED.IFIDD DD VOL=SER=ZX0000,DISP=SHR,UNIT=3330-1,
//    DSN=JLL.MARABLE.FIDD.HEX
//LKED.SYSIN DD *
 INCLUDE ADJUST
 INCLUDE IFIDD
//GO.FT23F001 DD UNIT=3330-1,VOL=SER=ZX0000,DISP=SHR,
//    DSN=JLL.ADJUST.SNP26
//GO.FT24F001 DD DSN=T.Y5V18C75.NCCVER24,VERYSRMX,
// VOL=,
//    UNIT=SYSDA,DISP=SHR
//GO.FT45F001 DD UNIT=3330,VOL=SER=ZX0000,DISP=SHR,
// DSN=JLL.AMPX.VERROT
//GO.FT46F001 DD UNIT=SYSDA,SPACE=(TRK,(600,50)),
// DISP=(NEW,PASS),DSN=&&JLLAMP,
//                DCB=(RECFM=VBS,LRECL=X,BLKSIZE=6400,BUFL=7160)
//GO.FT05F001 DD *
3
1$$   50   12   61   45   46   23   T
2$$   0   3R-1   -25   C   C   4291   0   T
3$$   F0   T
3$$   1395   1018   FC   T
3$$   1398   1018   FC   T
3$$   1399   1018   FC   T
3$$   1360   1018   FC   T
3$$   F0   T
3$$   F0   T
3$$   1306   2   FC   T
3$$   1306   4   FC   T
3$$   1306   102   F0   T
3$$   1276   2   F0   T
3$$   1278   4   F0   T
3$$   1211   2   F0   T
3$$   1311   4   F0   T
3$$   1311   102   F0   T
3$$   1324   102   F0   T
3$$   1326   2   FC   T
3$$   1326   4   F0   T
3$$   1326   102   F0   T
3$$   1328   102   F0   T
3$$   1395   2   FC   T
3$$   1395   4   FC   T
3$$   1395   102   F0   T
```

```
3$$   1395   18    F0   T
3$$   1395   452   F0   T
3$$   1398   2   F0   T
3$$   1398   51    F0   T
3$$   1398   52    F0   T
3$$   1398   53    F0   T
3$$   1398   54    F0   T
3$$   1398   55    F0   T
3$$   1398   56    F0   T
3$$   1398   57    F0   T
3$$   1398   2I    5E   6I   FC   T
3$$   1398   3I    62   66   F0   T
3$$   1398   9I    67   77   5I   F0    T
3$$   1398   102   F0   T
3$$   1398   18    F0   T
3$$   1398   452   F0   T
3$$   1399   2     F0   T
3$$   1399   4     F0   T
3$$   1399   102   F0   T
3$$   1399   18    F0   T
3$$   1399   452   F0   T
3$$   1380   2     F0   T
3$$   1380   4     F0   T
3$$   1380   102   F0   T
3$$   1380   18    F0   T
3$$   1380   452   F0   T
3$$  F0   T
4$$   5.900052+5   2.13791E-6   T
4$$   8.94721E+5   3.27265IE-6   T
4$$   5.5E765E+5   2.E512E-6   T
4$$   1.258172E+6   0.0    T
/*
// EXEC AMPX,REGION.GO=480K,BLKS=6400,SBUF=7160,
//              TIME=02
//GO.FT04F001 DD UNIT=SYSDA,SPACE=(TRK,(300,50))
//GO.FT09F001 DD UNIT=SYSDA,SPACE=(TRK,(300,50))
//GO.FT18F001 DD UNIT=SYSDA,SPACE=(TRK,(300,50))
//GO.FT19F001 DD UNIT=SYSDA,SPACE=(TRK,(300,50))
//GO.FT61F001 DD UNIT=SYSDA,DISP=(OLD,PASS),DSN=&&JLLAPM
//GO.FT57F001 DD UNIT=SYSDA,SPACE=(TRK,(600,50)),
// DISP=(NEW,PASS),DSN=&&CCWAJAX),
//              DCB=(RECFM=VBS,LRECL=X,BLKSIZE=6400,BUFL=7160)
//GO.FT58F001 DD UNIT=SYSDA,SPACE=(TRK,(600,50)),
// DISP=(NEW,PASS),DSN=&&CCWCME11,
