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# Application of a Computerized Vibroacoustic Data Bank for Random Vibration Criteria Development

Robin C. Ferebee



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# Application of a Computerized Vibroacoustic Data Bank for Random Vibration Criteria Development

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**Scientific and Technical  
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## TECHNICAL PAPER

# APPLICATION OF A COMPUTERIZED VIBROACOUSTIC DATA BANK FOR RANDOM VIBRATION CRITERIA DEVELOPMENT

## INTRODUCTION

The engine generated acoustic and aerodynamic fluctuating pressure environments produced by space launch vehicles create substantial vibratory motion of the vehicle structure. The prediction of these vibration environments is critical for the success of the missions. The broad band response characteristics of the structure preclude established analytical methods of prediction, so an extrapolation method based on past space vehicle testing programs was developed. This method relies on an established scaling technique to predict the new vehicle's response. Because of the large data base and the voluminous amount of criteria required to support Space Shuttle launches, an automated method was needed to speed up the prediction process. A computer system was developed that stores the data base and automatically scales the data to predict and formulate new component design and test criteria. This document serves as a review of the criteria derivation process and also as a user's manual for the computer programs.

## DATA BANK DEVELOPMENT

The information that is stored in the data bank came from past launch vehicle programs, mainly Saturn V and static Titan III tests and launches. The data were categorized according to the type of structure, i.e., ring frame, skin, skin-stringer, and honeycomb. In the future, the data bank will include more advanced structures, such as graphite-epoxy composites and fiberglass. The data were then sub-grouped according to specific structural parameters, such as the size of the ring frame or the thickness of the skin on the weight of the stringers. Generally, measurements in three directions were available: longitudinal (along the vehicle's axis), radial (perpendicular to the skin), and tangential (normal to the longitudinal and radial directions). In addition, measurements at four different flight conditions were included. These flight conditions are liftoff, Mach 1, maximum dynamic pressure (max Q), and a combination of Mach 1 and max Q; however, some measurements were taken only during static firings or Mobile Acoustic Research Laboratory (MARL). The MARL was a mobile structure that allowed test structures (such as the Saturn V Instrument Unit) to be placed next to static engine tests and exposed to the acoustic field.

Next, the 97.5 percent confidence level spectrum of each vibration measurement for all tests was computed. The 97.5 percent confidence level is a statistical function that encompasses 97.5 percent of the available data. This particular confidence level was chosen as a good compromise between conservatism and practicality. This confidence level was also calculated for the acoustic spectra that produced the vibration response in the structures.

For the convenience of storing only one spectrum for each measurement, the vibration and acoustic spectra were normalized to an arbitrary reference acoustic spectrum (Fig. 1). This particular spectrum has no meaning other than it is a typical Saturn V liftoff spectrum. The normalization was done according to the following equation:

$$G_R(f) = G_M(f) \left[ \frac{P_R(f)}{P_M(f)} \right]^2 ,$$

**ACOUSTIC SPECTRUM: REFERENCE**

**FLIGHT CONDITION: ALL**

**DOCUMENT: TN D-7159**

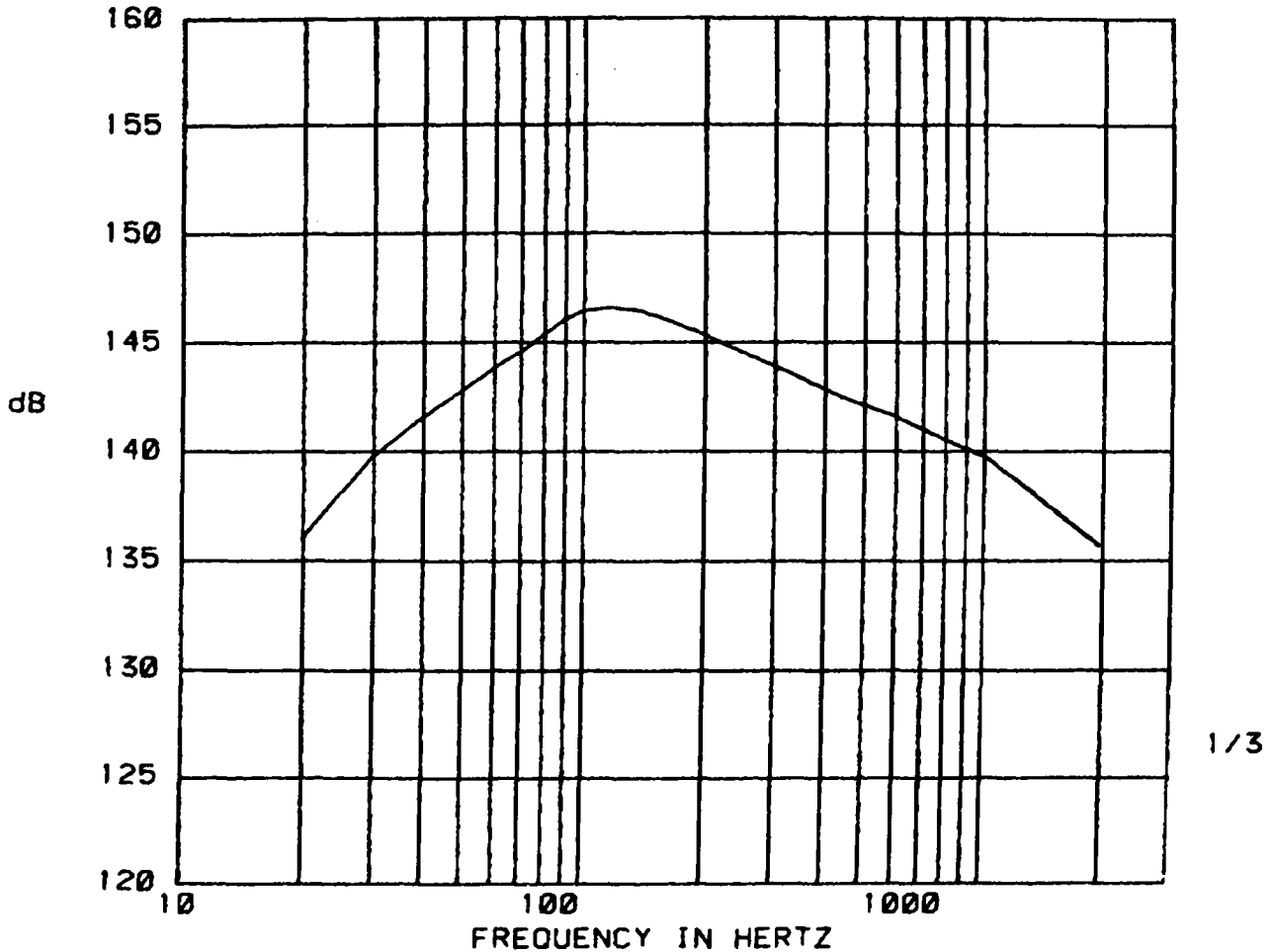


Figure 1. Reference acoustic function.

where the subscript M refers to the 97.5 percent confidence level spectrum of the measured data, and  $P_R$  refers to the aforementioned reference acoustic spectrum. This normalized vibration spectrum, along with its structural parameters, was then stored on a computer tape file.

**Random Vibration Criteria Development**

Vibration scaling using a data bank is based on the principle of dynamic similarity. In other words, the vibration response of a new structure is approximated by the ratio of the masses of the structures, multiplied by the ratio of the acoustic forcing function that produced the reference vibration response and the new acoustic forcing function. This is expressed in equation form as

$$G_N(f) = G_R(f) \left[ \frac{P_N(f)}{P_R(f)} \right]^2 \left[ \frac{W_R}{W_N} \right]^2 \quad (1)$$

where

$G_N(f)$  = the predicted vibration response of the new structure as a function of frequency

$G_R(f)$  = the data bank (reference) vibration response

$P_N(f)$  = the new acoustic forcing function

$P_R(f)$  = the reference acoustic forcing function

$W_R$  = the weight of the reference structure (over back-up area)

$W_N$  = the weight of the new structure (over back-up area).

After applying equation (1), the predicted vibration response is plotted versus frequency; and the criteria are developed from it.

### Component Mass Loading

Mounting a component to a skin panel mass-loads the panel and alters its response. The following correction factor can be added to equation (1) to account for the mass loading:

$$\frac{W_N}{W_N + W_C} \quad (A)$$

where

$W_N$  = weight of new structure

$W_C$  = weight of component.

