

AD A102750

LEVEL ~~II~~

15

ASD-TR-80-5037

DEVELOPMENT OF AN AIRCRAFT MANEUVER  
LOAD SPECTRUM BASED ON VGH DATA

JOHN W. LINCOLN  
STRUCTURES DIVISION  
DIRECTORATE OF FLIGHT SYSTEMS ENGINEERING

STRICTLY  
CONFIDENTIAL  
AUG 12 1981  
C

DTIC FILE COPY

JULY 1980

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

DEPUTY FOR ENGINEERING  
AERONAUTICAL SYSTEMS DIVISION  
AIR FORCE SYSTEMS COMMAND  
WRIGHT-PATTERSON AIR FORCE BASE, OH

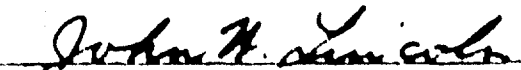
81 8 12 033

NOTICE

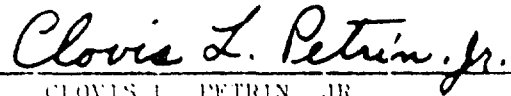
When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the government may have 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 report has been reviewed by the Information Office (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

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

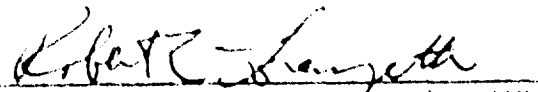


JOHN W. LINCOLN  
AEROSPACE ENGINEER  
STRUCTURES DIVISION  
DIRECTORATE OF FLIGHT SYSTEMS ENGINEERING



CLOVIS L. PETRIN, JR.  
CHIEF, STRUCTURES DIVISION  
DIRECTORATE OF FLIGHT SYSTEMS ENGINEERING

FOR THE COMMANDER



ROBERT C. LOREN, BTTI, LT COL, USAF  
ACTING DIRECTOR  
FLIGHT SYSTEMS ENGINEERING

"If your address has changed, if you wish to be removed from our mailing list, or if the addressee is no longer employed by your organization please notify ASD ENES, AF-PAFB, ON 45433 to help us maintain a current mailing list".

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

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

| REPORT DOCUMENTATION PAGE   |  | READ INSTRUCTIONS<br>BEFORE COMPLETING FORM |
|---|--|---|
| 1. REPORT NUMBER<br>ASD-TR-80-5037  | 2. GOVT ACCESSION NO.<br>AD-A102750                            | 3. RECIPIENT'S CATALOG NUMBER               |
| 4. TITLE (and Subtitle)<br>Development of an Aircraft Maneuver Load<br>Spectrum Based on VGH Data,  | 5. TYPE OF REPORT & PERIOD COVERED<br>Final Report.            |   |
|   | 6. PERFORMING ORG. REPORT NUMBER                               |   |
| 7. AUTHOR(s)<br>John W. Lincoln   | 8. CONTRACT OR GRANT NUMBER(s)                                 |   |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS<br>Aeronautical Systems Division (ASD/ENFS)<br>Wright-Patterson AFB OH 45433  | 10. PROGRAM ELEMENT, PROJECT, TASK<br>AREA & WORK UNIT NUMBERS |   |
| 11. CONTROLLING OFFICE NAME AND ADDRESS<br>Aeronautical Systems Division (ASD/ENFS)<br>Wright-Patterson AFB OH 45433  | 12. REPORT DATE<br>July 1980                                   |   |
|   | 13. NUMBER OF PAGES<br>82                                      |   |
| 14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)   | 15. SECURITY CLASS. (of this report)<br>Unclassified           |   |
|   | 15a. DECLASSIFICATION/DOWNGRADING<br>SCHEDULE                  |   |
| 16. DISTRIBUTION STATEMENT (of this Report)<br>Approval 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)<br>Velocity                      Probability<br>Load factor                    Stress exceedance<br>Altitude                        Test spectrum<br>Histogram   |  |   |
| 20. ABSTRACT (Continue on reverse side if necessary and identify by block number)<br>This report describes a procedure whereby a full scale aircraft maneuver load fatigue spectrum can be developed from recorded VGH data. It is assumed in this development that the internal loads (stresses) at the appropriate control points are available for combinations of velocity, load factor, altitudes and weight so that an interpolation on these points will provide the desired accuracy. The procedure will generate (for a control point) the cumulative probability of exceeding a given stress, exceedances per hour of a given |  |   |

DTIC  
EXTRACTED  
AUG 12 1981

DD FORM 1473

1 JAN 73

EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

stress level, the probability density function for stress and the stress spectrum. The aircraft spectrum is derived from the assumption that the aircraft test loads derived from a linear combination of balanced loading conditions will provide a good simulation of the stress history at and "between" the control points. The application of the program to new designs (mission analysis) and to tracking can be made without modification. The computer program for this calculation is included along with a sample problem. As an example of an application of this program, the stress exceedance functions for a control point on the wing of the F-4 are shown that were computed from the VGH data accumulated over a period of one year.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

## FOREWARD

This report was prepared by John W. Lincoln, Structures Division of the Directorate of Flight Systems Engineering. The work was done as a research and development task to assist in the spectrum development work for the F-4 durability and damage tolerance assessment.

TABLE OF CONTENTS

| SECTION   | PAGE |
|---|------|
| I INTRODUCTION  | 1    |
| II ANALYTICAL DERIVATION OF THE SPECTRUM                              | 4    |
| III DESCRIPTION OF THE COMPUTER PROGRAM                               | 12   |
| 1. NOTATION   | 12   |
| 2. INTERPOLATION PROCEDURE  | 13   |
| 3. COMPUTER FLOW DIAGRAM AND PROGRAM                                  | 17   |
| 4. EQUIVALENCE TABLES   | 19   |
| 5. INPUT DATA   | 21   |
| 6. SAMPLE PROBLEM   | 30   |
| IV EXAMPLE PROBLEM - F-4 STRESS SPECTRUM FOR<br>POSITIVE LOAD FACTORS | 49   |
| V CONCLUSIONS   | 51   |
| APPENDIX - SPECA PROGRAM LISTING                                      | 60   |

|                    |                                     |
|--------------------|-------------------------------------|
| Accession For      |                                     |
| NTIS GRA&I         | <input checked="" type="checkbox"/> |
| DTIC TAB           | <input type="checkbox"/>            |
| Unannounced        | <input type="checkbox"/>            |
| Justification      |                                     |
| By _____           |                                     |
| Distribution/      |                                     |
| Availability Codes |                                     |
| Avail and/or       |                                     |
| Dist               | Special                             |
| A                  |                                     |

## LIST OF SYMBOLS

|             |   |
|-------------|---|
| $N_{v_i}$   | The number of indicated airspeed intervals in the VGH histogram   |
| $N_{n_z}$   | The number of normal load factor intervals in the VGH histogram   |
| $N_h$       | The number of altitude intervals in the VGH histogram   |
| $N_w$       | The number of weight intervals in the VGH histogram   |
| $v_{ij}$    | Indicated airspeed for the VGH histogram intervals  |
| $n_{zj}$    | Normal load factor for the VGH histogram intervals  |
| $h_j$       | Altitude for the VGH histogram intervals  |
| $w_i$       | Aircraft weight for the VGH histogram intervals   |
| $H_j$       | The VGH histogram   |
| $N_t$       | The total number of load occurrences in the VGH histogram   |
| $P_j$       | The joint probability density function derived from the VGH histogram                                   |
| $N_{v_i}^R$ | The number of intervals in a refinement of an indicated airspeed interval in the VGH histogram          |
| $N_{n_z}^R$ | The number of intervals in a refinement of a normal load factor interval in the VGH histogram           |
| $N_h^R$     | The number of intervals in a refinement of an altitude interval in the VGH histogram                    |
| $N_w^R$     | The number of intervals in a refinement of a weight interval in the VGH histogram                       |
| $V_i$       | A surface, the ordinates of which are indicated airspeeds for determining the stress at a control point |
| $N_z$       | A surface, the ordinates of which are normal load factors for determining the stress at a control point |

|                  |   |
|------------------|---|
| $H$              | A surface, the ordinates of which are altitudes for determining the stress at a control point                 |
| $W$              | A surface, the ordinates of which are weights for determining the stress at a control point                   |
| $\hat{P}_J$      | The joint probability density function for the refined VGH histogram  |
| $N_p$            | The number of control points on the aircraft structure used in the derivation of the fatigue spectrum         |
| $P_{\psi^a}$     | The cumulative probability for the stress at the ath control point  |
| $P_{D_{\psi^a}}$ | The probability density function for the stress at the ath control point                                      |
| $A_{cb}^a$       | The stress for the ath load level at the bth point in the sky and the cth control point                       |
| $\Gamma_c^a$     | The fatigue test stress for the ath load level and the cth control point                                      |
| $\alpha^{ab}$    | Scaling coefficients for the ath load level and the bth point in the sky                                      |
| $\phi^a$         | A surface (generated from the surface $P_J$ ) from which $P_{\psi^a}$ can be determined for ath control point |
| $\psi^a$         | The stress surface for the ath control point  |
| $S^a$            | A set of ordinates of the graph 1 - $P_{\psi^a}$  |
| $S^a(i)$         | The ith member of $S^a$   |

## SECTION I

### INTRODUCTION

In the application of the mission analysis required by MIL-A-008866A (USAF) to fighter and attack aircraft a problem arises in the selection of the point in the sky (velocity, altitude, and weight) for the load factor spectrum for the combat segment of the mission. It can be shown that in many cases important differences in the spectrum can be obtained from two "reasonable" point selections.

The problem has been particularly severe on some existing aircraft in that a ten percent shift in the stress spectrum can produce a factor of two change in life. Therefore, when it is considered that essentially all of the fatigue damage for fighter and attack aircraft is done in the combat segment, this part of the mission deserves special attention.

From an examination of available VGH data, it is evident that in both the air-to-air and air-to-ground operations a fairly wide variation in velocity, altitude, and weight is observed. Therefore, it would be surprising if a single point in the sky would provide an accurate prediction of the stress spectrum for a control point. This is even more evident for those aircraft which experience non-linearities in the aerodynamic data (i.e., tip stall).

One possible solution is to use multiple points in the sky for this calculation. This can be effectively accomplished by taking the points in the sky and their relative frequency of occurrence that are obtained from that portion of the fleet that is equipped with multichannel recorders (twenty percent of the fleet, which is consistent with current policy, is believed to be an adequate sample). This can be done by taking the VGH histogram (the relative frequency of airspeed, normal load factor, altitude, and weight) and dividing by the total number of load occurrences to obtain the probability that a load will occur in a given interval of airspeed, normal load factor, altitude, and weight. A stress level is selected and a summation is made for each such probability where the corresponding stress at the midpoint of the interval of airspeed, etc, is greater than the selected stress level. This computation produces the cumulative probability of exceeding a stress level. Since the intervals used for the data collection were not designed for this calculation, a provision is made to subdivide the intervals to improve the accuracy of the calculation. This technique is explained in Section III. From the cumulative

probability, the number of stress exceedances per hour, the probability density function, and the stress spectrum can be obtained.

Having the functions referred to above for a number of control points that is adequate to cover the aircraft structure (this number may have to be obtained by trial and error), one may generate the full scale aircraft spectrum by assuming that an arbitrary loading at the control points of the structure can be derived from a linear combination of the loading imposed by balanced load conditions. If  $N_p$  control points are used, then  $N_p$  balanced load conditions are used to represent the control point load. The use of "representative" balanced load conditions should provide a satisfactory interpolation between control points. These intermediate points should be spot checked against the true spectrum to see if the control point coverage is adequate.

Of course, for a new design, the VGH data does not exist and consequently direct application of this method is impossible. In some cases it will be possible to overcome this difficulty by taking existing VGH data from older aircraft and by use of judgement adapt it to this procedure. In any event, the method should be applied when the proper data becomes available so that by suitable tests and analysis the appropriate changes may be made in the aircraft life predictions.

One important application of this procedure is fighter/attack tracking. The unusual technique is to use the fleet counting accelerometer data and compute the stress for a single point in the sky that is believed to be representative of the particular mission flown (i.e., air-to-air or air-to-ground). In lieu of this approach, one could compute from the VGH data the conditional probability of exceeding a stress given the normal load factor. If this function were available, it would be possible to track to any desired probability on even multiple probability levels depending on what results are desired. This function can be generated from this program by setting all occurrences equal to zero except those that fall in the desired load factor interval. The high positive and low negative load factors may require an extrapolation from neighboring load factors because there may be too few data points to adequately describe these functions.

The program that is discussed in this report is based on the load occurrences in the VGH histogram being dependent on indicated airspeed, normal load factor, altitude, and weight. The stress function is based on the same quantities. An immediate alternate that is

included is to use equivalent load factor instead of load factor. This removes the weight dependency and considerably reduces the magnitude of the input. This option is included in the computer program described in the text. Other alternates that could be obtained by a simple modification of the program are listed as follows:

| VGH data<br>based on   | Stress function<br>based on                               |
|--|---|
| 1. Indicated airspeed,<br>normal load factor,<br>altitude, and weight. | Mach no., normal load<br>factor, altitude, and<br>weight. |
| 2. Mach no., normal<br>load factor,<br>altitude, and weight.           | Mach no., normal load<br>factor, altitude, and<br>weight. |
| 3. Equivalent airspeed,<br>normal load factor,<br>and weight           | Equivalent airspeed, normal<br>load factor, and weight.   |

The extension of this program to include other degrees of freedom for the aircraft is immediately evident. The major difficulty is the management of the input data required for the load occurrences and the stress function.

## SECTION II

### ANALYTICAL DERIVATION OF THE SPECTRUM

The first step in the derivation of the fatigue spectrum is to solve for the stress probability distribution function. This requires that the histogram of occurrences in intervals of indicated airspeed, load factor, altitude, and weight be defined. To do this suppose that each of  $N_{v_i}$ ,  $N_{n_z}$ ,  $N_h$ , and  $N_w$  is a positive integer and

- (1)  $v_{ij}$  is a simple graph such that the x-projection of  $v_{ij}$  is the set of integers in  $[1, N_{v_i} + 1]$  and if  $i$  is an integer in  $[1, N_{v_i} + 1]$  and  $i + 1$  is in  $[1, N_{v_i} + 1]$  then the indicated airspeed  $v_{ij}(i)$  is less than the indicated airspeed  $v_{ij}(i + 1)$
- (2)  $n_{z_i}$  is a simple graph such that the x-projection of  $n_{z_i}$  is the set of integers in  $[1, N_{n_z} + 1]$  and if  $j$  is an integer in  $[1, N_{n_z} + 1]$  and  $j + 1$  is in  $[1, N_{n_z} + 1]$  then the normal load factor  $n_{z_i}(j)$ , is less than the normal load factor  $n_{z_i}(j + 1)$
- (3)  $h_i$  is a simple graph such that the x-projection of  $h_i$  is the set of integers in  $[1, N_h + 1]$  and if  $k$  is an integer in  $[1, N_h + 1]$  and  $k + 1$  is in  $[1, N_h + 1]$  then the altitude  $h_i(k)$ , is less than the altitude  $h_i(k + 1)$
- (4)  $w_i$  is a simple graph such that the x-projection of  $w_i$  is the set of integers in  $[1, N_w + 1]$  and if  $m$  is an integer in  $[1, N_w + 1]$  and  $m + 1$  is in  $[1, N_w + 1]$  the weight  $w_i(m)$ , is less than the weight  $w_i(m + 1)$

Further, suppose  $H_j$  is a simple surface such that

$[v_{ij}(i), n_{z_i}(j), h_i(k), w_i(m), H_j(v_{ij}(i), n_{z_i}(j), h_i(k), w_i(m)))]$  is a point of  $H_j$  only if

(1)  $i$  is in  $[1, N_{v_i}]$ ,  $j$  is in  $[1, N_{n_z}]$ ,  $k$  is in  $[1, N_h]$ ,  
 $m$  is in  $[1, N_w]$  and

(2)  $H_j(v_{ij}(i), n_{z_i}(j), h_i(k), w_i(m))$  is the number of "load occurrences" in the rectangular interval  $[v_{ij}(i), v_{ij}(i+1); n_{z_i}(j), n_{z_i}(j+1); h_i(k), h_i(k+1); w_i(m), w_i(m+1)]$  and these load occurrences are assumed to be uniformly distributed within the rectangular interval.

The surface  $H_j$  is called the VGH histogram for  $v_{ij}$ ,  $n_{z_i}$ ,  $h_i$ , and  $w_i$ .

The total number of load occurrences included in the VGH histogram  $H_j$  is

$$N_t = \sum_{i=1}^{N_{v_i}} \sum_{j=1}^{N_{n_z}} \sum_{k=1}^{N_h} \sum_{m=1}^{N_w} H_j(v_{ij}(i), n_{z_i}(j), h_i(k), w_i(m))$$

Therefore, by definition, the probability that the indicated airspeed, normal load factor, altitude, and weight is in the rectangular interval  $[v_{ij}(i), v_{ij}(i+1); n_{z_i}(j), n_{z_i}(j+1); h_i(k), h_i(k+1); w_i(m), w_i(m+1)]$  is

$$P_j(i,j,k,m) = \frac{H_j(v_{ij}(i), n_{z_i}(j), h_i(k), w_i(m))}{N_t}$$

Now suppose that if  $i$  is in  $[1, N_{V_i} - 1]$  then the interval  $[v_{ii}(i), v_{ii}(i + 1)]$  is covered by  $N_{V_i}^R$  equal intervals, if  $j$  is in  $[1, N_{n_z} - 1]$  then  $[n_{z_i}(j), n_{z_i}(j + 1)]$  is covered by  $N_{n_z}^R$  equal intervals, if  $k$  is in  $[1, N_h - 1]$  then  $[h_i(k), h_i(k + 1)]$  is covered by  $N_h^R$  equal intervals, and if  $m$  is in  $[1, N_w - 1]$  then  $[w_i(m), w_i(m + 1)]$  is covered by  $N_w^R$  equal intervals.

