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UTILIZATION OF TAPED RANDOM SPECTRA FOR VIBRATION TESTING.(U)

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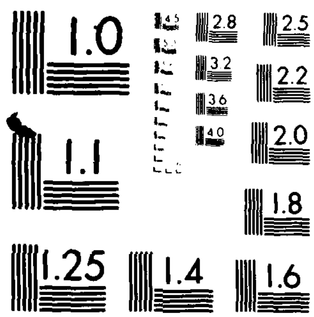

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PREFACE

This Final Technical Report was prepared by Grumman Aerospace Corporation, Bethpage, New York under Contract N00039-77-C-0360, for the Naval Electronic Systems Command, Washington, D.C. Mr. William E. Wallace Jr. (ELEX 4702) was the NAVELEX Project Engineer and Mr. Chester Nolf (ELEX 4702) was the technical advisor to NAVELEX.

The effort described was accomplished during the period September 1977 through December 1978.

In addition the Messrs. Hirschberger, Popolo, Devitt and Pokallus, other Grumman Study team members were: R. Esposito, A. Dantowitz, H. Quartin, and N. Arcas.

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SUMMARY

Random vibration, a test screen found to be extremely effective for disclosing workmanship problems in various equipment, is also extremely expensive to generate. ~~Grumman has conceived~~ a technique for economically producing random vibration utilizing an audio tape deck as a signal source. The concept was proven feasible on a production basis.

This study was undertaken to refine the technique, establish its validity for universal application and prepare a step-by-step procedure for its implementation.

A series of laboratory tests was conducted on various electronic units to evaluate variations in hardware and determine what impact this could have on the overall approach. In addition, tests were also performed on basic test equipment and tape decks to; establish any inherent performance limitations, assess the potential effect on the technique, and develop the compensating factors necessary to mitigate these problems.

The results obtained indicate that while some variations were apparent between items of generically identical manufacture and certain test equipment idiosyncrasies existed, compensating factors could be developed to account for these differences. Utilization of the required factors in the construction of a synthetic random tape permitted the generation of random vibration on actual hardware within acceptable tolerances.

A detailed procedure was prepared delineating the steps required to construct a synthetic random tape and to employ this tape to conduct random vibration acceptance tests.

1- INTRODUCTION

1.1 BACKGROUND

The use of random vibration as a screen for latent workmanship problems normally found in avionic equipment, has proven to be significantly more effective than the sinusoidal form of excitation normally employed. This fact has been demonstrated by Grumman and other organizations and is now required for acceptance testing by NAVMAT INSTRUCTION 3000.1A and MIL-STD-781C.

The major deterrent to universal acceptance of this technique is the impact this type of test would have on program costs since a random vibration facility is extremely expensive. The development of a technique which permitted economical generation of random vibration, would eliminate the high cost factor normally associated with this type of test.

There are currently several industry investigations being conducted to develop new, inexpensive random vibration generating systems. As a viable alternate to the development of totally new systems, Grumman has evolved a technique which capitalizes on the fact that most equipment manufacturers maintain electrodynamic sinusoidal test facilities and was structured to utilize these existing capabilities. This approach, which employs a $500.00 audio tape deck in lieu of $40,000 worth of standard random programming devices to excite the shaker system, is predicated on the fact that sine response data can be used to predict random transfer characteristics. The technique which was developed successfully and applied on a production basis is accomplished as follows:

- The system transfer characteristics to a 1.0g peak sine sweep input are recorded (Fig. 1).
- The synthetic random spectrum characteristics are calculated by adjusting the required random spectrum as a function of the transfer characteristics obtained.
- The resulting synthetic spectrum is recorded on tape (Fig. 2).
- The tape is then used to drive an electro-dynamic shaker system (Fig. 3).

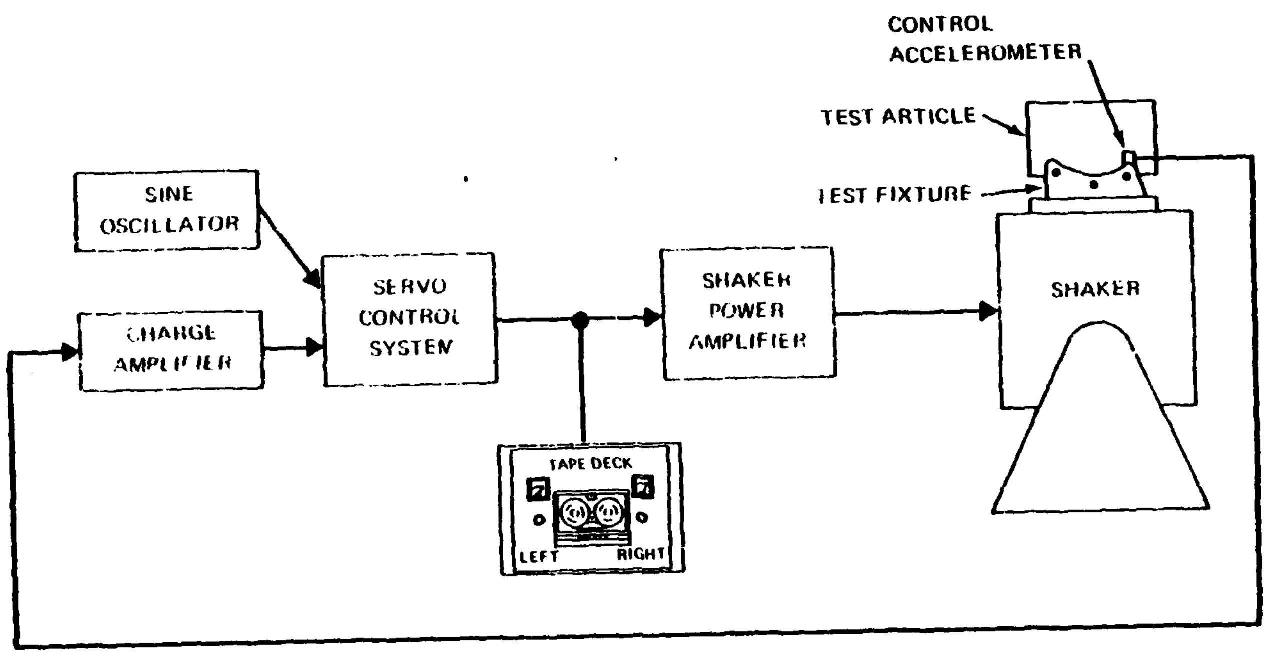

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Figure 1 System Transfer Characteristics Determination

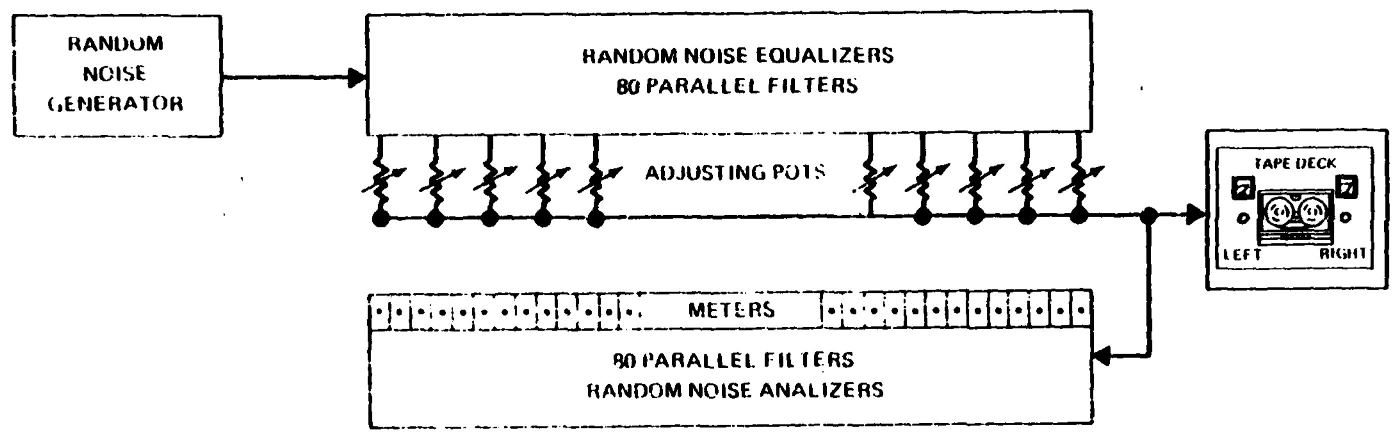

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Figure 2 Taping Synthetic Random

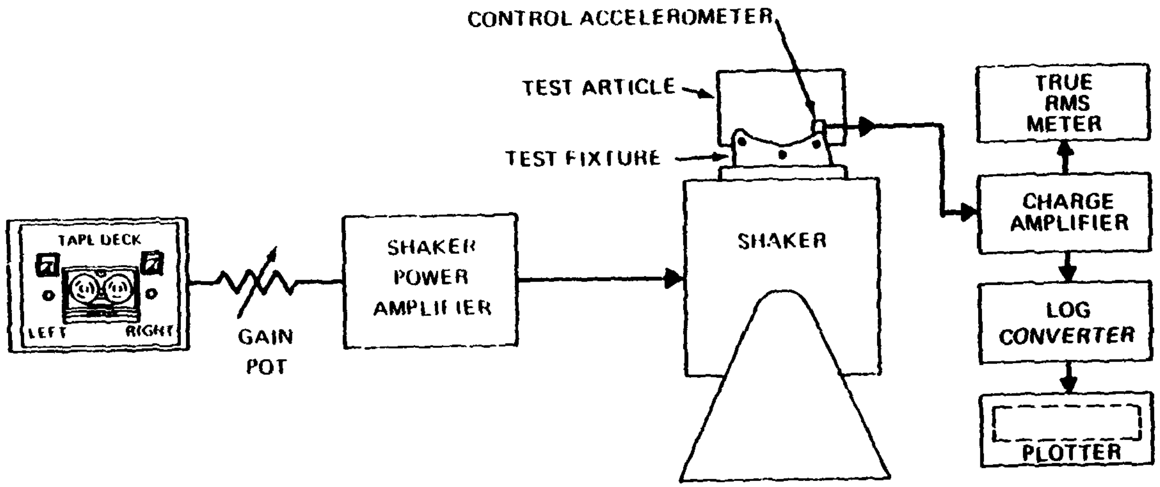

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Figure 3 Testing With Taped Synthetic Random

1.2 OBJECTIVES

The preliminary work accomplished showed that the technique was conceptually feasible. The principal objectives of this study were to:

- o Verify that the approach was valid for universal application.
- o Refine the technique and establish required factors and tolerances.
- o Select and evaluate suitable commercially available audio tape decks.
- o Prepare a detailed procedure which would permit implementation of the technique.

1.3 Approach

The total effort was divided into two tasks. Task A was structured to confirm the practicality of universal application of the technique and Task B was established to refine the concept and prepare a detailed procedures document.

Task A included the following interrelated activities:

- o A series of tests was conducted, using a mass mock-up of a computer, and audio tape decks, to confirm the overall approach and assess any variations occurring due to extended operation.
- o Variations in dynamic characteristic of generically identical and generically different electronic equipment were evaluated. This evaluation was performed to determine the range of variations that could be expected in response data, the magnitude of transfer errors and the need for and type of compensating factors required.
- o A comprehensive review of cassette tape decks and tapes was undertaken to select units potentially suitable for use with the technique. These items were thoroughly evaluated to determine inherent linearity and error characteristics and variations that might be time related.
- o Additional tasks included:
  - Investigation of various shaker system characteristics and their impact on the program.
  - Study of controls necessary for open loop operation.

Task B included the following activities:

- Preparation of synthetic random tapes was accomplished for six different production units in one to two different test axes.
- Random vibration tests were performed on multiple samples of these production units using the random tape technique.
- Analysis of the test data was undertaken to determine the test tolerances that could reasonably be maintained.
- An investigation of out-of-tolerance test results was conducted to determine the cause of the problem, and establish methods of compensation or correction for these conditions.
- Evaluation of test techniques to be applied in the recording and use of the test tape was performed and a detail procedure for application of the technique was prepared.
- Continued evaluation of commercial stereo cassette tape decks was accomplished to determine if their frequency response characteristics and long term stability would satisfy program requirements.
- The validity of the test procedure was verified by test laboratory personnel within Grumman, who were not involved in the technique's development.

2 - TECHNICAL DISCUSSION

2.1 INTRODUCTION

As previously indicated this study was accomplished in two separate phases, Task A and Task B.

- Task A included the following investigations:
  - Mass Mock-up.
  - Baseline Transfer Characteristics
  - Shaker System Variations
  - Open Loop Operation
  - Tape Deck

- Task B included the following investigations:
  - Evaluation of Production Hardware
  - Tape Decks - Evaluation
  - Preparation of Procedures
  - Verification of Procedure

The evaluations and investigations conducted and the results of these efforts are presented in the following sections of this report.

2.2 TASK A

2.2.1 MASS MOCK-UP INVESTIGATION

In order to develop and refine the techniques necessary for the preparation and performance of random vibration tests using synthetic tapes, an extensive evaluation was performed on a computer mass mock-up. Over 100 individual vibration test runs were made with this unit to identify significant parameters, and to develop and experimentally verify the technical methods and procedures utilized.

2.2.1.1 Test Article

The unit used in these tests is a very exact mass representation of an in-flight computer. This mass representation is complete to the circuit board level. Circuit board components have been simulated by small metallic representations glued to the boards. All electrical connectors and major wiring bundles have been included.

The Mass Mock-up weighs 40 lbs. and measures 13" x 13" x 7". It mounts on a flat surface using two spade lugs on the rear which slide into retainers, and two 1/4" dia. screws in a self-aligning spherical fitting designed to hold the unit in place. This type of mount is typical for replaceable electronic assemblies.

2.2.1.2 Test Set-up

All tests were performed on an MB model C-25H shaker (rated 1700 lbs. RMS force capacity - random) and an MB model T-351 Power Amplifier (rated 6KVA). The random control console used was a Ling Model ASDE-80 system, while the sinusoidal vibration control console was a hybrid system composed of a Spectral Dynamics Model 104A Sweep Oscillator and a Model 105B Servo Controller. See Figures 4, 5 and 6 which depict the test set-up pictorially and schematically.

2.2.1.3 Test Description

The following paragraphs describe in detail the specific tests that were conducted during this investigation. Testing consisted of 106 individual runs made on 20 calendar days. A detailed log was maintained by the laboratory personnel and a chronological summary of the log is presented in Appendix A.

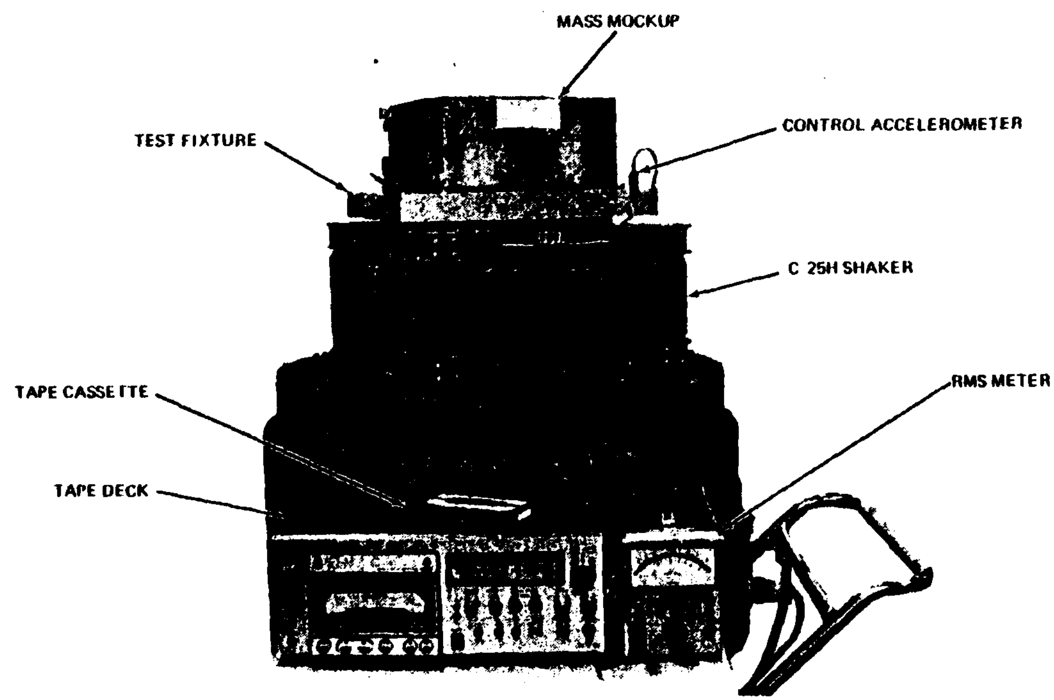

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Fig. 4 Test Setup

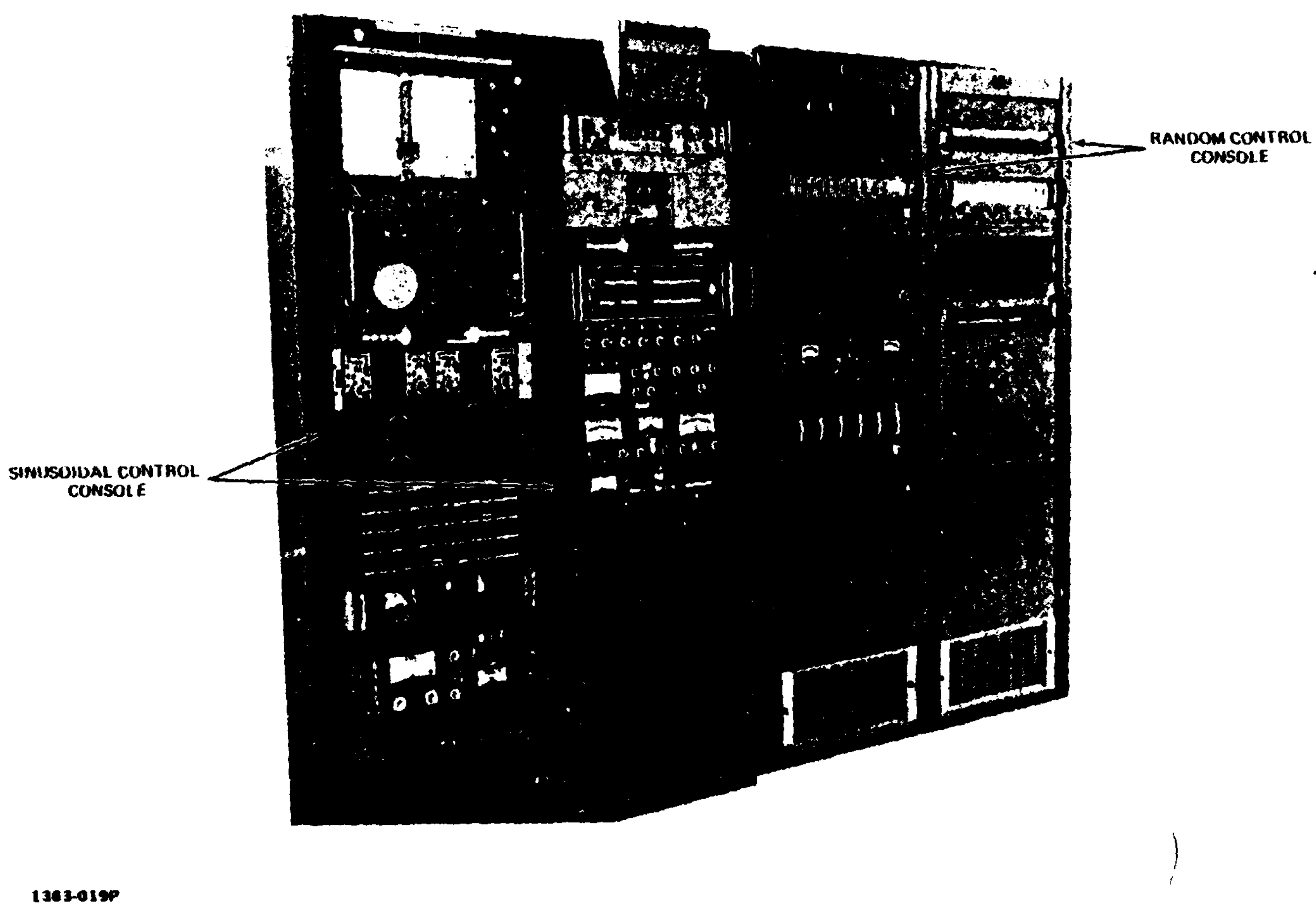

Fig. 5 Test Setup

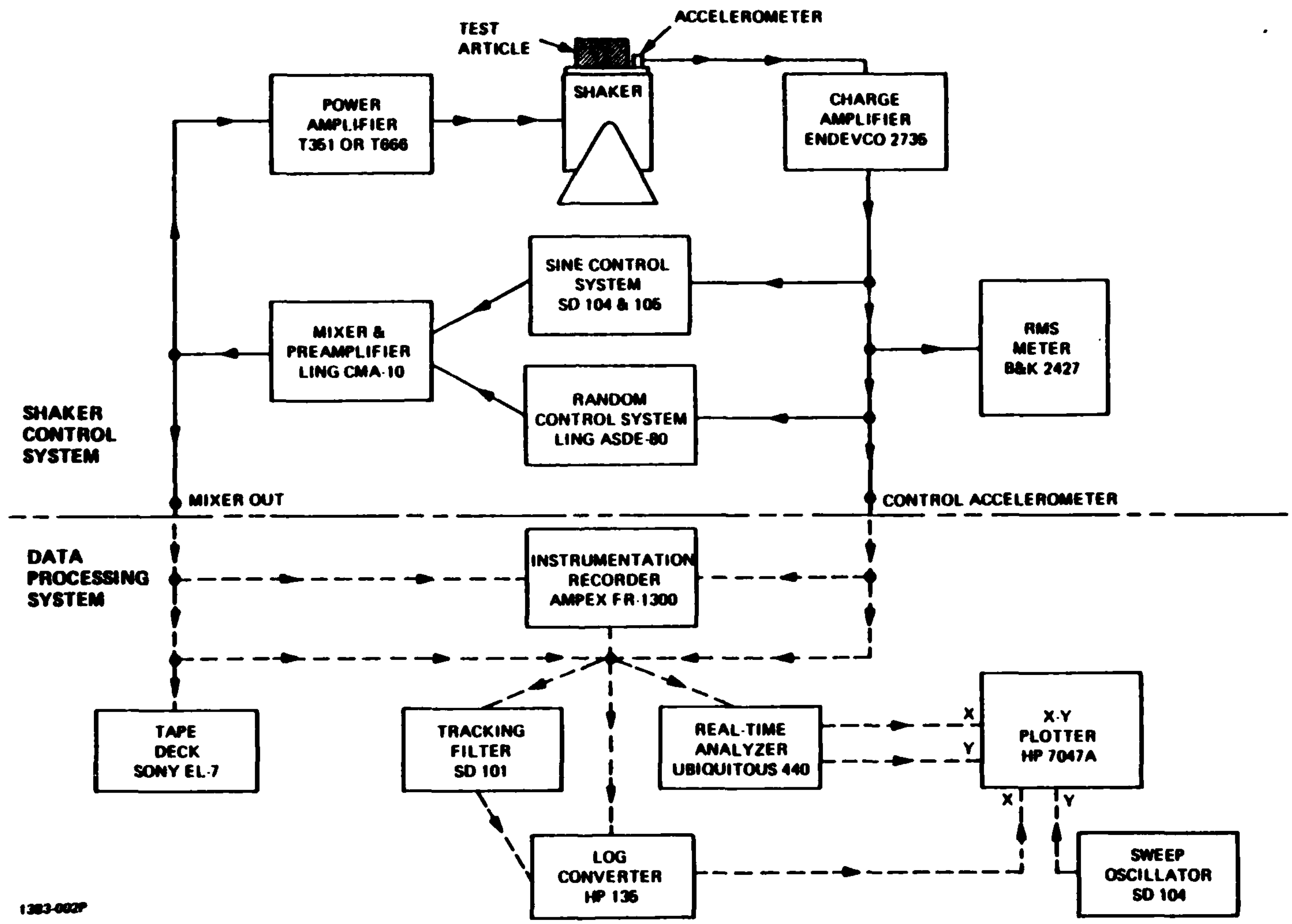

Fig. 6 Block Diagram of Normal Servo-Controlled Vibration System

Test operations with the mass mock-up were divided into the following categories for convenient, separate consideration:

- o Dynamic characteristics of the mass mock-up and shaker system.
- o Sinusoidal vibration testing techniques.
- o Random vibration testing with taped input.
- o Preparation and testing with synthetic random tape.

a. Dynamic Characteristics of the Mass Mock-up and Shaker System -

Several sinusoidal test sweeps were made over the frequency range of 20 to 2000 Hz. at amplitudes between 0.5 and 2.5g (peak) in order to measure the dynamic characteristics of the system. Four significant resonances were found:

(1) 213 Hz. - axial tie down resonance - relative gain 10.5 dB.

(2) 780 Hz. - 1st rocking mode - relative gain 5.5 dB.

(3) 1620 Hz. - major rocking mode - relative gain 23.5 dB.

(4) 1770 Hz. - 3rd rocking mode - relative gain 4.5 dB.

(Note: Relative gain is a measure of maximum to minimum output voltage at a resonant frequency).

Additional test runs were then made to determine the effect of variations in installation on these resonances. Only two parameters would normally be variable in the setup:

(1) torque on the two tie down bolts.

(2) alignment of the unit in the mount.

Test runs were made with tie down torques of 25, 50 (nominal) and 75 in. lbs. without any significant effect on the measured resonances. The MASS MOCK-UP was centered in its mount for these runs.

A second series of runs were made with the MASS MOCK-UP forced to an extreme left, center (nominal) and right position in its mount with a nominal bolt torque of 55 in. lbs. The only measurable effect was at the major rocking mode (1620 Hz). The resonant frequency varied between 1605 and

1635 Hz. (Δ = 30 Hz.) and the relative gain between 16 dB and 25 dB (Δ = 9 dB). A compensation factor for this frequency shift was derived and used in the calculations for the synthetic random tape as explained in subsequent paragraphs.

b. Sinusoidal Vibration Testing Techniques

The principal efforts during this phase were directed towards the following:

(1) performing sine sweeps with unfiltered control accelerometer.

(2) determining the magnitude of non-linearities in sine response.

(3) using taped sine as verification of the random test setup.

The advantage of performing the sinusoidal vibration sweep (to obtain sine transfer characteristics) with the control accelerometer unfiltered is that it minimizes the amount of test equipment a lab needs to perform this test. Several test runs were made with control both filtered and unfiltered with no significant effect on the measured transfer function (E/g). There is one minor problem associated with using unfiltered accelerometers when the taped sine sweep is played back thru the shaker system. This problem is manifested in the control accelerometer waveshape which becomes complex and noisy near resonant frequencies and is measured differently by different peak detecting devices and meters. It is suggested that average detecting measuring systems be used in the control and playback modes to provide closer correlation during playback. This is an area that will be investigated further during Task B.

An investigation was conducted to determine the effect of non-linearities in the sine response on the transfer characteristics. Two sine runs were made from 20 to 2000 Hz. and the sine transfer characteristics determined. The first sweep was made at an amplitude of 1.0g peak (which is the standard level we have used throughout the program) and the second at an amplitude of 2.5g peak (which is approximately equivalent in peak amplitude to the 6g rms random spectrum). The transfer functions (E/g) of these two runs were compared with that of a servo-controlled random test run and errors in the sine runs computed. It was found that the average error over the frequency range was ± 1.70 dB for the 1g peak sine sweep and ± 1.64 dB for the 2.5g peak sine sweep. The only significant difference occurred at the tie down resonant frequency (213 Hz.) where the 1g peak sine transfer function had an error of + 6.9 dB compared to + 2.5 dB error for the 2.5g peak sine data. This non-linearity is due to the increase in damping with amplitude at lower frequency resonances. A compensation factor for this non-linearity was derived and used in the calculations for the synthetic random tape as explained in subsequent paragraphs.

A limited evaluation was made when using the taped sine sweep to verify the random test setup. It was found that replaying the 1.0g peak sine sweep tape through the shaker system provided extremely accurate data on slight changes in the dynamic characteristics of the system. For example a - 15 dB drop out at the major rocking mode (1615 Hz.) (when playing back the sine tape) had an equivalent drop out of only - 3 dB at this frequency when playing back the random tape. This is due to the fact that the random spectrum is averaged over a wide band (50 Hz. in this case) while the sine data represents a single distinct frequency. While this does not diminish the usefulness of the sine tape in verifying the setup, it points up the need for improving correlation between the sine and random data.

c. Random Vibration Testing With Taped Input

Initial taped random tests were performed by recording the random output voltage of servo-controlled random tests and subsequently playing these back through the shaker system. Three different tape decks were used in this phase of the program:

(1) Nagra III (reel to reel type - 7-1/2 i.p.s. tape speed).

(2) Sony El-7 (ELcaset type - 3-3/4 i.p.s. tape speed).

(3) Hitachi D3500 (cassette type - 1-7/8 i.p.s. tape speed)

Results of these tests uncovered no operational problems associated with driving the shaker system with taped random noise. Random spectrums were uniformly within ± 3 dB of nominal except for a low frequency roll-off problem on the Nagra recorder.

d. Preparation and Testing With Synthetic Random Tape

Preparation and utilization of the synthetic random tape was scheduled for the latter part of Task A in order to permit evaluation of significant parameters and derivation of methods to compensate for them in the synthetic random tape. A single tape was prepared using the Sony El-7 recorder and played through the shaker system five times for verification of the spectrum. All spectrums were within ± 3 dB of nominal. The formulation and preparation of this tape has been described in some detail since it does represent the end product of this study program. The discussion was divided into three sequential phases:

- o formulation of the synthetic random spectrum.
- o synthesizing and recording the random spectrum.
- o test operations with the synthetic random tape.

(1) Formulation of the Synthetic Random Spectrum

The first step in this process was the measurement of the sine transfer characteristics for the system. For this purpose, data from one of the many 1g peak sine sweeps made on the MASS MOCK-UP (chosen at random), was used in the calculation. Figure 7 is a plot of the output voltage and acceleration recorded during this test run. The average amplitude of the voltage and acceleration in each of 83 bands was read from these plots and recorded. Figure 8 shows a portion of the tabulation sheet used. The sine transfer function (E/g) in each band was calculated by subtracting the recorded peak acceleration (g) from the recorded output voltage (E) and entered in the 3rd column of the tabulation sheet. (It should be noted that all data is handled in the logarithmic form (dB) so that mulitiplication and division can be simplified to computations involving only addition and subtraction).

The second step in the formulation is the addition of compensation factors for variances and non-linearities in the system. Three compensation factors were included:

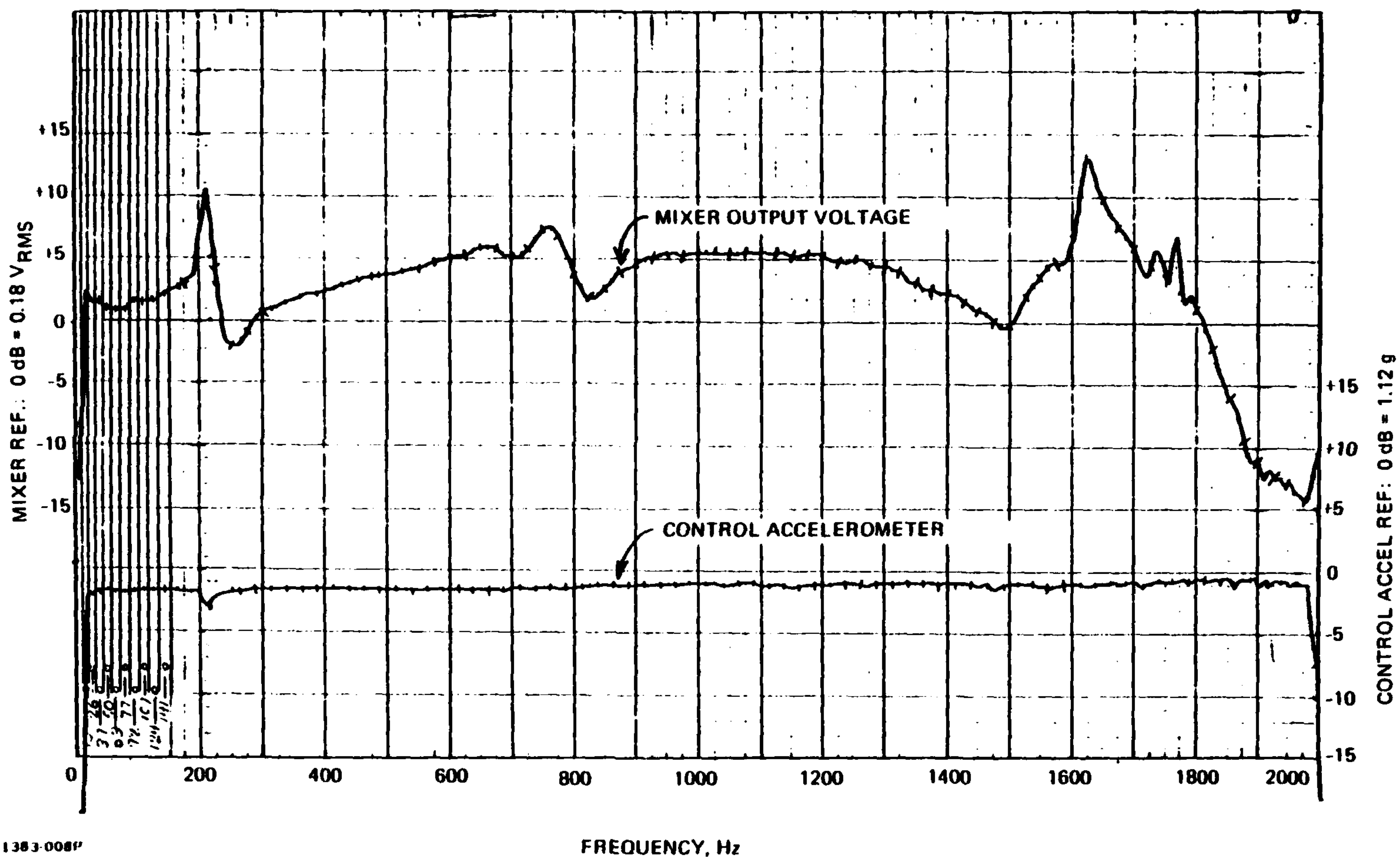

Fig. 7 Mixer Output Voltage and Acceleration

SYSTEM FILTERS			SINE DATA			COMPENSATION FACTORS			CORRECTED FUNCTIONS		SYNTHETIC RANDOM	
			(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
No.	B.W. (Hz)	C.F. (Hz)	Voltage E (dB)	Accel. g (dB)	E/g (dB)	Tape Deck (dB)	Linearity Factor (dB)	Variance Factor (dB)	Corrected E/g (dB)	Req'd g/Hz (dB)	Req'd E/Hz (dB)	Normalized (g^2/Hz)
8	16	107	+1.6	-1.6	+3.2	+0.9	-	-	+4.1	+10.0	+14.1	3.21
9	17	124	+1.7	-1.5	+3.2	+0.9	-	-	+4.1	+10.0	+14.1	3.21
10	18	141	+2.2	-1.5	+3.7	+0.9	-	-	+4.6	+10.0	+14.6	3.61
11	25	163	+2.7	-1.6	+4.3	+0.9	-	-	+5.2	+10.0	+15.2	4.14
12	25	188	+5.0	-1.7	+6.7	+0.9	-	- 0	+7.6	+10.0	+17.6	7.19
13	25	213	+8.5	-2.3	+10.8	+0.9	-3.0	-1.1	+7.6	+10.0	+17.6	7.19
14	25	238	+1.2	-1.9	+3.1	+0.8	-	- 0	+3.9	+10.0	+13.9	3.07
15	25	263	-1.3	-1.7	+0.4	+0.8	-	-	+1.2	+10.0	+11.2	1.65
16	25	288	-0.2	-1.6	+1.4	+0.8	-	-	+2.2	+10.0	+12.2	2.07

NOTES:

(A) (B) - Data is average level within a bandwidth (25 Hz maximum)

(C) - Sine transfer function E/g = (A) - (B)

(G) - Corrected sine transfer function E/g = (C) + (D) + (E) + (F)

(I) - Synthetic random spectrum E/Hz = (G) + (H)

(J) - Normalized random spectrum $g^2/\text{Hz} = 0.125 \times 10^{\left[\frac{(I)}{10}\right]}$
where 0 dB = 0.125 g^2/Hz (choice of reference explained in text)
and $dB_n = 10 \log(g_n^2/0.125)$

FIG. 8 TABULATION SHEET FOR SYNTHETIC RANDOM SPECTRUM

(1) Tape recorder characteristic: ± 1 dB gain from 20 to 2000 Hz.

(2) Non-linearity due to damping: - 3 dB at the tie down resonant frequency 213 Hz.

(3) Variance in resonant frequency: reduced the E/g at the three major resonant frequencies (213, 763, 1638 Hz.) to the mean of each and its two adjacent bands.

The compensation factors were added to the E/g in each band to yield a final corrected sine transfer function in column G. In column H the required random g/Hz. in each band is tabulated. (This is the nominal 6.0g rms spectrum used in all tests - refer to Figure I). The corrected sine transfer function E/g in each band is then added to the required random function g/Hz. for each band to generate the synthetic random voltage (E/Hz.) in each band. (Column I in chart).

The final step in the calculation is to normalize the synthetic random voltage (E/Hz.) expressed in dB to terms of g^2/Hz so it can be programmed into the automatic random equalization system, and the actual voltage spectrum generated. This is accomplished by establishing a dB reference such that all values of the synthetic random spectrum are within the analyzer range of the ASDE 80 System (.001 to 10.0 g^2/Hz). The reference used was 0 dB = .125 g^2/Hz. The synthetic random voltage in each band was normalized in this manner and tabulated in column J on chart. A plot of the synthetic random voltage (un-normalized) is presented in Figure J.

(2) Synthesizing and Recording the Random Spectrum

For this step the automatic random system was operated in a closed-loop mode, i.e., the output of the random equalization section is fed back into the analyzer section. The random system was then programmed to the normalized random spectrum derived in the previous step. The output voltage was analyzed with a spectrum analyzer and compared to the required voltage plotted in Figure 10. Minor adjustments were then made to the program to correct any slight deviations. The random output voltage was then recorded on a Sony ELcaset tape. Approximately ten minutes of this

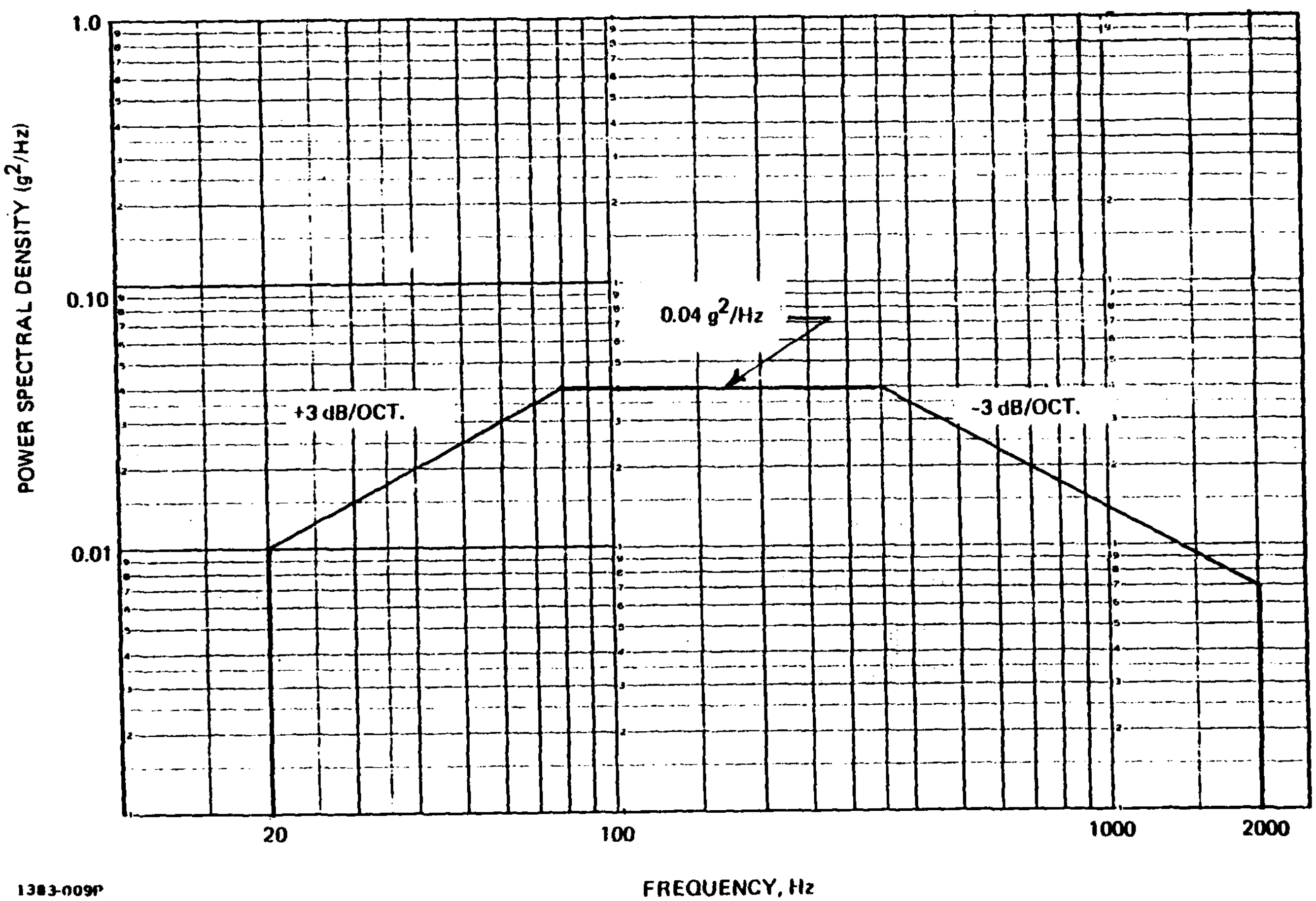

Fig. 9 Required Random Test Spectrum

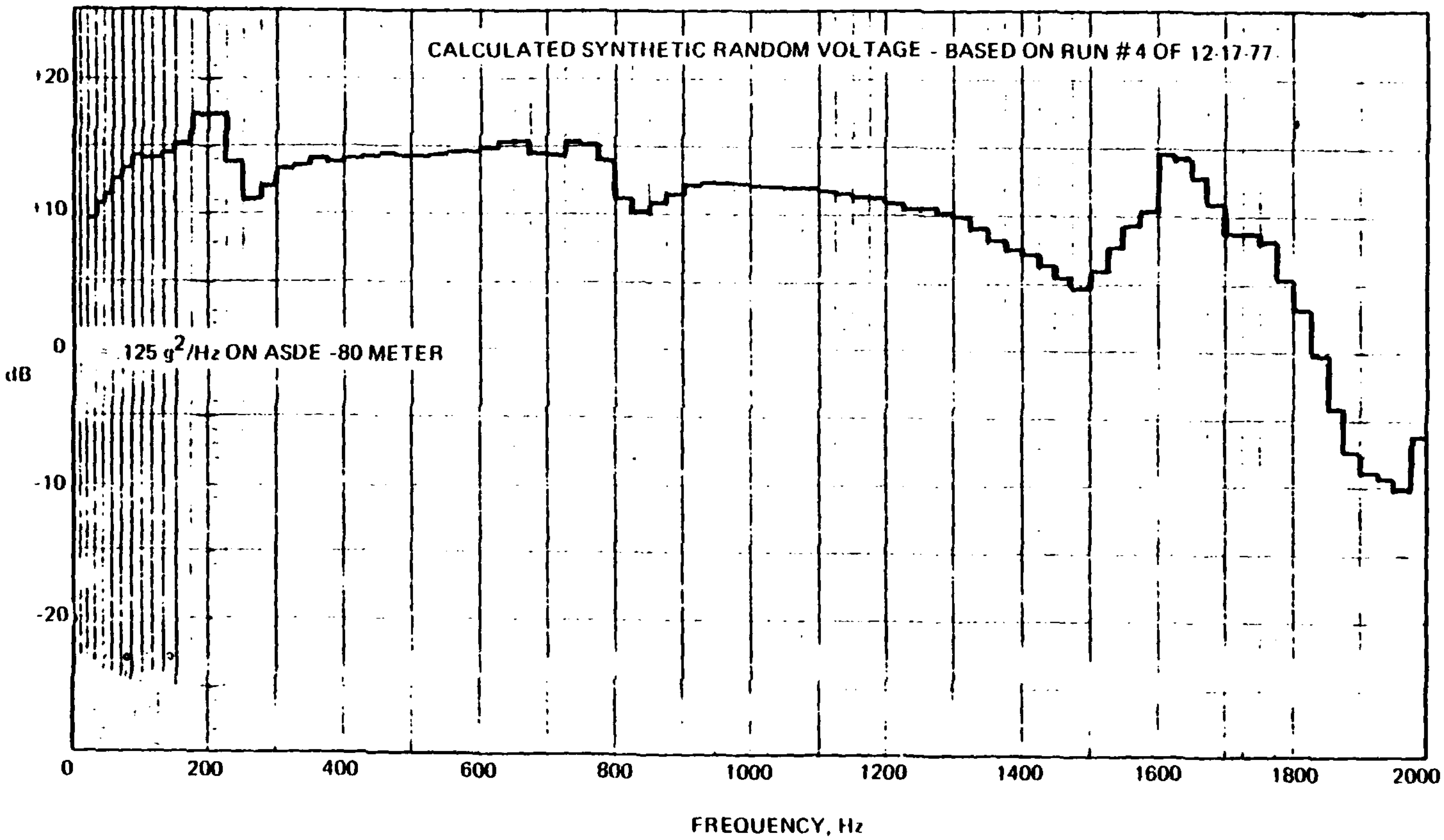

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FIG. 10 -SYNTHETIC RANDOM VOLTAGE

random spectrum was recorded. The tape was then played back into the spectrum analyzer to verify the spectrum. No errors in the taped spectrum were found.

(3) Test Operations With The Synthetic Random Tape

As previously noted the synthetic random tape was played through the shaker system with the MASS MOCK-UP, a total of five times. In two of the test runs the MASS MOCK-UP was forced to the extreme left and then right side of its mount since this had been shown to have the most significant effect on the major rocking mode frequency. Spectrum analysis of these five runs showed them all to be within + 2 and - 3 dB of nominal test level. (A typical spectrum analysis for one of the runs is shown in Figure 11).

The test results to date completely validate the methods utilized to synthesize the random tape. As demonstrated, compensation factors for various considerations can be readily applied and would appear to yield satisfactory results. More exact formulation of these compensation factors were undertaken during the evaluations conducted in Task B.

2.2.2 BASELINE TRANSFER CHARACTERISTIC INVESTIGATION

The purpose of this investigation was to review response data taken on various electronic equipment to determine the variability between units and the need for corrective factors to be utilized when defining a synthetic open loop taped random spectrum.

It has already been shown that the random synthesization technique is feasible on a one-for-one basis, as stated in paragraph 2.2.1 herein. The necessity for a more comprehensive analysis of the response data stems from the implementation methodology implicit in the technique. In actual practice only one sample of a particular generic type of equipment will be available for evaluation, i.e., the 1.0g peak sine sweep response curve, necessary to establish the equipment/retention fixture/shaker system transfer characteristics

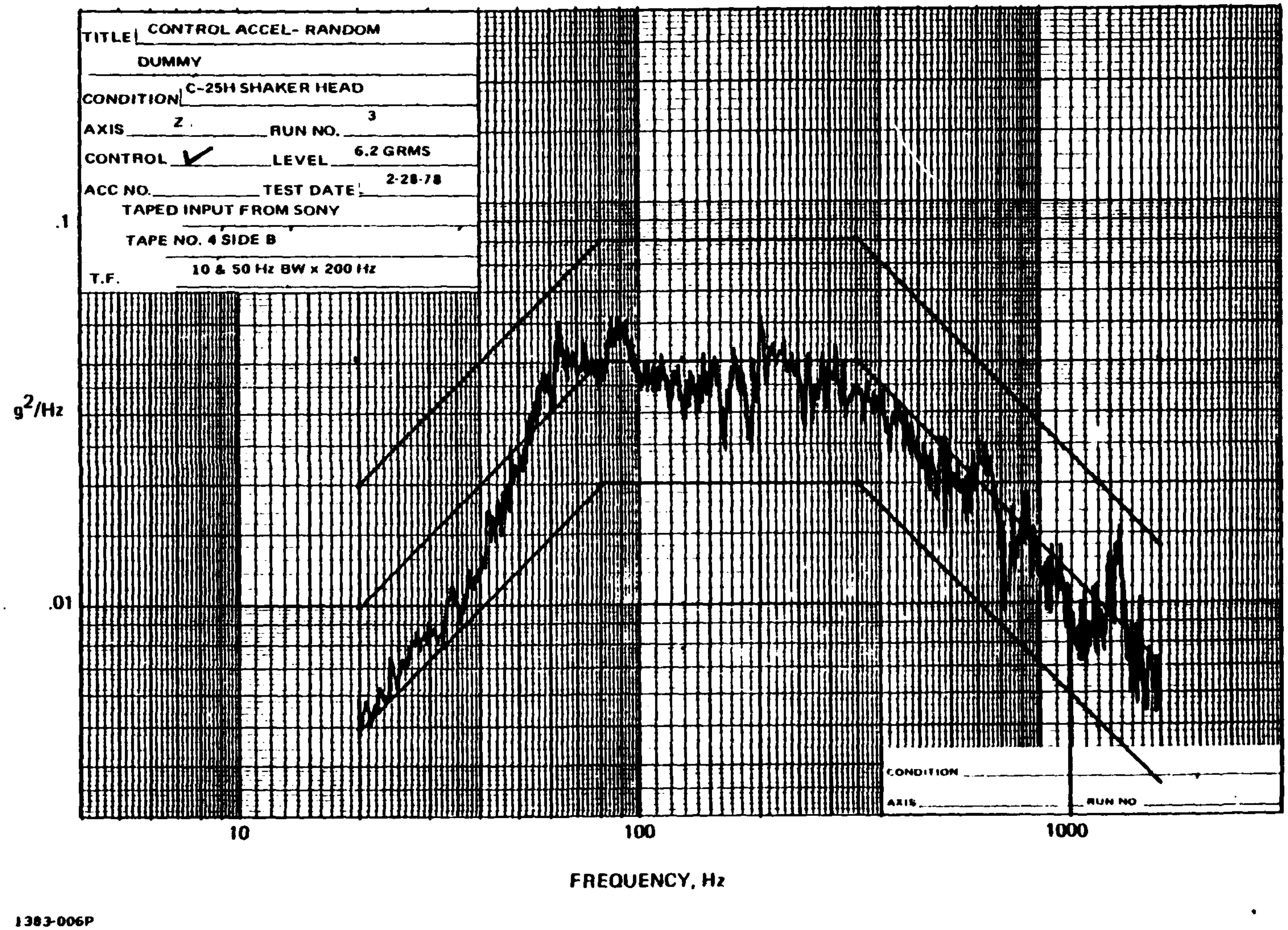


Fig.11 Taped Random Spectrum Analysis

will be generated for that sample only. Since a synthetic random spectrum is based on the characteristics of that specific sample, it is conceivable that response data of other units of the same generic type might exhibit higher or lower response characteristics. This may therefore dictate the application of suitable adjustment factors.