The scaling equation [equation (1)] is now

$$G_N(f) = G_R(f) \left[ \frac{P_N(f)}{P_R(f)} \right]^2 \left[ \frac{W_R}{W_N} \right]^2 \left[ \frac{W_N}{W_N + W_C} \right] \quad (1A)$$

## Statistical Analysis

The data stored in the data bank is the 97.5 percent confidence level of a large amount of data. All of the appropriate data from a test program were grouped by similar structure. Accelerometers mounted next to or on a component were excluded. Next, each spectrum was digitized and the confidence level computed. The confidence level is defined by

$$Y_i(97.5 \text{ percent C.L.}) = \bar{X}_i + N_i \sigma_i \quad (2)$$

where

$Y_i$  = confidence level

$\bar{X}_i$  = mean value (of ith frequency increment)

$N_i$  = N factor

$\sigma_i$  = standard deviation.

The mean is defined as

$$\bar{X}_i = \frac{1}{N} \sum_{j=1}^N X_i \quad , \quad (3)$$

where N is the number of samples, and  $X_i$  is the PSD value at the ith frequency increment.

The standard deviation is

$$\sigma_i = \left[ \sum_{j=1}^N \frac{(X_i - \bar{X}_i)^2}{N-1} \right]^{1/2} \quad (4)$$

This type of data is generally skewed from the standard normal distribution, so the skewness was also calculated using this equation:

$$S_i = \frac{[N(N-1)]^{1/2}}{N-2} \frac{\sum_{j=1}^N (X_i - \bar{X}_i)^3}{N \left[ \sum_{j=1}^N \frac{(X_i - \bar{X}_i)^2}{N} \right]^{3/2}} \quad (5)$$



The "N factor" takes the skewness into account:

$$N_i = 1.96 \exp(0.2055 S_i - 0.0155 S_i^2) \text{ [defined for 97.5 percent confidence level]} \quad (6)$$

When the final confidence level spectrum is calculated, it is stored on a tape or disk, along with some identifying structural parameters.

### The Computer System

The vibroacoustic data bank is designed for use with a desk-top computer with peripheral equipment, as shown in Figure 2. The dashed outlines indicate optional equipment. The system can accept data from a tape drive through a Norland 3001 signal processor, or through any other interface between a tape drive and the computer. Generally, however, data are obtained in the form of Power Spectral Density (PSD) plots that have been processed elsewhere. These plots may come from an existing data bank or from a new testing program. The PSD plots are placed on the digitizing tablet and traced point by point. The computer accepts the data and converts it into an acceptable form for storage, i.e., constant  $\Delta f$ . All identifying structural parameters are also entered at this point. The parameters and data are then output to the storage device, either a disk file or the internal tape unit. The programs include routines to display and edit raw data or scale and display processed data. The data can then be sent to a hard-copier for a permanent record.

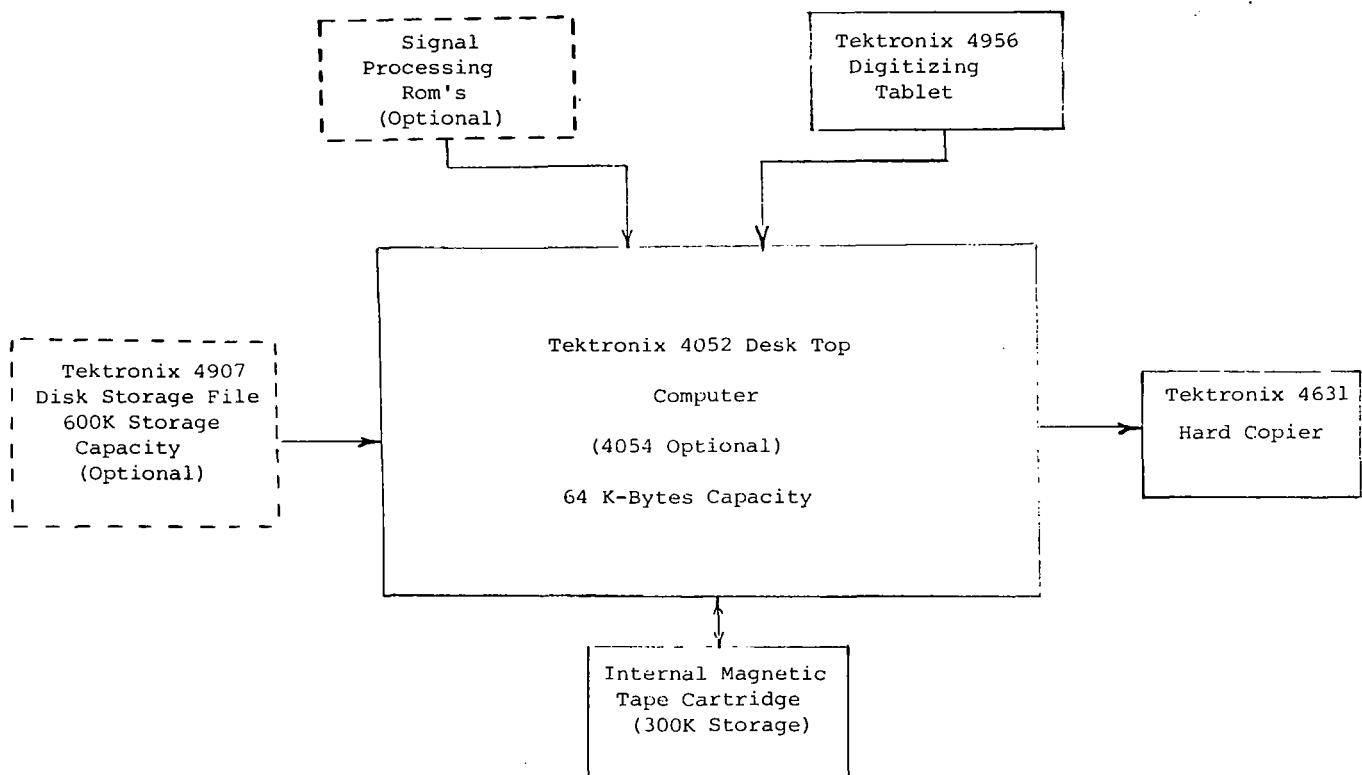
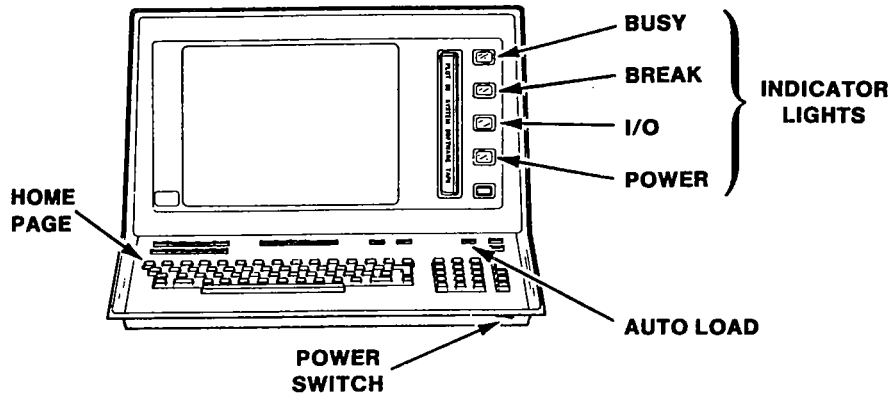


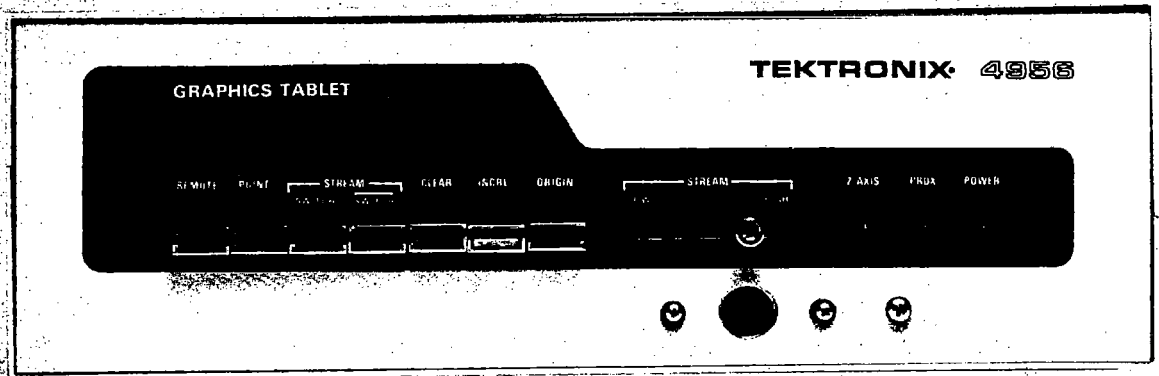
Figure 2. Vibroacoustic data bank schematic.

The 4052 and 4956 controller are shown in Figures 3 and 4.



Source: 4050 Series Graphic Computing System Operator's Manual, Tektronix, Inc., Oct. 1980, page 3-2.

