CONTRACT NAS5-15208

# Aerospace Systems Pyrotechnic Shock Data

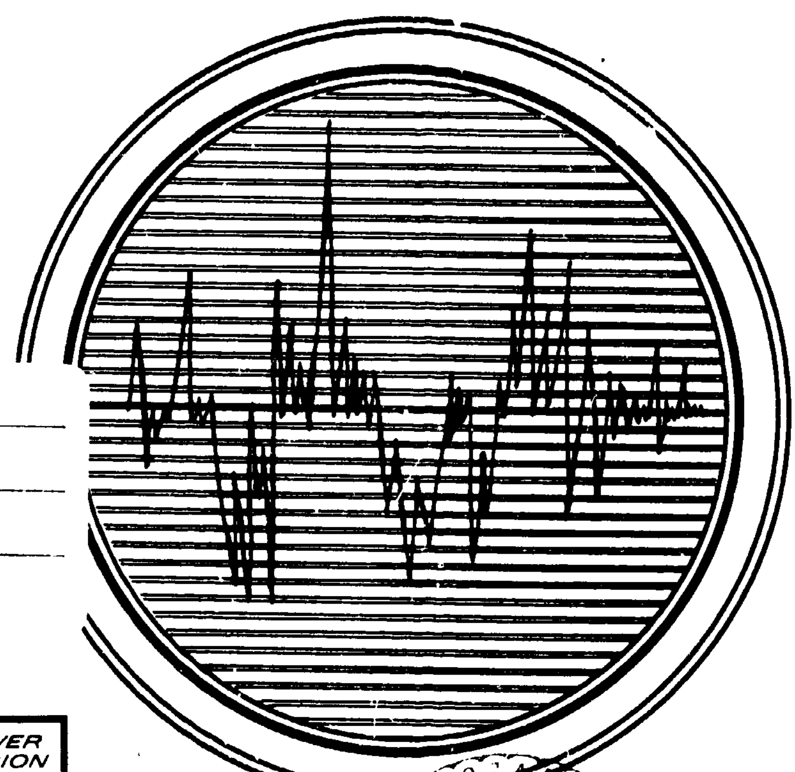
## (Ground Test and Flight)

Final Report

7 March 1970

### Volume I

### Summary and Analysis





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for

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

FINAL REPORT

For

# Aerospace Systems Pyrotechnic Shock Data (Ground Test and Flight)

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Volume I

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## ABSTRACT

The purpose of this document is to present the results of the study for NASA Goddard contract NAS5-15208. The principle purpose of this study was to compile and analyze pyrotechnic shock data from the aerospace industry to provide a single reference for shock data, and to develop an understanding of the parameters involved. The study consisted of the following:

A) Compilation of reduced pyrotechnic shock data representative of aerospace systems.

B) Definition of distinctive characteristics of pyrotechnic shock transients.

C) Evaluation of the quality of typically available pyrotechnic shock data.

D) Recommendation of measurement system(s) for ground test and flight.

E) Preparation of guidelines defining design information applicable to structure and/or equipment design.

F) Recommendation of test simulation techniques.

G) Classification of pyrotechnic systems as to the nature of resulting shock and/or damaging effects.

H) Evaluation of the effects of structural configuration and materials on resulting shock characteristics.

I) Formulation of a follow-on research program.

J) Application of shock propagation theory.

K) Ground test program.

A total of 2837 measurements were compiled and reduced and are presented in the data Volumes II through V. The data were obtained from a survey of the aerospace industry and government agencies and from a subcontracted effort from Lockheed Missiles and Space Company. Volume I contains a description of the work accomplished and a summary of the analyses. Volume VI presents a set of guidelines defining design information applicable to structure and equipment for designing to a pyrotechnic shock environment.

The conclusions of this study are presented in Section 5.1 of this volume. Recommendations for future study involve three specific areas; damage and failure criteria, shock propagation theory and simulation techniques. An outline for future test programs for these three topics is given in Section 2.9 of this volume.

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## LIST OF ABBREVIATIONS

| | |
|---|---|
| NASA | National Aeronautics and Space Administration |
| GSFC | Goddard Space Flight Center |
| LMSC | Lockheed Missiles and Space Company |
| MMC | Martin Marietta Corporation |
| FLSC | flexible linear shaped charge |
| MDF | mild detonating fuse |
| MM | Minuteman |

## LIST OF SYMBOLS

| | |
|---|---|
| $V_c$ | velocity of a compressional wave |
| $V_s$ | velocity of a shear wave |
| $\rho$ | density |
| $E$ | Young's modulus |
| $G$ | shear modulus |
| $a$ | acceleration |
| $v$ | equivalent velocity shock |
| $\omega$ | frequency, radians/second |
| $\alpha$ | slope parameter |
| $e^{-\alpha x}$ | exponential function of x |
| $f_n$ | natural frequency |
| $Q$ | amplification factor |
| $B$ | bandwidth |

## 1.0 INTRODUCTION

### 1.1 Purpose

The purpose of this report is to present the results and conclusions of the study performed under the Contract NAS5-15208, entitled "Aerospace Systems Pyrotechnic Shock Data (Ground Test and Flight)," sponsored by the Test and Evaluation Division of Goddard Space Flight Center.

### 1.2 Scope

This final report, contained in six volumes, describes the results of the work performed, the analyses and the data compiled during the course of this study. The specific work performed in the evaluation of pyrotechnic shock data are:

A) Compilation of "reduced" pyrotechnic shock data representative of aerospace systems.

B) Definition of distinctive characteristics of pyrotechnic shock transients.

C) Evaluation of the "quality" of typically available pyrotechnic shock data.

D) Recommendation of measurement system(s) for ground test and flight.

E) Preparation of guidelines defining design information applicable to structure and/or equipment design.

F) Recommendation of test simulation techniques.

G) Classification of pyrotechnic systems as to the nature of resulting shock and/or damaging effects.

H) Evaluation of the effects of structural configuration and materials on resulting shock characteristics.

I) Formulation of a follow-on research program.

J) Application of shock propagation theory to at least one class of pyrotechnic systems compiled in the study and compare results with measured data.

K) Performance of a ground test program utilizing full scale Titan III structure to provide specific information that will aid in the understanding of basic pyrotechnic shock transient phenomena.

This report also includes the data and analyses received from Lockheed Missiles and Space Company (LMSC) as a subcontract to this study.

1.3 Summary

The results of the work performed are included in Volume I of this report. Also included is a discussion of the general analyses performed on the compiled data. Acknowledgement of contributors is contained in Section 6.3 of Volume I.

The compiled data are contained in Volumes II and III of this report. Volumes IV and V contain the data and analyses submitted by Lockheed Missiles and Space Company under a subcontract, No. RC9-439031, "Compilation of Pyrotechnic Data". Volume VI contains the Design Guidelines Manual, which describes the use of the data and analyses contained in this final report, as well as design practices and principles, as applied to pyrotechnic shock.

## 2.0 DESCRIPTION OF WORK PERFORMED

### 2.1 The Compilation of Reduced Pyrotechnic Shock Data Representative of Aerospace Systems

The primary purpose of this effort was to compile pyrotechnic shock data and to categorize these data as to the type of pyrotechnic device and the type of structure on which the measurements were obtained. A survey requesting data was distributed to 175 aerospace companies and government agencies. Thirty of the 73 replies to the survey were able to contribute reports or papers containing pyrotechnic shock data. In addition to the survey, personal visits were made to nine companies to discuss and collect data. Acknowledgement to the contributors for their helpful cooperation is made in Section 6.3.

The data contained in the Martin Marietta Corporation files, received from the survey and compiled during the ground test performed under this contract, are presented in Volumes II and III of this final report. The compiled shock data and analyses received under a subcontract to Lockheed are presented in Volumes IV and V. These four volumes contain shock spectra for 2837 measurements, including 456 measurements compiled under the test program performed at Martin Marietta Corporation, Denver Division, and described in Section 2.11 and 451 measurements received from Lockheed.

In Volumes II and III, an attempt was made to arrange the data as to the type of pyrotechnic device and the type of structure on which the measurements were obtained. The classification scheme for Volumes II and III is shown in Table I. Notice that the first three divisions in Table I classify the data as to device, and for each device there are three classifications of structure. The number given to each section of data in the first three divisions follows the scheme in Table I and thus a section number, such as I.A.1, indicates that the data in that section is for a structure cutting device on a skin-ring-frame structure. Table II provides a summary and locations of the data presented in Volumes II through V.

The data in division IV of Volume III contains information from three extensive test programs on three different space vehicles. Each test program contains data from several different types of pyrotechnic devices on a particular vehicle. Division V contains flight data from four flight programs.

The reports and papers from which the data contained in Volumes II and III were obrained are listed in Section 6.1 of this volume.

TABLE I

OUTLINE OF DATA CLASSIFICATION SCHEME

I. Structure cutting charges (flexible linear shaped charge, mild detonating fuse, primachord, etc.)

- I.A The above pyrotechnic on a skin-ring-frame structure.
- I.B The above pyrotechnic on a truss structure.
- I.C The above pyrotechnic on a structure other than truss or skin-ring-frame.

II. Explosive nuts and bolts

- II.A The above pyrotechnic on a skin-ring-frame structure.
- II.B The above pyrotechnic on a truss structure.
- II.C The above pyrotechnic on a structure other than truss or skin-ring-frame.

III. Cartridge actuated device (pin pullers, bolt cutters, cable cutters, etc.)

- III.A The above pyrotechnic on a skin-ring-frame structure.
- III.B The above pyrotechnic on a truss structure.
- III.C The above pyrotechnic on a structure other than truss or skin-ring-frame.

IV. Space vehicle test data

V. Flight pyrotechnic shock data

TABLE II

SUMMARY OF PYROTECHNIC SHOCK DATA CONTAINED IN VOLUMES II THROUGH V

| VOLUME | SECTION | DATA SOURCE | PYROTECHNIC DEVICE | NO. OF MEASUREMENTS SHOCK SPECTRA | TIME HISTORIES |
|---|---|---|---|---|---|
| II | I.A.1 | Spartan Short Cylinder Separation Test | MDF | 22 | 22 |
| II | I.A.2 | Spartan Long Cylinder Separation Test | MDF | 19 | 19 |
| II | I.A.3 | Spartan Staging Separation Test | MDF | 55 | 55 |
| II | I.A.4 | MMIII Stage III/PBV Staging Test | Primachord | 94 | 94 |
| II | I.A.5 | MMIII Separation Tests | | | |
| | | Umbilical Separation Event | Bolt Cutter | 151 | 152 |
| | | Stage III/PBV Staging Event | Primachord | 315 | 315 |
| II | I.A.6 | Centaur Insulation Panel Separation Test | FLSC and MDF | 52 | 4 |
| II | I.A.7 | SBA Booster Separation Test | MDF | 13 | 13 |
| II | I.B.1 | Titan III-C Standard Payload Fairing Separation Test | Primaline | 48 | 48 |
| II | I.B.2 | Titan III-C Metal Fairing Separation Test | Primaline | 48 | 48 |
| II | I.B.3 | Titan III-C Universal Payload Fairing Separation Test | | | |
| | | Pin Release Event | Cable Cutter | 72 | 72 |
| | | Fairing Separation Event | Primaline | 72 | 72 |
| II | I.C.1 | MSS Shroud Separation Test | MDF | 24 | 24 |
| II | I.C.2 | Apollo Service Module Separation Test | MDF | 11 | 4 |

TABLE II (CONTINUED)

| VOLUME | SECTION | DATA SOURCE | PYROTECHNIC DEVICE | NO. OF MEASUREMENTS SHOCK SPECTRA | TIME HISTORIES |
|---|---|---|---|---|---|
| II | I.C.3 | Athena Re-entry Vehicle Separation Test | Primachord | 8 | 0 |
| III | II.A.1 | POGO Shroud Separation Test | Explosive Bolts | 13 | 0 |
| III | II.B.1 | Task K - Ground Tests | Separation Nuts | 456 | 456 |
| III | II.B.2 | Titan IIIM Separation Nut Tests | Separation Nuts | 202 | 204 |
| III | II.B.3 | Payload Truss Shock Propagation Tests | Separation Nuts | 83 | 83 |
| III | III.B.1 | OV5-2 Satellite Release Tests | Pin Puller | 30 | 30 |
| III | III.B.2 | Separation Shock Tests of TOS-M Spacecraft | Bolt Cutters | 68 | 12 |
| III | III.B.3 | OAO Separation Test | Bolt Cutters | 23 | 23 |
| III | III.C.1 | IDCSP/A Development Model 2 Separation Test | Bolt Cutters | 6 | 6 |
| III | III.C.2 | ATS Separation Test | Bolt Cutters | 14 | 14 |
| III | III.C.3 | OGO-F Antenna Ejection Tests | Bolt Cutters | 8 | 8 |
| III | IV.A | PRIME Re-entry Vehicle Shock Tests | | | |
| III | IV.A.1 | Booster Separation Event | Explosive Bolts | 27 | 0 |
| III | IV.A.2 | Parachute Hatch Separation Event | FLSC | 59 | 0 |
| III | IV.A.3 | Drogue Chute Ejection Mortar Event | Mortar | 25 | 0 |

TABLE II (CONTINUED)

| VOLUME | SECTION | DATA SOURCE | PYROTECHNIC DEVICE | NO. OF MEASUREMENTS SHOCK SPECTRA | TIME HISTORIES |
|---|---|---|---|---|---|
| III | IV.A.4 | Drogue Chute Separation Event | Separation Nut | 33 | 0 |
| III | IV.B | Mariner '67 Flight Acceptance Tests | | | |
| III | IV.B.1 | Shroud V-Band Release Event | Explosive Bolts | 19 | 19 |
| III | IV.B.2 | Spacecraft V-Band Release Event | Explosive Nut | 25 | 25 |
| III | IV.B.3 | Solar Panel Deployment Event | Pin Puller | 22 | 22 |
| III | IV.B.4 | PIPS 1 Event | Pin Puller | 17 | 17 |
| III | IV.B.5 | PIPS 2 Event | Pin Puller | 17 | 17 |
| III | IV.B.6 | Antenna Deployment Event | Pin Puller | 15 | 15 |
| III | IV.B.7 | Umbilical Door Slam Event | | 17 | 17 |
| III | IV.C | Shock Events from Surveyor Flights | | | |
| III | IV.C.1 | Atlas/Centaur Separation Event | FLSC | 15 | 7 |
| III | IV.C.2 | Shroud Separation Event | Separation Nuts | 11 | 4 |
| III | IV.C.3 | Insulation Panel Jettison Event | FLSC and MDF | 14 | 7 |
| III | IV.C.4 | Antenna Deployment Event | | 10 | 4 |
| III | IV.C.5 | Non-pyrotechnic Shock Event | ------------ | 21 | 9 |
| III | V.1 | Flight of Lunar Orbiters I and II Shroud Jettison Event | | 7 | 0 |
| III | V.2 | Flight Test of Delta Vehicle 41 (TOS-A) Solid Motor Jettison Event | Explosive Bolts | 5 | 5 |

TABLE II (CONTINUED)

| VOLUME | SECTION | DATA SOURCE | PYROTECHNIC DEVICE | NO. OF MEASUREMENTS SHOCK SPECTRA | TIME HISTORIES |
|---|---|---|---|---|---|
| | | Fairing Jettison Event | Explosive Bolts | 2 | 2 |
| III | V.3 | Flight Test of Delta Vehicle 43 (BIOS-A) | | | |
| | | Spacecraft Separation Event | Explosive Bolts | 12 | 12 |
| III | V.4 | Flight Test of Delta Vehicle 51 (BIOS-B) | | | |
| | | Fairing Jettison Event | Explosive Bolts | 5 | 5 |
| | | Spacecraft Separation Event | Explosive Bolts | 10 | 5 |

TABLE II (CONTINUED)

| VOLUME | SECTION | DESCRIPTION OF EVENT | PYROTECHNIC DEVICE | NO. OF MEASUREMENTS SHOCK SPECTRA | TIME HISTORIES |
|---|---|---|---|---|---|
| IV | II.A.1 | Booster Separation and Fairing Jettison | | 5 | 5 |
| IV | II.A.2 | Booster Separation and Fairing Jettison | MDF Pin Pullers | 16 | 60 |
| IV | II.A.3 | Booster Adapter Separation | MDF & FLSC | 24 | 111 |
| IV | II.A.4 | Booster Adapter Separation | MDF Explosive Nut | 27 | 34 |
| IV | II.A.5 | Shroud Separation | FLSC | 5 | 15 |
| IV | II.A.6 | Booster Adapter Separation | MDF | 17 | 21 |
| IV | II.A.7 | Satellite Booster Separation | Primachord | 210 | 120 |
| IV | II.B.1 | Fairing Jettison | Pin Puller | 0 | 60 |
| IV | II.B.2 | Fairing Jettison | Pin Pusher Puller | 48 | 48 |
| IV | II.B.3 | Fairing Jettison | Explosive Nut | 13 | 13 |
| V | II.C.1 | Subsatellite Qualification | Pin Puller | 0 | 11 |
| V | II.C.2 | Equipment Qualification | Pin Puller | 35 | 35 |

TABLE II (CONTINUED)

| VOLUME | SECTION | DESCRIPTION OF EVENT | PYROTECHNIC DEVICE | NO. OF MEASUREMENTS SHOCK SPECTRA | TIME HISTORIES |
|---|---|---|---|---|---|
| V | II.D.1 | External Pod Qualification | Primachord | 35 | 0 |
| V | II.D.2 | External Pod Qualification | Primachord | 15 | 0 |
| V | II.E.1 | Electronic Box Tests | MDF | 18 | 0 |
| V | II.E.2 | Electronic Box Tests | MDF | 30 | 6 |
| V | II.E.3 | Effect of Shock on Bonded Joints | MDF | 6 | 6 |
| V | II.E.4 | Electronic Box Tests | MDF | 6 | 0 |
| V | II.E.5 | Equipment Tests | MDF | 4 | 4 |
| V | II.E.6 | Electronic Box Tests | MDF | 12 | 12 |
| V | II.F.1 | Transfer Table Shock Testing | --------- | 12 | 12 |
| V | II.F.2 | Barrel Tester Development | MDF | 4 | 280 |

## 2.2 Definition of Distinctive Characteristics of Pyrotechnic Shock Transients Including an Assessment of Fourier Analyses

### 2.2.1 Introduction

The purpose of this effort was to utilize the compiled data to determine distinctive characteristics of shock transients including propagation velocity, frequency characteristics and attenuation of amplitude with distance from the shock source. This effort also included an analysis of shock transients by Fourier techniques and a comparison of the resulting Fourier spectra to the corresponding shock spectra. The characteristics listed below are discussed in the sections which follow:

| Section | Subject |
|---|---|
| 2.2.2 | Propagation Velocity |
| 2.2.3 | Frequency Characteristics |
| 2.2.4 | Equivalent Velocity Shock |
| 2.2.5 | Attenuation with Distance |
| 2.2.6 | Comparison of Fourier and Shock Spectrum Analyses |

### 2.2.2 Propagation Velocity

The MMC test data has provided information on the propagation velocity of stress waves in truss and airframe structures. (The complete discussion and data presentation are contained in Volume II, Section II.B.1). From these data, the propagation velocity for truss members is shown in Figure 1 and that for the Titan III C transtage skirt in Figure 2. The propagation velocity for a compression wave in a bar is given by the formula

$$v_o = \sqrt{E/\rho}$$

where

$E$ = Young's modulus

$\rho$ = density of the material

For steel and aluminum, the velocity is approximately 200,000 inches/second. The values as measured in Figure 1 for the primary truss members agree well with the theoretical value. However, Figure 1 illustrates that a compressional wave has been transformed to shear wave when the shock is transmitted from the primary structure to location 7 and 8 on the satellite mounting structure. The velocity of a shear wave is

$$V_s = \sqrt{G/\rho}$$

Where:

G = shear modulus of the material

An STL report, reference 72, describes the determination of propagation velocity through a spacecraft structure. Their analysis indicates that the propagation velocity is given by the above formula for $V_c$.

### 2.2.3 Frequency Characteristics

The MMC test data have been studied for various frequency effects. The summary below includes a discussion of high frequency, analog versus digital shock spectra, accelerometer mounting, trancation and DC shift in the time history.

It has been observed in some of the shock spectra for locations near the shock source that the peak of the spectra might be above the 10 K Hz range. This was anticipated from the initial analyses since in some cases the peak of the shock spectrum was only 30% above the peak of the acceleration time history. From the shock spectra of a simple half sine pulse, a value of at least 60% greater would be expected. Shock transients recorded at locations 1, 2, 3, 5 and 6 (See Section II.B.1 of Volume III for a description of the test and structure) were analyzed to a frequency of 32 KHz to determine the extent of high frequency energy present and the effect of intervening structure on this energy. The shock spectra are shown in Figures 3 through 17. (It should be recognized that the frequency response of the tape recording system was 20 KHz and the data above this frequency is questionable).

Analyses of these shock spectra indicate that the high frequency energy (16 - 20 KHz) is predominant near the shock source (location 1). As the distance between the transducer and shock source increases, the effect of intervening structure becomes more evident in the shock spectra. Comparing shock spectra at location 5 (Figure 12, 13, and 14) to shock spectra at location 1, 2 and 3 (Figures 3 through 11) indicates that the high frequency energy has been attenuated and/or dissipated by the structure, and structural resonances control the shock spectra. These effects are also indicated by Fourier spectrum analyses as discussed in a later section.

Notice that at location 2, longitudinal, (Figure 6) the predominant frequency is 1600 Hz. This frequency is the same as that predicted for the first longitudinal mode of the truss member at location 2. However, high frequency energy is still present.

These spectra were obtained by the use of a Ling SSA-100 analog shock spectrum analyzer. Figures 3, 6 and 12 compare the ranges of two analyses, 10-10,000 Hz and 320-32,000 Hz. These indicate good repeatability of an analog shock spectrum analyzer. The accuracy and repeatability of a digital shock spectrum analysis depends on the sample rate utilized.

Gertel and Holland, reference 15, suggest a minimum sample rate of 10 samples/cycle for the highest frequency of interest. The experience gained by MMC in this study corroborates their findings when performing digital shock spectrum analyses on transient data. The sample rate for a Fourier spectrum is discussed in Section 2.2.6.

One other effect on high frequency response should be mentioned. The Endevco 2225 accelerometers used in the MMC test are rated as having resonance at 80 KHz. An unpublished paper by G. K. Rasanan, Martin Marietta Corporation, Orlando, Florida, indicated that an Endevco 2225 mounted on an aluminum block (0.75 x 0.75 x 0.625 high) will have a resonance at 27 KHz under shock loading. This checks with the test data. The data in Figure 3 indicates a second peak around 25 KHz. It is therefore important to filter an analog time signal before any digital analyses are performed to avoid the problem of "fold over", i.e., folding the high frequency energy into the low frequency range in the process of sampling. The problem of sampling and fold over is discussed in more detail in Appendix A.

Another interesting effect has been observed on the shock spectra obtained from the test data. In the first few experiements conducted, the accelerometer blocks near the source of the shock experienced a bond failure. The failure generally took place within the time for passage of the first few acceleration pulses. When these time histories are compared to the time histories for the same accelerometer where no failure has taken place, the failure produces the effect of truncating an acceleration record. Shock spectra were produced for these "truncated" time histories and compared to the corresponding shock spectra for the completed time history. The surprising effect observed is that a truncated time history often results in a shock spectrum that is very similar to the spectrum for the completed time history. This effect is shown in Figures 18 and 19 which are data taken from the MMC ground test.

Figure 19 also indicates that the first pulse contains the high frequency energy and that the later pulses are due to a resonance around 1000 Hz.

Another effect observed on the ground test data was the effect on the resulting shock spectrum of a DC shift in an acceleration record. The time histories that contain a DC shift large enough to be visable on an oscillograph record will result in a shock spectrum which will contain a constant acceleration level in the low frequency range. On an acceleration shock spectrum, a constant acceleration will be a horizonal line. An example of this is shown in Figure 20. The DC shift in this acceleration time history was equivalent to 500 g's.

V. F. DeVost and P. S. Hughes, reference 3, describe the error introduced in a shock spectrum by a DC shift in the signal. A positive shift causes the constant velocity line to increase while a negative shift can cause the constant velocity portion to appear to be a constant displacement line by subtracting a DC signal that is equivalent to the velocity change in the signal. Recall that a constant velocity line on an acceleration shock spectrum on logrithmic paper will appear as a line of slope one while a constant displacement line appears as a line with slope two.

2.2.4 Equivalent Velocity Shock

Vigness, in reference 69, suggests that any complex shock spectrum can be reduced to an equivalent velocity shock spectrum. For a velocity shock, the resulting acceleration is proportional to the velocity by the relation

$$a = v\omega$$

where

$a$ = acceleration in feet per second squared

$v$ = equivalent shock velocity in feet per second

$\omega$ = frequency, radians/second.

When plotted on a log-log coordinates, this is a family of 45 degree straight lines, the parameter being the velocity. Figure 21 is a shock spectrum for location 2, longitudinal, with equivalent velocity shock lines superimposed on it. The numbers are the equivalent velocities in feet per second. For this particular example, the equivalent velocity line is approximately 1.5 ft/sec. The same basic equivalent velocity line ($45^{\circ}$ line) can be seen in Figures 3, 6, 12 and 21 through 25. Spectra for simple shock pulses are plotted on four-coordinate graph paper where the horizontal line is a constant velocity line in Figures 22 through 25.

Values of equivalent velocity shock were estimated for some of the spectra from the ground test program. Attenuation curves of equivalent velocity shock with increasing distance from the shock source are plotted in Figures 26 through 28. These curves suggest that the equivalent velocity of a shock spectrum might be an important parameter in various types of prediction schemes, such as attenuation with distance or damage potential. One difficulty in using equivalent velocity shock lies in determing the equivalent velocity line for the spectrum of a complex wave. The shock spectra for a number of transients from the ground test are plotted on four-coordinate graph paper and are shown in Figures 32 through 49. An inspection of these spectra indicates an area of constant velocity is present but open to subjective interpretation.

2.2.5 Attenuation with Distance

The complete set of data from the ground test has been used for the purpose of finding shock attenuation curves for truss and cylindrical airframe shell structures. The peak values of the shock spectra and acceleration time histories were tabulated from the 456 measurements obtained and read into the computer. The data were plotted as a function of distance from the shock source for each of three axes at each location. A separate plot for each of the four configurations along four shock paths on the truss and two shock paths on the skirt was made. These curves were produced on semilogarithmic paper and the best straight line drawn through the data points. The slopes of these lines were determined and are listed in Table III and IV. The parameter defining the slope in the tables is the constant in the following equation:

$$y = ae^{-\alpha x}$$

where $\alpha$ is measured in (inches)$^{-1}$. From these tables, average values for the type of structure and path represented in the ground test can be estimated and compared to other curves used in the aerospace industry. Figure 29 gives attenuation curves obtained from the literature for comparison purposes. The curve shown for Martin Marietta is the attenuation curve presently used to predict the amplitude of shock spectra. The remaining curves have been obtained from the following sources and are normalized to give percentage attenuation with distance from the shock source. Notice that each attenuation curve is normalized to one for the measurement closest to the shock source.

1) McDonnell Aircraft Corporation
   Shock and Vibration Bulletin #35, Part 6, 1966. Peak acceleration time history attenuation curve for flexible linear shaped charge (FLSC) on Gemini spacecraft separation tests.
2) Douglas Aircraft Company
   Technical Memorandum A2-260-ABD1-68TM-8, July 1968. Shock spectrum attenuation curve for flexible linear shaped charge (FLSC) - on third stage separation of the Saturn.
3) Lockheed Missile and Spacecraft Company
   SAE Aeronautic and Space Engineering, 1966. Peak acceleration time history attenuation curve for mild detonating fuse (MDF).
4) North American Rockwell Corporation
   Shock and Vibration Bulletin #37, Part 4. Shock spectrum and peak acceleration time history attenuation curve through honeycomb material used on the Apollo service module. The shock was generated by mild detonating fuse (MDF).

The two curves of McDonnell are for longitudinal and radial directions. The wide variation of shock attenuation definitely shows the extent of the influence of the different structures used in each test. Figures 30 and 31 contain curves using the data from Tables III and IV obtained from the ground tests. These data are presented with the Martin and Lockheed curves for comparison only. Primary structure is along the path through location 1, 2, 3, 5 while secondary structure refers to the paths through locations 1, 6, 7 and 1, 6, 8. (These locations are shown in Section II.B.1, Volume II).

TABLE III

SHOCK SPECTRUM ATTENUATION VALUES FROM GROUND TEST

| ACC Axis | Path Location Number | $\alpha$ - Value Test Configuration Number II | I | III | IV |
|---|---|---|---|---|---|
| Long. | 1-2-3-5 | .03 | .035 | .025 | .035 |
| | 1-2-3-4 | .04 | .045 | .035 | .045 |
| | 1-6-7 | .05 | .06 | .04 | .05 |
| | 1-6-8 | .04 | .04 | .03 | .04 |
| Lateral | 1-2-3-5 | .03 | .03 | .025 | .025 |
| | 1-2-3-4 | .03 | .03 | .025 | .025 |
| | 1-6-7 | .05 | .04 | .035 | .04 |
| | 1-6-8 | .04 | .03 | .03 | .035 |
| Vertical | 1-2-3-5 | .02 | .025 | .02 | .02 |
| | 1-2-3-4 | .025 | .03 | .02 | .025 |
| | 1-6-7 | .035 | .035 | .04 | .03 |
| | 1-6-8 | .035 | .025 | .025 | .025 |
| Long. | 12-13-16-18 | | .04 | Ring at Longeron | |
| | 12-13-15-17 | | .05 | Ring | |
| Radial | 12-13-16-18 | | .04 | | |
| | 12-13-15-17 | | .05 | | |
| Tangential | 12-13-16-18 | | .04 | | |
| | 12-13-15-17 | | .06 | | |

TABLE IV

ACCELERATION TIME HISTORY

ATTENUATION VALUES

| ACC Axis | Path Location Number | $\alpha$ - VALUE TEST CONFIGURATION NUMBER II | I | III | IV |
|---|---|---|---|---|---|
| Long. | 1-2-3-4 | .035 | .04 | .04 | .04 |
| | 1-2-3-5 | .03 | .035 | .03 | .035 |
| | 1-6-7 | .06 | .06 | .055 | .06 |
| | 1-6-8 | .04 | .04 | .04 | .04 |
| Lat. | 1-3-2-4 | .03 | .035 | .025 | .03 |
| | 1-2-3-5 | .025 | .035 | .025 | .025 |
| | 1-6-7 | .055 | .05 | .05 | .045 |
| | 1-6-8 | .04 | .04 | .04 | .035 |
| Vert. | 1-2-3-4 | .03 | .04 | .03 | .03 |
| | 1-2-3-5 | .025 | .035 | .025 | .025 |
| | 1-6-7 | .05 | .05 | .045 | .045 |
| | 1-6-8 | .04 | .04 | .035 | .035 |

2.2.6 Comparison of Fourier and Shock Spectrum Analyses

Fourier spectra analyses were performed on the MMC ground test and are shown in Figures 32 through 49. These Fourier spectra were plotted with their corresponding shock spectra on four coordinate-graph paper to provide a comparison between the two spectra. The methods of performing the Fourier spectra and shock spectra analyses are discussed in Appendix A.

Southworth, reference 71, derives the relationship between the residual shock spectra and the Fourier spectra. (A residual shock spectrum is the spectrum of maximum values that occur after the forcing function has ceased. This usually controls the low frequency or velocity shock region of the spectrum). The undamped residual shock spectrum ($d_r$) magnitude is proportional to the Fourier spectrum ($F(\omega)$) magnitude and is given by

$$\omega_n d_r = F(\omega)$$

The shock spectra shown in Figures 32 through 49 were derived using a damping value of 5% (Q = 10). As a result of the damping, the shock spectra are smoother and usually fall below the Fourier spectra levels.

The Fourier spectra were analyzed using a sampling rate of 100,000 samples/second and a length of record of 81.92 milliseconds. The effective frequency bandwidth (resolution) was 12.2 Hz, good to 50 KHz. (Examination of the Fourier spectra indicates energy present in the 20 KHz region). The Fourier spectra presented in this report were "smoothed" by averaging eight data points and plotting the results at the frequency corresponding to the middle of the eight point range. The result is approximately equivalent to having a frequency bandwidth of 100 Hz. The Fourier spectra show very definitely the frequency areas where energy is concentrated.

In general, the shock spectra have peaks at the same frequencies that the Fourier spectra do except that the shock spectra are smoother and tend to average the peaks over a wider range. However, the shock spectra give better definition in the low frequency range due to the large bandwidth smoothing of the Fourier spectra.

One object of the four coordinate-graph paper is to determine the trend of a shock spectrum in the areas of constant displacement, velocity or acceleration. Examination of these shock spectra show a characteristic shape present in all cases. Below 100 Hz, a small area of constant velocity exists preceeded by a constant acceleration line near 10 Hz, which could be due to a DC level in the acceleration time history. The second region is an area of constant displacement extending from approximately 100 Hz to frequencies below 1000 Hz. The third region is one of constant acceleration that is approximately equal to the peak acceleration measured on the acceleration time history and is usually reached above 10 KHz.

An examination of the shock and Fourier spectra leads to the following conclusions:

1) The shock spectra provide the same frequency information as do the Fourier spectra for typical pyrotechnic shock transients.
2) The four coordinate-graph paper readily presents a graphic display of displacement, velocity and acceleration controlled regions of the shock and Fourier spectra.
3) A characteristic constant velocity line is present but its interpretation is somewhat subjective.

Although the Fourier spectrum appears to offer the same information as does the shock spectrum, Fourier techniques have a great potential considering the vast areas of analysis that utilize the frequency domain techniques.

### 2.3 Evaluation of the Quality of Typically Available Pyrotechnic Shock Data

The objective of this effort is to evaluate the quality of typically available pyrotechnic shock data by assessing the parameters affecting the acquisition and reduction of the data. The particular items considered for such an evaluation are listed below:

Item 1 - Effective frequency range of the reduced data (considering the response characteristics of both the acquisition and reduction systems)

Item 2 - Dynamic range of transducer

Item 3 - Transducer installation and locations

Item 4 - Effect of anomalies

Item 5 - Signal-to-noise ratio

Item 6 - Error tolerance of data reduction equipment and misrepresentations in reduced data

Item 7 - Stress/Strain effects on measurement.

From the above list, Items 1, 2, 4 and 5 were selected to be incorporated into a numerical rating scheme which was used to determine the overall quality of the available aerospace shock data.

Although the quality of reduced shock data is definitely a function of both the transducer location and its installation (item 3 above), it was felt to be impractical to attempt to assign a numerical rating to this parameter.

Adequate installation of an accelerometer is a prerequisite to obtaining good data. The mounting system, an accelerometer block, for example, can noticeably alter the response characteristics of the accelerometer; however, the use of a block is frequently required to mount the accelerometer with the desired location and orientation. The topic of transducer mounting is considered in more detail in Section 2.4, "Recommendation of Measurement Systems for Ground Test and Flight". For quality rating purposes, it was noted whether or not a particular measurement involved the use of a block, but no numerical rating was assigned. However, if the accelerometer installation failed during shock testing, an appropriate numerical rating was assigned under Item 4, "effect of anomalies".

In considering the error tolerances of data reduction equipment, the survey of available data revealed that the rated plus or minus per cent error for tape decks, analog computers, analog to digital converters, and digital computers are virtually insignificant when compared to the error tolerance associated with the repeatability of shock data. For this reason, data reduction systems were not rated numerically for error tolerance.

The data compilation did reveal that reduced shock data is sometimes presented in a manner that is not a true representation of the data due to the method of reduction. The two most evident examples of misrepresentations are shock spectra with very coarse frequency increments and digital shock spectra that are carried out to higher frequencies than would be valid according to the digital sampling rate. Most of the shock spectra compiled involved a frequency increment at least as fine as three points per octave, which is considered to be near the minimum frequency resolution required to produce good data. A study of the effect of sample rate on digital shock spectrum has revealed that the validity of the spectrum tends to diminish for frequencies above 1/10 the sample rate. Whenever this problem exists, it is accounted for in the numerical rating scheme under Item 1, "Effective frequency range".

Item 7, "Stress/Strain effects on measurement", was not generally ascertained from the descriptive information available for the compiled data. Hence, no equitable rating scheme could be determined. The topic of stress/strain effects on measurement is discussed briefly in Section 2.4 "Recommendation of Measurement Systems for Ground Test and Flight:.

A formula for determing a numerical quality rating from 0 (unusable) to 10 (excellent) has been developed and implemented for Items 1, 2, 4 and 5. Prior to the overall rating, there are four intermediate ratings:

1) The rating $R_1$ (0-10) is based on the overall system <u>frequency</u> range.
2) The rating $R_2$ (0-10) is based on the accelerometer shock capability relative to the shock level being measured. (<u>dynamic range</u>)
3) The rating $R_3$ (0-10) is an evaluation of confidence in the data while in the presence of measurement anomalies such as DC - shifts, bond failures, and tape recorder levels being exceeded.
4) The rating $R_4$ (0-10) is an evaluation of confidence in the reduced data based on the <u>signal-to-noise ratio</u> present.

Since a deficiency in any one of the four rated items will result in a deficiency in the overall quality of the data, the total rating, $R_T$ (0-10) is based on a product of the subsidiary ratings as given by the equation below.

$$R_T = \frac{R_1 \times R_2 \times R_3 \times R_4}{10^3}$$

Table V describes the numerical subratings and Table VI includes some examples of quality rating for the compiled data. The interpretation of the total rating, $R_T$, is indicated below:

| | |
|---|---|
| 8-10 | excellent data |
| 6-8 | good data |
| 4-6 | average data |
| 2-4 | adequate data |
| 1-2 | may contain some usable data |
| 0 | unusable data |

The intermediate ratings, $R_1$ through $R_4$, are discussed in the paragraphs below.

TABLE V. DESCRIPTION OF SUBRATINGS

| $R_1$ - System Frequency Response | | $R_2$ - Accelerometer Dynamic Range | | $R_3$ - Measurement Anomalies | | $R_4$ - Signal-to-Noise Ratio | |
|---|---|---|---|---|---|---|---|
| Frequency Range | Rating Value | | | | | S/N Ratio | Rating Value |
| 20,000 | 10 | Shock in Range of Tranducer | 10 | No anomalies | 10 | 30 or greater | 10 |
| 10,000 | 8 | Shock at Range | 8 | DC Shift | | 20-30 | 9 |
| | | | | mild | 8-9 | | |
| | | | | large | 2-5 | | |
| 5,000 | 4 | Within 20% above Range | 4 | Calibration exceeded | | 10-20 | 8 |
| | | | | Less than 10% above | 6-8 | | |
| | | | | More than 10% above | 0-5 | | |
| 2,000 | 2 | Greater than 20% above Range | 1 | Accelerometer Installation failure | 5 | 5-10 | 4 |
| 1,000 | 1 | | | | | 2 or less | 0 |

TABLE VI. SAMPLE QUALITY RATING FORM ILLUSTRATING NUMERICAL RATING SCHEME

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 9 | Al block | 10-10,000 | 8 | Endevco 2225 | 10 | None | 10 | 25 | 9.5 | 7.6 |
| 10 | Al block | 10-10,000 | 8 | Endevco 2225 | 10 | None | 10 | 30 | 10 | 8.0 |
| 22 | No block | 10-10,000 | 8 | Endevco 2225 | 10 | None | 10 | 20 | 9 | 7.2 |
| 5 roll | Al block | 50-5,000 | 4 | Endevco 2225 | 10 | None | 10 | ---- | 5* | 2* |

*No time histories were available for evaluating the signal-to-noise ratio.

The system frequency response rating, $R_1$, is based on the frequency to which the data is realistically presented. Several frequencies, along with their corresponding ratings are presented in Table V to illustrate how this rating varies with frequency. Most pyrotechnic events are characterized by frequencies much higher than 1000 Hz. Therefore, it was decided that, unless information is presented to substantiate the relative unimportance of higher frequency information, the quality should be down-rated when being considered for shock data analysis.

The rating $R_2$ will be 10 whenever the accelerometer used for a particular measurement experiences a g-level that is within the shock capability prescribed by the manufacturer. When the level is at the limit of the accelerometer, the rating is 8; and when the limit is exceeded by no more than 20%, a 4 rating is given.

A rating of 10 for $R_3$ indicates that no anomalies are associated with a particular measurement. If an anomaly (i.e., accelerometer block bond failure, tape recorder level exceeded, dc shift, etc.) does exist, ratings less than 10 are given based on the estimated severity of the particular problem. A dc shift in a time history may appear rather severe while only affecting the low frequency region of the corresponding shock spectrum. Since this region of the spectrum is shifted higher than it would have been in the absence of a dc shift, the result is conservative. Furthermore, a relatively small dc shift has little effect on the shock spectrum while the effect of a large dc shift can often be adjusted out of the shock spectrum by interpolating a reasonable constant velocity line (45$^{o}$ line) to the spectrum's peak. For these reasons, a dc shift is not rated as severely as might have been anticipated.

When an accelerometer block near the shock source came unfastened due to the shock, a rating of 5 was given. Many times the bulk of the shock has passed before the block had time to fall off. This phenomenon is very similar to truncation of the time history. Such truncation usually results in a shock spectrum whose levels have been reduced primarily in the low frequencies. This sort of result can generally be treated with an interpolation scheme similar to that suggested for dc shifts. Hence a rating of 5 is not considered too high.

Finally, the signal-to-noise ratio is rated as $R_4$. Table V shows the ratings associated with several signal-to-noise ratios. When no data is available on the signal-to-noise ratio, a rating of 5* is given. The final rating is also marked with an asterix to indicate the absence of information. An example of this is shown in Table V.

The complete quality ratings for the data compiled are presented in tabular form in Appendix B. The average rating for all data, excluding ground test data, is 3.94. The average rating for flight data is 1.08, and the average rating for all ground test data is 4.06. These averages indicate that the quality of typically available pyrotechnic shock test data (ground test) in the aerospace industry is adequate, but not good. The primary reasons for the low ratings are that the valid frequency ranges of the reduced data are not high enough and that the signal-to-noise ratios are frequently too low. In general, the frequency range could have been improved by reducing the data over a larger frequency range or by digitizing the data at a higher sample rate. However, the signal-to-noise ratio problem is one of selecting appropriate calibration values prior to running a test. Furthermore, current systems used for measuring and telemetering flight data are generally employed to monitor random vibration over a limited frequency range not suitable for shock measurement.

## 2.4 Recommendation of Measurement Systems for Ground Test and Flight

The objective of this effort was to perform a study of available data acquisition/analysis equipment and recommend instrumentation systems for ground and flight tests.

### 2.4.1 General Requirements

Recommended requirements for equipment are described and examples of equipment items which meet these requirements are presented. It should be recognized that relaxation of certain recommended requirements may be necessary, (particularly for airborne systems), depending upon particular applications.

The measurement system should have a frequency response which is flat within $\pm$ 1db over the frequency range from 5 to 20,000 Hz. Piezoelectric type accelerometers designed for shock measurements to amplitudes of up to 20,000 g peak are recommended depending upon the type of pyrotechnic device and proximity of the transducer to the shock source. Charge amplifiers are recommended because of their frequency response characteristics, relative insensitivity to cable length, broad dynamic range, and low noise characteristics as compared to voltage amplifiers. The user should recognize, however, that consideration must be given to installation techniques and the environment in which the system must operate. Temperature effects on transducer, cables, or amplifier resulting in capacitance changes could produce erroneous output signals. Certain types of charge amplifiers exhibit undesirable dc drift characteristics. The drift may be readily compensated for through simple adjustments by a careful user during ground tests, but could not be alleviated during flight test measurements. Therefore, a voltage amplifier could very well be better suited for particular applications. In summary, the measurement system should be tested and qualified for the environments applicable for its intended use.

2.4.2 <u>Accelerometer Installation</u>

Methods of transducer installation vary throughout the aerospace industry. These include:

a) Bolted accelerometers

b) Bonded accelerometers

c) Accelerometers attached to mounting blocks which are bolted or bonded to structure.

Several experimenters have investigated different installation techniques and the effects of mounting methods on transducer performance characteristics. These are discussed below.

Nagy and Henley (Reference 6.2-42) conducted a study of the effects of vibration fixture stress concentrations (base-strain effects) on ring accelerometers. The primary effects observed were in the low frequency region applicable to vibration tests; however, similar effects may be applicable for shock measurements.

Velazquez at McDonnell Douglas tried several different attachment devices before achieving mounting integrity for transducers located near the shock sources during separation tests for the SPARTAN vehicle (Reference 6.1-2). The final mounting system included the following elements, (see Figure 117):

a) Oversize (1/4") special stud

b) Two mica washers

c) Spacer

d) Two more mica washers

e) Metal washer

f) Locknut or drilled and tapped holes to accept mounting stud.

g) DPM 3279 or Mereco X-305 cement was used between all moving parts of the installation assembly.

h) Torque values:

Accelerometer; 30 inch-pounds. (Studs for locknuts); 80 inch-pounds.

i) Accelerometer cables were taped or bonded to structure to prevent damage from air blast effects.

The mounting system was successful in keeping accelerometers attached to the structure. The effect on frequency response characteristics was not reported.

Rasanen (Reference 6.2-52) has investigated the effects of mounting configurations on frequency response characteristics of accelerometer systems. For the configurations studied, the stiffest mounting is the solid stud with a thin oil film at the transducer/structure interface. Variations in mounting geometry reduce the resonance frequencies from the rated frequencies stated by the manufacturers, and the reductions are dependent upon the stiffness of the structure on which the transucer is mounted. Comparisons of the resonance effects for three different mounting configurations of the same type accelerometer are shown in Figure 50.

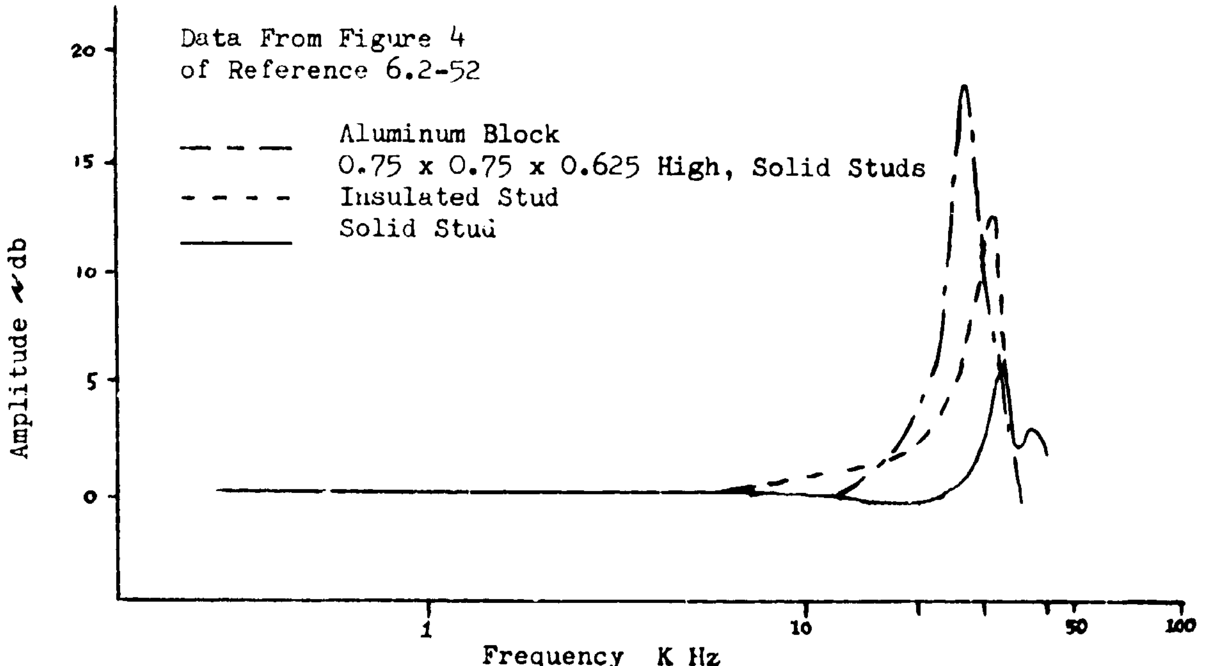



Figure 50. Comparison of Resonance Effects of Mounting Configuration for Endevco 2225.

The use of an airborne recorder presents desirable features in the approach to the problem of storage and recovery. The recorder can be turned on and off on command to obtain the shock events of interest and played back at a reduced speed to present the data in a frequency range compatible with telemetry system capabilities utilized for vibration data. The primary limitation in this technique is in obtaining a recorder capable of being certified to the flight environments (particularly where sterilization is required).

Constant bandwidth FM/FM telemetry equipment is presently available which will obtain shock data up to 8 KHz. The primary limitation of this technique is the cost and weight penalties associated with the limited number of channels per transmitter available.

The third method investigated for future application is the use of airborne memory banks to receive and store shock data. The memory bank system would be triggered by an event such as the ordnance fire switch. To obtain data to 10 KHz, an analog to digital converter with a sample rate of 100,000 samples per second would be required. Experience in pyrotechnic shock has shown that the required total data acquisition time (including a finite interval between the trigger signal and shock pulse arrival) is of the order of 100 milliseconds. Therefore, the total storage capability required for each channel is on the order of 10,000 data samples. The memory banks for several data channels could then be unloaded sequentially to a high frequency FM transmitter, or programmed to unload data at a lower rate commensurate with available telemetry channels.

For currently available equipment, the recommended flight measurement system should utilize accelerometers, charge amplifiers, and a constant bandwidth FM/FM telemetry system. The recommended system is based on considerations for weight, cost, and the advantages and limitations of the methods investigated. The development of flight measurement systems for future use should include an amplifier with programmable gain steps and a digital memory system for storage and recovery of the high frequency shock data.

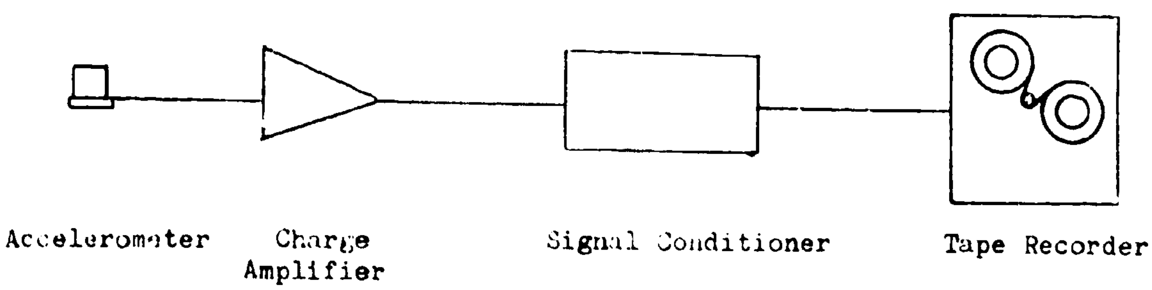
Further tests reported by Rasanen involved comparisons of resonance effects observed for the Endevco 2225 and Endevco 2220 accelerometers. The 2225 has a manufacturer's rated resonance frequency of 80 KHz, and the 2220 is rated at 50 KHz. The tests involved vibration excitation and shock pulse applications of varying durations. The test results indicated mounted resonances for the 2225 in the frequency range from 27 to 38 KHz. The 2220 was observed to be free of resonances below 50 KHz. The small size and low mass characteristics of the 2220 may present advantages for mounting locations where shock levels are less than its rated shock limit even though the rated resonance frequency is relatively low (50 KHz) for pyrotechnic shock measurements.

The recommended mounting configuration is the solid stud with a thin oil film at the transducer/structure interface.

In many applications, such as on flight hardware, it may not be possible to drill mounting holes. For these cases, the alternate recommended mounting configuration is the use of aluminum mounting blocks bonded to the structure. Anodizing the blocks provides electrical isolation and helps reduce noise levels from ground loops, etc.

2.4.3 Ground Test Measurement System

It is evident from information obtained during the compilation and rating of aerospace shock data that the general method used to acquire data is standard throughout the industry. The general instrumentation system used is shown in the block diagram as follows:



The differences which exist among the various instrumentation systems are a result of individual preferences or availability of equipment items. Examples of transducers and equipment which meet the requirements for pyrotechnic shock measurements are as follows:

| | |
|---|---|
| Accelerometers; | Endevco 2225 |
| | Endevco 2220 M1 |
| | Columbia 504-3 |
| Charge Amplifiers; | Kistler Model 504A |
| | Columbia 9000 series |
| | Endevco Model 2718A |
| | Unholtz-Dickie 11G-1 |

The choice of a magnetic tape recorder is largely dependent upon the type of test and number of measurements. An FM recorder with frequency response to at least 20,000 Hz and the capability of at least a 4 to 1 speed reduction between record and playback modes is recommended. A tape shuttle capability is extremely useful for quick-look data reduction analysis. Examples of tape recorders used in shock measurement systems are:

| | |
|---|---|
| Ampex | FR600, ES100, FR1800, FR1300 |
| Sangamo | 4500 |

The cost of accelerometer, cable and charge amplifier system ranges from approximately \$500 to \$1000 per channel. Tape recorder cost is a function of number of channels required, variety of tape speed combinations and associated electronics, and other optional features. For recorders of the quality required for these types of measurements, the price may range from approximately \$30 K to \$90 K.

2.4.4 Flight Measurement Systems

Accelerometers and charge amplifiers which meet the requirements for pyrotechnic shock measurements and can be qualified for the flight environment are readily available. Examples of such equipment are:

| | |
|---|---|
| Accelerometers | Endevco 2225 |
| | Endevco 2220 M1 |
| | Columbia 504-3 |
| Charge Amplifiers | Endevco Model 2640 Series |
| | Columbia Model 5600 Series |
| | Kistler Model 553 Series |

Charge amplifiers may be selected with bias, dual, or unbiased output, adjustable gain of from 1 to 100, and both high and low pass filters. The cost of the accelerometer, cable, and charge amplifiers system ranges from approximately $500 to $1000 per channel, depending upon options selected and environmental qualification requirements, (e.g., high temperatures requiring special provisions for transducers and/or amplifiers).

The possibility of utilizing the same basic instrumentation systems for high frequency vibration and shock measurements has been investigated. This result could be achieved through programmable ranging of the charge amplifier. Remote ranging of the amplifier could be accomplished by use of a ground transmitted signal, or initiated from the ordnance firing circuits at the flight regions of interest to obtain the pyrotechnic shock data. Unfortunately, surveys of airborne equipment catalogs and contacts with several manufacturer's representatives have indicated that there is no airborne amplifier with programmable ranging readily available.

The fundamental difficulty in obtaining flight measurements lies in the storage and recovery of high frequency data. During this investigation, the following techniques have been considered for acquiring shock data:

1) Airborne recorder
2) Constant bandwidth FM/FM telemetry
3) Airborne memory storage.

formatting, etc. For comparison, the average time required to produce a shock spectrum with one of the commercial analog analyzers described earlier is on the order of three minutes. This time includes, and is primarily dependent upon, changing paper on the X -Y recorder, rewinding tape, and re-establishing calibration ranges when necessary.

The majority of ground tests and measurement programs investigated involve numbers of measurements ranging from approximately 12 to 48. For this quantity of data, analog reduction process should be more economical than digital methods if the desired output is only acceleration time histories and shock spectra. If normalization of data and further comparative analyses are required, digital reduction techniques are desirable. Digital methods provide the additional advantage of producing formatted, annotated output plots requiring few or no additional manhours in preparing data for reports.

Discussions with individuals throughout the aerospace industry have indicated that differences of opinion exist concerning the frequency resolution required for shock spectrum analyses. Advocates of narrow band analyses point out that response oscillators spaced at one-third-octave center frequencies do not provide sufficient resolution to define narrow band structural resonances. For single-degree-of-freedom oscillators, the bandwidth (at the half-power point) is given by:

$$B = \frac{f_n}{Q}$$

where:

$B$ = bandwidth

$f_n$ = natural frequency of the oscillator

$Q$ = amplification factor $\left(Q = \frac{1}{2C/C_c}\right)$

For example, at frequencies of 800, 1000 and 1250 Hz, the bandwidths are approximately 80, 100, and 125 Hz respective for Q = 10. The shock spectrum amplitudes are subject to significant errors for structural

2.4.5 Data Reduction/Analysis Equipment

The basic methods used for data reduction are essentially standard throughout the aerospace industry. The differences which exist are a result of individual preferences in the resolution obtained in shock spectra analyses; i.e., choice of amplification factor (Q) and frequency spacing of response oscillators utilized in the analyses.

For quick-look data analysis and for small quantities of data, frequency analysis of shock transients can be most economically obtained by use of analog shock spectrum analyzers. The type of analyzer which employs a memory bank is particularly advantageous because of speed and accuracy. Examples of such analyzers which are currently available are the MB Electronics Model N980 and the Ling Electronics Model ASRA 40. For quick-look evaluation of the shock transients, an oscillograph recording is highly recommended over an oscilloscope. Rapid dc shift, signal over-range, etc., are much more readily detected from an oscillograph record than from an oscilloscope trace.

For Fourier spectra and/or large numbers of shock spectra analyses, digital reduction techniques should be utilized. For shock spectra, in particular, digitization rates of at least 10 times the highest frequency of interest should be employed to maintain accuracy of approximately 5%. For either analog or digital spectrum analyses, band pass filters should be utilized to eliminate dc shift, reduce noise, and prevent Nyquist foldover in the digital analyses.

Analog data reduction methods are the more economical for relatively few measurements, whereas the economic advantage for large quantities of data lies in digital methods. Obviously, there is a crossover point for economical data reduction dependent upon quantity of data, type of program, computer operating time, and operator manhours. For the computer program (SPOCK) described in Appendix A, the machine time (CDC-6560) required to produce a time history and associated shock spectrum is approximately 10 seconds. This time includes tape reading and output, but does not include analog to digital conversion, tape responses which occur at frequencies between these bandwidths. LMSC has presented comparison data (Figure II.A.1.8 of Volume IV) which indicate a total possible error as great as a factor of 8.25. However, it should be noted that this effect was observed on a non-typical shock spectrum (see Figure 51).

Comparisons of results from spectra which are more typical of pyrotechnic shock indicate that little information is lost in one-third-octave analyses compared to narrow band or one-sixth octave analyses. (See Figures 52 through 55). Comparison of these data indicates that the error associated with one-third octave analyses (as compared to narrow band analyses) is within the scatter associated with the repeatability of pyrotechnic shock data.

These comparisons indicate that one-third-octave analyses are adequate for typical pyrotechnic shock spectra. One-sixth-octave frequency spacing provides resolution which is well within the scatter of pyrotechnic shock data and is available on the MB model N 980 analyzer over the entire frequency range of the instrument and on the Ling Model ASRA 40 at frequencies above 1000 Hz. The increased resolution obtained from narrow band analyzers probably does not justify the additonal cost.

### 2.5 Preparation of Guidelines Defining Design Information Applicable to Structure and/or Equipment

A separate guidelines document (Volume VI) has been prepared. The purpose of this document is to present a set of guidelines defining design information applicable to structure and/or equipment for designing to a pyrotechnic shock environment. These guidelines include a description of various pyrotechnic devices and associated shock levels near the source (in terms of a shock spectrum which is defined and discussed in Section 1.0 of Volume VI). Attenuation curves for a variety of structures are included and methods of isolating equipment from a shock environment are discussed. Section 5.0 of Volume VI lists sources of information and data on many subjects associated with pyrotechnic shock.

These guidelines are the result of the study performed during this contract. The guidelines represent the first step in an attempt to present the designer with reliable information for designing to a pyrotechnic shock environment. Theoretical prediction of shock levels is presently beyond the state-of-the-art of this technology, therefore, empirical data are used. However, these empirical curves must be used with discretion. A better understanding of the complex problems associated with pyrotechnic shock can be obtained by referring to the complete results of this study.

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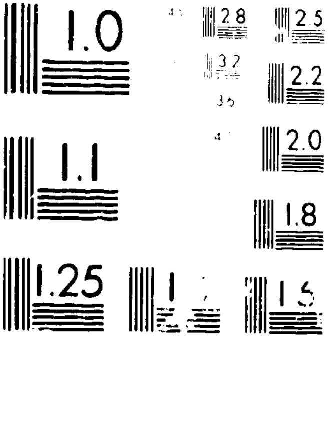


MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS

### 2.6 Recommendation of Test Simulation Techniques

The objective of this effort is to summarize and evaluate the present methods of simulating pyrotechnic shock, and recommend the most effective test simulation techniques. Pyrotechnic shock testing is usually performed for one of two purposes: either to determine the shock levels associated with a particular pyrotechnic event or to qualify airborne equipment to a predetermined shock environment. The test configuration associated with shock tests may involve some degree of structural simulation. For this case, ordnance devices are used to generate the shock. However, equipment shock testing may also involve the use of some mechanical means for producing a specified shock environment. Methods currently being employed for shock testing include mechanical shock machines, electrodynamic shakers, synthesis/analysis techniques using electro-dynamic shakers, and "barrel" tester techniques using ordnance devices.

#### 2.6.1 Simulation in Full-Scale Testing

Whenever a separation shock test is conducted, space limitations frequently require that the lower stage booster be simulated by adding a concentrated mass to the aft end of the test specimen. Most tests of this nature are conducted using a mass having the same weight as that of the expended booster. However, the results of two identical separation tests on the Minuteman III (Section I.A.4 of Volume II) using widely different weights to simulate the expended third stage booster indicate that this sort of weight simulation is not necessary, so long as a good separation is achieved.

For shock development tests and for test articles which are too large or heavy to test by conventional laboratory equipment, special test installations utilizing ordnance devices attached to actual or simulated structure are recommended. During the ground test program, a number of tests were conducted to determine the repeatability of the shock environment and the degree of structural simulation required.



2

The data from accelerometer locations 7 and 8 (Figure 56) at the mounting points of the OV5-2 satellite were selected to evaluate the effects of different test installations on the shock environment. The shock spectra were compared from the following test configurations: (See Figures 57 through 60).

Configuration I - Payload Truss Attached to Transtage Skirt.
Configuration II - Payload Truss Freely Suspended.
Configuration III - Payload Truss Attached to Rigid Support Fixture.
Configuration IV - Payload Truss Attached to Channel Adapters.

Good repeatability (within approximately ± 25% from mean of the shock spectrum) was obtained from multiple shocks for each configuration. The shock spectra from Configuration III (rigid fixture) were occasionally lower than those obtained from the transtage skirt configuration, and were not considered further in this analysis. Comparisons of the average shock spectra obtained at locations 7 and 8 for Configurations I, II, III and IV are presented in Figures 61 through 66. Examination of these data indicates that the use of channel adapters to simulate the transtage skirt structure would provide a good pyrotechnic shock test of the OV5-2 satellite. The shock spectra exhibit the same characteristics as those obtained from the transtage skirt installation, and the shock amplitudes are greater, thus providing a margin of safety for a conservative test. For the freely suspended truss configuration, the shock spectra exhibit higher levels in the range below 2000 Hz than do those from the other two configurations presented. Based on the information presented in these figures, it was felt that the suspended truss configuration would constitute an overly conservative test of the OV5-2 satellite.

The results illustrate that some degree of latitude in structural simulation in a test installation can be tolerated without adverse effects. However, it should be noted that the channel adapters referred to in the above discussion were selected because their longitudinal stiffness characteristics were similar to that of the transtage. From the available data, no definite conclusions can be drawn as to the degree of mounting simulation required to achieve an acceptable test.

The data from the ground test (Section II.B.1 of Volume II) also provided some information about the effects of mass loading. Configuration II included two series of three tests each: for the first three tests, no satellites were installed while for the second group of tests relatively massive dummy satellites were installed in the truss. Shock spectra comparing the effects of these two configurations at locations 7 and 8 are presented in Figures 67 through 72. These results indicate that the response at low frequencies become smaller upon installation of the dummy satellites. Besides this, little difference between the two configurations is exhibited in the response spectra.

Three tests were conducted to determine the shock levels associated with $2^{nd}/3^{rd}$ stage separation of the Spartan vehicle. These tests included three configurations: the short cylinder test, the long cylinder test, and a full-scale separation test. The tests are described in detail in Sections I.A.1, I.A.2 and I.A.3, of Volume II respectively. Figure 73 illustrates that the shock environment near the shock source compares very well among the three configurations. These results indicate that as long as the intervening structure between the shock source and the transducer location is not markedly changed rather crude simulation can be effectively employed. This, of course, assumes that the pyrotechnic charge and the separation joint parameters remain unchanged.

The discussion of simulation in full-scale testing to this point has only been concerned with structural simulation. However, three of the test programs presented in Volume III provide some information about possible methods of simulating the pyrotechnic device itself. For example, the Titan III-M separation nut comparison tests discussed in Section II.B.2, Volume III, indicate little difference between the shock characteristics of the three types of pyrotechnic configurations tested. (See Figures 74 through 97). This observation suggests that a full-scale separation test might be performed at slightly reduced expense by the use of somewhat different separation hardware than is called for in the flight event.

Titan III-C payload truss data (Section II.B.3 - four separation nuts) and TOS-M separation data (Section III.B.2 - two bolt cutters) illustrate the effect of firing only one pyrotechnic device rather than the multiple charges called for in the flight event. For the payload truss data, this comparison is indicated in Figures 113 through 116; and for the TOS-M, the comparison can be seen in Figures III.B.2-3 through III.B.2-14 of Volume III. At locations near the shock source, measurements indicate virtually the same shock levels whether all the devices were detonated or only the device nearest the particular measurement location. At locations remote from the shock source, shock levels on the TOS-M showed almost no dependence on which device or devices were fired. Looking at the payload truss data, Figures 115 and 116 indicate a higher level from the firing of all four nuts. Additional specific data are required to fully assess the effect of multiple (simultaneous) activations of pyrotechnics.

### 2.6.2 Simulation in Component Qualification Testing

A number of different component testing techniques are used throughout the aerospace industry to simulate the pyrotechnic shock environment. These techniques utilize electrodynamic shakers and several different types of shock machines including special designs constructed specifically to simulate the pyrotechnic shock transient. The type of test equipment used is generally dictated by the size and weight of components to be tested. Based on the information published in the literature and on contacts with laboratory personnel in the industry, it appears that the use of electrodynamic shakers and shock synthesis/analysis techniques encompass the broadest range of tests. The discussion below summarizes the primary techniques currently employed in shock testing.

Available shock machines include simple drop test facilities, mechanical sling-shot devices, pendulum hammers, and pressure driven impact machines. Such facilities are characterized by impacting a test specimen whose size is quite limited. Upon impact, a relatively simple, unbalanced acceleration pulse is imparted to the specimen. By varying the impact velocity and the texture and thickness of the material at the impact surface, the amplitude and duration of the shock pulse can be controlled. The inadequacies of such techniques for simulating pyrotechnic shock are numerous. (See References 31, 47 and 54).

1) In general, shock machines produce simple pulse(s) and therefore do not reproduce the complex waveform generated by the pyrotechnic devices. Consequently, the inherent assumption is made that simulation occurs by simulating the shock spectrum.
2) Shock machines are limited to relatively small test specimens and simplified mounting techniques.
3) The simple unbalanced acceleration pulse imparts a significant velocity shock (not characteristic of a complex pyrotechnic) which may produce a severe overtest in the low frequency range while under testing the high frequencies.
4) Any shock machine employing a rigid table furnishes the same simple input to all points contacting the table which is not characteristic of pyrotechnic shock transmission in aerospace structures.

In conclusion, although shock machines are undesirable for simulating complex shock motions, they are used extensively due to their relatively low cost and ability to produce a spectrum that envelop any given spectrum.

Electrodynamic shakers are used to apply a simple pulse to a test specimen for pyrotechnic shock qualification and acceptance purposes. This simulation technique again produces a simple pulse which imposes virtually all the limitations inherent in shock machines although a shaker can generally accommodate a larger test specimen.

Synthesis/analysis techniques for shock simulation employing electrodynamic shakers are based on wave trains which are more representative of shock time histories. (See References 31, 32, 36 and 45). A complex shock motion, not necessarily identical or even similar to that produced by the pyrotechnic device being simulated, is input to the mounted test specimen. The complex input motion is usually composed of the superposition of several damped sinusoids of different frequencies: this is the synthesis step. Analysis consists of monitoring the input to the specimen, immediately performing shock spectrum of the input and comparing the resulting spectrum with the specified spectrum. If the comparison is not satisfactory, the input motion is c[illegible]d to one that is likely to produce a more favorable comparison; and the above procedure is repeated. The process is continued until an acceptable test has been run.

One shortcoming of the synthesis/analysis technique is its inherent trial-and-error process associated with synthesis; however, instruments are commercially available which tend to minimize the number of trials necessary to create a satisfactory test. Ling Electronics and MB Electronics are two of the leaders in the industry at developing shock spectrum synthesis/analysis instrumentation. Both systems consist of a trial-and-error process in synthesizing waveform that will result in the desired shock spectrum; however, the two approaches for developing an appropriate waveform are quite different. The Ling instrument produces superimposed damped sinusoidal signals involving all 1/3 octave frequencies from 12.5 Hz to 10,000 Hz (30 frequency steps to generate the waveforms. On the other hand, the MB instrument produces superimposed sinusoidal signals involving all 1/3 octave frequencies from 12.5 Hz to 10,000 Hz (30 frequency steps) to generate the waveform. Because of the different method used to produce a spectrum, the MB instrument is capable of generating the same spectrum as the Ling instrument using a smaller amplitude signal.

In comparing the capabilities of the two systems, three conclusions are apparent:

1) Shakers and their input amplifiers are inherently limited as to the acceleration level that can be transmitted to the shaker head. For this reason, the MB machine can realize higher shock spectrum levels from a particular shaker installation due to its larger amplification factor.
2) To achieve the same shock spectrum, the Ling system would probably subject the test speciment to fewer stress reversals, but at higher stress levels.

There are some questions as to wheter or not pyrotechnic shock can be satisfactorily simulated by only simulating the shock spectrum and not requiring some degree of simulation of the input waveform. It is not currently known whether damage potential is related to the shock spectrum or to the pulse train that produces the spectrum. The data from the ground test provide two interesting relationships between a signal and its shock response spectrum:

1) Figures 32 through 49 illustrate that pyrotechnic shock data tends to have a Fourier spectrum that closely matches the shock spectrum.

2) An amplification factor between 1.5 and 5 usually results from pyrotechnic shock measurements.

Therefore, if the waveform is important and if the above relationships must hold to simulate the damage potential of pyrotechnic shock, the Ling system would be recommended. However, if the specified spectrum level could not be met by the Ling, the MB approach would be recommended.

Until more test comparisons are available or until more is known about waveform/damage potential effects, no reasonable conclusions can be stated with regard to the superiority of either approach to simulation.

Assuming either type of waveform is capable of simulating pyrotechnic shock, it would be desirable to eliminate the trial-and-error process from synthesis/analysis techniques. A control system which will produce an appropriate input waveform after one trial is currently in the conceptual design stage. This system (Reference 32) involves the use of a computer to produce a given time history on a shaker. After comparing an input and response functions in the frequency domain (comparing their Fourier transforms), the computer calculates the transfer function relating the two in the frequency domain. An inverse Fourier transform is run on the transfer function converting it back into the time domain, and the original input signal is operated on by the transfer function producing an input signal which should yield the desired response time history.

The proposed computerized synthesis/analysis system imposes somewhat of a financial restriction by requiring the use of a computer. Another limitation of the computerized system is that the shaker/mounting configuration is restricted to one very nearly resembling a linear system. Otherwise calculating the correct transfer function could again become a trial-and-error process.

The synthesis/analysis shock simulation technique has improved upon some of the shortcomings previously listed regarding the other simulation techniques for pyrotechnic shock testing. The technique is still subject to the disadvantage of not being able to accommodate large test specimens without imparing the linearity of the shaker system.

The methods previously discussed for simulating pyrotechnic shock as a means of laboratory testing have involved mechanical techniques for creating a shock environment. However, it is apparent that a realistic simulation of the pyrotechnic shock phenomenon can best be realized from a pyrotechnic source. The LMSC Barrel Tester uses 30 grains/foot MDF in combination with a 0.190 inch thick separation joint to qualify equipment. The Barrel Tester apparatus consists of several bays having different shock environments, thereby providing some versatility in testing. Further versatility can be implemented by modifying the separation joint. A more complete discussion of Barrel Tester techniques is presented in Section II.F.2 of Volume V.

### 2.6.3 Recommended Simulation Techniques

No specific recommendations regarding simulation in shock tests of full-scale structure can be made since each test program is subject to its own unique parameters. However, it has been shown in Section 2.6.1 that simulation can be employed when the limitations of the particular problem and when pertinent aspects of shock propagation theory are considered. The data indicate that mounting configuration, intervening structure, and the pyrotechnic event can be simulated in a manner that will reduce the expense of conducting the test.

The present state-of-the-art of pyrotechnic shock testing precludes the recommendation of one specific technique for component qualification testing. A correlation between damage potential and either shock spectrum or shock waveform has not been established. Until this relationship is established, the recommended testing techniques are those which simulate both the complex shock waveform and the shock spectrum.

## 2.7 Classification of Pyrotechnic Systems as to the Nature of Resulting Shock and/or Damaging Effects

The object of this effort is to tabulate the various types of ordnance devices utilized in aerospace systems with their explosive characteristics and resulting shock signature and/or damaging effects. A second objective is to compare different types of ordnance devices which are utilized on the same types of structures.

### 2.7.1 Structure Cutting Devices

The data from Division I of Volume II has been analyzed in order to tabulate the explosive character of structure cutting devices. Table VII lists the types of linear charges used in a number of tests and gives an indication of the magnitude of the resulting shock spectrum and the approximate distance of the measurement from the shock source. The measurement locations differ from test to test, which mades comparison difficult. However, this list indicates that the expansion bellows reduces the level of the shock source considerably compared to MDF and FLSC. The expansion bellows were used in Sections I.B.1, I.B.2 and I.B.3 of Volume II and are discussed in detail there. Essentially, an expansion bellows contains the linear charge within an expandable tube. The expansion of the bellows shears rivets holding the two structures together. The net result is that less material is severed in the process of structural separation.

The data in Table VII indicates that the grain size is an important parameter. The LMSC analysis (Section III) indicates that not only grain size but the thickness of severed material in the separation joint is important. Section III.B.2.3, contains a formula which shows that the level increases with material thickness and grain size. The thickness data for the tests in Table VII was not available, but the grain size appears to support LMSC conclusions.

TABLE VII

COMPARISON OF STRUCTURE CUTTING DEVICES

| SECTION | DEVICE | | DISTANCE FROM SHOCK SOURCE (INCH) | SHOCK SPECTRUM PEAK (g's) | FREQUENCY (Hz) |
|---|---|---|---|---|---|
| I.A.1 | MDF | 50 grains/foot | 7.5 | 50,000 | 6,000 |
| I.A.2 | MDF | 50 grains/foot | 23 | 25,000 | 5,000 |
| I.A.3 | MDF | 50 grains/foot | 7 | 40,000 | 7,000 |
| I.A.6 | FLSC | 7 grains/foot | | 8,000 | 8,000 |
| I.A.7 | MDF | 2½ grains/foot | 5 | 20,000 | 9,000 |
| I.B.1 | Primaline | 8 grains/foot | 3 | 1,000 | 4,000 |
| I.B.2 | Primaline | 8 grains/foot | 3 | 1,000 | 4,000 |
| I.B.3 | Primaline | 8 grains/foot | 3 | 500 | 1,000 |
| I.C.1 | MDF | 10 grains/foot | | 10,000 | 10,000 |
| I.C.2 | MDF | 7 grains/foot | | 10,000 | 4,000 |
| I.C.3 | Primacord | 9 grains/foot | 10 | 1,500 | 4,000 |

In Table VII, the three tests that utilized the expansion bellows, denoted by primaline, were the measurements closest to the source, and they are also the three smallest spectrum levels. A definite conclusion from Table VII is that containing a linear explosive in a device that severs less material will reduce the shock environment.

2.7.2 Comparison of Different Pyrotechnic Devices on the Same Structure

A series of test detonations of different types of separation hardware was conducted to compare the shock levels produced by Titan III-C separation nuts with those produced by separation nuts proposed for use on Titan III-M.

Three combinations of separation hardware were used during the test:

1) Single cartridge 3/4 inch nut;
2) Dual cartridge 3/4 inch nut;
3) Dual cartridge one-inch nut.

The test installation consists of two Titan III-C transtage skirt sections used to simulate the separation interface. One skirt section containing guidance and instrumentation trusses was attached to a base fixture. A second transtage skirt section was inverted and attached at each of the four matching longerons using the separation hardware applicable for each test. A description of the test installation and accelerometer locations are contained in Section II.B.2 of Volume III.

Three shocks were recorded for each of the three separation nut installations. Acceleration time histories and shock spectra analyses were obtained for each of the shock transients. Envelopes of the shock spectra obtained for each of the separation nut configurations were prepared, and comparisons of these envelopes from each accelerometer location are presented in Figures 74 through 97.

At airframe measurement locations, the 3/4 inch dual nut produces higher shock amplitudes at high frequencies than does either of the single nut configurations. (See Figures 74 through 76 and 89 through 94.

Comparisons of shock spectra envelopes from measurements on the guidance truss indicate that these high frequency components are, in general, not transmitted through truss members to equipment mounting points. For truss mounted equipment, there are no significant differences in the shock environments produced by the three different separate nut configurations.

The Universal Payload Fairing Separation tests offers a comparison of two pyrotechnic devices: a cartridge actuated cable cutter and a fairing separation by primaline linear explosive within a bellows assembly. This test is discussed in Section I.B.3 of Volume III. An inspection of the data for the two events shows that the fairing separation event was, in general, twice to three times the level of the cable cutting event. It should be noted that the primaline was contained in a bellows assembly which reduces the shock level considerably compared to a separation device that cuts the fairing.

Section II.B of Volume V contains a comparison of a standard fairing and an explosive nut fairing deployment mechanism.

An initial attempt was made to isolate the shock source without altering the basic mechanism, however, a reduction of only 29% was achieved. A second redesign using a spring loaded device achieved a shock reduction of 50% over the basic system. The third test replaced the pin puller by an explosive nut which achieves the same result without moving parts. This mechanism provided an average shock environment reduction of as much as 99% in the low frequencies to 81% in the high frequencies. These reports offer a good comparison of environments produced by three different designs of fairing separation devices.

Other data from which several pyrotechnics were compared on one structure involved the Prime, Mariner, Surveyor, and Minuteman vehicles. The Minuteman III data (Section I.A.5 of Volume II) illustrates that the staging event produces a much higher level than the umbilical separation event, as expected. The Prime data (Section III.A of Volume III) suggests that the hatch separation event using FLSC produces the most severe shock, while the explosive bolt is more severe than the separation and the mortar produces the lowest levels. Since the Mariner and Surveyor data compare levels on the spacecraft for events that occur both on the respective spacecraft and on their boosters, no valid comparison could be made of the relative shock environments produced by the different pyrotechnics.

Available data and experience indicate that there is a general order of heirarchy among the various pyrotechnics according to the severity of the environment produced. The suggested order of severity is listed below in the order of highest to lowest.

1) Linear explosives (MDF and FLSC) in separation joints;
2) Explosive bolts;
3) Separation nuts;
4) Pin-pullers, pin pushers, cable cutters, and bolt cutters.

This order does not necessarily hold in all cases but is suggested by the data that have been examined.

2.7.3 Failure Information

Information concerning damage effects and equipment malfunction is extremely limited. Disclosure of information concerning failures is not readily made, and where failures are known to have occurred, documentation has not been complete.

The lack of information is not necessarily an error of omission in all cases, but is due to the type of test conducted. Development tests are usually conducted to evaluate the function of a particular ordnance device and/or to testablish shock test criteria for equipment and components. For such test programs, "dummy" or inert equipment and components are usually installed. For qualification and/or acceptance tests utilizing full-scale payloads and structures, equipment and components have been previously qualified on a component level.

A limited amount of failure and damage information was obtained from data sources during this study. In almost all cases, the failure information did not include the shock environment. Volume IV contains most of the information on failure of a wide variety of equipment to a shock environment. The invormation was obtained from a series of test carried out over the last five years on the "barrel tester" developed by LMSC. Section VI of Volume V describes the barrel tester and shock environment.

Approximately 10 percent of the 119 items of equipment tested experienced failure traced to design or manufacturing defects. Of the items, 13.5 percent experienced relay chatter. Volume V describes the types of failures and the mounting configurations on these items. This description, along with the failure data below, points up the importance of shock testing to avoid possible mission failure. The following list gives a brief description of the failure and pertinent information received during this study.

1. <u>Titan III-C Airborne End Items</u>

   High Intensity Shock Test Program (Pyrotechnic Shock)

   1) Flight Control Computer (80801D15000-029)
      Out of tolerance transients were recorded on signal outputs. (Functional Failure).
   2) Flight Control Adapter Programmer (80801D11007-099)
      Out of tolerance transients were recorded on signal outputs. (Functional Failure).
   3) Pressure Regulating Switch (PD71S0070-039)
      Transfer from contact open to close occurred. The closure duration was approximately 1 to 1.5 milliseconds. (Functional Failure).
   4) Rate Gyro System (80801D3000-019)
      Out of tolerance transients were recorded on signal outputs. (Functional Failure).
   5) Relay, 20 - Ampere (PD73S0070-501).
      Chatter of relay contacts during shock exposure. (Functional Failure).

