

**COVERT and CAVALIER:
Two Computer Codes for Estimating
Uncertainties of Calculated Neutronics
Parameters Using Standard Interface
Files SENPRO and COVERX**

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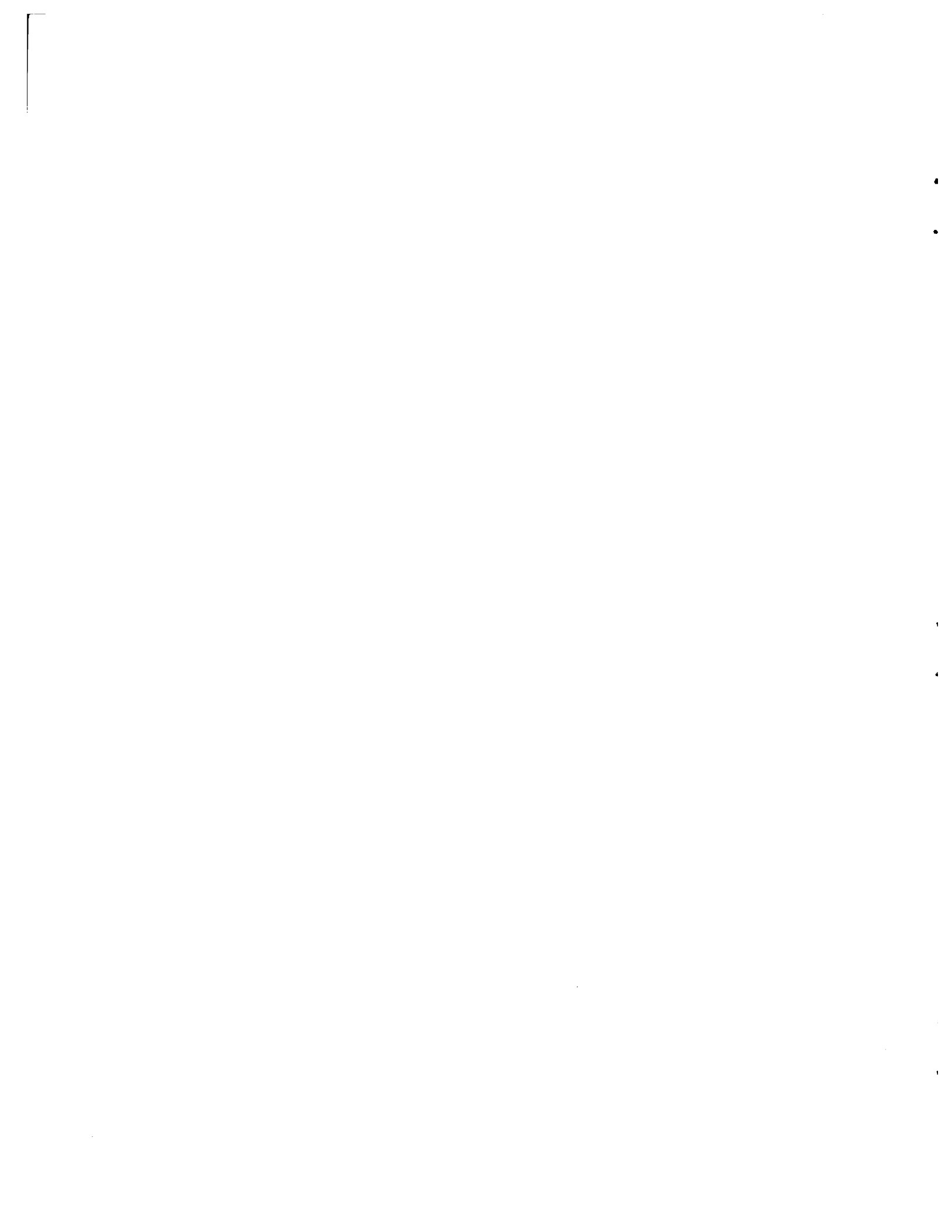