Figure 3. Tektronix 4052 Computer.



2210-04

Source: 4956 Graphic Tablet Operator's Manual, Tektronix, Inc., Sept. 1980, page 1-5.

Figure 4. Tektronix 4956 Tablet Controller.

## Application of Data Banks

The following procedure is suggested for developing new vibration criteria:

- 1) Examine the tape file directories, and find a structure that corresponds as closely as possible to the new structure.
- 2) Pick a back-up area that will be the same for the old and new structures.
- 3) Calculate the total weight of the old and new back-up structures.

$$W_{\text{TOTAL}} = W_{\text{RING}} + W_{\text{SKIN}} + W_{\text{STRINGERS}}$$

$$W_{\text{RING}} = \text{ring weight/unit length} \times \text{length}$$

$$W_{\text{SKIN}} = \text{thickness} \times \text{length} \times \text{width} \times \text{material density}$$

$$W_{\text{STRINGERS}} = \text{No. stringers} \times \text{weight/unit length} \times \text{length.}$$

- 4) Determine component weight.
- 5) Store new acoustic function on a tape file.
- 6) Run "PLOT" program and follow instructions.
- 7) Draw criteria lines over predicted spectrum.
- 8) If a revision of the criteria is needed, redraw the criteria lines or enter the new criteria by hand.

## PLOT PROGRAM ("PLOT")

This program allows the user to display and scale vibration and acoustic spectra.

### User Definable Keys

Twenty user definable keys are available to the user of the Tektronix 4052. Eleven of these keys are used in this program. The keys are used as follows (Fig. 5):

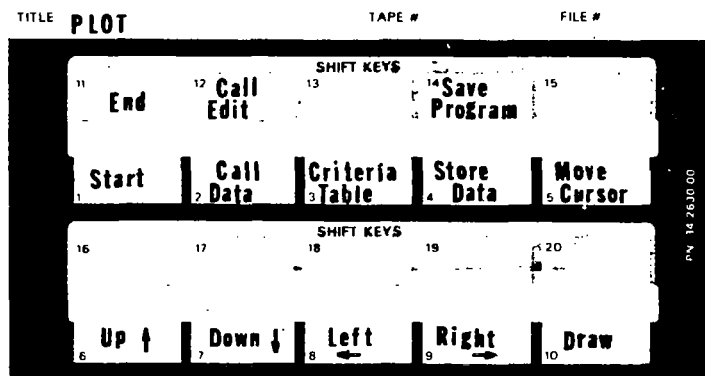


Figure 5. Location of user definable keys for "PLOT".

Keys 1 and 11 are used to start and stop the program, respectively. Keys 2 and 12 are used to call other programs. Make sure a program tape is in the slot before using these keys. Key number 5 is used to start drawing criteria lines on the plot. This key moves the cursor to a predefined spot on the graph and initializes some of the registers, Keys 6 through 9 are used to move the cursor around for drawing the criteria lines. When the cursor is at the desired location, key number 10 is pressed to draw a line between the two points. When the desired criterion is drawn, key number 3 is used to print a table of criteria points and slopes.

### Description of Program Options

To access the program, press the "AUTOLOAD" key or type FIND 4 and then OLD. When the "Start" key (U.D. Key No. 1) is pressed, the following message appears on the blank screen:

SELECT A DATA TAPE AND PRESS 'RETURN'.

This assures that a data tape is in the slot, and the programs will not be destroyed. After pressing the "Return" button, the following are listed:

SELECT ONE

- 1) PLOT DATA
- 2) PLOT MORE THAN ONE GRAPH
- 3) PLOT MEAN OR 97.5 PERCENTILE OF TWO OR MORE MEASUREMENTS
- 4) LIST FILE DIRECTORY
- 5) NORMALIZE A PSD
- 6) PRINT AN ACOUSTIC SPECTRUM

The user then selects the desired option. Option 1, PLOT DATA, plots a PSD exactly as it was stored on the tape (or disk). Option 2, PLOT MORE THAN ONE GRAPH, allows the user to display more than one PSD on the same page. No mathematical operations are performed on the data before it is displayed. Option 3, PLOT MEAN OR 97.5 PERCENTILE OF TWO OR MORE MEASUREMENTS, can display the desired statistical operation performed on data stored on the tape. Option 4, LIST FILE DIRECTORY, gives a listing of all data stored on the tape. Option 5, NORMALIZE A PSD, performs the scaling operations previously described and displays the results. Finally, option 6, PRINT AN ACOUSTIC SPECTRUM, displays an acoustic spectrum that has previously been stored on the tape. All PSD's are displayed on Log-Log plots from 20 to 2000 Hz with the amplitude scale automatically set, while acoustic spectra are displayed in semi-log form.

To display the option list after running the program, press the "Start" key (U.D. key No. 1).

#### Option 1. PLOT DATA

This part of the program allows the user to plot a PSD exactly as it is stored on tape. The PSD is displayed along with all of its identifying parameters. After selecting option 1, the screen will erase and display the following message:

ENTER STORAGE FILE NUMBER.

After typing the desired file number, the screen will display:

DO YOU WANT TO ENTER A CRITERIA ENVELOPE BEFORE PLOTTING?  
ENTER Y OR N.

This allows the user to enter criteria points to compare an old specification to a new spectrum. Typing a "Y" will make the machine display:

ENTER CRITERIA POINTS, PRESS RETURN WHEN FINISHED

FREQUENCY                      PSD

1)

Enter the criteria points, and press "Return" after each point. Press "Return" twice after entering the last point. The program will automatically display both the PSD and the specified criteria lines.

Typing an "N" after the criteria envelope question will display the specified PSD with all identifying parameters. An example is shown in Figure 6. On the right side of the page are printed the tape number, a slash (/), and the file number.

DOCUMENT: 7159/A117  
MEAS. DIRECTION: RADIAL  
FLIGHT CONDITION: STATIC  
MATERIAL: AL  
VEHICLE DIAMETER: 33 FT  
COMPOSITE: 39.77 Grms

SKIN THICKNESS: .071 IN  
RING SEPARATION: 27.0 IN  
RING WEIGHT: N/A  
STRINGER SEPARATION: 5.76 IN  
STRINGER WEIGHT: .86 LB/FT  
SURFACE WEIGHT: N/A

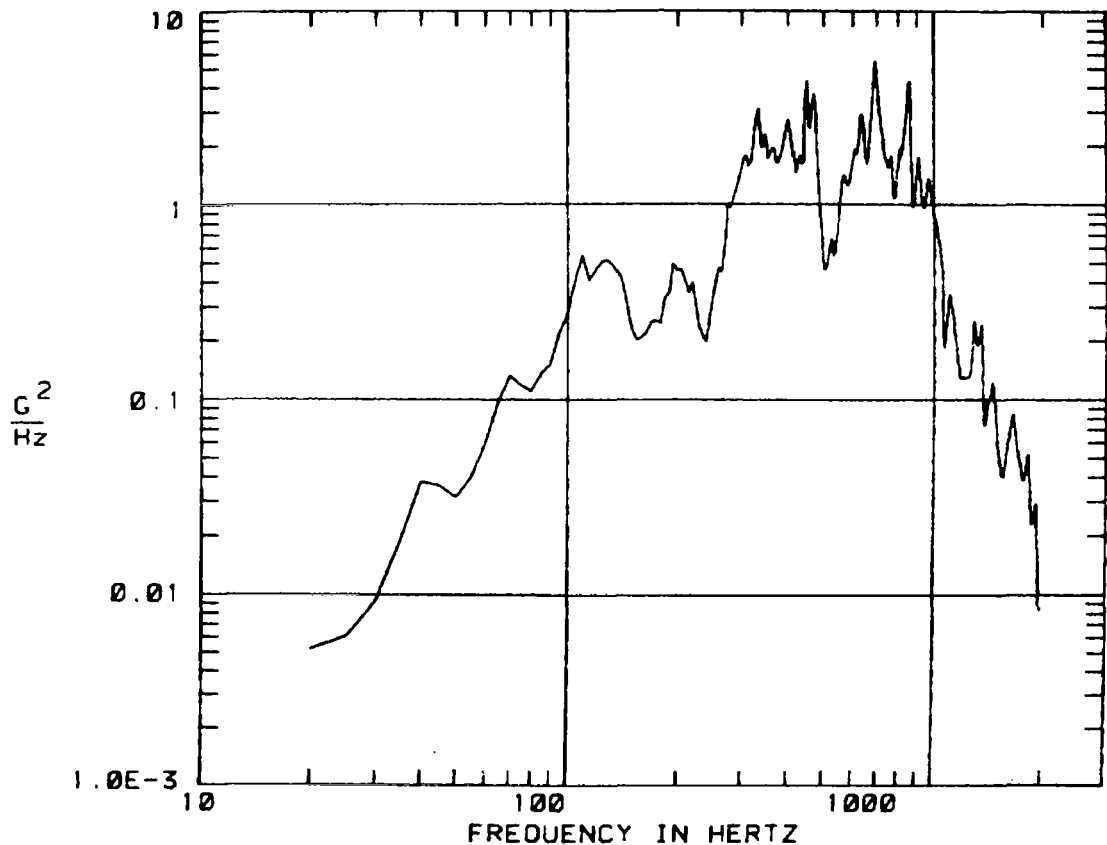


Figure 6. Vibration spectrum.

