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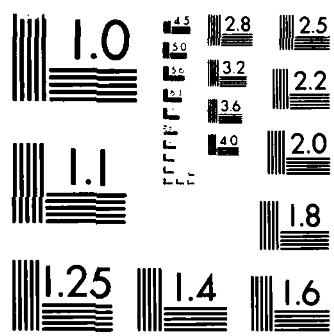

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Monterey, California

THESIS

VIBRATION ISOLATION OF A MICROPHONE

by

Charles Douglas Stehle

September 1985

Co-advisors: S. L. Garrett
O. B. Wilson

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A microphone vibration isolation system using a bungee elastic suspension, designed for use in a system (NASA Project G-313) to measure the ambient noise in the Space Shuttle's payload bay during launch is described. The isolator's transmissibility was measured using a computer controlled shaker table system programmed to simulate the Shuttle's vibrational spectrum in 21 third octave bands between 20 and 2000 Hertz. Static deflection and transient

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) response measurements verified the axial and radial transmissibility measurements. Free decay measurements were made at 5,20, and 65 °C. The isolator's natural frequency of 15 Hertz represents a substantial improvement over the isolator used previously whose lowest resonance was above 100 Hertz. Test procedures and calibration data for three microphones are included.

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Vibration Isolation of a Microphone

by

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Commander, United States Navy
B.S., United States Naval Academy 1968

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN ENGINEERING ACOUSTICS

from the

NAVAL POSTGRADUATE SCHOOL
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ABSTRACT

A microphone vibration isolation system using a bungee elastic suspension, designed for use in a system (NASA Project G-313) to measure the ambient noise in the Space Shuttle's payload bay during launch is described. The isolator's transmissibility was measured using a computer controlled shaker table system programmed to simulate the Shuttle's vibrational spectrum in 21 third octave bands between 20 and 2000 Hertz. Static deflection and transient response measurements verified the axial and radial transmissibility measurements. Free decay measurements were made at 5,20, and 65 °C. The isolator's natural frequency of 15 Hertz represents a substantial improvement over the isolator used previously whose lowest resonance was above 100 Hertz. Test procedures and calibration data for three microphones are included.

THESIS DISCLAIMER

The reader is cautioned that computer programs developed in this research may not have been exercised for all cases of interest. While every effort has been made, within the time available, to ensure that the programs are free of computational and logic errors, they cannot be considered validated. Any application of these programs without additional verification is at the risk of the user.

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I. INTRODUCTION

A. BACKGROUND

This thesis presents information on the development of a system to individually isolate three Endevco Model 2510 Transducers (microphones) from structure borne vibrations existing in the Space Transportation System (STS) Orbiter Vehicle's payload bay. Procedures for calibrating the microphones are also presented. The isolated microphones will be used to measure the acoustic characteristics of the payload bay as part of NASA Project G-313. The project was conceived from concern that earlier payloads may have been and future payloads may be damaged by airborne noise. The experiment will measure acoustic characteristics of the payload bay before and during launch. Results should be useful in predicting the acoustic environment in the payload bay.

During liftoff and atmospheric flight acoustic energy will be generated by:

- airflow over the airframe,
- main engine and solid rocket boosters, and
- airflow into and out of the bay through vents.

If the frequencies of these sources coincide with frequencies of resonance within the payload bay, acoustic levels inside the payload bay will be amplified. These frequencies and energy levels will be of particular concern. A resonance may occur in the payload bay if the acoustic wavelength at a source frequency is related to the dimension of the bay. For example, by assuming the payload bay to be a right circular cylindrical cavity with perfectly rigid boundaries the trapped energy will not be able to escape. The energy density will increase until the rate of energy losses at the boundaries, or in the medium, equals the rate acoustic energy is being generated. If wavelengths of the source are related to the dimensions of the cavity by integer or Bessel multipliers then a resonance may be excited in the cavity. Standing waves at these wavelengths and resonant frequencies will have greatly magnified pressure magnitudes and the pressure of any resulting acoustic waves may be large enough to have the potential to damage payloads.

The acoustic characteristics of the payload bay will be determined in three phases:

1. Prelaunch. The normal modes of the payload bay will be studied by exciting the standing waves of the bay's resonant frequencies with a loud speaker and swept tone from 18 to 1024 Hertz.
2. Launch. Acoustic pressures and frequencies will be measured and recorded for the first 10 seconds of flight.
3. Post Flight. Launch frequencies will be compared to prelaunch resonant frequencies in an effort to isolate source frequencies from payload bay resonant frequencies. An attempt will then be made to determine the source of tones recorded during launch.

This analysis of frequencies, pressure magnitude, and source will be useful in determining structural requirements for future shuttle payloads.

B. PREVIOUS ACOUSTIC MEASUREMENTS

Earlier NASA directed studies of the payload bay acoustic properties used analytical models and recorded flight data. The analytical model predicted the payload bay acoustic environment for a given exterior acoustic field. The payload bay was modeled with and without payloads and in each case with and without sound absorbing materials on the bulkheads. The Payload Acoustic Environment for Shuttle (PACES) computer program and a one-quarter scale model were used to determine the effect of payloads on the payload bay acoustic environment. These tests predicted that the magnitude of pressure waves would increase as dimensions of the payload increased [Ref. 1].

Actual vibro-acoustic data have been acquired and reported by the NASA Dynamic, Acoustic, and Thermal Environment (DATE) Activity. This data base consists of data recorded on DATE instrumentation, and the Development Flight Instrumentation system. Instrumentation included low and high frequency accelerometers on STS flights Two through Five, and microphones and high frequency accelerometers on STS flight Nine. Results indicated that the pressure equalization vents were a source of discrete frequency components between 280 and 340 hertz, with some tones at sound pressure levels high as 134 dB (re 20 μPa), [Ref. 2 : pp. 3, 17].

C. DEFICIENCIES IN EARLIER DATA

As reported in [Ref. 2 : p. 79], DATE activity noted data deficiencies include :

- lack of data from the foreward one-third of the payload bay,
- lack of data on transonic acoustic environment due to vent noise,
- unknown effects of launch vehicle configuration and changes in payload,
- unknown effects of launch site pad and terrain at Kennedy Space Center and Vandenberg Launch Site,
- possible error in microphone data due to mounting close to bulkhead and housing the microphone in a partial enclosure, and
- possible misinterpretation of DATE microphone data due to interaction of the microphone and the isolation system.

D. PREVIOUS MICROPHONE VIBRATION ISOLATOR

Since this is a report on the development of a new microphone mounting, a comparison with the mount used in earlier noise measurement is of interest. Because the previously used mount was not available estimates of its properties were obtained from a photograph, some material properties, and simple vibration isolator design theory. Figure 1.1 shows a Goddard Space Flight Center vibration isolated microphone used to gather acoustic data on a previous STS flight. The isolation system consists of a fixed-free mass loaded bar. The masses are a microphone and an equivalent mass, both attached to mounting plates which are affixed to a silicone rubber material that acts as a complex spring to provide a restoring and damping force. The resonant frequency was estimated using measurements taken from the photograph.

- Photo scale, .7 mm = 1 cm
- One mounting plate, 5 x 1.5 x .4 cm
- One mounting plate, aluminum, density = 2.7 gr/cm ^{2}
- One mounting plate, mass ,Mp = 8 grams
- One rubber isolator pad,L,W,t = 1.5 x 1.5 x .5 cm
- One rubber pad, mass Mi = negligible
- Rubber pad Durometer A30, shear modulus G = 3.5 x 10^5 Pascal
- Loss tangent = unknown
- One microphone, mass, Mm = 60 grams

Based on the shear modulus of elasticity, the effective Young's modulus stated in [Ref. 3 : p. 3] for one isolating pad is

$$E_{eff} = (1+\beta S^2)\,3\,G \qquad (1.1)$$

where for a rectangular pad

$$\beta = 2 \qquad (1.2)$$

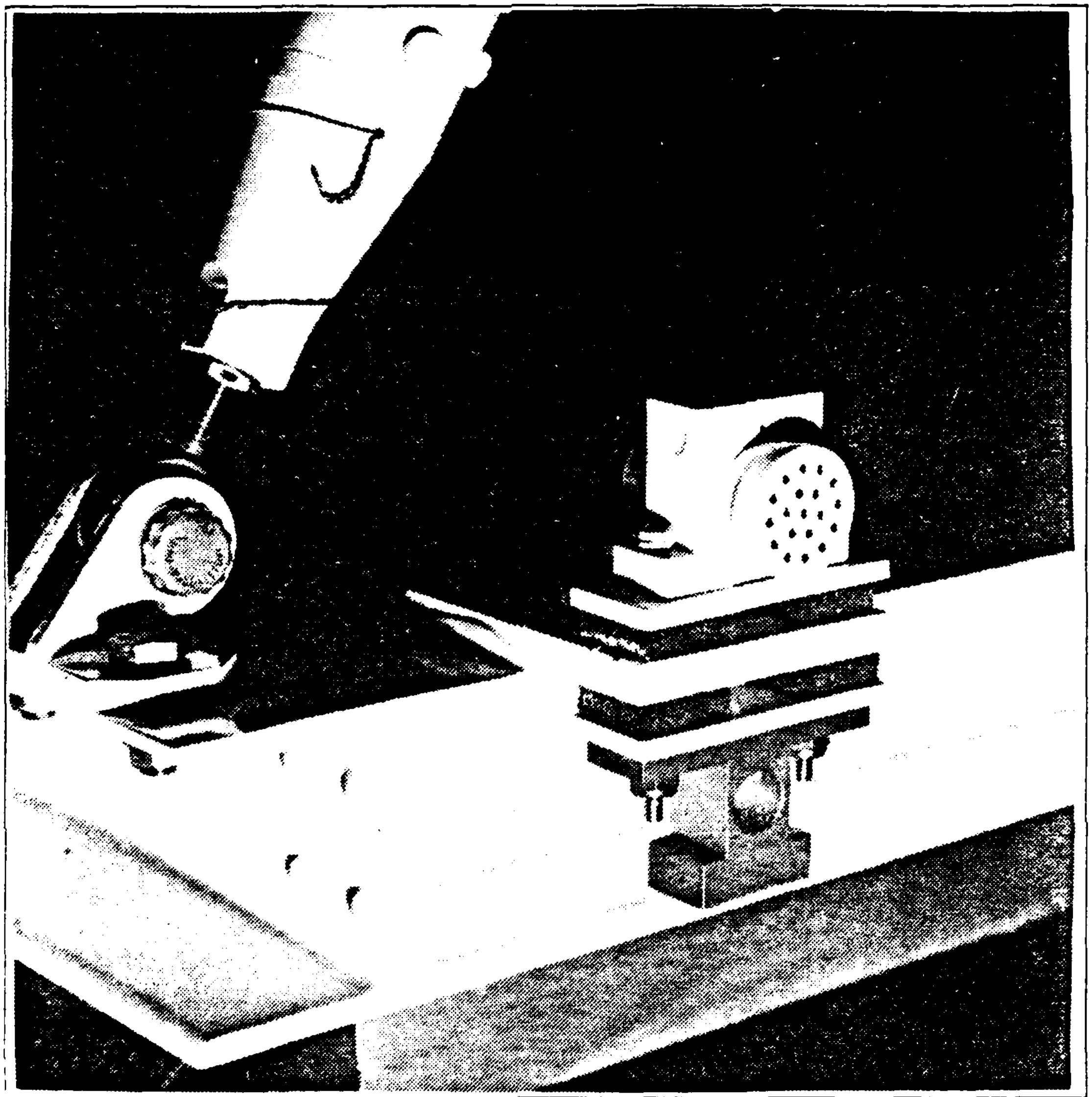

Figure 1.1 Microphone and GSFC Mount

and

$$S = \frac{\text{Area of one loaded face, } A = LW}{\text{total unloaded surface area, } 2(Lt + Wt)} \tag{1.3}$$

yielding

$$E_{eff} = 22 \times 10^5 \text{ Pascal} \tag{1.4}$$

Using this effective modulus, an equivalent compression stiffness may be calculated:

$$k_{\text{single pad}} = \frac{AE_{\text{eff}}}{t} \tag{1.5}$$

where 'A' is the area of one loaded surface and 't' is the distance between loaded surfaces. Thus

$$k_{\text{compression}} = 2k_{\text{single pad}} = 200 \times 10^3 \text{ N/m} \tag{1.6}$$

A resonant compression frequency is then calculated using the well known equation:

$$f_{\text{compression}} = \frac{1}{2\pi}\sqrt{k_{\text{compression}}/(Mm+Mp)} = 270 \text{ Hertz} \tag{1.7}$$

Similarly, for shear, the stiffness is:

$$k_{\text{shear}} = \frac{Glw}{t} = 35 \times 10^3 \text{ N/m} \tag{1.8}$$

and

$$f_{\text{shear}} = \frac{1}{2\pi}\sqrt{k_{\text{shear}}/(Mm+Mp)} = 110 \text{ Hertz} \tag{1.9}$$

As discussed in Part II, Theory, this implies that the isolator was, in fact, an amplifier in the frequency ranges of interest. In a recent contractor analysis of the isolator [Ref. 4 : pp. 1-3], resonant frequencies were measured to be approximately 100 Hertz in compression, and shear.

E. GET AWAY SPECIAL CONTAINER (GAS CAN)

Apparatus to measure and record the payload bay vibro-acoustic data is mounted in a GAS CAN, which in turn will be mounted on the forward bulkhead of the shuttle payload bay (Figure 1.2). The G-313 GAS CAN, is a standard five cubic foot cylindrical container, with a specially modified outer lid, and an additional specially fabricated inner pressure lid. The GAS CAN described in [Ref. 5 : p. 12] is made of aluminum throughout, and pressurized to maintain about one atmosphere of pressure. The standard lid was modified to house the three microphone isolation units, a speaker, and a Helmholz tube illustrated in Figure 1.3.

The inner pressure lid is an eight-inch deep flanged cap that mounts below the outer lid, and encloses the loud speaker sound source and three microphones mounted on the outer lid. This inner lid provides the pressure seal for all contents not mounted on the outer lid. Details of the electronic package, bubble memory unit, and power supply shown are discussed in other NPS Theses that support Project G-313. The mounting of these units in the GAS CAN is illustrated in Figure 1.4.

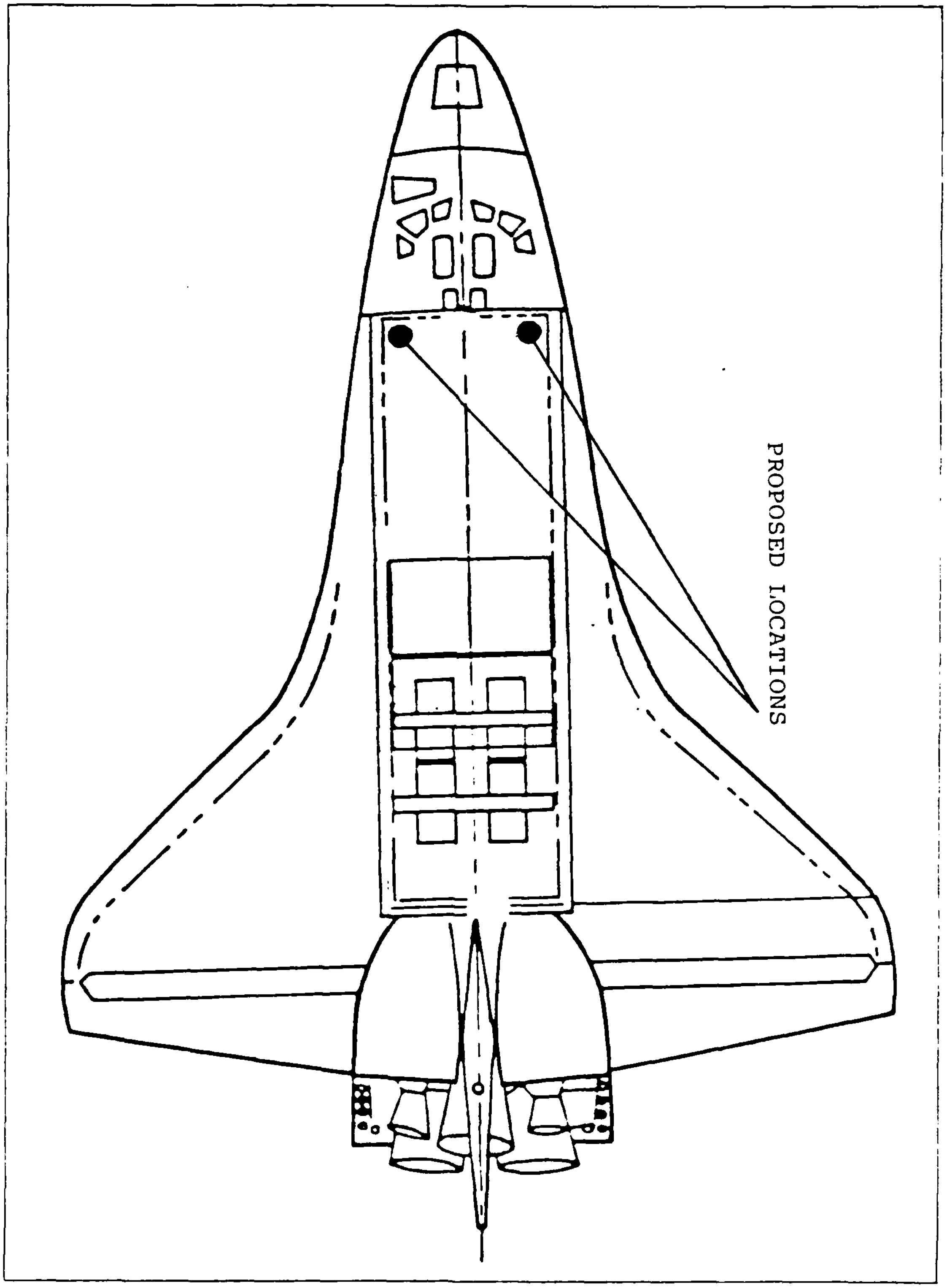

Figure 1.2 GAS CAN Location in Payload Bay

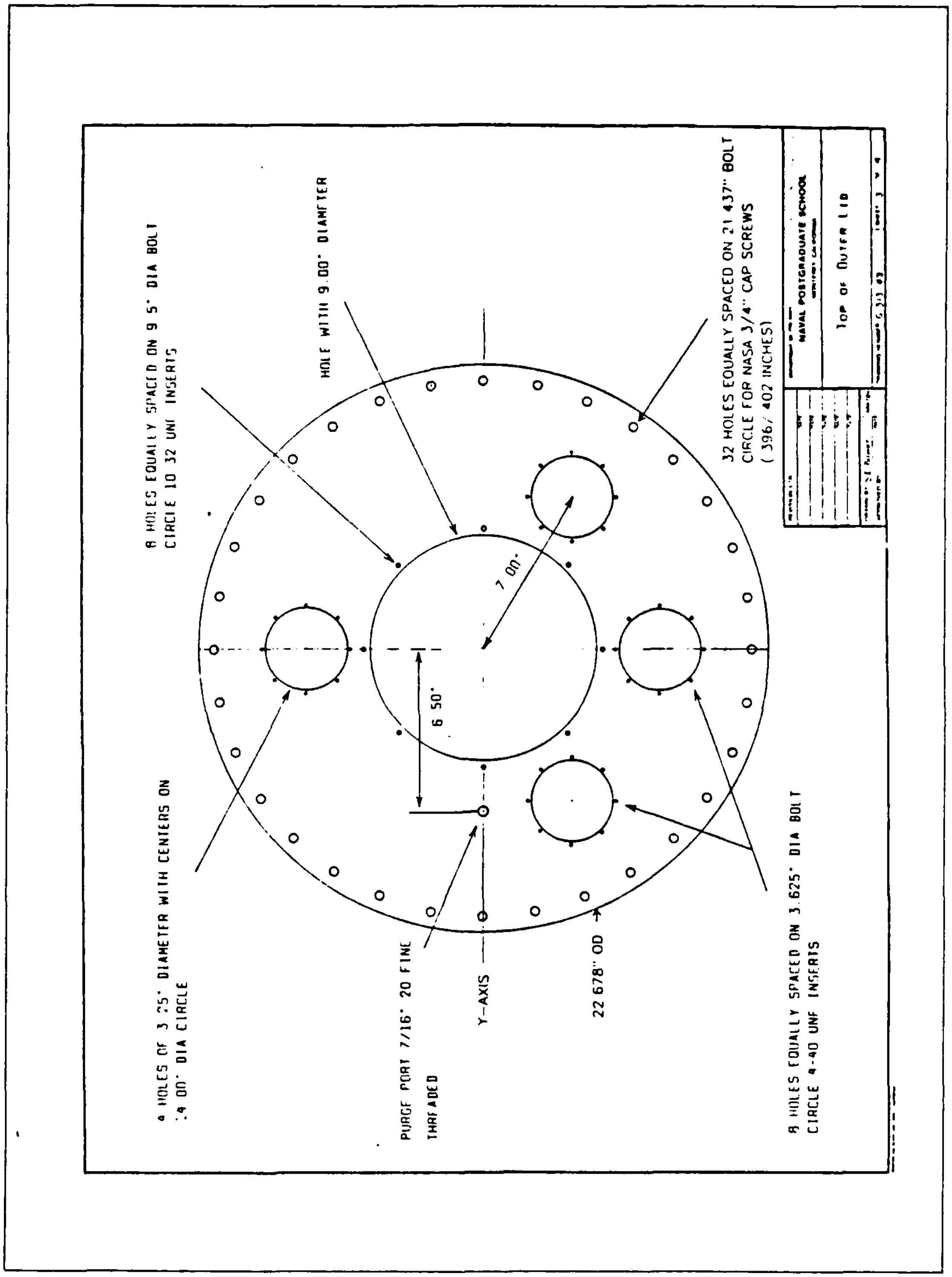

Figure 1.3 Modified GAS CAN Lid

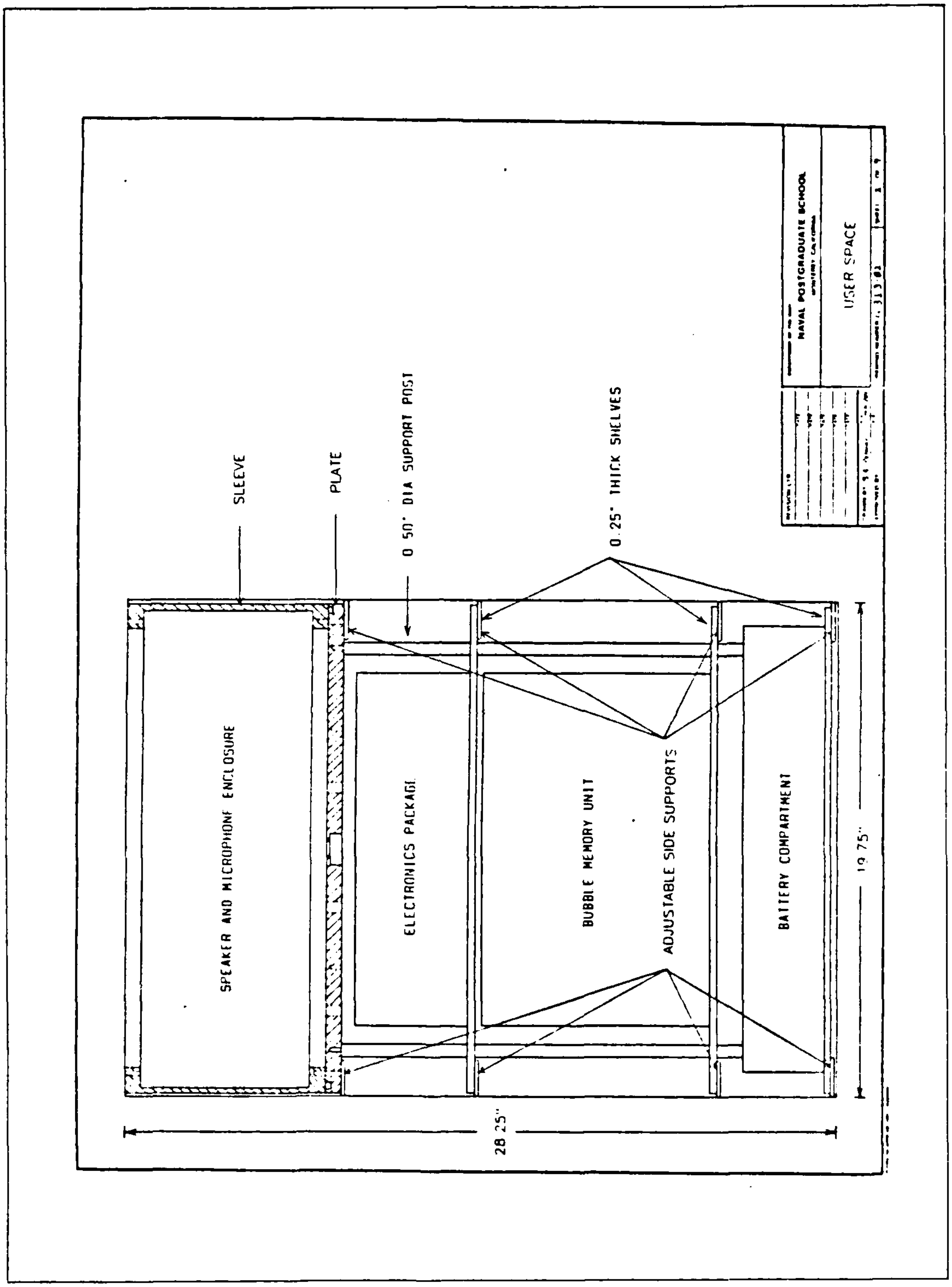

Figure 1.4 GAS CAN

II. THEORY

A. ISOLATION REQUIREMENTS

Figure 2.1 shows the maximum acceleration spectral density from random structure borne vibrations to which GAS payloads may be exposed. [Ref. 5 : p. 57]. These vibratory loads can interfere either constructively or destructively with airborne acoustic signals.