2. <u>SPRINT FLA 26 Autopilot</u>

Transistor failure as a result of the shock environment produced by a sequence of squib firings. (Mechanical failure).

3. <u>Nose-Fairing Separation Test - 823 Spacecraft</u>

Ordnance: Mild detonating fuse (MDF) at 10 grains/foot at the base of the nose fairing circumference. Flexible linear shaped charge (FLSC) at 5 grains/foot for the length of the nose fairing.

A total of fifty-one components were subjected to the separation shock. Five sustained physical damage of which three were considered to be potential sources of system malfunction. Many of the components were mounted on five test sample panels mounted at various locations on the spacecraft structure. Each panel consisted of a 3" x 4" x .060" aluminum sheet on which were mounted three glass diodes, two glass capacitors, two ceramic transformer core-spindle assemblies, and two memory cores. Two solar cell cover glasses were installed on each of three of the panels.

The separation shocks produced damage to components as follows:

| Component | Damage Description |
|---|---|
| X-R Detector Guard Section | Gain down 10% (Gain reduction was considered significant but not serious). |
| Gamma Detector | Gain down 15% (Gain reduction was considered significant but not serious). |
| Diodes (3 different test panels) | Loose particles were found inside glass envelope. Electrical shock showed normal performance. Particles could cause shorting if properly lodged. |
| Transformer Core | Ceramic transformer spindle broke off. |

4. <u>Production Environment Test (PET) on SPRINT</u>

Instrumented Warhead Section.

The stage separation shock was simulated by a 1 inch drop, steel on steel, utilizing an AVCO lead pellet machine. The shock spectrum is shown in Figure 98.

| Component | Failure Description |
|---|---|
| Subcarrier Oscillators (5). 1.3 KHz, 1.7 KHz, and 70 KHz. | Excessive noise "spikes" appeared at the time of shock. Four of the components successfully passed a re-test. One unit exhibited a band pass shift. |
| Frequency Monitor | Unit exhibited excessive noise at the time of shock application. The failure mode was repeated on re-test. |

5. Aerobee 350 Separation Tests

| Component | Failure Description |
|---|---|
| Shaped Charge | Charge failed to detonate over the entire length of circumference. (A 1½" to 2" segment of structure was not severed). Failure may have been caused by damage to the shaped charge or damage to one of the two squibs in the firing circuit causing it to fire "low order." |
| Squibs | Two squibs were mounted near the separation plane at test items. One of the squibs sustained damage to a bridge wire. |
| Relays<br>6-Pole relay | Inoperative because of excessive tension. |
| Latching relay | Intermittent operation. Malfunction may have been caused by magnetic chips found in the unit. |

6. OAO Sun Shade Ground Test

The sun shade latch fitting (containing the squib) broke off. Fragments from the fitting could have damaged the spacecraft. The fitting material was changed from nylon to titanium.

7. Numbus Paddle Tie-Down Mechanism

Pre-load pin failures occurred during a series of ground tests. The mode of failure could prevent proper release and deployment of the paddles. The pin failure was attributed to improper heat treatment.

It was concluded after studying the above failure data in detail that these data were insufficient to relate the shock environment causing failure to damage potential.

2.7.4 Summary of Relating Pyrotechnic Systems to Resulting Shock and/or Damaging Effects

Pyrotechnic systems cannot, in general, be classified as to the nature of the resulting shock and/or damaging effects. It is generally accepted that the shock environment produced by a pyrotechnic event is a complex function of the explosion, of the energy released by recoil and/or cutting of material, and of the structural response. Reduction of any one of these tends to reduce the severity of the overall environment.

A list of pyrotechnic devices according to the severity of the environment they produced follows:

1) Linear explosives (MDF and FLSC) in separation joints;
2) Explosive bolts;
3) Separation nuts;
4) Pin-pullers, pin pushers, cable cutters, bolt cutters.

This order does not necessarily hold in all cases but is implied by the data that have been examined. Prediction techniques based on the data that provided this list have been developed and are contained in Volume VI.

Failure data in the industry is not usually well documented or thoroughly studied. Detailed examination of available failure data yielded no suitable results relating the shock environment causing failure to damage potential.

## 2.8 Evaluation of the Effects of Structural Configuration and Materials on Resulting Shock Characteristics

The objective of this effort is to determine and evaluate the effects of intervening structure and material properties on shock amplitude, propagation velocity, and frequency content. The discussion in the previous section was concerned with shock characteristics associated with different pyrotechnics, whereas it is the intent in this section to consider shock characteristics as related to the structure in which propagation occurs.

### 2.8.1 Effect of Structure and Material on Propagation Velocity and Frequency Content

Analysis of wave propagation in bars and plates predicts three types of stress waves possible; compressional, shear and flexural. Compressional and shear waves will propagate with a single velocity, whereas a flexural wave will "disperse" with distance, i.e., the various frequency components of the pulse will propagate with a speed that depends on the value of the frequency.

These three types of waves have been detected in shock data and usually the data will be a combination of all three. This is due to the extreme complexity of the structure which causes reflection and transmission of a shock pulse. The value of propagation velocity in truss and skirt structures have been measured and are discussed in Section 2.2 of this Volume.

The longitudinal velocity in a single aluminum truss member near the shock source agreed with the theoretical value of 200,000 inches/second. For locations that were removed from the shock source by complex structure, the value of the propagation velocity often decreased to a value that was closer to the shear wave velocity. These values are shown in Figures 1 and 2.

The frequency content of a shock spectrum is affected by intervening structure. The data, in general, have shown that devices used for major separation events produce a spectrum near the shock source that contains high frequency energy, i.e., above 10 KHz. As the shock pulse propagates through the structure, local resonances of lower frequencies are excited. Generally, with an increase in the complexity of the structure and the increase in distance from the source, an increased number of resonances will be excited. The high frequency energy content was discussed in Section 2.2 and can be seen in Figures 3 through 17. The effect of structure on the ground test can also be seen in Figures 99 through 104 which compare the shock spectra for the various measurement locations on the truss and skirt. These spectra show data to only 10 KHz whereas the data in Figures 3 through 17 show the data for frequencies to 34 KHz for single locations. Notice that for the truss structure the lowest major frequency is above 1000 Hz, whereas for the skirt, major frequencies below Hz are evident.

Data for the effect of mass loading on frequency content are available from two tests; the ground test and MM III. The mass loading effect on both tests were discussed in Section 2.6, "simulation", and the data comparing the two configurations can be seen in Figures 67 through 72. The data from the MM III comparing two configurations with different masses are discussed in Volume II, Section I.A.4. In general, these two sets of data indicate a negligible effect on the frequency content of the spectra. However, the data from these two tests are insufficient to draw any definite conclusions, as it would seem reasonable to expect mass loading to affect frequency content.

2.8.2 Effect of Structure and Material on Shock Amplitude

The data in Section II.B.1 of Volume III has provided enough structural variations to generate qualitative observations in four areas:

1) The effect of four different mounting configurations;
2) The effect of mass loading (whether or not satellites were installed);
3) Amplitude decay with distance from shock source in a truss structure;
4) Amplitude decay with distance from shock source in a skin-ring-frame structure.

Figures 61 through 66 depict comparisons among the shock amplitudes at locations 7 and 8 for the truss mounting configurations. The shape of the four shock spectra are similar, but there are definite amplitude shifts. The relationships among the curves are the result of the structural mounting configurations -- results which could have been anticipated from shock propagation theory. It would be expected that the freely suspended configuration would exhibit the highest levels because the shock has no place to go except into the truss and the surrounding air, and shock propagation theory makes it clear that a compression wave will tend to propagate in all directions from the source. At a free boundary (air interface), most of the shock will reflect back into the structure. Also, it would be anticipated that the configuration of the truss mounted to the rigid fixture would exhibit the lowest levels in the truss. The explanation for this is that the rigid fixture provides more structure than do any of the other configurations for shock propagation before portions of the shock are reflected back into the truss.

Comparison of the effects of mounting the truss on the transtage and mounting it on the channel adapters atop the rigid fixture shows that the channel adapter configuration is slightly more severe. The channel adapters were selected because they closely simulated the longitudinal stiffness characteristics of the transtage. However, the length of the channel adapters was less than that of the transtage so the energy reflected from the channel/fixture interface was less attenuated upon re-entering the truss than was the energy reflected from the bottom of the transtage. This observation was not discussed under simulation techniques but indicates that when reflections of shock waves are important, structural dimensions are also important.

The effect of installing dummy satellites in the suspended truss is discussed under simulation in Section 2.6. Figures 67 through 72 were cited in comparing the configurations with and without the satellite. From these comparisons it appears that the mass loading due to the satellites has relatively little effect.

The attenuation of shock amplitude with distance from the source in a truss structure is depicted for longitudinal, lateral and vertical accelerometers in Figures 26 through 28. These comparisons indicate the evidence of attenuation with distance from the shock source. This result is presented in Figure 30. It has been pointed out that the frequency content has been altered by the presence of structural resonances. This implies that the only two effects on response amplitude are the attenation and the induced resonances. However, it is suspected that the intervening joints would have some effect, but the only noticeable effect of intervening joints was the amplitude reduction associated with a significant change in the direction of the shock path. This effect is best observed by comparing the g levels recorded at accelerometer locations 4 and 5.

The attenuation of shock amplitude with distance from the source in a skin ring-frame structure is depicted for longitudinal, tangential and radial accelerometers in Figures 102 through 104. These comparisons do not exhibit the pronounced attenuation with distance that was apparent for the truss. Also, the frequency content doesn't appear to be as stable as it was in the truss. The reason for this second phenomenon is the disparity of structure among the transducer locations 15, 16, 17 and 18. Figure 105 shows the structural configuration at location 17 which is typical for locations 15, 17, and Figure 106 shows the structural configuration at location 18 which is typical for locations 16 and 18. Notice the presence of the major longeron at location 16 and 18 and that not even a minor longeron is present at locations 15 and 17. A closer examination of Figures 102, 103 and 104, reveals that the responses at locations 15 and 17 are related while those at locations 16 and 18 are also related. Unfortunately, a cross comparison between the two signatures does not yield any obvious conclusions about the relative effects of shock transmission in the skin ring-frame compared to the transmission characteristics of a skin ring-frame/longeron configuration. The only certainty is that the transmission characteristics are not the same.

The Universal Payload Fairing Tests (UPLF) have provided data for comparison of three structural configurations subjected to the same type of pyrotechnic devices. Separation tests were conducted on three different Titan III C universal payload fairing configurations (15', 35' and 50' fairings). Fairing separation is accomplished in two distinct pyrotechnic events:

1. Eighteen spring loaded pins located around the circumference of the base of the payload fairing are released. Pin release is accomplished through actuation of an ordnance initiated cable cutter.

2. Separation of the fairing into longitudinal tri-sections is accomplished by detonation of primaline contained in a bellows assembly. The primaline shears the riveted joint to affect separation.

A complete description of the structure and accelerometer locations are given in Section I.B.3, Volume II. Selected measurements from this test program are presented in Figures 107 through 112 to compare the effect of structural configuration on the shock environment.

In general, the separation event produced a more severe shock environment than did the pin release event. The 35 foot fairing separation produced a more severe shock environment than either the 15 or 50 foot fairing. The higher shock environment produced by the 35 foot fairing is attributed to an improved alignment of this fairing (providing a good surface contact from the fairing to the transtage skirt structure) as compared to either the 15 or 50 foot fairings.

In general, the same environment was produced for all three firings and the biggest differences in shock levels were produced by a good contact surface. Other data have supported the observation that isolation can be achieved by a loose joint or a joint having an additional layer of material providing additional surfaces for reflections. An example of this type of isolation by additional material was reported by TRW Systems. A test was conducted where a 40 mil tungsten pad was placed at an interface and a 30% reduction in the shock levels was achieved. The pad was destroyed which might account for the isolation by absorption of energy. However, a recent test conducted by LMSC using various thickness of aluminum inserts in an aluminum structure resulted in zero attenuation. This would suggest that the reduction is not due to reflection of the pulse at an interface but could be due to the crushing of the insert material.

Data comparing shock environments for two types of material are contained in two tests in Section I.B.1 and I.B.2 of Volume II. The Titan III C metal fairing was made of aluminum. Almost all of the acceleration measurements were made at the same locations and the fairings were the same size and shape. Comparison of the shock spectra for those two tests does not indicate any definite reduction for either fairing. Considering the questionable quality of this data, the two environments do appear to be similar.

The effect of honeycomb on the shock environment can be seen from two tests as reported in Volume II, Sections I.C. and I.C.2. The MSS Shroud Separation Test in Section I.C.1 contains a honeycomb platform resting on a truss structure. An examination of the shock spectra for measurements directly below the platform and on the platform indicate that the large honecomb plate disperses the shock. This is probably due to the size of the plate rather than the honeycomb material.

The data in Section I.C.2 from the Apollo panel separation indicate that the honeycomb material is a very poor attenuator with distance. Accelerometers 4 and 9 are located on the outer panel (Figure I.C.2-4, Volume II) and are separated by a distance of 160 inches. The reduction in shock spectra was approximately 70%, which corresponds to the attenuation curve for honeycomb material from North American presented in Figure 29. The data for the chem-milled structure indicates an attenuation rate given by the other curves in Figure 29.

The effect of intervening structure can be seen in comparing the three tests of the Spartan vehicle, I.A.1, I.A.2, and I.A.3 in Volume II. In all three tests, a cylindrical structure was used for a separation test. In I.A.1, a telemetry rack was located 18¼ inches from the separation plane. In I.A.2, a telemetry rack was located 108" from the separation plane. In I.A.3, a structural interface was located 16" from the separation plane. Comparing accelerometers at 23 inches from the separation plane for tests 1 and 2, indicstes that the telementry rack in test 1 causes a considerable reduction in the shock level. Comparing accelerometers at 43 inches from separation in test 2 to the accelerometer at 39 inches in test 3 shows very definitely that the structural interface in I.A.3 causes a considerable reduction in the shock level. These three tests were also discussed in Section 2.6, on simulation.

2.8.3 Isolation

While it is good design practice to locate shock sensitive components at a distance from the source to allow attenuation, some configurations preclude this approach. Therefore, it is necessary to use attenuation devices to isolate regions of the vehicle that would otherwise experience shock levels in excess of the equipment qualification levels.

Isolation involves the use of devices that will abosrb potentially damaging shock energy and devices that will reduce transmissibility characteristics by reflecting this energy away from critical locations. Three general approaches to shock isolation have been considered:

1. Isolating the shock source from the vehicle structure;
2. Interposing an isolator in the structural path between the shock source and the component mounting location;
3. Isolating the component from the structure.

Generally, only the third approach has been employed enough to prove successful. However, some of the available data lend support to the other techniques.

The pyrotechnic shock tests of the Prime vehicle (Section IV.A, Volume III) involved the use of crushable isolators to absorb some energy and isolate the effect of explosive nuts and bolts from the structure. The per cent reduction in shock are tabulated along with the isolation device in Table VIII. These tests are discussed by Britton and Jones, and by Britton in the data references, Section 6.1.

## Table VIII

Comparison of Isolation Devices at Source from

Prime Pyrotechnic Shock Tests

| Pyro Device | Isolation Device | Reduction In Levels | Remarks |
|---|---|---|---|
| | Booster Separation Tests | | |
| 3 Explosive Bolts | Honeycomb Absorbers (3.1 $lb/ft^3$) | original configuration | absorbers crushed |
| 1 Explosive Bolt | Honeycomb Absorber (5.7 $lb/ft^3$) | 30% | absorber crushed |
| 2 Explosive Bolts - 1 Separation Nut | Honeycomb Absorbers (3.1 $lb/ft^3$ with nut) (5.7 $lb/ft^3$ with bolts) | 68% | Absorbers with bolts crushed with nut uncrushed |
| | Drogue Disconnect Tests | | |
| Separation Nut | Pyrotex (hard) washers | 0% | washers shattered |
| Separation Nut | 90 durometer Adiprene (soft) washers | 90% | ---- |

In Section II.C.2 of the Lockheed data compilation (Volume V) three means of isolating the effect of a pin-puller from the structure are discussed. Two of the methods investigated involve the use of a snubber assembly to alleviate the recoil shock of the device. When the snubber assembly included copper washers, 61% shock reduction resulted. When the copper washers were replaced by silicone rubber isolators, 95% reduction resulted, but the design was too flimsy to be efficient. The bracket type isolation of the pin-puller resulted in a good design and a shock reduction of 90%. The per cent reductions quoted above were based on levels at the critical equipment location; however, the reduced levels observed near the pin-puller were generally only 30% to 60% less than the unisolated case.

Very little effort has been expended in the industry to determine effective isolation techniques that involve increasing the attenuation characteristics of intervening structure. The tungsten pad discussed in the previous section (2.8.2), which provides a 30% shock reduction, is one of the few documented examples of this approach to isolation. It is anticipated that this technique could best be employed by modifying the structure to permit many structural interfaces with attenuation devices, such as the tungsten pad, at each interface. At worst, such an approach to isolation would permit many reflections of the shock pulse and would tend to spread the effects of the once concentrated shock energy. The greatest drawback to this technique is that the inclusion of many structural interfaces in the shock path could impare the structural integrity of the vehicle.

Roberge, reference 54, also indicates that shock transmission characteristics of a structural joint are an important factor in isolation. A riveted butt joint was found to produce no attenuction, while a matched angle joint produced attenuation of 30% to 60%.

Shock isolation at equipment mounting locations has been employed with varying success for a number of years. Much of the effort in this area has been geared toward designing mounting bracketry that will not transmit certain critical frequencies to the sensitive equipment - essentially a vibration isolation technique. Roberge, reference 54, compares the effects of stiff and soft mounting configurations for isolating equipment from the shock environment produced by a separation joint. The stiff mount resulted in 60% reduction in level of the time history peak across the mounting bracket and the soft mount resulted in 87% reduction in level across the mounting bracket. However, the reduction between the input to the mount and the response of a piece of equipment attached to the bracket was 86% for the stiff mount and 89% for the soft mount. It appears then that shock isolation does not depend on which frequencies are isolated but upon absorbing or rerouting the energy.

The Prime vehicle's hatch separation tests (data references 20 and 21) compare three shock isolators used at equipment mounting points. Table IX presents the results, where the percent reduction tabulated is compared to the unisolated configuration. This data indicates that soft mounts are much better than stiff ones; however, in view of other data, the evidence is not conclusive.

The Lockheed data compilation includes three relevant discussions of isolation at equipment mounting locations. Table X presents the percent reduction observed during the tests outlined in Sections II.A.3, II.B.1, and II.E.2 of Volume IV and V.

The discussion in Section 2.71 indicates that the expansion bellows employed in the three fairing separation tests (Sections I.B.1, I.B.2 and I.B.3 of Volume II) was a successful means of reducing the shock environment characteristic of a linear explosive. Rather than employing an isolation device per se, this involved a redesign of the separation joint by enclosing the pyrotechnic and severing less material, which reduced the shock level generated. Whether or not better separation designs are considered isolation devices is unimportant; they can reduce shock levels. Further discussions regarding modification of the pyrotechnic device to reduce shock levels are included in Sections II.A.3,

## Table IX

Comparison of Isolation Devices at Equipment Mounting Locations

| Isolation Device | Reduction in Level |
|---|---|
| Pyrotex (hard) Mounts | 50% |
| Adiprene (soft) Mounts | 86% |
| Lord Center Bonded Mounts | 68% |

Table X

LMSC - Results of Equipment Isolation Techniques

| Section No. | Isolation Device(s) | Shock Reduction |
|---|---|---|
| II.A.3 | Equipment Mounting Brackets Alone | 73% |
| | 1/8 inch silicon rubber inserts (40 durometer) at mounting bolts | 69% |
| | Use of both the above techniques simultaneously | * |
| II.B.1 | Use of internal bumpers, energy absorbers, and other isolators were used | 29% Maximum |
| II.E.2 | Equipment box on Z-brackets only | (approx.) 75%** |
| | Silicon elastomer vibration isolators at bolts on Z-bracket mounts | (approx.) 80-90%** |

* The individual effects were not additive when both devices were used.

** Levels at frequencies below 200 Hz were not significantly attenuated and the percent reduction presented is for frequencies greater than 400 Hz.

II.B.1, and II.B.2, II.B.3 and II.C.1 of the Lockheed data compilation presented in Volumes IV and V.

### 2.8.4 Summary of Structural and Material Effects of Resulting Shock Characteristics

Available data on shock propagation velocity have shown that compression and shear waves travel at the classical sonic velocity of the material. A third kind of wave, a flexural wave, is known to disperse as it travels because the different frequencies in the waveform propagate at different velocities.

The frequency content of a shock wave has been found to alter as it propagates. The most evident trend is for high frequency energy to be transformed into energy at lower frequencies by the excitation of structural resonances. Furthermore, the numerous reflections and recombinations of a shock wave in a complex structure alter the frequency content.

Attenuation of shock amplitude with distance has been determined empirically many times. The attenuation characteristics in truss members, skin, ring-frames, longerons, and chem-milled panels have been found to be similar. However, honeycomb material does not attenuate shock amplitude as well as do other aerospace structures.

Intervening structure is known to have significant effects in reducing shock amplitude. In particular, a large volume of intervening structure tends to disperse the energy over the entire volume at lower amplitudes. Also, structural interfaces usually reduce shock levels. However, welded joints in truss members are not characterized by reducing the shock environment.

Limited data on variation in material and on mass loading have not exhibited significant amplitude reduction.

Isolation devices near the shock source, in the intervening structure, and at critical equipment mounting locations have been capable of reducing shock amplitude by 50% to 90%. Isolating the shock source from the structure generally involves absorbing the energy, while isolation of an equipment location usually depends on limiting transmissibility to the equipment.

## 2.9 Formulation of a Follow-On Research Program

The objective of this effort is to define and outline a follow-on research program from the information obtained in the present study. The results of this investigation, which has utilized vast quantities of data and information obtained throughout the aerospace industry, have indicated several specific areas where additional investigation is required. These areas are as follows:

a. Test Simulation;

b. Techniques for Predicting Shock Propagation;

c. Damage and Failure Criteria.

### 2.9.1 Test Simulation

This investigation has revealed the need for a more thorough study of the basic requirements and methodology associated with simulation of the pyrotechnic shock environment, for both full scale and component shock testing

For full-scale tests such as spacecraft separation, a fundamental need is the development of testing techniques which would provide a reasonable margin of safety in shock amplitudes, as well as repeated applications of shock, in order to obtain confidence in the reliability of the design. Data from the ground test and other sources (as described in Section 2.6) have indicated that the required results may be achievable through the proper design of test fixtures or operations on the shock source(s).

The wide variety of equipment and techniques presently in use for testing components does little to impart confidence in this field of testing technology. There appears to be an urgent need for standardization in this area. To achieve a standard methodology, at least to the degree that vibration testing is currently standardized, will require definition of the parameter(s) (i.e., waveform, velocity, frequency content, number of stress reversals, etc.) which are significant in producing malfunction or failure.

### 2.9.2 Damage and Failure Criteria

An area of great importance but lacking in information concerns damage and failure of equipment and structure. An investigation that would relate failure of hardware to shock environment would add significantly to the state-of-the-art of pyrotechnic shock. This is a very broad area that encompasses many types of equipment and mounting methods and would require intensive study and failure testing to obtain meaningful results.

### 2.9.3 Techniques for Predicting Shock Propagation

A critical area that needs to be investigated is that of predicting shock propagation. The analysis to date has indicated that an analytical and experimental study of shock propagation of a fundamental nature is needed. This study should attempt to understand the basic mechanism of shock transmission and reflection at a joint in a bar type structure. An outline of such a study follows:

1) Perform mathematical analysis to develop a model. Analyses would include one dimensional wave solution, modal and Fourier techniques.
2) Perform an experiment on bar or truss structures which include joints.
3) Comparison of test data to analysis and extension of these techniques to available test data from actual aerospace structures.

Another area important to predicting shock environments is that of mass loading. The need exists to determine the relation between equipment weight and the associated pyrotechnic shock environment. This could be accomplished by performing tests and analyses on:

1) An individual equipment installation on an airframe (shell) structure.
2) An individual equipment installation on a truss structure.
3) An entire equipment truss with distributed masses simulating equipment items.

2.10 Application of Shock Propagation Theory

The objective of this task is to establish empirical/theoretical relationships for predicting shock criteria, and to apply these relationships to one class of pyrotechnic systems.

A study on shock propagation was performed during 1968, reference 60. An analytical study and experimental test program were conducted on a typical truss element that included several welded joints. The object of the study was to attempt to predict the transmission and reflection of a single pulse at a joint in a truss member and compare with experimental results. The results of such a study could then be used as a building block to predict the time history resulting from a single pulse in a complex structure.

A single pulse was produced by striking one end of a truss element with a steel ball. The resulting transmitted and reflected pulses were photographed. These results were used to compare to the analytical predictions.

An analysis that considered the joint as a rigid body failed to provide a solution to the problem. A second analysis utilized the test data in an attempt to correlate the results with a static force balance of the joint. This analysis used formulas developed by Donnell, Reference 10.

It is apparent that the mechanism of shock propagation is much too complex to be predicted by a simple mathematical model. Very little work has been done on wave transmission in a bar of variable cross-section, either analytical or experimental. Such a study may provide the basic understanding (knowledge) needed to arrive at a successful prediction method. A modal analysis or a finite difference method might prove tractable.

It was observed in truss data that very near the shock source, say 3 inches, the major frequency of the shock spectrum was above 10 KHz, while the spectra for locations distant from the shock source peak at frequencies well below 10 KHz. It is now well known that the intervening structure will affect the shock pulse but it is impossible to predict the exact manner in which it is altered using present state-of-the-art techniques.

Applying the one dimensional wave theory for a uniform bar will allow prediction of a major frequency for a truss structure. In a structure where the pyrotechnic device sends a pulse through a bar type truss memeber located close to the source, a resonance in the longitudinal direction will be excited. The structure will attemuate the high frequency (above resonance) and there will be a peak response at the resonance frequency. The value of this resonant frequency is given by the formula for the first fundamental mode of a bar:

$$f = \frac{V_c}{2L}$$

where

$f$ = frequency in Hz

$V_c$ = velocity of propagation, in/sec

$L$ = length of truss member between joints, inches.

This prediction method was compared with the results from the ground test. Location 2 was measured on a tube 65 inches long and the propagation velocity is approximately 205,000 inches/second. The predicted frequency is approximately 1600 Hz. The data in Figure 6 for location 2 longitudinal shows a resonance at 1600 Hz superimposed on a spectrum that has a peak beyond 10 KHz. However, the two transverse measurements at location 2 do not show any definite resonance in the lower frequencies.

This simple method provides a means of predicting frequencies caused by intervening structure in truss type members. A question arises in predicting the amplification factor of these resonance peaks above the basic constant velocity line on the shock spectrum. It will depend on the number of cycles of the time history. A sinusoid that decays in eight cycles has an amplification factor of 5 for a shock spectrum (based on Q = 10). An amplification factor of 10 would probably be conservative for most all cases.

## 2.11 Ground Test Program

A controlled pyrotechnic shock test program on full-scale structural components was conducted to provide specific information concerning:

1) The repeatability of pyrotechnic shock measurements;
2) The influence of intervening structure on shock propagation including the effect on amplitude, waveform, and velocity;
3) The collection of basic information to aid in the determination of structural simulation requirements for pyrotechnic shock testing.

A total of 19 tests were performed on 4 structural configurations as follows:

| | | |
|---|---|---|
| Configuration I | - | Payload truss installed on a transtage skirt which was mounted on the ground (Fig. 56). |
| Configuration $II_a$ | - | Payload truss freely suspended (Fig. 57). |
| Configuration $II_b$ | - | Payload freely suspended with dummy satellites installed. |
| Configuration III | - | Payload truss installed on a hydrostatic test tool (rigid fixture) (Fig. 58). |
| Configuration IV | - | Payload truss installed on channel adapters simulating longitudinal stiffness of transtage skirt (Fig. 59). |

For each test, one separation nut was detonated, and 24 accelerometers were monitored. The data obtained during these tests are presented in Section II.B.1 of Volume III; where the test configuration, data acquisition system, reduction process, and structural configurations are described in detail.

This test program resulted in a total of 456 time histories and shock spectra that were utilized in the performance of other tasks involved in this study.

## 3.0 SUMMARY OF ANALYSES

A summary of the analyses discussed for each task in Section 2.0 is given in this section.

### Data Compilation and Use

A total of 2837 shock spectra were compiled and reduced for this study. These data, together with descriptions of the tests, are contained in Volumes II through V of this report.

The data provided a large quantity of measurements for a variety of test configurations, structures and types of pyrotechnic devices. Table II in Section 2.1 provides a useful index to all of the data. This table describes the structure and type of device for each test in the four volumes and the number of measurements available. A list of the data sources is provided in Secion 6.1 for further reference.

### Repeatability

In the controlled ground test the repeatability of good shock spectrum data was determined to be less than a factor of 1.5. The spread of data in the Prime tests was found not to exceed a factor of two for two identical tests. Lockheed determined from a series of twenty-two tests on the barrel tester that a "factor of 1.59 is a conservative estimate of the distribution that can be expected from pyrotechnic shock data."

Overall, experience indicates that good shock data will have a spectrum repeatable within a factor of from 1.5 to 2.

### Shock Characteristics

The amplitude and frequency content of a shock spectrum depend on the type of pyrotechnic device and intervening structure. It has been found that near the shock source the main frequency content will be above 10 KHz. Frequency content around 25 KHz can be present and can be caused by the accelerometer mounting configuration (See Section 2.4).

A dc shift in the time history will produce a level of constant acceleration in the low frequency region of the shock spectrum. The shock spectrum of a truncated time history is quite often the same as the unaltered spectrum indicating that the first few pulses dominate the spectrum.

The four coordinate presentation of shock data clearly indicate the regions of constant displacement, constant velocity, and constant acceleration. It is possible that these parameters may be related to damage potential, especially the level of velocity content.

Attenuation

Attenuation curves from this study and from the literature are presented in Figures 29 through 31. It has been found that attenuation curves from time histories and from shock spectra are very similar for the same test. However, the attenuation for each structure is different and, as the curves in Figures 29 through 31 show, a range of attenuation is possible. It is interesting to note that honeycomb offers very little attenuation compared to other types of material and structure. Attenuation curves should be used with discretion.

Fourier Analyses

Fourier Spectra for a number of shock measurements are given in Figures 32 through 49. These Fourier spectra are compared to the associated shock spectrum in each case, and in general, the shapes and levels are similar. It is known that two different waveforms can produce the same shock spectrum, but they may not have the same damage potential. Since Fourier analysis produces a unique spectrum, it is expected that Fourier techniques would potentially be more useful than shock spectrum analysis, particulary for simulation, and should be explored in depth.

Quality

A large amount of pyrotechnic shock data has been quality rated by a rating scheme that is described in detail in Section 2.3. The average rating of all the data is 3.94, which can be described as adequate data. The average of the flight data is 1.08 which is rated as containing some usuable data.

The main source of low rating that can be easily corrected (for ground test data) is the lack of high frequency content in the shock spectra. The poor quality of the flight data is due to the present measurement techniques. Three possible techniques for obtaining flight data are:

1) Record the data at a high rate and play back at a slow rate;
2) The use of in-flight analysis;
3) Record the data on a recoverable recorder.

Measurement Systems

The measurement system should be tested and qualified to the environment applicable for its intended use. The recommended transducer mounting configuration is the solid stud with a thin oil film at the transducer/structure interface. (See Section 2.4).

The general method used to acquire data is standard throughout the industry and a wide range of instruments are available.

The fundamental difficulty in obtaining flight measurements lies in the storage and recovery of high frequency content.

The efficiency of spectra analyses depends on the quantity of data to be reduced. Analog techniques provide the least expensive method for a few measurements while a digital method would be preferred for a larger quantity of data.

Simulation

For shock development tests and for test articles which are too large or heavy to test by conventional laboratory equipment, special test installations utilizing ordnance devices attached to actual or simulated structure are recommended. The test results indicate that some degree of structural simulation can be tolerated. It has been found that some degree of overtesting can be achieved by a special mounting configuration as in the ground test program.

The MMIII test (I.A.4) results have shown that simulation of the lower end of a spacecraft by a weight appears to be effective as long as the separation hardware is unchanged.

For component testing, it is felt that convential shock machines do not simulate the complex shock motions the equipment experiences in actual practice. Current indications are that synthesis/analysis techniques could provide adequate simulation of the pyrotechnic shock for qualification testing, however, the cost differences must be recognized.

The "barrel tester" technique is an effective means of qualification testing for complex shock motions.

The present state-of-the-art of pyrotechnic shock testing precludes the recommendation of one specific technique for component qualification testing. A correlation between damage potential and either shock spectrum or shock waveform has not been established. Until this relationship is established, the recommended testing techniques are those which best simulate both the complex shock waveform and the shock spectrum.

Failure Information

Section 2.7.3 contains a limited amount of failure information from a number of different sources. This list indicates the type of failures that have been experienced due to pyrotechnic shocks but correlation of the failure with the shock environments is lacking.

Volumes IV and V of this report contains a significant amount of failure data on 119 items tested on the barrel tester. The shock environment is available for these data, but furnishes no conclusions about the damage potential of the shock.

Mass Effects

The ground test data (II.B.1) and the MMIII data (I.A.4) provides some information on the effects of mass loading, but the results are inconclusive. It is felt that mass loading, in general, will affect the shock environment. A series of tests to determine the effect of mass loading are planned and the results of these tests (when completed) will be made available as an addendum to this report.

### Shock Propagation

The state-of-the-art in predicting shock levels is based on attenuation curves and extrapolation of the data from previous experiments. For these purposes, this report will provide a valuable guide to the engineer.

Prediction techniques based on analytical models are nonexistant and need to be explored. The basic mechanism of shock propagation in complex structures can only be understood by developing a mathematical model and correlating this with experimental results.

### Explosive Devices and Their Characteristics

For separation devices, it is well known and documented that a bellows type of joint will significantly reduce the shock environment over a device that severs a significant amount of material.

Volume IV of this report correlates the increase in shock environment with an increase in both grain size and thickness of severed material. However, the total data indicate that the grain size is usually less important than material thickness.

It has been found that there is no significant difference in the shock environment produced by a single or a dual separation nut for truss structures.

In general, fairing separation is a more severe event than either the pin release or cable cutting event. An explosive bolt is more severe than an explosive nut. The levels associated with cartridge actuated devices are dependent upon the charge size, the recoil characteristics, and the energy released into the system by severing material, etc.

### Structural Effects

The intervening structure plays a most important role in attenuating the shock level, but the exact nature of this effect is unknown. It is interesting that a skin / ring-frame structure will produce a signature whose frequency content is more dispersed than in a truss structure. (See data of Section II.B.1 of Volume III).

Addition of extra material at a joint will provide attenuation as will a poor contact surface at a joint.

The shock levels in metal and phenolic appear the same, while honeycomb is a very poor attenuator when used as a load carrying structure.

Isolation

Isolation devices near the shock source, in the intervening structure, and at critical equipment mounting locations have been capable of reducing shock amplitude by 50 to 90%. Isolating the shock sources from the structure generally involves absorbing the energy, while isolation of an equipment location usually depends on limiting transmissibility to the equipment. Most data indicate that the softer (lower durometer) the isolation device, the greater the shock reduction.

## 4.0 NEW TECHNOLOGY

None

## 5.0 CONCLUSIONS AND RECOMMENDATIONS

### 5.1 Conclusions

The importance of understanding pyrotechnic shock problems has recently become acute within the aerospace industry. An examination of available data and literature throughout the industry have led to several definite conclusions regarding the handling of pyrotechnic shock problems. The specific results that have come into focus during the course of this study are listed below:

1) A standarized format for reporting shock data needs to be established throughout the aerospace industry. This format should include a detailed description of the pyrotechnic devices, structure and location of measurement transducers.

2) An agency needs to be established to accumulate and disseminate data obtained from pyrotechnic shock testing that goes unreported, and to aid in establishing standarized methods for shock testing and reporting. (The Shock and Vibration Digest, a publication of the Shock and Vibration Information Center, contains information on meetings and abstracts from a large number of periodicals).

3) The large amount of data in these volumes offers an excellent source of information to aid in the design and analysis for pyrotechnic environment.

4) Repeatability of shock data is characterized by a spread factor of 1.5 to 2.0. A spread greater than 2.0 is not considered good repeatability and the data acquisition/reduction system is questionable.

5) Attenuation data representative of the industry are presented for various structures in this report.

Attenuation curves offer a method of predicting shock environments but must be used with care and experience.

6) Significant high frequency energy (above 5 KHz) is present in pyrotechnic shock data but its effect on damage and failure is unknown.

7) Isolation devices can be employed either at the source or at equipment locations to reduce shock levels by as much as 50 to 90%.

8) Digital shock spectrum analysis requires a digitization rate of 10 samples per cycle of the highest frequency analyzed to produce accurate results.

9) The Fourier and shock spectrum of a pyrotechnic shock are similar in shape and level. The full potential of Fourier techniques has not been exploited; many pulses yield similar shock spectra but the Fourier spectra for pulses are different than for complex time histories. A digital Fourier analysis having a digitization rate of 10 samples per cycle of the highest frequency present in the transient produces accurate results. Care should be taken to avoid "fold over" effects.

10) Quality of pyrotechnic shock data in the aerospace industry could be improved by using "shock rated" accelerometers and extending the frequency range of the analysis.

11) The quality of flight data is poor for pyrotechnic shock analyses due to the limited capability of flight acquisition systems.

12) Measurement systems for ground tests of pyrotechnic shock are generally satisfactory throughout the industry.

13) The barrel tester technique and other methods using pyrotechnic devices to provide shock simulation for qualification testing of equipment are recommended over other simulation techniques.

14) The mechanical methods of shock simulation that provide the specified shock environment by means of a complex waveform simulating a pyrotechnic shock pulse are preferred over simple pulse shock tests.

15) An overtest can be achieved in full-scale testing by altering the mounted configuration of the test specimen. The test configuration required for obtaining an overtest of a given design is still determined largely by trial and error.

16) A general ordering of the commonly used pyrotechnic devices according to the severity of the environment produced follows:

A) linear explosives (MDF and FLSC) in separation joints;

B) explosive bolts;

C) separation nuts;

D) pin-pullers, pin pushers, cable cutters, bolt cutters.

This order does not necessarily hold in all cases but is representative of most data.

17) Failure data has not been sufficient to relate the shock environment to damage potential. The subject of damage and failure criteria needs to be studied in depth and include well-planned test(s).

18) The application of shock propagation theory to develop an analytical model for prediction of shock environments has been unsuccessful. A very real need exists to develop this area starting with the simplest models and substantiate with test data.

19) Peaks in the shock spectrum occur at frequencies that coincide with truss member resonances.

5.2 Recommendation for Future Study (See Section 2.9)

The results of this investigation, which has utilized vast quantities of data and information obtained throughout the aerospace industry, have indicated several specific areas where additional investitation is required. These areas are:

a. Test Simulation;

b. Techniques for Predicting Shock Propagation;

c. Damage and Failure Criteria;

d. Mass Loading Effects;

e. Transducer Mounting Effects.

It is recommended that an analytical and experimental study be performed to determine the basic mechanism of pyrotechnic shock propagation. This investigation should begin with simple pyrotechnics and structures and progress to the more complicated types as used in aerospace industry.

It is recommended that an investigation be performed that would relate failure of equipment to the shock environment. This study should determine the causes of failure and methods to prevent them, such as isolation and methods of design.

It is recommended that an investigation be performed to provide the basic requirements and methodology for simulation of the pyrotechnic shock environment of different devices, for both full scale and component qualification testing.

It is recommended that the effect of mass loading on the shock environment be investigated to aid in the state-of-the-art design of equipment mounting configurations.

It is recommended that an investigation be performed to determine transducer mounting effects on the frequency and amplitude characteristics of a shock transient.

6.0 BIBLIOGRAPHY

6.1 Data References

Cited below are the references from which the compiled data (Volumes II and III were obtained. The data references are listed in their order of useage, and following each data reference is a parenthetical expression indicating the section of the data volumes in which the data associated with that reference are presented.


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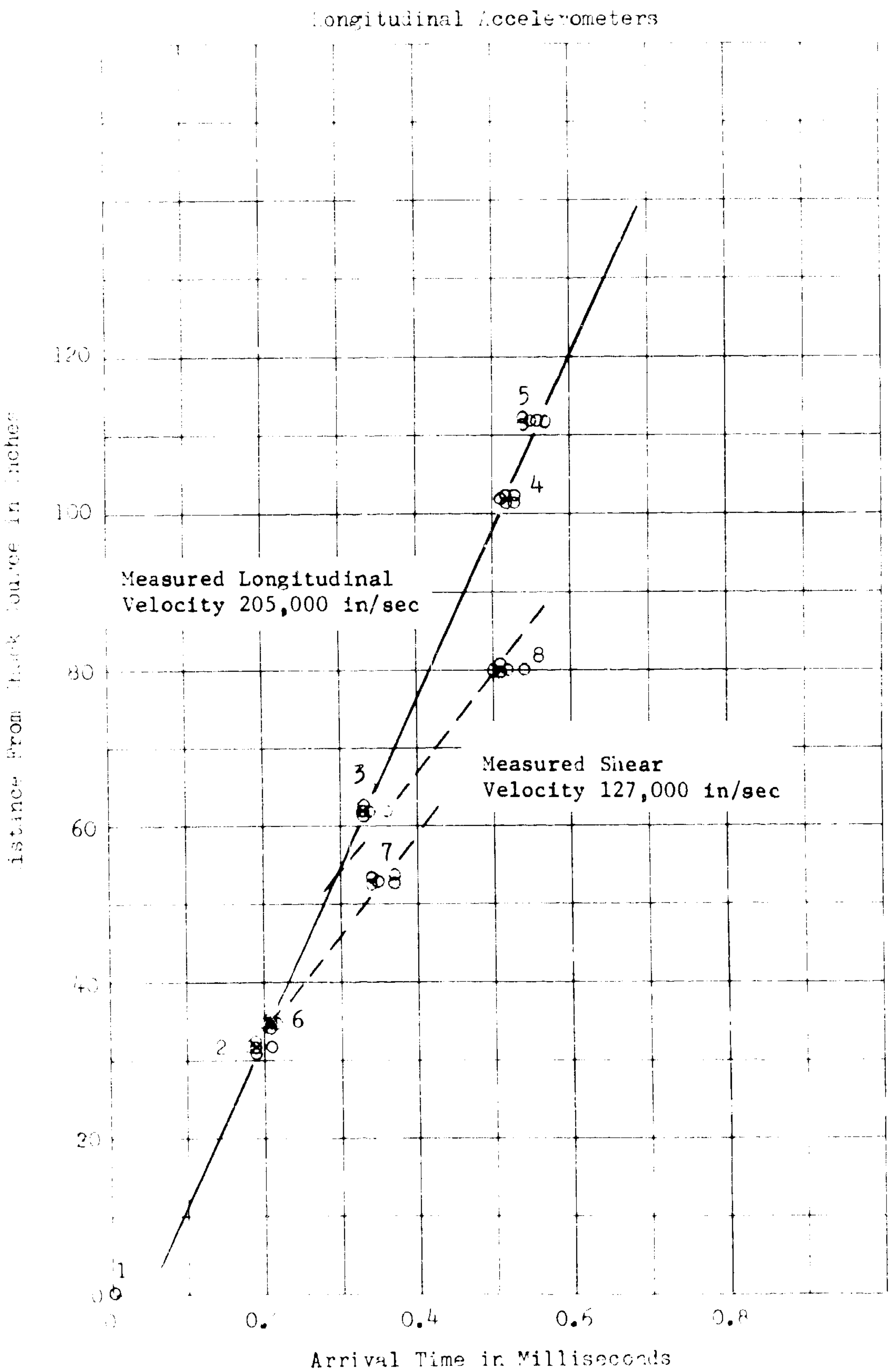


Figure 1. Distance Versus Time of Arrival of Shock Pulse in Truss Members

Longitudinal Accelerometers

Propagation Velocity in Transtage

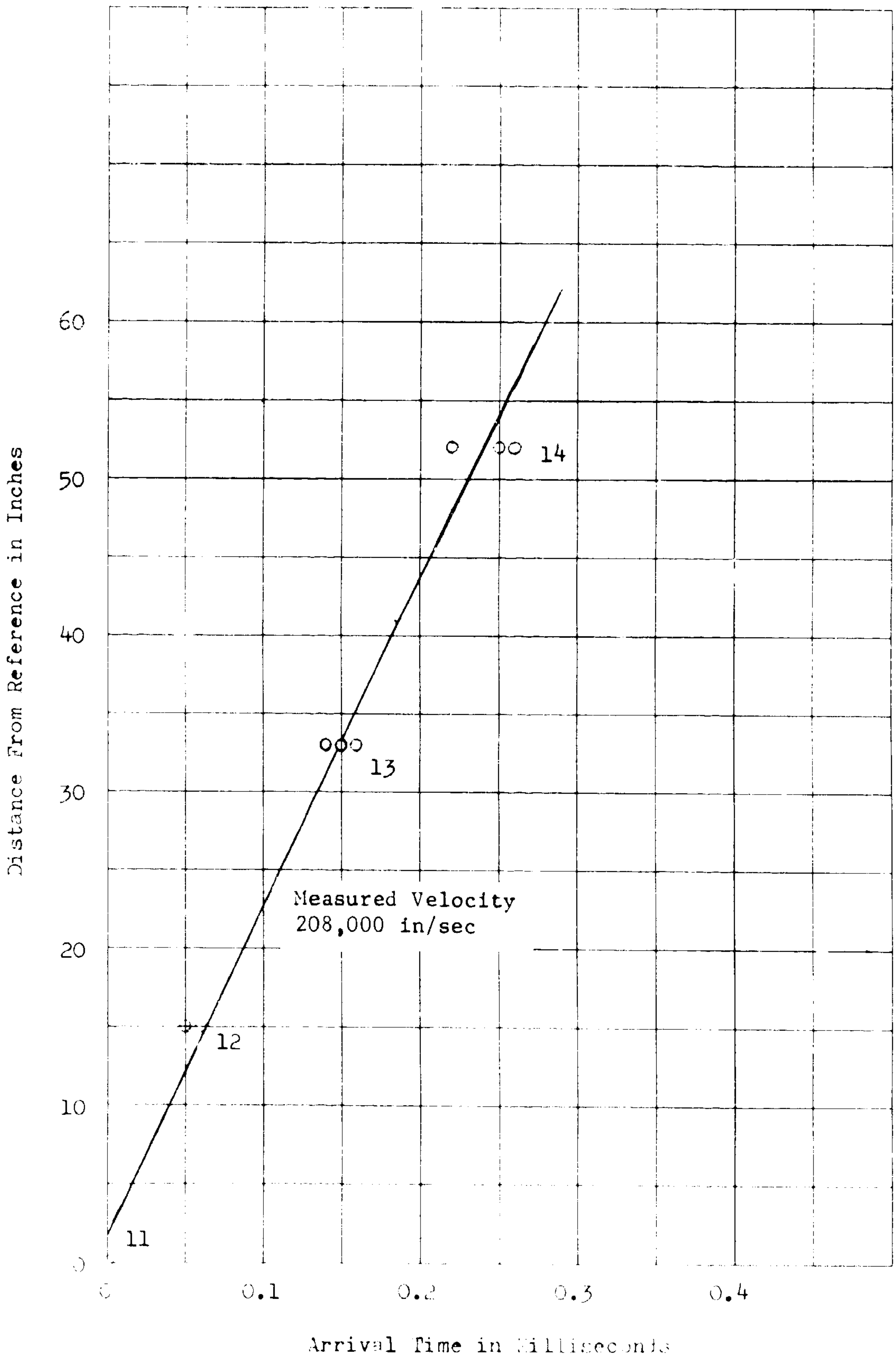


Figure 2. Distance Versus Time of Arrival of Shock Pulse in Transtage Skirt

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SHOCK TEST ANALYSIS DATA SHEET

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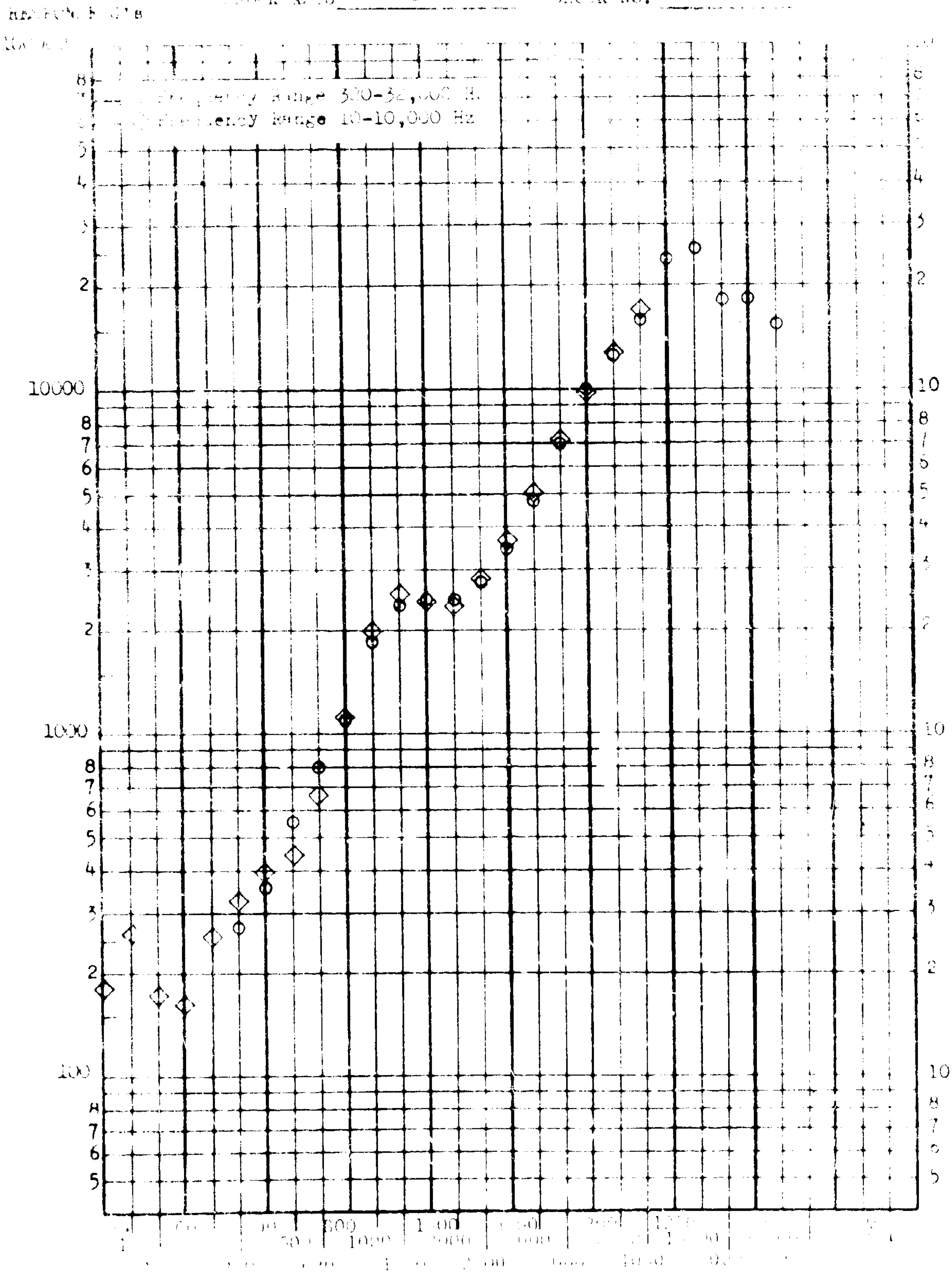


Figure [illegible] Shock Spectrum for Extended Frequency Range [illegible]

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SHOCK AXIS Loc. 1, Lateral SHOCK NO. 4, 5, and 6

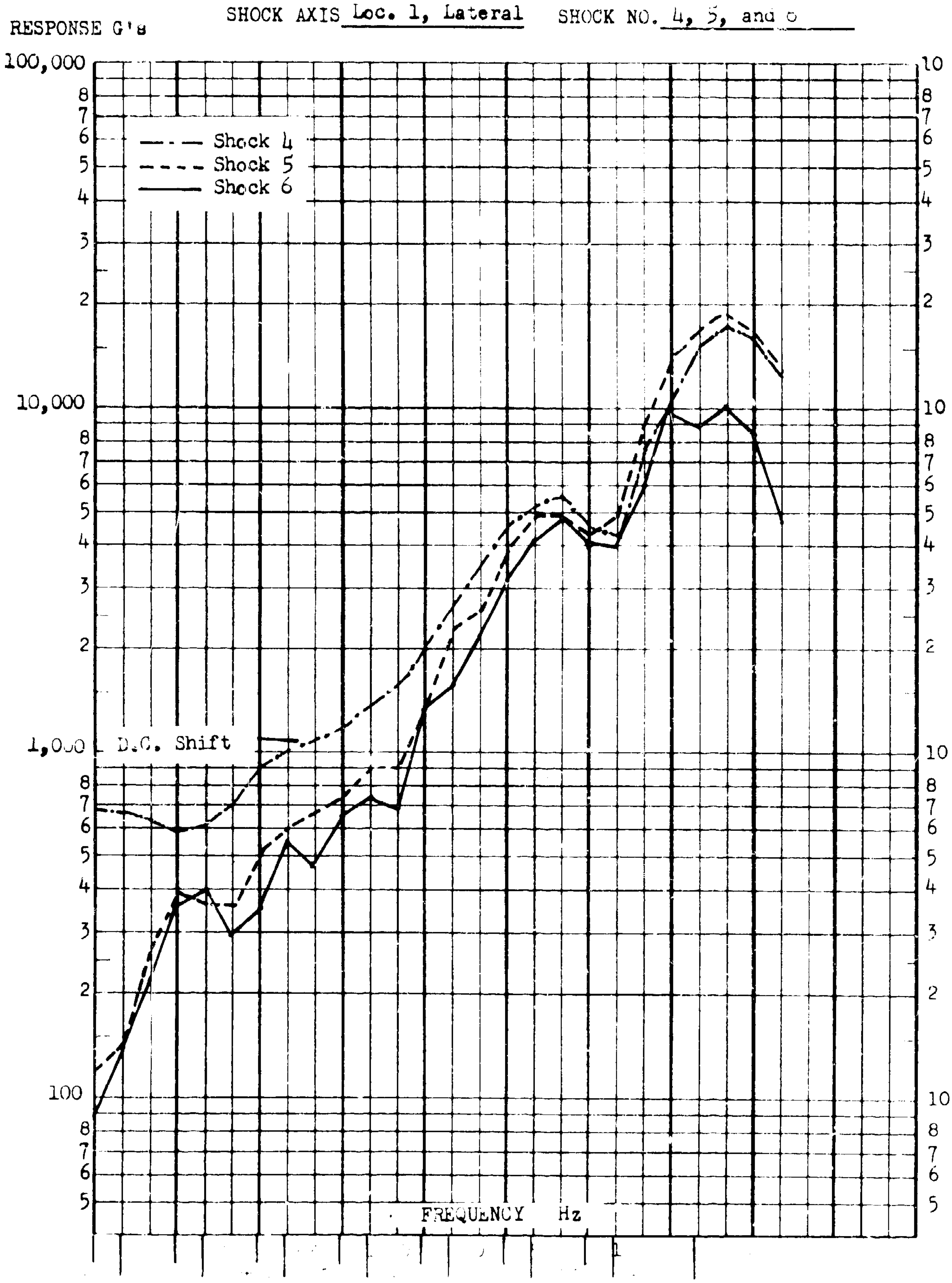


Figure . Shock Spectra For Location 1 - Lateral

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PICK UP LOC. 1, Vertical SHOCK NO.

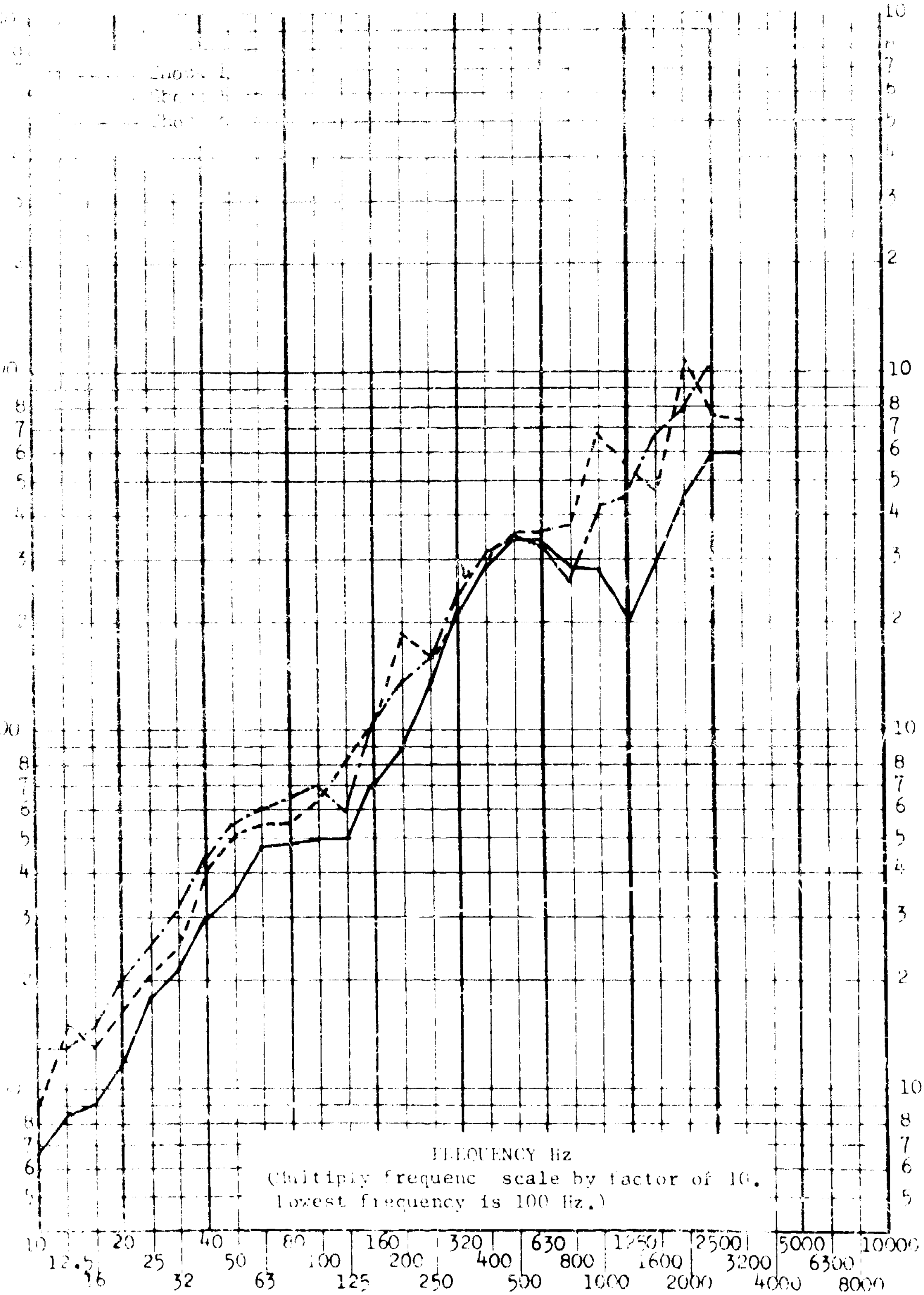


Figure . Shock Spectra For Location 1 - Vertical

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SHOCK TEST ANALYSIS DATA SHEET

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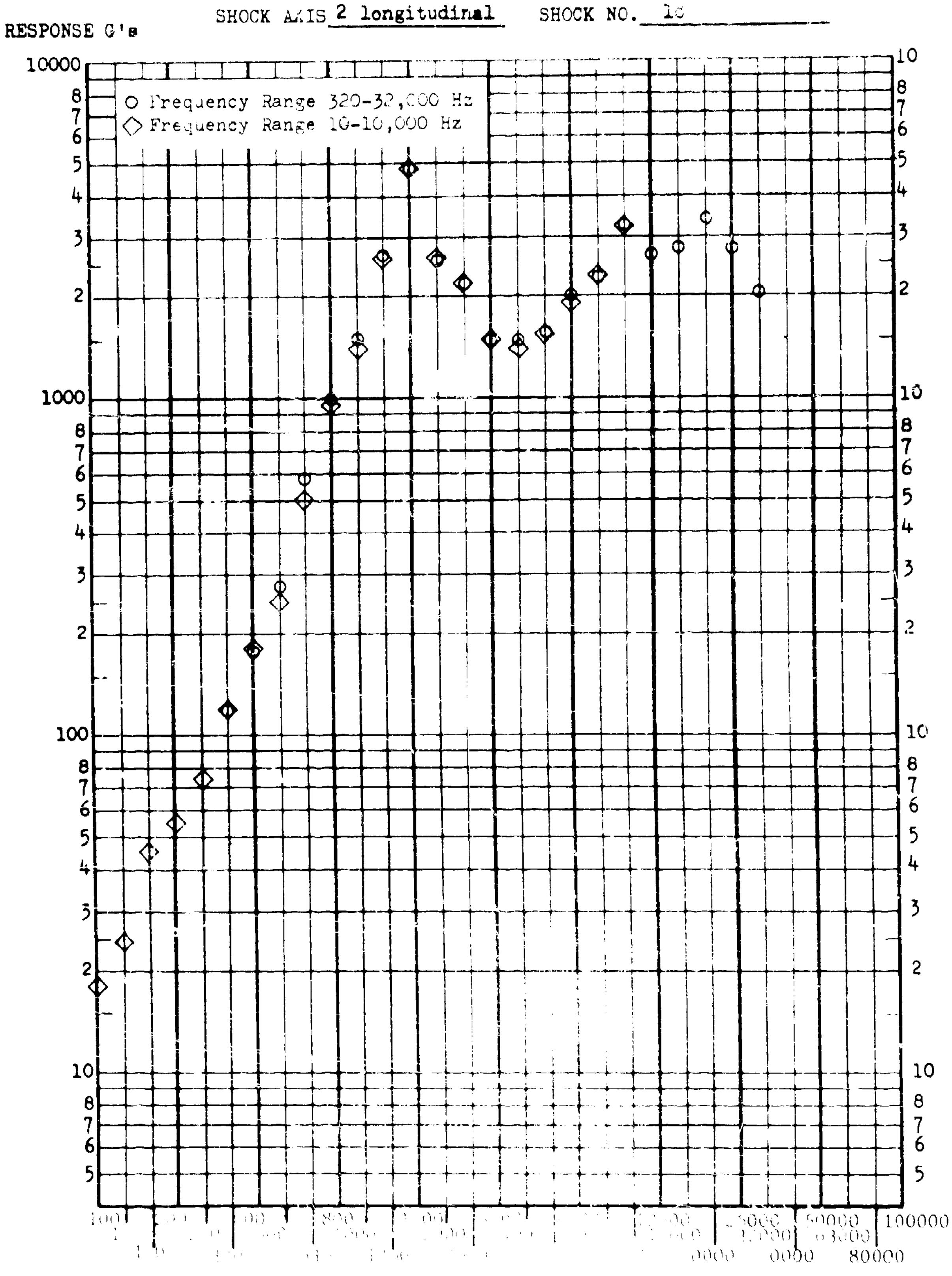


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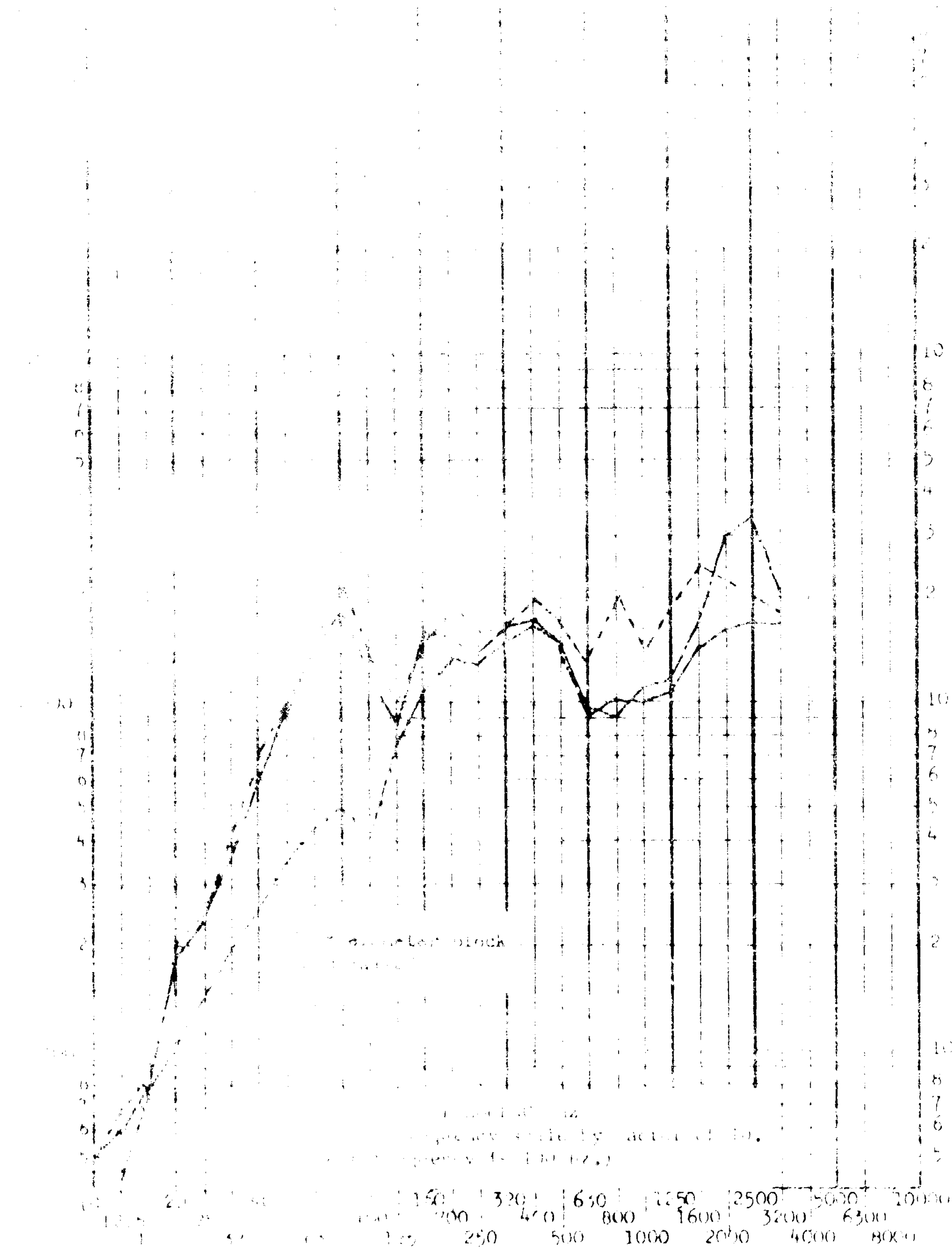160
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SHOCK TEST ANALYSIS DATA SHEET

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SHOCK AXIS Loc. 2, Vertical SHOCK NO. 4, 5, and 6

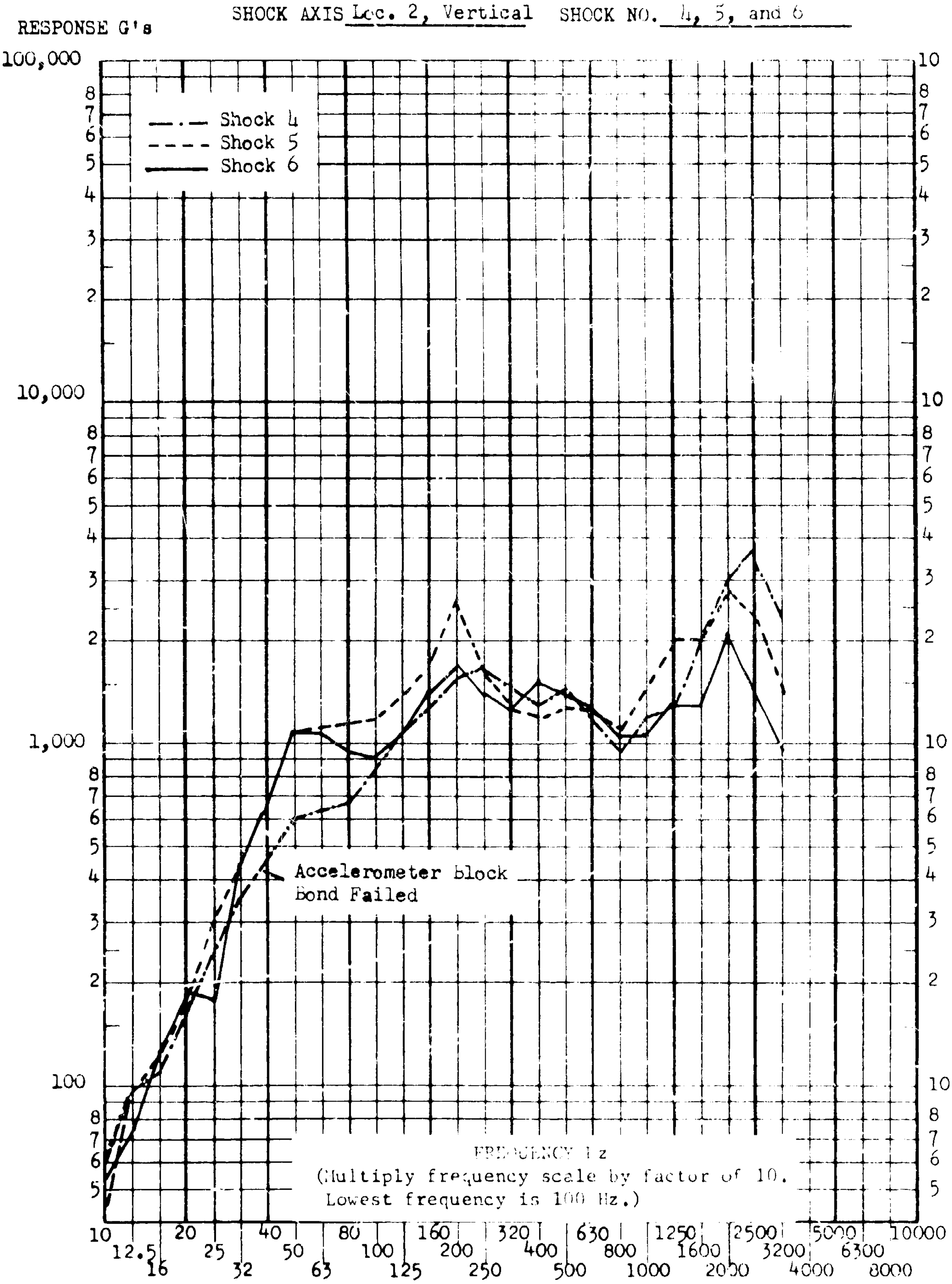


Figure . Shock Spectra For Location 2 - Vertical

TEST ITEM ______________ PART NO. ______________

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SHOCK AXIS Loc. 3, Long. SHOCK NO. 4, 5, and 6

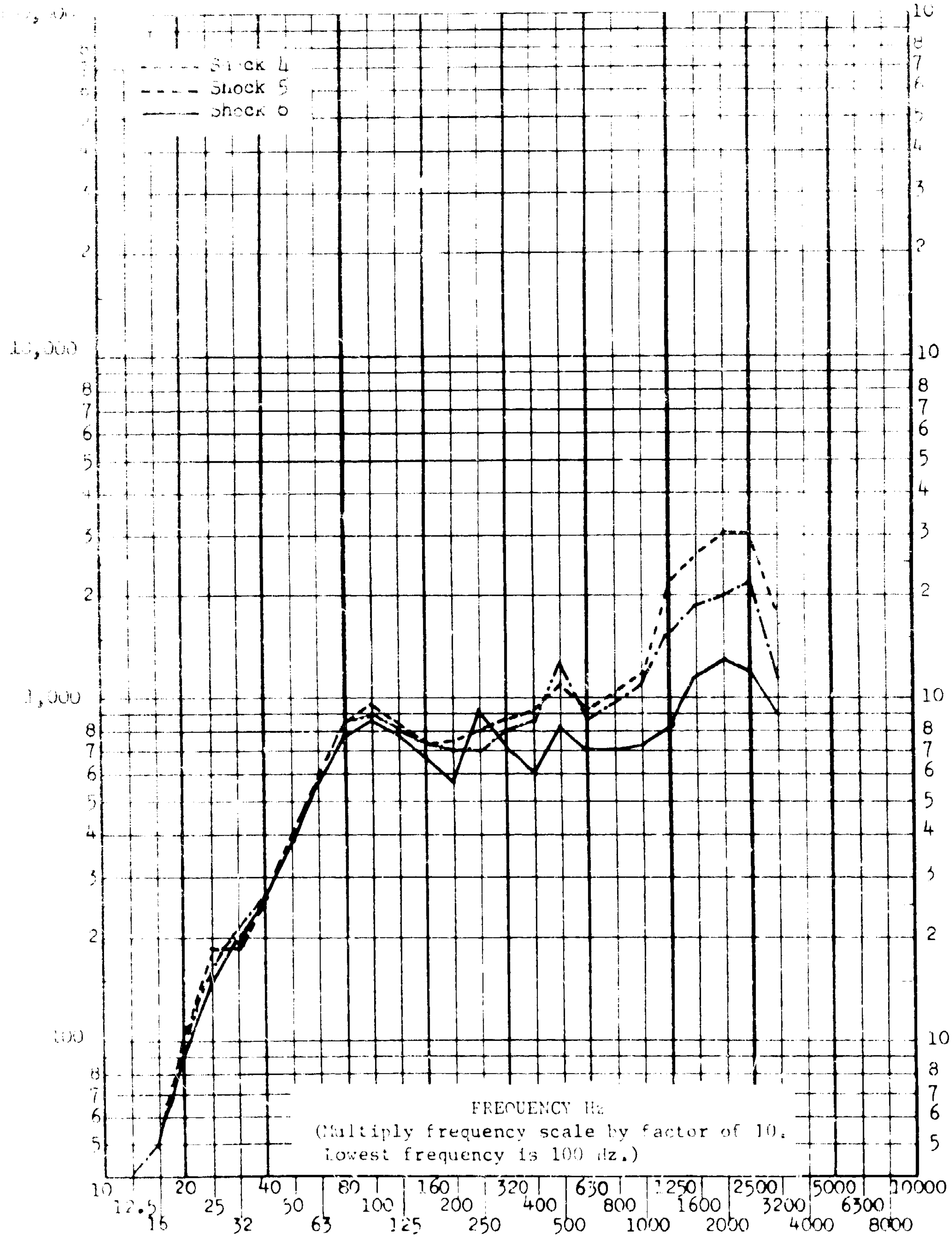


Figure . Shock Spectra For Location 3 - Longitudinal

SHOCK TEST ANALYSIS DATA SHEET

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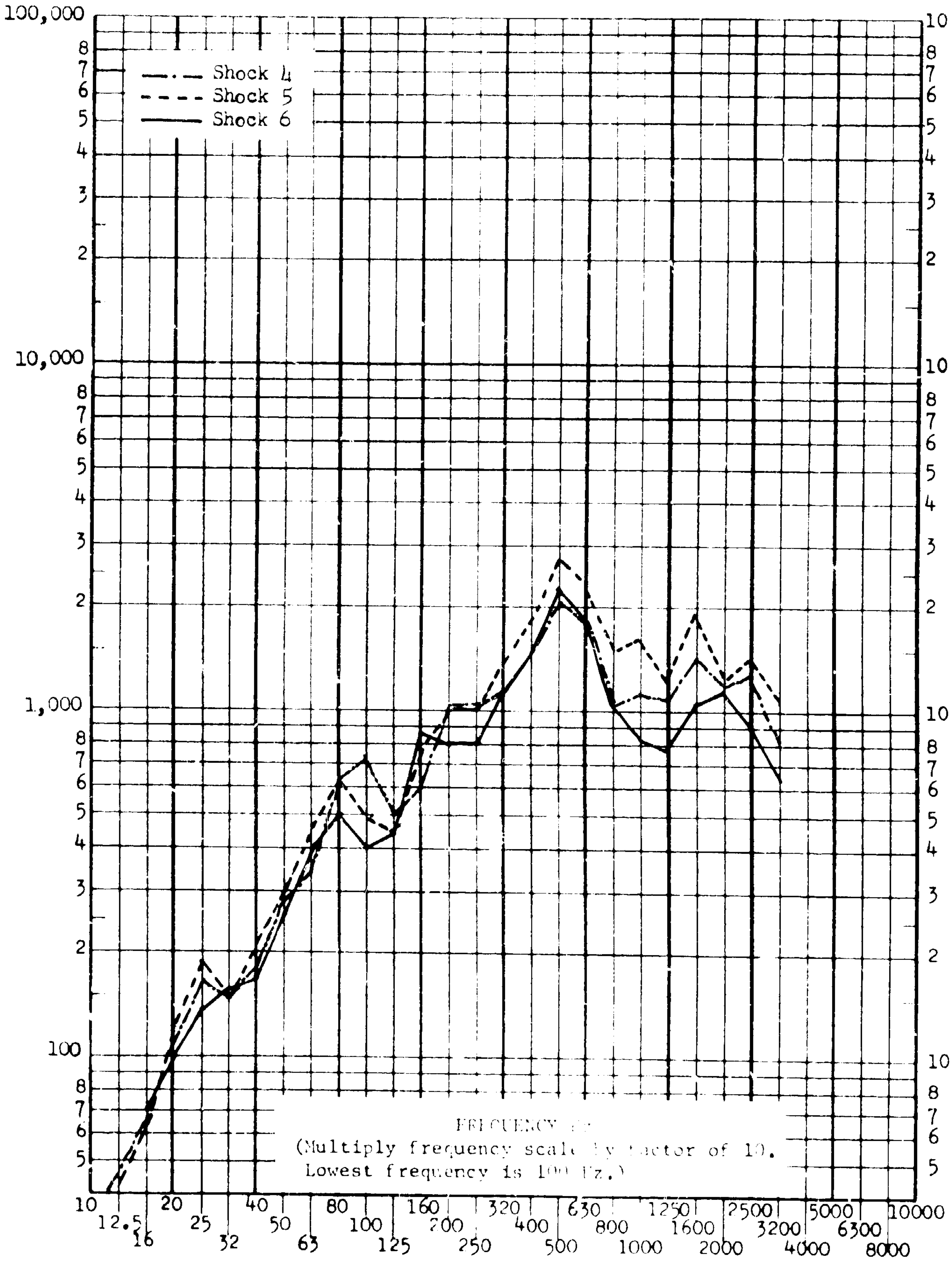


Figure 1 . Shock Spectra For Location 3 - Lateral

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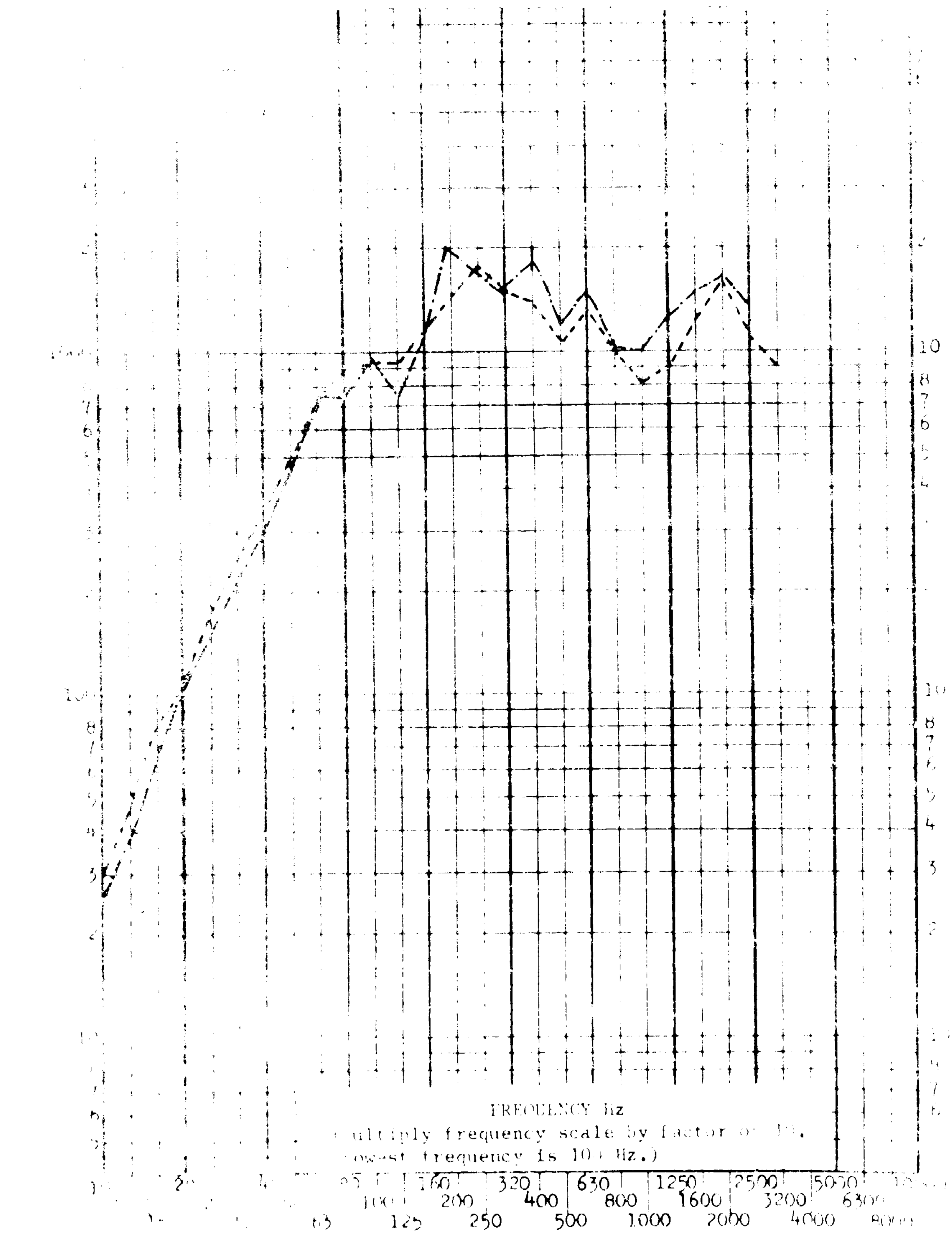