//              DCB=(RECFM=VBS,LRECL=X,BLKSIZE=6400,BUFL=7160)
//GO.FT59F001 DD UNIT=SYSDA,SPACE=(TRK,(300,50)),
// DISP=(NEW,PASS),DSN=&&CCWAJAX2,
//              DCB=(RECFM=VBS,LRECL=X,BLKSIZE=6400,BUFL=7160)
//GO.FT60F001 DD UNIT=SYSDA,SPACE=(TRK,(300,50)),
// DISP=(NEW,PASS),DSN=&&CCWCME12,
```

```
//                 XCB=(RECFM=VBS,LRECL=X,BLKSIZE=6400,BUFL=7160)
//GO.FT62F001 DD UNIT=3330,VOL=SER=ZX0000,DISP=(NEW,KEEP),
//   SPACE=(TRK,(200,10)),
//   DSN=CCB.AJSTED.AMPX.MASTER,
//                 XCB=(RELFD=VBS,LRECL=X,BLKSIZE=6400,BUFL=7160)
//SYSIN DD *
=AJAX
0$$ 57 61  1$$ 1  T
2$$ 61 -1  T
3$$ 1398   T
=COMET
-1$$  121  101  114   0  27  101  18  0  1  2  4  16  17  71  22  30
  41  32  37  0  E
0$$ 57 58 E
1$$  0
2$$   4  10001  E  T
=AJAX
0$$ 59 61  1$$ 1  T
2$$ 61 1  T
3$$ 1398  T
=COMET
-1$$  121  101  114   0  27  101  18  0  1  2  4  16  17  71  22  30
  41  32  37  0  E
0$$ 59 60 E
1$$  0
2$$  -4  10001  E  T
=AJAX
0$$ 62 58  1$$ 2  T
2$$ 58 0  T
2$$ 60 0  T
=MADE
1$$ 62 E  2$$ A2 10C E  T
/*
//
```

APPENDIX A

Fission Spectrum Parameters

The values of the fission spectrum parameters a and b at 1 MEV are listed for several materials. When b is zero a should be interpreted as θ for a Maxwellian spectrum. Otherwise the parameters are used in the definition of a Watt spectrum.

Material	a (eV)	b (eV^{-1})
^{235}U	9.88 E+5	2.249 E-6
^{238}U	8.95064 E+5	3.2953 E-6
^{239}Pu	9.66 E+5	2.842 E-6
^{240}Pu	1.361 E+6	0
^{241}Pu	1.3752 E+6	0
^{242}Pu	1.354 E+6	0

APPENDIX B

AJAX -- AMPX Module to Merge, Collect, Assemble, Re-Order, Join and/or Copy Selected Data Sets from AMPX Master Interfaces

N. M. Greene

AJAX (Automatic Joining of AMPX X-Sections) is a module to combine data from AMPX master interfaces. Options are provided to allow merging from any number of files in a manner as to allow the user to determine the final nuclide ordering. Any form of master interface (neutorn, gamma-ray, neutron-gamma) can be accessed. (In this discussion, interface, file, and library have the same meaning).

AJAX Input Data

Block 1

0$ Logical Assignments [2]

1. MMT - Logical number of new library (default = 1)
2. NMAX - Logical number of the input file which has the largest buffer requirements. (AJAX uses NMAX and MMT in determining total buffer requirements).

1$ Number of Files [1]

1. NFILE - Number of file requests to be made. (When "reordering" operations are performed which require the same file to be accessed several times, each access is counted to determine the value of NFILE).

T Terminate Block 1.

Blocks 2 and 3 are stacked, one after the other, NFILE times.