The specification for the vibration sensitivity of the model 2510 ENDEVCO microphone is the equivalent of 105 dB SPL, (re 20 μPa), at one peak g. Based on the vibration spectrum, the microphones will be exposed to a peak accleration of at least 7.5g. This results in an equivalent acoustic level of 123 dB SPL, a level that would be significant if purely acoustic.

RMS acceleration (g loads) for one third octave band center frequencies, f_c, were derived from figure 2.1 by first computing the bandwidth (BW), and then computing the g load:

$$BW = f_c(2^{1/3} - 1)2^{-1/6} \tag{2.1}$$

and for frequencies between 20 and 80 Hertz :

$$g\ \text{load} = \sqrt{.125(BW)(f_c)/80} \tag{2.2}$$

between 80 and 1000 Hertz:

$$g\ \text{load} = \sqrt{.125(BW)} \tag{2.3}$$

and between 1000 and 2000 Hertz:

$$g\ \text{load} = \sqrt{.125(BW)(1000)/f_c} \tag{2.4}$$

Table I lists the equivalent single frequency RMS g loads for one third octave band frequencies from 20 to 2000 Hertz and the corresponding bandwidths. The response of the

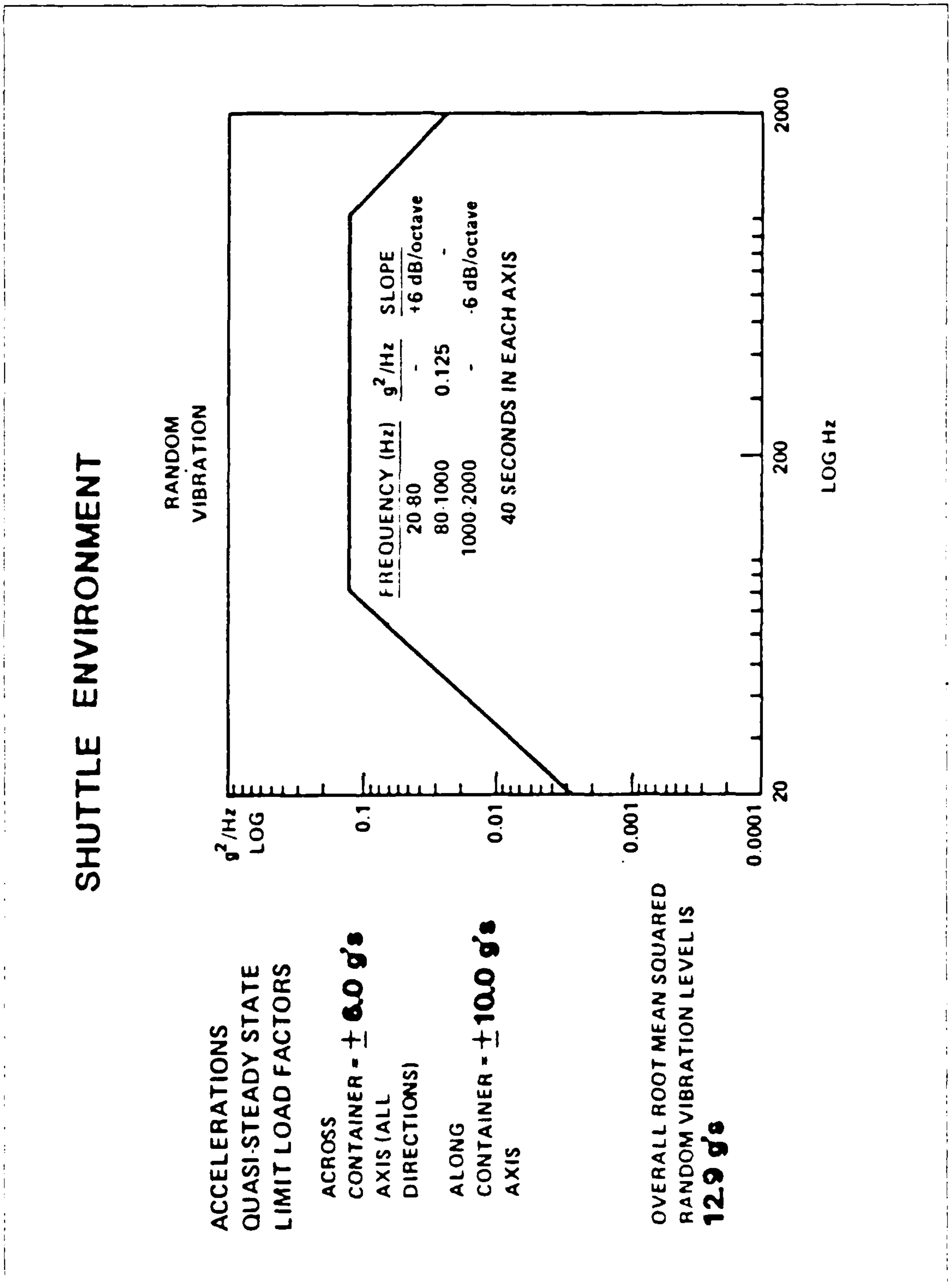

Figure 2.1 Payload Bay Random Vibro-Acoustic Acceleration Spectral Density

microphones to these vibration induced structural g loads may be reduced by mounting each microphone in a vibration isolation device.

TABLE I

VIBRATION G LOADS FOR SHUTTLE PAYLOADS

FREQ (HZ)	BAND WIDTH (HZ)	G LOAD (RMS)
20.0	4.6	.38
25.0	5.8	.48
31.5	7.3	.60
40.0	9.3	.76
50.0	11.6	.95
63.0	14.6	1.20
80.0	18.5	1.52
100.0	23.2	1.70
125.0	28.9	1.90
160.0	37.1	2.15
200.0	46.3	2.41
250.0	57.9	2.69
315.0	72.9	3.02
400.0	92.6	3.40
500.0	115.8	3.80
630.0	145.9	4.27
800.0	185.3	4.81
1000.0	231.6	5.38
1250.0	289.5	5.38
1600.0	370.5	5.38
2000.0	463.1	5.38

B. SINGLE DEGREE OF FREEDOM ISOLATORS

A single degree of freedom isolator requires only one axis of a coordinate system to describe the motion. As stated in [Ref. 3 : p. 22], the equation of motion for the mass of the simple spring mass damper system with a moving foundation shown in Figure 2.2 is :

$$m\ddot{x} + c(\dot{x} - \dot{y}) + k(x - y) = 0 \qquad (2.5)$$

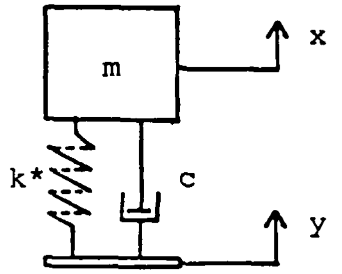

Figure 2.2   Simple Spring Mass Damper System

and if

$$z = x - y \tag{2.6}$$

and the foundation oscillates according to :

$$y(t) = Y_0 \cos \omega t \tag{2.7}$$

then

$$\ddot{z} + \frac{c}{m}\dot{z} + \frac{k}{m}z = \omega^2 Y_0 \cos \omega t \tag{2.8}$$

where

- X_o is the peak amplitude of the mass's displacement
- x is distance the mass is displaced
- Y_o is the peak amplitude of the foundation's displacement
- y is distance the foundation is displaced
- m is the mass of the object supported
- c is the damping coefficient
- k is the real spring constant or stiffness
- ω_n is the undamped natural resonant frequency
- ω is the angular frequency of the oscillating foundation

and

$$\omega_n = \sqrt{k/m} \tag{2.9}$$

In non-dimensional form this is:

$$\ddot{z} + \xi\omega_n^2 \dot{z} + \omega_n z = \omega^2 Y_0 \cos \omega t \tag{2.10}$$

where ξ is the viscous damping ratio

$$\xi = \frac{c}{c_c} \tag{2.11}$$

and

$$c_c = 2\sqrt{mk} \tag{2.12}$$

is the critical damping coefficient or that value of damping coefficient above which no oscillations occur. To solve this equation we must determine either ξ and ω_n, or the damping coefficient and the static spring constant.

1. Complex Spring Constant

Rubber materials provide both stiffness and damper characteristics, which may be represented by a complex spring constant, k*. As developed in [Ref. 3 : p. 22] and [Ref. 6 : pp. 4.8-4.11],

$$G_\omega^* = G_x(1 + j\delta) \tag{2.13}$$

where G* is the complex shear modulus of the material at frequency ω. Then

$$k^* = kG^* \tag{2.14}$$

where k, as stated in [Ref. 3 p. 23], is a geometric factor with dimensions of length. For compression

$$k_{compression} = \frac{(1+\beta S^2)\,3A}{t} \tag{2.15}$$

and for shear

$$k_{shear} = \frac{A}{t} \tag{2.16}$$

A, β, S and t are as described in equations 1.2, 1.3, 1.5. δ, the loss tangent, is the ratio of the imaginary to real modulus as shown in Figure 2.3.

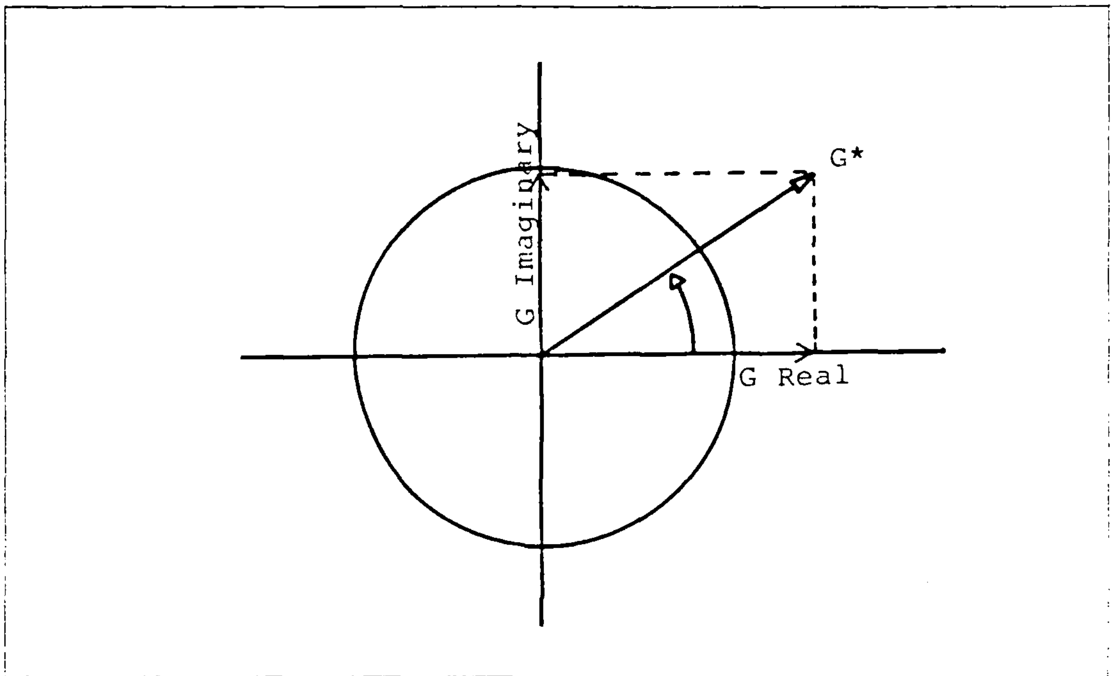

Figure 2.3 Complex Modulus of Elasticity

δ is also referred to as the loss factor and in many materials may be a function of frequency. It can be shown that for $\xi<.3$ that $\delta=2\xi$ [Ref. 3 : p. 3] Figure 2.4 is a simple system using a complex spring.

2. Viscous Damping Ratio

The solution to the homogenous equation of motion for the case where $\xi<1$ is a damped sinusoid that oscillates at the damped resonant frequency ω_d and decays exponentially from the initial displacement according to :

$$x(t) = X_0 e^{-\xi\omega_n t} \sin(\omega_d t + \phi) \tag{2.17}$$

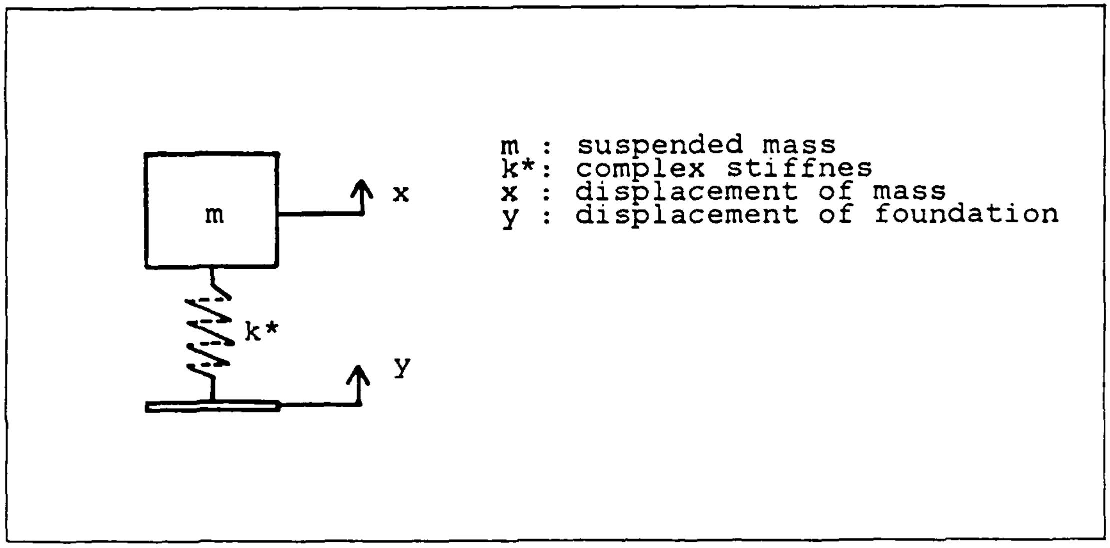

Figure 2.4 Complex Spring System

This represents the free vibrations of a damped system. The degree of damping, ξ, may be determined experimentally by logarithmic decrement techniques. The log decrement, Δ, is the natural logarithm of the ratio of amplitudes of two successive cycles of the damped free vibrations:

$$\Delta = \ln\frac{x_1}{x_2} \tag{2.18}$$

where

$$x_1 = X_0 e^{-\xi\omega_n t} \tag{2.19}$$

and

$$x_2 = X_0 e^{-\xi(\omega_n t + 2\pi)} \tag{2.20}$$

then

$$\frac{x_1}{x_2} = \frac{X_0 e^{-\xi\omega_n t}}{X_0 e^{-\xi(\omega_n t + 2\pi)}} \tag{2.21}$$

this reduces to

$$\frac{x_1}{x_2} = e^{\xi 2\pi} \tag{2.22}$$

so that

$$\Delta = \ln e^{\xi 2\pi} \tag{2.23}$$

thus

$$\xi = \frac{\Delta}{2\pi} \tag{2.24}$$

3. Transmissibility

The isolation system will be excited by shuttle vibrations that are equivalent to either a time variable force F(t) or displacement y(t) acting on the base of the microphone isolator. In either case, the transmissibility ϵ(dB) as developed in [Ref. 7 : p. 80] and [Ref. 3 : p. 27] will be :

$$\epsilon_{(dB)} = 20 \log \frac{\text{Force transmitted to microphone}}{\text{Force applied to base}} = 20 \log \frac{x}{y} \tag{2.25}$$

For the viscous damper the transmissibility is

$$\epsilon_{(dB)} = 10 \log \frac{1 + (2\xi \frac{\omega}{\omega_n})^2}{\{1 - (\frac{\omega}{\omega_n})^2\}^2 + (2\xi \frac{\omega}{\omega_n})^2} \tag{2.26}$$

and for the complex spring it is

$$\epsilon_{(dB)} = 20 \log \left[\frac{1 + \delta_\omega^{\,2}}{\left\{1 - \left(\frac{\omega}{\omega_n}\right)^2 \frac{G_0}{G_\omega}\right\}^2 + \delta_\omega^{\,2}} \right]^{1/2} \tag{2.27}$$

where ω is the operating frequency. For a rubber of Type I, [Ref. 3 : p. 27], the loss tangent is about .1 ,the shear modulus is independent of frequency and

$$G_0 = G_\omega^* \tag{2.28}$$

The isolators discussed in this report were analyzed using both viscous and complex models. The results are compared in Chapter IV.

III. EXPERIMENTAL APPARATUS

Experiments to measure the microphone's vibration response, and the transmissibility of the isolation systems employed a shaker table, a wave form generator, dual channel spectrum analyzer, two low noise preamps, three accelerometers, and an anechoic chamber. Microphone calibration and comparison, free decay, and environmental tests did not require the shaker table. A computer controlled interactive program was written to drive the shaker table and record results. Figure 3.1 is a block diagram of the apparatus as well as lines of control and information flow. A copy of the program is in Appendix A.

A. VIBRATION EXPERIMENTS

Vibration experiments were performed to determine the response of the microphones to vibration and the transmissibility of the isolation system.

1. Shaker Table

The Model 120-S PERMA DYNE Shaker Table was the primary experimental apparatus. The unit is an electrodynamic shaker that was used to produce sinusoidal acceleration wave forms. The force generated by the shaker was proportional to the instantaneous current supplied by the APS Model 114 Power Amplifier. The shaker used a symmetrical permanent magnet circuit for maximum force/current linearity and minimum stray field. The shaker table was used to vibrate both the microphones, and the vibration isolation system at the one-third octave band frequencies and g loads listed in Table I. Microphones were vibrated radially in both the X and Y lateral directions across the face of the microphone and in the axial, or Z longitudinal, direction perpendicular to the face of the microphone. The

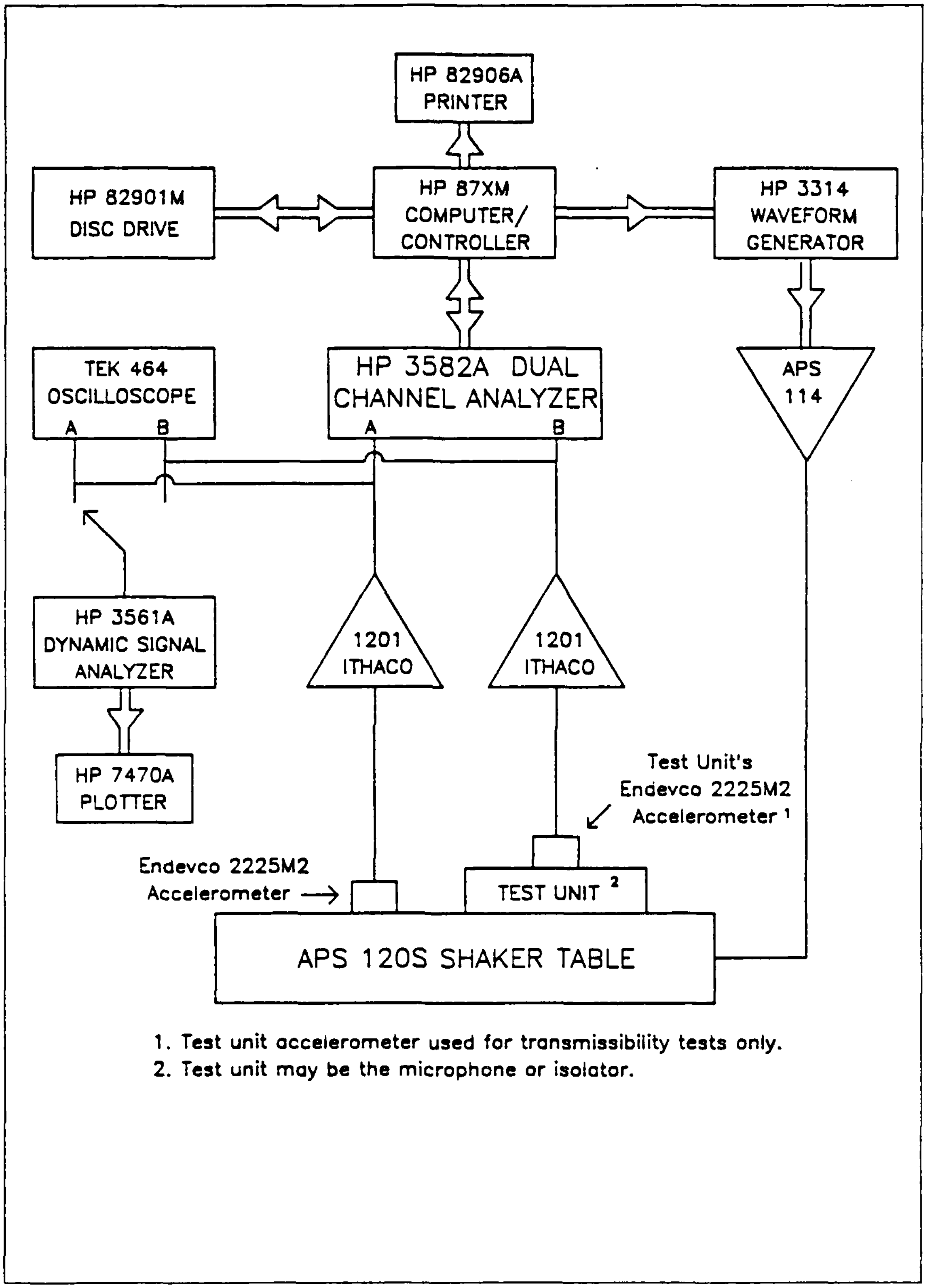

Figure 3.1 Experimental Apparatus

isolation system was vibrated in the radial (X lateral) and axial (Z longitudinal) directions.

2. <u>Preamplifiers</u>

Two low noise ITHACO amplifiers amplified the microphone and accelerometer output voltages by a factor of 100 during shaker table tests and by 10 during free decay tests. A bandwidth was selected to pass frequencies between 3 and 3000 Hertz during shaker tests and between 3 and 30 Hertz during free decay tests. The preamps were always operated on "BATTery" to reduce electronic noise. Line losses to the preamps were accounted for in the control program by using voltage divider techniques on the circuit shown in Figure 3.2.