In order to evaluate the feasibility of applying the synthetic random spectrum technique over a broad range of test articles in day to day laboratory operations, a program was initiated to measure the dynamic transfer characteristics of a large and diverse population of electronic assemblies. The Environmental Test Laboratory located in the GAC Avionics Center, Plant 08, was chosen for this investigation since this laboratory routinely performs 200 random vibration tests a year on avionic equipment associated with GAC aircraft programs. For this study, data was acquired on only the more frequently tested electronic units (see Appendix B), to assure the acquisition of enough data for statistical analysis of the results. Four electronic units were chosen:

Unit #	Equipment Type
1	Data Converter
2	Programmer
3	Multiple Display
4	Computer

2.2.2.1 Data Acquisition and Analysis

Sinusoidal and random vibration data was acquired on each of the electronic equipment types by subjecting each of the units to the following tests:

- Sinusoidal

  A sweep was performed from 20 to 2000 Hz. at a constant level of 1.0g peak. The sweep rate was one octave/min.

- Random

  Two curves were generated, applying the spectrum shown in Figure 9, as follows:

(a) One minute at half power (approx. 3.0 Grms)

(b) Five minutes at full power (approx. 6.0 Grms)

During each of these test periods two parameters were recorded:

(a) Control acceleration.

(b) Mixer/amplifier output voltage.

This data was subsequently analyzed using a Real Time Analyzer with 5 Hz. bandwidth filters, and X-Y plots were made of amplitude versus frequency. A typical plot (for the mass mock-up) is shown in Figure 7. . A block diagram for the test setup is presented in Figure 6 .

Since a considerable amount of data was generated, several computer programs were written and utilized to expedite the evaluation.

The initial program digitized the X-Y response curves (both the acceleration (g) and mixer/amplifier voltage (E)) for each of the 83 frequency bandwidths, with each point representing the amplitude at the center frequency of the bandwidth. The output of the program produced an (E/g) relationship value required for further analysis.

A second program was written to provide the mean $(E/g)^2$ value for each of the individual units and also the generic means for each of the equipment types examined. This program also provided a common base for accurate evaluation and comparison purposes, necessitated by the fact that some shaker control input variation existed. This variation occurred since the data was acquired over several months, and normal day to day differences in shaker system controls were reflected in the overall level of the mixer output voltage. Normalization to a common mean level was provided by the second computer program, which established a normalizing factor (generic mean divided by unit mean) which was then applied by multiplying each of the 83 bandwidth values for all units within a generic type. The resulting correct (E/g) relationships were then processed to determine the maximum, minimum and mean values for each bandwidth. The program also identified the specific unit (by number) associated with the maximum and minimum values. A graphic representation depicting the sinusoidal response relationship between maximum, mean and minimum values was plotted in frequency (Hz) versus $(E/g)^2$ values. These curves are shown in Figures 12, 13, 14 and 15. An additional curve

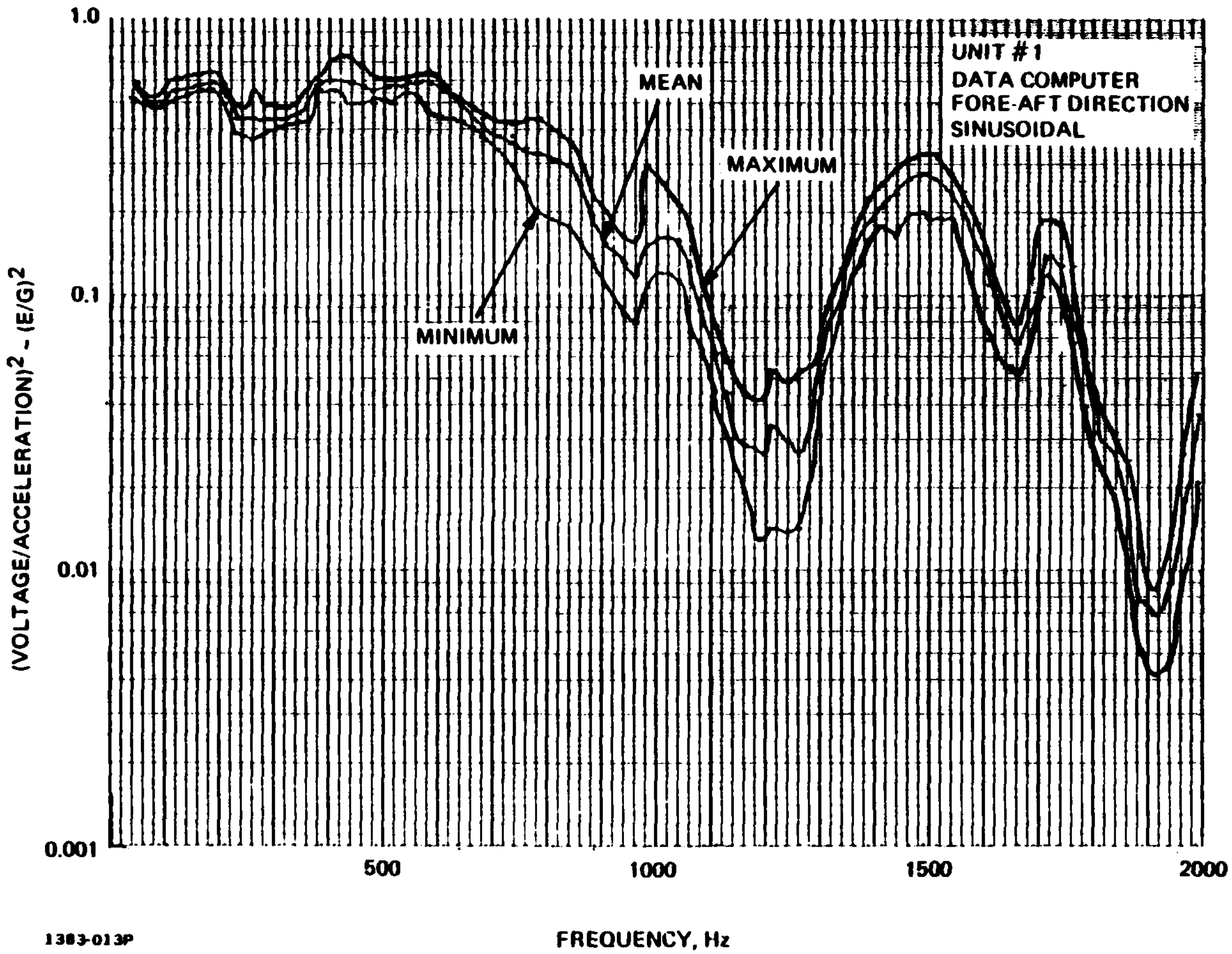


Fig. 12 Plot of Frequency Versus $(\text{Voltage/Acceleration})^2$ - $(E/G)^2$

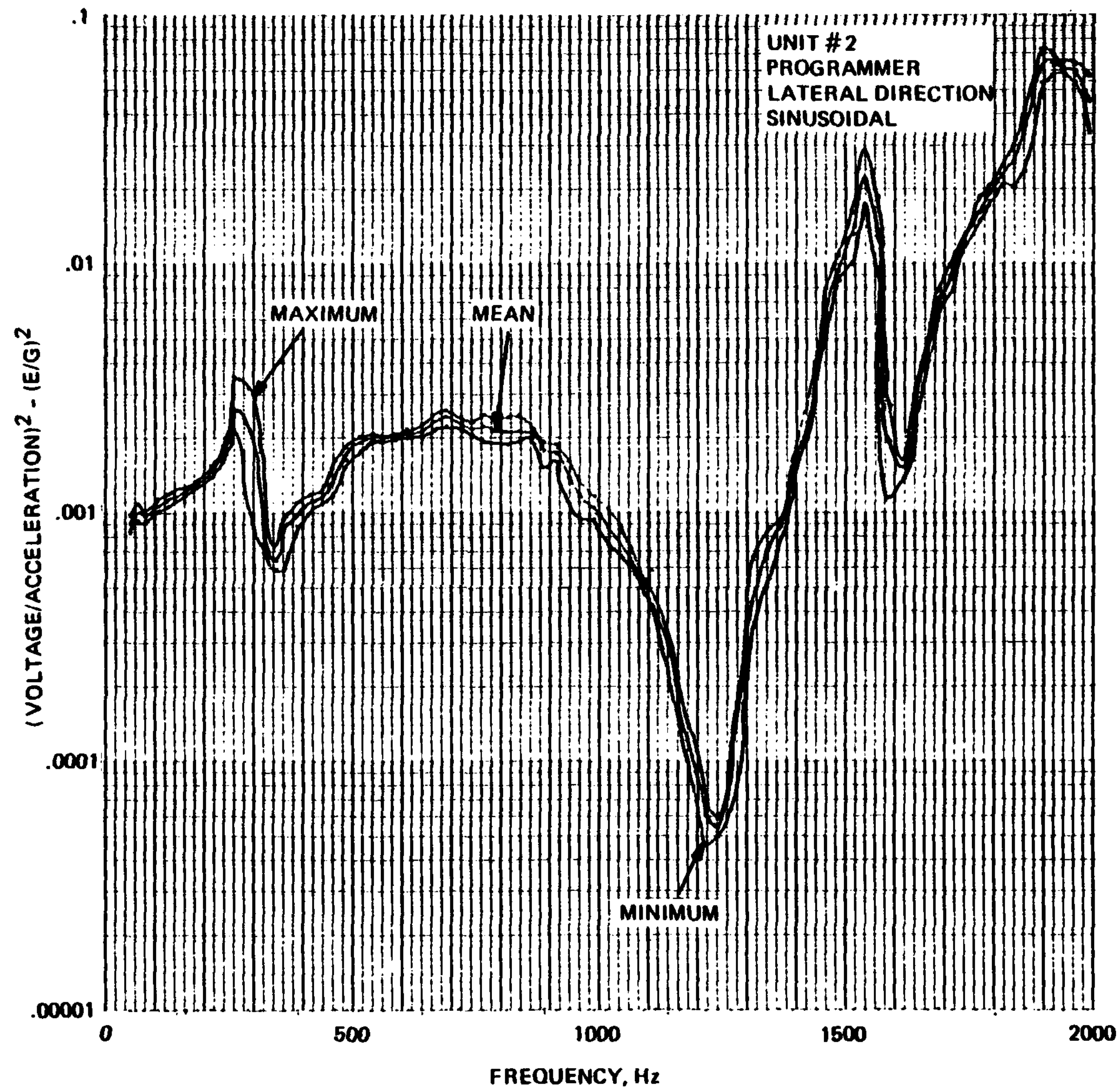


Fig.13 Plot of Frequency Versus (Voltage/Acceleration)^2 - (E/G)^2

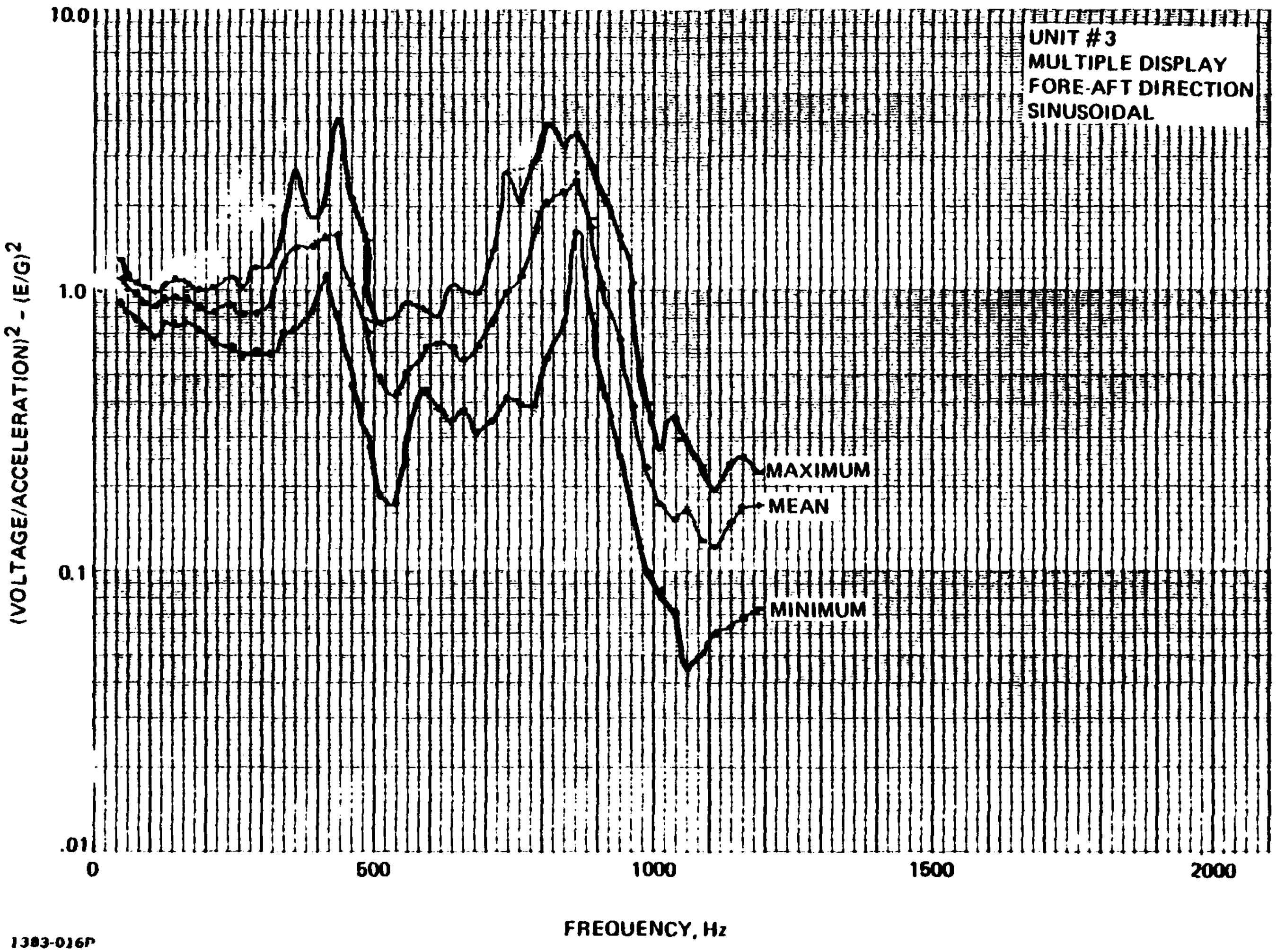


Fig. 14 Plot of Frequency Versus (Voltage/Acceleration)^2 - (E/G)^2

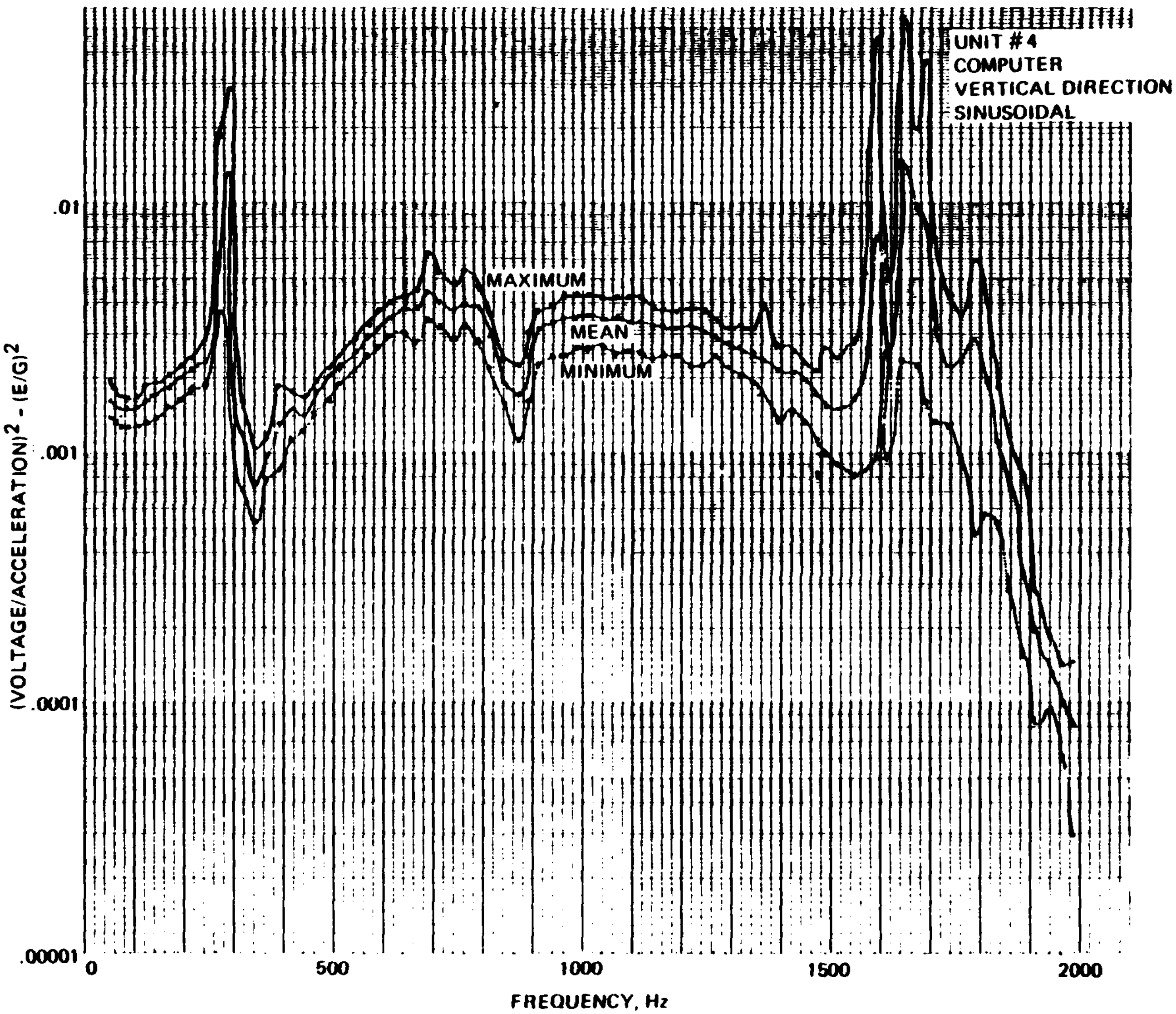


Fig. 15 Plot of Frequency Versus $(\text{Voltage/Acceleration})^2$ - $(E/G)^2$

(Figure 16) for unit Type #2 was generated to examine the random vibration transfer characteristics and permit sine-random comparisons for one generic type of equipment.

2.2.2.2 Results of Analyses

Examination of the sine data (Figures 12, 13, 14 and 15) for each of the generic types investigated, indicates an insignificant (average less than 1.0 dB) variation in response level over the total bandwidth except at equipment and fixture resonances. The variation at resonant conditions averaged 3.0 dB. This level of variation can be accounted for during the development of the synthesized random test profile and its feasibility has been demonstrated in the mass mock-up discussion (reference 2.2.1).

The minimal overall variation plus the demonstrated practicality of accounting for resonance variations confirms the fact that for any equipment type, one sinusoidal frequency sweep can be utilized to represent the transfer characteristic of that generic group.

It should also be noted that a 5 Hz. filter (extremely narrow) was utilized for both random and sine data during this investigation in order to obtain very precise data. In actual practice, random analysis filter bandwidths in the range of 25 to 100 Hz. are permitted by Military Specifications. Data averaging over this wider bandwidth significantly reduces the amplitudes of narrow resonant peaks.

A review of the random vibration data acquired on unit type #2, again indicates an insignificant variation throughout the 20-2000 Hz. range except at resonant conditions. This variation is even less than the sinusoidal variation for the same unit type and indicates that the 1.0g peak sine level input, used for response determination can be used and appears to have minimal non-linear input level effects.

Since some variations occur in resonant condition frequencies, a factor necessary to correct this variation, must be considered. A review of this variation was conducted by examining resonant frequency shifts for the various units studied. Preliminary indications are that a tolerance band of approximately ± 3% should be provided for frequencies below 1000 Hz., and a value of approximately ± 5% applied between 1000-2000 Hz.

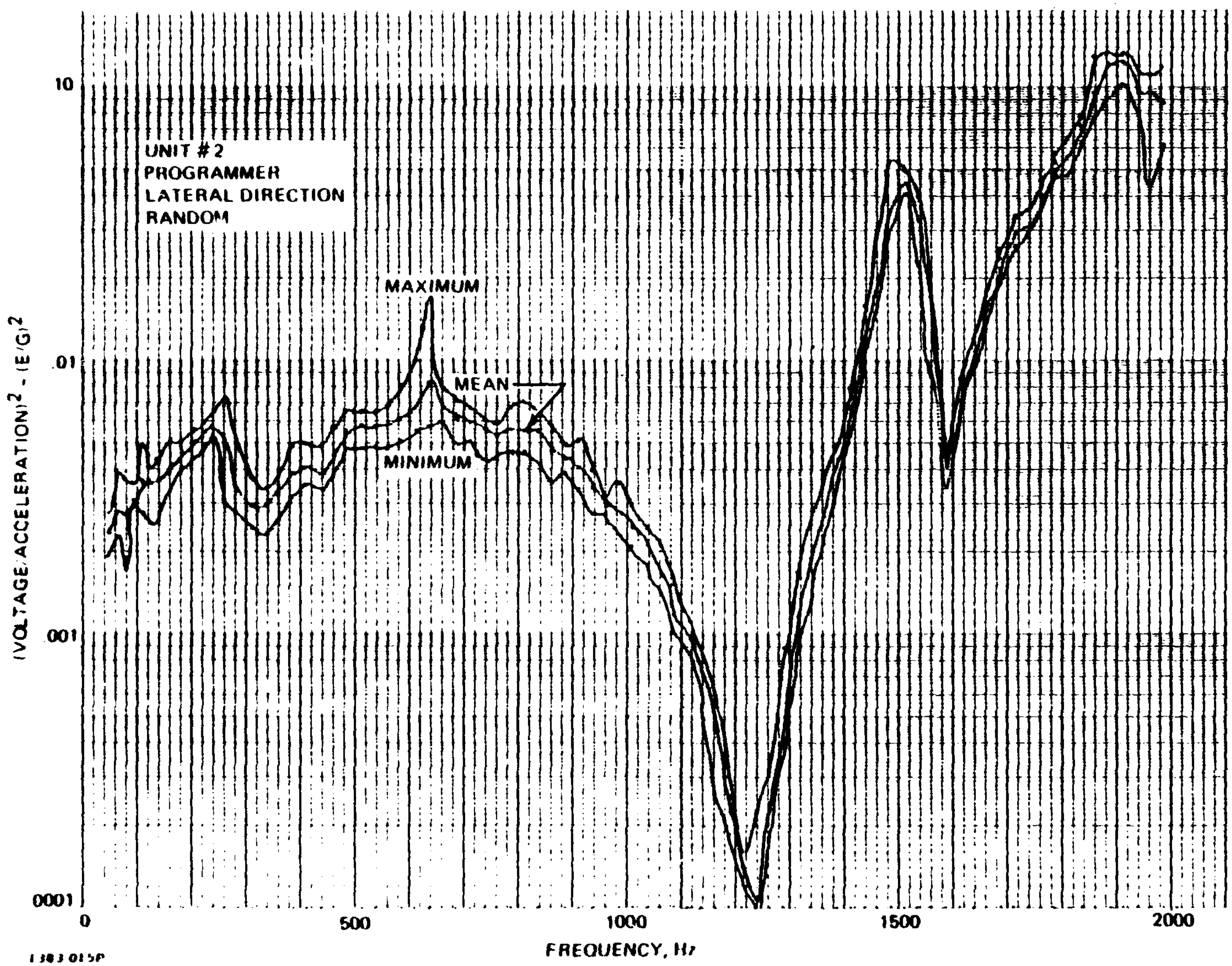


Fig. 16 Plot of Frequency Versus (Voltage/Acceleration)^2 - (E/G)^2

To determine the approximate level of transfer error existing between the developed synthesized random spectrum and the required random spectrum, a comparison study was completed for one of the generic types of electronic equipment, i.e., Group #2. This study compared the maximum and mean value for the sine and random $(E/g)^2$ values at each bandwidth and concluded that the maximum variation in resonant frequency bands was approximately $\pm$ 3.5 dB. As previously indicated this situation can be compensated for in the development of the synthesized random spectrum.

Further tests and data analysis undertaken in Task B finalized the correction factors necessary relating to the level and frequency variations.

2.2.3 SHAKER SYSTEM VARIATIONS

During this program phase four different electrodynamic shaker system arrangements (see Figure 17) were utilized in obtaining equipment response data. No significant problems were encountered with any of the systems or set-ups employed. In order to evaluate variations due to extended usage an in-depth study was made of the characteristics of one shaker system to assess any changes occurring over a long time period. It was important that relatively stationary characteristics were maintained to minimize the need for additional compensation due to shaker systems variation.

This investigation included two basic evaluations:

(a) Shaker system characteristics as a function of time.

(b) Shaker system characteristics with variable operational parameters.

2.2.3.1 Shaker System Characteristics As a Function of Time

For this series of tests the MB model C25HB Shaker (rated 2300 lbs. RMS force capacity - random), driven by the MB model T-666 Power Amplifier (rated 15 KVA) was used. The shaker was attached to a GAC oil film slip table to which only the test fixture for the test article had been bolted. A 1g peak sine sweep with the empty fixture was made and sine transfer characteristics determined. Eight sine runs were made, distributed evenly over a six month period. No special attempt was

Fig. 17 - Shaker Systems Used In Program

Mass Mock-up & Unit #4	C-25H shaker head (rated 1700 lbs RMS force capacity - random) and T351 Power Amplifier (rated 6 KVA)
Unit #1 Unit #3 & #6	C-25HB shaker head (rated 2800 lbs RMS force capacity - random) with oil film slip table and T-666 Power Amplifier (rated 15 KVA)
Unit #5 Unit #2 Unit #7	C-10 shaker systems (rated 850 lbs RMS force capacity - random with flexure table and T351 Power Amplifier.
Mass Mock-up &	C-10 shaker head and T351 Power Amplifier
Unit #4	" "
Unit #7	" "
Unit #2	" "

made to duplicate the setup from test to test, except that normally required by good laboratory practices.

Sinusoidal data plots for each run were made in the normal manner used for production hardware. For the purpose of this investigation data was read from the plots at 7 different frequencies which represent the minimum and maximums of the transfer function. The amplitude at each data point was normalized to a 0 dB reference at 600 Hz. to account for minor variations in system gains and instrumentation calibrations from run to run.

The maximum variation in resonant frequency was + 29 Hz and - 14 Hz with an average max/min variation over the seven frequencies and 8 data plots of ± 12.5 Hz. This represents only half a bandwidth with the random equalization system which is used in synthesizing the random tape, and as such would be considered insignificant.

The maximum variation in the transfer function (E/g) was + 2.1 dB and - 2.3 dB with an average max/min variation over the seven frequencies and 8 data plots of ± 1.3 dB. Considering the sensitivity of the sine run compared to the random run, we could expect a random spectrum variation of less than 0.5 dB.

2.2.3.2 Shaker System Characteristics With Variable Operational Parameters

In order to evaluate the effect of shaker system gains on the dynamic characteristics of a setup, a series of 1.0g peak sine sweeps were made using the MASS MOCK-UP. For these tests, the MASS MOCK-UP was removed and the shaker system operated with only the test fixture bolted to the shaker head.

The shaker system as previously noted is composed of an MB C-25H shaker and an MB T351 Power Amplifier. Only two variables are readily controlled by the operator of the system:

(a) Shaker field current - which is directly proportional to force which the shaker can develop.
(b) Output tube plate voltage - which is directly proportional to the output voltage and inversely proportional to the output current of the power amplifier.

A third variable was also included in this test, tightness of control accelerometer. Although it is unrelated to system gain, it is a variable that could be easily introduced into a test setup and result in possible errors in the transfer function.

Four test runs were made with the mixer output voltage recorded in each. The variable in each run was as follows:

(a) Nominal test conditions.
(b) Control accelerometer only finger tight.
(c) Shaker field current 25% below nominal.
(d) Output tube plate voltage 15% below nominal.

The relative gain of the mixer output was measured at the four major resonances with the following results:

	760 Hz.	1550 Hz.	1615 Hz.	1765 Hz.
Run #1 (nominal)	4.5 dB	19.5 dB	6.2 dB	7.4 dB
Run #2 (accel loose)	4.3 dB	17.3 dB	7.6 dB	9.6 dB
Run #3 (-25% field)	4.7 dB	19.7 dB	5.6 dB	7.7 dB
Run #4 (-15% plate)	4.8 dB	19.2 dB	6.4 dB	8.0 dB

The variations in system gain (Run #3 and 4) have a negligible effect on transfer characteristics with a worst case of ±0.6 dB from nominal. The looseness in the control accelerometer has a more significant effect at the higher frequency resonances: ± 2.2 dB from nominal.

In summary, the result of these and other tests with this shaker system lead to the conclusion that minor variations in system parameters have little or no effect on transfer characteristics. The significance to the taped random technique is two fold:

(a) Normal degradation of system gain due to aging of components will not be a problem.
(b) Requirements for exact duplication of all system parameters in each test setup can be relaxed.

It should be noted that these results are preliminary since they involve a single shaker system. A more extensive evaluation of all three shaker systems will be undertaken in the next phase of the program.

2.2.4 OPEN LOOP OPERATION

In a standard vibration test facility a servo, utilizing an accelerometer as a feedback device, is used to drive a shaker system. This closed loop mode of operation normally provides good control of the vibration systems power levels. However, if the feedback loop is lost, the servo rapidly increases the drive voltage to the shaker in an attempt to re-establish the lost feedback signal level. This can result in overtest and equipment damage. The open loop mode of operation utilized in the taped random approach utilizes manual control, wherein the operator becomes the feedback loop, and should incur no greater potential for equipment damage than the automatic system. The purpose of this discussion is to review open loop testing with the taped random technique and demonstrate how levels can be controlled with a minimum risk of overtest.

2.2.4.1 Manual Control of System

The essential element of this technique is manual control of the shaker amplitude. With manual control a single gain control is substituted for the sine or random servo system employed in most modern vibration systems. This is inherently a safer system than servo-control since problems in the accelerometer feedback system will not automatically increase the shaker amplitude as it will in a servo system. The main disadvantage of course is control speed. Even the most skilled operator could not keep pace with the quickly changing input voltages required during a constant acceleration frequency sweep. However, if the operator is supplied with preprogrammed voltages (rather than the normal constant voltage from an oscillator) necessary to maintain an acceleration level, he needs to manually adjust the vibration level only once at the start of the vibration test. This is the only control the operator need adjust for the test since all the other control variables have been pre-recorded on the tape used to drive the system. A control feedback is still provided to the operator in the form of an RMS meter which indicates control acceleration and which was utilized in setting the gain control initially.

This is the heart of the proposed test system and is basically the same for both sine and random testing.

2.2.4.2 Sinusoidal Testing With Taped Input

Preparation of the sinusoidal tape is the simpler of the two tasks since it utilizes the original tape which was recorded during the servo-controlled sine sweep for determination of transfer characteristics. The essential elements of the servo-controlled sine sweep (during tape recording) are as follows:

(a) Sweep 2000 to 20 Hz.
(b) Control amplitude of 1.0g peak.
(c) Sweep rate 1 oct/min.
(d) Dwell 1 minute at 2000 Hz. at start of sweep.

As was pointed out in previous sections, the control accelerometer need not be filtered for this test but if the equipment is available, it is desirable.

The frequency range of 2000 to 20 Hz. was chosen to provide transfer functions for the normal range of random vibration test spectrums. The sweep rate is that normally specified in MIL-STD Qualification Tests and is slow enough to allow resonant amplitudes to rise to 90 to 100% of their peak for accurate transfer function calculations. An amplitude of 1g peak was chose for two reasons:

(a) Small enough amplitude at 20 Hz. (0.05" D.A) to permit a constant g sweep over the entire frequency range.
(b) Amplitude is well below qualification levels in the mid and high frequency ranges where variations in test article characteristics could cause higher level spikes.

A one minute dwell is recorded at 2000 Hz. at the start of the tape to permit the operator (when using a tape input to the shaker system) to adjust his system gain control until he reads 1g on his RMS meter. Gain is adjusted at 2000 Hz. rather than 20 Hz. since any operator error resulting in over-shooting the 1g peak amplitude will have minimal effect on the test article.

During the playback of the tape through the system the operator will monitor the acceleration level on the RMS meter to verify that the acceleration stays within required tolerance levels. (These tolerances will be developed in Task B of the Program). Graphic recording techniques using oscillographs or X-Y plotters would be desirable in pinpointing problem areas but are not considered essential for test operations.

2.2.4.3 Random Testing With Taped Input

The technical details associated with preparation of the synthetic random tape is discussed in depth in paragraph 2.2.1. Testing operations required utilizing the random tape are identical to those conducted using the sine tape. The operator increases his gain control until he reads the correct G rms level (for the spectrum) on his RMS meter. Since the random noise is a stationary process he can start and stop the tape at any point to verify test article operation and then resume testing. At least 10 minutes of random noise should be recorded on a tape.

There is however no method of verifying the test spectrum during the test without an expensive spectrum analyzer. While this would be a desirable asset to this procedure, the program method of verifying the spectrum with a prior taped sine sweep is a viable and satisfactory alternative.

2.2.4.4 Overtest Protection

In any testing operation, the best safeguard is an alert operator. Utilizing this manual control system, the operator directly controls the vibration level of the system with the gain control. He can reduce the level at any time during a test run if he suspects a problem.

One of the potential problems associated with this system is the use of the wrong tape cassette with a test article. It has been pointed out in the general discussion of this technique that each tape is tailored for a particular type of test article for a specific test axis on a particular fixture and shaker system. The use of the wrong tape would not necessarily be apparent when running a random test (without a spectrum analyzer) but would be readily detected with the sine run. For this reason it is recommended that the sine run be recorded immediately before the random run on the tape cassette and that a sine run always be conducted prior to a random test run.

A failure in the control accelerometer feedback will not result in an overtest as it might in a servo-controlled system. The operator will immediately detect a loss of signal on his RMS meter and car turn down the gain and correct the problem.

2.2.5 TAPE DECK EVALUATION

The success and feasibility of the taped random technique was extremely dependent on the availability of an economical audio tape deck which could meet the performance requirements of the program. A comprehensive investigation was therefore included in the study to:

(a) Review specifications for a variety of tape decks and select a suitable unit.

(b) Procure and test the tape deck selected to verify its short and long term capabilities.

The operating log presented in Appendix C summarizes the tasks performed during this investigation.

2.2.5.1 Specification Review

An in-depth review of various audio trade journals provided the initial information required to selectively contact equipment manufacturers and discuss the program needs in terms of their units performance. In effect, this review served as a screen which reduced a large number of available decks to only a few potential candidates. Following this phase of the effort, the manufacturers of the candidate units were requested to submit specifications for review. After a detailed evaluation of this documentation two units were purchased and subsequently evaluated. Unit number one was a Sony Elcaset Model EL-7 and was considered the primary candidate since it apparently met or exceeded all our requirements. The second unit a Hitachi Model D3500, also met the study requirements, and was purchased to provide a second, more economical source for the tape deck.

2.2.5.2 Test and Evaluation Program

Each of the units was initially checked to confirm operational status after delivery. A limited test program was then conducted to verify manufacturers claims.

Figure 18 depicts the setup that was used during these preliminary as well as subsequent tests. Table 1 presents the results of the preliminary tests conducted.

Detailed Evaluation Test Program

The tests performed in this section were selected in order to best

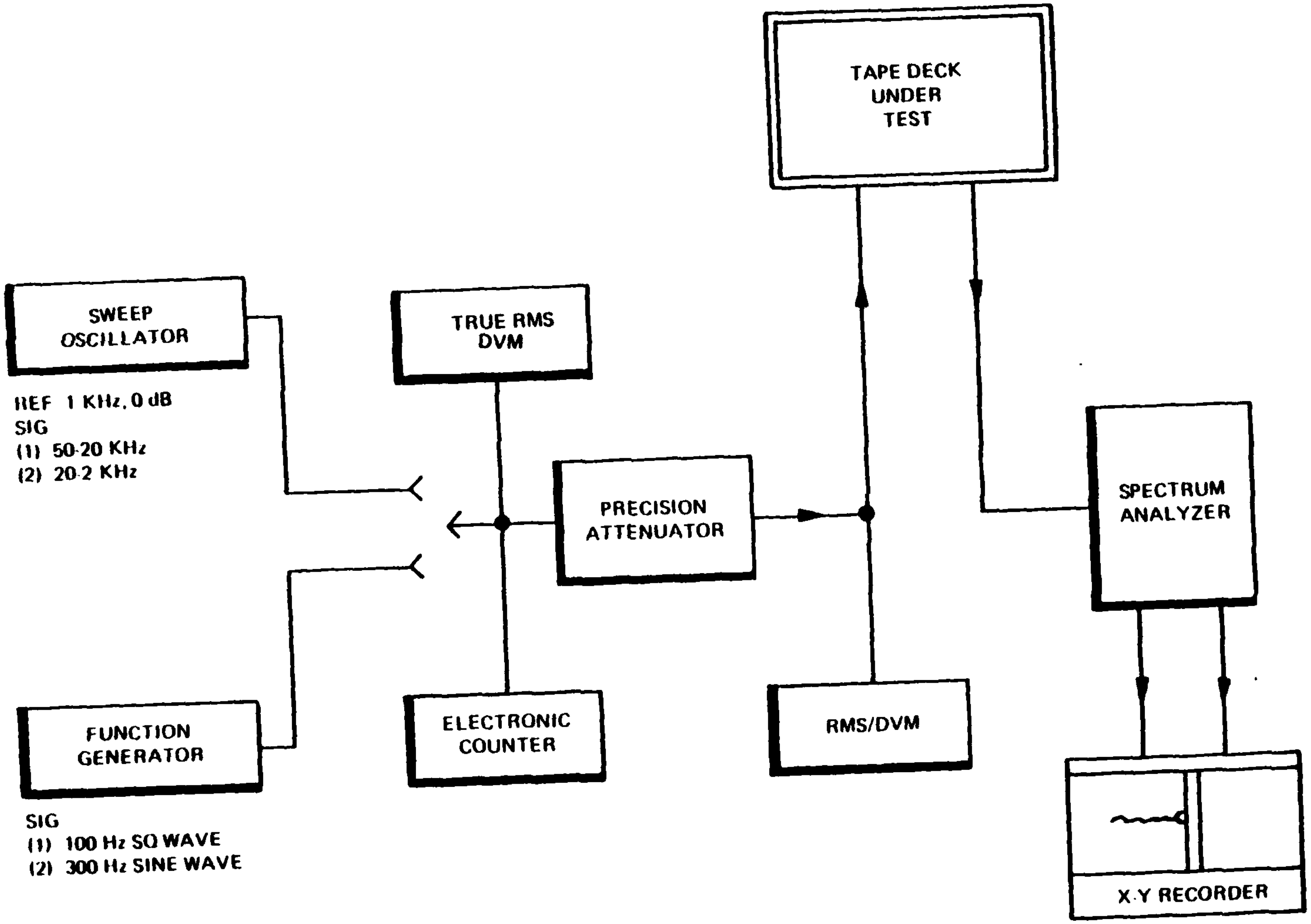


Figure 18 Tape Deck Test Setup

2935-23W

TABLE 1 - INITIAL MEASUREMENTS

Specimen: SONY ELcaset EL-7 with SLH-60 Type I tapes.

Tests: Operational check of Manufacturer's Specifications.

PARAMETER	MANUFACTURER'S DATA	TEST RESULTS
Freq. Response	25 - 20000 Hz ±3dB	20 - 16300 Hz ± 3dB
Sig. to noise ratio	59 dB at peak level	58.6 dB
(DOLBY NR off)		
Line Input	0.095V(-18dB) into 100Kohms	0.057 VRMS
Line Output	0.775V(0dB) into 100Kohms	0.712 VRMS

demonstrate the tape deck's capability to meet the unique program requirements. These requirements can be summarized as follows:

(a) Linear frequency response over a range of 20 to 2000 Hz.

(b) Usable dynamic range of 40 dB.

(c) Stability and repeatability of tape system.

The techniques normally used in evaluation of audio decks were not employed since the data would not be applicable to the tape deck final utilization. The tests were therefore modified in order to present more meaningful information when determining the error contributed by the tape deck in meeting these requirements.

It should be noted that the Hitachi deck became inoperative after a very limited amount of testing and was returned to the manufacturer for repair.

2.2.5.2.1 <u>Frequency Response Tests</u>

These tests were conducted to determine the magnitude of the error introduced by the tape deck when the voltages are played back over the 20 to 2000 Hz. frequency band. They included the following tests:

- Frequency Response With Nominal Input Signal

  A constant level sinusoidal input signal, indicating 0 dB on each recorder VU meter (highest mfg. recommended level for continuous recording) was recorded in a frequency sweep from 20 to 2000 Hz. The tape was then played back through the spectrum analyzer to measure the linearity of the recorder. Using the indicated level at 1000 Hz as the 0 dB reference, the following errors were found over the frequency range:

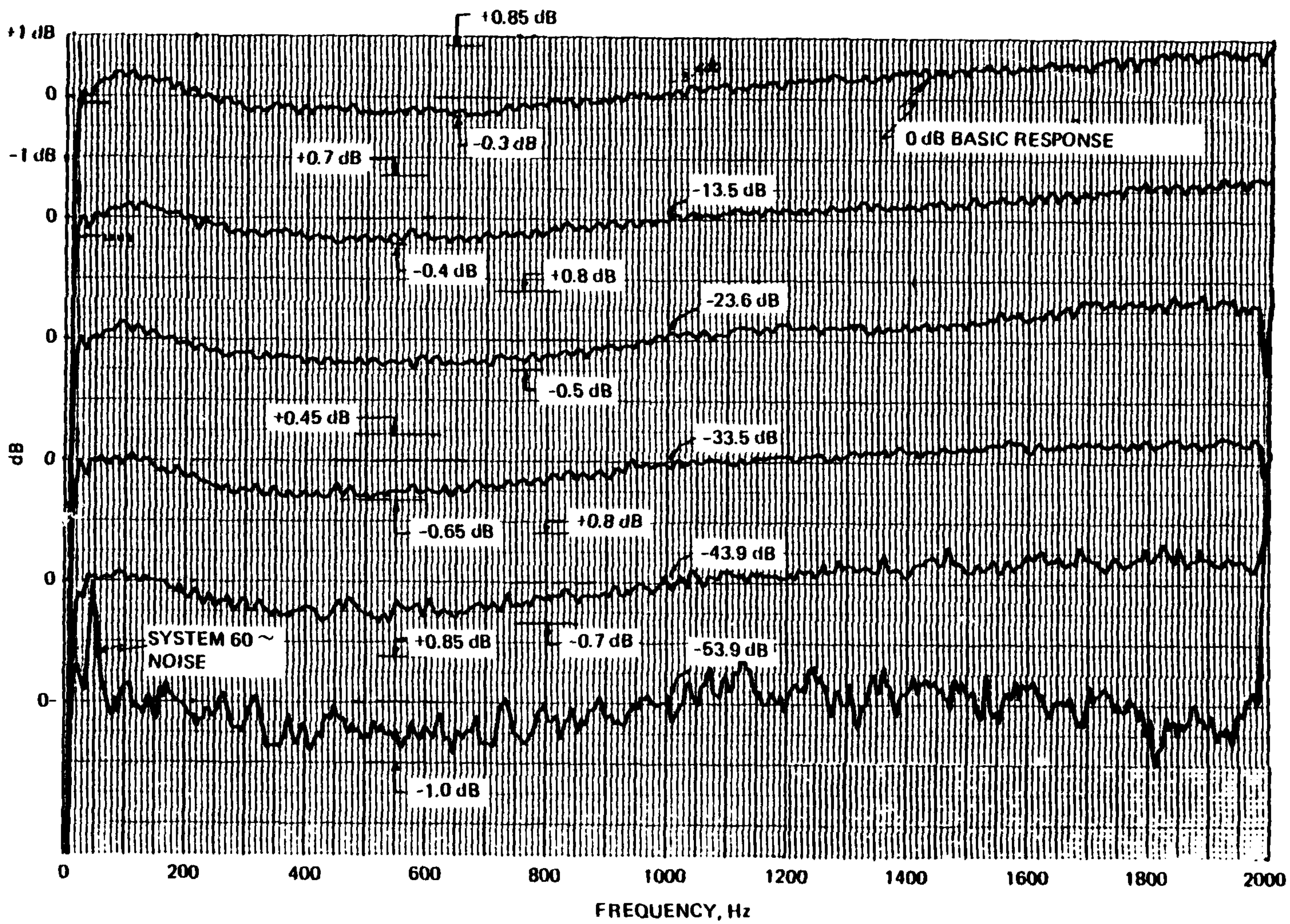
  (a) Sony EL-7 - + 0.85dB, - 0.3dB, ref: Figure 19.

  (b) Hitachi D3500 - + 1 dB, - 6.5 dB

  An exploded view of the low frequency (20 Hz.) response of the recorder was made using the same 0 dB input with the following results:

  (a) Sony EL-7 output signal was only - 0.8 dB at 20 Hz. ref: Figure 20.

  (b) Hitachi D3500 was not specifically tested at this level.



1383-012P

Fig. 19 Response vs Signal Level (Playback - Sony EL-7)

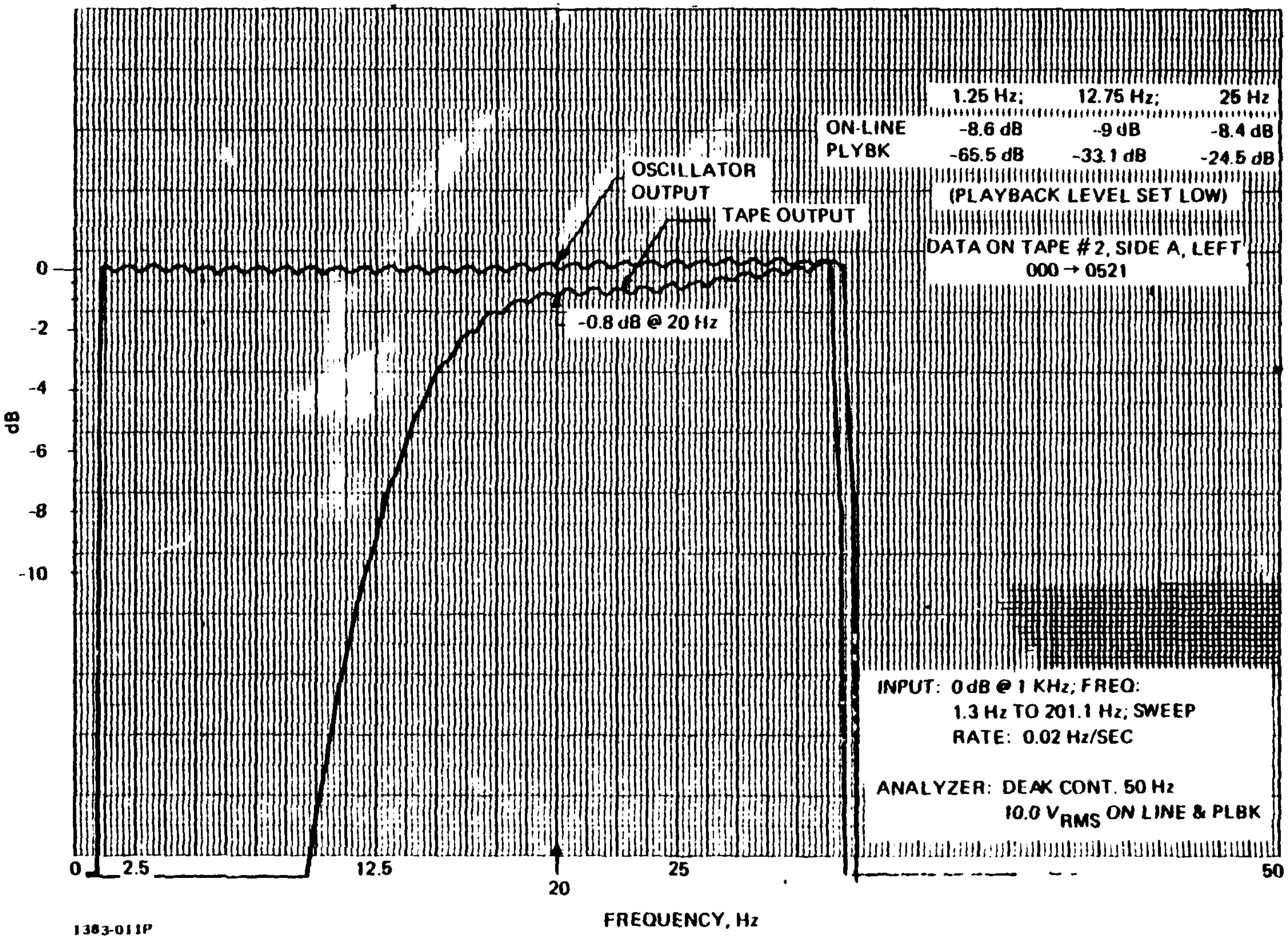


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Fig. 20 Low Frequency Response (Sony EL-7)

- Usable Dynamic Range

In order to determine the change in frequency response as a function of input signal level, a series of recordings of a constant amplitude sinusoisal signal were made with the input voltage in each frequency sweep at -10, -20, -30, -40, and -50 dB below the 0 dB level used in the previous tests. Response data for the Sony is presented in Table 2 and Figure 19.

The results of these tests can be summarized as follows:

(a) Sony - no significant errors introduced when the input signal varies from 0 dB to -40 dB.

(b) Hitachi - the response plots indicate significant non-linearity when the input signal is approximately -20 dB, with the error increased by approximately 3 dB at both the high and low frequency.

- Stability and Repeatability of Tape System

This investigation was performed in two parts to evaluate both the short and long term variations in the tape system response. Test data is available only for the Sony due to operational problems with the Hitachi which were previously noted.

For short term response,a tape (No. 1) was recorded with a sine sweep recorded at different level as described in previous paragraphs. This tape was played back and the data analyzed periodically every few days to determine whether the response error increases with repeated utilization.

For long term response a similar tape (No. 3) was recorded and periodically every few weeks, played back and the data analyzed to determine whether the recorder performance had deteriorated. The results of both of these investigations are presented in Table 2. No significant variations were found in either program.