Option 2. PLOT MORE THAN ONE GRAPH

This option displays more than one PSD on the same page for comparison. After choosing this option, the screen will erase and display this message:

PRESS "A" FOR ACOUSTIC OR RETURN FOR PSD'S:

Press the appropriate key and the next message will appear:

ENTER NUMBER OF GRAPHS

Enter the number of files you wish to plot. The next message will be

ENTER FILE NUMBERS.

Enter the file numbers, pressing "Return" after each. The computer will then draw the graphs. When finished, the cursor will return to the "Home" position so that the user can add a title. Type the title, then press the END key (U.D. key No. 11) to stop the program. An example is shown in Figure 7.

THREE PSDS PLOTTED ON SAME PAGE

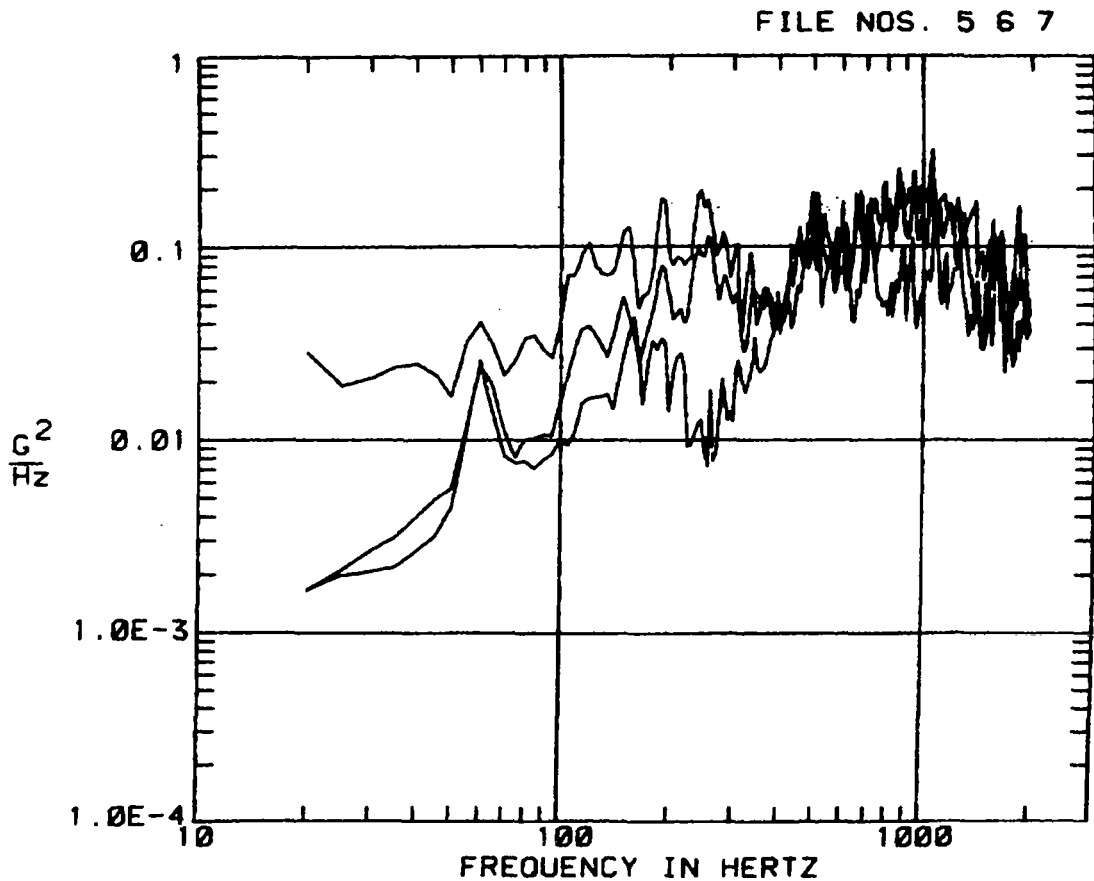


Figure 7. Multiple plots.

### Option 3. PLOT MEAN OR 97.5 PERCENTILE OF TWO OR MORE MEASUREMENTS

Option 3 will calculate two statistical functions (as described earlier) of spectra stored on the tape. After selecting option 3, this message will appear:

PRESS "A" FOR ACOUSTIC OR RETURN FOR PSD'S:

Press the appropriate key, and the next message will appear:

ENTER NUMBER OF GRAPHS

Enter the number of files you wish to plot. Remember that at least three spectra should be used to have a meaningful result. Next, this message will appear:

ENTER FILE NUMBERS.

Enter the file numbers of the PSD's you wish to average, pressing "Return" after each one. The next message will be

ENTER 3 FOR 97.5 PERCENTILE OR 4 FOR MEAN:

Choose the desired operation, and the computer will display the result. The program ends automatically.

### Option 4. LIST FILE DIRECTORY

This option will show what data are on a tape. The listing of data includes the skin thickness, ring weight, measurement direction, stringer weight, flight conditions, and file number. This option allows the user to select the data that best fit the situation. When the screen fills up with the listing, press the "Page" button to continue. When the listing stops, press the "Page" button to end the program.

### Option 5. NORMALIZE A PSD

Option 5 allows the user to scale an existing PSD to a new situation. The normalization is according to the equations already described. Many situations are allowed, ranging from duplicating the original data to scaling for acoustic spectra, surface mass ratio, and component mass. See Appendix A for a flowchart.

When option 5 is chosen, the screen erases; and the following statement appears:

ENTER FILE NUMBER OF NEW ACOUSTIC SPECTRUM:

Be sure the right tape is in the slot, and enter the file number of the new acoustic spectrum [ $P_N$  in equation (1)].

Next, this statement appears:

CHANGE TAPE IF NEEDED

ENTER FILE NUMBER CONTAINING REF. VIBRATION SPECTRUM:

If not using a disk file, it may be necessary to change tapes to access the proper files. Be sure the correct tape (or disk) is in the slot, and enter the file number of the data bank vibration spectrum [ $G_R$  in equation (1)]. The next two statements are

ENTER REFERENCE STRUCTURE WEIGHT:

ENTER NEW STRUCTURE WEIGHT:

Enter the correct numbers as determined by equation (1). The next statements are

ENTER COMPONENT MASS (IF NONE, ENTER ZERO):

Enter the correct number, and the next statement will be

ENTER FILE NUMBER CONTAINING REFERENCE ACOUSTIC SPECTRUM:

This is  $P_R$  in equation (1). The tape may have to be changed before entering the file number. The screen then displays:

DO YOU WANT TO ENTER A CRITERIA ENVELOPE BEFORE PLOTTING?  
ENTER Y OR "RETURN":

This allows the user to superimpose an existing criteria on the scaled PSD. If a "Y" is entered, follow the instructions given under option 1. If "Return" is pressed, the scaled PSD will be displayed. The cursor then moves to the upper left corner of the screen and allows the user to enter a title. When the appropriate title is entered, the program prompts for the parameters pertinent to the new structure. Enter the appropriate parameters for each (press "Return" to skip a parameter). The criteria can then be drawn.

#### DRAWING THE CRITERIA

Once a scaled PSD is displayed on the screen, a criteria envelope can be drawn around it. To draw criteria, press the "Move Cursor" key (U.D. key No. 5); and a small pointer will appear on the left edge of the plot. Press and hold down the appropriate user definable key (Nos. 6-9) to move the cursor to the starting point. Press the "Draw" key (No. 10) once. Then move to the next point, and press the "Draw" key again. The cursor will automatically move to the nearest integer criteria slope. Keep moving the cursor until all the lines are drawn. To start over with the criteria, press the "Move Cursor" key again; however, the previous line will not be erased. When finished drawing the criteria, make a copy of the finished PSD and criteria; and then press the key marked "Criteria Table" (U.D. key No. 3); and a table will be listed. When the table is printed, the cursor returns to the upper left corner of the screen and waits for a title (up to 150 characters). The position of the cursor can be manipulated using the space bar (move to right), the back-space key (left), and the line feed key (down). When the title is entered, press the "End" key (U.D. key No. 11) to end the program. An example of a normalized PSD with criteria is shown in Figure 8.