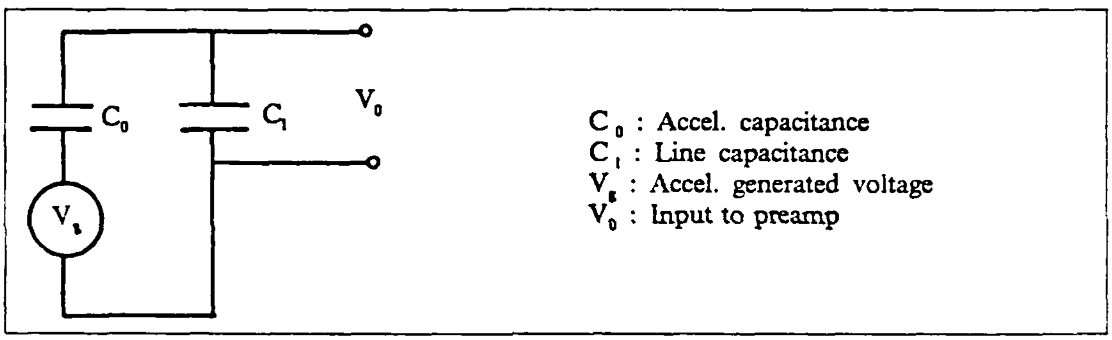

Figure 3.2 Microphone-Amplifier Circuit

The acceleration sensitivity was determined using the manufacturer's charge sensitivity and capacitance as follows:

$$\frac{1}{m} = \frac{V}{g} = \frac{Q/g}{C} = \frac{.717 \text{ pC/g}}{830 \text{ pf}} = 8.64 \times 10^{-4} \text{ V/g} \qquad (3.1)$$

so that

$$m = 1158 \text{ g/V} \qquad (3.2)$$

Applying the voltage divider equation the voltage due to acceleration (V_g) is determined:

$$V_g = \left(\frac{C_a + C_l}{C_a} \right) V_0 = 1.398\, V_0 \qquad (3.3)$$

then the accelerometer's acceleration or g load is

$$a = V_g m = 1.398\, V_0 (\, 1158 \text{ g/V}\,) = 1618\, V_0 \qquad (3.4)$$

3. Accelerometers

Three ENDEVCO Model 2225M2 accelerometers were used to determine the shaker table g load, isolated microphone replica g loads, and to measure the amplitude and frequency spectrum during free decay tests of the vibration isolation system. The specifications for each accelerometer are in Table II.

TABLE II

ACCELEROMETER SPECIFICATIONS

Serial Number	Charge Sensitivity (pC/g)	Capacitance (pF)	Transverse Sensitivity (% max)	Voltage Sensitivity (mV/g)*
FD 95	.717	830	.8	.618
FA 27	.728	820	.7	.633
FA 15	.717	792	.7	.639

*Includes line loss capacitance = 308.3 +/- 7.5 pf.

4. Oscilloscope

A Tektronix Model 464 Oscilloscope was used to monitor the shaker table and test item accelerometer output wave forms for erratic behavior. The oscilloscope was not computer controlled.

5. <u>Computer Controlled Apparatus</u>

An HP-87XM desk top computer was used to control frequency and voltage inputs to the shaker amplifier, and to obtain the required g load from the shaker table. At the required g load the computer controlled equipment measured, recorded, and printed the microphone output voltage response, or isolator transmissibility, and test item data. Figure 3.3 is a sample printed output.

a. Hewlett-Packard HP-87XM

The HP-87XM Series 80 Personal Computer contains 124K bytes of memory, and was fitted with Input/Output and Plotter ROM's. Mass storage and printed output were provided via HP-IB connections to an 82190A Flexible Disc Drive (two drives), and an HP-82906A Printer, respectively.

b. Hewlett-Packard HP 3314A Function Generator

The Function Generator was used to provide continuous sine waves to the shaker amplifier at frequencies and voltages controlled by the HP-87XM via the HP-IB.

c. Hewlett-Packard HP3582A Spectrum Analyzer

The HP-3582A is a dual channel spectrum analyzer that provides simultaneous frequency and voltage analysis of dual inputs. It was controlled via the HP-IB from the HP-87XM to take four samples of the accelerometer voltage measuring shaker table loads, then measure the RMS average amplitude of this voltage. If, based on manufacturer's calibration and line losses, the accelerometer voltage corresponded to the required g load, the computer directed the analyzer to read the output voltage of the test item at that frequency. If the g load was too low or too high a corresponding linear adjustment of the function generator's output voltage was made and the entire process repeated. Required g load tolerance was selected interactively.

Channel A read shaker table g load voltage, and Channel B read test item voltages. In the dual channel

ITEM RESPONSE TO VIBRATION

VIBRATION IS PARALLEL TO THE FACE OF ITEM;Y LATERAL AXIS

ITEM NAME:	MICROPHONE
MANUFACTURER:	ENDEVCO
PART NO.:	GC1346742-11-031
SERNO:	BJ66
DATA FILE NAME:	YBJ6611:D701
DATA DISC LABEL:	C

FREQ (HZ)	ITEM VOLTS (uV)	SPL/ XMISS (DB)	INPUT VOLTS (MV)	ACCEL VOLTS (MV)	REQ'D G LOAD (G's)	OBS G LOAD (G's)	NO. TRIES
20.0	4.0	79.39	303.0	.234	.38	.38	3
25.0	2.4	75.16	227.0	.297	.48	.48	3
31.5	7.0	84.34	156.0	.370	.60	.60	2
40.0	11.9	88.92	97.9	.470	.76	.76	2
50.0	10.1	87.50	97.7	.587	.95	.95	2
63.0	10.1	87.50	166.0	.735	1.20	1.19	3
80.0	12.8	89.56	272.0	.932	1.52	1.51	2
100.0	11.9	88.92	359.0	1.050	1.70	1.70	3
125.0	12.5	89.35	441.0	1.170	1.90	1.89	2
160.0	11.9	88.92	541.0	1.320	2.15	2.14	2
200.0	20.4	93.60	636.0	1.480	2.41	2.39	2
250.0	60.4	103.03	735.0	1.650	2.69	2.67	2
315.0	85.4	106.04	755.0	1.870	3.02	3.03	2
400.0	58.9	102.81	853.0	2.100	3.40	3.40	2
500.0	59.2	102.86	920.0	2.350	3.80	3.80	2
630.0	63.2	103.43	938.0	2.640	4.27	4.27	2
800.0	69.0	104.19	848.0	2.980	4.81	4.82	2
1000.0	61.6	103.20	584.0	3.340	5.38	5.40	2
1250.0	141.0	110.40	86.8	3.320	5.38	5.37	2
1600.0	211.0	113.90	760.0	3.320	5.38	5.37	3
2000.0	158.0	111.38	1422.0	3.330	5.38	5.39	3

OVERALL BAND SPL: 118.2 DB. REF LEVEL 4.26mV @ 140 DB.

COMMENTS:
SPL/XMISS: READ 'SPL' FOR MEASURED VOLTAGE RESPONSE.
READ 'XMISS' FOR MEASURED TRANSMISSIBILITY.
G LOADS OBTAINED WERE WITHIN 1.0% OF DESIRED VALUES.
ALL VOLTAGES ARE WITHOUT AMPLIFICATION AND INCLUDE
LINE LOSSES TO PREAMP.
TEST CONDUCTED IN ANECHOIC CHAMBER. Y RADIAL VIBRATIONS.
MICROPHONE UNCAPPED AND ORIENTED AWAY FROM CABLE PORTS.

Figure 3.3 Sample Computer Printout

mode, 128 bins were available for the 500 Hertz span selected and corresponded to a 7.25 Hertz bandwidth. Dual channel configurations, parameters, and specifications are shown in Table III.

TABLE III

HP 3582A SPECIFICATIONS AND SETTINGS

	CHANNEL A	CHANNEL B
CONFIGURATION:		
Sensitivity	1 Volt	30 mVolt
Span	500 Hz	500 Hz
Passband shape	Flat top	Flat top
Number of Averages	4	4
PARAMETERS:		
Time Record Length	2 sec	
Point Spacing	4 Hz	
Equivalent Noise BW	7.24 Hz	

6. Free Decay Experiments

Free decay measurements of the isolation system were made to acquire independent values of the system's damped resonant frequency ω_d, and the viscous damping ratio ξ. Decay measurements used the previously discussed ITHACO preamps and ENDEVCO accelerometers, and the following additional apparatus.

a. Microphone Replica

A microphone replica identical in shape to the test microphone was machined from aluminum. A cutout was made on one side to house an accelerometer to measure radial vibrations. A threaded shaft was attached to the bottom of the replica to attach another accelerometer to measure axial vibrations. The replica was mounted in the isolator for axial and radial free decay and for static spring constant tests. Figure 3.4 shows the microphone and microphone replica with installed accelerometers. Total mass of the microphone replica and attached accelerometers is 47.7 grams. The actual microphone mass is 40 grams.

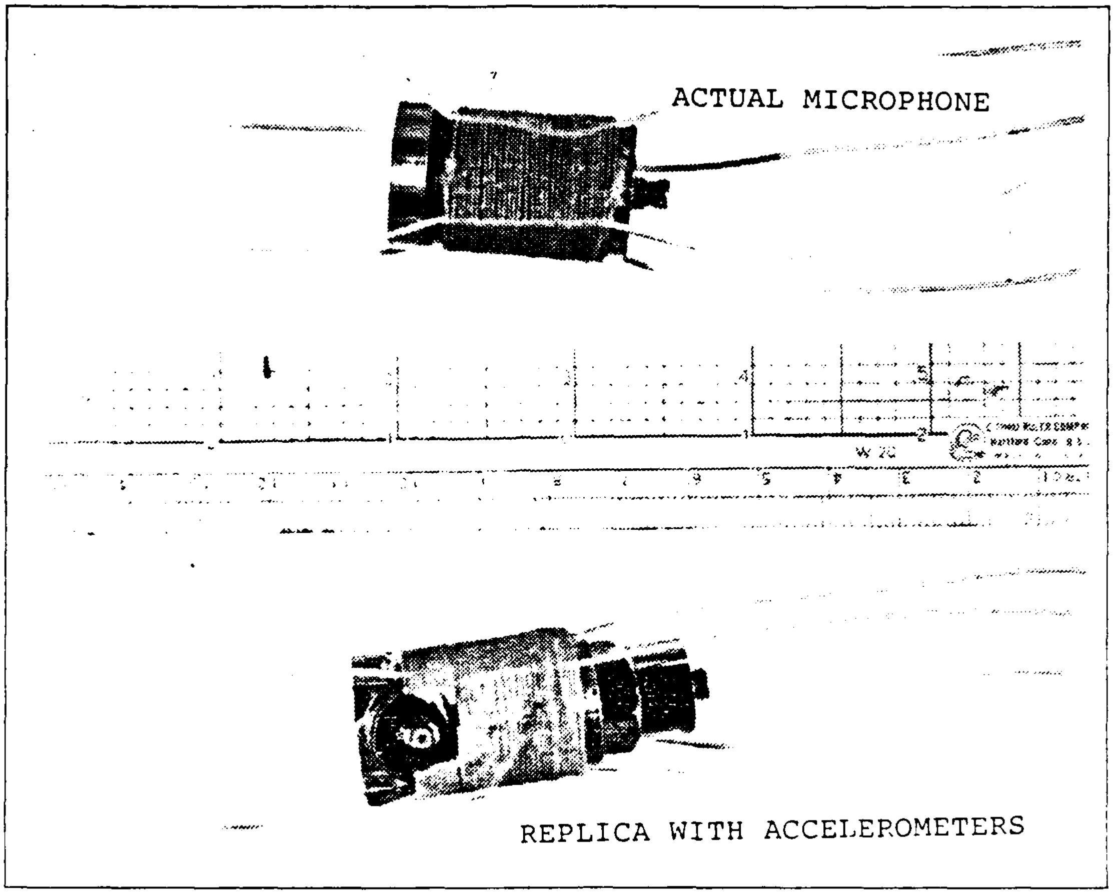

Figure 3.4 Actual Microphone and Replica

b. Hewlett-Packard 3561A Dynamic Signal Analyzer

The HP 3561A is a single-channel, Fast Fourier Transform Signal Analyzer. It is capable of measuring full scale input signals from 22.39 Vrms to 2.82 mVrms. Although it may be remotely programmable via an HP-IB, this capability was not used. The HP-IB interface was used to provide plots of the frequency and time response using an HP 7470A plotter. To obtain the free decay trace and frequency spectrum, the analyzer was operated in the manual arm, and source trigger options over a span of 100 Hertz. Resolution at this span setting was .25 Hertz. The test was conducted by orienting the isolation system to excite the microphone shape and the selected accelerometer. The replica was gently displaced and then released. The output of the accelerometer positioned along the axis of vibration triggered the analyzer to obtain traces of the free decay and frequency response. The trace was then dumped to an HP 7470A plotter via HP-IB. Figure 3.5 shows the plotted output of a free decay test. Figure 3.6 shows the analyzer settings.

B. STATIC DISPLACEMENT

Radial and axial static stiffnesses for the suspension system were determined by static displacement techniques. The microphone replica was suspended in the isolating canister using the test material. A wire was tied around the replica and the free end passed through the side or bottom of the canister for radial or axial tests as appropriate. The canister was mounted on a ring stand and a ruler placed along the length of the exposed wire. A hanger was attached to a loop at the end of the wire. Weights were added to the hanger and the deflection of the replica noted. Similar techniques were used to determine the Young's modulus for a single strand of the bungee material.

C. MICROPHONE CALIBRATION

Calibration and comparison experiments were performed to verify the test microphone's frequency response. The first experiment compared ENDEVCO microphone serial number BJ-66 to a GenRad one half inch Electret Condenser microphone type 1560-p-42, Serial No. 4656. Table IV is performance data for the GenRad microphone. [Ref. 8 : p. v]. The second experiment compared BJ-66 to ENDEVCO microphones BJ-56 and BD-37. These experiments were conducted inside the anechoic chamber at the Naval Postgraduate School.

In each experiment, the microphones were placed immediately adjacent to each other, 24 feet diagonally across the

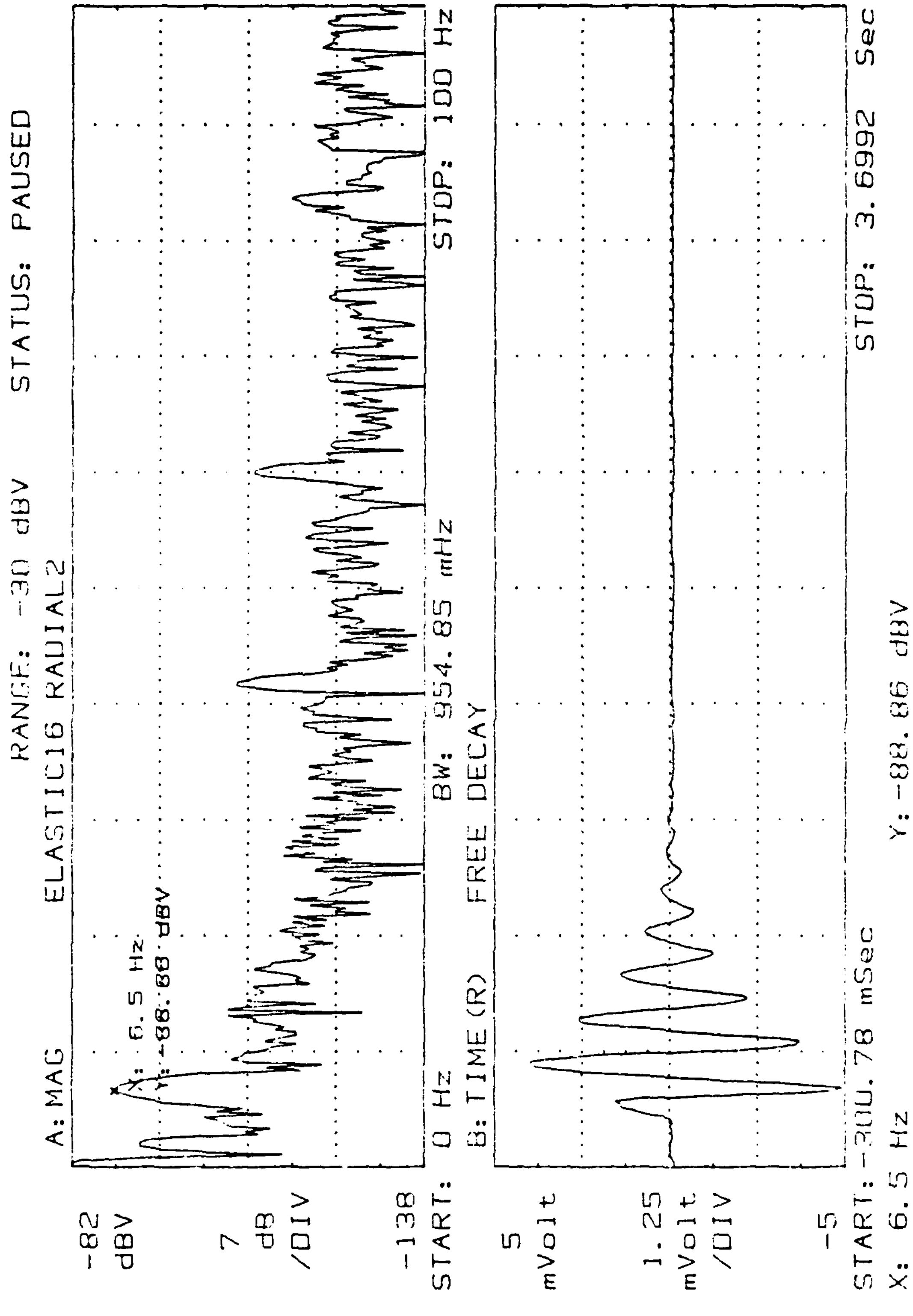

Figure 3.5 Free Decay Frequency Spectrum and Amplitude

```
                                  RANGE:  -20 dBV     STATUS:  PAUSED

                NARROW BAND MODE                     EXT SAMPLE OFF
FREQUENCY:
    BASEBAND              START:   0 Hz
                          STOP:    100 Hz
                          TIME:    4   Sec
TRIGGER:
    INPUT                 DELAY:  -300 mSec
    MANUAL  ARM           POS SLOPE                  % OF RANGE:   0 %
AVERAGE:
    OFF

WINDOW:
    FLAT TOP              BW:   954.85 mHz

SOURCE:
    OFF
INPUT:
    AC COUPLING           ICP CURRENT OFF            A WEIGHT FLTR OFF
    AUTO RANGE OFF        AUTO CAL OFF               CAL SIGNAL OFF
UNITS:
    X:  HZ
    Y:  dBV
```

Figure 3.6 HP 3561 Analyzer Free Decay Settings chamber from a 14 inch diameter speaker, and five feet above speaker level. An HP 3314A Function Generator was programmed to sweep from 25 to 2500 Hertz at a sweep interval of 100 msec to provide broadband excitation of the microphones. Figure 3.7 shows the output spectrum of the Function Generator.

TABLE IV

TYPICAL PERFORMANCE OF GENRAD ELECTRET

Frequency Range (Hz)	System Sensitivity re 1 Volt/Pa	Dynamic Range* re 20 μPa
15 - 19K	-40 dB	30 - 145 dB

* 'A' weighted noise level to max RMS sinewave signal without clipping.

Microphone response was recorded on the HP 3561A Dynamic Signal Analyzer using both linear 0-2000 Hertz and one third octave bands from 12.5 to 20,000 hertz. The results of the calibrations are presented in Chapter IV.

D. ENVIRONMENTAL EXPERIMENTS

Three environmental experiments were conducted to determine if temperature affected the damping and resonant frequency properties of the microphone isolation system. Tests were conducted using the microphone replica and isolation system at 5 °C and 65 °C, the expected minimum and maximum environment temperatures during launch. No significant deviations from resonant frequencies or damping ratios obtained at 20 °C were noted. The test apparatus included the microphone replica,the microphone suspension system, an insulated refrigeration unit and a hot plate. The insulated refrigeration unit was used to cool it to 5 °C and the free

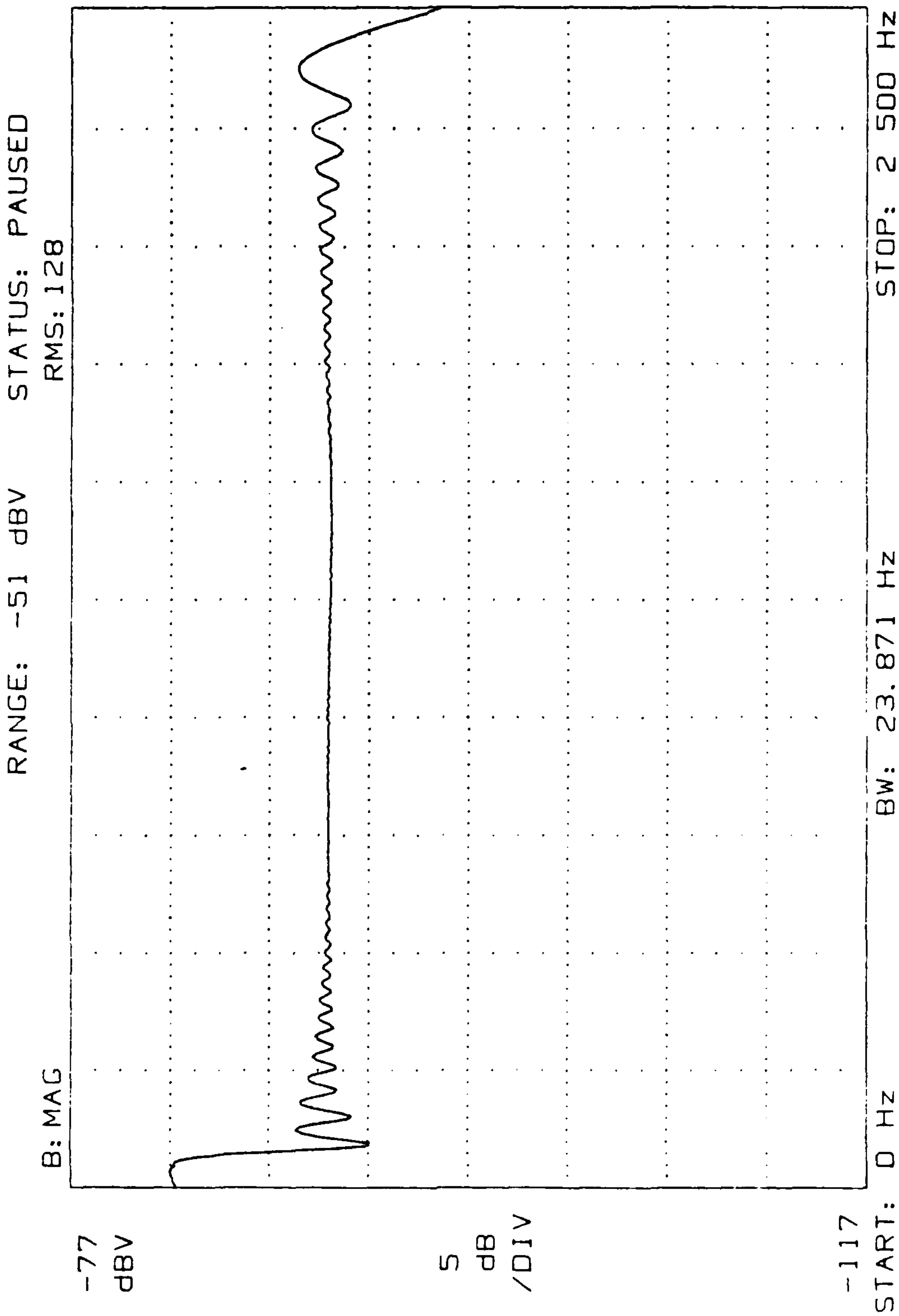

Figure 3.7 Broadband Output of Signal Source

decay noted. After securing the refrigeration unit , the hot plate was placed in the unit and at 80 °C the free decay was again tested. A low temperature test was also performed on a strand of the microphone suspension material. A 2 inch length of material was attached to the ends of two copper rods and cooled to -144°C by liquid nitrogen and then stretched a minimum of 1 inch without breaking.

IV. RESULTS

Triaxial vibration response data was obtained for ENDEVCO microphone serial number BJ-66. Acoustic tests were made to compare the three ENDEVCO microphones and the GenRad microphone with BJ-66. Table V summarizes the microphone vibration and noise response in the x,y,and z directions without the isolator. Radial and axial transmissibility tests were conducted on similarly constructed isolation systems using different materials: bungee cord and elastic thread. The bungee material was selected. The isolator had a resonant frequency below 15 Hertz for each axis.

TABLE V

ENDEVCO MICROPHONE BJ-66 RESPONSE SUMMARY[1]

DIRECTION	EQUIVALENT[2] OVERALL SPL dB re 20 μPa	MICROPHONE[3] OVERALL dBV(RMS) re 1 Volt(20 μPa)	SHAKER[4] NOISE dBV(RMS)re 1 Volt(20 μPa)
X Lateral	117	-73 (115)	-83 (105)
Y Lateral	118	-73 (115)	-83 (105)
Z Longitudinal	126	-67 (121)	-76 (112)

1. With no amplification.
2. Microphone output when attached to shaker.
3. Microphone output as measured on HP 3561 while attached to shaker table.
4. A measure of ambient shaker noise. Microphone output as measured on HP 3561 while isolated from vibration but located in same position relative to shaker table.