Since it was supposed that the load occurrences are within the rectangular interval  $[v_{ii}(i), v_{ii}(i + 1); n_{z_i}(j), n_{z_i}(j + 1); h_i(k), h_i(k + 1); w_i(m), w_i(m + 1)]$  then the probability that the indicated airspeed, normal load factor, altitude, and weight is in the rectangular interval

$$\left[ v_{ii}(i), v_{ii}(i) + \frac{v_{ii}(i + 1) - v_{ii}(i)}{N_{V_i}^R}; \right.$$

$$n_{z_i}(j), n_{z_i}(j) + \frac{n_{z_i}(j + 1) - n_{z_i}(j)}{N_{n_z}^R};$$

$$h_i(k), h_i(k) + \frac{h_i(k + 1) - h_i(k)}{N_h^R};$$

$$\left. w_i(m), w_i(m) + \frac{w_i(m + 1) - w_i(m)}{N_w^R} \right]$$

is

$$\hat{P}_J(i, j, k, m) = \frac{H_J(v_i(i), n_z(j), h(k), w(m))}{N_t N_{V_i}^R N_{n_z}^R N_h^R N_w^R}$$

(1) Now suppose that  $V_i$  is a simple surface such that the x-y projection of  $V_i$  is the set of integers in the rectangular

interval  $[1, N_{v_i} + 1; 1, N_{v_i}^R]$  and if  $i$  and  $i + 1$  are integers

in  $[1, N_{v_i} + 1]$  and  $i_R$  is an integer in  $[1, N_{v_i}^R]$  then

$$v_i(i, i_R) = v_{ii}(i) + \left(\frac{i_R - 0.5}{N_{v_i}^R}\right) (v_{ii}(i + 1) - v_{ii}(i))$$

- (2)  $N_z$  is a simple surface such that the x-y projection of  $N_z$  is the set of integers in the rectangular interval  $[1, N_{n_z} + 1; 1, N_{n_z}^R]$  and if  $j$ , and  $j + 1$  are integers in

$[1, N_{n_z} + 1]$  and  $j_R$  is an integer in  $[1, N_{n_z}^R]$  then

$$N_z(j, j_R) = n_{z_i}(j) + \left(\frac{j_R - 0.5}{N_{n_z}^R}\right) (n_{z_i}(j + 1) - n_{z_i}(j))$$

- (3)  $H$  is a simple surface such that the x, y projection of  $H$  is the set of integers in the rectangular interval  $[1, N_h + 1; 1, N_h^R]$  and if  $k$  and  $k + 1$  are integers in  $[1, N_h + 1]$  and

$k_R$  is an integer in  $[1, N_h^R]$  then

$$H(k, k_R) = h_i(k) + \left(\frac{k_R - 0.5}{N_h^R}\right) (h_i(k + 1) - h_i(k))$$

- (4)  $W$  is a simple surface such that the x, y projection of  $W$  is the set of integers in the rectangular interval  $[1, N_w + 1; 1, N_w^R]$  and if  $m$  and  $m + 1$  are integers in  $[1, N_w + 1]$

and  $m_R$  is an integer in  $[1, N_w^R]$  then

$$W(m, m_R) = w_i(m) + \left(\frac{m_R - 0.5}{N_w^R}\right) (w_i(m + 1) - w_i(m))$$

The assumption is made that the stress at a point in the structure depends only on the indicated airspeed, normal load factor, altitude and weight. Therefore, if it is supposed that each of  $a$  and  $N_p$  is a positive integer such that  $a$  is in  $[1, N_p]$

and  $\psi^a$  is a simple surface such that  $(V_i(i, i_R), N_z(j, j_R), H(k, k_R), W(m, m_R), \psi^a(V_i(i, i_R), N_z(j, j_R), H(k, k_R), W(m, m_R)))$  is a point of  $\psi^a$  only if  $i$  is in  $[1, N_{V_i} + 1]$ ,  $i_R$  is in  $[1, N_{V_i}^R]$ , ...,  $m$  is in  $[1, N_w + 1]$ ,  $m_R$  is in  $[1, N_w^R]$  and  $\psi^a(V_i(i, i_R), N_z(j, j_R), H(k, k_R), W(m, m_R))$  is the stress for the ath control point corresponding to the indicated airspeed  $V_i(i, i_R)$ , the normal load factor  $N_z(j, j_R)$ , the altitude  $H(k, k_R)$ , and the weight  $W(m, m_R)$ .

The surfaces  $\psi^a$  and  $\hat{P}_j$  are used in the calculation of the cumulative probability of exceeding a given stress as follows: Suppose that  $N_{\Gamma_L}$  is a positive integer and  $\Gamma_L$  is a uniformly increasing sequence with x-projection  $[1, N_{\Gamma_L}]$  and  $\phi^a$  is a simple surface such that

- (1)  $\phi^a(i, j, k, m, i_R, j_R, k_R, m_R) = \hat{P}_j(i, j, k, m)$   
if  $\psi^a(V_i(i, i_R), N_z(j, j_R), H(k, k_R), W(m, m_R)) > \Gamma_L(b)$
- (2)  $\phi^a(i, j, k, m, i_R, j_R, k_R, m_R) = 0$   
if  $\psi^a(V_i(i, i_R), N_z(j, j_R), H(k, k_R), W(m, m_R)) \leq \Gamma_L(b)$

Therefore, the probability that the stress is greater than  $\Gamma_L(b)$  is

$$P_{\psi^a}(\Gamma_L(b)) = \sum_{i=1}^{N_{V_i}} \sum_{j=1}^{N_{n_z}} \sum_{k=1}^{N_h} \sum_{m=1}^{N_w} \sum_{i_R=1}^{N_{V_i}^R} \sum_{j_R=1}^{N_{n_z}^R} \sum_{k_R=1}^{N_h^R} \sum_{m_R=1}^{N_w^R} \phi^a(i, j, k, m, i_R, j_R, k_R, m_R)$$

The probability density function  $P_{D_{\psi^a}}$  is the derivative of the cumulative probability function  $P_{\psi^a}$ . This derivative is computed as follows: Suppose  $a$  is an integer in  $[1, N_p]$  and that  $\zeta^a$  is a simple graph with x-projection the interval  $[1, N_{\Gamma_L}]$  such that

- (1) if  $b$  is an integer in  $[1, N_{\Gamma_L}]$  then  $\zeta^a(b) = P_{\psi^a}(b)$  and
- (2) if  $c$  is a number in  $[b, b + 2]$  there exists a  $u_1, u_2,$   
and  $u_3$  such that  $\zeta^a(c) = u_1 c^2 + u_2 c + u_3$  where  $u_1, u_2,$   
 $u_3$  are determined from the equations

$$\begin{array}{rcl} \zeta^a(b) & = & b^2 \quad b \quad 1 \quad u_1 \\ \zeta^a(b+1) & & (b+1)^2 \quad (b+1) \quad 1 \quad u_2 \\ \zeta^a(b+2) & & (b+2)^2 \quad (b+2) \quad 1 \quad u_3 \end{array}$$

Therefore

- (1) if  $b = 1$

$$P_{D_{\psi^a}}(1) = 2u_1 \Gamma_L(1) + u_2$$

$$P_{D_{\psi^a}}(2) = 2u_1 \Gamma_L(1) + u_2$$

- (2) if  $b$  is in  $[2, N_{\Gamma_L} - 3]$

$$P_{D_{\psi^a}}(b+1) = 2u_1 \Gamma_L(b+1) + u_2$$

- (3) if  $b = N_{\Gamma_L} - 2$

$$P_{D_{\psi^a}}(N_{\Gamma_L} - 1) = 2u_1 \Gamma_L(N_{\Gamma_L} - 1) + u_2$$

$$P_{D_{\psi^a}}(N_{\Gamma_L}) = 2u_1 \Gamma_L(N_{\Gamma_L}) + u_2$$

The next step in the derivation of the fatigue loading spectrum is to determine the stress and the frequency of that stress in the spectrum. This is done by an indirect process as shown below. Suppose that the fatigue test spectrum is to be composed of  $N$  cycles at  $M$  stress levels. Further, suppose that  $a$  is a positive integer in  $[1, N_p]$  and  $S^a$  is a sequence of  $M$  numbers such that  $s^a(i)$  and  $s^a(j)$  are members of  $S^a$  only if  $0 < s^a(i) < s^a(j) < 1$  and  $i < j$ .

Therefore, each member of  $S^a$  corresponds to an ordinate of the graph  $1-P_{\psi}a$ . The  $M$  abscissas corresponding to these  $M$  ordinates are defined as the  $M$  stress levels of the spectrum for the  $a$ th control point. The graph  $1-P_{\psi}a$  is known at  $N_{\Gamma_L}$  points. Consequently, an approximation to  $1-P_{\psi}a$  must be found in order to compute the spectrum stress levels. Suppose  $\beta$  is a simple graph with  $x$ -projection the interval  $[\Gamma_L(1), \Gamma_L(N_{\Gamma_L})]$  and if  $k$  is in  $[1, N_{\Gamma_L}]$  then  $\beta(\Gamma_L(k)) = 1-P_{\psi}a(\Gamma_L(k))$ . Further, suppose that if  $i-1$ ,  $i$ , and  $i+1$  are in  $[1, N_{\Gamma_L}]$ ,  $\delta_L$  is  $\Gamma_L(k+1) - \Gamma_L(k)$ , and  $x$  is in  $[-\delta_L, \delta_L]$  then

$$\beta(x + \Gamma_L(k)) = \begin{bmatrix} 1 & \frac{x}{\delta_L} & (\frac{x}{\delta_L})^2 \end{bmatrix} \begin{bmatrix} 0 & 1 & 0 \\ -\frac{1}{2} & 0 & \frac{1}{2} \\ \frac{1}{2} & -1 & \frac{1}{2} \end{bmatrix} \begin{bmatrix} \beta(\Gamma_L(k-1)) \\ \beta(\Gamma_L(k)) \\ \beta(\Gamma_L(k+1)) \end{bmatrix}$$

It follows then that if  $i$  is in  $[1, M)$  there exists an integer  $k$  such that  $P_{\psi}a(\Gamma_L(k-1)) \leq s^a(i) \leq P_{\psi}a(\Gamma_L(k))$  and a number  $x$  such that  $\beta(x + \Gamma_L(k)) = s^a(i)$ . The number  $x$  is obtained from a solution of a quadratic equation and  $x + \Gamma_L(k)$  is the stress corresponding to  $s^a(i)$ .

The fraction of the  $N$  cycles,  $n_i$ , that are associated with the  $i$ th stress level is defined as follows:

$$n_1 = \frac{s(1) + s(2)}{2}$$

$$n_i = \frac{s(i+1) - s(i-1)}{2} \quad 1 < i < M$$

$$n_M = 1 - \frac{(s(M) + s(M-1))}{2}$$

It follows then that if  $i$  is in  $[1, M]$  and if the sequence  $S^a$  is used for each of the control points then there will be an equal number of loading cycles for the  $i$ th load level for each of the control points.

The final step is to determine a set of coefficients which when multiplied by the stresses corresponding to balanced load conditions for the aircraft will produce the desired stress levels at the aircraft control points. Suppose  $a$  is a positive integer in  $[1, M]$ ,  $b$  is a positive integer in  $[1, N_p]$ , and  $c$  is a positive integer in  $[1, N_p]$ . Therefore, if  $A_{cb}^a$  is the stress for the  $a$ th load level at the  $b$ th point in the sky and the  $c$ th control point and  $r_c^a$  is the stress desired in the fatigue test for the  $a$ th load level and the  $c$ th control point then there exists a set of coefficients  $\alpha_{cb}^a$  such that  $r_c^a = A_{cb}^a \alpha_{cb}^a$ .

### SECTION III

#### DESCRIPTION OF THE COMPUTER PROGRAM

##### 1 NOTATION

The right hand side of the following relations are defined in Section II.

$$NT421 = N_{v_i}$$

$$NT422 = N_{n_z}$$

$$NT423 = N_h$$

$$NT424 = N_w$$

$$NT = N_t$$

$$PJT = \hat{P}_J$$

$$NRVI = N_{v_i}^R$$

$$NRNZ = N_{n_z}^R$$

$$NRH = N_h^R$$

$$NRW = N_w^R$$

$$VII = v_{ij}$$

$$NZI = n_{z_i}$$

$$HI = h_i$$

$$WI = w_i$$

$$VI = V_i$$

$$NZ = N_z$$

$$H = H$$

$$W = W$$

$$NPS = N_p$$

$$PPSI = P_{\psi} a \text{ (The } a \text{ is not explicitly identified in the program)}$$

$$PDPSI = P_{D_{\psi}} a \text{ (The } a \text{ is not explicitly identified in the program)}$$

$$PS = A$$

PLD =  $\Gamma$   
 ALPHA =  $\alpha$   
 FVI =  $v_{ii}(N_{v_i} + 1)$   
 FNZ =  $n_{zi}(N_{n_z} + 1)$   
 FH =  $h_i(N_h + 1)$   
 FW =  $w_i(N_w + 1)$   
 FACTØR - Stress scaling factor. FACTØR = 1 unless otherwise specified.  
 HØURS - The number of hours of data in the VGH histogram  
 PSIL =  $\Gamma_L$   
 AREAN =  $s^a$   
 DELTA =  $\delta_L$   
 APDPSI(I) = 1.0 - PPSI(I)  
 PSILL (I) - The stress level that is the abscissa of the point of PPSI whose ordinate is AREAN(I)  
 FRAC(I) - The fraction of the total number of cycles in the spectrum that correspond to PSILL  
 NPSIL =  $N_{\Gamma_L}$   
 NPSILL = M  
 EXCEED(I) - The number of exceedances per hour of the stress PSIL(I)  
 NZERO - Control number to zero the input numbers at the start of a run and then prevent them from being zeroed between cases  
 NPSCT - Control number for counting the number of control points for which a spectrum has been computed in a single run

## 2 INTERPOLATION PROCEDURE

Since the stress is initially calculated for only a finite set of points on the stress surface, an assumption must be made to determine the stress for a given indicated airspeed, normal load factor, altitude, and weight. Specifically, the problem may be expressed as follows: Given that NT421, NT422, NT423, NT424, NRVI, NRNZ, NRH, and NRW is a positive integer and I is in [1,NT421], J is in [1,NT422], K is in [1,NT423], M is in [1,NT424], IR is in [1,NRVI], JR is in [1,NRNZ], KR is in [1,NRH], MR is in [1,NRW] and a is in [1,N<sub>p</sub>] it is required to create an approximation in the form

$$\xi^a(I, J, K, M, IR, JR, KR, MR) =$$

$$\Xi^a(VI(I, IR), NZ(J, JR), H(K, KR), W(M, MR))$$

for the stress as expressed by

$$\psi^a(I, J, K, M, IR, JR, KR, MR) =$$

$$\Psi^a(VI(I, IR), NZ(J, JR), H(K, KR), W(M, MR))$$

where  $\Xi^a$  is a ruled surface based on  $2^4 = 16$  points of  $\psi^a$ . The method of choosing these 16 points and the calculation of the stress approximation is described below.

The first step is to define the function TABLE which contains the projections and ordinates of the  $\Psi^a$  surface.

Suppose each of NTAB1, NTAB2, NTAB3, and NTAB4 is a positive integer and that

$$NN12 = NTAB1 + NTAB2$$

$$NN13 = NN12 + NTAB3$$

$$NN14 = NN13 + NTAB4$$

$$NP = NTAB1 \cdot NTAB2 \cdot NTAB3 \cdot NTAB4$$

$$NF = NN14 + NP$$

Further, suppose that TABLE is a simple graph such that the x-projection of TABLE is the set of integers in the interval [1, NF] and each of I1, I2, I3, and I4 is a positive integer.

Also,

- (1) if I1 and I1 + 1 are in [1, NTAB1] then the indicated airspeed TABLE (I1) is less than the indicated airspeed TABLE (I1 + 1)
- (2) if I2 and I2 + 1 are in [NTAB1 + 1, NN12] then the normal load factor TABLE (I2) is less than the normal load factor TABLE (I2 + 1)
- (3) if I3 and I3 + 1 are in [NN12 + 1, NN13] then the altitude TABLE (I3), is less than the altitude TABLE (I3 + 1)
- (4) if I4 and I4 + 1 are in [NN13 + 1, NN14] then the weight TABLE (I4) is less than the weight TABLE (I4 + 1)
- (5) if I1 is in [1, NTAB1], I2 is in [NTAB1 + 1, NN12], I3 is in [NN12 + 1, NN13], I4 is in [NN13 + 1, NN14]

and  $n$  is in  $[NN14 + 1, NF]$  and is equal to  $NN14 + (I4 - NN13 - 1) \cdot NTAB3 \cdot NTAB2 \cdot NTAB1 + (I3 - NN12 - 1) \cdot NTAB2 \cdot NTAB1 + (I2 - NTAB1 - 1) \cdot NTAB1 + I1$  then the stress TABLE ( $n$ ) is the stress that corresponds to the indicated airspeed TABLE ( $I1$ ), the normal load factor TABLE ( $I2$ ), the altitude TABLE ( $I3$ ) and the weight TABLE ( $I4$ ).