VALVE BOX  
 MEAS. DIRECTION: RADIAL  
 FLIGHT CONDITION: LIFTOFF  
 MATERIAL: AL  
 VEHICLE DIAMETER: N/A  
 COMPOSITE: 14.71 Grms

SKIN THICKNESS: .18 IN

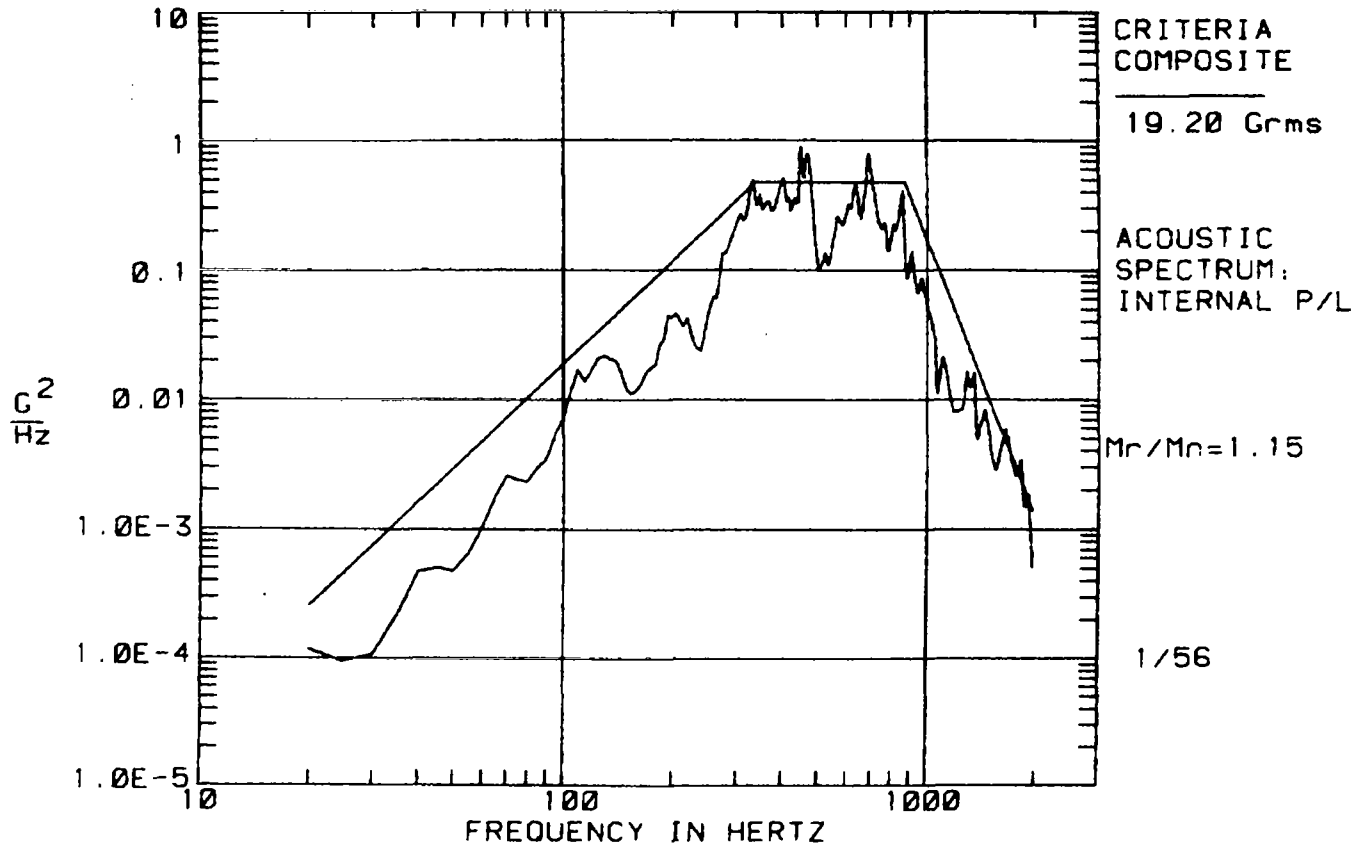


Figure 8. Scaled vibration spectrum with criteria.

Option 6. PRINT AN ACOUSTIC SPECTRUM

This option prints an acoustic spectrum as it is stored on tape. After selecting the option, the following message is printed:

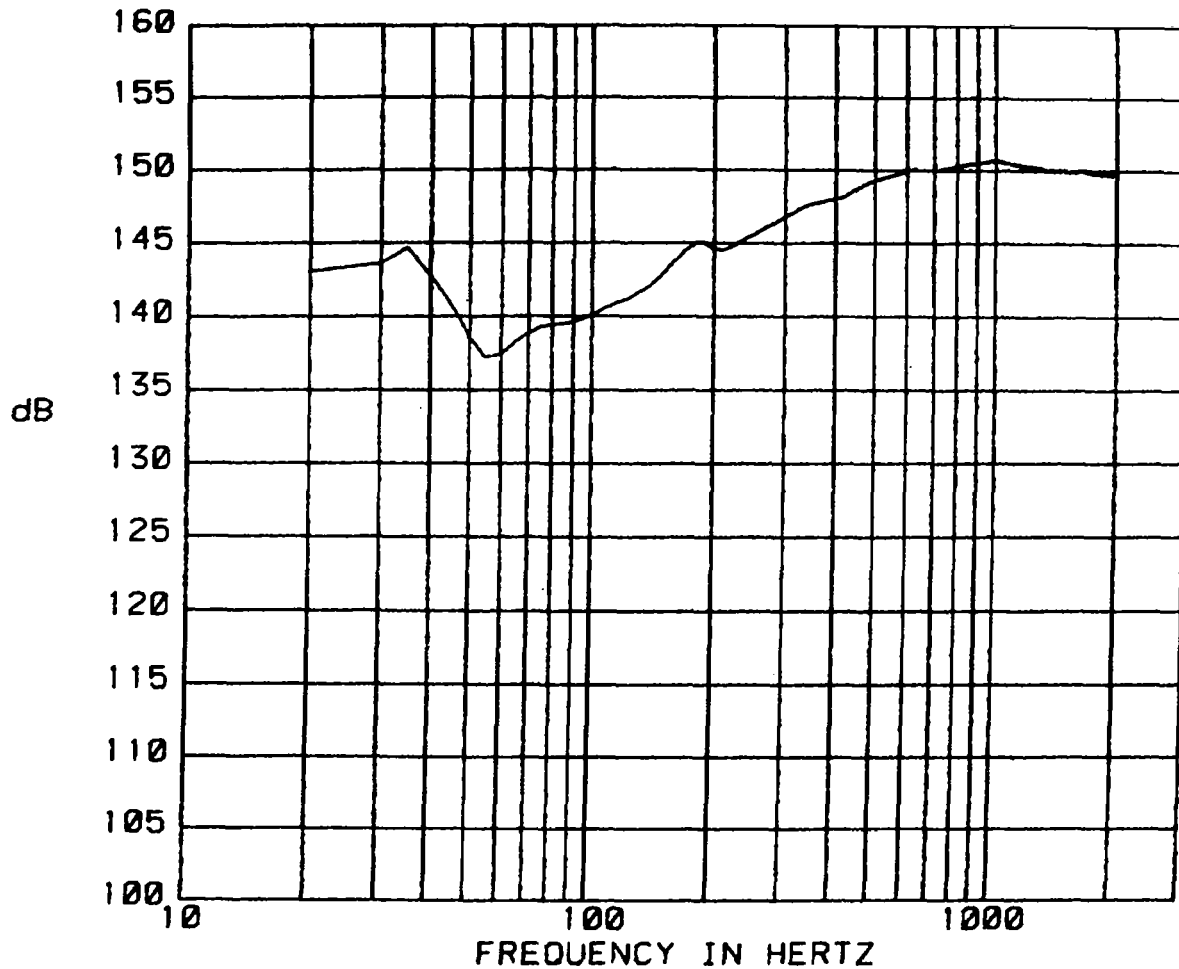
ENTER STORAGE FILE NUMBER.

Enter the appropriate number, and the spectrum will be displayed. The program terminates automatically. An example is shown in Figure 9.

ACOUSTIC SPECTRUM:7159/A109

FLIGHT CONDITION:STATIC

DOCUMENT:DATA BANK



4/59

Figure 9. Acoustic spectrum.

### THE DATA ENTRY PROGRAM ("DATA")

The data entry program is used to store vibration and acoustic spectra in the computer data bank. Data can be entered using the 4956 Graphic Tablet or by hand. To use the graphic tablet, the PSD's must be in Log-Log format and the acoustic spectra must be in semi-log form; but they can be in any form if entering by hand. This program also stores some of the structural parameters on one tape file for easy reference.

