FBEC OFFICE FILE COPY

AFFDL-TR-76-113
Volume I
ADA 041 371

STRESS HISTORY SIMULATION

Volume I
A USER'S MANUAL FOR A COMPUTER PROGRAM TO GENERATE STRESS HISTORY SIMULATIONS

MCDONNELL DOUGLAS CORPORATION
MCDONNELL AIRCRAFT COMPANY
P.O. BOX 516
ST. LOUIS, MISSOURI 63166

MARCH 1977

Approved for public release; distribution unlimited

AIR FORCE FLIGHT DYNAMICS LABORATORY
AIR FORCE WRIGHT AERONAUTICAL LABORATORIES
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

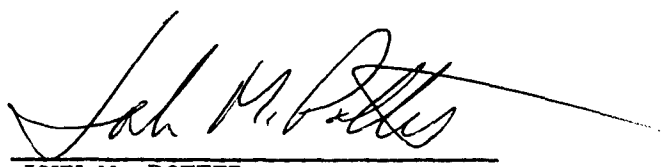
Best Available Copy

20060921240

NOTICES

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

This technical report has been reviewed and is approved for publication.



JOHN M. POTTER
Project Engineer

ROBERT M. BADER, Chf
Structural Integrity Br

FOR THE COMMANDER

HOWARD L. FARMER, Colonel, USAF
Chief, Structural Mechanics Division

Copies of this report should not be returned unless return is required by security considerations, contractual obligations, or notice on a specific document.

"This report has been reviewed and cleared for open publication and/or public release by the appropriate Office of Information (OI) in accordance with AFR 190-17 and DODD 5230.9. There is no objection to unlimited distribution of this report to the public at large or by DDC to the National Technical Information Service (NTIS)."

AIR FORCE - 8 JUL 77 - 300

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFFDL-TR-76-113 Vol. I	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE *(and Subtitle)* STRESS HISTORY SIMULATION Volume I - A User's Manual for a Computer Program to Generate Stress History Simulations		5. TYPE OF REPORT & PERIOD COVERED Final Report May 1975-July 1976 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) H. D. Dill H. T. Young		8. CONTRACT OR GRANT NUMBER(s) F33615-75-C-3112
9. PERFORMING ORGANIZATION NAME AND ADDRESS McDonnell Aircraft Company P.O. Box 516 St. Louis, Mo. 63166		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 486U0213
11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Flight Dynamics Laboratory (FBE) Wright-Patterson Air Force Base, Ohio 45433		12. REPORT DATE March 1977 13. NUMBER OF PAGES 57
14. MONITORING AGENCY NAME & ADDRESS*(if different from Controlling Office)*		15. SECURITY CLASS. *(of this report)* Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*

Approved for public release: distribution unlimited

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Spectrum Generation
Spectrum Loads
Overloads
Crack Growth Interaction
Mathematical Models

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

This report presents a description of a computer program to generate stress histories using random noise theory. A Gaussian random time history is generated and searched to detect peaks and valleys. The Gaussian peak and valley history is transformed to simulate real time history. The resulting list of peaks and valleys is filtered, using input rise and fall criteria, in order to eliminate stress excursions that the user does not wish to consider. Volume II of this report describes a computer program that uses as input lists

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

of filtered peaks and valleys, generated by this program, and performs operations to combine and create variations of the input lists. Both of the computer programs were used in a study of load sequence effects on crack growth, summarized in AFFDL-TR-76-112, "Effects of Fighter Attack Spectrum on Crack Growth".

FOREWORD

This report was prepared by McDonnell Aircraft Company (MCAIR), St. Louis, Missouri, for the Structural Integrity Branch, Structural Mechanics Division, Air Force Flight Dynamics Laboratory, Wright-Patterson Air Force Base, Ohio under Contract F33615-75-C-3112, Project 486U "Advanced Metallic Structures", Work Unit 486U0213, "Effect of Fighter Attack Spectrum on Crack Growth". The contract was administered by Mr. John M. Potter, Project Engineer, AFFDL/FBE.

The computer program that was developed and used during this study was accomplished by the Strength Department of McDonnell Aircraft Company (MCAIR). The study manager for MCAIR was J. F. Schier. Principal authors of this report are H. D. Dill and H. T. Young. L. F. Impellizzeri and F. R. Foster contributed to spectra development in the study, and C. R. Wilson assisted in computer program development.

This report covers work accomplished during the time period May 1975 through July 1976.

This report was released by the authors in August 1976 for publication.

TABLE OF CONTENTS

Section	Page
1. SUMMARY	1
2. PROGRAM OUTLINE	6
3. INPUT DATA REQUIREMENTS	13
4. OUTPUT DESCRIPTION	16
5. REFERENCES	17
Appendix A - Program List	19
Appendix B - Sample Problem with Input Data Listing	31
Appendix C - Input Data for Study Spectra	44
Appendix D - List of Computer Program Symbols and Definitions	50

SYMBOLS

A_K	Coefficient defined by Equations (3) and (4)
B_K	Random phase angle, $0 \leq B_K \leq 2\pi$
C1, C2, C3	Coefficients in the equation $x = C1 + C2\ t + C3\ t^2$, used to search for a peak or valley value
D_K	Harmonic coefficient, see Figure 1
IFSET	HARM subroutine control, IFSET = 1 sets up sine and inverse tables and calculates Fourier transform
J	Integer representing time in HARM subroutine
M	Mean value used in mapping Gaussian to simulated real time history
M1	$N = 2^{M1}$, see N
N	Number of points to be computed in the random time history
NØPTS	The number of points in the linear interpolation of subroutine TLU
NR	Factor by which the PSD frequency axis is extended to increase the sensitivity of the output
NSPD	Number of input data points on the PSD vs frequency graph
NX	Number of divisions of the PSD graph used in analysis
N_o	Theoretical number of mean level crossings per unit time
N_p	Theoretical number of peaks per unit time
$N_{Total,x}$	Theoretical number of Gaussian peaks exceeding the value x in the total time represented by the Gaussian time history
$N_{Total,y}$	Theoretical number of simulated real peaks exceeding the value y in the total time represented by the Gaussian time history
N_x	Theoretical number of Gaussian peaks exceeding the value x per unit time
N_y	Theoretical number of simulated real peaks exceeding the value y per unit time
P(x)	Probability of not exceeding x, normal probability distribution
PMAX, PMIN	In order for a peak and valley to be counted and included in the output list, the maximum rise or fall must exceed the input value of PMAX, and the minimum rise and fall must exceed the input value of PMIN

PSD	Power Spectral Density
R	Transformation exponent used in mapping Gaussian to simulated real time history
SL1	Difference in value of two consecutive Gaussian time history points, i, i + 1
SL2	Difference in value of next two consecutive points, i + 1, i + 2, see SL1
S	Power spectral density
t	Time
X	An independent value, also a Gaussian history value
XVAL	Independent variable to ue used in interpolation in a two-dimensional table
y	A dependent value, also a simulated real time history value
YVAL	Dependent variable determined by interpolation of a two-dimensional table.
σ	Standard deviation
ω	Frequency
ω_u	Upper limit of frequency of input power spectral density

1. SUMMARY

Load factor time histories developed using random noise simulation have been shown to correlate well with measured flight load factor histories. This makes random noise theory attractive for generation of fatigue test spectra. A common fault of other methods of load factor history simulation is arbitrary, unrealistic, coupling of peaks and valleys. The random noise theory approach requires that the random load factor time history be generated possessing a specified power spectral density (PSD) shape, and mean and RMS level. An advantage of the random noise theory approach is that both the exceedance content and the frequency content of the process can be preserved. The preservation of the frequency content assures that proper coupling of peaks and valleys is attained.

Volume II of this report, Reference 1, describes a computer program that uses as input lists of filtered peaks and valleys generated by this program, and performs operations to combine and create variations of the input lists. Both of these computer programs were used in a study of load sequence effects on crack growth, summarized in Reference 2. The input data for the spectra generated for that study are listed in Appendix C.

Gaussian Time History Generation

The theory used in formulating the program is described in Reference 2. The basic equation used in forming the random stress history is,

$$x_t = \sqrt{2} \sum_{K=0}^{N-1} D_K \cos (2\pi\omega_K t + B_K) \tag{1}$$

where the term D_K is defined in Figure 1. Making the substitution $D_K = \sqrt{S_K \Delta\omega}$ and assuming $\Delta\omega$ is constant throughout the summation described by Equation 1, that equation can be re-written,

$$x_t = \sqrt{2\Delta\omega} \sum_{K=0}^{N-1} \sqrt{S_K} \cos (2\pi\omega_K + B_K) \tag{2}$$

Rather than solving this equation directly, considerable efficiency is attained by use of the Fast Fourier Transform (FFT) outlined in Reference 3. The FFT computes N points in the random time history for N input values of A_K, where A_K is computed,

$$\text{Re } A_K = \sqrt{2\Delta\omega} \sqrt{S_K} \cos B_K \tag{3}$$

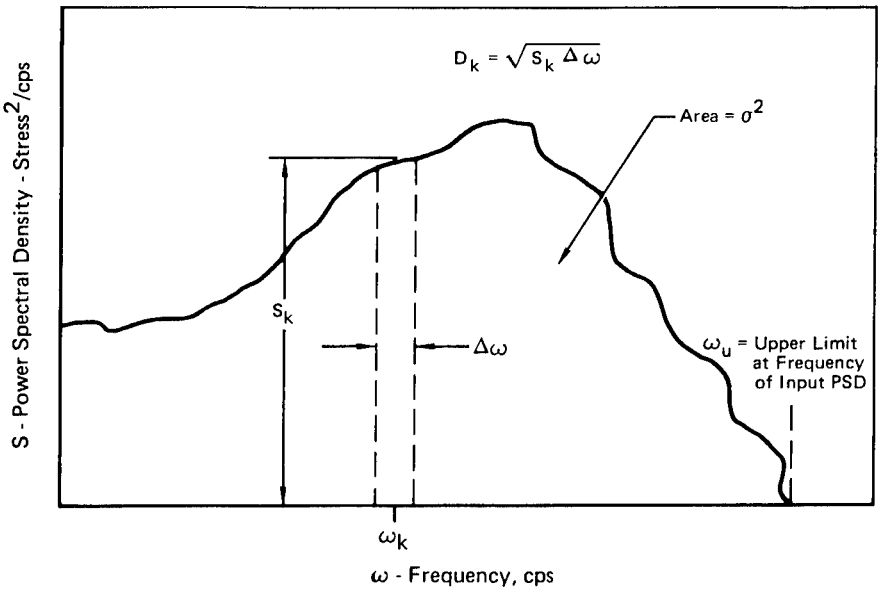


FIGURE 1. POWER SPECTRAL DENSITY USED IN RANDOM STRESS HISTORY GENERATION

$$\text{Im } A_K = \sqrt{2\Delta\omega}\ \sqrt{S_K}\ \sin B_K \tag{4}$$

Summarizing the generation of Gaussian random time histories:

- o "N" values of PSD (S_K) are determined from the PSD curve corresponding to K = 0, 1, ..., N-1
- o "N" random phase angles (B_K) between 0 and 2π are generated.
- o An array of N complex coefficients, A_K, are calculated as shown in Equations (3) and (4).
- o The Fast Fourier Transform is used to generate a time history of N values of load factor x_t, as defined by Equation (2).