Shock Spectra For Location 3 - Vertical

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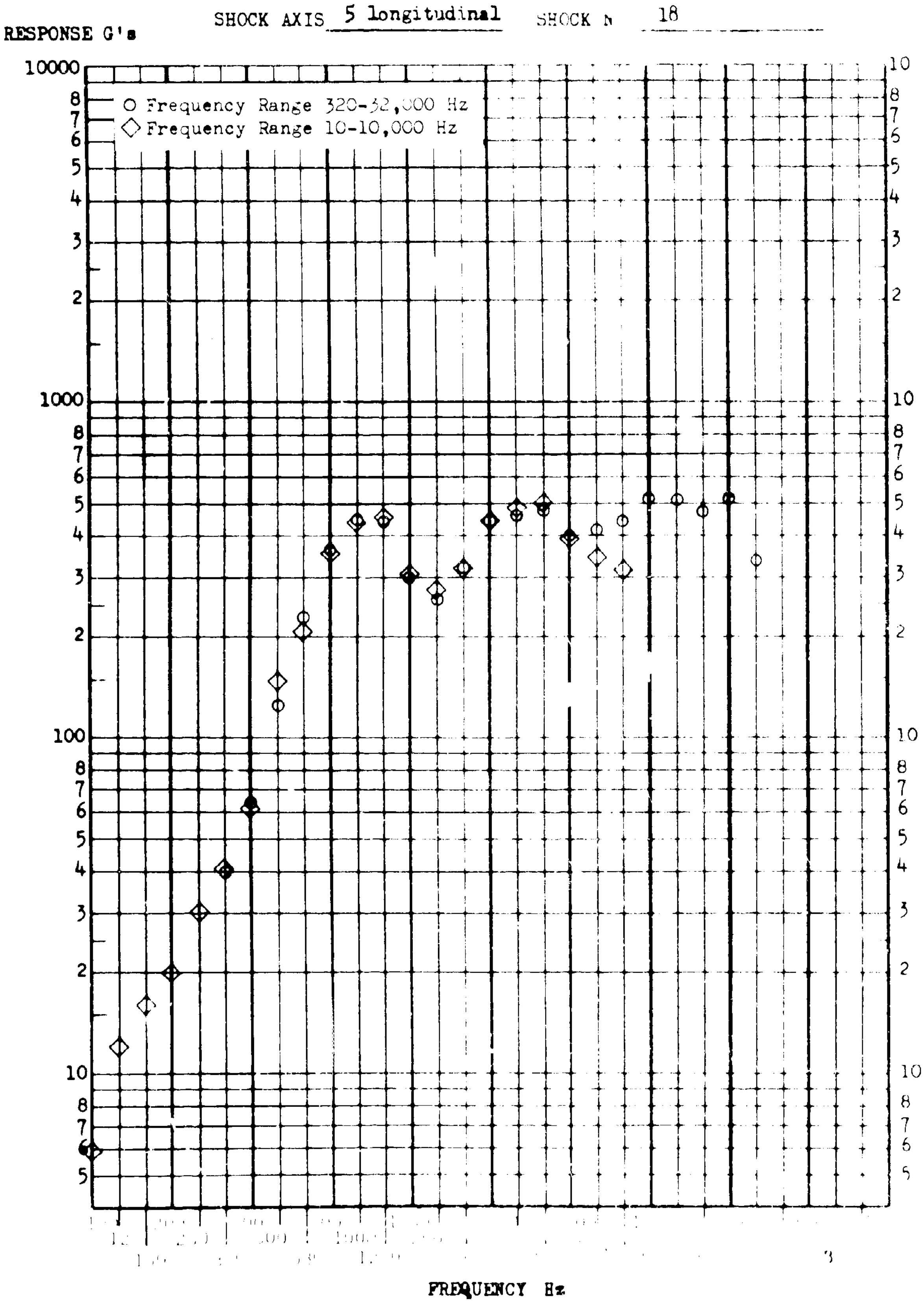


Figure 1[illegible]. Shock [illegible]

ANALYSIS DATA SHEET

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SHOCK AXIS Loc. 5, Lateral SHOCK NO. 4, 5, and 6


Figure . Shock Spectra For Location 5 - Lateral

SHOCK TEST ANALYSIS DATA SHEET

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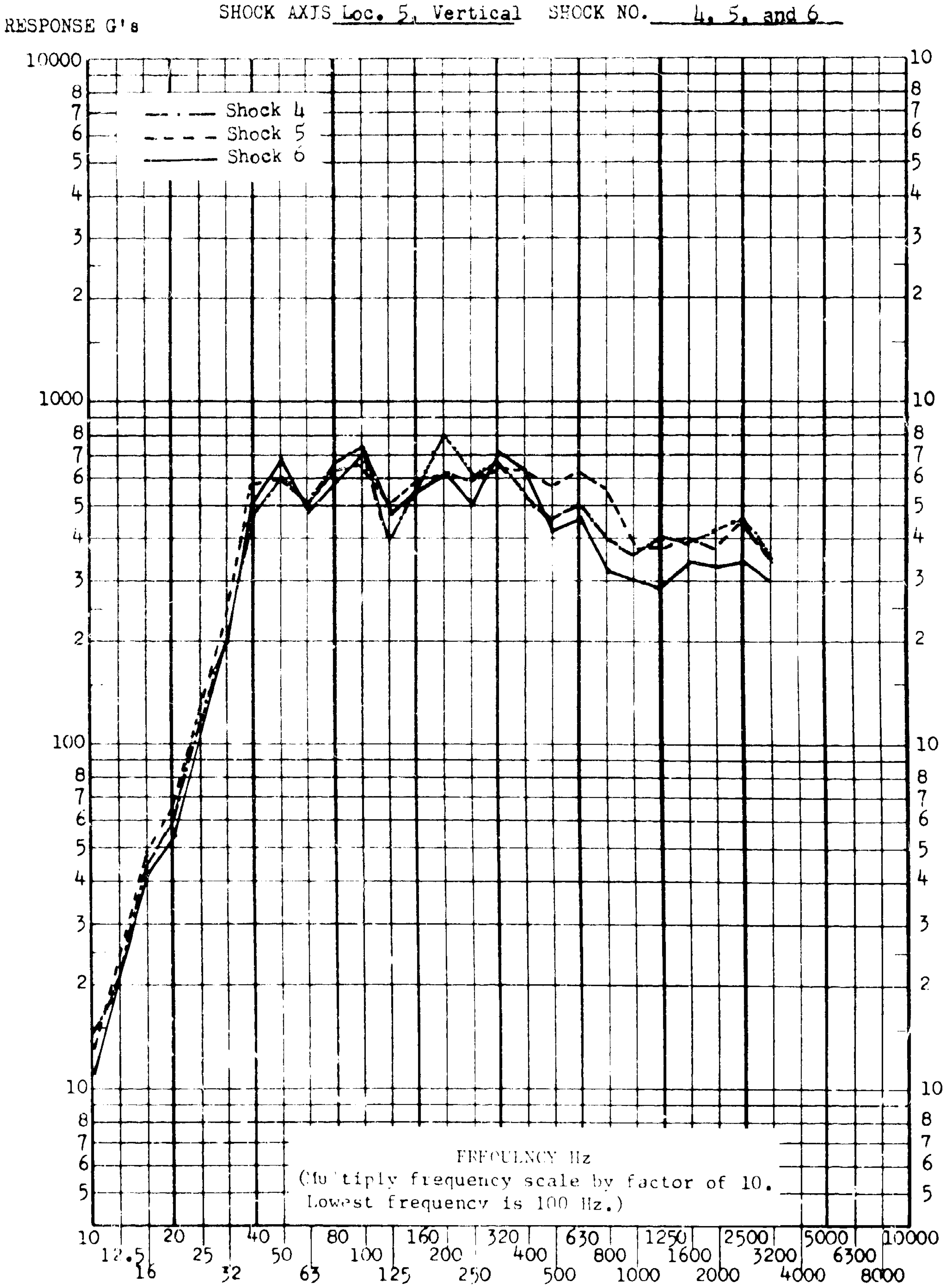


Figure . Shock Spectra for Location 5 - Vertical

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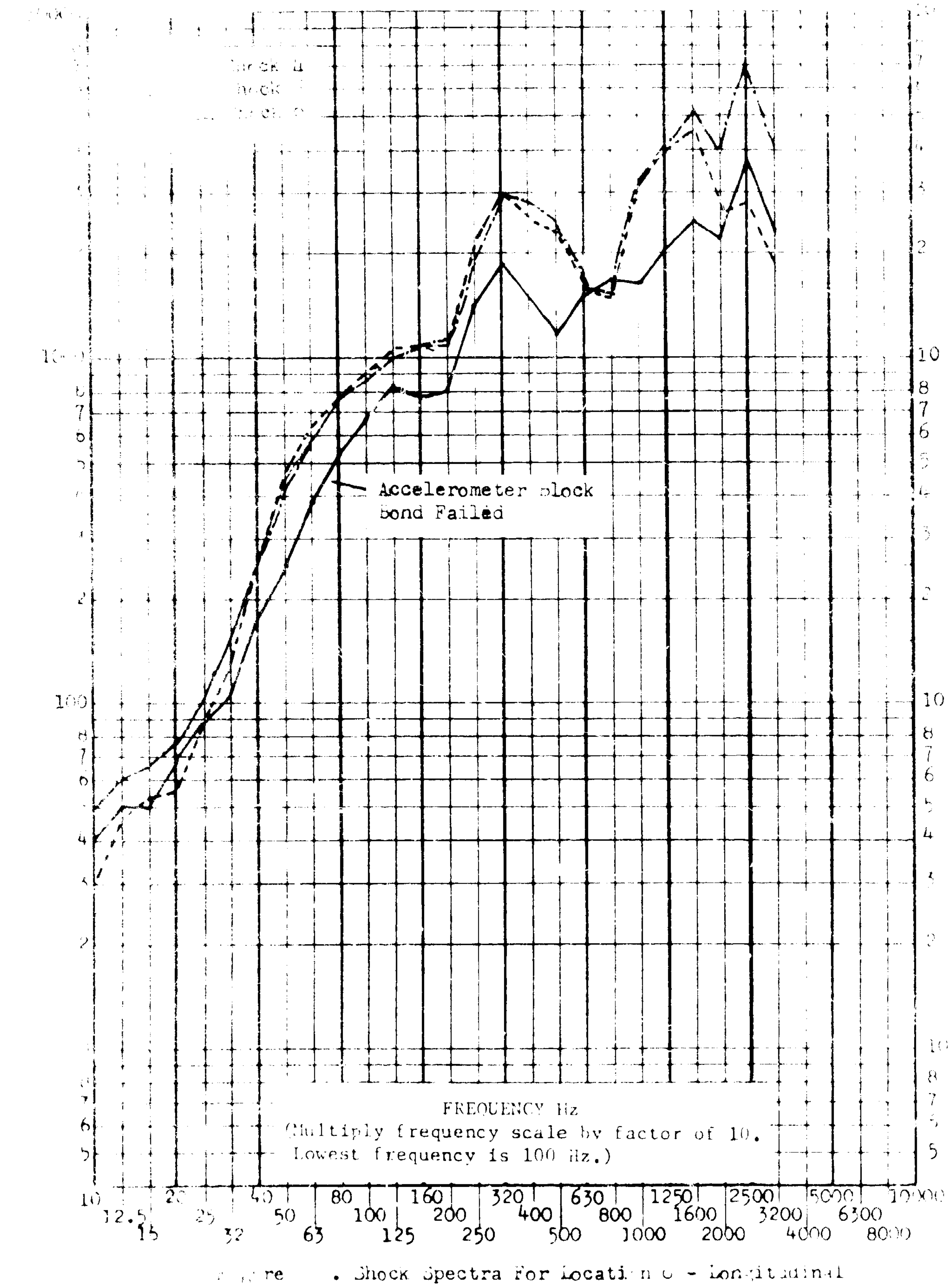


Figure . Shock Spectra For Location 5 - Longitudinal

SHOCK TEST ANALYSIS DATA SHEET

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SERIAL NO. ________________ TEST DATE ________________

SHOCK AXIS Loc. 6, Lateral SHOCK NO. 4, 5, and 6

RESPONSE G's

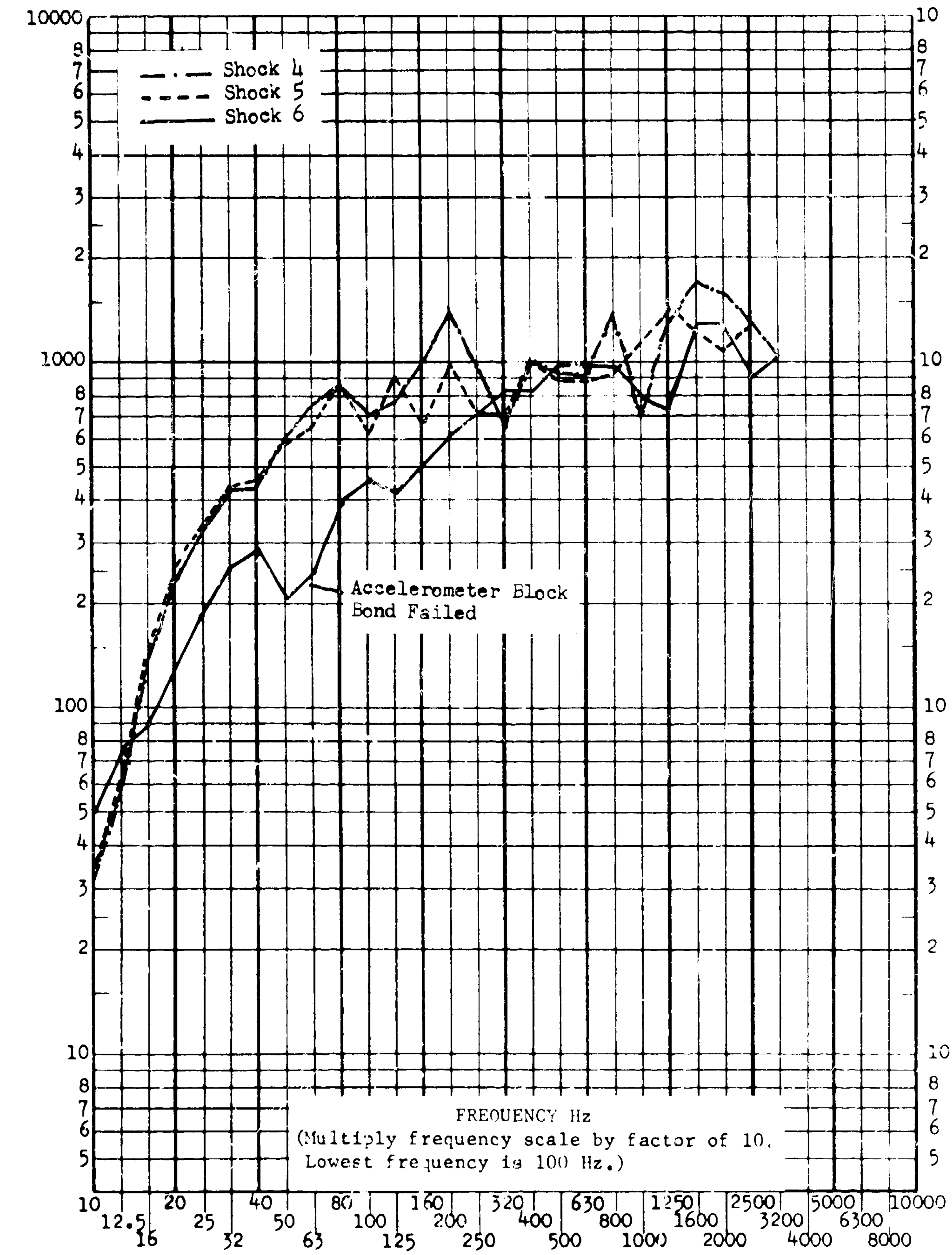



Figure 15. Shock Spectra For Location 6 - Lateral

SHOCK TEST ANALYSIS DATA SHEET

TEST ITEM ________________ PART NO. ________________

SERIAL NO. ________________ TEST DATE ________________

SHOCK AXIS Loc. 6, Vertical SHOCK NO. 4, 5, and 6

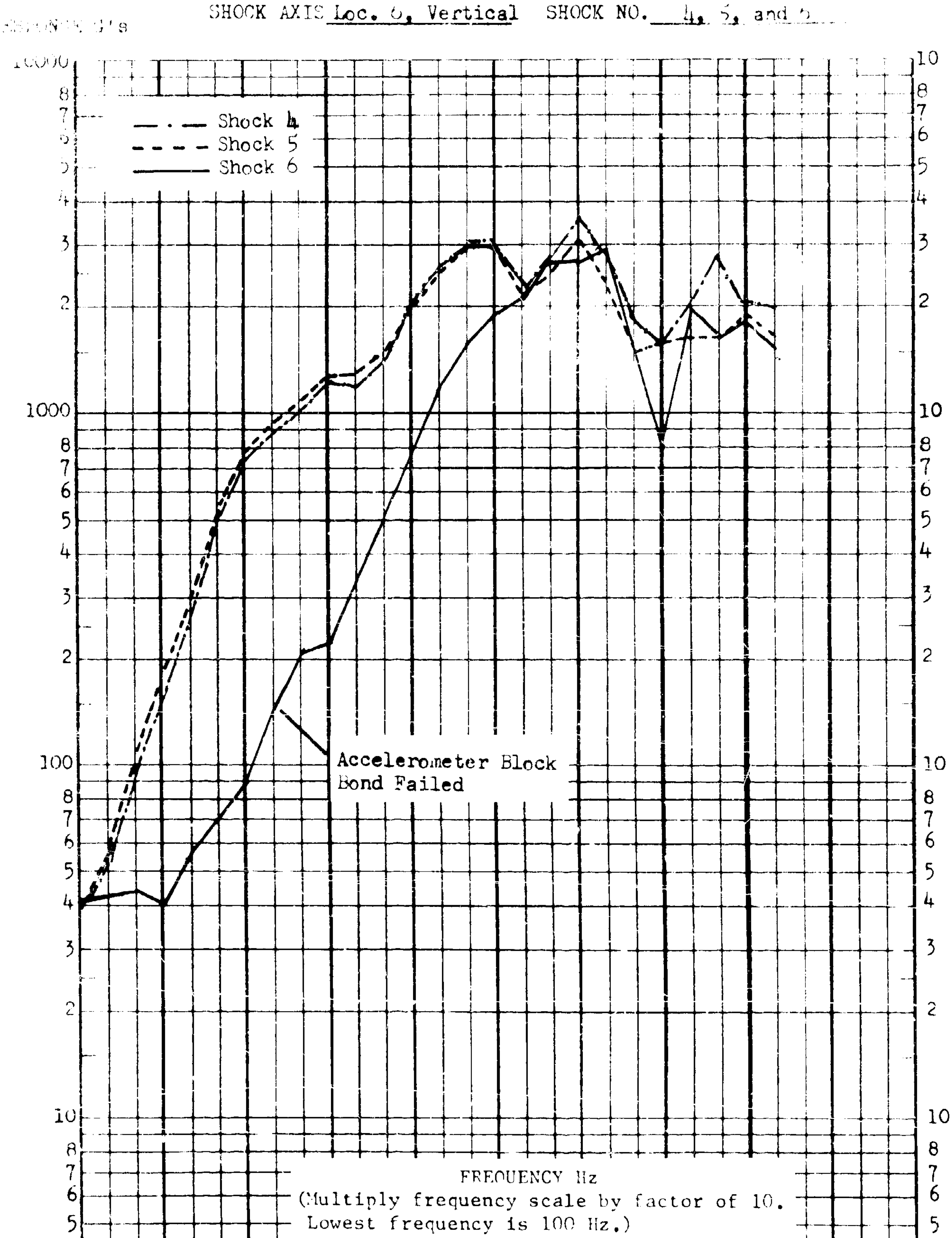



Figure 1 . Shock Spectra For Location 6 - Vertical

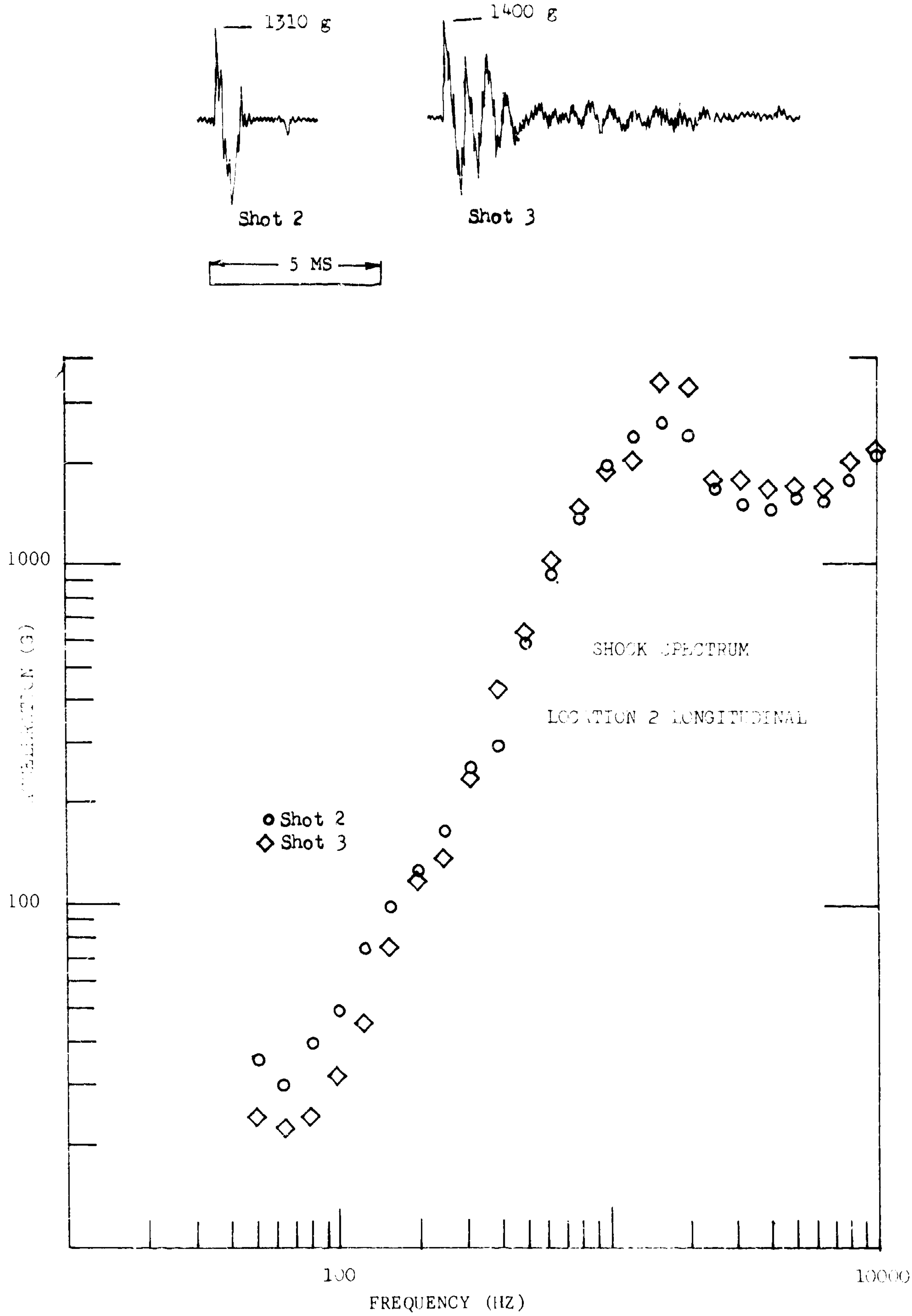



Figure Shock Spectra and Time Histories for Location 2 Longitudinal

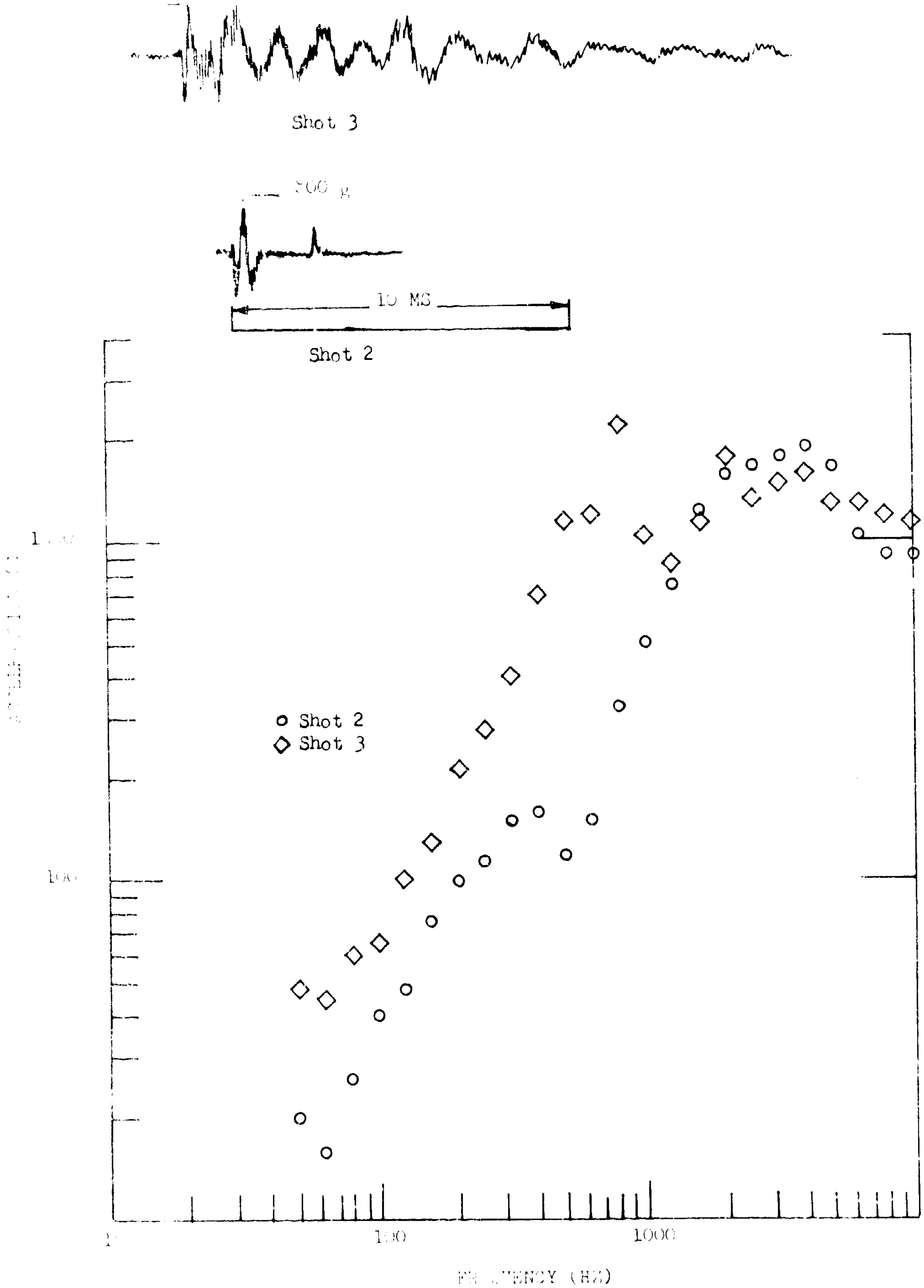



Figure 1· Shock Spectra and Time Histories for Location 2 Lateral

SHOCK TEST ANALYSIS DATA SHEET

TEST ITEM ______________ PART NO.______________

SERIAL NO.______________ TEST DATE______________

SHOCK AXIS______________ SHOCK NO.______________

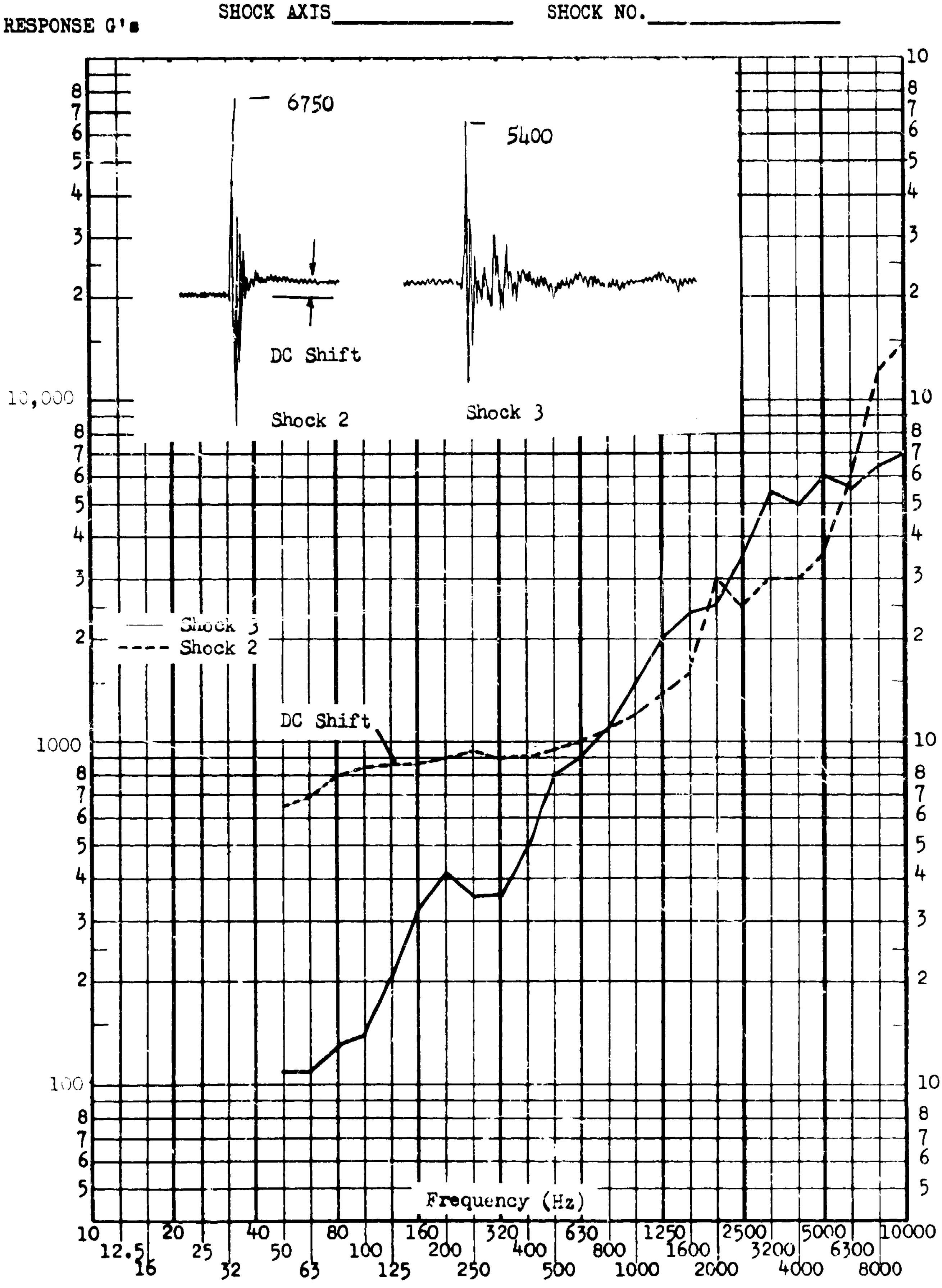



Figure 2[illegible] Shock Spectrum for Location 1 Lateral

SHOCK TEST ANALYSIS DATA SHEET

TEST NO. ______

TEST ITEM Configuration IV PART NO.________

SERIAL NO.________ TEST DATE Sept. 24-25, 1968

SHOCK AXIS 2 Longitudinal SHOCK NO. Shock 15

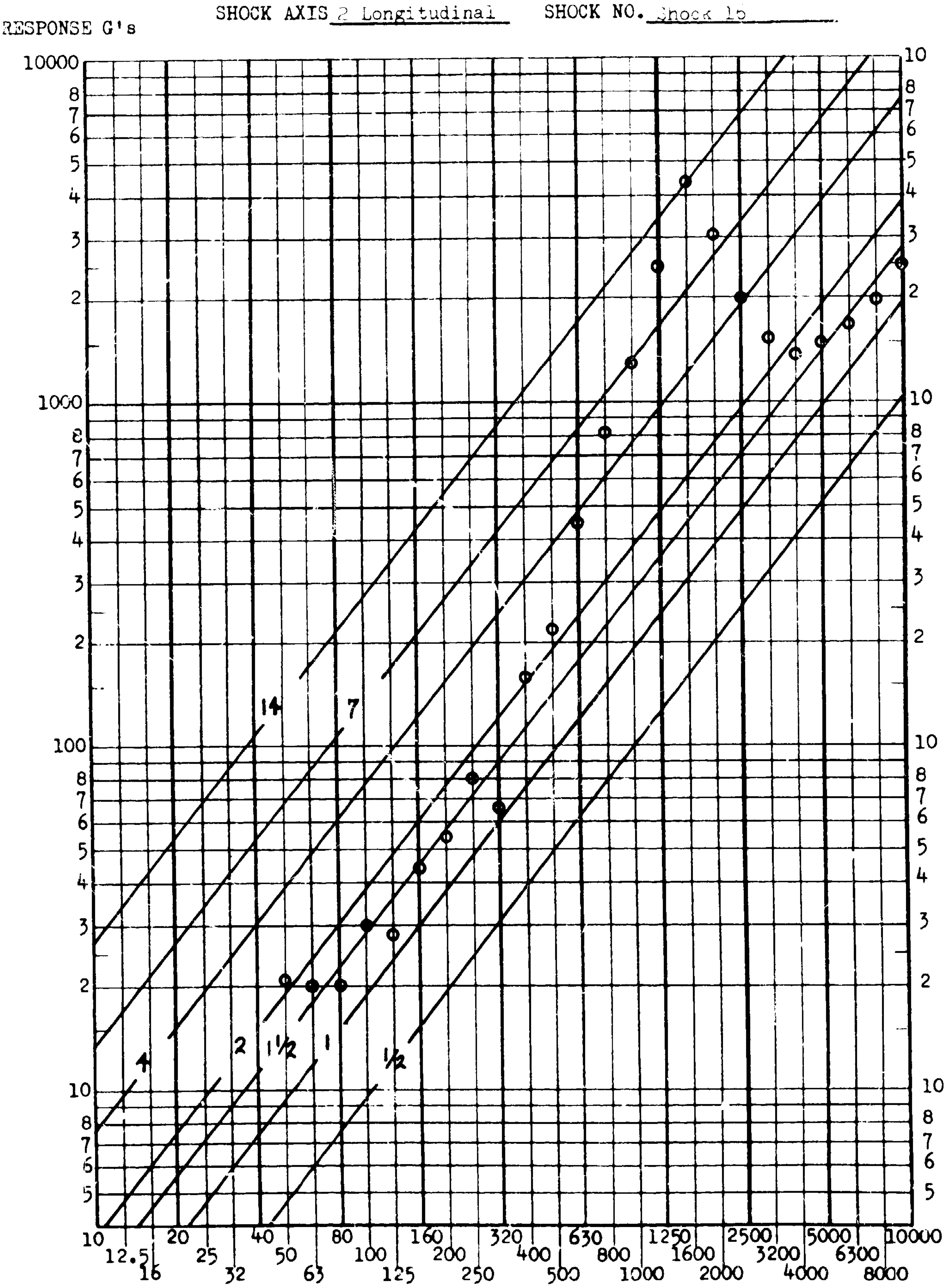
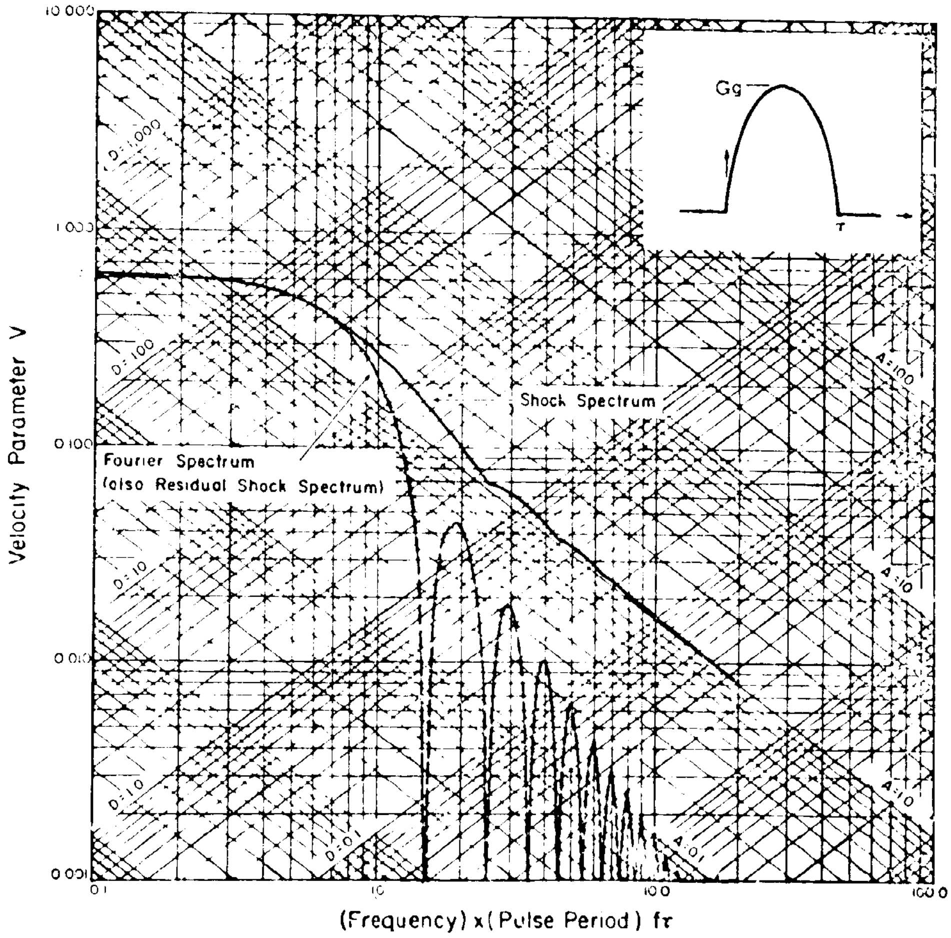


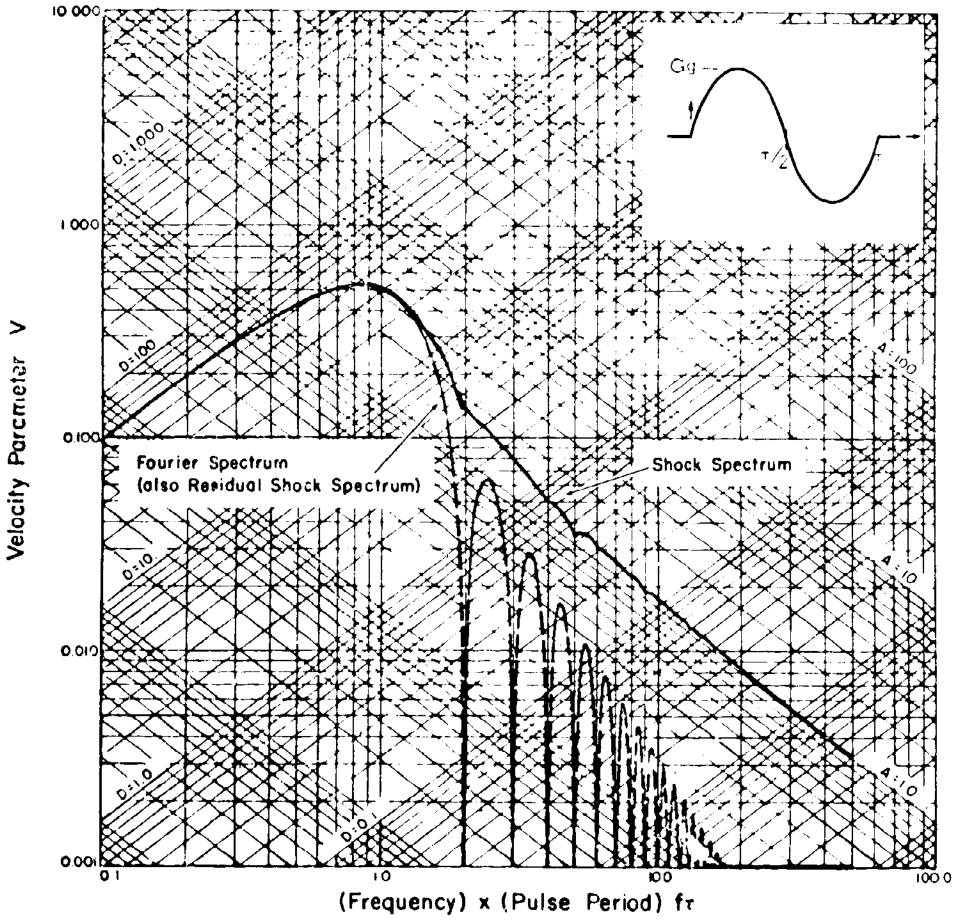

Figure 21 . Equivalent Velocity Shock Grid




| PARAMETER | FOURIER SPECTRUM | SHOCK SPECTRUM |
|---|---|---|
| d = (G-²) • (D) in. | deflection component | relative deflection response |
| v = (Gg-) • (V) in./sec | velocity component | pseudo velocity response |
| a = (Gg) • (A) in./sec² | acceleration component | equivalent static acceleration |

Figure 22. Fourier and Shock Spectra for Half-Cycle Sine Acceleration Pulse

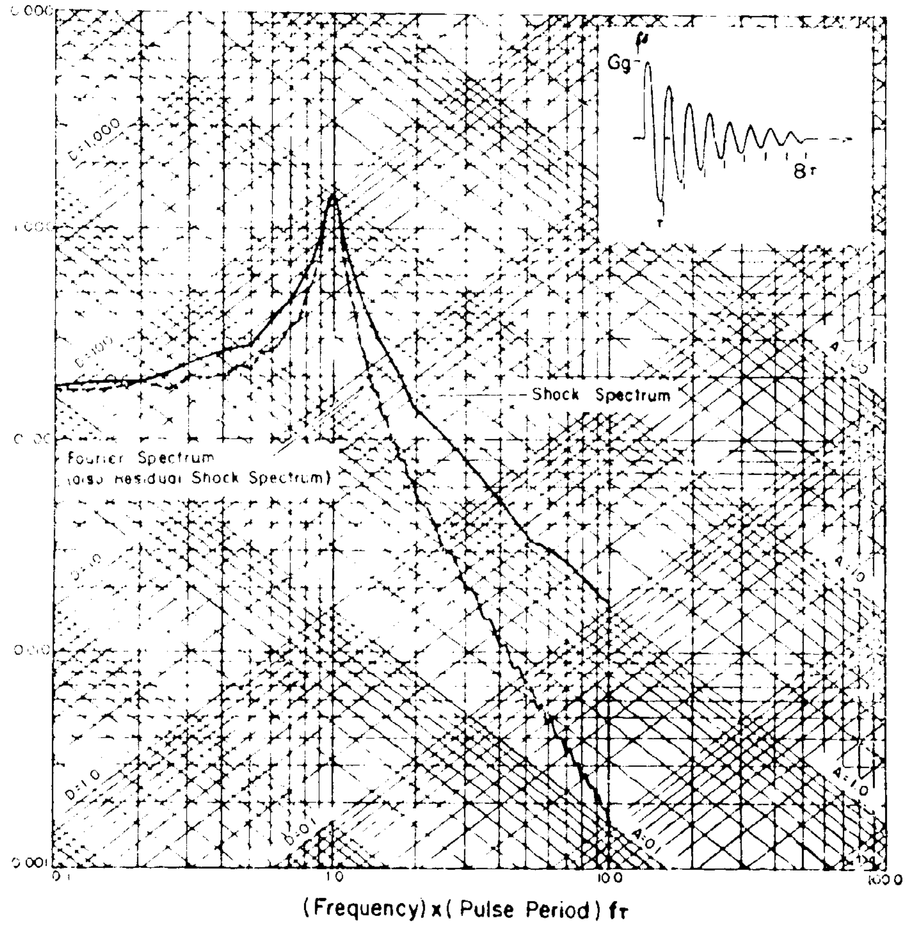
(Figure 2, page 252, reference 16)




| PARAMETER | FOURIER SPECTRUM | SHOCK SPECTRUM |
|---|---|---|
| d = $(G\tau^2)\cdot(D)$ in. | deflection component | relative deflection response |
| v = $(Gg\tau)\cdot(V)$ in./sec | velocity component | pseudo velocity response |
| a = $(Gg)\cdot(A)$ in./sec$^2$ | acceleration component | equivalent static acceleration |

Figure 23. Fourier and Shock Spectra for Full-Cycle Sine Acceleration Pulse

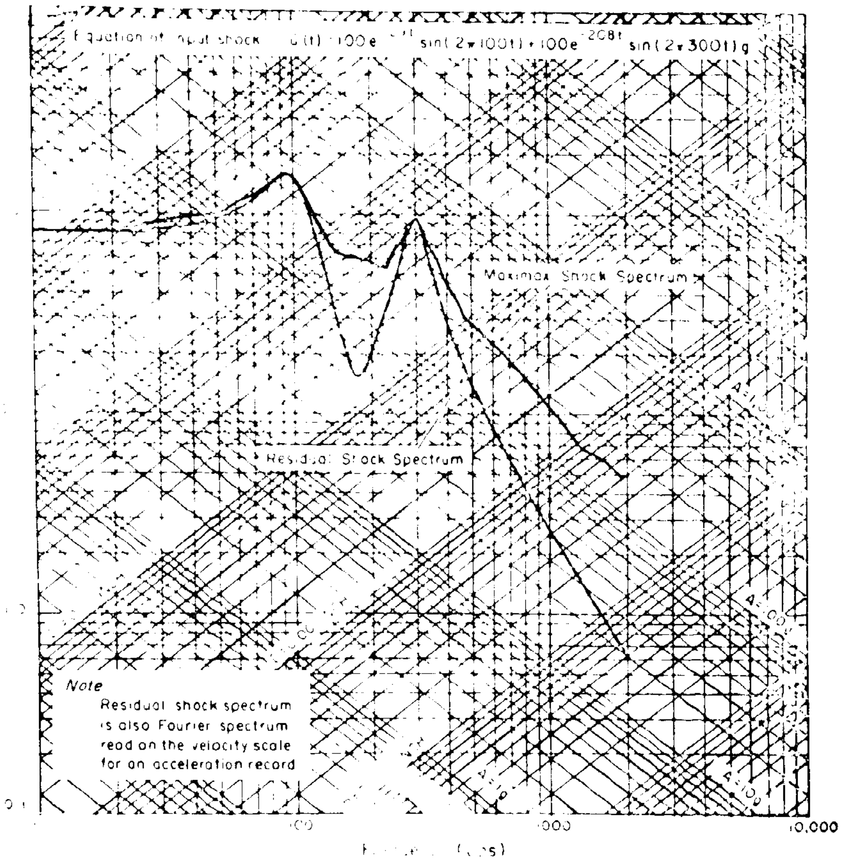
(Figure 3, page 253, reference 16)




| PARAMETER | FOURIER SPECTRUM | SHOCK SPECTRUM |
|---|---|---|
| $d = (G\tau^2)\cdot(D)$ in. | deflection component | relative deflection response |
| $v = (Gg\tau)\cdot(V)$ in./sec | velocity component | pseudo velocity response |
| $a = (Gg)\cdot(A)$ in./$sec^2$ | acceleration component | equivalent static acceleration |

Figure . Fourier and Shock Spectra for Decaying Sinusoidal Acceleration Pulse with 8 Cycles and Amplitude Ratio = 1/2

(Figure 4, page 2?4, reference 1



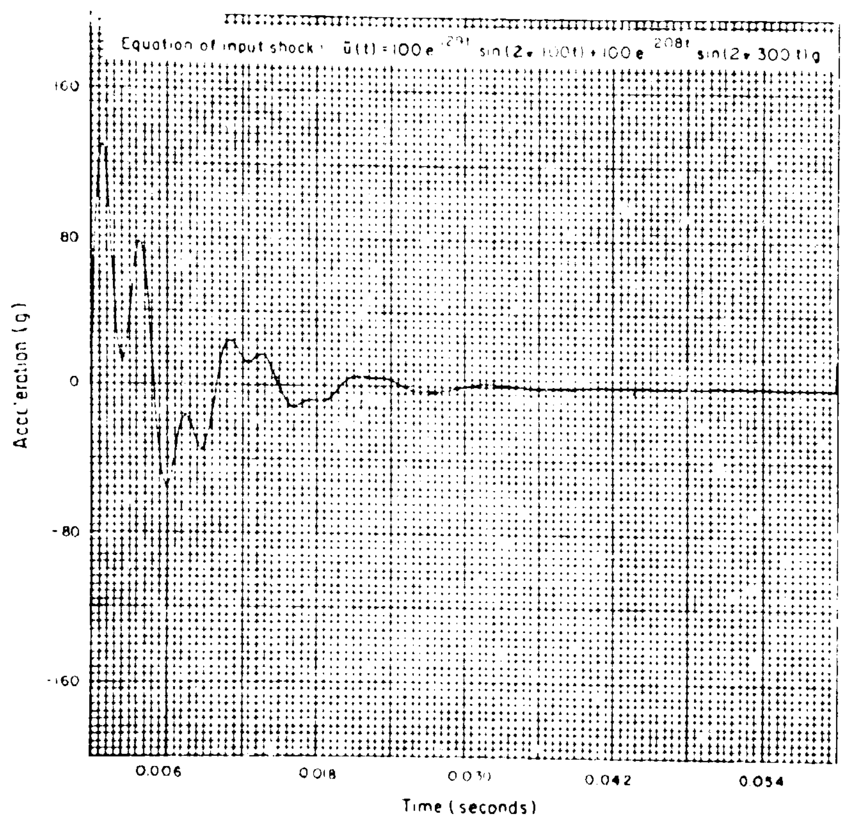




Figure 25. Fourier and Shock Spectra for Complex Wave
(Figure 11 and 12, page 261 and 262, reference 16)

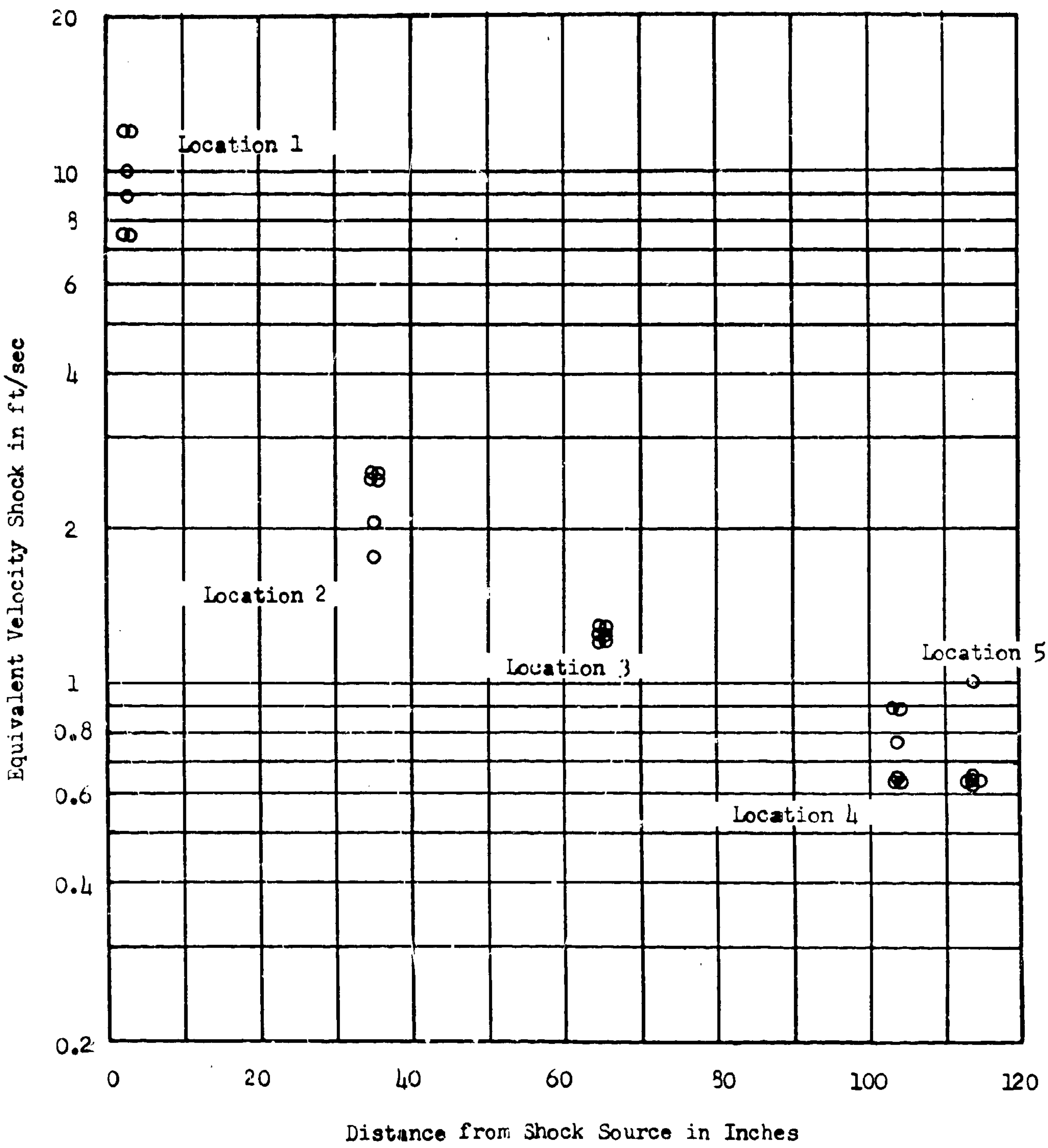



Figure 26. Equivalent Velocity Shock Attenuation Curve for Longitudinal Accelerometers--Shots 1-6

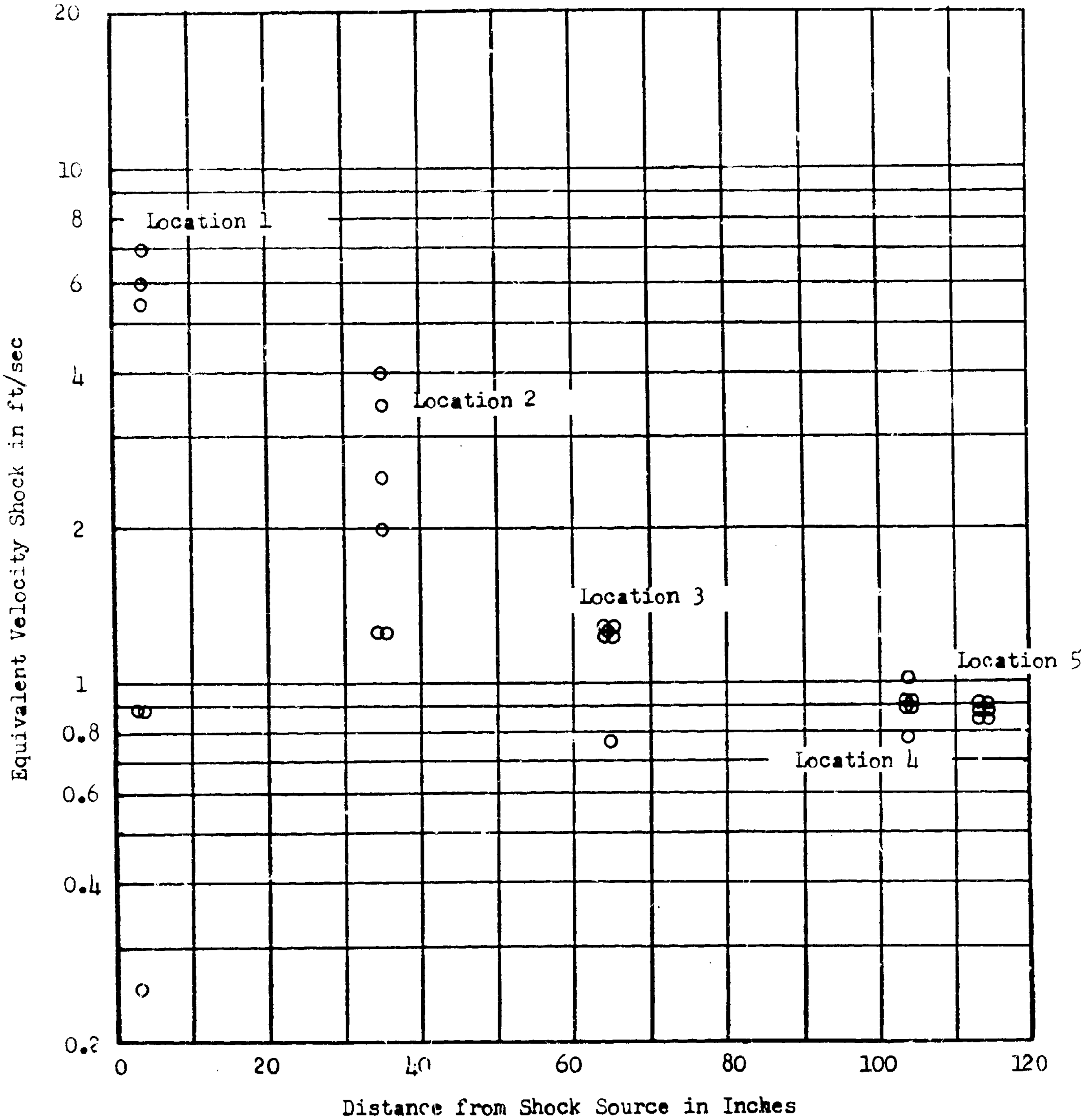



Figure 17. Equivalent Velocity Shock Attenuation Curve for Lateral Accelerometers--Shots 1-6

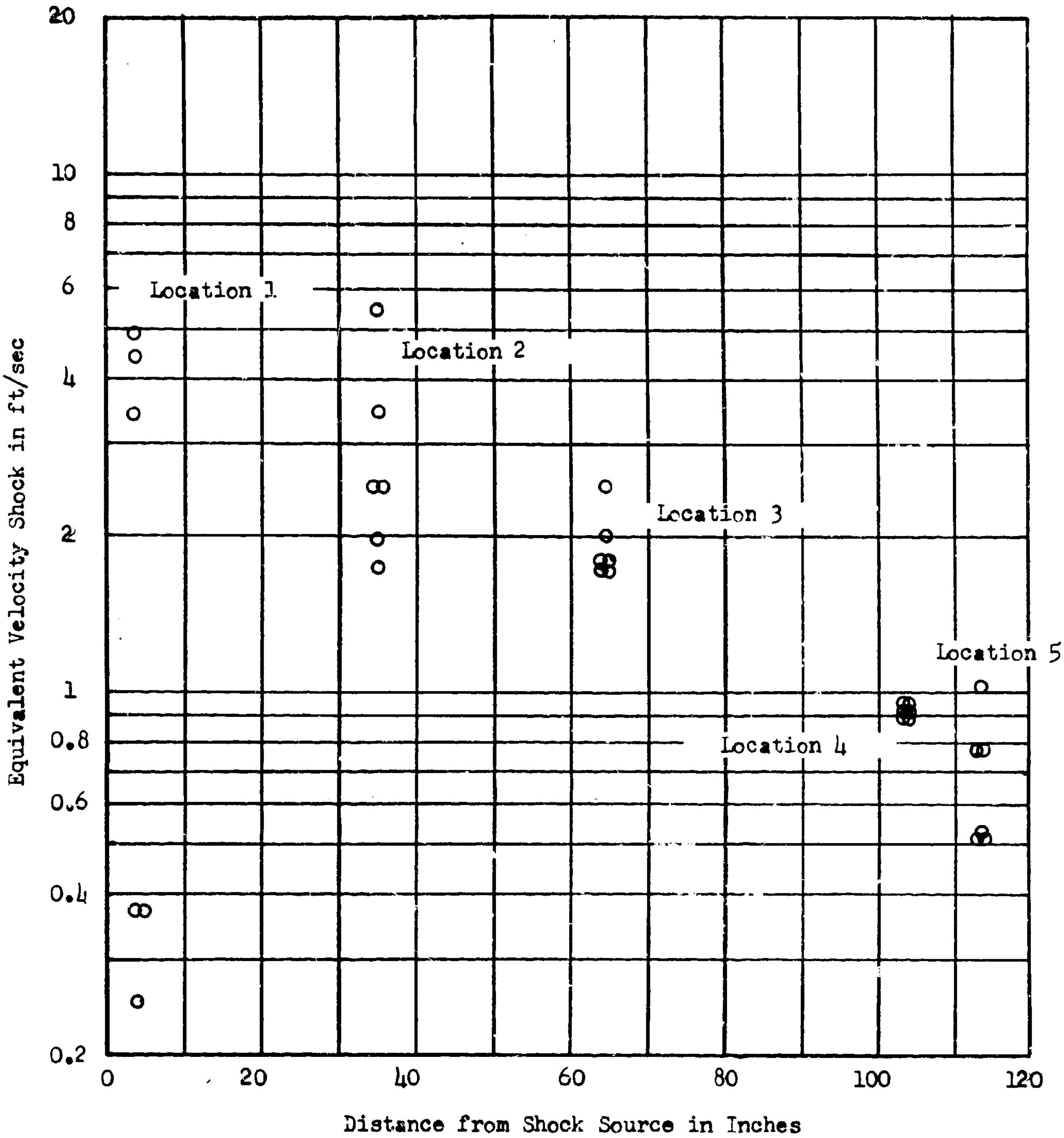



Figure 28. Equivalent Velocity Shock Attenuation Curve for Vertical Accelerometers--Shots 1-6