Block 2

2$ File and Option Selection [2]

1. NF - Logical number of file considered
2. IOPT* = -N Delete N nuclides from NF to create the new file on MMT

---

*Sets with duplicate identifiers will not be entered on MMT. The first occurrence of an identifier selects that set for the new library.

= 0 Add all nuclides to the new file on MMT

= N Add N nuclides from NF to create the new file on MMT

T Terminate Block 2.

Block 3 {Enter only when IOPT≠0}

3$ Nuclides Selected [|IOPT|]
Identifiers of nuclides which are to be added or deleted from NF

4$ New Identifiers [|IOPT|] {Enter only if an identifier is to be changed.} This array allows changing the identifier given in the 3$ array when it is selected for the new library.

T Terminate Block 3.

9.20.2 AJAX Input/Output Specifications

The following devices are normally needed to execute AJAX:

Logical Number	Purpose
5	Card input
6	Standard output
15	Scratch device
16	Scratch device
18	Scratch device
19	Scratch device
MMT(1)	Master file to be created
NF	File(s) to be merged onto MMT

COMET -- AMPX Module to Correct Selected Portions of AMPX Master Interfaces

N. M. Greene

COMET (Correct Old Master Excessive Tolerances) is a module to correct selected portions of an AMPX master interface. A complete library can be easily corrected. Operations are provided to ensure that transfer matrices normalize to the proper one-dimensional values, or vice versa. Note that COMET copies the whole library, not just selected master data sets. Although coupled neutron-gamma libraries can be read in, COMET only "operates" on the neutron data on a master library.

COMET Input Data Block 1

-1$ Special Vector Manipulations [200] (Default = all zeroes) These commands are used when it is desired that certain groupings of cross sections sum to a "total value". For example, it is desirable that $\sigma_a = \sigma_c + \sigma_f$ or that all inelastic partial values sum to the total inelastic values. This array is made up of strings of MT numbers as follows:

Primary MT number--Secondary MT number(s)--Zero

This string directs COMET to ensure that the sum of the cross sections identified by the secondary MT numbers sums to the cross sections identified by the primary identifier. Zeroes serve as "string delimiters." A positive primary identifier says to sum the secondaries and replace (or form) the primary values. A negative primary identifier says to normalize the secondaries such that they sum to the primary. Up to 20 strings can be specified. A negative secondary says to subtract this process so that one can form, for example, $\sigma_c = \sigma_a - \sigma_f$.

0$ Logical Assignments [3]

1. MMTO - Old master library (28)
2. MMTN - New master library (1)
3. MSC - scratch device (18)

1$ Option Trigger [1]

1. IOPT

-1 - Go directly to RECTRY on MMTO and skip any "correcting". This corrects the "Table of Contents". The correction is made on MMTO. (MMTN is not used).

0 - "Correct" the complete master library on MMTO and write a new one on MMTN.

N - "Correct" N sets from MMTO and write on MMTN.

2$ MT - Numbers of processes to be corrected [100]

Place up to 100 MT numbers into the 2$ array. A negative MT number says to force the 1D cross section to agree with the appropriate transfer matrix sums while a positive MT

number forces the transfer matrix to be normalized to the 1D value. Also, enter a signal defined as 10000 + MT to have the reaction type designated by MT located in the 1D array placed in the infinite dilution array associated with the Bondarenko factors for the process identified by MT. This is crucial in preparing cross section sets where the total cross section has been calculated as the sum of adjusted partials. The signal for the total cross section is 10001.

T Terminate Block 1.

Block 2 {Input if IOPT > 0}

3$ Identifiers for master data sets to be "corrected" [IOPT]

T Terminate Block 2.