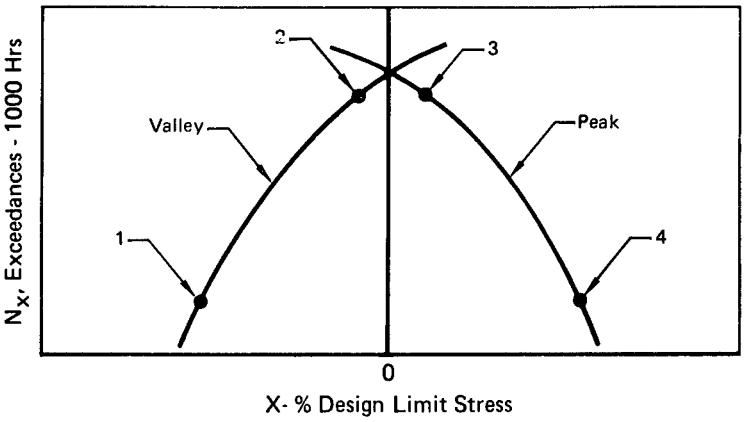
Mapping of Gaussian Process to Real

The exceedance curve for a Gaussian random time history is symmetrical with zero mean, as depicted in Figure 2. Actual exceedance curves for fighter aircraft are asymmetrical with a non-zero mean, also depicted in Figure 2, Gaussian random histories are adjusted so that exceedance curves for the Gaussian process and the actual exceedance curves are matched. This is accomplished using the transformations:

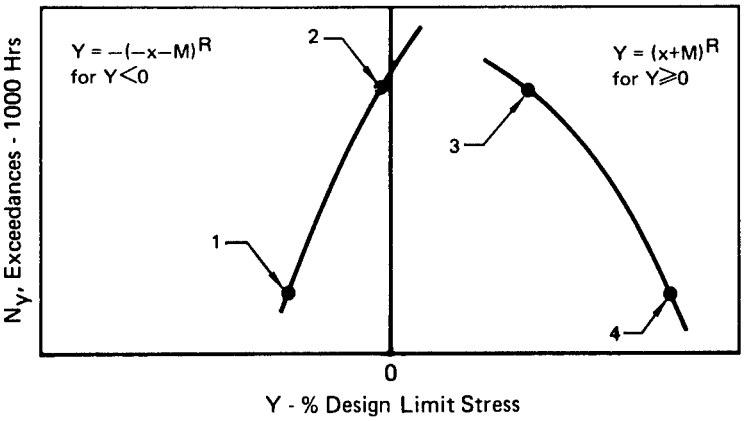
$$y = (x + M)^R \qquad \text{for positive } x + M \tag{5}$$

$$y = -(-x - M)^R \qquad \text{for negative } x + M \tag{6}$$

Numbered points are used to transform the
Gaussian data to the actual process



Exceedance Curve for Gaussian Random
Time History is Symmetrical with a Zero Mean



Actual Exceedance Curves are
Asymmetrical with a Non-Zero Mean

FIGURE 2. COMPARISON OF EXCEEDANCE CURVES

and conversely,

$$x = y^{1/R} - M \qquad \text{for positive } y \tag{7}$$

$$x = -(-y)^{1/R} - M \qquad \text{for negative } y \tag{8}$$

The exceedance curve for the Gaussian process is:

$$N_x = N_p\, P(x/a\sigma) + N_o[1 - P(x/b\sigma)]e^{-x^2/2\sigma^2} \tag{9}$$

This equation also describes the exceedance curve for the actual process when the substitutions indicated by Equations (7) and (8) are performed. The values M, R, N_p and σ are unknowns, and are determined through a trial and error process by the user. Using the actual exceedance curves, two points on the valley curve and two points on the peak curve are selected. This results in four sets of values of N and y. By using Equation (9) in combination with Equations (7) and (8), four non-linear simultaneous equations can be written, relating N and y with M, R, N_p, and σ as the unknowns.

The ratio N_o/N_p can be determined for any given PSD shape using Equations (10) and (11),

$$N_o^2 = \frac{\int_o^{\omega_u} \omega^2 S(\omega)\, d\omega}{\int_o^{\omega_u} S(\omega)\, d\omega} \tag{10}$$

$$N_p^2 = \frac{\int_o^{\omega_u} \omega^4 S(\omega)\, d\omega}{\int_o^{\omega_u} \omega^2 S(\omega)\, d\omega} \tag{11}$$

The values of M and R are required for program input. The area of the PSD vs frequency plot is σ^2, i.e.,

$$\sigma^2 = \int_o^{\omega_u} S_\omega d\omega \tag{12}$$

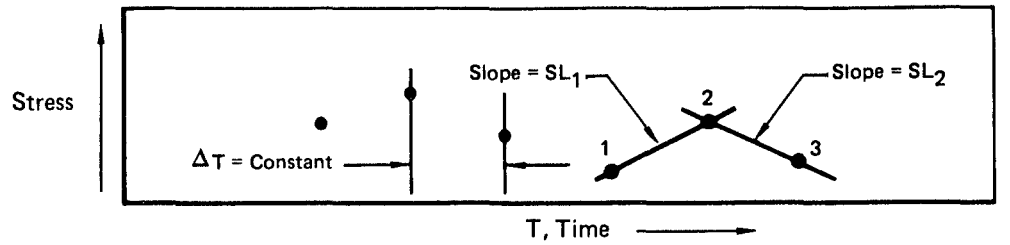
The value of σ can be employed by the user to scale the input values of PSD to obtain the proper area.

Search for Peaks and Valleys

The time history generated by the technique outlined in the previous sections results in a series of stress values at constant time intervals, as depicted in the following sketch. The presence of a peak or valley is detected when there is a difference in sign of slope between two consecutive sets of points. The value of the peak or valley is determined by assuming a quadratic relation of the form,

$$x = C1 + C2\ t + C3\ t^2 \tag{13}$$

and solving for the maximum value of x.



Rise and Fall Counting

Counting accelerometers and VGH recorders are the primary basis of measuring the service experience of fighter aircraft, summarized in exceedance tables. This data, obtained from flight measured accelerations, has a rise and fall counting criterion applied to eliminate small load factor excursions. For example, VGH recorders require from .4g to 1.2g rise or fall, depending on the g level, before the peak or valley is counted. In a similar manner, the simulated real time stress time history is filtered, using input rise and fall criteria, in order to eliminate excursions that the user does not wish to consider.

2. PROGRAM OUTLINE

This program, based on random noise theory, generates random time histories for baseline spectra. The program is based on the theory described in Reference 2, and summarized in Section 1. Input to the program includes control numbers, the number of time points to be computed, the PSD as a function of frequency, an initial number to be used in the random number generator, the rise and fall criteria to be used for cycle counting, and Gaussian to simulated real transformation constants. Output includes a sequential list of peaks and valleys. Input and output are described in Sections 3 and 4, respectively.

The procedure used in developing the stress random time history is outlined in Figure 3. The first step is the reading of the input by the main program, and printing of the input. This is followed by computation of the A(K) coefficients described by Equations (3) and (4), where S(K) is the PSD, and B(K) is a random phase angle, computed using the techniques described in Reference 1. With the A(K) coefficients determined, subroutine HARM is called, which transforms the A(K) values into the Gaussian random time history. The main program stores the real part of the Gaussian time history in the last half of the A(K) matrix, searches for peaks and valleys and stores the peaks and valleys in the first half of the A(K) matrix and equations (9), (10), and (11). The main program then prints the Gaussian occurrence and exceedance tables.

Next, the main program tabulates the actual Gaussian peak and valley occurrence and exceedance arrays as determined from the list of peaks and valleys. Subroutine EXCED is then called, which computes the theoretical exceedance array, based on the input PSD values. The main program then prints the Gaussian occurrence and exceedance tables.

The next process is the transformation of the Gaussian process peak and valley stress history into a simulated real peak and valley stress history using the technique outlined in Section 1. The main program then tabulates the actual transformed peak and valley occurrence and exceedance arrays as determined from the list of transformed peaks and valleys. Subroutine EXCEED is again called, to compute the theoretical exceedance table, based on the input PSD values and transformation constants. The main program then prints the transformed peak and valley occurrence and exceedance tables.

Subroutine FILTER is called to apply the input rise and fall criteria to the transformed, i.e., simulated real peak and valley stress history. The main

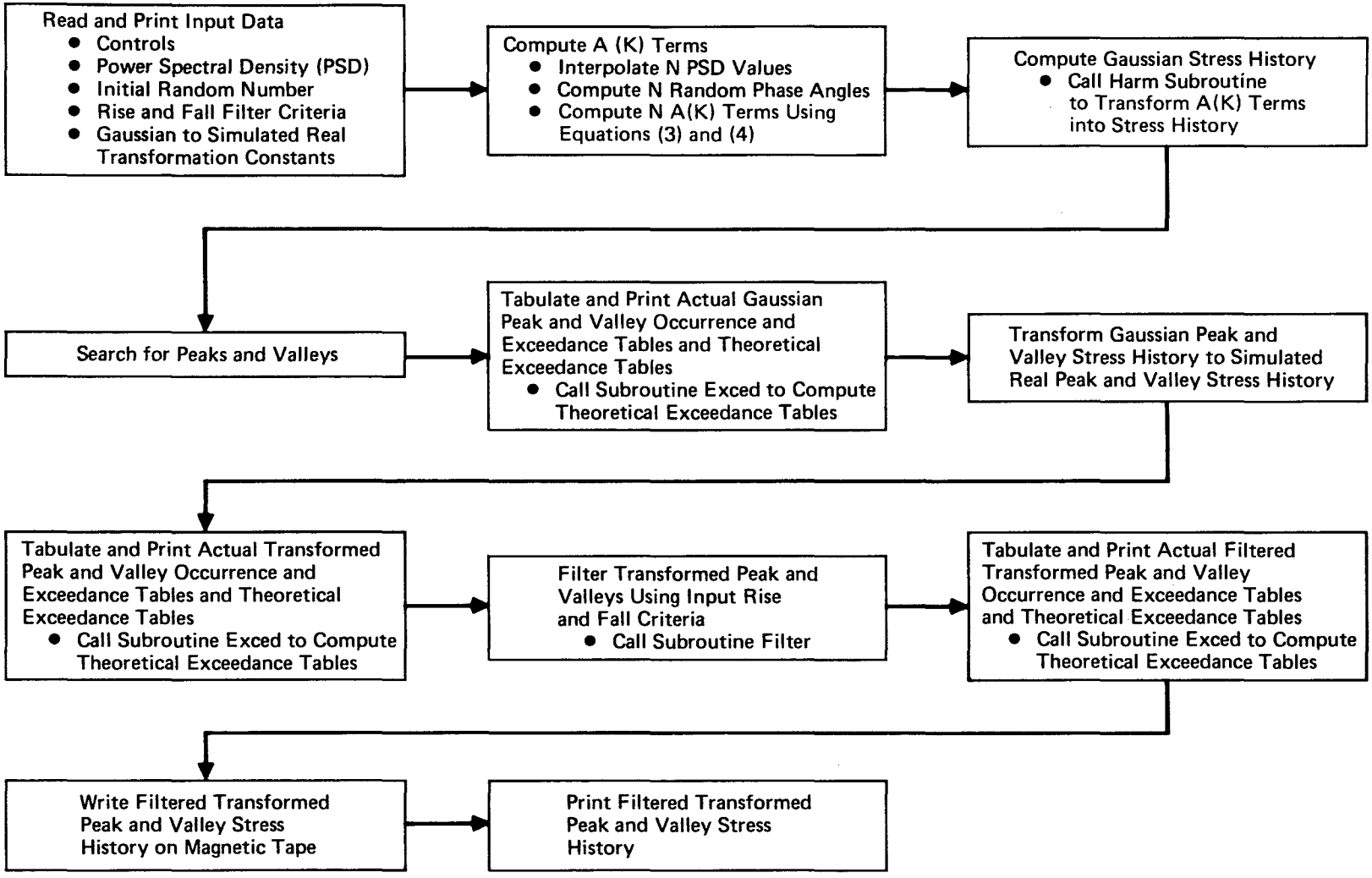


FIGURE 3. PROCEDURE USED IN DEVELOPING STRESS RANDOM TIME HISTORY

program then tabulates the actual occurrence and exceedance arrays based on the filtered transformed history. Subroutine EXCEED is again called, to compute the theoretical exceedance table, based on the input PSD values and transformation constants. The main program then prints the filtered transformed peak and valley occurrence and exceedance tables.

Finally, the filtered simulated loads are recorded on magnetic tape or disk for use by the program described in Volume II and then printed.

The program consists of a main program and five subroutines, outlined in Figure 4. The function of each subroutine is described in the following paragraphs.

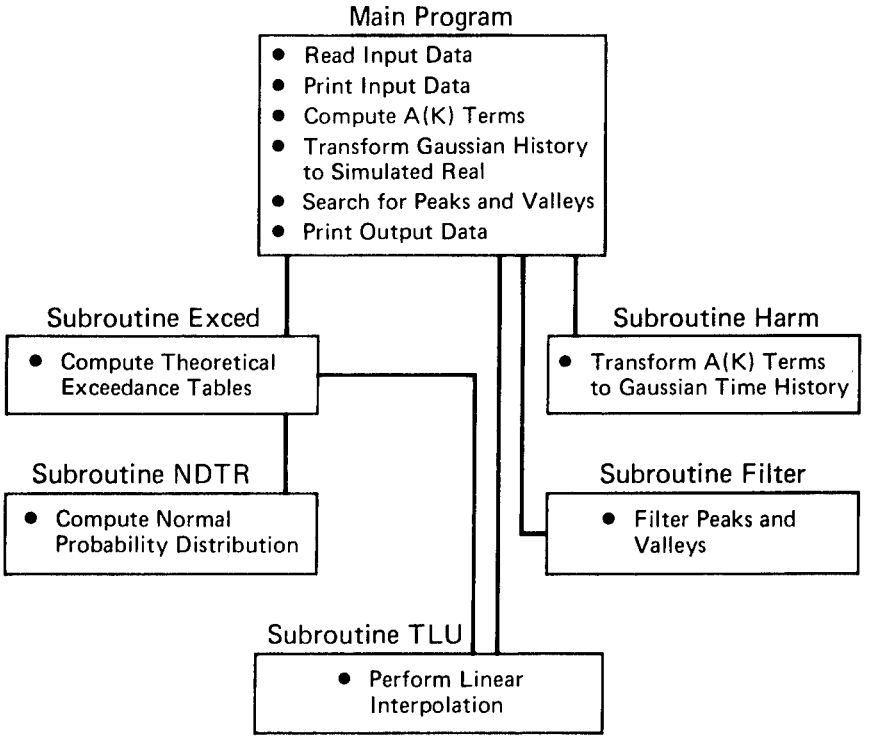


FIGURE 4. SUBROUTINES USED IN DEVELOPING STRESS RANDOM TIME HISTORY

Main Program

The main program reads and prints the input data. The A(K) coefficients are computed, and subroutine HARM is called, which transforms the A(K) values into the Gaussian random time history. The time history is searched to determine peaks and valleys. The main program transforms the Gaussian peak and valley values to simulated real values. The actual occurrence and exceedance arrays for the Gaussian values, transformed values, and filtered transformed values are tabulated by the main program. All output is printed or written by the main program.