A. VIBRATION RESPONSE OF BJ-66

ENDEVCO transducer serial BJ-66, P/N GC 1346742-11-031 was the primary test microphone. Figure 4.1 represents the microphone response to vibration and shaker noise, and

Figure 4.2 the response to airborne shaker noise only. One third octave band plots of internal microphone noise, shaker table noise, and both shaker vibrations and noise are shown in Figure 4.3 The overall sound pressure levels were 10 to 15 dB below those expected to exist, and the difference between vibration/noise levels and noise only levels was an average of 15 dB. This low response to vibration enhances the microphone's use for measuring acoustic pressure magnitude. The quality of the data could be improved significantly at frequencies less than 100 Hertz by developing an isolator that would lower the vibration response at least 10 dB from peak levels below 100 Hertz.

B. SENSITIVITY COMPARISON

Tests were conducted in the anechoic chamber to determine the sensitivity of BJ-66, and to verify that each microphone had similar acoustic response. Sensitivity tests were performed by comparing the voltage output of BJ-66 to the GenRad one-half inch Electret. [Ref. 8 : p. 27] specifies that the Electret microphone has a sensitivity of -61.8 Volts/μbar. Tests showed that BJ-66's average response exceeded that of the Electret by 3.2 dB as shown in Figure 4.4 The sensitivity of the ENDEVCO was then determined as follows:

$$\begin{aligned} \text{sensitivity} &= \text{GenRad sense} - 20 \log 200 - 3.2 \text{ dB} \\ &= 111 \text{ dB re 1 Volt}/\mu\text{bar} \end{aligned} \tag{4.1}$$

This compares favorably to the sensitivity listed on the specification sheet of -113 dB re 1 Volt/ μbar. Figure 4.5 depicts the difference in level between the outputs of the ENDEVCO and the GenRad microphones in one third octave frequency bands for preamp settings of X100 for the ENDEVCO and X1 for the GenRad. No statistical data was obtained. Figure 4.6 is a linear comparison of voltage response to

ITEM RESPONSE TO VIBRATION

VIBRATION IS PARALLEL TO THE FACE OF ITEM; X LATERAL AXIS

ITEM NAME:	MICROPHONE
MANUFACTURER:	ENDEVCO
PART NO.:	GC1346742-11-031
SERNO:	BJ66
DATA FILE NAME:	XBJ66U1A:D701
DATA DISC LABEL:	C

FREQ (HZ)	ITEM VOLTS (uV)	SPL/ XMISS (DB)	INPUT VOLTS (MV)	ACCEL VOLTS (MV)	REQ'D G LOAD (G's)	OBS G LOAD (G's)	NO. TRIES
20.0	6.4	83.55	299.0	.234	.38	.38	4
25.0	7.9	85.40	227.0	.295	.48	.48	3
31.5	9.5	86.93	155.0	.373	.60	.60	2
40.0	12.5	89.35	98.1	.470	.76	.76	2
50.0	11.0	88.24	98.9	.590	.95	.95	2
63.0	22.0	94.26	167.0	.738	1.20	1.19	3
80.0	25.0	95.37	275.0	.937	1.52	1.52	2
100.0	23.5	94.83	355.0	1.050	1.70	1.70	2
125.0	28.7	96.57	442.0	1.170	1.90	1.89	2
160.0	33.0	97.78	541.0	1.320	2.15	2.14	2
200.0	42.1	99.90	638.0	1.480	2.41	2.39	2
250.0	57.4	102.59	735.0	1.650	2.69	2.67	2
315.0	27.5	96.20	755.0	1.870	3.02	3.03	2
400.0	27.5	96.20	857.0	2.100	3.40	3.40	2
500.0	39.1	99.26	924.0	2.350	3.80	3.80	2
630.0	53.7	102.01	942.0	2.640	4.27	4.27	2
800.0	79.3	105.40	853.0	2.980	4.81	4.82	2
1000.0	94.0	106.87	592.0	3.350	5.38	5.42	2
1250.0	101.0	107.50	87.1	3.320	5.38	5.37	2
1600.0	213.0	113.98	767.0	3.320	5.38	5.37	3
2000.0	28.1	96.39	1451.0	3.300	5.38	5.34	2

OVERALL BAND SPL: 116.8 DB. REF LEVEL 4.26mV @ 140 DB.

COMMENTS:
SPL/XMISS: READ 'SPL' FOR MEASURED VOLTAGE RESPONSE.
READ 'XMISS' FOR MEASURED TRANSMISSIBILITY.
G LOADS OBTAINED WERE WITHIN 1.0% OF DESIRED VALUES.
ALL VOLTAGES ARE WITHOUT AMPLIFICATION AND INCLUDE LINE LOSSES TO PREAMP.
TEST CONDUCTED IN ANECHOIC CHAMBER. RADIAL VIBRATIONS.
MICROPHONE WAS UNCAPPED AND ORIENTED AWAY FROM CABLE PORTS

Figure 4.1 Microphone BJ-66 Lateral Response to Shaker Vibration and Shaker Noise

ITEM RESPONSE TO VIBRATION

TEST ITEM IS NOT VIBRATING, BUT IS EXPOSED TO SHAKER NOISE

ITEM NAME: MICROPHONE
MANUFACTURER: ENDEVCO
PART NO.: GC1346742-11-031
SERNO: BJ66
DATA FILE NAME: NBJ66UX9:D701
DATA DISC LABEL: C

FREQ (HZ)	ITEM VOLTS (uV)	SPL/ XMISS (DB)	INPUT VOLTS (MV)	ACCEL VOLTS (MV)	REQ'D G LOAD (G's)	OBS G LOAD (G's)	NO. TRIES
20.0	.3	57.10	299.0	.234	.38	.38	1
25.0	.3	57.10	227.0	.298	.48	.48	1
31.5	1.2	69.14	155.0	.366	.60	.59	1
40.0	.9	66.64	98.1	.471	.76	.76	1
50.0	1.2	69.14	98.9	.590	.95	.95	1
63.0	1.2	69.14	167.0	.744	1.20	1.20	1
80.0	2.4	75.16	275.0	.947	1.52	1.53	1
100.0	4.9	81.18	355.0	1.040	1.70	1.68	1
125.0	7.3	84.70	442.0	1.160	1.90	1.88	1
160.0	8.5	86.04	541.0	1.310	2.15	2.12	1
200.0	18.6	92.80	638.0	1.470	2.41	2.38	1
250.0	50.4	101.46	735.0	1.640	2.69	2.65	1
315.0	69.9	104.30	755.0	1.860	3.02	3.01	1
400.0	42.7	100.02	857.0	2.090	3.40	3.38	1
500.0	36.0	98.54	924.0	2.340	3.80	3.79	1
630.0	43.0	100.08	942.0	2.630	4.27	4.25	1
800.0	31.4	97.35	853.0	2.960	4.81	4.79	1
1000.0	28.7	96.57	592.0	3.340	5.38	5.40	1
1250.0	20.4	93.60	87.1	3.240	5.38	5.24	1
1600.0	23.5	94.83	767.0	3.290	5.38	5.32	1
2000.0	42.7	100.02	1451.0	3.300	5.38	5.34	1

OVERALL BAND SPL: 109.8 DB. REF LEVEL 4.26mV @ 140 DB.

COMMENTS:
SPL/XMISS: READ 'SPL' FOR MEASURED VOLTAGE RESPONSE.
READ 'XMISS' FOR MEASURED TRANSMISSIBILITY.
ALL VOLTAGES ARE WITHOUT AMPLIFICATION AND INCLUDE LINE LOSSES TO PREAMP.
TEST CONDUCTED IN ANECHOIC CHAMBER. RADIAL VIBRATIONS.
MICROPHONE UNCAPPED AND ORIENTED AWAY FROM CABLE PORTS.
VOLTAGE LEVELS CORRESPOND TO THOSE FROM FILE 'XBJ66U1A'

Figure 4.2 Microphone BJ-66
Response to Shaker Table Noise Only

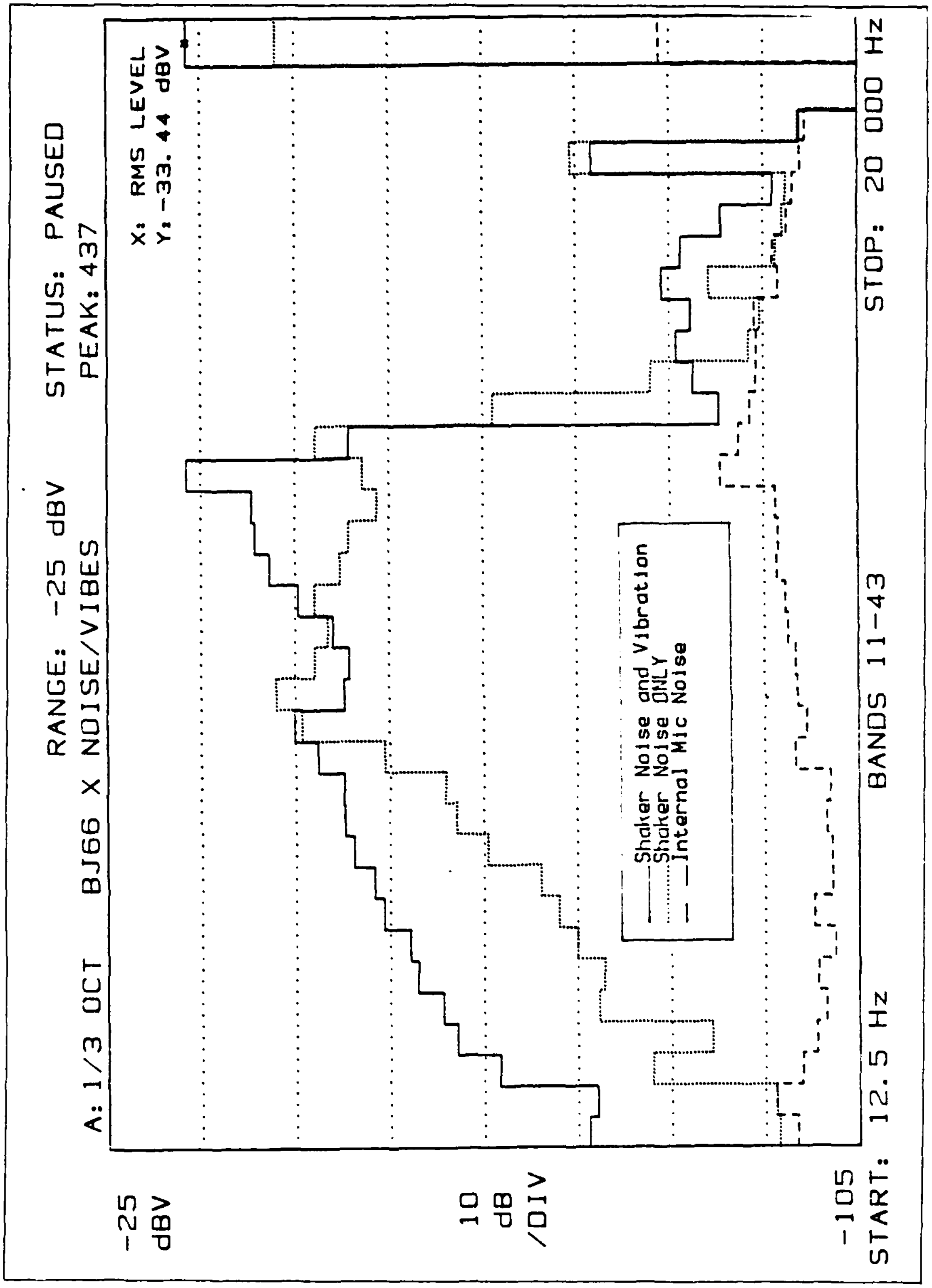

Figure 4.3 BJ-66 Lateral Third Octave
Vibration/Noise Response

broadband noise between 25 and 2500 Hertz. A trace of the source was shown in Figure 3.7.

C. COMPARISON OF ENDEVCO BJ-56 AND BD-37 TO BJ-66

A comparison of the three ENDEVCO microphones response to identical acoustic signal showed each had nearly identical response. The test was conducted in the anechoic chamber using the same 25 to 2500 Hertz source. Figure 4.7 shows the output of each microphone and the internal noise level for BJ-66. Internal noise for each microphone was also nearly identical.

D. FREE DECAY AND STATIC DEFLECTION

Axial and radial test results were used to determine values of the damping coefficient, and damped and natural resonant frequencies of the isolator constructed with the bungee material. Separate damping ratios were determined for the positive and negative peaks of the amplitude traces and an average taken. Static tests of a single strand of bungee material was used to determine the material's Young's modulus. Table VI is a summary of the results.

Figure 4.8 and 4.9 shows the frequency spectrum and amplitude trace for a radial free decay test of the bungee material. Figures 4.15 and 4.14 are plots of static spring constant test data. The bungee material was selected to isolate the microphone because it was linear over the expected range of displacement and it was easy to handle. The bungee material's tension was easier to set and the material was easier to control. The bungee material did not absorb epoxy resin and when it came into contact with the epoxy resin it could be peeled away without affecting its elastic properties. No difference was noted in free decay properties between 5 ^{o}C and 60 ^{o}C. Base ten logarithmic plots of amplitude ratios versus period for axial and radial free decay are shown in figures 4.10, through 4.13.

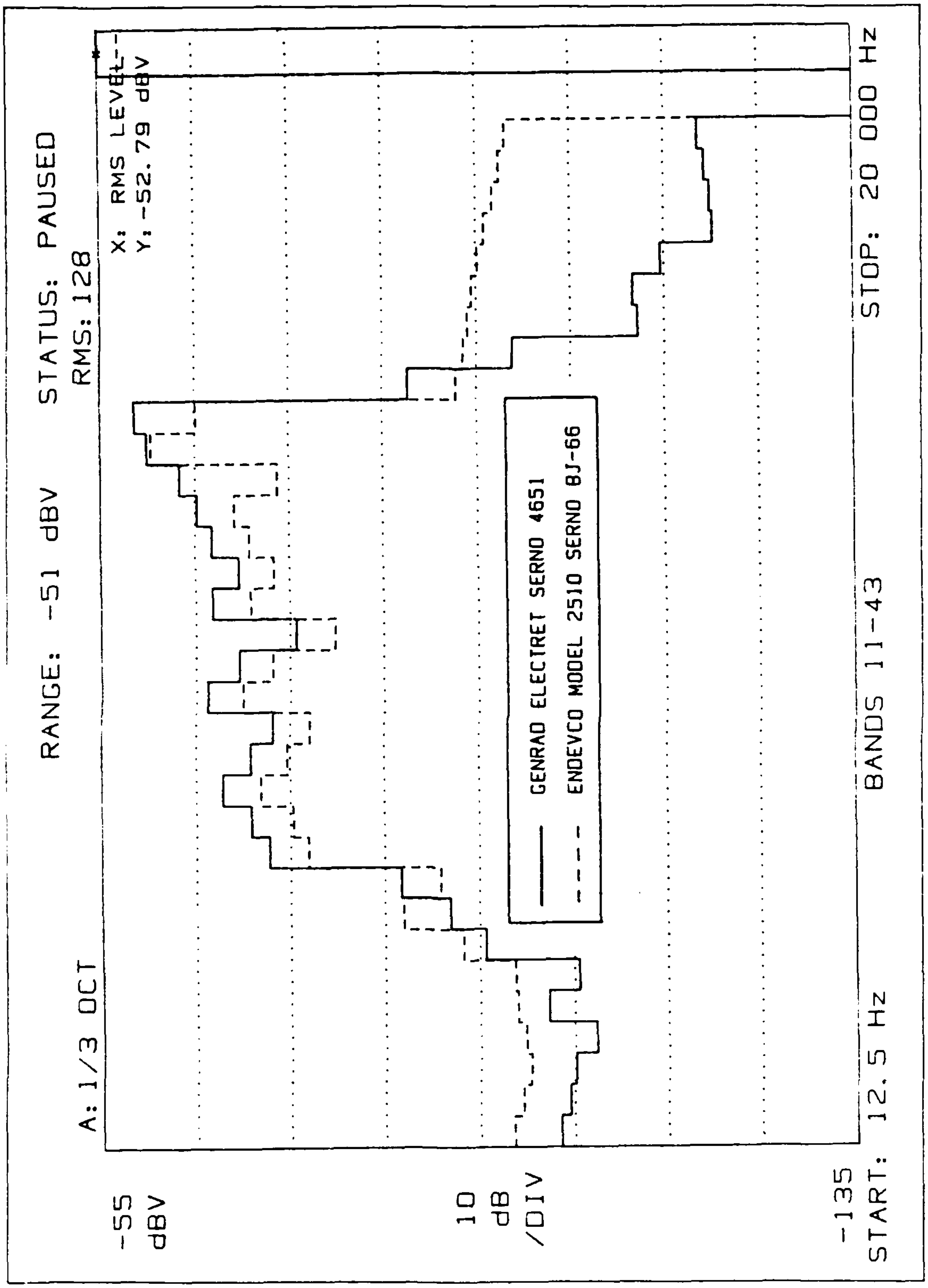

Figure 4.4 Third Octave Voltage Response of BJ-66 and Electret to an Identical Signal

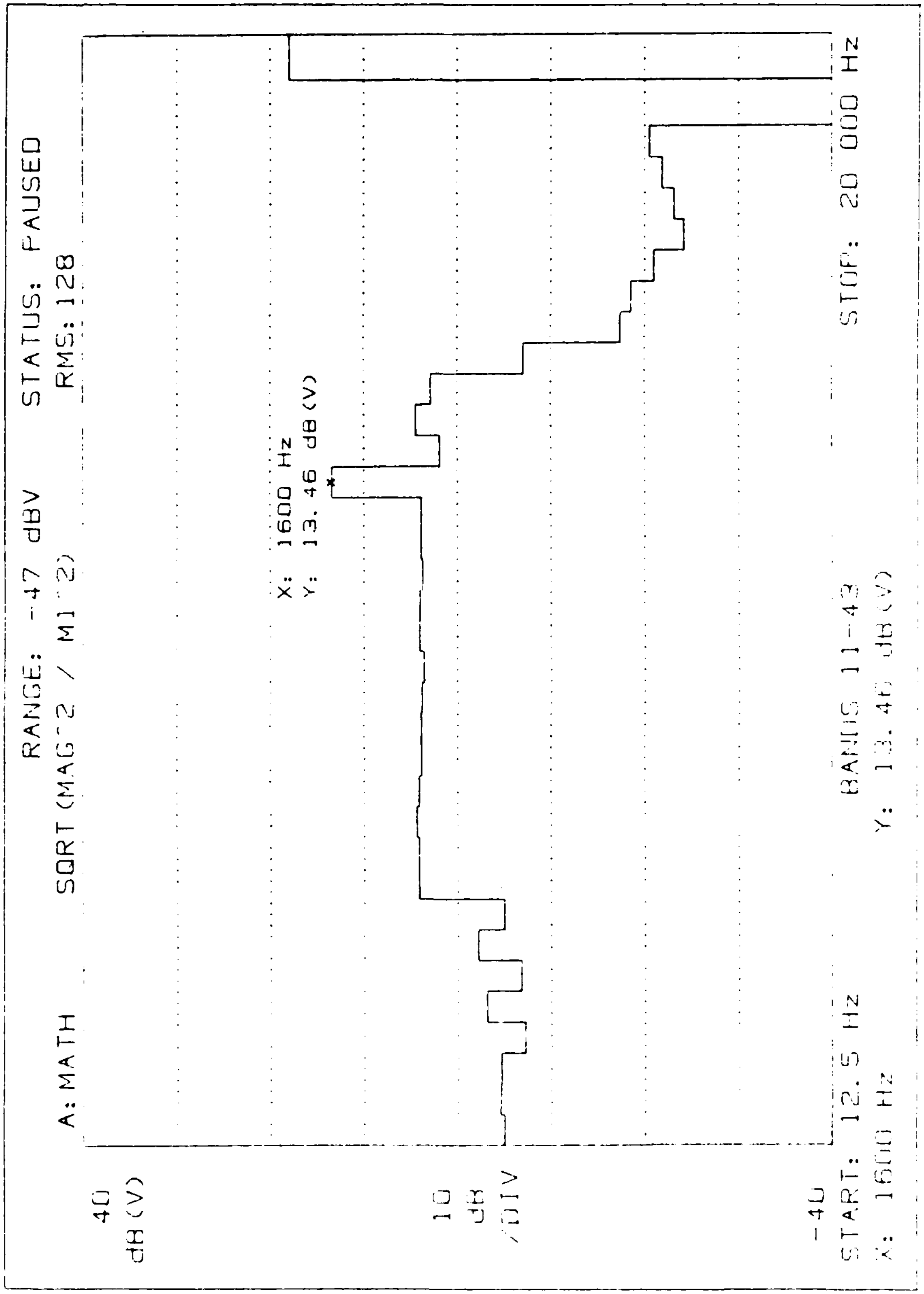

Figure 4.5 DB Level Difference (Electret - BJ-66)