COMET Input/Output Assignments

COMET requires the following input/output assignments:

Logical	Purpose
5	Card input
6	Standary output
9	Scratch device (random access)
17	Scratch device
MMTO(28)	Old master library
MMTN(1)	New master library
MCS(18)	Scratch Device

DIAL--AMPX Module to Produce Selected Edits from AMPX Interfaces

N. M. Greene

DIAL (Display AMPX Libraries) is provided to produce edits from AMPX master interfaces or working interfaces.

DIAL Input Data

Block 1

0$ Logical Assignments [2]

1. MMT - Master interface logical assignment (1)
2. MWT - Working interface logical assignment (0)
   Caution -- A single DIAL execution should edit either a master or a working interface, not both. If editing a working interface, MMT must be set to zero.

1$ Editing Options [4]

1. NEDIT - Number of data sets to be edited (0)
   A zero edits a complete interface.
2. NIDN - 0; no effect
   1, edit one-dimensional neutron cross sections
3. NIDG - 0, no effect
   1, edit one-dimensional gamma cross sections
4. NRN - 0, no effect
   1, edit resonance data and Bondarenko factor data

2$ Transfer Matrices to be Edited [100]

3$ Maximum Order of Scattering to be Edited [100]

The 2$ and 3$ arrays select two-dimensional array edits. Place up to 100 MT numbers in the 2$ array to select the desired processes. Corresponding entries in the 3$ array specify the maximum order of cross sections to be edited for the different processes. For example, if one desires edits of P_3 elastic data, and nothing else, the input data would read:

2$$ 2 FO 3$$ 3 FO

To edit the total transfer matrix on a working interface, specify

2$$ 1 FO 3$$ (order of P_n) FO

T Terminate Block 1.

Block 2 (This block is required if NEDIT > 0)

4$ Identifiers of Data Sets to be Edited [NEDIT] }NEDIT > 0}

T Terminate Block 2.

DIAL Input/Output Assignments

Dial requires the following input/output assignments:

Logical Number	Purpose
5	Card input
6	Standard output
MMT(1)	Master interface
MWT(0)	Working interface

RADE--AMPX Module to Check AMPX Master Cross Section Libraries

RADE (Rancid AMPX Data Exhorcist) is provided to check the multigroup libraries produced by the various AMPX modules. It will check neutron, gamma, or coupled neutron-gamma libraries.

In its present version, the check includes:

1. $\sigma_T \stackrel{?}{=} \sigma_a + \sigma_s$

2. $\sigma_{in} \stackrel{?}{=} \Sigma\, \sigma_{in}^{partial}$

3. $\sigma_a \stackrel{?}{=} \sigma_c + \sigma_f$

4. $\sigma_c \stackrel{?}{=} \sigma_{n\gamma} + \sigma_n + \sigma_{np} + \sigma_{nd} + \cdots$

5. $\sigma_{e\ell} \stackrel{?}{=} \sum_{g'} \sigma_{e\ell,0}\ (g \to g')$

6. $\sigma_0\ (g \to g') \stackrel{?}{>} 0$

7. $\sigma_T, \sigma_a, \sigma_f, \sigma_{n\gamma}, \sigma_{np}, \ldots \stackrel{?}{>} 0$

8. $-1 \leq \bar{\mu}(g \to g') = \dfrac{\sigma_1(g \to g')}{3\sigma_0(g \to g')} \leq 1$

In addition to these checks, the code will compute an estimate of the capture binding energy for each neutron group in a coupled neutron-gamma set. On option, one can request a display of differential cross sections.

RADE Input Data

Block 1

1$ Checking Commands [4]

1. MMT - Check the AMPX master Interface on logical MMT. This can be a neutron, gamma, or coupled neutron-gamma library.
2. MWT - Check the AMPX Working/Weighted Interface on logical MWT. This operation is not operable in the present version.
3. MAN - Check the ANISN binary formatted library on logical MAN.
4. IFM - -1, ANISN library is binary formatted;
   0, ANISN library is BCD free form;
   1, ANISN library is BCD fixed form.