Subroutine EXCED

This subroutine computes theoretical exceedance tables for the Gaussian and transformed, i.e., simulated real stress time histories. The solution for the Gaussian time history is obtained from the equation for exceedance per unit time, Equation (9), where N_o and N_p are computed from Equations (10) and (11). The Gaussian exceedance is computed

$$N_{Total,x} = t \times N_x \tag{14}$$

where t is the time period represented by the input values of PSD maximum frequency ω_u, and the number of computed time points. The theoretical exceedances for the transformed stress history is also obtained from Equation (9), with transformation indicated by Equations (7) and (8),

$$N_{Total,y} = t \times N_y \tag{15}$$

Subroutine TLU

This subroutine provides a linear interpolation table look-up procedure. Input to the routine is a list of independent and dependent values, x and y, the number of points in this list, NOPTS, and the independent value for which interpolation is desired, XVAL. Output of the routine is interpolated value of the dependent value, YVAL. When the range of the table is exceeded, linear extrapolation is used.

Subroutine FILTER

This subroutine applies the rise and fall criteria to the transformed peak and valley list.

Filtering is accomplished by using the input values P_{MAX} and P_{MIN} on adjacent half cycles throughout the time history. A peak and valley that meets either the P_{MAX} or P_{MIN} rise and fall criteria is counted only if the succeeding half cycle exceeds the remaining rise and fall criterion. If a half cycle fails to exceed the proper rise or fall requirement, the non-qualifying peak or valley is removed from the time history. The two adjacent peaks or valleys are now compared, resulting in the retention of either the largest peak or the smallest valley. The process continues by checking to see if the next half cycle exceeds the remaining rise and fall criterion. For example, in Figure 5, ranges 4-5, 6-7, 7-8, 9-10, 10-11, 11-12, and 12-13 do not meet the rise and fall criterion. Sequential applications of the filtering checks results in the load sequence shown as "Fourth Pass".

Subroutine HARM

For one dimension, as used in this program, the HARM subroutine, described fully in Reference 3, computes the complex Fourier series,

$$X(J) = \sum_{K=o}^{N-1} A(K)\ e^{2\pi i\ JK/N} \qquad (16)$$

where J = 0, 1 ---- N-1

The theory of the transformation is described in Reference 3. Input to the subroutine consists of N, the real and imaginary parts of A(K), and the value of IFSET. Although the routine is capable of transforming three-dimensional arrays, in this program only a single dimensional array is required. Therefore, M(1) = M1 where $N = 2^{M1}$ is the number of time points to be computed, and M(2) = M(3) = 0. The real and imaginary parts of A(K) are computed by the main program, as previously described. IFSET is an option parameter which is set to 1 in order to have the routine calculate the Fourier transform.

Output of the routine is the history X(J) stored in the A(K) matrix. The real part of A(K) is stored in even numbered locations and the imaginary part of A(K) is stored in odd numbered locations, sequentially. Subroutine HARM is a portion of the IBM Scientific Subroutine Package.

Subroutine NDTR

This subroutine is called by subroutine EXCED, in order to compute the theoretical exceedance table. The subroutine computes the normal probability distribution

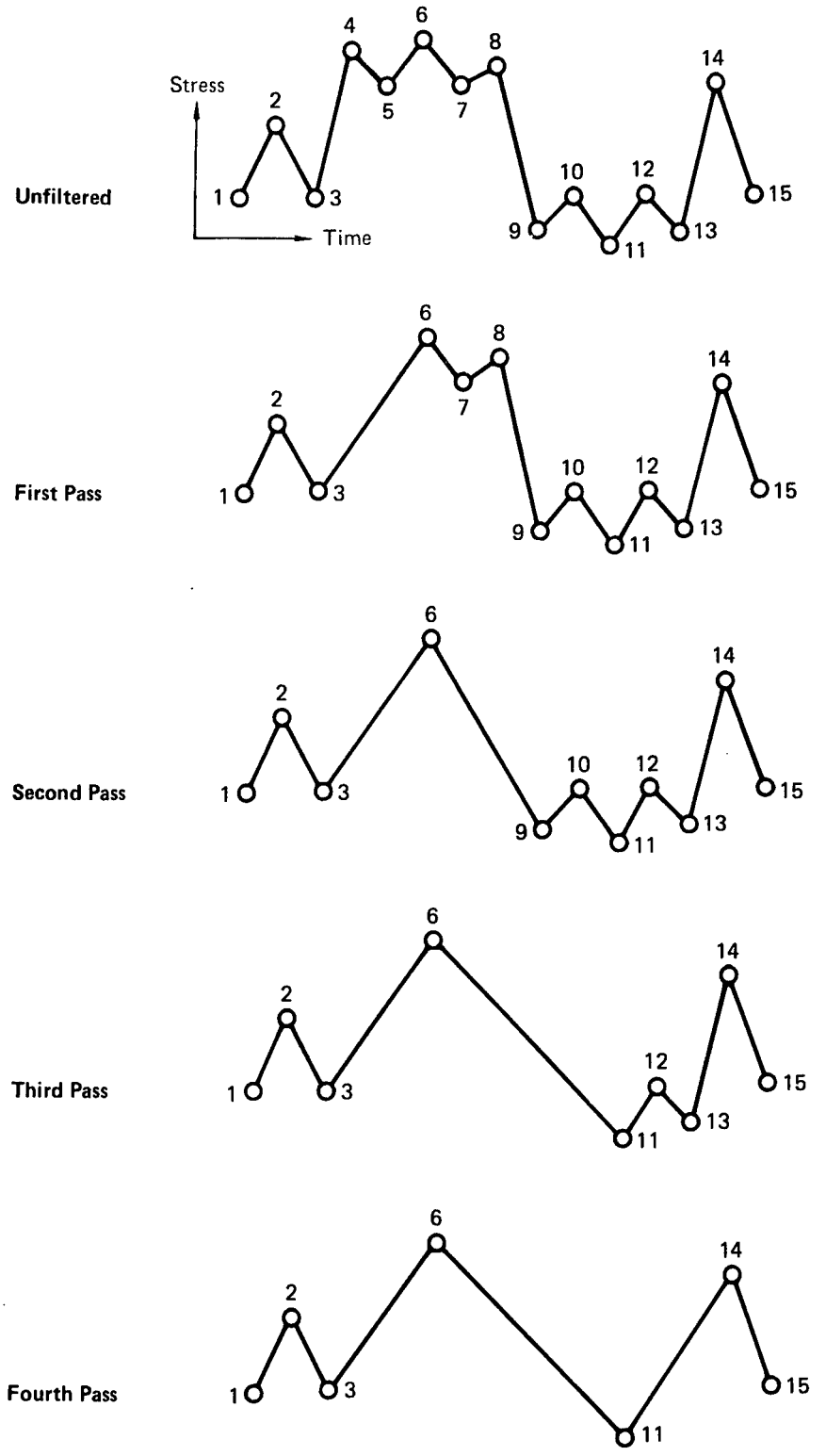


FIGURE 5. APPLICATION OF FILTERING RULES TO STRESS HISTORY

$$y = P(x) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} \exp\ (-u^2/2)\,du \tag{17}$$

The following approximation is used:

$$P\ (x) = 1 - f(x)\ \sum_{i=1}^{5} a_i w^i;\ x \geq 0 \tag{18}$$

where

$w = 1/(1 + px)$

$f(x) = \exp\ (-x^2/2)/\sqrt{2\pi}$

$p = 0.2316419$

$a_1 = 0.3193815$

$a_2 = -0.3565638$

$a_3 = 1.781478$

$a_4 = -1.821256$

$a_5 = 1.330274$

The theory is described in Reference 4. Subroutine NDTR is a portion of the IBM Scientific Subroutine Package.

3. INPUT DATA REQUIREMENTS

Input to the program consists of the number of time points to be computed, the power spectral density (PSD) as a function of frequency, the rise and fall criteria to be used with cycle counting, and an initial number to be used in the random number generator. The input data format is described in the computer program listing, via comment cards, Appendix A. Example input is presented in Appendix B.

The maximum number of time points that may be computed in a single case is $2^{15} = 32{,}678$. The number of time points to be computed is controlled by an input control number, and may be any power of 2, up to the maximum value.

The power spectral density is usually input as (% Design limit stress)^2 vs frequency, cps. Program input includes the number of points to be input, and the frequency and PSD value for each of the input points. Experience has shown that many peaks and valleys will be missed if the upper limit of the PSD plot is not artificially extended with zero values for PSD, as depicted in Figure 6. The time represented by the input values of PSD upper frequency and the number of time points to be computed is,

$$t = \frac{N}{\omega_u}$$

By increasing ω_u artificially, the time t is reduced for a given number of time points, N, effectively increasing the number of points per unit time and hence per peak. Trial runs have shown that the use of $NR' = 2^{NR} = 4$, as defined in Figure 6, will usually result in adequate sensitivity and peaks and valleys will not be missed.

The HARM subroutine requires as input a value of A(K) for each time point computed. Each value of A(K) requires a value of PSD to be interpolated. Because the number of time points to be computed, typically 32,768, is usually much larger than required to adequately define the shape of the PSD plot, constant values of PSD are used in ranges, as shown in the example of Figure 6. In that example, the number of time points is 128 and the frequency scale has been multiplied by four to increase the sensitivity of the output. Therefore, 128/4 = 32 values of PSD are required in the computation of the A(K) terms. In this example, 8 constant values of PSD are used to represent the 32 required values.

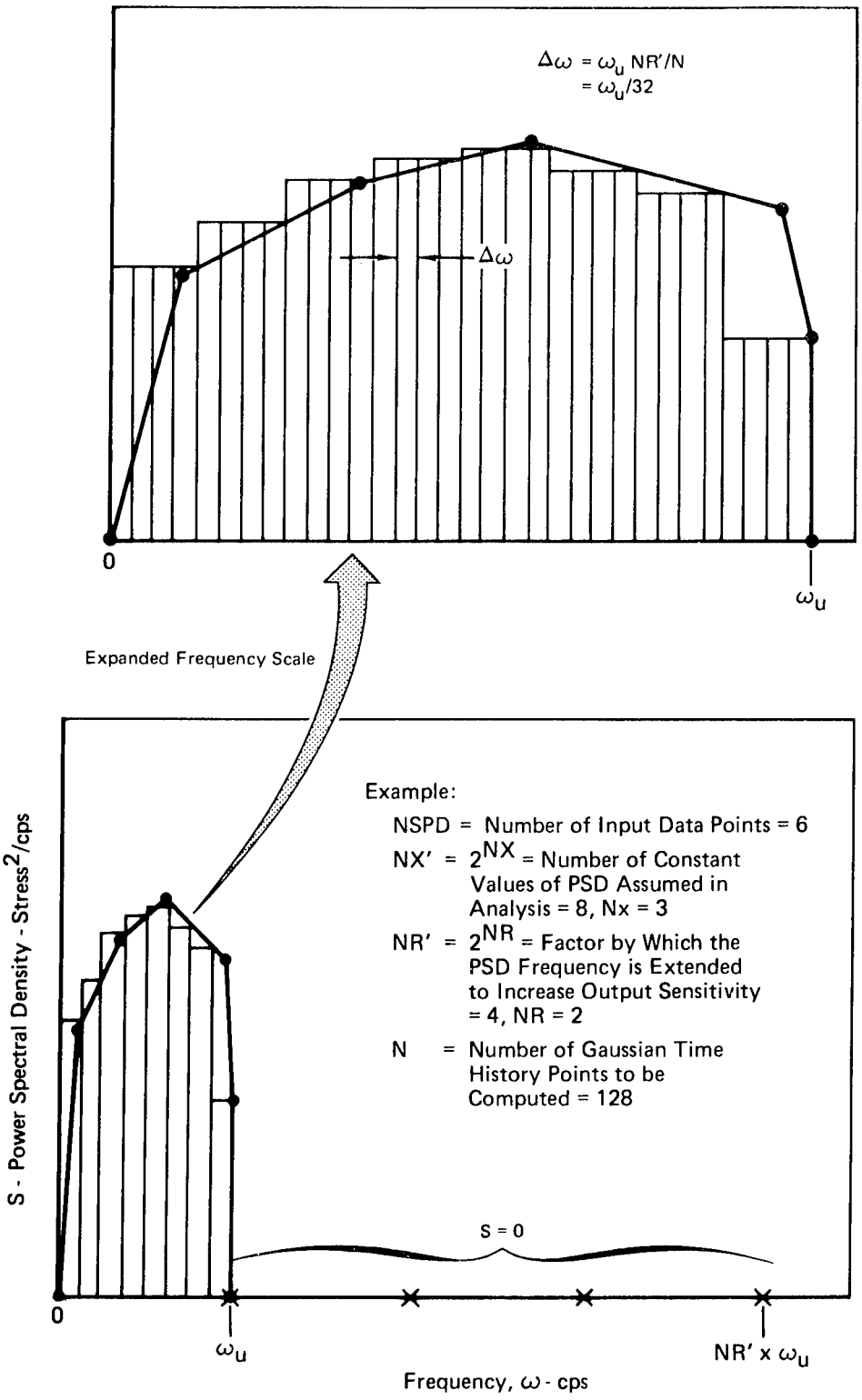


FIGURE 6. EXAMPLE OF PSD INPUT FOR RANDOM LOAD HISTORY

Other input to the program controls the size and sensitivity of the occurrence and exceedance tables.