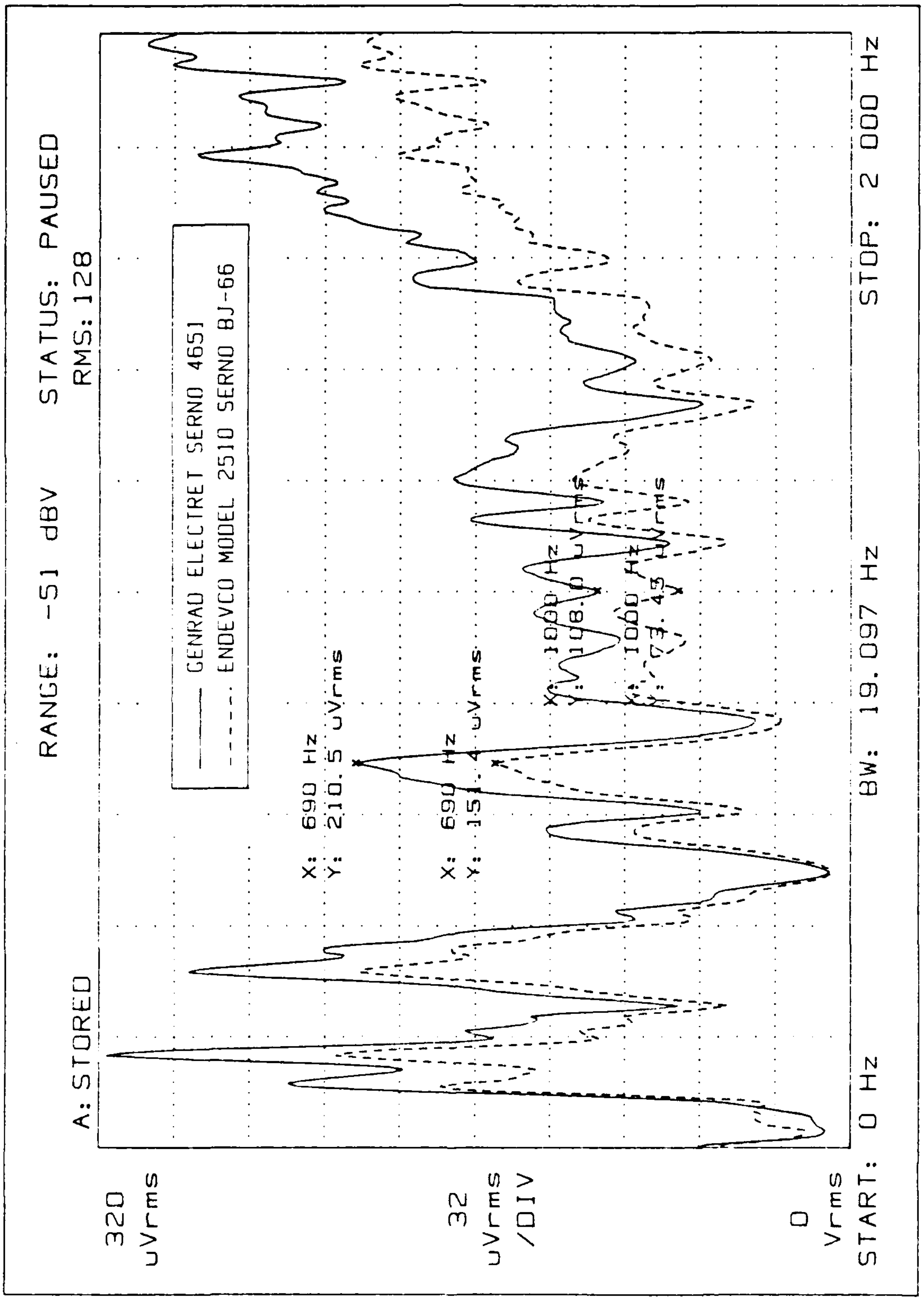

Figure 4.6 Linear Voltage Response for BJ-66 and Electret

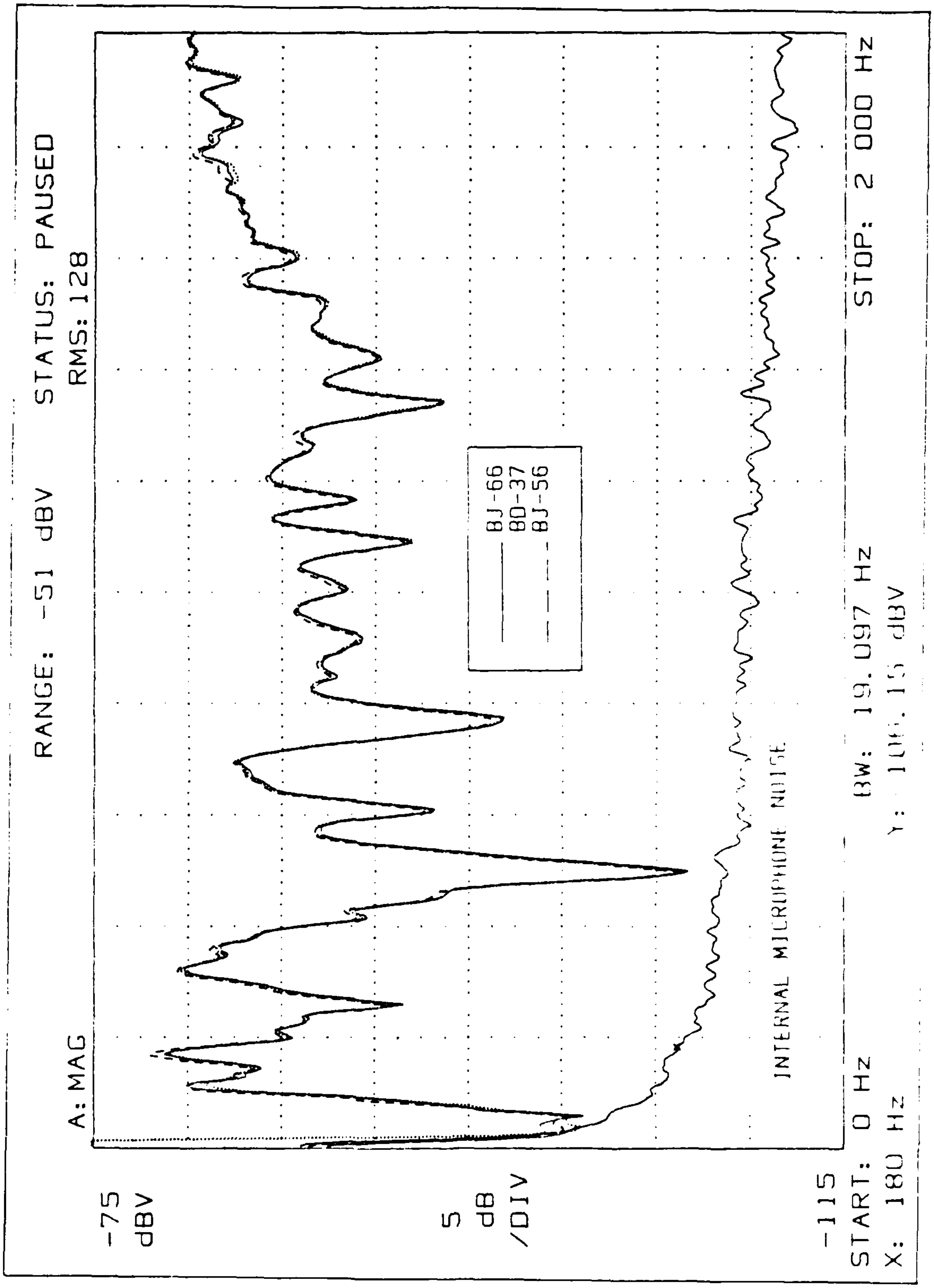

Figure 4.7 Comparisons of BJ-66, BD-37, and BJ-56 Voltage Response

TABLE VI

FREE DECAY AND STATIC DEFLECTION RESULTS

	Static Deflection Axial	Static Deflection Radial	Free Decay Axial	Free Decay Radial
Stiffness (N x 10/m)	.156	.129	NA	NA
Damping Ratio	NA	NA	.043	
Resonant Freq.(Hz)	10	9	11	14

Young's modulus : 20×10^5 Pascal

The cotton covered elastic thread's stiffness was non-linear. The outer covering of cotton absorbed epoxy and capillary action transmitted epoxy past the point of contact.

E. TRANSMISSIBILITY

A comparison was made between results of actual transmissibility tests of each bungee material isolation system and the transmissibility predicted from the damping ratio and the loss tangent. The predicted and actual transmissibility were nearly identical from -3 dB at 20 Hertz to -32 dB at 100 Hertz. The microphone's inherent vibration insensitivity, plus the low transmissibility of the isolation system will allow the microphone to respond satisfactorily to air-borne acoustic vibrations at, or above 20 Hertz. Figures 4.16 and 4.17 are the transmissibility curves for the bungee material. Curves for the predicted viscous and complex modulus transmissibilities were obtained using equations 2.25 and 2.26 respectively.