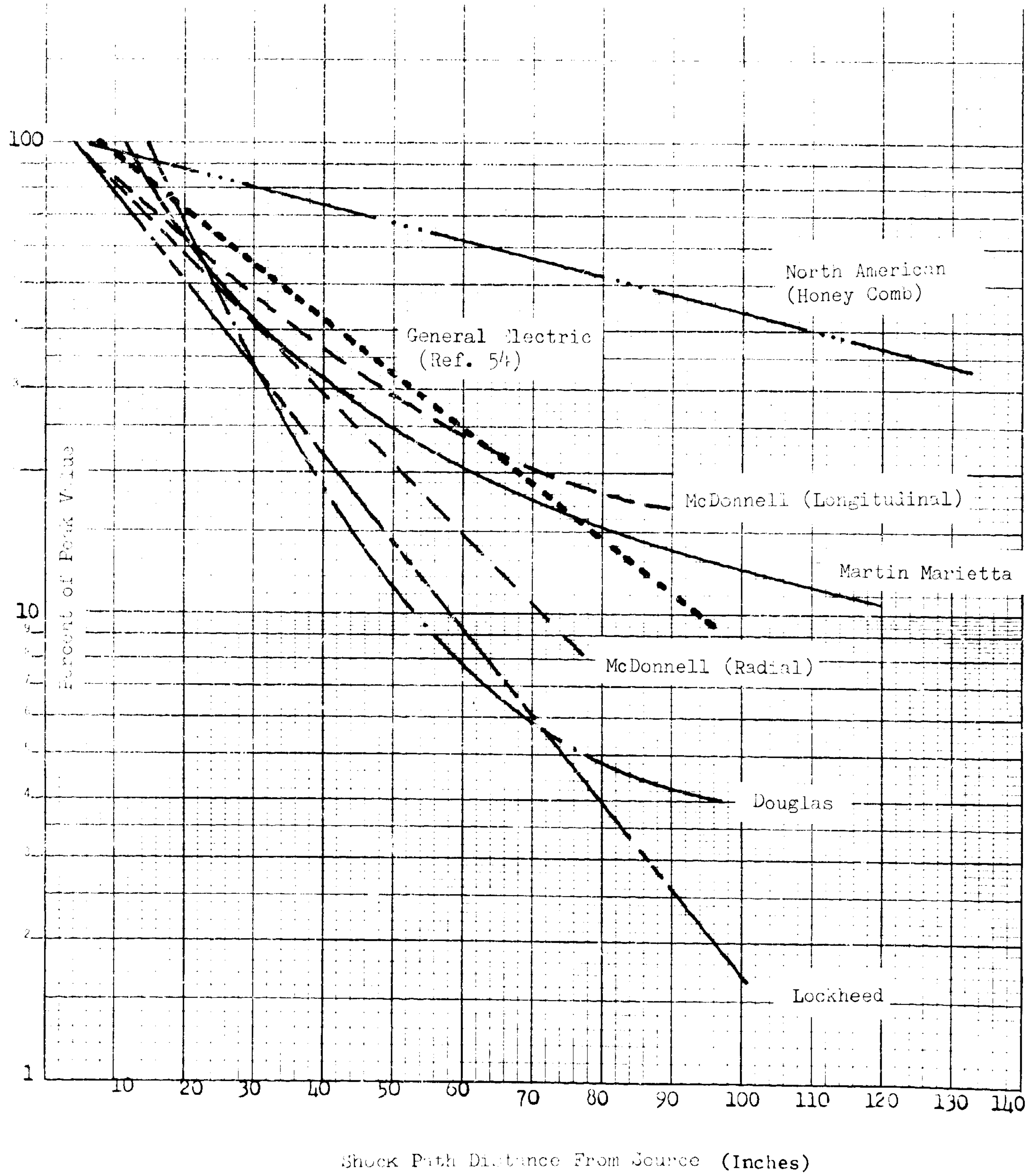



Figure 29 . Normalized Attenuation Curves

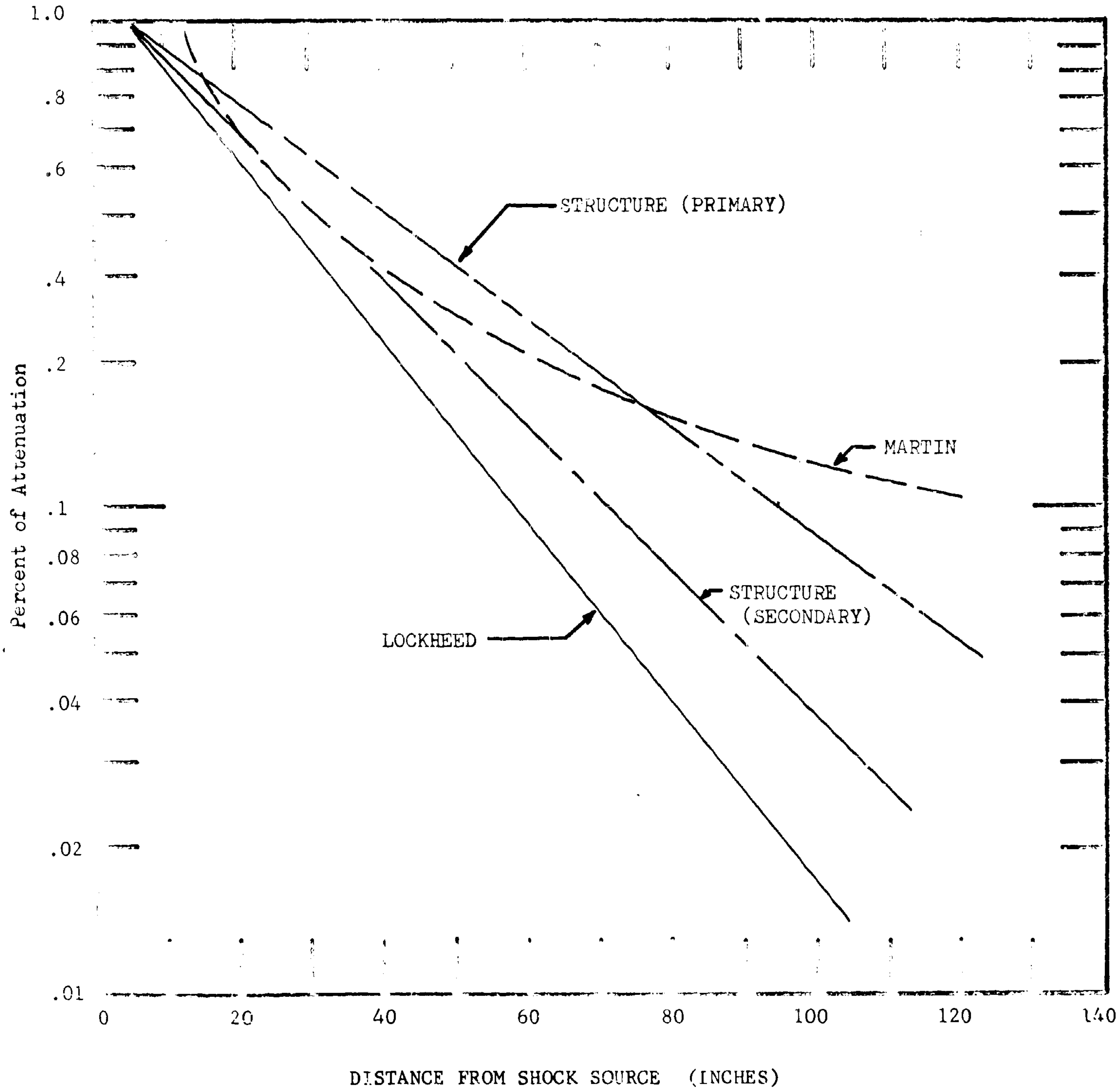



Figure 30. Shock Spectrum Attenuation
Curves for Truss Structure

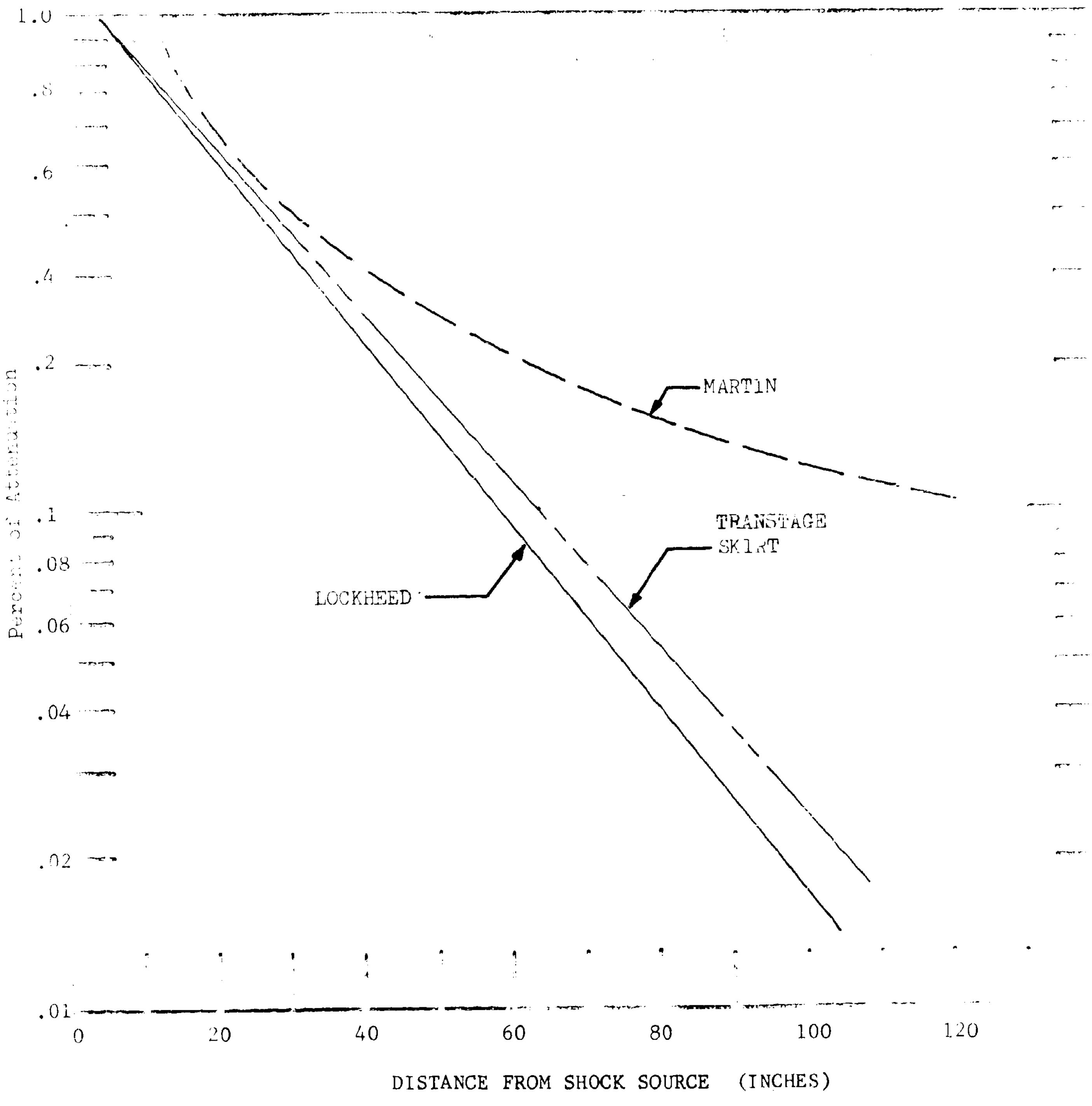



Figure 31 . Shock Spectrum Attenuation Curve for Skirt Structure

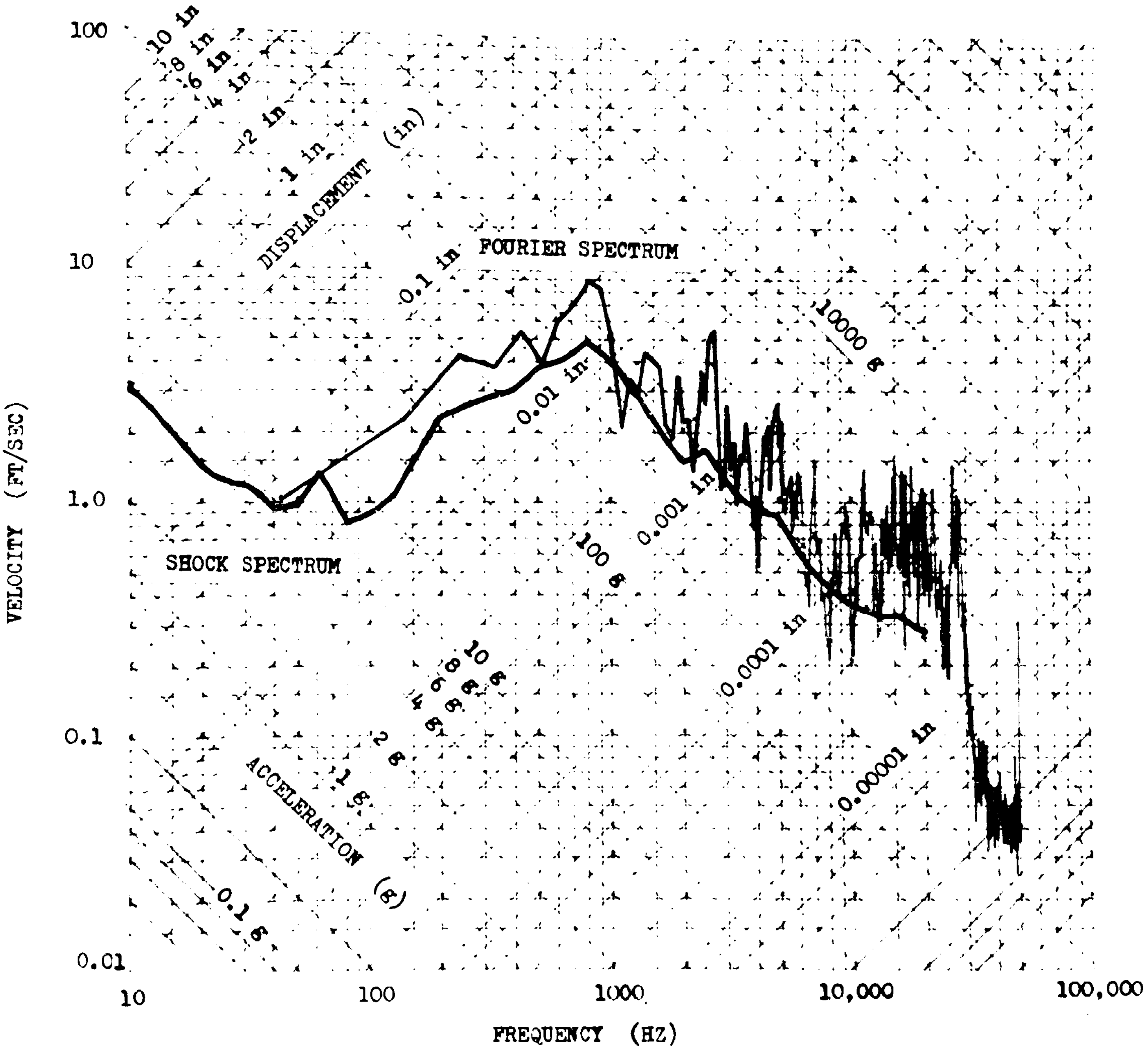



Figure 32 . Shock and Fourier Spectra for Location 3 Longitudinal Test 6

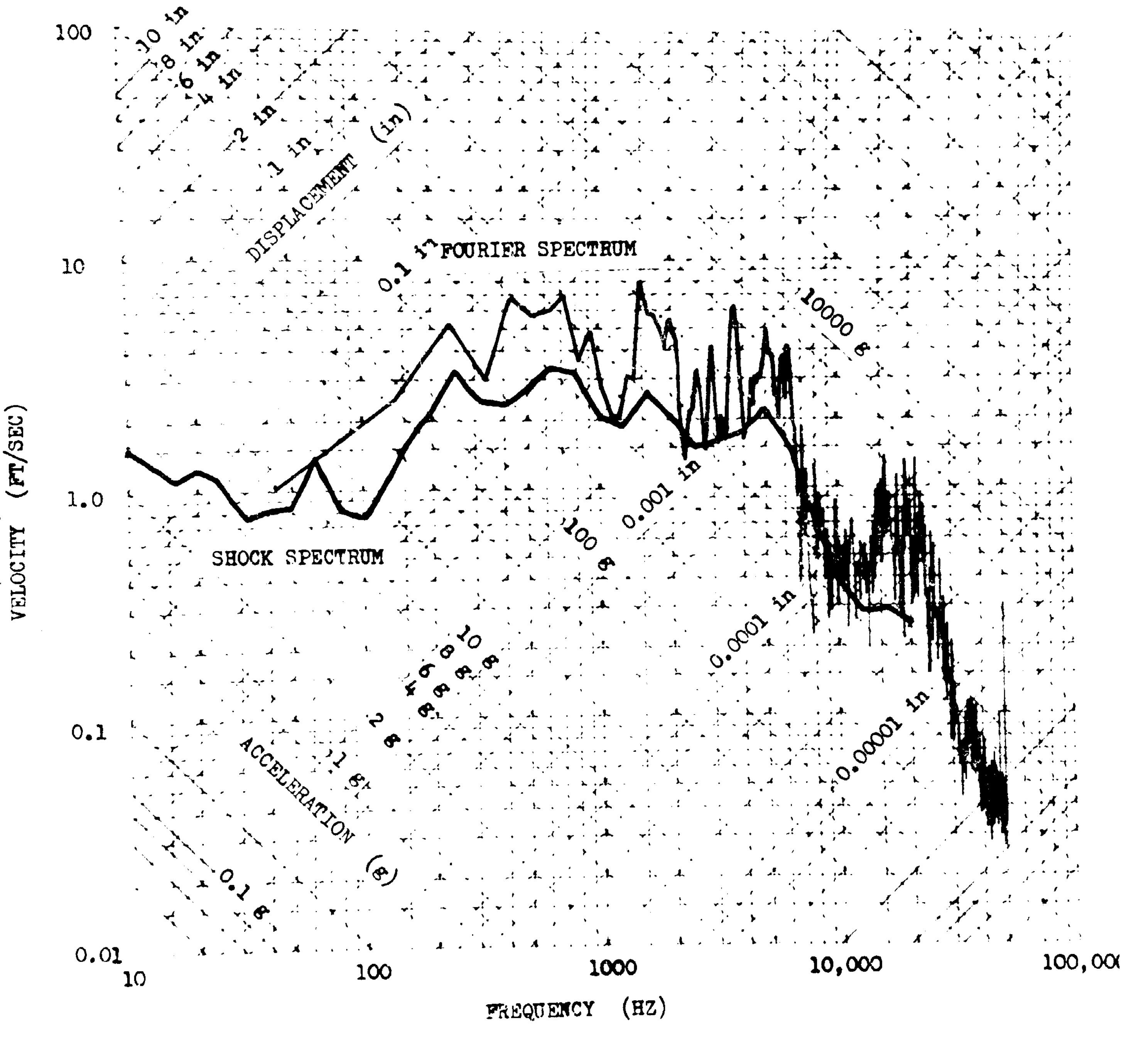



Figure 33. Shock and Fourier Spectra for Location 3 Lateral Test 6

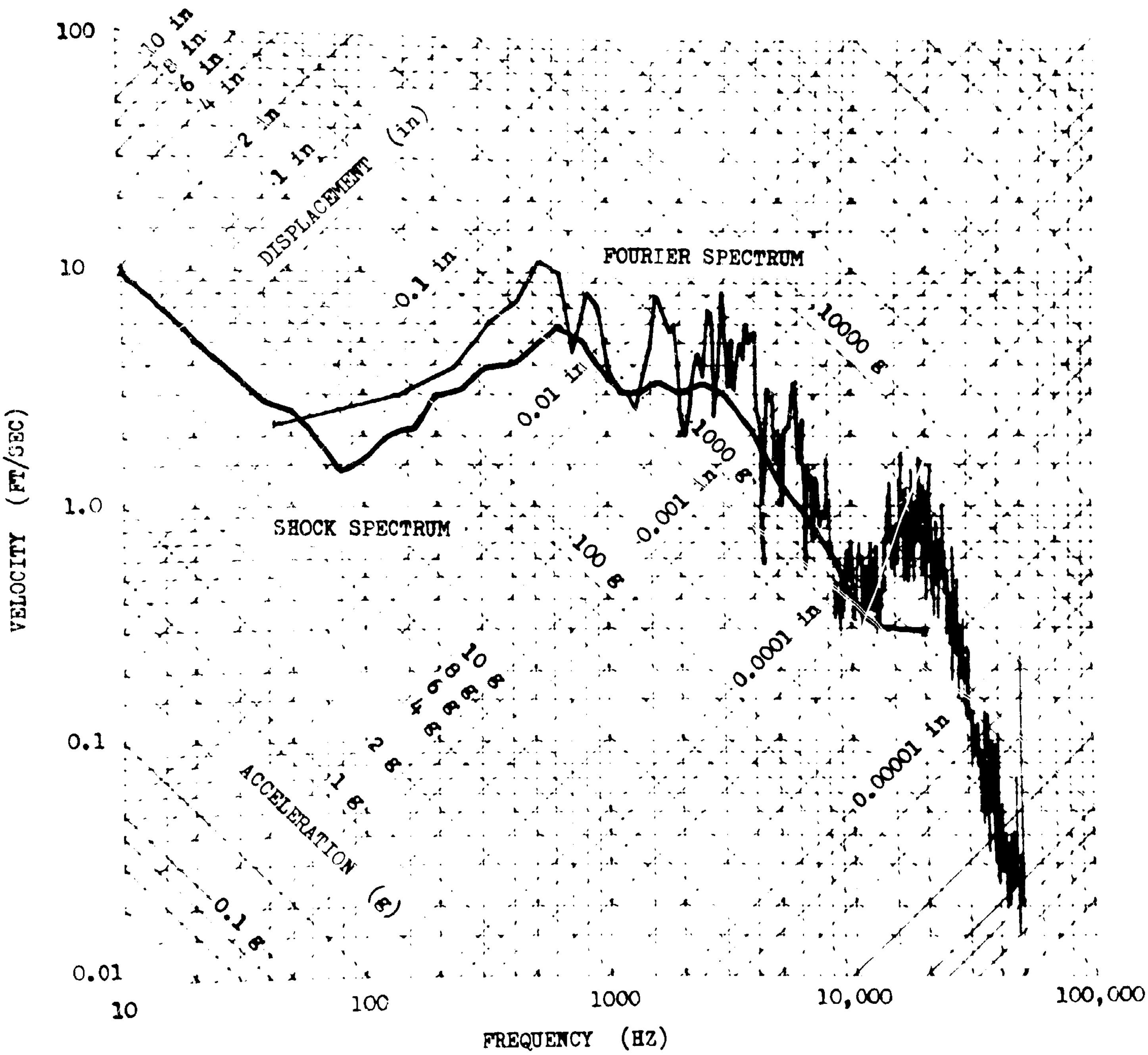



Figure 34. Shock and Fourier Spectra for Location 3 Vertical Test 6

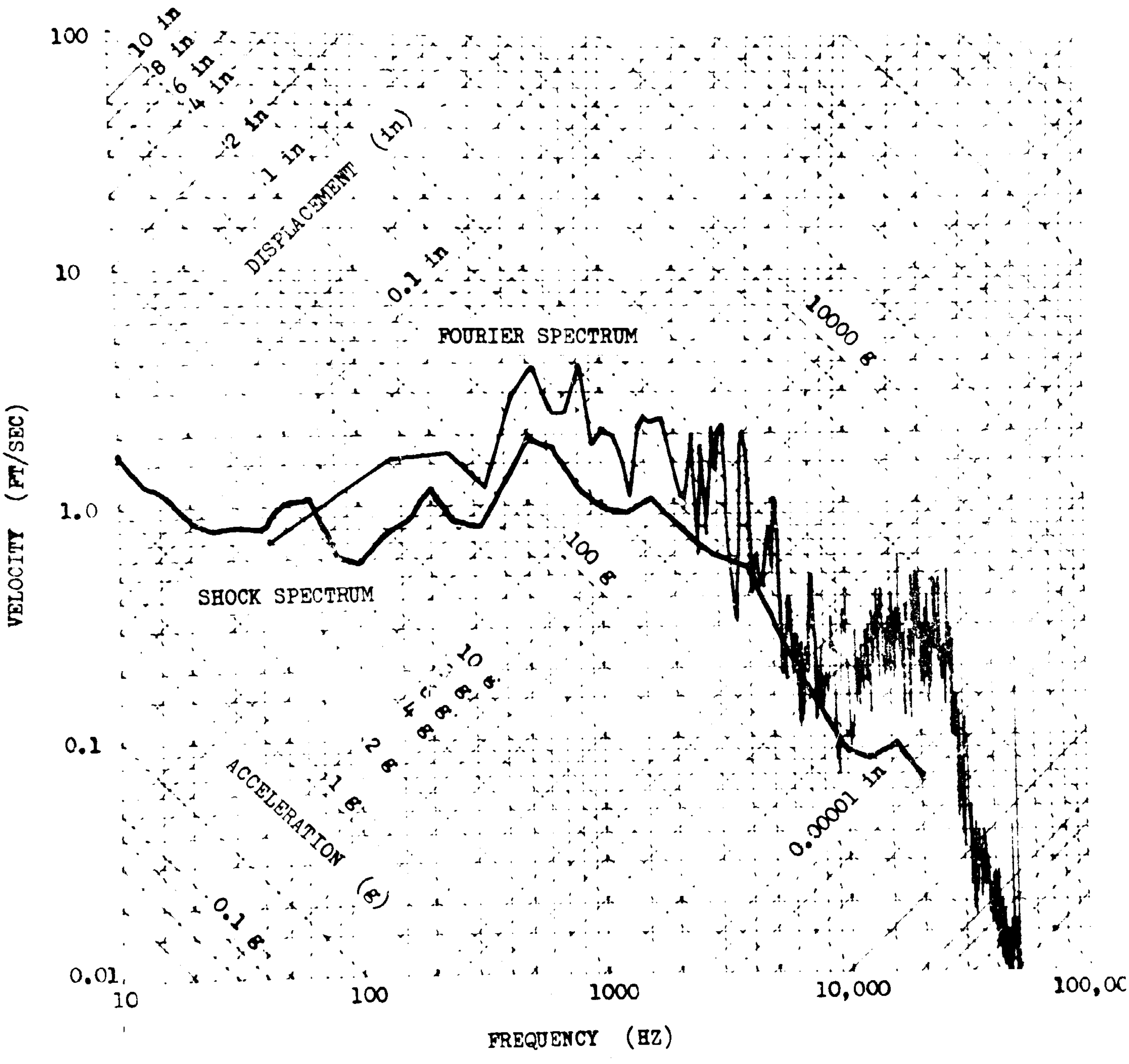



Figure 35. Shock and Fourier Spectra for Location 4 Longitudinal Test 6

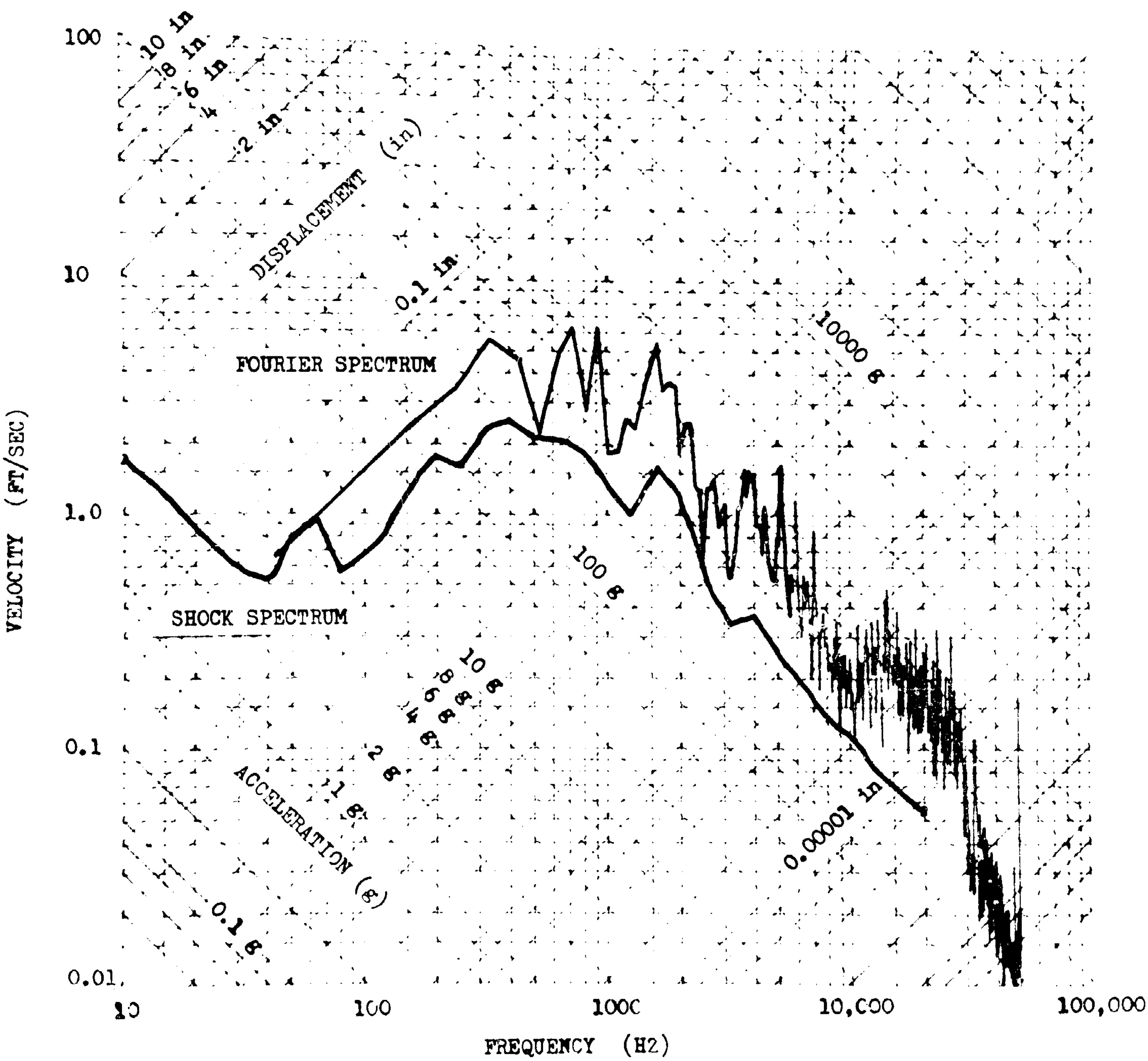



Figure 36. Shock and Fourier Spectra for Location 4 Lateral Test 6

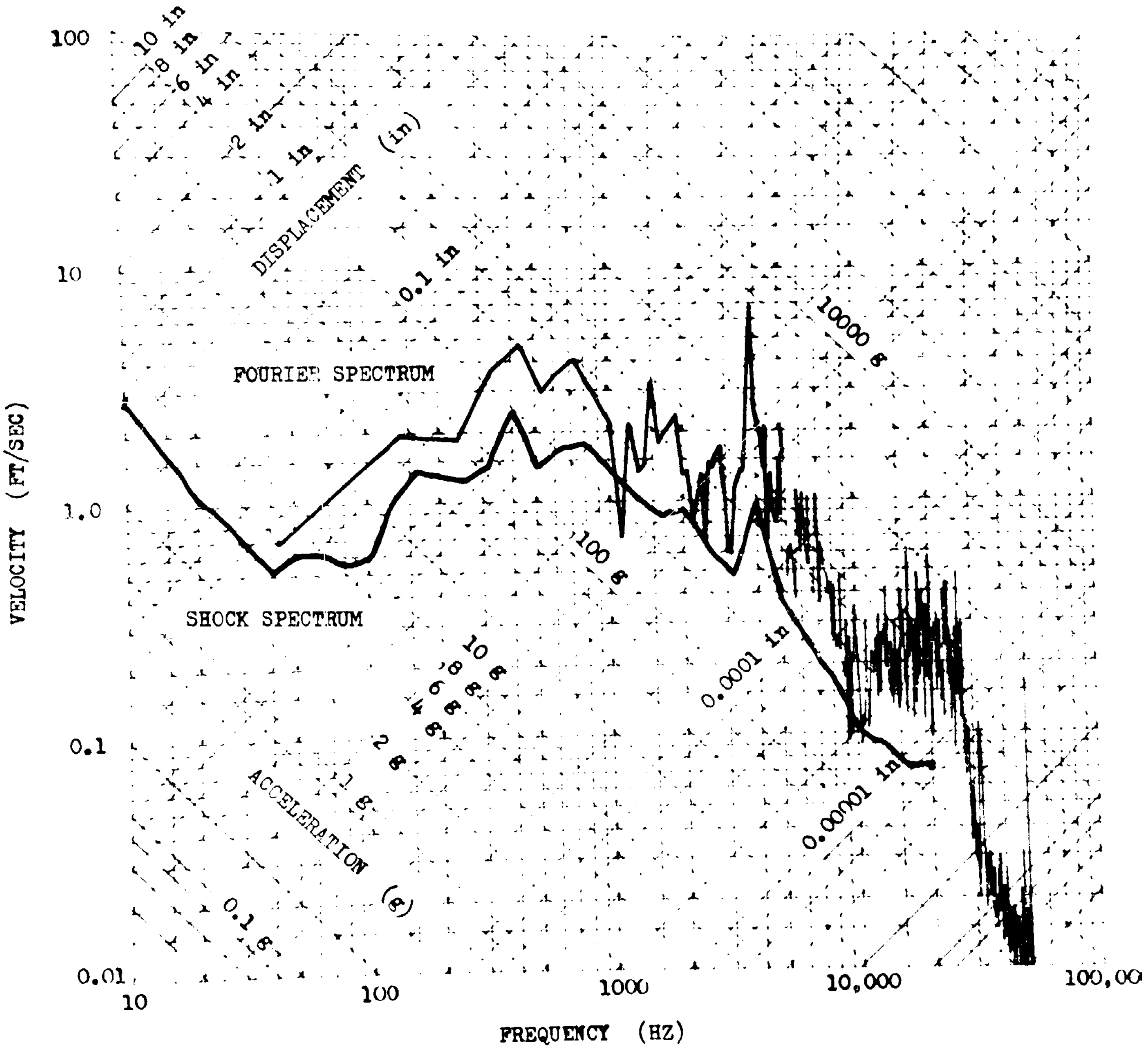



Figure 37. Shock and Fourier Spectra for Location 4 Vertical Test 6

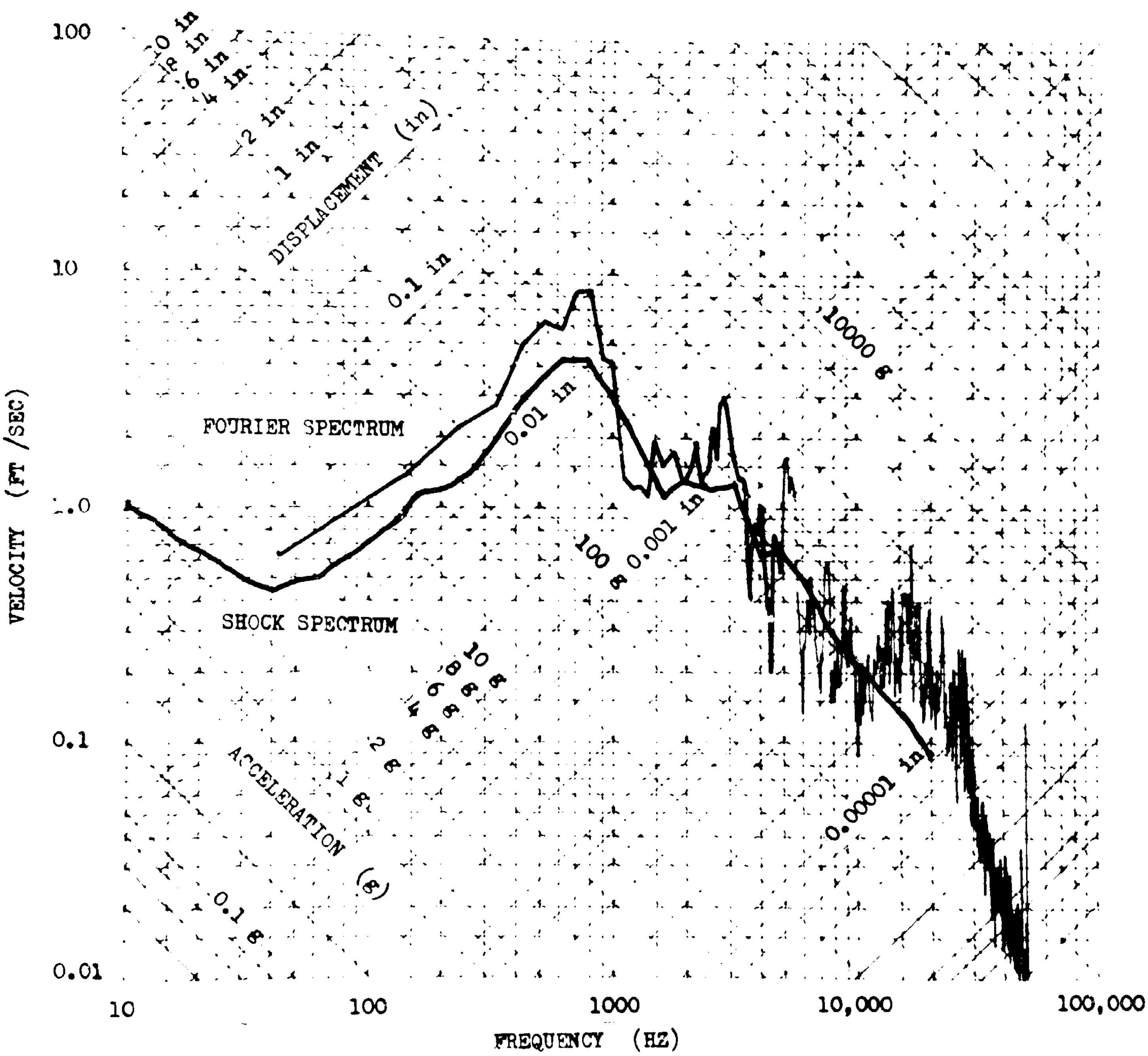



Figure 38. Shock and Fourier Spectra for Location 5 Longitudinal Test 5

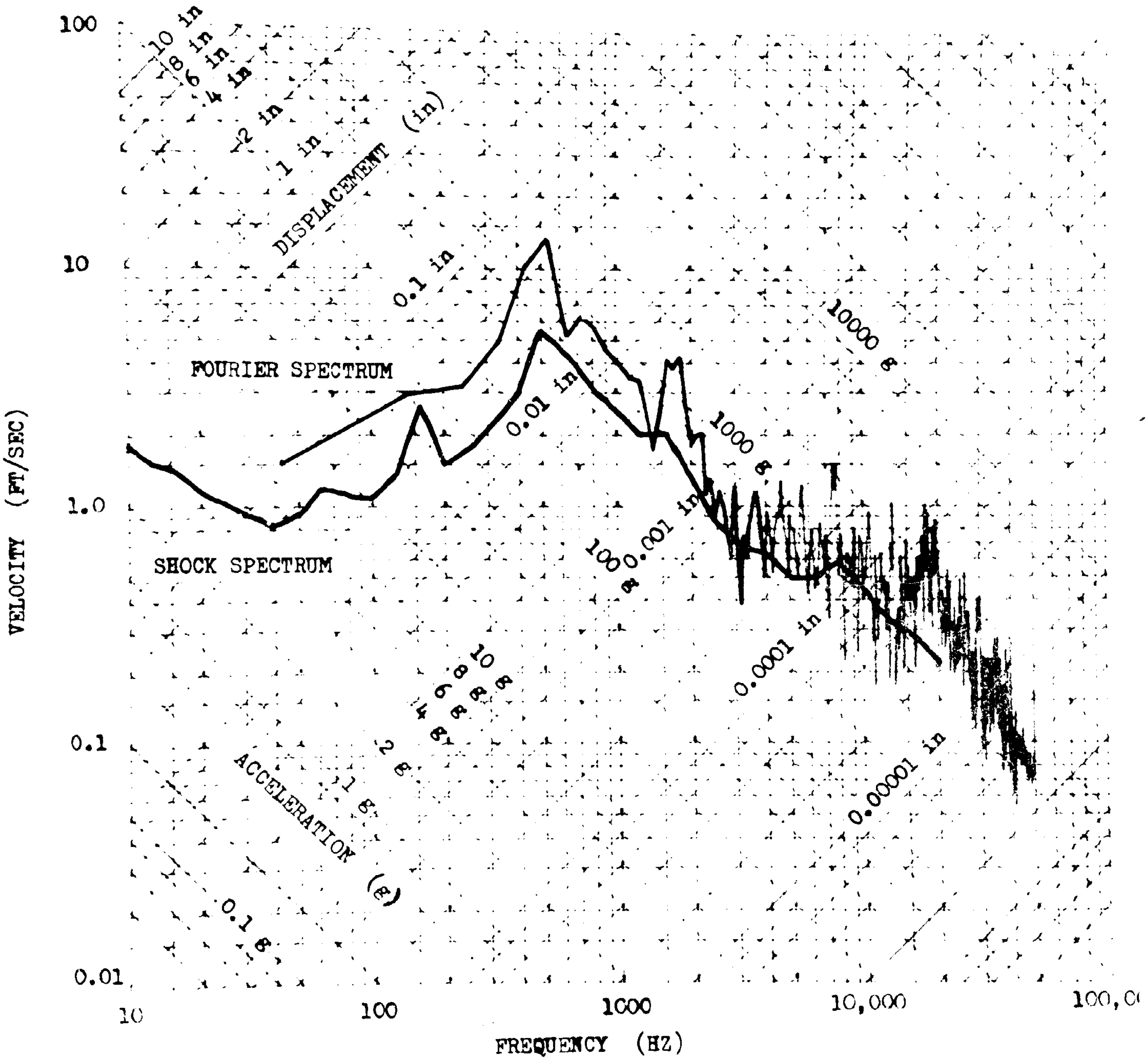



Figure 39. Shock and Fourier Spectra for Location 5 Lateral Test 5

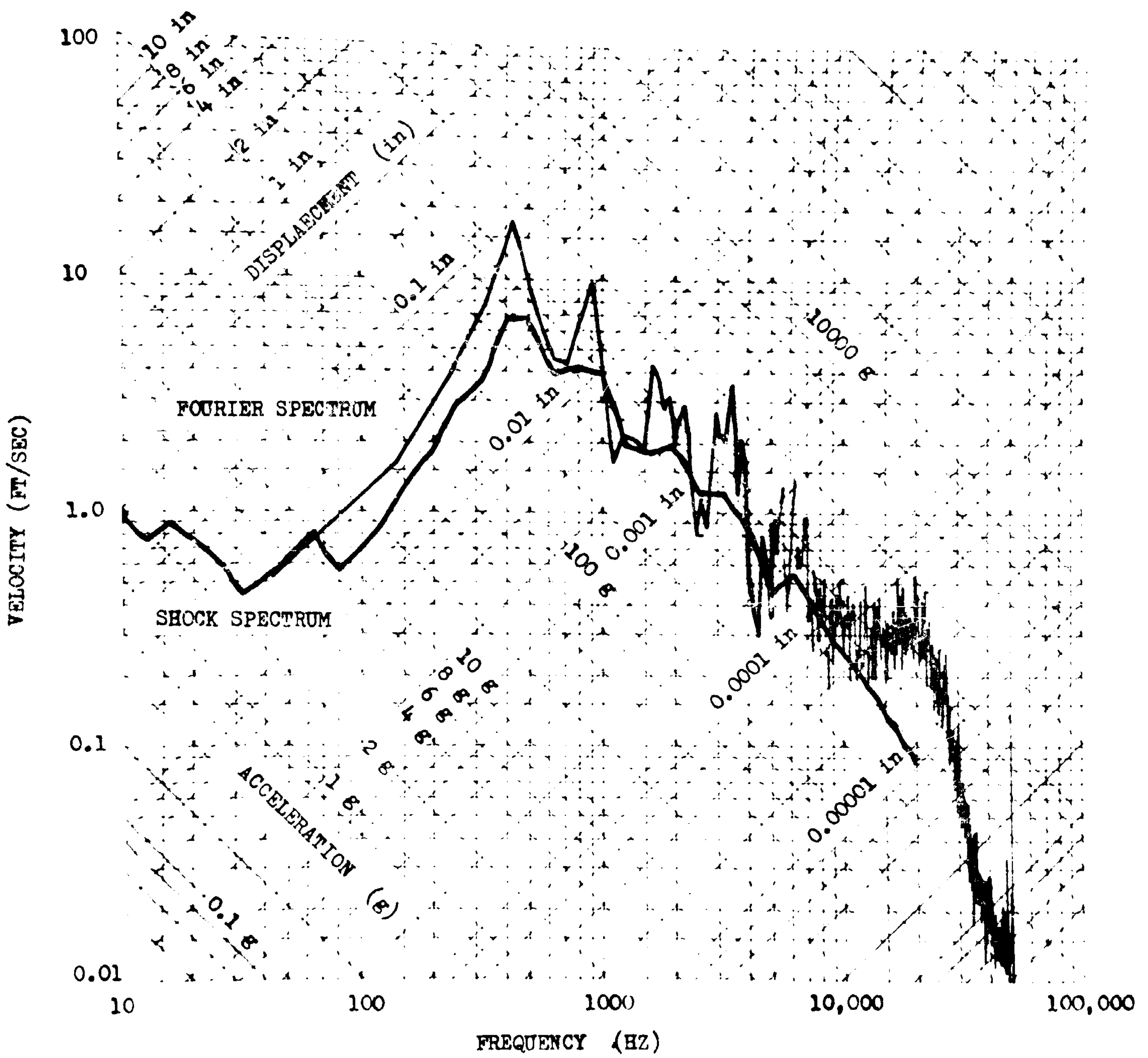



Figure 40. Shock and Fourier Spectra for Location 5 Vertical Test 5

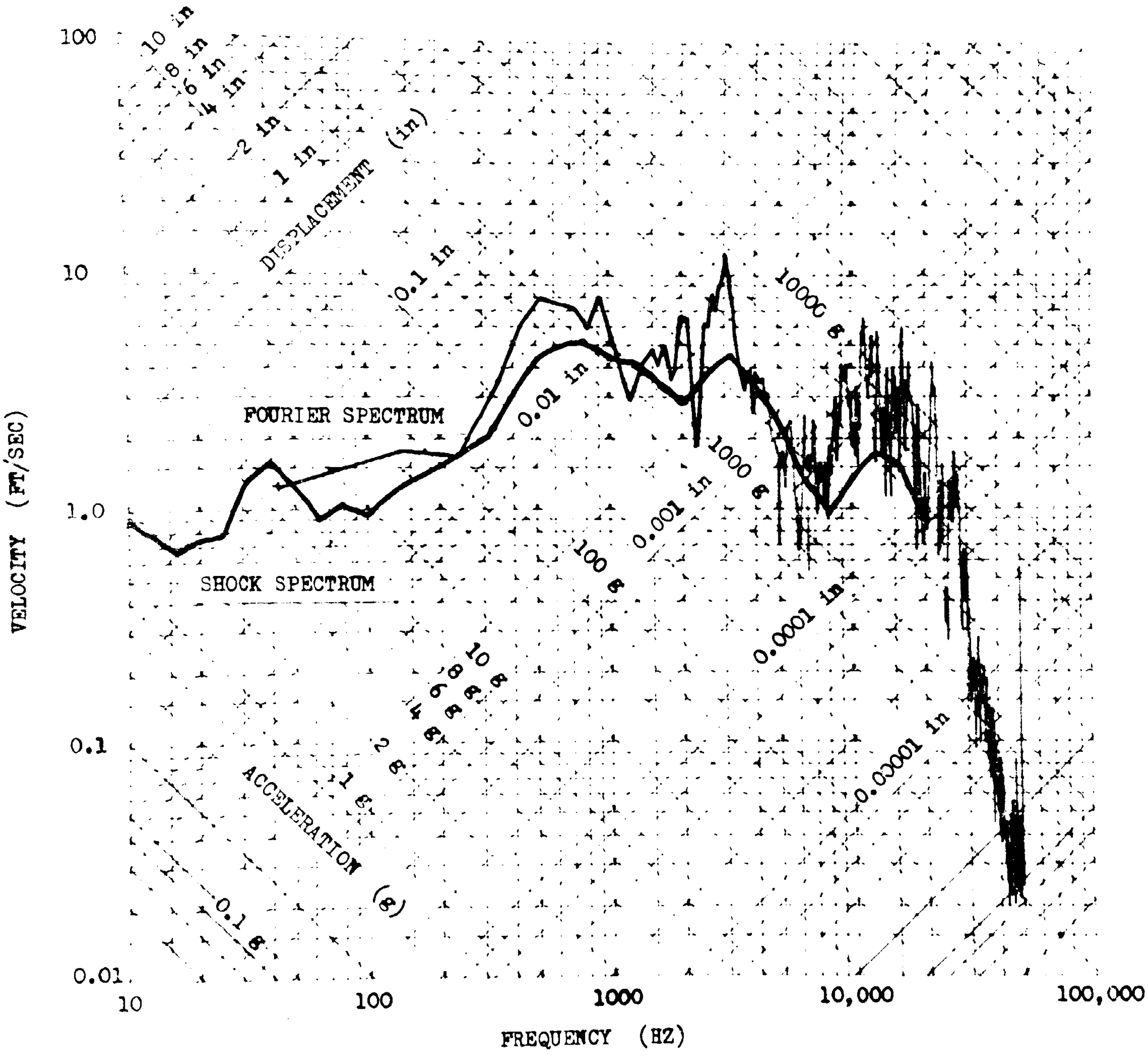



Figure 41. Shock and Fourier Spectra for Location 6 Longitudinal Test 5

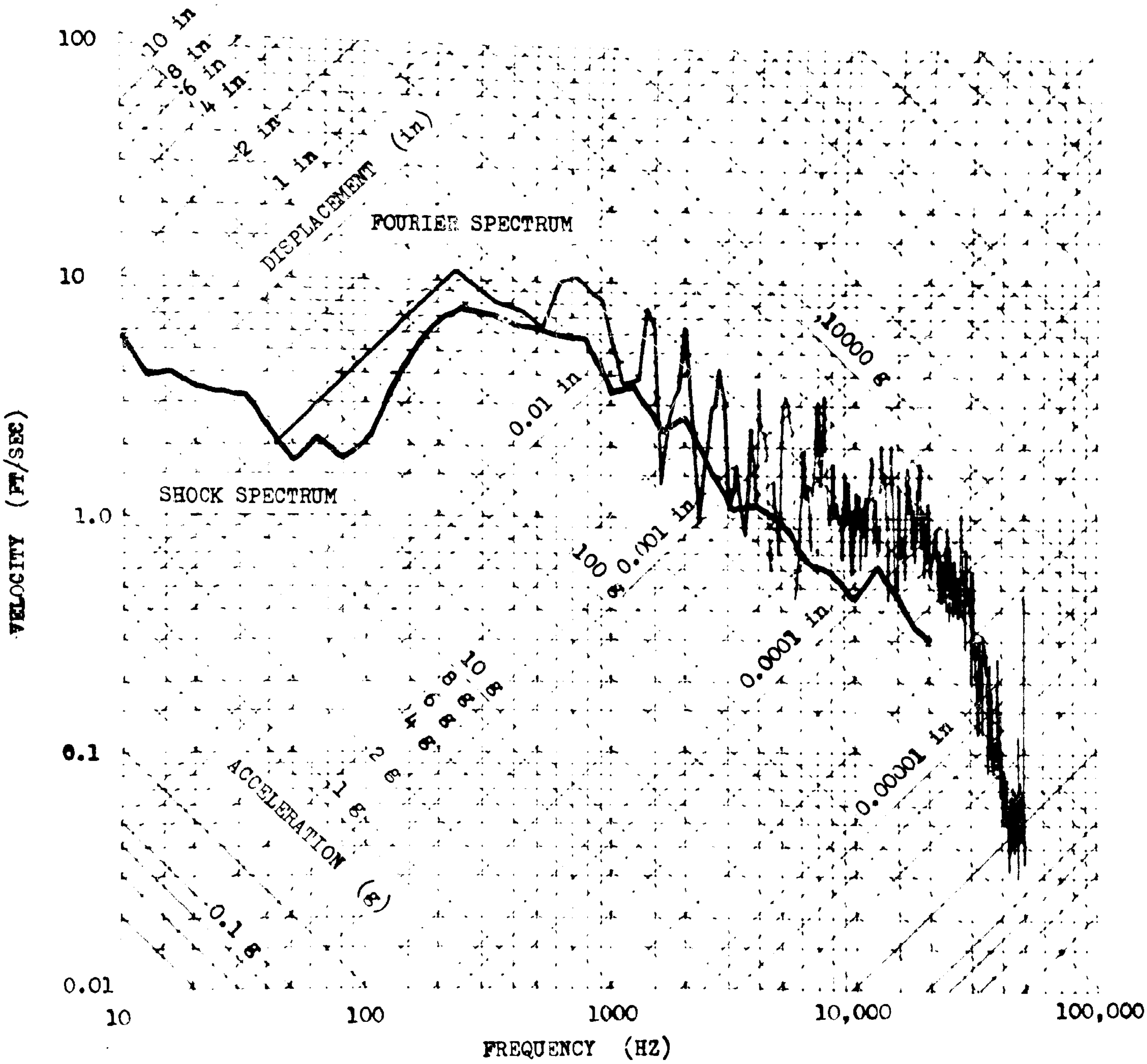



Figure 42. Shock and Fourier Spectra for Location 6 Lateral Test 5

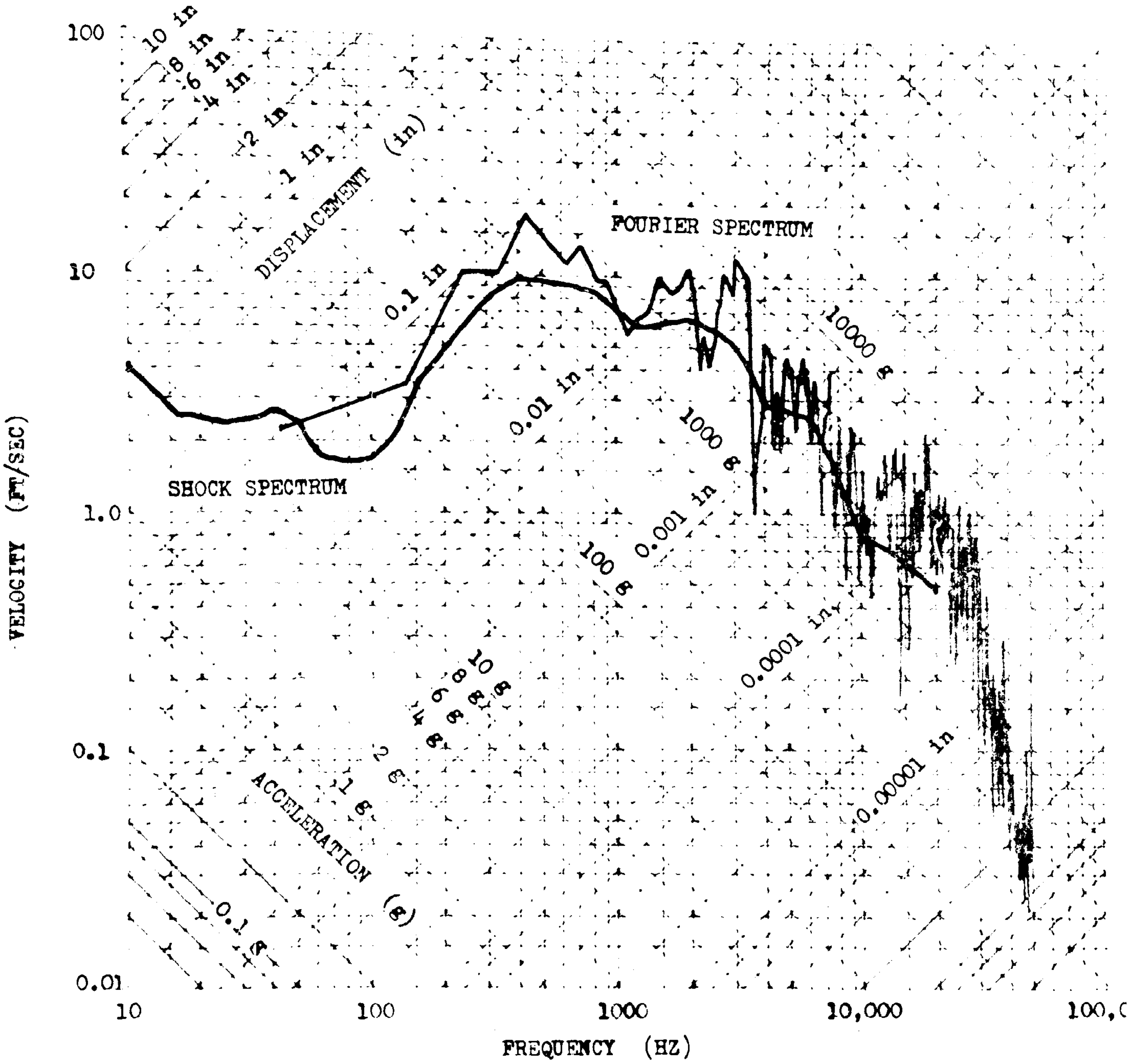



Figure 43. Shock and Fourier Spectra for Location 6 Vertical Test 5

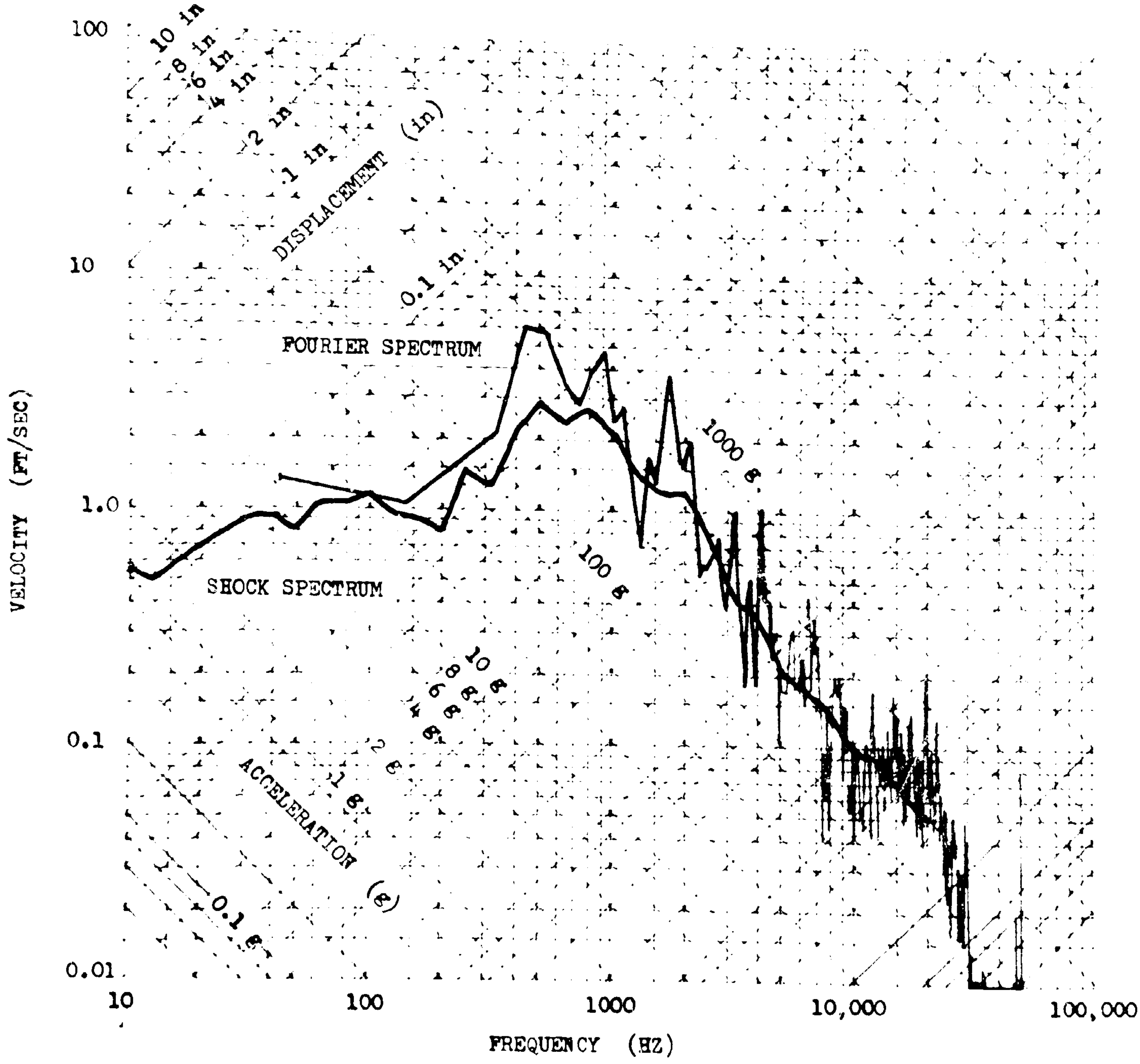



Figure 44. Shock and Fourier Spectra for Location 7 Longitudinal Test 5

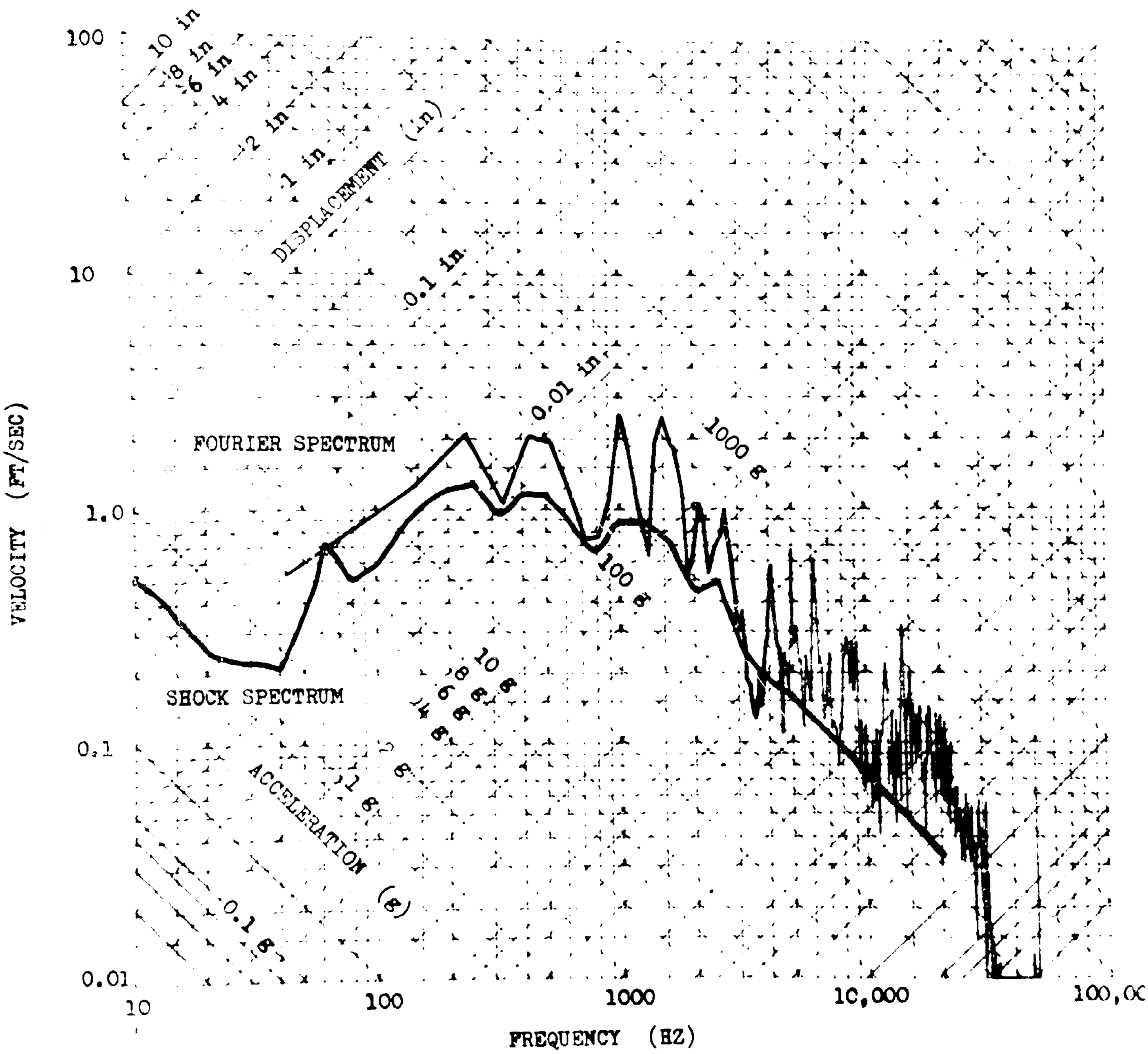



Figure 45 . Shock and Fourier Spectra for Location 7 Lateral Test 5

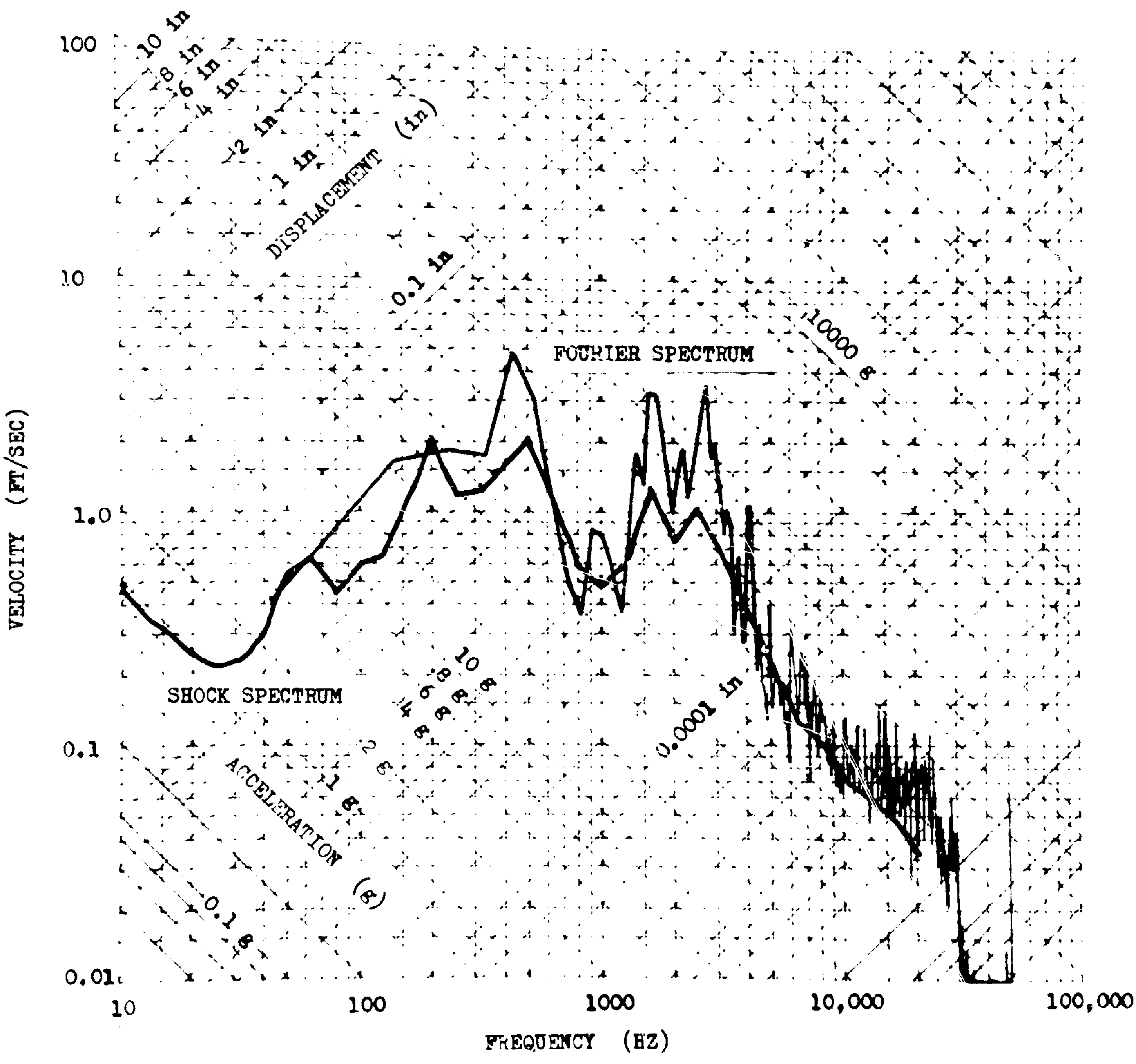



Figure 46 . Shock and Fourier Spectra for Location 7 Vertical Test 5

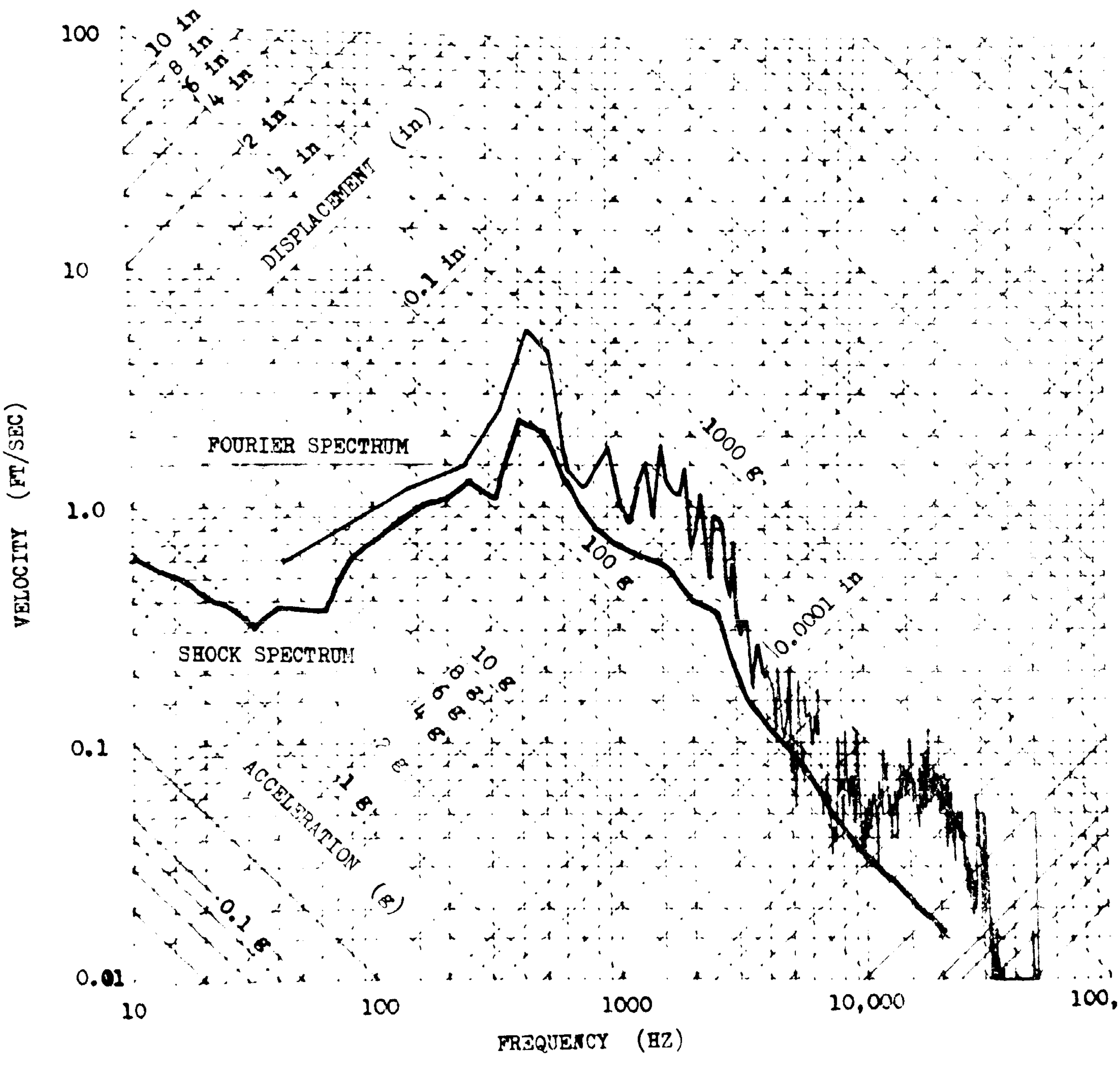



Figure 47. Shock and Fourier Spectra for Location 8 Longitudinal Test 5

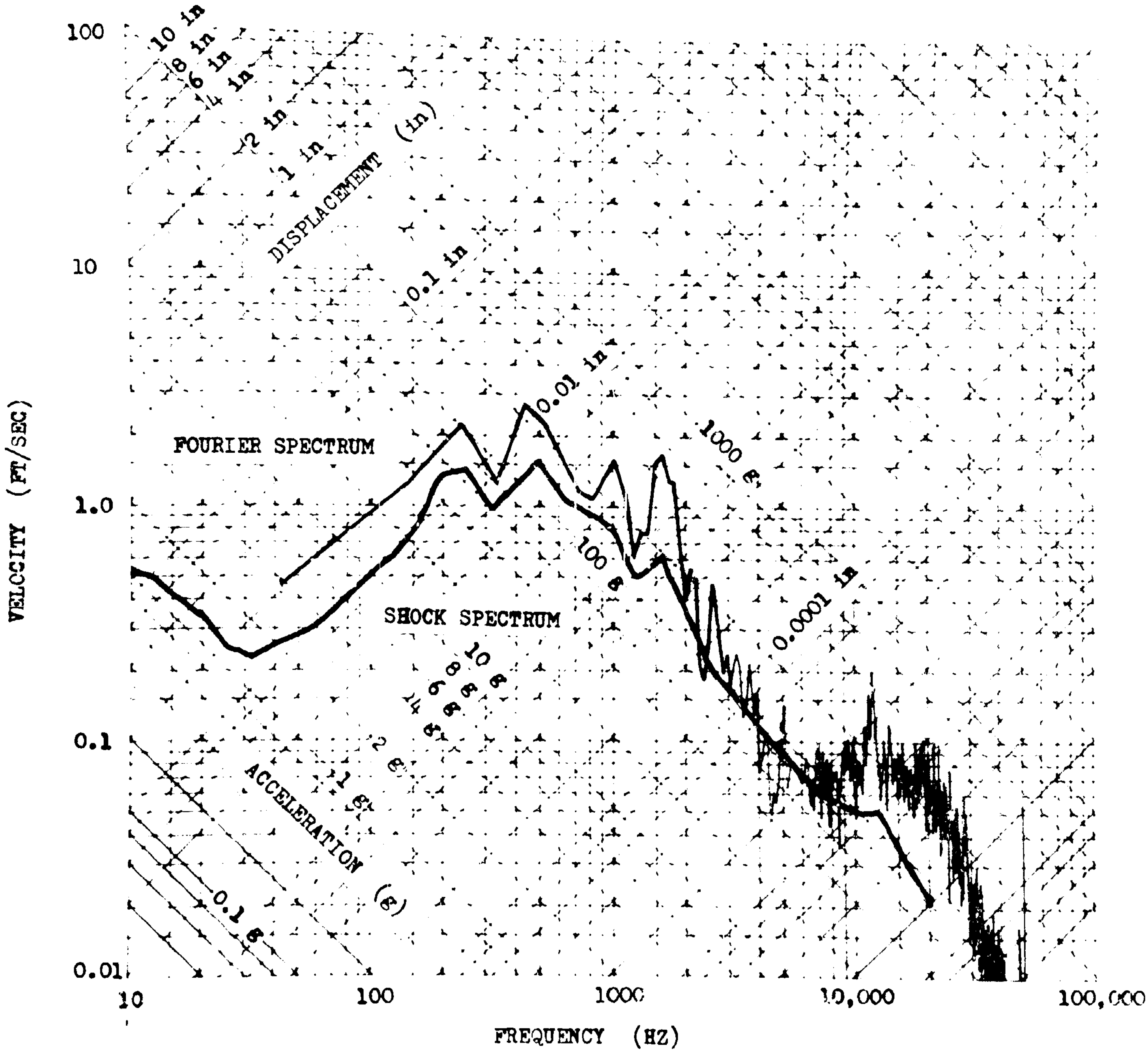



Figure 48. Shock and Fourier Spectra for Location 8 Lateral Test 5

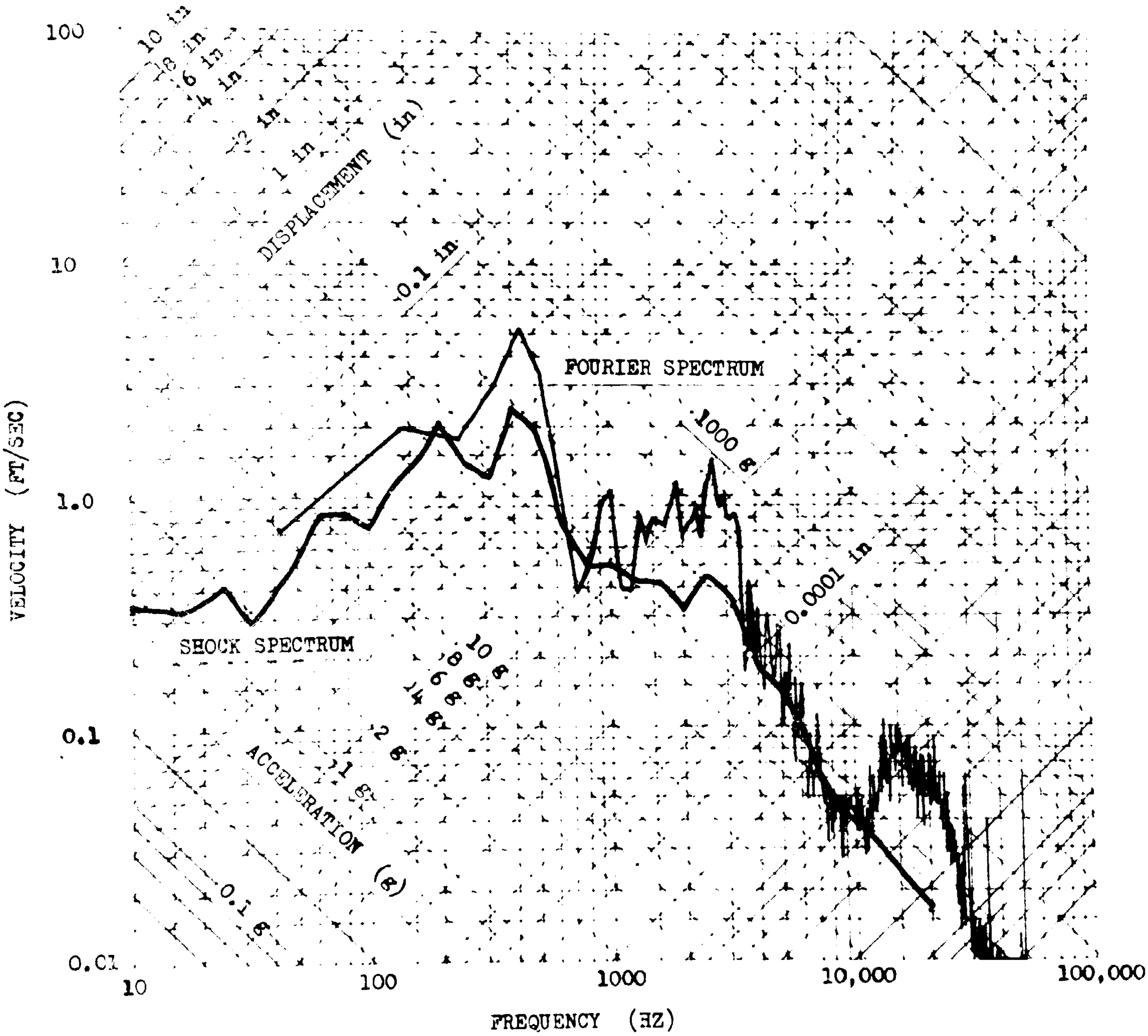
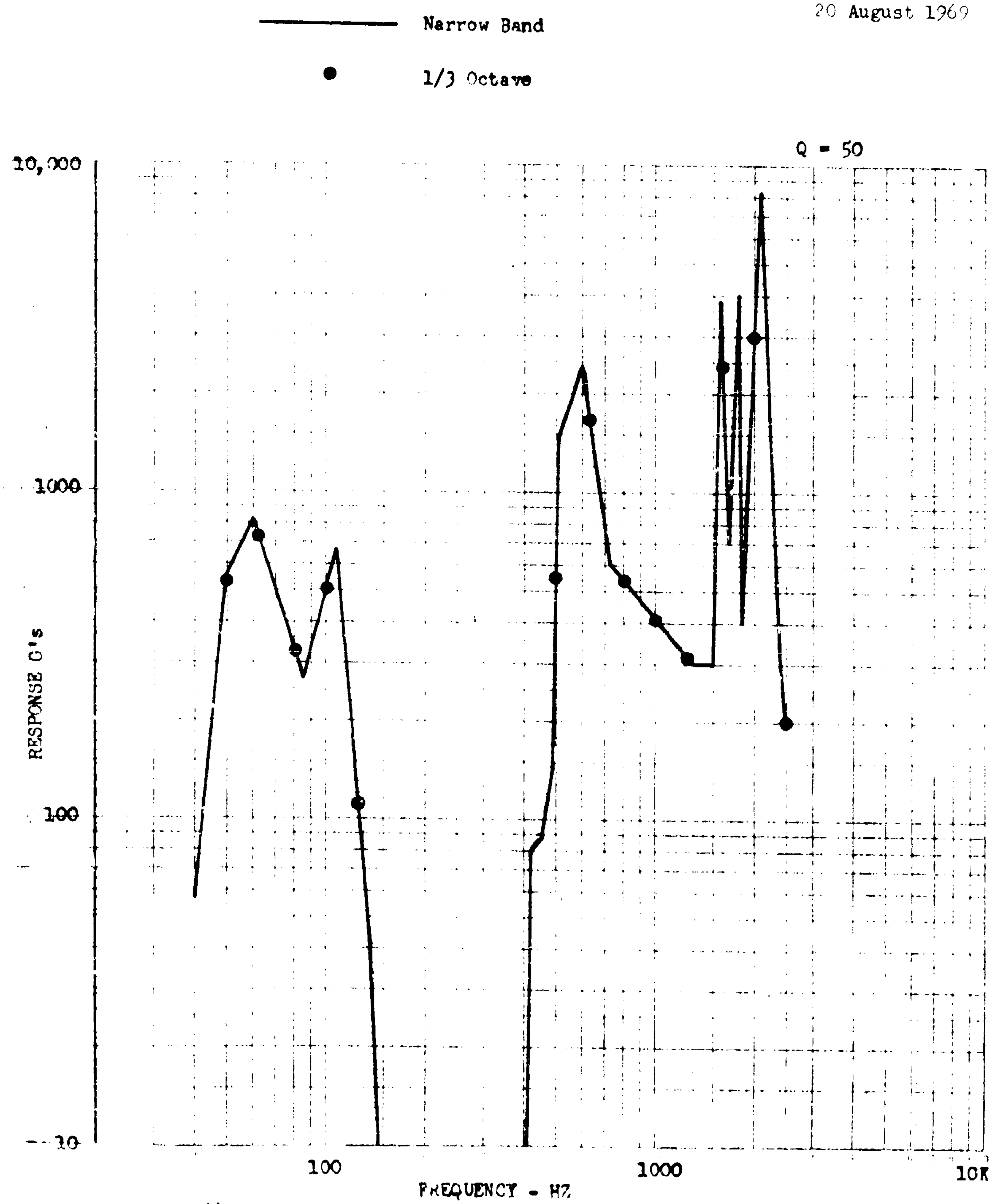



Figure 49 . Shock and Fourier Spectra for Location 8 Vertical Test 5




51

Figure 51 COMPARISON OF NARROW BAND AND 1/3 OCTAVE ANALYSIS - ACCEL. NO. 3

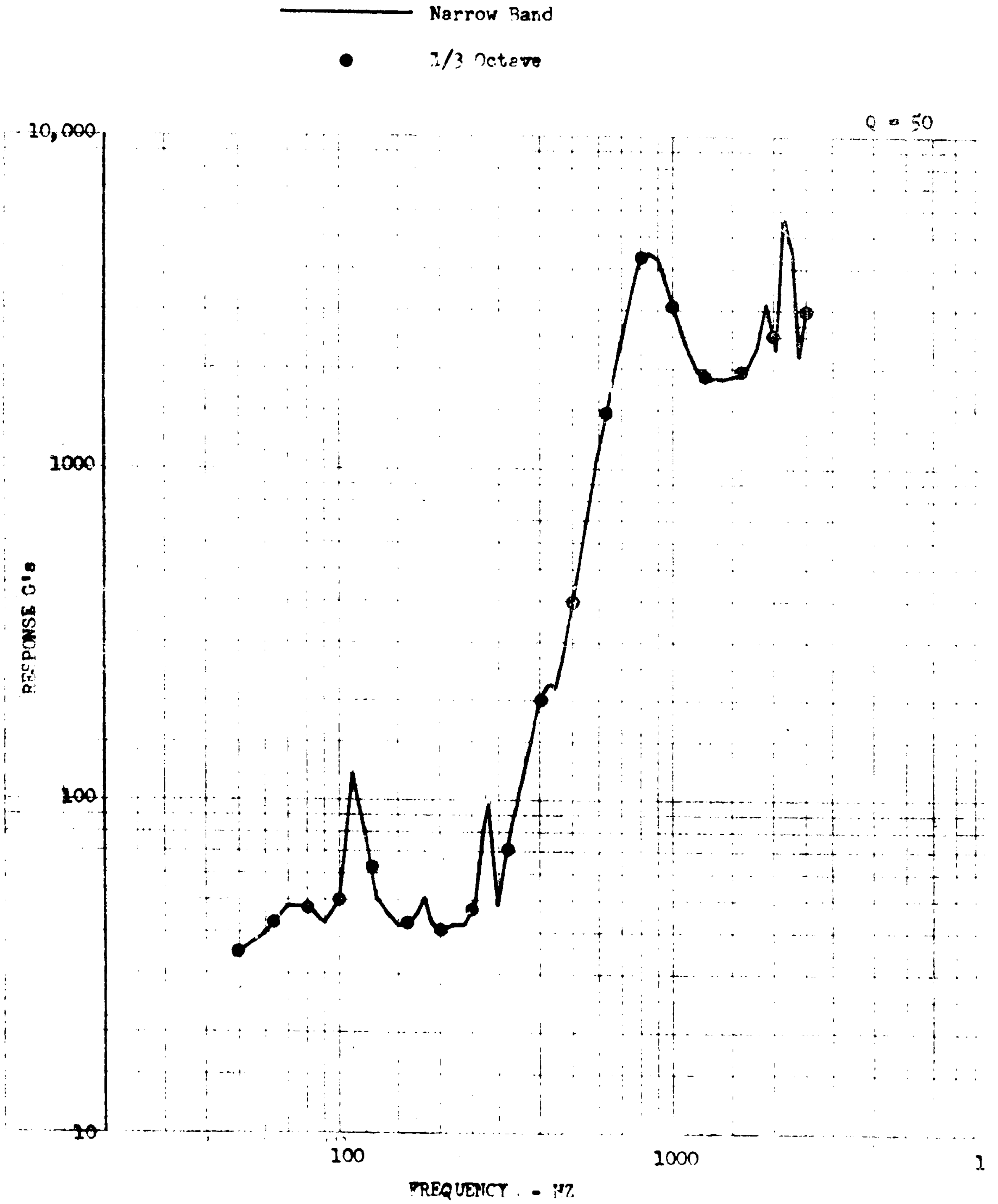



Figure 52 COMPARISON OF NARROW BAND AND 1/3 OCTAVE ANALYSIS - ACCEL. NO. 1

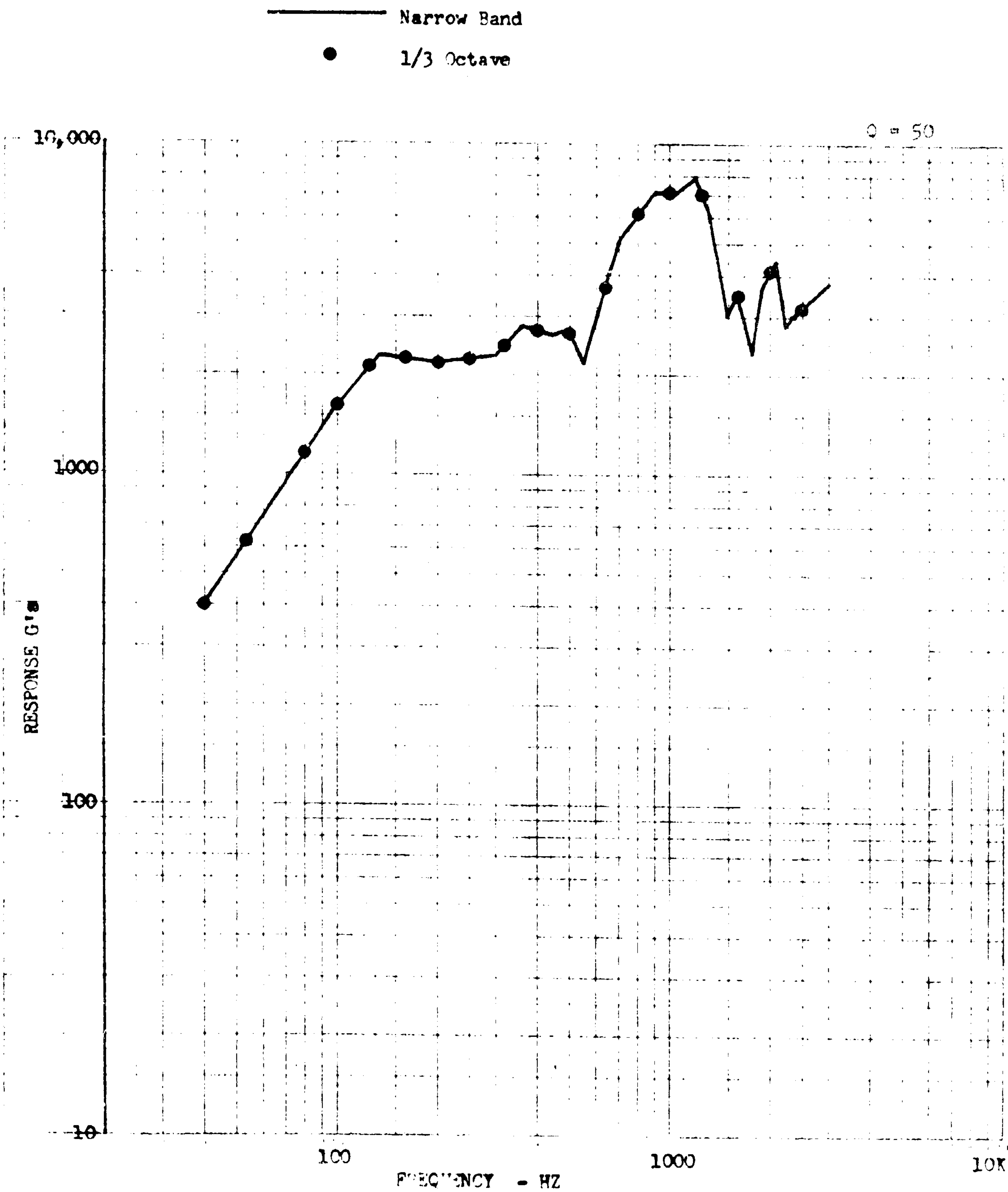



Figure 53 COMPARISON OF NARROW BAND AND 1/3 OCTAVE ANALYSIS - ACCEL. NO. 5

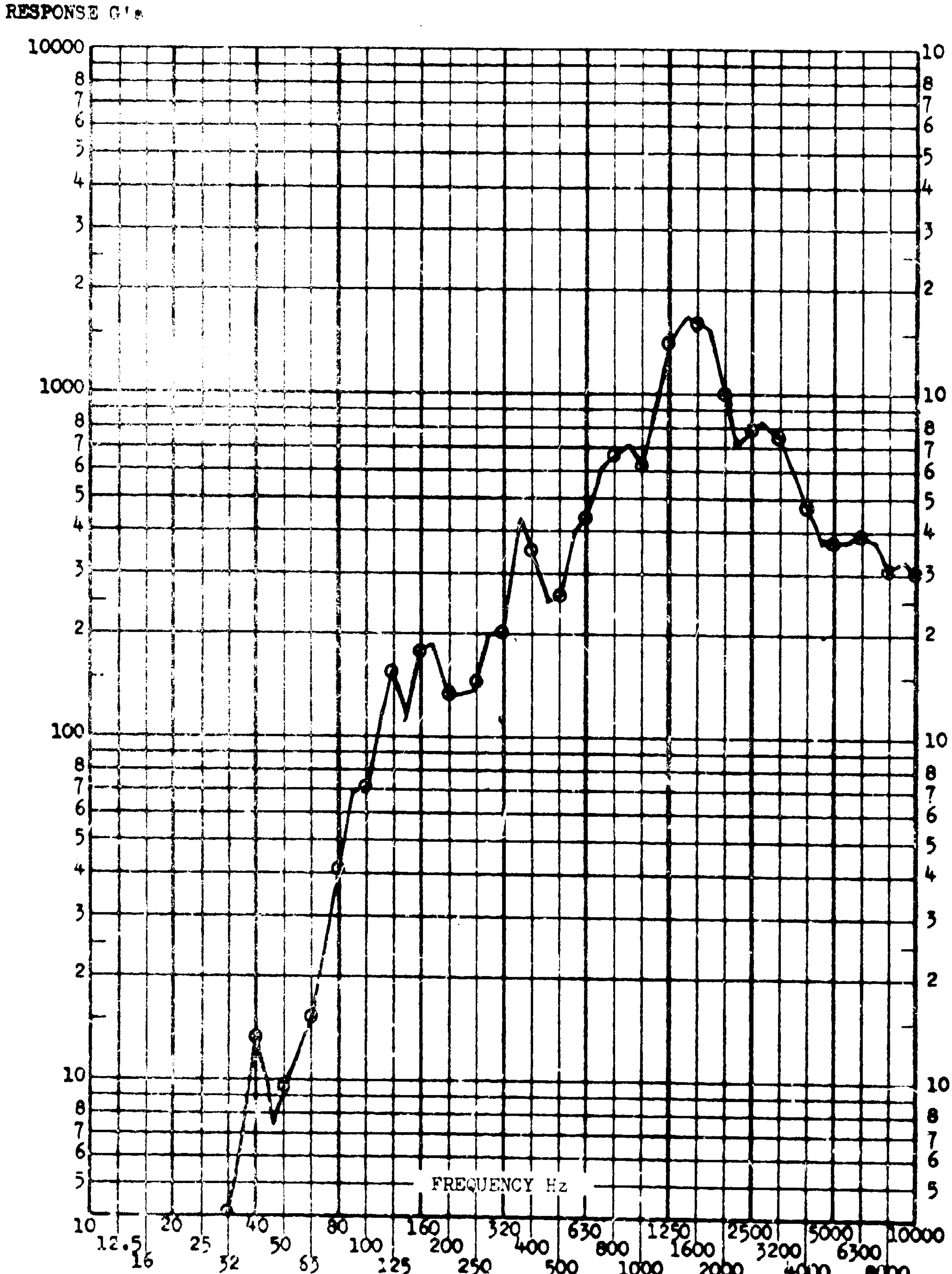



Figure 54 Comparison of 1/6 Octave and 1/3 Octave Analyses - Accelerometer No. 20 From Apollo Service Module

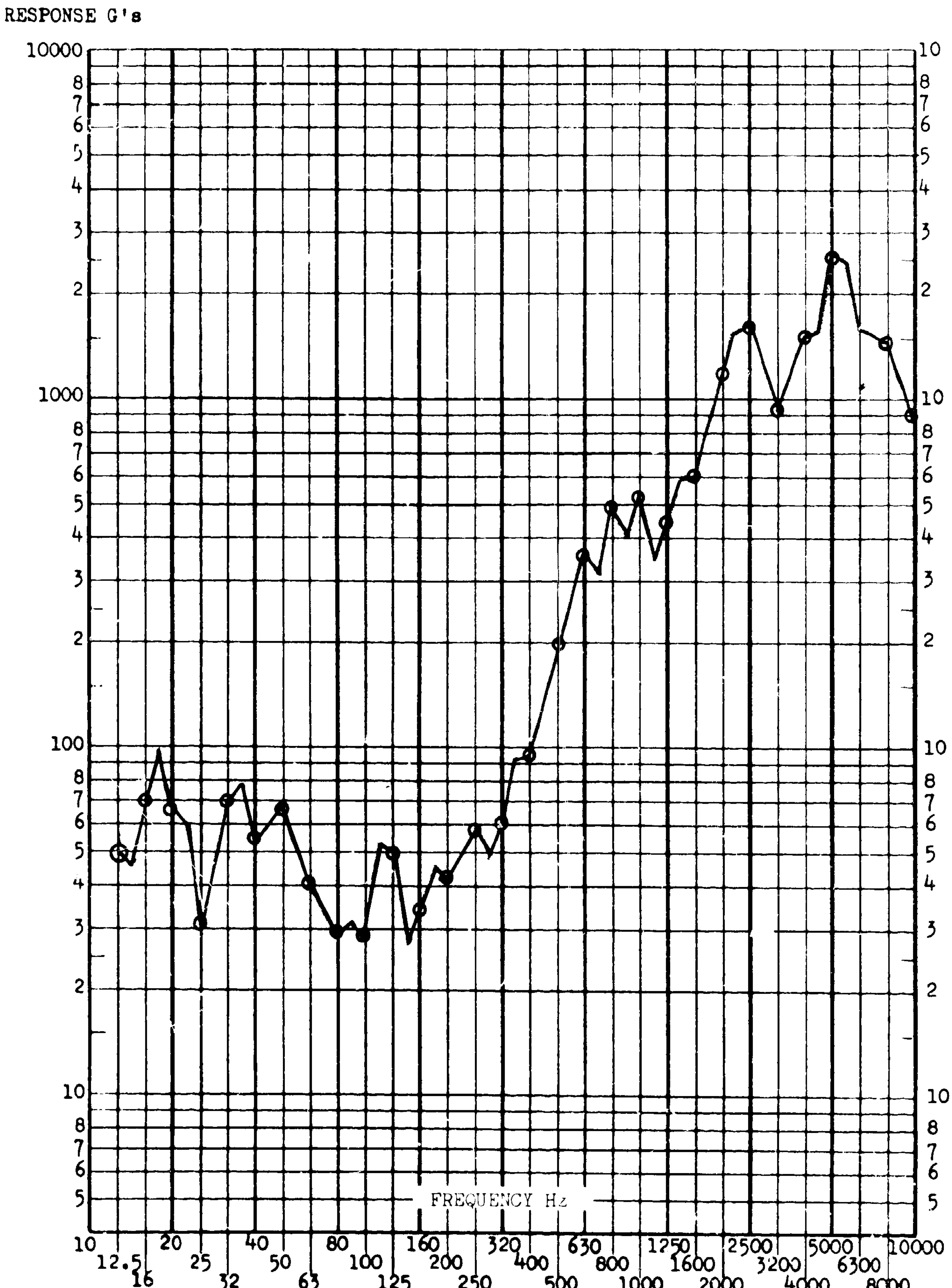



Figure 55 Comparison of 1/6 Octave and 1/3 Octave Analyses -Accelerometer No. 6 From MSS Shroud Separation