TABLE 2 - RESPONSE DATA

Test Specimen: SONY Elcaset Elcaset EL-7 MAX. ERROR VS. SIGNAL LEVEL

PLAYBACK DATES:	+3dB		0dB		-10dB		-20dB		-30dB		-40dB		-50dB	
SHORT TERM	+	-	+dB	-dB	+dB	-dB	+dB	-dB	+dB	-dB	+dB	-dB	+dB	-dB
12-21-77			1.0	0.5	1.0	0.4	0.8	0.6	0.8	0.8	0.6	0.8	0.7	1.2
1-3-78	-	-	0.85	0.3	0.7	0.4	0.8	0.5	0.45	0.65	0.8	0.7	0.85	1.0
1-5-78	-	-	0.6	0.4	0.7	0.45	0.65	0.6	0.65	0.6	0.6	0.65	0.55	1.05
1-10-78	-	-	0.9	0.55	0.8	0.50	0.70	0.65	0.50	1.0	0.5	1.0	0.55	1.55
1-12-78	-	-	1.0	0.70	0.6	0.6	0.70	0.6	0.40	1.0	0.6	0.6	0.50	0.9
1-16-78	-	-	0.6	0.50	0.7	0.4	0.70	0.4	0.55	0.70	0.7	0.6	0.4	1.3
1-26-78 A	-	-	0.6	0.40	0.7	0.35	0.75	0.4	0.40	0.65	0.6	0.6	1.15	1.25
1-26-78 B	-	-	-	-	-	-	-	-	0.50	0.6	0.7	0.75	-	-
1-31-78	-	-	0.6	0.80	0.6	0.8	0.7	0.5	0.45	0.75	0.5	0.60	1.0	0.7
2-2-78	-	-	0.6	0.60	0.8	0.7	0.5	0.70	0.55	0.95	0.55	0.85	0.8	0.9
2-14-78	-	-	0.55	0.65	0.75	0.7	0.75	0.65	0.45	0.75	0.65	0.90	0.5	1.55
2-17-78	-	-	0.75	0.55	0.65	0.65	0.70	0.65	0.50	0.80	0.70	0.85	0.3	1.4
2-22-78	-	-	0.70	0.70	0.65	0.75	0.65	0.65	0.40	0.75	0.40	0.80	1.25	1.1
2-28-78	-	-	0.70	0.60	0.6	0.6	0.7	0.5	0.8	0.70	0.80	0.75	0.9	0.99
3-1-78	-	-	0.75	0.40	0.65	0.60	0.7	0.6	0.45	0.60	0.65	0.65	0.75	2.05
6-7-78	-	-	0.65	0.70	0.80	0.80	0.70	0.80	0.40	1.2	0.40	1.0	1.1	1.2
7-5-78	-	-	0.60	0.50	0.65	0.50	0.55	0.60	0.50	0.7	0.45	0.70	0.3	1.9
8-23-78	-	-	1.0	0.70	0.70	0.60	0.60	0.80	0.40	1.2	0.60	1.0	-	-
9-21-78	-	-	1.0	0.50	0.70	0.80	0.60	0.80	0.60	0.8	0.60	1.20	-	-
11-4-78	-	-	0.80	0.70	0.60	0.80	0.70	0.60	0.60	0.70	0.40	1.1	-	-
AVERAGE	-	-	0.75	.56	.70	.60	0.68	0.61	0.52	0.80	0.59	0.81	0.73	1.25
LONG TERM														
1-9-78	1.0	1.3	0.8	0.55	0.9	0.5	0.75	0.55	0.45	0.75	0.65	0.9	-	-
2-14-78	0.75	0.8	0.7	0.8	0.70	0.7	0.70	0.4	0.6	0.65	0.30	0.9	-	-
3-1-78	0.6	1.3	0.7	0.7	0.6	0.5	0.65	0.35	0.65	0.40	0.50	0.70	-	-
6-7-78	.65	1.05	0.75	1.0	0.70	0.80	0.80	0.50	0.60	0.80	0.45	0.80	-	-
7-5-78	.75	1.40	0.80	1.4	0.70	1.20	0.65	1.1	0.55	1.30	0.30	1.20	-	-
8-23-78	.50	1.70	0.65	1.2	0.55	1.05	0.70	0.50	0.55	1.0	0.40	1.30	-	-
11-4-78	.70	1.50	0.80	1.1	0.60	1.20	0.60	1.0	0.50	1.1	0.50	1.10	-	-
AVERAGE	0.71	1.30	0.74	0.96	0.68	0.85	0.69	0.63	0.56	0.84	0.44	0.99	-	-

2.2.5.2.2 Additional Tape System Tests

Several other tests to evaluate characteristics of the tape system were performed, and are summarized below:

(a) Circuit Loading - a test was run to measure the effect on frequency response of varying shaker system input impedances. Loading was varied over a range of 100K to 1K ohms. Both tape decks are within -4 dB at 5K ohms but drop to -12 and -7 dB at an input loading of only 1K ohm.

(b) Time Base Distortion - a test was performed to measure time base distortion due to such causes as tape stretch or binding, variation in tape deck speed, etc. A 100 Hz. squarewave and a 300 Hz. sinewave were recorded on the Sony. The tape was played back 30 times and the data analyzed to measure actual frequency. With an analyzer resolution of 1 Hz no frequency shifts were observed.

(c) Tape Deck Cleaning - an improvement of approximately 0.2 dB in response error resulted when the heads were cleaned after 60 hours of use.

(d) Dolby Noise Reduction - this tape deck feature is effective only above 2000 Hz. and had no measurable effect on the data.

2.2.5.3 Summary of Test Results

(1) Hitachi D3500

- Frequency response at the low end (20 Hz) indicates a problem with the level being greater than 6 dB
- Frequency response as a function of input signal deteriorates between -10 and -30 dB
- Failure of the unit prevented checking the manufacturers data and of establishing some confidence of the units long term operation

(2) Sony EL-7

- Frequency response of ± 1 dB from 20 to 2 KHz
- Frequency response as a function of input signal from 0 dB to -40 dB remains within the ± 1 dB band.

- Moderate testing on a day to day basis does not cause immediate deterioration of either the tape deck or the tape.
- All other contingency checks, Dolby, cleaning, etc., appear satisfactory.
- Time base distortion does not appear to be a major consideration.

The design of the Sony tape deck has been considerably altered to overcome the dynamic and frequency response problems of the standard cassette tape deck, i.e., the Hitachi. The larger cassette (ELcaset), stationary heads and higher playing speeds make the Sony closely resemble a reel to reel recorder.

The results of the evaluation clearly indicate the Sony tape deck is the superior of the two units tested. The tape deck meets all the immediate requirements of the program, which was verified during the sythesizing of the first random tape. The recorded voltage included an error attributable to the recorder of ± 1 dB. The first and subsequent playbacks indicate the tape deck operation was satisfactory.

2.3 TASK B

2.3.1 EVALUATION OF PRODUCTION HARDWARE

In Task B, the major effort concentrated on the application of the taped random technique to actual production tests. Six different production electronic assemblies, utilized in two different Grumman aircraft, were chosen for evaluation based on the frequency of testing in the Plant 8 Environmental Laboratory, Calverton, N. Y. Four of the units were tested in two different test axes in effect providing ten distinct test setups. Ten test tapes were prepared and used to perform a total of 28 individual test sequences. Appendix B, Task B, tabulates the data for the production units tested.

2.3.1.1 Preparation of Tapes

All tapes prepared for the production hardware were recorded using the Sony Elcaset Tape Deck. A typical test setup is shown in Figure 18. Each cassette included the data for a single type of production unit. When testing was conducted in two axes, the data for one axis was recorded on side A of the cassette, and the other axis on side B of the cassette. The sequence of data recorded on the tape cassette is shown in Table 3.

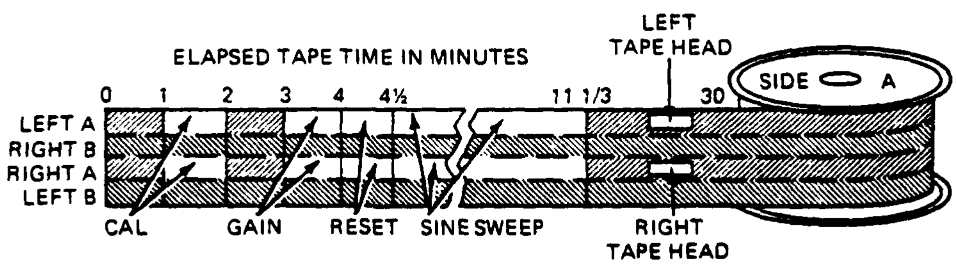
2.3.1.1.1 Recording of Sine Sweep for Transfer Functions

The sine sweep was made at an amplitude of 1.0g peak (with the control accelerometer unfiltered) and the frequency swept from 2000 to 20 Hz at a logarithmic rate of 1 octave per minute. The amplitude was servo controlled during the sweep using the unfiltered control accelerometer feedback. The input voltage to the power amplifier was recorded on the left channel of the tape deck, and the control acceleration on the right channel. A one minute dwell at a designated constant frequency and at an amplitude of 1.0g (peak) was recorded on the tape prior to the start of the sweep. This served as a gain reference for the test operator when performing the sine test using this tape. Initially, the gain reference frequency selected for all tapes was 2000 Hz. Unfortunately this initial selection, made early in the program, did not produce acceptable results on all production test units. A new set of guidelines was therefore derived for the choice of the gain reference frequency and implemented in preparation of subsequent tapes. These new guidelines are discussed in par. 2.3.1.3.4.

Table 3 Sequential Listing of Data Recorded on Tape

Elapsed Tape Time	Title of Segment	Left Recorder Channel (P.A. Input Voltage)	Right Recorder Channel (Control Acceleration)
0 Min to 1.0 Min		No Signal Recorded	No Signal Recorded
1.0 Min to 2.0 Min	Calibration	Sine Signal – P.A. Input Voltage (1K Hz typ.)	3.0g peak Sine Signal – Charge Amplifier (1K Hz typical)
2.0 Min to 3.0 Min		No Signal Recorded	No Signal Recorded
3.0 Min to 4.0 min	Gain Reference	Sine Signal – P.A. Input Voltage	1.0g peak Sine Signal – Charge Amplifier
4.0 Min to 4.5 Min	Reset Frequency	Low Level Sine Signal – P.A. Input Voltage	Low Level Sine Signal – Charge Amplifier
4.5 Min to 11.3 Min	Sine Sweep	Varying Sine Signal – P.A. Input Voltage (freq. 2000 to 20 Hz)	1.0g peak Sine Signal – Charge Amplifier (freq. 2000 to 20 Hz)
11.3 Min to 30.0 Min		No Signal Recorded	No Signal Recorded

NOTE: Table above applies to the tape when cassette is placed in recorder with side "A" marker facing outward. Because of the narrow width and staggering of the tape heads, a completely separate recording in the reverse direction can be obtained when cassette is reversed with side "B" marker facing outward. See illustration below.



2935-10W

2.3.1.1.2 Synthesization of Random Spectrum

The sine tapes for each test setup were played back through the Ubiquitous 440A Real Time Analyzer using 5 Hz bandwidth filters. This data was used to calculate the sine transfer functions (E/g) for the test system in the same manner as described in para. 2.2.1.3, Task A. The sine transfer function in each bandwidth was then modified by the addition of the following compensation factors:

a. Tape Deck Response Characteristics

b. Resonance Linearity Factor

c. Resonance Variance Factor

d. Lower Tolerance Limit Factor

a) The Sony Elcaset Tape Deck which was used for production unit evaluations has approximately a 1 dB increase in amplitude from 20 to 2000 Hz. The compensation factor was therefore the inverse of this value i.e., a +1 dB factor at 20 Hz decreasing to 0 dB at 2000 Hz.

b) The compensation factor for linearity is intended to correct for difference in response between a 1.0g (peak) sine run and a 6.0 Grms random test due to non-linear damping effects. (Ref. Task A para.2.2.1.3) None were used when production unit tapes were prepared.

c) The variance compensation factor is used to correct for shifts in resonant and anti-resonant frequencies. It was found in the Task A baseline study (ref.para.2.2.2.2),that this shift would normally be in the range of ±3%. A set of rules was derived for the determination of compensation factors at significant inflection points in the P.A. input voltage curve. (both maxima and minima points). These rules are presented in the order in which they were applied to the production unit:

(1) determine frequency of inflextion point

(2) calculate average sine transfer function (E/g) in the 25 Hz bandwidth in which the inflection point occurs, and the adjacent 25 Hz band on either side (for an inflection point between bands use ± 2 bandwidths in average)

(3) reduce the E/g function to the average value in any of the three or four bands where it is exceeded. (reduction is not to exceed -3 dB)

The purpose of applying only negative compensation factors (E/g will always be reduced) was to minimize the possibility of overshooting the test level due to a slight shift in frequency.

d) A compensation factor was applied to center the test amplitude within the tolerance band. The tolerance band applied to the production units were obtained from MIL-STD-810C Method 514.2:

"20 to 500 Hz + 3 dB, - 1.5 dB
500 to 2000 Hz ± 3 dB
except deviations as large as ± 6 dB
shall be allowed over a cumulative
bandwidth of 100 Hz maximum, between
500 and 2000 Hz"

In order to comply with this lower tolerance limit of -1½ dB, a compensation factor of +1 dB was applied to the transfer functions below 500 Hz.

The sine transfer function (E/g) was corrected with these compensation factors and multiplied by the required random test spectrum to determine the synthetic random voltage. This random voltage spectrum was then normalized in terms of g^2/Hz to facilitate programming compatible with the Ling ASDE/ESDE 80 Random Control Console which was used to synthesize the spectrum. The formulas and procedures used in these calculations are presented in para.2.2.1.3. A sample sine transfer curve is presented in Figure 21 The calculation sheets for the synthetic random spectrum are shown in Figure 22

2.3.1.1.3 <u>Recording Random Spectrum on Tape</u>

The synthetic random voltage for each production unit was recorded in parallel on both the left and right channel of the tape immediately after the sine sweep data on the tape. Where a particular production unit was tested in two axis, the random spectrum for the 1st axis was recorded on side A and the second axis on side B.

2.3.1.2 <u>Test Operations Using The Tape</u>

Vibration testing with the taped input was performed on production hardware from Grumman aircraft programs which was directed to the test Lab for Engineering investigation of functional problems or verification of repair actions. The units were, for the most part, new production electronic assemblies which had either not yet been installed on aircraft, or had been removed from the aircraft after one or two flight tests.

GRUMMAN AEROSPACE CORPORATION

TITLE Power Amplifier Input Voltage

DATE 6-6-78

DATA TAPE Sony No. 10

TEST ARTICLE Unit No. 5

S/N HJR-029

ADDRESS (1) Side B 063 → 160

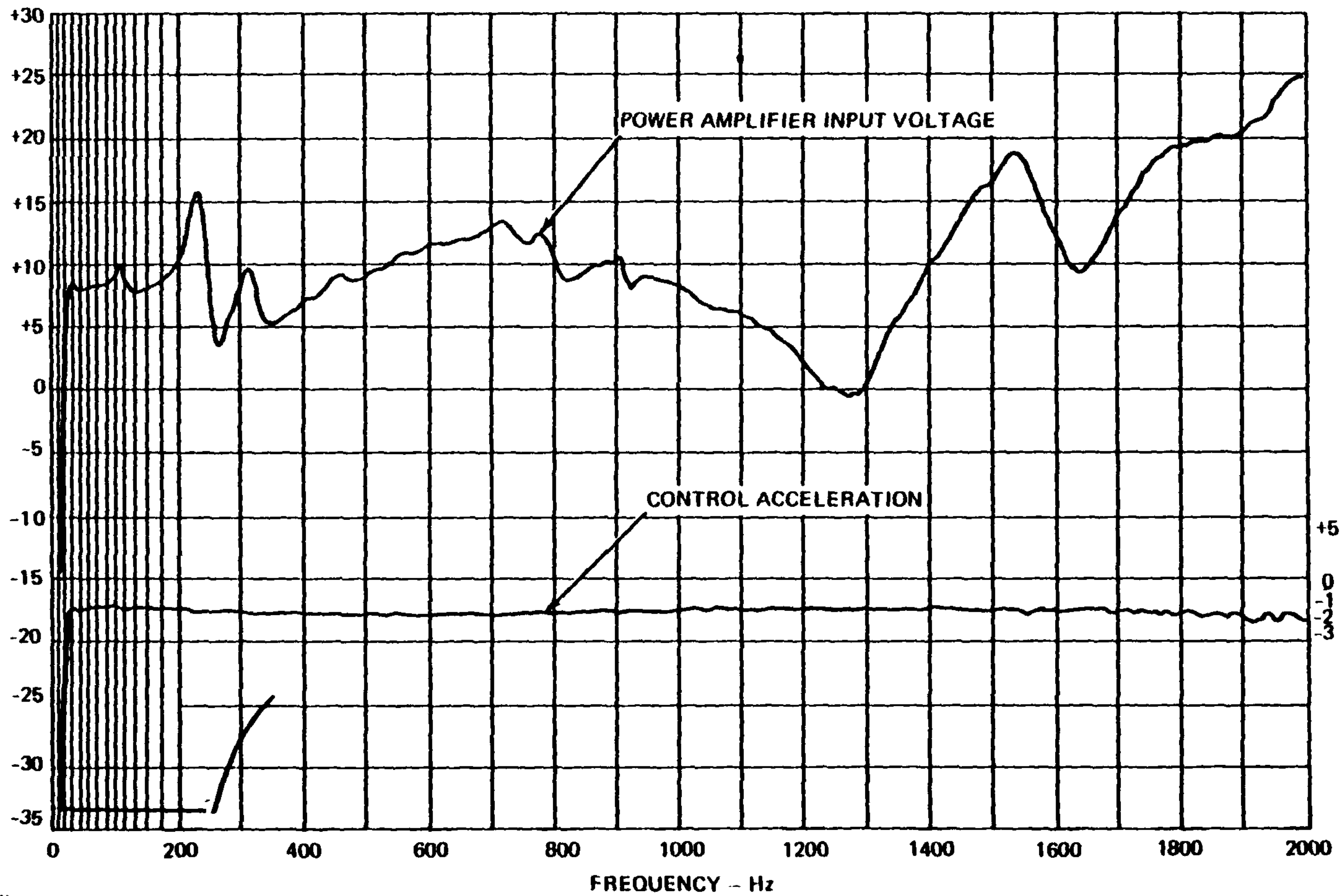
TEST CONDITION Sine Sweep

AXIS Y

ADDRESS (2)

DATA ANALYSIS Ubiquitous 5 Hz Filters

SIGNAL SOURCE Servo Control



2935-26W

Figure 21 Sine Transfer Curve (Unit No. 5)

TEST ARTICLE: UNIT NO. 5 S/N: HJR - 029

TEST CONDITIONS: C-10 Flexure Table - Sine AXIS: Y

RUN NO: 3 DATE: 6-1-78

SYSTEM FILTERS			SINE DATA			COMPENSATION FACTORS			CORRECT. FUNC.		SYNTHETIC RAND.	
			(A)	(B)	(C)	(D)*	(E)	(F)	(G)	(H)	(I)	(J)
No.	B.W. (Hz)	C.F. (Hz)	Volt E (dB)	Accel. g (dB)	E/g (dB)	Tape Deck (dB)	Linear. Factor (dB)	Var. Factor (dB)	Correct E/g (dB)	Req'd. g/Hz (dB)	Req'd. E/Hz (dB)	Normalized (g^2/Hz)
1	10	15	-	-	-	-	-	-	-	-	-	-
2	11	26	8.5	-1.5	10.0	2.0	-	-	12.0	5.2	17.2	0.420
3	12	37	8.2	-1.4	9.6	1.9	-	-	11.5	6.8	18.3	0.541
4	13	50	8.3	-1.3	9.6	1.9	-	-	11.5	8.0	19.5	0.713
5	14	63	8.5	-1.2	9.7	1.9	-	-	11.6	9.2	20.8	0.962
6	14	77	8.6	-1.1	9.7	1.9	-	-	11.6	9.8	21.4	1.10
7	15	92	9.0	-1.0	10.0	1.9	-	-	11.9	10.0	21.9	1.24
8	16	107	9.6	-1.1	10.7	1.9	-	-	12.6	10.0	22.6	1.46
9	17	124	8.1	-1.2	9.3	1.9	-	-	11.2	10.0	21.2	1.06
10	18	141	8.1	-1.1	9.2	1.9	-	-	11.1	10.0	21.1	1.03
11	25	163	8.6	-1.1	9.7	1.9	-	-	11.6	10.0	21.6	1.16
12	│	188	9.6	-1.2	10.8	1.9	-	-	12.7	10.0	22.7	1.49
13	│	213	13.2	-1.3	14.5	1.9	-	-2.9	13.5	10.0	23.5	1.79
14	│	238	12.3	-1.4	13.7	1.8	-	-4.1	11.4	10.0	21.4	1.10
15	25	263	4.9	-1.3	6.2	1.8	-	-	8.0	10.0	18.0	0.505

* LOW TOLERANCE COMPENSATION FACTOR INCLUDED

Fig.22a TABULATION SHEET FOR SYNTHETIC RANDOM SPECTRUM

SYSTEM FILTERS			SINE DATA			COMPENSATION FACTORS			CORRECT. FUNC.		SYNTHETIC RAND.	
			(A)	(B)	(C)	(D)*	(E)	(F)	(G)	(H)	(I)	(J)
No.	B.W. (Hz)	C.F. (Hz)	VOLT E (dB)	Accel. g (dB)	E/g (dB)	Tape Deck (dB)	Linear. Factor (dB)	Var. Factor (dB)	Correct E/g (dB)	Req'd. g/Hz (dB)	Req'd. E/Hz (dB)	Normalized (g^2/Hz)
16	25	288	7.4	-1.4	8.8	1.8	-	-	10.6	10.0	20.6	0.919
17		313	8.8	-1.4	10.2	1.8	-	-1.2	10.8	10.0	20.8	0.962
18		338	6.6	-1.5	8.1	1.8	-	-	9.9	10.0	19.8	0.782
19		363	5.9	-1.5	7.4	1.8	-	-	9.2	9.9	19.1	0.650
20		388	6.7	-1.6	8.3	1.8	-	-	10.1	9.5	19.6	0.730
21		413	7.4	-1.6	9.0	1.8	-	-	10.8	9.3	20.1	0.819
22		438	8.8	-1.6	10.4	1.7	-	-	12.1	9.0	21.1	1.03
23		463	9.3	-1.6	10.9	1.7	-	-	12.6	8.8	21.4	1.10
24		488	9.0	-1.6	10.6	1.7	-	-	12.3	8.5	20.8	0.962
25		513	9.6	-1.6	11.2	1.7	-	-	12.9	8.4	21.3	1.08
26		538	10.2	-1.7	11.9	0.7	-	-	12.6	8.1	20.7	0.940
27		563	11.0	-1.6	12.6	0.7	-	-	13.3	7.9	21.2	1.06
28		588	11.4	-1.6	13.0	0.7	-	-	13.7	7.7	21.4	1.10
29		613	12.0	-1.6	13.6	0.7	-	-	14.3	7.6	21.9	1.24
30		638	12.1	-1.7	13.8	0.6	-	-	14.4	7.4	21.8	1.21
31		663	12.1	-1.6	13.7	0.6	-	-	14.3	7.2	21.5	1.13
32		688	12.9	-1.6	14.5	0.6	-	-	15.1	7.1	22.2	1.33
33	25	713	13.5	-1.6	15.1	0.6	-	-	15.7	6.9	22.6	1.46

* LOW TOLERANCE COMPENSATION FACTOR INCLUDED

Fig. 22b TABULATION SHEET FOR SYNTHETIC RANDOM SPECTRUM

SYSTEM FILTERS			SINE DATA			COMPENSATION FACTORS			CORRECT. FUNC.		SYNTHETIC RAND.	
			(A)	(B)	(C)	(D)*	(E)	(F)	(G)	(H)	(I)	(J)
No.	B.W. (Hz)	C.F. (Hz)	VOLT E (dB)	Accel. g (dB)	E/g (dB)	Tape Deck (dB)	Linear. Factor (dB)	Var. Factor (dB)	Correct E/g (dB)	Req'd. g/Hz (dB)	Req'd. E/Hz (dB)	Normalized (g^2/Hz)
34	25	738	12.6	-1.6	14.2	0.6	-	-	14.8	6.8	21.6	1.16
35		763	12.2	-1.6	13.8	0.6	-	-	14.4	6.6	21.0	1.01
36		788	11.8	-1.5	13.3	0.6	-	-	13.9	6.5	20.4	0.877
37		813	9.4	-1.5	10.9	0.6	-	-	11.5	6.4	17.9	0.493
38		838	9.3	-1.5	10.8	0.5	-	-	11.3	6.2	17.5	0.450
39		863	9.9	-1.3	11.2	0.5	-	-	11.7	6.1	17.8	0.482
40		888	10.3	-1.3	11.6	0.5	-	-	12.1	5.9	18.0	0.505
41		913	9.5	-1.3	10.8	0.5	-	-	11.3	5.8	16.8	0.383
42		938	9.2	-1.2	10.4	0.5	-	-	10.9	5.7	16.6	0.366
43		963	9.1	-1.3	10.4	0.5	-	-	10.9	5.6	16.5	0.357
44		988	8.9	-1.2	10.1	0.5	-	-	10.6	5.5	16.1	0.326
45		1013	8.0	-1.1	9.1	0.5	-	-	9.6	5.4	15.0	0.253
46		1038	7.1	-1.1	8.2	0.4	-	-	8.6	5.3	13.9	0.196
47		1063	6.8	-1.1	7.9	0.4	-	-	8.3	5.2	13.5	0.179
48		1088	6.4	-1.0	7.4	0.4	-	-	7.8	5.1	12.9	0.156
49		1113	5.8	-1.0	6.8	0.4	-	-	7.2	5.0	12.2	0.133
50		1138	5.0	-1.0	6.0	0.4	-	-	6.4	4.9	11.3	0.108
51	25	1163	4.2	-1.0	5.2	0.4	-	-	5.6	4.8	10.4	0.088

* LOW TOLERANCE COMPENSATION FACTOR INCLUDED

Fig. 22c TABULATION SHEET FOR SYNTHETIC RANDOM SPECTRUM

SYSTEM FILTERS			SINE DATA			COMPENSATION FACTORS			CORRECT. FUNC.		SYNTHETIC RAND.	
			(A)	(B)	(C)	(D)*	(E)	(F)	(G)	(H)	(I)	(J)
No.	B.W. (Hz)	C.F. (Hz)	VOLT E (dB)	Accel. g (dB)	E/g (dB)	Tape Deck (dB)	Linear. Factor (dB)	Var. Factor (dB)	Correct E/g (dB)	Req'd. g/Hz (dB)	Req'd. E/Hz (dB)	Normalized (g^2/Hz)
52	25	1188	3.1	-1.1	4.2	0.4	-	-	4.6	4.7	9.3	0.068
53		1213	1.7	-1.1	2.8	0.4	-	-	3.2	4.6	7.8	0.048
54		1238	0.2	-1.1	1.3	0.3	-	-	1.6	4.5	6.1	0.033
55		1263	0.3	-1.1	0.8	0.3	-	-	1.1	4.4	5.5	0.028
56		1288	0.0	-1.1	1.1	0.3	-	-	1.4	4.3	5.7	0.030
57		1313	2.8	-1.0	3.8	0.3	-	-2.0	2.1	4.3	6.4	0.035
58		1338	4.9	-1.1	6.0	0.3	-	-	6.3	4.2	10.5	0.090
59		1363	7.0	-1.1	8.1	0.3	-	-	8.4	4.2	12.6	0.146
60		1388	9.2	-1.1	10.3	0.3	-	-	10.6	4.1	14.7	0.236
61		1413	11.1	-1.1	12.2	0.3	-	-	12.6	4.0	16.6	0.366
62		1438	13.1	-1.2	14.3	0.2	-	-	14.5	3.9	18.4	0.553
63		1463	15.0	-1.2	16.2	0.2	-	-	16.4	3.8	20.2	0.838
64		1488	16.5	-1.2	17.7	0.2	-	-	17.9	3.8	21.7	1.18
65		1513	18.1	-1.2	19.3	0.2	-	-	19.5	3.7	23.2	1.67
66		1538	19.0	-1.2	20.2	0.2	-	-0.9	19.5	3.6	23.1	1.63
67		1563	17.2	-1.2	18.4	0.2	-	-	18.6	3.5	22.1	1.03
68		1588	14.0	-1.1	15.1	0.2	-	-	15.3	3.4	18.7	0.593
69	25	1613	11.2	-1.1	12.3	0.2	-	-0.6	11.9	3.4	15.8	0.271

* LOW TOLERANCE COMPENSATION FACTOR INCLUDED

Fig. 22d TABULATION SHEET FOR SYNTHETIC RANDOM SPECTRUM

SYSTEM FILTERS			SINE DATA			COMPENSATION FACTORS			CORRECT. FUNC.		SYNTHETIC RAND.	
			(A)	(B)	(C)	(D)*	(E)	(F)	(G)	(H)	(I)	(J)
No.	B.W. (Hz)	C.F. (Hz)	VOLT E (dB)	Accel. g (dB)	E/g (dB)	Tape Deck (dB)	Linear Factor (dB)	Var. Factor (dB)	Correct E/g (dB)	Req'd. g/Hz (dB)	Req'd. E/Hz (dB)	Normalized (g^2/Hz)
70	25	1638	9.8	-1.1	10.9	0.1	-	-	11.0	3.3	14.3	0.215
71		1663	10.9	-1.1	12.0	0.1	-	-0.2	11.9	3.2	15.1	0.259
72		1688	13.3	-1.3	14.6	0.1	-	-	14.7	3.2	17.9	0.493
73		1713	15.6	-1.3	16.9	0.1	-	-	17.0	3.1	20.1	0.819
74		1738	17.3	-1.3	18.6	0.1	-	-	18.7	3.1	21.8	1.21
75		1763	18.8	-1.4	20.2	0.1	-	-	20.3	3.0	23.3	1.71
76		1788	19.5	-1.5	21.0	0.1	-	-	21.1	2.9	24.0	2.01
77		1813	19.8	-1.5	21.3	0.1	-	-	21.4	2.9	24.3	2.15
78		1838	20.0	-1.7	21.7	-	-	-	21.7	2.8	24.5	2.25
79		1863	20.3	-1.7	22.0	-	-	-	22.0	2.8	24.8	2.42
80		1888	20.5	-1.6	22.1	-	-	-	22.1	2.7	24.8	2.42
81		1913	21.5	-1.9	23.4	-	-	-	23.4	2.7	26.1	3.26
82		1938	22.6	-1.8	24.4	-	-	-	24.4	2.6	27.0	4.01
83		1963	24.0	-1.7	25.7	-	-	-	25.7	2.5	28.2	5.29
84	25	1988	24.6	-1.8	26.4	-	-	-	26.4	2.5	28.9	6.21

* LOW TOLERANCE COMPENSATION FACTOR INCLUDED

Fig. 22e TABULATION SHEET FOR SYNTHETIC RANDOM SPECTRUM

All vibration tests were performed with all bench checkout interface cables connected to the production unit. The initial unit in each series was used to make the sine transfer tape and then the random portion of the test was conducted in the normal manner using the automatic random control system. Subsequent production units were tested using the taped input. The test for each item consisted of two runs:

a. Run No. 1 - Taped Sine Sweep
   - o 1.0g (peak) sine sweep from 2000 Hz to 20 Hz at a rate of 1 octave per minute
   - o on line plot made of control accelerometer using Ubiquitous 440A Real Time Analyzer with 5 Hz BW filters.

b. Run No. 2 - Taped Random Run
   - o 5 minute random test with an overall Grms = 6.3 (see note below)
   - o on-line plot made of control accelerometer using Ubiquitous 440A Real Time Analyzer with 5 Hz BW filters
   - o recording of control accelerometer made using Ampex FR-1300 Instrumentation Recorder for subsequent analysis with wider analyzer filter bandwidth of 25 and 50 Hz

NOTE: Unit No. 4 was not tested to the nominal 6.0 Grms test spectrum (see details of special test spectrum for Unit No. 4 in para. 2.3.1.2.2.)

A summary tabulation of all test data taken on the production units is presented in Appendix B, Task B. A brief description of each type of production unit which was tested including significant details of the test setup and data is discussed in the subsequent paragraphs.

2.3.1.2.1 Unit No. 1 (Converter)

Description of Test Article

This unit is an electronic data converter used to convert flight measurements to digital format for display on a CRT. It measures 10" W x 22" L x 9" H, weighs 56 lbs, and mounts to a flat surface with two retaining pins at one end and two bolted flanges at the other end.

Description of Test Setup

The unit was tested in the "X" axis only, which is an axis parallel with its longitudinal plane. Tests were performed on a Grumman oil film slip table driven by an MB C-25HB shaker (rated 5000 lbs force - sine)

Random Test Spectrum

The random test spectrum utilized in the test program was:

Frequency Range	Spectral Density
20 to 80 Hz	+3 dB/oct rise to .04 g^2/Hz
80 Hz to 350 Hz	0.04 g^2/Hz
350 Hz to 2000 Hz	-3 dB/oct roll off

Summary of Test Results

A total of five units were tested. Low frequency (below 1000 Hz) test results were universally within tolerances. Out-of-tolerance conditions of ± 6 dB (using narrow band analysis - 5 Hz) were noted in two of the test units at 1300 Hz and above 1800 Hz. It should be noted that when analyzed with the widest bandwidth filters permitted by MIL-STD-810C (100 Hz above 1000 Hz) the entire spectrum falls within tolerance. See Figures 23 thru 26).

The initial out-of-tolerance problem was attributed to a teardown repair and reassembly of the shaker system which occured in the time between initial sine transfer function recording and the taped random test on the fourth unit (S/N HJR-035). Therefore, a new synthetic random tape was recorded using the sine transfer data from this fourth unit (S/N HJR-035).

The test of the final unit (S/N HJR-037), however, also resulted in a ± 6 dB spread at 1300 Hz. This condition was not noted during the taped sine sweep. The problem was therefore suspected to be caused by misalignment of the slip table due to a break in the oil film at higher shaker amplitudes (6.3 Grms) which did not appear at the lower 1.0 (peak) sine sweep amplitude. As noted before however, these exceedances fall within MIL-STD-810C tolerances when analyzed with the wider filters permitted by the specification.

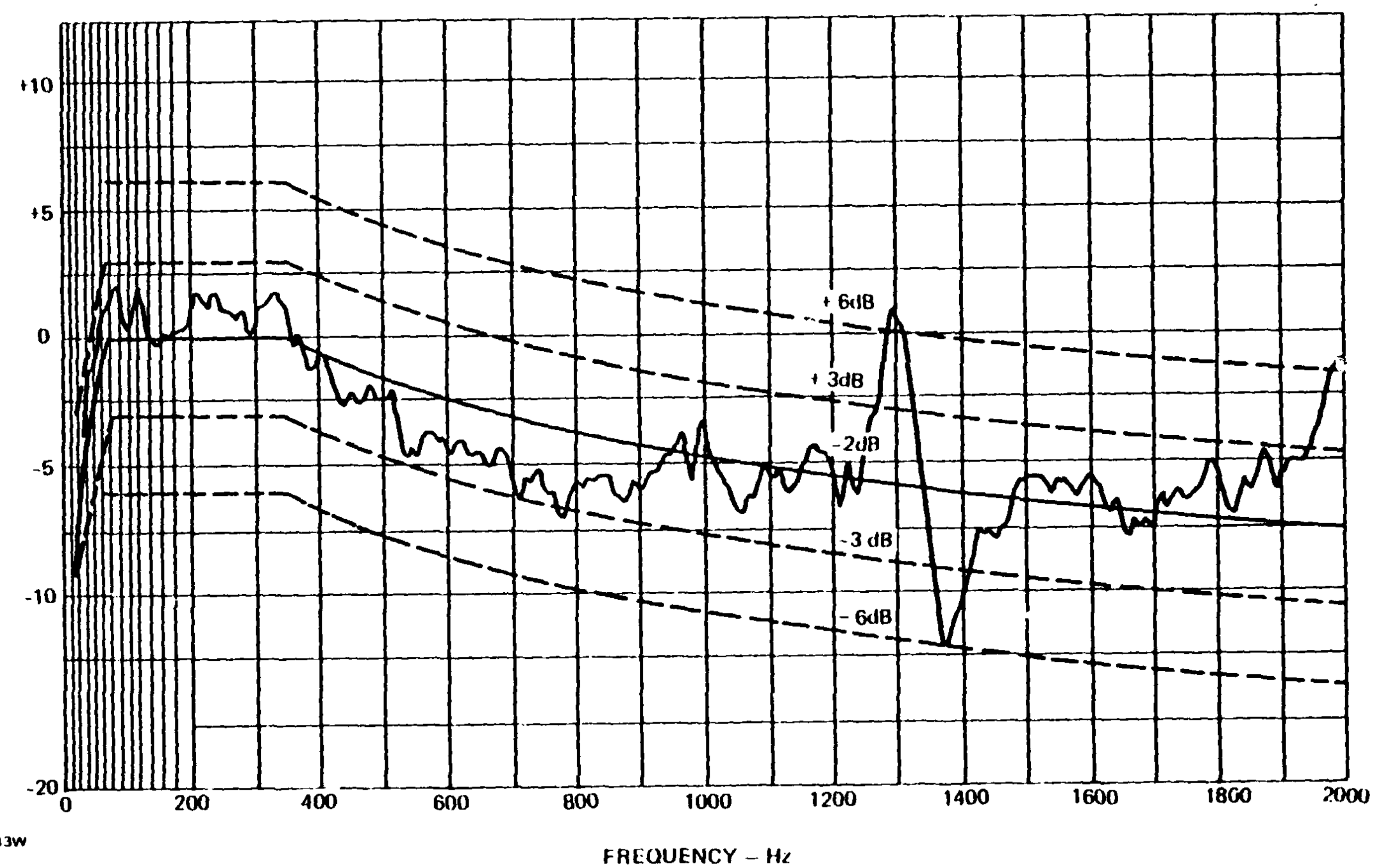
2.3.1.2.2 Unit No. 4 (Computer)

Description of Test Article

This unit is an electronic computer used to convert signal data for use in flight control and display systems. It measures 13" W x 13" L x 7" H, weighs 40 lbs, and mounts to a flat surface using two spade lugs which slide

GRUMMAN AEROSPACE CORPORATION

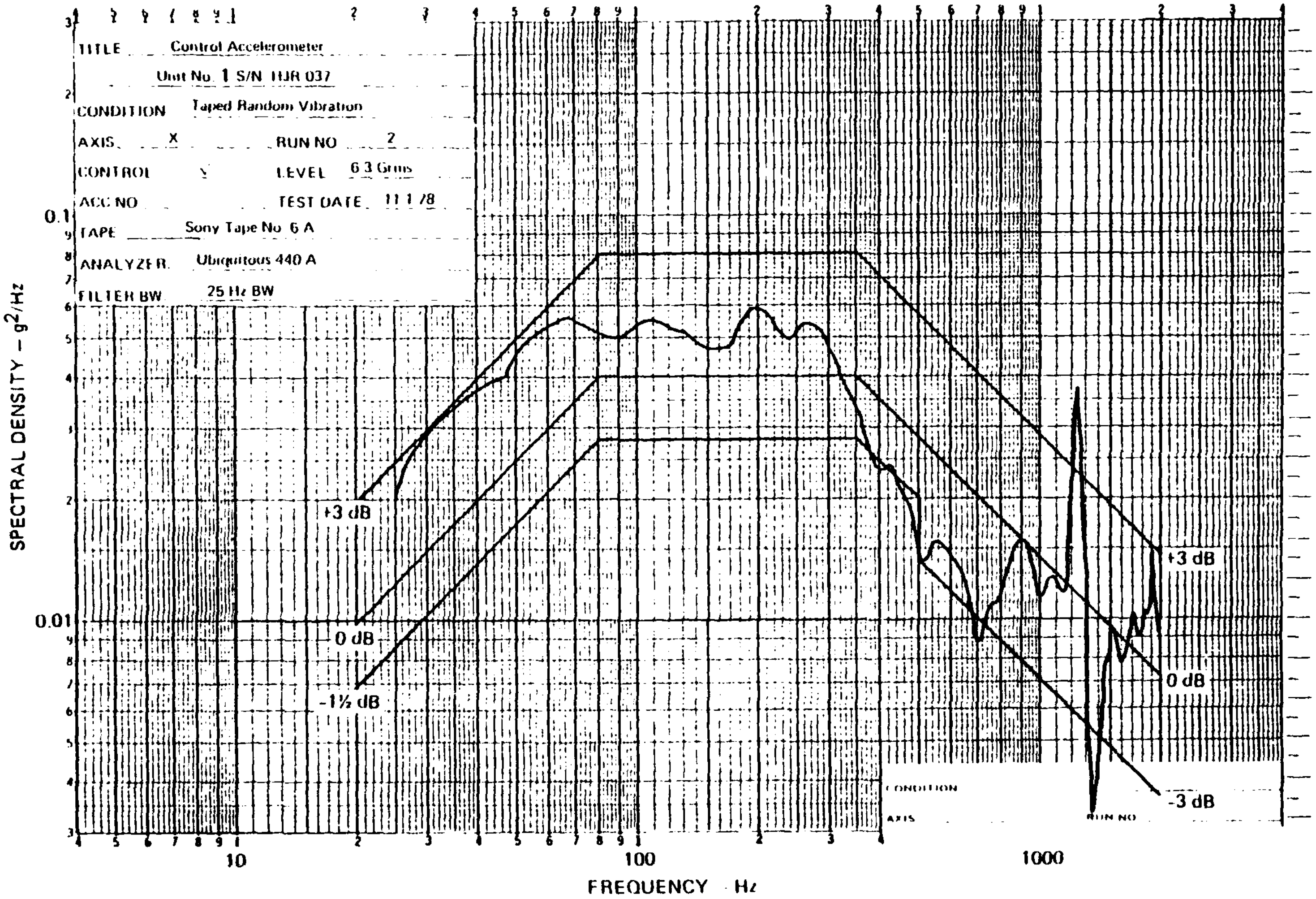
TITLE Control Accelerometer	DATE 11-1-78	DATA TAPE on-line analysis
TEST ARTICLE Unit No. 1	S/N HUR-037	ADDRESS (1)
TEST CONDITION Random Vibration	AXIS X	ADDRESS (2)
DATA ANALYSIS Ubiquitous 5Hz BW		SIGNAL SOURCE Sony Tape No. 6A



2935-33W

Figure 23 Unit No. 1 Spectrum Analysis (5 Hz)

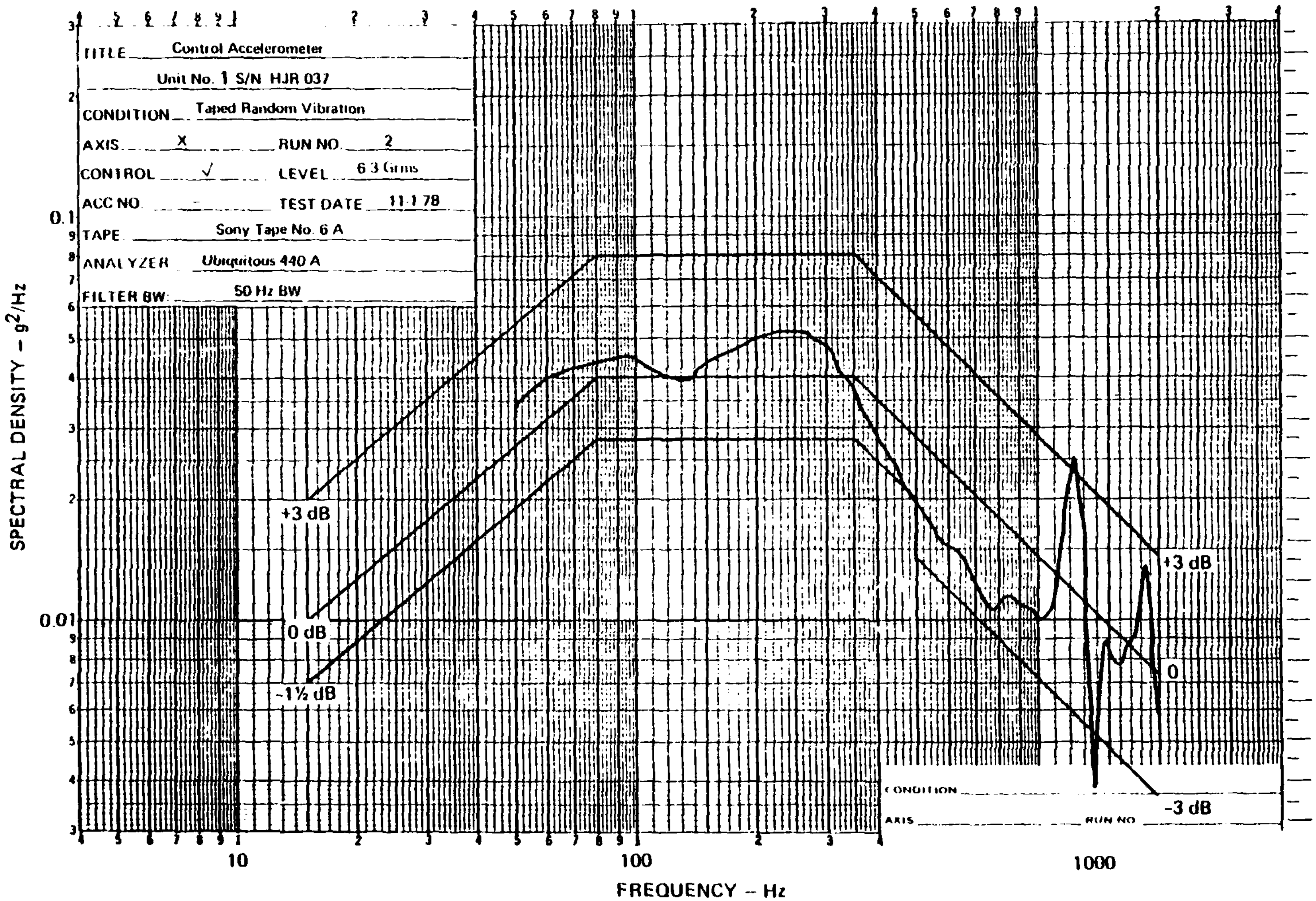
GRUMMAN AEROSPACE CORPORATION



2953-34W

Figure 24 Unit No. 1 Spectrum Analysis (25 Hz)

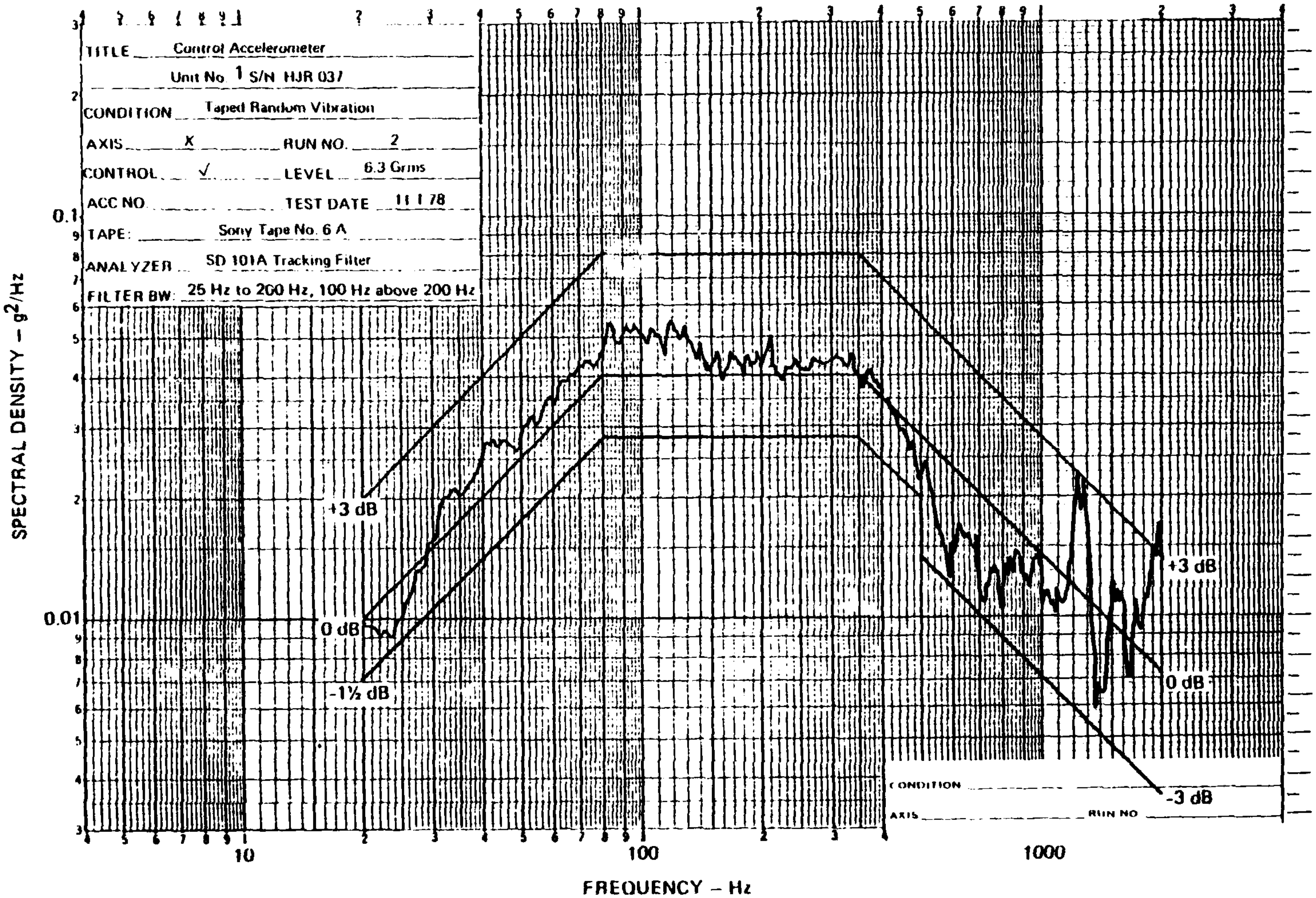
GRUMMAN AEROSPACE CORPORATION



2935-36W

Figure 25 Unit No. 1 Spectrum Analysis (50 Hz)

GRUMMAN AEROSPACE CORPORATION



2935-35W

Figure 26 Unit No. 1 Spectrum Analysis (25 Hz/100 Hz) into retainers, and two $\frac{1}{4}$" dia. screws in a self aligning spherical fitting designed to clamp down tho front of the unit.

Description of Test Setup

The unit was tested in the "Z" axis only which is an axis perpendicular to the mounting surface of the unit. Tests were performed on a MB Model C-10E shaker (rated 1200 lbs force -sine). A Kimbal Model 5030-3 Head Expander was used to adapt the test fixture to the shaker head.