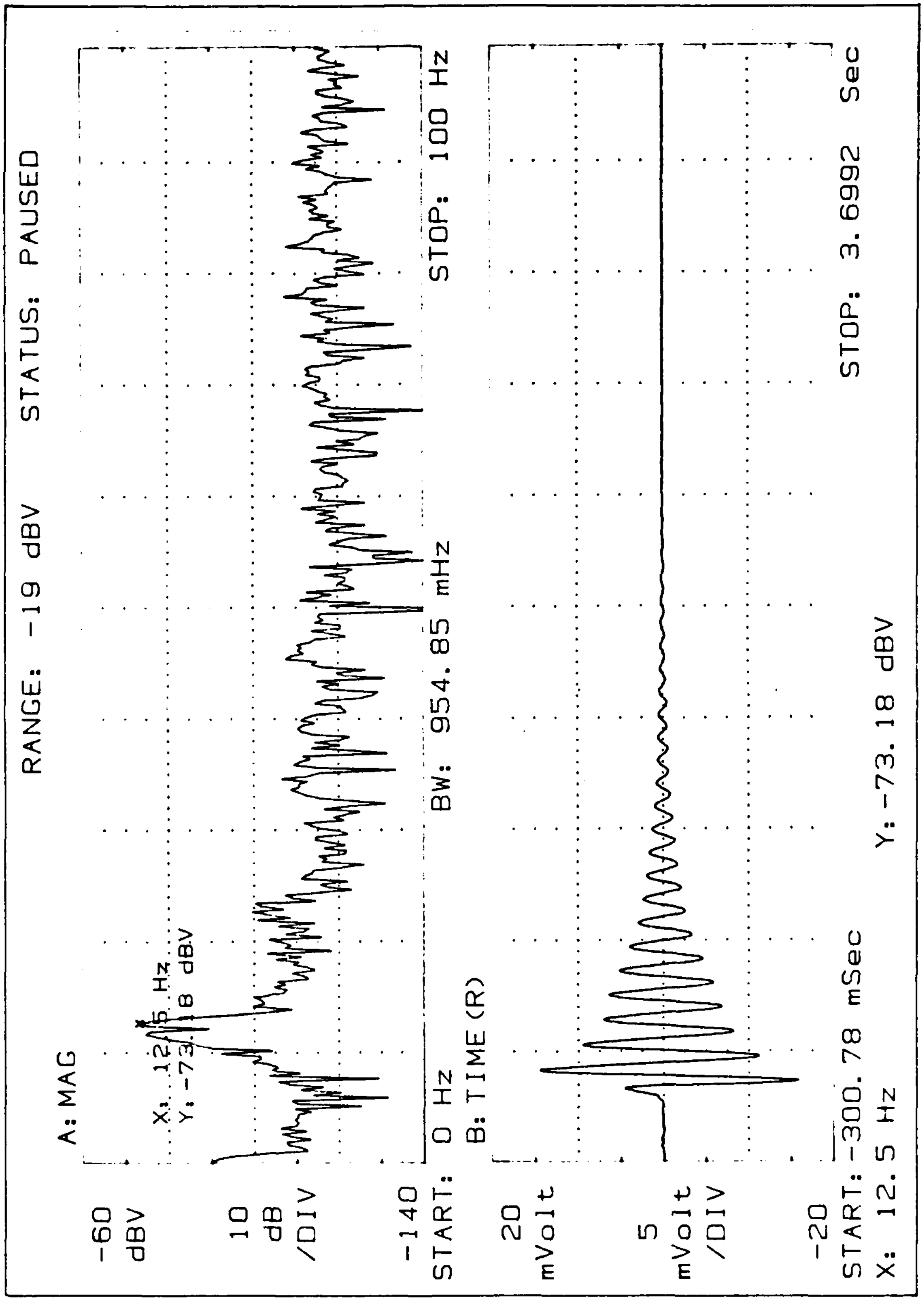

Figure 4.8   Bungee Suspension Radial Free Decay Trace

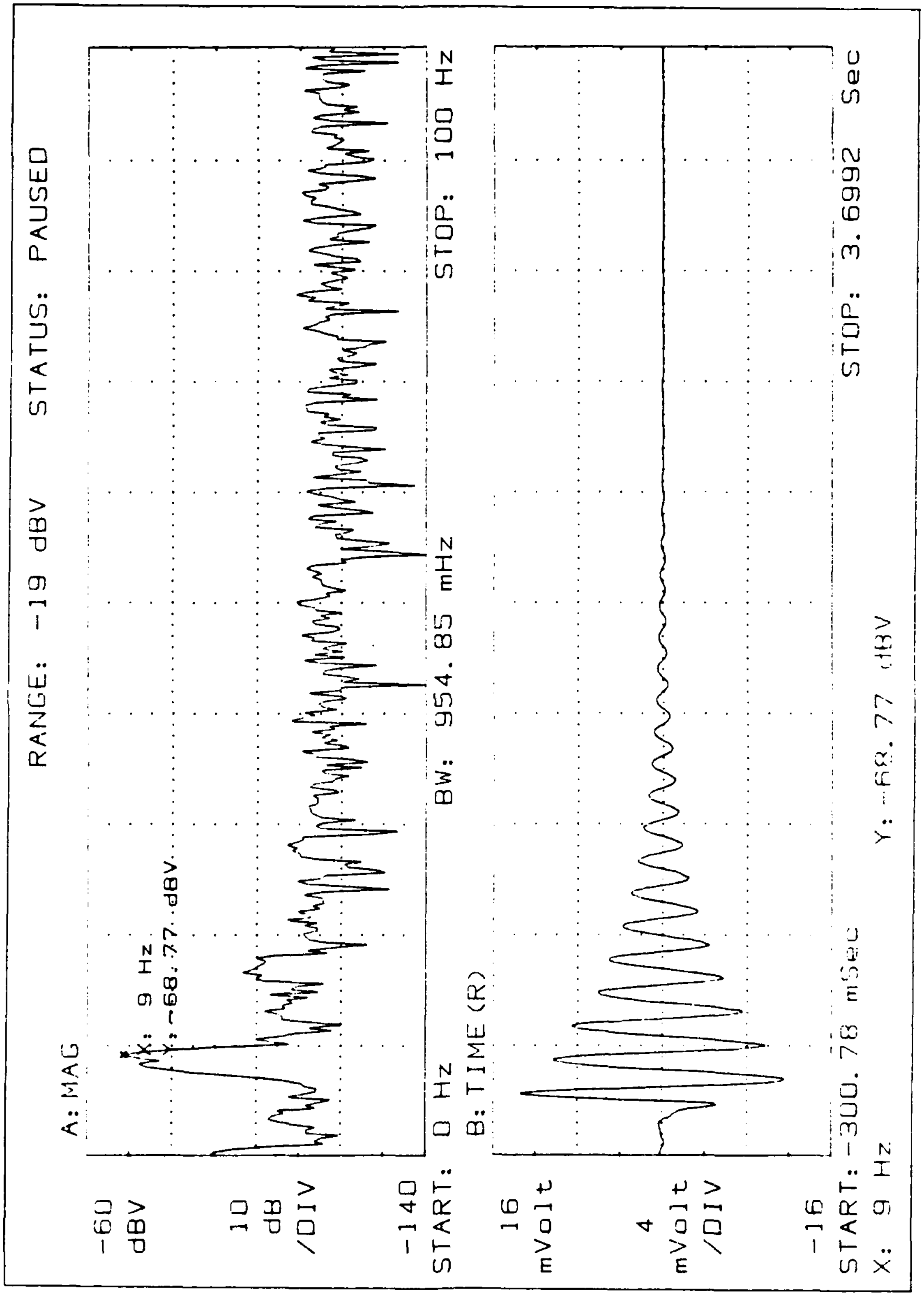

Figure 4.9 Bungee Suspension Axial Free Decay Trace

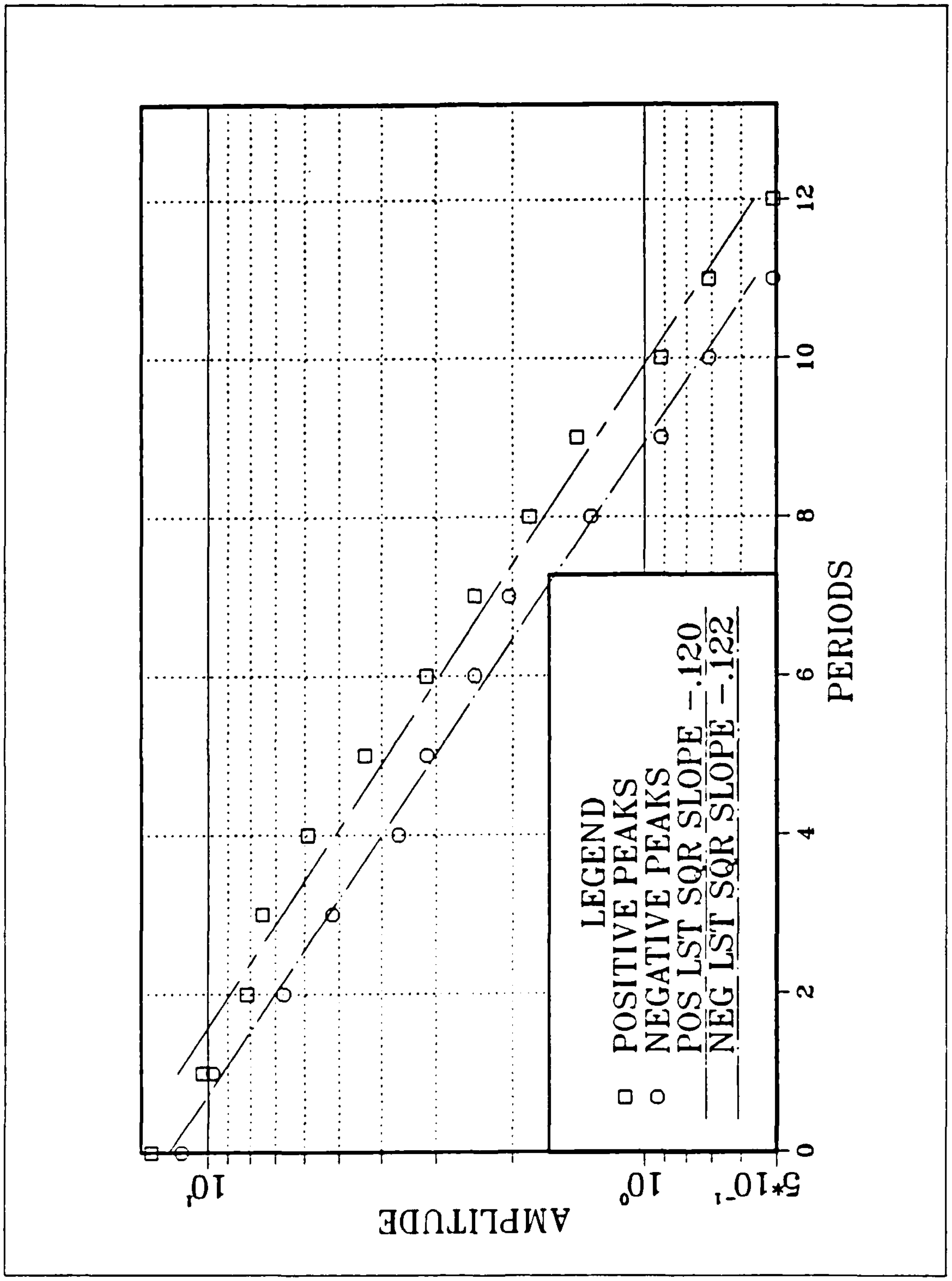

Figure 4.10 Bungee Suspension Axial Amplitude Ratios

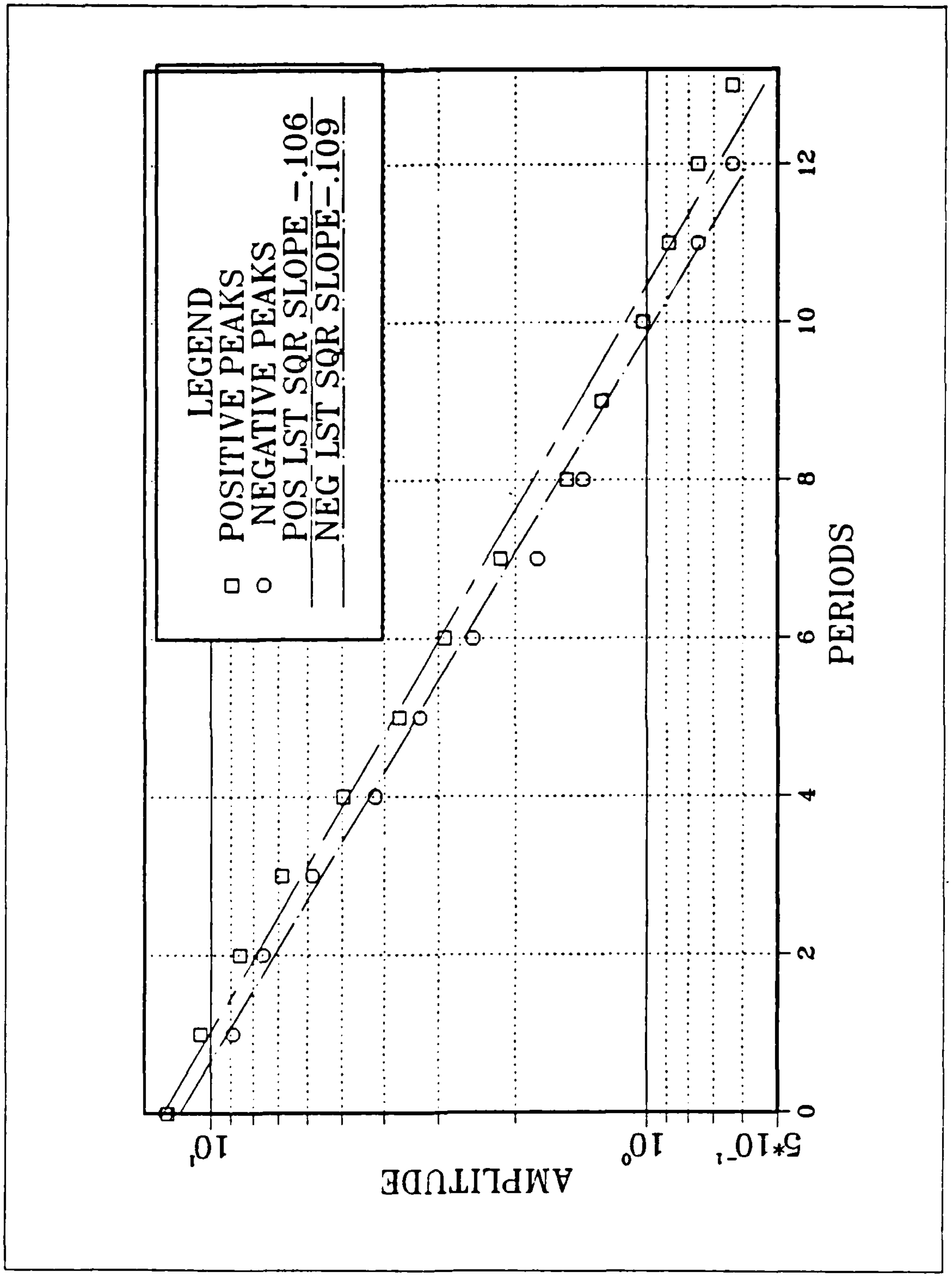

Figure 4.11 Bungee Suspension Axial Amplitude Ratios

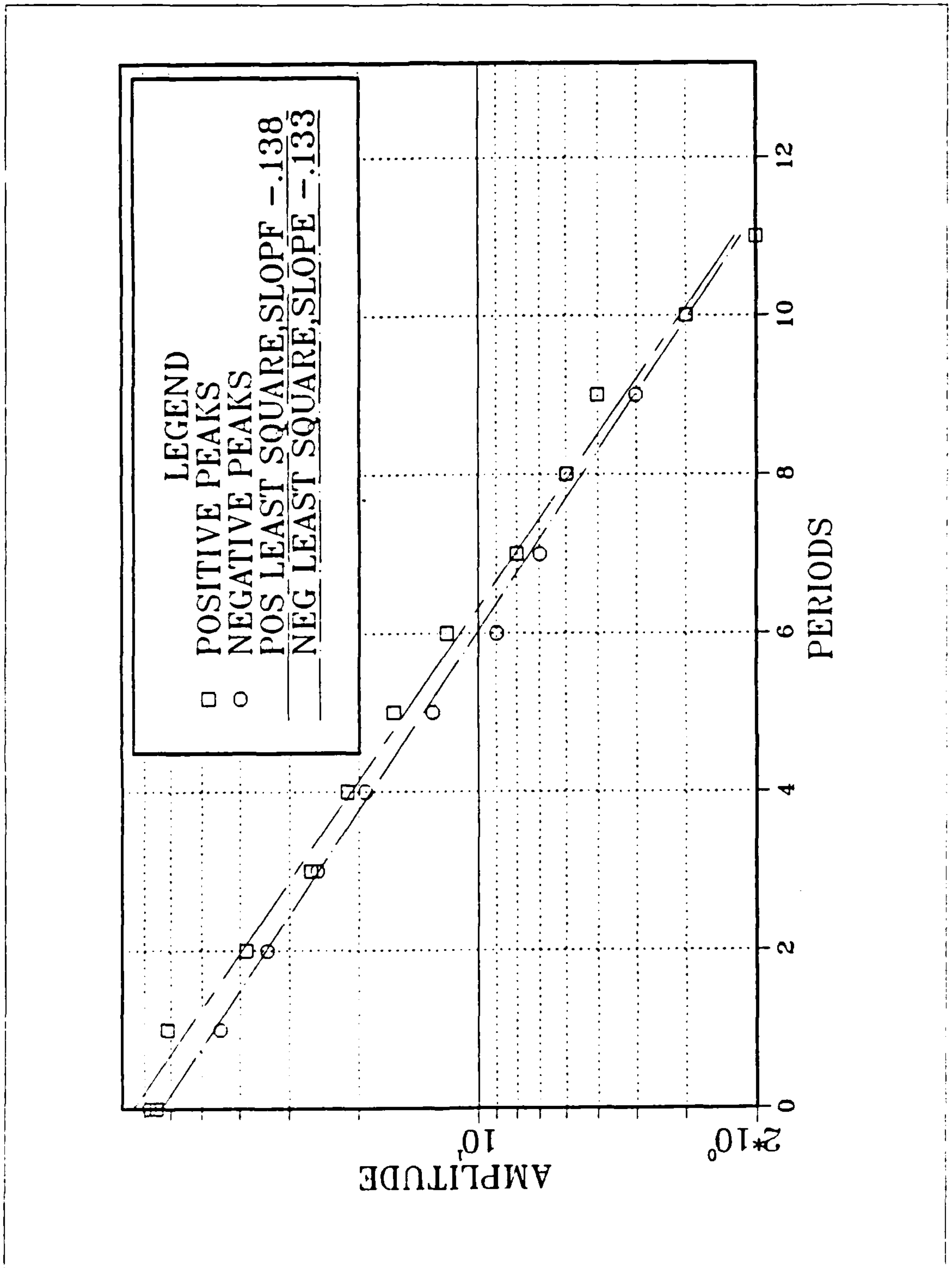

Figure 4.12 Bungee Suspension Axial Amplitude Ratios

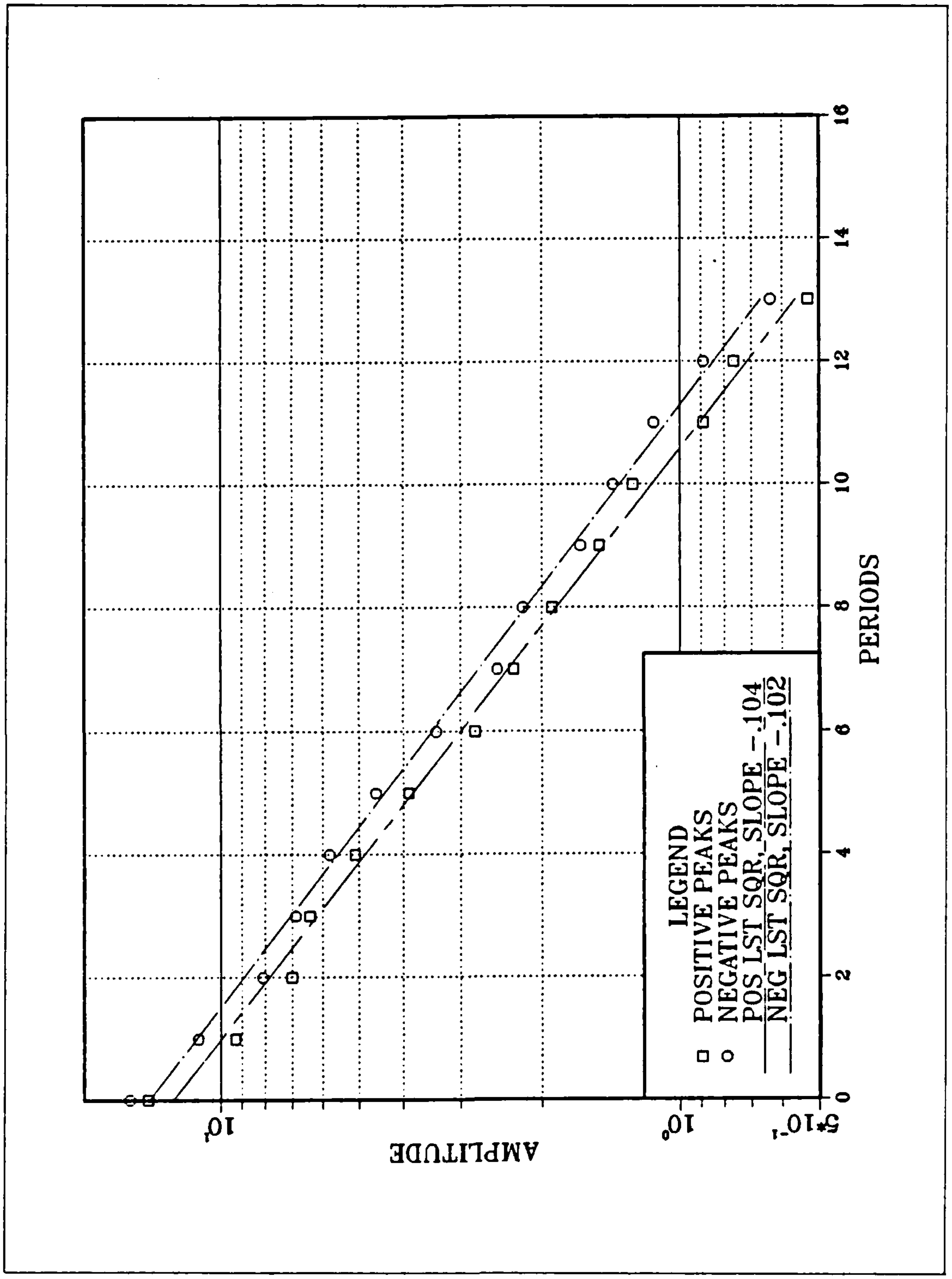

Figure 4.13 Bungee Suspension Radial Amplitude Ratios

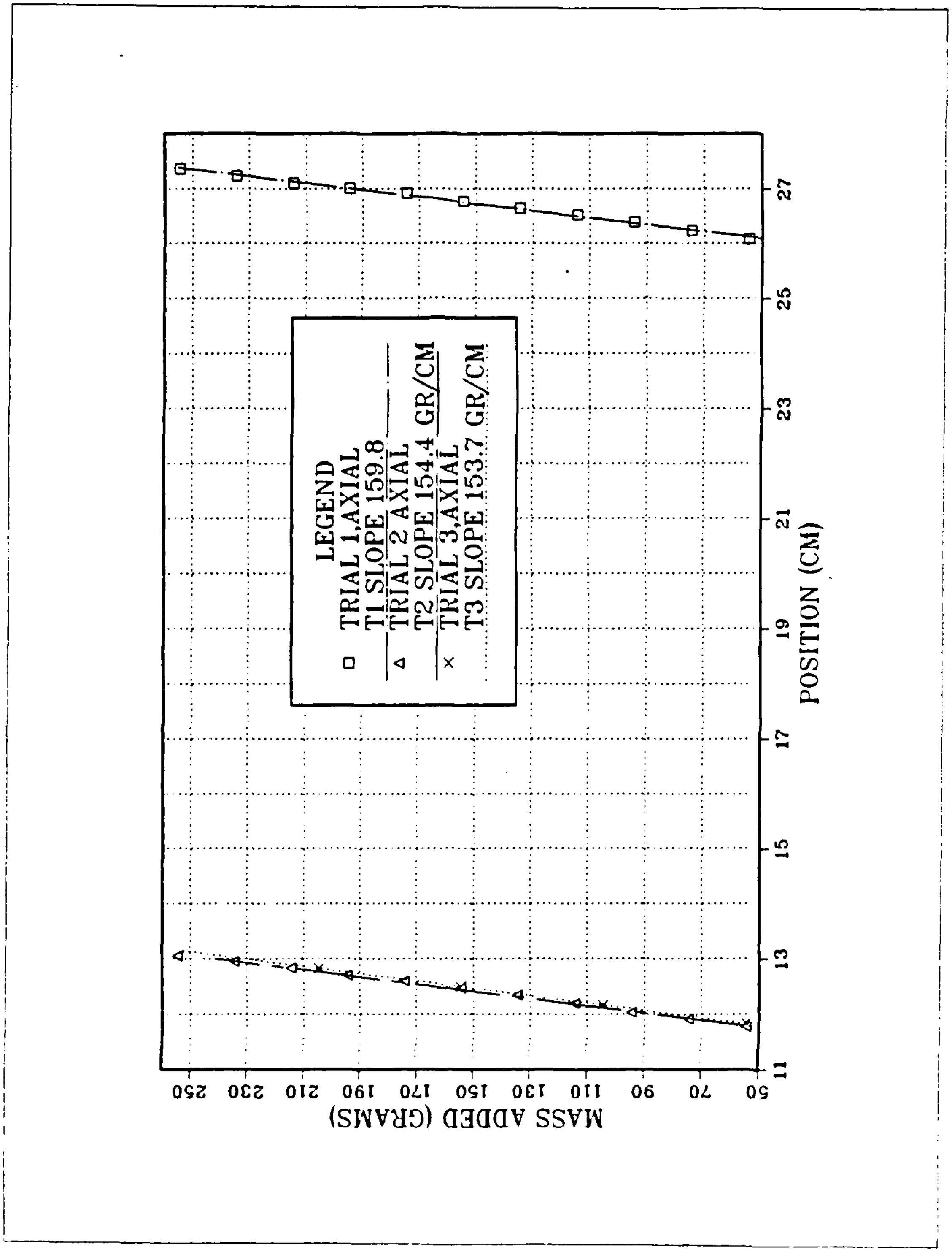

Figure 4.14 Bungee suspension Axial Displacement vs Mass Added

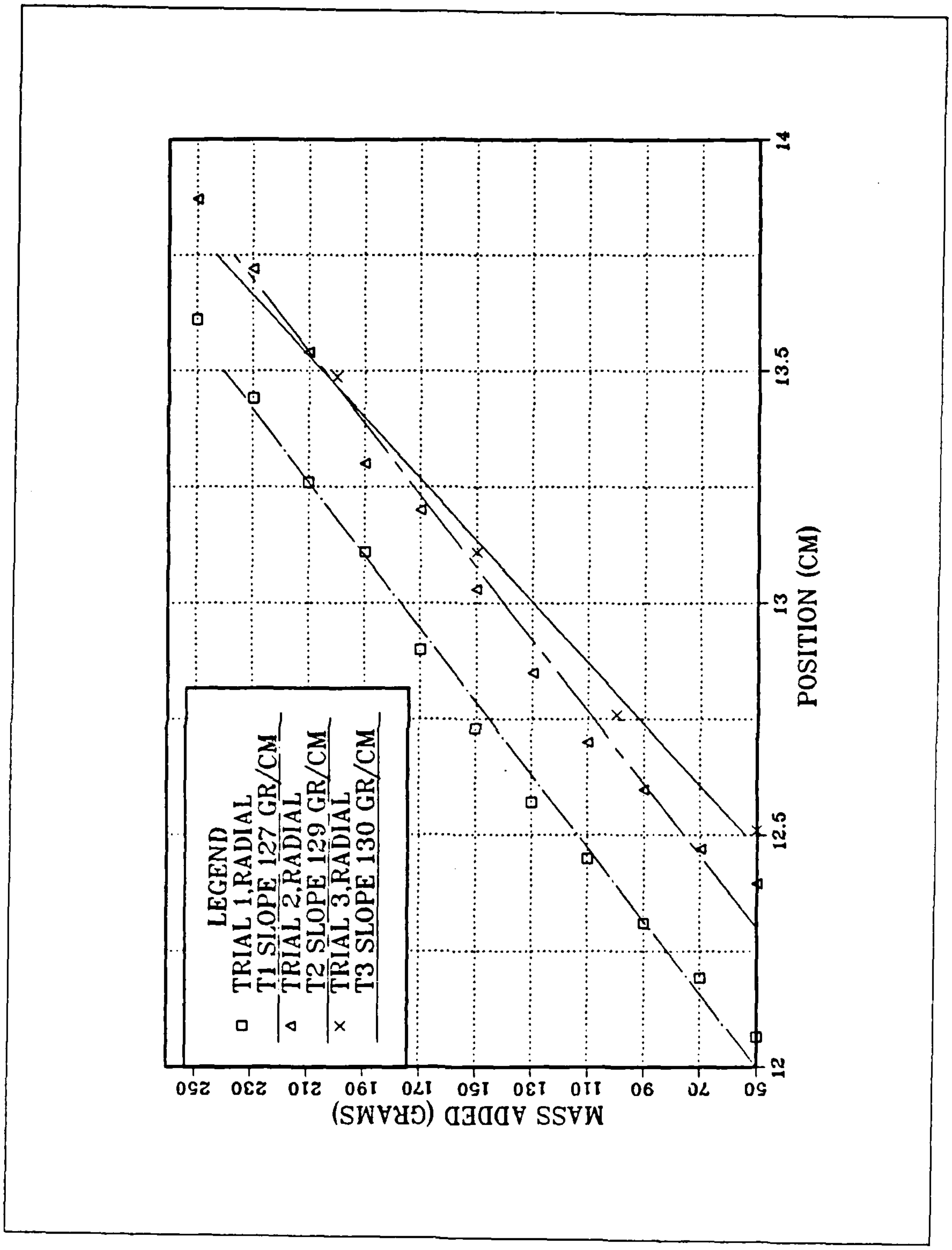

Figure 4.15 Bungee suspension Radial Displacement vs Mass Added

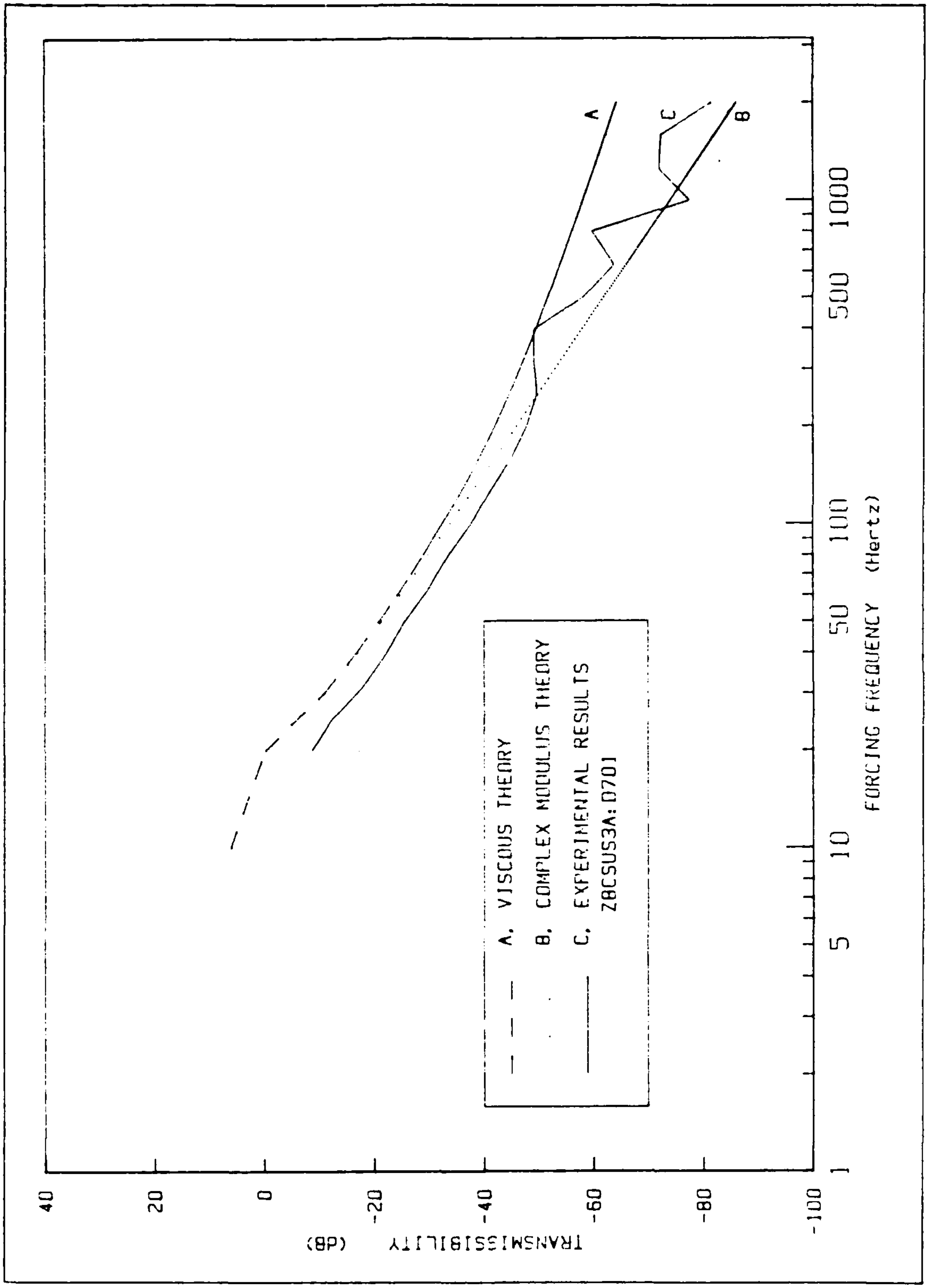

Figure 4.16 Axial Transmissibility for Bungee Isolator

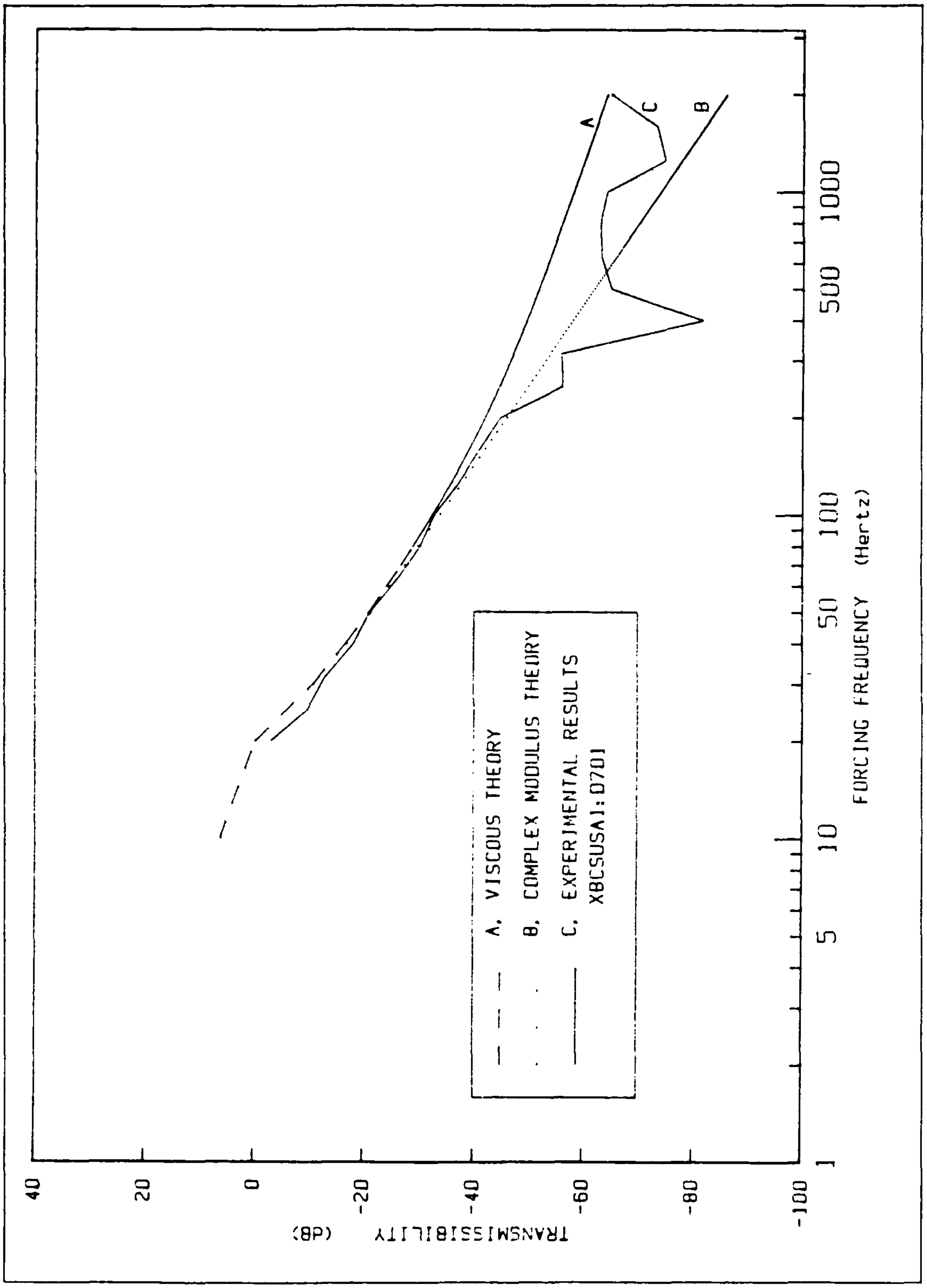

Figure 4.17 Radial Transmissibility for Bungee Isolator

V. SUMMARY AND CONCLUSIONS

A microphone vibration isolator for the ENDEVCO model 2210 microphone has been designed, built and tested in the laboratory. It provides isolation from expected structural vibrations which should permit ambient noise measurements to be made from about 20 Hz and higher without contamination due to vibration induced signals.

A. MICROPHONE VIBRATION ISOLATION SYSTEM FOR NASA PROJECT G-313

Figure 5.1 is a drawing of a microphone suspended in one of the three vibration isolation canisters. The suspension material is bungee. It is attached to the microphone and canister by wraps of kite string. The string is coated with Stycast epoxy 1266 (Emeron and Cumming, Canton, MA.) using a 10 gram to 2.8 gram ratio.

B. RECOMMENDATIONS

A vibration cancelling microphone, with a resonant frequency below 20 Hertz should be produced and procured, and incorporated in a program to regularly monitor payload bay acoustic pressure levels. Alternatively this experiment should be flown regularly on STS flights to record the acoustic pressure amplitudes in the payload bay under various configurations.