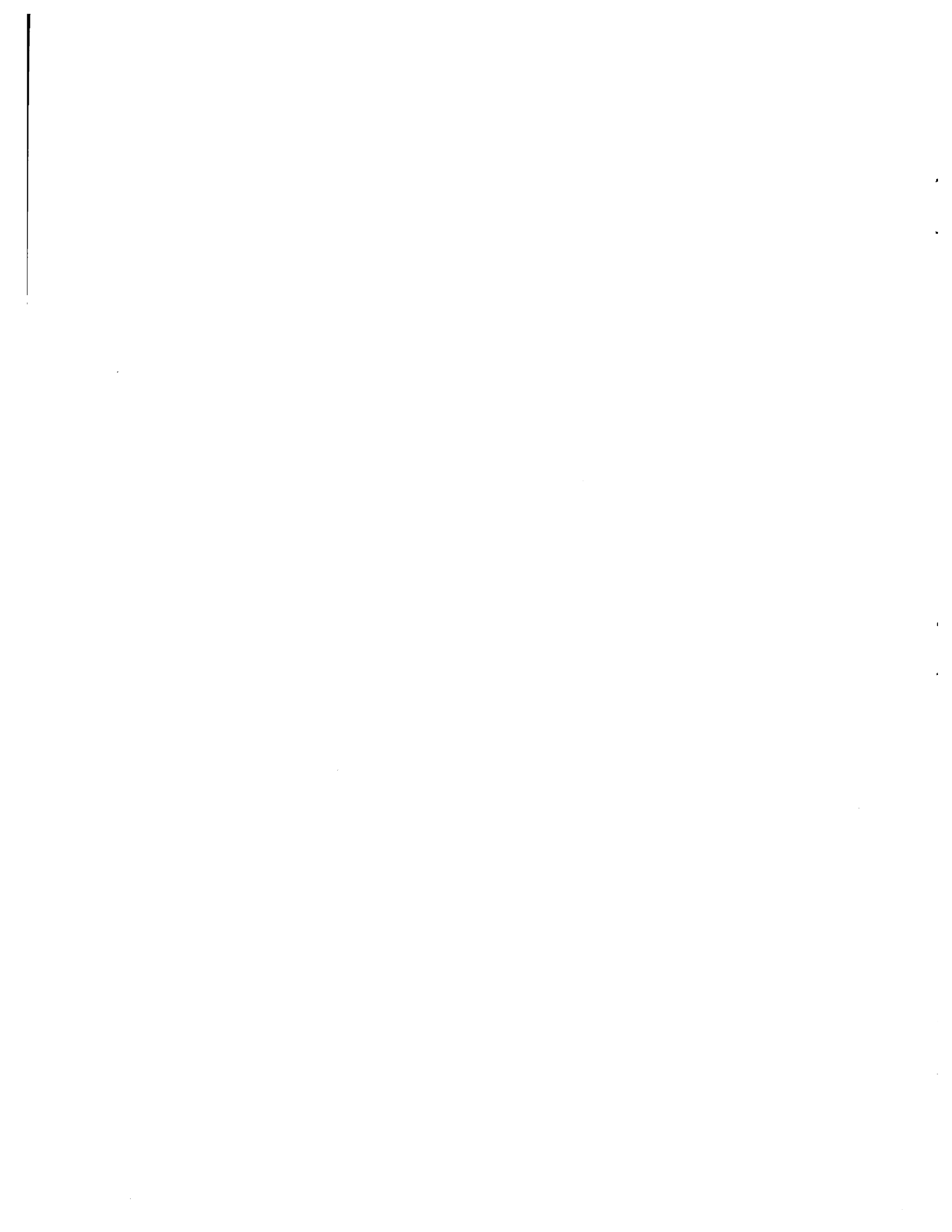
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1

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 benchmarks² 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 format³ 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 files, it is necessary to have codes which can read such files as well as codes to solve the pertinent algorithms. This report documents two such codes. The first, CAVALIER, is used to estimate the uncertainties in calculated neutronics parameters using sensitivity coefficients⁶ 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:

$$\left[(\text{S.D.})^R \right]^2 = \sum_{\substack{i,j \\ g,g'}} S_{gi}^R (\text{cov})_{gg'}^{i,j} S_{g'j}^R \quad (1)$$

where: S_{gi}^R is the relative sensitivity coefficient for response R to the cross section σ_g^i of type i (denoting nuclide and reaction) in group g. This sensitivity is given by

$$S_{gi}^R = \frac{\sigma_g^i}{R} \frac{\partial R}{\partial \sigma_g^i} \quad (2)$$

$(\text{cov})_{gg'}^{i,j}$ is the relative covariance of cross sections σ_g^i and $\sigma_{g'}^j$.