Random Test Spectrum

This was the only unit, of all those tested, that was subjected to vibration using a special random test spectrum:

Frequency Range	Spectral Density
20 to 60 Hz	6 dB/oct rise to $0.03g^2/Hz$
60 to 400 Hz	$0.03g^2/Hz$
400 to 500 Hz	9 dB/Oct roll off to $0.015g^2/Hz$
500 to 2000 Hz	3 dB/oct roll off to $0.0037g^2/Hz$
Overall Grms = 4.9	

Summary of Test Results

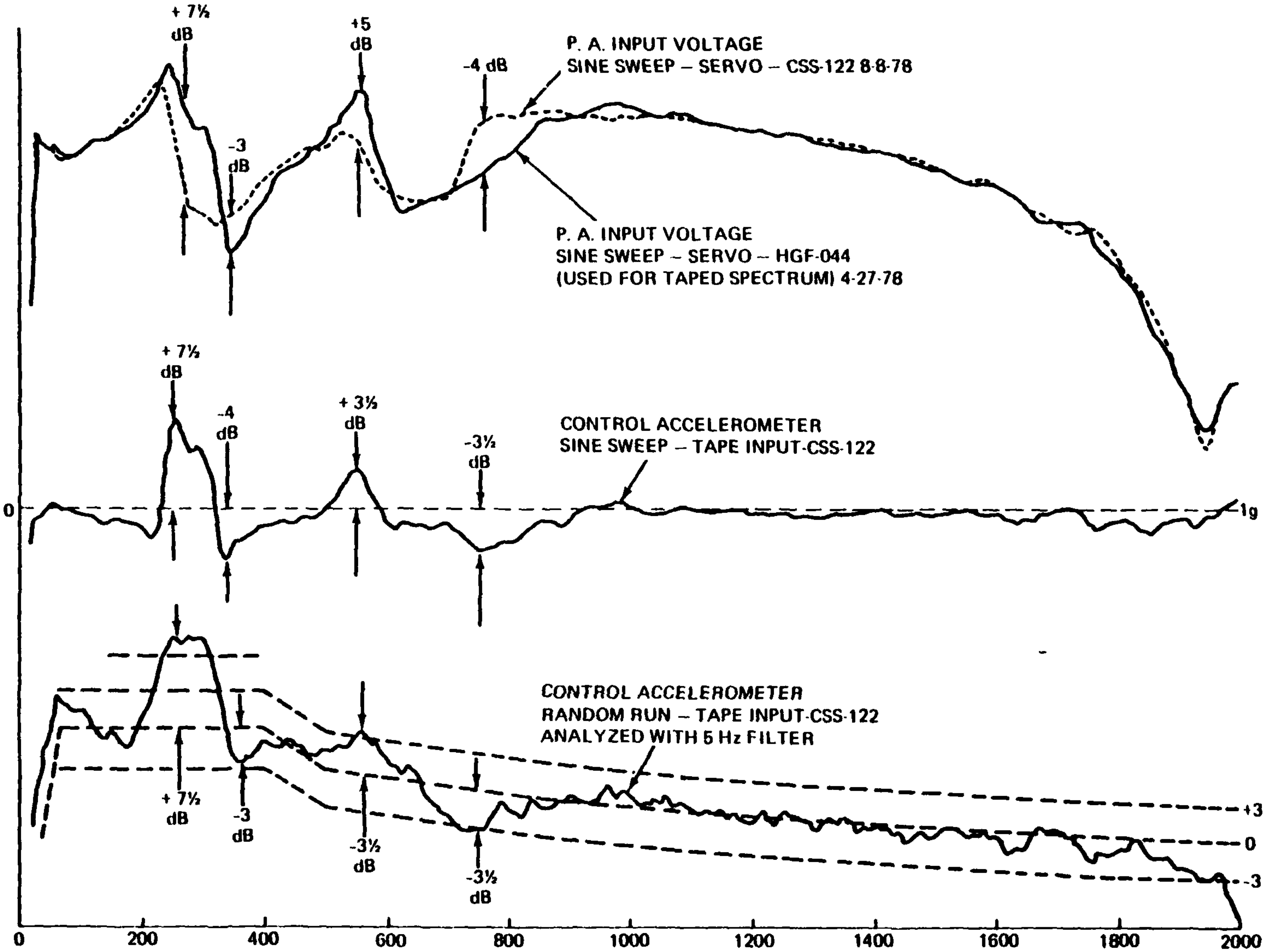
Three units were tested and showed a + 6 to 8 dB out-of-tolerance (narrow band analysis) condition at the unit tie-down resonant frequency of 250 Hz. A comparison of P.A. input voltages for the sine-transfer unit and the test unit showed the problem to be partially due to a 30 Hz (down) shift in the resonant frequency. (see test curves Figure 27). Investigation made with the Mass Mock-up of Unit No. 4 in this test setup revealed that this resonant frequency is extremely sensitive to misalignment or misassembly of the tie-down hardware.

This out-of-tolerance condition, when analyzed with the side band filter (50 Hz) permitted by the MIL-STD-810C, still resulted in a + 5 dB exceedance. It was noted in the investigation of this problem that no linearity compensation factor for this resonance had been applied in the synthetic random calculation. As a result of the Task A study, a linearity compensation factor of -3 dB had been recommended for this resonance. This would have resulted in an in tolerance level at this frequency.

2.3.1.2.3 Unit No. 5 (Computer)

Description of Test Article

This unit is an electronic computer used to process data for the



2935-25W

Figure 27 Unit No. 4 Production Tests

flight control system. It measures 9" W x 15" L x 7" H,weighs 33.2 lbs and mounts on a flat surface using the same tie-down hardware as Unit No.4, para 2.3.1.2.2.

Description of Test Setup

The unit was tested in the "X" and "Y" axis which are the two axes parallel to the mounting surface of the unit. The "X" axis is in-line with the mounts (front-rear) and the "Y" axis is perpendicular to the mounting axis (side-side). Tests were performed on a Grumman flexure table driven by an MB model C-10E shaker. (rated 1200 lbs force-sine).

Random Test Spectrum

(see Para. 2.3.1.2.1)

Summary of Test Results

A total of three units (2 axes each) were tested. All sine sweep data averaged about + 5 dB high. This was due to a change in the response characteristics at 2000 Hz which was used for the gain reference frequency in recording the sine tape. The change was also reflected in the random data which showed a drop off of -6.0 dB above 1850 Hz. The test procedure was later modified to avoid designation of resonant frequencies or high frequencies (greater than 1500 Hz) as gain references.

One or two narrow exceedances were noted in both axes at 1100, 1300 and 1500 Hz. These were of the order of 4 to 5 dB and are believed due to changes in the setup and alignment of the flexure table.

The "X" axis tie-down resonance occurred at 500 Hz and resulted in only one unit having a slight out-of-tolerance exceedance of +3.3 dB.

The "Y" axis tie-down resonance occurred at 250 Hz. Slight changes in frequency resulted in narrow exceedances as large as +7.5/-17 dB (on the sine sweep). However, when the random data was analyzed with a wide band filter (50 Hz) the curve at this frequency fall within the tolerances. (see test curve of Figure 28 through 31).

2.3.1.2.4 Unit No. 7 (Programmer)

Description of Test Article

This unit is an electronic programmer used to control engine parameters. It measures 5" W x 15" L x 7" H, weighs 14.1 lbs and mounts on a flat surface using the same tie-down hardware as Unit #4, para. 2.3.1.2.2.

GRUMMAN AEROSPACE CORPORATION

TITLE Control Accel. Output — DATE 10-2-78 — DATA TAPE

TEST ARTICLE Unit No. 5 — S/N HJR-016 — ADDRESS (1)

TEST CONDITION Sine Sweep — AXIS Y — ADDRESS (2)

DATA ANALYSIS 5 Hz Filters — SIGNAL SOURCE Sony Tape No. 10 B

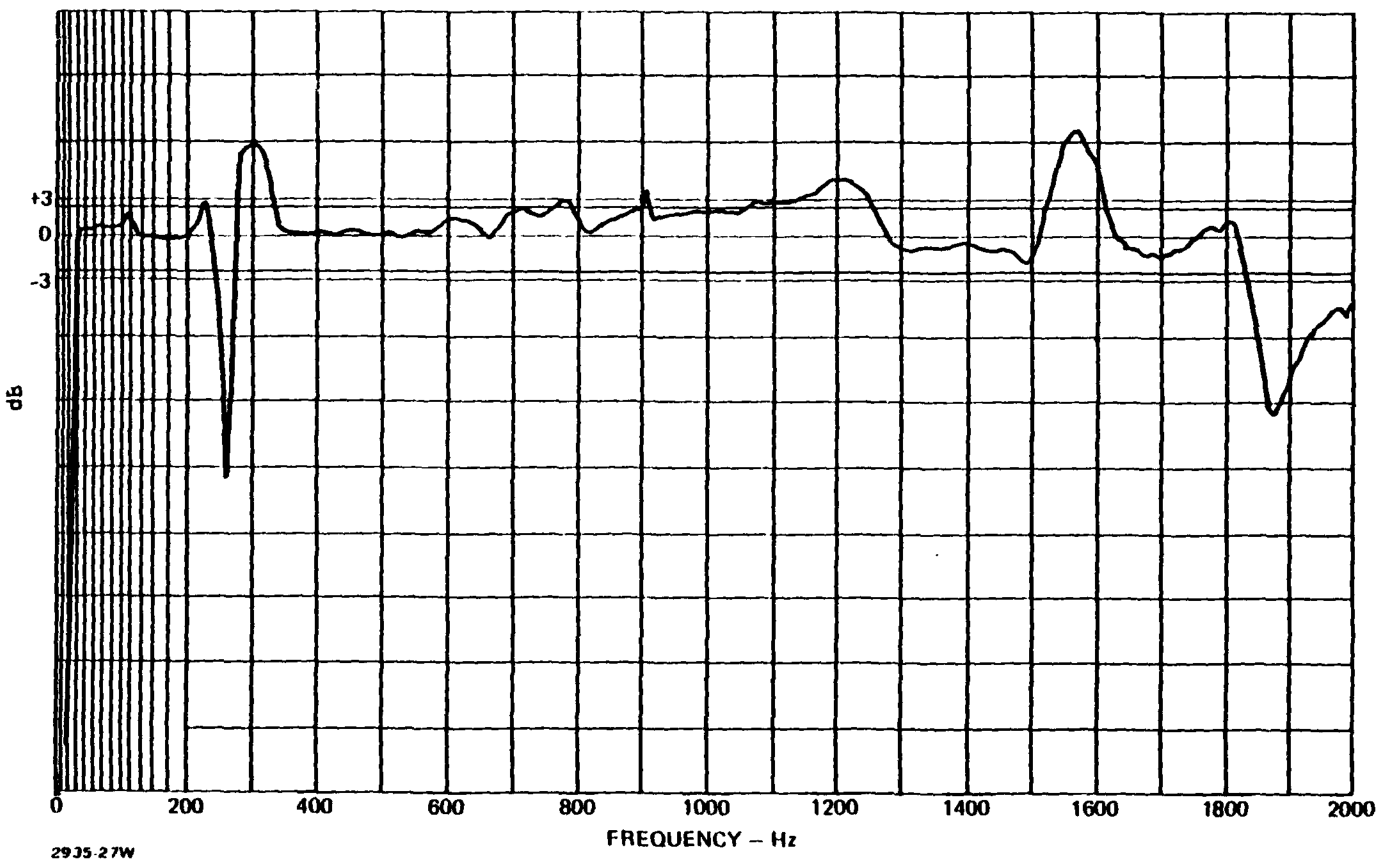


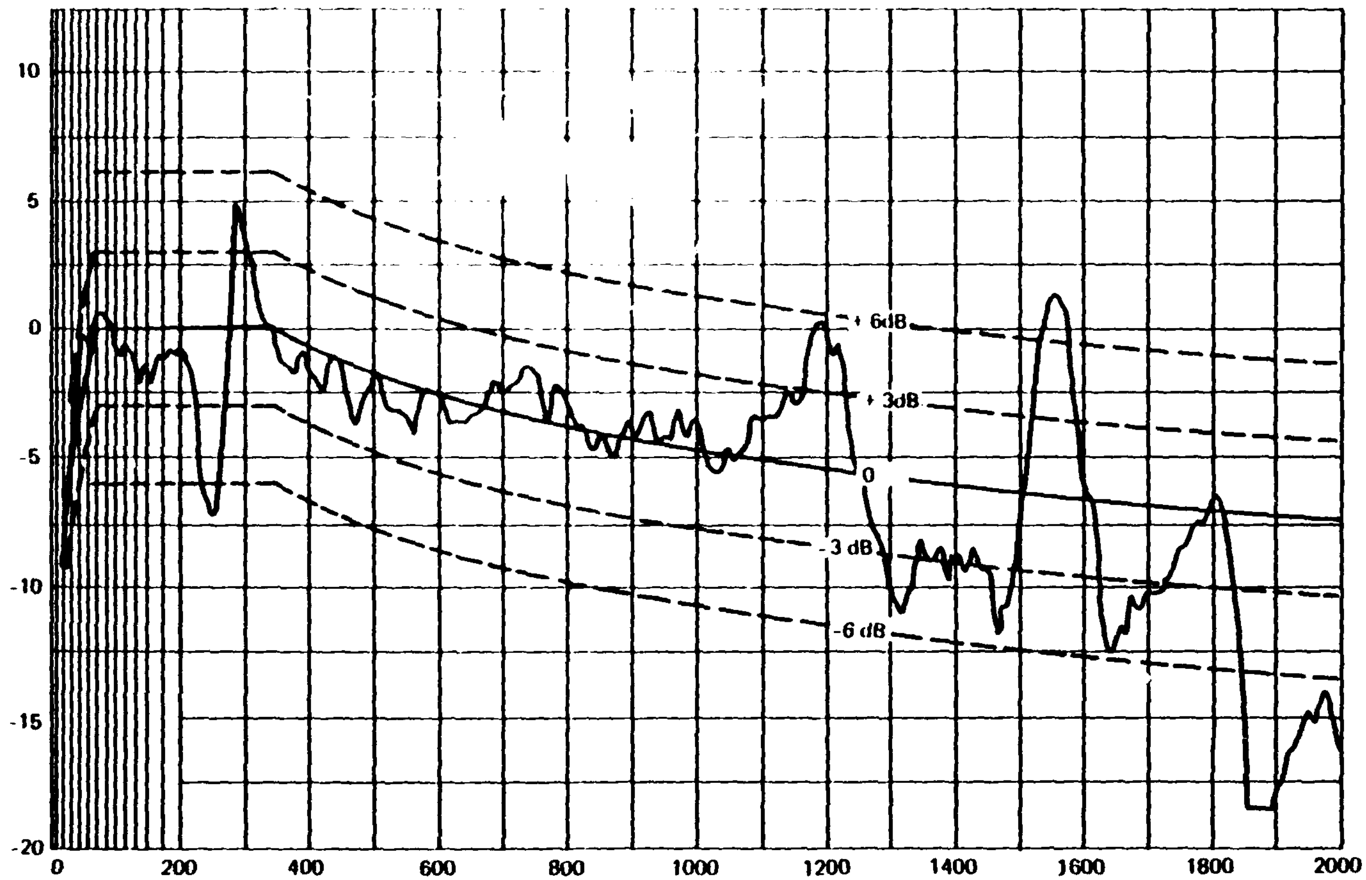
Figure 28 Sine Sweep Curve (Unit No. 5)

GRUMMAN AEROSPACE CORPORATION

TITLE Control Accelerometer
TEST ARTICLE Unit No. 5
TEST CONDITION Random
DATA ANALYSIS 5 Hz Filters

DATE 10 2 78
S/N HJR 016
AXIS Y

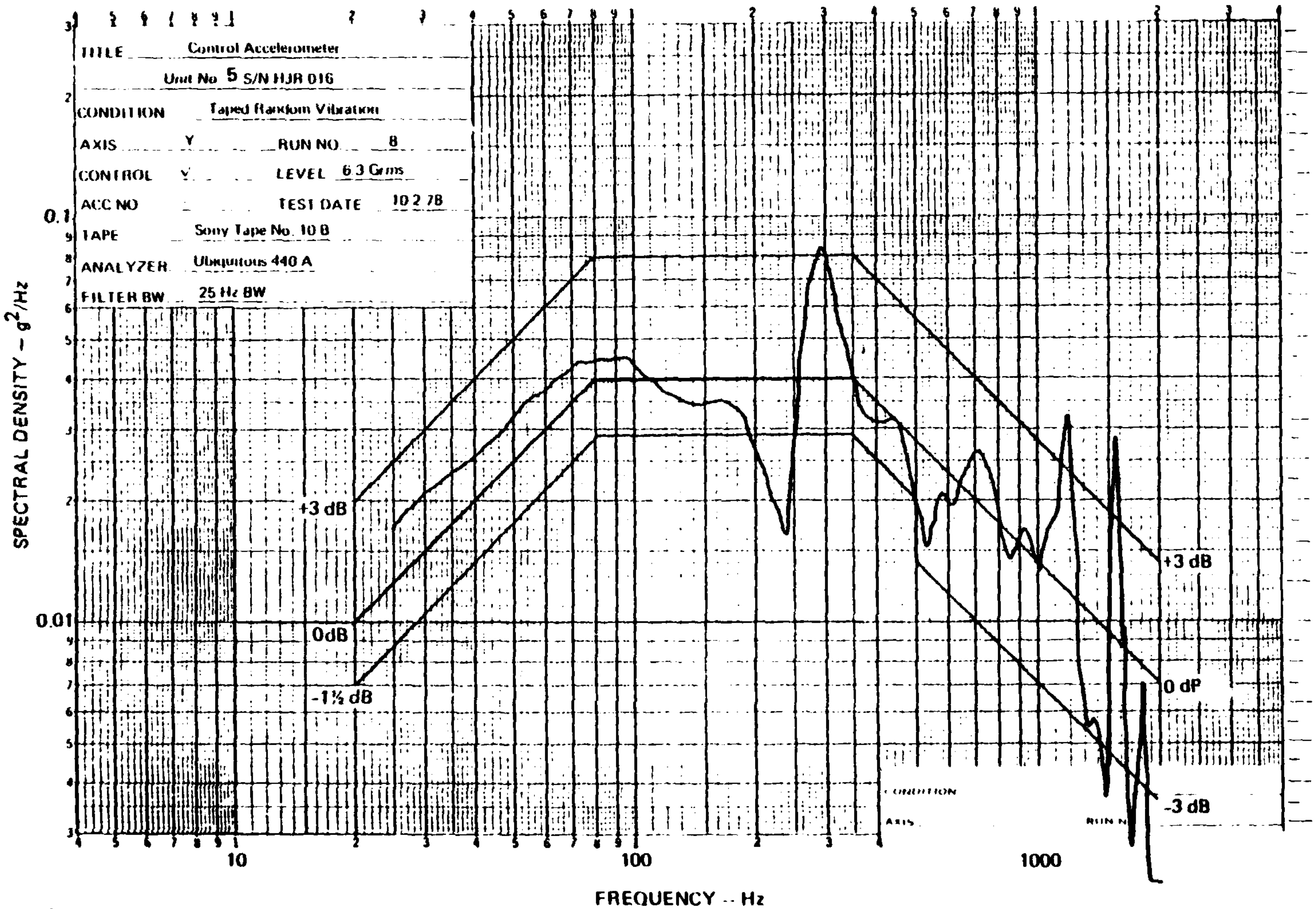
DATA TAPE
ADDRESS (1) 010-02-06-00 (0334)
ADDRESS (2)
SIGNAL SOURCE Sony Tape No. 10B



2935 28W

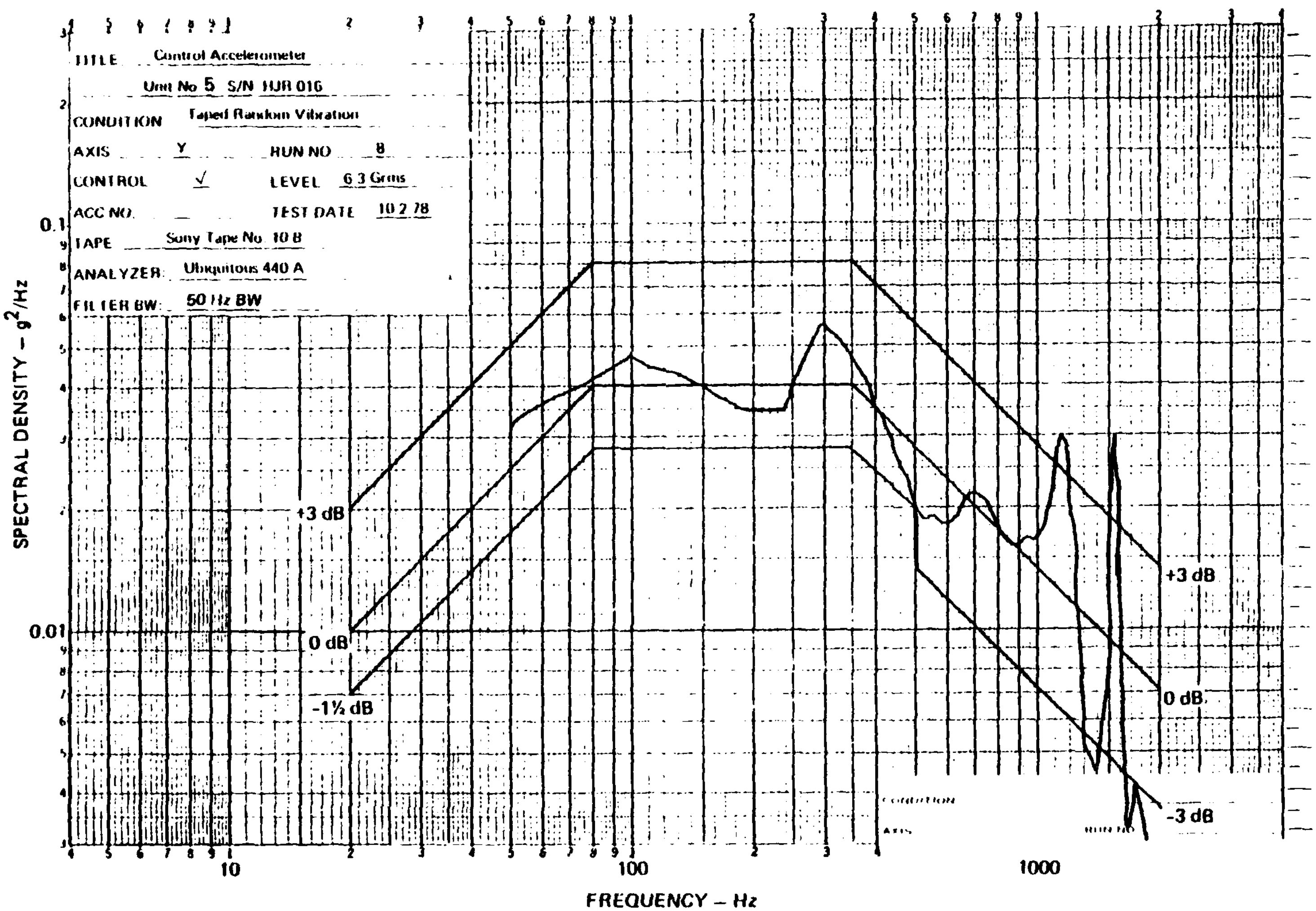
Figure 29 Unit No. 5 Spectrum Analysis (5 Hz)

GRUMMAN AEROSPACE CORPORATION



2935-31W

Figure 30 Unit No. 5 Spectrum Analysis (25 Hz)



2935-30W

Figure 31 Unit No. 5 Spectrum Analysis (50 Hz)

Description of Test Setup

The unit was tested in the "X" and "Y" axis which are the two axes parallel to the mounting surface of the unit. The "X" axis is in-line with the mounts (front-rear) and the "Y" axis is perpendicular to the mounting axis (side-side). Tests were performed on a Grumman flexure table driven by an MB model C-10E shaker (rated 1200 lbs force - sine).

Random Test Spectrum

(see Para. 2.3.1.2.1)

Summary of Test Results

A total of three units (2 axes each) were tested. All sine sweep data averaged about +4 dB high. This was due to the use of 2000 Hz as the gain reference frequency (as discussed in para. 2.3.1.2.3 for Unit No. 5).

High frequency exceedances in the range of 3 to 5 dB were encountered at several frequencies above 1100 Hz. These are suspected to be due to variations in flexure table setup and alignment. Since they are extremely narrow, they would probably be within tolerance when analyzed with the wider filter bandwidths (100 Hz) permitted by MIL-STD-810C.

Low frequencies (less than 1000 Hz) were all within tolerance. The tie-down resonance in the "Y" axis at 210 Hz showed a slight shift in two of the units but remained within tolerance.

2.3.1.2.5 Unit No. 2 (Computer)

Description of Test Article

This unit is an electronic computer used in the automatic flight control system of the aircraft. It measures 5" W x 16" L x 7" H, weighs 14.7 lbs and mounts on a flat surface using the same tie-down hardware as Unit No. 4 para. 2.3.1.2.2.

Description of Test Setup

The unit was tested in the "X" and "Y" axis which are the two axes parallel to the mounting surface of the unit. The "X" axis is in-line with the mounts (front-rear) and the "Y" axis is perpendicular to the mounting axis (side-side) test was performed on a Grumman flexure table driven by an MB model C-10E shaker (rated 1200 lbs force - sine)

Random Test Spectrum

(see Para. 2.3.1.2.1)

Summary of Test Results

A total of three units (2 axis each) were tested. All sine sweep data averaged +5 dB high due to the choice of 2000 Hz as the gain reference frequency as discussed in para. 2.3.1.2.3 for Unit No. 5.

Low frequencies (less than 1000 Hz) were all within tolerance. The tie-down resonance in the "Y" axis at 240 Hz showed a slight shift in two of the units, but did not result in an out-of-tolerance condition in the random tests.

A high frequency drop out of greater than -6 dB was noted in all units above 1750 Hz. The problem appeared to be due to the alignment and setup of the flexure table as noted previously. Tests conducted with the fixture only showed that gross misalignment of the flexure table would shift resonant frequencies up to 100 Hz and distort the sine transfer curve significantly.

2.3.1.2.6 Unit No. 8 (Signal Data Converter)

Description of Test Article

This unit is an electronic s[illegible] data converter used with CRT displays for flight data. It measure 7.5" W x 26" L x 9½" H, weighs 60.41 lbs and mounts on two flat rails located on the bottom of the unit (along its longitudinal axis). It is fastened to the rails with four 1/4" dia. screws secured through mounting flanges on the unit.

Description of Test Setup

The unit was tested in the "X" and "Z" axis. The "X" axis is parallel to the mounting rails and bottom surface of the unit. The "X" axis test was performed on a Grumman oil film slip table driven by an MB model C-25HB shaker (rated 5000 lbs force - sine). The "Z" axis is perpendicular to the mounting surface of the unit. The "Z" axis test was performed on the MB model C-25H shaker (rated 3500 lbs force - sine).

Random Test Spectrum

(See Para. 2.3.1.2.1)

Summary of Test Results

One unit was tested (2 axis test).

The low frequency (below 1000 Hz) in the "X" axis was within tolerance. Two exceedances were noted (narrow band analysis) in the "x" axis above 1000 Hz. The first was +4 dB at 1200 Hz which would be within tolerance with the wider filter analysis. The second was a +12 dB exceedance at 1970 Hz.

This level would also be reduced using the wider filters and was probably due to slip table alignment as discussed in para. 2.3.1.2.5.

The "Z" axis test results were within tolerance only up to 600 Hz. Most of the problem with this unit were attributed to poor fixture design and assembly errors. The fixture overhangs the shaker head with a resultant sharp fixture resonance at 1060 Hz. The mass distribution with respect to the shaker head was unsymmetrical requiring the addition of a counterweight which created additional resonances. The use of rubber damping material below the counterweight further complicated the system. A complete fixture redesign was indicated.

2.3.1.3 Analysis of Results

The overall results of the test on production hardware were successful. Of the twenty eight tests that were run, only one yielded unacceptable results. Most of the problems encountered were due to lack of precision in duplicating the mechanical test setup. These and other procedural problems encountered were discussed and incorporated in the detailed procedure (Appendix D) which also described the techniques to preclude such problems.

The discussion of the test results are divided into the following section:

a. Method of data analysis
b. Statistical evaluation of data
c. Development of tolerances
d. Type of problems encountered.

2.3.1.3.1 Method of Data Analysis

As previously discussed, the goal for these production tests, using the taped random noise was to comply with test tolerances specified in MIL-STD-810C. The required tolerances developed as part of this study is specified in para.2.3.1.3.3. MIL-STD-810C also prescribes the method of analyzing the random spectrum:

> "Confirmation of these tolerances shall be made by use of an an analysis system providing statistical accuracies corresponding to a bandwidth-time constant product: BT = 50 minimum. Specific analyzer characteristics shall be as specified below:
>
> (a) On line, contiguous filter, equalization/analysis system having a bandwidth as follows:

B = 25 Hz, maximum between 20 and 200 Hz

B = 50 Hz, maximum between 200 and 1000 Hz

B = 100 Hz, maximum between 1000 and 2000 Hz"

The analyzer used for the major portion of the data analysis was the Model 440A Mini-Ubiquitous Spectrum Analyzer manufacured by Nicolet Scientific Corp. The bandwidth-time constant for all random analysis was maintained at 64 (BT = 64). The data from each test run was analyzed as follows:

(1) Sine sweep analyzed with analyzer in peak detecting mode using 5 Hz BW filters.

(2) Random data analyzed with analyzer in averaging mode using 5 Hz, 25 Hz, and 50 Hz BW filters in separate test plots.

For convenience the narrow band analysis (5 Hz BW filters) was plotted on graph paper with a linear frequency scale to permit more precise frequency determination. For determination of compliance with the tolerance requirements the data was analyzed with the wide band filters (25 Hz and 50 Hz BW) and plotted in the conventional manner using graph paper with a logarithmic frequency scale. It should be noted that while a 100 Hz bandwidth filter can be used above 1000 Hz, the Ubiquitous Analyzer utilized, did not have this capability. Where the 100 Hz BW was used (ref. Figure 26) a Spectral Dynamics Mode 101-A Tracking Filter was employed.

2.3.1.3.2 Analysis of Data

For the purpose of this analysis, only the random data analyzed with the 50 Hz bandwidth is usable above 200 Hz, it can be applied to all tolerance exceedances found since none occurred below 200 Hz. The data from the two Unit No. 8 tests was not included in this analysis since no wide band analysis data was available. The data tabulated below represents 26 individual test units.

Table 4 - Summary of Random Tolerance Exceedances				
Statistical Parameters Based on 26 test items	Frequency Band in Hz			
	20 to 1000	1000 to 1500	1500 to 1750	1750 to 2000
Percentage of test items having out-of-tolerance points	15%	35%	46%	88%
Average value of exceedance (without regard to sign)	4.7 dB	3.6 dB	4.2 dB	5.5 dB
Average value of exceedance (with regard to sign	+4.7 dB	+0.7 dB	+0.4 dB	-5.5 dB

There were actually only four tolerance exceedances below 1000 Hz and all but one (+3.3 dB on Unit No. 5) occurred on Unit No. 4. The problem with Unit No. 4 was associated with the tie-down resonance (as discussed in para. 2.2.2). The fact that all the tolerance exceedances were positive indicates that the compensation factors for Unit No. 4 could be adjusted to eliminate this problem. And, in fact, they should have been, since Task A results indicate that this unit needed a linearity compensation factor of -3 dB. (ref. Task A para.2.2.1.3). This factor was accidentally omitted in calculating the synthetic random spectrum for this unit.

The high frequency range of 1000 to 1750 Hz has average exceedances of approximately -4 dB which were only slightly above tolerance. It should also be noted that if the data has been analyzed with a 100 Hz bandwidth filter (as permitted in this frequency range). The exceedances would average only slightly above +3 dB.

Another significant statistic is the average exceedance with respect to sign which averaged only about $+\frac{1}{2}$ dB in this frequency range. This would seem to indicate that the variance compensation factors could be decreased about -1 dB since the desired bias of tolerance exceedances should be on the negative side. This change was incorporated into the formal procedure (Appendix D).

The frequency region above 1750 Hz gave almost uniformly poor results. This area appears to be most sensitive to minor variations in the test setup. The trend in this frequency range was heavily toward low tolerance exceedances. Since this portion of the frequency spectrum contributes little strain energy to the test article, it is recommended that large tolerance exceedances be permitted. This recommendation was also included in the formal procedure. (Appendix D)

2.3.1.3.3 Development of Tolerances

As previously noted, the reference tolerances applied to random vibration tests on the production hardware originally were those defined in MIL-STD-810C used for qualification tests. While these were obtainable in about 50% of the tests (excluding the drop-out problem above 1750 Hz) it was not considered a reasonable tolerance to apply to this type of test. Based on the test results with production hardware it is recommended that the following tolerance be applicable to taped random tests:

"20 to 1000 Hz ± 3 dB
1000 to 2000 Hz ± 6 dB

with the exception that low tolerance exceedances of -12 dB will be allowed over a cumulative bandwidth of 300 Hz between 1000 and 2000 Hz."

The permissible bandwidths for analysis are those specified in MIL-STD-810C and tabulated in para. 2.3.1.

Since it was assumed that many of the testing laboratories using this tape technique will not have spectrum analysis equipment to verify tolerances, an alternate method was recommended. This method, which utilizes the results of the taped 1.0g (peak) sine sweep, is discussed in detail in para. 2.3.1.4.

2.3.1.3.4 Type of Problems Encountered

The problems encountered during tests of productions hardware with the tape technique fall into two categories:

a. Hardware problems
b. Procedural problems.

The most significant hardware problem was encountered during the tests conducted on Unit No. 8 (in the vertical "Z" axis - see para.2.3.1.2.6) The test fixture was too flexible and included unsymmetrical weight distribution. It demonstrated the need for careful design of test fixtures to provide maximum rigidity for the test article.

Another, though less severe problem, were the quick release mounts

NAVELEX
Final Technical Report
December 1978

UTILIZATION OF TAPED RANDOM SPECTRA FOR VIBRATION TESTING

Prepared For
Naval Electronic Systems Command
Washington, D. C. 20360

By

Grumman Aerospace Corporation
Bethpage, New York 11714

Work Has Been Completed
In Fulfillment Of
Contract No. N00039-77-C-0360

Approved For Public Release
Distribution Unlimited

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PREFACE

This Final Technical Report was prepared by Grumman Aerospace Corporation, Bethpage, New York under Contract N00039-77-C-0360, for the Naval Electronic Systems Command, Washington, D.C. Mr. William E. Wallace Jr. (ELEX 4702) (ELEX470W) was the NAVELEX Project Engineer and Mr. Chester Nolf (ELEX 4702) was the technical advisor to NAVELEX.

The effort described was accomplished during the period September 1977 through December 1978.

In addition the Messrs. Hirschberger, Popolo, Devitt and Pokallus, other Grumman Study team members were: R. Esposito, A. Dantowitz, E. Quartin, and N. Arcas.

used on many of the replacable electronic assemblies. This mount proved very sensitive (with respect to shift in the tie-down resonant frequency) to alignment, torque, and test article stiffness. The only solution is to maintain extreme precision in duplicating the mechanical setup from test to test.

The most common problems encountered were caused by imprecise duplication of the test setup used for taping the sine transfer tape. The testing of ten different items on three shaker systems, using, in may cases, the same test fixture, required many disassemblies of setups, realignment of slip and flexure tables, and relocation of tie-down mounts on the fixtures. Each disassembly and hardware relocation between the original taping of the sine sweep and the performance of the production test increases the possibility for misalignment from the original setup. Therefore it is strongly recommended that each test article have its own dedicated test fixture to minimize disassembly cycles. Whenever disassembly and realignment of a slip table is required, it is recommended that the sine transfer characteristics of the fixture only be verified prior to testing the production unit. These recommendations are incorporated in the procedure (Appendix D).

The major procedural problem encountered during the testing was the use of 2000 Hz as the gain reference for the sine sweep tape. This resulted in the 1.0g (peak) sine sweep using the tape input averaging 5 dB high (ref. para. 2.2.3) in several of the units. The frequency range between 1750 and 2000 Hz was most sensitive to minor variations in the test setup and should not be used as the band from which the gain reference frequency is selected. The procedure provides for the gain reference frequency selection in a resonant free band 100 Hz wide in the frequency range of 300 to 1500 Hz.

Minor procedural problems were corrected where found and incorporated in the formal procedure (Appendix D). A procedure verification test was also performed to further verify and correct any procedural problems encountered in actual use (see para. 2.3.4).

It should be noted that no problems were encountered in two areas where potential problems were anticipated:

a. Test article variations

b. Variations in test spectra.

No problems were found, attributable to variation in the test article. While only three units of each type were tested, there were in most cases units from two or three different manufacturing lots (as indicated by the prefix to the serial number) with as many as 100 units separating the manufacture of the units tested. Most problems examined were caused by the mechanical setup variability described in preceeding paragraphs.

In order to examine the effect of a test spectrum variation on the taped technique, one of the production units, Unit No. 4 was tested with a different random spectrum than was used for the other production units. (Ref. para. 2.3.1.2.2) This spectrum had steeper slopes than the normal spectrum with a +6 dB per octave rise initially and a short segment of -9 dB/oct roll off in the mid frequency range. No significant problems were noted in the synthesization of non-standard acceptance test random spectrum. The only problem encountered during this test was at the tie-down resonance (as discussed in para. 2.3.1.2.2) which occurred at 250 Hz in the flat portion of the spectrum.

These situations are unique to this type of attachment hardware i.e., "Mil Spec" swing bolts and high torque nuts, where excessive inputs will result in an off loading on the bolt hardware. For these conditions, a linearity compensation factor may be required in the development of the synthesized random spectrum.

2.3.1.4 Utilization of Sine Sweep Data to Predict Random

One of the basic premises for the application of the taped random technique is the use of the sine sweep data to predict variations in the random spectrum. During the testing of the production hardware, a plot of peak g versus frequency was made during the taped sine sweep; and a plot of power spectral density (g^2/Hz) vs frequency during the random portion of the test. Since the spectral density is avaraged over the bandwidth analyzed, the analyzed bandwidth should be as small as practical for a meaningful comparison. For the production tests conducted the bandwidth of the analyzer was maintained at 5 Hz, since this was the narrowest filter that encompassed the full 2000 Hz test range.

A tabulation was made for each test listing all data points that exceeded the ± 3 dB tolerance band in either the sine run or the narrow band analysis of the random spectrum. (Appendix B). The difference between the random amplitude measured and amplitude predicted by the sine sweep (at that frequency) was determined. This value was corrected for the variance and low frequency tolerance (para. 2.3.1) compensation factors (since they were applied only to the random and not the sine) to determine the error in the random data in predicted by the sine data. This data is summarized in Table 5. A graphical example is presented in Figure 27 which shows the effect of a shift in resonant frequency on the sine sweep and narrow band random analysis.

Table 5 - Summary of Error in Predicting Random With Sine Data
Average Error (20 to 2000 Hz - 131 data points) = 2.06 dB (without regard to sign)
Average Error (20 to 2000 Hz - 131 data points) = -0.35 dB (with regard to sign)
Average Error (20 to 1000 Hz - 34 data points) = 1.10 dB (without regard to sign)
Average Error (1000 to 2000 Hz - 97 data points) = 2.40 dB (without regard to sign)

Table 5 above shows an overall average error of 2 dB in using the sine data to predict the random spectrum. The errors are distributed normally with respect to sign, averaging only -0.35 dB. We further divided the data into two bands corresponding to the tolerance bands specified in para. 2.3.1.3.3. In the low frequency band (20 to 1000 Hz), with an allowable tolerance of ± 3 dB, the average error was 1.1 dB. In the high frequency band (1000 to 2000 Hz), with an allowable tolerance of ± 6 dB, the average error was 2.4 dB. Since the average error band is within 40% of the tolerance band, the method of predicting the random spectrum using the sine sweep data produces reasonably accurate results.

One further factor, filter bandwidth, must be applied in using the sine data to determine if the random spectrum will comply with test tolerances. The military specification permits averaging the random spectrum over wider bandwidths than the 5 Hz bandwidth used to correlate the sine and random data. (The applicable bandwidths per MIL-STD-810C were tabulated in para. 2.3.1). The effect of averaging the random data over wider bandwidths can be graphically seen in Figures 28 to 31. The sine sweep curve (Figure 28) shows a narrow -17 dB drop in the acceleration level at 260 Hz. The narrow band spectrum analysis (averaging over a 5 Hz band) shows a -7 dB drop. The 25 Hz BW filter (Figure 30) reduces this to a -4 dB drop and the 50 Hz BW filter (Figure 31) which is the widest permissable at this frequency, shows it to be within tolerance with a -1 dB amplitude. While this dramatic reduction is peculiar to a very narrow high amplitude spike, the effect of averaging will reduce apparent tolerance exceedances to acceptable in-tolerance conditions.

In order to apply this averaging effect to the sine data a table was prepared to determine the reduction in amplitude that can be applied to a tolerance exceedance in the sine sweep data. (assuming the use of the widest filter permitted by the military specifications). This table, including directions for its use, are presented in the procedure. (Appendix D).

2.3.2 TAPE DECK EVALUATION

In Task A the Tape Deck evaluation consisted of two major areas, 1)the continuing evaluation of the primary tape deck, the Sony EL-7 and 2) the procurement and evaluation of a replacement for the inoperative Hitachi D3500.

2.3.2.1 Sony Tape Deck

The Sony EL-7 deck was periodically tested using the response tapes recorded during Task A. Table 2 includes the results of these response tests. A review of this data indicates that no major shifts or anomalies were observed after approximately 300 hours of operation.

Most of these operating hours involved recording and subsequent playback of sine and random vibration spectrums. During Task B eight production hardware tapes were recorded and played back numerous times without an operational failure of either the Sony EL-7 or a cassette.

The operating log presented in Appendix C reflects the specific tasks performed with the Sony EL-7.

2.3.2.2 Replacement Tape Deck Evaluation

2.3.2.2.1 Specification Review

A review of the manufacturer's specification and trade journals, originally solicited for Task A indicated that the Harman/Kardon HK2000 could replace the Hitachi D3500, and serve as a second backup unit. The operating log summarizing the tasks performed during this investigation is contained in Appendix C.

2.3.2.2.2 Test And Evaluation Program

The unit was initially checked to confirm its operational status after delivery. A limited test program was then conducted to verify the manufacturer's claims. Figure 18, of the Task A report, depicts the setup used during these preliminary, as well as subsequent tests. Table 6 presents the results of the preliminary tests.

Detailed Test Program

Since the Harman/Kardon was considered the backup tape deck and the schedule constraints restrictive, the test evaluation as originally performed on the Sony EL-7 was not exactly duplicated. The tests that were performed were those necessary to confirm the major evaluation requirements, and determine

TABLE 6 INITIAL MEASUREMENTS

Specimen: Harman/Kardon HK2000 with FeCr-60 Tapes

Tests: Operational check of Manufacturer's Specifications.

Parameter	Manufacturer's Data	Test Results
Frequency Response	20-16000Hz, ± 3dB	20-13500Hz +1, -3dB
Sig. to Noise Ratio w/Dolby on)	-62dB	-57dB
Line Inputs	0.050 & 0.200 vrms	.027 vrms & .196 vrms
Line Output	1.350 vrms	1.348 vrms

the compensation necessary to use the tape deck during the random vibration testing of production hardware.

2.3.2.2.2.1 Frequency Response Tests

These tests were conducted on the Harman/Kardon tape deck in accordance with those described in Para. 2.2.5.2.1.

- Frequency Response With Nominal Input Signal

The basic response, at the maximum recommended recording level of 0 dB, is shown in Figure 32. Comparison with the Task A results, using each curve's 0 dB reference, indicates the following:

a. Sony EL-7 - +.85 dB, -0.3 dB, reference Figure 19
b. Hitachi D3500 - +1.0dB, -6.5dB
c. Harman/Kardon HK2000 - +0.4dB, -2.6dB, reference Figure 32

An exploded view of the low frequency (20 Hz) response of the recorder was made yielding a similar comparison:

a. Sony EL-7, output was only -0.8dB at 20 Hz, reference Figure 20
b. Hitachi D3500, not specifically tested at this level.
c. Harman/Kardon HK2000, -2.6dB at 20 Hz but with +0.4dB at 25 Hz, reference Figure 33

- Usable Dynamic Range

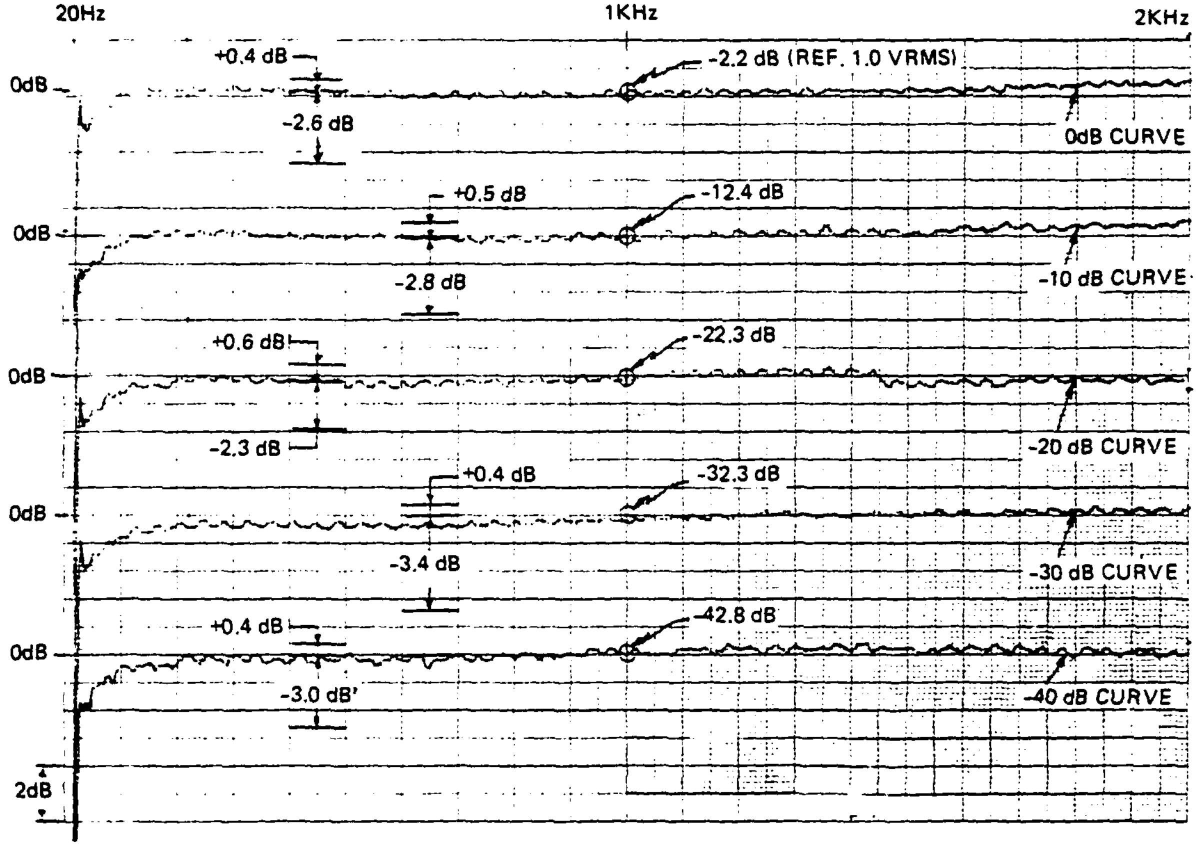
The response of the Harman/Kardon, to various input voltage levels is presented in Figure 32 and in Table 7. The results of this test indicate that no major response changes occur with decreasing signal levels, within the range of 0 to -40 dB.

- Stability and Repeatability of the Tape System

This investigation was performed in order to monitor the tape deck's output variation as a function of time. Unlike the more extensive evaluation conducted on the Sony, the Harman/Kardon's response tapes were only played back periodically. The results, of the playbacks, are presented in Table 7.

2.3.2.2.2.2 Additional Tape System Tests

Several additional tests were conducted on the Harman/Kardon, similar to those performed in paragraph 2.2.5.2.2.



2935-38W

Figure 32 Response vs Signal (Playback – Harman/Kardon)

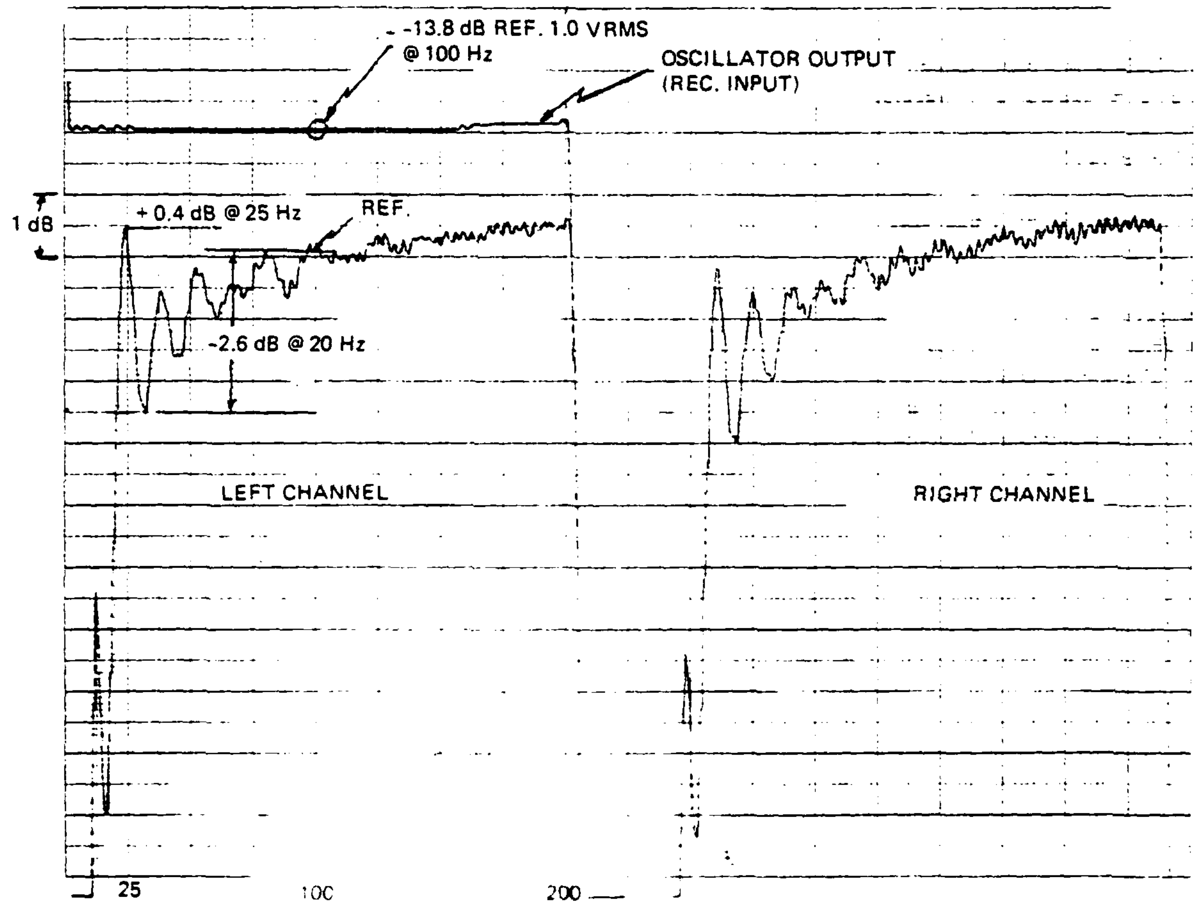


Figure 33 Low Frequency Response for Both Left & Right Channels (Harman-Kardon)

TABLE 7 - RESPONSE DATA

TEST SPECIMEN: HARMAN/KARDON HK2000

DATE	MAX. ERROR VS SIGNAL LEVEL											
	+3dB		0dB		-10dB		-20dB		-30dB		-40dB	
	+dB	-dB	+dB	-dB	+dB	-dB	+dB	-dB	+dB	-dB	+dB	-dB
6-15-78 (1)L	-	-	0.5	1.95	0.6	2.2	0.65	2.40	.55	2.6	.45	2.2
6-15-78 (1)R	-	-	0.8	2.40	1.05	2.7	1.20	3.1	0.8	3.1	0.80	2.6
7-11-78 (2)L	0.5	2.2	0.35	2.6	1.2	2.8	0.45	2.55	0.30	2.5	0.45	2.15
8-24-78 (2)L	0.5	2.7	0.50	2.3	0.2	2.6	0.45	2.80	0.20	2.1	0.20	3.10
9-21-78 (2)L	0.8	2.4	0.50	2.5	0.8	2.6	0.50	2.50	0.40	3.6	1.0	2.80
11-4-78 (1)L	-	-	0.4	2.6	0.5	2.8	0.6	2.3	0.4	3.4	0.4	3.0
11-17-78 *(2)L	0.8	2.2	0.60	2.0	1.2	2.4	0.4	2.4	0.30	2.8	-	-
11-17-78 *(2)L	0.9	2.8	0.8	2.6	1.2	3.0	0.4	2.8	0.20	3.6	0.4	3.0
11-20-78 (2)L	1.0	2.8	0.6	2.5	1.6	2.2	0.4	3.1	0.20	3.2	0.6	3.1
11-20-78 (2)R	0.6	2.6	0.7	2.5	1.5	2.4	0.8	3.3	0.6	3.6	0.6	3.1
AVERAGE	0.73	2.53	0.58	2.4	.99	2.8	.59	2.73	.40	3.1	.54	2.78

(1) or (2) Designates Tape I.D.