As described in the explanation of subroutine FILTER in Section 2, input rise and fall criteria are applied to the transformed peak and valley list. Peaks and valleys that do not meet the required rise and fall criteria are removed from the time history.

Transformation of the Gaussian to simulated real time history is controlled thru input of the values, M and R, defined by Equations (5) and (6).

4. OUTPUT DESCRIPTION

The output consists of six sections. The first section is an echo of the input to permit a check.

The second section contains the elapsed time represented by the number of time points generated and the upper frequency of the PSD plot, and the theoretical values of N_o and N_p as defined by Equations (10) and (11).

The third section contains the occurrence and exceedance tables for the Gaussian time history. First the peak and valley occurrences are printed for the time period considered, then the exceedances for that time period are printed. This is followed by a list of the theoretical exceedances as computed by Equation (9). The next output is the total number of peaks and valleys in the Gaussian time history multiplied by two, and the most current value of the random number, IX.

The fourth section contains the occurrence and exceedance tables for the transformed, i.e., simulated real, time history. The output format is similar to that for the third section. The next output is the total number of peaks and valleys in the transformed time history, multiplied by two; this number is the same as for the Gaussian history.

The fifth section contains the occurrence and exceedance tables for the filtered transformed time history, in a format similar to that for the third section. The next output is the total number of peaks and valleys in the filtered transformed time history, multiplied by two.

The sixth section of output is a list of filtered transformed peaks and valleys in sequential order as created by this simulation process.

Example output is presented in Appendix B.