$(\text{S.D.})^R$ 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, IOU
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 $^{238}\text{U}(n,f)$, $^{238}\text{U}(n,\gamma)$, $^{239}\text{Pu}(n,f)$, $^{239}\text{Pu}(n,\gamma)$, $^{239}\text{Pu}(\bar{\nu})$ including the correlation between $^{239}\text{Pu}(n,f)$ and the $^{239}\text{Pu}(n,\gamma)$ cross sections. The calculated responses for this sample are multiplication factor (IRESP=1 and NTRN=0), central reaction rate ratios $^{28}\text{C}/^{49}\text{f}$ (IRESP=4 and NTRN=1), and $^{28}\text{f}/^{49}\text{f}$ (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:

<u>Assembly</u>	<u>Response</u>	<u>Standard Deviation (%)</u>
ZPR-6/7	k	3.57
ZPR-6/7	$^{28}\text{C}/^{49}\text{f}$	8.86
ZPR-6/7	$^{28}\text{f}/^{49}\text{f}$	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 $^{239}\text{Pu}(n,f)$ and the $^{239}\text{Pu}(n,\gamma)$ 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.FISS.SPEC.V1.OCT2477  
//GO.FT21F001 DD DUMMY  
//GO.FT05F001 DD *  
    (1 blank card)  
/*
```

The blank card could be replaced by the following:

```
Q 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

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. "Cross Section Evaluation Working Group Benchmark Specifications," BNL-19302 (ENDF-202) (November 1974).
3. 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).
4. J. D. Drischler and C. R. Weisbin, "Compilation of Multigroup Cross-Section Covariance Matrices for Several Important Reactor Materials," ORNL-5318 (ENDF-235) (October 1977).
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).
6. J. H. Marable, J. D. Drischler, and C. R. Weisbin, "SENDIN and SENTINEL: Two Computer Codes to Assess the Effects of Nuclear Data Changes," ORNL/TM-5946 (ENDF-250) (July 1977).