L or R Designated Recorder Channel

* - Pre-clean data and Post Cleaning of the Recorder Head

a. Circuit Loading - A test was run to measure the effect on frequency response as a function of various loads on the tape deck output circuit. Loading was varied over a range of 100K to 500 ohms. The unit's output dropped by approximately -3dB when the load was lowered to 5000 ohms.

b. Tape Deck Cleaning - No obvious improvement in response was observed when the heads were cleaned after 100 hours of use.

c. On-line Playback - A comparison, of output levels, while simultaneously recording versus the normal playback presented two different response characteristics. The manufacturer was contacted and confirmed there was a difference due to the circuitry design of the filters. Therefore, with this particular recorder, the on-line playback cannot be used to represent a recorder's response.

d. Dolby Noise Reduction - This tape deck feature, as with the Sony unit, is effective only in frequencies above 2000 Hz and has no measurable effect on the frequency range of concern.

e. Subsonic Filtering - This high pass filter caused greater attentuation in the 20 to 200 Hz frequency band but considerably lowered a high level signal at 25 Hz and therefore was used throughout the test program.

2.3.2.3 <u>Summary of Test Results</u>

a. Sony EL-7

o Frequency response characteristics remained relatively stable over the one year program and after approximately (300) hours of operation.

o Normal handling of both the tape deck and cassettes induced no mechanical failures.

b. Harman/Kardon HK2000

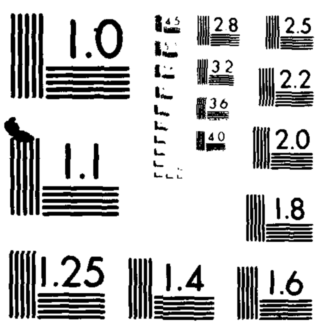
o Frequency response of +1dB to -3dB from 20 to 2 KHz.

o Frequency response versus input signal levels from 0dB to -40dB remain within the +1dB to -3dB band.

o Moderate testing over a five month period does not cause any immediate deterioration of the tape deck, although one cassette was broken.

AD-A099 789 GRUMMAN AEROSPACE CORP BETHPAGE NY F/G 14/2
UTILIZATION OF TAPED RANDOM SPECTRA FOR VIBRATION TESTING.(U)
DEC 78 G HIRSCHBERGER, J J POPOLO, J DEVITT N00039-77-C-0360
UNCLASSIFIED NL

2 of 3



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

- All other contingencies checked, Dolby, cleaning, Subsonic filtering, etc., appear satisfactory.

2.3.2.4 Conclusions

The Sony and the Harman/Kardon are both capable of meeting the program requirements as proven by using both the record and playback functions with synthesized random tape. The Sony is the superior of the three tape decks tested. The additional testing performed during Task B confirmed the Task A test results and established the long term durability of the Sony EL-7 deck.

Comparison of the frequency response characteristics demonstrate that the Sony has a flatter response with narrower excursions. The Harman/Kardon response (under 200 Hz), although acceptable is not as good as that demonstrated by the Sony. "Ease of handling", although a subjective quantity, was found to be preferrable with the Sony. The larger cassettes are bulky but appear to be more ruggedly built.

2.3.3 PREPARATION OF PROCEDURE

The purpose of this study program was to develop a technique for economically generating random vibration utilizing an audio tape deck to drive an electrodynamic shaker system. The study effort results have been documented in this final report. A detailed procedure, delineating the specific steps required for implementing the technique was also prepared and is included as part of this report in Appendix D.

2.3.4 PROCEDURE VERIFICATION TEST

A test program was conducted to verify that the operational portion of the formal procedure (Appendix D) could be successfully run by an outside facility with test personnel unfamiliar with the taped random technique. The facility used was the Grumman Environmental Test Laboratory located in Plant 5, Bethpage, N. Y. A test engineer and technician were assigned to the program who had no previous experience with the technique.

The test program was accomplished in three phases as follows:

a. Recording Sine Transfer Tape (Plant 5, Bethpage)
b. Synthesizing of Random Tape (Plant 8, Calverton)
c. Testing with the Taped Input (Plant 5, Bethpage)

2.3.4.1 Recording of Sine Transfer Tape

The Plant 5 test engineer was suppli with a draft copy of Chapter 3 of the procedure (See Appendix D), the Harman/Kardon HK2000 Tape Deck and a blank cassette.

The test was performed on an L.A.B. Corporation Model 5430-30 "VA-Press" slip table. The slip table was driven by a Ling Model 335 shaker (15,000 lb. sine force rating). A 60 lb. machined aluminum test fixture was bolted to the slip table for the test. The fixture was designed to hold multiple relay packages but none were bolted to the fixture during this test program to avoid accidental damage.

A preliminary 1.0g (peak) sine sweep was made to determine recording levels, followed by the test sine sweep recorded on the tape. Only two minor problems arose during the test which resulted in subsequent modification to the procedure.

The first problem was encountered during the recording of a 3.0g (peak) acceleration calibration signal on the tape. It was found that the calibration signal from the charge amplifier (which had an output sensitivity of 10 mv/g) was too low in amplitude (30 mv peak) to permit attainment of the required OdB reading on the tape decks VU meter. The procedure was therefore amended to recommend a 100 mv/g sensitivity setting on the charge amplifier for sinusoidal tests. This setting had been used throughout Task B of the study program to improve signal to noise ratio when operating at only 1.0g (peak) amplitude.

The second problem encountered involved the selection of the gain reference frequency to be recorded at the start of the sine sweep. The guidelines established in the procedure suggested that the reference frequency be between 500 and 1200 Hz in the center of a 200 Hz band of relative constant amplitude (P.A. input voltage). For this test there was no frequency band in this range with a constant amplitude. (See plot of P.A. input voltage versus frequency in Figure 34). The only relatively constant portion of the amplitude curve was between 1500 and 1900 Hz, therefore, 1700 Hz was chosen as the gain reference frequency. The procedure was subsequently modified to open the requirements to a 100 Hz wide band of constant amplitude between 300 and 1500 Hz.

2.3.4.2 Synthesizing of Random Tape

The taped sine sweep recorded in Plant 5 was then played back in Plant 8 through a Ubiquitous 440A Real Time Analyzer (5 Hz BW filters) and an X-Y plot of the control accelerometer and P.A. input voltage versus frequency was made. This data was used to calculate the synthetic random voltage for the system which was then recorded on the tape cassette immediately after the sine sweep. The procedures employed were used to verify those outlined in Chapter 4, (Appendix D). No significant problems were encountered in the synthesization of the random tape.

2.3.4.3 Testing with the Taped Input

The test tape and tape deck were returned to the Plant 5 Test Laboratory for the final phase of the program. The bolt connection between fixture and slip table, and between slip table and shaker head were loosened and re-torqued to specification prior to the test.

The sine sweep portion of the tape was played through the shaker system and on-line plot was made of the control accelerometer using the Ubigitous 440A Real Time Analyzer. The data was within +1 to -2dB for the entire sweep except for a -21/2 dB drop between 1950 to 2000 Hz (see Figure 35). Since these were within the allowable tolerances specified in the procedure, the tape was advanced

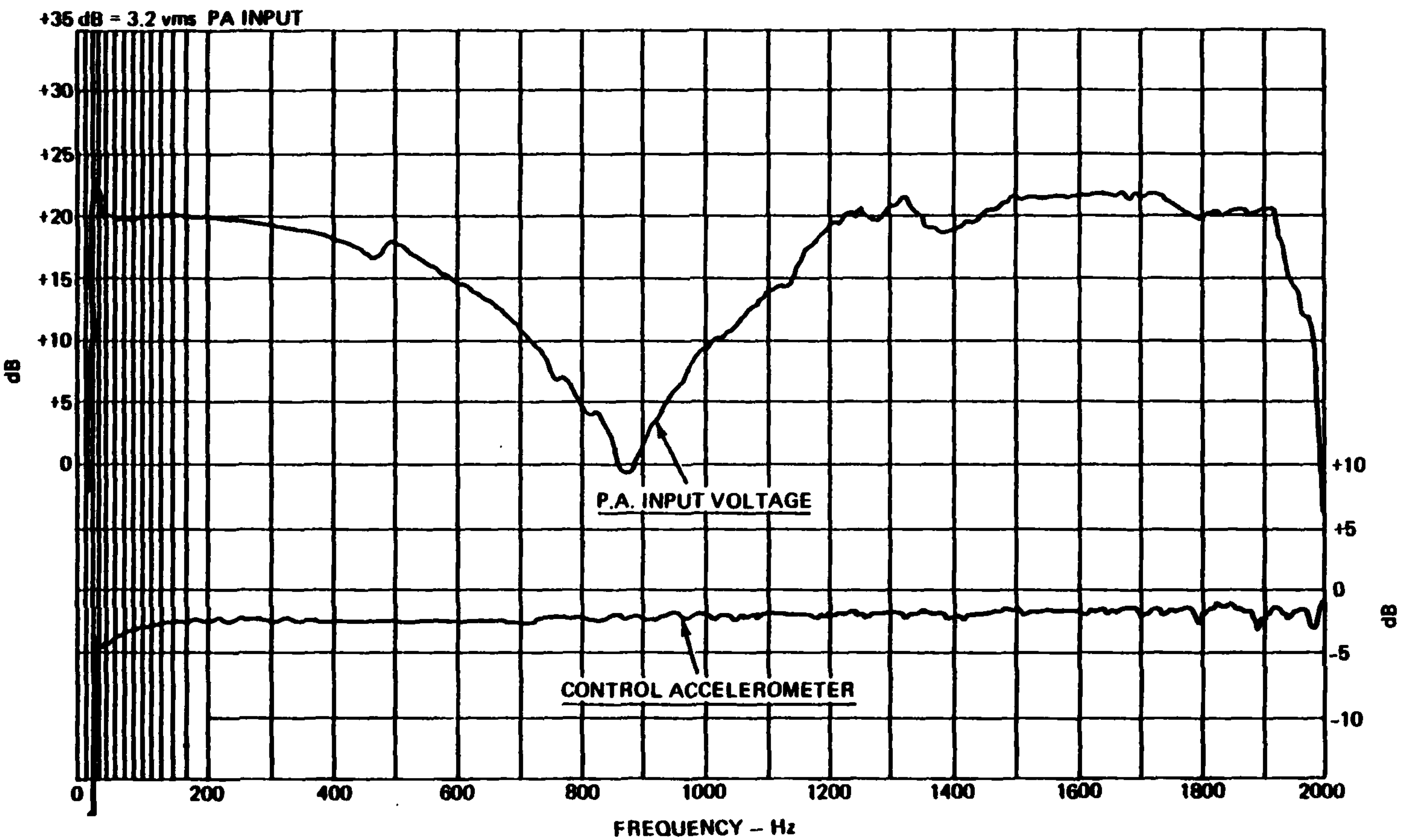
GRUMMAN AEROSPACE CORPORATION

TITLE P.A. Input & Control Accel. DATE 10-30-78 DATA TAPE H.K. – 1X Side A

TEST ARTICLE LVPM Fixture S/N – ADDRESS (1) Counter 052 to 119

TEST CONDITION 1g sine sweep AXIS "X" ADDRESS (2) –

DATA ANALYSIS Ubiquitous – 5 Hz BW SIGNAL SOURCE servo control



2935-37W

Figure 34 Sine Transfer Tape Data

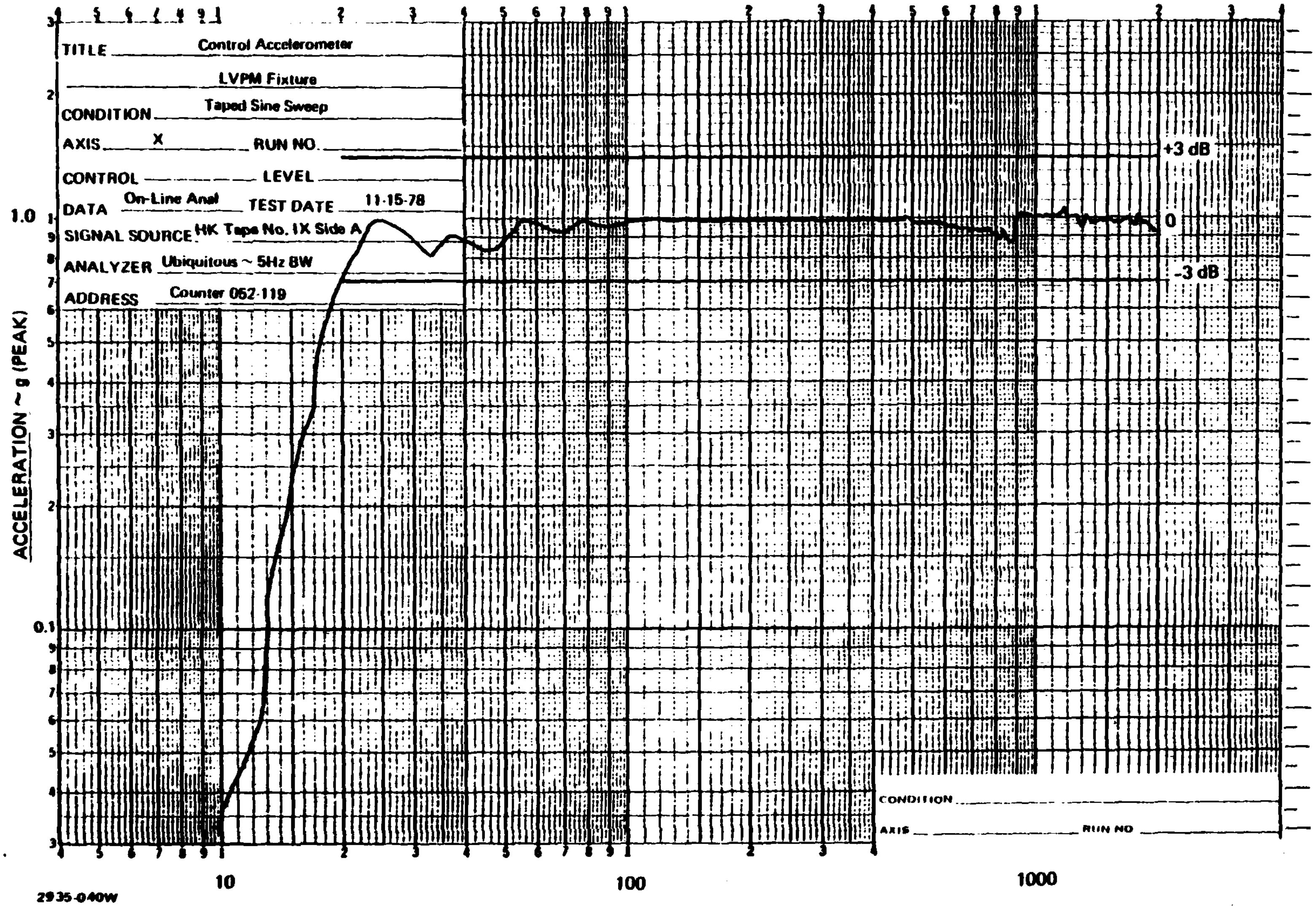


Figure 35 Taped Sine Sweep Data

to the start of the random vibration recording.

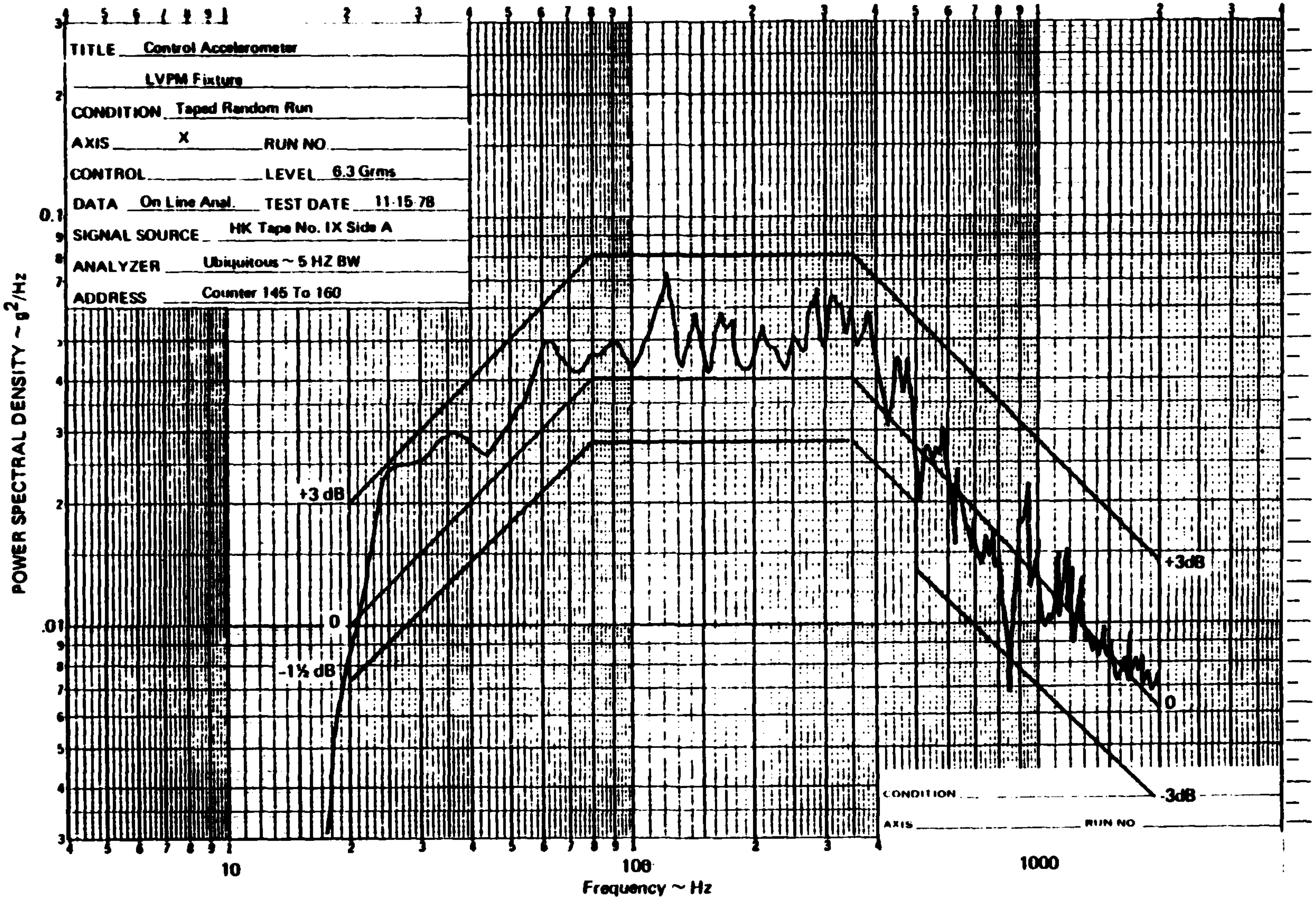
The random vibration test was run for approximately 4 minutes with an overall amplitude of 6.3 Grms indicated on the true RMS meter. On-line plots of power special density versus frequency were made from the control accelerometer using the Ubiguitous 440A Real Time Analyzer. Individual plots were made with 5 Hz, 12.5 Hz, 25 Hz and 50 Hz Bandwidth filters. The narrow band analysis (5 Hz BW) showed only one out of tolerance point at 835 Hz with a narrow -4dB drop out. (see Figure 36). With the 12.5 Hz BW filter or wider this drop out is reduced to -2dB and the entire spectrum is within tolerance. (see Figure 37) (It should be noted that this drop out was caused by a -1.7dB compensation factor applied at this frequency in case of a frequency shift down in the resonant frequency of the system.)

One procedural problem was uncovered during playback of the sine portion of the tape. Using the tape counter to locate the start of the gain reference signal on the tape, the test operator started to turn up the shaker gain before the tape had actually reached the start of the gain reference signal. This resulted in the shaker level coming on at 4 to 5 g which the test conduction quickly reduced to 1 g. This pointed up the need for a visual indication of signal output from the tape deck before the shaker gain is turned up. The procedure was therefore revised to ensure that the test operator visually observes signal level on the tape deck's VU meter before turning up system gain.

2.3.4.4 <u>Result of Procedure Verification Tests</u>

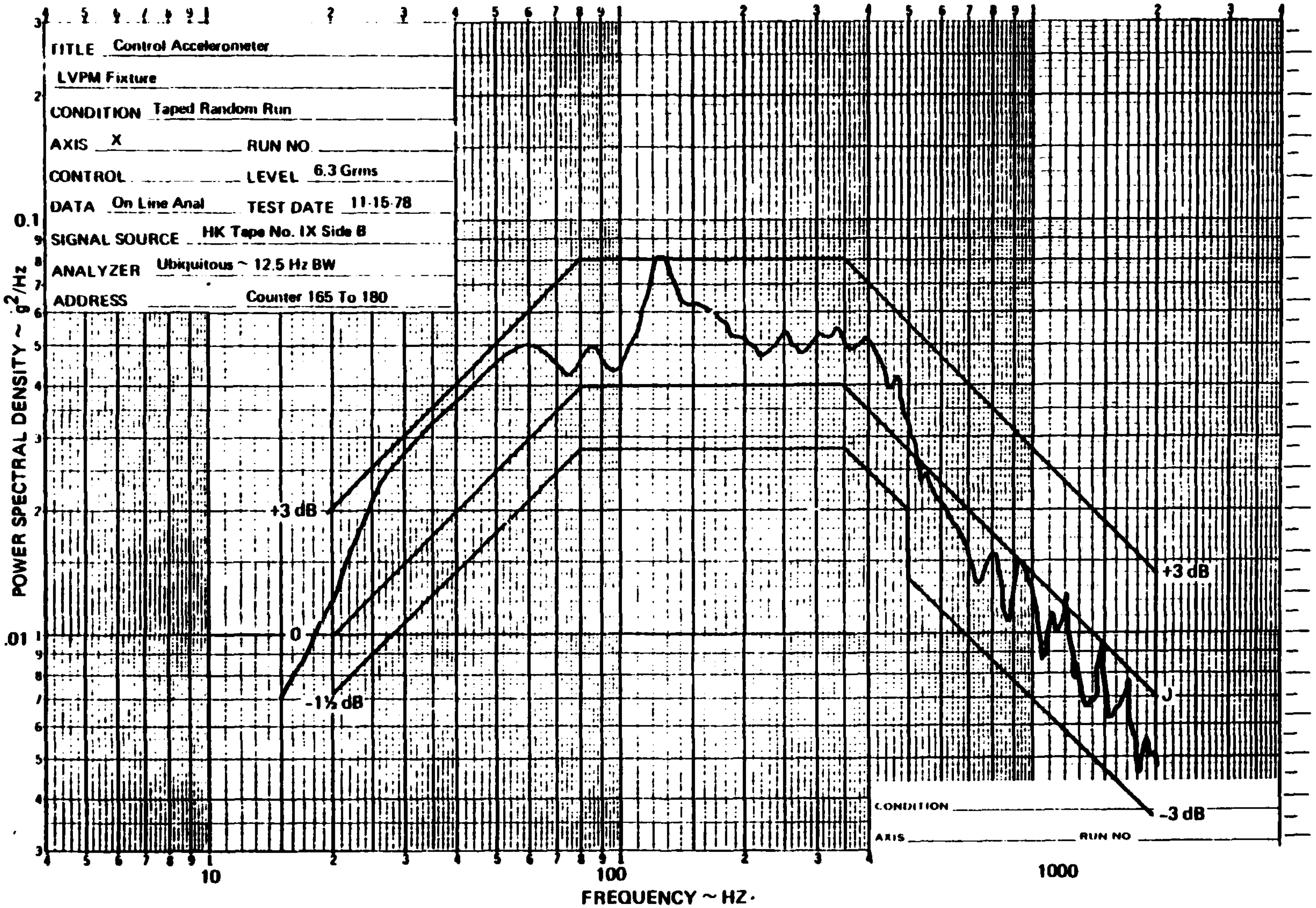
In addition to the procedural changes discussed in the previous paragraphs, the tape data sheet was modified to provide more detail on recorded signal location on the tape.

The mechanics of performing the test went fairly smoothly. The initial recording of the tape took about four hours but the playback test required only one and a half hours. As familarity with the tape system increases, it should require less time than it takes to run a conventional random vibration test.



2935-041W

Figure 36 Taped Random Run ~ 5 Hz BW Analysis



2935-042W

Figure 37 Taped Random Run 12.5 Hz BW Analysis

3 - CONCLUSION

3-1 OVERVIEW

The results of this program show that the taped random technique can be successfully applied for conducting random vibration tests of production hardware during acceptance testing.

The study indicates that the variations between generally identical equipment can be accomodated by the application of compensation factors that were developed. Allowable tolerances were also developed to: assure consistency in spectrum definition during testing and minimize overtest potential. These tolerances are ± 3 dB for the frequency range of 20 - 1000 Hz, and ± 6 dB for the frequency range of 1000 - 2000 Hz. The testing procedures developed during this test program have been designed to minimize the amount of new equipment necessary as well as the required skill level of the test conductor. The measure of success in this regard is that a test laboratory currently performing sinusoidal acceptance tests, purchase an inexpensive stereo cassette deck to achieve a random test capability. The preparation of the synthetic random tape can be accomplished remotely and at moderate expense by any test laboratory with random noise equilization and analysis equipment.

The study resulted in the following specific conclusions:

3.2 TASK A

3.2.1 MASS MOCK-UP EVALUATION

a. No problems were found in the operation of the shaker system with any of the tape decks used.

b. Input acceleration to the unit measured during taped random vibration tests were uniformly good, with spectrum levels within 3 dB of the nominal spectrum. (This is within MIL-STD-810C tolerance for qualification tests).

c. Sinusoidal vibration tests used to measure transfer characteristics can be performed without filtering of the control accelerometer. (This is important since it minimizes the quality of equipment a lab must have to perform this test).

d. Compensation factors can be used in preparing the synthetic random tape to account for tape deck characteristics, as well as non-linearities and variance in the dynamic characteristics of the test article. (This technique of applying compensation factors for anticipated variances reduces the risk of overtest and permits a greater amount of flexibility in duplicating the exact setup from test to test).

e. Utilization of the sinusoidal tape to verify the test setup prior to random tests appears to be extremely accurate. Further testing during Task B is anticipated to de-sensitize it in order to provide better correlation with random test results.

3.2.2 BASELINE TRANSFER CHARACTERISTIC EVALUATION

a. Variations in average sinusoidal response characteristics over the total bandwidth was minimal (less than ±1.0dB) from unit to unit within a particular type and also between different types of equipment.

b. The variation at resonant conditions averaged approximately ±3dB. This level of variability can readily be accomodated in the form of a suitable, universal factor, utilized during the formulation of the synthetic spectrum.

c. Variations in random vibration data is even less than the sinusoidal differences and indicates that the 1.0 peak sine utilized for response determination appears to have universal non-linear impact level effects.

d. Frequency variations between units occurring at resonant conditions can also be accounted for during the formulation of the synthetic spectrum. Preliminary results indicate that a tolerance band of ±3%. be utilized below 1000 Hz and a value of ±5% applied for frequencies between 1000 - 2000 Hz.

e. Transfer errors between synthesized and actual random calculated for one sample type, showed that a maximum variation was approximately ±3.5dB.

3.2.3 SHAKER SYSTEM VARIATION

a. No significant problems which could impact the technique were encountered with any of the shaker system, test set-up arrangement employed during the program.

b. Extensive tests with the C-25H shaker system show that minor variations in system parameters or gains have negligible effect on transfer characteristics. The signficance of these tests to the taped random program is twofold:

   (1) Normal degradation of system gains due to aging of components is not expected to be a problem.

   (2) Exact duplication of all shaker system control parameters from test to test is not a critical requirement.

3.2.4 TAPE DECK EVALUATION

a. The results of the specification evaluation concluded that two units, the SONY Elcaset model EL-7 and Hitachi model D3500 met or exceeded program cost and technical requirements.

b. The SONY tape deck was clearly the superior of the two units when used in conducting the taped random technique and met all immediate program requirements.

c. Long term operation appears to be satisfactory and no major problems or degradation are anticipated over an extended operating time period.

3.3 TASK B

3.3.1 PRODUCTION HARDWARE TESTS

a. Measurements of power spectral density input to the production units were within Mil Spec tolerances for the majority of the units. A new level of tolerances was derived (based on the production unit data) which can be more readily obtained with the tape technique without compromising test ingetrity.

b. The problems that were encountered were investigated to determine the source of the trouble. Most were found to be caused by variations in the mechanical setup of the tests. Where corrective action was indicated, modifications were made to the procedures to incorporate the necessary changes.

c. Use of the sine sweep data to predict the random spectrum variations was found to yield errors less than 40% of the allowable tolerances. This was considered a satisfactory accuracy for this type of test, and detail procedures were derived to use this method.

3.3.2 PROCEDURE VERIFICATION TESTS

a. A detailed procedure for applying the random tape technique was written based on methods evolved during the test program on production hardware.

b. A test program using the tape technique was successfully performed by inexperienced test personnel in another test lab. using the draft test procedure. The few minor problems encountered were corrected in the final test procedure. (Appendix D)

3.3.3 TAPE DECK EVALUATION

a. Test operations with the Sony Elcaset model EL-7 presented no problems. Frequency response characteristics are excellent and no changes were noted during the year it was in use.

b. Test operations with Harman Kardon model D3500 were also trouble free, though the test period of evaluation was considerably limited in comparison with the Sony Elcaset. The frequency response characteristics, while not as linear as the Sony Elcaset, did satisfy program requirements.

4- APPLICATION AND LIMITATIONS

4.1 INTRODUCTION

The utilization of this technique in the industry has been extremely limited because of the few requirements for random vibration tests outside of space applications. As random testing experience grows due to increased random vibration requirements, the true range of this technique's application and limitations can be accurately assessed. Some projections in these areas can be made based on the results of this study program.

4.2 APPLICATION OF THE TAPE TECHNIQUE

The development of the taped random technique was directed primarily towards repetitive testing of identical units, such as a Reliability Acceptance Test (RAT) program on a military component. Although its main appeal is to the small laboratory without any random equalization equipment, it offers distinct operating advantages to the larger better equipped laboratories as well. It facilitates the performance of acceptance tests at the production site since only a small sinusoidal shaker system has to be located in the area. It frees the complex and expensive random equipments as well as its highly skilled operators from supporting factory acceptance tests. It can provide back-up support to existing random equipment during periods when "down" for repair or maintenance. The technique can also provide a convenient way of performing random tests with multiple control points. The synthetic random voltage can be calculated to provide control by averaging, highest or lowest in any frequency band, or any other complex distribution.

The tape technique would seem ideally suited towards long term vibration testing on a single test article. With a single test article and test setup no significant changes in the transfer characteristics should occur thus providing an accurate repeatable random spectrum. This type of test, normally used for Reliability demonstrations, is discussed in Section 5.0

4.3 LIMITATIONS ON THE USE OF THE TECHNIQUE

As stressed in preceeding sections, the primary requirement for successful utilization of this technique is exact mechanical duplication from test to test. The effect of differences between production units can be minimized by designing the test fixture for high mass and rigidity relative to the test article. Test articles with soft or flexible mounts can be expected to show wider variations in the sine transfer characteristics than can be adequately compensated for with the procedures develcped. The application of the technique to this type of test article or with poorly designed fixtures and undersized shaker systems should be avoided.

As discussed previously, the application of this technique can be expected to result in wider tolerance variations than required for qualification testing under applicable Military Test Specifications. For this reason, qualification testing or testing at close to qualification vibration amplitudes should not be attempted in order to avoid the possibility of over testing.

It should be anticipated that in the course of several years of performing acceptance tests on a product, modifications to the product, maintenance on the test system or replacement of equipment will necessitate the replacement of the test tape. It is also conceivable that it may prove practical to prepare two or three different tapes, each with minor variation in the random spectrum to correct for repetitive problems encountered during long production run tests. In any case, the time and expense involved in preparing a new tape is minimal, thus the user is urged to constantly monitor the results of the sine sweep data, and initiate the recording of a new test tape whenever repetitive shifts in the sine transfer characteristics are observed.

5- RECOMMENDATIONS FOR FURTHER STUDY

There are several areas that warrent further study. Foremost among these is the application of the tape technique to long term Reliability Demonstration tests. This type of test typically requires that a single test article be exposed to repeated mission simulation tests combining the environments of temperature, humidity and random vibration. The random vibration portion of the mission simulation cycle can require four different test spectrums and run continuously for periods of up to six hours. Since the performance of this type of test requires that expensive random vibration control equipment as well as skilled operators be available on a 24 hr. per day basis, the application of the taped random technique offers a significant potential for savings. An adaptation of the tape techniques for this purpose should be investigated.

Further refinements to the tape technique should also be pursued. These include four particular areas:

a)- a technique to adjust the random equalization at the test site to adjust for an out-of-tolerance condition. Some of the methods that could be evaluated include the use of tunable bandpass filters or a set of audio equalizers to accomplish equalization adjustment.

b)- a practical method of applying the compensation factors to the sine sweep portion of the tape so that their effect can be seen prior to running the random portion of the tape.

c)- computerization of the random synthesization process using the various rules for compensation developed in the program. This would greatly reduce the cost of preparing a synthetic random tape.

d)- application of a digital tape technique to facilitate acquisition and process of data, as well as operation of test.

APPENDIX A

SUMMARY OPERATING LOG OF MASS MOCK-UP TEST OPERATIONS (TASK A)

1977

Nov 7 - Examined feasibility of using unfiltered control signal in servo loop - 4 Runs - looks feasible

Nov 8 - Worked on compensation techniques for recording sine sweep on NAGRA-III recorder - 1 Run

Nov 9 - Recorded sine sweep on NAGRA & played it back thru shaker system. Readjusted compensation and optimized servo compressor speed - 13 Runs - control problem at 1780 Hz

Nov 21 - Used Nov 9th sine tape and NAGRA recorder to drive system. - Significant problems @ 1630 & 1780 Hz - 7 Runs - problem @ 1630 Hz due to improper recording technique, problem @ 1780 Hz is a freq shift in response.

Nov 22 - Used Nov 9th sine tape & NAGRA recorder to drive system. Measured freq of voltage peaks - 1 Run

Nov 23 - Made extensive sine survey of shaker system & fixture to map dynamic characteristics - 3 Runs

Nov 28 - Continued sine survey of shaker system with mass mock-up attached. Very sharp rocking mode at 1750 Hz cause of previous problem - 3 Runs

Dec 2 - Made servo control sine sweeps at different "g" levels to check for linearity - 6 Runs. There appears to be a drop in freq & response with higher g's.

Dec 10 - Recorded sine sweep on Hitachi Recorder and played back thru system - 3 Runs - tape speed on Hitachi oscillating resulting in slight reduction in frequency of voltage peaks. Control problem above 1600 Hz

Dec 14 - Investigated control problem above 1600 Hz and made new sine tape with NAGRA recorder & played it back thru system - 29 Runs - Problem with control due to operating log converter in a peak detecting mode with unfiltered signal. Tape results look good.

Dec 15 - Made new sine tapes for both NAGRA & Hitachi Recorder. - 1 Run - Both tapes showed good fidelity except for low freq roll-off on NAGRA.

SUMMARY OPERATING LOG OF MASS MOCK-UP TEST OPERATIONS (TASK A)

Dec 16 - Recorded random tape (servo control) on both NAGRA and Hitachi Recorder and played back NAGRA thru system. - 3 Runs - tape results look good ± 3dB except for low freq roll-off. Hitachi recorder intermittant.

Dec 17 - Played sine and random tape on NAGRA thru the system. - 2 Runs - Random tape looks good ± 3dB and sine also good except for peak @ 1610 Hz

Dec 17 - Linearity investigation - made 1g and 2½g sine sweep and 6.0 Grms random run (all servo controlled) Computed the transfer function data for each run - 3 Runs - 2½g run is closer by 4dB to random at tiedown resonance - identical otherwise

1978

Jan 10 - Recorded sine and random tape (servo controlled) with SONY Elcaset - 2 Runs

Jan 11 - Played sine and random tape recorded on Jan 10 on SONY Elcaset thru the system. - 2 Runs. Data looked good except for some 3db spikes above 1600 Hz

Feb 4 - Played sine and random tape recorded on Jan 10 on SONY Elcaset thru the system. - 3 Runs - Both runs had a drop out at 1600 Hz caused by a shift in resonance from 1635 Hz to 1605 Hz

Feb 4 - Investigated possible cause of shift in frequencies and response. Made repeated sine sweeps (servo controlled) while varying system parameters. Noted no significant change due to varying electrical parameter or tiedown torque. Alignment of mass mock-up in mount gave largest variation at 1600 Hz with a Δ of 30 Hz and 6.7dB in response.

Feb 22 - Prepared synthetic random tape from sine data recorded on Dec 17th. Applied compensation factors for tape recorder, linearity and variance in mount alignment. Recorded on SONY Elcaset.

Feb 23 - Played random tape of Feb 22 on SONY Elcaset thru system. Mounted mass mock-up in three different mount positions - 3 Runs - Data looked good. All spectrum within ± 3dB.

Feb 23 - Played sine tape recorded on Jan 10 on SONY Elcaset thru the system. Data looked good except for 10dB notch at 1780 Hz. Increased the time constant of recorder by adding capacitor across input. - 3 Runs. - Eliminated notch completely.

SUMMARY OPERATING LOG OF MASS MOCK-UP TEST OPERATIONS (TASK A)

Feb 24 - Re-aligned mass mock-up in mount and played sine tape recorder on Jan 10 on SONY Elcaset thru the system. Got a wide 8dB drop out at 1630 Hz. Drop out reduced to -2½dB using 500 mfd capacitor at recorder to increase time constant - 5 Runs

Feb 28 - Played random tape of Feb 22 and sine tape of Jan 10 on SONY Elcaset thru the system. Random run was within ± 3dB. Sine run was down 4dB @ 1610 Hz - 3 Runs

SUMMARY OPERATING LOG OF TEST OPERATIONS (TASK B)

Mar. 13	-	Unit #1 S/N HGF-038 Made two 1 g sine sweeps in "X" axis and recorded sine transfer sweep on Sony Tape #6 Side A - 2 Runs
Mar. 28	-	Unit #1 Calculated synthetic random spectrum and recorded it on Sony Tape #6 Side A - 3 Verification Plots
Mar. 29	-	Unit #1 S/N HGF-038, HJR-021 & HJR-022 Made 1 g sine sweep and 6.3 Grms random run in the "X" axis using Sony Tape #6 Side A - 7 Runs
Apr. 27	-	Unit #4 S/N HGF-044 Made two 1 g sine sweeps in "Z" axis and recorded sine transfer sweep on Sony Tape #7 Side A - 2 Runs
May 16 May 18 May 19	-	Unit #1 Calculated new synthetic random spectrum to include a +1 dB compensation factor from 20 to 500 Hz in order to meet - 1½ db tolerance in this range. Recorded new random spectrum on Sony Tape #6 Side A - 5 Verification Plots
May 23	-	Unit #4 Calculated synthetic random spectrum and recorded it on Sony Tape #7 Side A - 4 Verification Plots
May 25	-	Unit #2 S/N HGF-038 Made two 1 g sine sweeps in "X" axis and recorded sine transfer sweep on Sony Tape #8 Side A. Made one 1 g sine sweep in "Y" axis and recorded sine transfer sweep on Sony Tape #8 Side B - 3 Runs
May 31	-	Unit #8 S/N JHA-011 & S/N EPG-002 Made a 1 g sine sweep in "X" axis on S/N JHA-011 and recorded sine transfer sweep on Sony tape #9 Side A. Made two 1g sine sweeps in "Z" axis on S/N EPG-002 and recorded sine transfer sweep on Sony Tape #9 Side B - 3 Runs
Jun 1	-	Unit #5 S/N HJR-029 Made two 1g sine sweeps in "X" axis and recorded sine transfer sweep on Sony Tape #10 Side A. Made two 1g sine sweeps in the "Y" axis and recorded sine transfer sweep on Sony Tape #10 Side B. Played back both tapes through shaker system to verify test levels - 6 Runs

SUMMARY OPERATING LOG OF TEST OPERATIONS (continued)

Jun 2 - Unit #7 S/N GRU-073 Made two 1g sine sweeps in "X" axis and recorded sine transfer sweep on Sony Tape #11 Side A. Made two 1g sine sweeps in "Y" axis and recorded sine transfer sweep on Sony Tape #11 Side B. Played back both tapes through the shaker system to verify test levels - 7 Runs

Jun 14 - Mass Mock-Up of Unit #4 - Made two 1g sine sweeps in "Z" axis using Sony Tape #4 Side A - 2 Runs

Jul 27 - Unit #1 S/N HJR-035 - Made 6.3 Grms random run in "X" axis using Sony Tape #6 Side A. Made 1g sine sweep in "X" axis to re-record sine transfer sweep on Sony Tape #6 Side A. (previous run accidentally erased) - 5 Runs

Aug 4 - Unit #5 Calculated synthetic random spectrum in "X" axis and recorded it on Sony Tape #10 Side A. Calculated synthetic random spectrum in "Y" axis and recorded it on Sony Tape #10 Side B - 8 Verification Plots

Aug 7 - Unit #7 Calculated synthetic random spectrum in "X" axis and recorded it on Sony Tape #11 Side A. Calculated synthetic random spectrum in "Y" axis and recorded it on Sony Tape #11 Side B - 8 Verification Plots

Aug 8 - Unit #4 S/N CSS-122 Made 1g sine sweep and 5.3 Grms random run in "Z" axis using Sony Tape #7 Side A - 3 Runs

Aug 9 - Unit #8 Calculated synthetic random spectrum in "X" axis and recorded it on Sony Tape #9 Side A. Calculated synthetic random spectrum in "Z" axis and recorded it on Sony Tape #9 Side B - 8 Verification Plots

Aug 10 - Unit #2 Calculated synthetic random spectrum in "X" axis and recorded it on Sony Tape #8 Side A. Calculated synthetic random spectrum in "Y" axis and recorded it on Sony Tape #8 Side B - 8 Verification Plots.

Aug. 11 - Mass Mock-Up of Unit #4 - made 1g sine sweeps to investigate effect of mis-locating the control accelerometer, and the effect of bench check equipment cables on the sine transfer characteristic - 4 Runs

SUMMARY OPERATING LOG OF TEST OPERATIONS (continued)

Aug 15 - Unit #1 Calculated new synthetic random spectrum in "Z" axis and recorded it on Sony Tape #6 Side A. (Major slip table and shaker disassembly and repair since first recording made). - 4 Verification Plots.

Aug 17 - Mass Mock-Up of Unit #4 - made 1g sine sweeps to investigate the effect of mis-installing the mounting hardware and the test article to the fixture - 14 Runs.

Aug 28 Aug 31 - Unit #8 S/N EPG-005 - made 1g sine sweep and a 6.2 Grms random run in the "X" axis using Sony Tape #9 Side A. Made a 1g sine sweep and a 6.2 Grms random in the "Z" axis using Sony Tape #9 Side B - 15 Runs

Sept 6 - Mass Mock-Up of Unit #4 - Made 1g sine sweeps in "Z" axis and recorded sine transfer sweep on Harman Kardon Tape #3A and on Sony Tape #11A. Calculated synthetic random spectrum and recorded it on Harman Kardon Tape #3A - 3 Runs.

Sept 7 - Mass Mock-Up of Unit #4 - Made 1g sine sweep and 6.3 Grms random run in "Z" axis using Harman Kardon Tape #3A - 2 Runs.

Sept 13 to Sept 18 - Unit #8 Fixture Only - Made 1g sine sweeps to investigate problems in "Z" axis tests of Aug 28th - 17 Runs.

Sept 25 to Sept 27 - Unit #2 S/N HJR-041, GRU-014 & HJR-002 - Made 1g sine sweeps and 6.3 Grms random runs in the "X" axis using Sony Tape #8 Side A. Made 1g sine sweeps and 6.3 Grms random runs in the "Y" axis using Sony Tape #8 Side B - 20 Runs.

Oct 2 Oct 6 - Unit #5 S/N CSS-148, HJR-016 & HJR-001 - Made 1g sine sweeps and 6.3 Grms random runs in the "X" axis using Sony Tape #10 Side A - Made 1g sine sweeps and 6.3 Grms random runs in the "Y" axis using Sony Tape #10 Side B - 15 Runs.

Oct 6 Oct 9 - Unit #7 S/N GRU-073, HJR-082 & CSS-013 - Made 1g sine sweeps and 6.3 Grms random runs in the "X" axis using Sony Tape #11 Side A. Made 1g sine sweeps and 6.3 Grms random runs in the "Y" axis using Sony Tape #11 Side B - 16 Runs.

SUMMARY OPERATING LOG OF TEST OPERATIONS (continued)

Oct 30 - LVPM Fixture - Procedure Verification - made 1g sine sweeps in "X" axis and recorded on Harman Kardon Tape #1X Side A - 2 Runs.

Oct 31 - LVPM Fixture - Procedure Verification - calculated synthetic random spectrum and recorded it on Harman Kardon Tape #1X Side A - 4 Verification Plots.

Nov 1 - Unit #1 S/N HJR-037 - made 1g sine sweep and 6.3 Grms random run in "X" axis using Sony Tape #6 Side A - 3 Runs.