## Data Tape Format

Before storing data on a tape, files must be marked as follows:

File No. 1 (760 bytes) – A “cushion” file used as a header.

File No. 2 (10,000 bytes) – Reserved for file directory.

File No. 3-64 (4250 bytes each) – data files.

To initialize a tape for data storage, first rewind the tape by typing:

**FIND O**

This will search for the beginning of the tape. When the “I/O” light goes out, type:

**MARK 1,500.**

Then type:

**MARK 1,10000.**

Then:

**MARK 61,4250.**

This will mark off the 61 data files.

## User Definable Keys

The user definable keys used in this program are shown in Figure 10.

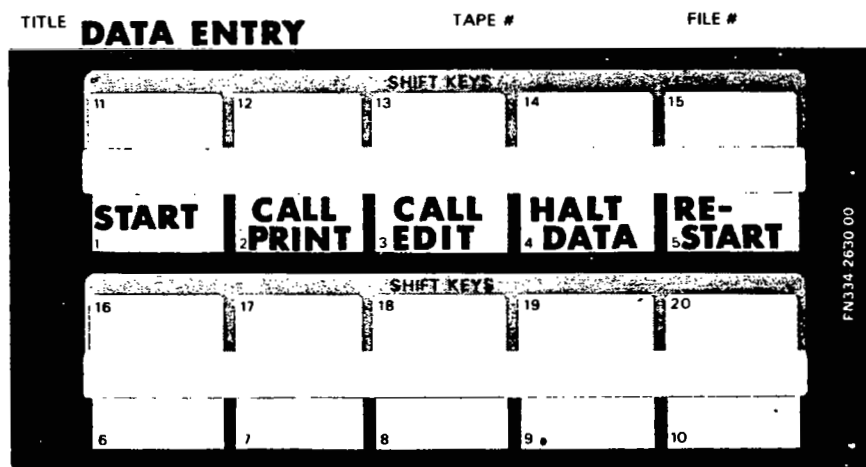


Figure 10. Location of user definable keys for “DATA.”

Key 1 is used to initialize the system and start the program. Keys 2 and 3 are used to call other programs. (Be sure a program tape is in the slot when using these keys.) Key 4 is pressed when data entry is finished. (This key does the same thing as the green button on the graphic tablet cursor). Key 5 can be used to restart the data entry process if a mistake is made.

### The 4956 Graphic Tablet

The Tektronix 4956 is a digitizing tablet used to speed the entry of PSD plots and acoustic spectra. Several digitizing modes are available, but the two of most use are "Point" mode and "Stream" mode. In "Point" mode, a point is digitized whenever the pen or cursor switch is pressed. In "Stream" mode, points are digitized continuously. (See Figure 4 for a description of the 4956.)

#### Cursor and Pen

The digitizing tablet can be used with either a pen or a cursor. The cursor is more convenient because it contains the buttons that control various functions [4]. When using the pen, user definable keys on the computer must be pressed to control the functions. The functions of the cursor buttons in this program are as follows:

- Yellow – digitizes points (same as pressing pen)
- Green – halts data input (same as U.D. key No. 4)
- Blue – start data entry over (same as U.D. key No. 5)
- White – not used.

#### How to Use the Tablet

The graphic tablet has hundreds of magnetized wires running from top to bottom and across the tablet. For the most accuracy, one axis of the plot to be digitized must be parallel to these wires. To make sure of this, place a strip of tape running parallel to the wires; and align the plot's axis with the strip of tape. To align the tape, digitize two widely separated points; and examine the variable that is returned. When the x or y variables from the two points are the same, they are generated by the same wire. Align the tape with the two digitized points. Affix the plot to be digitized to the tablet with masking tape, making sure that one axis is aligned as described. The plot is now ready to be digitized.

#### How to Use the Program

This program is stored on the program tape in file No. 2. To access it, type

FIND 2

then

OLD.

To start the program, press the "Start" key (U.D. key No. 1); and the following message will appear:

SELECT A DATA TAPE AND PRESS 'RETURN'

Make sure a data tape is in the slot when using this program. After pressing "Return", the menu will appear:

- SELECT ONE
- 1) ENTER A PSD
  - 2) LOAD FILE DIRECTORY
  - 3) ENTER AN ACOUSTIC SPECTRUM
  - 4) ENTER AN ACOUSTIC SPECTRUM BY HAND

To select the appropriate program option, enter the number and press "Return".

### Description of Program Options

#### Option 1. ENTER A PSD

This is the part of the program that stores PSD data on the tape or disk. After selecting the PSD, preparing the graphic tablet as described above, and marking files on the tape, select this option; and the following message will appear:

ENTER STORAGE FILE NUMBER

Enter the file number on which the data will be stored. Then the computer will prompt for several identifying structural parameters. Enter the parameters when prompted.

Next, the computer will ask for initialization factors for the graphic tablet. Be sure the tablet controller is in the "Point" mode. The following message will appear:

ENTER MINIMUM VALUE.

Enter the minimum amplitude scale printed on the lower left corner of the plot. Next, this message will appear:

ENTER MAXIMUM VALUE.

Enter the maximum amplitude scale printed on the upper left corner of the plot. Then, this message will appear:

PRESS PEN TO LOWER LEFT CORNER OF PLOT (@10 HZ).

Digitize the point corresponding to the minimum amplitude value entered earlier at 10 Hz. For example, if the minimum value entered was 0.001, press the pen (or cursor) to the point 10 Hz, 0.001  $g^2$ /Hz. Then, the computer will print

PRESS PEN TO UPPER RIGHT CORNER OF PLOT (@2000 HZ).

Digitize the point corresponding to the maximum value entered earlier and 2000 Hz. The computer will respond to all inputs with a "beep". The digitizing window is now set, and the computer will draw and label a scale corresponding to the values entered.

## Digitizing the PSD

The computer will accept data from 20 Hz to 2000 Hz. Anything outside of this window will be invalid. Begin digitizing by pressing the cursor to the point at 20 Hz. Continue digitizing points, allowing at least a 5-Hz increment between points. At just beyond 2000 Hz, the computer will automatically terminate digitizing. If it fails to do so, press the green cursor button (or U.D. key No. 4) to terminate. The computer will then interpolate and store the parameters and data on the tape file. The next message will be

**DATA STORED IN FILE  
PRESS "D" TO STORE IN FILE DIRECTORY.**

By pressing "D" at this point, the pertinent parameters will automatically be stored in the file directory. Press "Return" to skip this step.

### Option 2. LOAD FILE DIRECTORY

This option loads selected parameters on file No. 2. File No. 2 is a directory that allows the user to examine the structural parameters of each file and select the one that best fits the new structure. After selecting option 2, the following message will appear:

**PRESS "A" TO RELOAD OR "RETURN" TO ADD TO FILE:**

By pressing "A", the entire contents of file No. 2 will be erased; and the parameters from all tape files will be stored in the directory. This takes about 30 min for a complete tape. To add parameters to the directory, press "Return"; and the following message will appear:

**ENTER NUMBER OF FIRST FILE:**

Then

**ENTER NUMBER OF LAST FILE:**

Enter the number of the first file to be added, then the number of the last file. The selected parameters for these files and all in between will be added to the directory. When reloading, the same message will appear — just add the numbers of the first and last data files on the tape (numbers 3 and 64 on a full tape). This program ends automatically.

### Option 3. ENTER AN ACOUSTIC SPECTRUM

This option uses the 4956 Graphics Tablet to load an acoustic spectrum onto a tape file. The program can digitize either in the "Point" mode or continuously from 20 Hz to 2000 Hz. After selecting this option, this message will appear:

**ENTER STORAGE FILE NUMBER:**

Enter the number of the file where the data will be stored. Be sure a properly formatted data tape is in the slot. Next, some parameters will be displayed. Enter the appropriate parameters or press "Return" to skip them.

After the parameters are entered, the next statement will be:

ENTER "P" TO CONVERT TO 1/3 OCTAVE VALUES:

This option will convert spectrum level values to 1/3-octave values. Press "Return" to reject this option. Next, this message will appear

ENTER MINIMUM VALUE:

Enter the low value in the digitizing window, and this message will appear

ENTER MAXIMUM VALUE:

Enter the high value in the digitizing window, and the next message will appear

PRESS PEN TO LOWER LEFT CORNER (10 HZ)

Digitize the point at 10 HZ and the low value entered earlier. Be sure the tablet is in the "Point" mode. The next message will be

PRESS PEN TO UPPER RIGHT CORNER (2000 HZ).

Digitize the point at 2000 Hz and the high value entered earlier.