The positive integers  $I1$ ,  $I2$ ,  $I3$ , and  $I4$  are determined as follows: A search is made for the integer  $i$  that will determine the smallest number TABLE ( $i$ ) that equals or exceeds  $VI(I,IR)$ . If  $i = 1$  satisfies this requirement then  $I1$  is set equal to 2. If  $i$  is in  $[2, NTAB1]$  then  $I1$  is set equal to  $i$ . If no  $i$  can be found in  $[2, NTAB1]$  then  $I1$  is set equal to  $NTAB1$ . A search is made for the integer  $j$  that will determine the smallest number TABLE ( $j$ ) that equals or exceeds  $NZ(J,JR)$ . If  $j = NTAB1 + 1$  then  $I2$  is set equal to  $NTAB1 + 2$ . If  $j$  is in  $[NTAB1 + 2, NN12]$  then  $I2$  is set equal to  $j$ . If no  $j$  can be found to satisfy the requirement then  $I2$  is set equal to  $NN12$ . Also, a search is made for the integer  $k$  that will determine the smallest number TABLE ( $k$ ) that equals or exceeds  $H(K,KR)$ . If  $k = NN12 + 1$  then  $I3$  is set equal to  $NN12 + 2$ . If  $k$  is in  $[NN12 + 2, NN13]$  then  $I3$  is set equal to  $k$ . If no  $k$  can be found in  $[NN12 + 2, NN13]$  then  $I3$  is set equal to  $NN13$ . A final search is made for the integer  $m$  that will determine the smallest number TABLE ( $m$ ) that equals or exceeds  $W(M,MR)$ . If  $m = NN13 + 1$  then  $I4$  is set equal to  $NN13 + 2$ . If  $m$  is in  $[NN13 + 2, NN14]$  then  $I4$  is set equal to  $m$ . If no  $m$  can be in  $[NN13 + 2, NN14]$  then  $I4$  is set equal to  $NN14$ .

The next step is to identify the integers required for the final calculations.

With

$$NP12 = NTAB1 \cdot NTAB2$$

$$NP13 = NP12 \cdot NTAB3$$

these are:

$$N2222 = NN14 + (I4 - NN13 - 1) \cdot NP13 + (I3 - NN12 - 1) \cdot NP12 + (I2 - NTAB1 - 1) \cdot NTAB1 + I1$$

$$N1222 = N2222 - 1$$

$$N2122 = N2222 - NTAB1$$

$$N1122 = N2122 - 1$$

$$N2212 = N2222 - NP12$$

N1212 = N2212 - 1  
 N2112 = N2212 - NTAB1  
 N1112 = N2112 - 1  
 N2221 = N222 - NP13  
 N1221 = N2221 - 1  
 N2121 = N2221 - NTAB1  
 N1121 = N2121 - 1  
 N2211 = N2221 - NP12  
 N1211 = N2211 - 1  
 N2111 = N2211 - NTAB1  
 N1111 = N2111 - 1

Therefore, if

$$X1RAT = \frac{VI(I,IR) - TABLE(I1-1)}{TABLE(I1) - TABLE(I1-1)}$$

$$X2RAT = \frac{NZ(J,JR) - TABLE(I2-1)}{TABLE(I2) - TABLE(I2-1)}$$

$$X3RAT = \frac{H(K,KR) - TABLE(I3-1)}{TABLE(I3) - TABLE(I3-1)}$$

$$X4RAT = \frac{W(M,MR) - TABLE(I4-1)}{TABLE(I4) - TABLE(I4-1)}$$

then

AMP111 = TABLE(N1111) + X1RAT(TABLE(N2111) - TABLE(N1111))  
 AMP211 = TABLE(N1211) + X1RAT(TABLE(N2211) - TABLE(N1211))  
 AMP121 = TABLE(N1121) + X1RAT(TABLE(N2121) - TABLE(N1121))  
 AMP221 = TABLE(N1221) + X1RAT(TABLE(N2221) - TABLE(N1221))  
 AMP112 = TABLE(N1112) + X1RAT(TABLE(N2112) - TABLE(N1112))  
 AMP212 = TABLE(N1212) + X1RAT(TABLE(N2212) - TABLE(N1212))  
 AMP122 = TABLE(N1122) + X1RAT(TABLE(N2122) - TABLE(N1122))  
 AMP222 = TABLE(N1222) + X1RAT(TABLE(N2222) - TABLE(N1222)),

AMP11 = AMP111 + X2RAT(AMP211 - AMP111)  
 AMP12 = AMP112 + X2RAT(AMP212 - AMP112)  
 AMP22 = AMP122 + X2RAT(AMP222 - AMP122),

AMP1 = AMP11 + X3RAT(AMP21 - AMP11)  
 AMP2 = AMP12 + X3RAT(AMP22 - AMP12),

$$\xi^a(K,J,K,M,IR,JR,KR,MR) = (AMP1 + X4RAT(AMP2 - AMP1)) \cdot FACTOR$$

It is seen that the sixteen points on the  $\psi^a$  surface are reduced to eight points on the  $\Xi^a$  surface by an interpolation on the indicated airspeed. The eight points are reduced to four points on the  $\Xi^a$  surface by an interpolation on the normal load factor. Next, the

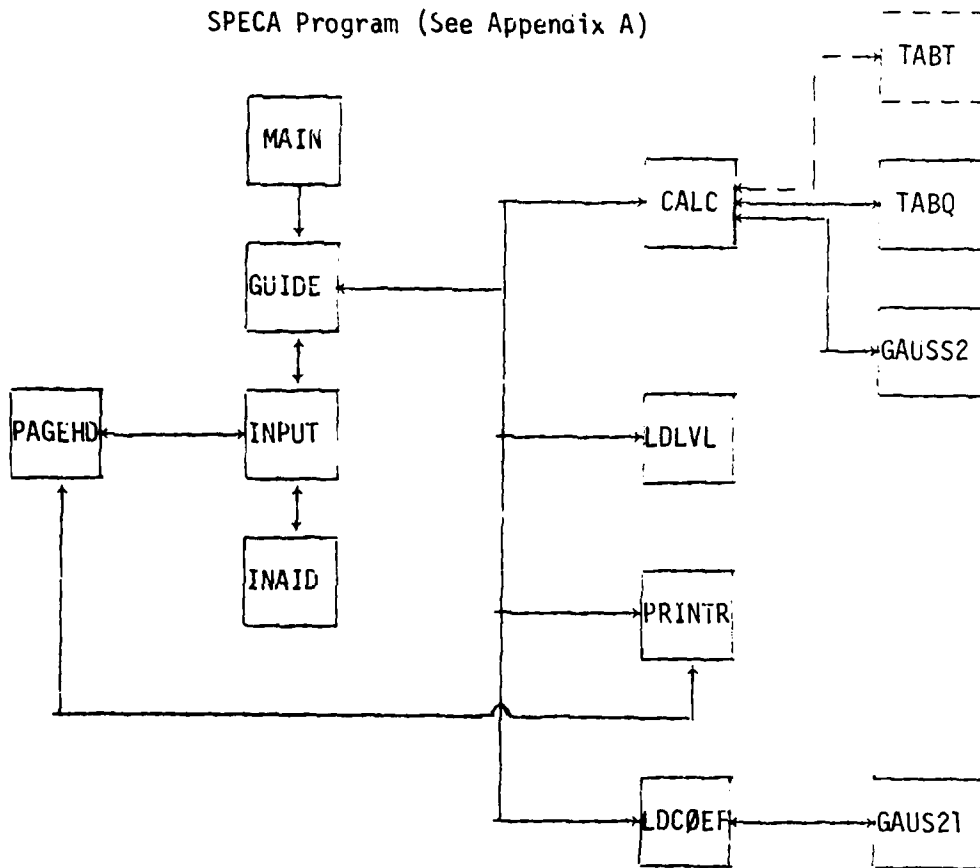
four points are reduced to two points on the  $\Xi^a$  surface by an interpolation on the altitude, and finally these two points are reduced to the desired stress by an interpolation on the weight.

Note that the number FACTØR is used to scale the calculation made in the table look up routine.

### 3 COMPUTER FLOW DIAGRAM AND PROGRAM

The computer routine was coded in FORTRAN Extended Language with the main program and subroutines arranged as follows:

SPECA Program (See Appendix A)



MAIN - Main Program - Sets NZERØ and NPST to zero and transfers program control to GUIDE

GUIDE - Subroutine - Initially zeros input and output numbers and after first case zeros output numbers before the calculations are performed. GUIDE, the main controlling subroutine, transfers control to INPUT, CALC, LDLVL, PRINTR, and LDCDEF in turn.

INPUT - Subroutine - Reads in all input data including the VGH histogram and the stress table. There are two formats for reading in floating point numbers and three formats for reading in fixed point numbers. The details of the data input are discussed later in this section.

INAID - Subroutine - Called by INPUT and has the purpose of writing out certain input data.

- (1) NRVI, NRNZ, NRH, NRW
- (2) FACTOR
- (3) PSIL
- (4) AREAN
- (5) PS
- (6) Stress table
- (7) VGH histogram table
- (8) FVI, FNZ, FH, FW

Also, INAID sets NZERO=1 for control of data handling in GUIDE

PAGEHD - Subroutine - Writes out page heading including run identification, date and page number

CALC - Subroutine - Computes PPSI and PDPSI

LDLVL - Subroutine - Computes PSIL and FRAC

LDCDEF - Subroutine - Computer ALPHA

TABQ - Subroutine - Called from CALC to perform the interpolation discussed in Section IV, B, that computes the stress corresponding to a given indicated airspeed, normal load factor, altitude, and weight.

TABT - Subroutine - called from CALC as an alternate to TABQ for the interpolation to compute the stress corresponding to a given indicated airspeed, equivalent normal load factor, and altitude.

GAUSS2 - Subroutine - Called from CALC to solve the simultaneous equations that are required to pass second order equations through the points of PPSI so that the differentiation for PDPSI can be performed. The subroutine uses the Gauss-Jordan method for solving the sets of simultaneous equations.

GAUSS1 - Subroutine - Called from LDCDEF and is used to solve the set of equations  $PLD(I) = PS(K,J) \cdot ALPHA(J)$ . This subroutine is identical to GAUSS2 except for a DIMENSION statement change.

PRINTR - Subroutine - Called from GUIDE to write out computed output data. In particular, PRINTR prints

- (1) PPSI
- (2) EXCEED
- (3) HOURS
- (4) PDPSI
- (5) PSILL, FRAC

#### 4 EQUIVALENCE TABLES

The technique that has been used in coding this routine is to place all input and output numbers in blank common. All input and output floating point numbers are called parameters and are contained in P (dimensioned 10,000). All input and output fixed point numbers are called integers and are contained in NTEGER (dimensioned 100). To make the program more easily interpreted, EQUIVALENCE statements are used to provide the P and NTEGER numbers with more recognizable names. The SPECA program parameter and integer tables are given below.

PARAMETER EQUIVALENCE TABLE

| P | Dimension | Term    | P    | Dimension | Term         |
|---|-----------|---------|------|-----------|--------------|
| 1 | (1)       | FMN,FVI | 1201 | (100)     | APDPSI(1)    |
| 2 | (1)       | FNZ     | 1300 |           | APDPSI(100)  |
| 3 | (1)       | FH      | 1301 | (100)     | PSIL(1)      |
| 4 | (1)       | FW      | 1400 |           | PSIL(100)    |
| 5 | (1)       | FACTØR  | 1401 | (100)     | FRAC(1)      |
| 6 | (1)       | HØURS   | 1500 |           | FRAC(100)    |
| . |           |         | 1501 | (100,25)  | PLDS(1,1)    |
| . |           |         | 4000 |           | PLDS(100,25) |
| . |           |         | 4001 | (25)      | ALPHA(1)     |
| . |           |         | 4025 |           | ALPHA(25)    |

| P    | Dimension | Term       | P    | Dimension | Term        |
|------|-----------|------------|------|-----------|-------------|
| 100  | (1)       | NT         | .    |           |             |
| 101  | (100)     | PSIL(1)    | .    |           |             |
| 200  |           | PSIL(100)  | .    |           |             |
| 201  | (100)     | AREAN(1)   | 5001 | (25)      | VII(1)      |
| 300  |           | AREAN(100) | 5025 |           | VII(25)     |
| 301  | (25,25)   | PS(1,1)    | 5026 | (25)      | NZI(1)      |
| 925  |           | PS(25,25)  | 5050 |           | NZI(25)     |
| .    |           |            | 5051 | (25)      | HI(1)       |
| .    |           |            | 5075 |           | HI(25)      |
| .    |           |            | 5076 | (25)      | WI(1)       |
| 1001 | (100)     | PPSI(1)    | 5100 |           | WI(25)      |
| 1100 |           | PPSI(100)  | .    |           |             |
| 1101 | (100)     | PDPSI(1)   | .    |           |             |
| 1200 |           | PDPSI(100) | 6001 | (100)     | EXCEED(1)   |
|      |           |            | 6100 |           | EXCEED(100) |

INTEGER EQUIVALENCE TABLE

| NTEGER | Dimension | Term   | NTEGER | Dimension | Term     |
|--------|-----------|--------|--------|-----------|----------|
| 1      | (1)       | IDENT  | .      |           |          |
| 2      | .         | NPF1   | .      |           |          |
| 3      | .         | NPF2   | .      |           |          |
| 4      | .         | NPF3   | 56     | (2)       | NTB41(1) |
| 5      |           | NPF4   | 57     |           | NTB41(2) |
| 6      |           | NTI4   | 58     | (2)       | NTB42(1) |
| 7      |           | NTW4   | 59     |           | NTB42(2) |
| 8      |           | MONTH  | 60     | (2)       | NTB42(1) |
| 9      |           | DAY    | 61     |           | NTB43(2) |
| 10     |           | YEAR   | 62     | (2)       | NTB44(1) |
| 11     |           | NPSIL  | 63     |           | NTB44(2) |
| 12     |           | NPSILL | 64     | (1)       | NTB21    |
| 13     |           | NPS    | 65     | (1)       | NTB22    |
| 14     |           | NMORE  |        |           |          |
| 15     |           | NRMN   |        |           |          |
| 16     |           | NRNZ   |        |           |          |
| 17     |           | NRH    |        |           |          |
| 18     |           | NRW    |        |           |          |
| 19     |           |        |        |           |          |
| 20     |           |        |        |           |          |
| 21     |           | NTB    |        |           |          |
| .      |           |        |        |           |          |
| .      |           |        |        |           |          |
| 49     |           | NPAGE  |        |           |          |

5 INPUT DATA

All of the input data described below is read into the program by means of the subroutine INPUT. INPUT is a general purpose subroutine for reading data from cards. For this program, the full capabilities of INPUT are not required and consequently there will be some zeros in the input that serve to bypass certain options.

The following deck arrangement is recommended:

1415 Format

|       |      |   |   |   |      |      |       |     |      |       |        |     |    |
|-------|------|---|---|---|------|------|-------|-----|------|-------|--------|-----|----|
| IDENT | NPF1 | 0 | 0 | 0 | NTI4 | NTW4 | MONTH | DAY | YEAR | NPSIL | NPSILL | NPS | 21 |
|-------|------|---|---|---|------|------|-------|-----|------|-------|--------|-----|----|

715 Format

|      |      |     |     |   |   |     |
|------|------|-----|-----|---|---|-----|
| NRVI | NRNZ | NRH | NRW | 0 | 0 | NIB |
|------|------|-----|-----|---|---|-----|

72H Format

|                 |
|-----------------|
| Run Description |
|-----------------|

72H Format

|                 |
|-----------------|
| Run Description |
|-----------------|

315

|   |   |   |
|---|---|---|
| 1 | 6 | 1 |
|---|---|---|

6E10.3 Format

|     |     |    |    |        |       |
|-----|-----|----|----|--------|-------|
| FVI | FNZ | FH | FW | FACTØR | HØURS |
|-----|-----|----|----|--------|-------|

315 Format

|     |                |   |
|-----|----------------|---|
| 101 | 100 +<br>NPSIL | 1 |
|-----|----------------|---|

6E10.3 Format

PSIL(1) - PSIL(NPSIL)

315 Format

|     |                 |   |
|-----|-----------------|---|
| 201 | 200 +<br>NPSILL | 1 |
|-----|-----------------|---|

6E10.3 Format

AREAN(1) - AREAN(NPSILL)

If NPS > 1 go to (a)

If NPS = 0 go to (b)

(a) 315 Format

|     |             |   |
|-----|-------------|---|
| 301 | 300+<br>NPS | 1 |
|-----|-------------|---|

6E10.3 Format

PS(1,1) - (PS(NPS,1))

315 Format

|     |              |   |
|-----|--------------|---|
| 326 | 325 +<br>NPS | 1 |
|-----|--------------|---|

6E10.3 Format

PS(1,2) - PS(NPS,2)

3I5 Format

|     |       |   |
|-----|-------|---|
| 351 | 350 + | 1 |
|     | NPS   |   |

6E10.3 Format

|                     |
|---------------------|
| PS(1,3) - PS(NPS,3) |
|---------------------|

.  
.  
.

3I5 Format

|        |         |   |
|--------|---------|---|
| 301 +  | 300 +   | 1 |
| 25(NPS | (NPS-1) |   |
| -1)    | -25+NPS |   |

6E10.3 Format

|                         |
|-------------------------|
| PS(1,NPS) - PS(NPS,NPS) |
|-------------------------|

- (b) If NTI4 > 0 go to (c) to read NI14 table(s). For the first run in a computer input the stress table and the VGH histogram table must be read. Subsequent runs may require no new tables (NTI4 = 0), one new table (NTI4 = 1), or two new tables (NTI4 = 2).