2$ Options [20]

1. IOPT1 - number of angles at which a display of differential cross sections is desired. These angles will be equally spaced in the cosine range, -1 to +1. These edits are for the group integrated cross sections and not for each group-to-group transfer.
2. IOPT2 - The ϵ, in the 1/1000's of a percent, to which checks are made; e.g., IOPT2=1 is equivalent to 0.001% checking. This is the default value when IOPT2 is not input or when a zero value is input.
3. IOPT3

   . Future checking options; skip or input zeroes.
   .
   .

20. IOPT20

3$ ANISN Options [7] MAN ≠ 0

1. NSET - number of ANISN sets to check.
2. IHT - position of σ_T.
3. IHS - position of σ_{gg}.
4. ITL - table length.
5. NL - maximum order of scattering.
6. IGM - number of neutron groups.
7. IPM - number of photon groups.

T Terminate this block.

Block 2 {Input only when MAN > 0}

4$ Identification Numbers of P_0 Sets on ANISN Binary Library on Logical MAN [NSET]

5$ Order of Scattering for Sets of ANISN Data on Logical MAN [NSET]

7* Neutron Group Structure, high-to-low in eV [IGM+1]

8* Gamma Group Structure, high-to-low in eV [IPM+1]

T Terminate this block.

RADE Input/Output Specifications

RADE requires the following input/output assignments:

Logical	Purpose
5	Card Input
6	Standard Output
18	Scratch Device
19	Scratch Device
MMT	Master Library
MWT	Working Library
MAN	ANISN Library

XV. THE NUTCRACKER MODULE

The module NUTCRACKER solves the so-called "inverse problem" of reactor sensitivity theory. Specifically, this problem is as follows. Assume the following are given: (1) a specified reactor system with known sensitivity coefficients, (2) specific performance parameter accuracy requirements (e.g., ½% in k, etc.), (3) a cross section correlation matrix, and (4) a cost functional which gives the cost of an experimental program to measure the required cross sections to within an accuracy specified by the variables $x_1, x_2, \ldots x_n$ (these represent the rms standard deviations of the individual group cross sections). Then, what are the optimum set of standard deviations on the experimentally measured cross sections which will give a minimum cost to the experimental program and at the same time satisfy the accuracy requirements of the design performance parameters?

Let us represent the variable standard deviations of the cross sections by the vector $\underline{x}$ and the cost function by $C(\underline{x})$. Let D be the correlation matrix and $\underline{S}^r$ the sensitivity coefficient vector of performance parameter r. Then we minimize $C(\underline{x})$ subject to the constraints:

$$S^r X D X \tilde{S}^r \leq V_r$$

$$x_i \geq 0$$

where $\sim$ indicates the transposed matrix, X is a diagonal matrix with diagonal elements $x_1, x_2, \ldots x_n$, and V_r is the maximum value allowed by the constraint on the r^{th} performance parameter variance.

This is a nonlinear programming problem with nonlinear (quadratic) inequality constraints. The module NUTCRACKER uses a modification EXCOST of an existing code[1] for nonlinear optimization subject to nonlinear constraints. This subroutine uses a gradient search procedure, with refinements for recognizing patterns in the response surfaces and boundaries on the variables.

The following is a brief survey of the subroutines used by NUTCRACKER. EXCOST finds the optimum x's subject to the constraints which depend on the input correlations and sensitivities. VMIN is a quadratic optimization subject to one linear constraint and inequality constraints corresponding to a positive weight vector with a sum of unity. (This routine is not required for the present problems which have but a single weight and a single correlation matrix.) EVAL is a subroutine which returns to the calling routine EXCOST the cost of attaining the accuracy specified by vector x. Other routines, in addition to the FIDO generalized input routines, are as follows: Routine ILYICH apportions lengths of the required storage arrays. It calls DATAIN for input, sets some initial convergence and tolerance criteria, calls LIADOV, then calls DATOUT which outputs the results. LIADOV initializes the data required by the two optimization routines EXCOST and VMIN and controls the loop which alternate the above two optimization routines. SPUFFT searches through the COVERX file, XNITIL sets preliminary initial values of the relative standard deviations x for entry into EXCOST, SCALAR calculates inner or dot products of two vectors, and AMATQ4 is a matrix-inversion routine. MAKEM forms the quadratic required by VMIN; MAKEQ, STOREQ, and GETQ form, store, and retrieve the matrices Q^r which form the inequality constraints for EXCOST ($\tilde{x}Q^r x \leq V_r$), and GETS retrieves the sensitivity coefficients as needed.