If the option was selected to convert to 1/3-octave values, put the tablet in the "Switch Stream" mode; and press the "INCRE" (blue) filter on the controller box. Begin digitizing at 20 Hz, and follow the curve continuously. The program will automatically digitize and ring the bell at each 1/3-octave frequency. If the bell fails to ring, go back to the last 1/3-octave frequency, and digitize until the bell rings; then, continue. The program continues and terminates automatically after the last point is entered. It is a good idea to press the "Clear" button after the program terminates. This clears the memory buffer on the 4956 and insures that no extraneous points remain in memory.

#### Option 4. ENTER AN ACOUSTIC SPECTRUM BY HAND

When an acoustic spectrum is tabulated instead of plotted, this option allows the spectrum to be stored on tape for later plotting or recalled for scaling. After selecting this option, the following message will appear:

ENTER STORAGE FILE NUMBER:

Be sure a data tape is in the slot, and enter the file number. The next message will be

ENTER "P" TO CONVERT TO 1/3 OCTAVE VALUES:

If the values are given in 1/3-octave band levels, press "Return" to reject the option. If not, press "P"; and the program will convert spectrum level values to 1/3-octave band values. All acoustic spectra must be consistent. Next, the computer will prompt for the acoustic spectrum parameters. Enter each of these and the minimum and maximum values. (These need not be accurate; they are just used to scale the plot. They should, however, incorporate all of the 1/3-octave band values.)

Next, the computer will display this message

**ENTER DECIBEL VALUES CORRESPONDING TO THE 1/3 OCTAVE FREQUENCIES  
20 HZ - - - - -**

When prompted, enter the decibel value for each frequency. After the value at 2000 Hz is entered, the program will interpolate between values and store them on the tape file. The next message will be

**PRESS "D" TO STORE IN FILE DIRECTORY.**

If "D" is pressed, selected parameters will be stored on the file. Press "Return" to by-pass the option and end the program.

### **THE STATISTICAL DATA ANALYSIS AND STORAGE PROGRAM ("STAT")**

This program will calculate the mean and 97.5 percent confidence level spectrum of several vibration or acoustic spectra. The spectra are entered into the computer memory using the 4956 Graphics Tablet, and the final spectrum is stored on a tape file. The equations used to calculate the confidence level were described previously. Due to memory space, a maximum of eight spectra can be processed at one time. See Appendix B for a flowchart.

To use the program, press the "Auto Load" key or type:

**FIND 5**

then

**OLD.**

This will load the program into memory. The user definable key assignments and tape file marking are the same as for the data entry program. To start the program, press the "Start" Key (U.D. key No. 1). The following message will appear:

**SELECT A DATA TAPE AND PRESS "RETURN".**

Be sure that a data tape is in the slot. The next message will be

**PRESS "A" FOR ACOUSTIC SPECTRA OR "RETURN" FOR PSD'S:**

Then

**ENTER STORAGE FILE NUMBER:**

Select the type of spectra and the tape file number. The next message will be

**ENTER 3 FOR 97.5 PERCENTILE OR 4 FOR MEAN;**

Select the confidence level or mean by entering the appropriate number. The next message will be

**ENTER THE NUMBER OF SPECTRA:**



Enter the number of spectra to be analyzed. Remember that a sample of at least three spectra is needed for a meaningful confidence level. If acoustic spectra are being digitized, the next message will be

ENTER "P" TO CONVERT TO 1/3 OCTAVE.

If the acoustic spectra are in spectrum level units, then they must be converted to 1/3-octave band levels. If they are already in 1/3-octave form, press "Return" to bypass this option. Next, the screen will display

ENTER MINIMUM VALUE:

then

ENTER MAXIMUM VALUE:

Enter the minimum and maximum values on the first spectrum. The screen will then display

PRESS PEN TO LOWER LEFT CORNER (10 HZ)

Digitize the point corresponding to 10 Hz and the minimum value entered earlier. Then, the screen will print

PRESS PEN TO UPPER RIGHT CORNER (2000 HZ).

Digitize the point at the maximum and 2000 Hz. Then, begin digitizing as described in the data entry program description. When digitizing acoustic spectra in the continuous mode, be sure to press the "Clear" button on the 4956 controller after the last point is digitized. The program will then recycle back to the point where it asks for a minimum and maximum value. Continue digitizing until all of the spectra are done. The program will then ask for some parameters that will be stored on the tape. Enter the parameters as prompted. After storing the statistical function on the tape, the program will terminate automatically.

## EDITOR PROGRAM ("EDIT")

This program allows the user to access a data file and make corrections to the data or the parameters. This program will also transfer data to another file and list the file directory.

### User Definable Keys

Five user definable keys are used with this program. Keys 1 and 11 are used to start and stop the program, respectively. Keys 2 and 12 are used to call the "PLOT" program and the "DATA" program, respectively. Key 4 will list everything that is on a data file. The location of the keys is shown in Figure 11.

### Program Options

To load the editor program, place the program tape in the slot; and press the "Autoload" key or type:

FIND 3

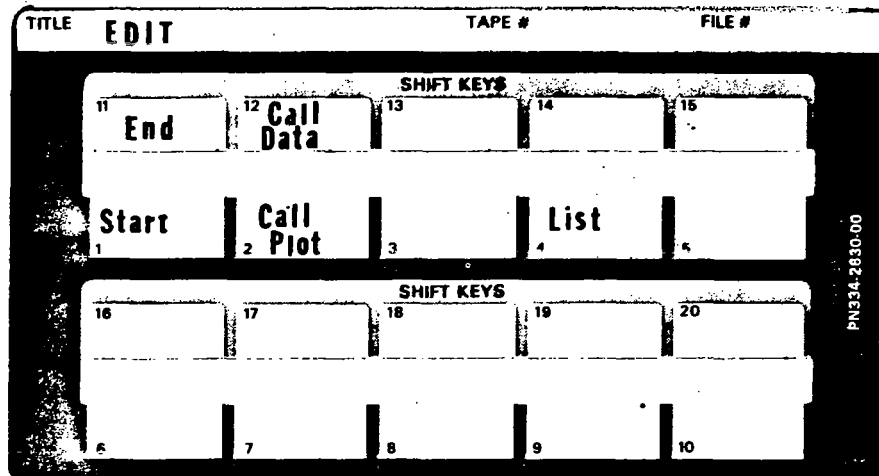


Figure 11. Location of user definable keys for "EDIT".

Then type:

OLD.

When the BUSY and I/O lights go out, press the "Start" key (U. D. Key No. 1); and the following list will appear:

- SELECT ONE
- 1) LIST AND EDIT DATA
  - 2) TRANSFER DATA TO ANOTHER FILE
  - 3) PRINT FILE DIRECTORY
  - 4) CHANGE PARAMETERS.

Select the option and press "Return".

Option 1. LIST AND EDIT DATA

This option gives access to a data file for changes. After selecting the option, this message will appear:

ENTER STORAGE FILE NUMBER.

Be sure a data tape is in the slot, and enter the number of the file you want to edit. The structural parameters will then be listed followed by all of the data. The data is displayed by index number, frequency, and value. When the page fills up, press the "Page" button to continue. When all 397 points are listed, the following message will be displayed:

DO YOU WANT TO CHANGE DATA (Y OR N).

If all of the data is correct, press "Return", and the program will end automatically. If editing is desired, press "Y"; and this message will appear:

ENTER INDEX OF VALUE TO BE CHANGED.

The index is the number in parentheses. Enter the index number, and the value at that frequency will be displayed:

AT A FREQUENCY OF \_\_\_ HZ, THE VALUE IS \_\_\_\_\_  
CHANGE VALUE TO \_\_\_\_\_

Enter the corrected value. Because there is a fixed frequency interval, the frequency value is not accessible. After entering the correction, it will be confirmed:

VALUE IS NOW:

DO YOU WISH TO CHANGE DATA (Y OR N)

If no more data are to be changed, press "N"; and the corrected data will be stored on the tape.

#### Option 2. TRANSFER DATA TO ANOTHER FILE

After selecting this option, the following message will appear:

ENTER FILE NUMBER YOU WANT TO MOVE.

Be sure a data tape is in the slot, and enter the file number. Then this message will appear:

CHANGE TAPE NOW

ENTER NEW FILE LOCATION.

If the file is to be stored on another tape, change it now; then, enter the new file number. The data will be written on the new file just as it was stored on the old file. When it is finished writing, this message will be printed:

PRESS "D" TO STORE ON FILE DIRECTORY.

Pressing "Return" will end the program automatically.

#### Option 3. PRINT FILE DIRECTORY

This option is described in the "PLOT" program section.

#### Option 4. CHANGE PARAMETERS

This option allows access to the structural parameters that describe the data on a tape file. After selecting the option, this message will appear:

ENTER STORAGE FILE NUMBER.