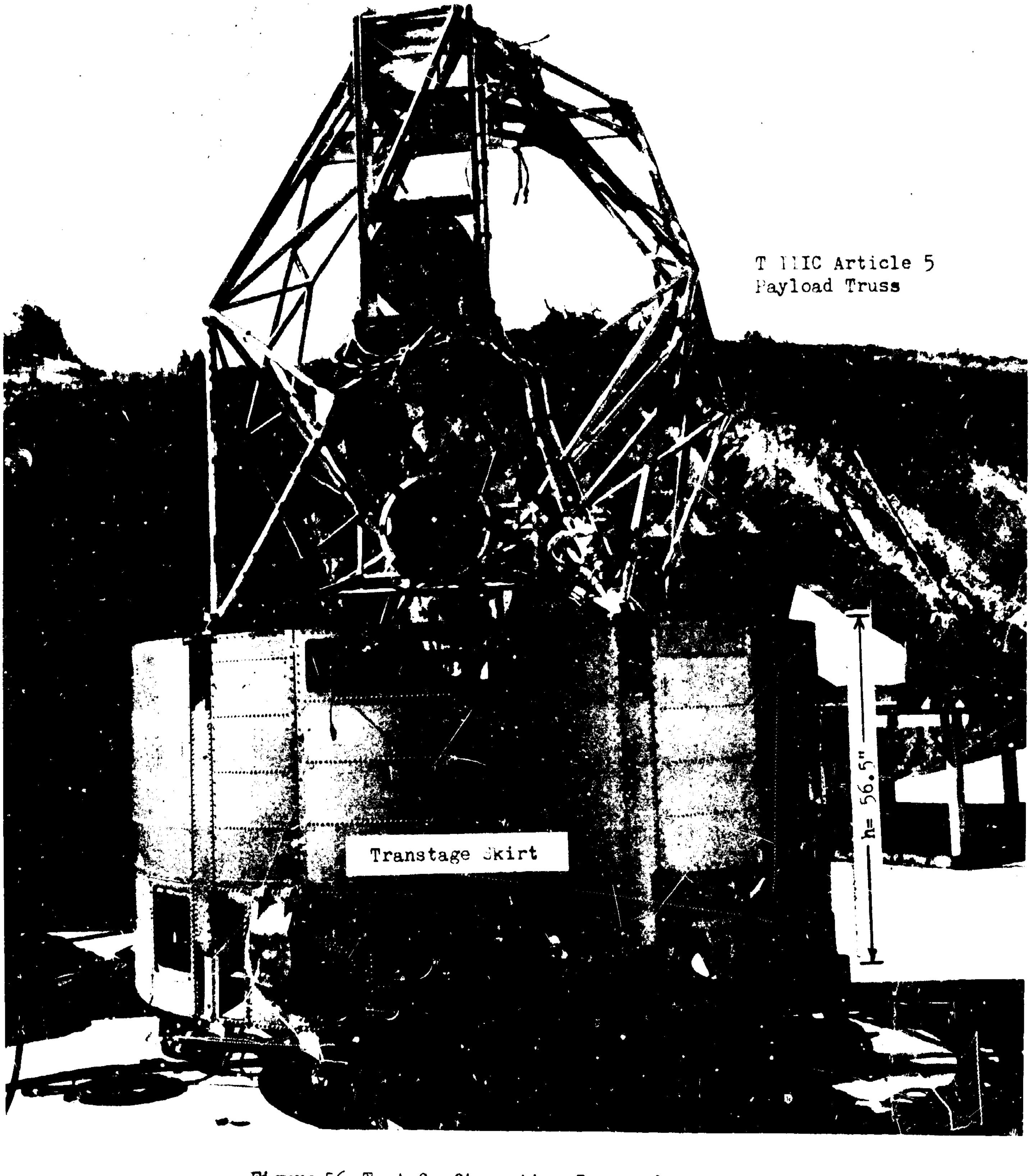



Figure 56 Test Configuration I - Payload Truss Installed on Transtage Skirt

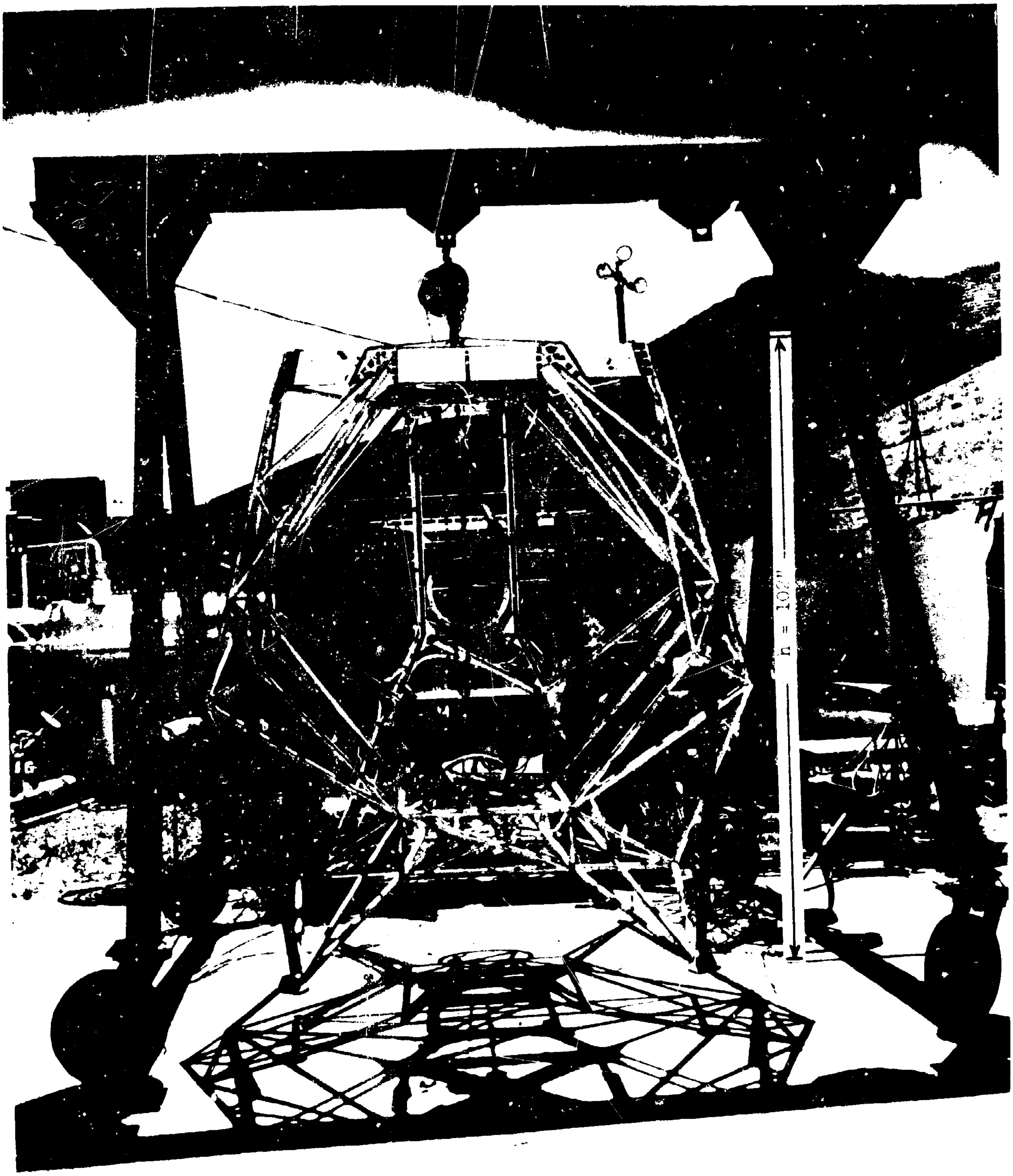



Figure 57 Test Configuration II - Payload Truss Freely Suspended

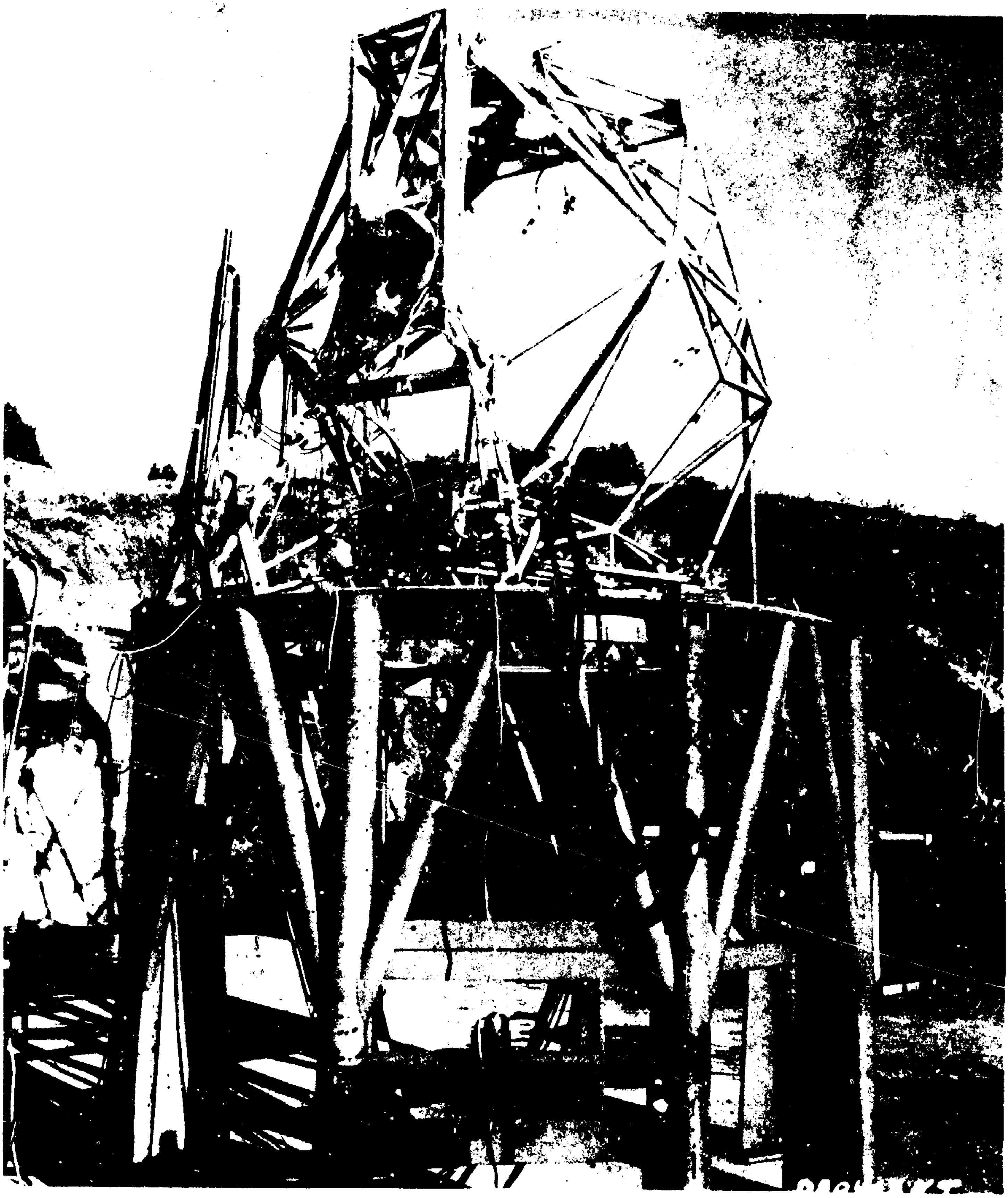


Figure 58 Test Configuration III - Payload Truss Attached to Rigid Support Fixture

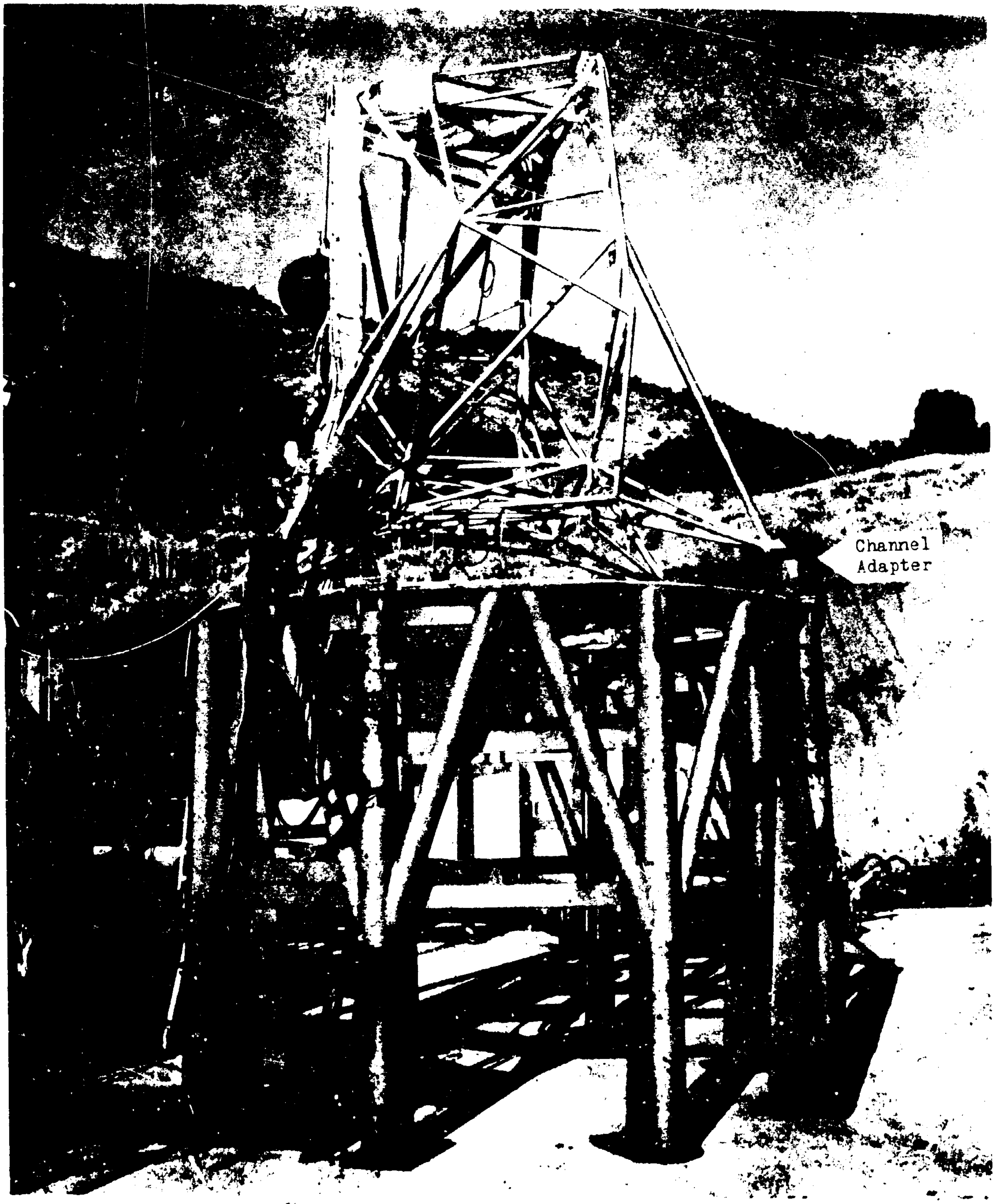



Figure 59 Test Configuration IV - Payload Truss Installed On Channel Adapters

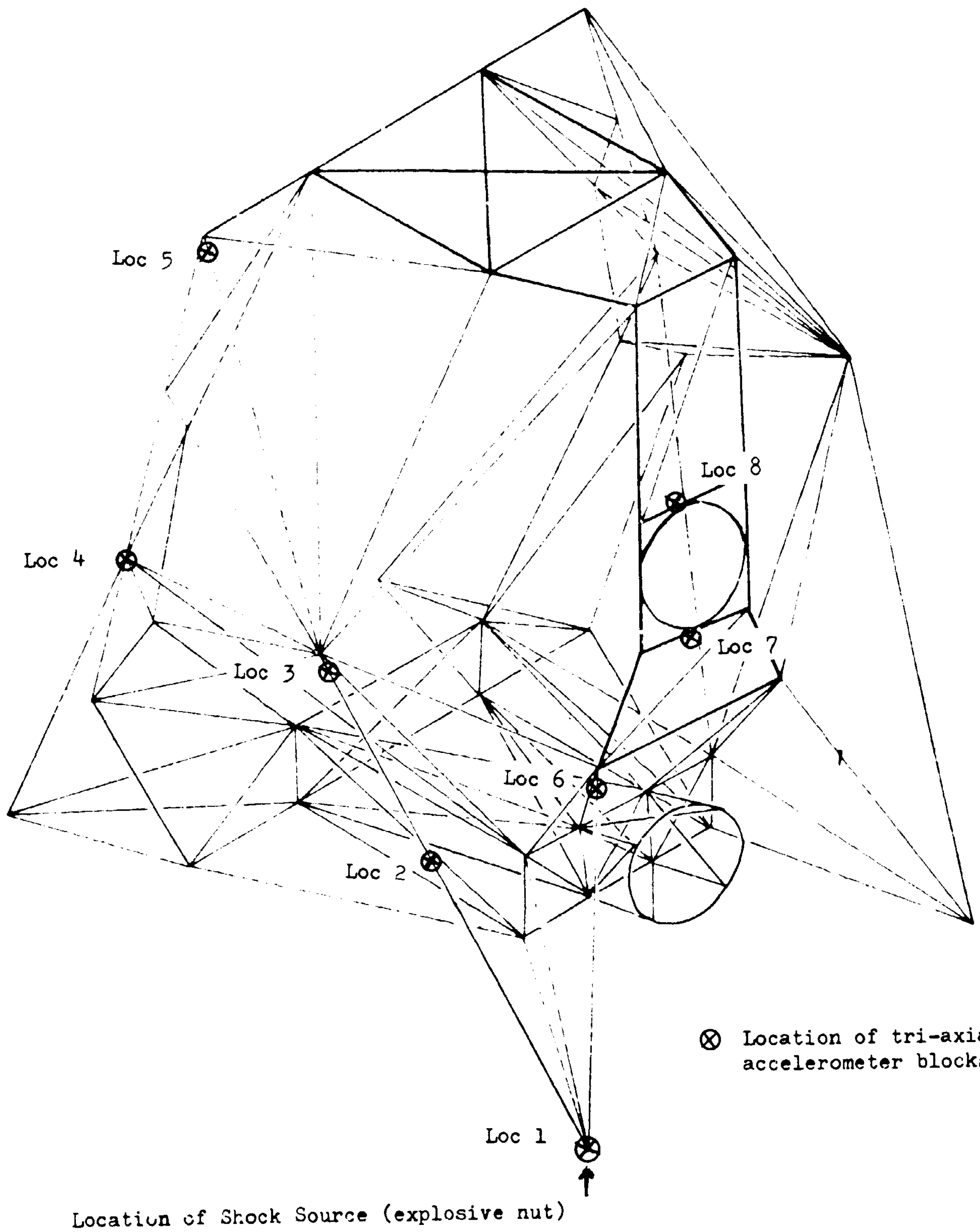



Figure 60 Locations of Accelerometers on Payload Truss

SHOCK TEST ANALYSIS DATA SHEET

TEST ITEM ______________ PART NO. ______________

SERIAL NO. ______________ TEST DATE ______________

SHOCK AXIS 7 Longitudinal SHOCK NO. ______________

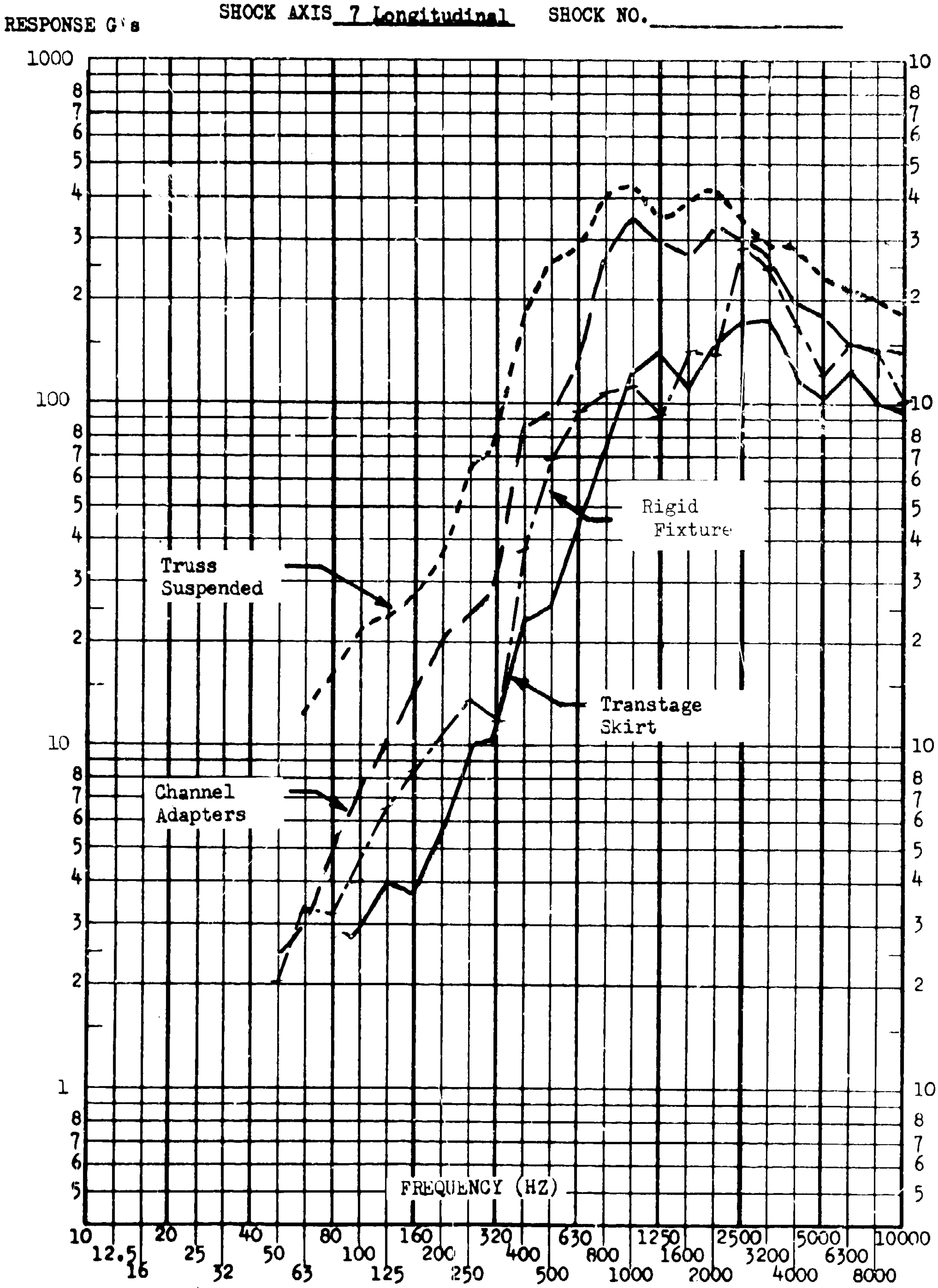



Figure 61 . Comparison of Shock Spectra For Different Test Configurations. Location 7 - Longitudinal

SHOCK TEST ANALYSIS DATA SHEET

TEST ITEM ______________ PART NO. ______________

SERIAL NO. ______________ TEST DATE ______________

SHOCK AXIS 7 Lateral SHOCK NO. ______________

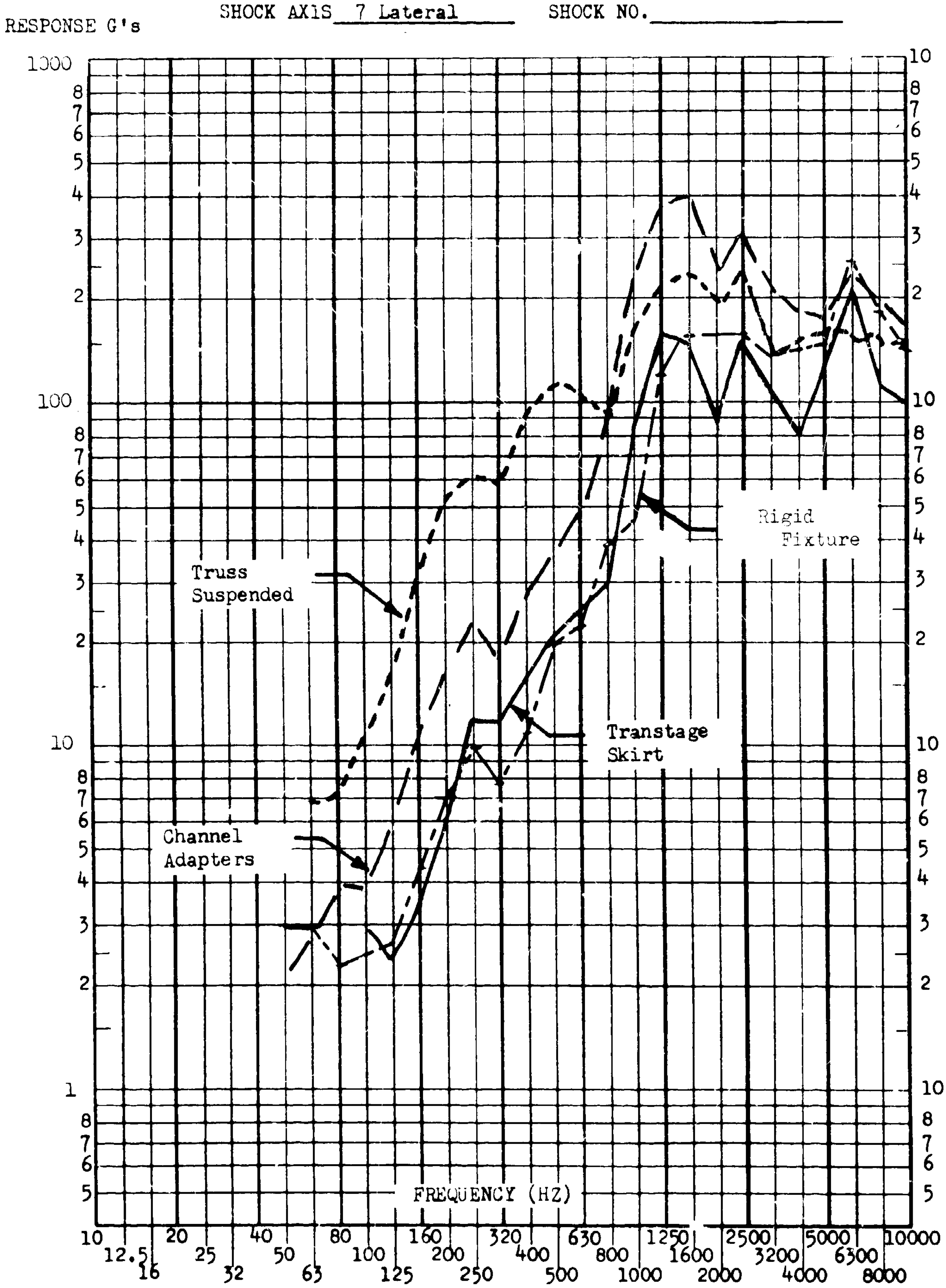



Figure 62. Comparison of Shock Spectra For Different Test Configurations. Location 7 - Lateral

SHOCK TEST ANALYSIS DATA SHEET

TEST ITEM ______________ PART NO. ______________

SERIAL NO. ______________ TEST DATE ______________

SHOCK AXIS 7 Vertical ______ SHOCK NO. ______________

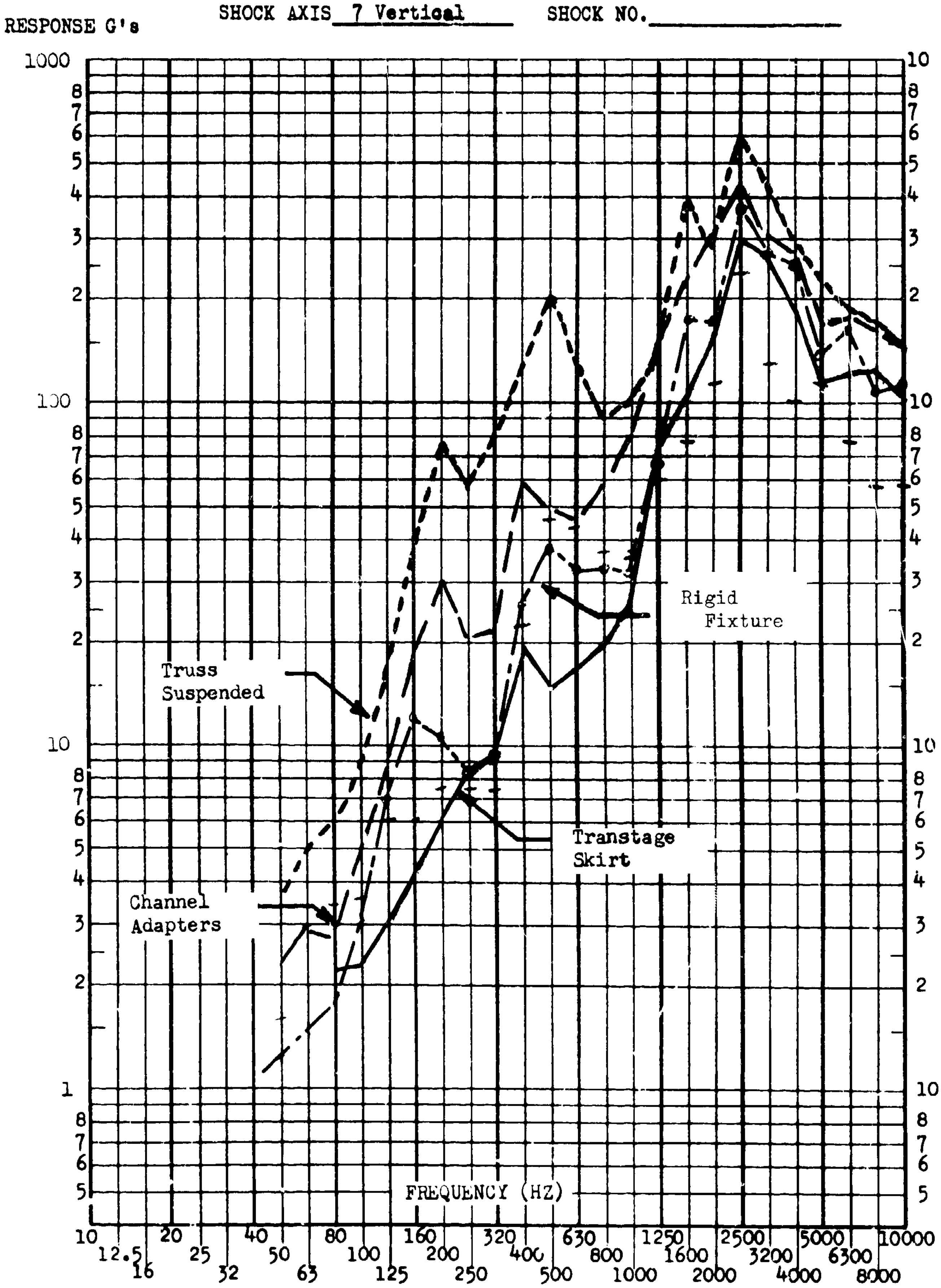



Figure 63 . Comparison of Shock Spectra For Different Test Configurations.
Location 7 - Vertical

SHOCK TEST ANALYSIS DATA SHEET

TEST ITEM ______________ PART NO. ______________

SERIAL NO. ______________ TEST DATE ______________

SHOCK AXIS 8 Longitudinal SHOCK NO. ______________

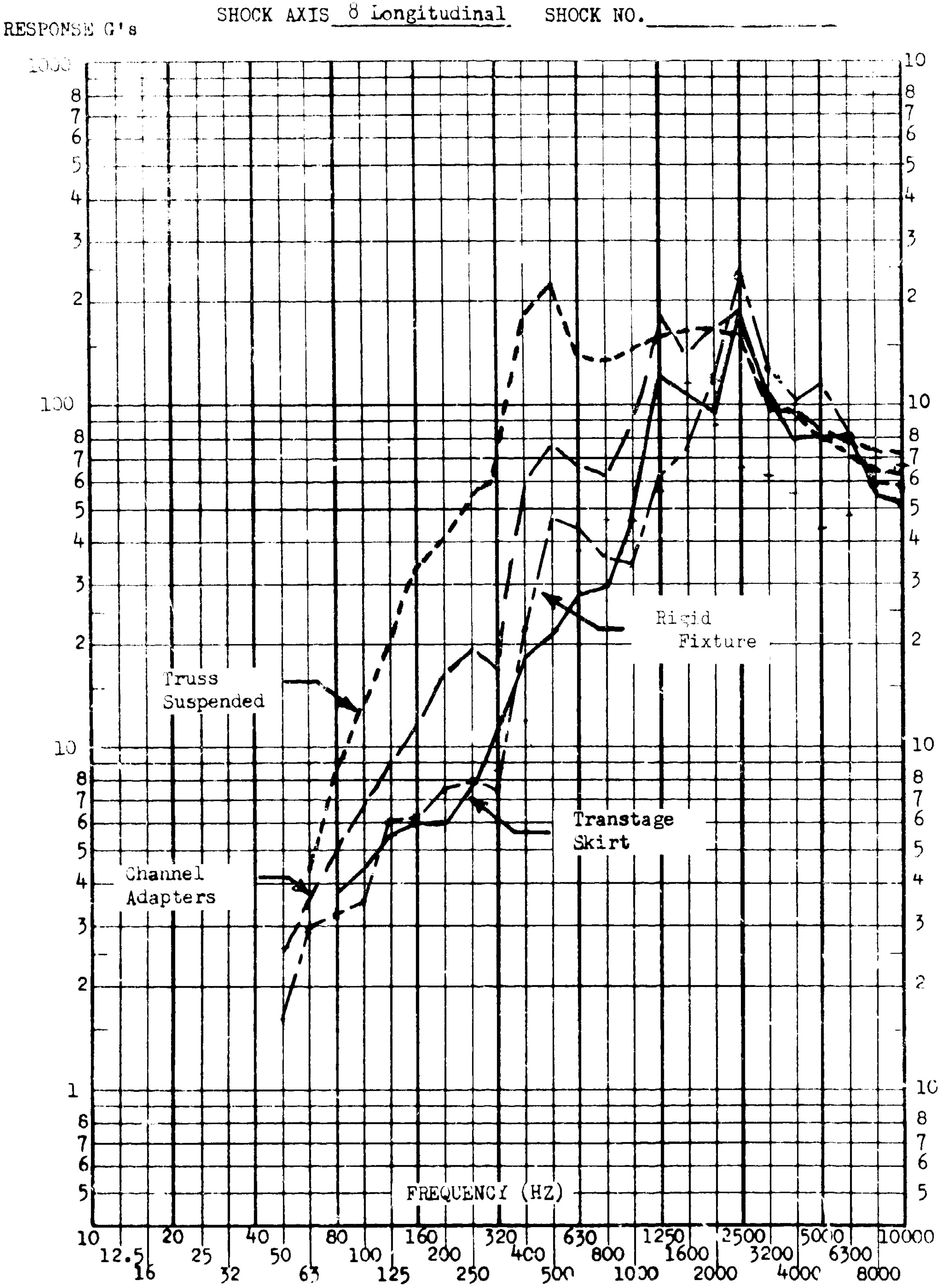



Figure 64. Comparison of Shock Spectra For Different Test Configurations.
Location 8 - Longitudinal

SHOCK TEST ANALYSIS DATA SHEET

TEST ITEM ________________ PART NO. ________________

SERIAL NO. ________________ TEST DATE ________________

SHOCK AXIS 8 Lateral SHOCK NO. ________________

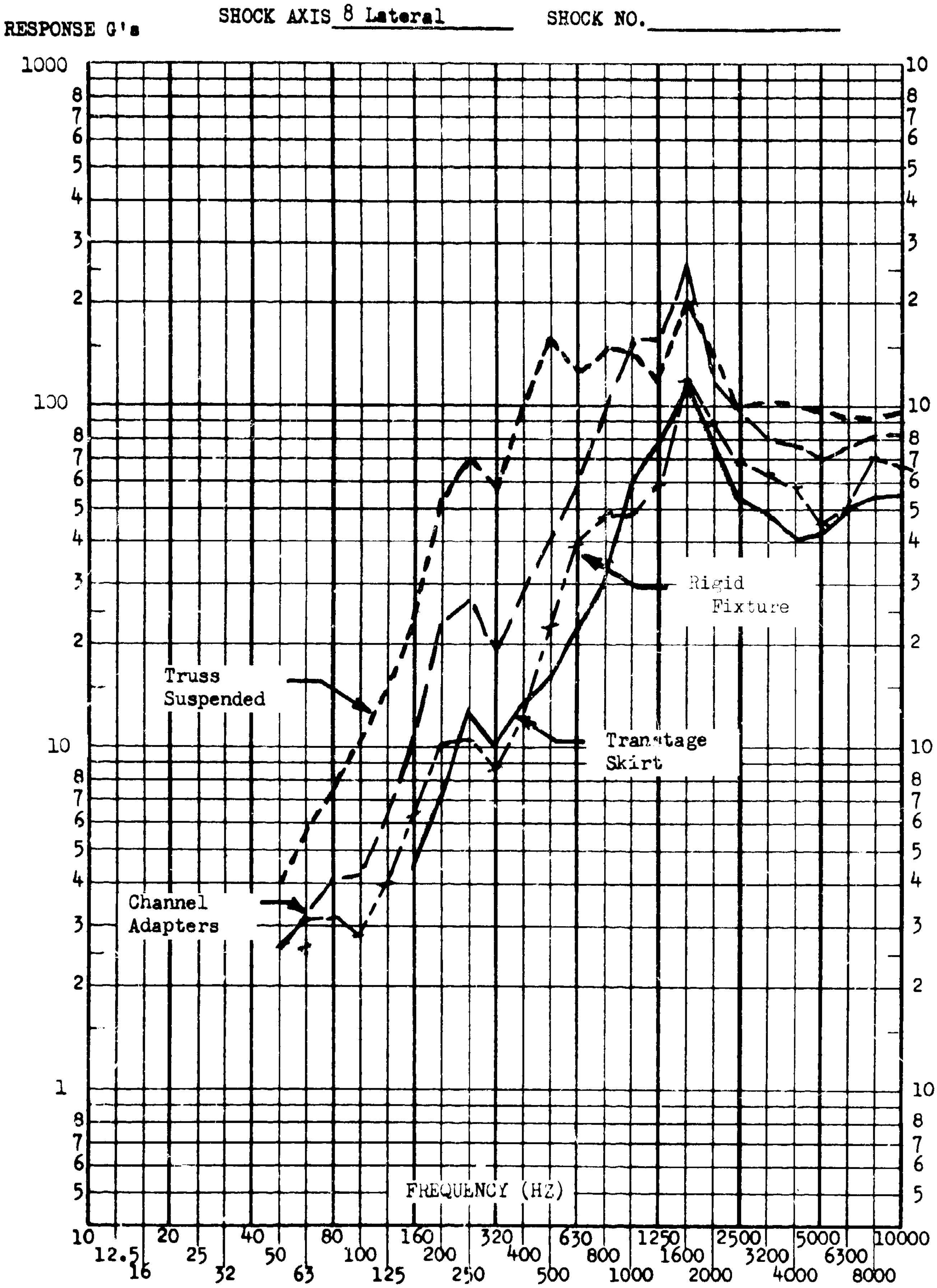



Figure 65 . Comparison of Shock Spectra For Different Test Configurations. Location 8 - Lateral

SHOCK TEST ANALYSIS DATA SHEET

TEST ITEM ________________ PART NO.________________

SERIAL NO.________________ TEST DATE________________

SHOCK AXIS 8 Vertical ________ SHOCK NO.________________

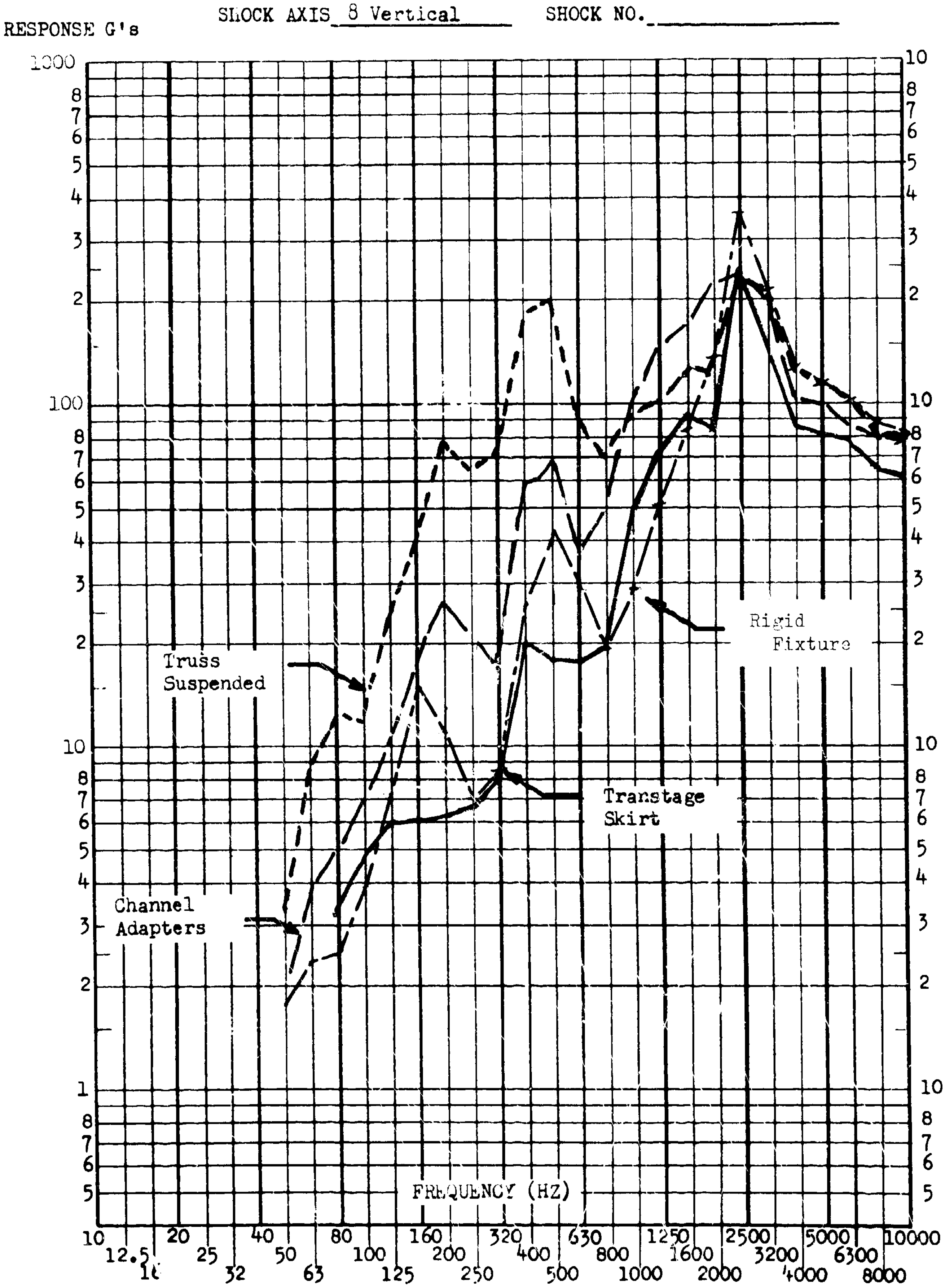



Figure 66 . Comparison of Shock Spectra For Different Test Configurations. Location 3 - Vertical

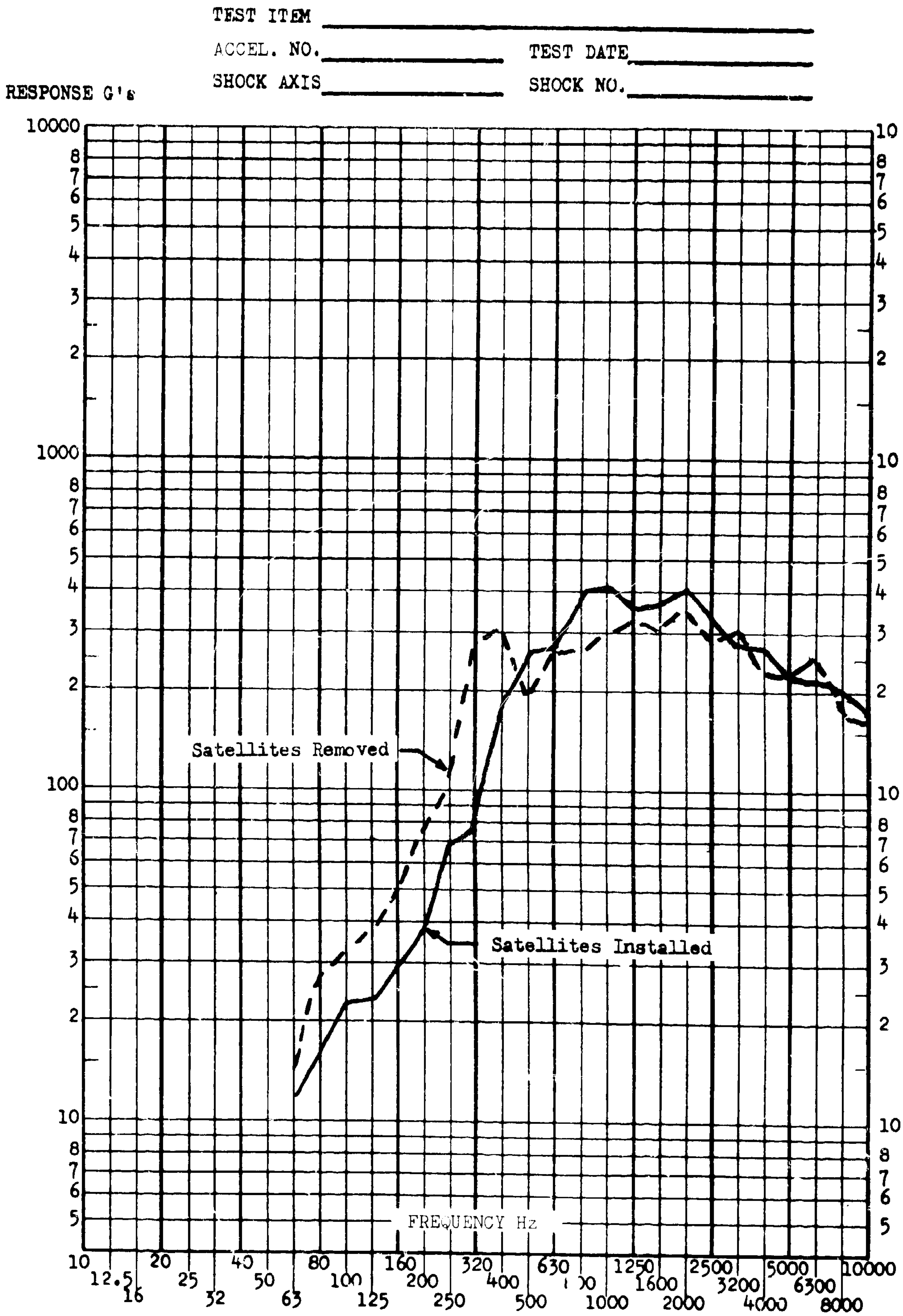



Figure 67 Comparison of Shock Spectra For Location 7 - Longitudinal

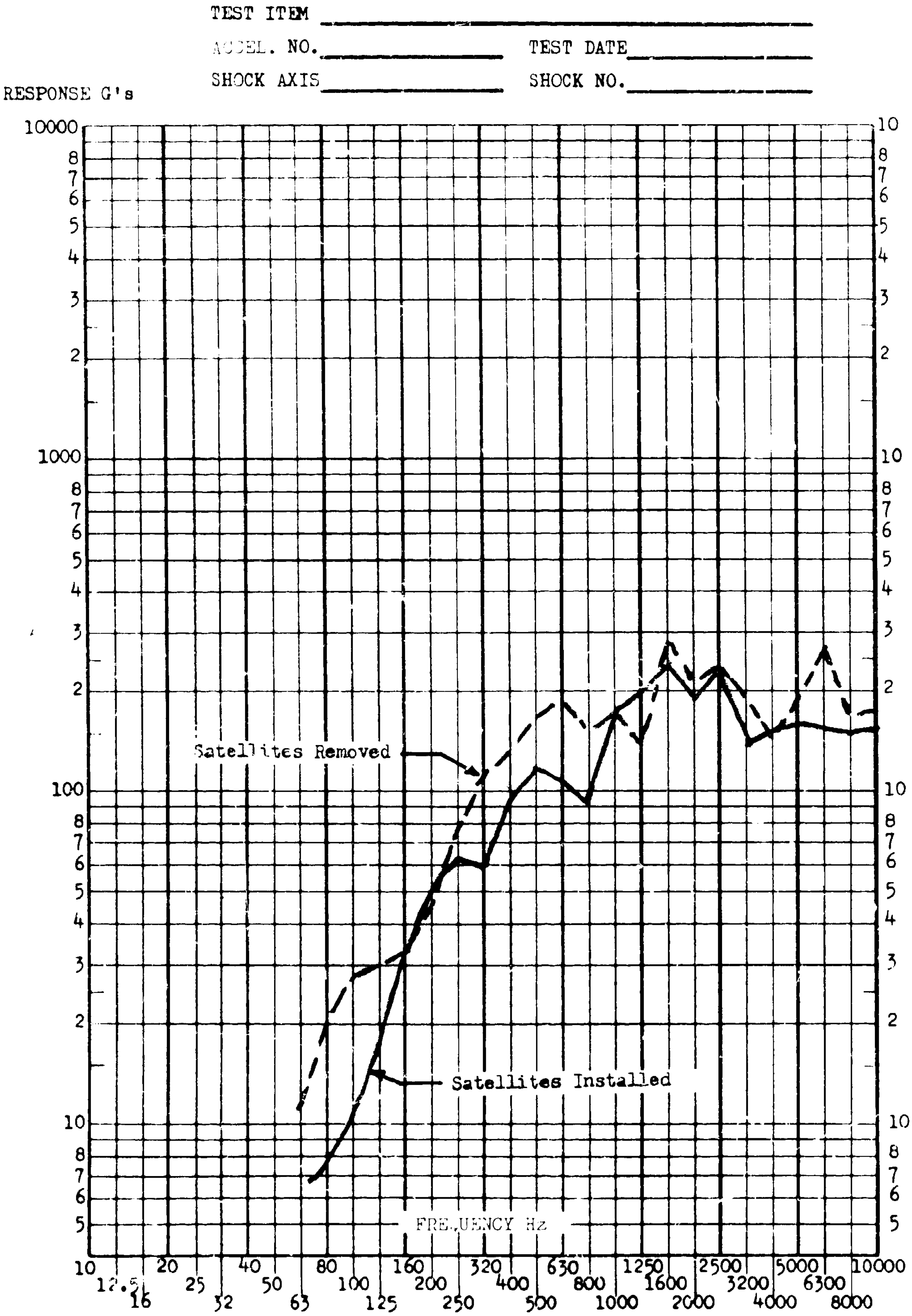



Figure 68 Comparison of Shock Spectra For Location 7 - Lateral

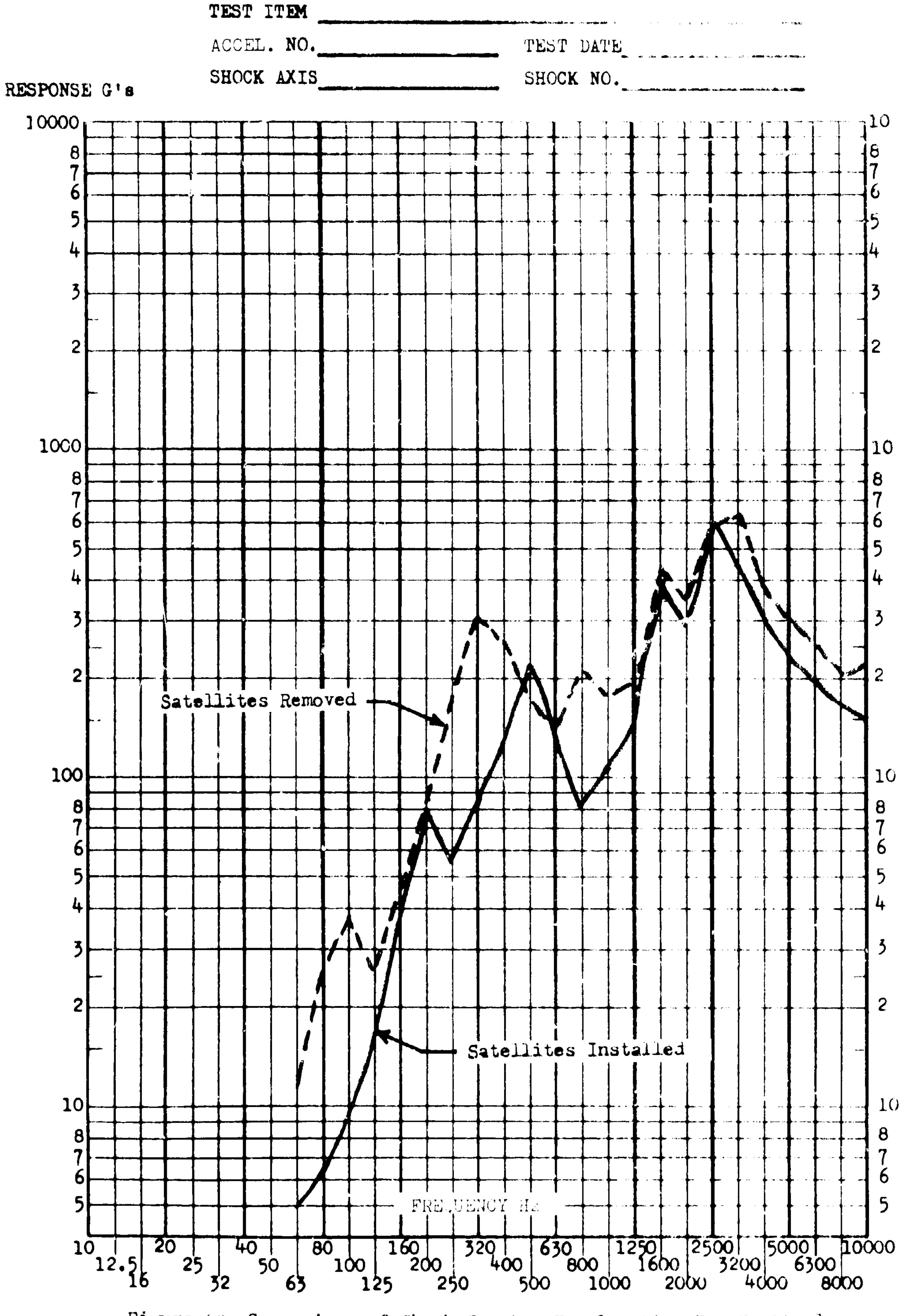



Figure 69 Comparison of Shock Spectra For Location 7 - Vertical

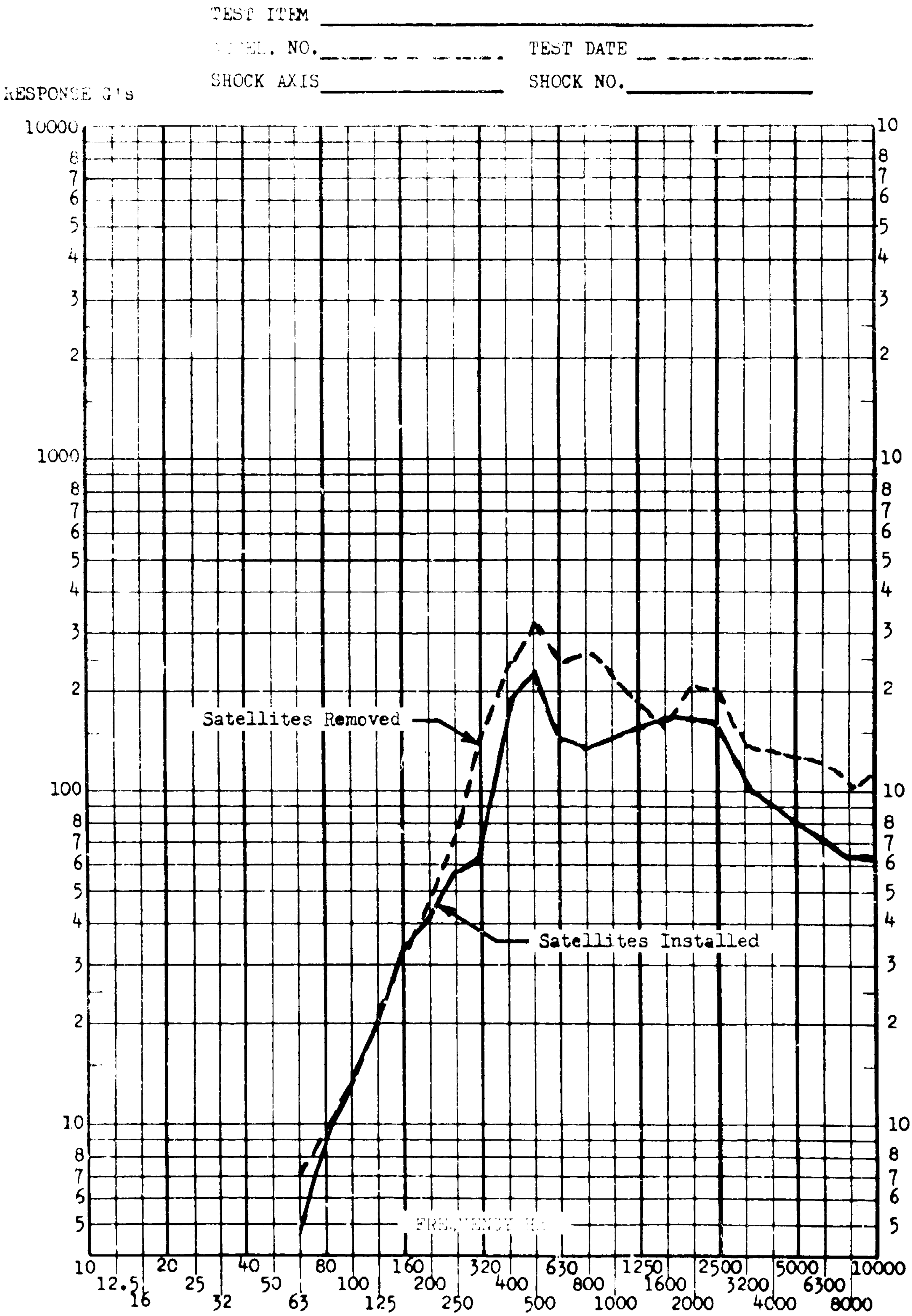



Figure 70 Comparison of Shock Spectra For Location 8 - Longitudinal

TEST ITEM ______________

[illegible] NO. ______________ TEST DATE ______________

SHOCK AXIS ______________ SHOCK NO. ______________

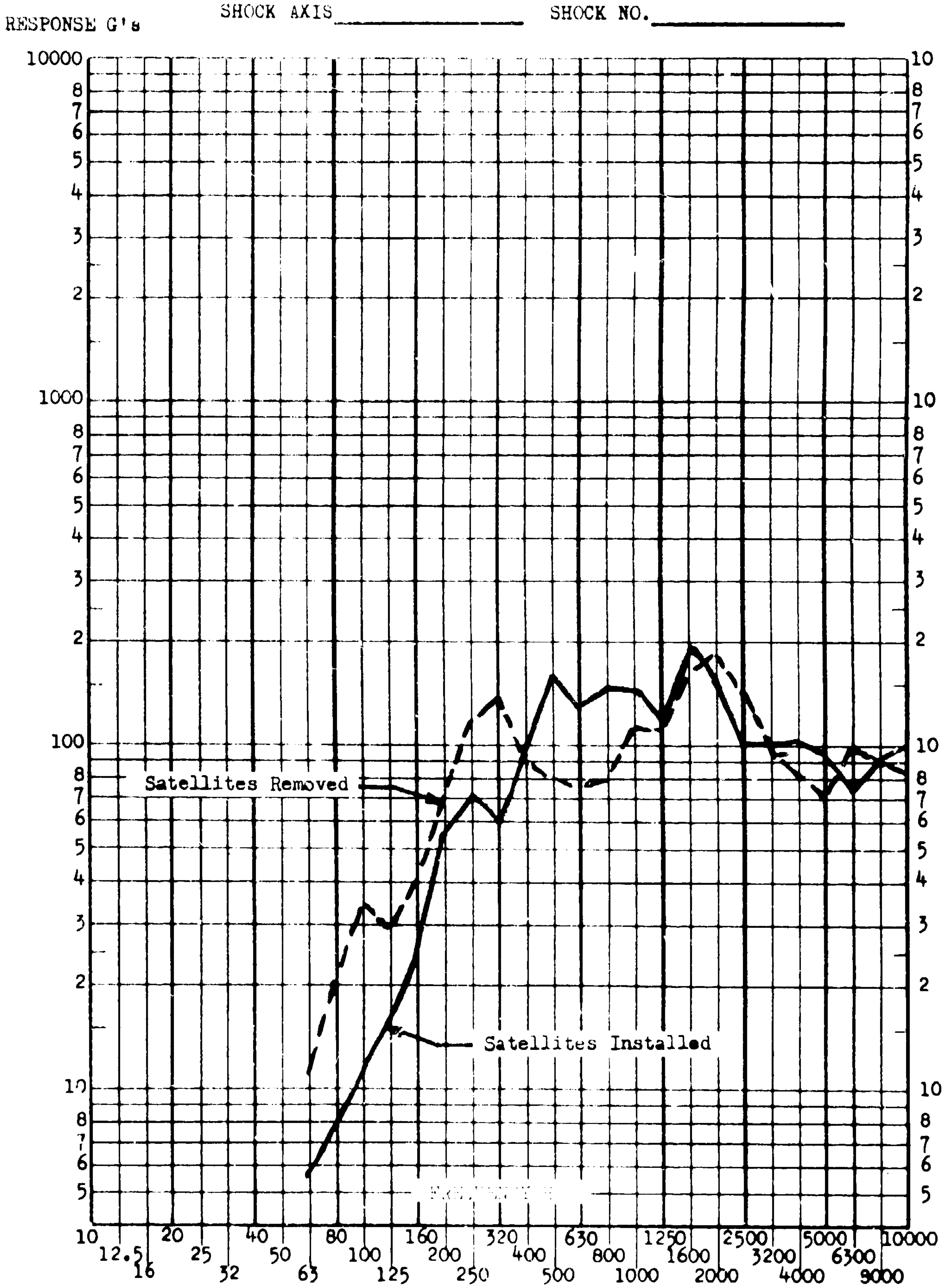



Figure 71 . Comparison of Shock Spectra For Location 8 - Lateral

TEST FIRM
... NO. TEST DATE
SHOCK AXIS SHOCK NO.

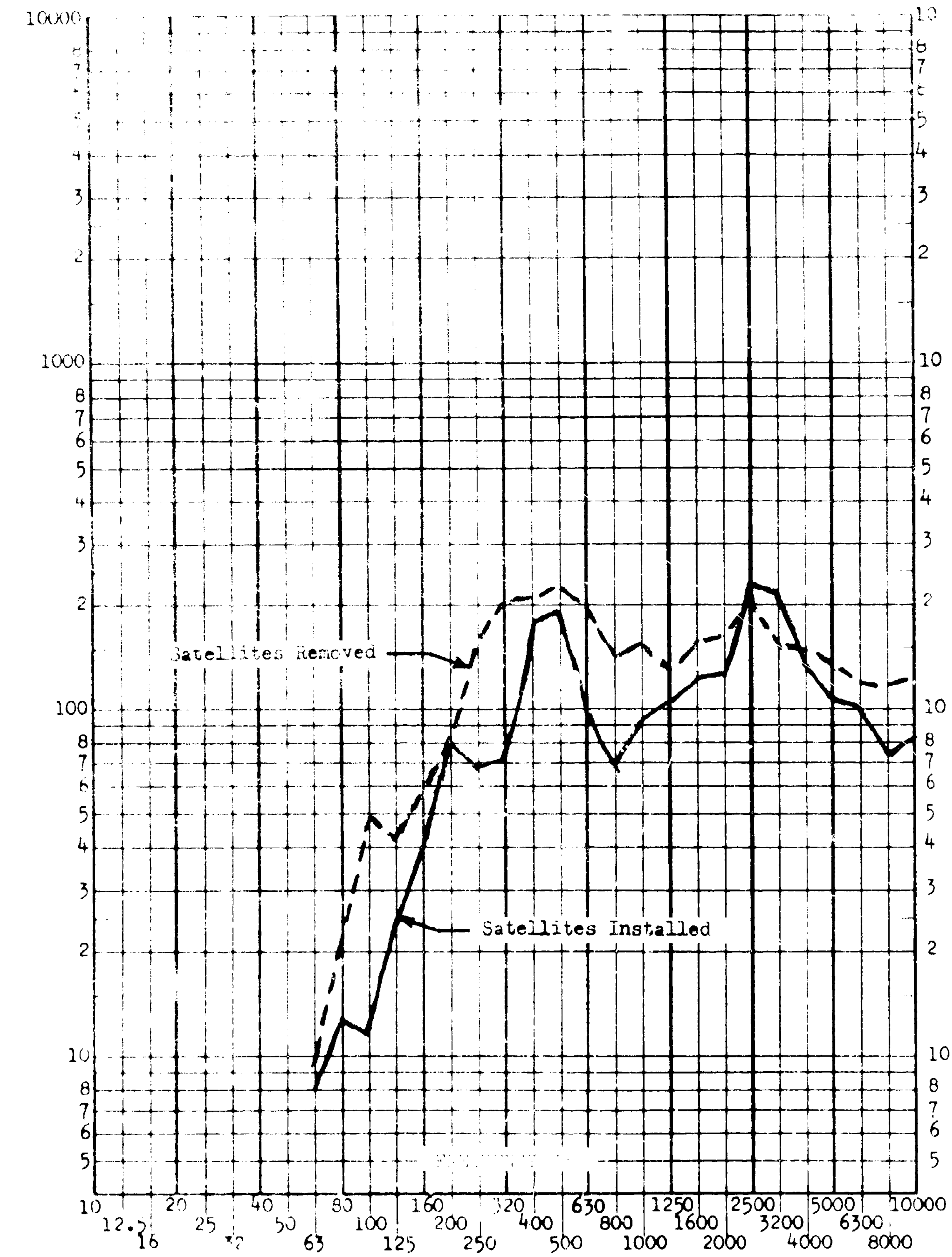



Figure .. Comparison of Shock Spectra For Location C - Vertical

TEST ITEM

ACCEL. NO. TEST DATE

SHOCK AXIS SHOCK NO.