REFERENCE

1. Kenneth E. Cross, "A Gradient Projection Method for Constrained Optimization," Report K-1746 (May 30, 1968), Union Carbide Corporation Nuclear Division Computing Technology Center, Oak Ridge, Tennessee.

NUTCRACKER INPUT

1$$ Integer Parameters [i2]

1. NP — The number of variable cross section standard deviations.
2. N — The total number of cross section standard deviations = variable ones plus fixed ones (for present problems NP=N=NG).
3. METH — The number of correlation matrices (METH=1 for present problems).
4. INEQ — The number of performance parameters which have given accuracy requirements with corresponding inequality constraints.
5. NS — Unit number of SENPRO file, if NS=0 the sensitivity coefficients must appear in the card input stream on the 6** card.
6. ID1 — An instruction for obtaining the correlation matrix (matrices). If ID1=0 the off-diagonal triangular elements are given in the input card data stream. If ID1 = -1 the correlation matrix (and some other information) will be found on a COVERX file residing on a unit with reference number IDD1.
7. IDD1 — (see 6. ID1)
8. ID2 — Set to 0, reserved for future options.
9. IDD2 — Set to 0, reserved for future options.
10. MINI — An instruction determining the form of the cost function.

MINI = ±1, ±2, ±3, ±4

If MINI = 1 $\quad$ Cost = $C(x) = \sum_i 1/x_i$

-1 $\quad$ Cost = $C(x) = \sum_i (1/x_i)^2$

2 $\quad$ Cost = $C(x) = \sum_i (C_i/x_i)$

-2 $\quad$ Cost = $C(x) = \sum_i (C_i/x_i)^2$

MINI = 3, -3, 4, -4 correspond to 1, -1, 2, -2 except terms for which $x_i \leq I_i$ are not included.

11. IC — Is sequential data set reference number from which cost coefficients C_i will be read in. If IC = 0 no coefficients are read. If, however, the correlation matrix was read from a COVERX file, C_i's will already be set equal to the group cross section standard deviations which were on that file. If IC = 5, cost coefficients are in the input card stream.

12. IXFACT — An instruction and scale factor for obtaining initial preliminary values of the vector x. If IXFACT > 0.0 then initial values are read in from the 14** card and then multiplied by IXFACT. If IXFACT ≤ 0.0 all components of x along the principle axes are equal, and the value is determined from the constraints.

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4$$ Sensitivity Coefficient Identifiers on SENPRO

[5*METH*INEQ]. Omit if NS = 0 and if ID1 = 0.

1. IASB Assembly identifier
2. IRESP Response identifier
3. MAT Material identifier
4. MT Reaction identifier
5. NTRN Reaction rate ratio identifier

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Note: Complete the five-integer sequence to identify all needed sensitivity coefficients

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6** Sensitivity Coefficients [5*METH*INEQ]

Omit if NS ≠ 0.

8** Correlation Matrix Elements [(N-1)*N/2]

Omit if ID1 ≠ 0.

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10** Maximum Allowed Relative Variances [INEQ]

12** Cost coefficients C_i [NP]

Omit if IC = 0.

16**1 Fixed, nonvariable standard deviations

x_i (i=NP+1,N) [N-NP] Omit if N = NP

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14** Initial values of X_i (i=1,NP) [NP] Omit if IXFACT ≤ 0

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