Nov 1 - Unit #4 S/N JCU-004 & HJR-025 - made 1g sine sweeps and 6.3 Grms random runs in the "Z" axis using Sony Tape #7 Side A - 5 Runs

Nov 15 - LVPM Fixture - Procedure Verification - made 1g sine sweep and 6.3 Grms random run in the "X" axis using Harman Kardon Tape #1X Side A - 2 Runs

APPENDIX F

SUMMARY TEST LOG - ELECTRONIC EQUIPMENT (TASK A)

UNIT #1			UNIT #2			UNIT #3			UNIT #4			UNIT #5		
S/N	Date	Axis	S/N	Date	Axis	S/N	Date	Axis	S/N	Date	Axis	S/N	Date	Axis
HGF-018	3-8	X	HGE-009	5-3	X	HJR-001	2-3	X	HGE-010	3-18	Z	HGF-012	5-3	X
HGF-018	3-10	Y	HGE-009	3-9	Z	HJR-001	2-11	X	HSF-005	3-18	Z	HGF-012	5-3	Y
HGF-018	3-10	Z	GRV-030	3-10	Z	HGF-044	2-11	X	HGE-019	4-6	Z			
HGE-007	4-5	X	GRV-037	6-14	X	HGF-022	2-11	X	HGE-017	4-6	Z			
HGE-003	4-5	X	HGE-002	6-14	X	GRV-052	2-11	X	HGE-010	4-6	Z			
HGE-003	4-7	X	GRV-015	6-14	X	HGF-048	2-11	X	HGE-001	5-25	Z			
HGF-015	5-3	X	GRV-015	6-14	Y	HJR-009	2-13	X	HGF-014	5-25	Z			
HGE-020	6-1	X	HGE-019	6-14	Y	HGE-046	2-13	X	HGE-010	5-25	Z			
HGF-007	6-9	X	HGE-019	6-15	X	HGF-045	2-13	X	GDA-044	5-26	Z			
Rework Slip Table			GRV-030	6-15	X	HGF-032	2-13	X	HGE-026	9-20	Z			
HGF-034	8-29	X	GRV-030	6-15	Y	HGF-041	2-13	X	HGE-028	9-20	Z			
HGE-034	9-1	X	HGE-002	6-15	Y	HGF-037	2-13	X	HGF-051	10-6	Z			
GDA-005	10-24	X	GRV-015	6-17	Z	HJR-001	2-9	Z	GRV-023	10-6	Z			
GDA-005	10-28	X	HGE-019	6-17	Z	HGF-022	2-11	Z	HGF-044	10-6	Z			
HGF-035	11-18	X	HGE-002	6-17	Z	HJR-001	2-10	Z	HGE-010	10-6	Z			
GRU-010	12-13	X	GRV-037	6-17	Z	HGF-044	2-11	Z	HGF-044	11-17	Z			
GDA-012	12-13	X	GRV-030	6-17	Z	GVR-052	2-11	Z	HGF-047	11-17	Z			
GZZ-002	12-13	X	GRV-010	6-29	Z	HGF-048	2-11	Z	HGF-048	11-17	Z			
MJR-006	12-15	X	HGE-004	9-19	X	HJR-001	2-3	Y	HGE-032	11-17	Z			
HJR -012	1-24	X	HGE-004	9-19	Y	HJR-001	2-3	Y						
GRU-001	2-16	X	HGE-004	9-19	Z	HGF-022	2-9	Y						
						'GF-044	2-9	Y						
						GRV-052	2-9	Y						
						HGF-048	2-9	Y						

SUMMARY TEST LOG - ELECTRONIC EQUIPMENT (TASK A)

UNIT #6			UNIT # 7		
S/N	Date	Axis	S/N	Date	Axis
HGE-009	4-1	X	HGF-044	10-2	X
GRV-033	4-1	X	GRU-073	10-2	X
GRV-033	4-1	Y	GRV-095	11-14	X
HGE-009	4-1	Y	GRV-095	11-14	Y
GRV-033	4-4	Z	GRV-095	11-14	Z
			CSS-285	2-10	X

SUMMARY OF TEST DATA (TASK B)

UNIT #1 - "X" TAPE #6A based on A/N H6F-038 tested 3-13-78

Test Article	Axis Date	Out of Tolerance Amplitudes ±3dB					
		Sine (5HzBW)		Random (5HzBW)		Random (50HzBW)	
		Hz	dB	Hz	dB	Hz	dB
	3-29-78	1080-1135	+4.0	1060-1120	+4.5	-	-
	X	-	-	1880-1950	+5.5	-	-
HGF-038		-	-	530-540	-4.0	-	-
	3-29-78	-	-	1850-1950	+6.5	1800-1900	+4.0
	X	-	-	1210-1240	+6.0	-	-
HJR-022		-	-	1080-1150	+5.0	-	-
		-	-	535-540	-4.5	-	-
		-	-	210-220	-3.3	-	-
	3-29-78	-	-	1860-1980	+5.5	-	-
	X	-	-	1090-1150	+4.0	-	-
HJR-021		-	-				
RECORDED NEW UNIT #1 TAPE ON MAY 19 (TAPE 6A based on S/N HGF - 038 tested 3-13-78)							
	7-27-78	-	-	1300-1360	+5.0	1280-1310	+3.1
	X	NO DATA (Tape erased accidentally)		-	-	1750-2000	-3.5
HJR-035				-	-	-	-
RECORDED NEW UNIT #1 TAPE ON AUG. 15 (TAPE 6A based on S/N HJR - 035 tested 7-27-78)							
	11-1-78	-	-	1950-2000	+6.0	-	-
	X	-	-	1360-1410	-5.5	1340-1400	-4.0
HJR-037		-	-	1270-1330	+6.5	1210-1250	+3.3

SUMMARY OF TEST DATA (TASK B)							
UNIT #2 - "X" TAPE #8A based on S/N H6F-045 tested 5-25-78							
Test Article	Axis - Date	Out of Tolerance Amplitudes ±3dB					
		Sine (5HzBW)		Random (5HzBW)		Random (50HzBW)	
		Hz	dB	Hz	dB	Hz	dB
	X	1930-2000	-4.5	-	-	1800-2000	>-5.5
	9-26-78	1765-1790	-4.5	1810-1840	-6.5	-	-
HJR-041		1530-1620	-17.5			-	-
	X	1890-2000	-6.0	1840-2000	-4.0	1830-2000	>-5.5
	9-26-78	1815-1850	-13.5	1810-1840	-11.5	-	-
GRU-014							
	X	1870-200	-6.0	1870-2000	-4.5	1750-2000	>-5.5
	9-26-78	1815-1840	-7.0	1810-1835	-11.5	-	-
HJR-002							

SUMMARY OF TEST DATA (TASK B)							
UNIT #2 "Y" TAPE #8B based on S/N HGF-045 tested 5-25-78							
Test Article	Axis - Date	Out of Tolerance Amplitudes ±3dB					
		Sine		Random (5HzBW)		Random (50HzBW)	
		Hz	dB	Hz	dB	Hz	dB
	Y	1850-2000	-5.0	1870-2000	-4.5	1800-2000	>-5.5
	9-26-78	1820-1850	-17.5	1815-1850	-11.0		
HJR-041		185-265	+4.5	220-260	+3.5		
	Y	1890-2000	-5.5	1890-2000	-4.0	1730-2000	>-5.5
	9-26-78	1830-1870	-18.5	1820-1870	>-11.5		
GRU-014							
	Y	1870-2000	-5.0	1850-2000	-5.0	1730-2000	>-5.5
	9-26-78	1815-1860	-11.0	1810-1840	>-11.0		
HJR-002		235-255	+3.5	235-255	+3.3		

SUMMARY OF TEST DATA (TASK B)							
UNIT #4 "Z" TAPE #7A based on S/N HGF-044 tested 4-27-78							
Test Article	Axis - Date	Out of Tolerance Amplitudes ±3dB					
		Sine (HzBW)		Random (5HzBW)		Random (50HzBW)	
		Hz	dB	Hz	dB	Hz	dB
CSS-122	8-8-78 Z	750-770	-3.1	690-770	-4.5	-	-
		535-570	+3.7	-	-	-	-
		330-350	-3.5	350-370	-4.0	-	-
		240-315	+7.5	235-310	+6.0	200-290	+5.0
		-	-	1930-2000	-6.0	1700-2000	>-3.0
JCU-004	11-1-78 Z	530-570	+4.5	550-570	+3.5	-	-
		305-330	+5.0	270-335	+7.0	230-290	+4.8
		265-280	-9.5	220-240	-3.1	-	-
				1880-2000	-5.0	off	paper
				630-640	+3.5	-	-
HJR-025	11-1-78 Z	530-565	+3.5	520-570	+3.5	-	-
		335-345	-3.5	-	-	-	-
		260-320	+8.0	255-315	+8.2	210-300	+5.5
		225-245	-5.2	215-235	-4.8	-	-
				1885-1920	-3.6	off	paper

SUMMARY OF TEST DATA (TASK B)							
UNIT #5 - "X" TAPE #10A based on S/N HJR-029 tested 6-1-78							
Test Article	Axis - Date	Out of Tolerance Amplitudes ±3dB					
		Sine (5HzBW)		Random (5HzBW)		Random (50HzBW)	
		Hz	dB	Hz	dB	Hz	dB
	X	1920-2000	-19.9	1920-2000	-11.0	1900-2000	-5.5
HJR-001	10-6-78	1780-1880	+ 3.5	-	-	-	-
		1530-1615	+ 6.0	1530-1580	+ 7.5	1540	+3.3
		1080-1280	+ 5.0	1180-1250	+ 5.5	-	-
				1620-1680	- 6.0	1650	-3.2
				1315-1480	- 4.5	-	-
	X	1880-2000	- 7.0	1820-2000	- 7.5	1850-2000	>-6.0
CSS-148	10-2-78	1530-1620	+ 7.5	1530-1580	+ 7.0	1560-1580	+4.5
		1180-1260	+ 6.5	1200-1230	+ 6.0	1190-1210	+3.3
		510-540	+ 4.5	490- 520	+ 4.0	475- 490	+3.3
				1620-1690	- 5.0	1660-1680	-4.0
				1310-1480	- 4.0	1350-1450	-3.5
	X	1920-2000	- 8.0	1920-2000	>- 9.0	1860-2000	>-5.5
HJR-016	10-2-78	1860-1920	-11.0	1840-1920	-11.0	-	-
		1735-1780	+ 4.0	-	-	-	-
		1520-1620	+ 8.0	1530-1580	+ 7.0	1560-1610	+4.0
		1080-1270	+ 5.5	1180-1230	+ 5.0	-	-
		520- 540	+ 3.5	520- 530	+ 3.3	-	-
				1620-1690	- 6.0	1670-1700	-3.7

SUMMARY OF TEST DATA (TASK B)

UNIT #5 - "Y" TAPE #10B based on S/N HJR-029 tested 6-1-78

Test Article	Axis - Date	Out of Tolerance Amplitudes ±3dB					
		Sine (5HzBW)		Random (5HzBW)		Random (50HzBW)	
		Hz	dB	Hz	dB	Hz	dB
	Y	1930-2000	-10.0	1920-2000	>-11.0	1950-2000	>-5.5
HJR-001	10-6-78	1520-1615	+10.0	1520-1600	+ 8.5	1500-1590	+5.5
		1080-1260	+ 5.5	1160-1240	+ 6.0	1100-1220	+4.5
		760- 800	+ 3.7	-	-	-	-
		285- 330	+ 4.5	-	-	-	-
		260- 275	- 7.0	-	-	-	-
		215- 235	+ 4.2	-	-	-	-
				1620-1670	- 5.5	-	-
				1320-1480	- 4.0	1290-1410	-4.0
	Y	1920-2000	- 7.5	1840-2000	>-11.0	1850-2000	>-5.5
CSS-148	10-2-78	1860-1920	-17.0				
		1530-1610	+ 7.0	1525-1590	+ 6.5	1520-1580	+3.5
		1170-1250	+ 5.0	1175-1230	+ 5.0	1150-1190	+3.3
		280- 310	+ 4.5	-	-	-	-
		220- 240	+ 7.5	200- 220	+ 3.5	-	-
				1620-1680	- 6.0	-	-
				1290-1490	- 4.0	-	-
	Y	1900-2000	- 7.0	1900-2000	- 7.0		
HJR-016	10-2-78	1860-1900	-12.5	1840-1900	>-11.0	1860-2000	>-5.5
		1525-1615	+ 8.0	1515-1580	+ 7.5	1520-1600	+5.0
		1150-1250	+ 4.5	1170-1230	+ 5.0	1110-1200	+3.5
		275- 330	+ 6.5	275- 310	+ 4.0	-	-
		240- 270	-17.0	220- 270	- 6.5	-	-
				1620-1720	- 4.5	-	-
				1300-1490	- 4.0	1300-1420	-3.5

SUMMARY OF TEST DATA (TASK B)							
UNIT #7 - "X" TAPE #11A based on S/N GRU-073 tested 6-2-78							
Test Article	Axis - Date	Out of Tolerance Amplitudes ±3dB					
		Sine (5HzBW)		Random (5HzBW)		Random (50HzBW)	
		Hz	dB	Hz	dB	Hz	dB
	X	1840-1880	-4.0	1815-1910	-4.5	1300-2000	-3.5
GRU-073	10-6-78	1665-1680	-3.5	1640-1730	-5.5	1670-1780	-4.0
		1555-1625	+9.5	1540-1615	+9.0	1530-1600	+4.5
		1180-1280	+5.5	1170-1260	+5.2	1130-1230	+4.0
				1430-1510	-4.5	-	
	X	1550-1620	+8.0	1535-1615	+7.0	-	-
HJR-082	10-9-78	1200-1280	+5.0	1180-1250	+5.0	-	-
				1900-2000	-3.5	1880-2000	-4.0
				1820-1900	-5.0	1800-1830	-4.0
				1630-1720	-6.5	-	-
				1430-1520	-4.5	-	-
	X	1670-1820	-3.5	1630-1730	-6.5	1680-1730	-4.5
CSS-013	10-9-78	1550-1620	+6.0	1590-1615	+6.5	1520-1580	+3.8
				1820-2000	-4.0	1830-2000	-3.3
				1430-1520	-4.5	-	-

SUMMARY OF TEST DATA (TASK B)							
UNIT #7 "Y" TAPE #11B based on S/N GRU-073 tested 6-2-78							
Test Article	Axis - Date	Out of Tolerance Amplitudes ±3dB					
		Sine (5HzBW)		Random (5HzBW)		Random (50HzBW)	
		Hz	dB	Hz	dB	Hz	dB
GRU-073	Y 10-6-78	1890-1990	- 6.0	1870-2000	- 7.5	1820-2000	>- 5.5
		1650-1700	- 4.0	1635-1730	- 6.0	1660-1710	- 4.0
		1540-1630	+11.5	1530-1620	+ 8.5	1520-1580	+ 4.5
		1150-1270	+ 5.5	1135-1260	+ 4.0	-	-
		185- 220	+ 5.5	-	-	-	-
				1430-1520	- 6.5	-	-
HJR-082	Y 10-9-78	1910-1980	- 5.0	1850-2000	- 9.0	1860-2000	>- 5.5
		1555-1615	+ 6.0	1540-1615	+ 7.5	1510-1560	+ 4.0
		200- 220	+ 4.5	180- 210	+ 3.2	-	-
				1635-1740	- 7.0	1680-1720	- 3.7
				1430-1520	- 6.5	1400-1460	- 3.2
				1150-1260	+ 4.5	-	-
CSS-013	Y 10-9-78	1910-1990	- 5.0	1860-2000	- 8.0	1830-2000	>- 5.5
		1550-1620	+ 8.0	1640-1615	+ 8.0	1490-1570	+ 5.0
		1180-1260	+ 5.0	1140-1235	+ 4.5	1100-1160	+ 3.3
		200- 220	+ 6.0	185- 212	+ 3.5	-	-
				1630-1735	- 6.5	1640-1710	- 5.0
				1460-1520	- 5.5	-	-

SUMMARY OF TEST DATA (TASK B)							
UNIT #8 - "X" TAPE #9A based on S/N JHA-011 tested 5-31-78							
Test Article	Axis - Date	Out of Tolerance Amplitudes ±3dB					
		Sine (5Hz BW)		Random (5HzBW)		Random (50HzBW)	
		Hz	dB	Hz	dB	Hz	dB
	X	1970-2000	+4.0	1900-2000	+11.0		
ERG-005	8-28-78	1180-1250	+6.5	1190-1250	+ 3.2		
		1100-1140	-3.5	1070-1130	- 3.5		
		1000-1060	-4.5	-	-		
				1340-1380	- 3.5		
				560- 780	- 4.0		

SUMMARY OF TEST DATA (TASK B)							
UNIT #8 - "Z" TAPE #9B based on SIN EPG-002 tested 5-31-78							
Test Article	Axis - Date	Out of Tolerance Amplitudes ±3dB					
		Sine (5HzBW)		Random (5HzBW)		Random (50HzBW)	
		Hz	dB	Hz	dB	Hz	dB
	Z	1820-1830	- 3.5	-	-		
EPG-005	8-28-78	1750-1780	- 5.0	1740-1820	- 6.5		
		1480-1570	- 5.5	1460-1560	- 6.0		
		1380-1410	- 4.5	1365-1400	- 4.5		
		1330-1365	+ 4.0	-	-		
		1240-1315	+ 8.0	1280-1320	+ 4.0		
		1090-1190	+ 7.5	1130-1190	+ 4.5		
		1050-1080	+ 5.0	-	-		
		880-1035	- 9.5	920-1010	- 5.5		
		650- 790	+ 8.5	635- 830	+ 9.0		
		535- 610	-12.5	530- 610	-10.5		
		510- 515	+ 3.5	-	-		
		195- 205	+ 4.0	-	-		

APPENDIX C

OPERATIONAL SUMMARY LOG - TAPE DECK

SONY EL-7

DATE	TASK	DATE	TASK
10-8-77		2-14-78	Response Test Tapes 1 and 3
to	Eval. of Mfr Data	2-17-78	Response Test Tapes 1 and 2
10-13-77		2-22-78	Playback Tape #1, Rec. #4
10-14-77	Draft Purchase Req.	2-23-78	Playback Tape #4, Random
12-19-77	Receiving Delivery	2-24-78	Playback Tape #4 Sine
12-21-77	Initiated Familiarity Tests	2-28-78	Playback Tape #4
12-22-77	Initiated Response Tests	3-1-78	Playback Tapes 2 and 3
1-3-78	Continued Response Tests	3-2-78	Playback Tape #1
1-4-78	Continued Response Tests	3-13-78	Recorded Tape #6, Unit #1 Sine
1-5-78	Continued Response Tests	3-27-78	Recorded Tape #7, Unit #4 Sine and Random
1-9-78	Continued Response Tests	5-8-78	Playback Tape #6 for Random
1-10-78	Rec. Vibration Data	5-19-78	Playback Tapes #6 and #7
1-11-78	Playback Vib. Tape	5-23-78	Re-recorded Tape #7, Unit #4
1-12-78	Playback Vib. Tape	5-25-78	Recorded Tape #8, Unit #2 X and Y
1-16-78	Playback Vib. Tape	5-31-78	Recorded Tape #9, Unit #8 X and Z
1-17-78	Response Test and Cleaning	6-1-78	Recorded Tape #10, Unit #5 X and Y
1-26-78	Response Test Tape #1	6-2-78	Recorded Tape #11, Unit #7 X and Y
1-31-78	Response Test Tape #1	6-6-78	Playback Tapes 9, 10 and 11
2-2-78	Response Test Tape #1	6-7-78	Response Tapes 1 and 3
2-4-78	Response Test Tape #4	7-5-78	Response Tapes 1 and 3

SONY EL-7 (continued)

DATE	TASK
7-6-78	Response Tapes 1 and 3
7-27-78	Recorded Tape #6 and Tested Unit #1
8-4-78	Recorded Random on Tape #10
8-7-78	Recorded Random on Tape #11
8-8-78	Tested Unit #4 W/Tape #7
8-9-78	Recorded Random on Tape #9
8-10-78	Recorded Random on Tape #8
8-14-78	Recorded Tape #6, Unit #1
8-23-78	Response Tapes 1 and 3
8-28-78	Tested Unit #8 W/Tape #9
8-31-78	Recorded Tape #12 Sine
9-6-78	Recorded Tape #13 Sine
9-26-78	Tested Unit #2 W/Tape #8
9-27-78	Tested Unit #2 W/Tape #8
10-2-78	Tested Unit #5 W/Tape #10
10-6-78	Tested Unit #5 W/Tape #10
10-9-78	Tested Unit #7 W/Tape #11
11-1-78	Tested Unit #1 and #4 W/Tape #6 and #7
11-4-78	Response Tape #1 and #3
11-30-78	Playback Tape #1

OPERATIONAL SUMMARY LOG - TAPE DECK

HITACHI D3500		HARMAN/KARDON HK2000	
DATE	TASK	DATE	TASK
10-8-77		6-1-78	Received Delivery
to	EVAL. of Mfr. Data	6-7-78	Eval Mfg. Data & Recorded Tape #1
10-13-77		6-8-78	Playback Tape #1
10-14-77	Draft Purchase Req.	6-9-78	Recorded Tape #1
11-11-77	Received Delivery	6-12-78	Low Freq. Response Test & Equal. Tech.
11-19-77	Started Evaluation	6-13-78	Repeated Low Freq. Response
11-23-77	Freq. Response	6-15-78	Playback Tape #1
12-3-77	Freq. Response	7-10-78	Recorded Tape #2
12-5-77	Freq. Response	7-11-78	Playback Tape #2
12-7-77	Freq. Resp. vs. Sig Level	8-24-78	Playback Tape #2
12-8-77	Freq. Resp. vs. Control Level	9-6-78	Recorded Tape #3 Unit #4 Dummy
12-9-77	Freq. Resp. vs. Dolby Pos.	9-20-78	Recorded Tape #4
12-10-77	Freq. Response	9-21-78	Playback Tape #2
12-16-77	Rec. Random Vib.	10-30-78	Recorded Tape "1X" at Bethpage
12-17-77	Rec. Unit #4 Dummy Vib.	11-1-78	Recorded Random on Tape "1X".
12-19-77	Recorder Failed	11-4-78	Playback Tape #1
1-5-78	Shipped to Supplier	11-10-78	Powered W/O Playback or Rec.
		11-14-78	Powered W/O Playback or Rec.
		11-15-78	Playback Tape "1X" at Bethpage
		11-17-78	Playback Tape #2 Twice
		11-20-78	Playback Tape #2 Twice

APPENDIX D

(Publication No.)

TECHNICAL MANUAL

PROCEDURE FOR THE GENERATION AND APPLICATION OF RANDOM VIBRATION UTILIZING A CASSETTE TAPE DECK

15 December 1978

ACKNOWLEDGEMENTS

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CHAPTER 1

INTRODUCTION

1-1 SCOPE. This manual describes the detailed procedures necessary for generating random vibration using an electrodynamic vibration system and a cassette tape deck as a signal source.

1-2 BACKGROUND. The use of random vibration as a screen for latent workmanship defects found in electronic equipment, has proven to be more effective than the sinusoidal form of excitation normally employed. The major deterrent to universal acceptance of this technique is the impact this type of test would have on program costs since a random vibration test facility is extremely expensive.

A concept for economically generating random vibration was evolved and has been developed which capitalizes on the fact that most major electronic equipment manufacturers maintain basic electrodynamic sinusoidal vibration test facilities. This technique, which was structured to utilize these existing facilities, employs a cassette tape deck, in lieu of expensive random programming devices, to excite the basic shaker system.

This method of random vibration generation is accomplished as follows:

a. The system transfer characteristics to a 1.0g (peak) sine sweep input are recorded (Figure 1-1).

b. The synthetic random spectrum requirements are calculated by adjusting the required random spectrum as a function of the transfer characteristics obtained.

c. The resulting synthetic spectrum is then recorded on tape (Figure 1-2).

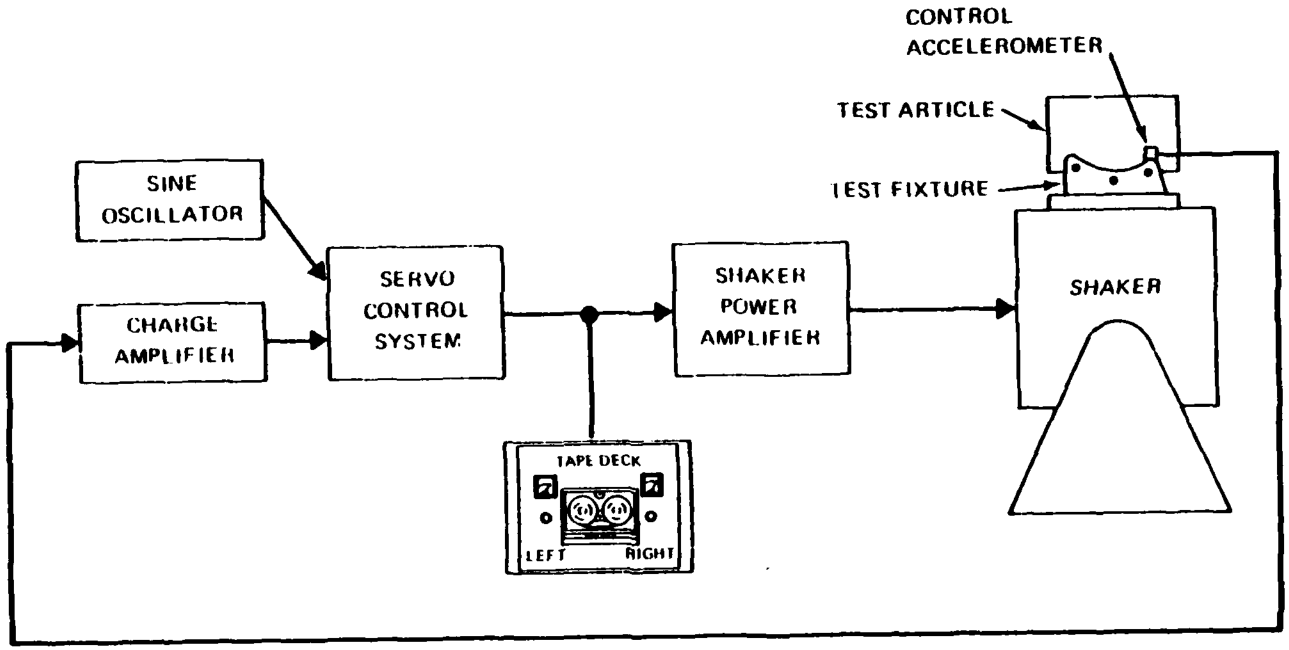

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Figure 1-1 System Transfer Characteristics Determination

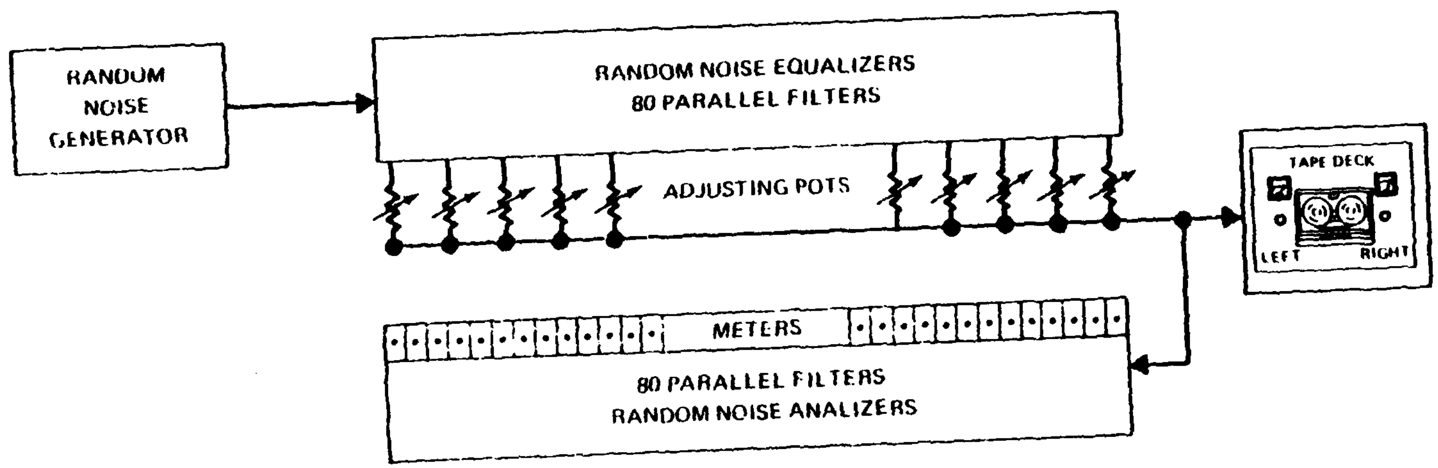

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Figure 1-2 Taping Synthetic Random

d. The tape is then used to drive an electrodynamic shaker system (Figure 1-3).

1-3 THEORY OF OPERATION. This section describes the basic concepts associated with the taped random technique. The concepts themselves are not new, but the availability of highly linear and reliable stereo cassette tape decks has provided a practical and inexpensive vehicle for use in the test laboratory.

This discussion encompasses two major aspects of the taped random technique:

a. Test concepts

b. Test operations

1-3.1 Test Concepts. The basic premise upon which the taped random vibration technique has been structured is that a low amplitude sinusoidal frequency sweep can be used in determining the equalization required to shape a specific random spectrum for a test system.

In order to use the random equalization so derived in test operations, two conditions should exist:

a. The dynamic characteristics of the vibration system must not vary significantly.

b. The random noise spectrum must be reproduced accurately without significant variations.

This requirement for system stability is of primary importance for making the technique practical in day to day test operations with many samples of a specific product.

The degree of success in achieving these conditions will determine the type of limitations and test tolerances that must be applied to the technique.

This section will examine these requirements and the methods developed to assure their achievement.

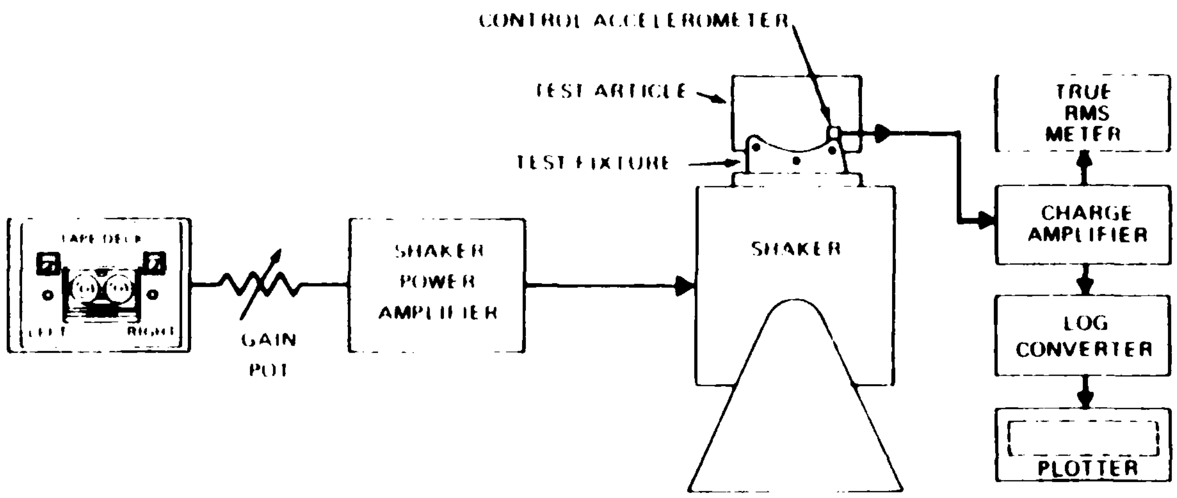

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Figure 1-3 Testing With Taped Synthetic Random

1-3.1.1 Sine and Random Equalization. An electrodynamic shaker operates in the same manner as a loud speaker does in a high fidelity audio system. A low level audio signal is applied to a power amplifier to drive the loudspeaker or shaker with oscillatory motion. In the case of a shaker the amplitude of the low level audio signal is adjusted at the input of the power amplifier to achieve a specified motion on the shaker armature, (to which the test article is fastened). The amplitude of the required input voltage required to achieve a constant motion of the shaker armature varies with the frequency of the input signal. This non-linearity is due to electrical and mechanical resonances in the shaker system as well as mechanical resonances in the test package. The process by which the amplitude of the input voltage is varied over the frequency range to compensate for these resonances is called equalization.

In performing a normal 1.0g sinusoidal vibration sweep, equalization is accomplished automatically by the servo-controller which varies the amplitude of the oscillator voltage as much as required to hold the measured acceleration on the shaker head at 1.0g. A similar process is performed by an automatic random equalization system which varies the spectral density within a frequency band as required to maintain a preset spectral density as measured by the random analysis system in that band.

If no random analysis system is available at the test site, another method must be used to determine the required random equalization. Since the required equalization depends only on the dynamic characteristics of the vibration system and not on the type of excitation (sinusoidal or random noise) the sinusoidal equalization factors can be used to determine those required by the random noise spectrum.

The method used to measure these equalization factors and modify them for the random spectrum is discussed in detail in paragraph 1-3.2.

1-3.1.2 <u>System Stability.</u> Once the process of synthesizing the random equalization is accomplished using the sine sweep data, the next step is to determine if system stability permits the use of the same random equalization factors over and over again in day to day testing. (An automatic random equalization system continually samples the spectral density levels at the shaker head and adjusts the equalization every few seconds as required.)

Since the sine equalization factors are being used to predict the random equalization, the factors that affect the sine equalization can be examined to gauge their effect on the random spectrum. It was pointed out in paragraph 1-3.1 that electrical and mechanical resonances of the shaker system are the main causes of variations in the input voltage required for constant shaker head motion. Since the resonant frequencies vary with the mass and stiffness of the system (mechanical) as well as the capacitance and inductance of the circuitry (electrical) variations of these parameters must be minimized by imposing the following restrictions on the use of a particular equalization curve:

a. No changes in the shaker and power amplifier.

b. No changes in the test article.

c. No changes in the test conditions, i.e., (test axis, alignment, hardware, torque, etc).

If these potential variables are stabilized the single equalization curve should be usable indefinitely, without problems.

Another possible source of instability not directly related to the equalization curve is the medium used to reproduce the equalization voltage, namely the magnetic tape system. The tape system used must be capable of accurate reproduction of the equalization voltage through repeated playbacks in day to day test operations. The detailed procedures used in evaluating the fidelity and stability of the tape system are presented in Chapter 2 and 4.

1-3.1.3 System Limitations. The requirement for system stability discussed in the previous paragraphs imposes restrictions on the type of vibration system that the taped technique should be applied to. This technique is ideally suited to single product acceptance test programs where the entire vibration system (with the exception of the test article) remains unchanged from test run to test run. The effect of minor differences between test articles can be minimized by testing with fixtures that are significantly more massive than the test article. Rigidity of the fixture should be maximized to limit the number of resonance that must be equalized.

Because these conditions cannot always be realized in practice, the application of the technique stresses the details of the test setup to assure the highest degree of uniformity from setup to setup. Test setups with high degrees of flexibility, non-linearities, or high mechanical noise levels should be avoided in the application of this technique.

The verification of tolerances applied to the taped random vibration test presents problems since it is assumed that many of the test laboratories utilizing this random technique will not have spectrum analysis equipment. A technique was therefore developed to use a low level sine frequency sweep to determine if the random test will be within tolerance. These tolerances are discussed in detail in Chapter 5 and 6.

1-3.2 Test Operations. The application of the taped random technique to test operations has been subdivided into five principle chapters:

a. Tape Deck Requirements

b. Obtaining Sine Transfer Data

c. Preparation of Synthetic Random Tape

d. Testing with Tape Random

e. Troubleshooting the System

A principle ground rule in preparing this procedure was to direct it toward a single shaker laboratory operation with a minimum of sinusoidal vibration equipment. Chapters 1, 2, 3 and 5 meet this requirement with the only new equipment requirement being the tape deck.

Chapter 4, Preparation of the Synthetic Random Tape is the exception to this ground rule. This task requires, as a minimum, a random vibration control console and a spectrum analyzer. The procedure however, has been designed so that preparation of the random tape can be handled by an outside agency remote from the testing laboratory performing the test.

1-3.2.1 Tape Deck Requirements. The only new equipment required to implement this test technique is a tape deck. The many inexpensive stereo cassette decks on the market today adequately fill the recording and playback requirements of the technique. Open reel recorders were not used because of the greater potential for tape damage due to handling.

The frequency response characteristics of a particular tape deck must be determined experimentally to verify that it satisfies program requirements. Minor non-linearities in the frequency responses must be measured and compensation factors determined to linerize the tape deck response when recording the synthetic random signal. The tape deck requirements and the procedure for evaluating response characteristics and determining the compensation factor are discussed in detail in Chapters 2 and 6.

1-3.2.2 Obtaining Sine Transfer Data. Random equalization (para. 1-3.1.1) is accomplished synthetically using the results of a 1.0g sinusoidal frequency sweep. The sine data in the form of transfer functions (Power Amplifier Input

Voltage ÷ peak acceleration - E/g) provides the basis for the random equalization process. Since the accurate determination of the transfer functions require a real time analyzer or equivalent, for data analysis, a tape recording of the two required parameters is made for transmittal to the agency which will prepare the synthetic random tape.

This tape recording of the 1.0g sine frequency sweep will serve another important function besides providing the transfer function data. It will provide a means of verifying the test setup prior to performing the random vibration test. In this sense, it substitutes for a spectrum analysis of the random test for which the target test laboratory is not equipped.

The utilization of this recording of the 1.0g sine frequency sweep to verify the test setup by playback through the shaker system necessitated two special requirements for the frequency sweep:

a. Frequency is swept from upper limit (2000 Hz) to lower limit (20 Hz) to minimize the potential for structural damage due to incorrect system gain adjustment at the start of the sweep.

b. A one minute single frequency dwell at 1.0g is provided on the tape prior to the start of this frequency sweep. This serves as a reference for setting the system gains for 1.0g amplitude during playback.

Another important consideration in recording the sine sweep is the configuration of the vibration system. Since this frequency sweep will serve as the random equalization reference for all subsequent tests, the vibration system must be identical to that anticipated for subsequent production testing. A prototype or mockup of the test article cannot be substituted for the actual production unit. All test support equipment such as cooling air hoses, electrical checkout cables, etc. which will be used on the production units, must be installed for this test run.

1-3.2.3 Preparation of Synthetic Random Tape. The preparation of the synthetic random tape is the most demanding task associated with the tape technique and, as pointed out previously, requires the more sophisticated equipment. For this reason, we have included under this heading all the tasks which require this level of equipment and which can be performed by a remotely located agency.

There are several important preliminary steps leading to the actual synthesizing of the random voltage and recording it on tape:

a. Playback of the 1.0g sine frequency sweep tape through an analyzer to determine the sine transfer functions.

b. Playback of the tape deck reference tape to determine recorder characteristics.

c. Determination of compensation factors to be applied to the sine transfer functions. These compensation factors are used to correct the final random equalization for faults in the sine equalization, or anticipated variations in the test setup. Some examples are:

   o Non-linear tape recorder characteristics.

   o Non-linear damping characteristics of the test setup (between 1.0g sine equalization and 6.0 Grms random equalization).

   o Variations in resonant frequencies from test to test of ± 3% (determined empirically).

d. Calculation of the random voltage spectrum based on the random equalization calculated above and the required test spectrum.

The final step is to synthesize the required random voltage spectrum using a random equalization/analysis system. (It should be noted that the term synthetic random refers to the method used for equalization rather than the quality of the random signal. The voltage recorded is a true non-periodic random noise signal with a Gaussian distribution of amplitudes with peaks up to 3 times the RMS value). This random voltage is recorded on the sine sweep tape immediately after the sine frequency sweep. This facilitates the playback of the sine sweep before running the random portion of the test as setup verification.

The completed tape contains all the data necessary to perform the sine and random vibration test on a specific vibration system.

1-3.2.4 Testing with Taped Random. The use of a tape to drive a vibration test system is much simpler in execution than a conventional servo-control system. Since the tape already has all the equalization information programmed on it, the test conductor needs only adjust the vibration system gain control to the required acceleration amplitude and the tape does the rest. The acceleration amplitude is continuously monitored on the RMS meter by the test conductor so that he can reduce the test level or terminate the test in case of a system malfunction.

A gain reference signal is recorded on the tape at the start of the sine sweep to provide a reference with which the test conductor can set his system gain for a reading of 1.0g (peak) on his RMS meter. The reference signal frequency is chosen in a non-resonant frequency range to reduce the possibility of a shift in the transfer function from test to test. Once the gain is set and the sine frequency sweep started, the test conductor monitors the acceleration amplitude on the RMS meter to determine if the amplitude stays within the allowable tolerance band around 1.0g throughout the frequency sweep. If it does, this demonstrates that the transfer characteristics used to derive the random equalization have not changed. The test conductor can then proceed to run the random portion of test by advancing the tape to the random portion of the tape and increasing the system gain control until the required overall Grms is read on the RMS meter.

If however, an out-of-tolerance condition is noted during the 1.0g sine sweep the test conductor must troubleshoot the system to evaluate the significance of the tolerance exceedance and take corrective action if indicated.

1-3.2.5 Troubleshooting the System. The tolerances to be applied to the 1.0g sine sweep have been over-simplified so that the test conductor can determine compliance by visually monitoring the RMS meter during the sweep. If a tolerance exceedance is noted he must obtain qualitative data on the bandwidth and amplitude of the exceedance in order to determine its effect on the random vibration test. This will probably require that the sine sweep portion of the tape be rerun and a plot of acceleration versus frequency made. With this plot the test conductor can determine if a significant problem exists or whether the random test can be performed. Guidelines for this evaluation are presented in Chapter 6.

If a problem with the vibration system is verified the test conductor must troubleshoot the system to isolate and correct the problem. In order to efficiently troubleshoot the system a reference tape should be made:

a. Side A of the tape will contain the tape deck frequency response data. (Procedure outlined in Chapter 2)

b. Side B of the tape will contain a 1.0g sine frequency sweep of the vibration system with the test article removed - fixture only. (Procedure outlined in Chapter 3)

The frequency response tape (reference tape side A) can be used to verify performance of the tape deck without operating the shaker system. The fixture-only sine sweep tape (reference tape side B) can be used to isolate problems in the vibration system without subjecting the test article to repeated sine sweeps during troubleshooting operations. This tape should be recorded at the start of the program and retained as a troubleshooting aid for the duration of the test program.

1-3.3 Sequence of Operations. A typical sequence of test operations is shown in Figure 1-4. The test flow starts at the planning phase of the program and runs through a typical production test sequence. Tape #1 is the reference tape which has the recorder characteristics recorded on side A, and the fixture-only sine sweep on side B. Tape #2 is the production tape with both the sine sweep and the synthesized random recorded on side A. The sine sweeps of Tape #1 and Tape #2 should be recorded at the same time to minimize any setup differences. The troubleshooting process required when test article or test facility problems occur, is iterative and may require two or three sine test cycles for problem resolution.

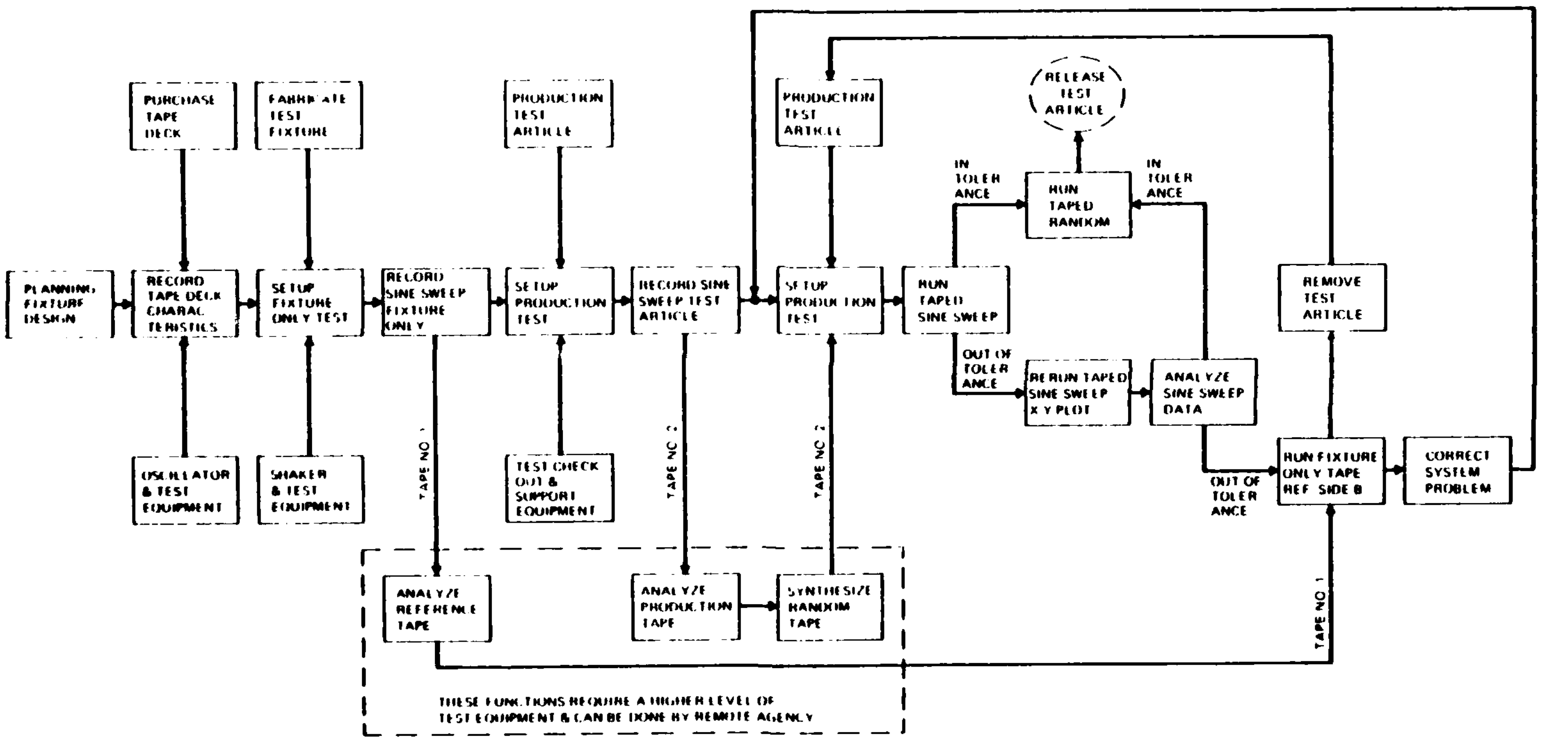

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Figure 1-4 Sequence of Test Operations

CHAPTER 2

TAPE DECK REQUIREMENTS

2-1 GENERAL. A two channel (stereo) tape deck shall be used as the vehicle for generating random vibration. This unit shall be either a compact cassette (standard size) or the larger, ELCASET type. Selection of the deck shall be based primarily on the ability of the unit to meet the low frequency and dynamic range requirements established for this technique. The tape deck selected shall also be simple to operate, purchased from a reputable manufacturer and embody a proven history of reliability and longevity.

2-2 SPECIFIC REQUIREMENTS. The tape deck selected shall meet the following requirements:

a. Frequency response: 20-2000 Hz, ± 3 dB

b. Dynamic range: The unit shall be capable of recording input signals with variations of 40 dB within the frequency response requirements defined in a. above.

c. Signal to noise ratio: 50 dB min.

d. Wow and flutter: 0.07% max.

e. Tape speed: 1 7/8 or 3 3/4 inches/second

f. Tape counter: The unit shall incorporate a tape counter with reset.

g. Metering; The unit shall include a VU meter for each channel which will function in both record and playback modes.

2-3 REFERENCE TAPE-TAPE DECK FREQUENCY RESPONSE. In establishing the synthesized random spectrum an adjustment may be required to account for certain variations in the tape decks' response. The purpose of this procedure, delineated in subsequent paragraphs, is to define the methodology required to generate a tape embodying these characteristics.

The tape thus generated will serve to establish: a record of output versus input voltage over both the frequency and dynamic ranges and also will provide a baseline of operation for future comparisons after extended usage.

2-3.1 Technique. Since a variety of tape decks and test equipment exist commercially, it would not be practical to generate a procedure applicable to all such items. The procedure defined has, therefore, been tailored to a particular tape deck and equipment set-ups and will serve as a guide in establishing procedures for similar equipment.

2-3.1.1 Equipment. The following equipment was used to evaluate a SONY EL-7 and a Harman-Kardon HK2000 tape deck:

a. Sweep Oscillator: Spectral Dynamics, Model SD104A-5 (Provides a constant output voltage from 20-2000Hz).

b. Precision Attenuator: Hewlett-Packard, Model 350D, (Provides a convenient method of decreasing oscillator output voltage in even 10 dB increments from 0-40 dB).

c. A.C. Digital Voltmeter: Fluke, Model 8800A (Indicates the rms output voltage of the oscillator at the reference frequency).

d. Frequency Counter: General Radio, Model 1192B. (Sets the reference frequency of 1000 Hz and adjusts the sweep limits of the oscillator)

2-3.1.2 Recording The Reference Tape. Figure 2-1 depicts, in block diagram form, the set-up required to record the reference tape. The following step-by-step procedure defines the requirements necessary to perform the recording:

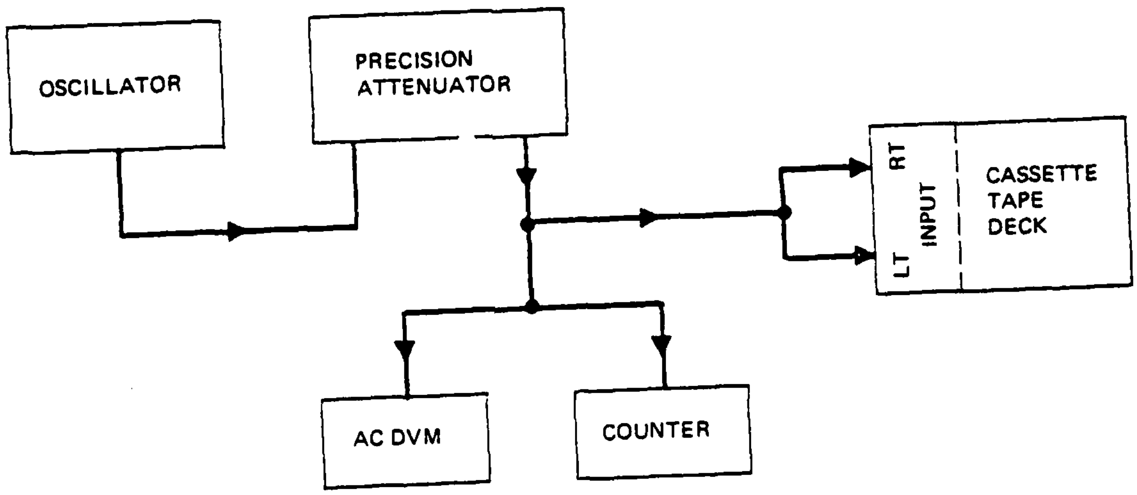

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Figure 2-1 Test Setup

l. Set the following tape deck selector switches to the "OFF" position:

(1) MPX Filter

(2) Memory

(3) DOLBY'NR'

m. Rewind the tape deck to start and reset the counter to zero.

n. Reset the oscillator to the manual mode, preset to 1000 Hz in step e.

o. Record the reference voltage and adjust the tape deck's "record level" potentiometers until both VU meters indicate 0dB (+0dB, -1dB). Record at this level for 10 seconds. (After performing this adjustment do not alter the "record level" potentiometer positions).

p. After completing this 10 second recording enter the counter number on the Tape Deck Data Sheet (Figure 2-2) and reset the oscillator to the automatic sweep mode.

q. Record approximately 10 seconds at the lower limit of 20 Hz and then activate the sweep up mode.

r. After the upper limit (2000 Hz) has been attained, stop recording and enter the counter numbers on the Tape Deck Data Sheet (Figure 2-2).

s. Reset the oscillator to the lower sweep limit (20 Hz) and set the attenuator for -10dB.

t. Repeat steps q. thru s. for attenuator levels of -20dB, -30dB and -40dB.

u. An oscilloscope can be used to verify the data taken by observing the recorder playback.

Company Name: ____________________

Address: ____________________

____________________, Tel. No. __________

I) Recording Data Date: __________

A) Recorded By: ____________________ Dept: __________

B) Tape Recorder Mfr: ____________________

Model No: ____________________; Ser. No. __________

C) Recording Tape Mfr: ____________________; Tape Type: __________

D) Tape I.D. or Ser. No.: ____________________

E) Recorder Max. Input: __________ Vrms; Ref. Volt. __________ Vrms, 1000 Hz (0dB)

F) Tape Counter Data

Side 'A'

Ref. Volt. From __________ To __________;

0dB From __________ To __________;

-10dB From __________ To __________;

-20dB From __________ To __________;

-30dB From __________ To __________;

-40dB From __________ To __________;

G) Remarks/Anomalies: ____________________

____

____

II) Playback Info.: Date: __________

A) Playback By: __________; Company __________

B) Tape I.D. or Ser. No.: __________

C) Recorder Mfr.: ____________________

D) Recorder Model No.: __________ Ser. No. __________

E) Analyzer I.D.: ____________________

1) Filter Bandwidths: __________ Hz; Freq. Range __________ Hz

2) Input Volt. Range: __________ Vrms

F) Plot Sensitivity: __________ dB/Inch (Y axis); __________ Hz/In. (X axis)

G) Data Points at 1000 Hz

0dB Curve __________ dB;

-10dB Curve __________ dB;

-20dB Curve __________ dB;

-30dB Curve __________ dB;

-40dB Curve __________ dB;

H) Remarks/Anomalies: ____________________

____

2935-3W

Figure 2-2 Tape Deck Data Sheet

a. Enter all the manufacturers information on the Tape Deck Data Sheet, Figure 2-2, including the maximum line input voltage established by the manufacturer.

b. Establish the *rms reference* voltage representing the OdB signal and enter this value on the Tape Deck Data Sheet (Figure 2-2). (A level of approximately 85% to 90% of the manufacturer's maximum line input voltage is recommended).

c. Connect the sweep oscillator output to the attenuator input and set the attenuator to 0dB.

d. Connect the counter and A.C.-DVM to the attenuator output.

e. Set the oscillator to the manual mode and adjust the frequency to 1000 Hz (± 1 Hz).

f. Adjust the oscillator output voltage to the reference level (established in b.) while monitoring the attenuator output. After adjustment is made do not change the oscillator output controls.

g. Place the oscillator in the linear sweep mode, set a sweep rate of 6 Hz/sec (+2, -0 Hz/sec.) and then reset the frequency to 20 Hz.

h. Set the oscillator to automatic sweep and alternately adjust the lower limit to 20 Hz (+ 0 Hz -5 Hz) and the upper limit to 2000 Hz (+50 Hz, -0 Hz).

i. Connect the attenuator output to both line inputs of the tape deck

j. Insert a cassette in a position which will record on side "A" only.

k. Set the tape deck switch selectors to the proper "Record" positions. Verify that the tape deck equalization (if selectable) matches the cassette tape type and record this information on the Tape Deck Data Sheet (Figure 2-2).

CHAPTER 3

OBTAINING SINE TRANSFER CHARACTERISTICS

3-1 SCOPE. This chapter defines the step by step procedures for setting up the electrodynamic shaker system and recording the data necessary to determine the sine transfer characteristics of a specific test system configuration.

3-2 TEST SETUP. As indicated in Chapter 1, Background, the taped random vibration test technique will yield satisfactory results only if conditions from set up to set up are duplicated exactly. Therefore, it is extremely important that the detailed procedures delineated in the following paragraphs be rigorously observed.

3-2.1 Mechanical Test Setup

3-2.1.1 Secure the test article to the test fixture in a manner that can be exactly reproduced on subsequent units. Tighten all bolts to specification requirements with a torque wrench. Connect and support all hoses, ducts, cables, etc. in a manner which can be duplicated for subsequent units.

3-2.1.2 Secure the test fixture to the shaker head or auxiliary table in a specified orientation (with respect to the shaker trunnion) and torque the tie down bolts to specification requirements.

NOTE

The test fixture shall be of rigid construction and shall be designed to minimize low frequency resonances. To minimize the handling and disassembly cycles required, the use of multipurpose fixtures (those utilized for more than one test article) is not recommended.

3-2.1.3 Attach the control accelerometer to the test fixture in close proximity to one of the test article attachment points. The precise location shall be selected to minimize mechanical noise feedback from the test article and resonant peaks (as determined from prior data).

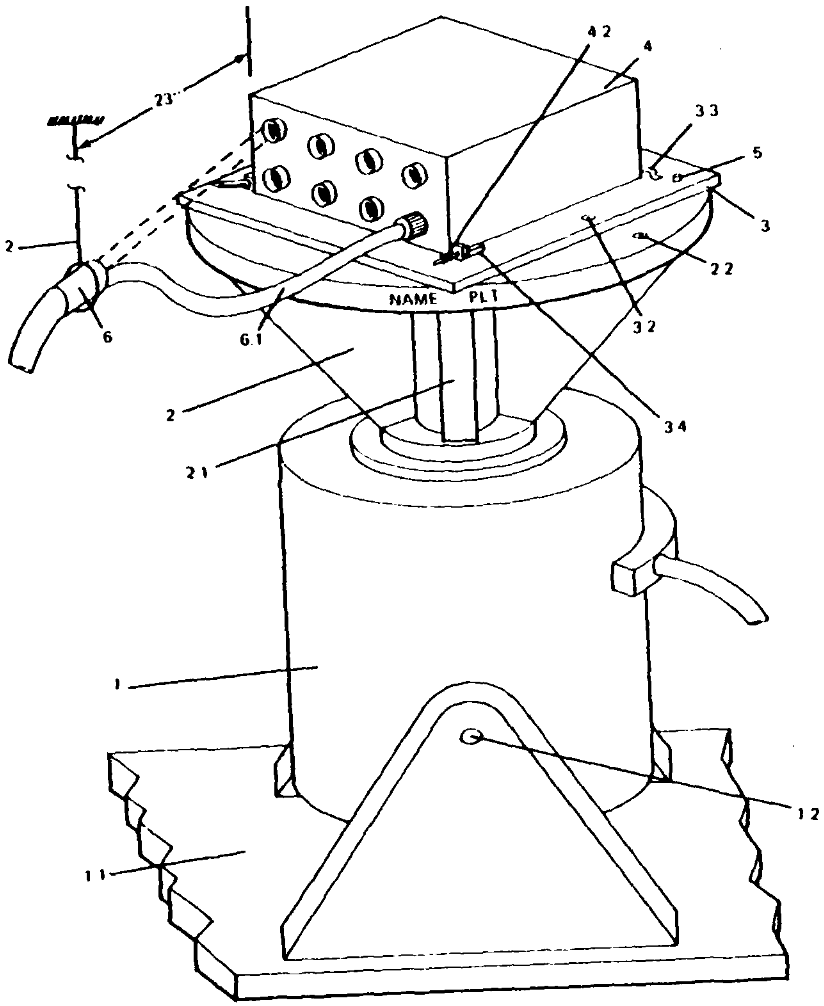
3-2.1.4 Document the complete details of the mechanical test set-up so that they can be reproduced exactly in subsequent tests. This documentation shall include a sketch or photographs of the set-up plus a specification sheet which lists: the vibration equipment used, location of control accelerometer, location and bolt torque of attachment hardware, and identification and location of all cables, hoses and ducts connected to the test article. A sample specification sheet (Figure 3-1) has been included which describes the equipment, etc., used in conducting an actual test.