Enter the file number, and the parameters will be displayed:

- |   |                   |   |                      |
|---|-------------------|---|----------------------|
| ① | DOCUMENT:         | ⑦ | SKIN THICKNESS:      |
| ② | MEAS. DIRECTION:  | ⑧ | RING SEPARATION:     |
| ③ | FLIGHT CONDITION: | ⑨ | RING WEIGHT:         |
| ④ | MATERIAL:         | ⑩ | STRINGER SEPARATION: |
| ⑤ | VEHICLE DIAMETER: | ⑪ | STRINGER WEIGHT:     |
|   |                   | ⑫ | SURFACE WEIGHT:      |

ENTER NUMBER OF PARAMETER TO BE CHANGED.  
ENTER 0 TO CHANGE SCALE FACTORS

The numbers of each parameter are given in the circles. Enter the number, and the next message will be

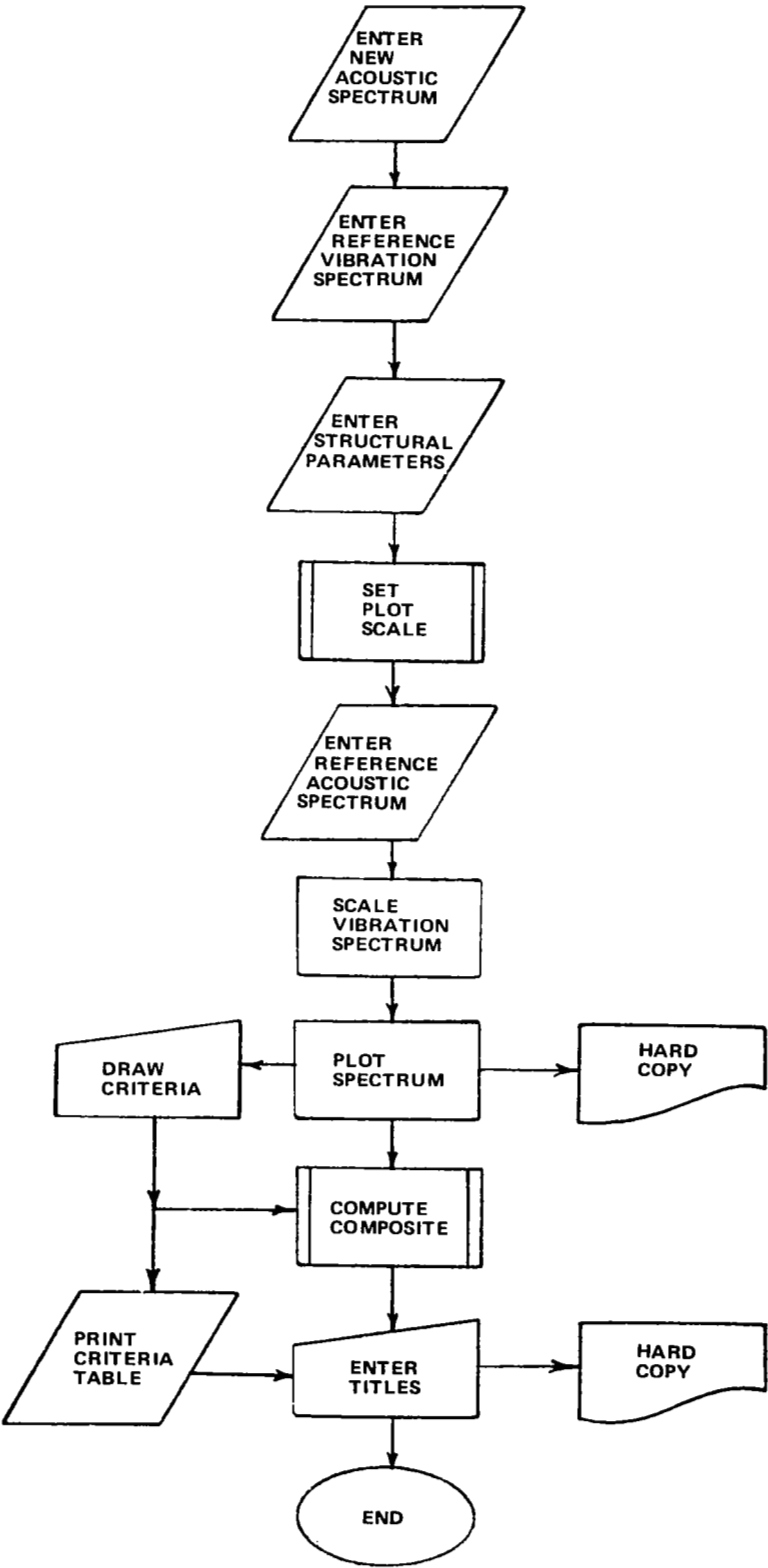
MAKE CHANGE

Enter the corrected parameter, and press "Return." The next message will be

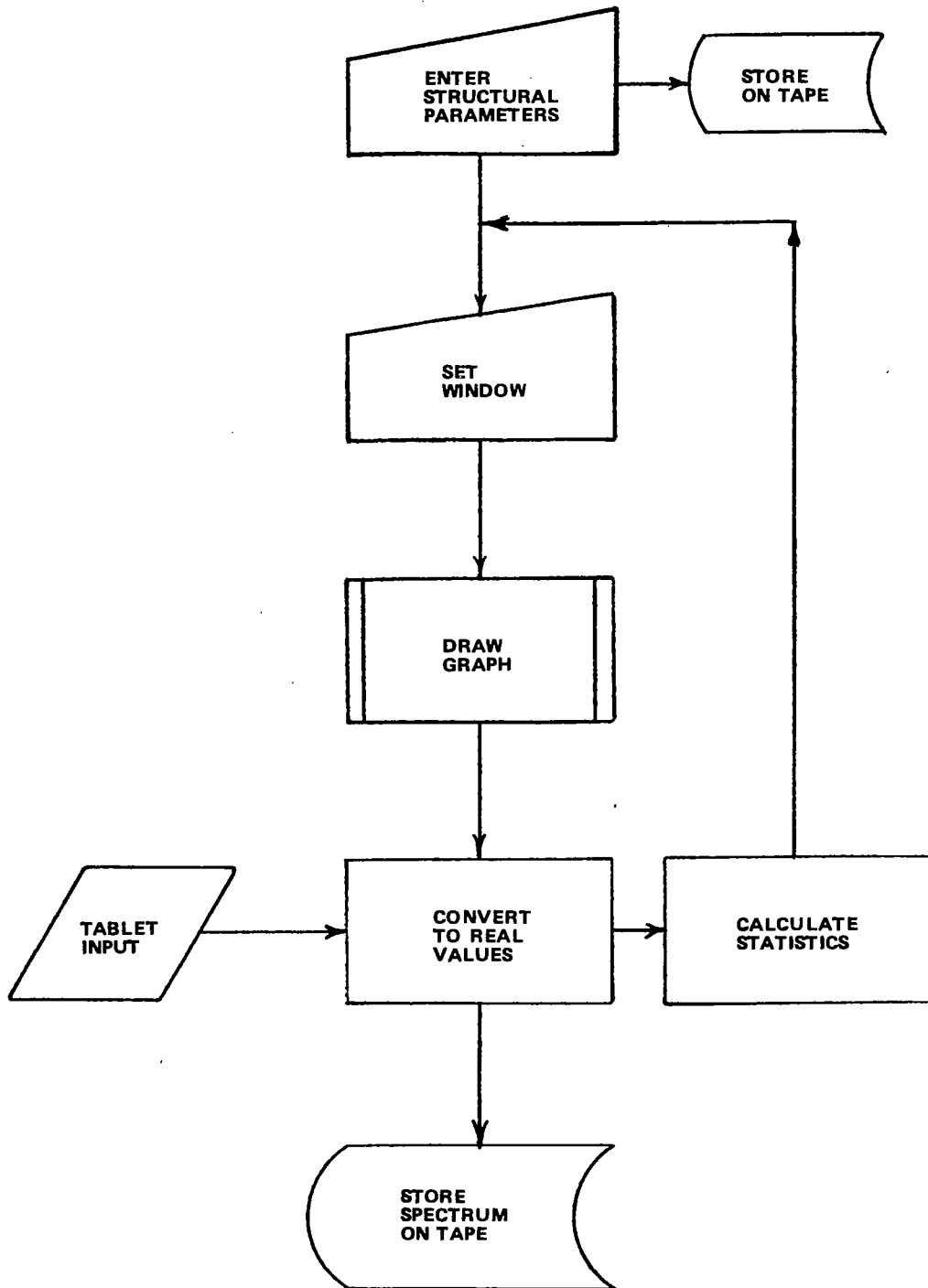
ANY OTHER CHANGES? (Y OR N)

Enter "N" to end the program or "Y" to change other parameters.

APPENDIX A. PLOT PROGRAM FLOWCHART



APPENDIX B. DATA ENTRY PROGRAM FLOWCHART.



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