5. REFERENCES

1. Young, H. T., Foster, F. R., and Dill, H. D., "Stress HIstory Simulation, Vol. II - A User's Manual for a Computer Program to Modify Stress History Simulations," AFFDL-TR-76- , Vol. II, November 1976.
2. Dill, H. D., and Saff, C. R., "Effect of Fighter Attack Spectrum on Crack Growth," AFFDL-TR-76-112, November 1976.
3. Cooley, J. W., and Tukey, J. W., "An Algorithm for the Machine Calculation of Complex Fourier Series," Mathematics of Computations, Vol. 19, April 1965, p. 297.
4. System/360 Scientific Subroutine Package, Version III, Programmer's Manual, IBM Report GH20-0205-4, August 1970.

```
LEVEL 21,7 ( JAN 73 )                          OS/360  FORTRAN H

          COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=55,SIZE=0000K,
                             SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
                C
                C                                SPECGN1
                C  THIS PROGRAM GENERATES THE GAUSSIAN RANDOM TIME HISTORY DATA.
                C  THE PROGRAM WAS WRITTEN AT MCDONNELL AIRCRAFT COMPANY FOR THE
                C  IBM 370-195 OS USING FORTRAN IV DURING SEPTEMPER OF 1975 BY
                C  HAROLD DILL,CHARLES WILSON AND TOM YOUNG...
                C
   ISN 0002           REAL MEAN
   ISN 0003           INTEGER ANDZ
   ISN 0004           DIMENSION A(65536),S(8192),INV(8192),M(3),PSD(256),W(256)
                     1,NPEAKS(60,4),PL(60,2)
   ISN 0005           IN=5
   ISN 0006           IO=6
   ISN 0007           IPASS=0
   ISN 0008    7777   IFIN=0
                C
                C  THE INPUT DATA FOLLOWS...
                C
                C
                C                  INPUT DATA REQUIREMENTS
                C                  ----- ---- ------------
                C
                C       INPUT TO THE PROGRAM CONSISTS OF THE NUMBER OF TIME POINTS
                C       TO BE COMPUTED, THE POWER SPECTRAL DENSITY (PSD) AS A FUNCTION
                C       OF FREQUENCY, THE RISE AND FALL CRITERIA TO BE USED WITH CYCLE
                C       COUNTING, AND AN INITIAL NUMBER TO BE USED IN THE RANDOM
                C       NUMBER GENERATOR.
                C
                C
                C       INPUT DATA FORMAT
                C       ----- ---- ------
                C
                C       THE PROGRAM INPUT IS:
                C       M1,NR,NX,NSPD,IX                                  5I5
                C       W(1),PSD(1),W(2),PSD(2),W(3),PSD(3)               6E10.0
                C       W(4),PSD(4),W(5),PSD(5),W(6),PSD(6)               6E10.0
                C       ... W(NPSD),PSD(NPSD)                             6E10.0
                C       NDZ,DZ,PMAX,PMIN,MEAN,R,INC                       I5,F5.0,4E10.0
                C       ANDZ,ADZ                                          I5,F5.0
                C
                C       WHERE:
                C
                C       N=2**M1    = NUMBER OF POINTS TO BE COMPUTED IN THE RANDOM TIME
                C                    HISTORY, M1 MAX. IS 15, N MAX. IS 32768.
                C       NR'=2**NR  = FACTOR BY WHICH THE PSD FREQUENCY AXIS IS EXTENDED
                C                    TO INCREASE THE SENSITIVITY OF THE OUTPUT,
                C                    NR=2,NR'=4 IS TYPICAL.  TRIAL RUNS HAVE SHOWN
                C                    THAT MANY PEAKS WILL BE MISSED IF THE VALUES NR=0,
                C                    NR'=1 ARE USED.
                C       NX'=2**NX  = NUMBER OF DIVISIONS OF THE PSD GRAPH USED
                C                    IN ANALYSIS.
```

```
C      NSPD       = NUMBER OF INPUT DATA POINTS ON THE PSD VS
C                   FREQUENCY GRAPH.
C      IX         = INTEGER USED AS STARTING SEED IN RANDOM NUMBER
C                   GENERATION.
C      W(I),PSD(I)
C                 = FREQUENCY AND VALUE OF PSD.
C      NDZ        = NUMBER OF INCREMENTS TO BE USED IN THE OUTPUT
C                   OF GAUSSIAN PEAK AND VALLEY EXCEEDANCE TABLES.
C       NZ        = VALUE OF THE INCREMENT TO BE USED IN OUTPUT OF
C                   OF GAUSSIAN PEAK AND VALLEY EXCEEDANCE TABLES.
C
C      THE SECOND SET OF VALUES OF ANDZ AND ADZ INDICATED IN THE
C      INPUT ARE USED FOR OUTPUT OF THE EXCEEDANCE TABLE FOR THE
C      SIMULATED REAL TIME HISTORY.
C
C       PMAX,PMIN = IN ORDER FOR A PEAK AND VALLEY TO BE COUNTED
C                   AND INCLUDED IN THE OUTPUT LIST, THE MAXIMUM
C                   RISE OR FALL MUST EXCEED THE INPUT VALUE OF
C                   PMAX, AND THE MINIMUM RISE AND FALL MUST
C                   EXCEED THE INPUT VALUE OF PMIN.  IF THE MAXIMUM
C                   RISE OR FALL EXCEEDS PMAX, AND THE MINIMUM
C                   RISE OR FALL EXCEEDS PMIN, THE CYCLE IS
C                   COUNTED.
C       MEAN      = MEAN VALUE IN MAPPING GAUSSIAN TO SIMULATED REAL
C                   TIME HISTORY.
C       K         = TRANSFORMATION EXPONENT USED IN MAPPING GAUSSIAN
C                   TO SIMULATED REAL TIME HISTORY.
C       INC       = INDICATOR USED TO CONTROL ADJUSTMENT OF
C                   SIMULATED REAL TIME HISTORY.
C                     INC = 1, NO ADJUSTMENT IS MADE.
C                     INC = 0, ADJUSTMENT IS MADE.
C      THIS ADJUSTMENT CAPABILITY WAS INCORPORATED IN THE PROGRAM
C      IN ORDER TO MATCH THE BASELINE AIR-TO-GROUND EXCEEDANCE
C      CURVES, WHICH HAVE NO PEAKS GREATER THE 80% DLS.  IF INC=0
C      ALL PEAKS GREATER THE 80% AND LESS THAN 90% DLS ARE RE-SET
C      TO 80% DLS.
ISN 0009       IF(IPASS.EQ.0)READ(IN,1001,END=8888)M1,NR,NX,NSPD,IX
ISN 0011       IF(IPASS.EQ.1)READ(IN,7001,END=8888)IX
ISN 0013  7001 FORMAT( I5 )
ISN 0014       WRITE(IO,3001)M1,NR,NX,NSPD,IX
ISN 0015  3001 FORMAT('1   M1=',I5,'   NR=',I5,'   NX=',I5,'   NSPD=',I5,
     *         '   IX=',I5)
ISN 0016       IF(IPASS.EQ.0)READ(IN,1002)(W(I),PSD(I),I=1,NSPD)
ISN 0018       WRITE(6,79)
ISN 0019    79 FORMAT(//'   I          W(I)          PSD(I)',/)
ISN 0020       WRITE(6,81)(I,W(I),PSD(I),I=1,NSPD)
ISN 0021    81 FORMAT(I5,2E15.7)
ISN 0022       M(1)=M1
ISN 0023       M(2)=0
ISN 0024       M(3)=0
ISN 0025       N=2**M1
ISN 0026       N2 =2*N
ISN 0027       IF(IPASS.EQ.0)NXX=NX
```

```
ISN  0029            IF(IPASS.EQ.0)NRR=NR
ISN  0031            IF(IPASS.EQ.1)NX=NXX
ISN  0033            IF(IPASS.EQ.1)NR=NRR
ISN  0035            NX=2**NX
ISN  0036            NR=2**NR
ISN  0037            N1=N/(NX*NR)
ISN  0038            IFSET=1.
ISN  0039            DW=W(NSPD)/NX/N1
ISN  0040       1004 FORMAT(/' ANDZ =',I5,'           ADZ =',F5.0)
ISN  0041            TIME=N
ISN  0042            TIME=TIME/(NR*W(NSPD)*3600.)
ISN  0043       3004 FORMAT(//' THE ELAPSED TIME FOR THIS RUN IS',F12.6,' HOURS.'/)
ISN  0044               IX=IX+500
ISN  0045            IX=IX*2+1
ISN  0046            IF(IPASS.EQ.0)READ(IN,1003)NDZ,DZ,PMAX,PMIN,MEAN,R,INC
ISN  0048            IF(IPASS.EQ.0)NNDZ=NDZ
ISN  0050            IF(IPASS.EQ.0)DDZ=DZ
ISN  0052            IF(IPASS.EQ.1)NDZ=NNDZ
ISN  0054            IF(IPASS.EQ.1)DZ=DDZ
ISN  0056            IF(IPASS.EQ.0)READ(IN,1003) ANDZ,ADZ
ISN  0058            IPASS=1
ISN  0059            WRITE(6,82) NDZ,DZ,PMAX,PMIN,MEAN,R,INC
ISN  0060            WRITE(IO,1004)ANDZ,ADZ
ISN  0061            WRITE(IO,3004) TIME
ISN  0062         82 FORMAT(//6X,'NDZ =',I7,10X,'DZ =',E15.7,10X,'PMAX =',F10.2,
                    *10X,'PMIN =',F10.2//6X,'MEAN =',F10.3,10X,'R =',F10.3,
                    *10X,'INC =',I5,10X//)
ISN  0063            K=0
                C
                C  THE FOLLOWING DO LOOP COMPUTES THE  A(K)  TERMS...
                C
ISN  0064            DO 10 I=1,NX
ISN  0065            WI=DW*I*N1
ISN  0066            CALL TLU(W,PSD,NSPD,WI,S2)
ISN  0067            S2=SQRT(S2*2.0*DW)
ISN  0068            DO 5 J=1,N1
ISN  0069            K=K+1
ISN  0070            IX=IX*1029
ISN  0071            NIX=IX/1048576
ISN  0072              IX=IX-NIX*1048576
ISN  0073            B=IX/166886.
ISN  0074            A(K)=S2*COS(B)
ISN  0075            K=K+1
ISN  0076            A(K)=S2*SIN(B)
ISN  0077          5 CONTINUE
ISN  0078         10 CONTINUE
ISN  0079            K1=K+1
ISN  0080            IF(K1.GE.N2) GO TO 16
ISN  0082            DO 15 K=K1,N2
ISN  0083         15 A(K)=0.
ISN  0084         16 CONTINUE
ISN  0085            CALL HARM(A,M,INV,S,IFSET,IFERR)
                C
```

```
                C THE  A  MATRIX IS NOW THE TIME HISTORY...
                C A(ODD) 1,3,5,...,ETC IS THE REAL PART...
                C A(EVEN) 2,4,6,...,ETC IS THE IMAGINARY PART...
                C
ISN 0086              IFSET=2
ISN 0087              IF(IFERR.NE.0) STOP 100
ISN 0089              DO 20 I=1,4
ISN 0090              DO 20 J=1,60
ISN 0091           20 NPEAKS(J,I)=0
                C
                CC THE REAL PART OF THE  A  MATRIX IS MOVED TO THE LATTER PART
                C OF THE  A  MATRIX...
                CC
ISN 0092              K=N2
ISN 0093              NM1=N2-1
ISN 0094              DO 30 I=1,NM1,2
ISN 0095              A(K)=A(N2-I)
ISN 0096           30 K=K-1
                C
                CC SEARCH FOR PEAKS AND VALLEYS AND THEN STORE THE VALUE AND TIME
                C IN THE FIRST PART OF THE  A  MATRIX...
                C
ISN 0097              IA1=N+1
ISN 0098           95 CONTINUE
ISN 0099              K=0
ISN 0100              NMAX=N-1
ISN 0101              SL2=A(IA1+1)-A(IA1)
ISN 0102              Y1=A(IA1+1)
ISN 0103              DO 60 I=2,NMAX
ISN 0104              SL1=SL2
ISN 0105              SL2=A(IA1+I)-A(IA1+I-1)
ISN 0106              NSL=SL1/ABS(SL1)-SL2/ABS(SL2)
ISN 0107              IF(NSL)40,60,40
ISN 0108           40 C1=A(IA1+I-2)
ISN 0109              C2=(3*SL1-SL2)/2.
ISN 0110              C3=(SL2-SL1)/2.
ISN 0111              XM=-C2/(2.*C3)
ISN 0112              X1=I-1
ISN 0113              XM=XM+X1
ISN 0114              YM=C1-C2**2/(4.*C3)
ISN 0115              A(K+1)=XM/NR/W(NSPD)
ISN 0116              A(K+2)=YM
ISN 0117              IZ=ABS(YM)/DZ+1
ISN 0118              IF(IZ.GT.(NDZ+1)) IZ=NDZ+1
ISN 0120              IF(YM.LT.0.) IZ=IZ+NDZ+1
ISN 0122              KZ=1
ISN 0123              IF(NSL.LT.0)KZ=2
                C
                CC SET UP A GAUSSIAN PEAK AND VALLEY OCCURENCE TABLE...
                C
ISN 0125              NPEAKS(IZ,KZ)=NPEAKS(IZ,KZ)+1
ISN 0126              K=K+2
ISN 0127           60 CONTINUE
```

```
ISN  0128              KKK=K
ISN  0129              NPKR=K
ISN  0130       4451   NDZ1=NDZ+1
ISN  0131              I1=NDZ
ISN  0132              NPEAKS(NDZ1,3)=NPEAKS(NDZ1,1)
ISN  0133              NPEAKS(NDZ1,4)=NPEAKS(NDZ1,2)
ISN  0134              NDZ2=2*NDZ1
ISN  0135              NPEAKS(NDZ2,3)=NPEAKS(NDZ2,1)
ISN  0136              NPEAKS(NDZ2,4)=NPEAKS(NDZ2,2)
ISN  0137       445    I2=NDZ2-1
ISN  0138              DO 70 I=1,NDZ
ISN  0139              DO 75 K=1,2
ISN  0140              NPEAKS(I1,K+2)=NPEAKS(I1+1,K+2)+NPEAKS(I1,K)
ISN  0141              NPEAKS(I2,K+2)=NPEAKS(I2+1,K+2)+NPEAKS(I2,K)
ISN  0142       75     CONTINUE
ISN  0143              I1=I1-1
ISN  0144              I2=I2-1
ISN  0145         70   CONTINUE
ISN  0146              IF( IFIN.EQ.1 ) GO TO 91
ISN  0148              CALL EXCED(W,PSD,NSPD,NX,NDZ,DZ,F0,FP,PL,MEAN,R,IFIN,TIME)
ISN  0149              WRITE(IO,2001)
ISN  0150              DO 90I=1,NDZ1
ISN  0151              DNZ=DZ*I
ISN  0152              DNZ1=DZ*(I-1)
                       C
                       C  WRITE THE PEAK EXCEEDANCE TABLE...
                       C
ISN  0153              WRITE(IO,2002) DNZ1,DNZ,(NPEAKS(I,J),J=1,4),PL(I,1)
ISN  0154         90   CONTINUE
ISN  0155              DO 100 I=1,NDZ1
ISN  0156              DNZ=-DZ*I
ISN  0157              DNZ1=-DZ*(I-1)
ISN  0158              K=I+NDZ1
                       C
                       C  WRITE THE VALLEY EXCEEDANCE TABLE...
                       C
ISN  0159              WRITE(IO,2002) DNZ1,DNZ,(NPEAKS(K,J),J=1,4),PL(I,2)
ISN  0160       100    CONTINUE
ISN  0161        91    CONTINUE
ISN  0162              WRITE(IO,63) NPKR
ISN  0163        63    FORMAT(//' NPKR=',I10//)
ISN  0164              IF(IFIN.EQ.2) CALL FILTER(A,KKK,PMIN,PMAX,NPKR)
ISN  0166              IF(IFIN.EQ.2)K=NPKR
ISN  0168              IF(IFIN.EQ.2)GO TO 71
                       C
                       C  WRITE THE FILTERED PEAK AND VALLEY TABLE...
                       C
ISN  0170              IF(IFIN.EQ.3)WRITE(2)NPKR,(A(I),I=2,NPKR,2)
ISN  0172              IF( IFIN.EQ.3 ) WRITE(IO,1005)
ISN  0174              IF(IFIN.EQ.3)WRITE(6,72)(A(I),I=2,NPKR,2)
ISN  0176       72     FORMAT(10F10.1)
ISN  0177              IF(IFIN.EQ.3)GO TO 7777
ISN  0179              IF(IFIN.EQ.1) GO TO 69
```

```
ISN 0181            IFIN=1
ISN 0182         66 DO 2220 I=1,4
ISN 0183            DO 2220 J=1,60
ISN 0184       2220 NPEAKS(J,I)=0
ISN 0185            NDZ=ANDZ
ISN 0186            DZ=ADZ
ISN 0187            NSL=(A(4)-A(2))/ABS(A(4)-A(2))
                C
                CC SET UP THE PEAK AND VALLEY OCCOURENCE TABLE THE
                C  REAL - TRANSFORMED LOADS...
                C
ISN 0188            DO 660 I=2,NPKR,2
ISN 0189            NSL=-NSL
ISN 0190            YM=A(I)
ISN 0191            IZ=ABS(YM)/DZ+1
ISN 0192            IF(IZ.GT.(NDZ+1))IZ=NDZ+1
ISN 0194            IF(YM.LT.0.) IZ=IZ+NDZ+1
ISN 0196            KZ=1
ISN 0197            IF(NSL.LT.0)KZ=2
ISN 0199            NPEAKS(IZ,KZ)=NPEAKS(IZ,KZ)+1
ISN 0200       660  CONTINUE
ISN 0201            GO TO 4451
ISN 0202       1001 FORMAT(14I5)
ISN 0203       1002 FORMAT(6E10.0)
ISN 0204       1003 FORMAT(I5,F5.0,4E10.0,I5,E10.0)
ISN 0205       1005 FORMAT('1                LIST OF FILTERED PEAKS AND VALLEYS'/
                   *'                ---- -- -------- ------ --- -------'/)
ISN 0206       2001 FORMAT(6X,'NZ RANGE  PEAKS  VALLEYS  PEAK     VALLEY   THEORITICAL',
                   1 /31X,'EXCEED   EXCEED      EXCEED',/
                   *6X,55('='),/)
ISN 0207       2002 FORMAT(2X,F6.1,'=',F6.1,I7,I8,I8,I8,F12.1)
                C
                CC TRANSFORMS THE GAUSSIAN PEAK AND VALLEY LIST TO REAL...
                C
ISN 0208         69 DO 64 I=2,NPKR,2
ISN 0209            A(I)=(ABS(A(I)+MEAN))**R*((A(I)+MEAN)/(ABS(A(I)+MEAN)))
ISN 0210            IF( INC.EQ.1 ) GO TO 64
ISN 0212            IF( A(I).GT.80.0 .AND. A(I).LT.90.0 ) A(I)=70.0
ISN 0214            IF( A(I).GT.90.0 ) A(I)=80.0
ISN 0216         64 CONTINUE
ISN 0217         71 IFIN=IFIN+1
ISN 0218            WRITE(IO,89) IX
ISN 0219         89 FORMAT(/' THE MOST CURRENT VALUE OF IX IS',I10/)
ISN 0220            GO TO 66
ISN 0221       8888 STOP 1776
ISN 0222            END
```

```
LEVEL 21.7 ( JAN 73 )                          OS/360  FORTRAN H

          COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=55,SIZE=0000K,
                             SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
                C
                C
                C
                C
                C
                C
                C
                C
                C
  ISN 0002            SUBROUTINE EXCED (W,PSD,NSPD,NX,NDZ,DZ,F0,FP,PL,MEAN,R,IFIN,TIME)
                C
                C   SUBROUTINE EXCEED COMPUTES THE THEORETICAL EXCEEDANCE TABLES
                C   BASED ON THE INPUT (PSD,R,MEAN)...
                C
  ISN 0003            DIMENSION W(1),PSD(1),PL(60,2)
  ISN 0004            REAL*8 MEAN
  ISN 0005            REAL K1,K2
  ISN 0006            IF( IFIN.EQ.0 ) WRITE(6,301)
  ISN 0008          301 FORMAT('1',
                     *       '                GAUSSIAN EXCEEDANCE TABLE'/
                     *       '                -------- ---------- -----'/)
  ISN 0009            IF( IFIN.EQ.2 ) WRITE(6,302)
  ISN 0011          302 FORMAT('1',
                     *       '                REAL EXCEEDANCE TABLE UNFILTERED'/
                     *       '                ---- ---------- ----- ----------'/)
  ISN 0012            IF( IFIN.EQ.3 ) WRITE(6,303)
  ISN 0014          303 FORMAT('1',
                     *       '                REAL EXCEEDANCE TABLE FILTERED'/
                     *       '                ---- ---------- ----- --------'/)
  ISN 0015            VAR=0.
  ISN 0016            SMOM=0.
  ISN 0017            FMOM=0.
  ISN 0018            DW=W(NSPD)/NX
  ISN 0019            DO 10 I=1,NX
  ISN 0020            WI=DW*I
  ISN 0021            CALL TLU(W,PSD,NSPD,WI,S)
  ISN 0022            VAR=S*DW+VAR
  ISN 0023            SMOM=WI**2*S*DW+SMOM
  ISN 0024         10 FMOM=WI**4*S*DW+FMOM
  ISN 0025            F0=SMOM/VAR
  ISN 0026            FP=FMOM/SMOM
  ISN 0027            F0=SQRT(F0)*3600.*TIME
  ISN 0028            FP=SQRT(FP)*3600.*TIME
  ISN 0029            IF(IFIN.EQ.0) WRITE(6,15)F0,FP
  ISN 0031         15 FORMAT(//6X,'NO =',E15.7,10X,'NP =',E15.7//)
  ISN 0032            R1=F0/FP
  ISN 0033            K1=SQRT(1.0-R1**2)
  ISN 0034            K2=K1/R1
  ISN 0035            ND=NDZ+1
  ISN 0036            DO 20 I=1,ND
  ISN 0037            DO 20 J=1,2
  ISN 0038            IF( IFIN.EQ.0 ) GO TO 21
  ISN 0040            XN=(((I-1)*DZ)**(1.0/R)+(-1)**J*MEAN)/SQRT(VAR)
  ISN 0041            GO TO 23
```

```
ISN  0042          21   XN=(I-1)*DZ/SQRT(VAR)
ISN  0043          23   X1=XN/K1
ISN  0044               IF( X1.LT.6.0 ) GO TO 22
ISN  0046               PL(I,J)=0.
ISN  0047               GO TO 20
ISN  0048          22   CALL NDTR(X1,P1,D1)
ISN  0049               X2=XN/K2
ISN  0050               CALL NDTR(X2,P2,D2)
ISN  0051               P1=1.0-P1
ISN  0052               P2=1.0-P2
ISN  0053               PL(I,J)=FP*(P1+R1*(1.0-P2)/EXP(XN**2/2.))
ISN  0054          20   CONTINUE
ISN  0055               RETURN
ISN  0056               END
```

```
LEVEL 21.7 ( JAN 73 )                                   OS/360  FORTRAN H

          COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=55,SIZE=0000K,
                             SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
  ISN 0002            SUBROUTINE FILTER(A,NPK,PMIN,PMAX,NPKR)
                      C
                      C SUBROUTINE FLILTER APPLIES THE RISE AND FALL CRITERION TO THE
                      C LIST OF PEAKS AND VALLEYS...
                      C
  ISN 0003            DIMENSION A(NPK)
  ISN 0004            KV=2
  ISN 0005            KP=4
  ISN 0006            NV=6
  ISN 0007            NP=8
  ISN 0008            IF(A(2).LT.A(4)) GO TO 500
  ISN 0010            KP=2
  ISN 0011            KV=4
  ISN 0012            NP=6
  ISN 0013            NV=8
                      C
  ISN 0014          400 CONTINUE
                      C
                      CC          WE NOW END WITH A VALLEY AND ARE SEARCHING FOR THE NEXT PEAK
                      CC
                      C           HAVE WE USED UP THE A ARRAY
  ISN 0015            IF(NV.GT.NPK) GO TO 600
  ISN 0017            PR=PMAX
                      C
                      CC          DOES THE NEXT RISE HAVE TO BE PMAX, OR IS PMIN ENOUGH
                      C
  ISN 0018            IF((A(KP)-A(KV)-PMAX).GE.0.) PR=PMIN
                      C
                      CC          IS THE NEXT PEAK LARGE ENOUGH TO COUNT
                      C                                  NO   YES  YES
  ISN 0020            IF(A(NP)-A(KV)-PR) 405,430,430
                      C
  ISN 0021          405 CONTINUE
                      C
                      CC          NOT ENOUGH RISE
                      CC
                      CC          BUT IS IT LARGER THAN CURRENT PEAK
                      C                                NO   NO   YES
  ISN 0022            IF (A(NP)-A(KP)) 415,415,410
  ISN 0023          410 CONTINUE
                      C
                      CC          REPLACE CURRENT PEAK
  ISN 0024            A(KP)=A(NP)
  ISN 0025            A(KP-1)=A(NP-1)
  ISN 0026            NP=NP+4
                      C           THROW AWAY CURRENT VALLEY
  ISN 0027            KV=KV-4
                      C           WAS IT THE FIRST VALLEY
  ISN 0028            IF(KV.NE.0) GO TO 500
  ISN 0030            A1=A(1)
  ISN 0031            A2=A(2)
```

```
ISN 0032            A(1)=A(3)
ISN 0033            A(2)=A(4)
ISN 0034            A(3)=A1
ISN 0035            A(4)=A2
ISN 0036            KV=2
ISN 0037            KP=4
ISN 0038            GO TO 500
ISN 0039          415 CONTINUE
                  C
                  CC          IS NEXT VALLEY LOWER THAN CURRENT VALLEY
                  C                        YES  NO  NO
ISN 0040            IF(A(NV)-A(KV)) 420,425,425
ISN 0041          420 CONTINUE
                  C
                  CC          REPLACE CURRENT VALLEY
                  C
ISN 0042            A(KV)=A(NV)
ISN 0043            A(KV-1)=A(NV-1)
ISN 0044            NP=NP+4
ISN 0045            NV=NV+4
ISN 0046            GO TO 400
ISN 0047          425 CONTINUE
                  C
                  CC          KEEP LOOKING
                  C
ISN 0048            NV=NV+4
ISN 0049            NP=NP+4
ISN 0050            GO TO 400
ISN 0051          430 CONTINUE
                  C
                  CC          WE HAVE THE NEXT PEAK, NOW MOVE IT DOWN TO THE NEXT AVAILABLE
                  CC          LOCATION
                  C
ISN 0052            A(KP+4)=A(NP)
ISN 0053            A(KP+3)=A(NP-1)
ISN 0054            KP=KP+4
ISN 0055            NP=NP+4
ISN 0056          500 CONTINUE
                  C
                  CCC         WE NOW END WITH A PEAK AND ARE LOOKING FOR THE NEXT VALLEY
                  C
                  CC          HAVE WE USED UP THE A ARRAY
ISN 0057            IF(NP.GT.NPK) GO TO 600
ISN 0059            PR=PMAX
                  C
                  CC          DOES THE NEXT FALL HAVE TO BE PMAX, OR IS PMIN ENOUGH
                  C
ISN 0060            IF((A(KP)-A(KV)-PMAX).GE.0.) PR=PMIN
                  C
                  CC          IS THE NEXT VALLEY LOW ENOUGH TO COUNT
                  C                          NO  YES YES
ISN 0062            IF(A(KP)-A(NV)-PR) 505,530,530
ISN 0063          505 CONTINUE
```

```
                C
                C          NOT ENOUGH FALL
                C
                C          BUT IS IT LOWER THAN THE CURRENT VALLEY
                C                              YES NO  NO
ISN 0064              IF(A(NV)-A(KV)) 510,515,515
ISN 0065          510 CONTINUE
                C
                C          REPLACE CURRENT VALLEY
ISN 0066              A(KV)=A(NV)
ISN 0067              A(KV-1)=A(NV-1)
ISN 0068              NV=NV+4
                C          THROW AWAY CURRENT PEAK
ISN 0069              KP=KP-4
                C          BUT WAS IT THE FIRST PEAK
ISN 0070              IF(KP.NE.0) GO TO 400
ISN 0072              A1=A(1)
ISN 0073              A2=A(2)
ISN 0074              A(1)=A(3)
ISN 0075              A(2)=A(4)
ISN 0076              A(3)=A1
ISN 0077              A(4)=A2
ISN 0078              KP=2
ISN 0079              KV=4
ISN 0080              GO TO 400
ISN 0081          515 CONTINUE
                C
                C          IS NEXT PEAK HIGHER THAN CURRENT PEAK
                C                              NO NO  YES
ISN 0082              IF(A(NP)-A(KP)) 525,525,520
ISN 0083          520 CONTINUE
                C
                C     REPLACE CURRENT PEAK
                C
ISN 0084              A(KP)=A(NP)
ISN 0085              A(KP-1)=A(NP-1)
ISN 0086              NP=NP+4
ISN 0087              NV=NV+4
ISN 0088              GO TO 500
ISN 0089          525 CONTINUE
                C
                C          KEEP LOOKING
                C
ISN 0090              NV=NV+4
ISN 0091              NP=NP+4
ISN 0092              GO TO 500
ISN 0093          530 CONTINUE
                C
                C     WE HAVE THE NEXT VALLEY, NOW MOVE IT TO THE NEXT AVAILABLE LOATION
                C
                C
ISN 0094              A(KV+4)=A(NV)
ISN 0095              A(KV+3)=A(NV-1)
```

```
ISN 0096              KV=KV+4
ISN 0097              NV=NV+4
ISN 0098              GO TO 400
ISN 0099          600 CONTINUE
ISN 0100              NPKR=MAX0(KP,KV)
ISN 0101              RETURN
ISN 0102              END
```



```
LEVEL 21,7 ( JAN 73 )                                   OS/360  FORTRAN H

          COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=55,SIZE=0000K,
                             SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
ISN 0002                SUBROUTINE TLU(X,Y,NOPTS,XVAL,YVAL)
                        C
                        C TLU IS A LINEAR INTERPOLATION TABLE LOOK-UP SUBROUTINE...
                        C
ISN 0003                      DIMENSION X(1),Y(1)
ISN 0004                      I=1
ISN 0005                1776  IF(X(I)-XVAL )1777,1780,1780
ISN 0006                1777  IF(X(I+1)-XVAL )1778,1781,1779
ISN 0007                1778  I=I+1
ISN 0008                      IF(NOPTS-I)1782,1776,1776
ISN 0009                1779  RATIO=(XVAL -X(I))/(X(I+1)-X(I))
ISN 0010                      YVAL =RATIO*(Y(I+1)-Y(I))+Y(I)
ISN 0011                      GO TO 1783
ISN 0012                1780  YVAL =Y(I)
ISN 0013                      GO TO 1783
ISN 0014                1781  YVAL =Y(I+1)
ISN 0015                      GO TO 1783
ISN 0016                1782  I=NOPTS
ISN 0017                      YVAL=(XVAL-X(I))*(Y(I)-Y(I-1))/(X(I)-X(I-1))+Y(I)
ISN 0018                1783  RETURN
ISN 0019                      END
```