NOTE

> The test article used in determining the sine transfer function must be mechanically identical to subsequent production units which are to be tested.

3-2.2 Electrical Test Setup

3-2.2.1 Configure the shaker power amplifier for the specified test conditions, i.e., the shaker system shall be adjusted for the calculated power and peak voltage requirements for the random spectrum which will be used (see Chapter 1, Theory of Operation). Set all variables such as plate voltage, field current, amplifier gain, output transformer tap, etc. to these calculated conditions which will be used for the 1g (peak) sine run, as well as for the subsequent taped random test.



1 **Setting Up Shaker (MB C10E-5, S/N 779)**
  1.1 Shaker is mounted on GAC 14103 transport dolly
  1.2 *Right side shaker trunnion used as reference for fixture alignment*

2 **Installing Head Expander (Kimball 5039-3)**
  2.1 Align head expander leg below name plate with shaker right side trunnion (reference 1.2)
  2.2 Bolt head expander to shaker head using thirteen MS 16995 122 cap screws and AN 960 616 flat washers. Torque to 30 ft. lbs.

3 **Installing fixture Plate (Computer – CET-1183-1)**
  3.1 Align right front corner of fixture plate (stamped FR) with right side trunnion (reference 1.2)
  3.2 Bolt fixture plate to head expander using twelve an 6 10 bolts and AN 960 16 flat washers. Torque to 30 ft. lbs.
  3.3 Bolt two inboard Support Fittings GS 25D2 to fixture plate per drawing number CET 1183 1 using two (each) MS 16995 74 cap screws and MS 35338 11 split spring lockwashers. Torque to 15 in lbs. Mark right side mount RR 1 and left side mount RL 2 with black paint
  3.4 Bolt two outboard Support Fittings GS 25D1 to fixture plate per drawing number CET 1183 1 using two (each) MS 16995 74 cap screws and MS 35338 11 split spring lockwashers. Torque to 15 in. lbs. *Mark right side mount FR 1 and left side mount F 2 with black paint.*

4 **Mounting Test Article (Computer)**
  4.1 Slide rear end of test article into the two inboard Support Fittings (reference 3.3) and engage front mounts with the two outboard *Support Fittings (reference 3.4)*
  4.2 Install an MS-35338 82 split spring lockwashers below the AN 34C 416 nut (production nut installed on test article) on each of the two front mounts. Torque these two mount nuts to 45 50 in. lbs to secure test article to fixture plate.

  Note: Torque should be applied in small increments *alternately to front mounts to keep unit centered* within the mounts.

5 **Attaching Control Accelerometer (Endevco 2217E, S/N T6 40)**
  5.1 *Install control accelerometer* with an Endevco 2986B Isolation Mount to the right rear corner of the fixture plate per drawing number CET 1183-1. Torque to 5 in. lbs.

6 **Installing test set interface cable (EG-116745-3)**
  6.1 Connect interface cable to eight connectors on the front panel of the test article. Secure connector dust covers to the cable using *masking tape*
  6.2 Support interface cable at junction collar with 1/4" O.D. bungee cord fastened to ceiling support point

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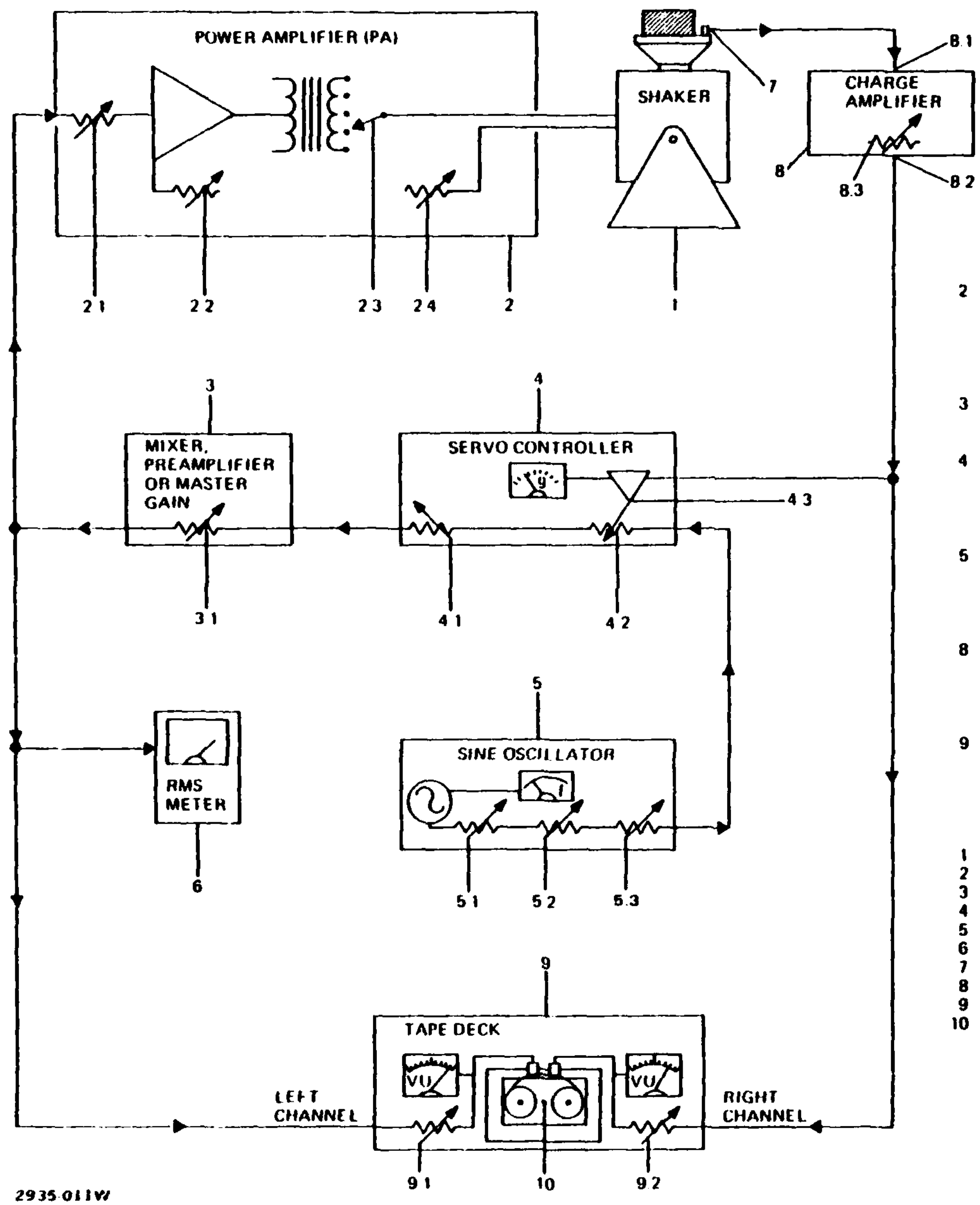
Figure 3-1 Sample Mechanical Specification Sheet



SIGNIFICANT VARIABLES AND SETTINGS

2 POWER AMPLIFIER
- 2.1 Amplitude Control set at 5.0
- 2.2 Plate Voltage set at 6.5 KV
- 2.3 Output Transformer Tap set for "C-10 Sine"
- 2.4 Field Current Control set at 9.2 amps

3 MIXER AMPLIFIER
- 3.1 Sine Gain Control set at 5.0, all others at 0

4 SERVO CONTROLLER
- 4.1 Amplitude Control set at 5.0
- 4.2 Acceleration Set Level set at 1.0g (peak)
- 4.3 Compressor set on Auto with speed setting of 4.0

5 SINE OSCILLATOR
- 5.1 Sweep Rate Set at 0.32 decades per minute
- 5.2 *Lower Frequency Limit set at 20 Hz*
- 5.3 Upper Frequency Limit set at 2000 Hz

8 CHARGE AMPLIFIER
- 8.1 Input Sensitivity set for 11.1 pcb per g
- 8.2 Output Sensitivity set at 100 mv per g
- 8.3 Band Pass Filter in (2500 Hz upper limit)

9 CASSETTE RECORDER
- 9.1 *Left Channel Record Level*
- 9.2 Right Channel Record Level

EQUIPMENT UTILIZED IN THE TEST

1 MB C-10E 5 Shaker S/N 779
2 MB Power Amplifier T351-A S/N 154
3 Ling Clipper-Mixed Amplifier CMA-10 S/N 139
4 Spectral Dynamics Amplitude Servo/Monitor SD-105A S/N 185
5 Spectral Dynamics Sweep Oscillator SD 104A 5 S/N 1183
6 B&K Digital Voltmeter 2427 S/N 672733
7 Endevco Accelerometer 2217E S/N TG-40 on 2986B Isolation
8 Endevco Charge Amplifier 2735 S/N 37421
9 Sony Elcaset EL-7 S/N 1493
10 Sony Tape Cassette SLH-60 Type 1 S/N 8

Figure 3-2 Sample Electrical Specification Sheet

3-2.2.2 Connect the output from the control charge amplifier in parallel to the tape deck and the sine-servo controller inputs. Then connect the input to the left channel of the tape deck in parallel with the input to the power amplifier from the servo controller output thru the pre-amplifier or gain controls which are normally used. (see Figure 3-2 for sample block diagram)

3-2.2.3 Configure the sinusoidal vibration system in the manner normally used for conducting a 1.0g (peak) sine sweep from 2000 to 20 Hz at a logarithmic sweep rate of one octave per minute.

3-2.2.4 Document the details of all electrical parameters so that they can be reproduced exactly in subsequent test set-ups. This documentation shall include a block diagram schematic of the test set-up plus a data sheet listing: all equipment used, control settings of the equipment and significant voltage and current readings. Figure 3-2 has been included as a sample electrical specification sheet for an actual test conducted.

3-3 TEST PROCEDURE. The following procedures shall be utilized for producing a tape recording of the transfer characteristic of the system under test. Table 3-1 depicts the data to be recorded as well as the sequence and duration of each data segment. The procedure is presented in the four sequential steps necessary for obtaining a successful tape recording:

a. Preliminary Test Run

b. Recording Calibrating Signal

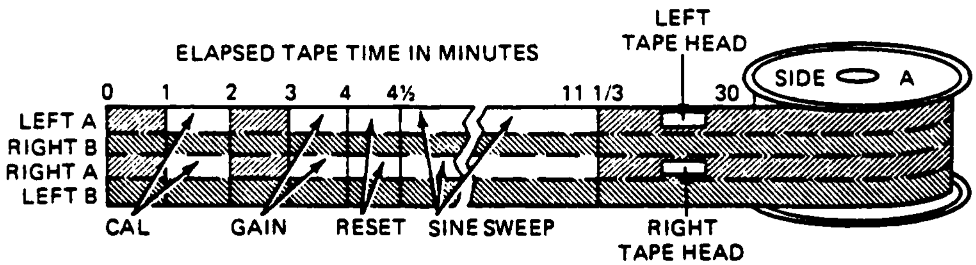
c. Recording Gain Reference Signal

d. Recording Sinusoidal Sweep

Table 3-1 Sequential Listing of Data Recorded on Tape

Elapsed Tape Time	Title of Segment	Left Recorder Channel (P.A. Input Voltage)	Right Recorder Channel (Control Acceleration)
0 Min to 1.0 Min		No Signal Recorded	No Signal Recorded
1.0 Min to 2.0 Min	Calibration	Sine Signal – P.A. Input Voltage (1K Hz typ.)	3.0g peak Sine Signal – Charge Amplifier (1K Hz typical)
2.0 Min to 3.0 Min		No Signal Recorded	No Signal Recorded
3.0 Min to 4.0 min	Gain Reference	Sine Signal – P.A. Input Voltage	1.0g peak Sine Signal – Charge Amplifier
4.0 Min to 4.5 Min	Reset Frequency	Low Level Sine Signal – P.A. Input Voltage	Low Level Sine Signal – Charge Amplifier
4.5 Min to 11.3 Min	Sine Sweep	Varying Sine Signal – P.A. Input Voltage (freq. 2000 to 20 Hz)	1.0g peak Sine Signal – Charge Amplifier (freq. 2000 to 20 Hz)
11.3 Min to 30.0 Min		No Signal Recorded	No Signal Recorded

NOTE: Table above applies to the tape when cassette is placed in recorder with side "A" marker facing outward. Because of the narrow width and staggering of the tape heads, a completely separate recording in the reverse direction can be obtained when cassette is reversed with side "B" marker facing outward. See illustration below.



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3-3.1 Preliminary Test Run - A preliminary test run shall be conducted before the actual sine tape recording run. The objectives of this initial run are:

a. To measure the maximum power amplifier input voltage required during the sine sweep.

b. To determine the frequency of the gain reference which will be recorded on the tape.

The power amplifier input voltage measurement will be used to set the recording level of the left tape channel. The gain reference (see Chapter 1, Theory of Operation) is required to provide the operator with a stationary taped signal which will permit adjustment of system gains necessary to obtain a 1g (peak) sine level.

3-3.1.1 Set up the sinusoidal oscillator and servo control equipment for a 1.0g (peak) sine sweep from 2,000 to 20 Hz at a logarithmic rate of one octave per minute. Connect the control accelerometer to the accelerometer input of the servo controller to complete the servo loop (see Figure 3-2).

3-3.1.2 Connect an RMS voltmeter or equivalent in parallel with the input to the shaker power amplifier to monitor voltage during the sine sweep (see Figure 3-2).

3-3.1.3 Energize the shaker system using the nominal values of the parameters discussed in para. 3-2.2.1. Perform the 1g sinusoidal sweep described above. Monitor and record the power amplifier input voltage during the frequency sweep to determine the following data points:

a. Maximum power amplifier input voltage and the frequency of this voltage.

b. Gain reference frequency. The choice of this frequency is arbitrary but should be guided by the following ground rules.

(1) The frequency should be above 300 Hz to minimize the potential . r structural damage from potential mistakes made during initial adjustment of the shaker system gain.

(2) The frequency should be at the center of a 100 Hz or wider frequency band in which the power amplifier input voltage remains relatively constant. This will avoid resonant peaks whose frequency may shift slightly from setup to setup.

(3) In cases where several non-resonant bands are available, the frequency selected shall be one in which the amplitude of the power amplifier input voltage is close to the average for the various bands.

(4) Frequencies above 1500 Hz should be avoided since this region is most sensitive to minor variations in the test setup.

Record the gain frequency on the Tape Data Sheet. (Figure 3-3)

3-3.1.4 It is recommended that the preliminary test run be repeated as required so that an accurate determination of the data points can be obtained. The use of an X-Y plotter, if available, will greatly facilitate test data acquisition.

3-3.2 Recording Calibration Signal. Recording a calibration signal of known frequency and voltage on both tape channels serves the following purposes:

a. It provides a known reference for verifying tape system validity during troubleshooting operations.

b. It is used to set the tape deck input level to provide maximum dynamic range during subsequent recordings. This is especially important for the power amplifier input voltage recording when the full 40 dB usable recorder range is often required.

Tape No.: ____________ Side: ____________ Date: ____________

Test Article: ____________ S/N. ____________

Part No.: ____________ AXIS: ____________

Test Specification: ____________

Test Location: ____________

Test Engineer: ____________

Cassette Deck: ____________

Preliminary Run Data:

- Maximum P.A. Input Voltage: ____________ Vrms ____________ Hz
- Gain Reference: ____________ Vrms ____________ Hz

Tape Data:

Tape Counter	Elapsed Time	Title of Segment	*Left*-PA Input Voltage		Right-Control Accel		Comments
			Voltage	Frequency	Voltage	Frequency	
		Calibration					
		Gain Reference					
		Reset Frequency					
		Sine Sweep					
		Random					

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Figure 3-3 Tape Data Sheet

3-3.2.1 Apply a 3.0g (peak) signal at approximately 1000 Hz to the right (control accelerometer) channel of the tape deck (a charge amplifier output sensitivity of 100 mv/g is recommended for the sine tests to minimize noise and provide higher recording level to the tape deck). The output calibration signal of the accelerometer charge amplifier may be used for this purpose. Adjust the tape deck input level to obtain a 0 dB reading on the right channel VU meter.

3-3.2.2 Apply a voltage signal at 1000 Hz to the left (power amplifier input voltage) channel of the tape deck. This shall be accomplished by turning off the power to the shaker system and using the compressor-off mode of the servo-controller to provide the required 1000 Hz signal. Adjust the output level of the servo-controller to approximately 10% higher amplitude than that measured in the preliminary test run (reference paragraph 3-3.1.3). Then, adjust the tape deck input level to obtain a 0 dB reading on the left channel VU meter. This will provide an undistorted recording range of +4 dB/-40 with respect to the maximum level required for the sine sweep.

3-3.2.3 Set the tape counter at zero and then advance the tape (without recording) for one minute of elapsed time. Stop the recorder at the conclusion of one minute.

3-3.2.4 Place the tape deck in the record mode and record the two calibration signals for one minute of elapsed time. Stop the tape deck at the conclusion of the one minute.

3-3.2.5 Record all significant parameter measurements, including tape counter readings, in the appropriate box on the Tape Data Sheet (Figure 3-3).

3-3.3 Recording Gain Reference Signal. As previously discussed, the purpose of the gain reference signal is to provide the shaker system operator with a stationary signal of sufficient duration to permit the shaker system gain adjustment necessary to obtain a 1g (peak) at the control accelerometer.

3-3.3.1 Set up the sinusoidal oscillator and servo control equipment for a 1g (peak) sine sweep from 2000 to 20 Hz at a logarithmic sweep rate of one octave per minute.

3-3.3.2 Advance the tape using the playback control (without recording) for one minute of elapsed time. Stop the recorder at the conclusion of one minute.

NOTE

The tape deck must be left running once it is started (for recording the gain reference signal) until the end of the sweep. This is done so that no system input levels need be changed once they are set using the gain reference.

3-3.3.3 Adjust the upper frequency limit of the sweep oscillator from 2000 Hz to the frequency chosen as the gain reference (see paragraph 3-3.1.3)

3-3.3.4 Energize the shaker system with the nominal parameter values used in the preliminary run (paragraph 3-2.2.1). Bring the level to 1g (peak) at the gain level frequency.

3-3.3.5 Place the tape deck in the record mode and record the gain reference signal and control accelerometer output for one minute.

3-3.3.6 Record all significant parameter measurements (including tape counter readings) in the appropriate box on the Tape Data Sheet (Figure 3-3).

3-3.4 Recording Sinusoidal Sweep. As indicated in paragraph 3-3.3.1, the tape deck is left running after the gain reference signal has been recorded. It is important that the transition from this single frequency dwell be made without changing any of the shaker system gains and without consuming excessive tape time.

3-3.4.1 After recording the gain reference signal for one minute, reduce the servo controller "set" level to minimum (less than 0.3g peak) and reset the upper frequency limit of the sweep oscillator to 2000 Hz.

3-3.4.2 With the upper sweep frequency limit at 2000 Hz, readjust the servo controller "set" level to 1.0g (peak) and start the sweep oscillator sweeping down.

3-3.4.3 When the sweep oscillator stops at 20 Hz, reduce the servo level to minimum and stop the tape deck.

3-3.4.4 De-energize the shaker system. Record all significant data on the Tape Data Sheet (Figure 3-3).

NOTE

If the test laboratory has random test equipment, proceed to Chapter 4. If, however, no such capability exists, the response tapes generated shall be forwarded to the agency for synthetic random tape preparation. When the tapes are prepared/returned, proceed to Chapter 5.

CHAPTER 4

PREPARATION OF SYNTHETIC RANDOM TAPE

4-1 SCOPE. This section describes the procedures required to:

a. Determine the sine transfer characteristics of a particular test system utilizing the sine sweep tape (ref. Chapter 3).

b. Perform the calculations necessary for defining the synthetic random spectrum.

c. Record the random vibration spectrum tape.

4-2 DETERMINATION OF SINE TRANSFER CHARACTERISTICS. The processing of the taped sinusoidal sweep to establish system transfer characteristics can be accomplished in various ways depending on the analysis equipment available. The end product is a series of sine transfer functions presented in E/g terms i.e., power amplifier (P.A.) input voltage (E) ÷ control acceleration (g). Each E/g value is distinct for the frequency band into which the spectrum is divided.

4-2.1 Playback the sine sweep segment of the tape (see Chapter 3, para. 3-3) through a real time analyzer or equivalent in order to remove unwanted noise and harmonics from the test data. An X-Y plot of both the left channel, i.e., the P.A. input voltage and the right channel, i.e., the control acceleration, is required. (see Figures 4-1 and 4-2).

4-2.2 Sub-divide the filtered data into frequency bands. The number and width of these frequency bands must correspond to those of the random analyzer/equalizer system utilized to shape the synthetic random spectrum. (Example: If an 80 line random system is used there will be 80 bands of 25 Hz each over

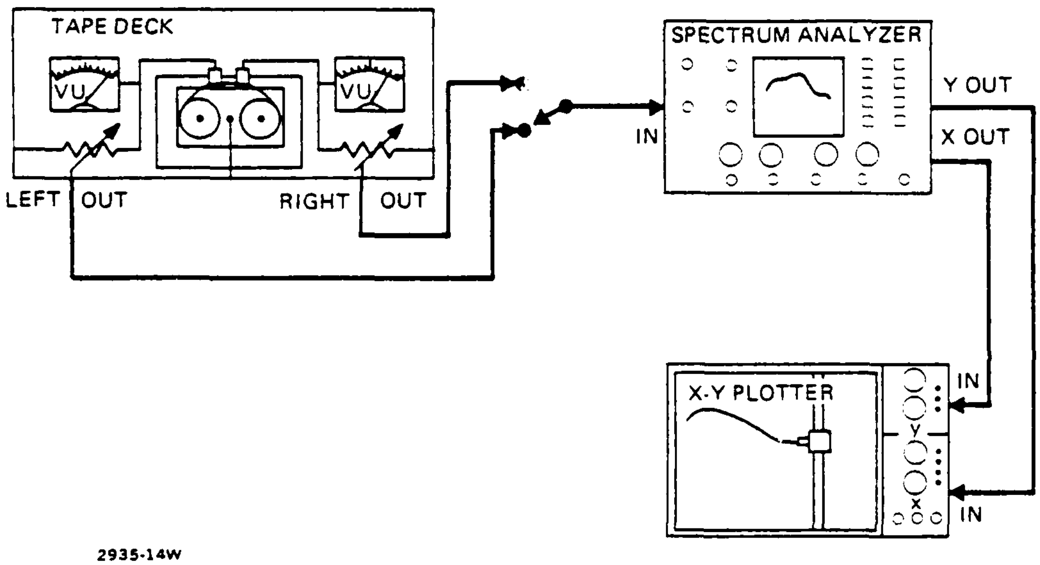
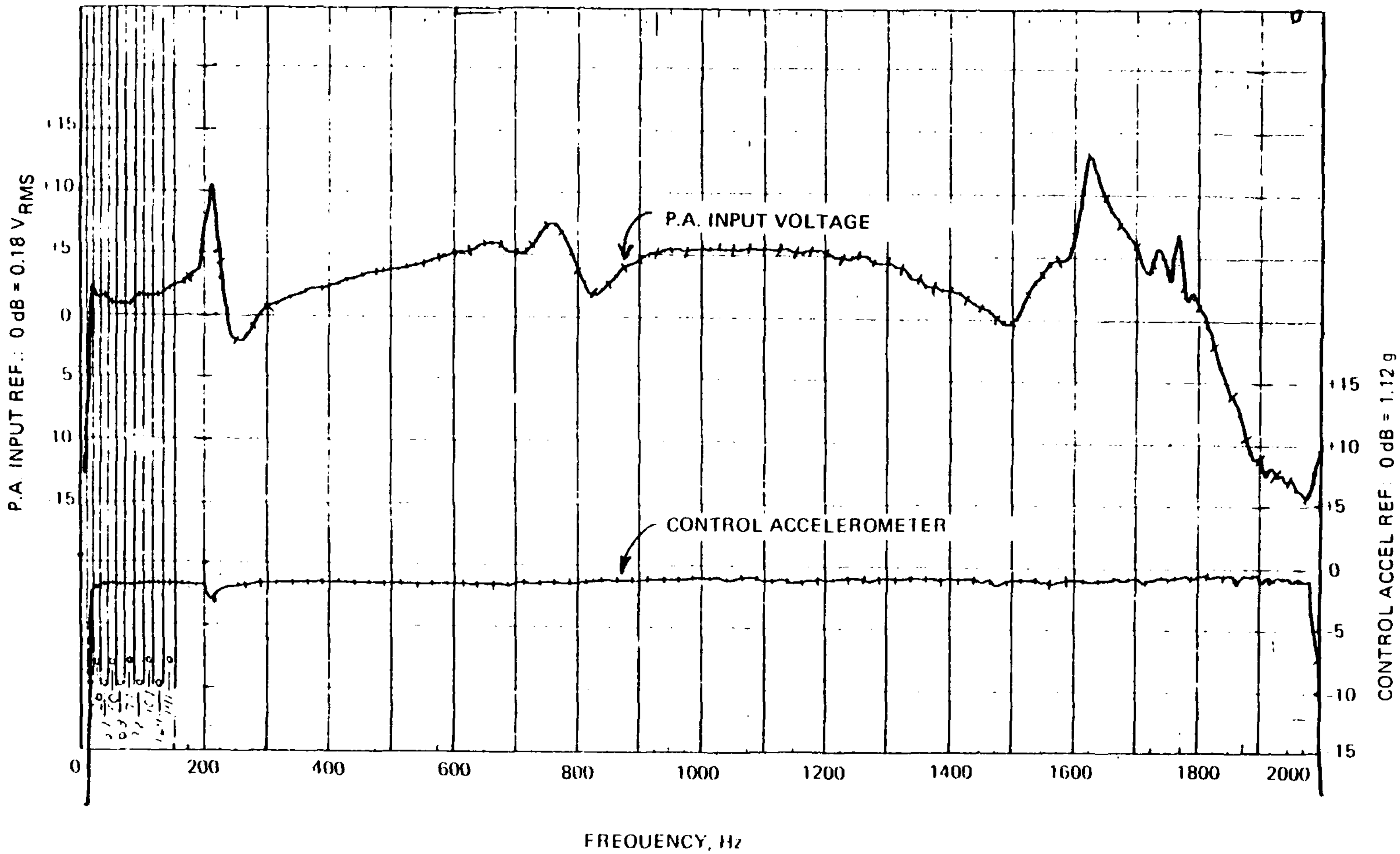


Figure 4-1 Setup for Playback of Tape Through a Spectrum Analyzer



2935-24W

Figure 4-2 P.A. Input Voltage and Acceleration vs Frequency

the frequency range from 0 to 2000 Hz). A sample tabulation is shown in Figure 4-3.

4-2.3 Within each frequency band divide the average amplitude of the P.A. input voltage (E) by the corresponding average amplitude of the control acceleration (g) in that band, to yield the sine transfer function (E/g). The absolute values of voltage and acceleration are not required, thereby making it more convenient to operate in logarithmic terms (dB's). As shown in the sample Tabulation Sheet (Figure 4-3) the sine transfer function (E/g) in each band was calculated by subtracting the control acceleration from the P.A. input voltage.

NOTE

When working in logarithmic form (dB), multiplication and division can be simplified to computations involving only addition and subtraction.

4-3 COMPENSATION FACTORS. Once the sine transfer characteristics (E/g) of the test system have been calculated (see Figure 4-3, column (C)), factors can be applied to compensate for variables or non-linearities which influence the correlation between the sine and random characteristics. Three types of compensation factors have been identified and are discussed in detail:

a. Cassette tape deck characteristics

b. Variances in sine transfer characteristics

c. Non-linearities in sine response.

4-3.1 <u>Cassette Tape Deck Characteristics</u>. Each tape cassette deck has differences in frequency response characteristics. Slight variations can often

SYSTEM FILTERS			SINE DATA			COMPENSATION FACTORS			CORRECT. FUNC.		SYNTHETIC RAND.	
			(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
No.	B.W. (Hz)	C.F. (Hz)	Volt. E (dB)	Accel. g (dB)	E/g (dB)	Tape Deck (dB)	Linear. Factor (dB)	Var. Factor (dB)	Correct E/g (dB)	Req'd. g/Hz (dB)	Req'd. E/Hz (dB)	Normalized (g^2/Hz)
8	16	107	+1.6	-1.6	+3.2	+0.9	-	-	+4.1	+10.0	+14.1	3.21
9	17	124	+1.7	-1.5	+3.2	+0.9	-	-	+4.1	+10.0	+14.1	3.21
10	18	141	+2.2	-1.5	+3.7	+0.9	-	-	+4.6	+10.0	+14.6	3.61
11	25	163	+2.7	-1.6	+4.3	+0.9	-	-	+5.2	+10.0	+15.2	4.14
12	25	188	+5.0	-1.7	+6.7	+0.9	-	-	+7.6	+10.0	+17.6	7.19
13	25	213	+8.5	-2.3	+10.8	+0.9	-3.0	-1.1	+7.6	+10.0	+17.6	7.19
14	25	238	+1.2	-1.9	+3.1	+0.8	-	-0	+3.9	+10.0	+13.9	3.07
15	25	263	-1.3	-1.7	+0.4	+0.8	-	-	+1.2	+10.0	+11.2	1.65
16	25	288	-0.2	-1.6	+1.4	+0.8	-	-	+2.2	+10.0	+12.2	2.07

NOTES:

(A) and (B) - Data is average level within a bandwidth (25 Hz maximum)

(C) - Sine transfer function E/g = (A) - (B)

(G) - Corrected sine transfer function E/g = (C) + (D) + (E) + (F)

(I) - Synthetic random spectrum E/Hz = (G) + (H)

(J) - Normalized random spectrum $g^2/\text{Hz} = 0.125 \times 10^{\left\{\frac{(I)}{10}\right\}}$
where 0 dB = 0.125 g^2/Hz (choice of reference explained in text)
and $dB_n = 10 \log(g_n^2/0.125)$

FIGURE 4-3 TABULATION SHEET FOR SYNTHETIC RANDOM SPECTRUM be found between identical models due to manufacturing tolerances. These characterisitcs must be compensated for during preparation of the synthesized random tape, to assure that a tape deck with a 5 dB roll-off at 20 Hz will not result in an under test.

The procedure for testing a tape cassette deck to determine its frequency characteristics is described in detail in Chapter 2, Tape Deck Requirements. The average deviation in playback from the signal recorded in each band is computed as shown in para 4-3.1.3. Acompensation factor is then determined for each band to offset this deviation. As an example, if the playback is down - 3 dB in the 20 to 31 Hz band, a +3 dB compensation factor would be applied to that band. A sample compensation factor is tabulated in Figure 4-3, Column D.

The following paragraphs describe the procedure required to obtain a graphical plot or tabulation of the tape deck's response characteristics previously recorded on a tape cassette (as described in Chapter 2). Although this procedure has been tailored to specific items utilized, similar type equipment may be substituted and should provide equivalent results.

4-3.1.1 Equipment Description. The equipment described below was used to recover the test data previously recorded (see Chapter 2) on two tape decks, a Sony EL-7 and a Harmon-Kardon HK2000.

a. Spectrum Analyzer: Nicolet Scientific Corporation, Model 440 (used to monitor the recorded output voltage as a function of frequency. This analyzer provided data at a bandwidth of 5 Hz. Alternate equipment with a bandwidth no greater than 25 Hz is acceptable.

b. X-Y Recorder: Hewlett-Packard, Model 7047A (used, in conjunction with the analyzer to provide the final plot of voltage versus frequency).

4-3.1.2 Playback Procedure

a. Review the applicable portions of the Tape Deck Data Sheet, Chapter 2, Figure 2-2, to verify that the reference tape identification/serial is the correct one for this application.

b. Connect the tape deck's left channel output to the analyzer input.

NOTE

Verification of the right channel output should be accomplished using the same procedure described herein. Significant difference between channels should be noted in the remarks section of Chapter 2, Figure 2-2.

c. Set the analyzer input frequency range and voltage level to encompass the 2,000 Hz frequency range and the voltage level listed in Chapter 2, Figure 2-2. (furnished with the pre-recorded tape).
Record this information, plus the filter bandwidths in the Playback section of Figure 2-2.

d. Set the analyzer output mode to provide a frequency scale and logarithmic amplitude (dB) scale.

e. Set the X-Y recorder to the correct sensitivities to record the anticipated levels.

NOTE

The Y axis (amplitude) sensitivity should be capable of detecting a one dB variation.

f. Using the pre-recorded reference voltage (@ 1000 Hz), set the playback level control so that the output voltage level is at the -3 dB value of the analyzer's full scale input range.

NOTE

Once the playback level has been established at 1000 Hz, do not readjust the level control again for the balance of the procedure.

g. Playback the first (0 dB) curve into the analyzer and record the actual dB level (@ 1000 Hz) on the Tape Deck Data Sheet, (Chapter 2, Figure 2-2).

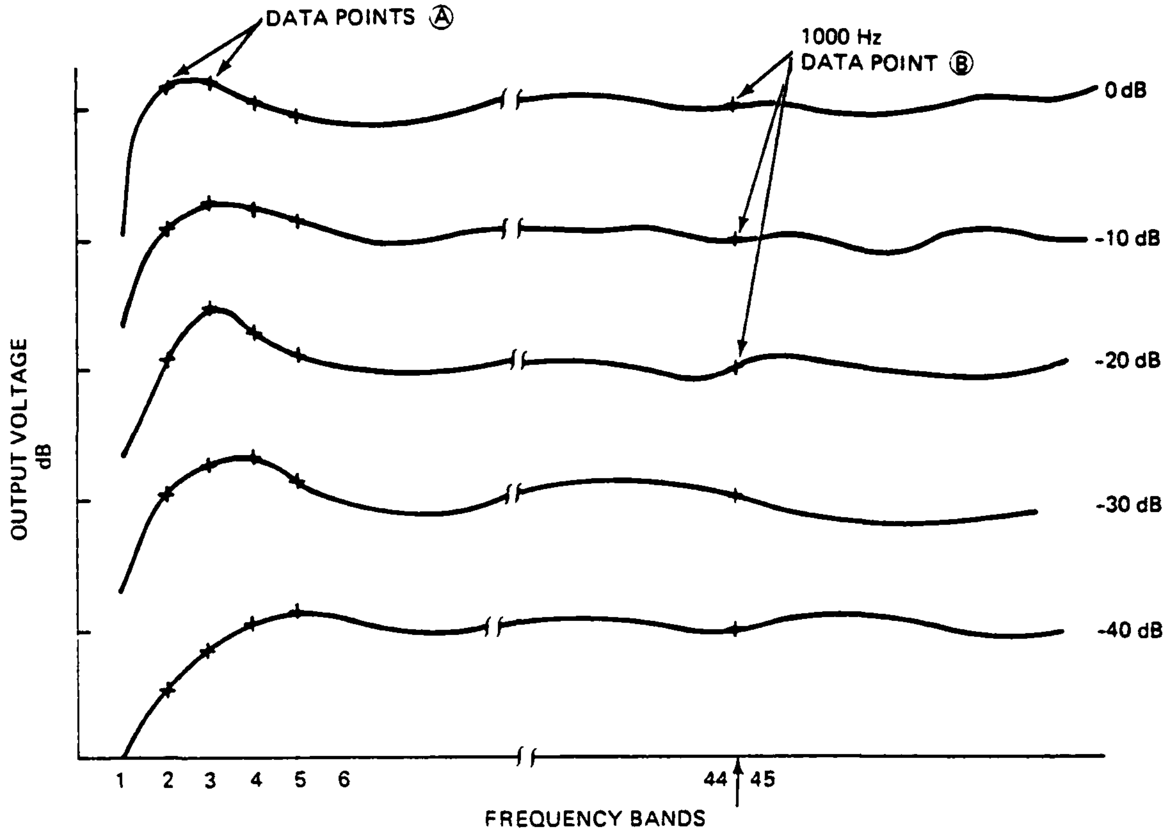
h. Using the output level (@ 1000 Hz), set the X-Y plotter pen to a convenient level at the top of the graph paper during playback of the curve.

i. Plot the 0 dB curve, which is the first recorded on the tape.

j. Repeat steps g through i for the -10, -20, -30 and -40 dB curves. The output at 1000 Hz., for each curve, may be used as the reference point for that curve and may also be used to locate the plotter pen on the graph paper. Place each curve at a convenient point below the proceeding curve (reference Figure 4-4)

4-3.1.3 Data Analysis. The output voltage plots generated during tape playback(para. 4.3.1.2) are to be used to determine the compensation (in dB) necessary to assure correct tape deck response.

a. Sub-divide the curve into frequency bands corresponding to those for the random analyzer/equalizer system that is used to shape the synthetic random spectrum. Chapter 4, para 4-2.2.



Filt. Band No.	~ 0dB Curve ~ Ref. Pt. Ⓑ	Data Pt. Ⓐ	Ⓐ-Ⓑ	-10 dB Ⓐ-Ⓑ	-20 dB Ⓐ-Ⓑ	-30 dB Ⓐ-Ⓑ	-40 dB Ⓐ-Ⓑ	Overall Ave.
1	-2.2 dB	-4.8 dB	-2.6 dB					
2	↓	-1.7 dB	+0.5 dB					
3	↓	-3.0 dB	-0.8 dB	-1.3 dB	-1.94 dB	-2.1 dB	-2.32 dB	-2.2 dB
4	↓	-3.2 dB	-1.0 dB					
5	↓	-3.4 dB	-1.2 dB					

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Figure 4-4 Data Analysis Technique w/Typical Examples

b. Determine the dB level for each frequency band.

c. Determine the difference in dB level between each curve data point (A) (see Figure 4-4) and its corresponding reference point (B) (see Figure 4-4) at 1000 Hz, for each of the five curves.

d. Average all five difference values to determine the overall average for each frequency band.

The overall average established in d, represents the compensation require to account for any tape deck response characteristics.

4-3.2 Variance in Sine Transfer Characteristics. It was empirically determined that sine transfer characteristics (E/g) varied in frequency between test units and from day to day test operations. These variations were approximately, ±3% (Frequency) and less than ±3 dB (Amplitude) as measured at minimum and maximum peaks in the (E/G) curve). In order to compensate for these variances in the preparation of the synthetic random tape a method was evolved to minimize the potential for overtesting at resonances and anti-resonances of the vibration system by reducing the synthetic random voltage requirements in these frequency bands and also to prevent undertesting at conditions of amplitude variances. The results of these investigations concluded that no positive compensation factors, resulting in an increase in voltage requirements were to be used and negative compensation factors were limited to -4 dB, to reduce the under test potential.

The choice of points in the sine transfer characteristics requiring compensation are chosen at frequency bands in which large abrupt changes or peaks, either positive or negative, exist in the transfer characteristics.

Calculate the required compensation factors for each of these frequency bands as follows:

4-3.2.1 Frequency Variation. Utilizing the test data transfer characteristic curve obtained in Chapter 3, determine for each resonance or anti-resonance, two frequency bands (in accordance with the procedure delineated below) and select the one that encompasses the fewest number of cycles:

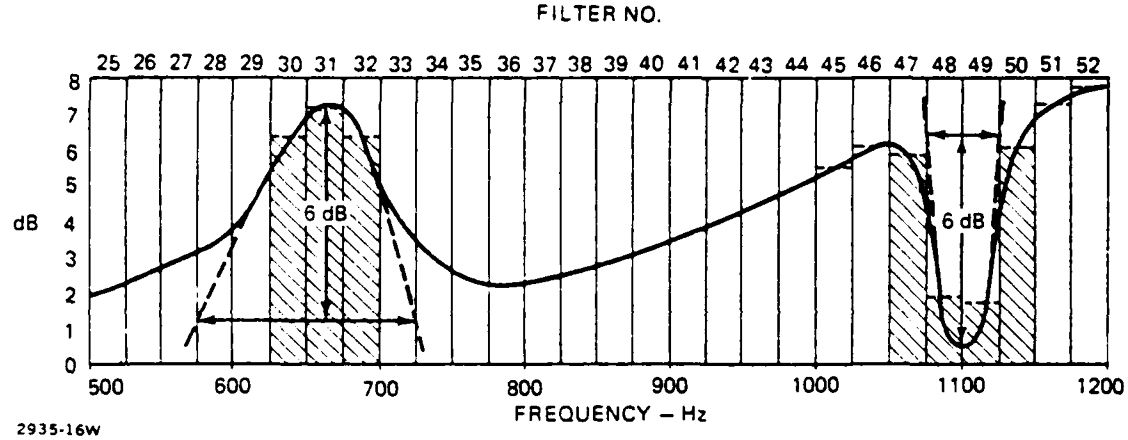
a. Establish the center frequency and calculate a value equal to ±6% of that frequency. (The ±6% includes ±3% to reflect the variance in unit to unit resonances and ±3% which considers the slopes reflecting the increase and decrease of the resonant reference).

b. At each center frequency determine the bandwidth at the half level points (-6 dB), and increase that bandwidth by adding ±3% of the center frequency to reflect unit to unit resonances.

4-3.2.2 Amplitude Variation. Determine the average amplitude variation in dB for each filter bandwidth within the frequency variation established in par. 4-3.2.1. (a minimum of three 25 Hz bands is required). Reduce each of these amplitudes by 0.5 dB to compensate for resonant and anti-resonant conditions. Then calculate the overall mean amplitude of the average level of each of these bands. Typically this would include one or two 25 Hz filters on either side of the maximum or minimum peak response frequencies.

4-3.2.3 Compensation Factor. In each filter bandwidth determine the compensation factor by subtracting its unmodified amplitude from the mean amplitude calculated in 4-3.2.2. The positive differences are discarded and the negative differences are then added to the filter amplitude to reduce the level to the calculated mean.

A sample curve which illustrates the procedures described in par. 4-3.2.1 and 4-3.2.2 for a typical maximum and minimum peak is shown in Figure 4-5. The



2935-16W

Figure 4-5 Sample Curve – Variance Compensation Factors

calculations utilizing these procedures are presented for two examples:

Example No. 1. (E/g) maximum peak occurs in filter No. 1 which has an average amplitude of 7.1 dB.

a. Calculate the frequency variance.

(1) Center frequency of filter No. 31 is 662 Hz.

(2) ±6% of 622 Hz = ±39.72 Hz or 79.44 Hz.

(3) The half level bandwidth (-6 dB) = 150 Hz.

(4) ±3% of 662 Hz = ±19.86 Hz

(5) ±19.86 Hz (39.72 Hz) + 150 Hz = 189.72 Hz

(6) Select 79.44 Hz since this is the lower of the two values

This frequency spread encompasses a range of 662 Hz ±39.72 Hz or 622.28 to 701.72 Hz, and includes filter No.s 30, 31 and 32.

b. Calculate mean amplitude in the compensation band

SUM OF AVERAGE AMPLITUDE IN EACH BAND			
Filter No.	Amplitude (A)	Correction Factor (B)	(A)-(B)
30	6.1 dB	-0.5 dB	5.6 dB
31	7.1 dB	-0.5 dB	6.5 dB
32	6.2 dB	-0.5 dB	5.7 dB
			Total = 17.8 dB

o Mean = 17.8 dB/3 = 5.9 dB

c. Calculate compensation factor

Filter No. 30: 5.9 dB (mean) - 6.1 dB (A) = -0.3 dB

Filter No. 32: 5.9 dB (mean) - 7.1 dB (A) = -1.2 dB

Filter No. 32: 5.9 dB (mean) - 6.2 dB (A) = -0.3 dB

Example No. 2. (E/g) minimum peak occurs between filter Nos. 48 and 49, with an average amplitude of 1.8 dB.

a. Calculate the frequency variance

(1) Center frequency between filter No. 48 and 48 is 1100 Hz.

(2) ±6% of 1100 Hz = ±66 Hz or 132 Hz.

(3) The half level bandwidth (-6 dB) = 54 Hz

(4) ±3% of 1100 Hz = ±33 Hz

(5) ±33 Hz (66 Hz) + 54 Hz = 120 Hz

(6) Select 120 Hz since this is the lower of the two values.

This frequency spread encompasses a range of 1100 Hz ±60 Hz or 1040 to 1160 Hz and includes filter Nos. 47, 48, 49 and 50 (only full bands are to be considered).

b. Calculate the mean amplitude in the compensation bands.

SUM OF AVERAGE AMPLITUDE IN EACH BAND			
Filter No.	Amplitude (A)	Correction Factor(B)	(A)+(B)
47	5.8 dB	-0.5 dB	5.3 dB
48	1.8 dB	-0.5 dB	1.3 dB
49	1.7 dB	-0.5 dB	1.2 dB
50	6.0 dB	-0.5 dB	5.5 dB
		Total =	13.3 dB

o Mean = 13.3 dB/4 = 3.3 dB

c. Calculate compensation factor

Filter No. 47: 3.3 dB (mean) -5.8 dB (A) = -2.5 dB

Filter No. 48: 3.3 dB (mean) -1.8 dB (A) = +1.5 dB *

Filter No. 49: 3.3 dB (mean) -1.7 dB (A) = +1.6 dB *

Filter No. 50: 3.3 dB (mean) -6.0 dB (A) = -2.7 dB

NOTE

*Positive compensation factors are not used in order to minimize overtest potential.

The calculated compensation factors are tabulated in column F of the sample Tabulation Sheet, Figure 4-3.

NOTE

This method of compensation has been kept simplistic to provide the evident application to typical test articles. Individual test systems may lend themselves to more precise methods of variance compensations.

4-3.3 Non-Linearity in Sine Response. In Chapter 2, Theory of Operation, one of the premises of the tape technique was linear behavior of the vibration system with respect to frequency and amplitude. This idealization is not often realized in actual test operations. In the initial study program conducted a $2\frac{1}{2}$g (peak) sine sweep yielded more accurate transfer characteristics, (for the required 6.0 Grms random spectrum), than did the ± 1.0g (peak) sine sweep. The difference was only significant at low frequency resonances and anti-resonances where friction damping decreased in effectiveness as amplitude increased.

This situation does not follow non-linear vibration theory and tends to be unique to black box attachment hardware. This hardware, such as standard "Mil-spec" swing bolts and high-torque cam locking nuts, tend to respond in a non-linear fashion when the attachment load is momentarily exceeded. Therefore, since it is not considered desirable to increase the amplitude of the initial sine sweep to $2\frac{1}{2}$g (peak), i.e., to minimize the risk of accident over test, the following is recommended. Where it can be determined that a resonant condition exists, due to mounting hardware, decrease the synthesized random spectrum, in those filter bands affected, to a maximum of -3 dB.

4-3.4 Corrected Sine Transfer Characteristics. The sine transfer functions determined, (ref. para. 4.2.3) and tabulated in column (c) of Figure 4-3 are corrected using the various compensation factors described in the preceeding paragraphs. Since the data is in logarithimic terms (dB's) as shown in the example, the three different types of compensation factors, referenced in columns D, E, and F in Figure 4-3, can be added directly to the sine transfer functions to yield the corrected sine transfer characteristics, tabulated in column G. This sample calculation is carried out on an individual basis for each of the system filters shown.

4-4 SYNTHETIC RANDOM VOLTAGE. The calculation of the synthetic random voltage is influenced by only two factors: 1) the sine transfer function, and 2) the required random test spectrum. Since the former has already been extensively covered in previous paragraphs, this section will examine the determination of the random voltage using the nominal random test spectrum, and how it should then be normalized to conform with the random equalization system utilized in the synthesization.

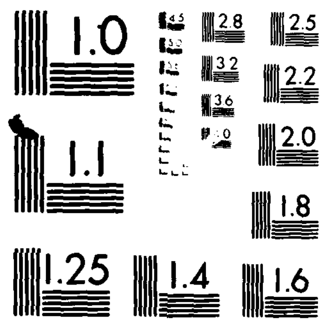
4-4.1 Required Random Test Spectrum. The random test spectrum to be utilized in a particular test program is described in the appropriate test specification. It will generally be specified in terms of g^2/Hz in flat areas of the spectrum, and in terms of dB per octave slopes in other (varying amplitude) areas. For example, the test spectrum used exclusively in this procedure in examples is specified as follows:

AD-A099 789 GRUMMAN AEROSPACE CORP BETHPAGE NY F/G 14/2
UTILIZATION OF TAPED RANDOM SPECTRA FOR VIBRATION TESTING.(U)
DEC 78 G HIRSCHBERGER, J J POPOLO, J DEVITT N00039-77-C-0360

UNCLASSIFIED NL

3 of 3

END
DATE
FILMED
5 81
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

Frequency Band	Spectrum Density
20 to 80 Hz	+3 dB/oct rise to $.04g^2/Hz$
80 to 350 Hz	$0.04g^2/Hz$
350 to 2000 Hz	-3 dB/oct roll off from $.04g^2/Hz$

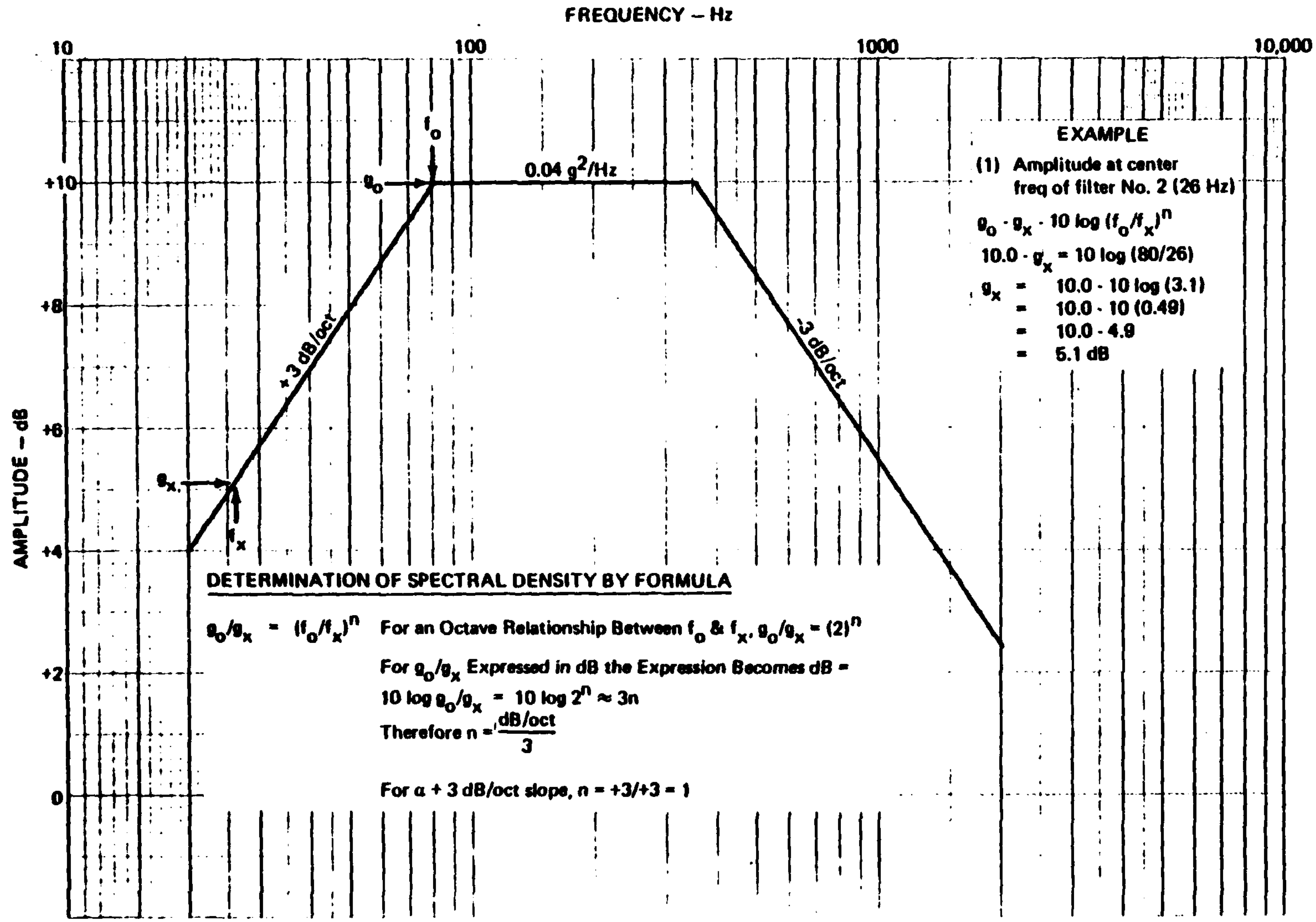
Overall Grms = 6.0

For convenience in performing the subsequent synthetic random voltage caclulation the required test spectrum can be put in logarithmic terms (dB) specified for each of the bandwidths used in the random equalization system. This is accomplished by assigning a positive dB value to the highest spectral density amplitude. The dB value should be chosen high enough so that the lowest amplitude value can still be represented by a positive dB value. (This will avoid sign mistakes in the calculations). For the sample spectrum above a value of +10.0 dB was designated for $0.04g^2/Hz$ and the spectrum in dB is determined graphically or by formula as shown in Figure 4-6. The dB value determined for the center frequency of each filter bandwidth is tabulated in column H as shown in Figure 4-3.