If NTI4 = 0 go to (g)

- (c) 5I10 Format

|   |       |       |       |       |
|---|-------|-------|-------|-------|
| I | NTAB1 | NTAB2 | NTAB3 | NTAB4 |
|---|-------|-------|-------|-------|

(Stress table control cards)

6E10.3 Format

TABLE(1) - TABLE(NTAB1)  
(indicated airspeeds for the stress table)

6E10.3 Format

TABLE(NTAB1+1) - TABLE(NN12)  
(normal load factors for the stress table)

6E10.3 Format

TABLE(NN12+1) - TABLE(NN13)  
(altitudes for the stress table)

If NTB = 1 go to (d)

If NTB = 2 go to (e)

(d)

6E10.3 Format

TABLE(NN13+1) - TABLE(NN14)  
(weights for the stress table)

6E10.3 Format

TABLE(NN14+1) - TABLE(NF)  
(stress amplitudes for the stress table)  
(see Section 3.2 for ordering of these entries)

go to (f)

(e)

E10.3 Format

WTTB3  
(ref. weight)

6E10.3 Format

TABLE(NN13+1) - TABLE(NF)  
(stress amplitudes for the stress table)  
(see Section 3.2 for ordering of these entries)

(f)

5I10 Format

|   |       |       |       |       |
|---|-------|-------|-------|-------|
| 2 | NT421 | NT422 | NT423 | NT424 |
|---|-------|-------|-------|-------|

(VGH histogram control cards)

6E10.3 Format

VII(1) - VII(NT421)  
(indicated airspeeds for VGH histogram table)

NZI(1) - NZI(NT422)  
(normal load factor for VGH histogram table)

HI(1) - HI(NT423)  
(altitudes for VGH histogram table)

WI(1) - WI(NT424)  
(weights for VGH histogram table)

$\sum^a (VII(1), NZI(1), HI(1), WI(1)) -$   
 $\sum^a (VII(NT421), NZI(NT422), HI(NT423), WI(NT424))$   
(load occurrences in VGH histogram table)  
(see discussion below for ordering of these entries)

(g) END OF FILE

The first card contains 14 fixed point (integer) numbers arranged in 15 fields. These 14 entries in order on this card are

- (1) IDENT - run number
- (2) NPF1 = 3 if  $N_p = 1$   
= 3 +  $N_p$  if  $N_p > 1$
- (3) 0
- (4) 0
- (5) 0
- (6) NI14 - the number of quadruple tables to be read (for this count the stress table and the VGH histogram table are each considered quadruple tables.)

- (7) NIW4 = 1 for print of quadruple tables  
= 0 otherwise
- (8) MONTH - month in date for page heading
- (9) DAY - day in date for page heading
- (10) YEAR - year in date for page heading
- (11) NPSIL =  $N_{FL}$
- (12) NPSILL = M
- (13) NPS - the number of control points if  $N_p > 1$  . NPS = 0  
if  $N_p = 1$
- (14) 21

The second card contains seven fixed point numbers arranged in 15 fields. In order these entries are

- (1) NRVI =  $N_{v_i}^R$
- (2) NRNZ =  $N_{n_z}^R$
- (3) NRH =  $N_h^R$
- (4) NRW =  $N_w^R$
- (5) 0
- (6) 0
- (7) NTB = 1 if the load occurrences in the VGH histogram depend on indicated airspeed, normal load factor, altitude, and weight.  
NTB = 2 if the load occurrences in the VGH histogram depend on indicated airspeed, equivalent normal load factor, and altitude

The third and fourth cards contain a 72H field each for the purpose of run description, etc.

The fifth card contains 1, 6, and 1 in 15 fields

The sixth card contains six floating point numbers arranged in E10.3 fields. These six numbers are placed in the following order:

- (1) FVI =  $v_i (N_{v_i} + 1)$

$$(2) \text{ FNZ} = n_z(N_{n_z} + 1)$$

$$(3) \text{ FH} = h(N_h + 1)$$

$$(4) \text{ FW} = w(N_w + 1)$$

(5) FACTØR - stress scaling factor

(6) HØURS - number of hours of data in the VGH histogram

The seventh card contains the three fixed point numbers 101, 100 + NPSIL, 1 in order in 15 fields. NPSIL must not exceed 100.

The next card(s) contain(s) the numbers PSIL(1) through PSIL(NPSIL) in E10.3 fields, six numbers per card.

The next entry contains the fixed point numbers 201, 200 + NPSILL, 1 in order in 15 fields. NPSILL must not exceed 100.

Following this card the floating point numbers AREAN(1) through AREAN(NPSIL), arranged in E10.3 fields, six numbers per card, are entered.

If NPS = 0 then the PS matrix is omitted from the input deck.

If NPS  $\neq$  0 then the PS matrix is placed next in the input deck. PS is dimensioned (25,25) and is equivalenced to P such that P(301) = PS(1,1). Therefore, it follows that P(300+NPS) = PS(NPS,1), P(326) = PS(1,2), and P(301+25(NPS-1)) = PS(1,NPS). Consequently the NPS blocks of data are read in as follows:

First block -

The first card contains the fixed point numbers 301, 300+NPS, 1 arranged in 15 fields.

The next entries are the floating point numbers PS(1,1) through PS(NPS,1) in E10.3 fields, six numbers per card.

Second block -

The first card contains the fixed point numbers 326, 325+NPS, 1 arranged in 15 fields.

The next entries are the floating point numbers  $PS(1,2)$  through  $PS(NPS,2)$  in E10.3 fields, six numbers per card.

·  
·  
·

Nr'Sth block -

The first card contains the fixed point numbers  $301+25(NPS-1)$ ,  $300+(NPS-1)(25) + NPS$  arranged in 15 fields.

The next entries are the floating point numbers  $PS(1,NPS)$  through  $PS(NPS,NPS)$  in E10.3 fields, six numbers per card.

The remaining entries are the stress table and the VGH histogram table. These entries are prepared as follows:

If  $I = 1$  then the entry is the stress table where there are  $NP = NTAB1 \cdot NTAB2 \cdot NTAB3 \cdot NTAB4$  points defined by  $NTAB1$  indicated airspeeds,  $NTAB2$  normal load factors,  $NTAB3$  altitudes,  $NTAB4$  weights. These points are entered as ordinates of the simple graph TABLE which was defined in paragraph 2 of this section.

The first card for the stress table contains five (5) fixed point numbers in 15 fields in the order:

- (1) 1
- (2)  $NTAB1$
- (3)  $NTAB2$
- (4)  $NTAB3$
- (5)  $NTAB4$

The next card(s) contain(s) the indicated airspeeds (floating point numbers)  $TABLE(1)$  through  $TABLE(NTAB1)$  arranged in E10.6 fields, six numbers per card.

The next entries are the normal load factors  $TABLE(NTAB1 + 1, NN12)$  (see paragraph 2 for definition of arguments) arranged in E10.3 fields six numbers per card.

Next, the card(s) that contain the altitudes  $TABLE(NN12+1)$  through  $TABLE(NN13)$  arranged in E10.3 fields, six numbers per card are entered in order.

The next entries depend on the number NTB.

If NTB = 1 the card(s) that contain(s) the weights TABLE(NN13+1) through TABLE(NN14) arranged in E10.3 fields, are entered with six numbers per card.

The next card(s) contain(s) the stresses TABLE(NN14+1) through TABLE(NF) arranged in E10.3 fields, six numbers per card. The ordering of the stresses in this entry is defined in paragraph 2 of this section.

If NTB = 2 a card is entered that contains the reference weight WTTB3 in an E10.3 field.

The next card(s) contain(s) the stresses TABLE(NN13+1) through TABLE(NF) arranged in E10.3 fields, six numbers per card. The number NF must not exceed 2000. The ordering of the stresses in this entry is defined in paragraph 2 of this section. (Note that NTAB4 = 1 for this case.)

This completes the stress table

If I = 2 then the entry is the VGH histogram table where there are NP24 = NT421 \* NT422 \* NT423 \* NT424 regions defined by NT421 indicated airspeed intervals, NT422 normal load factor intervals, NT423 altitude intervals, and NT424 weight intervals.

The first card for the VGH histogram table contains five fixed point numbers in 15 fields in the order

- (1) 2
- (2) NT421
- (3) NT422
- (4) NT423
- (5) NT424

Following this card are the card(s) with the indicated airspeeds (floating point numbers) VII(1) through VII(NT421) arranged in E10.3 fields, six numbers per card.

The next card(s) contain the normal load factors NZI(1) through NZI(NT422) arranged in E10.3 fields, six numbers per card.

Next are the card(s) that contain the altitudes HI(1) through HI(NT423) arranged in E10.3 fields, six numbers per card.

The weight entries WI(1) through WI(NT424) arranged in E10.3 field, six numbers per card, are next.

The final card(s) in the VGH histogram deck are the load occurrences in regions defined by the indicated airspeeds, normal load factors, altitudes, and weights. If  $i$  is in [1, NP] then these entries are  $\{V(i), NZI(1), HI(1), WI(1)\}$  through  $\{V(NT421), NZI(NT422), HI(NT423), WI(NT424)\}$  arranged in E10.3 fields, six numbers per card. If  $i$  is in [1, NT421],  $j$  is in [1, NT422],  $k$  is in [1, NT423], and  $m$  is in [1, NT424] then the stress that corresponds to  $VII(i), NZI(j), FI(k), WI(m)$  is the  $((m-1) \cdot NT421 + NT422 + NT423 + (k-1) \cdot NT421 + NT422 + (j-1) \cdot NT421 + i)$ th entry on these cards. The number  $NT421 + NT422 + NT423 + NT424 + NT421 \cdot NT422 + NT423 \cdot NT424$  must not exceed 2000.

## 6 SAMPLE PROBLEM

A sample run is presented for the purpose of acquainting the user with the input data cards and the output. The data used does not represent any particular aircraft or usage. It is assumed that two control points are sufficient in this case to define the full scale aircraft fatigue spectrum. The input cards are as follows:

```

100  5  0  0  0  2  1  3  30 1973  23  12  2  21
   2  2  2  2  0  0  1
      CHECK OUT RUN FOR SPECA PROGRAM
      V G H DATA IN TABLE CONTROL POINT NUMBER 1 (REVISION 2)
   1  6  1
650.0  7.0  40000.0  36000.0  1.0  500.0
 101 123  1
20000.0  22000.0  24000.0  26000.0  28000.0  30000.0
32000.0  34000.0  36000.0  38000.0  40000.0  42000.0
44000.0  46000.0  48000.0  50000.0  52000.0  54000.0
56000.0  58000.0  60000.0  62000.0  64000.0
 201 212  1
0.05  0.10  0.20  0.25  0.30  0.40
0.50  0.60  0.70  0.80  0.90  0.95
 301 302  1
20000.0  35000.0

```



| 3.0     | 6.0     | 8.0     |         |         |         |
|---------|---------|---------|---------|---------|---------|
| 5000.0  | 20000.0 | 35000.0 |         |         |         |
| 25000.0 | 30000.0 | 35000.0 |         |         |         |
| 10000.0 | 20000.0 | 24000.0 | 36000.0 | 39000.0 | 40000.0 |
| 45000.0 | 50000.0 | 53000.0 | 17000.0 | 18000.0 | 20000.0 |
| 25000.0 | 27000.0 | 30000.0 | 51000.0 | 53000.0 | 54000.0 |
| 15000.0 | 17000.0 | 18000.0 | 26000.0 | 28000.0 | 29000.0 |
| 32000.0 | 34000.0 | 36000.0 | 25000.0 | 26000.0 | 27000.0 |
| 42000.0 | 43000.0 | 44000.0 | 55000.0 | 56000.0 | 57000.0 |
| 21000.0 | 22000.0 | 24000.0 | 36000.0 | 38000.0 | 39000.0 |
| 55000.0 | 57000.0 | 58000.0 | 19000.0 | 21000.0 | 22000.0 |
| 30000.0 | 32000.0 | 33000.0 | 45000.0 | 46000.0 | 48000.0 |
| 27000.0 | 29000.0 | 32000.0 | 49000.0 | 50000.0 | 53000.0 |
| 62000.0 | 64000.0 | 65000.0 | 24000.0 | 25000.0 | 27000.0 |
| 39000.0 | 41000.0 | 42000.0 | 58000.0 | 60000.0 | 61000.0 |
| 22000.0 | 24000.0 | 25000.0 | 33000.0 | 35000.0 | 36000.0 |
| 48000.0 | 49000.0 | 51000.0 |         |         |         |

Based on this input the following output listing was obtained.

CHECK OUT RUN FOR SPECIA PROGRAM  
 V G M DATA IN TABLE CONTROL POINT NUMBER 1 (REVISION 2)

HISTOGRAM SUBDIVISIONS

|      |   |
|------|---|
| NSVT | 2 |
| NSNZ | 2 |
| NSM  | 2 |
| NSW  | 2 |

LOAD MAGNIFICATION FACTOR = 1.0000

INTERNAL LOAD LEVELS FOR INTEGRATION OF JOINT DENSITY FUNCTION

|    |            |    |            |    |            |    |            |
|----|------------|----|------------|----|------------|----|------------|
| 1  | 2.0000E+04 | 2  | 2.2000E+04 | 3  | 2.4000E+04 | 4  | 2.6000E+04 |
| 5  | 2.8000E+04 | 6  | 3.0000E+04 | 7  | 3.2000E+04 | 8  | 3.4000E+04 |
| 9  | 3.6000E+04 | 10 | 3.8000E+04 | 11 | 4.0000E+04 | 12 | 4.2000E+04 |
| 13 | 4.4000E+04 | 14 | 4.6000E+04 | 15 | 4.8000E+04 | 16 | 5.0000E+04 |
| 17 | 5.2000E+04 | 18 | 5.4000E+04 | 19 | 5.6000E+04 | 20 | 5.8000E+04 |
| 21 | 6.0000E+04 | 22 | 6.2000E+04 | 23 | 6.4000E+04 | 24 | 0.         |

CUMULATIVE AREAS OF LOAD PROBABILITY DENSITY FUNCTION FOR SPECTRUM LOAD LEVELS

|   |            |    |            |    |            |    |            |
|---|------------|----|------------|----|------------|----|------------|
| 1 | 2.0000E-01 | 2  | 1.0000E-01 | 3  | 2.0000E-01 | 4  | 2.5000E-01 |
| 5 | 3.0000E-01 | 6  | 4.0000E-01 | 7  | 5.0000E-01 | 8  | 6.0000E-01 |
| 9 | 7.0000E-01 | 10 | 8.0000E-01 | 11 | 9.0000E-01 | 12 | 9.5000E-01 |





RUN NO 100      DATE 6/30/1973      PAGE NO 4  
 INTERNAL LOAD CUMULATIVE PROBABILITY FUNCTION      LOAD      CUM PROR      CUM PROR  
 2.600000E+04      1.000000E+00      2.400000E+04      1.000000E+00  
 2.600000E+04      9.410190E-01      3.000000E+04      8.310203E-01  
 3.200000E+04      5.860719E-01      3.600000E+04      6.227599E-01  
 3.800000E+04      3.221785E-01      4.200000E+04      4.738843E-01  
 4.400000E+04      1.181107E-01      4.800000E+04      3.880130E-02  
 5.000000E+04      1.780409E-02      5.400000E+04      1.887717E-04  
 5.600000E+04      0.      6.000000E+04      0.      0.  
 6.200000E+04      0.      6.400000E+04      0.      0.

CUMULATIVE NUMBER OF EXCEEDANCES PER 1000 HRS

| LOAD EXCEEDANCES | LOAD EXCEEDANCES | LOAD EXCEEDANCES |
|------------------|------------------|------------------|
| 2.000000E+04     | 2.200000E+04     | 2.400000E+04     |
| 3.457400E+05     | 3.457400E+05     | 3.457400E+05     |
| 3.391775E+05     | 2.800000E+04     | 2.875775E+05     |
| 2.372250E+05     | 3.400000E+04     | 1.461650E+05     |
| 1.139030E+05     | 4.000000E+04     | 6.011675E+04     |
| 4.042500E+04     | 4.600000E+04     | 1.344500E+04     |
| 6.162500E+03     | 5.200000E+04     | 6.250000E+01     |
| 0.               | 6.800000E+04     | 0.               |
| 0.               | 6.400000E+04     | 0.               |

BASED ON 500.00 HOURS

INTERNAL LOAD PROBABILITY DENSITY FUNCTION

| LOAD         | PROB DEN     | LOAD         | PROB DEN     | LOAD         | PROB DEN     |
|--------------|--------------|--------------|--------------|--------------|--------------|
| 2.000000E+04 | 3.957324E-14 | 2.200000E+04 | 7.567652E-19 | 2.400000E+04 | 4.745257E-06 |
| 2.600000E+04 | 1.713600E-05 | 2.800000E+04 | 3.714743E-05 | 3.000000E+04 | 6.316602E-05 |
| 3.200000E+04 | 7.180790E-05 | 3.400000E+04 | 6.552801E-05 | 3.600000E+04 | 5.546979E-05 |
| 3.800000E+04 | 6.60551E-05  | 4.000000E+04 | 3.707356E-05 | 4.200000E+04 | 3.155189E-05 |
| 4.400000E+04 | 2.37231E-05  | 4.600000E+04 | 1.974184E-05 | 4.800000E+04 | 1.523544E-05 |
| 5.000000E+04 | 9.78087E-06  | 5.200000E+04 | 4.811829E-06 | 5.400000E+04 | 4.605678E-07 |
| 5.600000E+04 | 4.71423E-06  | 5.800000E+04 | 0.           | 6.000000E+04 | 0.           |
| 6.200000E+04 | 0.           | 6.400000E+04 | 0.           | 0.           | 0.           |

RUN NO 100      DATE 8/30/1973      PAGE NO 7

| CYCLIC LOADING FRACTIONS |             |             |             |
|--------------------------|-------------|-------------|-------------|
| LOAD                     | FRACTION    | FRACTION    |             |
| 2.76794E+04              | 7.50000E-02 | 3.85308E+04 | 7.50000E-02 |
| 3.11171E+04              | 5.00000E-02 | 3.31768E+04 | 1.00000E-01 |
| 3.46790E+04              | 1.00000E-01 | 3.95591E+04 | 1.00000E-01 |
| 6.12075E+04              | 1.00000E-01 | 4.73436E+04 | 7.50000E-02 |

TOTAL LOAD CYCL S = 172870.