APPENDIX B SAMPLE PROBLEM WITH INPUT DATA LISTING

INPUT DATA

```
AIR-TO-AIR BASELINE
   15     2      7    46   759
 0.          4904.      .0022      3903.      .0044      2561.
 .0067       2240.      .0089      2138.      .0111      1817.
 .0133       1977.      .0156      3126.      .0178      3794.
 .02         3088.      .0222      2093.      .0244      1316.
 .0267        995.      .0289      1303.      .0311      1406.
 .0333       1027.      .0356       802.      .0378       757.
 .04          629.      .0422       443.      .0444       334.
 .0467        379.      .0489       488.      .0511       417.
 .0533        315.      .0556       308.      .0578       276.
 .06          244.      .0622       205.      .0644       154.
 .0667        160.      .0689       160.      .0711       160.
 .0733        160.      .0756       141.      .0778       128.
 .08          116.      .0822       109.      .0844        83.
 .0867         49.      .0889        51.      .0911        60.
 .0933         57.      .0956        47.      .0978        40.
 .1            45.
   12   5.       10.0       10.0       22.2      1.128      1
   13  10.
```

M1= 15 NR= 2 NX= 7 NSPD= 46 IX= 759

I	W(I)	PSD(I)
1	0.0	0.4904000E+04
2	0.2200000E-02	0.3903000E+04
3	0.4400000E-02	0.2561000E+04
4	0.6700002E-02	0.2240000E+04
5	0.8900002E-02	0.2138000E+04
6	0.1110000E-01	0.1817000E+04
7	0.1330000E-01	0.1977000E+04
8	0.1560000E-01	0.3126000E+04
9	0.1780000E-01	0.3794000E+04
10	0.2000000E-01	0.3088000E+04
11	0.2220000E-01	0.2093000E+04
12	0.2440000E-01	0.1316000E+04
13	0.2670000E-01	0.9950000E+03
14	0.2890000E-01	0.1303000E+04
15	0.3110000E-01	0.1406000E+04
16	0.3330000E-01	0.1027000E+04
17	0.3560000E-01	0.8020000E+03
18	0.3780000E-01	0.7570000E+03
19	0.4000000E-01	0.6290000E+03
20	0.4220000E-01	0.4430000E+03
21	0.4440000E-01	0.3340000E+03
22	0.4670000E-01	0.3790000E+03
23	0.4890000E-01	0.4880000E+03
24	0.5110000E-01	0.4170000E+03
25	0.5330000E-01	0.3150000E+03
26	0.5560000E-01	0.3080000E+03
27	0.5780000E-01	0.2760000E+03
28	0.6000000E-01	0.2440000E+03
29	0.6220000E-01	0.2050000E+03
30	0.6440002E-01	0.1540000E+03
31	0.6669998E-01	0.1600000E+03
32	0.6889999E-01	0.1600000E+03
33	0.7110000E-01	0.1600000E+03
34	0.7330000E-01	0.1600000E+03
35	0.7560003E-01	0.1410000E+03
36	0.7779998E-01	0.1280000E+03
37	0.7999998E-01	0.1160000E+03
38	0.8219999E-01	0.1090000E+03
39	0.8440000E-01	0.8300000E+02
40	0.8670002E-01	0.4900000E+02
41	0.8890003E-01	0.5100000E+02
42	0.9109998E-01	0.6000000E+02
43	0.9329998E-01	0.5700000E+02
44	0.9560001E-01	0.4700000E+02
45	0.9780002E-01	0.4000000E+02
46	0.1000000E+00	0.4500000E+02

NDZ = 12 DZ = 0.5000000E+01 PMAX = 10.00 PMIN = 10.00

MEAN = 22.200 R = 1.128 INC = 1

ANDZ = 13 ADZ = 10.