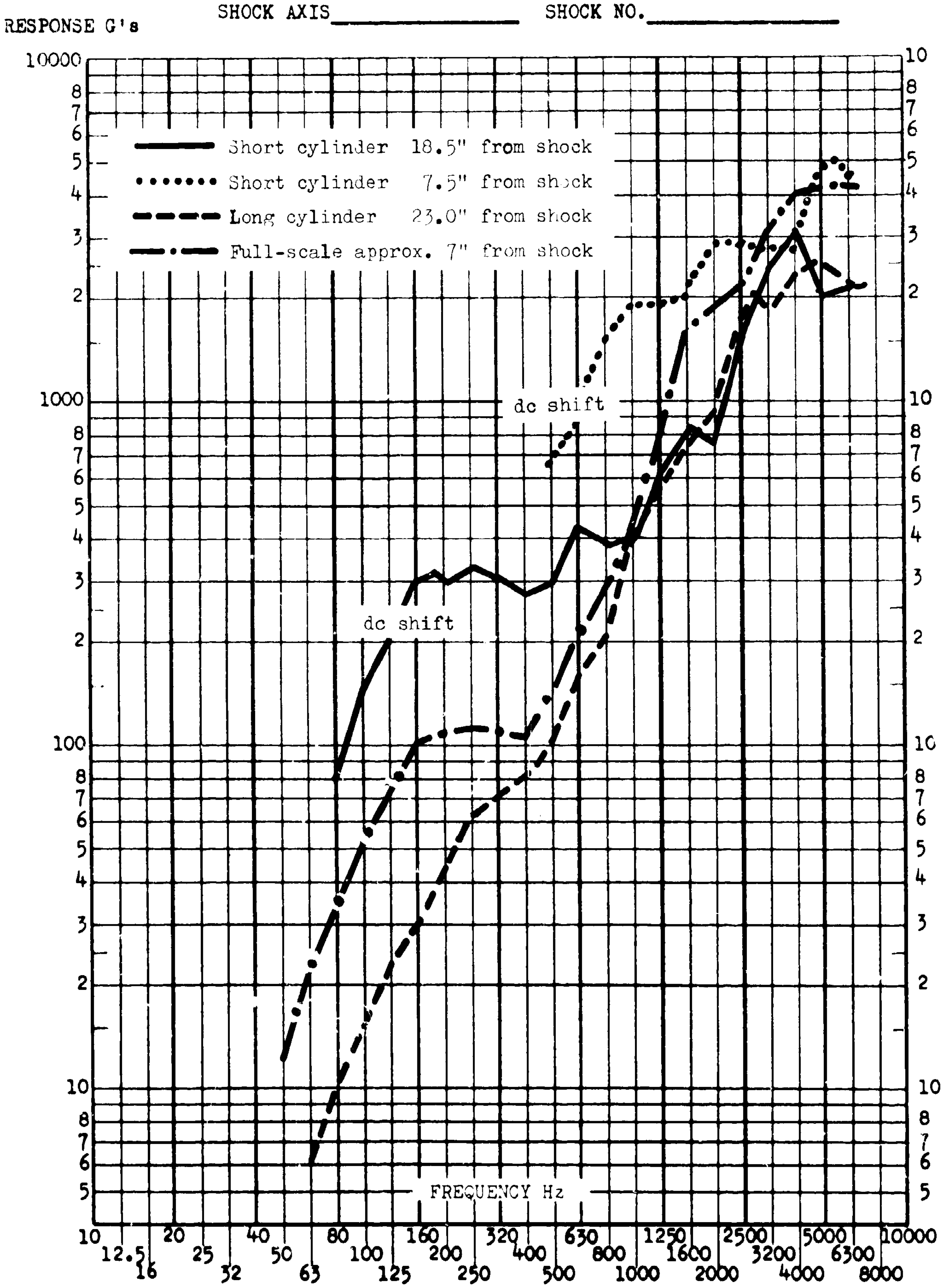



Figure 73 Comparison of Spartan Test Data

SHOCK TEST ANALYSIS DATA SHEET

PAGE NO. ____
TEST NO. ____

TEST ITEM ____________ PART NO. ____________

SERIAL NO. ____________ TEST DATE ____________

Shock Axis Accelerometer 1 Longitudinal Axis SHOCK NO. ____________

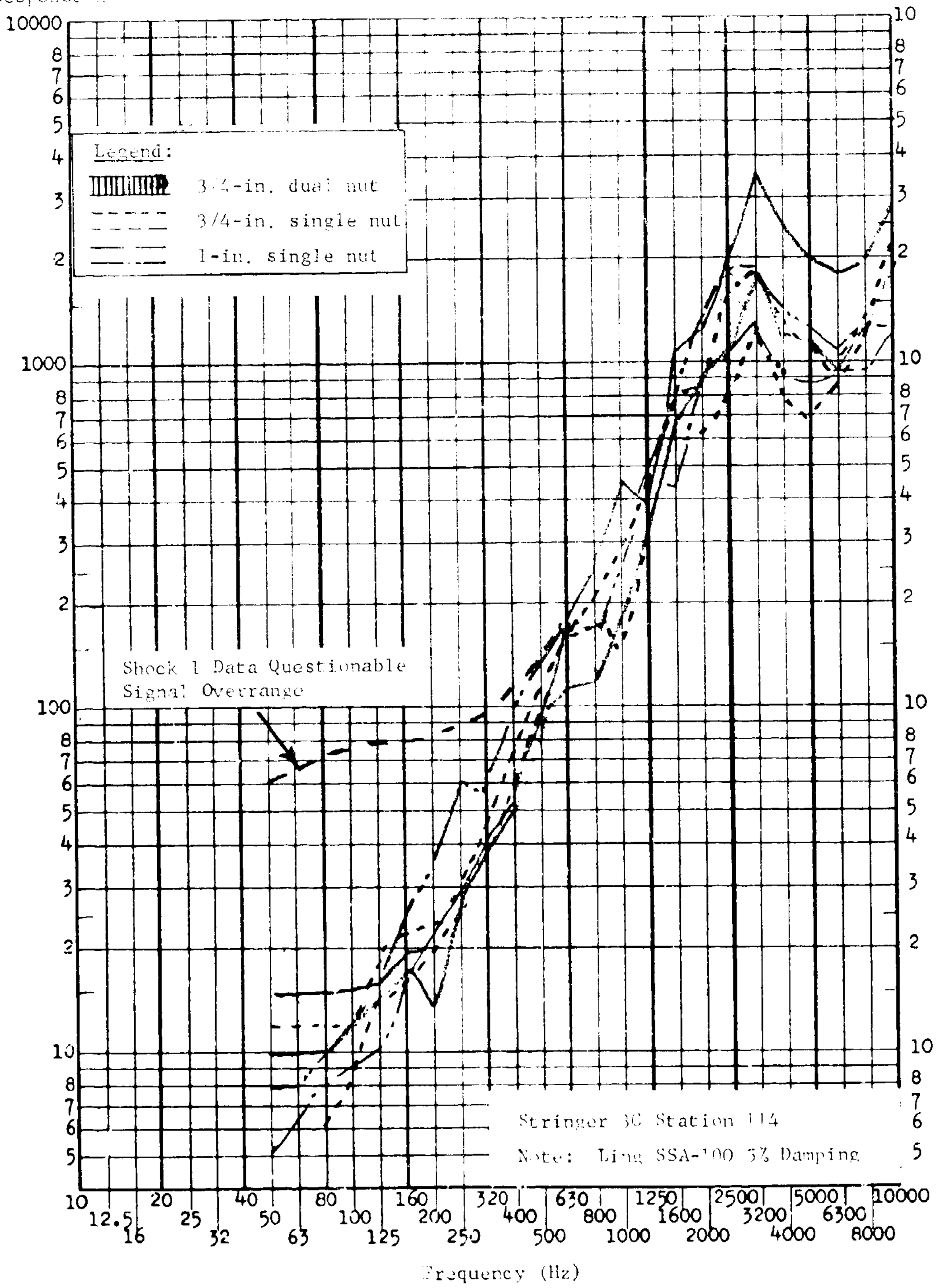



Figure 74 Comparison of Shock Spectra Envelopes -- Accelerometer 1

PAGE NO. ____
TEST NO. ____

**SHOCK TEST ANALYSIS DATA SHEET**

TEST ITEM ______________ PART NO. ______________

SERIAL NO. ______________ TEST DATE ______________

Shock Axis Accelerometer 2 Radial SHOCK NO. ______________

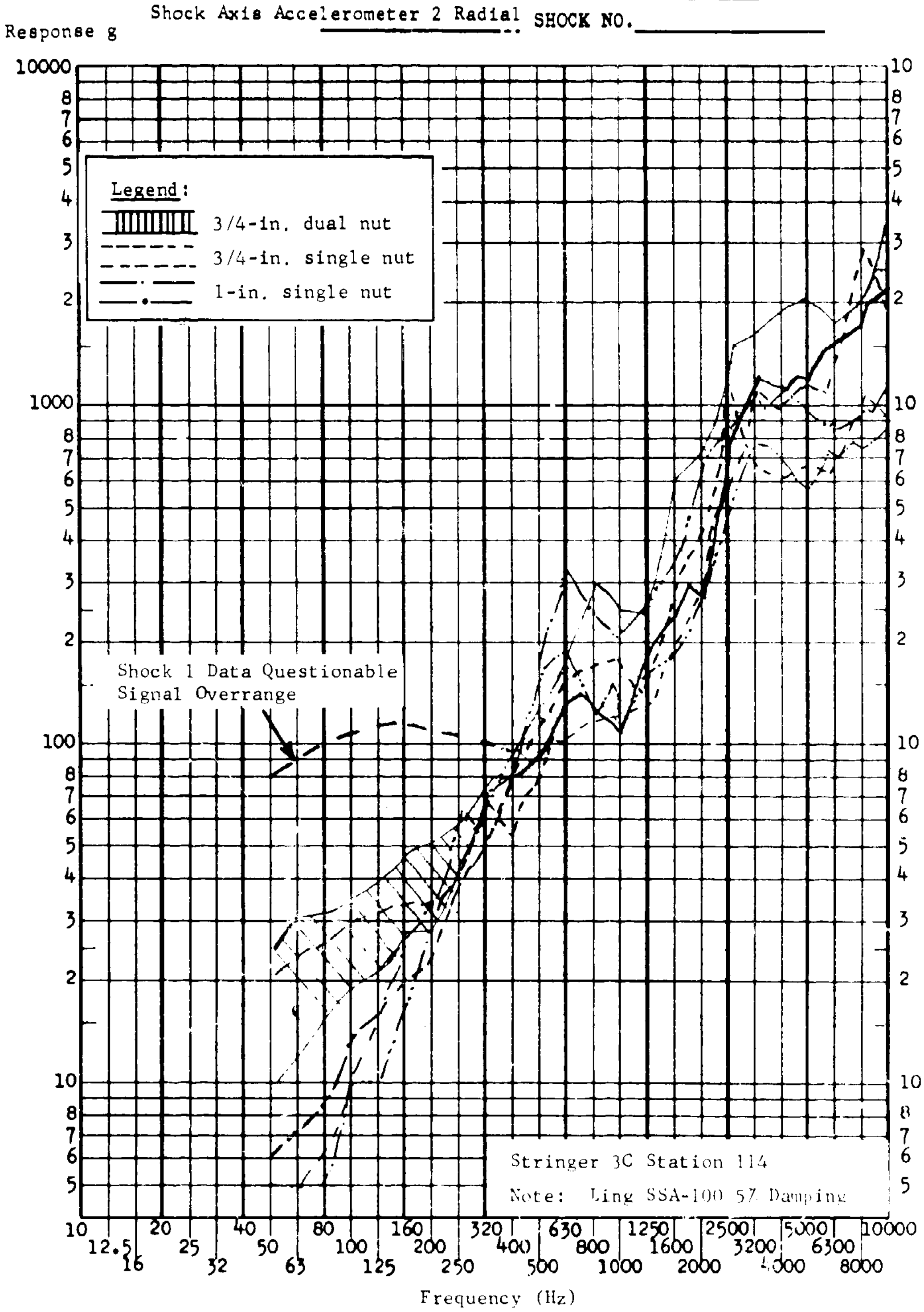



Figure 75 Comparison of Shock Spectra Envelopes -- Accelerometer 2

**SHOCK TEST ANALYSIS DATA SHEET**

PAGE NO. _____

TEST NO. _____

TEST ITEM ____________ PART NO.____________

SERIAL NO.____________ TEST DATE____________

Shock Axis Accelerometer 3 Tangential SHOCK NO.____________

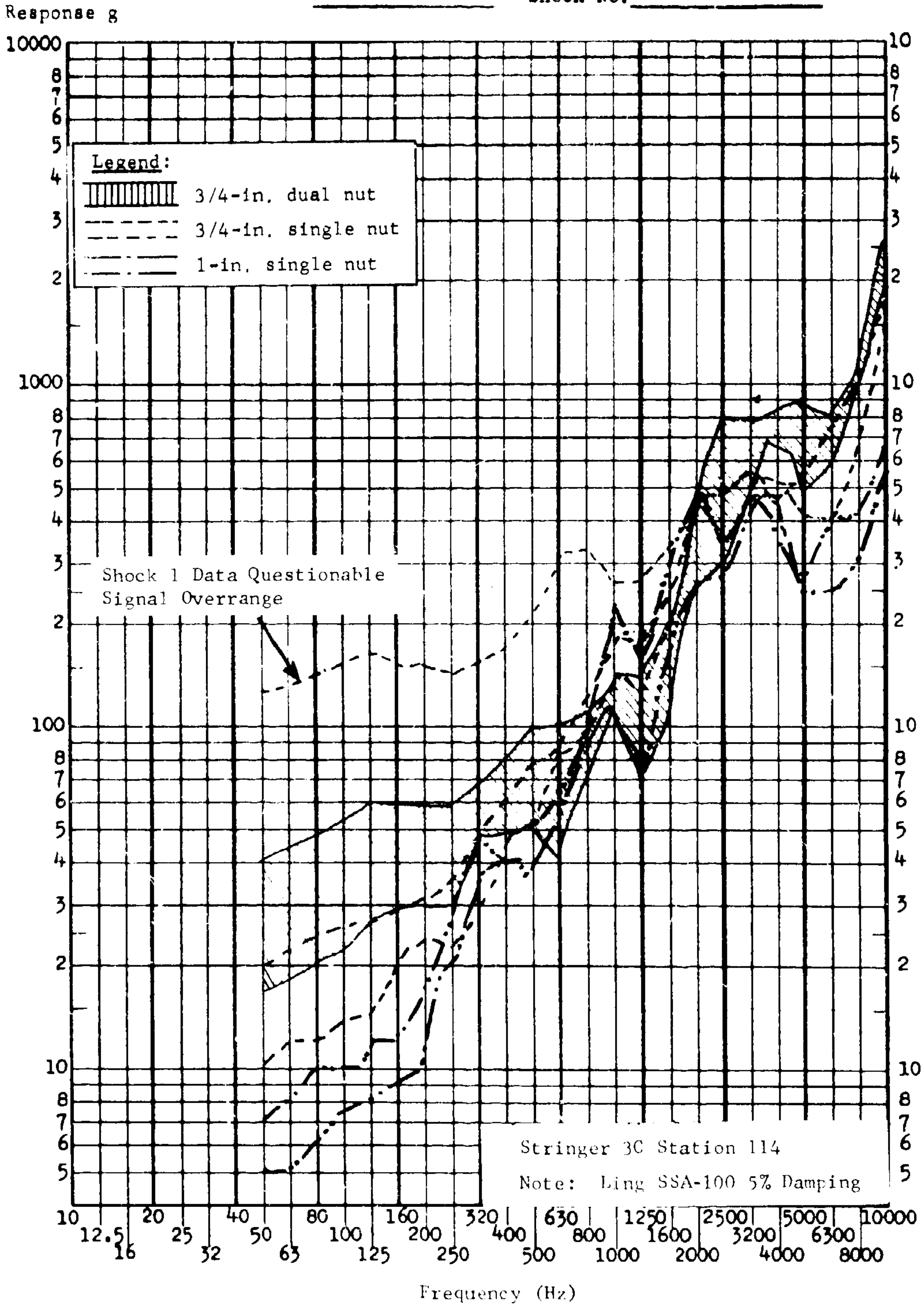



Figure 76 Comparison of Shock Spectra Envelopes -- Accelerometer 3

PAGE NO. ______
TEST NO. ______

## SHOCK TEST ANALYSIS DATA SHEET

TEST ITEM ______________ PART NO. ______________

SERIAL NO. ______________ TEST DATE ______________

Shock Axis Accelerometer 4 Longitudinal SHOCK NO. ______________

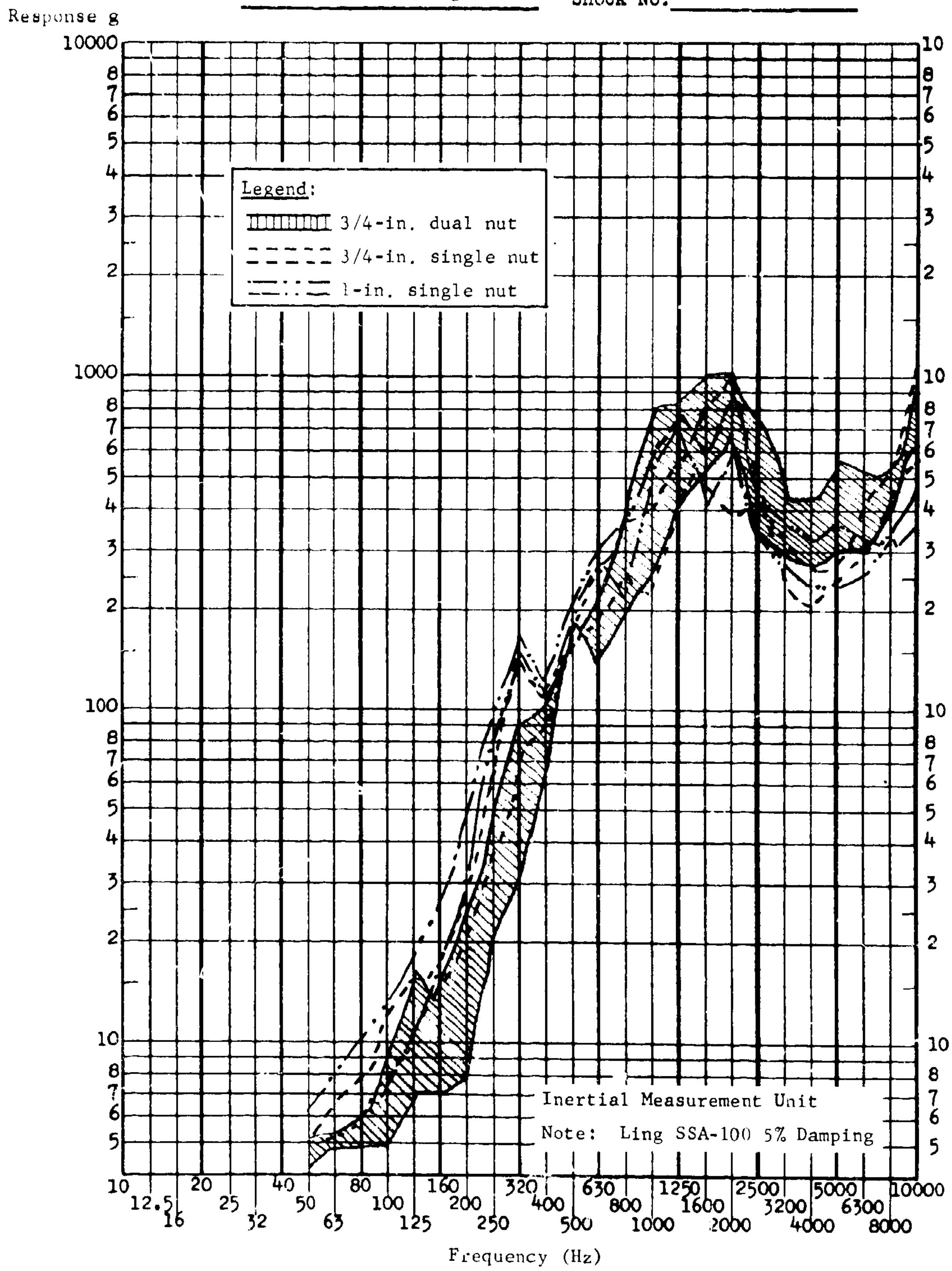



Figure 77 Comparison of Shock Spectra Envelopes -- Accelerometer 4

PAGE NO. _____

SHOCK TEST ANALYSIS DATA SHEET

TEST NO. _____

TEST ITEM __________ PART NO. __________

SERIAL NO. __________ TEST DATE __________

Shock Axis Accelerometer 5 Vertical SHOCK NO. __________

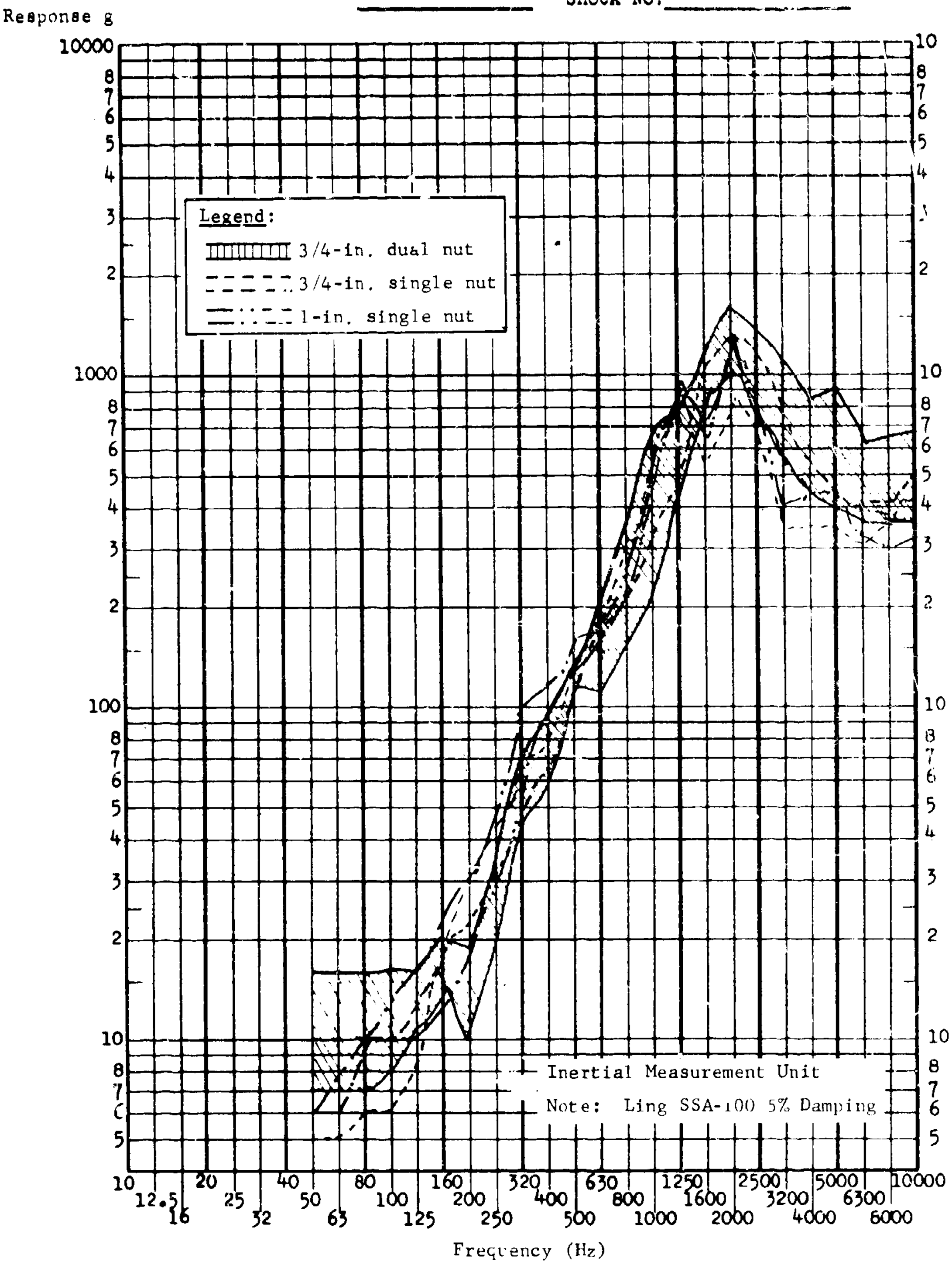



Figure 78 Comparison of Shock Spectra Envelopes -- Accelerometer 5

SHOCK TEST ANALYSIS DATA SHEET

PAGE NO. ______

TEST NO. ______

TEST ITEM ______________ PART NO. ______________

SERIAL NO. ______________ TEST DATE ______________

Shock Axis Accelerometer 6 ______________ SHOCK NO. ______________

Response g

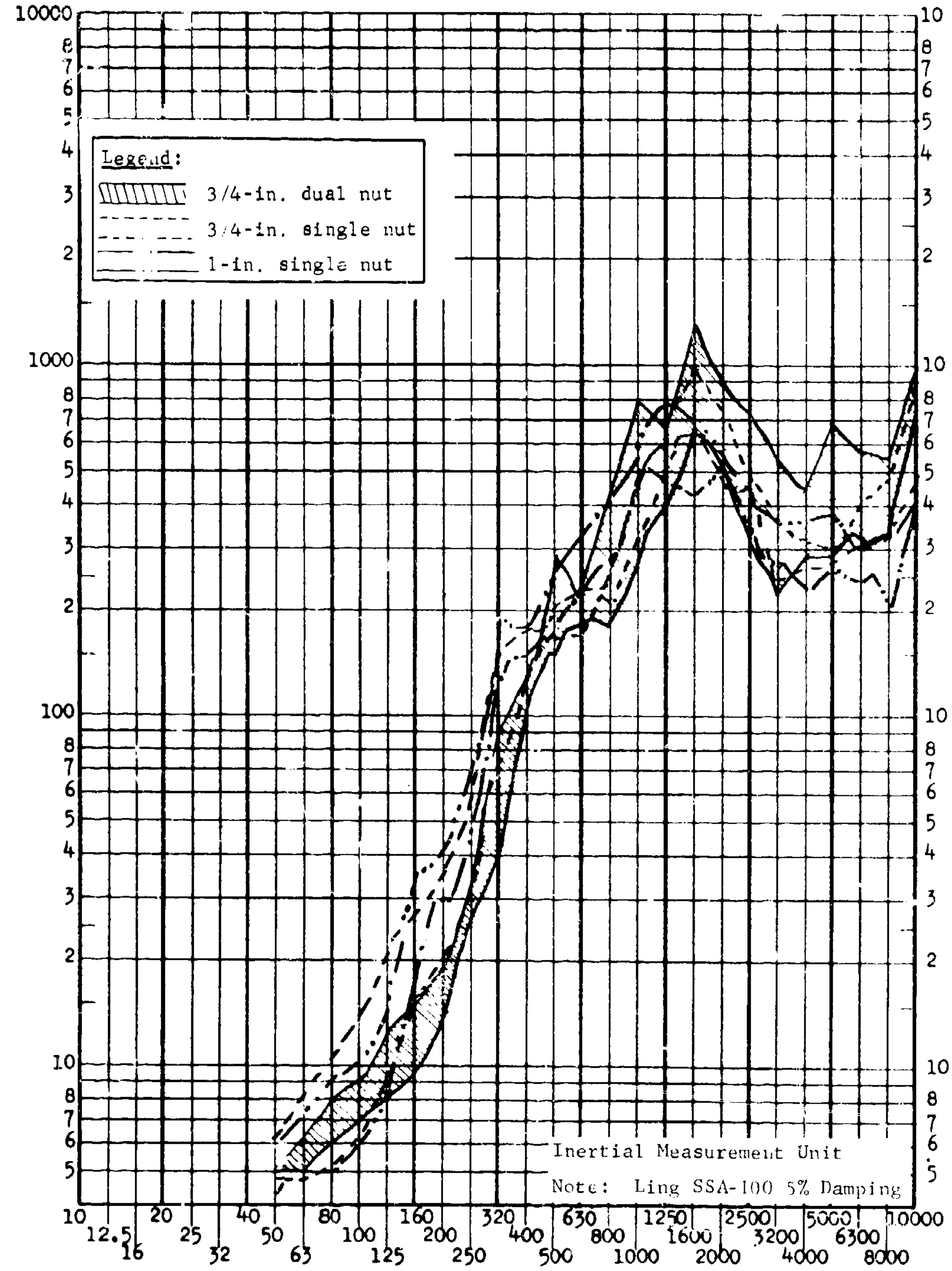



Figure 79 Comparison of Shock Spectra Envelopes -- Accelerometer 6

PAGE NO. ______

SHOCK TEST ANALYSIS DATA SHEET

TEST NO. ______

TEST ITEM ______ PART NO. ______

SERIAL NO. ______ TEST DATE ______

Shock Axis Accelerometer 7 Longitudinal SHOCK NO. ______

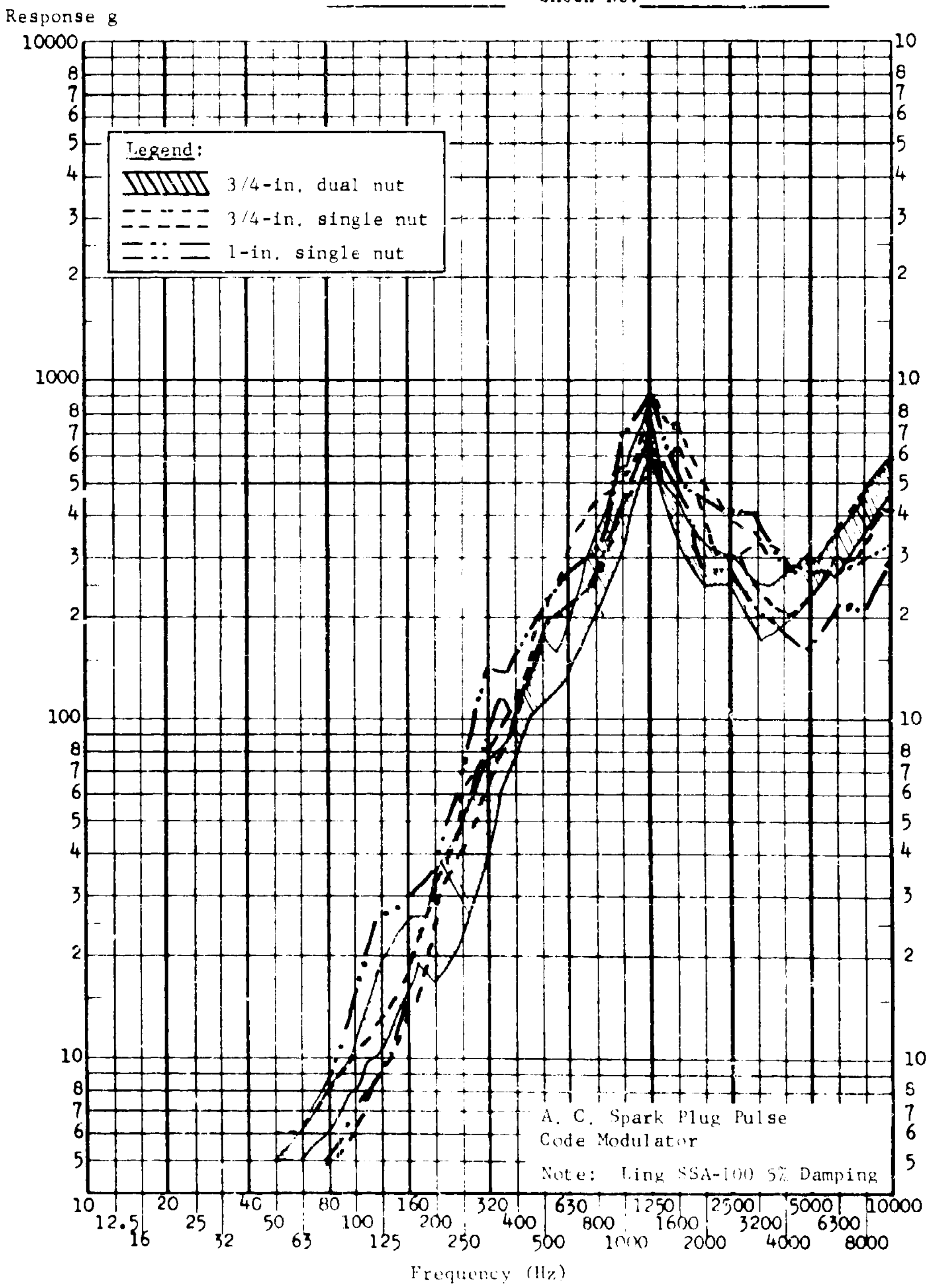



Figure 39 Comparison of Shock Spectra Envelopes -- Accelerometer 7

PAGE NO. ____
TEST NO. ____

SHOCK TEST ANALYSIS DATA SHEET

TEST ITEM ______________ PART NO. ______________

SERIAL NO. ______________ TEST DATE ______________

Shock Axis Accelerometer 8 Vertical SHOCK NO. ______________

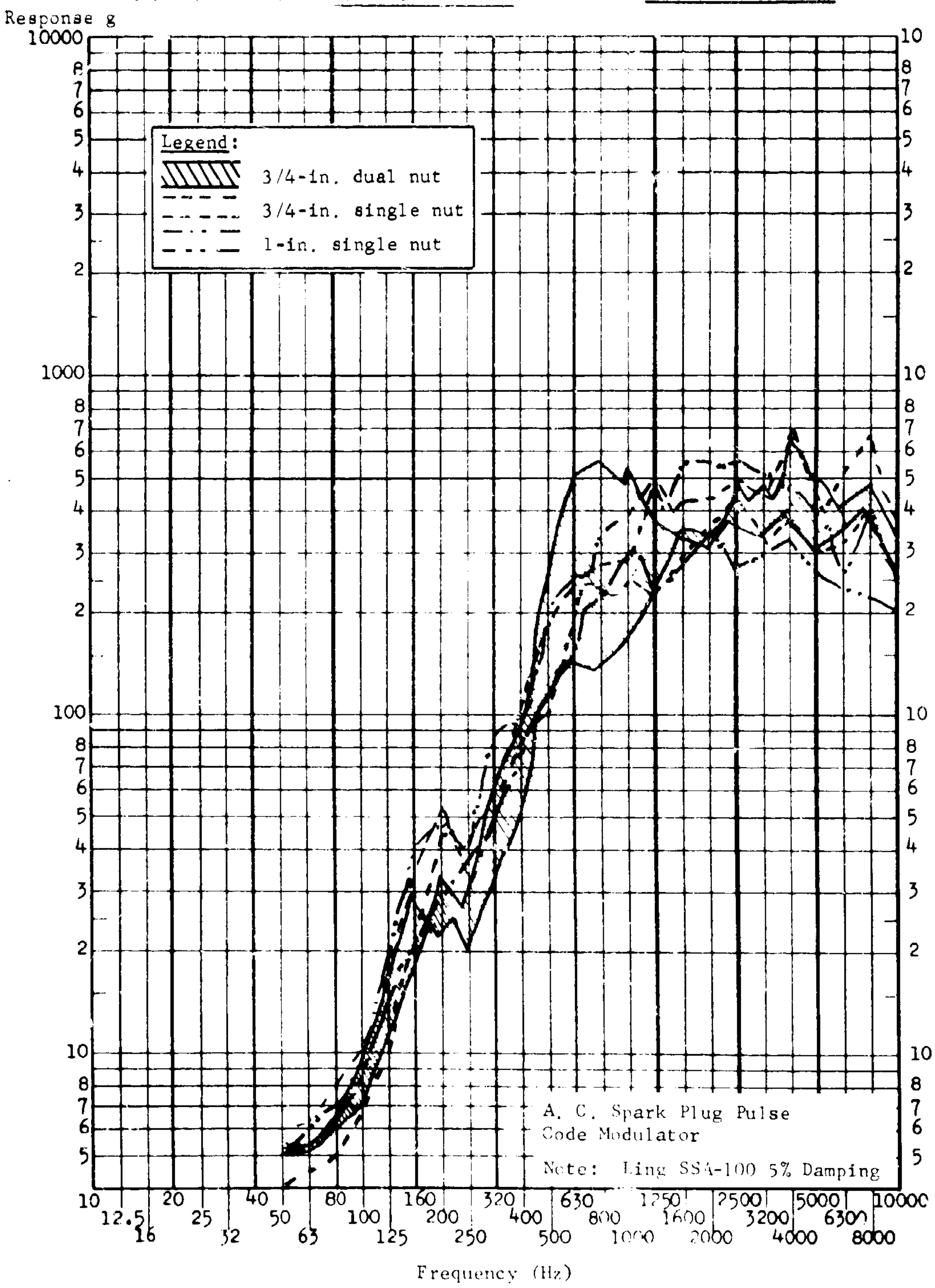



Figure 81 Comparison of Shock Spectra Envelopes -- Accelerometer 8

PAGE NO. ____

SHOCK TEST ANALYSIS DATA SHEET

TEST NO. ____

TEST ITEM ______________ PART NO. ______________

SERIAL NO. ______________ TEST DATE ______________

Shock Axis Accelerometer 9 Latitudinal SHOCK NO. ______________

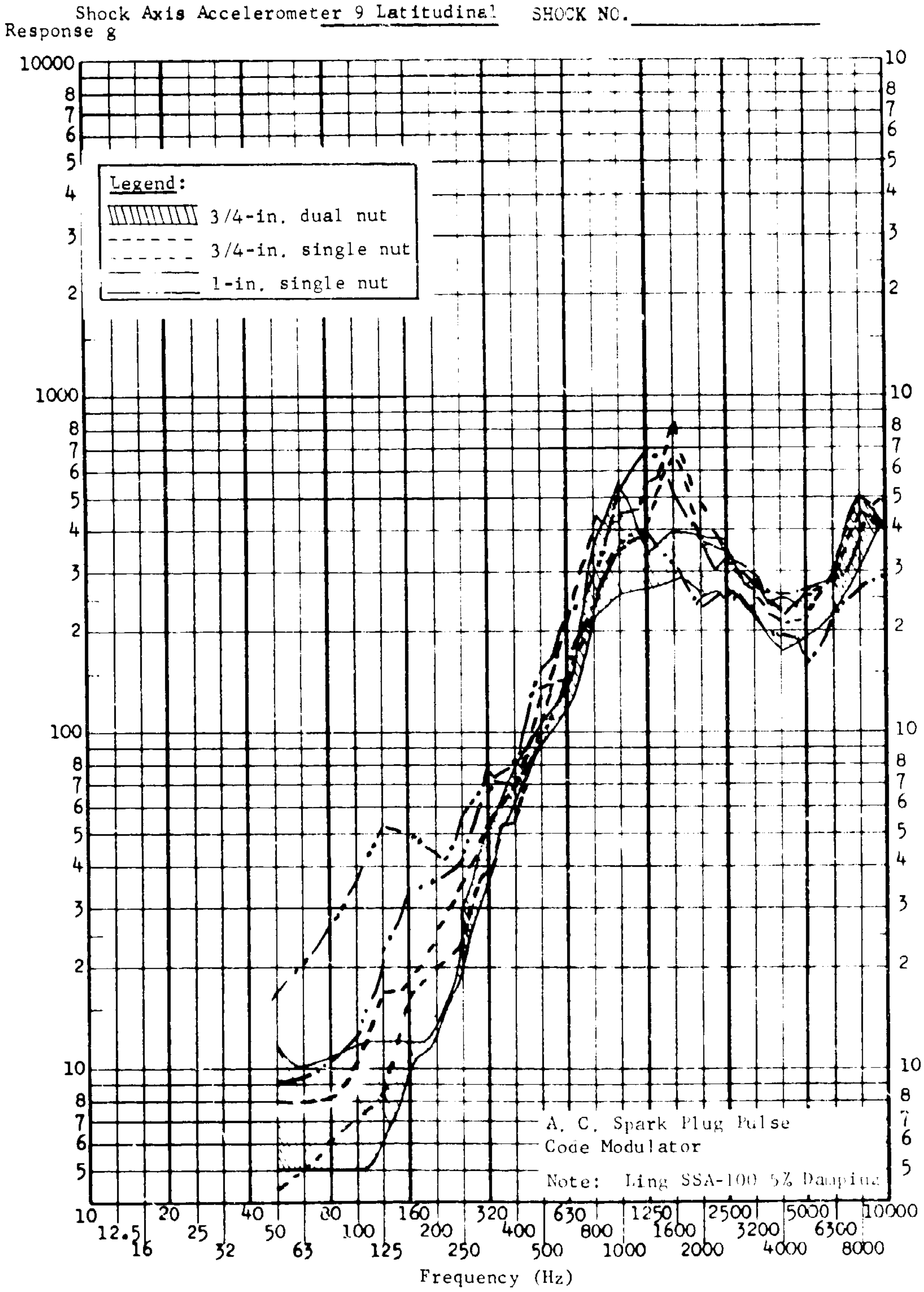



Figure 82 Comparison of Shock Spectra Envelopes -- Accelerometer

SHOCK TEST ANALYSIS DATA SHEET

PAGE NO. __

TEST NO. ______

TEST ITEM ______________ PART NO.______________

SERIAL NO.______________ TEST DATE______________

Shock Axis Accelerometer 10 Longitudinal SHOCK NO.______________

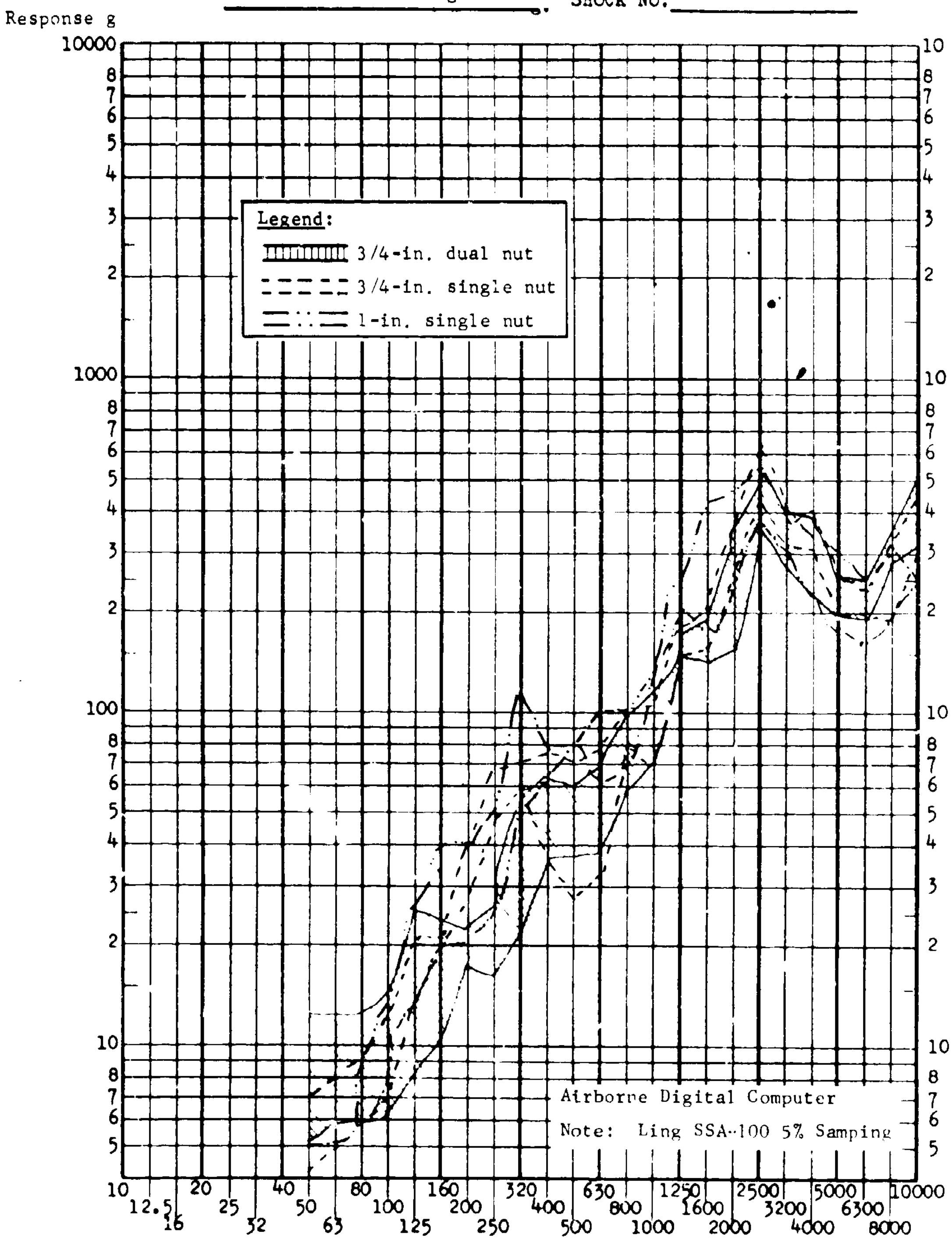



Figure 83 Comparison of Shock Spectra Envelopes -- Accelerometer 10

PAGE NO.

SHOCK TEST ANALYSIS DATA SHEET

TEST NO. ______

TEST ITEM ______________ PART NO.______________

SERIAL NO.______________ TEST DATE______________

Shock Axis Accelerometer 11 Vertical SHOCK NO.______________

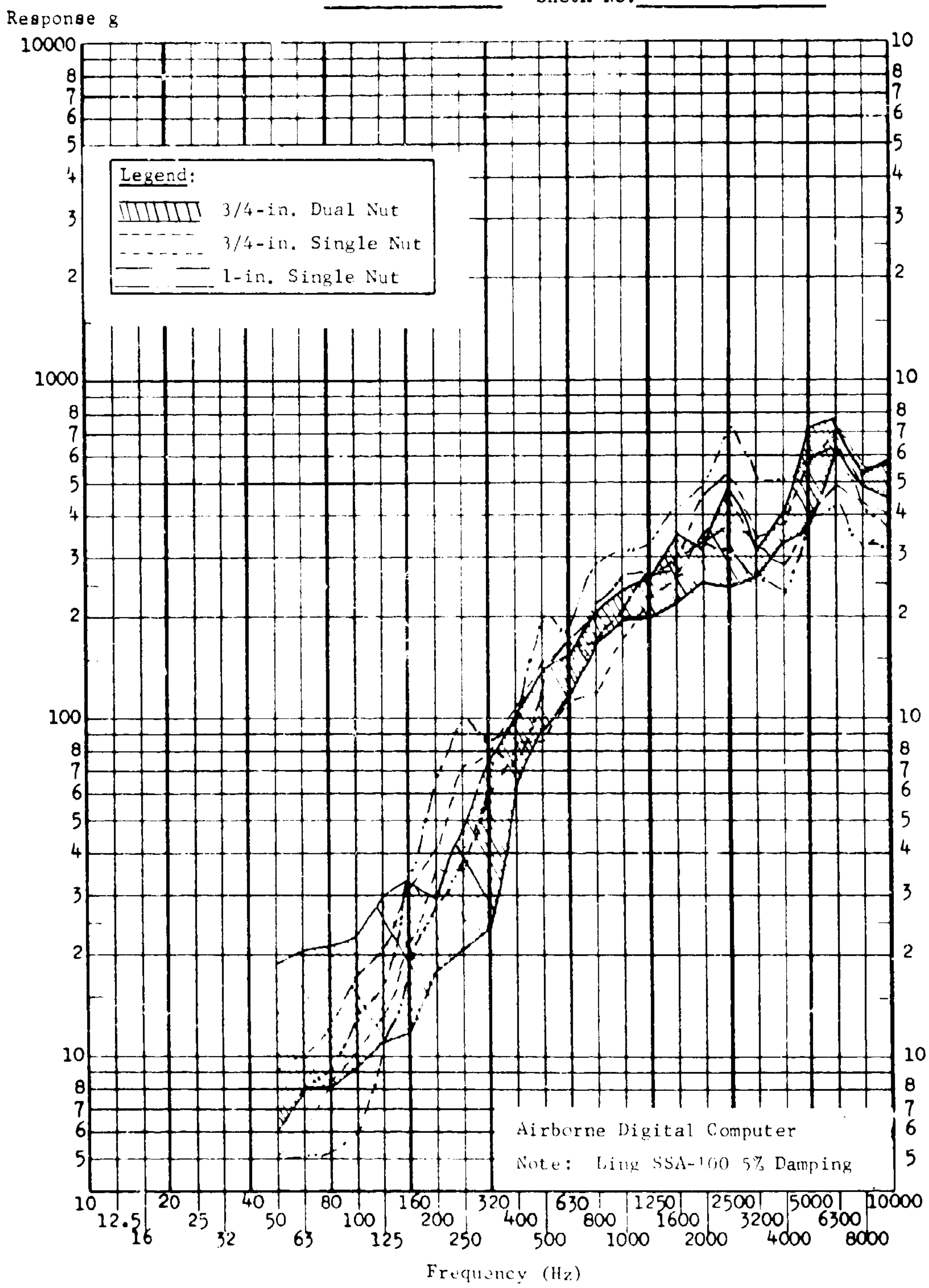



Figure 34 Comparison of Shock Spectra Envelopes -- Accelerometer 11

SHOCK TEST ANALYSIS DATA SHEET

PAGE NO.

TEST NO. ______

TEST ITEM ______________ PART NO. ______________

SERIAL NO. ______________ TEST DATE ______________

Shock Axis Accelerometer 12 Latitudinal SHOCK NO. ______________

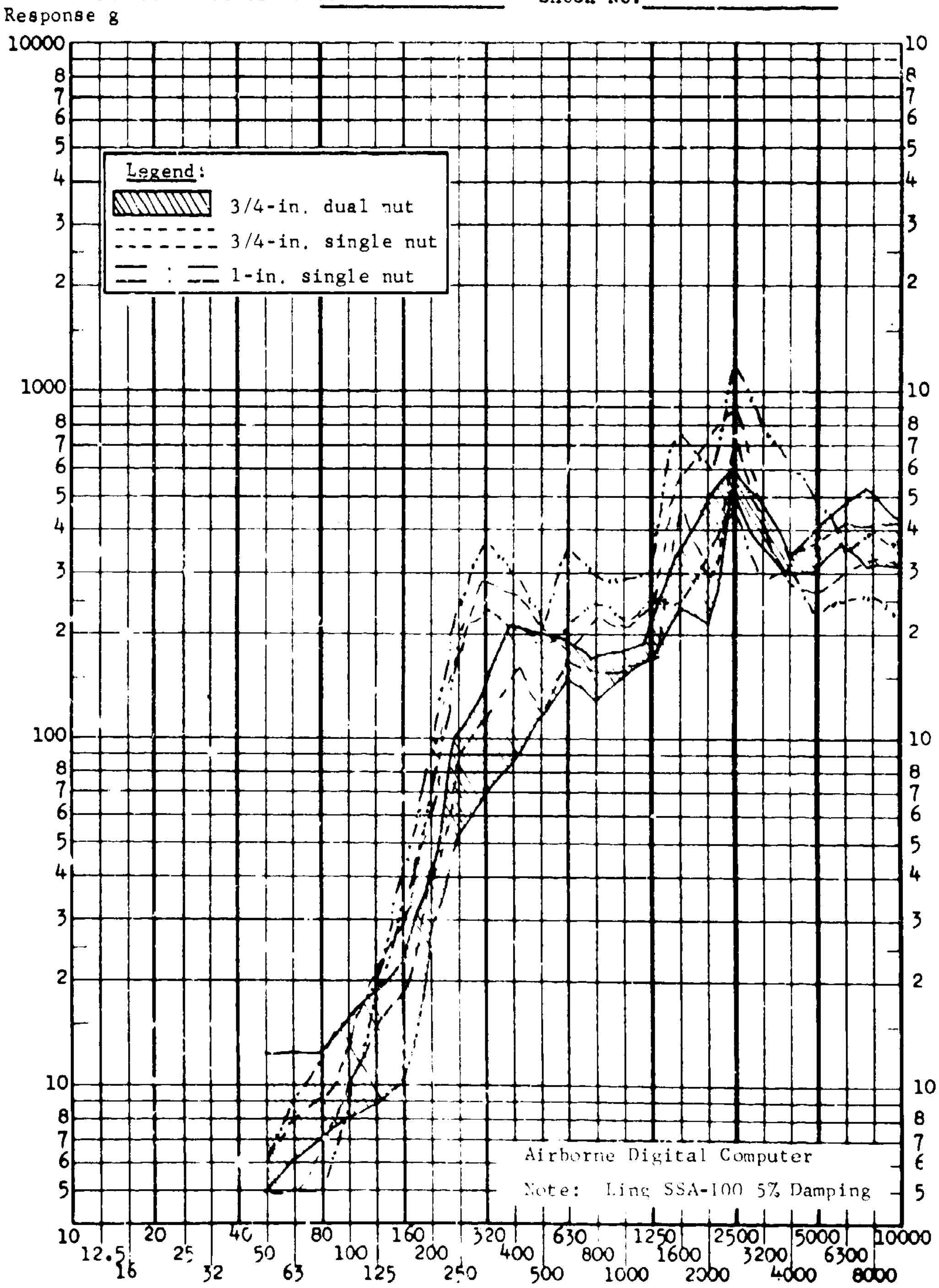



Figure 85 Comparison of Shock Spectra Envelopes -- Accelerometer 12

PAGE NO.

SHOCK TEST ANALYSIS DATA SHEET

TEST NO. ______

TEST ITEM ______________ PART NO. ______________

SERIAL NO. ______________ TEST DATE ______________

Shock Axis Accelerometer 13 Longitudinal SHOCK NO. ______________

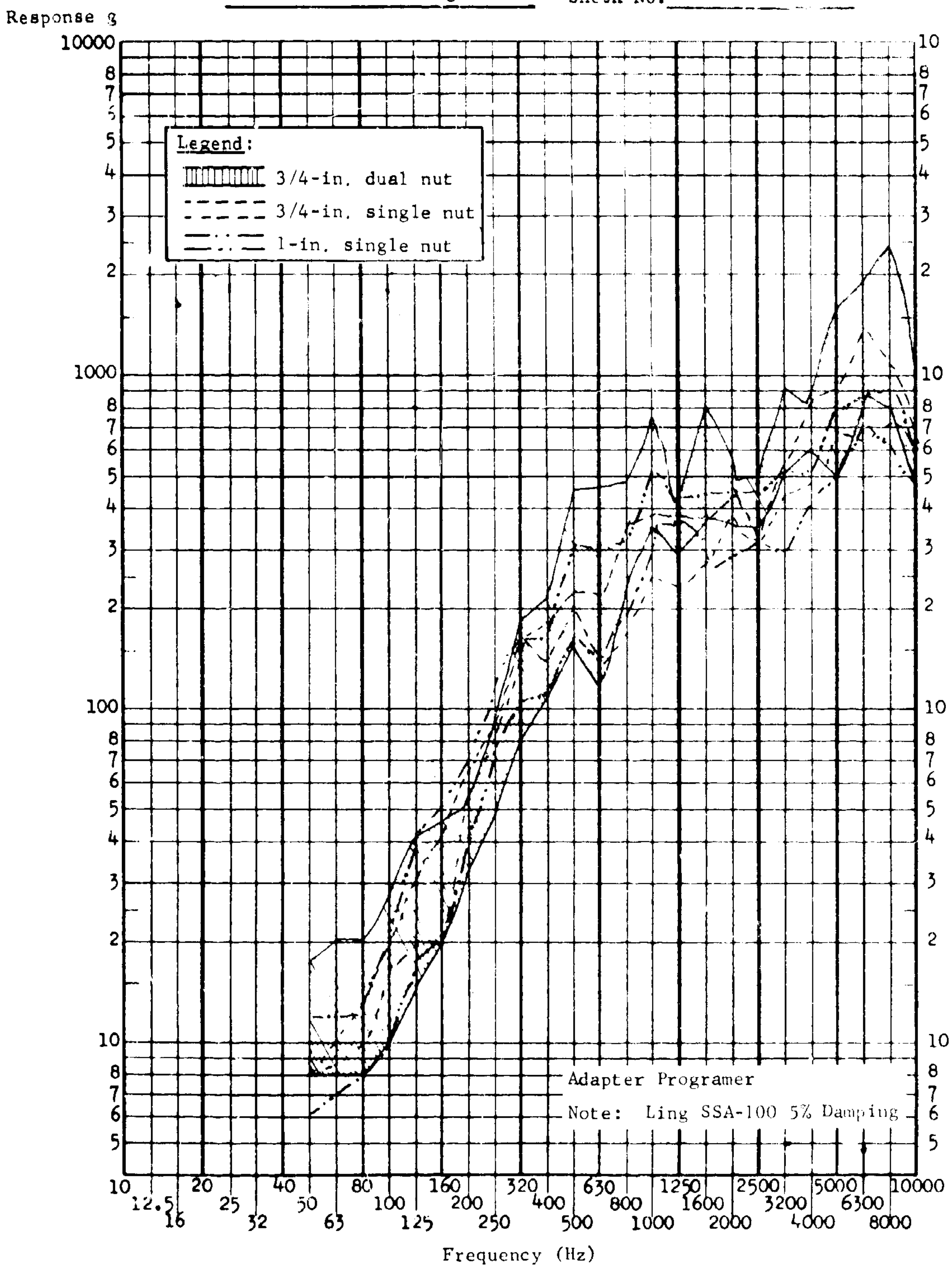



Figure 86 Comparison of Shock Spectra Envelopes -- Accelerometer 13

SHOCK TEST ANALYSIS DATA SHEET

PAGE NO.

TEST NO. ______

TEST ITEM ______________ PART NO.______________

SERIAL NO.______________ TEST DATE______________

Shock Axis Accelerometer 14 Vertical SHOCK NO.______________

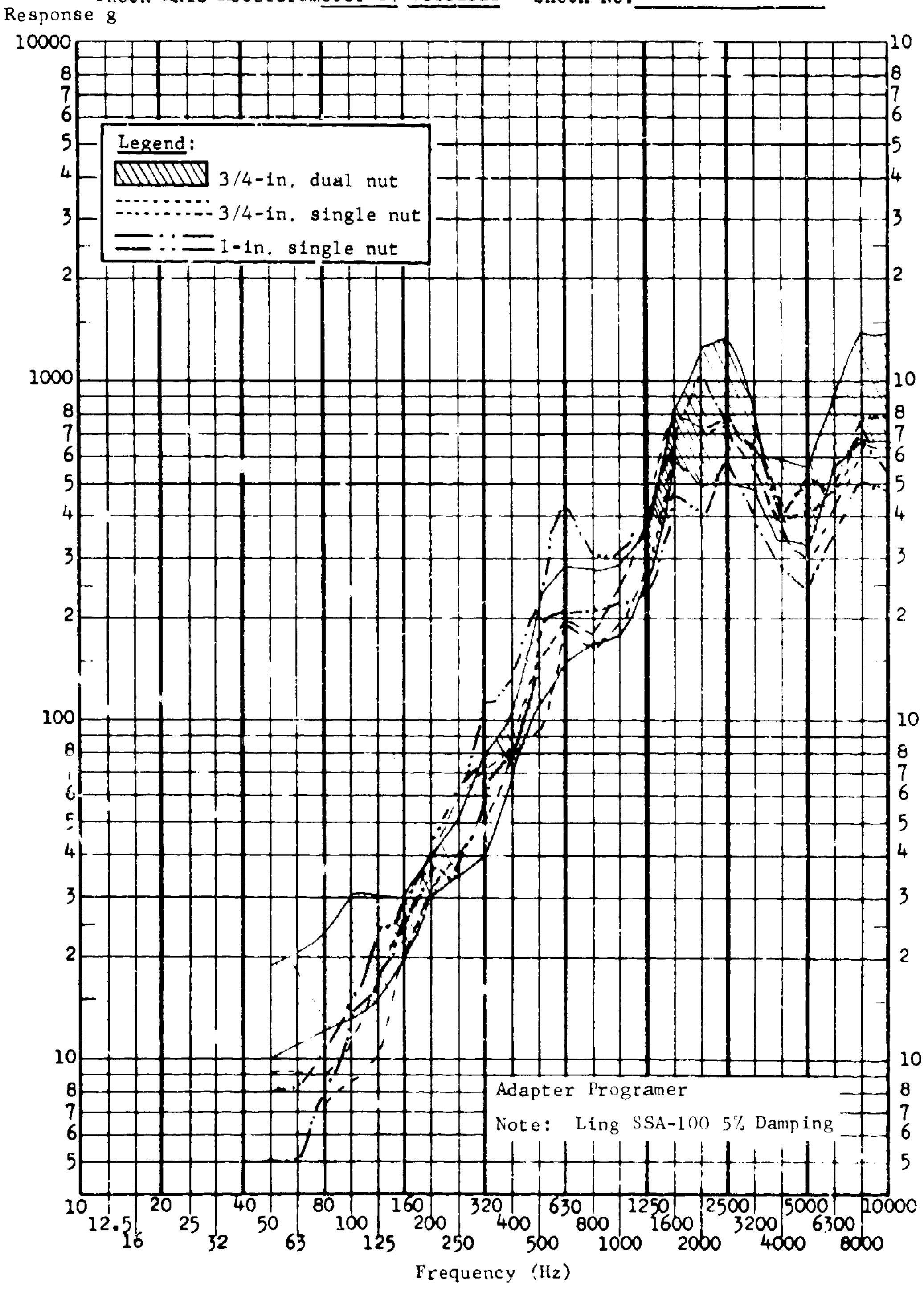



Figure 87 Comparison of Shock Spectra Envelopes -- Accelerometer 14

SHOCK TEST ANALYSIS DATA SHEET

PAGE NO.

TEST NO. _____

TEST ITEM __________ PART NO. __________

SERIAL NO. __________ TEST DATE __________

Shock Axis Accelerometer 15 Latitudinal SHOCK NO. __________

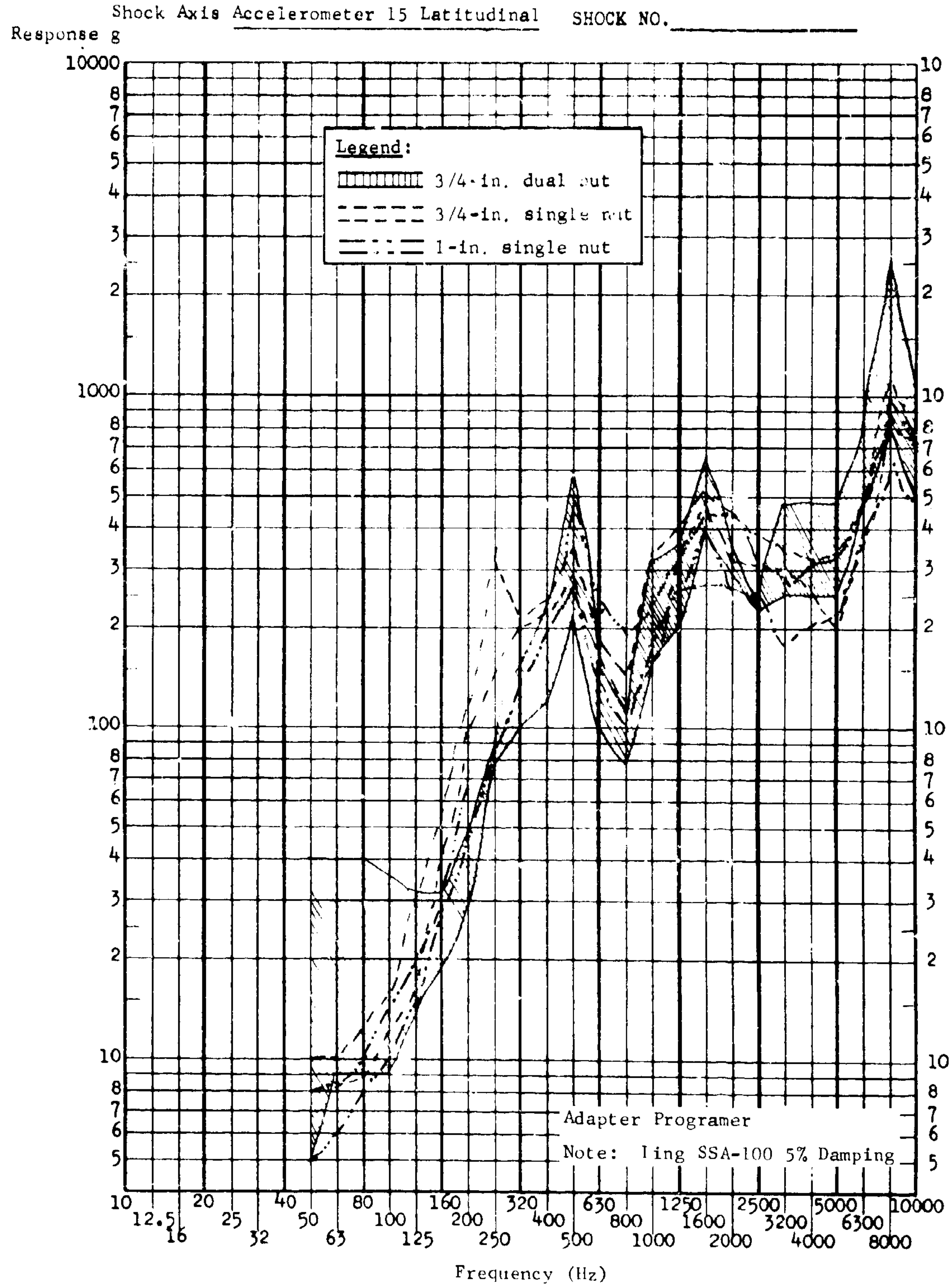



Figure 88 Comparison of Shock Spectra Envelopes -- Accelerometer 15

PAGE NO.

SHOCK TEST ANALYSIS DATA SHEET

TEST NO. ______

TEST ITEM ______________ PART NO. ______________

SERIAL NO. ______________ TEST DATE ______________

Shock Axis Accelerometer 16 Longitudinal SHOCK NO. ______________

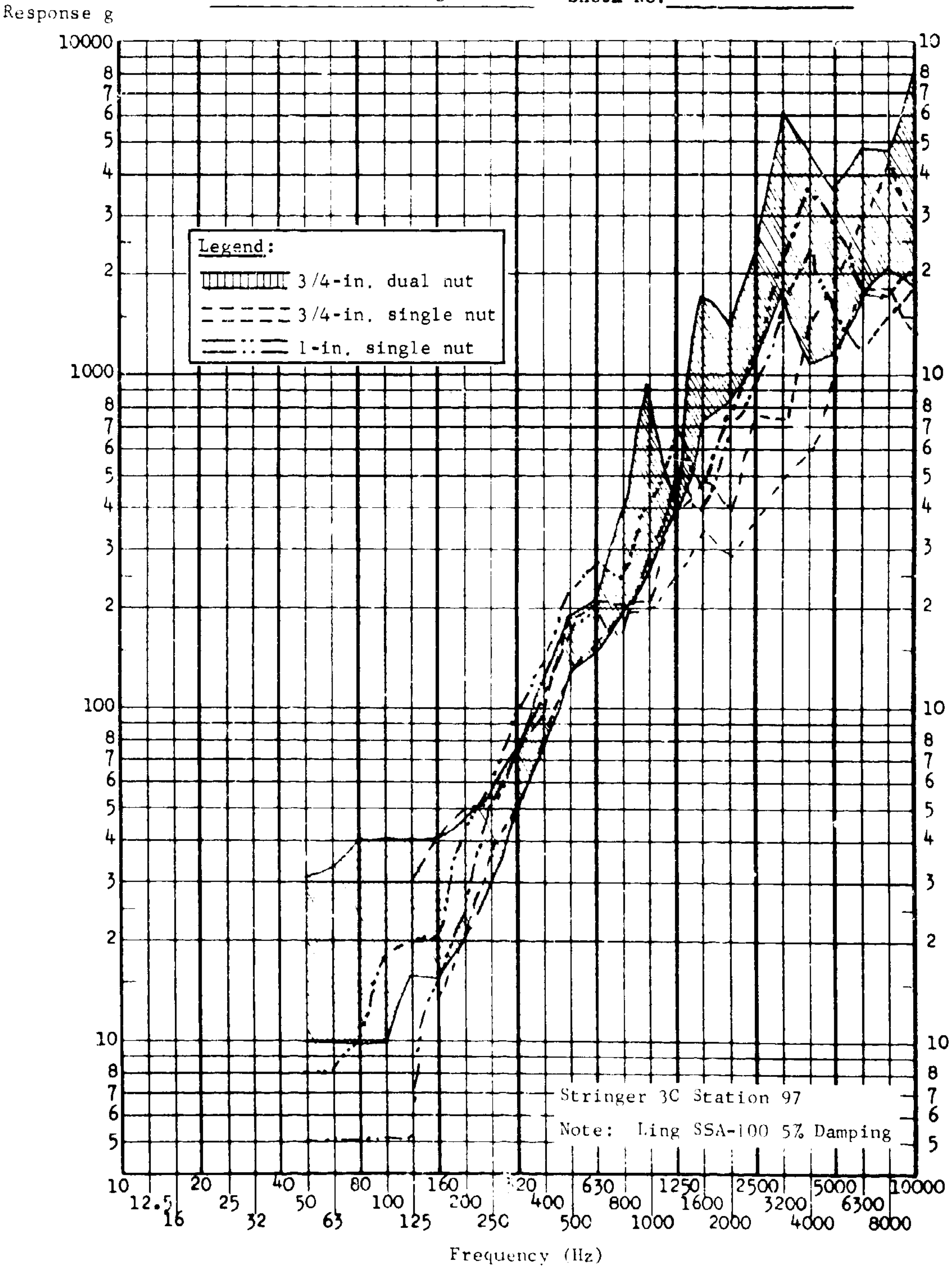



Figure 89 Comparison of Shock Spectra Envelopes -- Accelerometer 16

PAGE NO.

TEST NO. _____

SHOCK TEST ANALYSIS DATA SHEET

TEST ITEM ______________ PART NO.______________

SERIAL NO.______________ TEST DATE______________

Shock Axis Accelerometer 17 Radial SHOCK NO.______________

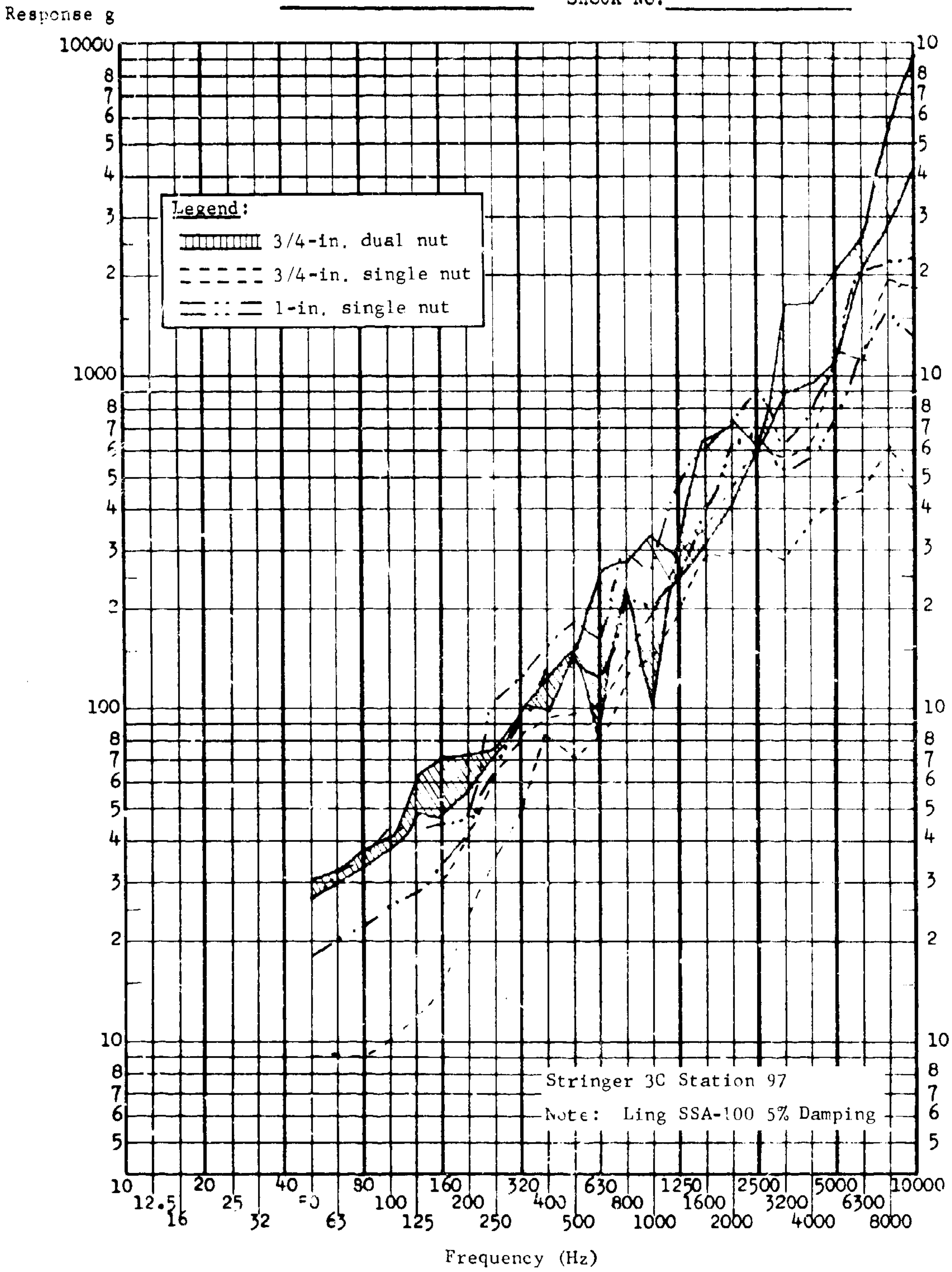



Figure 90 Comparison of Shock Spectra Envelopes -- Accelerometer 17

PAGE NO. ______

TEST NO. ______

SHOCK TEST ANALYSIS DATA SHEET

TEST ITEM ______________ PART NO. ________________

SERIAL NO. ______________ TEST DATE ________________

Shock Axis Accelerometer 18 Tangential SHOCK NO. ________________

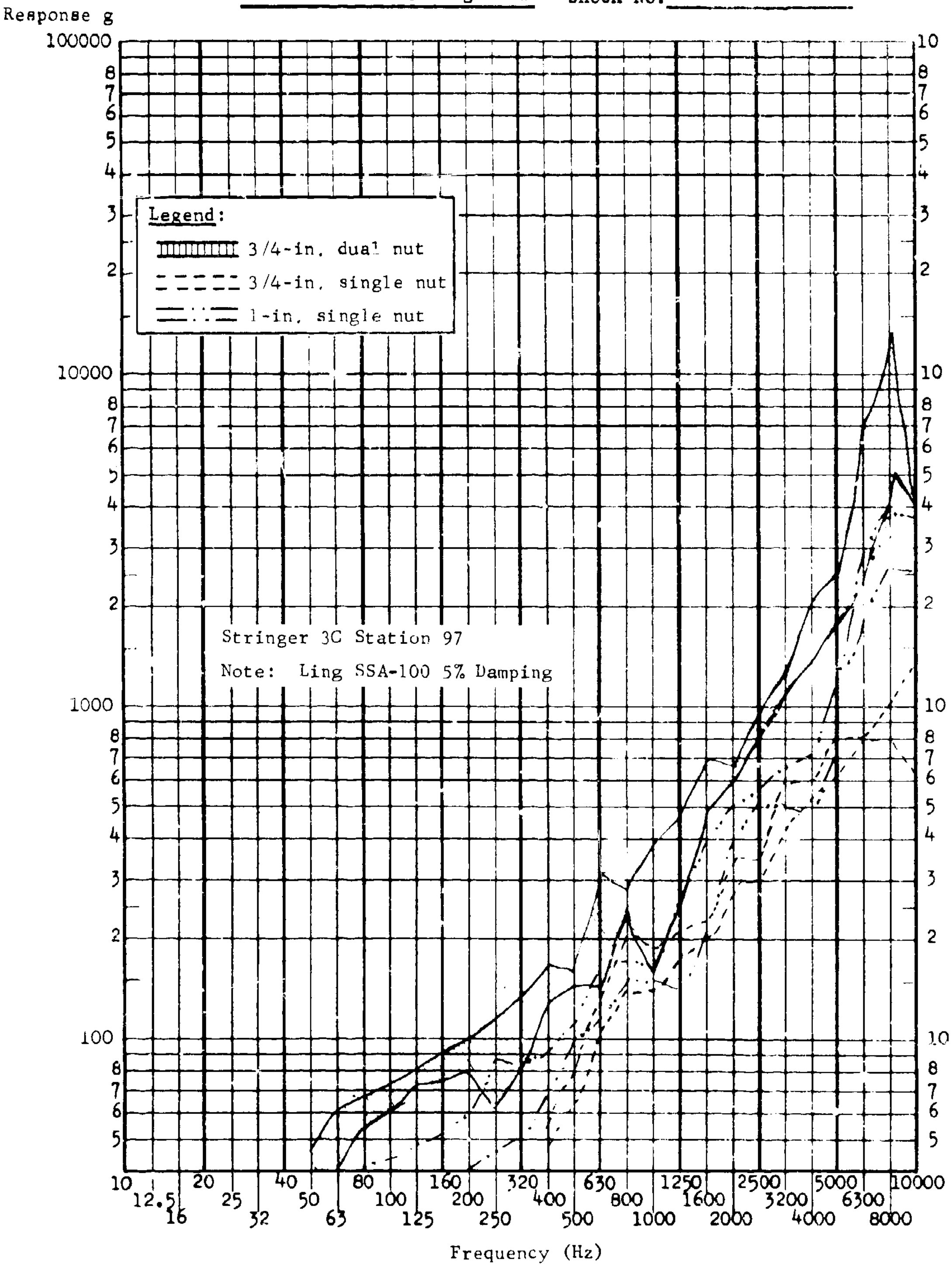



Figure 91 Comparison of Shock Spectra Envelopes -- Accelerometer 18

PAGE NO. ______

TEST NO. ______

SHOCK TEST ANALYSIS DATA SHEET

TEST ITEM ______________ PART NO. ______________

SERIAL NO. ______________ TEST DATE ______________

Shock Axis Accelerometer 19 Longitudinal SHOCK NO. ______________

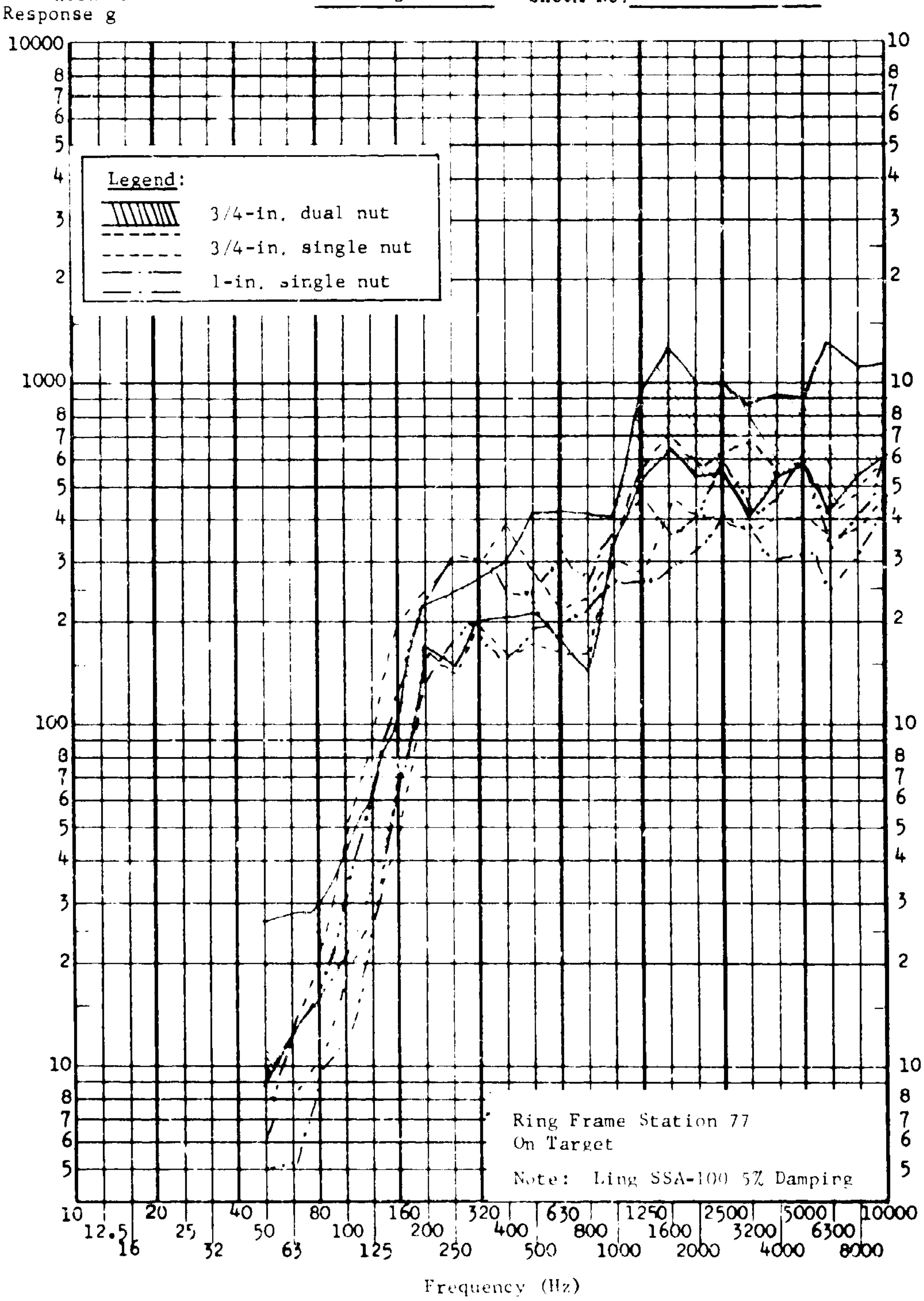



Figure 92 Comparison of Shock Spectra Envelopes -- Accelerometer 19

PAGE NO. ____
TEST NO. ____

SHOCK TEST ANALYSIS DATA SHEET

TEST ITEM __________ PART NO. __________

SERIAL NO. __________ TEST DATE __________

Shock Axis Accelerometer 20 Radial SHOCK NO. __________

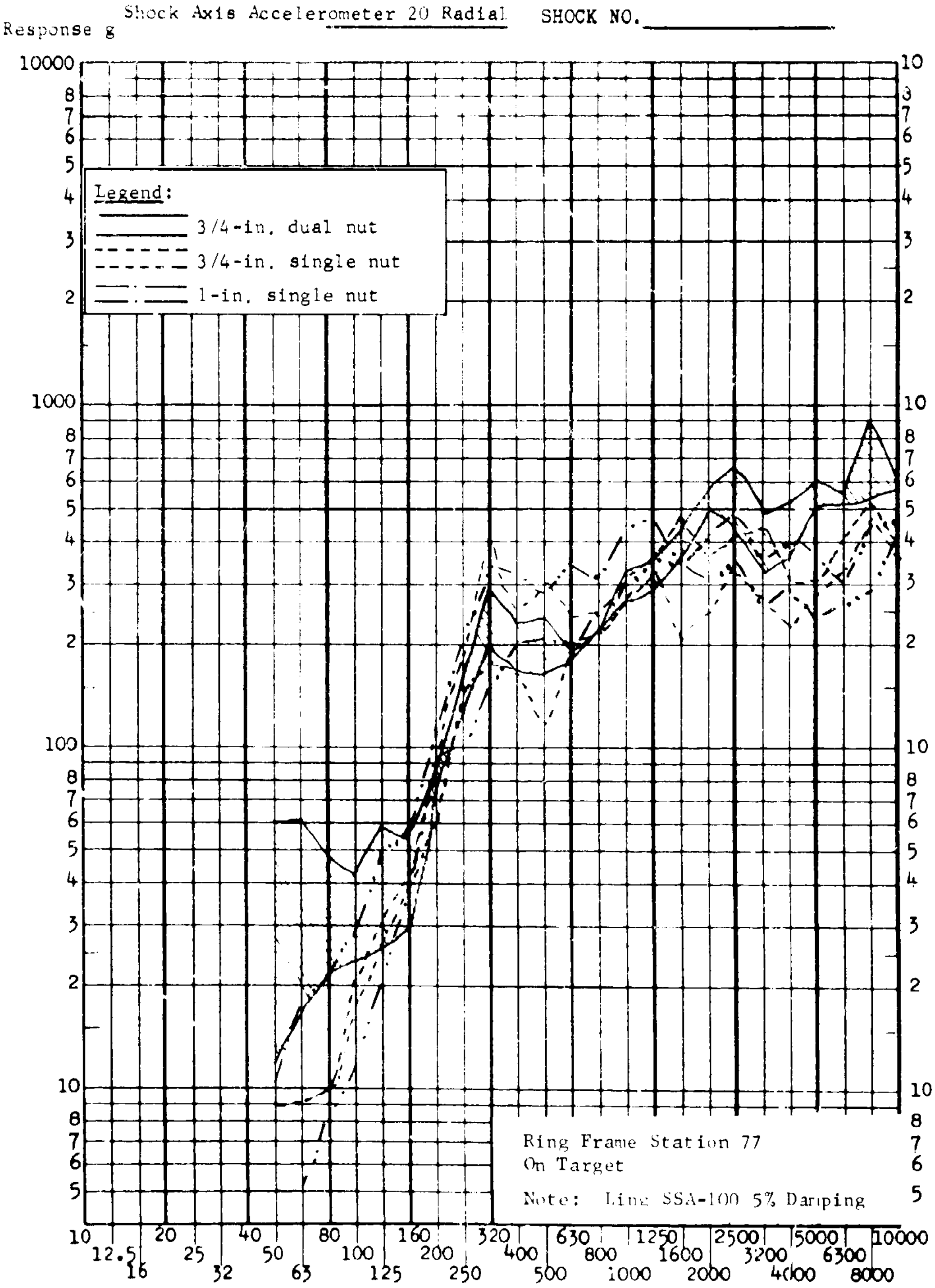



Figure 93 Comparison of Shock Spectra Envelope -- Accelerometer 20

PAGE NO. ______

SHOCK TEST ANALYSIS DATA SHEET

TEST NO. ______

TEST ITEM ______________ PART NO.________________

SERIAL NO.______________ TEST DATE________________

Shock Axis Accelerometer 21 Tangential SHOCK NO.________________

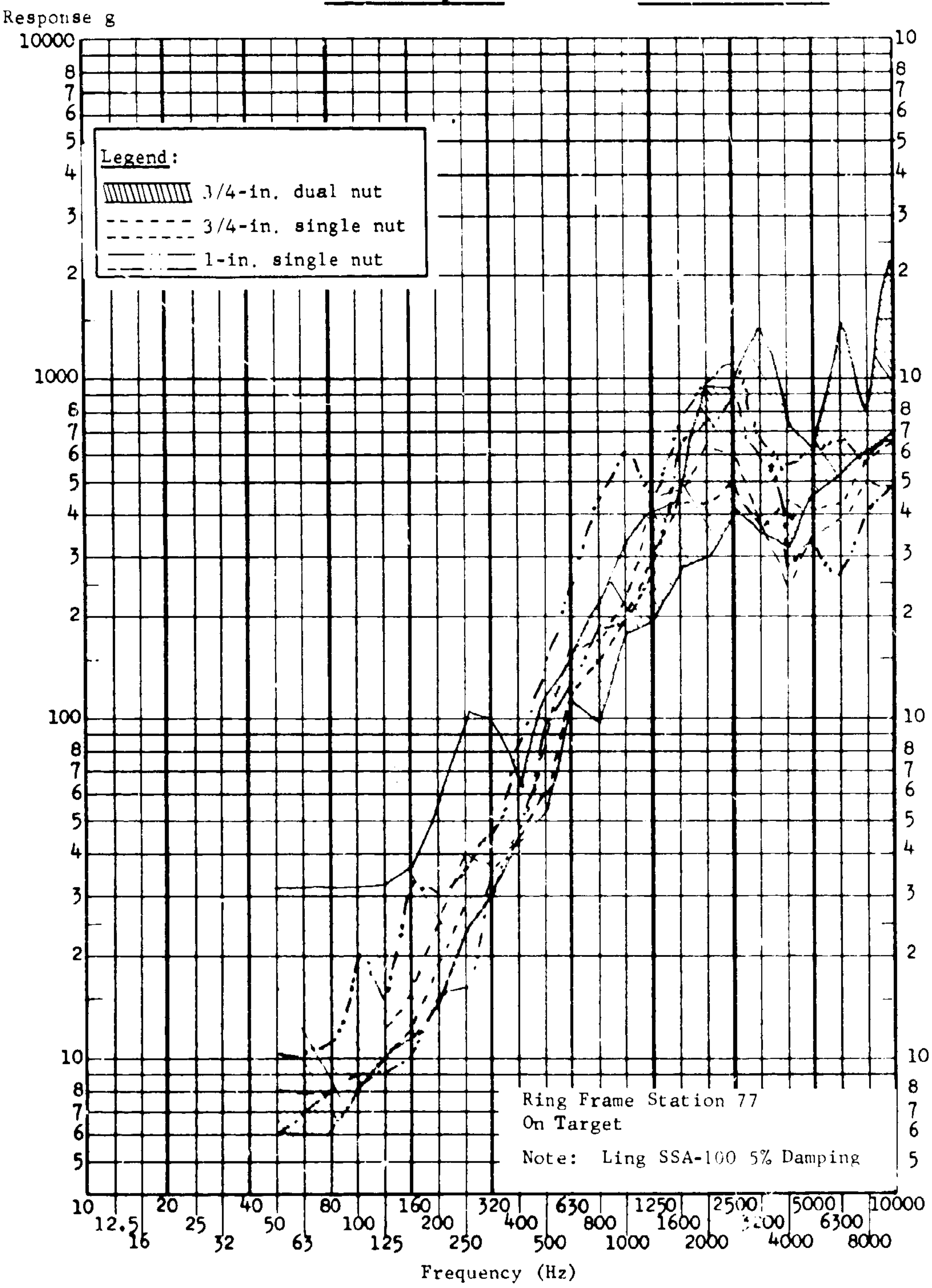



Figure 94 Comparison of Shock Spectra Envelope -- Accelerometer 21

SHOCK TEST ANALYSIS DATA SHEET

PAGE NO.

TEST NO.