RUN NO 100 DATE 8/18/1973 PAGE NO 8  
 CHECK OUT FOR SPECIA PROGRAM  
 V G M DATA IN TABLE CONTROL POINT NUMBER 2

HISTOGRAM SUBDIVISIONS  
 NWT E 2  
 NWJ E 2  
 NWK E 2  
 NWN E 2

LOAD MAGNIFICATION FACTOR = 1.0000

INTERNAL LOAD LEVELS FOR INTEGRATION OF JOINT DENSITY FUNCTION

|    |            |    |            |    |            |    |            |
|----|------------|----|------------|----|------------|----|------------|
| 1  | 2.0000E+04 | 2  | 2.2000E+04 | 3  | 2.4000E+04 | 4  | 2.6000E+04 |
| 5  | 2.8000E+04 | 6  | 3.0000E+04 | 7  | 3.2000E+04 | 8  | 3.4000E+04 |
| 9  | 3.6000E+04 | 10 | 3.8000E+04 | 11 | 4.0000E+04 | 12 | 4.2000E+04 |
| 13 | 4.6000E+04 | 14 | 4.8000E+04 | 15 | 4.8000E+04 | 16 | 5.0000E+04 |
| 17 | 5.2000E+04 | 18 | 5.4000E+04 | 19 | 5.6000E+04 | 20 | 5.8000E+04 |
| 21 | 6.0000E+04 | 22 | 6.2000E+04 | 23 | 6.4000E+04 | 24 | 0.         |

CUMULATIVE AREAS OF LOAD PROBABILITY DENSITY FUNCTION  
 FOR SPECTRUM LOAD LEVELS

|   |            |    |            |    |            |    |            |
|---|------------|----|------------|----|------------|----|------------|
| 1 | 5.0000E-01 | 2  | 1.0000E-01 | 3  | 2.0000E-01 | 4  | 2.5000E-01 |
| 5 | 3.0000E-01 | 6  | 4.0000E-01 | 7  | 5.0000E-01 | 8  | 6.0000E-01 |
| 9 | 7.0000E-01 | 10 | 8.0000E-01 | 11 | 9.0000E-01 | 12 | 9.5000E-01 |

BALANCED LOAD COMPLETION MATRIX  
2.0000000000  
2.5000000000  
3.5000000000





| INFORMATIONAL LOAD CUMULATIVE PROBABILITY FUNCTION |             |             |             |
|--|-------------|-------------|-------------|
| LOAD   | CUM PROB    | LOAD        | CUM PROB    |
| 2.00000E+04  | 1.30000E+00 | 2.20000E+04 | 1.00000E+00 |
| 2.40000E+04  | 4.41000E-01 | 2.80000E+04 | 9.31444E-01 |
| 2.80000E+04  | 6.48444E-01 | 3.40000E+04 | 9.29371E-01 |
| 3.20000E+04  | 3.21667E-01 | 4.00000E+04 | 1.68157E-01 |
| 3.60000E+04  | 1.04673E-01 | 4.60000E+04 | 2.78279E-02 |
| 4.00000E+04  | 4.71514E-02 | 5.20000E+04 | 7.59241E-04 |
| 4.40000E+04  | 0.          | 5.80000E+04 | 0.          |
| 4.80000E+04  | 0.          | 6.40000E+04 | 0.          |

RUN NO. 100

DATE 8/30/1973

PAGE NO. 13

CUMULATIVE NUMBER OF EXCEEDANCES PER 1000 HRS

| LOAD        | EXCEEDANCES  | LOAD        | EXCEEDANCES  | LOAD        | EXCEEDANCES  |
|-------------|--------------|-------------|--------------|-------------|--------------|
| 2.00000E+04 | 3.457400E+05 | 2.20000E+04 | 3.457400E+05 | 2.40000E+04 | 3.457400E+05 |
| 2.60000E+04 | 3.191775E+05 | 2.40000E+04 | 3.217650E+05 | 3.00000E+04 | 2.674450E+05 |
| 3.20000E+04 | 2.161775E+05 | 3.00000E+04 | 1.871650E+05 | 3.60000E+04 | 1.653150E+05 |
| 3.80000E+04 | 1.106525E+05 | 3.60000E+04 | 6.276500E+04 | 4.20000E+04 | 5.61375E+04  |
| 4.40000E+04 | 3.750375E+04 | 4.20000E+04 | 2.246125E+04 | 4.80000E+04 | 9.621250E+03 |
| 5.00000E+04 | 1.637500E+03 | 4.80000E+04 | 2.625000E+02 | 5.40000E+04 | 6.250000E+01 |
| 5.60000E+04 | 0.           | 5.40000E+04 | 0.           | 6.00000E+04 | 0.           |
| 6.20000E+04 | 0.           | 6.00000E+04 | 0.           |             |              |

BASED ON 500.00 HOURS

RUN NO. 100      DATE 8/30/1971      PAGE NO. 15  
 INTERNAL LOAD PROBABILITY DENSITY FUNCTION

| LOAD        | PROB DEN    | LOAD        | PROB DEN    | LOAD        | PROB DEN    |
|-------------|-------------|-------------|-------------|-------------|-------------|
| 2.00000E+04 | 3.95732E-15 | 2.20000E+04 | 6.56265E-19 | 2.40000E+04 | 4.74525E-06 |
| 2.40000E+04 | 1.73160E-05 | 2.60000E+04 | 3.71976E-05 | 3.00000E+04 | 6.17425E-05 |
| 3.20000E+04 | 7.25558E-05 | 3.40000E+04 | 6.58440E-05 | 3.60000E+04 | 5.51761E-05 |
| 3.80000E+04 | 6.52207E-05 | 4.00000E+04 | 3.79714E-05 | 4.20000E+04 | 3.27271E-05 |
| 4.40000E+04 | 2.57979E-05 | 4.60000E+04 | 2.01614E-05 | 4.80000E+04 | 1.50679E-05 |
| 5.00000E+04 | 6.76718E-06 | 5.20000E+04 | 1.13862E-06 | 5.40000E+04 | 1.49910E-07 |
| 5.60000E+04 | 4.51929E-06 | 5.80000E+04 | 0.          | 6.00000E+04 | 0.          |
| 6.20000E+04 | 0.          | 6.40000E+04 | 0.          | 0.          | 0.          |

RUN NO 100      DATE 8/30/1971      PAGE NO 15  
 CYCLIC LOADING FRACTIONS      LOAD      FRACTION      LOAD      FRACTION  
 2.742045E+04 7.500000E-02      2.823156E+04 7.500000E-02      3.041958E+04 7.500000E-02  
 3.100111E+04 5.000000E-01      3.177553E+04 7.500000E-02      3.313918E+04 1.000000E-01  
 3.448541E+04 1.000000E-01      3.617520E+04 1.000000E-01      3.747583E+04 1.000000E-01  
 4.100155E+04 1.000000E-01      4.634577E+04 7.500000E-02      4.671048E+04 7.500000E-02

TOTAL LOAD CYCLES = 172870

- COEFFICIENTS FOR FREQUENCY LEVEL NO. 1  
2.693505E+00 -1.004975E+00
- COEFFICIENTS FOR FREQUENCY LEVEL NO. 2  
5.611910E+00 -2.009584E+00
- COEFFICIENTS FOR FREQUENCY LEVEL NO. 3  
2.745611E+00 -2.112111E+00
- COEFFICIENTS FOR FREQUENCY LEVEL NO. 4  
2.826665E+00 -2.261331E+00
- COEFFICIENTS FOR FREQUENCY LEVEL NO. 5  
2.088666E+00 -2.310071E+00
- COEFFICIENTS FOR FREQUENCY LEVEL NO. 6  
2.012610E+00 -2.410121E+00
- COEFFICIENTS FOR FREQUENCY LEVEL NO. 7  
3.149611E+00 -2.519111E+00
- COEFFICIENTS FOR FREQUENCY LEVEL NO. 8  
2.308727E+00 -2.665667E+00
- COEFFICIENTS FOR FREQUENCY LEVEL NO. 9  
2.602903E+00 -2.700571E+00
- COEFFICIENTS FOR FREQUENCY LEVEL NO. 10  
2.731335E+00 -2.90615E+00
- COEFFICIENTS FOR FREQUENCY LEVEL NO. 11  
4.033415E+00 -3.226731E+00
- COEFFICIENTS FOR FREQUENCY LEVEL NO. 12  
4.247171E+00 -3.197371E+00

END-OF-FILE ENCOUNTERED. STOPPAGE - INPUT  
ERROR NUMBER 2068 DETECTED BY IMPC= AT ADDRESS 000160  
CALLED FROM INPUT AT LINE 0361  
CALLED FROM QUITC AT LINE 0312  
CALLED FROM SPECB AT LINE 0310

#### SECTION IV

##### EXAMPLE PROBLEM - F-4 STRESS SPECTRUM FOR POSITIVE LOAD FACTORS

The data base for this problem is four quarters of VGH data starting with the second quarter of 1972 and finishing with the first quarter of 1973. The VGH histogram intervals for these data are the following:

Indicated airspeed (knots)

150, 200, 250, 300, 350, 400, 450, 500, 550, 625, and 700

Normal load factor (equivalent)

1.4, 1.8, 2.2, 2.6, 3.0, 3.8, 4.6, 5.4, 6.6, 7.8, and 9.0

Altitude (feet)

0, 1000, 2000, 5000, 10,000, 15,000, 20,000, 30,000, 40,000, and 50,000

Weight (pounds)

37,500 (reference weight)

The stress table was set up with the following indicated airspeed, normal load factor, altitude, and weight combinations:

Indicated airspeed (knots)

175, 225, 275, 325, 375, 425, 475, 525, 575, and 625

Normal load factor

2.4, 2.8, 3.4, 4.2, 5.0, 6.0, 7.2, and 8.9

Altitude (feet)

500, 1500, 3500, 7500, 12500, 17500, 25000, and 35000

Weight (pounds)

37,500

The VGH histogram table was made up using all of the available data for the air-to-air and air-to-ground operations for the four quarters without distinguishing the various F-4 models except that only the unslatted configurations were considered. The numbers of hours of data in each category and their corresponding numbers of positive and negative load occurrences are shown in Table 1.

The number of stress exceedances per 1000 hours for load reference station (LRS) 180, defined in Figure 1 is shown in Figure 2 through Figure 7. Figure 2 through Figure 5 shows the variation from quarter to quarter of the VGH data. The stress exceedance graphs appear to show a small degree of scatter except for the SEA air-to-air first quarter where there was an overt change in the mission although it was still categorized as air-to-air. The four quarters of data are combined in Figures 6 and 7 to show the differences between the CONUS and SEA in the air-to-air operation and the air-to-ground operation.

## SECTION V

### CONCLUSIONS

The procedure described in this report can eliminate much of the uncertainty that can occur in the derivation of the maneuver load stress spectrum. For new aircraft an estimate must be made of the VGH histogram to obtain the spectrum. This estimate can be updated during Task V of ASIP to derive a better estimate for the operational life of the fleet. This procedure can be immediately applied to fleet tracking by computing the conditional probability of exceeding a stress level given the normal load factor.

The application to full scale aircraft testing makes use of the assumption that the stress is matched at a specified number of control points by a linear combination of the same number of balanced loading conditions. This technique is believed to be more accurate than the usual process of a damage match at the specified control points in that the troublesome damage calculation is eliminated. The stress spectra at points other than control points are presumed to be matched satisfactorily by using representative loading conditions. It is, of course, theoretically better to use all points of the sky that occur in the VGH histogram. This, however, may be impractical due to test equipment limitations.

The procedure as applied to the F-4 fleet indicates that in general the stress spectra do not show significant changes from quarter to quarter. Also, when an operational change is made the method will reflect that change. When CONUS and SEA data are compared there appears to be a reasonably good correlation between the spectra generated in training and the spectra generated in combat.

TABLE 1. F-4 VGH DATA SUMMARY

| PERIOD | TYPE     | HOURS   | + COUNTS | - COUNTS | TOTAL COUNTS |
|--------|----------|---------|----------|----------|--------------|
| 2Q 72  | CONUS AA | 196.87  | 13981    | 4541     | 18522        |
| 2Q 72  | SEA AA   | 65.84   | 4047     | 662      | 4709         |
| 2Q 72  | CONUS AG | 251.70  | 30723    | 9432     | 40155        |
| 2Q 72  | SEA AG   | 1248.94 | 93027    | 13258    | 106285       |
| 3Q 72  | CONUS AA | 290.22  | 17470    | 5259     | 22729        |
| 3Q 72  | SEA AA   | 393.26  | 30842    | 6366     | 37208        |
| 3Q 72  | CONUS AG | 469.64  | 38968    | 9934     | 48902        |
| 3Q 72  | SEA AG   | 802.74  | 66446    | 12485    | 78931        |
| 4Q 72  | CONUS AA | 184.92  | 9404     | 3138     | 12542        |
| 4Q 72  | SEA AA   | 164.35  | 7862     | 1933     | 9795         |
| 4Q 72  | CONUS AG | 89.16   | 5959     | 1265     | 7224         |
| 4Q 72  | SEA AA   | 502.09  | 28254    | 4819     | 33073        |
| 1Q 73  | CONUS AA | 123.18  | 7983     | 2231     | 10214        |
| 1Q 73  | SEA AA   | 133.96  | 6100     | 1358     | 7458         |
| 1Q 73  | CONUS AG | 194.38  | 17828    | 4001     | 21829        |
| 1Q 73  | SEA AG   | 933.87  | 42342    | 8229     | 50571        |

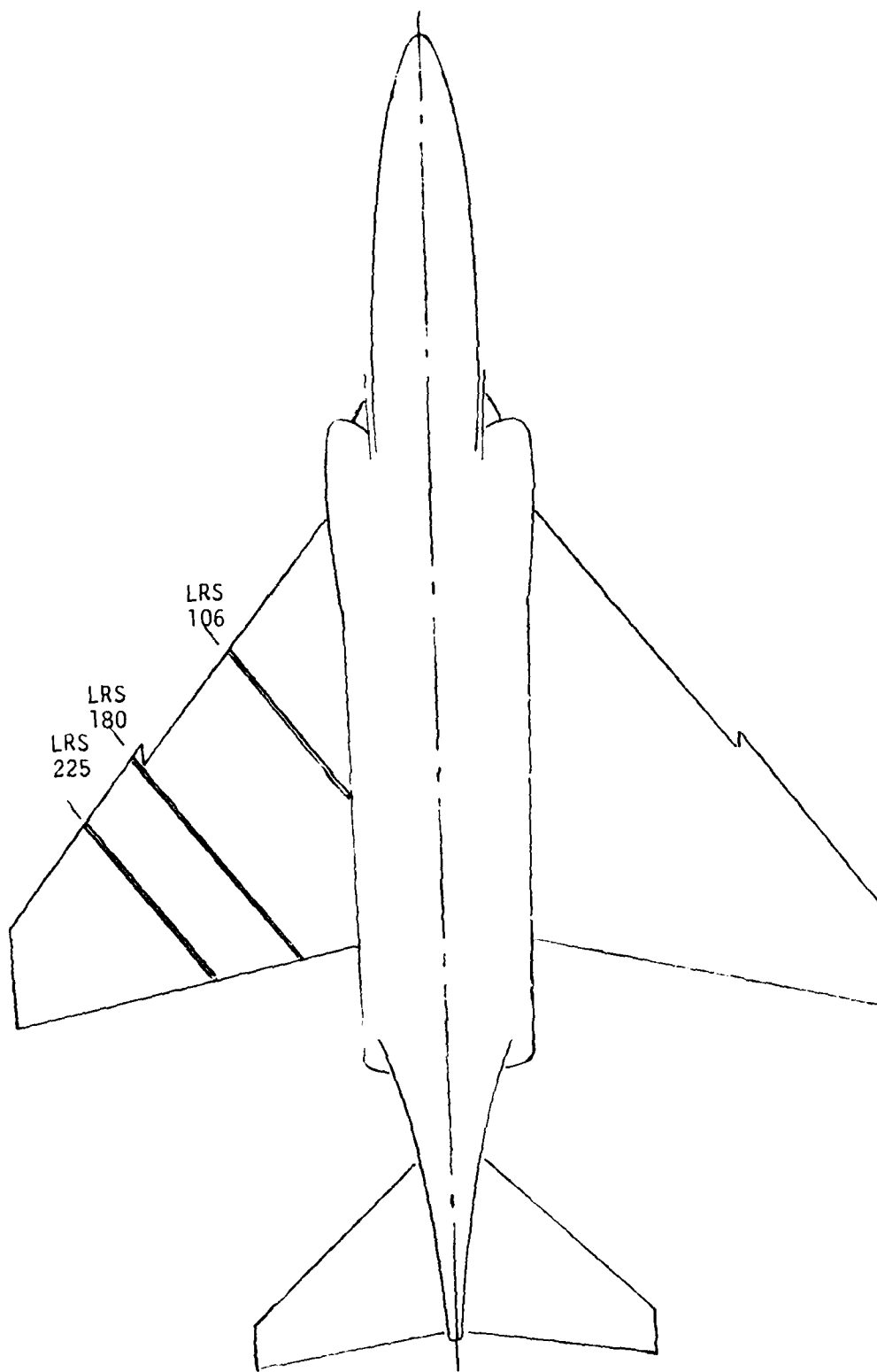


Figure 1. F-4 Wing Load Reference Station Locations

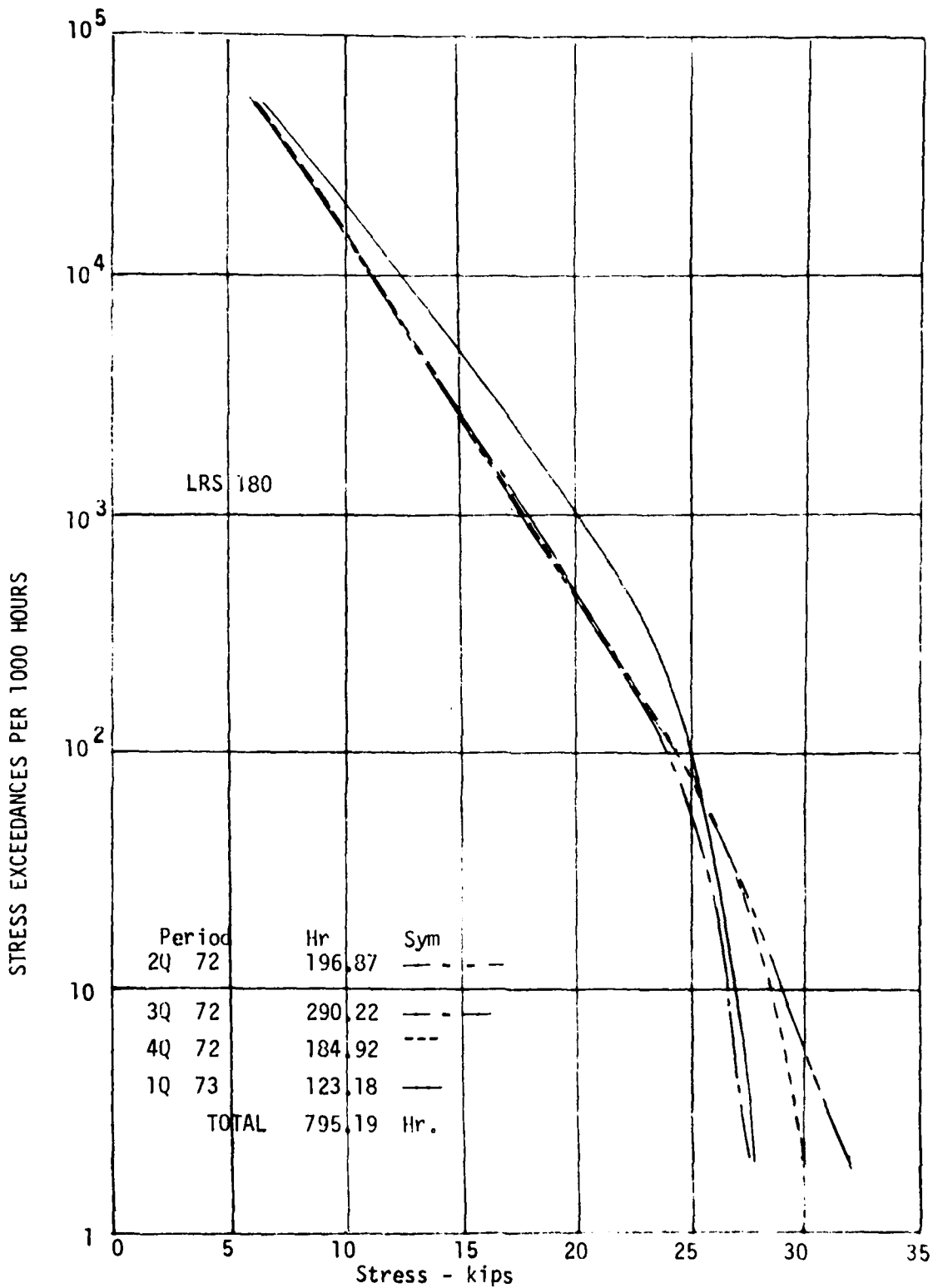


Figure 2. F-4 Spectra - CONUS Air-to-Air (All Models)