4-4.2 Calculation of Required Synthetic Random Voltage (E/Hz). The actual synthetic random voltage (E/Hz) required to drive the vibration system to the required random spectrum level is determined by multiplying the sine transfer function by the required test spectrum:

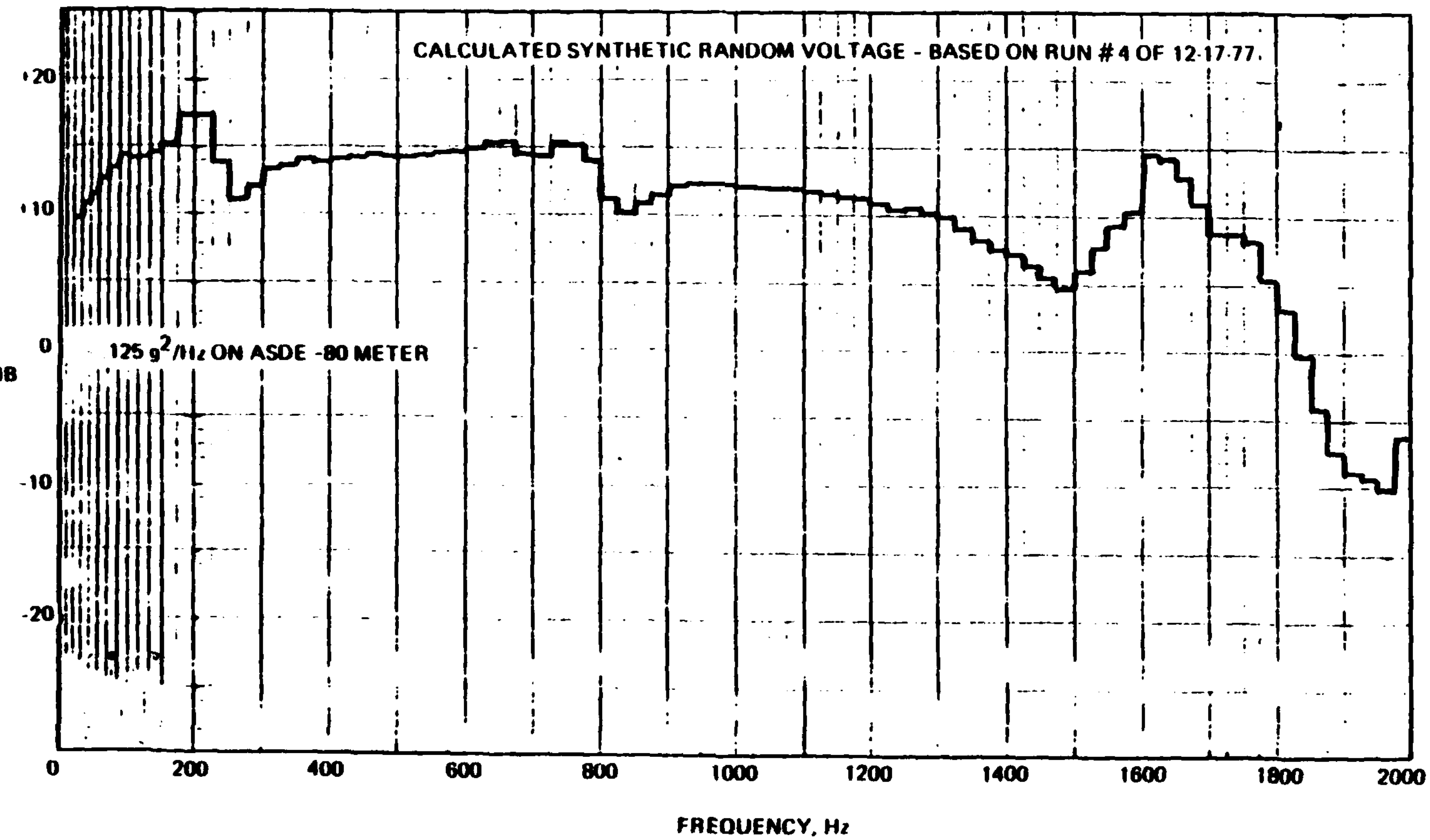
$$E/_{g} \times g/_{Hz} = E/_{Hz}$$

Utilizing the logarithmic form (dB) the required random spectrum (column (H) of Figure 4-3) should be added to the tabulated sine transfer functions (column (G) Figure 4-3). This will yield the resultant synthetic random voltage necessary for each individual filter bandwidth. (column I of Figure 4-3). This data is plotted graphically in Figure 4-7.



2935-18W

Figure 4-6 Sample of Required Test Spectrum



2935-22W

Figure 4-7 Synthetic Random Voltage

4-4.3 Normalization of Synthetic Random Voltage (g^2/Hz). The final step in the calculation is to normalize the synthetic random voltage into terms that can be programmed into the random equalization system used for recording the synthesized random tape. Since most random equalization systems are designed to handle the spectrum in terms of g^2/Hz rather than E/Hz expressed in dB (column (I) of Figure 4-3) normalization factors must be derived to make this transformation.

The first step in the normalization calculation is to choose a 0 dB reference in g^2/Hz such that all the synthetic voltages (when normalized) will fall within the dynamic range of the analyzer. This is accomplished by assigning the highest synthetic random voltage (column (I) of Figure 4-3) a g^2/Hz value equal to 80% of the highest equalization range.

Example:

- o Dynamic range of equalizer: .001 to 10.0 g^2/Hz
- o Highest synthetic random voltage: + 18.05 dB,

  set + 18.05 dB = 80% of 10.0 g^2/Hz = 8.0 g^2/Hz (g_x) and solve for go(where dB = 10 log g_x/g_o

  18.05 dB = 10 log 8.0 -10 log g_o

  $\therefore g_o = .125\ g^2/\text{Hz}$ (0 dB reference for normalization)

- o To solve for g_x (normalized spectral density) for any bandwidth filter (X) use the following equation:

  $$dB_x = 10 \log g_x/g_o$$

  $$dB_x = 10 \log g_x/.125$$

  $$\therefore g_x = .125 \times 10^{\left\{\frac{dB_x}{10}\right\}} \quad \text{(normalization equation)}$$

The normalization equation is then applied to the value of the synthetic random voltage in each bandwidth (column (I) Figure 4-3) to determine the normalized spectral density - g^2/Hz which is tabulated in column (J), Figure 4-3. An example utilizing the E/Hz dB value (column I) for Filter No. 14 is detailed below:

Filter No. 14 synthetic random voltage: +13.9 dB

normalization reference: 0 dB = 0.125 g^2/Hz

$$\text{then } g_x \text{ (Filter No. 14)} = 0.125 \times 10^{\left\{\frac{13.9}{10}\right\}}$$

$$= 3.07 \; g^2/\text{Hz}$$

4-5 RECORDING OF SYNTHETIC RANDOM TAPE. The preparation of the synthetic random tape is handled in a manner similar to that used when conducting a normal random vibration test except that no shaker system is utilized. The output of the random equalization system is directed instead to the cassette tape deck. It should be pointed out that the synthezation of the random tape requires laboratory facilities which include as a minimum; a 30 channel equalization system (filter bandwidths the maximum size permitted for analysis (see Chapter 6, Table 6-1), a guassian noise generator, and a spectrum analyzer with a statistical accuracy of 100 degrees of freedom minimum with filter bandwidths reference above.

The actual process of generating the random tape will be divided into three sections:

a. Programming of Random Equalization System

b. Recording of Tape

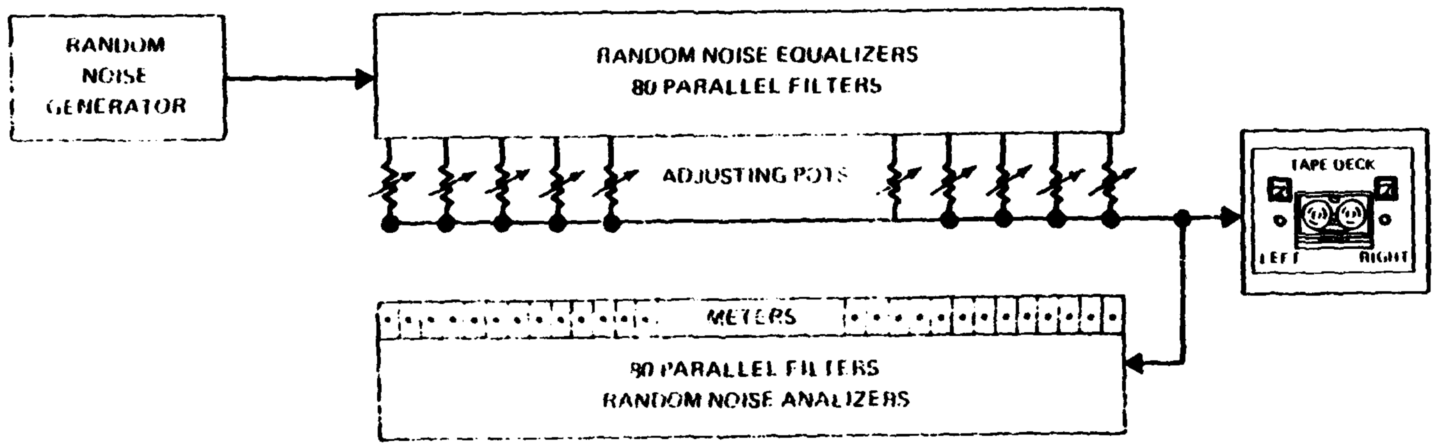
c. Verification of Random Spectrum

4-5.1 Programming of Random Equalization System. While a minimum of 30 channels of equalization (over the 20 to 200 Hz frequency range) is technically acceptable, experience has shown that for good results the equalization filter bandwidth should be half or a third of the maximum permittable analyzing bandwidth. It is therefore suggested that the equalization system have as a minimum, 80 channels dividing the test range into 25 Hz bandwidths. Since the operating conditions for the equalization system are dynamically stable during the recording of the tape, a manual equalization system will provide acceptable results.

4-5.1.1 The random equalization system is operated in a closed loop mode, i.e. the output of the equalization system is fed back into the analysis section of the random control system. (It should be noted that this technique was developed using a Ling ASD/ESD 80 Random Control System - it can be applied with only minor modifications to other systems currently in use.) Figure 4-8 shows a block diagram of the setup.

4-5.1.2 Program the equalization system using the normalized synthetic random voltages for each bandwidth which were calculated in para. 4-3.3 and tabulated in column (J) of the tabulation sheet. (For the Ling ASD/ESD 80 System. This is done by adjusting potentiometers in each equalizer bandwidth until the corresponding analyzer meter in the band reads the correct spectral density g^2/Hz)

4-5.1.3 When all equalization channels have been programmed, the spectrum shape of the synthetic random voltage should be verified by a spectrum analysis. (see para. 4-4.3). The resulting spectrum analysis should be compared to the required synthetic random voltage which is shown graphically in Figure 4-7. Deviations in excess of ±0.5 dB should be corrected by readjusting the equalization in the frequency bands which are out-of-tolerance. The spectrum analysis should be re-run and the process repeated as required to meet the ± 0.5 dB tolerance.



2935-20W

Figure 4-8 Taping Synthetic Random

4-5.2 Recording the Tape. The recording of the synthetic random spectrum on the cassette is procedurely identical to that used in the recording of the sine transfer tape described in Chapter 3, Obtaining Sine Transfer Characteristics. The recording is made on the same tape cassette as the sine sweep in accordance with the sequential steps outlined in subsequent paragraphs.

4-5.2.1 Verify that the tape cassette is the correct one for the test article and test setup. Determine which side of the cassette corresponds to the test axis or condition to be recorded. Load the cassette into the tape deck with the side designation required (A or B) facing outward.

4-5.2.2 Rewind the tape cassette to its start position and then set the tape deck counter to 000.

4-5.2.3 Determine the tape deck counter reading for the end of the sine sweep. This information is on the Tape Data Sheet, Figure 3-3.

4-4.2.4 Advance the tape using the fast-forward control till the tape deck counter reads 2 to 3 counts above that locating the end of the sine sweep.

4-5.2.5 Advance the tape using the play-back control (without recording) for one minute of elapsed time. Stop the recorder at the conclusion of one minute.

4-5.2.6 Switch the tape deck VU Meter for the left channel to record (input) if manual switching is required.

4-5.2.7 Adjust the tape deck recording level control for the left channel so that the left channel VU Meter reads between 0 and -1.0 dB. The master gain control of the random equalization system may also have to be adjusted.

4-5.2.8 Place the tape deck in the record mode and record the random voltage signal for an elapsed time fo 17.5 minutes.

4-5.2.9 At the conclusion of 17.5 minutes gradually reduce the record level control on the left channel to minimum. (For an elapsed time of approximately 15 seconds).

4-5.2.10 Allow the tape deck to run with minimum input signal until it automatically stops at the end of the tape.

4-5.2.11 Record all significant parameters (including tape recorder reading) on the Tape Data Sheet, Figure 3-3.

4-5.3 Verification Of Random Spectrum. Before using the random tape in test operations, it is essential to verify the spectrum shape of the synthetic random voltage over the 17.5 minutes of recording. This is especially important when recording with older random equalization systems where the level in individual filter bandwidths can drift off the set point.

4-5.3.1 It is recommended that the analysis be made with a real time analyzer using narrow band filters of 10 Hz bandwidth or less. The sampling parameters should be adjusted to yield a minimum statistical accuracy of 100 degrees of freedom. A block diagram of the setup for spectrum analysis is shown in Figure 4-1.

4-5.3.2 As a minimum, four samples of the recorded random spectrum should be analized:

a. After 1 minute of elapsed time

b. After 5 minutes of elapsed time

c. After 10 minutes of elapsed time

d. After 15 minutes of elapsed time.

4-5.3.3 Rewind the tape to the counter reading corresponding to 1 minute of elapsed time in the recorded random spectrum (see Figure 3-3).

4-5.3.4 Activate the playback mode of the tape and adjust the output control level to a convenient setting for the analyzer to be used.

4-5.3.5 Start the analyzer sampling of the playback data. When the analyzer has sampled sufficient data for the required averaging confidence, the tape deck should be stopped.

4-5.3.6 The random spectrum computed by the analyzer should then be compared with the required synthetic random spectrum (shown graphically in Figure 4-7). A convenient way of doing this is to plot the analyzer output directly on the graph paper containing the graphic outline of the required spectrum. It should be noted that the absolute values of the recorded voltages are not significant so the "Y" axis pen position can be adjusted to superimpose these plots. (provided the span adjustment is not changed - 10 dB/inch in the sample shown in Figure 4-7).

4-5.3.7 A ± 1.0 dB tolerance should be applied in comparing the recorded spectrum with the required spectrum. Exceedance in excess of ± 1.0 dB will require the re-equalization of the random spectrum and re-recording of the tape.

4-5.3.8 The tape should then be advanced to the counter reading corresponding to 5 minutes of elapsed time in the random recording and the analysis repeated as described in preceeding paragraphs. Repeat with tape at elapsed time of 10 and 15 minutes.

4-5.3.9 Following the successful verification of the recorded random spectrum, the recording tabs on the tape cassette should be moved or broken off (per manufacturer's directions) to prevent accidental errasure of the data.

NOTE

If the reverse side of the tape is to be used do not position the "record" defeat tabs until both sides have been recorded.

CHAPER 5

TESTING WITH TAPED RANDOM

5-1 SCOPE. This chapter defines the procedures required for setting up the vibration system and for the playback of the sine and random tape recording through that system. Application of these procedures will verify the random test setup and insure the performance of the specified random spectrum vibration test.

5-2 TEST SET-UP. As indicated in Chapter 1, Background, the taped random vibration test technique will yield satisfactory results only if conditions from setup to setup are duplicated exactly. Therefore, it is extremely important that the detailed procedures in the following paragraphs be rigorously observed. The mechanical setup for this test should be identical to that described in Chapter 3, para. 3-2.1. The electrical setup as described in Figure 3-2 differs in one significant feature from that utilized in recording the sine tape, i.e., the input to the shaker system is provided by the cassette tape deck.

5-2.1 Electrical Test Set-Up

5-2.1.1 Connect the left channel output of the cassette tape deck to the power amplifier input (see Figure 5-1).

NOTE

The right channel output is not connected during playback. It contains the recorded reference control accelerometer signal.

5-2.1.2 Connect a true rms meter to record the servo output of the control accelerometer charge amplifier (see Figure 5-1). During the sinusoidal test run, the signal can also be monitored by the servo-controller meter. Where equipment is

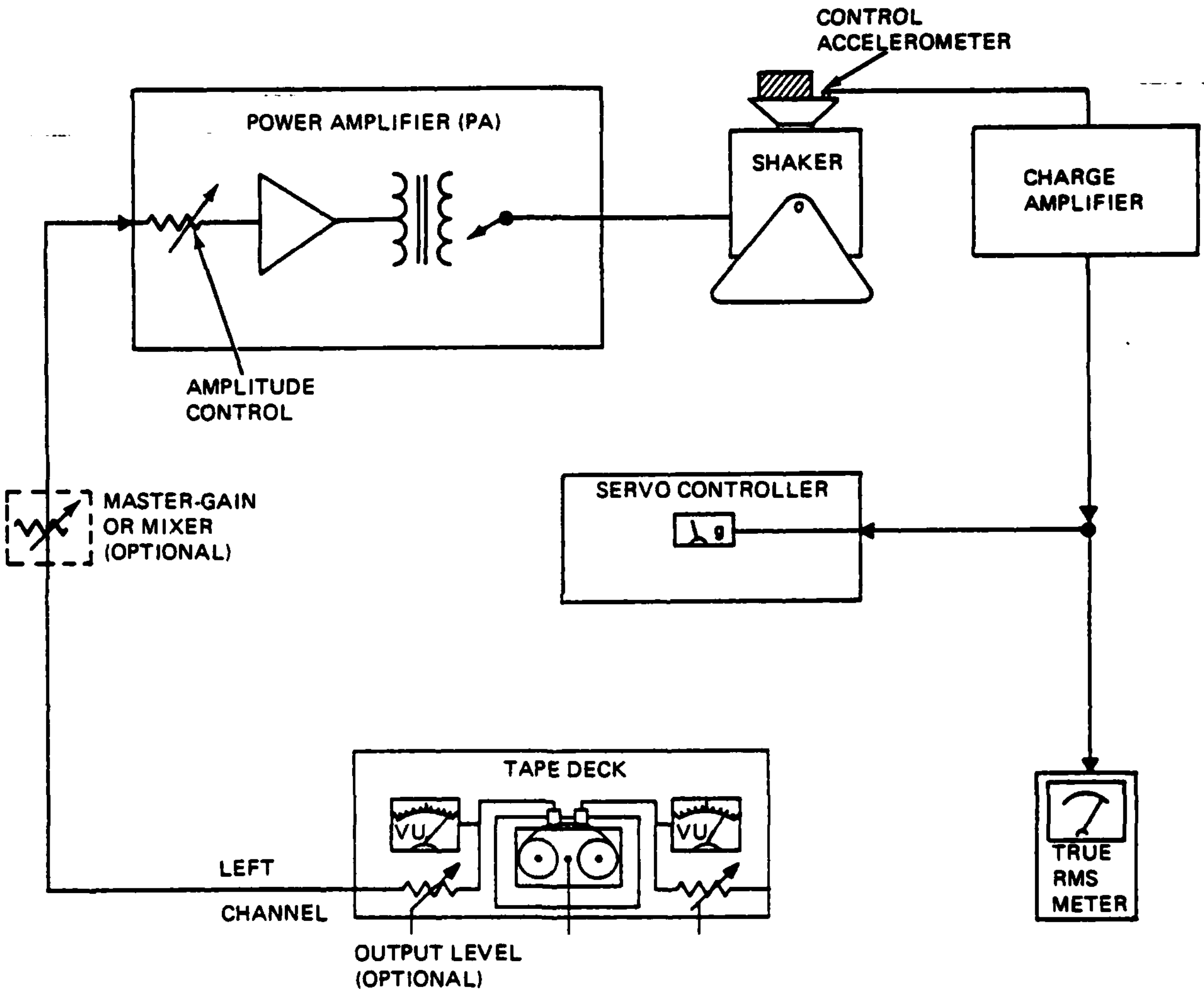


Figure 5-1 Electrical Test Setup

available, it is strongly recommended than an X-Y plot of acceleration versus frequency be generated.

5-2.1.3 Configure the power amplifier at the same settings used in recording the sine tape as described in Chapter 3, paragraph 3-2.2.1 and tabulated in the Sample Electrical Specification Sheet (see Figure 3-2).

5-2.2 Deviations From Specifications - In circumstances where unavoidable deviations from the Mechanical or Electrical Specification Sheets (see Figure 3-1 and 3-2) exist, i.e., test equipment unavailablility, changes in hardware, electrical parameters or interfaces, it is strongly recommended that the test article be removed and a fixture-only sine sweep be made for comparison. This procedure is detailed in Chapter 6, Troubleshooting, paragraph 6-3.1 All deviations shall be recorded on the Acceptance Test Data Sheet (Figure 5-2).

5-3 TEST PROCEDURE. The following procedures shall be utilized in performing the sine and random vibration tests incorporating the pre-recorded cassette tape as an input to the shaker system. The procedure is presented in two sequential steps:

a. Tape sine sweep

b. Taped random vibration test.

5-3.1 Taped Sine Sweep - As indicated in Chapter 2, Theory of Operation, the purpose of the sine sweep is to replace the random noise spectrum analysis normally required to verify the input spectrum applied to the test article. This is accomplished by accurately monitoring the control accelerometer for deviations about the required 1.0g (peak) input during the application of the sine sweep discussed in Chapter 3, paragraph 3-3.3.4.

5-3.1.1 Prior to test, verify, that the tape cassette title discription cor-

Tape No.__________ Side:__________ Date:__________

Test Article:__________ S/N __________

Part No.__________ Axis __________

Test Specification:__________

Test Location__________

Test Enginer:__________

Deviations from Electrical and Mechanical Specification Sheets

____

____

____

____

Note: Add additional Sheets, if required

I – Sine Sweep Test Data

Run No.	Start		End		Amplitude Deviations			Comments
	Time	Counter	Time	Counter	Freq	Band	Ampl.	

II – Random Test Data

- Nominal Test Grms __________
- Correction for Bandpass __________
- Correction for Exclusions __________

Test Grms __________

Run No.	Start		End		Grms	Test Article Functional Data	Comments
	Time	Counter	Time	Counter			

2935-5W

Figure 5-2 Acceptance Test Data Sheet

5-3.1.9 The tape deck will run continuously from that point until the end of the sine sweep. The tape is programmed to initiate the following sequential events:

a. One minute of dwell at 1.0g (peak) at the gain reference frequency

b. Twenty second drop in level while frequency is reset to 2000 Hz.

c. Ten second increase in level at 2000 Hz to approximately 1.0g (peak)

d. Seven minute frequency sweep from 2000 to 20 Hz.

e. Ten second decrease in level at 20 Hz.

5-3.1.10 During the frequency sweep from 2000 to 20 Hz, the control acceleration amplitude shall be monitored continuously with the rms voltmeter or servo-controller "g" meter. Deviations from the nominal 1.0g (peak) level or the rms voltage equivalent, shall be recorded when the value exceeds the tolerance band specified in Table 5-1. The tape deck counter time shall also be recorded on the Acceptance Test Data Sheet (see Figure 5-2).

TABLE 5-1

Tolerance Band For Sine Amplitude Deviations

Frequency Range		Upper Amplitude Limit		Lower Amplitude Limit	
Hz	Sweep Time	db	g	db	g
2000 to 1000	0 to 1 min.	+6	2.0	-6	0.5
1000 to 20	1 to 6:40 min.	+3	1.4	-3	0.7

5-3.1.11 It should not be necessary to change the amplitude or master-gain setting during the sweep once it is set during the gain reference recording portion of the tape. If a variation does exist, i.e., the amplitude consistently averages higher than the upper tolerance band (see Table 5-1), the master-gain shall be reduced to an average amplitude closer to the 1.0g (peak) level and the responds to the test article and setup. Insert the tape cassette into the deck such that the side designation which corresponds to the required test axis or condition, faces outward.

5-3.1.2 Utilizing the electrical configuration described in paragraph 5-2.1, verify that the amplitude or master gain control of the shaker system is in the zero or off position.

5-3.1.3 Rewind the tape cassette to the start position and set the tape deck counter to 000.

5-3.1.4 From the Tape Data Sheet Chapter 3, (see Figure 3-3) determine the tape deck counter reading locating the recorded Gain Reference Signal.

5-3.1.5 Prior to test, switch the left channel tape deck VU meter to output if manual switching is required. If the tape deck utilized has an output level control, move it to the full output position.

5-3.1.6 Advance the tape using the fast-forward control until the tape deck counter reads two to three counts beyond the start of the recorded Gain Reference Signal.

5-3.1.7 Verify that the shaker system is in a "run" or operate mode and activate the playback control on the tape deck.

5-3.1.8 Observe the left channel VU meter for a positive reading (above-20dB) when the tape reaches the Gain Reference Signal. When a positive reading is observed slowly increase the amplitude or master-gain control of the shaker system until a 1.0g (peak) or its equivalent rms voltage is read on the rms voltmeter or servo-controller "g" meter.

NOTE

It should not be necessary to readjust the amplitude or master gain control to maintain the overall Grms level. If any change is evident during the test period it may indicate a problem involving the test article or test equipment. If the change is greater than 10% of the test level, terminate the test by turning the amplitude or master gain to zero (off) and refer to Chapter 6, Troubleshooting, paragraph 6-3.

change noted on the Acceptance Test Data Sheet (see Figure 5 2).

5-3.1.12 At the conclusion of the frequency sweep portion of the tape, as evidenced by a drop in amplitude on the RMS voltmeter and left channel VU meter, the amplitude or master gain control shall be reduced to zero (off) and the tape deck stopped.

NOTE

If amplitude variations during the test run exceeded the tolerance bands, in Table 5-1, proceed to Chapter 6, Troubleshooting.

5-3.2 Taped Random Vibration Test - This section outlines the procedures required to perform the random vibration test using the tape deck unit. During the random vibration test the true RMS voltmeter shall be utilized to accurately measure the overall RMS amplitude of the vibration spectrum (see Figure 5-1).

5-3.2.1 The nominal Grms for the required test spectrum was established by basic test specification. This value may have to be modified to correct for charge amplifier bandpass.

5-3.2.1.1 The correction for the charge amplifier bandpass may be necessary to compensate for control accelerometer and charge amplifier sensitivity to the vibration energy above the nominal 2000 Hz upper limit of the test spectrum. This energy is associated with mechanical noise and harmonics of the test spectrum. An increase of 5% in the nominal Grms level is recommended to compensate for this energy.

NOTE

If the charge amplifier or RMS voltmeter have a 2000 Hz low pass filter, no correction factor is necessary.

5-3.2.2 Prior to the test verify that the shaker system is in an operate mode and the amplitude or master gain control is in the zero or off position.

5-3.2.3 Advance the tape using the fast forward control until the tape deck counter reads two to three counts beyond the start of the Random Noise Spectrum (see Tape Deck Sheet, Chapter 3, Figure 3-3.

5-3.2.4 Activate the playback control of the tape deck. Observe the left channel VU meter for a positive reading (above-20dB) indicating the start of the random signal. At this point slowly increase the amplitude or master gain until a reading of the required Grms times the charge amplifier sensitivity is realized on the True RMS voltmeter (Example: a 6.0 Grms test with a charge amplifier sensitivity of 10 mv/g will read 60 mv_{rms} on the voltmeter).

5-3.2.5 At the conclusion of the required random test time, the amplitude or master gain control shall be reduced to zero (off) and the tape deck de-energized.

5-3.2.6 The maximum duration of the taped random signal is 17.5 minutes. The end of the signal is indicated by a gradual decrease in noise level over 15 seconds followed by 45 seconds of no signal. Test time duration greater than 17 minutes will require rewinding the tape to the random signal start location on the tape deck counter and then repeating steps 5-3.2.4 and 5-3.2.5.

CHAPTER 6

TROUBLESHOOTING THE SYSTEM

6-1 SCOPE This chapter describes the procedures to be used in two principal areas:

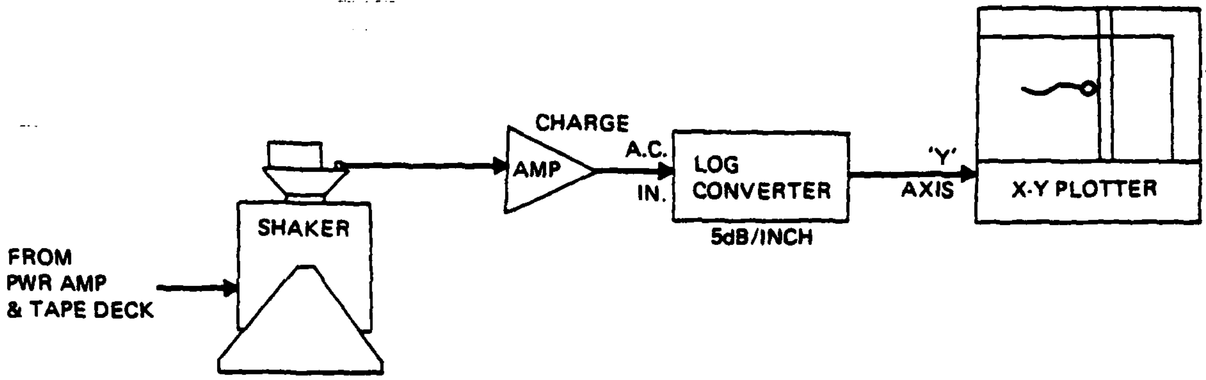
a. analysis of the sine sweep data to determine the significance of an out-of-tolerance problem.

b. troubleshooting of the various systems to isolate the cause of the problem.

6-2 ANALYSIS OF SINE SWEEP DATA. Most potential problems that may be encountered when applying the tape technique should appear as out-of-tolerance acceleration amplitudes during the taped sine sweep. (see Chapter 5, par. 5.3.1). Not all of these out-of-tolerance conditions present during the sine sweep will result in significant problems in the random portion of the test. Therefore, before proceeding to troubleshooting, some guidelines for measurement and interpretation of the sine sweep data are provided.

6-2.1 Measurement of Sine Sweep Response. Accurate determination of bandwidth, frequency and acceleration amplitude are required for meaningful interpretation of the sine sweep data. Therefore, it is suggested that if out-of-tolerance conditions are noted on the RMS voltmeter during the initial sine sweep (see Chapter 5, para. 5.3.1), a second sine sweep be made during which a plot of acceleration versus frequency be recorded. This data can be acquired utilizing an x-y recorder with a time drive and log converter as shown in Figure 6-1 and 6-2. An oscillograph or similar recorder can also be used.

6-2.2 Exclusions to Sine Sweep Tolerances. Three types of exceptions to the



Procedure:

1 Perform the Sine Sweep in accordance with Chapter 5, Paragraph 5-3.1 but with the set-up of Figure 5-1 modified as shown above and described below:

   a) Connect the Charge Amp. "Servo Out," to Log Converter "AC Input"

   b) Connect the Log Conv. "Output" to the Plotter "Y axis input"

   c) Set Plotter "X axis" to "Time Function" selecting a sweep rate to capture at least a seven minute sweep.

   d) Set Plotter "Y axis" sensitivity to 5dB/inch using the Charge Amp. Calib. Signal and Log Conv. Attenuator

2 Set the tape to the 2000 Hz dwell point prior to sweeping

3 Start tape and sweep activating the Plotter Sweep two-three counts, using the tape counter, prior to the actual sweep

4 The plot may be made on either plain or graph paper.

5 Prepare an overlay, similar to Figure 6-2 of Frequency versus Elapsed Time for a one octave/min. sweep rate. Figure 6-2 was drafted for 8½ x 11 paper with a Plotter Sweep Rate of 50 seconds per inch.

6 Since the Plotter Sweep was started while the tape was at the 2000 Hz dwell the first few seconds of the plot will be a flat line. Deviation from the line indicates "start of sweep."

7 By placing the 2000 Hz point of the overlay atop the "start of sweep" point the frequency, at points along the plot, may be determined.

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Figure 6-1 Block Diagram for Acceleration Vs Frequency Plots

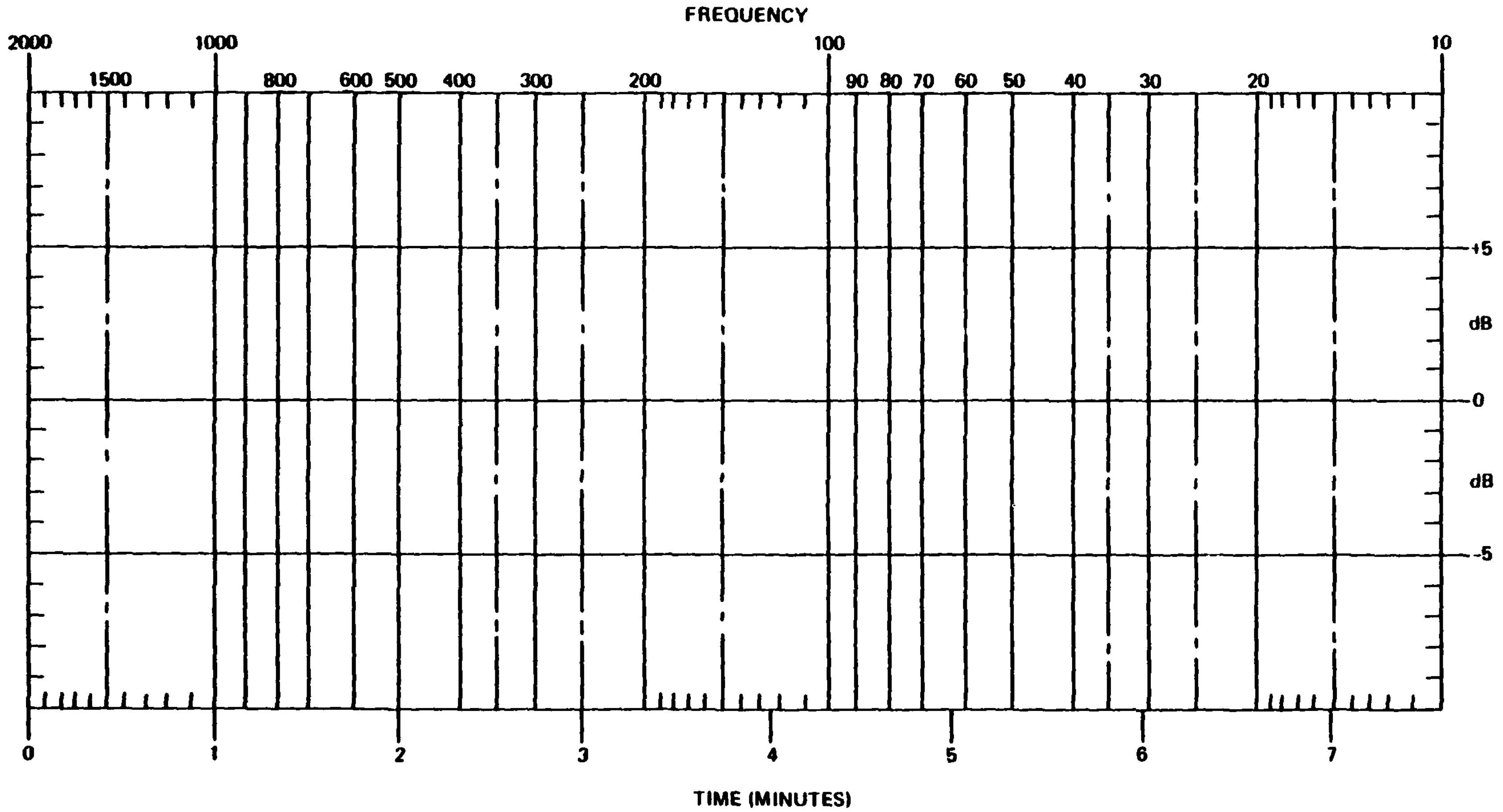

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Figure 6-2 Frequency vs Elapsed Time for One Octave/Min Sweep Rate and Plotter Rate of 50 Sec./Inch

general sine tolerance specified in Chapter 5, Table 5.1, have been identified and will be discussed in detail in subsequent paragraphs:

a. Compensation Factor Exclusions

b. Bandwidth Exclusions

c. Lower Tolerance Exclusions

6-2.2.1 Compensation Factor Exclusions. As explained in detail in Chapter 4, para. 4.2.4, compensation factors have been applied to the random tape to correct tape deck characteristics and shifts in resonant frequencies. Since these factors have not been included in the sine portion of the tape, these deviations should be considered to predict their effect when running the random noise test. For example, Chapter 4, Figure 4-2, shows a total for linearity and vaiance compensation factors of -4.0 dB for filter No. 13 (213 Hz). Therefore a +7 dB spike at this frequency in the sine sweep will be reduced to a +2.9 dB spike in the random portion of the test, which is within acceptable tolerances.

6-2.2.2 Bandwidth Exclusions. As discussed in Chapter 1, Theory of Operation, the measurement of a random spectrum is accomplished by averaging the vibration energy over a finite band of frequencies with maximum bandwidths ranging from 25 to 100 Hz. For example a +7 dB spike of 30 Hz duration at 1500 Hz in the sine sweep would increase the random spectrum in a 100 Hz bandwidth (1450 to 1550 Hz) by only +2 dB which would be within the required random spectrum tolerences. A tabulation of sine-random equivalents for different bandwidths when measured at the half signal level (-6 dB) is presented in Chapter 5, Table 5.2. The deviations noted during the sine sweep (after correction for compensation factors - para. 6.2.2), should be reduced by the bandwidth factor tabulated in Table 6-1 and 6-2. (but not to less than 0 dB, the nominal noise level).

Table 6-1 - Sine - Random Equivalents for Analysis Bandwidths (Maxima)

Frequency Range	Maximum Bandwidth	dB Change in Random Deviation Per Sine BW								
		10	20	30	40	50	60	75	100	150
20 to 200 Hz	25 Hz	-4	-1	0	0	0	0	0	0	0
200 to 1000 Hz	50 Hz	-7	-4	-2	-1	0	0	0	0	0
1000 to 2000 Hz	100 Hz	-10	-7	-5	-4	-3	-2	-1	0	0

6-2.2.3 Lower Tolerance Exclusions. Since reductions in amplitude, particularly at higher frequencies, do not threaten the structural integrity of the test article or the validity of the random test, we can apply less stringent tolerances in this region. Since most significant structural resonance occur below 1000 Hz, the allowable amplitude drop outs above 1000 Hz will be -12 dB with a maximum cumulative bandwidth of 300 Hz.

6-2.3 Non-Exclusion Area of the Spectrum. No exclusions from the upper tolerance band, (ref. Chapter 5, Table 5-1), will be permitted because of the potential for damage to the test article. Likewise no exclusions from the lower tolerance band (see Table 5-1) below 1000 Hz will be permitted since it may compromise the validity of the test as a quality control tool.

If amplitude deviations (in excess of the tolerance limits which cannot be disposed of or reduced in accordance with par. 6-2.2) are found, refer to the Troubleshooting Section, par. 6-3 for methods of isolating and correcting the cause of the tolerance deviations.

6-3 SYSTEM TROUBLESHOOTING. When it is clearly established that an out-of-tolerance acceleration density level in the random portion of the test exists, random testing should be postponed until the source of the problem is found and

TABLE 6-2 SINE-RANDOM EQUIVALENTS FOR ANALYSIS BANDWIDTHS (Minima)

Resonant BW / Filter BW	10			20			40			60			75		
	25	50	100	25	50	100	25	50	100	25	50	100	25	50	100
-1 dB	-.37	-.18	-.09	-.78	-.37	-.18	-	-.78	-.37	-	-	-.57	-	-	-.73
-2 dB	-.69	-.33	-.16	-1.52	-.69	-.33	-	-1.52	-.69	-	-	-1.09	-	-	-1.41
-3 dB	-.97	-.46	-.22	-2.21	-.97	-.47	-	-2.21	-.97	-	-	-1.54	-	-	-2.03
-4 dB	-1.20	-.56	-.27	-2.85	-1.20	-.56	-	-2.85	-1.20	-	-	-1.95	-	-	-2.61
-5 dB	-1.39	-.64	-.31	-3.44	-1.39	-.64	-	-3.44	-1.39	-	-	-2.29	-	-	-3.12
-10 dB	-1.94	-.86	-.41	-5.52	-1.94	-.86	-	-5.52	-1.94	-	-	-3.49	-	-	-4.88
-15 dB	-2.13	-.93	-.44	-6.47	-2.13	-.93	-	-6.47	-2.13	-	-	-3.78	-	-	-5.62
	-2.22	-.97	-.46	-6.98	-2.22	-.97	-	-6.98	-2.22	-	-	-3.98	-	-	-6.02

Example:

At a frequency of 1250 Hz, a spike of -5 dB (minima value) of 40 Hz bandwidth measured at the half signal level (+6 dB), will result in an equivalent random -1.39 dB spike when analyzed with a 100 Hz bandwidth filter.

corrective action applied. The specific troubleshooting methods to be utilized are discussed in two parts:

a. Troubleshooting aids

b. Troubleshooting guides

6-3.1 Troubleshooting Aids. In Chapter 1 it was directed that a reference tape be made to provide base-line data for use in troubleshooting. This tape will provide test signals for checking out the tape deck as well as sine transfer data for the vibration system without the test article. (fixture only).

6-3.1.1 Side A of the reference tape will consist of the tape deck frequency response sine sweep which was described in detail in Chapter 2.

6-3.1.2 Side B of the reference tape consists of a sine transfer characteristic tape, as described in Chapter 3, except that the test article was not installed on the vibration fixture. (fixture-only sine sweep)

6-3.2 Troubleshooting Guide. The following guide is intended to assist the test conductor in isolating the cause of some of the more obvious problems that could occur, when using the tape test technique. It does not provide an in-depth solution to these problems since many will require equipment repair or the preparation of new tapes. It is again stressed that the tape technique requires exact duplication of test conditions. Even minor variations may shift the dynamic characteristics of the setup beyond the compensation range of the tape. The variations must be corrected or a new tape synthesized to reflect the altered test conditions.

6-3.2.1 Isolating the Problem Area. All the anticipated problems can be isolated to three separate though interdependent systems:

a. Tape System

b. Vibration System

c. Test Article

These systems can be further sub-divided into subsystems as follows:

a. Tape System

- o tape deck
- o tape cassette

b. Vibration System

- o power amplifier and shaker
- o test fixtures
- o test instrumentation

c. Test Article

- o test article mechanical configuration
- o support equipment intefaces

6-3.2.2 *Troubleshooting Procedures.* In order to isolate the cause of a problem to a particular system or subsystem a series of verification checks should be made within the subsystem which reveal the source of the problem. Figure 6-3 is a troubleshooting guide for verifying the function of each subsystem. The sequential order in which the checks are performed must be determined on the basis of most probable cause for a particular test symptom. Table 6-2 presents a tabulation of possible test symptoms and a list of most probable causes.

Once the source of a problem has been isolated corrective action may be initiated. It is recommended that all troubleshooting on the vibration system be performed with the test article removed using the reference tape (fixture only sine sweeps). Testing with the test article should not be resumed until the

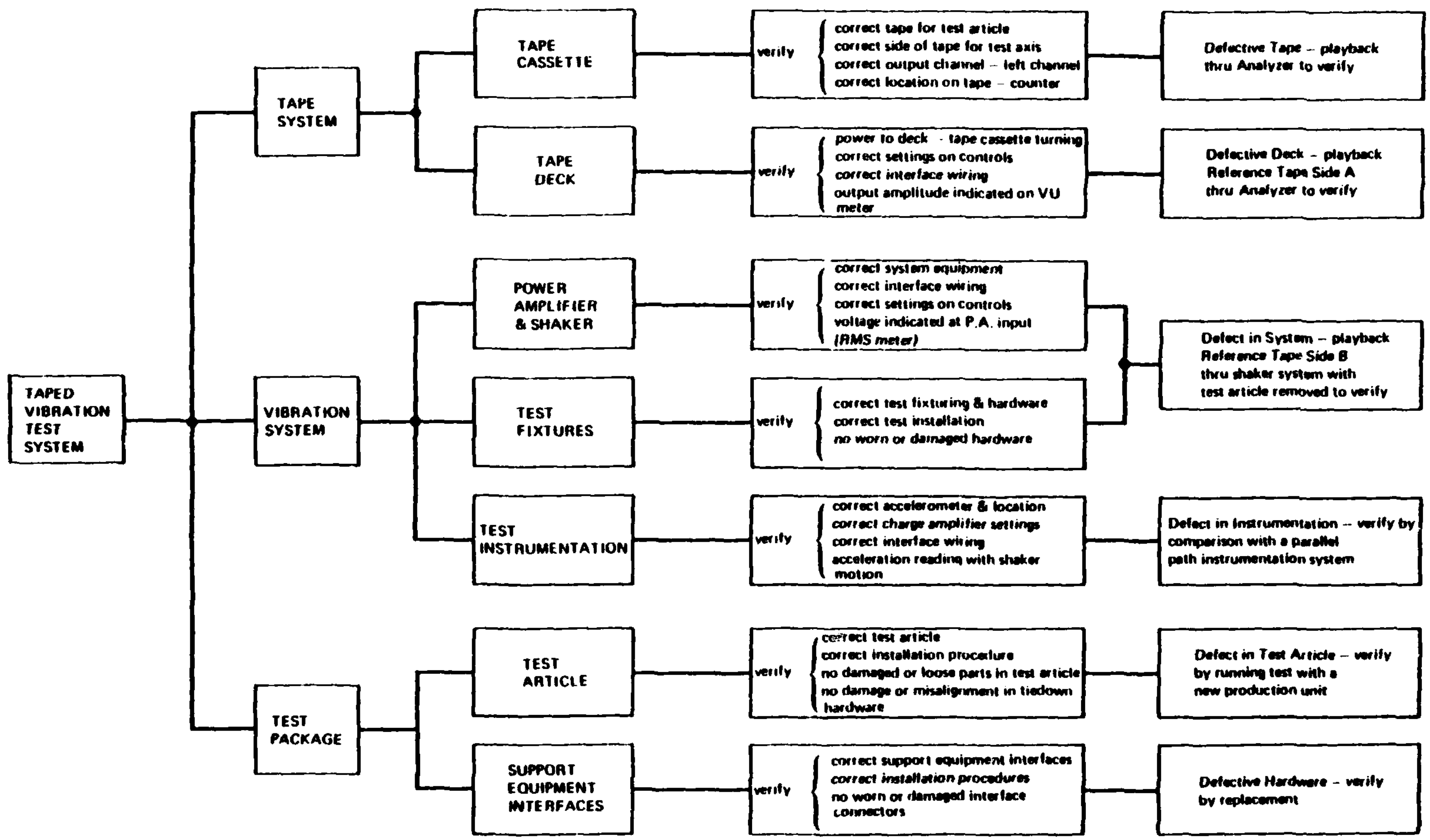

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Figure 6-3 Troubleshooting Guide

Table 6-3 Most Common Test Problems & Probable Causes

Test Symptom	Most Probable Causes (in decreasing order)	Comments
No vibration amplitude on shaker	1 – Tape Deck 2 – Tape Cassette 3 – Power Amplifier & Shaker	Check for output voltage from the tape deck.
Insufficient vibration level on shaker	1 – Tape Deck 2 – Test Instrumentation 3 – Power Amplifier & Shaker 4 – Tape Cassette	Insufficient gain – check settings of all gain controls and shaker field current.
Over-all level too high or low but within tolerance	1 – Test Article 2 – Test Fixtures 3 – Support Equipment Interface	Probably shift in response characteristics at gain reference frequency. Will not affect random test results.
Minor out-of-tolerance acceleration levels	1 – Test Fixtures 2 – Test Article 3 – Support Equipment Interface 4 – Power Amplifier & Shaker 5 – Tape Deck 6 – Tape Cassette 7 – Test Instrumentation	Probably a shift in response characteristics caused by minor variations in mechanical setup of vibration system.
Major out-of-tolerance acceleration levels	1 – Tape Cassette 2 – Test Fixtures 3 – Test Article 4 – Power Amplifier & Shaker 5 – Support Equipment Interface 6 – Tape Cassette 7 – Test Instrumentation	Most probable cause would be the wrong tape being used. Variations in the mechanical setup is also a strong possibility.
Abrupt change in random vibration level	1 – Test Article 2 – Test Fixtures 3 – Power Amplifier & Shaker 4 – Tape Deck 5 – Support Equipment Interface 6 – Tape Cassette 7 – Test Instrumentation	Very possibly will indicate a mechanical failure of the test article or its attachment hardware.
Vibration Amplitude on shaker but no acceleration level on RMS voltmeter	1 – Test Instrumentation	Accelerometer not connected to the charge amplifier is most likely cause

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fixture-only sine sweeps produce in-tolerance results.

In cases where the problem cannot be resolved, but the response characteristics appear repeatable, a new tape should be made following the procedures outlined in previous chapters. This might be the case where a pre-existing vibration system problem such as a weak output tube, misaligned slip table, etc. is detected during maintenance and corrected. It would be good practice to run the fixture-only reference tape after any major maintenance or repair procedures are performed on the vibration system in order to detect this type of problem before production tests are run.

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