TEST ITEM ______________ PART NO.______________

SERIAL NO.______________ TEST DATE______________

Shock Axis Accelerometer 22 Longitudinal SHOCK NO.______________

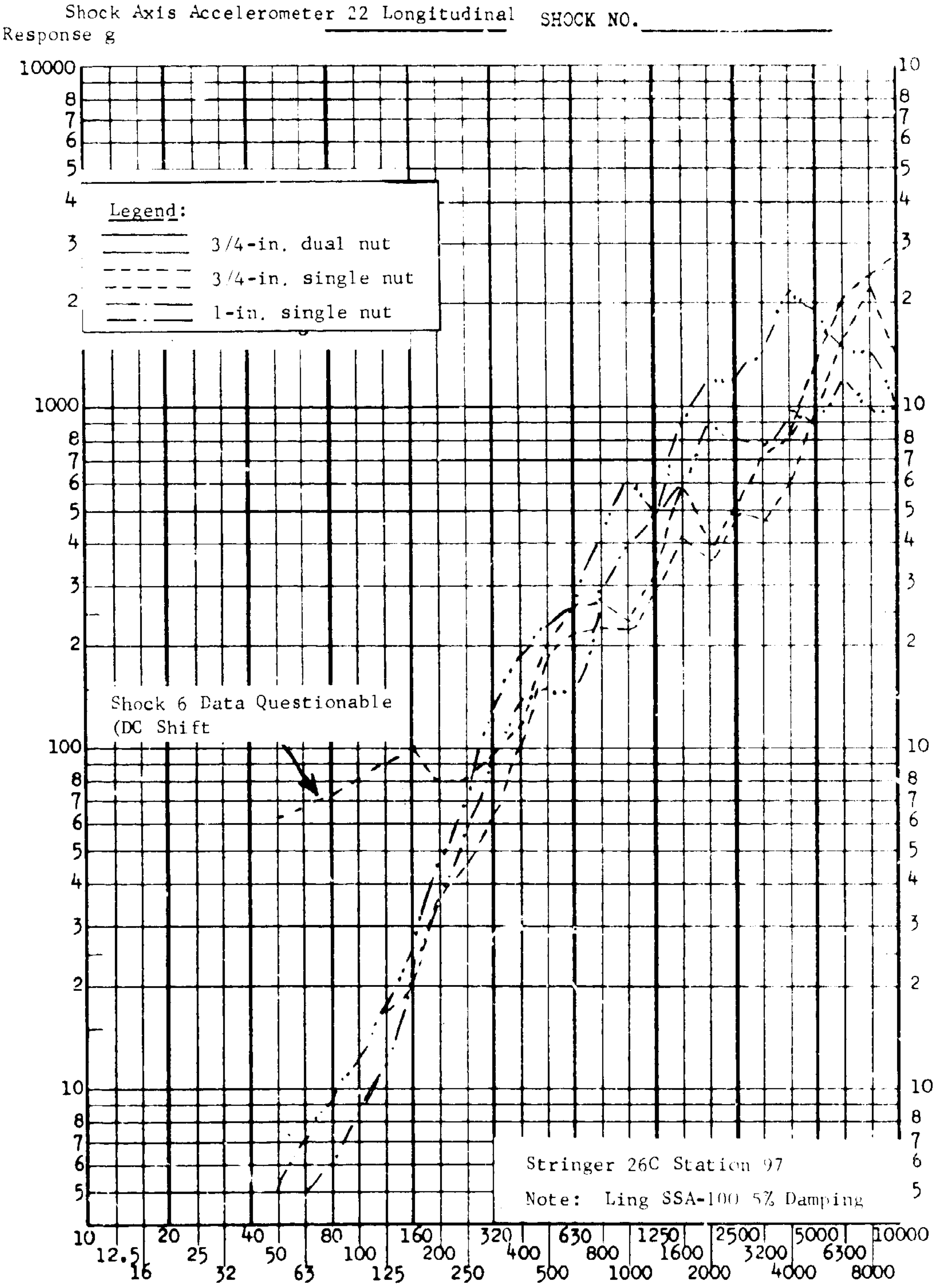



Figure 95 Comparison of Shock Spectra Envelopes -- Accelerometer 22

PAGE NO. ______
TEST NO. ______

SHOCK TEST ANALYSIS DATA SHEET

TEST ITEM ______________ PART NO.________________

SERIAL NO.______________ TEST DATE________________

Shock Axis Accelerometer 23 Radial SHOCK NO.________________

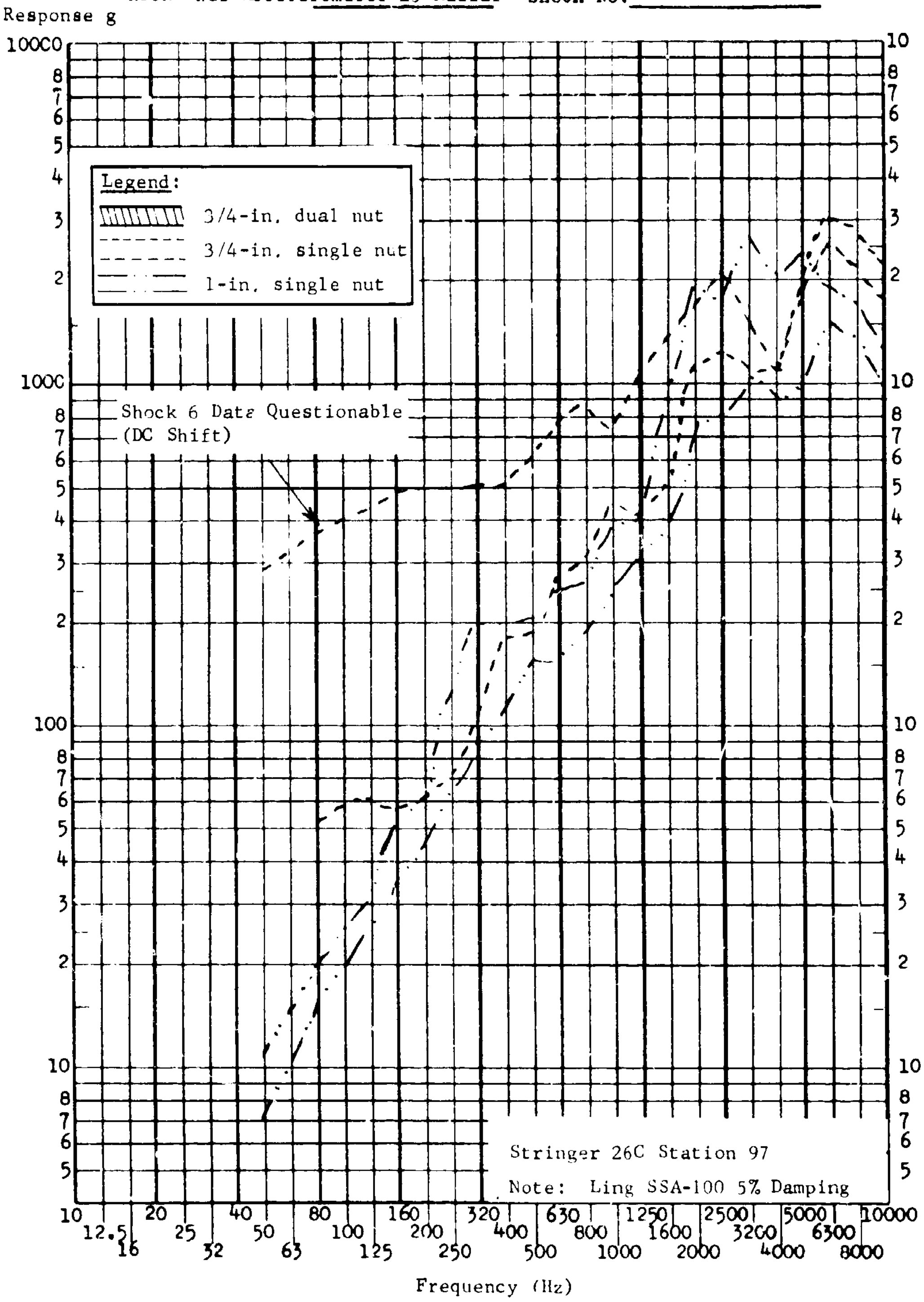



Figure 96 Comparison of Shock Spectra Envelopes -- Accelerometer 23

PAGE NO.

SHOCK TEST ANALYSIS DATA SHEET

TEST NO. ______

TEST ITEM ______________ PART NO.______________

SERIAL NO.______________ TEST DATE______________

Shock Axis Accelerometer 24 Tangential SHOCK NO.______________

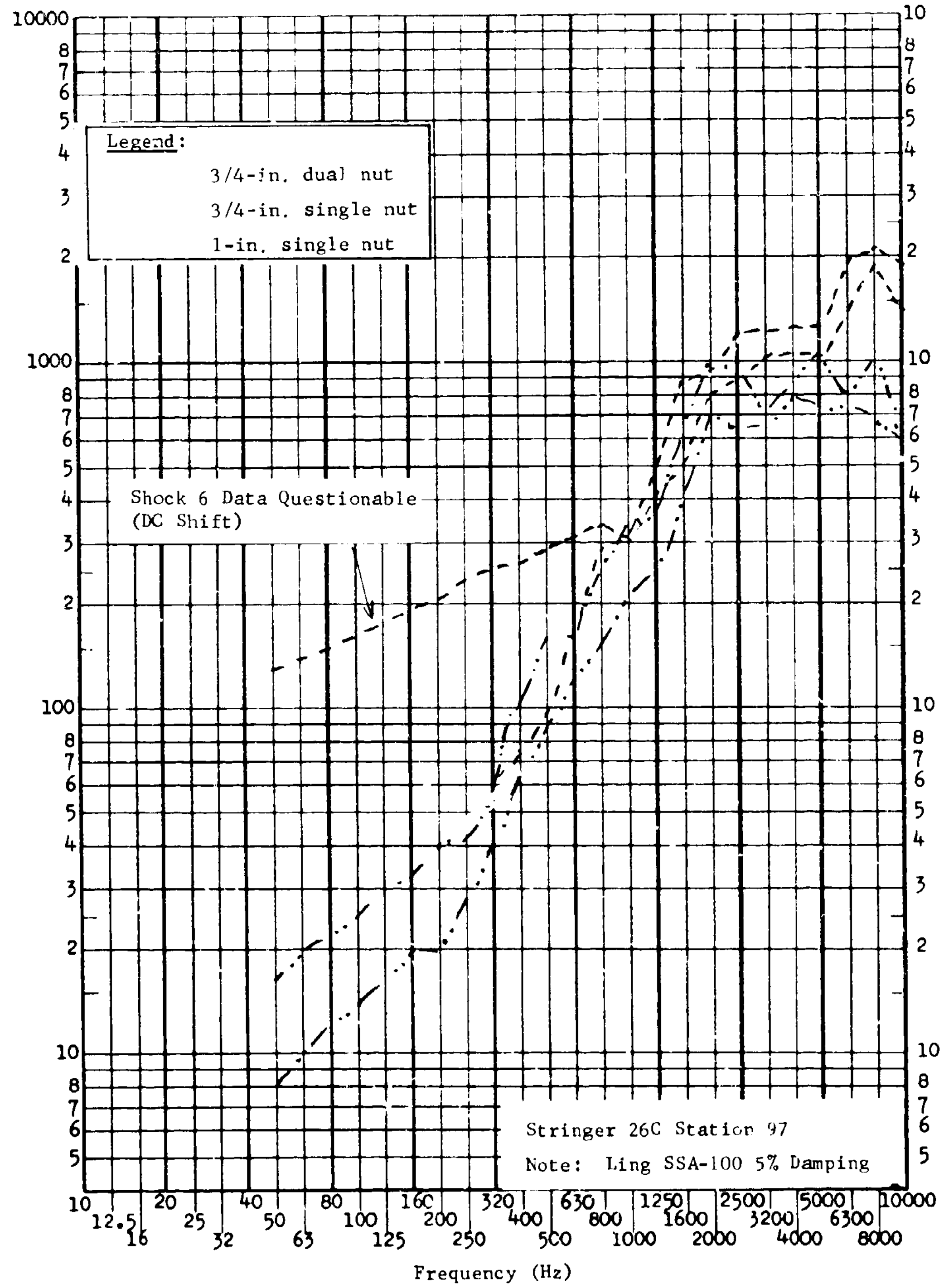



Figure 97 Comparison of Shock Spectra Envelopes -- Accelerometer 24

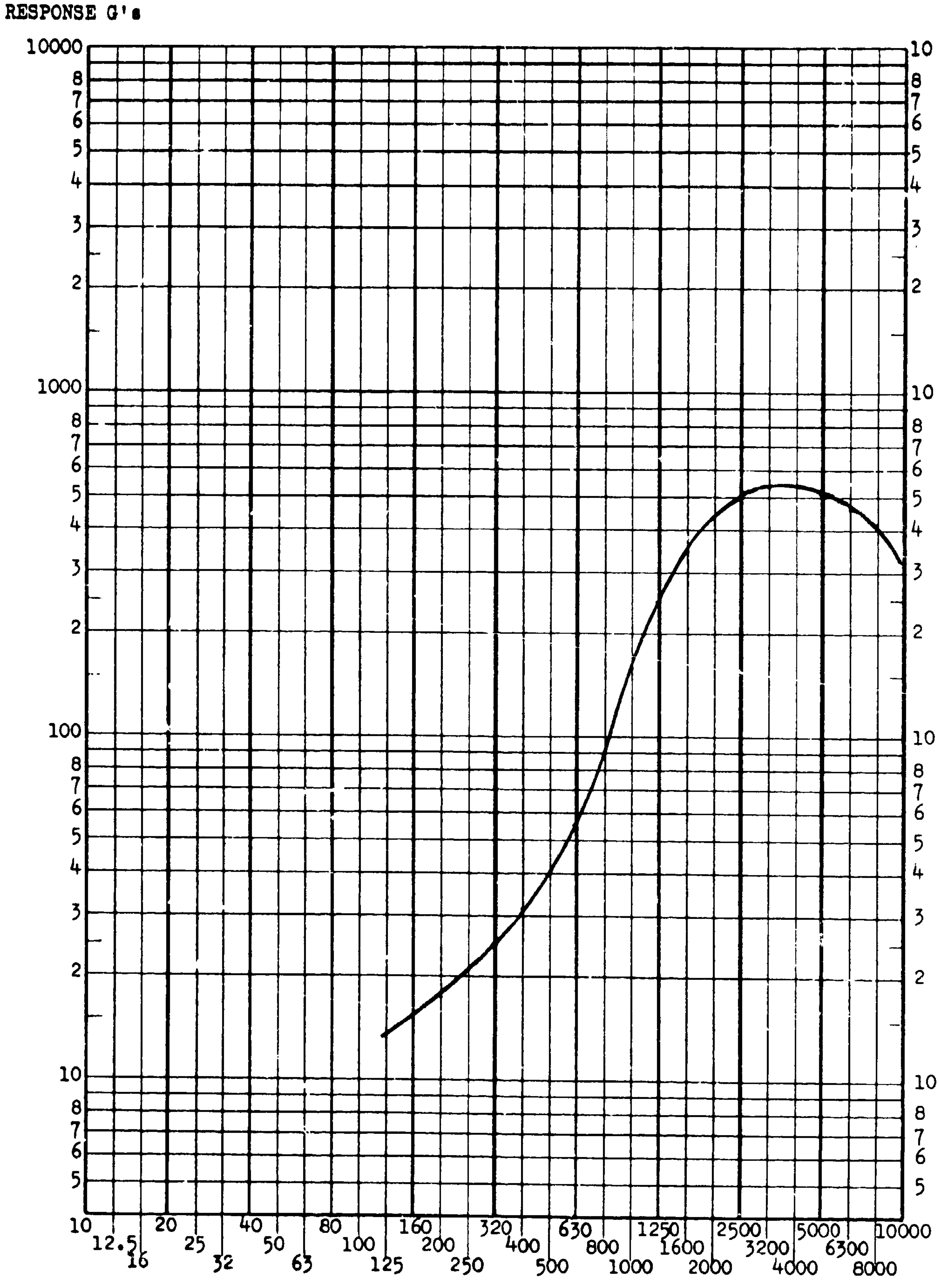



Figure 98. Production Environmental Test Shock Spectrum. (See 2.6.II)

TEST ITEM ______________ PART NO. ______________

SERIAL NO. ______________ TEST DATE ______________

SHOCK AXIS Longitudinal Accelerometers SHOCK NO. 16, 17, 18 and 19

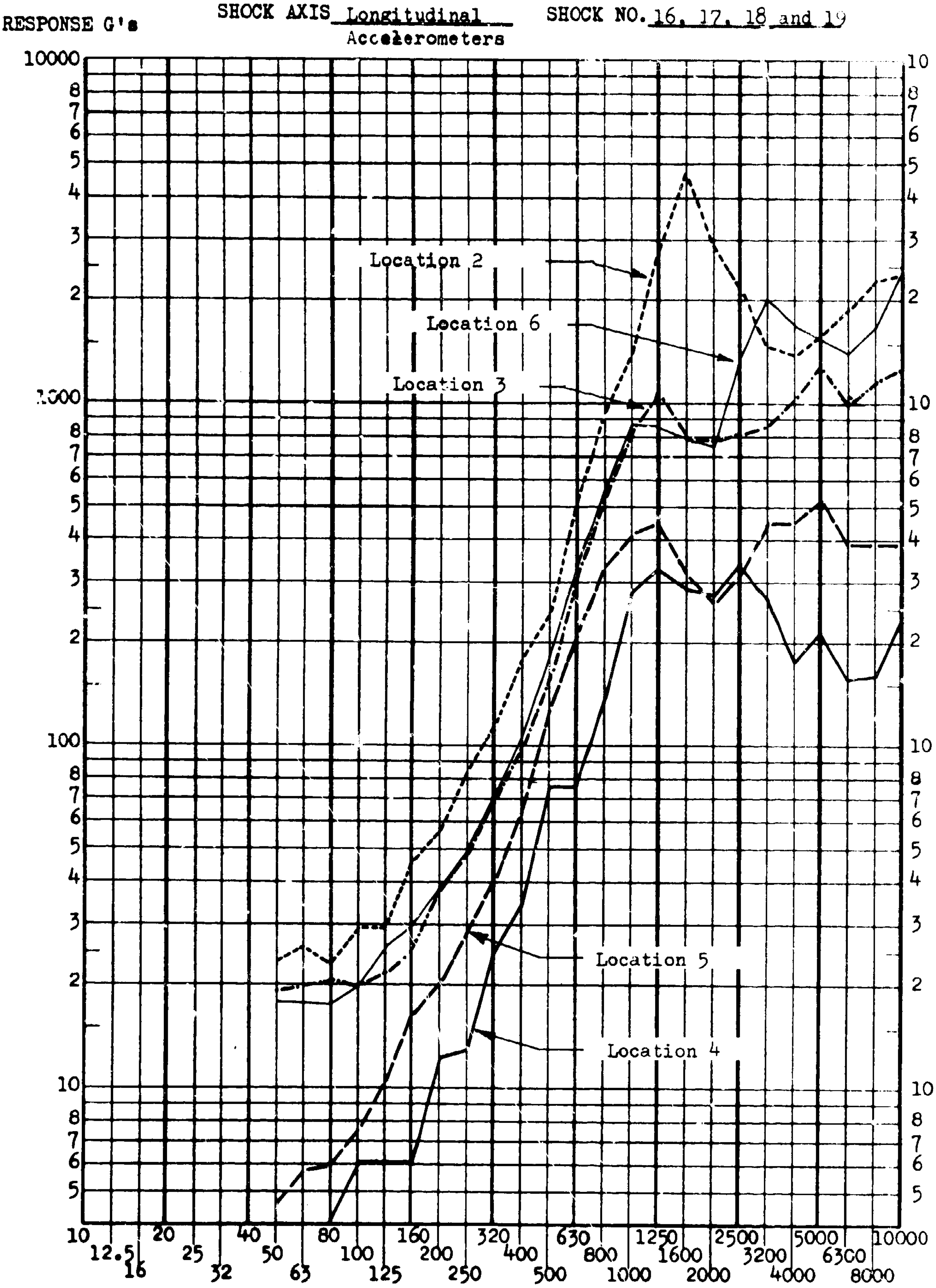



Figure 99 Shock Spectra Variation with Location for Longitudinal Truss Locations

TEST ITEM ______ PART NO. ______

SERIAL NO. ______ TEST DATE ______

SHOCK AXIS Lateral SHOCK NO. 16, 17, 18 and 19

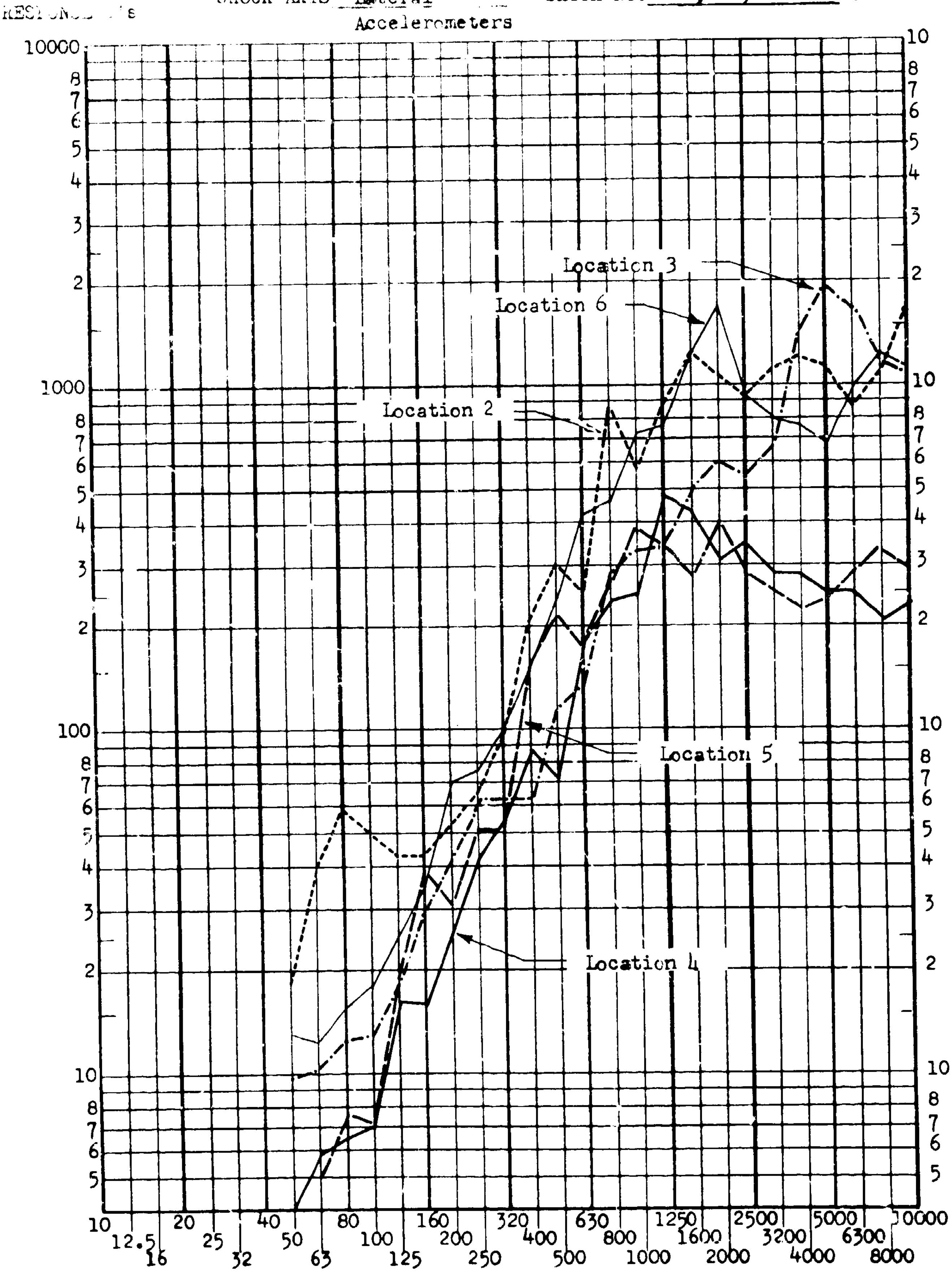



Figure 100 ... 5 ... Lateral Truss Location

TEST ITEM ______________ PART NO. ______________

SERIAL NO. ______________ TEST DATE ______________

SHOCK AXIS Vertical Accelerometers SHOCK NO. 16, 17, 18 and 19

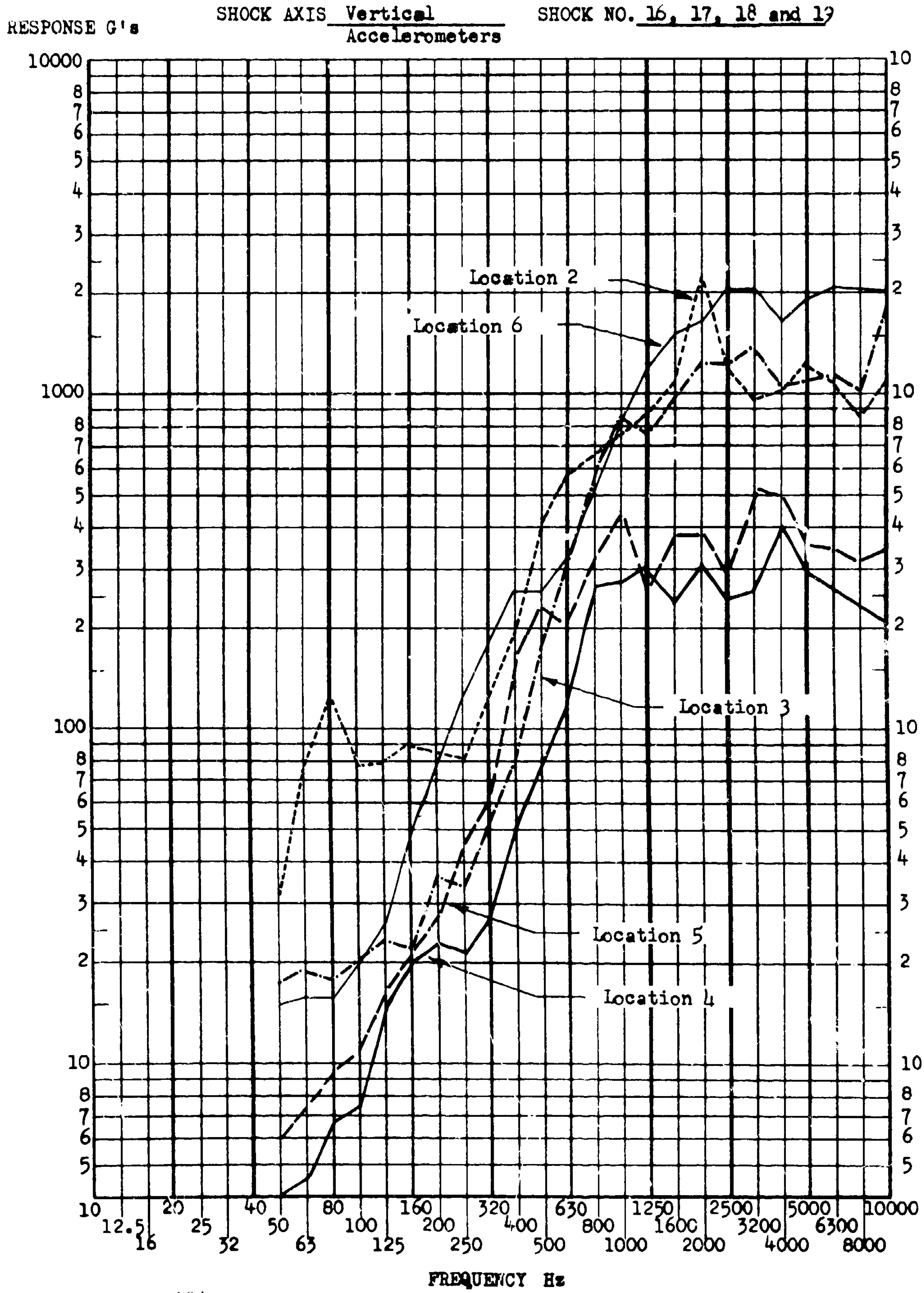



Figure 101 Shock Spectra Vari[illegible] Location for Vertical Truss

[illegible]

TEST ITEM ______ PART NO. ______

SERIAL NO. ______ TEST DATE ______

SHOCK AXIS Longitudinal Accelerometers SHOCK NO. 9, 10, 11 and 12

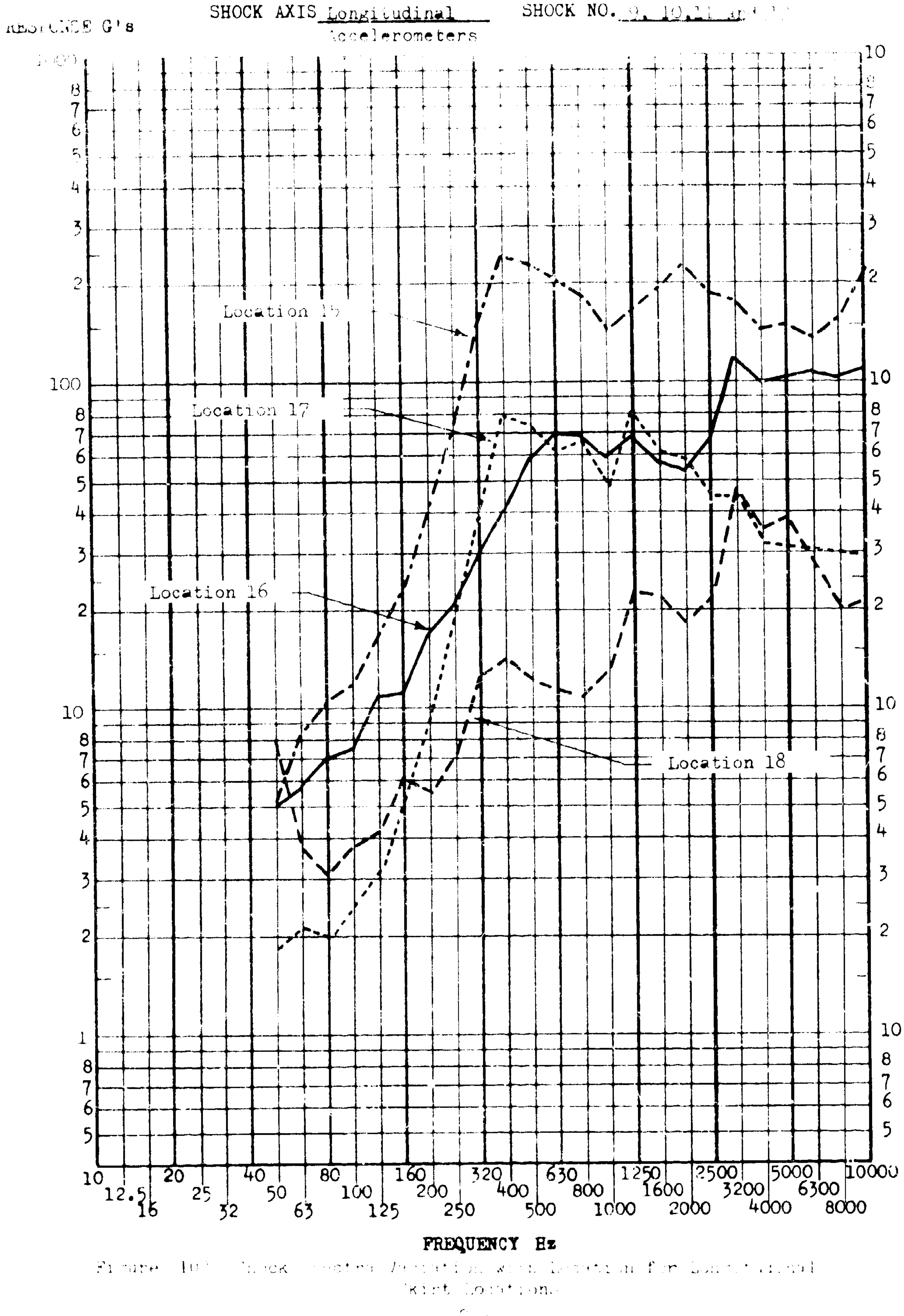


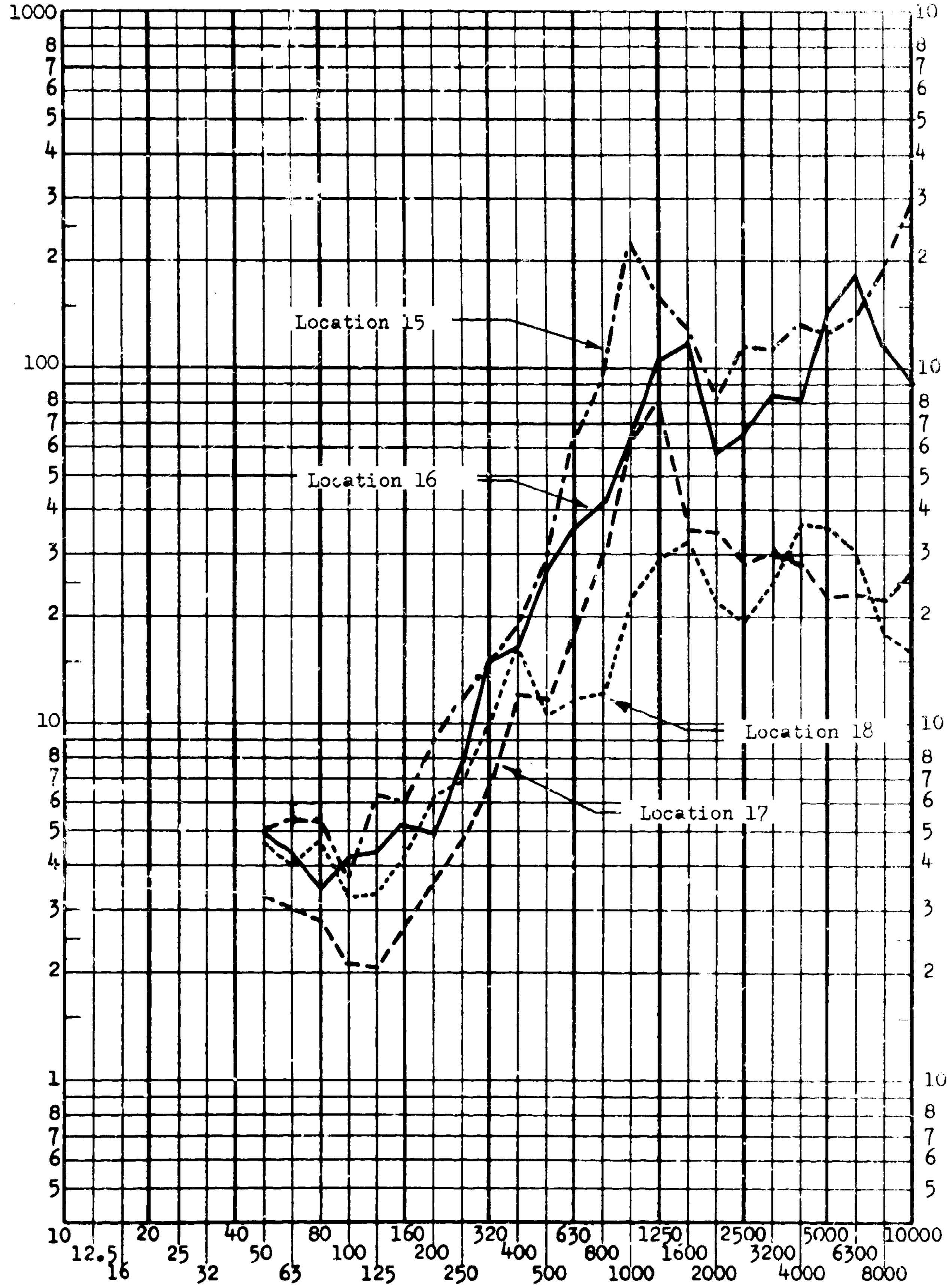

Figure 10[illegible] Shock Spectra Variation with Location for Longitudinal Skirt Locations.

TEST ITEM ______________ PART NO. ______________

SERIAL NO. ______________ TEST DATE ______________

SHOCK AXIS Tangential Accelerometers SHOCK NO. 9, 10, 11 and 12

RESPONSE G's




**FREQUENCY Hz**

Figure 103 Shock Spectra Variation with Location for Tangential Skirt Locations

TEST ITEM ____________

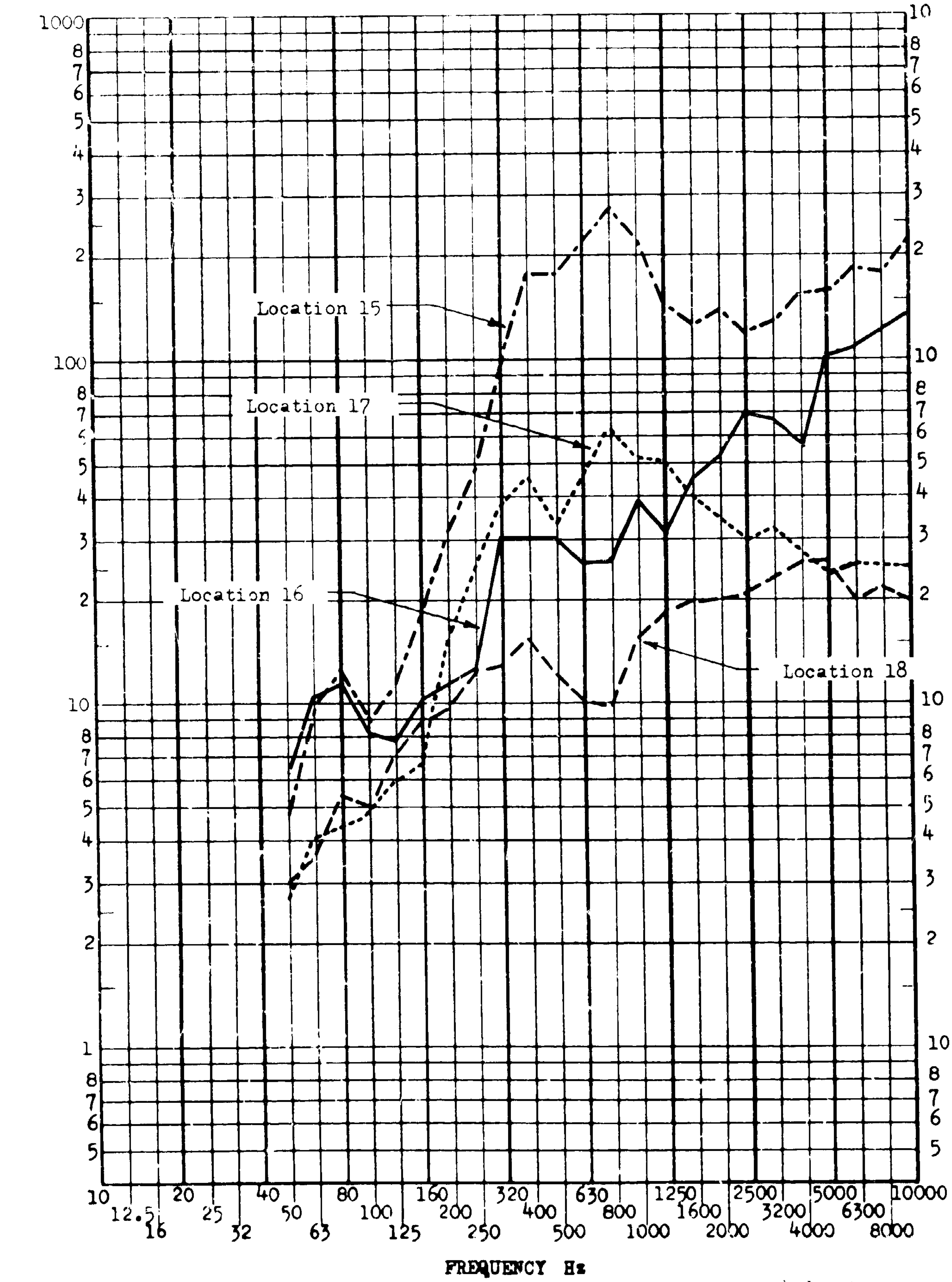
PART NO. ____________

SERIAL NO. ____________

TEST DATE ____________

SHOCK AXIS Radial Accelerometers

SHOCK NO. 9, 10, 11 and 12




[illegible] 104 [illegible]

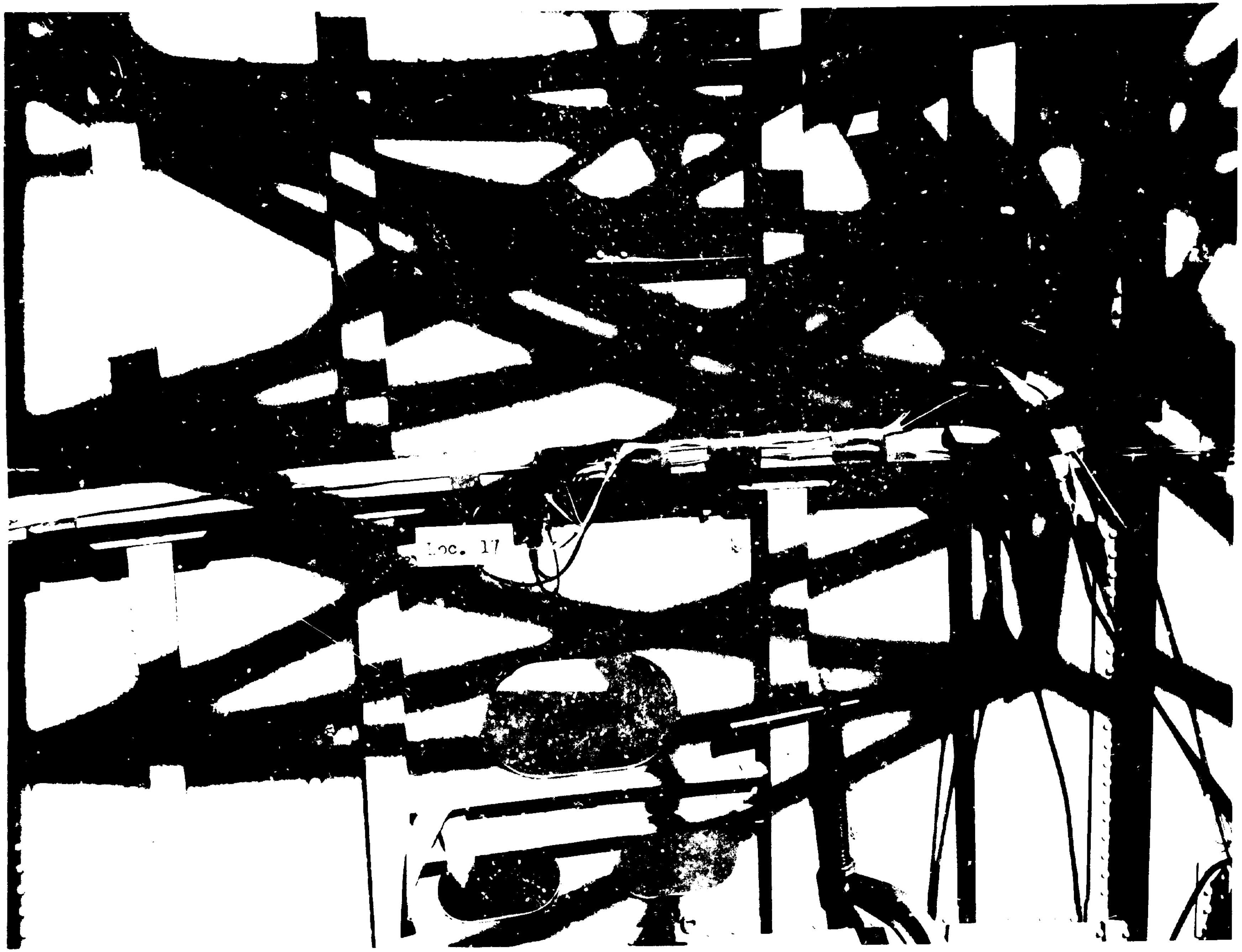



Figure 105 Installation of [illegible] at location 17

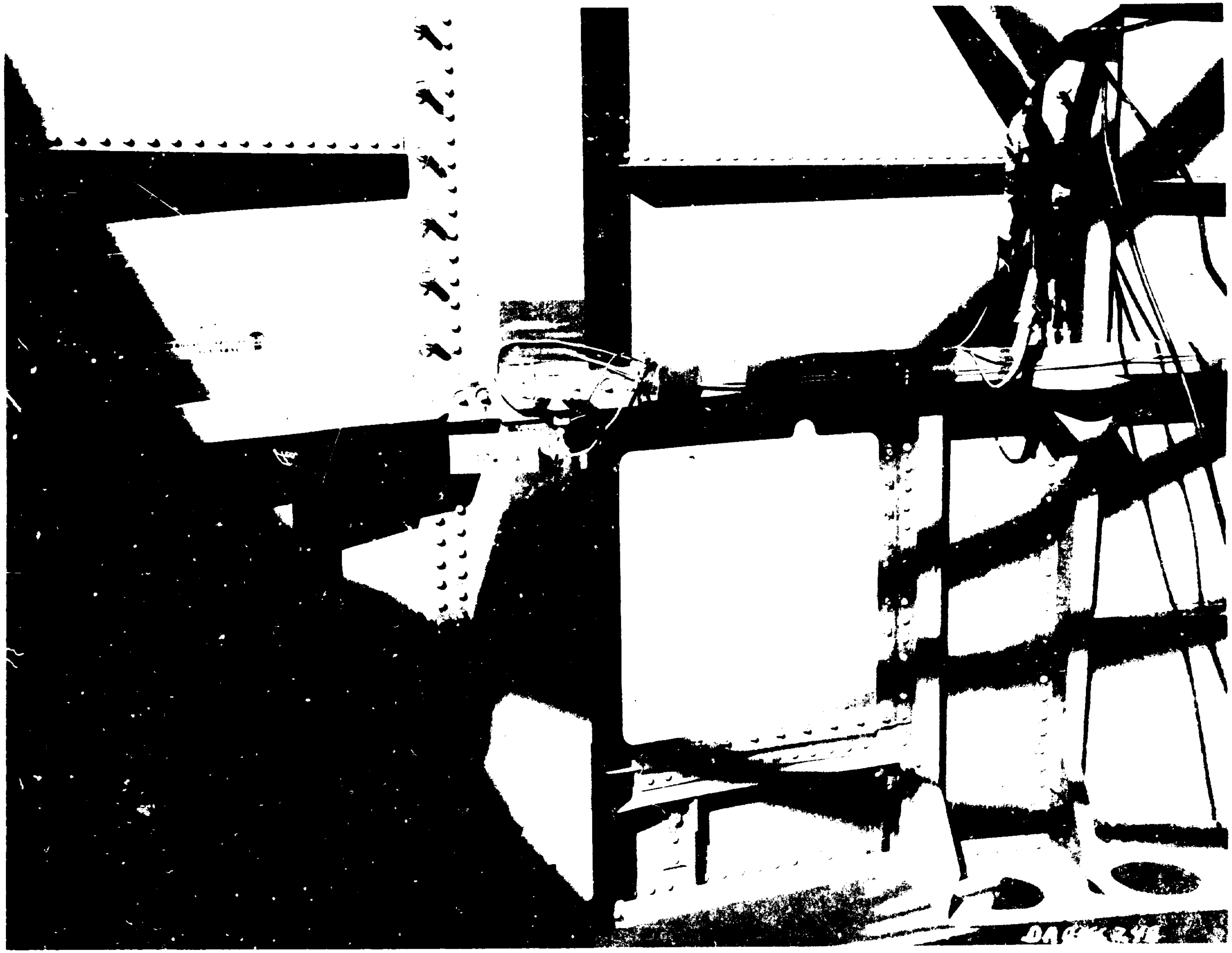


Figure 106 Installation of Accelerometers at Location 15

SHOCK TEST ANALYSIS DATA SHEET

TEST ITEM UPLF PART NO.

SERIAL NO. TEST DATE July, 1968

SHOCK AXIS 3A21 Tangential SHOCK NO. Fairing Release

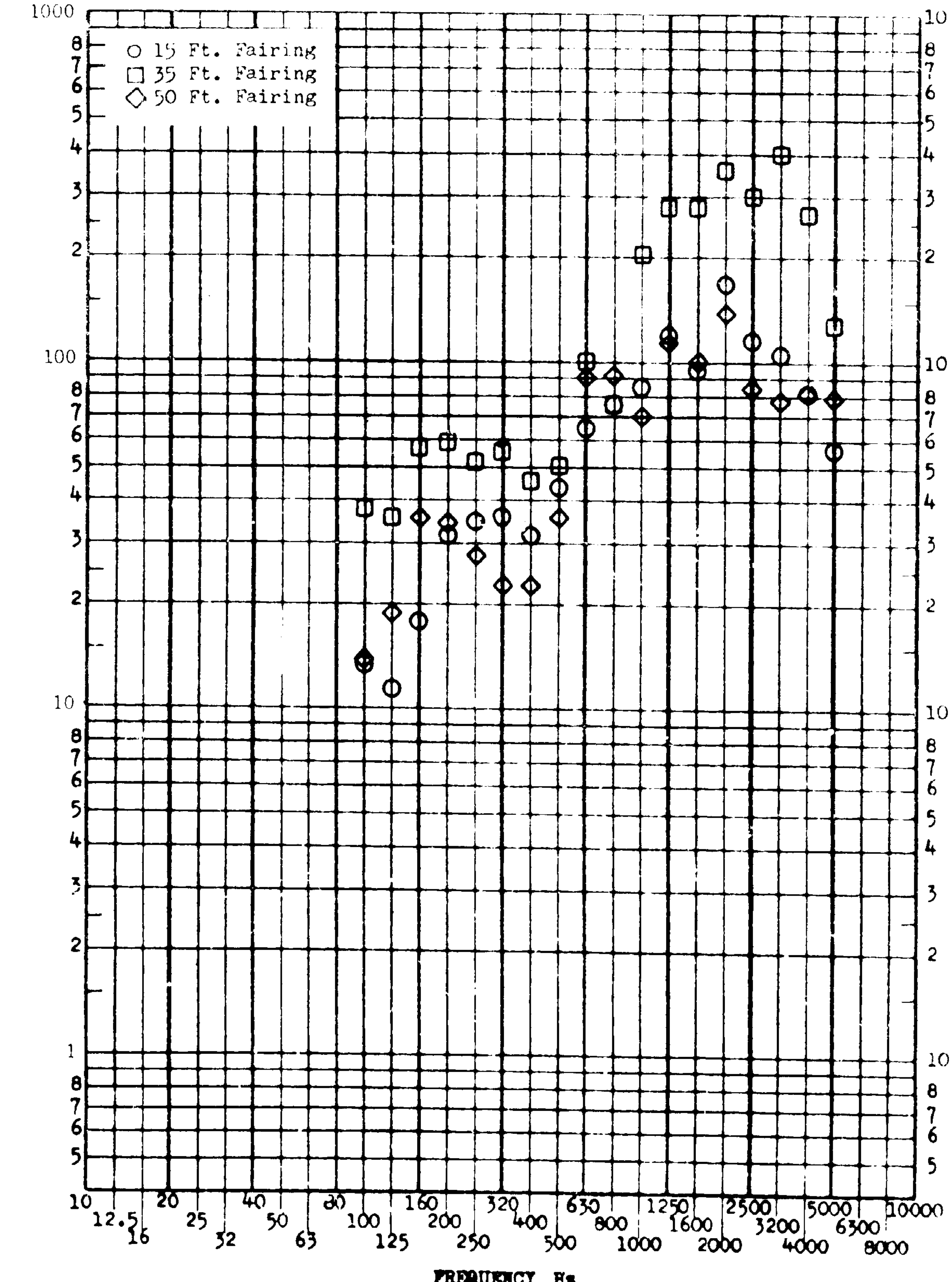



Figure 107 Shock Spectra for Fairing Release for Location 3A21 Tangential

SHOCK TEST ANALYSIS DATA SHEET

TEST ITEM UPLF PART NO.

SERIAL NO. TEST DATE July 1968

SHOCK AXIS 3A1 Longitudinal SHOCK NO. Pin Release

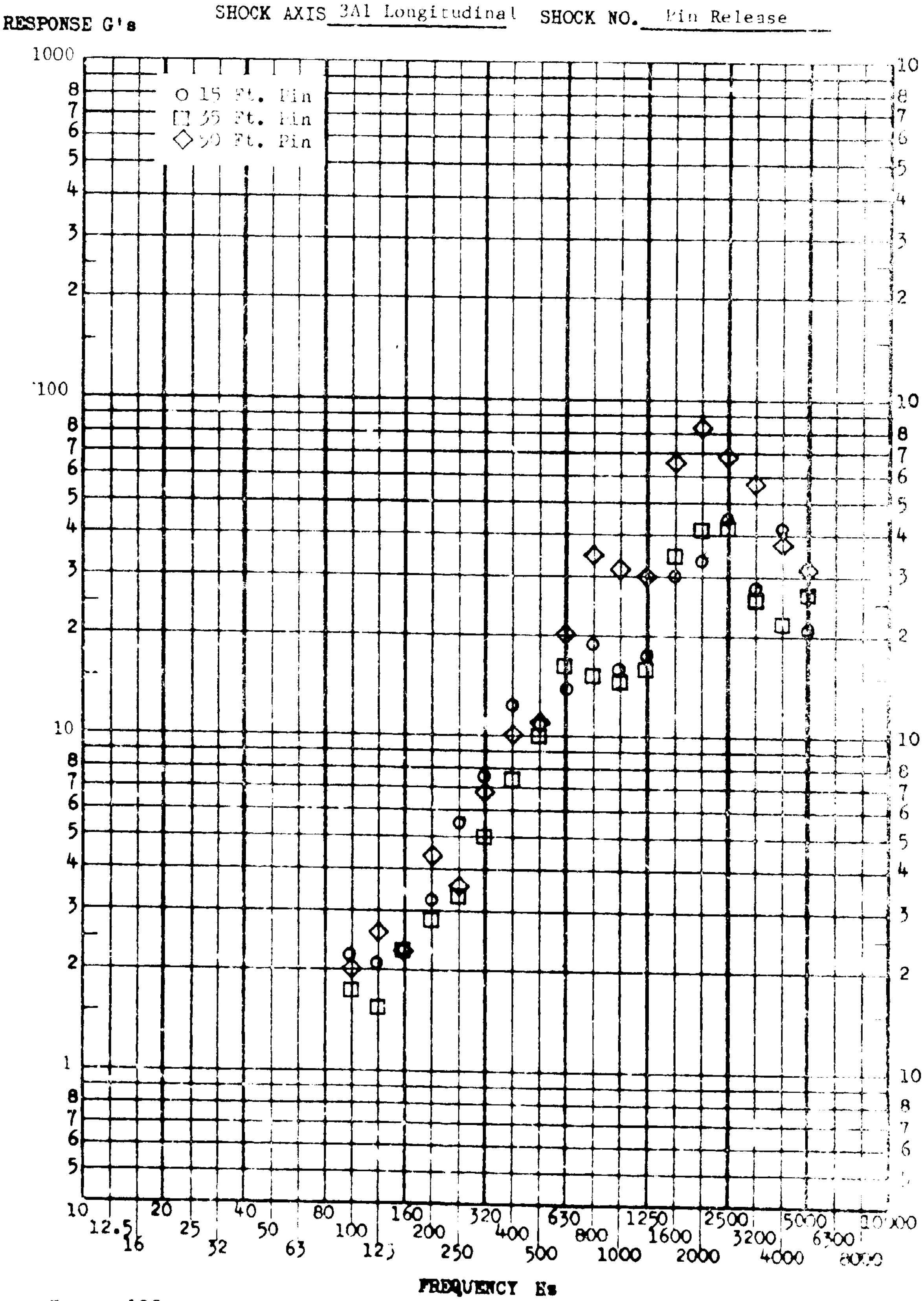



Figure 108 Shock Spectra for Pin Release for Location 3A1 Longitudinal

SHOCK TEST ANALYSIS DATA SHEET

TEST ITEM UPLF PART NO.

SERIAL NO. TEST DATE July 1968

SHOCK AXIS 3A13 Longitudinal SHOCK NO. Pin Release

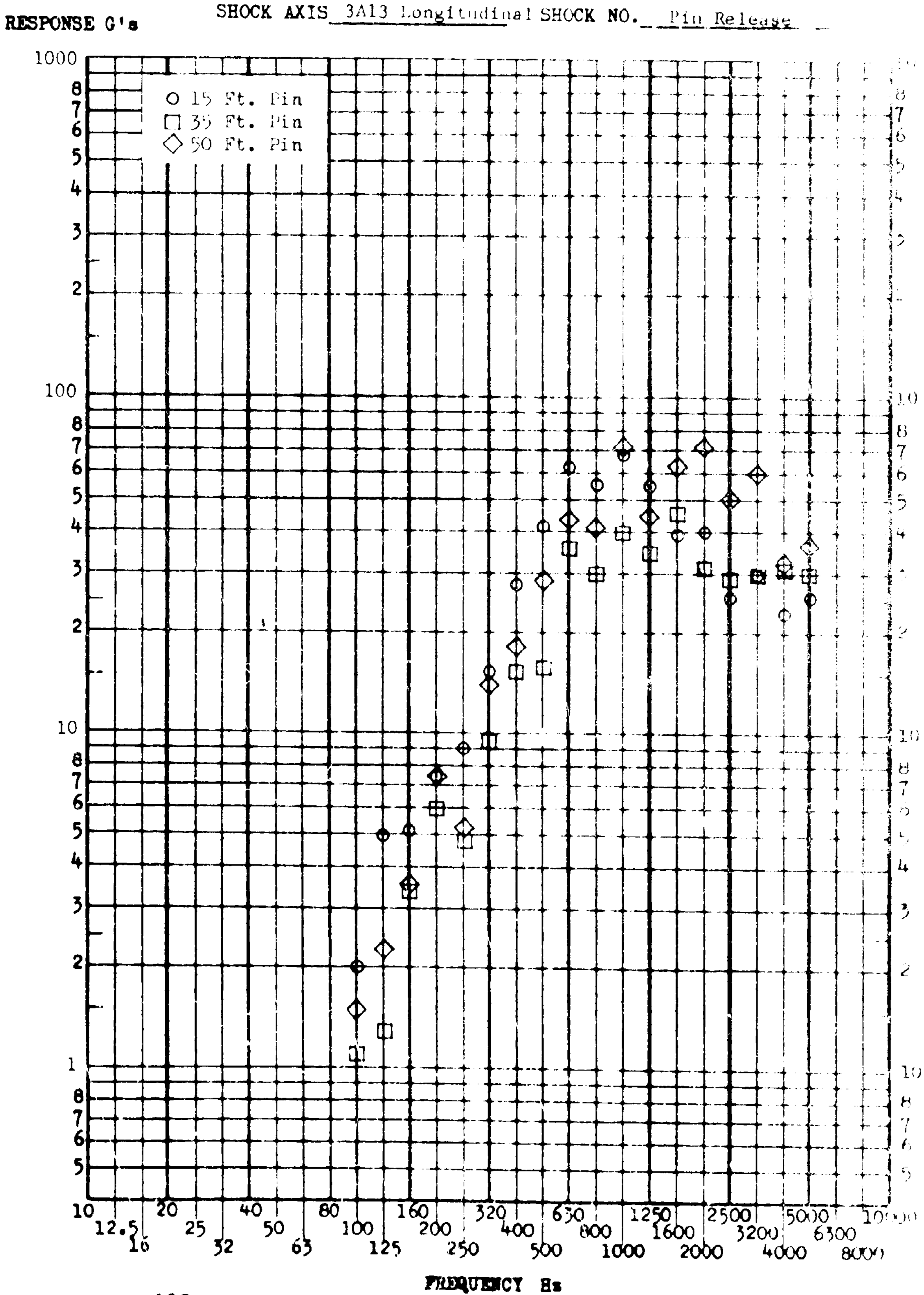



Figure 109 Shock Spectra for Pin Release for Location 3A13 Longitudinal

SHOCK TEST ANALYSIS DATA SHEET

TEST ITEM UPLF PART NO.

SERIAL NO. TEST DATE July 1968

SHOCK AXIS 3A21 Tangential SHOCK NO. Pin Release

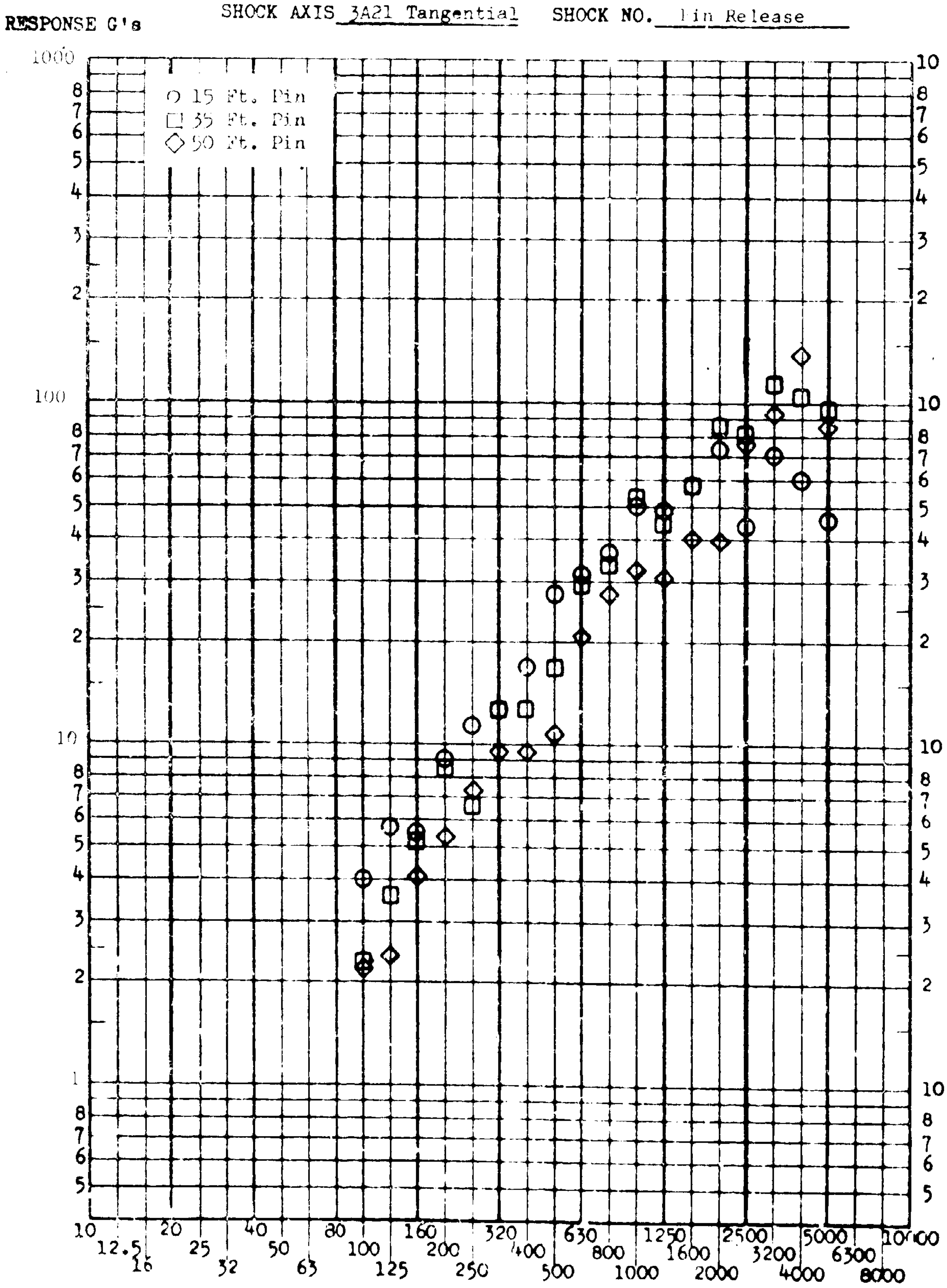



Figure 110 Shock Spectra for Pin Release for Location 3A1 Tangential

SHOCK TEST ANALYSIS DATA SHEET

TEST ITEM UPLF PART NO.

SERIAL NO TEST DATE July 1968

SHOCK AXIS 3A1 Longitudinal SHOCK NO. Fairing Release

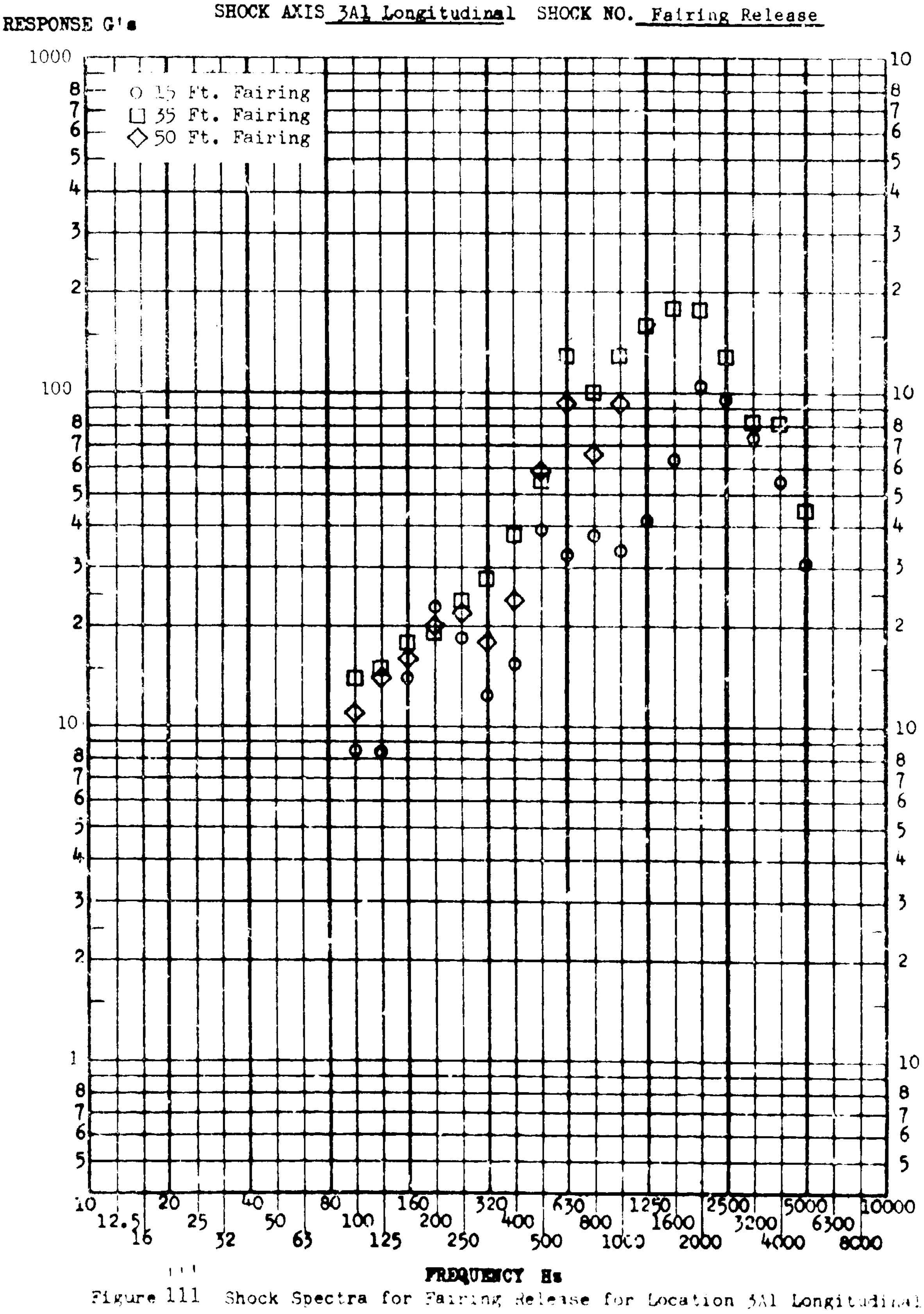



Figure 111 Shock Spectra for Fairing Release for Location 3A1 Longitudinal

SHOCK TEST ANALYSIS DATA SHEET

TEST ITEM UPLF PART NO. ____________

SERIAL NO. ____________ TEST DATE July 1968

SHOCK AXIS 3A13 Longitudinal SHOCK NO. Fairing Release

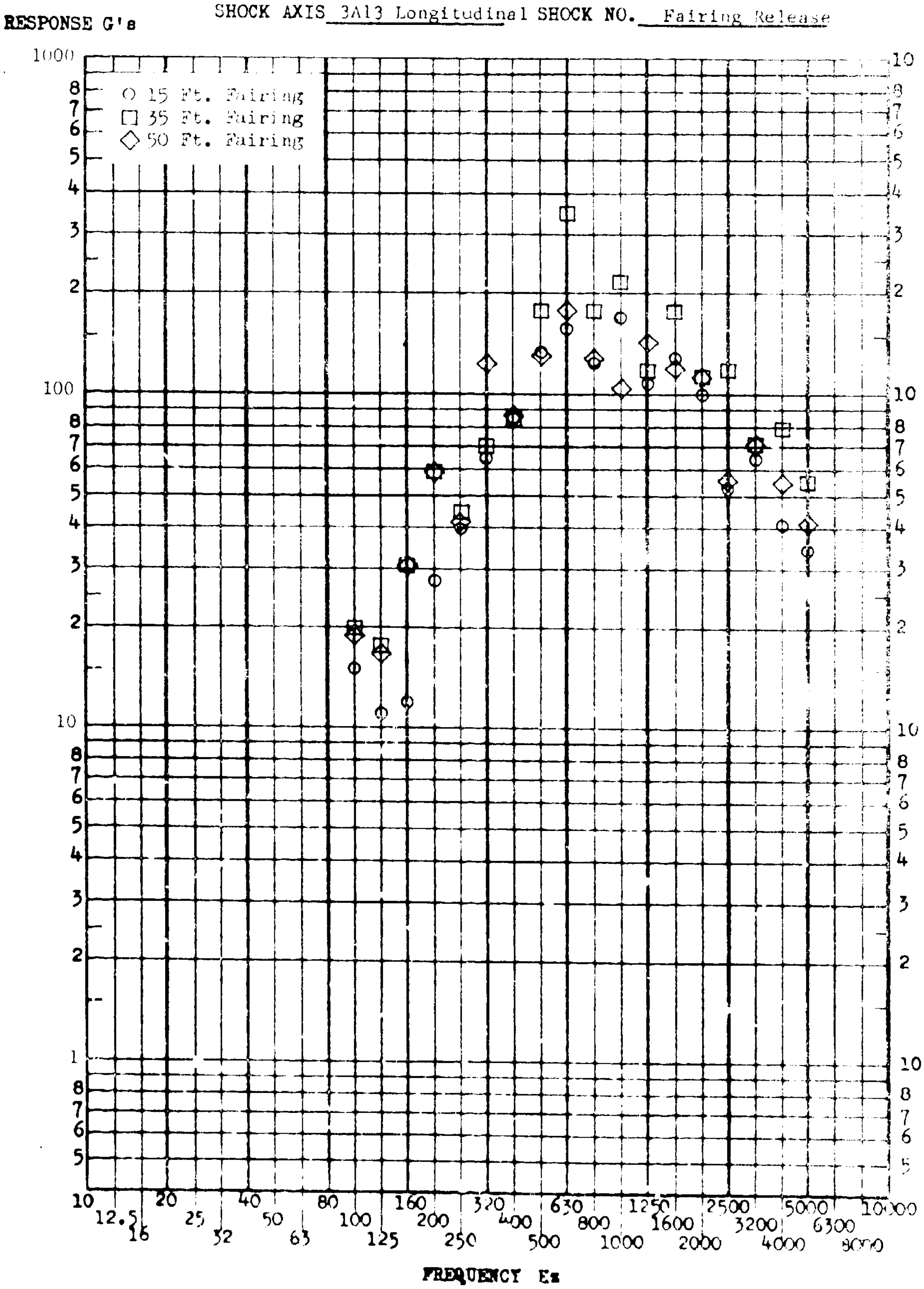



Figure 112 Shock Spectra for Fairing Release for [illegible] 3A14 Longitudinal

**TEST ITEM** Payload Truss Separation Tests

ACCEL. NO. 5 **TEST DATE**

**SHOCK AXIS** BL **SHOCK NO.** 1, 2, and 3

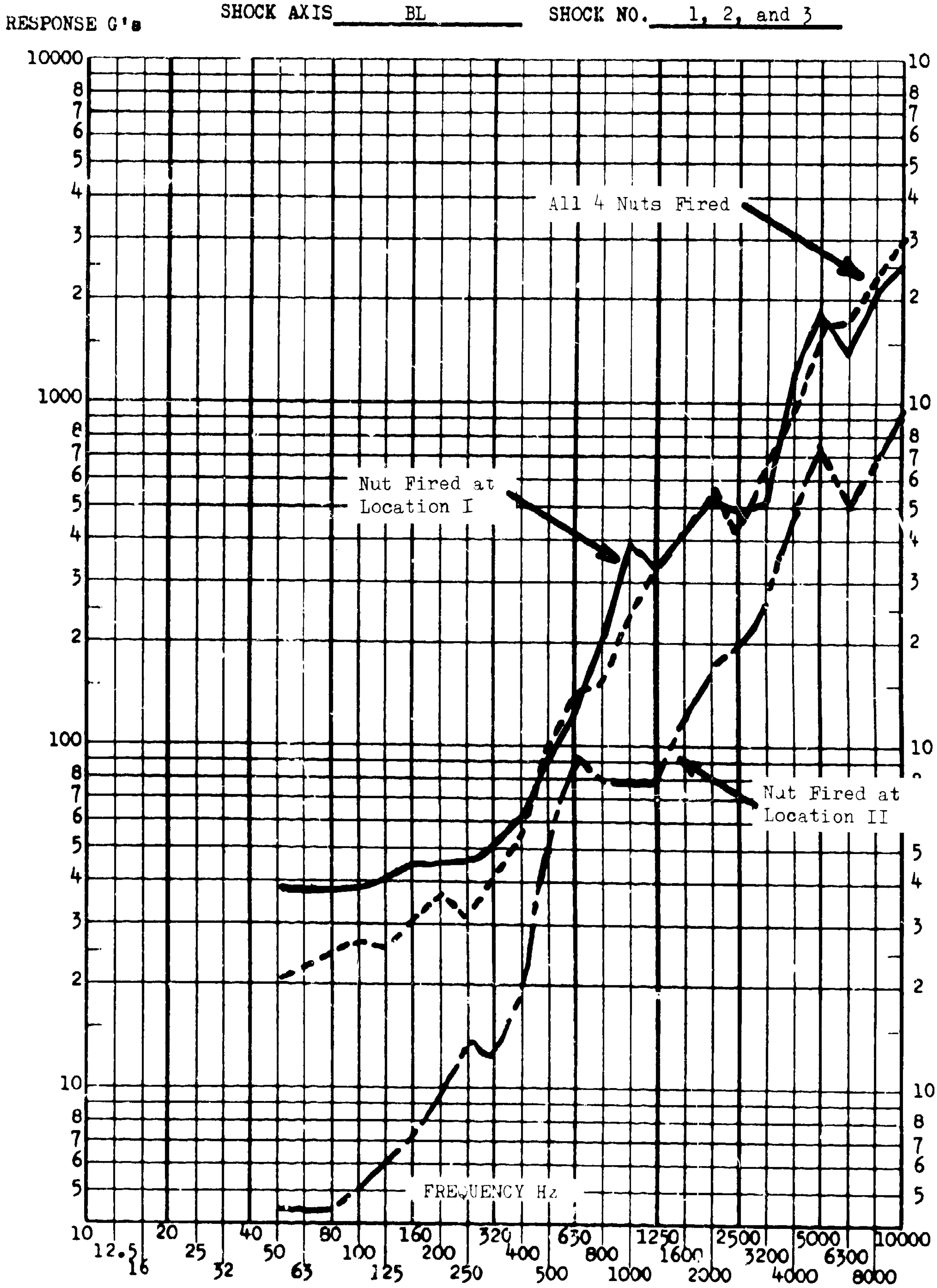



Fig. 1[illegible]. Comparison of Single and Multiple [illegible]ges at Accelerometer 5BL --- Near Nut Number I.

TEST ITEM [illegible]

[illegible] NO. 5 TEST DATE

SHOCK AXIS VERT SHOCK NO. 1, 2, and 3

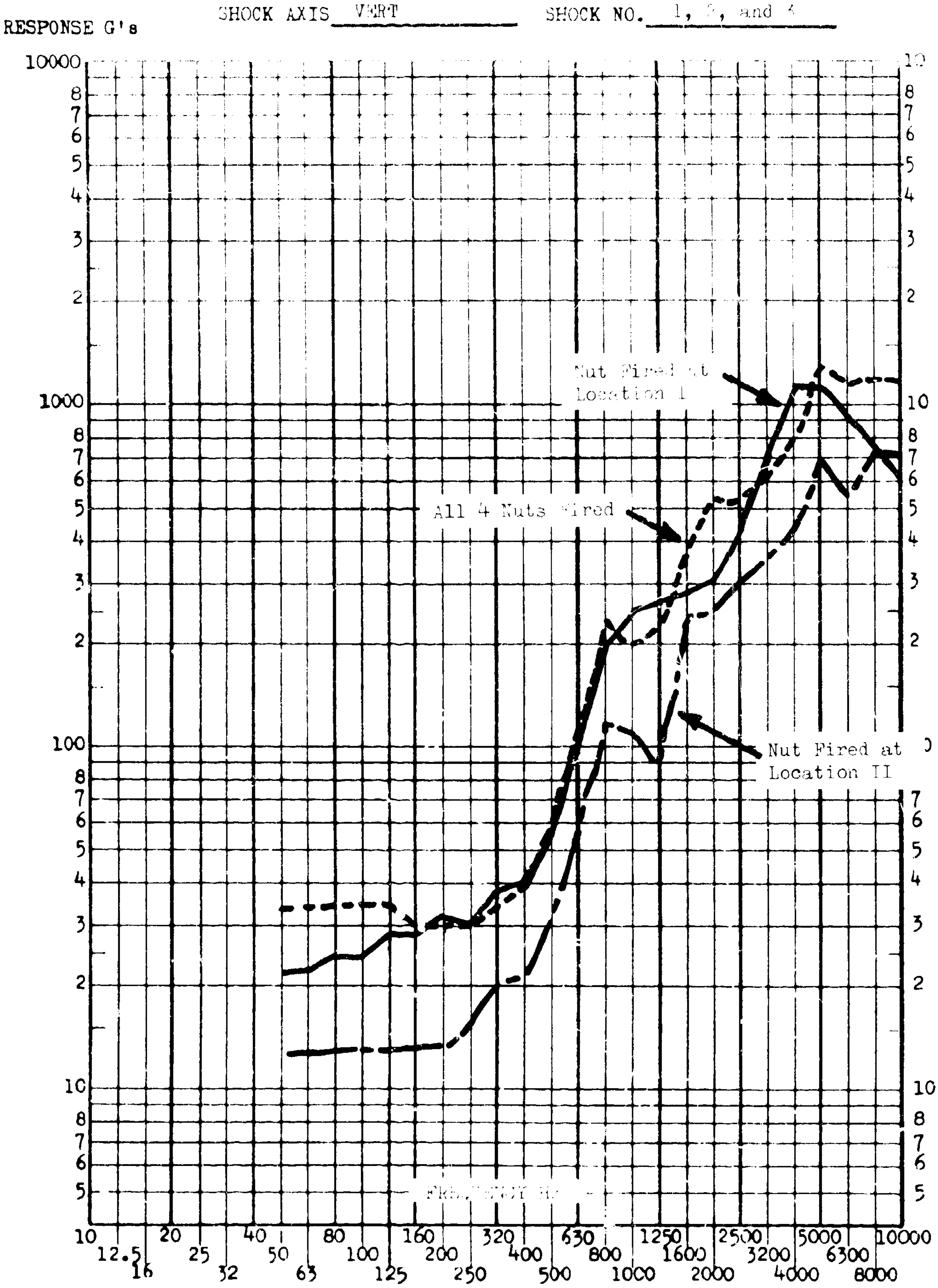



Figure [illegible]. Comparison of Single and Multiple Charges at Accelerometer [illegible] --- [illegible] Number 1.