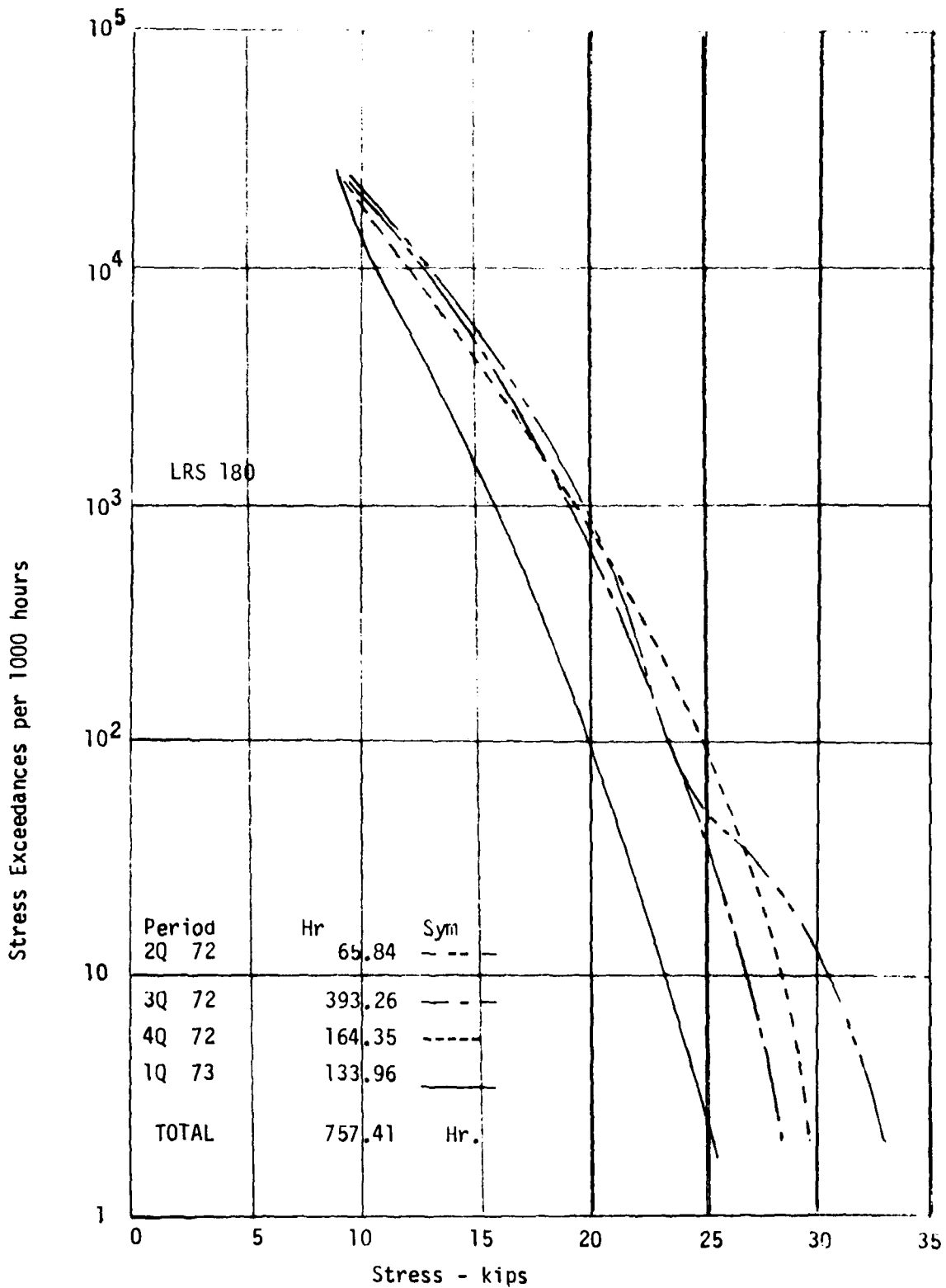


Figure 3. F-4 Spectra - SEA Air-to-Air (All Models)

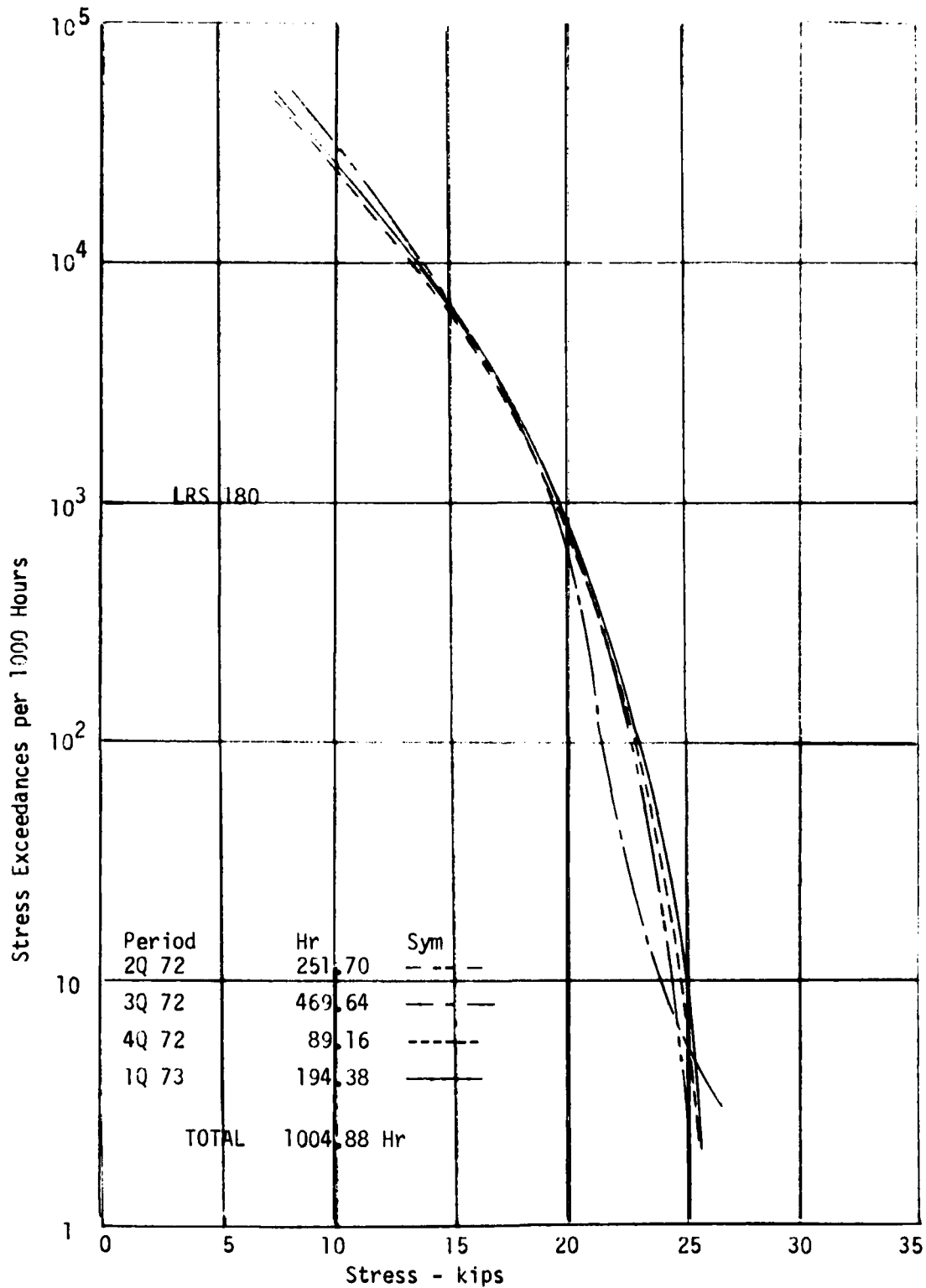


Figure 4. F-4 Spectra - CONUS Air-to-Ground (All Models)

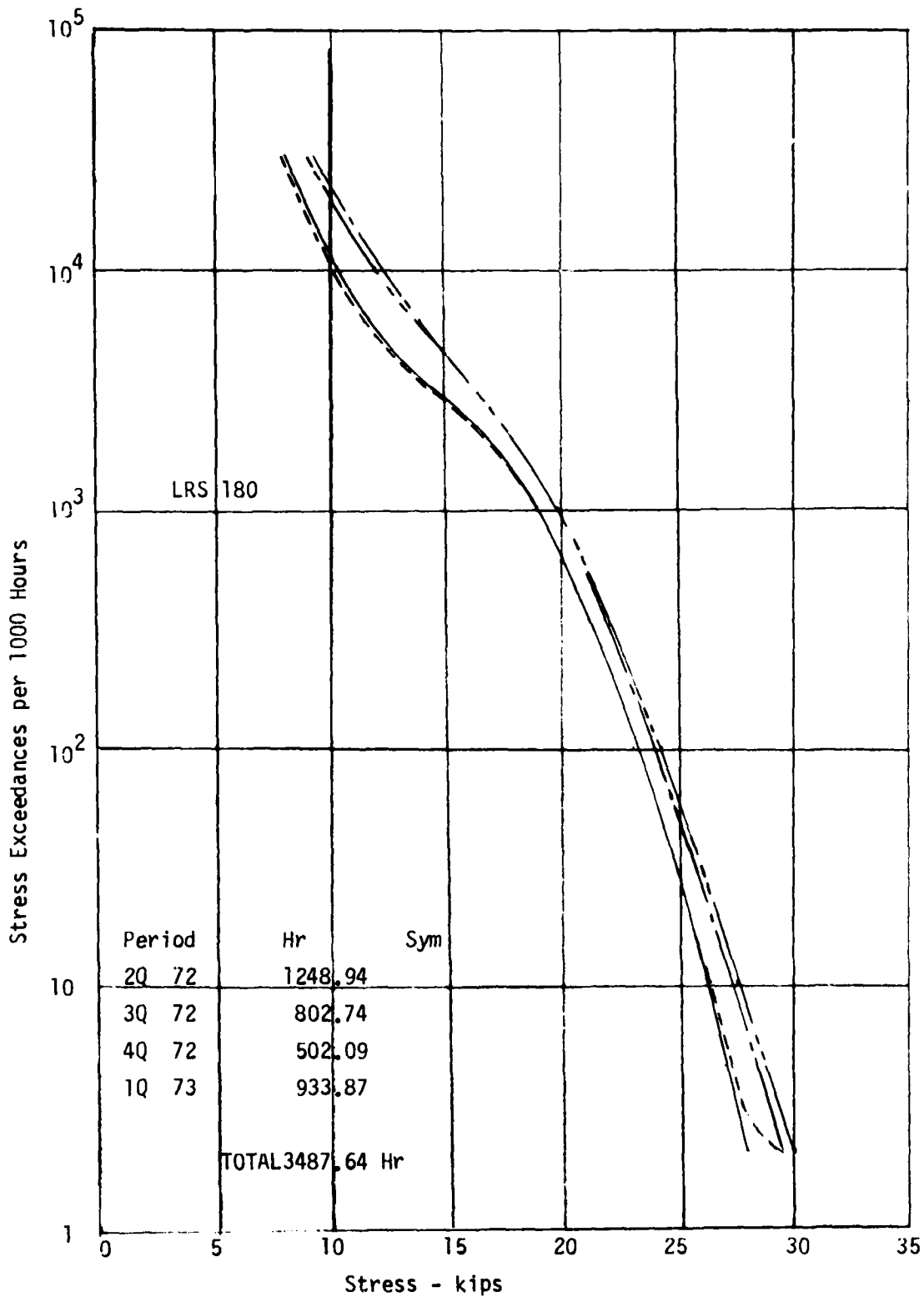


Figure 5. F-1 Spectra - SEA Air-to-Ground (All Models)