APPENDIX A

The Format for Standard Interface File COVERX for
Multigroup Cross-Section Covariance Matrices

```

C*****
C                                     REVISED 11/01/77
C
CF      COVERX
CE      THIS FILE CONTAINS CROSS SECTIONS,
CE      STANDARD DEVIATIONS, AND
CE      PY DESIGNATION EITHER COVARIANCE,
CE      RELATIVE COVARIANCE,
CE      OR CORRELATION MATRICES.
C
CE      A FILE SUCH AS THIS IS NEEDED BY ORNL - FORSS
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      ***** (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 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          NNGROUP, NNGRUP, NGGRUP, NTYPE, NMMP, NMTRIX, NHOLL
C
CW          7
C
CB          FORMAT(4H 1D ,7I6)
C
CD          NNGROUP      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          NMMP         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-----
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 CRRR
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-----

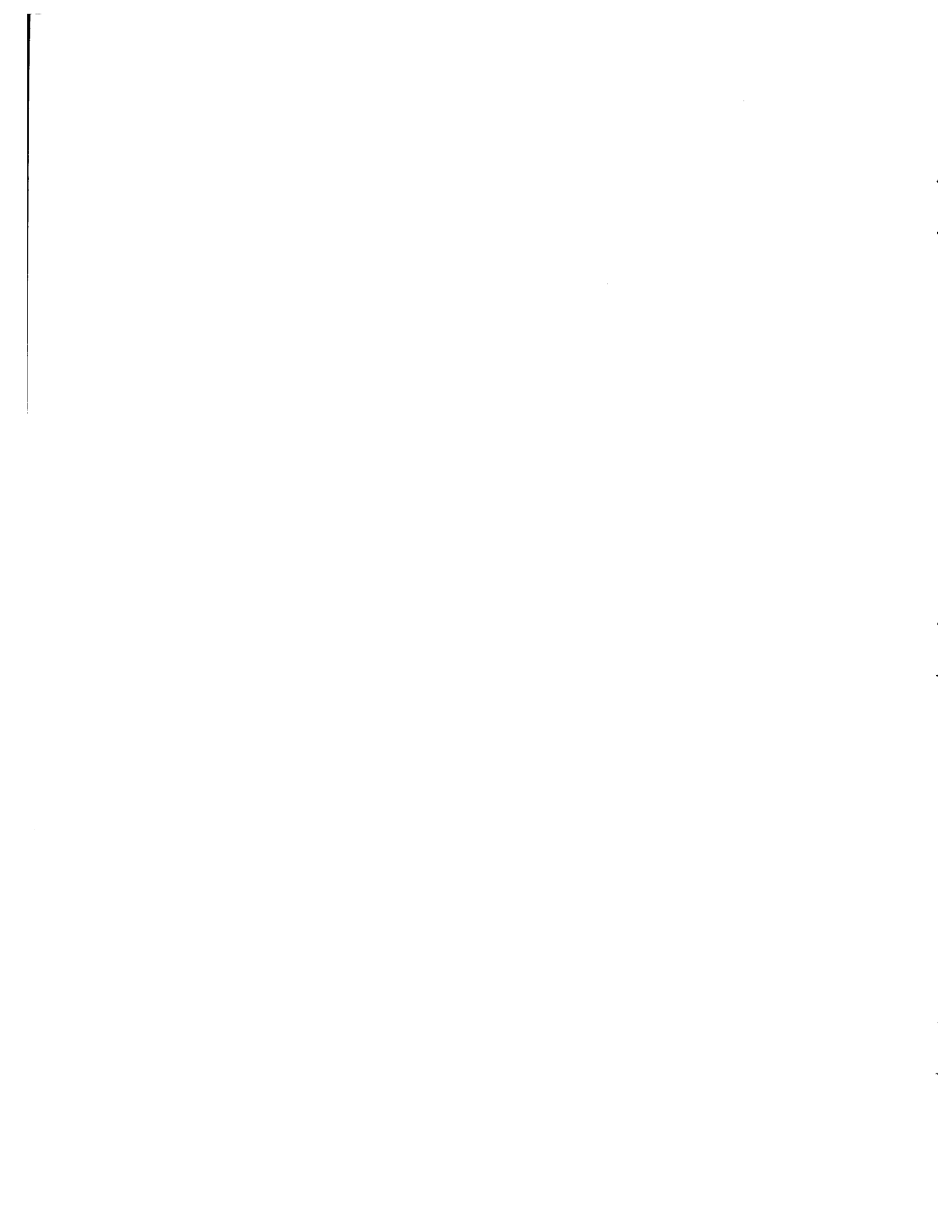
```

```

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  
CW          KMAX  
C  
CB          FORMAT(4H 9D ,5E12.4/(6E12.4))  
C  
C  
CD          COV          NTYPE MATRIX DATA  
C-----  
COEF
```



APPENDIX B

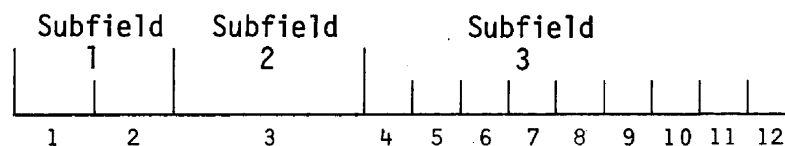
The FIDO Input System

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 placed 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	REMARKS (DO NOT PUNCH)
1	1	\$					Begin the 1\$ array, fixed-field, integral
13							Enter 1.
28		F					Fill array with 2.
37	2	*					Begin the 2* array, fixed-field, real.
48							Enter 1.234.
61							" "
1	5	-					" "
18	3	-					" "
28							" 7.0
37							A blank field is always ignored.
48		T					Terminate this block.
61							No entries may follow T on a card.
1	3	*					Begin 3* array, fixed-field real.
18	9	I					Enter 0,1,2,3,4,5,6,7,8,9,10,10.
28	3	R					as real numbers.
37	3	*					Repeat 3* in free-field, skip
48	1	1					to 11th entry, correct sequence to
61							----9,10,11,12.
1	4	*					Begin 4* array, free-field, real.
18	2	Q					Enter 1,2,3,4, 1,2,3,4, 1,2,3,4.
28							End reading this array; remainder of array unchanged.
37							Terminate this block.
48							
61							

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.