THE ELAPSED TIME FOR THIS RUN IS 22.755539 HOURS.

GAUSSIAN EXCEEDANCE TABLE

NO = 0.2292718E+04 NP = 0.4580586E+04

NZ RANGE	PEAKS	VALLEYS	PEAK EXCEED	VALLEY EXCEED	THEORITICAL EXCEED
0.0- 5.0	905	581	3258	1000	3436.7
5.0- 10.0	968	283	2353	419	2493.5
10.0- 15.0	728	104	1385	136	1495.9
15.0- 20.0	424	25	657	32	718.8
20.0- 25.0	166	7	233	7	271.0
25.0- 30.0	57	0	67	0	79.1
30.0- 35.0	10	0	10	0	17.8
35.0- 40.0	0	0	0	0	3.1
40.0- 45.0	0	0	0	0	0.4
45.0- 50.0	0	0	0	0	0.0
50.0- 55.0	0	0	0	0	0.0
55.0- 60.0	0	0	0	0	0.0
60.0- 65.0	0	0	0	0	0.0
0.0- -5.0	634	883	1103	3362	3436.7
-5.0- -10.0	330	951	469	2479	2493.5
-10.0- -15.0	104	789	139	1528	1495.9
-15.0- -20.0	26	452	35	739	718.8
-20.0- -25.0	8	199	9	287	271.0
-25.0- -30.0	1	68	1	88	79.1
-30.0- -35.0	0	18	0	20	17.8
-35.0- -40.0	0	2	0	2	3.1
-40.0- -45.0	0	0	0	0	0.4
-45.0- -50.0	0	0	0	0	0.0
-50.0- -55.0	0	0	0	0	0.0
-55.0- -60.0	0	0	0	0	0.0
-60.0- -65.0	0	0	0	0	0.0

NPKR= 17446

NPKR= 17446

THE MOST CURRENT VALUE OF IX IS 297431

REAL EXCEEDANCE TABLE UNFILTERED

NZ RANGE	PEAKS	VALLEYS	PEAK EXCEED	VALLEY EXCEED	THEORITICAL EXCEED
0.0- 10.0	35	623	4356	4176	4577.6
10.0- 20.0	198	1101	4321	3553	4534.7
20.0- 30.0	607	1184	4123	2452	4318.9
30.0- 40.0	991	781	3516	1268	3712.5
40.0- 50.0	1117	349	2525	487	2672.4
50.0- 60.0	810	112	1408	138	1518.9
60.0- 70.0	410	22	598	26	659.0
70.0- 80.0	149	4	188	4	215.1
80.0- 90.0	35	0	39	0	52.6
90.0- 100.0	4	0	4	0	9.7
100.0- 110.0	0	0	0	0	1.3
110.0- 120.0	0	0	0	0	0.1
120.0- 130.0	0	0	0	0	0.0
130.0- 140.0	0	0	0	0	0.0
0.0- -10.0	5	164	5	186	162.8
-10.0- -20.0	0	20	0	22	18.4
-20.0- -30.0	0	2	0	2	1.3
-30.0- -40.0	0	0	0	0	0.1
-40.0- -50.0	0	0	0	0	0.0
-50.0- -60.0	0	0	0	0	0.0
-60.0- -70.0	0	0	0	0	0.0
-70.0- -80.0	0	0	0	0	0.0
-80.0- -90.0	0	0	0	0	0.0
-90.0--100.0	0	0	0	0	0.0
-100.0--110.0	0	0	0	0	0.0
-110.0--120.0	0	0	0	0	0.0
-120.0--130.0	0	0	0	0	0.0
-130.0--140.0	0	0	0	0	0.0

NPKR= 17446

THE MOST CURRENT VALUE OF IX IS 297431

REAL EXCEEDANCE TABLE FILTERED

NZ RANGE	PEAKS	VALLEYS	PEAK EXCEED	VALLEY EXCEED	THEORITICAL EXCEED
0.0= 10.0	1	553	2513	2336	4577.6
10.0= 20.0	22	788	2512	1783	4534.7
20.0= 30.0	141	634	2490	995	4318.9
30.0= 40.0	409	276	2349	361	3715.5
40.0= 50.0	751	74	1940	85	2672.4
50.0= 60.0	639	10	1189	11	1518.9
60.0= 70.0	369	1	550	1	659.0
70.0= 80.0	143	0	181	0	215.1
80.0= 90.0	34	0	38	0	52.6
90.0= 100.0	4	0	4	0	9.7
100.0= 110.0	0	0	0	0	1.3
110.0= 120.0	0	0	0	0	0.1
120.0= 130.0	0	0	0	0	0.0
130.0= 140.0	0	0	0	0	0.0
0.0= -10.0	1	156	1	178	162.8
-10.0= -20.0	0	20	0	22	18.4
-20.0= -30.0	0	2	0	2	1.8
-30.0= -40.0	0	0	0	0	0.1
-40.0= -50.0	0	0	0	0	0.0
-50.0= -60.0	0	0	0	0	0.0
-60.0= -70.0	0	0	0	0	0.0
-70.0= -80.0	0	0	0	0	0.0
-80.0= -90.0	0	0	0	0	0.0
-90.0=-100.0	0	0	0	0	0.0
-100.0=-110.0	0	0	0	0	0.0
-110.0=-120.0	0	0	0	0	0.0
-120.0=-130.0	0	0	0	0	0.0
-130.0=-140.0	0	0	0	0	0.0

NPKR= 10056

LIST OF FILTERED PEAKS AND VALLEYS

APPENDIX C

INPUT DATA FOR STUDY SPECTRA

The input data used in generating the spectra analyzed in the study summarized in Reference 2 are presented in this section. Fifteen different input data sets were used with this program. The titles associated with the data sets are not part of the input data.

```
AIR-TO-AIR BASELINE
   15     2      7    46   759
 0.                4904.      .0022      3903.      .0044      2561.
 .0067             2240.      .0089      2138.      .0111      1817.
 .0133             1977.      .0156      3126.      .0178      3794.
 .02               3088.      .0222      2093.      .0244      1316.
 .0267              995.      .0289      1303.      .0311      1406.
 .0333             1027.      .0356       802.      .0378       757.
 .04                629.      .0422       443.      .0444       334.
 .0467              379.      .0489       488.      .0511       417.
 .0533              315.      .0556       308.      .0578       276.
 .06                244.      .0622       205.      .0644       154.
 .0667              160.      .0689       160.      .0711       160.
 .0733              160.      .0756       141.      .0778       128.
 .08                116.      .0822       109.      .0844        83.
 .0867               49.      .0889        51.      .0911        60.
 .0933               57.      .0956        47.      .0978        40.
 .1                  45.
   12    5.        10.0        10.0        22.2       1.128       1
   13   10.
  800
 9873
 7829
 3649
 4556
 6969
49601
```

AIR-TO-GROUND BASELINE

```
   15     2     7   101   759
0.          241.        .0008       266.        .0016       221.
.0024       143.        .0032       121.        .004        117.
.0048       117.        .0056       113.        .0064       169.
.0072       213.        .008        194.        .0088       219.
.0096       315.        .0104       396.        .0112       365.
.012        251.        .0128       204.        .0136       206.
.0144       181.        .0152       189.        .016        219.
.0168       214.        .0176       201.        .0184       201.
.0192       202.        .02         222.        .0208       256.
.0216       241.        .0224       184.        .0232       160.
.024        149.        .0248       124.        .0256       120.
.0264       131.        .0272       133.        .028        132.
.0288       117.        .0296        89.        .0304        81.
.0312        85.        .032         98.        .0328       119.
.0336       106.        .0344        83.        .0352        80.
.036         87.        .0368       102.        .0376       102.
.0384        75.        .0392        55.        .04          56.
.0408        65.        .0416        73.        .0424        84.
.0432        87.        .0440        68.        .0448        61.
.0456        70.        .0464        66.        .0472        52.
.048         48.        .0488        49.        .0496        51.
.0504        47.        .0512        43.        .052         48.
.0528        52.        .0536        47.        .0544        36.
.0552        28.        .0560        33.        .0568        34.
.0576        25.        .0584        26.        .0592        34.
.06          33.        .0608        24.        .0616        21.
.0624        21.        .0632        18.        .064         19.
.0648        25.        .0656        29.        .0664        25.
.0672        23.        .068         27.        .0688        30.
.0696        25.        .0704        17.        .0712        16.
.072         18.        .0728        17.        .0736        14.
.0744        13.        .0752        15.        .076         14.
.0768        13.        .0776        16.        .0784        15.
.0792        11.        .08          11.
   15     1.        10.0        10.0        6.5         1.6      0
   13    10.
  936
 2649
 3619
 4271
 5863
 6987
```