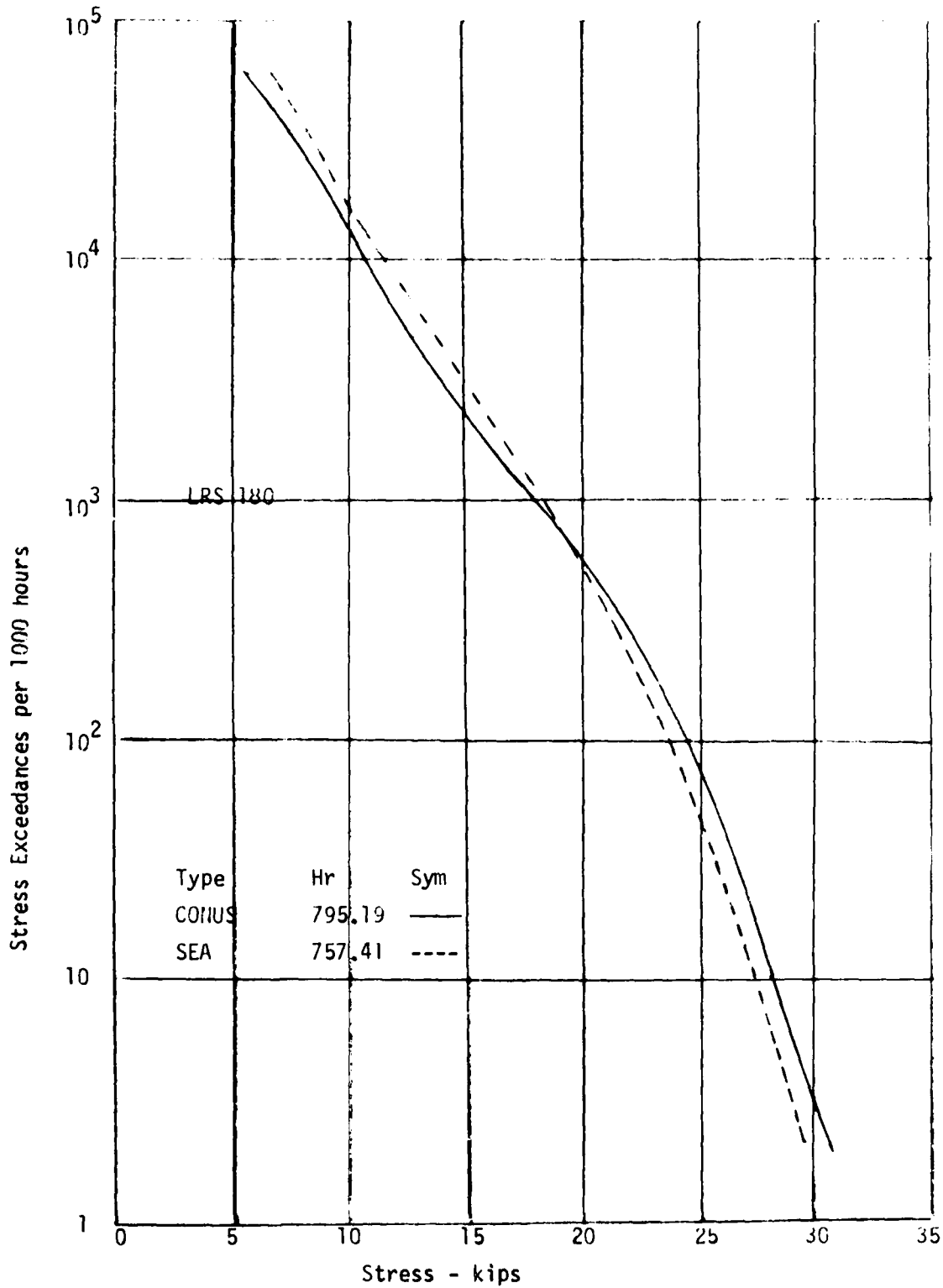


Figure 6. F-4 Spectra - Air-to-Air (All Models)  
for One Year of VGH Data

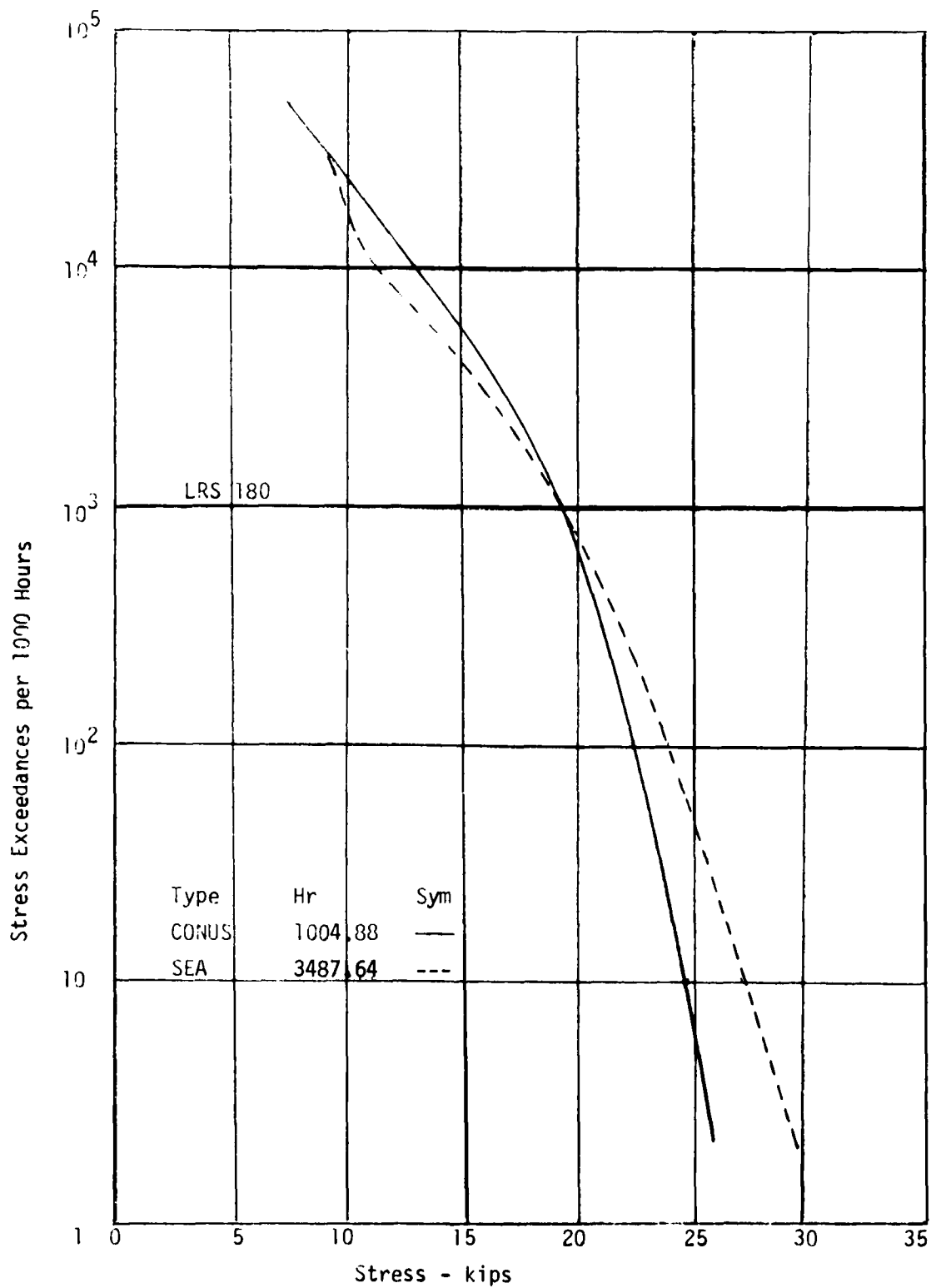


Figure 7. F-4 Spectra - Air-to-Ground (All Models) for One Year of VGH Data

## APPENDIX - SPECA PROGRAM LISTING

The listing given below is a FORTRAN extended language routine. This listing contains all of the statements for the version described in the Introduction of this report. Section 3.3 gives a brief description of each of the sub-routines in this listing.

```

PROGRAM SPECI INPUT, OUTPUT, TAPLS=INPUT, TAPEL=OUTPUT
PROGRAM FOR COMPUTING AIRCRAFT INTERNAL LOAD PROBABILITY
DENSITY FUNCTIONS
REVISION 2 COMMON P(10000), NTEGER(100), TRL(12000,2),
5      1 TABL(1500,1)
      EQUIVALENCE (NTEGER(48), NZERO), (NTEGER(50), MPSCF)
      NZERO = 0
      MPSCF = 0
      CALL GUDFI
      GO TO 10
      EN)
10
30

```

```

MAIN 1
MAIN 2
MAIN 21
MAIN 3
MAIN 31
MAIN 4
MAIN 5
MAIN 51
MAIN 6
MAIN 7
MAIN 8

```

```

SUBROUTINE GUIDE
SUBROUTINE FOR CALLING INPUT DATA AND CALCULATING ROUTINES
COMMON F(10000), NTEGER(100), TABL4(2000,2),
5 TABL2(500,1)
EQUIVALENCE (INTEGER(13), MPS)
EQUIVALENCE (INTEGER(68), NZERO)
EQUIVALENCE (P(5), FACTOR)
10 DO 20 I = 1, 10000
20 IF (NZERO) 40, 10
30 P(I) = 0.1
40 DO 30 I = 1, 100
50 M(IGR(I)) = 0
60 GO TO 44
70 DO 47 I = 1001, 10000
80 P(I) = 0.1
90 FACTOR = 1.0
100 CALL INFUT
110 CALL CALC
120 CALL LDWL
130 CALL PRINTP
140 IF (MPS) 60, 60, 50
150 CALL LCOEF
160 RETURN
170 END
180
190
200
210
220
230
240
250
260
270
280
290
300
310
320
330
340
350
360
370
380
390
400
410
420
430
440
450
460
470
480
490
500
510
520
530
540
550
560
570
580
590
600
610
620
630
640
650
660
670
680
690
700
710
720
730
740
750
760
770
780
790
800
810
820
830
840
850
860
870
880
890
900
910
920
930
940
950
960
970
980
990
1000
1010
1020
1030
1040
1050
1060
1070
1080
1090
1100
1110
1120
1130
1140
1150
1160
1170
1180
1190
1200
1210
1220
1230
1240
1250
1260
1270
1280
1290
1300
1310
1320
1330
1340
1350
1360
1370
1380
1390
1400
1410
1420
1430
1440
1450
1460
1470
1480
1490
1500
1510
1520
1530
1540
1550
1560
1570
1580
1590
1600
1610
1620
1630
1640
1650
1660
1670
1680
1690
1700
1710
1720
1730
1740
1750
1760
1770
1780
1790
1800
1810
1820
1830
1840
1850
1860
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
2110
2120
2130
2140
2150
2160
2170
2180
2190
2200
2210
2220
2230
2240
2250
2260
2270
2280
2290
2300
2310
2320
2330
2340
2350
2360
2370
2380
2390
2400
2410
2420
2430
2440
2450
2460
2470
2480
2490
2500
2510
2520
2530
2540
2550
2560
2570
2580
2590
2600
2610
2620
2630
2640
2650
2660
2670
2680
2690
2700
2710
2720
2730
2740
2750
2760
2770
2780
2790
2800
2810
2820
2830
2840
2850
2860
2870
2880
2890
2900
2910
2920
2930
2940
2950
2960
2970
2980
2990
3000
3010
3020
3030
3040
3050
3060
3070
3080
3090
3100
3110
3120
3130
3140
3150
3160
3170
3180
3190
3200
3210
3220
3230
3240
3250
3260
3270
3280
3290
3300
3310
3320
3330
3340
3350
3360
3370
3380
3390
3400
3410
3420
3430
3440
3450
3460
3470
3480
3490
3500
3510
3520
3530
3540
3550
3560
3570
3580
3590
3600
3610
3620
3630
3640
3650
3660
3670
3680
3690
3700
3710
3720
3730
3740
3750
3760
3770
3780
3790
3800
3810
3820
3830
3840
3850
3860
3870
3880
3890
3900
3910
3920
3930
3940
3950
3960
3970
3980
3990
4000
4010
4020
4030
4040
4050
4060
4070
4080
4090
4100
4110
4120
4130
4140
4150
4160
4170
4180
4190
4200
4210
4220
4230
4240
4250
4260
4270
4280
4290
4300
4310
4320
4330
4340
4350
4360
4370
4380
4390
4400
4410
4420
4430
4440
4450
4460
4470
4480
4490
4500
4510
4520
4530
4540
4550
4560
4570
4580
4590
4600
4610
4620
4630
4640
4650
4660
4670
4680
4690
4700
4710
4720
4730
4740
4750
4760
4770
4780
4790
4800
4810
4820
4830
4840
4850
4860
4870
4880
4890
4900
4910
4920
4930
4940
4950
4960
4970
4980
4990
5000
5010
5020
5030
5040
5050
5060
5070
5080
5090
5100
5110
5120
5130
5140
5150
5160
5170
5180
5190
5200
5210
5220
5230
5240
5250
5260
5270
5280
5290
5300
5310
5320
5330
5340
5350
5360
5370
5380
5390
5400
5410
5420
5430
5440
5450
5460
5470
5480
5490
5500
5510
5520
5530
5540
5550
5560
5570
5580
5590
5600
5610
5620
5630
5640
5650
5660
5670
5680
5690
5700
5710
5720
5730
5740
5750
5760
5770
5780
5790
5800
5810
5820
5830
5840
5850
5860
5870
5880
5890
5900
5910
5920
5930
5940
5950
5960
5970
5980
5990
6000
6010
6020
6030
6040
6050
6060
6070
6080
6090
6100
6110
6120
6130
6140
6150
6160
6170
6180
6190
6200
6210
6220
6230
6240
6250
6260
6270
6280
6290
6300
6310
6320
6330
6340
6350
6360
6370
6380
6390
6400
6410
6420
6430
6440
6450
6460
6470
6480
6490
6500
6510
6520
6530
6540
6550
6560
6570
6580
6590
6600
6610
6620
6630
6640
6650
6660
6670
6680
6690
6700
6710
6720
6730
6740
6750
6760
6770
6780
6790
6800
6810
6820
6830
6840
6850
6860
6870
6880
6890
6900
6910
6920
6930
6940
6950
6960
6970
6980
6990
7000
7010
7020
7030
7040
7050
7060
7070
7080
7090
7100
7110
7120
7130
7140
7150
7160
7170
7180
7190
7200
7210
7220
7230
7240
7250
7260
7270
7280
7290
7300
7310
7320
7330
7340
7350
7360
7370
7380
7390
7400
7410
7420
7430
7440
7450
7460
7470
7480
7490
7500
7510
7520
7530
7540
7550
7560
7570
7580
7590
7600
7610
7620
7630
7640
7650
7660
7670
7680
7690
7700
7710
7720
7730
7740
7750
7760
7770
7780
7790
7800
7810
7820
7830
7840
7850
7860
7870
7880
7890
7900
7910
7920
7930
7940
7950
7960
7970
7980
7990
8000
8010
8020
8030
8040
8050
8060
8070
8080
8090
8100
8110
8120
8130
8140
8150
8160
8170
8180
8190
8200
8210
8220
8230
8240
8250
8260
8270
8280
8290
8300
8310
8320
8330
8340
8350
8360
8370
8380
8390
8400
8410
8420
8430
8440
8450
8460
8470
8480
8490
8500
8510
8520
8530
8540
8550
8560
8570
8580
8590
8600
8610
8620
8630
8640
8650
8660
8670
8680
8690
8700
8710
8720
8730
8740
8750
8760
8770
8780
8790
8800
8810
8820
8830
8840
8850
8860
8870
8880
8890
8900
8910
8920
8930
8940
8950
8960
8970
8980
8990
9000
9010
9020
9030
9040
9050
9060
9070
9080
9090
9100
9110
9120
9130
9140
9150
9160
9170
9180
9190
9200
9210
9220
9230
9240
9250
9260
9270
9280
9290
9300
9310
9320
9330
9340
9350
9360
9370
9380
9390
9400
9410
9420
9430
9440
9450
9460
9470
9480
9490
9500
9510
9520
9530
9540
9550
9560
9570
9580
9590
9600
9610
9620
9630
9640
9650
9660
9670
9680
9690
9700
9710
9720
9730
9740
9750
9760
9770
9780
9790
9800
9810
9820
9830
9840
9850
9860
9870
9880
9890
9900
9910
9920
9930
9940
9950
9960
9970
9980
9990
10000

```





```

115      READ (5,140) (TABLK(K,I), K = 1, NIT13)
        READ (5,140) (TABLK(K,I), K = NIT13+1, NIT12)
        READ (5,140) (TABLK(K,I), K = NIT12+1, NIT11)
        GO TO (654,656), I
        GO TO (656,660), NTD
120      READ (5,140) (TABLK(K,I), K = NIT13+1, NIT14)
        READ (5,140) (TABLK(I), K = NIT14+1, NF)
        GO TO 670
        READ (5,140) MITR3
        NF = NIT13 + NTP
125      READ (5,140) (TABLK(K,I), K = NIT13+1, NF)
        CONTINUE
        CALL INALC
        RETURN
        END
        DEIN1004
        DEIN1005
        DEIN1006
        DEIN1007
        DEIN1008
        DEIN1009
        DEIN1010
        DEIN1011
        DEIN1012
        DEIN1013
        DEIN1014
        DEIN1015
        DEIN1016
        DEIN1017
        DEIN1018
        DEIN1019
        DEIN110
        DEIN111
    
```







```

C SURROUTINE CALC SURROUTINE CALC
SURROUTINE FOR COMPUTING PROBABILITY DENSITY FUNCTIONS
COMMON F(10000), NTEGER(100), TABL4(2000,2),
5 TABL2(500,3)
REAL NZ, NT, NZI(25), NTR
DIMENSION PSIL(100), PPSI(100), POPSI(100), A(3,6),
1 1(13,2)
DIMENSION HI(25), HII(25), VII(25)
DIMENSION NTB4(12), NTB42(2), NTB43(2), NTB44(2)
EQUIVALENCE IP(1), FVI, (P(2), FN2), (P(3), FN1),
10 (P(4), FM), (P(5), FACTOR)
EQUIVALENCE IP(100), NF
EQUIVALENCE IP(101), PSIL, (P(1001), PPSI),
15 (P(1101), POPSI)
EQUIVALENCE IP(5001), VII, (P(5026), NZI),
(P(5076), KI)
EQUIVALENCE INTEGER(11), MPSIL
EQUIVALENCE INTEGER(15), MPPSI
EQUIVALENCE INTEGER(18), MRH
20 (INTEGER(17), NRH), (INTEGER(18), MRM)
EQUIVALENCE INTEGER(21), NTB1
EQUIVALENCE INTEGER(56), NTB41, (INTGER(16), MRM2),
(INTEGER(15A), NTB42), CALC 1
(INTEGER(60), NTB43), INTEGER(62), NTB44,
(INTEGER(65), MFB22) CALC 9
C COMPUTE THE TOTAL NUMBER OF OCCURRENCES FROM HISTY
NP12 = NP41(1) + NTB42(1) CALC 10
NP13 = NP12 + NTB43(1) CALC 101
NM14 = NTB41(1) + NTB42(1) + NTB43(1) + NTB44(1) CALC 102
NM22 = NTB41(2) + NTB42(2) CALC 103
NM23 = NM22 + NTB43(2) CALC 11
NM24 = NM23 + NTB44(2) CALC 12
NP22 = NTB41(2) + NTB42(2) CALC 13
NP23 = NP22 + NTB43(2) CALC 131
NP24 = NP23 + NTB44(2) CALC 14
NM24P1 = NP24 + 1 CALC 15
NM24P2 = NP24 + NP24 CALC 16
NF = 0 + 0 CALC 17
DO 10 I = NM24P1, NMP24 CALC 18
NT = TABL4(I,2) + NT CALC 181
RNZ = NFVI CALC 182
RM = NRM CALC 183
RM = NRM CALC 184
NTR = NT + RVI + RNZ + RM + RM CALC 185
NTB21 = NTB41(2) CALC 186
NTB22 = NTB42(2) CALC 190
NTB23 = NTB43(2) CALC 191
NTB24 = NTB44(2) CALC 192
DO 12 I = 1, NTB21 CALC 193
VII(1) = TABL4(I,2) CALC 194
VII(NTB21+1) = FVI CALC 195
DO 14 J = 1, NTB22 CALC 196
JTB = J + NTB41(2) CALC 197
NZI(J) = TABL4(JTB,2) CALC 198
NZI(NTB22+1) = FNZ CALC 199
DO 16 K = 1, NTB23 CALC 200
KTB = K + NM22 CALC 201
HII(K) = TABL4(KTB,2) CALC 203