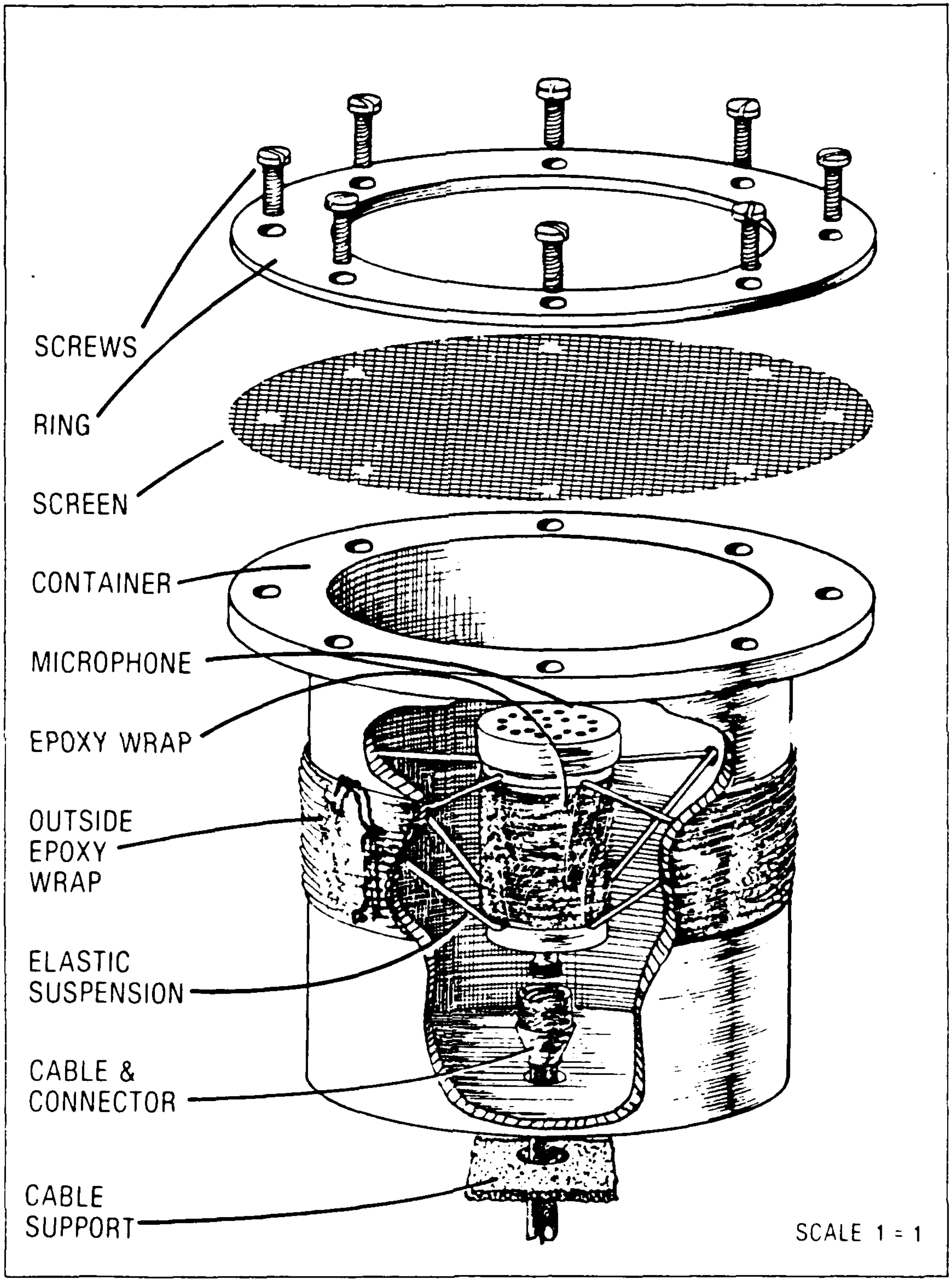

Figure 5.1 Microphone Suspended in Isolating Canister

APPENDIX A

SHAKER TABLE CONTROL PROGRAM

```
! ##########################################################################
! ##########################################################################
!                              SHAKER CONTROL
!
! This is a control program for space research project NPS-401. It controls
! a shaker table to produce the g loads for EITHER the one third octave band
! frequencies and g loads contained in the  NASA GAS Experimenter's
! Handbook or frequency and g load pairs input by the user.
! The program will obtain a volt/g value at the selected frequency and
! then compute the initial voltage. Linear corrections wil be used to
! in NASA's EXPERIMENTER's HANDBOOK. The program will control a function
! generator,shaker table,and FFT. The function generator will produce a
! sinusoid at the selected frequency and at a voltage amplitude necessary
! to produce the desired g load.
! Required equipment:
!               a. 2 pre amps with roll off control
!               b. computer controlled spectrum analyzer
!               c. computer controlled function generator
!               d. computer terminal
!               e. disk drive
!               f. printer
!               g. shaker table with amp
!               h. impedance matching connections as required
! The acceleration will be measured on a previously calibrated
! accelerometer: ENDEVCO ACCELEROMETER 2225M2,SERNO FD95. G load response
! will be measured with the axis of vibration oriented with respect to the
! article under test. Orientation  of vibration axis will be as follows:
!
!               a.parallel to the longitudinal axis of the base
!               b.parallel to the lateral axis of the base
!               c.perpendicular to the plane of the base
!
! After data is recorded the sound pressure level is calculated.
! The reference voltage and db level is input interactively.
!
!
!
! When required an identical  test article was mounted opposite the
! article under test for balance.
! Required data files:
!               a. None. Entries required are in program or are
! input interactively.
!
! Program data lines:
!                a. Required g loads, G_REQ(M), and FREQ(M) are read
!                   in interactively in ROUTINE titled 'KEYBOARD'
!                   or from data line entries in ROUTINE 'PROGRAM DATA'.
```

```
48 ! Created data files:(data files are created by interactive inputs
49 ! and purged before each run.)
50 !               a. L'CODE'RUN#:D701, contains array FREQ(M);G_LOAD1(M)
51 !                  the measured g load;G_REQ(M),the required g load;
52 !                  and SPL(M), the sound pressure level.
53 !                  Used when the axis of vibration is parallel to
54 !                  the longitudinal axis of the base plate.
55 !
56 !               b. W'CODE'RUN#:D701, same as LCODE but used when
57 !                  the vibrating axis is parallel to the lateral
58 !                  or width axis of the base plate.
59 !               c. V'CODE'RUN#:D701, same as LCODE but used when
60 !                  the vibrating axis is perpendicular to the base
61 !                  plate.
62 !
63 !                d.N'CODE'RUN#:D701, used whenever the test item is
64 !                  exposed ONLY to shaker table NOISE;NOT vibrations.
65 !                e.I'CODE'RUN#:D701, used whenever the test item is
66 !                  ISOLATED from BOTH noise AND vibrations.
67 !                  from BOTH noise and vibration.
68 !
69 ! TITLE : VOLTAGE RESPONSE TO G LOADS (VOLTRES4) INTERACTIVE INPUTS
70 !
71   GOSUB DIMENSION_ARRAYS
72   GOSUB INTRODUCTION
73   GOSUB TEST_EQUIPMENT_PARAMETERS
74   GOSUB TEST_ITEM_DATA
75   GOSUB TEST_CONDITIONS_FILENAME_INPUTS
76   GOSUB CONCATENATE_FILENAME_INPUTS
77   GOSUB SELECT_DATA_ENTRY_METHOD
78   GOSUB PRINT_HEADERS
79   GOSUB CALIBRATE_EQUIPMENT
80   GOSUB TEST_AT_FREQUENCY_G_LOAD_PAIRS
81   GOSUB PRINT_OVERALL_RESULTS
82   GOSUB CLOSE_FILES_AND_NULL_OUTPUTS
83   GOSUB ANOTHER_RUN
84   END
85   !
86   ! ************************************************************************
87   ! ***************  DIMENSION_ARRAYS  **********************************
88   ! ************************************************************************
89   DIMENSION_ARRAYS:
90     OPTION BASE 1 ! Sets all array subscripts to start at 1 vice 0.
91     DIM G_LOAD1(25),G_LOAD2(25),G_REQ(25),G_PER_VOLT(25),SPL(25)
92     DIM VOLT_A(25),VOLT_B(25),FREQ(25),VOLT_I(25),ITERATIONS(25)
93     DIM A(25),B(25),C(25),D(25)
94     DIM AXIS$[80]
95     DIM COMMENTS1$[60]
96     DIM COMMENTS2$[60]
97     DIM COMMENTS3$[60]
98     DIM NAME$[28]
99 !
100   RETURN
```

```
101 ! ****************************************************************
102 ! ******************** INTRODUCTION ******************************
103 ! ****************************************************************
104  INTRODUCTION:
105 !
106  CLEAR
107  DISP " THIS PROGRAM CONTROLS A FUNCTION GENERATOR THAT INPUTS"
108  DISP " FREQUENCIES AND VOLTAGES TO A SHAKER TABLE TO PRODUCE"
109  DISP " A SPECIFIED G LOAD. THE PROGRAM OUTPUTS THE FOLLOWING:"
110  DISP "          A.*FREQUENCY"
111  DISP "          B.INPUT VOLTAGE AND TEST ITEM* OUTPUT VOLTAGE"
112  DISP "          C.REQUIRED AND OBTAINED* G LOADS"
113  DISP "          D.NUMBER OF ITERATIONS TO ACHIEVE REQUIRED G LOAD*"
114  DISP "          E.EQUIVALENT SOUND PRESSURE LEVEL REF INPUT VALUES*."
115  DISP "          F.OVERALL SOUND PRESSURE LEVEL*"
116  DISP "          G.TRANSMISSIBILITY OF ISOLATION MOUNT*"
117  DISP
118  DISP "ITEMS MARKED WITH * ARE RECORDED ON DATA DISK."
119  DISP
120  DISP " PRESS 'CONT'."
121  WAIT 20000
122  CLEAR
123 DISP "PROGRAM CODES FOR COMPUTER CONTROLLED EQUIPMENT ARE AS "
124 DISP "FOLLOWS:"
125 DISP
126 DISP "          1. PRINTER            : 702 "
127 DISP "          2. FUNCTION GENERATOR : 707 "
128 DISP "          3. SPECTRUM ANALYZER  : 711 "
129 DISP "          4. DATA DISC DRIVE    : 701 "
130 DISP "          5. PLOTTER IS         : 705 "
131 DISP
132 DISP "PRESS CONT"
133 WAIT 10000
134 CLEAR
135  DISP "YOU WILL BE ASKED TO MAKE VARIOUS ENTRIES DURING THE "
136  DISP "INITIALIZATION PHASE.  AFTER TYPING IN THE ENTRY PRESS"
137  DISP "THE 'END LINE' KEY. IF A YES RESPONSE IS DESIRED ENTER"
138  DISP " A '1', ENTER A '2' FOR A NO."
139  DISP
140  DISP "PRESS 'CONT'."
141  WAIT 5000
142 CLEAR
```

```
143  DISP "THE FOLLOWING IS A LIST OF INPUTS NECESSARY FOR PROPER"
144  DISP "PROGRAM OPERATION:                                        "
145 !
146  DISP "  1.MAX VOLTAGE FROM FUNCTION GEN TO SHAKER TABLE IN "
147  DISP "    MILLIVOLTS:V_MAX."
148  DISP "  2.PRE AMP GAIN VALUES "
149  DISP "  3.ACCELEROMETER G SENSITIVITY IN G's per VOLT."
150  DISP "  4.DESIRED TOLERANCE FROM G REQUIRED."
151  DISP "  5.TEST ITEM NOMENCLATURE"
152  DISP "  6.TEST ITEM MANUFACTURER"
153  DISP "  7.TEST ITEM SENSITIVITY AT SPECIFIED DB LEVEL IN mV"
154  DISP "  8.DESIRED TEST FREQUENCY GLOAD PAIRS IN HZ AND RMS G's."
155  DISP "  9.INITIAL VOLTAGE IN mV."
156  DISP " 10.SENSITIVITY OF ACCELEROMETERS IN mV/G FOR TRANSMISSIBILITY."
157 DISP
158 DISP "PRESS 'CONT'."
159 PAUSE
160 CLEAR
161 !
162 RETURN
163 !
164 ! *********************************************************************
165 ! ***************************  TEST_EQUIPMENT_PARAMETERS  ************
166 ! *********************************************************************
167 TEST_EQUIPMENT_PARAMETERS:
168  ROUTINE=1
169  DISP "ENTER THE DAY, MONTH, AND YEAR; IE 24 JULY 84"
170  INPUT TODAY$
171  !
172  CLEAR
173  DISP "ENTER DATA DISC NAME (A,B,C ETC.)"
174  INPUT DATA_DISC$
175 !
176 CLEAR
177 !
178  DISP "ENTER MAX VOLTAGE FROM FUNCTION GENERATOR TO SHAKER TABLE IN"
179  DISP "MILLIVOLTS. MAX VOLTAGE SHOULD NOT EXCEED 3000mV."
180  INPUT V_MAX
181 !
182  CLEAR
```

```
183  DISP "ENTER MAX NUMBER OF TRIES TO ACHIEVE REQUIRED G LOAD BEFORE"
184  DISP "MOVING ON TO THE NEXT FREQ/G_LOAD PAIR. THE FIRST 5 ATTEMPTS"
185  DISP "USE A LINEAR ALGORITHM, ATTEMPTS 6 AND UP USE A CUBIC."
186  DISP "IF USE OF CUBIC IS REQUIRED USUALLY SOMETHING IS WRONG"
187  DISP "WITH THE EQUIPMENT OR THE WAY THE ITEM IS ATTACHED TO "
188  DISP "THE SHAKER TABLE. 10 IS RECOMMENDED."
189  INPUT MAX_TRIES
190 CLEAR
191  DISP "ENTER THE START VOLTAGE IN mV TO BE USED AT START OF "
192  DISP "FREQUENCY G LOAD PAIR."
193  INPUT INITIAL_VOLTAGE
194 CLEAR
195 !
196  DISP "ENTER PREAMP GAIN FOR THE ACCELEROMETER OR FFT INPUT A ."
197  INPUT GAIN_A
198 !
199  DISP "ENTER PREAMP GAIN FOR THE TEST ITEM OR FFT INPUT B "
200  DISP " EXAMPLE: IF 20 DB ENTER 10, IF 40 DB ENTER 100"
201  INPUT GAIN_B
202 !
203 CLEAR
204 !
205  DISP "ENTER ACCELERATION SENSITIVITY FOR ACCELEROMETER IN G's PER VOLT."
206   INPUT ACCEL_SENSE
207 !
208 !
209 !
210 CLEAR
211 !
212  DISP "ENTER TOLERANCE BETWEEN DESIRED AND OBTAINED G LOADS (RMS G)"
213  DISP "I.E., FOR 5% ENTER 5"
214  INPUT T
215 CLEAR
216  DISP "ENTER A COMMENT LESS THAN 60 CHARACTERS IF DESIRED. IF YOU"
217  DISP "HAVE NO COMMENTS ENTER DOUBLE QUOTE MARKS. THEN PRESS "
218  DISP "'END LINE ."
219  DISP "xxxxxxx COMMENT LENGTH xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx"
220  INPUT COMMENTS1$
221 CLEAR
222  DISP "ENTER ANOTHER COMMENT LESS THAN 60 CHARACTERS IF DESIRED. IF YOU"
223  DISP "HAVE NO COMMENTS ENTER DOUBLE QUOTE MARKS. THEN PRESS "
224  DISP "xxxxxxx COMMENT LENGTH xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx"
225  DISP "'END LINE'."
226  INPUT COMMENTS2$
227 CLEAR
228  GOSUB DISPLAY_EQUIPMENT_PARAMETERS
229  GOSUB CHANGE_INPUTS
230  CLEAR
```

```
231 ! *********************************************************************
232 ! ********************  DISPLAY_EQUIPMENT  ***************************
233 ! *********************************************************************
234 !
235  DISPLAY_EQUIPMENT_PARAMETERS:
236  DISP "DATE.........................";TODAY$
237  DISP "PREAMP GAIN FOR CHANNEL A ....";GAIN_A
238  DISP "ACCELEROMETER SENSITIVITY.....";ACCEL_SENSE;"G PER VOLT"
239  DISP "PREAMP GAIN FOR CHANNEL B IS..";GAIN_B
240  DISP "DATA DISC LABEL...............";;;DATA_DISC$
241  DISP "INITIAL VOLTAGE...............";INITIAL_VOLTAGE
242  DISP
243  DISP "COMMENTS"
244  DISP COMMENTS1$
245  DISP COMMENTS2$
246 !
247 RETURN
248 ! ***********************************************************************
249 ! *****************TEST_ITEM_DATA,ROUTINE 2****************************
250 ! ***********************************************************************
251 '
252   TEST_ITEM_DATA:
253   ROUTINE=2
254   DISP " ENTER TEST ITEM NOMENCLATURE."
255   INPUT NAME$
256 CLEAR
257 '
258   DISP "ENTER MANUFACTURER'S NAME:"
259   INPUT MAN$
260 CLEAR
261   DISP "ENTER PART NUMBER:"
262   INPUT PN$
263 CLEAR
264   DISP "ENTER SERIAL NO:"
265   INPUT SERNO$
266 CLEAR
267   DISP "IF YOU WANT SOUND PRESSURE LEVELS OF THE TEST ITEM"
268   DISP "BASED ON A VOLTAGE SENSITIVITY AND DB REFERENCE LEVEL"
269   DISP "FOR THE TEST ITEM,USED FOR MIKE RESPONSE, ENTER '1'."
270   DISP
271   DISP "IF YOU WANT TO COMPUTE THE VIBRATION TRANSMISSIBILITY IN DB"
272   DISP "FOR AN ISOLATION MOUNT BY MEASURING THE OUTPUT OF BOTH AN"
273   DISP "ACCELEROMETER ISOLATED FROM VIBRATION AND AN ACCELEROMETER"
274   DISP "THAT IS NOT ISOLATED ENTER '2'."
275   INPUT SPL_TRANSMISSIBILITY
276   ON SPL_TRANSMISSIBILITY GOTO 281,291
277   DISP "ENTER VOLTAGE SENSITIVITY IN MILLIVOLTS PER DB REFERENCE LEVEL "
278   DISP "FOR TEST ITEM AND LEAD TO PRE AMP.  "
279   INPUT TEST_SENSE
280 CLEAR
```

```
281   DISP "ENTER THE MAX DECIBEL REFERENCE LEVEL IN DB's ."
282   INPUT DB_REF_LEVEL
283   VPG_VIBE=1/ACCEL_SENSE*1000 ! mVolts/G
284   VPG_ISOL=0
285   GOTO 300
286 CLEAR
287   DISP "ENTER SENSITIVITY OF UNISOLATED VIBRATING ACCELEROMETER IN mV/g"
288   INPUT VPG_VIBE
289   DISP
290   DISP "ENTER SENSITIVITY OF VIBRATION ISOLATED ACCELEROMETER IN mV/g."
291   INPUT VPG_ISOL
292 CLEAR
293   DB_REF_LEVEL=0
294   TEST_SENSE=0
295   GOSUB DISPLAY_TEST_ITEM_DATA
296   GOSUB CHANGE_INPUTS
297 CLEAR
298 !
299   RETURN
300 ! ************************************************************************
301 ! **********************  DISP_TEST_ITEM  ******************************
302 ! ************************************************************************
303 !
304  DISPLAY_TEST_ITEM_DATA:
305  DISP "ITEM NAME:...";NAME$
306  DISP "MANUFACTURER:";MAN$
307  DISP "PART NO.:....";PN$
308  DISP "SERNO:.......";SERNO$
309  DISP "VIBE ACCELEROMETER SENSITIVITY:";VPG_VIBE;"mV/G"
310  DISP "ISOL ACCELEROMETER SENSITIVITY:";VPG_ISOL;"mV/G"
311  DISP "TEST ITEM SENSITIVITY:";TEST_SENSE;"MILLIVOLTS @ DB REF LEVEL"
312  DISP "TEST ITEM DB REFERENCE LEVEL:";DB_REF_LEVEL
313  !
314 RETURN
315 ! **********************************************************************
316 ! ******************  ROUT_#3_TEST_COND_FILENAME_INPUT  ***************
317 ! **********************************************************************
318   TEST_CONDITIONS_FILENAME_INPUTS:
319   ROUTINE=3
320   DISP "ENTER '1' IF VIBRATING AXIS IS PERPINDICULAR TO THE FACE OF "
321   DISP "          THE TEST ITEM OR AXIALLY (Z LONGITUDINAL AXIS)."
322   DISP "ENTER '2' IF VIBRATING AXIS IS PARALLEL TO THE FACE OF THE "
323   DISP "          TEST ITEM  RADIALLY (X LATERAL DIRECTION)."
324   DISP "ENTER '3' IF VIBRATING AXIS IS PARALLEL TO THE FACE OF THE "
325   DISP "          TEST ITEM RADIALLY (Y LATERAL DIRECTION)."
326   DISP "ENTER '4' IF TEST ITEM IS NOT VIBRATING BUT IS EXPOSED TO "
327   DISP "SHAKER NOISE"
328   DISP
329   DISP "ENTER '5' IF TEST ITEM IS ISOLATED FROM NOISE AND VIBRATION."
330   INPUT AXIS
331 CLEAR
```

```
332  IF AXIS=1 THEN 333 ELSE 337
333    AXIS$="VIBRATION IS PERPINDICULAR TO THE FACE OF ITEM;Z LONG. AXIS."
334    A$="Z" ! Assigns 'L' as the first letter in the filename.
335    GOTO 363
336 !
337  IF AXIS=2 THEN 338 ELSE 342
338    AXIS$="VIBRATION IS PARALLEL TO THE FACE OF ITEM;X LAT DIRECTION."
339    A$="X" ! Assigns 'W' as the first letter in the filename.
340    GOTO 363
341 !
342  IF AXIS=3 THEN 343 ELSE 347
343    AXIS$="VIBRATION IS PARALLEL TO THE FACE OF ITEM;Y LAT DIRECTION."
344    A$="Y" ! Assigns 'N' as the first letter in the filename.
345    GOTO 363
346 !
347  IF AXIS=4 THEN 348 ELSE 353
348    AXIS$="TEST ITEM IS NOT VIBRATING, BUT IS EXPOSED TO SHAKER NOISE"
349    A$="N" ! Assigns letter 'N' as first letter in file name
350    AXIS$="TEST ITEM IS NOT VIBRATING, BUT IS EXPOSED TO SHAKER NOISE"
351    GOTO 357
352 !
353  IF AXIS=5 THEN 354
354    AXIS$="TEST ITEM IS ISOLATED FROM SHAKER NOISE AND VIBRATION"
355    A$="I"
356 CLEAR
357  DISP "ENTER THE RUN NUMBER. IE IF THIS IS THE SECOND RUN FOR THESE "
358  DISP "TEST CONDITIONS ON THIS TEST ITEM THEN ENTER '2'."
359  INPUT RUN_NO
360 CLEAR
361 !
362  DISP "ENTER AN 8 CHARACTER OR LESS ALPHANUMERIC CODE THAT WILL BE  "
363  DISP "USED TO CREATE THE FILENAME. THE CODE SHOULD BE PECULIAR TO "
364  DISP "THIS TEST ITEM. IT SHOULD DESCRIBE CONDITIONS OTHER THAN THE "
365  DISP "ENVIRONMENT OR RUN NUMBER. example BJ56C, BJ56 IS PART OF THE"
366  DISP "SERIAL NUMBER AND 'C' INDICATES THAT THE MIKE WAS CAPPED."
367  DISP
368  DISP
369  DISP "THE SERIAL NUMBER FOR ITEM UNDER TEST IS:";SERNO$
370  INPUT CODE$
371 !
372  D$=":D701" ! Disk drive code
373 CLEAR
374  GOSUB DISPLAY_TEST_CONDITIONS
375  GOSUB CHANGE_INPUTS
376  RETURN
```

```
377 ! ************************************************************************
378 ! ***************************  _DISPLAY_TEST_COND_  *********************
379 ! ************************************************************************
380 !
381 DISPLAY_TEST_CONDITIONS:
382 FILE$=A$&CODE$&RUN_NO$&D$
383   DISP "CONDITIONS:.......";AXIS$
384   DISP "AXIS CODE:........";A$
385   DISP "ITEM CODE :.......";CODE$
386   DISP "FILE NAME WILL BE:";FILE$
387 !
388 RETURN
389 ! ************************************************************************
390 ! **************************   CONCATENATE_FILENAME_INPUTS   *************
391 ! ************************************************************************
392   CONCATENATE_FILENAME_INPUTS:
393 ! Concatenate the data file name.
394 !
395 FILE$=A$&CODE$&RUN_NO$&D$
396 !
397 CLEAR
398   DISP "DOES A DATA FILE NAMED ";FILE$;" ALREADY EXIST?"
399   DISP "ENTER 1 IF YES"
400   DISP "ENTER 2 IF NO "
401   INPUT EXIST
402   IF EXIST=1 THEN PURGE FILE$ ELSE 406
403   CREATE FILE$,125,8
404   ASSIGN# 1 TO  FILE$
405   RETURN
406   IF EXIST=2 THEN CREATE FILE$,125,8 ELSE 398
407   ASSIGN# 1 TO  FILE$
408 CLEAR
409 !
410 RETURN
```

```
411 ! ######################################################################
412 ! ##########################  SELECT_DATA_ENTRY_METHOD  ################
413 ! ######################################################################
414 SELECT_DATA_ENTRY_METHOD:
415 !
416 DISP "ENTER THE NUMBER (1 or 2) THAT REPRESENTS THE METHOD TO"
417 DISP "BE USED TO SELECT TEST FREQUENCY AND G LOAD PAIRS."
418 DISP
419 DISP "ENTER '1' TO USE THIRD OCTAVE BAND FREQUENCIES: 20 TO 2000 HZ,"
420 DISP "AND G LOADS ASSOCIATED WITH FIGURE 1 VIBRATIONS,ACCELERATION"
421 DISP "SPECTRAL  DENSITY GRAPH CONTAINED IN THE NASA GET AWAY SPECIAL"
422 DISP "EXPERIMENTER'S HANDBOOK."
423 DISP
424 DISP "ENTER '2' TO INPUT YOUR OWN SELECTED FREQUENCY AND G LOAD PAIRS."
425 !
426  INPUT METHOD
427  ON METHOD GOSUB PROGRAM_DATA ,KEYBOARD_ENTRY
428  RETURN
429   PROGRAM_DATA:
430   NF=21
431   RESTORE 434
432     FOR L=1 TO NF
433     READ FREQ(L)
434     DATA 20,25,31.5,40,50,63,80,100,125,160
435     DATA 200,250,315,400,500,630,800,1000,1250,1600,2000
436 !
437     NEXT L
438 !
439    RESTORE 442
440    FOR L=1 TO NF
441     READ G_REQ(L)
442     DATA .38,.48,.6,.76,.95,1.2,1.52,1.7,1.9,2.15
443     DATA 2.41,2.69,3.02,3.4,3.8,4.27,4.81,5.38,5.38,5.38,5.38
444 !
445     NEXT L
446 !
447    CLEAR
448    DISP "THIRD OCTAVE BAND FREQUENCIES AND "
449    DISP "REQUIRED RMS G LOADS ARE AS FOLLOWS:"
450    DISP USING 451 ; "FREQ","G LOAD","FREQ","G LOAD"