INSTRUMENTATION AND NAVIGATION BASELINE

```
   15     2     7   101  2485
0.          72.8        .0008       80.4        .0016       66.8
.0024       43.2        .0032       36.5        .004        35.5
.0048       35.4        .0056       34.2        .0064       51.2
.0072       64.4        .008        58.8        .0088       66.4
.0096       95.2        .0104      120.         .0112      110.
.012        76.         .0128       61.6        .0136       62.4
.0144       54.8        .0152       57.2        .016        66.4
.0168       64.8        .0176       60.8        .0184       60.8
.0192       61.2        .02         67.2        .0208       77.6
.0216       72.8        .0224       55.6        .0232       48.4
.024        45.2        .0248       37.4        .0256       36.3
.0264       39.5        .0272       40.4        .028        40.
.0288       35.5        .0296       26.9        .0304       24.4
.0312       25.7        .032        29.6        .0328       35.9
.0336       32.1        .0344       25.         .0352       24.1
.036        26.2        .0368       30.8        .0376       31.
.0384       22.8        .0392       16.8        .04         16.9
.0408       19.7        .0416       22.1        .0424       25.4
.0432       26.2        .044        20.7        .0448       18.5
.0456       21.2        .0464       19.9        .0472       15.8
.048        14.6        .0488       14.8        .0496       15.3
.0504       14.4        .0512       13.         .052        14.6
.0528       15.7        .0536       14.2        .0544       10.9
.0552        8.5        .056        10.4        .0568       10.2
.0576        7.7        .0584        7.7        .0592       10.1
.06          9.9        .0608        7.2        .0616        6.2
.0624        6.2        .0632        5.5        .064         5.6
.0648        7.7        .0656        8.8        .0664        7.5
.0672        7.         .068         8.3        .0688        9.
.0696        7.5        .0704        5.1        .0712        4.8
.072         5.6        .0728        5.         .0736        4.1
.0744        4.1        .0752        4.7        .076         4.4
.0768        4.1        .0776        4.9        .0784        4.6
.0792        3.4        .08          3.3
   10     1         10.0        10.0        6.0         1.75     1
   12    10.
```

```
EXCEEDANCE CURVE VARIATION NO. 1
    15     2     7    46   759
0.          2300.       .0022       1830.       .0044       1200.
.0067       1050.       .0089       1000.       .0111        850.
.0133        925.       .0156       1460.       .0178       1780.
.02         1450.       .0222        980.       .0244        616.
.0267        466.       .0289        610.       .0311        658.
.0333        481.       .0356        375.       .0378        354.
.04          294.       .0422        207.       .0444        156.
.0467        177.       .0489        228.       .0511        195.
.0533        147.       .0556        144.       .0578        129.
.06          114.       .0622       95.6        .0644       72.1
.0667       74.9        .0689       74.9        .0711       74.9
.0733       74.9        .0756        66.        .0778       59.9
.08         54.3        .0822        51.        .0844       38.8
.0867       22.9        .0889       23.9        .0911       28.1
.0933       26.7        .0956        22.        .0978       18.7
.1          21.1
    12    5.          10.0        10.0        22.2       1.128     1
    16   10.
   800
  9873
  7829
  3649
  4556
  6969
 49601
  2017
  3493
  4217
  5184
EXCEEDANCE CURVE VARIATION NO. 2
    15     2     7    46   759
0.          3060.       .0022       2430.       .0044       1600.
.0067       1400.       .0089       1330.       .0111       1130.
.0133       1230.       .0156       1940.       .0178       2370.
.02         1930.       .0222       1300.       .0244        819.
.0267        620.       .0289        811.       .0311        875.
.0333        640.       .0356        499.       .0378        471.
.04          391.       .0422        275.       .0444        207.
.0467        235.       .0489        303.       .0511        259.
.0533        196.       .0556        192.       .0578        172.
.06          152.       .0622        128.       .0644       95.9
.0667       99.6        .0689       99.6        .0711       99.6
.0733       99.6        .0756       87.8        .0778       79.7
.08         72.2        .0822       67.8        .0844       51.6
.0867       30.5        .0889       31.8        .0911       37.4
.0933       35.5        .0956       29.3        .0978       24.9
.1          28.1
    12    5.          10.0        10.0        22.2       1.128     1
    16   10.
   800
  9873
  7829
  3649
  4556
  6969
 49601
  2017
  3493
```

```
EXCEEDANCE CURVE VARIATION NO. 3
   15     2     7    46   759
0.          3930.       .0022       3120.       .0044       2050.
.0067       1800.       .0089       1710.       .0111       1450.
.0133       1580.       .0156       2490.       .0178       3040.
.02         2480.       .0222       1670.       .0244       1050.
.0267        796.       .0289       1040.       .0311       1120.
.0333        822.       .0356        641.       .0378        605.
.04          502.       .0422        353.       .0444        266.
.0467        302.       .0489        389.       .0511        333.
.0533        252.       .0556        247.       .0578        221.
.06          195.       .0622        164.       .0644        123.
.0667        128.       .0689        128.       .0711        128.
.0733        128.       .0756        113.       .0778        102.
.08         92.7        .0822        87.1       .0844        66.3
.0867       39.2        .0889        40.8       .0911        48.
.0933       45.6        .0956        37.6       .0978        32.
.1          36.1
   12    5.          10.0        10.0        22.2      1.128     1
   16   10.
  800
 9873
 7829
 3649
 4556
 6969
49601

EXCEEDANCE CURVE VARIATION NO. 4
   15     2     7    46   759
0.          6000.       .0022       4760.       .0044       3130.
.0067       2750.       .0089       2610.       .0111       2210.
.0133       2410.       .0156       3800.       .0178       4640.
.02         3780.       .0222       2550.       .0244       1600.
.0267       1210.       .0289       1590.       .0311       1710.
.0333       1250.       .0356        978.       .0378        923.
.04          766.       .0422        539.       .0444        406.
.0467        461.       .0489        594.       .0511        508.
.0533        385.       .0556        377.       .0578        337.
.06          298.       .0622        250.       .0644        188.
.0667        195.       .0689        195.       .0711        195.
.0733        195.       .0756        172.       .0778        156.
.08          141.       .0822        133.       .0844        101.
.0867       59.8        .0889       62.3        .0911       73.2
.0933       69.6        .0956       57.4        .0978       48.8
.1          55.1
   12    5.          10.0        10.0        22.2      1.128     1
   16   10.
  800
 9873
 7829
 3649
 4556
 6969
49601
```

```
EXCEEDANCE CURVE VARIATION NO. 5
   15     2     7    46   759
0.          7200.       .0022       5710.       .0044       3760.
.0067       3300.       .0089       3130.       .0111       2650.
.0133       2890.       .0156       4560.       .0178       5570.
.02         4540.       .0222       3060.       .0244       1920.
.0267       1450.       .0289       1910.       .0311       2050.
.0333       1500.       .0356       1170.       .0378       1110.
.04          919.       .0422        647.       .0444        487.
.0467        553.       .0489        713.       .0511        610.
.0533        462.       .0556        452.       .0578        404.
.06          358.       .0622        300.       .0644        226.
.0667        234.       .0689        234.       .0711        234.
.0733        234.       .0756        206.       .0778        187.
.08          169.       .0822        160.       .0844        121.
.0867       71.8        .0889       74.8        .0911       87.8
.0933       83.5        .0956       68.9        .0978       58.6
.1          66.1
   12    5.          10.0        10.0        22.2        1.128      1
   16   10.
  800
 9873
 7829
 3649
 4556
 6969
49601

EXCEEDANCE CURVE VARIATION NO.6
   15     2     7    46   759
0.          8500.       .0022       6740.       .0044       4440.
.0067       3890.       .0089       3690.       .0111       3130.
.0133       3410.       .0156       5380.       .0178       6570.
.02         5360.       .0222       3610.       .0244       2270.
.0267       1710.       .0289       2250.       .0311       2420.
.0333       1770.       .0356       1380.       .0378       1310.
.04         1080.       .0422        763.       .0444        575.
.0467        653.       .0489        841.       .0511        720.
.0533        545.       .0556        533.       .0578        477.
.06          422.       .0622        354.       .0644        267.
.0667        276.       .0689        276.       .0711        276.
.0733        276.       .0756        243.       .0778        221.
.08          199.       .0822        189.       .0844        143.
.0867       84.7        .0889       88.3        .0911        104.
.0933       98.5        .0956       81.3        .0978       69.1
.1          78.
   12    5.          10.0        10.0        22.2        1.128      1
   16   10.
  800
 9873
 7829
 3649
 4556
 6969
```

```
COUPLING PEAKS AND VALLEYS NO. 1
   15      2      7      6 4598
0.          2093.       .035       2093.       .0351      262.
.1          262.        .1001      0.          .1228      0.
   12    5.          10.0        10.0        22.2        1.128     1
   16   10.
 1234
 5876
 5934
 1747
 6985
 5445
 7656
 9874

COUPLING PEAKS AND VALLEYS NO. 2
   15      2      7      6 6585
0.          226.        .0192      226.        .0193      56.5
.08         56.5        .0801      0.          .0979      0.
   15    1.          10.0        10.0        6.5         1.6       0
   13   10.
 3258
  475
 5811
 1357
 9753
 2244
 8357

COUPLING PEAKS AND VALLEYS NO. 3
   15      2      7      4  759
0.          902.5       .1         902.5       .1001      0.
.1407       0.
   12    5.          10.0        10.0        22.2        1.128     1
   16   10.
 3649
 4556
 6823
 1593
 9873

COUPLING PEAKS AND VALLEYS NO. 4
   15      2      7      4  123
0.          97.25       .08        97.25       .0801      0.
.1002       0.
   15    1.          10.0        10.0        6.5         1.6       0
   13   10.
 5803
 4444
  759
 5858
 6556

COUPLING PEAKS AND VALLEYS NO. 5
   15      0      7      6 9873
0.          0.          .0125      0.          .0126      18418.
.0174       18418.      .0175      0.          .1136      0.
   12    5.          10.0        10.0        22.2        1.128     1
   16   10.
 7829
 3649
 4587
 4854
  800

COUPLING PEAKS AND VALLEY NO. 6
   15      0      7      6 8745
0.          0.          .01        0.          .0101      1588.
.0149       1588.       .015       0.          .0836      0.
   15    1.          10.0        10.0        6.5         1.6       0
   13   10.
 8520
 6574
 4696
 2000
  169
```

APPENDIX D

LIST OF COMPUTER PROGRAM SYMBOLS AND DEFINITIONS

A(K)	Coefficient defined by Equations (3) and (4); also, as output by HARM subroutine the coefficient is a value of the Gaussian time history
A1	First peak or valley in Gaussian time history
A2	Time of first peak or valley in Gaussian time history
ADZ	Value of the increment used in output of simulated real time peak and valley exceedance tables
ANDZ	Number of increments used in output of simulated real time peak and valley exceedance tables
B	Random phase angle $0 \leq B \leq 2\pi$
C1,C2,C3	Coefficients in the equation $x = C1 + C2\ t + C3\ t^2$, used to search for a peak or valley value
DNZ	Upper value of a range used in output of peak and valley exceedance tables
DNZ1	Lower value of a range used in output of peak and valley exceedance tables
DW	Frequency interval of the power spectral density analysis
DZ	Value of the increment to be used in output of peak and valley exceedance tables
FMØN	Fourth moment of the power spectral density graph about the PSD axis
FO	Theoretical number of mean level crossings per unit time
FP	Theoretical number of peaks per unit time
I1	Subscript of the range of a peak being tabulated in the exceedance tables
I2	Subscript of the range of a valley being tabulated in the exceedance tables
IA1	Number of points in the Gaussian time history, N, plus 1
IFERR	HARM subroutine error indicator
IFIN	An identifier indicating whether the A(K) matrix is Gaussian, unfiltered simulated real, or filtered simulated real
IFSET	HARM subroutine control, IFSET = 1 sets up sine and inverse tables and calculates Fourier transform
IN	Identifies computer unit used for input

APPENDIX D

LIST OF COMPUTER PROGRAM SYMBOLS AND DEFINITIONS

A(K)	Coefficient defined by Equations (3) and (4); also, as output by HARM subroutine the coefficient is a value of the Gaussian time history
A1	First peak or valley in Gaussian time history
A2	Time of first peak or valley in Gaussian time history
ADZ	Value of the increment used in output of simulated real time peak and valley exceedance tables
ANDZ	Number of increments used in output of simulated real time peak and valley exceedance tables
B	Random phase angle $0 \leq B \leq 2\pi$
C1,C2,C3	Coefficients in the equation $x = C1 + C2\ t + C3\ t^2$, used to search for a peak or valley value
DNZ	Upper value of a range used in output of peak and valley exceedance tables
DNZ1	Lower value of a range used in output of peak and valley exceedance tables
DW	Frequency interval of the power spectral density analysis
DZ	Value of the increment to be used in output of peak and valley exceedance tables
FMØN	Fourth moment of the power spectral density graph about the PSD axis
FO	Theoretical number of mean level crossings per unit time
FP	Theoretical number of peaks per unit time
I1	Subscript of the range of a peak being tabulated in the exceedance tables
I2	Subscript of the range of a valley being tabulated in the exceedance tables
IA1	Number of points in the Gaussian time history, N, plus 1
IFERR	HARM subroutine error indicator
IFIN	An identifier indicating whether the A(K) matrix is Gaussian, unfiltered simulated real, or filtered simulated real
IFSET	HARM subroutine control, IFSET = 1 sets up sine and inverse tables and calculates Fourier transform
IN	Identifies computer unit used for input

INC	Indicator used to control adjustment of simulated real time history
IØ	Identifies computer unit used for output
IX	Random number $0 \geq IX \geq 1048576$
IZ	Subscript of the range of a peak or valley being tabulated in the occurrence tables
K	Subscript of the A(K) terms, see A(K)
KKK	The number of Gaussian, or unfiltered simulated real peaks and valleys, times 2
KP	The subscript of the current peak being evaluated in the FILTER subroutine
KV	The subscript of the current valley being evaluated in the FILTER subroutine
K1	An integer used to control the computation of the A(K) terms in MAIN; also, the quantity $\sqrt{1-R1^2}$ in EXCED subroutine
K2	The quantity K1/R in EXCED subroutine
M	Three term array input to HARM subroutine; M(1)=M1, M(2)=M(3)=0
M1	$N = 2^{M1}$, See N
MEAN	Mean value used in mapping Gaussian to simulated real time history
N	Number of points to be computed in the random time history
N1	In formulating the A(K) terms, the number of times the PSD is assumed constant within each frequency range, DW
N2	The quantity 2 x N
NDZ	Number of increments to be used in output of Gaussian peak and valley
NDZ1	The integer NDZ+1
NIX	Quotient of division performed in random number generation
NMAX	The integer N - 1
NM1	The integer 2N - 1
NP	The subscript of the next peak being evaluated in the FILTER subroutine
NOPTS	The number of points in the linear interpolation table used in subroutine TLU
NPKR	Total number of peaks and valleys times 2
NPEAKS	Number of peaks or valleys within a range in the occurrence and exceedance tables

NR	Factor by which the PSD frequency axis is extended to increase the sensitivity of the output
NSL	Indicator describing whether a time history data point is a peak, neither a peak or valley, or a valley
NSPD	Number of input data points on the PSD vs frequency graph
NX	Number of divisions of the PSD graph used in analysis
PL	Theoretical exceedance value
PMAX,PMIN	In order for a peak and valley to be counted and included in the output list, the maximum rise or fall must exceed the input value of PMAX, and the minimum rise or fall must exceed the input value of PMIN
PR	Current value of filter criterion, PMAX or PMIN in subroutine FILTER
P1	Probability of not exceeding X1, normal probability distribution
P2	Probability of not exceeding X2, normal probability distribution
PSD	Value of power spectral density
R	Transformation exponent used in mapping Gaussian to simulated real time history
R1	Rate of FO to FP
S	Value of PSD
S2	Product $\sqrt{2\Delta\omega}\ \sqrt{S_K}$, see Equations (3) and (4)
SL1	Difference in value of two consecutive Gaussian time history points, i, i + 1
SL2	Difference in value of next two consecutive, i + 1, i + 2, see SL1
SMØN	Second moment of the power spectral density graph about the PSD axis
TIME	Total time represented by Gaussian time history
VAR	Area of the power spectral density graph
W	Frequency for an input value of power spectra density
WI	Frequency for a value of power spectral density
X	Independent variable in a two-dimensional table
XN	Normalized lower value of a range used in output of peak and valley exceedance tables
XM	Time of a Gaussian peak or valley

X1	The quantity XN/K1
X2	The quantity XN/K2
XVAL	Independent variable to be used in interpolation in a two-dimensional table
Y	Dependent variable in a two-dimensional table
YM	Value of a Gaussian peak or valley
YVAL	Dependent variable determined by interpolation of a two dimensional table

☆ U. S. GOVERNMENT PRINTING OFFICE: 1977 — 757-001/505