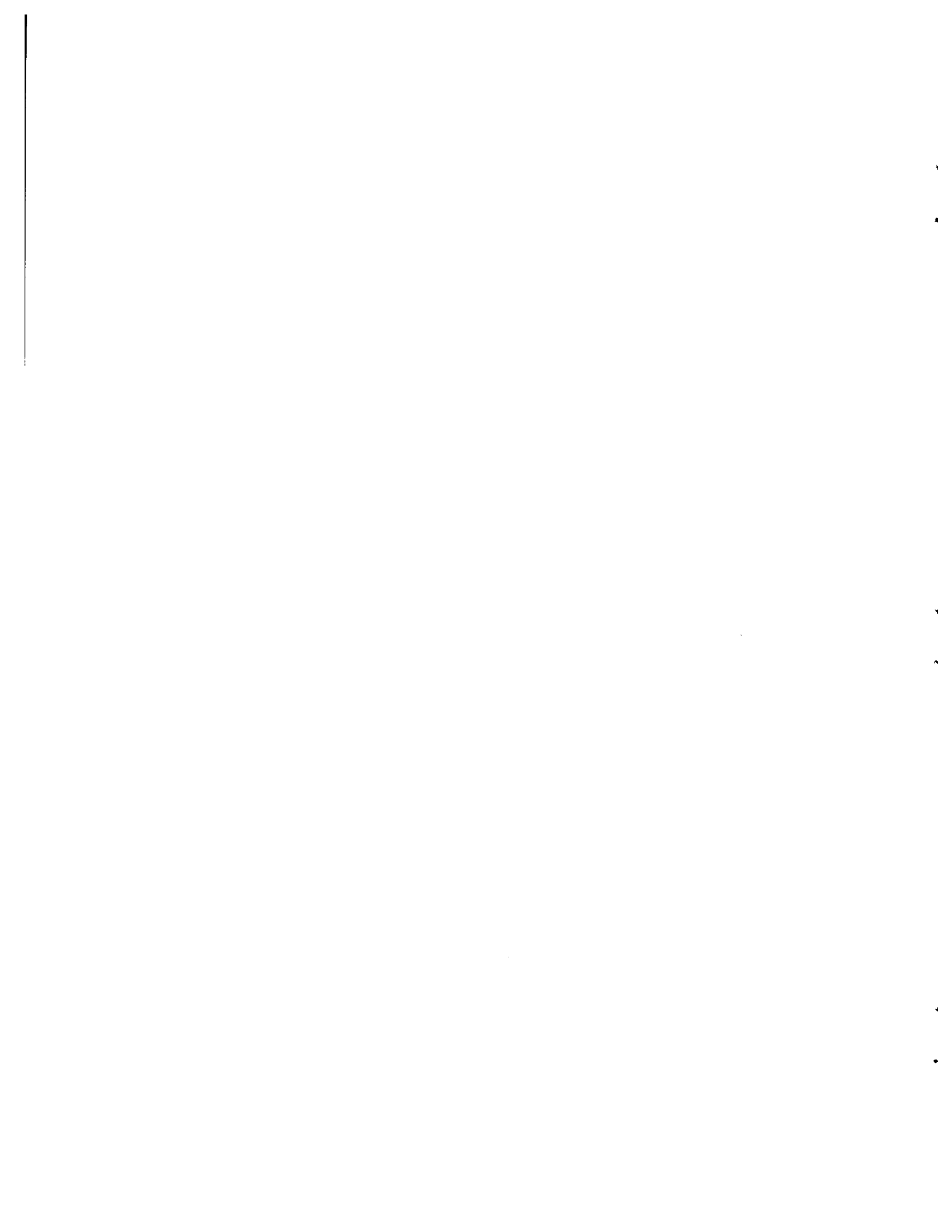
The array originator field can begin in any position. The array identifiers and type indicators are used as in fixed-field input. The type indicator is entered twice, to designate free-field input (i.e., "\$\$" or "***"). The blank third subfield required in fixed-field input is not required. For example: 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.



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