```

```

MI(MF423+1) = FM
DO 10 M = 1, NT424
MTR = M + N23
MI(M) = TABL4(MTR,2)
MI(MT424+1) = FM
DO 30 I = 1, NT421
DO 30 J = 1, NT422
DO 30 K = 1, NT423
DO 30 M = 1, NT424
N222 = NA24 * (M - 1) * NP23 + (K - 1) * NP22
MI(MT424+1) = I
PJT = TABL4(MT222,2) / NTP
DO 30 IP = 1, NPV1
DO 30 JP = 1, NPAZ
DO 30 KP = 1, NPH
DO 30 MA = 1, NPM
RIR = IK
RJP = JP
RNR = NR
RMR = MR
RATIR = (PTR - 0.5) / RVI
RAYJR = (EJR - 0.5) / RNZ
RATJR = (EJR - 0.5) / RH
RATMR = (EMR - 0.5) / RM
VI = VII(1) * RAYJR + (VTI(1) - VII(1))
M = MI(K) * RAYJR + (MI(K) - MI(K))
M = MI(M) * RAYMR + (MI(M) - MI(M))
GO TO (200, 300), NTR
CALL TAPQ (TABL4(1), VI, N7, M, CSI, NTR4(1)),
NTR4(1), NTR4(1))
GO TO 14
300 1 NTR4(2(1),
NTR4(1))
CALL TART (TABL4(1), VI, N2, M, CSI, NTR4(1)),
NTR4(1))
PSI = CSI * FACTOR
DO 30 II = 1, NPSIL
PPSI(II) = PSI + PPSI(II)
CONTINUE
MPLM2 = NPSIL - 2
DO 130 I = 1, MPLM2
II = I + 1
I2 = I + 2
A(1,1) = PSIL(1) **2
A(1,2) = PSIL(1)
A(1,3) = 1.0
A(2,1) = PSIL(1) **2
A(2,2) = 1.0
A(3,1) = PSIL(1) **2
A(3,2) = PSIL(1)
A(3,3) = 1.0
A(4,4) = - PPSI(1)
A(2,4) = - PPSI(1)
A(3,4) = - PPSI(1)
CALL GAUSS2(1,1,1,0E-07,4,X,K3)
IF (K3-1) 60, 80, 60

```

```
115      6C      WRITE (6,70) K3          CALC 72
120      70      FORMAT (10X, 26HGAUSS2 ERPOK SIGNAL + K3 = , 13)    CALC 73
125      80      IF (I-1) 160, 100, 90    CALC 74
130      90      IF (I-NPLP2) 120, 110, 160    CALC 75
135      100     PDPST(I) = 2.0 * X(I) * PSIL(I) + X(I)2    CALC 76
140      110     GO TO 120    CALC 77
145      120     PDPST(I) = 2.0 * X(I) * PSIL(I) + X(I)2    CALC 78
150      130     PDPST(I) = 2.0 * X(I) * PSIL(I) + X(I)2    CALC 79
155      140     CONTINUE    CALC 80
160      150     RETURN    CALC 81
165      160     END    CALC 82
```

```

SUBROUTINE LOLVL
  SUBROUTINE FOR COMPUTING INTERNAL LOAD LEVELS FOR
  A GIVEN DISTRIBUTION OF LOAD CYCLES
  COMMON P(10000), NIEGR(100), FARL(2000,2),
  DIMENSION PPSI(100), APOPSI(100),
  PSILL(100), AREAN(100), PSIL(100), FRAC(100),
  EQUIVALENCE (P(101), PSILL),
  1 P(201), AREAN(1), PPSI(1), PPSI(1), APOPSI(1),
  2 P(1301), PSILL(1), AREAN(1), FRAC(1),
  EQUIVALENCE (NIEGR(11), NPSIL), (NIEGR(12), NPSILL),
  DELTA = PSIL(2) - PSIL(1)
  DO 10 J = 1, NPSIL
    APOPSI(J) = 1.0 - PPSI(J)
    IF (AREAN(J) - APOPSI(J)) 20, 50, 50
  20 WRITE (6,40)
  30 FORMAT (10X, 50#ERRR MESSAGE - AREAN(1) LESS THAN APOPSI(1) )
    CALL PRINTR
    IF (AREAN(NPSIL) - APOPSI(NPSIL)) 99, 99, 60
  60 WRITE (6,70)
  70 FORMAT (10X, 50#ERRR MESSAGE - AREAN(NPSIL) GREATER THAN APOPSI(NPSIL) )
    CALL PRINTR
  90 DO 100 J = 1, NPSIL
    DO 100 I = 1, NPSIL
      IF (I-1) 120, 120, 130
      P1 = APOPSI(I)
      P2 = APOPSI(I+1)
      P3 = APOPSI(I+2)
      GO TO 140
      P1 = APOPSI(I+1)
      P2 = APOPSI(I)
      P3 = APOPSI(I+1)
      A = 0.5 * P1 - P2 + 0.5 * P3
      B = -0.5 * P1 + 0.5 * P3
      C = P2 - AREAN(I)
      DISC = B * P2 + A * P3
      IF (DISC) 142, 144, 144
      WRITE (6,143) DISC
    142 FORMAT (10X, 6#DISC =, E15.6)
    CALL PRINTR
    144 ETA = (-P + SORT(DISC)) / (2.0 * A)
    IF (I-1) 150, 150, 160
    PSILL(I) = PSIL(I) + ETA * DELTA
    GO TO 180
    PSILL(I) = PSIL(I) + ETA * DELTA
    GO TO 180
  170 CONTINUE
  180 CONTINUE
  NPR = NPSIL - 1
  FRAC(1) = (AREAN(1) + AREAN(2)) / 2.0
  DO 190 I = 2, NPR
    FRAC(I) = (AREAN(I) + AREAN(I+1)) / 2.0
    FRAC(NPSIL) = 1.0 - (AREAN(NPSIL) +

```

LOLV 458  
LOLV 46  
LOLV 47

1 AREAMPSILL-103 / 2.0  
RETURN  
END

60

```

C      SUBROUTINE LDCOEF
C      SUBROUTINE FOR COMPUTING THE LOAD CONDITION COEFFICIENTS
C      COMMON P(10000), MTEG(9100), TAPLE(200,2),
C      TABL2(500,3)
C      DIMENSION PSILL(1000), PS(25,25), ALPHA(25),
C      EQUVALENT(4(30)), PSI, (PI(30)), PSILL,
C      FCJVALENCE INTEGER(12), NPSTILL, (NTEG(913)), NPST,
C      INFLGER(43), NPAGE), (INTEG(450)), NPSC(1)
C      NPSC(1) = MTEG(1)
C      DO 10 I = 1, NPSTILL
C      PLSII(NPSC(I)) = PSILL(I)
C      IF (NPST(I) - NPS) 30, 20, 20
C      DO 50 J = 1, NPS
C      DO 50 J = 1, NPS
C      ATII(J) = PS(I,J)
C      JNPS = J + NPS
C      IF (I - J) 40, 30, 40
C      ATII(JNPS) = 1.0
C      GO TO 50
C      ATII(JNPS) = 0.0
C      CONTINUE
C      CALL GAUSS21 (NPS, NPS, 1.0E-07, A, ATIW, K3)
C      IF (K3 - 1) 60, 75, 60
C      WRITE (4,70) K3
C      FORMAT (10X, 24HGAUSS21 ERROR SIGNAL - K3 = , I3 )
C      NPAGE = NPAGE + 1
C      CALL PAGE(0)
C      DO 120 I = 1, NPSTILL
C      DO 80 J = 1, NPS
C      PLO(I,J) = PLSII(I,J)
C      DO 90 K = 1, NPS
C      ALPHA(K) = 0.0
C      DO 90 L = 1, NPS
C      ALPHA(K) = ATIW(K,L) * PLO(L) + ALPHA(K)
C      WRITE (6,100) I
C      FORMAT (/10X, 36HCOEFFICIENTS FOR FREQUENCY LEVEL NO. , I5 )
C      WRITE (6,110) (ALPHA(I), IA = 1, NPS)
C      FORMAT (1PE12.6)
C      CONTINUE
C      RETURN
C      END

```

COEF 1  
COEF 2  
COEF 3  
COEF 4  
COEF 5  
COEF 6  
COEF 7  
COEF 8  
COEF 9  
COEF 10  
COEF 11  
COEF 12  
COEF 13  
COEF 14  
COEF 15  
COEF 16  
COEF 17  
COEF 18  
COEF 19  
COEF 20  
COEF 21  
COEF 22  
COEF 23  
COEF 24  
COEF 25  
COEF 26  
COEF 27  
COEF 28  
COEF 29  
COEF 30  
COEF 31  
COEF 32  
COEF 33  
COEF 34  
COEF 35  
COEF 36  
COEF 37  
COEF 38  
COEF 39  
COEF 40  
COEF 41  
COEF 42

```

1  AMP, NTAB1, NTAB2, NTAB3)
C  SUBROUTINE FOR STRAIGHT LINE INTERPOLATION IN A TRIPLE
C  TABLE LOOK UP
5  DIMENSION TABLE (2000)
   10  I1 = 1, NTAB1
   IF (TABLE(I1)) - X1ARG) 10, 20, 20
   CONTINUE
   I1 = NTAB1
   IF (I1 - 1) 30, 30, 40
   I1 = 2
   NTAB1 = NTAB1 + 1
   NTAB2 = NTAB1 + NTAB2
   15  00 50 I2 = NTAB1, NM12
   IF (TABLE(I2) - X2ARG) 50, 60, 60
   CONTINUE
   I2 = NM12
   IF (I2 - 1) 70, 70, 80
   I2 = NTAB1 + 2
   NTAB1 = NM12 + 1
   20  NM13 = NM12 + NTAB3
   00 90 I3 = NTAB1, NM13
   IF (TABLE(I3) - X3ARG) 90, 100, 100
   CONTINUE
   I3 = NM13
   IF (I3 - 1) 110, 110, 120
   I3 = NM12 + 2
   NP12 = NTAB1 + NTAB2
   NP13 = NP12 + NTAB3
   30  N222 = NM13 + I3 - NM12 - 1) * NP12 +
   N122 = N222 - 1
   N112 = N222 - NTAB1
   N113 = N222 - 1
   N121 = N221 - 1
   N211 = N221 - NTAB1
   N111 = N211 - 1
   X1PAT = (Y1ARG - TABLE(I1-1)) /
   X2PAT = (Y2ARG - TABLE(I2-1)) /
   40  (TABLE(I1) - TABLE(I1-1)) /
   (TABLE(I2) - TABLE(I2-1))
   X3PAT = (Y3ARG - TABLE(I3-1)) /
   (TABLE(I3) - TABLE(I3-1))
   APP11 = TABLE(N111) + X1PAT * (TABLE(N211) -
   TABLE(N111))
   AMP21 = TABLE(N121) + X1PAT * (TABLE(N211) -
   TABLE(N121))
   AMP12 = TABLE(N112) + X1PAT * (TABLE(N212) -
   TABLE(N112))
   AMP22 = TABLE(N122) + X1PAT * (TABLE(N222) -
   TABLE(N122))
   AMP3 = AMP11 + X2PAT * (AMP21 - AMP11)
   AMP4 = AMP12 + X2PAT * (AMP22 - AMP12)
   AMP = AMP3 + X3PAT * (AMP2 - AMP3)
   RETURN
   END

```

```

SUBROUTINE JABO (TABLE, XIARG, X2ARG, XIARG, X2ARG, XIARG,
1 XARG, AMP, NTAB1, NTAB2, NTAB3, NTAB4)
SUBROUTINE FOR STRAIGHT LINE INTERPOLATION IN A QUADRUPL
2 TABLE LOOK UP
3
4 DIMENSION TABLE (2000)
5 DO 10 I1 = 1, NTAB1
6 IF (TABLE(I1) - XIARG) 10, 20, 20
7 CONTINUE
8 XI = NTAB1
9 IF (I1 - 1) 30, 30, 40
10 IF (I1 = 2)
11 XI = 2
12 NTIP1 = NTAB1 + 1
13 NTIP2 = NTAB1 + NTAB2
14 DO 50 I2 = NTIP1, NN12
15 IF (TABLE(I2) - X2ARG) 50, 60, 60
16 CONTINUE
17 I2 = NN12
18 IF (I2 - NTIP1) 70, 70, 80
19 I2 = NTAB1 + 2
20 NTIP1 = NTIP1 + 1
21 NN13 = NN12 + NTAB3
22 DO 90 I3 = NTIP1, NN13
23 IF (TABLE(I3) - X3ARG) 90, 100, 100
24 CONTINUE
25 I3 = NN13
26 IF (I3 - NTIP1) 110, 110, 120
27 I3 = NN12 + 2
28 NTIP1 = NTIP1 + 1
29 NN14 = NTIP1 + NTAB4
30 DO 130 I4 = NTIP1, NN14
31 IF (TABLE(I4) - X4ARG) 130, 140, 140
32 CONTINUE
33 I4 = NN14
34 IF (I4 - NTIP1) 150, 150, 160
35 I4 = NN13 + 2
36 NTIP1 = NTAB1 + NTAB2
37 NTIP2 = NTIP1 + NTAB3
38 NTIP3 = NTIP2 + NTAB4
39 IF (TABLE(NTIP3) - XI) * NTIP3 + I1
40 NTIP2 = NTIP2 - 1
41 NTIP1 = NTIP1 - 1
42 NTIP2 = NTIP2 - 1
43 NTIP1 = NTIP1 - 1
44 NTIP2 = NTIP2 - 1
45 NTIP1 = NTIP1 - 1
46 NTIP2 = NTIP2 - 1
47 NTIP1 = NTIP1 - 1
48 NTIP2 = NTIP2 - 1
49 NTIP1 = NTIP1 - 1
50 NTIP2 = NTIP2 - 1
51 NTIP1 = NTIP1 - 1
52 NTIP2 = NTIP2 - 1
53 NTIP1 = NTIP1 - 1
54 NTIP2 = NTIP2 - 1
55 XIARG = XIARG - TABLE(NTIP1)
56 X2ARG = X2ARG - TABLE(NTIP2)
57

```

```

1  (TABLE(12) - TABLE(12-1)) * X2RAT = (X2RAT - TABLE(12-1)) /
60 (TABLE(13) - TABLE(13-1)) * X2RAT = (X2RAT - TABLE(13-1)) /
1  (TABLE(14) - TABLE(14-1)) * X2RAT = (X2RAT - TABLE(14-1)) /
1  TABLE(N111) = TABLE(N111) * X1RAT * (TABLE(N211) -
65 TABLE(N111))
1  TABLE(N112) = TABLE(N112) * X1RAT * (TABLE(N212) -
TABLE(N112))
1  TABLE(N121) = TABLE(N121) * X1RAT * (TABLE(N212) -
70 TABLE(N121))
1  TABLE(N122) = TABLE(N122) * X1RAT * (TABLE(N222) -
TABLE(N122))
1  TABLE(N111) = TABLE(N111) * X1RAT * (TABLE(N211) -
TABLE(N111))
1  TABLE(N121) = TABLE(N121) * X1RAT * (TABLE(N212) -
75 TABLE(N121))
1  TABLE(N122) = TABLE(N122) * X1RAT * (TABLE(N222) -
TABLE(N122))
1  TABLE(N122) = TABLE(N122) * X1RAT * (TABLE(N222) -
TABLE(N122))
AMP11 = APP11 * X2RAT * (AMP21 - AMP11)
AMP21 = APP12 * X2RAT * (AMP21 - AMP12)
AMP12 = APP11 * X2RAT * (AMP21 - AMP12)
AMP22 = APP12 * X2RAT * (AMP22 - AMP12)
AMP1 = AMP11 * X2RAT * (AMP21 - AMP11)
AMP2 = AMP12 * X2RAT * (AMP22 - AMP12)
AMP = AMP1 * X1RAT * (AMP2 - AMP1)
RETURN
END

```



```

SUBROUTINE GAUSS2(M,CP,AK,KERN,
DIMENSION A(3,4), X(3,1)
5
MPN=MPM
DO 34 I=1,M
  KP=0
  DO 12 K=1,M
    IF 17 AND (AK(L1))11,12,12
    ZEAL'S (AK,L1)
  KPEK
12 CONTINUE
13 DO 14 J=1,NPM
  ZEAL(L,J)
  AK(L,J)=AKP(J)
14 AKG(J)=2
20 TEIAMS (AIL,L1)=EP150+50,30
30 IF 14-N131,40,40
  LPI=L+1
20 DO 34 K=LPI,N
  TEI(K,L1)32,34,32
  RPTID=AK(L1)/AIL(L1)
33 AK(L1)=AK(L1)-RATIO*AIL(J)
34 CONTINUE
40 IF 43 I=1,M
  I=I+1
  DO 43 J=1,M
    JPN=J+N
    S=0.1
    IF 11-N141,43,43
    IPI 11+1
    DO 42 K=IPI,M
      S=S+AI(K)*KPK(K,J)
    X(I1,J)=I*AI1(JPN)-S/A(I1,I1)
    K=K+1
  GO TO 75
50 K=K+2
75 CONTINUE
  RETURN
  END
GAUS 001
GAUS 002
GAUS 003
GAUS 004
GAUS 005
GAUS 006
GAUS 007
GAUS 008
GAUS 009
GAUS 010
GAUS 011
GAUS 012
GAUS 013
GAUS 014
GAUS 015
GAUS 016
GAUS 017
GAUS 018
GAUS 019
GAUS 020
GAUS 021
GAUS 022
GAUS 023
GAUS 024
GAUS 025
GAUS 026
GAUS 027
GAUS 028
GAUS 029
GAUS 030
GAUS 031
GAUS 032
GAUS 033
GAUS 034
GAUS 035
GAUS 036
GAUS 037
GAUS 038
GAUS 039
GAUS 040

```





```

      MPAGE 8, MPAGE 1
      CALL PAGEHO
      WRITE (6, F0)
      60  FORMAT(10X, 20MCYCLIC LOADING FRACTIONS.)
      WRITE (6, F0)
      70  FORMAT (19X, 4NLOAD, 5X, 8NFRACTION, 19X, 4NLOAD, 5X,
      1  8NFRACTION, 19X, 4NLOAD, 5X, 8NFRACTION)
      DO 80 I = 1, MPSILL, 3
      85  I1 = I + 1
      86  I2 = I + 2
      80  WRITE (6, 30) PSILL(I), F0AC(I), PSILL(I1), F0AC(I1),
      1  PSILL(I2), F0AC(I2)
      90  FORMAT(10X, 19NCTAL LOAD CYCLES =, F12.0)
      RETURN
      END
      PNT 28
      PNT 29
      PNT 30
      PNT 31
      PNT 32
      PNT 33
      PNT 34
      PNT 35
      PNT 36
      PNT 37
      PNT 38
      PNT 39
      PNT 391
      PNT 392
      PNT 40
      PNT 41

```