451    IMAGE 6X,4A,2X,6A,6X,4A,2X,6A
452 !
453    FOR L=1 TO 10
454      DISP USING 455 ; FREQ(L),G_REQ(L),FREQ(L+10),G_REQ(L+10)
455      IMAGE 5X,4D.D,3X,DD.DD,7X,4D.D,3X,DD.DD
456    NEXT L
457      DISP USING 458 ; FREQ(21),G_REQ(21)
458      IMAGE 26X,4D.D,3X,DD.DD
459   RETURN
```

```
460 ! ************************************************************************
461 ! ************************    KEYBOARD_ENTRY    ***********************
462 ! ************************************************************************
463  KEYBOARD_ENTRY:
464    ROUTINE=4
465    DISP "ENTER NUMBER OF FREQUENCY,G LOAD PAIRS TO BE TESTED."
466    DISP "NUMBER OF PAIRS MUST NOT EXCEED 25."
467 !
468    INPUT NF
469    FOR L=1 TO NF
470     DISP "ENTER THE NUMBER";L;"TEST FREQUENCY  AND G LOAD PAIR."
471     DISP "ENTER FREQUENCY IN HERTZ AND G LOAD IN RMS G's."
472     DISP "FOR 200 HZ AND 1.21 (RMS) G ENTER: 200,1.21 ."
473     INPUT FREQ(L),G_REQ(L)
474    NEXT L
475 CLEAR
476   GOSUB PERUSE
477 !
478    RETURN
479   PERUSE:
480    DISP "IF YOU WOULD LIKE TO REVIEW"
481    DISP "THE FREQ/G PAIRS ENTERED "
482    DISP "THEN ENTER '1', IF NOT ENTER '2'."
483    INPUT REVIEW
484    IF REVIEW=1 THEN GOSUB DISPLAY  ELSE RETURN
485    RETURN
486    DISPLAY:
487     FOR L=1 TO NF
488      DISP FREQ(L),G_REQ(L)
489     NEXT L
490      GOSUB CHANGE_INPUTS
491    RETURN
492 ! ************************************************************************
493 ! **************************  CHANGE_INPUTS  **************************
494 ! ************************************************************************
495 CHANGE_INPUTS:
496   DISP
497   DISP
498   DISP "IF YOU WOULD LIKE TO MODIFY ANY OF THE "
499   DISP "THESE ENTRIES ENTER '1'; IF NOT ENTER '2'."
500   DISP
501   INPUT CHANGES
502    IF CHANGES=1 THEN 503 ELSE RETURN
503      ON ROUTINE GOSUB TEST_EQUIPMENT_PARAMETERS ,TEST_ITEM_DATA ,TEST_CONDITIONS_FILENAME_INPUTS
,KEYBOARD_ENTRY
504 RETURN
```

```
505 ! ######################################################################
506 ! ######################  PRINT_HEADERS  ###############################
507 ! ######################################################################
508  PRINT_HEADERS:
509  PRINTER IS 702
510  PRINT CHR$ (12)
511  PRINT CHR$ (27)&"&k9S"
512  PRINT USING 513 ; TODAY$
513  IMAGE 50X,17A
514 !
515  PRINT
516  PRINT USING 517 ; "ITEM RESPONSE TO VIBRATION"
517  IMAGE 10X,16X,26A
518  PRINT
519  PRINT USING 520 ; AXIS$
520  IMAGE 10X,80A
521  PRINT
522  PRINT USING 523 ; "ITEM NAME:";NAME$
523  IMAGE 10X,30A,X,27A
524  PRINT USING 523 ; "MANUFACTURER:";MAN$
525  PRINT USING 523 ; "PART NO.:";PN$
526  PRINT USING 523 ; "SERNO:";SERNO$
527  PRINT USING 528 ; "ACCEL PRE AMP GAIN:";GAIN_A
528  IMAGE 10X,30A,4D.D
529  PRINT USING 528 ; "TEST ITEM PRE AMP GAIN:";GAIN_B
530  PRINT USING 523 ; "DATA FILE NAME:";FILE$
531  PRINT USING 523 ; "DATA DISC LABEL:";DATA_DISC$
532  IMAGE 10X,15A,X,15A
533  PRINT
534 !
535  IMAGE 10X,28A,X,DD,20A
536  PRINT
537 !
538 ! Some abbreviations.
539 !
540 O$="OBS" ! observed
541 N$="NO."
542 V$="VOLTS"
543 R$="REQ'D"
544 ! Print headings for printed output.
545 PRINT USING 546 ; "FREQ","ITEM","SPL/","INPUT","ACCEL",R$,O$,N$
546 IMAGE 10X,4A.4X,5A,3X,5A,2X,5A,3X,5A,2X,5A,4X,3A.5X,3A
547 PRINT USING 548 ; V$,"XMISS",V$,V$,"G LOAD","G LOAD","TRIES"
548 IMAGE 18X,5A,2X,5A,3X,5A,3X,5A,2X,6A,2X,6A,2X,6A
549 PRINT USING 550 ; "(HZ)","(uV)","(DB)","(MV)","(MV)","(G's)","(G's)"
550 IMAGE 10X,4A,4X,4A,4X,4A.4X,5A,3X,5A,2X,5A.2X,5A
551 !
552 RETURN
```

```
553 ! ##########################################################################
554 ! ##########################  CALIBRATE_EQUIP  ############################
555 ! ##########################################################################
556  CALIBRATE_EQUIPMENT:
557  DISP "EQUIPMENT IS BEING CALIBRATED AND SET."
558 !
559 ! Set equipment initial parameters.
560 ! 707 addresses the HP3314A Function Generator.
561 ! 711 addresses the HP3582A Spectrum analyzer.
562 ! See appropriate manual for decoding.
563 OUTPUT 711 ;"PRS"
564 OUTPUT 711 ;"IM2AC1BC1AS5BS5MD3SP9SC1AV2MP63MN1"
565 OUTPUT 711 ;"AA1AB1NU2"
566 !
567 ! Set function generator
568 OUTPUT 707 ;"CADE1FU1MO1LV1SR1SL1"
569 !
570  RETURN
571 ! ##########################################################################
572 ! ##################  TEST_FREQUENCY_G_LOAD_PAIRS  ####################
573 ! ##########################################################################
574  TEST_AT_FREQUENCY_G_LOAD_PAIRS:
575  SUM_SPL=0
576  FOR M=1 TO NF
577 !
578 !
579   DISP "TEST FREQUENCY:";FREQ(M)
580   DISP "REQUIRED G LOAD:";G_REQ(M)
581   GOSUB RESET_COUNTERS_ADDERS
582   GOSUB VOLTAGE_LIMIT_CHECK
583   GOSUB OUTPUT_FREQUENCY_AND_VOLTAGE
584   GOSUB TEST_PARAMETERS
585   GOSUB MEASURE_Gs_ADJUST_VOLTAGE
586   GOSUB MEASURE_AND_RECORD_FINAL_VALUES
587   GOSUB PRINT_INDIVIDUAL_RESULTS
588   DISP "NEXT FREQUENCY,G REQUIRED INPUT FOR TEST."
589 !
590   NEXT M
591  RETURN
```

```
592 ! ***********************************************************************
593 ! ***************************  TEST_PRAMETERS  **************************
594 ! ***********************************************************************
595  TEST_PARAMETERS:
596   DISP "TEST FREQUENCY:";FREQ(M);"HZ"
597   DISP "REQUIRED G LOAD:";G_REQ(M);"G's"
598 !
599   G_MAX=T/100*G_REQ(M)+G_REQ(M)
600   G_MIN=G_REQ(M)-T/100*G_REQ(M)
601   DISP "G LOAD TOLERANCE IS + OR -";T;"% ; FROM";G_REQ(M);"."
602   DISP "G LOAD RANGE IS FROM";G_MIN;"TO";G_MAX;"."
603  RETURN
604 ! ***********************************************************************
605 ! **********************************************************************
606 ! ***********************  VOLTAGE_LIMIT_CHECK  ***********************
607 ! **********************************************************************
608 !
609 VOLTAGE_LIMIT_CHECK:
610  DISP "CHECKING THAT REQUIRED VOLTAGE DOES NOT EXCEED";;V_MAX
611  IF ABS (V)>V_MAX THEN 612 ELSE RETURN
612  DISP "SELECTED INPUT VOLTAGE OF";V;"EXCEEDS SHAKER TABLE "
613  DISP "YOUR PRE SET LIMIT WAS";V_MAX;"MILLIVOLTS."
614  WAIT 5000
615  GOSUB CLOSE_FILES_AND_NULL_OUTPUTS
616  GOSUB ANOTHER_RUN
617  END
618 ! **********************************************************************
619 ! *******************  OUTPUT_FREQ_AND_VOLTAGE  ***********************
620 ! **********************************************************************
621 OUTPUT_FREQUENCY_AND_VOLTAGE:
622  INITIAL_VOLTAGE=100
623  DISP "RUNNING FUNCTION GENERATOR AND FFT AT THIS TIME."
624  DISP
625  OUTPUT 707 ;"FR",FREQ(M),"HZ"
626  OUTPUT 707 ;"AP",V,"MV"
627 !
628  OUTPUT 711 ;"AA1"
629  OUTPUT 711 ;"AD",FREQ(M),"RE"
630  WAIT 4500
631 !
632  OUTPUT 711 ;"LMK,AA0"
633  ENTER 711 ; TEMP_A
634  DISP "TEMP_A LINE 6915";TEMP_A
635  G_MEAS=TEMP_A*ACCEL_SENSE/GAIN_A
636  DISP "G MEAS:";TEMP_A*ACCEL_SENSE/GAIN_A
637  WAIT 2000
638 DISP
639  RETURN
```

```
640 ! ********************************************************************
641 ! ********************  MEASURE_Gs_ADJ_VOLTAGE  *******************
642 ! ********************************************************************
643   MEASURE_Gs_ADJUST_VOLTAGE:
644     DISP
645     DISP
646     DISP "I AM COMPUTING THE G's OBTAINED AND WILL SEE IF "
647     DISP "THE MEASURED G IS WITHIN LIMITS SPECIFIED. IF NOT"
648 ! Records values obtained on run number 'N'. Moves to next pair.
649     DISP "WITHIN LIMITS A NEW VOLTAGE WILL BE CALCULATED."
650    IF N+1=MAX_TRIES+1 THEN G_MIN=G_MEAS
651 ! Determine if the created g load is within limits specified.
652    IF G_MIN<= G_MEAS AND G_MEAS<= G_MAX THEN RETURN ELSE GOSUB DETERMINE_NEW_VOLTAGE
653 RETURN
654 ! ********************************************************************
655 ! *********************  DETERMINE_NEW_VOLTAGE  *********************
656 ! ********************************************************************
657   DETERMINE_NEW_VOLTAGE:
658     X=G_MEAS
659     Y=V
660     IF N>1 THEN GOSUB LEAST_SQUARE_COEFFICIENTS
661     IF N<5 THEN GOSUB LINEAR  ELSE GOSUB CUBIC
662        GOSUB VOLTAGE_LIMIT_CHECK
663        GOSUB OUTPUT_FREQUENCY_AND_VOLTAGE
664        GOSUB MEASURE_Gs_ADJUST_VOLTAGE
665     RETURN
666  LINEAR:
667   IF G_MEAS<G_MIN THEN 676 ELSE 689
668     DISP "ATTEMPT :";N;"G_LOAD TOO SMALL "
669     DISP "FOR TEST VOLTAGE :";V;"MILLIVOLTS"
670     CORRECTION=G_REQ(M)/G_MEAS
671     DISP "G_MIN:";;;;G_MIN
672     DISP "G_MEAS:";;;G_MEAS
673     DISP "G_REQ(M):";G_REQ(M)
674     DISP "CORRECTION FACTOR:";CORRECTION
675     V=V*CORRECTION
676     IF V<100 THEN V=INT ((V+.05)*10)/10 ELSE V=INT (V-.5)
677     DISP "NEW INPUT VOLTAGE IS :";V;"MILLIVOLTS"
678     N=N+1
679    RETURN
680 !
```

```
681    IF G_MEAS>G_MAX THEN 682
682     DISP
683     DISP "ATTEMPT NO.:";N;"G_LOAD TOO BIG."
684     DISP "FOR TEST VOLTAGE :";V;"MILLIVOLTS"
685     DISP "G_MAX:";;;;;G_MAX
686     DISP "G_MEAS:";;;;G_MEAS
687     DISP "G_REQ(M):";;G_REQ(M)
688     CORRECTION=G_REQ(M)/G_MEAS
689     DISP "CORRECTION FACTOR:";CORRECTION
690     V=V*CORRECTION
691     IF V<100 THEN V=INT ((V+.05)*10)/10 ELSE V=INT (V+.5)
692     DISP "NEW INPUT VOLTAGE IS :";V;"MILLIVOLTS."
693      N=N+1
694    RETURN
695    RESET_COUNTERS_ADDERS:
696 !
697    N=1
698    V=INITIAL_VOLTAGE
699     DISP "RESETTING"
700     DISP
701    SUM_X=0
702    SUM_X2=0
703    SUM_X3=0
704    SUM_X4=0
705    SUM_X4=0
706    SUM_X5=0
707    SUM_X6=0
708    SUM_Y=0
709    SUM_XY=0
710    SUM_X2Y=0
711    SUM_X3Y=0
712    X=0
713    Y=0
714  GOSUB LEAST_SQUARE_COEFFICIENTS
715   RETURN
716  LEAST_SQUARE_COEFFICIENTS:
717 !
718    DISP "SUMMING COEFFICIENTS"
719 !
720   SUM_X=SUM_X+X
721   SUM_X2=SUM_X2+X^2
722   SUM_X3=SUM_X3+X^3
723   SUM_X4=SUM_X4+X^4
724   SUM_X5=SUM_X5+X^5
725   SUM_X6=SUM_X6+X^6
726   SUM_Y=SUM_Y+Y
727   SUM_XY=SUM_XY+X*Y
728   SUM_X2Y=SUM_X2Y+X^2*Y
729   SUM_X3Y=SUM_X3Y+X^3*Y
730 !
731  RETURN
```

```
732 ! *******************************************************************
733 ! *****************************   CUBIC  ******************************
734 ! *******************************************************************
735  CUBIC:
736  DISP "COMPUTING CUBIC COEFFICIENTS"
737  B21=SUM_X*SUM_X-N*SUM_X2
738  C21=SUM_X*SUM_X2-N*SUM_X3
739  D21=SUM_X*SUM_X3-N*SUM_X4
740  T21=SUM_X*SUM_Y-N*SUM_XY
741  B31=SUM_X*SUM_X2-N*SUM_X3
742  C31=SUM_X2*SUM_X2-N*SUM_X4
743  D31=SUM_X2*SUM_X3-N*SUM_X5
744  T31=SUM_X2*SUM_Y-N*SUM_X2Y
745  B41=SUM_X*SUM_X3-N*SUM_X4
746  C41=SUM_X2*SUM_X3-N*SUM_X5
747  D41=SUM_X3*SUM_X3-N*SUM_X6
748  T41=SUM_Y*SUM_X3-N*SUM_X3Y
749  C32=B31*C21-B21*C31
750  D32=B31*D21-B21*D31
751  T32=T21*B31-B21*T31
752  C42=C21*B41-B21*C41
753  D42=D21*B41-B21*D41
754  T42=T21*B41-B21*T41
755  D43N=C42*T32-C32*T42
756  D43D=C42*D32-C32*D42
757  D=D43N/D43D
758  C=(T42-D*D42)/C42
759  B=(T21-C*C21-D*D21)/B21
760  A=(SUM_Y-SUM_X*B-SUM_X2*C-SUM_X3*D)/N
761  DISP "THE  'A' COEFFICIENT =";A
762  DISP "THE  'B' COEFFICIENT =";B
763  DISP "THE  'C' COEFFICIENT =";C
764  DISP "THE  'D' COEFFICIENT =";D
765  X=G_REQ(M)
766  V=A+B*X+C*X*X+D*X*X*X
767  IF V<100 THEN V=INT ((V+.05)*10)/10 ELSE V=INT (V+.5)
768 !
769  DISP "NEW VOLTAGE FOR";G_REQ(M);"IS";V
770  N=N+1
771 RETURN
```

```
772 ! ##########################################################################
773 ! ##################   MEASURE_AND_RECORD_FINAL_VALUES   ####################
774 ! ##########################################################################
775 ! ##########################################################################
776   MEASURE_AND_RECORD_FINAL_VALUES:
777   DISP "I AM MEASURING FINAL RESULTS FOR DISPLAY AND RECORDING."
778   DISP
779   WAIT 10000
780   VOLT_I(M)=V
781   G_LOAD1(M)=G_MEAS
782   ITERATIONS(M)=N
783 ! Read FFT channel B to obtain test item voltage.
784 ! Turn channel A back on.
785   OUTPUT 711 ;"LMK,AA1"
786   ENTER 711 ; TEMP_B
787   DISP "TEMP_B LINE 8450";TEMP_B
788 ! Enters FFT chan B  voltage in millivolts and takes into account
789 ! preamp gain.
790   VOLT_B(M)=TEMP_B*1000/GAIN_B ! millivolts
791 !
792 ON SPL_TRANSMISSIBILITY GOSUB TEST_ITEM_SPL ,TRANSMISSIBILITY_DB
793 !
794 ! Begin combining band sound pressure levels.
795   SUM_SPL=SUM_SPL+10^(SPL(M)/10)
796   VB=VOLT_B(M) ! Millivolts
797    PRINT# 1 ; FREQ(M),G_LOAD1(M),VB,ITERATIONS(M),SPL(M)
798   RETURN
799 !
800 TEST_ITEM_SPL:
801    IF VOLT_B(M)=0 THEN SPL(M)=0 ELSE GOTO 803
802      RETURN
803   SPL(M)=20*LGT (VOLT_B(M)/TEST_SENSE)+DB_REF_LEVEL
804 RETURN
805 !
806 TRANSMISSIBILITY_DB:
807   SPL(M)=20*LGT (TEMP_B/GAIN_B/VPG_ISOL/(TEMP_A/GAIN_A/VPG_VIBE))
808  RETURN
809 !
```

```
810 ! ********************************************************************
811 ! ********************  PRINT_INDIVIDUAL_RESULTS  **********************
812 ! ********************************************************************
813  PRINT_INDIVIDUAL_RESULTS:
814 ! Some abbreviations.
815     GPV=G_MEAS/V
816     VB=VOLT_B(M)*1000 ! Converted to microvolts
817     SPL=SPL(M)
818     GR=G_REQ(M)
819     GL1=G_LOAD1(M)
820     VA=TEMP_A*1000/GAIN_A
821     DISP USING 822 ; "FREQ","ITEM","SPL/","INPUT","ACCEL",R$,O$,N$
822     IMAGE 10X,4A,4X,5A,3X,5A,2X,5A,3X,5A,2X,5A,4X,3A,5X,3A
823     DISP USING 824 ; V$,"XMISS",V$,V$,"G LOAD","G LOAD","TRIES"
824     IMAGE 18X,5A,2X,5A,3X,5A,3X,5A,2X,6A,2X,6A,2X,6A
825     DISP USING 826 ; "(HZ)","(uV)","(DB)","(MV)","(MV)","(G's)","(G's)"
826     IMAGE 10X,4A,4X,4A,4X,4A,4X,5A,3X,5A,2X,5A,2X,5A
827     DISP USING 828 ; FREQ(M),VB,SPL,V,VA,GR,GL1,ITERATIONS(M)
828     IMAGE 10X,4D.D,2X,4D.D,2X,3D.DD,X,4D.D,3X,D.3D,3X,D.DD,3X,D.DD,5X,2D
829     PRINT USING 830 ; FREQ(M),VB,SPL,V,VA,GR,GL1,ITERATIONS(M)
830     IMAGE 10X,4D.D,2X,4D.D,2X,3D.DD,X,4D.D,3X,D.3D,3X,D.DD,3X,D.DD,5X,2D
831  RETURN
```

```
832 ! ************************************************************************
833 ! **************  PRINT_OVERALL_RESULTS  *****************************
834 ! ************************************************************************
835  PRINT_OVERALL_RESULTS:
836 !   Compute overall band SPL
837     OVERALL_BAND_LEVEL=10*LGT (SUM_SPL)
838 !
839     WAIT 6000
840     CLEAR
841     DISP "OVERALL BAND SOUND PRESSURE LEVEL:";OVERALL_BAND_LEVEL
842     PRINT USING 843 ; "OVERALL BAND SPL:";OVERALL_BAND_LEVEL;"DB. REF LEVEL";TEST_SENSE;"mV @";DB_
REF_LEVEL;"DB."
843     IMAGE /,10X,17A,4D.D,X,14A,4D.DD,4A,X,DDD,X,3A
844  PRINT
845  PRINT USING 855 ; "COMMENTS:"
846  PRINT
847  PRINT USING 850 ; "SPL/XMISS: READ 'SPL' FOR MEASURED VOLTAGE RESPONSE."
848  PRINT USING 851 ; "READ 'XMISS' FOR MEASURED TRANSMISSIBILITY."
849  PRINT USING 852 ; "G LOADS OBTAINED WERE WITHIN";T;"% OF DESIRED VALUES."
850  IMAGE 10X,60A
851  IMAGE 21X,50A
852  IMAGE 10X,28A,DD.D,20A
853  PRINT USING 855 ; "ALL VOLTAGES ARE WITHOUT AMPLIFICATION AND INCLUDE"
854  PRINT USING 855 ; "LINE LOSSES TO PREAMP."
855  IMAGE 10X,57A
856 ! Print to disk
857  PRINT# 1 ; OVERALL_BAND_LEVEL
858     OUTPUT 707 ;"AP",0,"MV"
859     OUTPUT 711 ;"AA0AB0"
860     DISP "ENTER ANY(60 CHR MAX) COMMENT  ABOUT THE RUN JUST COMPLETED."
861 DISP "ENTER";"";" IF YOU HAVE NO COMMENTS, THEN PRESS 'END LINE'."
862 DISP "XXXXXXXXXX COMMENT   LENGTH XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX"
863      INPUT COMMENTS3$
864 !
865     DISP "COMMENTS:";COMMENTS1$&COMMENTS2$
866  PRINT USING 869 ; COMMENTS1$
867  PRINT USING 869 ; COMMENTS2$
868  PRINT USING 869 ; COMMENTS3$
869  IMAGE 10X,60A
870  RETURN
871 ! ************************************************************************
872 ! *****************  CLOSE_FILES_AND_NULL_OUTPUTS  *********************
873 ! ************************************************************************
874  CLOSE_FILES_AND_NULL_OUTPUTS:
875     OUTPUT 707 ;"AP",0,"MV"
876     OUTPUT 711 ;"AA0AB0"
877     ASSIGN# 1 TO  *
878     CLEAR
879  !
880  RETURN
```

```
881 ! ***********************************************************************
882 ! **********************  ANOTHER_RUN  ****************************
883 ! ***********************************************************************
884  ANOTHER_RUN:
885   DISP "IF YOU DESIRE ANOTHER RUN ENTER '1',IF NOT ENTER '2'."
886   INPUT AGAIN
887   WAIT 10000
888   CLEAR
889   ON AGAIN GOTO 893,890
890     DISP "THANK YOU FOR YOUR HELP. SEE YOU TOMMORROW. HP-87."
891     PRINT CHR$ (27)&"&k0S"
892    RETURN
893    RESET_CONDITIONS:
894 !
895     DISP "CONDITION 1: ITEM AND ALL CONDITIONS REMAIN UNCHANGED."
896     DISP "CONDITION 2: ITEM IS UNCHANGED, CONDITIONS CHANGE."
897     DISP "CONDITION 3: ITEM AND CONDITIONS CHANGE."
898     DISP "IF TEST EQUIPMENT SETTINGS OR PARAMETERS CHANGE "
899     DISP "PRESS  'RUN'."
900     DISP "ENTER THE CONDITION NUMBER DESIRED."
901     INPUT CONDITION
902     IF CONDITION=1 THEN 903 ELSE 915
903       RUN_NO=VAL (RUN_NO$)+1
904       RUN_NO$=VAL$ (RUN_NO)
905       GOSUB CONCATENATE_FILENAME_INPUTS
906       GOSUB SELECT_DATA_ENTRY_METHOD
907       GOSUB PRINT_HEADERS
908       GOSUB CALIBRATE_EQUIPMENT
909       GOSUB TEST_AT_FREQUENCY_&_LOAD_PAIRS
910       GOSUB PRINT_OVERALL_RESULTS
911       GOSUB CLOSE_FILES_AND_NULL_OUTPUTS
912       GOSUB ANOTHER_RUN
913     RETURN
914     !
915     IF CONDITION=2 THEN 923 ELSE 934
916       GOSUB TEST_CONDITIONS_FILENAME_INPUTS
917       GOSUB CONCATENATE_FILENAME_INPUTS
918       GOSUB SELECT_DATA_ENTRY_METHOD
919       GOSUB PRINT_HEADERS
920       GOSUB CALIBRATE_EQUIPMENT
921       GOSUB TEST_AT_FREQUENCY_&_LOAD_PAIRS
922       GOSUB PRINT_OVERALL_RESULTS
923       GOSUB CLOSE_FILES_AND_NULL_OUTPUTS
924       GOSUB ANOTHER_RUN
925     RETURN
926     !
```

```
927     ON CONDITION=3 GOTO 928
928       GOSUB TEST_ITEM_DATA
929       GOSUB DISPLAY_TEST_ITEM_DATA
930       GOSUB TEST_CONDITIONS_FILENAME_INPUTS
931       GOSUB CONCATENATE_FILENAME_INPUTS
932       GOSUB SELECT_DATA_ENTRY_METHOD
933       GOSUB PRINT_HEADERS
934       GOSUB CALIBRATE_EQUIPMENT
935       GOSUB TEST_AT_FREQUENCY_&_LOAD_PAIRS
936       GOSUB PRINT_OVERALL_RESULTS
937        GOSUB CLOSE_FILES_AND_NULL_OUTPUTS
938       GOSUB ANOTHER_RUN
939     RETURN
```

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