TEST ITEM Payload Truss Separation Tests

ACCEL. NO.______ TEST DATE______

SHOCK AXIS BL SHOCK NO. 3 and 6

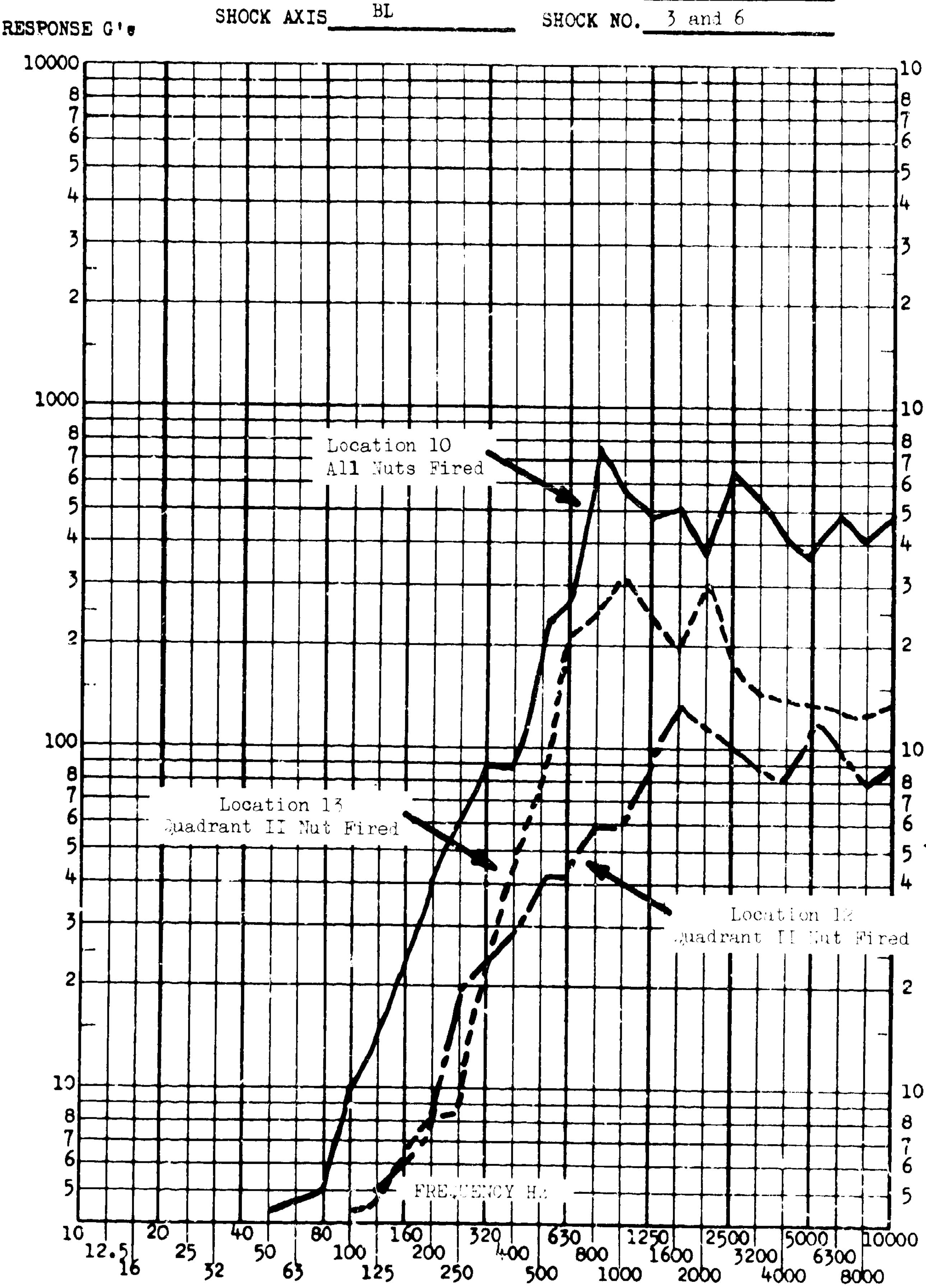



Figure 115. Comparison of Single and Multiple Charges at Similar Locations

TEST ITEM ayload Truss eparation Tests

ACCEL. NO. ________ TEST DATE ________

SHOCK AXIS WL SHOCK NO. 3 and 6

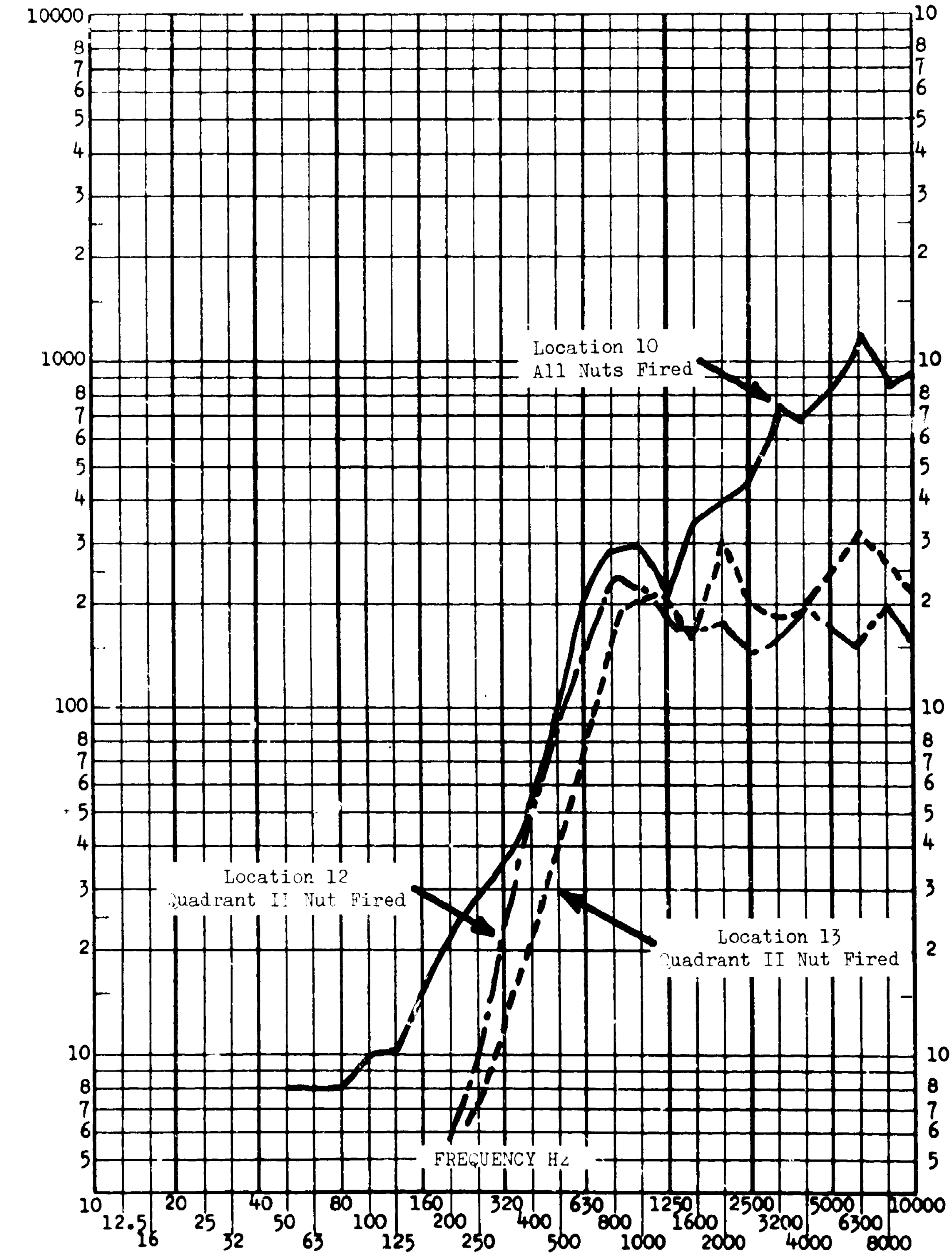



Figure 116. Comparison of Single and Multiple Charges at Similar Location

5

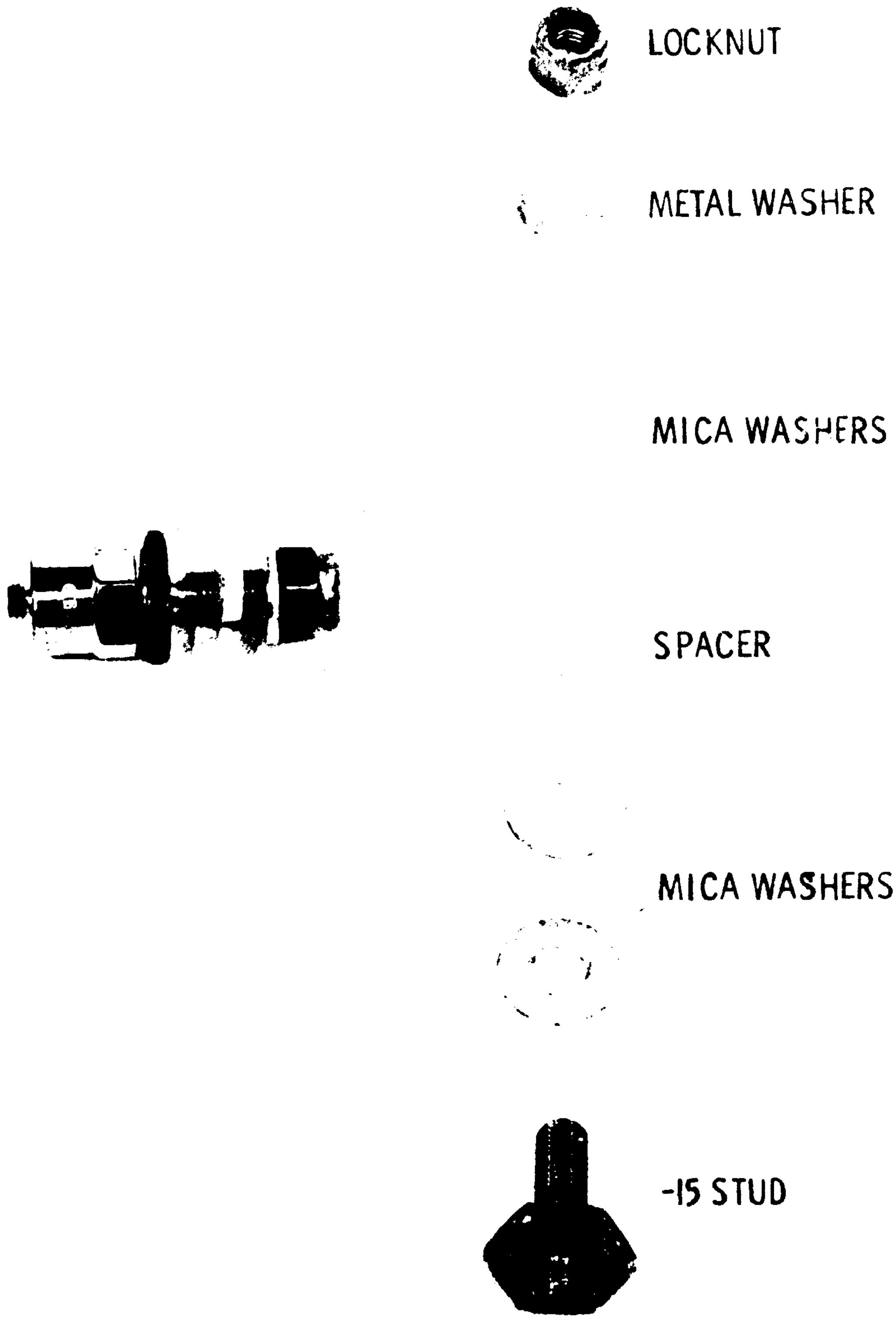



Figure 117. Final Accelerometer Mounting System

# APPENDIX A

# METHODS OF FOURIER AND SHOCK SPECTRA ANALYSIS

A.1 Fourier Transform Methods

An inspection of the literature in the field of shock and vibration indicates that very little practical application of Fourier transform techniques has been accomplished. This is due to the absence of an efficient, accurate and economical method of producing a Fourier transform of a complex digital record. A straightforward application of the definition of a Fourier series transformation to N samples of data requires $N^2$ computations which represents appreciable computer time if N is large. Recently a method of determining a Fourier transform was discovered that reduces the computations from $N^2$ to $N \log_2 N$. This reduces the number of computations by the factor $(\log_2 N)/N$. The basic method is called the "Fast Fourier Transform" technique. The 1967 June issue of the IEEE Journal of Audio and Electroacoustics, volume AU-15, number 2, was devoted to the description and applications of this technique. A very good article that gives an insight into the details of this technique is in the December issue of the same Journal by E. O. Brigham and R. E. Morrow (Reference 2).

A computer program has been developed under this technique and is available through the SHARE library. The basic subroutine program is called P. K. FORT and performs a complex Fourier transformation on a complex function (complex in the mathematical sense). Another subroutine called HARM has the ability to perform a three dimensional, complex Fourier Transformation, but can be used to obtain a one dimensional transformation. The listing of FORT is contained at the end of this section.

One aspect of this algorithm that is peculiar to these programs is the number of data samples (N) which can be used. The program can operate only on an integral number of samples which is a power of two, i.e. $2^M = N$. FORT is limited to M = 13 and HARM is limited to M = 20. ($2^{13}$ = 8192).

There are three parameters important to any analysis of sampled data; the sample rate (SR), the number of samples (N), and the time interval (T) of the record being analyzed. They are related by

$$SR \cdot T = N \qquad (1)$$

Two of these are selected for a particular problem and the third is determined by equation (1). Because of the special nature of FORT, the number of samples (N) has to be set equal to a power of 2. A Fourier transform converts a time series into a function of frequency. The frequency resolution depends on the length of the time record (T) and is given by:

$$F = \frac{1}{T} \qquad (2)$$

The choice of the frequency resolution and sample rate will depend on the particular problem and the desired information. There is one factor limiting the sample rate and that is "frequency foldover" or "aliasing". The minimum sample rate must be twice the frequency for which energy is presented in a given time signal. If the sample rate is less than this value the energy present above one half the sample rate will be "folded over" into the frequency range less than one half the sample rate. The resulting Fourier transform will give a false indication of energy. Another important factor affecting the sample rate is the number of samples per cycle for the highest frequency present. Theoretically, for an infinite record of random noise that is stationary, the minimum sample rate is two samples per cycle. However, for transient or non-stationary time signals the recommended sample rate is from 5 to 10 samples per cycle. It appears to be generally agreed that 10 samples per cycle is sufficient but there is no agreement on a minimum sample rate for transient data. If the analog data has been filtered to a specific frequency then a sample rate of twice this frequency will be sufficient for Fourier spectra.

Therefore, the actual sample rate, the length of record, and the number of samples must be selected for each problem and depend on the type of results desired. One other important phenomenon governing the choice of the above parameters is frequency speading. If the energy is contained in a narrow frequency band and the resolution is much larger than this bandwidth, the energy will appear to be "spread" over the frequency bandwidth F.

The two programs, FORT and HARM, have been successfully employed on a number of real time histories and on a theoretical pulse. The work on the theoretical pulse provided the initial experience and a check on the accuracy of the programs. Section 2.2.6 contains Fourier spectra obtained using this method.

The original time histories were digitized on a Redcor analog to digital converter at a sample rate of 100,000 samples per second. The information present on these FM tapes is band limited by the recording amplifiers to 20 K Hz. The number of samples analyzed was 8192, i.e. M = 13. FORT was used to perform the Fourier transformation. The length of record was T = 8192/100,000 = 81.92 milliseconds. The frequency resolution was

$$F = \frac{1}{0.08192} = 12.2 \text{ Hz.}$$

The result is a complex valued function that gives information on the energy content every 12.2 Hz to 50 K Hz. The information present at 10 K Hz has then been sampled at a rate of 10 samples per cycle. Because of the high sample rate, fold over is not a problem. The frequency resolution at the very low frequencies (below approximately 100 Hz) may not be adequate for an exact definition of the energy present at these frequencies.

It is important to note that the calculation of the Fourier transform (utilizing either FORT or HARM) includes a normalization factor 1/N in the computations. To obtain results which are properly scaled in the frequency domain, each output data point must be multiplied by N · t, which is equal to the record length (T).

SUBROUTINE FORT

```
      SUBROUTINE FORT(A,M,S,IFS,IFERR)
C
C     FOURIER TRANSFORM SUBROUTINE, PROGRAMMED IN SYSTEM/360,
C     BASIC PROGRAMMING SUPPORT, FORTRAN IV. FORM C28-6504
C     THIS DECK SET UP FOR IBSYS ON IBM 7094.
C
C     DOES EITHER FOURIER SYNTHESIS,I.E.,COMPUTES COMPLEX FOURIER SERIES
C     GIVEN A VECTOR OF N COMPLEX FOURIER AMPLITUDES,OR, GIVEN A VECTOR
C     OF COMPLEX DATA X DOES FOURIER ANALYSIS, COMPUTING AMPLITUDES.
C     A IS A COMPLEX VECTOR OF LENGTH N=2**M COMPLEX NOS. OR 2*N REAL
C     NUMBERS. A IS TO BE SET BY USER.
C     M  IS AN INTEGER 0.LT.M.LE.13, SET BY USER.
C     S IS A VECTOR S(J)= SIN(2*PI*J/NP ), J=1,2,....,NP/4-1,
C     COMPUTED BY PROGRAM.
C     IFS IS A PARAMETER TO BE SET BY USER AS FOLLOWS-
C     IFS=0 TO SET NP=2**M AND SET UP SINE TABLE.
C     IFS=1 TO SET N=NP=2**M, SET UP SIN TABLE, AND DO FOURIER
C     SYNTHESIS, REPLACING THE VECTOR A BY
C
C     X(J)= SUM OVER K=0,N-1 OF A(K)*EXP(2*PI*I/N)**(J*K),
C     J=0,N-1, WHERE I=SQRT(-1)
C
C     THE  X-S  ARE STORED WITH   RE X(J) IN CELL  2*J+1
C     AND  IM X(J)  IN CELL  2*J+2  FOR  J=0,1,2,...,N-1.
C     THE  A-S  ARE STORED IN THE SAME MANNER.
C
C     IFS=-1   TO SET  N=NP=2**M,SET UP SIN TABLE, AND DO FOURIER
C     ANALYSIS, TAKING THE INPUT VECTOR A AS X AND
C     REPLACING IT BY THE A  SATISFYING THE ABOVE FOURIER SERIES.
C     IFS=+2 TO DO FOURIER SYNTHESIS ONLY, WITH A PRE-COMPUTED S.
C     IFS=-2 TO DO FOURIER ANALYSIS ONLY, WITH A PRE-COMPUTED S.
C     IFERR   IS SET BY PROGRAM TO-
C     =0 IF NO ERROR DETECTED.
C     =1 IF M IS OUT OF RANGE., OR, WHEN IFS=+2,-2, THE
C     PRE-COMPUTED S TABLE IS NOT LARGE ENOUGH.
C     =-1 WHEN IFS =+1,-1, MEANS ONE IS RECOMPUTING S TABLE
C     UNNECESSARILY.
C
C     NOTE- AS STATED ABOVE, THE MAXIMUM VALUE OF M FOR THIS PROGRAM
C     ON THE IBM 7094 IS 13. FOR 360 MACHINES HAVING GREATER STORAGE
C     CAPACITY, ONE MAY INCREASE THIS LIMIT BY REPLACING 13 IN
C     STATEMENT 3 BELOW BY LOG2 N, WHERE N IS THE MAX. NO. OF
C     COMPLEX NUMBERS ONE CAN STORE IN HIGH-SPEED CORE.  ONE MUST
C     ALSO ADD MORE  DO  STATEMENTS TO THE BINARY SORT ROUTINE
C     FOLLOWING STATEMENT  24  AND CHANGE THE EQUIVALENCE STATEMENTS
C     FOR THE  K-S.
C
      DIMENSION A(1), S(1), K(14)
      EQUIVALENCE (K(13),K1),(K(12),K2),(K(11),K3),(K(10),K4)
      EQUIVALENCE (K( 9),K5),(K( 8),K6),(K(7),K7),(K( 6),K8)
      EQUIVALENCE (K( 5),K9 ),(K( 4),K10),(K( 3),K11),(K( 2),K12)
      EQUIVALENCE (K( 1),K13),( K(1),N2)
      IF(M)2,2,3
```

```
    7 CALL HARM (A,M,INV,S,IL,IFERR)
      GO TO 9
    6 CALL FORT (A,M,S,IL,IFERR)
C     IF IFERR IS ZERO THE SUBROUTINE HAS EXECUTED CORRECTLY
    9 WRITE (6,106)IFERR
C     THE COMPUTER TIME EXPENDED AFTER EXECUTION HAS BEEN RETURNED TO
C     THE MAIN PROGRAM IS PRINTED OUT
      CALL CPWMS(B)
      WRITE(6,110)B
C     THE FREQUENCY INCREMENT IS 1.0 DIVIDED BY THE LENGTH OF RECORD
C     THE REASON FOR THIS IS THAT ONLY SINUSOIDS OF CERTAIN
C     FREQUENCIES WILL FIT AN INTEGRAL NUMBER OF CYCLES INTO THE
C     CHOSEN TIME INTERVAL
C     THE FREQUENCY SCALE IS GENERATED IN ANV WHILE THE CO IS PLACED
C     IN S
      DEL=1.0/2.048
      S(1)=A(1)*2.048
      DO 13 I=2,101
      ANV(I)=ANV(I-1)+DEL
   13 S(I)=A(2*I-1) *2.048
C     PLOT THE REAL PART OF THE TRANSFORM
      READ (5,101)PTITLE
      CALL PLOT1 (ANV, S,101,1,0.0,5.0,4HFREQ,2HCO,PTITLE,0,1,1,2048)
C     THE QUAD IS PLOTTED IN A SIMILAR MANNER
      DO 15 I=1,101
   15 S(I)=A(2*I)*2.048
      READ (5,101)PTITLE
      CALL PLOT1 (ANV, S,101,1,0.0,5.0,4HFREQ,4HQUAD,PTITLE,0,1,1,2048)
C     NOW THE MAGNITUDE OF THE FOURIER TRANSFORM IS CALCULATED
C     AND PLOTTED
      DO 16 I=1,101
   16 S(I)=SQRT((A(2*I-1)**2)+(A(2*I)**2))*2.048
      READ (5,101)PTITLE
      CALL PLOT1 (ANV, S,101,1,0.0,5.0,4HFREQ,3HMAG,PTITLE,0,1,1,2048)
C     FINALLY THE PHASE IS DETERMINED AND PLOTTED
      DO 17 I=1,101
   17 S(I)=ATAN2((A(2*I)),(A(2*I-1)))*57.3
      READ (5,101)PTITLE
      CALL PLOT1 (ANV, S,101,1,0.0,5.0,4HFREQ,5HPHASE,PTITLE,0,1,1,2048)
C     DUE TO ADDITIONAL INTEREST THE ASSOCIATED PSD IS CALCULATED
C     AND PLOTTED
      DO 18 I=1,101
   18 S(I)=2.048 *((A(2*I-1)**2)+(A(2*I)**2)) *2.0
      READ (5,101)PTITLE
      CALL PLOT1 (ANV, S,101,1,0.0,5.0,4HFREQ,3HPSD,PTITLE,0,1,1,2048)
C     SUBROUTINE START ALSO SERVES TO STOP THE PROGRAM ONCE THE
C     DATA CARDS ARE EXHAUSTED
      GO TO 5
      STOP
      END
```

## SHOCK SPECTRUM METHOD

Reference [12] describes a method of performing a shock spectrum by using a recursive filter. A recursive filter is an efficient method of calculating the response of single degree of freedom oscillator and is discussed in detail in Reference [12]. This method was used to calculate the shock spectra presented in section 2.2.6. A listing of the program called SPOCK is contained in this section.

```
      SUBROUTINE SPOCK(R,Q,SR,NS,IL,SS,TM,FQ,L1,NF)
      DIMENSION R(1),SS(1),TM(1),FQ(1),PTITLE(4)
C     SUBROUTINE PRODUCES SHOCK SPECTRUM AND TIME OF OCCURANCE OF MAX
C          AMPLITUDE FOR THIRD OCTAVE BAND FREQUENCIES FROM  10HZ TO
C          20000HZ OR FOR ANY SET OF FREQUENCIES THE USER DESIRES.
C     AN OPTION IS PROVIDED TO PLOT THE SHOCK SPECTRUM AND TIME SPECTRUM
C          ON LOG AND SEMILOG GRAPHS
C     MAIN PROGRAM MUST CALL INIT28C
C     MAIN PROGRAM DIMENSIONS  SS,TM,FQ, EQUAL TO  NF. SEE BELOW NF.
C     THE OUTPUT CAN BE READ IN THE MAIN PROGRAM AS SS,TM,FQ.
C     SUBROUTINE ARGUMENTS
C          R= VECTOR OF INPUT TIME HISTORY. SIZE MUST BE AT LEAST (NS)
C          Q= AMP FACTOR =1.0/2*(DAMPING RATIO). MUST NOT EXCEED 100.
C          SR= SAMPLE RATE USED TO SAMPLE TIME HISTORY R(I).
C          NS= NUMBER OF SAMPLES OF TIME HISTORY
C                RECALL THE FORMULA SR*T=NS  WHERE T=TIME DURATION
C                AND 1.0/T = FREQUENCY RESOLUTION
C          IL= OUTPUT OPTION NUMBER
C            = 0 (DOES NOT PLOT SPECTRA)
C            = 1 (PLOTS SHOCK AND TIME SPRCTRA)
C          SS = SHOCK SPECTRA VALUES
C          TM = MAX AMP TIME VALUES
C          FQ = FREQ VALUES
C             THE ABOVE THREE MUST BE DIMENSIONED EXACTLY  (34) IN
C             THE CALL ING PROGRAM IF L1 = 0.  IF L1 = 1 THEN THE USER
C             DIMENSIONS THESE THREE  FOR THE NUMBER OF FQ(I).
C     TWO PTITLE S MUST BE READ AS DATA EACH TIME SPOCK IS CALLED  IF IL=1
C     THE ACC SHOCK SPECTRUM VALUES SS(I) ARE IN UNITS OF INPUT ACC
C     TO CONVERT TO VEL SHOCK SPECTRUM  SS(I) =SS(I)/(6.28*FQ(I))
C         L1 = 1  USER SETS UP FQ(I) VALUES DESIRED IN CALLING PROGRAM
C            = 0  FQ(I) DETERMINED BY PROGRAM WHICH SETS UP 34 FREQ
C             AT THIRD OCTAVE FREQ
C         NF = NUMBER OF FREQUENCIES FQ(I).  DIMENSION 34 IF L1 = 0.
C
C     CHECK VALUE OF DAMPING RATIO
C
      IF(Q.GT.101.)1,2
    2 CONTINUE
      IF (L1.GT.0.0) GO TO 10,11
   11 CONTINUE
C     SET UP THIRD OCTAVE BAND FREQ
      FQ(1)=10.
      FQ(2)=12.5
      FQ(3)=16.
      FQ(4)=20.
      FQ(5)=25.
      FQ(6)=32.
      FQ(7)=40.
      FQ(8)=50.
      FQ(9)=63.
      FQ(10)=80.
      DO 4 I = 11,34
    4 FQ(I) = FQ(I-10)*10.0
   10 CONTINUE
C     SETS UP CONSTANTS USED IN FILTER
      T= 1.0/SR
      QINV=1.0/Q
      DO 5 J=1,NF
      W = 6.2831853]*FQ(J)
      PO =W*T*QINV
      SQR= SQRT(4.0*Q*Q-1.0)
      ARG = PO*.5*SQR
```

```
      P1=PO*EXP(-PO*.5)*(((2.0*Q*Q-1.0)*SIN(ARG)/SQR) - COS(ARG))
      Q1=-2.0*EXP(-PO*.5)*COS(ARG)
      Q2= EXP(-PO)
C     INITILIZE THE CONSTANTS
      Z = ABS(R(1))
      C1 = R(1)
      C2 = R(1)
C      CALCULATE THE OUTPUT OF FILTER FOR EACH INPUT POINT
      DO 21 I = 2,NS
      C = PO*R(I) + P1*R(I-1) -Q1*C1 - Q2*C2
      C2 = C1
      C1 = C
C     CHECK FOR MAX VALUE OF OUTPUT
      X = ABS(C)
      IF(Z.GT.X) 21,23
   23 Z = X
      N = I
   21 CONTINUE
      SS(J) = Z
      TM(J) = N*T
    5 CONTINUE
      IF(IL.EQ.1) 30,31
   30 CONTINUE
  101 FORMAT(4A10)
      READ(5,101)PTITLE
      CALL PLOT2(FQ,SS,34,1,4HFREQ,2HSS,PTITLE,3,0,34)
      READ(5,101)PTITLE
      CALL PLOT2(FQ,TM,34,1,4HFREQ,4HTIME,PTITLE,3,0,34)
   31 CONTINUE
      GO TO 3
    1 WRITE(5,102)
  102 FORMAT(10X,*YOU HAVE EXCEEDED A Q=100, PROGRAM STOP*)
      STOP
    3 CONTINUE
      RETURN
      END
```

# APPENDIX B

## QUALITY RATING SHEETS

## Quality Rating Sheets

The effort on Task C resulted in a quality rating of the data compiled under Tasks A and K. A discussion of the rating scheme is contained in Section 2.3 of this volume. The rating sheets contained in this appendix are in the same order as the reports appear in Volumes II & III.

QUALITY RATING FOR SECTION

I.A.1

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | No Block | 4K | 4 | E-2225 M5 | 10 | -------- | 10 | 2.2 | 1 | 0.4 |
| 1 | No Block | 16K | 9 | E-2225 M5 | 10 | -------- | 10 | 16.5 | 85 | 7.6 |
| 2A | No Block | 4K | 4 | E-2225 M5 | 10 | -------- | 10 | 6.4 | 4 | 1.6 |
| 2 | No Block | 16K | 9 | E-2225 M5 | 10 | -------- | 10 | 10 | 8 | 7.2 |
| 3 | No Block | 4K | 4 | E-2225 M5 | 10 | -------- | 10 | 2.8 | 1 | 0.4 |
| 3 | No Block | 16K | 9 | E-2225 M5 | 10 | -------- | 10 | 11.5 | 8 | 7.2 |
| 4 | No Block | 4K | 4 | E-2225 M5 | 10 | -------- | 10 | 3.6 | 1 | 0.4 |
| 4 | No Block | 16K | 9 | E-2225 M5 | 10 | -------- | 10 | 23.4 | 9 | 8.1 |
| 5 | No Block | 4K | 4 | E-2225 M5 | 10 | -------- | 10 | 4.7 | 4 | 1.6 |
| 5 | No Block | 16K | 9 | E-2225 M5 | 10 | -------- | 10 | 12 | 8 | 7.2 |
| 6 | No Block | 4K | 4 | E-2225 M5 | 10 | -------- | 10 | 4.1 | 4 | 1.6 |
| 6 | No Block | 16K | 9 | E-2225 M5 | 10 | -------- | 10 | 19.5 | 9 | 8.1 |
| 7 | No Block | 4K | 4 | E-2225 M5 | 10 | -------- | 10 | — | 5* | 2.0* |
| 7 | No Block | 16K | 9 | E-2225 M5 | 10 | -------- | 10 | 4.5 | 4 | 3.6 |
| 8 | No Block | 4K | 4 | E-2225 M5 | 10 | -------- | 10 | 16.5 | 8.5 | 3.4 |
| 8 | No Block | 16K | 9 | E-2225 M5 | 10 | -------- | 10 | 22.1 | 9 | 8.1 |
| 9 | No Block | 4K | 4 | E-2225 M5 | 10 | -------- | 10 | — | 5* | 2.0* |
| 9 | No Block | 16K | 9 | E-2225 M5 | 10 | -------- | 10 | 5.3 | 4 | 3.6 |
| 10 | No Block | 4K | 4 | E-2225 M5 | 10 | -------- | 10 | — | 5* | 2.0* |
| 10 | No Block | 16K | 9 | E-2225 M5 | 10 | -------- | 10 | 15 | 8.5 | 7.6 |
| 13 | No Block | 4K | 4 | E-2225 M5 | 10 | -------- | 10 | 15 | 8.5 | 3.4 |
| 14 | No Block | 4K | 4 | E-2225 M5 | 10 | -------- | 10 | 15.6 | 8.5 | 3.4 |

QUALITY RATING FOR SECTION

I.A.2

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | No Block | 4K | 4 | E-2225 M5 | 10 | **----- | 10 | 190 | 10 | 4 |
| 2A | No Block | | | E-2225 M5 | 10 | | 10 | 122 | 10 | |
| 3 | No Block | | | E-2225 M5 | 10 | | 10 | 40 | 10 | |
| 4 | No Block | | | E-2225 M5 | 10 | | 10 | 135 | 10 | |
| 5 | No Block | | | E-2225 M5 | 10 | | 10 | 64 | 10 | |
| 6 | No Block | | | E-2225 | 10 | | 10 | 182 | 10 | |
| 7 | No Block | | | E-2225 | 10 | | 10 | 144 | 10 | |
| 8A | No Block | | | E-2225 M5 | 10 | | 10 | 200 | 10 | |
| 9A | No Block | | | E-2225 M5 | 10 | | 10 | 58 | 10 | |
| 10 | No Block | | | E-2225 M5 | 10 | | 10 | 54 | 10 | |
| 11A | No Block | | | E-2225 M5 | 10 | | 10 | 30 | 10 | |
| 12 | No Block | | | E-2225 M5 | 10 | | 10 | 40 | 10 | |
| 13 | No Block | | | E-2225 M5 | 10 | | 10 | 16 | 8.5 | 3.4 |
| 14 | No Block | | | E-2225 M5 | 10 | | 10 | 41 | 10 | 4 |
| 15 | No Block | | | E-2225 M5 | 10 | | 10 | 36 | 10 | 4 |
| 16A | No Block | | | E-2225 M5 | 10 | | 10 | 40 | 10 | 4 |
| 17 | No Block | | | E-2225 M5 | 10 | | 10 | 10 | 8 | 3.2 |
| 16 | No Block | | | E-2225 M5 | 10 | | 10 | 19 | 9 | 3.6 |
| 11 | No Block | | | E-2225 M5 | 10 | | 10 | 30 | 10 | 4 |

* From Pictures

** No anomalies were stated in report.

QUALITY RATING FOR SECTION

I.A.3

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 3 | No Block | 4000 | 4 | E-2225 M5 | 10 | ------- | 10 | 27 | 10 | 4 |
| 4 | No Block | | | E-2225 M5 | 10 | | 10 | 22 | 9 | 3.6 |
| 5 | No Block | | | E-2225 M5 | 10 | | 10 | 40 | 10 | 4 |
| 6 | No Block | | | E-2225 M5 | 10 | | 10 | 25 | 9.5 | 3.8 |
| 9 | No Block | | | E-2225 M5 | 10 | | 10 | — | 5* | 2* |
| 10 | No Block | | | E-2225 M5 | 10 | | 10 | — | 5* | 2* |
| 11 | No Block | | | E-2225 M5 | 10 | | 10 | — | 5* | 2* |
| 12 | No Block | | | E-2225 M5 | 10 | | 10 | 14 | 8 | 3.2 |
| 13 | No Block | | | E-2225 M5 | 10 | | 10 | 22 | 9 | 3.6 |
| 13-4 | No Block | | | E-2225 M5 | 10 | | 10 | 24 | 9 | 3.6 |
| 14 | No Block | | | E-2225 | 10 | | 10 | 50 | 10 | 4 |
| 15 | No Block | | | E-2225 | 10 | | 10 | 42 | 10 | 4 |
| 16 | Block | | | E-2225 | 10 | | 10 | 21 | 9 | 3.6 |
| 17 | No Block | | | E-2225 | 10 | | 10 | 9 | 8 | 3.2 |
| 18 | Block | | | E-2211 | 10 | | 10 | 26 | 9.5 | 3.8 |
| 19 | No Block | | | E-2225 | 10 | | 10 | 32 | 10 | 4 |
| 20 | No Block | | | E-2211 | 10 | | 10 | — | 5* | 2* |
| 22 | No Block | | | E-2225 | 10 | | 10 | — | 5* | 2* |
| 23 | No Block | | | E-2225 | 10 | | 10 | 24 | 9.5 | 3.8 |
| 24 | No Block | | | E-2225 | 10 | | 10 | 29 | 10 | 4 |
| 25 | No Block | | | E-2225 | 10 | | 10 | 22 | 9 | 3.6 |
| 26 | No Block | | | E-2225 | 10 | | 10 | 21 | 9 | 3.6 |
| 27 | No Block | | | E-2225 | 10 | | 10 | 12 | 8 | 3.2 |
| 28 | No Block | | | E-2225 | 10 | | 10 | 10 | 8 | 3.2 |
| 29 | No Block | | | E-2225 | 10 | | 10 | 17 | 8.5 | 3.4 |
| 30 | No Block | | | E-2225 | 10 | | 10 | 21 | 9 | 3.6 |
| 31 | No Block | | | E-2225 | 10 | | 10 | 23 | 9 | 3.6 |
| 32 | No Block | | | E-2225 | 10 | | 10 | 16 | 8.5 | 3.4 |
| 33 | No Block | | | E-2225 | 10 | | 10 | 8 | 8 | 3.2 |

- E = Endevco Corporation
- DPM = 3279 cement

QUALITY RATING FOR SECTION

I.A.3

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 34 | No Block | 4000 | 4 | E-2225 | 10 | ------- | 10 | 6 | 8 | 3.2 |
| 35 | No Block | | | E-2211 | 10 | | 10 | 45 | 10 | 4 |
| 36 | No Block | | | E-2225 | 10 | | 10 | 34 | 10 | 4 |
| 38 | No Block | | | E-2225 | 10 | | 10 | 52 | 10 | 4 |
| 39 | No Block | | | E-2225 | 10 | | 10 | 31 | 10 | 4 |
| 40 | No Block | | | E-2211 | 10 | | 10 | 89 | 10 | 4 |
| 41 | No Block | | | E-2211 | 10 | | 10 | 38 | 10 | 4 |
| 43 | No Block | | | E-2211 | 10 | | 10 | 42 | 10 | 4 |
| 44 | No Block | | | E-2225 | 10 | | 10 | 38 | 10 | 4 |
| 47 | No Block | | | E-2225 | 10 | | 10 | 25 | 9.5 | 3.8 |
| 48 | No Block | | | E-2225 | 10 | | 10 | 20 | 9 | 3.6 |
| 49 | No Block | | | E-2225 | 10 | | 10 | — | 5* | 2* |
| 50 | No Block | | | E-2225 | 10 | | 10 | 37 | 10 | 4 |
| 52 | No Block | | | E02272 | 10 | | 10 | 35 | 10 | 4 |
| 53 | No Block | | | E-2272 | 10 | | 10 | 17 | 8.5 | 3.4 |
| 54 | No Block | | | E-2272 | 10 | | 10 | 30 | 10 | 4 |
| 56 | No Block | | | E-2272 | 10 | | 10 | 20 | 9 | 3.6 |
| 57-4 | No Block | | | E-2220 | 10 | | 10 | — | 5* | 2* |
| 58 | No Block | | | E-2220 | 10 | | 10 | 25 | 9.5 | 3.8 |
| 59 | No Block | | | E-2220 | 10 | | 10 | 40 | 10 | 4 |
| 60 | No Block | | | E-2220 | 10 | | 10 | 15 | 8.5 | 3.4 |

* Strain gage accelerometers

QUALITY RATING FOR SECTION

I.A.4

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 1-R-C2 | Al. Block | 5K | 4 | End. 2225 | 10 | ------- | 10 | 12 | 8 | 3.2 |
| 2-R-B3 | Al Block | | | | | | | 30 | 10 | 4.0 |
| 4-L-B3 | | | | | | | | 25 | 9 | 3.6 |
| 5-L-B3 | | | | | | | | 25 | 9 | 3.6 |
| 5-R-B3 | | | | | | | | 30 | 10 | 4.0 |
| 5-T-B3 | | | | | | | | 40 | 10 | 4.0 |
| 7-L-C2 | | | | | | | | 15 | 8 | 3.2 |
| 7-P-C2 | | | | | | | | 15 | 8 | 3.2 |
| 7-Y-C2 | | | | | | | | 8 | 7 | 2.8 |
| 8-Y-B3 | | | | | | | | 30 | 10 | 4.0 |
| 8-Y-C2 | | | | | | | | 5 | 4 | 1.6 |
| 9-L-B3 | | | | | | | | 10 | 8 | 3.2 |
| 9-P-B3 | | | | | | | | 8 | 7 | 2.8 |
| 9-Y-B3 | | | | | | | | 10 | 8 | 3.2 |
| 11-L-AB3 | No Block | | | | | | | 30 | 10 | 4.0 |
| 11-L-BB3 | | | | | | | | 25 | 9 | 3.6 |
| 11-L-CB3 | | | | | | | | 25 | 9 | 3.6 |
| 13-L-B3 | Al. Block | | | | | | | 10 | 8 | 3.2 |
| 13-P-B3 | Al. Block | | | | | | | 6 | 5 | 2.0 |
| 13-Y-B3 | | | | | | | | 8 | 7 | 2.8 |
| 14-L-B3 | | | | | | | | 12 | 8 | 3.2 |
| 14-P-B3 | | | | | | | | 10 | 8 | 3.2 |
| 14-Y-B3 | | | | | | | | 13 | 8 | 3.2 |
| 16-L-C2 | | | | | | | | 8 | 7 | 2.8 |
| 16-P-C2 | | | | | | | | 10 | 8 | 3.2 |
| 16-Y-C2 | | | | | | | | 10 | 8 | 3.2 |
| 17-L-C2 | | | | | | | | 20 | 9 | 3.6 |
| 17-P-C2 | | | | | | | | 15 | 8 | 3.2 |
| 17-Y-C2 | | | | | | | | 15 | 8 | 3.2 |

QUALITY RATING FOR SECTION
I.A.4

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 20-R-B3 | Al. Block | 5K | 4 | End. 2225 | 10 | ------- | 10 | 16 | 8 | 3.2 |
| 20-T-R3 | | | | | | | | 15 | 8 | 3.2 |
| 21-F-B3 | | | | | | | | 10 | 8 | 3.2 |
| 21-Y-B3 | | | | | | | | 25 | 9 | 3.6 |
| 22-L-C2 | | | | | | | | 16 | 8 | 3.2 |
| 23-L-C2 | | | | | | | | 16 | 8 | 3.2 |
| 23-P-C2 | | | | | | | | 20 | 9 | 3.6 |
| 23-Y-C2 | | | | | | | | 20 | 9 | 3.6 |
| 24-L-C2 | | | | | | | | 10 | 8 | 3.2 |
| 24-P-C2 | | | | | | | | 10 | 8 | 3.2 |
| 24-Y-C2 | | | | | | | | 10 | 8 | 3.2 |
| 25-L-C2 | | | | | | | | 20 | 9 | 3.6 |
| 25-P-C2 | | | | | | | | 12 | 8 | 3.2 |
| 25-Y-C2 | | | | | | | | 20 | 9 | 3.6 |
| 26-L-B3 | No Block | | | | | | | 6 | 5 | 2.0 |
| 27-L-B3 | | | | | | | | 16 | 8 | 3.2 |
| 28-L-B3 | | | | | | | | 12 | 8 | 3.2 |
| 29-L-B3 | Al. Block | | | | | | | 12 | 8 | 3.2 |
| 29-R-B3 | | | | | | | | 15 | 8 | 3.2 |
| 31-T-B3 | | | | | | | | 7 | 6 | 2.4 |
| 31-L-B3 | | | | | | | | 8 | 7 | 2.8 |
| 1-L-C2 | | | | | | | | 30 | 10 | 4.0 |
| -B3 | | | | | | | | 20 | 9 | 3.6 |
| 2-L-C2 | | | | | | | | 18 | 8 | 3.2 |
| -B3 | | | | | | | | 18 | 8 | 3.2 |
| 3-L-C2 | | | | | | | | 20 | 9 | 3.6 |
| -B3 | | | | | | | | 20 | 9 | 3.6 |
| 4-R-C2 | | | | | | | | 15 | 8 | 3.2 |
| -B3 | | | | | | | | 25 | 9 | 3.6 |

QUALITY RATING FOR SECTION

I.A.4

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 4-T-C2 | Al. Block | 5K | 4 | End. 2225 | 10 | ------- | 10 | 15 | 8 | 3.2 |
| -B3 | | | | | | | | 20 | 9 | 3.6 |
| 6-L-C2 | | | | | | | | 15 | 8 | 3.2 |
| -B3 | | | | | | | | 30 | 10 | 4.0 |
| 6-R-C2 | | | | | | | | 20 | 9 | 3.6 |
| -B3 | | | | | | | | 18 | 8 | 3.2 |
| 8-T-C2 | | | | | | | | 10 | 8 | 3.2 |
| -B3 | | | | | | | | 18 | 8 | 3.2 |
| 8-L-C2 | | | | | | | | 12 | 8 | 3.2 |
| -B3 | | | | | | | | 8 | 7 | 2.8 |
| 8-P-C2 | | | | | | | | 10 | 8 | 3.2 |
| -B3 | | | | | | | | 10 | 8 | 3.2 |
| 10-L-AC2 | No Block | | | | | | | 10 | 8 | 3.2 |
| -B3 | | | | | | | | 15 | 8 | 3.2 |
| 10-L-BC2 | | | | | | | | 20 | 9 | 3.6 |
| -B3 | | | | | | | | 30 | 10 | 4.0 |
| 10-L-CC2 | | | | | | | | 15 | 8 | 3.2 |
| 10-L-CB3 | | | | | | | | 25 | 9 | 3.6 |
| 12-L-C2 | Al. Block | | | | | | | 30 | 10 | 4.0 |
| -B3 | | | | | | | | 20 | 9 | 3.6 |
| 12-P-C2 | | | | | | | | 7 | 6 | 2.4 |
| -B3 | | | | | | | | 8 | 7 | 2.8 |
| 12-Y-C2 | | | | | | | | 15 | 8 | 3.2 |
| -B3 | | | | | | | | 15 | 8 | 3.2 |
| 15-L-C2 | | | | | | | | 5 | 4 | 1.6 |
| -B3 | | | | | | | | 13 | 8 | 3.2 |
| 15-P-C2 | | | | | | | | 7 | 6 | 2.4 |
| -B3 | | | | | | | | 10 | 8 | 3.2 |
| 15-Y-C2 | | | | | | | | 10 | 8 | 3.2 |
| -B3 | | | | | | | | 16 | 8 | 3.2 |

QUALITY RATING FOR SECTION

I.A.4

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_7$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 20-L-C2 | Al. Block | 5K | 4 | End. 2225 | 10 | -------- | 10 | 20 | 9 | 3.6 |
| -B3 | | | | | | | | 20 | 9 | 3.6 |
| 21-L-C2 | | | | | | | | 15 | 8 | 3.2 |
| -B3 | | | | | | | | 25 | 9 | 3.6 |
| 22-Y-C2 | | | | | | | | 18 | 8 | 3.2 |
| -B3 | | | | | | | | 8 | 7 | 2.8 |

QUALITY RATING FOR SECTION

I.A.5

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 1X-1 | ---------- | 150 - 400 | 1 | ------------ | 10 | ------- | 10 | 1.6 | 0 | 0.0 |
| 2 | | | | | | | | 1.7 | 0 | 0.0 |
| 3 | | | | | | | | 3 | 2 | .2 |
| 1Y-1 | | | | | | | | 2.2 | 1 | .1 |
| 2 | | | | | | | | 2.9 | 2 | .2 |
| 3 | | | | | | | | 2.8 | 2 | .2 |
| 1Z-1 | | | | | | | | 2.7 | 2 | .2 |
| 2 | | | | | | | | 1.7 | 0 | 0 |
| 3 | | | | | | | | 2.6 | 1 | .1 |
| 2X-1 | | 100-5000 | 4 | | | | | 6.6 | 5 | 2.0 |
| 2 | | | | | | | | 5.9 | 5 | 2.0 |
| 3 | | | | | | | | 12.6 | 8 | 3.2 |
| 2Y-1 | | | | | | | | 2.6 | 1 | .4 |
| 2 | | | | | | | | 2.6 | 1 | .4 |
| 3 | | | | | | | | 2.8 | 1 | .4 |
| 2Z-1 | | | | | | | | 3.6 | 2 | .8 |
| 2 | | | | | | | | 3.8 | 3 | 1.2 |
| 3 | | | | | | | | 10.8 | 8 | 3.2 |
| 3X-1 | | | | | | | | 2.4 | 1 | .4 |
| 2 | | | | | | | | 5.5 | 4 | 1.6 |
| 3 | | | | | | | | 7 | 6 | 2.4 |
| 3Y-1 | | | | | | | | 10 | 8 | 3.2 |
| 2 | | | | | | | | 9.3 | 8 | 3.2 |
| 3 | | | | | | | | 10 | 8 | 3.2 |
| 3Z-1 | | | | | | | | 6.6 | 5 | 2.0 |
| 2 | | | | | | | | 3.6 | 2 | .8 |
| 3 | | | | | | | | 9.8 | 8 | 3.2 |
| 4R-1 | | | | | | | | 16 | 8 | 3.2 |
| 2 | | | | | | | | 18 | 8 | 3.2 |
| 3 | | | | | | | | 23.2 | 9 | 3.6 |

QUALITY RATING FOR SECTION

I.A.5

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 4T-1 | ---------- | 100-5000 | 4 | ------------ | 10 | -------- | 10 | 5.8 | 4 | 1.6 |
| 2 | | | | | | | | 8.5 | 7 | 2.8 |
| 3 | | | | | | | | 16 | 8 | 3.2 |
| 4Z-1 | | | | | | | | 4.0 | 3 | 1.2 |
| 2 | | | | | | | | 4.0 | 3 | 1.2 |
| 3 | | | | | | | | 13.8 | 8 | 3.2 |
| 5X-1 | | | | | | | | 13.7 | [illegible] | [illegible].2 |
| 2 | | | | | | | | 16 | 8 | 3.2 |
| 3 | | | | | | | | 16 | 8 | 3.2 |
| 5Y-1 | | | | | | | | 19.8 | 9 | 3.6 |
| 2 | | | | | | | | 26.3 | 9 | 3.6 |
| 3 | | | | | | | | 17.7 | 8 | 3.2 |
| 5Z-1 | | | | | | | | 14.0 | 8 | 3.2 |
| 2 | | | | | | | | 14.5 | 8 | 3.2 |
| 3 | | | | | | | | 22.8 | 9 | 3.6 |
| 5X-1 | | | | | | | | 14.4 | 8 | 3.2 |
| 2 | | | | | | | | 29 | 10 | 4.0 |
| 3 | | | | | | | | 21.8 | 9 | 3.6 |
| 6Y-1 | | | | | | | | 21.3 | 9 | 3.6 |
| 2 | | | | | | | | 37.7 | 10 | 4.0 |
| 3 | | | | | | | | 18.3 | 8 | 3.2 |
| 6Z-1 | | | | | | | | 16.2 | 8 | 3.2 |
| 2 | | | | | | | | 23.5 | 9 | 3.6 |
| 3 | | | | | | | | 27.6 | 9 | 3.6 |
| 7R-1 | | | | | | | | 11.3 | 8 | 3.2 |
| 2 | | | | | | | | 14.6 | 8 | 3.2 |
| 3 | | | | | | | | 33 | 10 | 4.0 |
| 7T-1 | | | | | | | | 7.0 | 6 | 2.4 |
| 2 | | | | | | | | 9.6 | 8 | 3.2 |
| 3 | | | | | | | | 9.0 | 8 | 3.2 |

QUALITY RATING FOR SECTION

I.A.5

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 7Z-1 | ---------- | 100-5000 | 4 | ------------ | 10 | ------- | 10 | 13 | 8 | 3.2 |
| 2 | | | | | | | | 15.8 | 8 | 3.2 |
| 3 | | | | | | | | 17 | 8 | 3.2 |
| 8R-1 | | | | | | | | 19.8 | 9 | 3.6 |
| 2 | | | | | | | | 22 | 9 | 3.6 |
| 3 | | | | | | | | 23.3 | 9 | 3.6 |
| 8T-1 | | | | | | | | 9.9 | 8 | 3.2 |
| 2 | | | | | | | | 15.1 | 8 | 3.2 |
| 3 | | | | | | | | 17.2 | 8 | 3.2 |
| 8Z-1 | | | | | | | | 5.6 | 4 | 1.6 |
| 2 | | | | | | | | 10.6 | 8 | 3.2 |
| 3 | | | | | | | | 1[illegible].6 | 8 | 3.2 |
| 9R-1 | | | | | | | | .0 | 2 | .8 |
| 2 | | | | | | | | 5 | 3 | 1.2 |
| 3 | | | | | | | | [illegible].2 | 7 | 2.8 |
| 9Z-2 | | | | | | | | 7.7 | 6 | 2.4 |
| 3 | | | | | | | | 9.8 | 8 | 3.2 |
| 10R-1 | | | | | | | | 17.5 | 8 | 3.2 |
| 2 | | | | | | | | 15 | 8 | 3.2 |
| 3 | | | | | | | | 13.3 | 8 | 3.2 |
| 10Z-1 | | | | | | | | 26.2 | 9 | 3.6 |
| 2 | | | | | | | | 25.9 | 9 | 3.6 |
| 3 | | | | | | | | 49 | 10 | 4.0 |
| 11R-1 | | | | | | | | 5.7 | 4 | 1.6 |
| 2 | | | | | | | | 4.1 | 3 | 1.2 |
| 3 | | | | | | | | 11 | 8 | 3.2 |
| 11Z-1 | | | | | | | | 19.4 | 9 | 3.6 |
| 2 | | | | | | | | 28.4 | 9 | 3.6 |
| 3 | | | | | | | | 25.6 | 9 | 3.6 |

QUALITY RATING FOR SECTION

I.A.5

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 12Z-1 | ---------- | 100-5000 | 4 | -------------- | 10 | ------- | 10 | 28.6 | 9 | 3.6 |
| 2 | | | | | | | | 31.6 | 10 | 4.0 |
| 3 | | | | | | | | 28.6 | 9 | 3.6 |
| 14R-3 | | | | | | | | 34.3 | 10 | 4.0 |
| 14Z-1 | | | | | | | | 11.2 | 8 | 3.2 |
| 2 | | | | | | | | 11.1 | 8 | 3.2 |
| 3 | | | | | | | | 12.4 | 8 | 3.2 |
| 16Z-1 | | | | | | | | 46.6 | 10 | 4.0 |
| 2 | | | | | | | | 27.8 | 9 | 3.6 |
| 3 | | | | | | | | 22.2 | 9 | 3.6 |
| 23X-1 | | | | | | | | 9.2 | 8 | 3.2 |
| 2 | | | | | | | | 15.4 | 8 | 3.2 |
| 3 | | | | | | | | 15.4 | 8 | 3.2 |
| 23Y-1 | | | | | | | | 5.2 | 4 | 1.6 |
| 2 | | | | | | | | 11.6 | 8 | 3.2 |
| 3 | | | | | | | | 7.2 | 6 | 7.4 |
| 23Z-1 | | | | | | | | 7.9 | 6 | 3.4 |
| 2 | | | | | | | | 10.3 | 8 | 3.2 |
| 3 | | | | | | | | 8.1 | 7 | 2.8 |
| 24X-1 | | | | | | | | 10 | 8 | 3.2 |
| 2 | | | | | | | | 21 | 9 | 3.6 |
| 3 | | | | | | | | 16.6 | 8 | 3.2 |
| 24Y-1 | | | | | | | | 12.4 | 8 | 3.2 |
| 2 | | | | | | | | 35.5 | 10 | 4.0 |
| 3 | | | | | | | | 16.7 | 8 | 3.2 |
| 24Z-1 | | | | | | | | 22 | 9 | 4.6 |
| 2 | | | | | | | | 37.3 | 10 | 4.0 |
| 3 | | | | | | | | 23.3 | 9 | 3.6 |

QUALITY RATING FOR SECTION

I.A.5

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| -7 | Al. Block | 5000 | 4 | --------------- | 10 | --------- | 10 | 15 | 8 | 3.2 |
| 26Z-8 | | | | | | | | 15 | 8 | 3.2 |
| 27X-4 | | | | | | | | 11 | 8 | 3.2 |
| -5 | | | | | | | | 12 | 8 | 3.2 |
| -6 | | | | | | | | 8 | 7 | 2.8 |
| -7 | | | | | | | | 6 | 5 | 2.0 |
| -8 | | | | | | | | 8 | 7 | 2.8 |
| 27X-9 | | | | | | | | 12 | 8 | 3.2 |
| 27Y-4 | | | | | | | | 8 | 7 | 2.8 |
| -5 | | | | | | | | 13 | 8 | 3.2 |
| -6 | | | | | | | | 13 | 8 | 3.2 |
| -7 | | | | | | | | 16 | 8 | 3.2 |
| 27Y-8 | | | | | | | | 10 | 8 | 3.2 |
| 27Y-9 | | | | | | | | 21 | 9 | 3.6 |
| 27Z-4 | | | | | | | | 18 | 8 | 3.2 |
| -5 | | | | | | | | 15 | 8 | 3.2 |
| -6 | | | | | | | | 14 | 8 | 3.2 |
| -7 | | | | | | | | 14 | 8 | 3.2 |
| -8 | | | | | | | | 9 | 8 | 3.2 |
| 27Z-9 | | | | | | | | 20 | 9 | 3.6 |
| 28X-4 | | | | | | | | 24 | 9 | 3.6 |
| -5 | | | | | | | | 25 | 9 | 3.6 |
| -6 | | | | | | | | 20 | 9 | 3.6 |
| -7 | | | | | | | | 24 | 9 | 3.6 |
| -8 | | | | | | | | 23 | 9 | 3.6 |
| 28X-9 | | | | | | | | 14 | 8 | 3.2 |
| 28Y-4 | | | | | | | | 35 | 10 | 4.0 |
| -5 | | | | | | | | 10 | 8 | 3.2 |
| -6 | | | | | | | | 28 | 9 | 3.6 |
| -7 | | | | | | | | 16 | 8 | 3.2 |
| -8 | | | | | | | | 14 | 8 | 3.2 |

QUALITY RATING FOR SECTION

I.A.5

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| -5 | Al. Block | 5000 | 4 | ------------- | 10 | ------- | 10 | 22 | 9 | 3.6 |
| -6 | | | | | | | | 21 | 9 | 3.6 |
| -7 | | | | | | | | 12 | 8 | 3.2 |
| -8 | | | | | | | | 15 | 8 | 3.2 |
| 24X-9 | | | | | | | | 13 | 8 | 3.2 |
| 24Y-4 | | | | | | | | 37 | 10 | 4.0 |
| -5 | | | | | | | | 26 | 9 | 3.6 |
| -6 | | | | | | | | 23 | 9 | 3.6 |
| -7 | | | | | | | | 19 | 9 | 3.6 |
| -8 | | | | | | | | 14 | 8 | 3.2 |
| 24Y-9 | | | | | | | | 19 | 9 | 3.6 |
| 24Z-5 | | | | | | | | 26 | 9 | 3.6 |
| -6 | | | | | | | | 26 | 9 | 3.6 |
| -7 | | | | | | | | 28 | 9 | 3.6 |
| -8 | | | | | | | | 22 | 9 | 3.6 |
| 24Z-9 | | | | | | | | 31 | 10 | 4.0 |
| 25Z-8 | | | | | | | | 7 | 6 | 2.4 |
| -9 | | | | | | | | 9 | 8 | 3.2 |
| 26X-4 | | | | | | | | 29 | 10 | 4.0 |
| -5 | | | | | | | | 17 | 8 | 3.2 |
| -6 | | | | | | | | 17 | 8 | 3.2 |
| -7 | | | | | | | | 7 | 6 | 2.4 |
| -8 | | | | | | | | 8 | 7 | 2.8 |
| 26X-9 | | | | | | | | 43 | 10 | 4.0 |
| 26Y-4 | | | | | | | | 22 | 9 | 3.6 |
| 26Y-8 | | | | | | | | 20 | 9 | 3.6 |
| -9 | | | | | | | | 34 | 10 | 4.0 |
| 26Z-4 | | | | | | | | 40 | 10 | 4.0 |
| -5 | | | | | | | | 15 | 8 | 3.2 |
| -6 | | | | | | | | 37 | 10 | 4.0 |

QUALITY RATING FOR SECTION

I.A.5

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| -7 | Al. Block | 5000 | 4 | --------------- | 10 | --------- | 10 | 20 | 8 | 3.2 |
| -8 | | | | | | | | 15 | 8 | 3.2 |
| 21Y-9 | | | | | | | | 13 | 8 | 3.2 |
| 21Z-5 | | | | | | | | 14 | 8 | 3.2 |
| -6 | | | | | | | | 35 | 10 | 4.0 |
| -7 | | | | | | | | 12 | 8 | 3.2 |
| -8 | | | | | | | | 20 | 9 | 3.6 |
| 21Z-9 | | | | | | | | 20 | 9 | 3.6 |
| 22X-8 | | | | | | | | 31 | 10 | 4.0 |
| -9 | | | | | | | | 20 | 9 | 3.6 |
| 22Y-8 | | | | | | | | 15 | 8 | 3.2 |
| -9 | | | | | | | | 17 | 8 | 3.2 |
| 22Z-8 | | | | | | | | 6 | 5 | 2.0 |
| -9 | | | | | | | | 32 | 10 | 4.0 |
| 23X-4 | | | | | | | | 26 | 9 | 3.6 |
| -5 | | | | | | | | 18 | 8 | 3.2 |
| 23X-6 | | | | | | | | 40 | 10 | 4.0 |
| -8 | | | | | | | | 12 | 8 | 3.2 |
| -9 | | | | | | | | 16 | 8 | 3.2 |
| 23Y-4 | | | | | | | | 18 | 8 | 3.2 |
| -5 | | | | | | | | 8 | 7 | 2.8 |
| -6 | | | | | | | | 6 | 5 | 2.0 |
| -7 | | | | | | | | 11 | 8 | 3.2 |
| 23Y-8 | | | | | | | | 4 | 3 | 1.2 |
| 23Z-4 | | | | | | | | 25 | 9 | 3.6 |
| -5 | | | | | | | | 36 | 10 | 4.0 |
| -6 | | | | | | | | 33 | 9 | 3.6 |
| -7 | | | | | | | | 16 | 8 | 3.2 |
| 23Z-8 | | | | | | | | 12 | 8 | 3.2 |
| 24X-4 | | | | | | | | 36 | 10 | 4.0 |

QUALITY RATING FOR SECTION

I.A.5

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 18Z-5 | Al. Block | 5000 | 4 | -------------- | 10 | ------- | 10 | [illegible] | 9 | 3.6 |
| -6 | | | | | | | | 51 | 10 | 4.0 |
| -7 | | | | | | | | 17 | 8 | 3.2 |
| -8 | | | | | | | | 10 | 8 | 3.2 |
| 18Z-9 | | | | | | | | 8 | 7 | 2.8 |
| 19Z-5 | | | | | | | | 23 | 9 | 3.6 |
| -6 | | | | | | | | 15 | 8 | 3.2 |
| -7 | | | | | | | | 16 | 8 | 3.2 |
| 19Z-8 | | | | | | | | 14 | 8 | 3.2 |
| 19Z-9 | | | | | | | | 18 | 8 | 3.2 |
| 20X-5 | | | | | | | | 11 | 8 | 3.2 |
| -6 | | | | | | | | 15 | 8 | 3.2 |
| -7 | | | | | | | | 14 | 8 | 3.2 |
| -8 | | | | | | | | 14 | 8 | 3.2 |
| 20X-9 | | | | | | | | 11 | 8 | 3.2 |
| 20Y-5 | | | | | | | | 9 | 8 | 2.8 |
| -6 | | | | | | | | 13 | 8 | 3.2 |
| -7 | | | | | | | | 13 | 8 | 3.2 |
| -8 | | | | | | | | 8 | 7 | 2.8 |
| 20Y-9 | | | | | | | | 12 | 8 | 3.2 |
| 20Z-5 | | | | | | | | 4 | 3 | 1.2 |
| -6 | | | | | | | | 23 | 9 | 3.6 |
| -7 | | | | | | | | 24 | 9 | 3.6 |
| -8 | | | | | | | | 7 | 6 | 2.4 |
| 20Z-9 | | | | | | | | 19 | 9 | 3.6 |
| 21X-5 | | | | | | | | 4 | 3 | 1.2 |
| -6 | | | | | | | | 16 | 8 | 3.2 |
| -7 | | | | | | | | 13 | 8 | 3.2 |
| 21X-9 | | | | | | | | 16 | 8 | 3.2 |
| 21Y-5 | | | | | | | | 10 | 8 | 3.2 |
| -6 | | | | | | | | 21 | 8 | 3.2 |

QUALITY RATING FOR SECTION
I.A.5

| Meas'm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 16Z-6 | Al. Block | 5000 | 4 | --------------- | 10 | ---------- | 10 | 27 | 9 | 3.6 |
| -7 | | | | | | | | 29 | 10 | 4.0 |
| -8 | | | | | | | | 26 | 9 | 3.6 |
| -9 | | | | | | | | 27 | 9 | 3.6 |
| 16R-4 | | | | | | | | 32 | 10 | 4.0 |
| -5 | | | | | | | | 20 | 9 | 3.6 |
| -6 | | | | | | | | 16 | 8 | 3.2 |
| 16R-7 | | | | | | | | 27 | 9 | 3.6 |
| -8 | | | | | | | | 17 | 8 | 3.2 |
| -9 | | | | | | | | 18 | 8 | 3.2 |
| 16T-5 | | | | | | | | 11 | 8 | 3.2 |
| -6 | | | | | | | | 17 | 8 | 3.2 |
| -7 | | | | | | | | 22 | 9 | 3.6 |
| -9 | | | | | | | | 9 | 8 | 3.2 |
| 17Z-5 | | | | | | | | 31 | 10 | 4.0 |
| -6 | | | | | | | | 33 | 10 | 4.0 |
| -7 | | | | | | | | 35 | 10 | 4.0 |
| -8 | | | | | | | | 24 | 9 | 3.6 |
| 17Z-9 | | | | | | | | 15 | 8 | 3.2 |
| 17R-5 | | | | | | | | 20 | 9 | 3.6 |
| -6 | | | | | | | | 32 | 10 | 4.0 |
| -7 | | | | | | | | 25 | 9 | 3.6 |
| -8 | | | | | | | | 18 | 8 | 3.2 |
| 17R-9 | | | | | | | | 25 | 9 | 3.6 |
| 17T-5 | | | | | | | | 19 | 9 | 3.6 |
| -6 | | | | | | | | 32 | 10 | 4.0 |
| -7 | | | | | | | | 24 | 9 | 3.6 |
| -8 | | | | | | | | 18 | 8 | 3.2 |
| 17T-9 | | | | | | | | 17 | 8 | 3.2 |

QUALITY RATING FOR SECTION
I.A.5

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 14R-7 | Al. Block | 5000 | 4 | ---------------- | 10 | --------- | 10 | 16.2 | 8 | 3.2 |
| -8 | | | | | | | | 19 | 9 | 3.6 |
| -9 | | | | | | | | 14.3 | 8 | 3.2 |
| 14T-5 | | | | | | | | 3.5 | 2 | .8 |
| -6 | | | | | | | | 4.7 | 4 | 1.6 |
| 14T-7 | | | | | | | | 16.8 | 8 | 3.2 |
| -8 | | | | | | | | 9.5 | 8 | 3.2 |
| 14Z-4 | | | | | | | | 14.5 | 8 | 3.2 |
| -5 | | | | | | | | 9.4 | 8 | 3.2 |
| -6 | | | | | | | | 9.0 | 8 | 3.2 |
| 14Z-7 | | | | | | | | 11.0 | 8 | 3.2 |
| -8 | | | | | | | | 11.1 | 8 | 3.2 |
| 15R-5 | | | | | | | | 10.6 | 8 | 3.2 |
| -6 | | | | | | | | 22.3 | 9 | 3.6 |
| 15Z-4 | | | | | | | | 44 | 10 | 4.0 |
| -5 | | | | | | | | 16 | 8 | 3.2 |
| -6 | | | | | | | | 16 | 8 | 3.2 |
| 15Z-7 | | | | | | | | 34 | 10 | 4.0 |
| -8 | | | | | | | | 32 | 10 | 4.0 |
| -9 | | | | | | | | 34 | 10 | 4.0 |
| 15R-7 | | | | | | | | 22 | 9 | 3.6 |
| -8 | | | | | | | | 23 | 9 | 3.6 |
| -9 | | | | | | | | 20 | 9 | 3.6 |
| 15T-5 | | | | | | | | 22 | 9 | 3.6 |
| -6 | | | | | | | | 23 | 9 | 3.6 |
| 15T-7 | | | | | | | | 30 | 10 | 4.0 |
| -9 | | | | | | | | 17 | 8 | 3.2 |
| 16Z-4 | | | | | | | | 14 | 8 | 3.2 |
| -5 | | | | | | | | 46 | 10 | 4.0 |

QUALITY RATING FOR SECTION
I.A.5

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 12R-7 | Al. Block | 5000 | 4 | --------------- | 10 | ------- | 10 | 16.8 | 8 | 3.2 |
| -8 | | | | | | | | 21.3 | 9 | 3.6 |
| -9 | | | | | | | | 27.7 | 9 | 3.6 |
| 12T-5 | | | | | | | | 23.3 | 9 | 3.6 |
| -6 | | | | | | | | 23 | 9 | 3.6 |
| 12T-7 | | | | | | | | 35.7 | 10 | 4.0 |
| -8 | | | | | | | | 22.7 | 9 | 3.6 |
| 12Z-4 | | | | | | | | 34 | 10 | 4.0 |
| -5 | | | | | | | | 15.8 | 8 | 3.2 |
| -6 | | | | | | | | 43 | 10 | 4.0 |
| 12Z-7 | | | | | | | | 21.2 | 9 | 3.6 |
| -8 | | | | | | | | 20 | 9 | 3.6 |
| 13R-5 | | | | | | | | 27 | 9 | 3.6 |
| -6 | | | | | | | | 25.6 | 9 | 3.6 |
| 13P-7 | | | | | | | | 27.6 | 9 | 3.6 |
| -8 | | | | | | | | 25.6 | 9 | 3.6 |
| -9 | | | | | | | | 31.2 | 10 | 4.0 |
| 13T-5 | | | | | | | | 14.5 | 8 | 3.2 |
| -6 | | | | | | | | 17.2 | 8 | 3.2 |
| 13T-7 | | | | | | | | 12 | 8 | 3.2 |
| -8 | | | | | | | | 12.6 | 8 | 3.2 |
| -9 | | | | | | | | 25 | 9 | 3.6 |
| 13Z-4 | | | | | | | | 18.5 | 8 | 3.2 |
| -5 | | | | | | | | 27.5 | 9 | 3.6 |
| -6 | | | | | | | | 15.3 | 8 | 3.2 |
| 13Z-7 | | | | | | | | 22.3 | 9 | 3.6 |
| -8 | | | | | | | | 17.2 | 8 | 3.2 |
| 14R-4 | | | | | | | | 15 | 8 | 3.2 |
| -5 | | | | | | | | 12 | 8 | 3.2 |
| -6 | | | | | | | | 20.5 | 9 | 3.6 |

QUALITY RATING FOR SECTION

I.A.5

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 7Z-4 | Al. Block | 5000 | 4 | ------------- | 10 | ------- | 10 | 18.5 | 8 | 3.2 |
| 8R-4 | | | | | | | | 22.8 | 9 | 3.6 |
| 8T-4 | | | | | | | | 28 | 9 | 3.6 |
| 8Z-4 | | | | | | | | 20 | 9 | 3.6 |
| -5 | | | | | | | | 18.2 | 8 | 3.2 |
| 9R-7 | | | | | | | | 21.3 | 9 | 3.6 |
| -8 | | | | | | | | 4.9 | 4 | 1.6 |
| -9 | | | | | | | | 22.5 | 9 | 3.6 |
| 9T-8 | | | | | | | | 15 | 8 | 3.2 |
| -9 | | | | | | | | 18.5 | 8 | 3.2 |
| 9Z-5 | | | | | | | | 19.6 | 9 | 3.6 |
| -6 | | | | | | | | 25 | 9 | 3.6 |
| 9Z-7 | | | | | | | | 39 | 10 | 4.0 |
| -8 | | | | | | | | 6.5 | 5 | 2.0 |
| -9 | | | | | | | | 22.6 | 9 | 3.6 |
| 11R-5 | | | | | | | | 8.4 | 7 | 2.8 |
| -6 | | | | | | | | 9.8 | 7 | 2.8 |
| 11R-7 | | | | | | | | 27.8 | 9 | 3.6 |
| -8 | | | | | | | | 22 | 9 | 3.6 |
| -9 | | | | | | | | 19.4 | 9 | 3.6 |
| 11T-5 | | | | | | | | 9.6 | 7 | 2.8 |
| -6 | | | | | | | | 16.7 | 8 | 3.2 |
| 11T-7 | | | | | | | | 21.2 | 9 | 3.6 |
| -8 | | | | | | | | 19.3 | 9 | 3.6 |
| -9 | | | | | | | | 39.3 | 10 | 4.0 |
| 11Z-5 | | | | | | | | 16.6 | 8 | 3.2 |
| -6 | | | | | | | | 19.8 | 9 | 3.2 |
| 12R-4 | | | | | | | | 22.8 | 9 | 3.6 |
| -5 | | | | | | | | 14.2 | 8 | 3.2 |
| -6 | | | | | | | | 17.8 | 8 | 3.2 |

QUALITY RATING FOR SECTION

I.A.5

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 28Y-2 | --------- | 100-5000 | 4 | ------------- | 10 | -------- | 10 | 15.3 | 8 | 3.2 |
| 3 | | | | | | | | 16.3 | 8 | 3.2 |
| 28Z-1 | | | | | | | | 5.6 | 4 | 1.6 |
| 2 | | | | | | | | 13.3 | 8 | 3.2 |
| 3 | | | | | | | | 11.5 | 8 | 3.2 |
| 1X-4 | Al. Block | 5000 | | | | | | 6.9 | 5 | 2.0 |
| 1Y-4 | Al. Block | | | | | | | 15.7 | 9 | 3.6 |
| 1Z-4 | | | | | | | | 18 | 8 | 3.2 |
| 2X-4 | | | | | | | | 13.6 | 8 | 3.2 |
| 2Y-4 | | | | | | | | 10.3 | 8 | 3.2 |
| 2Z-4 | | | | | | | | 11.3 | 8 | 3.2 |
| 3X-4 | | | | | | | | 13 | 8 | 3.2 |
| -5 | | | | | | | | 12.1 | 8 | 3.2 |
| 3Y-4 | | | | | | | | 52.7 | 10 | 4.0 |
| -5 | | | | | | | | 24.5 | 9 | 3.6 |
| 3Z-4 | | | | | | | | 16.8 | 8 | 3.2 |
| -5 | | | | | | | | 21.3 | 9 | 3.6 |
| 4R-4 | | | | | | | | 15.4 | 8 | 3.2 |
| -5 | | | | | | | | 16.4 | 8 | 3.2 |
| 4T-4 | | | | | | | | 24.7 | 9 | 3.6 |
| 4Z04 | | | | | | | | 22 | 9 | 3.6 |
| 5X-4 | | | | | | | | 22.8 | 9 | 3.6 |
| 5Y-4 | | | | | | | | 46 | 10 | 4.0 |
| 5Z-4 | | | | | | | | 23.4 | 9 | 3.6 |
| 6X-4 | | | | | | | | 16.3 | 8 | 3.2 |
| 6Y-4 | | | | | | | | 10.7 | 8 | 3.2 |
| 6Z-4 | | | | | | | | 13.8 | 8 | 3.2 |
| 7R-4 | | | | | | | | 22.5 | 9 | 3.6 |
| -5 | | | | | | | | 29.3 | 9 | 3.6 |
| 7T-4 | | | | | | | | 12.9 | 8 | 3.2 |

QUALITY RATING FOR SECTION

I.A.5

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 25X-1 | ---------- | 100-5000 | 4 | ------------- | 10 | ---------- | 10 | 6.6 | 5 | 2.0 |
| 2 | | | | | | | | 23 | 9 | 3.6 |
| 3 | | | | | | | | 11.2 | 8 | 3.2 |
| 25Y-1 | | | | | | | | 14.3 | 8 | 3.2 |
| 2 | | | | | | | | 26.5 | 9 | 3.6 |
| 3 | | | | | | | | 24.3 | 9 | 3.6 |
| 25Z-1 | | | | | | | | 8 | 7 | 2.8 |
| 2 | | | | | | | | 16 | 8 | 3.2 |
| 3 | | | | | | | | 16.2 | 8 | 3.2 |
| 26X-1 | | | | | | | | 10 | 8 | 3.2 |
| 2 | | | | | | | | 17.4 | 8 | 3.2 |
| 3 | | | | | | | | 18 | 8 | 3.2 |
| 26Y-1 | | | | | | | | 10.6 | 8 | 3.2 |
| 2 | | | | | | | | 16 | 8 | 3.2 |
| 3 | | | | | | | | 11.1 | 8 | 3.2 |
| 26Z-1 | | | | | | | | 21.6 | 9 | 3.6 |
| 2 | | | | | | | | 27 | 9 | 3.6 |
| 3 | | | | | | | | 7.6 | 1 | .4 |
| 27X-1 | | 1000-5000 | | | | | | 1.6 | 0 | 0 |
| 2 | | | | | | | | 15 | 8 | 3.2 |
| 3 | | | | | | | | 7.1 | 6 | 2.4 |
| 27Y-1 | | | | | | | | 2.9 | 2 | .8 |
| 2 | | | | | | | | 20 | 9 | 3.6 |
| 3 | | | | | | | | 20 | 9 | 3.6 |
| 27Z-1 | | 500-5000 | | | | | | 2.4 | 1 | .4 |
| 2 | | | | | | | | 23.8 | 9 | 3.6 |
| 3 | | | | | | | | 15.3 | 8 | 3.2 |
| 28X-1 | | 100-5000 | | | | | | 4.6 | 3 | 1.2 |
| 2 | | | | | | | | 12 | 8 | 3.2 |
| 3 | | | | | | | | 13.8 | 8 | 3.2 |

QUALITY RATING FOR SECTION

I.A.5

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 28Y-9 | Al. Block | 5000 | 4 | -------------- | 10 | ---------- | 10 | 12 | 8 | 3.2 |
| 28Z-5 | | | | | | | | 16 | 8 | 3.2 |
| -6 | | | | | | | | 23 | 9 | 3.6 |
| -7 | | | | | | | | 38 | 10 | 4.0 |
| -8 | | | | | | | | 21 | 9 | 3.6 |
| 28Z-9 | | | | | | | | 9 | 7 | 2.8 |
| 30Z-5 | | | | | | | | 20 | 9 | 3.6 |
| -6 | | | | | | | | 15 | 8 | 3.2 |
| -7 | | | | | | | | 28 | 9 | 3.6 |
| -8 | | | | | | | | 21 | 9 | 3.6 |
| -9 | | | | | | | | 35 | 10 | 4.0 |
| 25Y-9 | | | | | | | | 17 | 8 | 3.2 |
| 30R-6 | | | | | | | | 9 | 7 | 2.8 |
| -7 | | | | | | | | 18 | 8 | 3.2 |
| -8 | | | | | | | | 14 | 8 | 3.2 |
| 30T-5 | | | | | | | | 15 | 8 | 3.2 |
| -6 | | | | | | | | 10 | 8 | 3.2 |
| -7 | | | | | | | | 14 | 8 | 3.2 |
| -8 | | | | | | | | 13 | 8 | 3.2 |
| 31Z-8 | | | | | | | | 19 | 9 | 3.6 |
| 31Z-9 | | | | | | | | 29 | 9 | 3.6 |
| 31R-8 | | | | | | | | 10 | 8 | 3.2 |
| -9 | | | | | | | | 19 | 9 | 3.6 |
| 31T-5 | | | | | | | | 11 | 8 | 3.2 |
| -6 | | | | | | | | 14 | 8 | 3.2 |
| -7 | | | | | | | | 15 | 8 | 3.2 |
| -8 | | | | | | | | 10 | 8 | 3.2 |
| -9 | | | | | | | | 15 | 8 | 3.2 |
| 32X-5 | | | | | | | | 20 | 9 | 3.6 |
| 33R-6 | No Block | | | | | | | 21 | 9 | 3.6 |

QUALITY RATING FOR SECTION

T.A.5

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| -7 | No Block | 5000 | 4 | | 10 | | 10 | 17 | 8 | 3.2 |
| 34R-6 | Al. Block | | | | | | | 15 | 8 | 3.2 |
| -7 | | | | | | | | 21 | 9 | 3.6 |
| -8 | | | | | | | | 13 | 8 | 3.2 |
| 35R-6 | No Block | | | | | | | 22 | 9 | 3.6 |
| -7 | No Block | | | | | | | 45 | 10 | 4.0 |
| 36R-7 | Al. Block | | | | | | | 19 | 9 | 3.6 |
| -8 | Al. Block | | | | | | | 16 | 8 | [illegible] |
| 35R-6 | No Block | | | | | | | 19 | 9 | 3.[illegible] |
| 101T-9 | Al. Block | | | | | | | 29 | 9 | 3.[illegible] |
| 101Z-9 | | | | | | | | 14 | 8 | 3.[illegible] |
| 102Z-9 | | | | | | | | 22 | 9 | 3.6 |
| 104T-9 | | | | | | | | 26 | 9 | 3.6 |
| 105Z-9 | No Block | | | | | | | 34 | 10 | 4.0 |
| 107X-9 | Al Block | | | | | | | 35 | 10 | 4.0 |
| 111Z-9 | | | | | | | | 19 | 9 | 3.6 |
| 112X-9 | | | | | | | | 15 | 8 | 3.2 |
| 112Y-9 | | | | | | | | 19 | 9 | 3.6 |
| 116Z-9 | | | | | | | | 25 | 9 | 3.6 |

QUALITY RATING FOR SECTION

I.A.6

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 5000 | 4 | End 2221D | 10 | None | 10 | ------- | 5* | 2* |
| 2 | | | | 2221D | | | | ------- | | 2* |
| 3 | | | | 2221D | | | | ------- | | |
| 7 | | | | 2252 | | | | | | |
| 8 | | | | 2252 | | | | | | |
| 9 | | | | 2252 2225 | | | | | | |
| 10 | | | | 2252 | | | | | | |
| 11 | | | | 2221D | | | | | | |
| 12 | | | | 2242C 2215 | | | | | | |
| 13 | | | | 2221D | | | | | | |
| 14 | | | | 2242C | | | | | | |
| 15 | | | | 2221D | | | | | | |
| 16 | | | | 2221D | | | | | | |
| 19 | | | | 2221D | | | | | | |
| 20 | | | | 2221D | | | | 60 | 10 | 4 |
| 21 | | | | 2221D | | | | ------- | 5* | 2* |
| 22 | | | | 2221D | | | | 40 | 10 | 4 |
| 23 | | | | 2221D | | | | ------- | 5* | 2* |
| 24 | | | | 2221D | | | | ------- | 5* | 2* |
| 25 | | | | 2225 2242C | | | | 30 | 10 | 4 |
| 26 | | | | 2252 | 5 | | | ------- | 5* | 1* |
| 27A | | | | 2252 2225 | 10 | | | 40 | 10 | 4 |
| 28 | | | | 2252 | 8 | | | ------- | 5* | 1.6* |
| 29 | | | | 2252 | 10 | | | ------- | 5* | 2* |
| 33 | | | | 2221D | 10 | | | ------- | 5* | 2* |

QUALITY RATING FOR SECTION
I.A.7

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 1X-2 | Al. Block | 10 K Hz | 8 | End. 2225 | 10 | -------- | 10 | 110 | 10 | 8 |
| 35X-1 | | | | | | | 10 | 25 | 9 | 7.2 |
| -2 | | | | | | | 10 | 20 | 9 | 7.2 |
| 35R-1 | | | | | | | 10 | 14 | 8 | 6.4 |
| -2 | | | | | | | 10 | 12 | 8 | 6.4 |
| 36X-1 | | | | | | | 10 | 24 | 9 | 7.2 |
| -2 | | | | | | | 10 | 30 | 10 | 8 |
| 36R-1 | | | | | | | 10 | 23 | 9 | 7.2 |
| -2 | | | | | | | 10 | 18 | 8 | 6.4 |
| 37X-1 | | | | End. 2220 | | take level ex- ceeded | 4 | 90 | 10 | 3.2 |
| -2 | | | | | | | 10 | 28 | 9 | 7.2 |
| 37R-1 | | | | | | | 10 | 45 | 19 | 8 |
| -2 | | | | | | dc-shift | 2 | 15 | 8 | 1.2 |

QUALITY RATING FOR SECTION
I.B.1

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 3A1/T1 | Al. Block | 1250 | 2 | ------------ | 10 | -------- | 10 | 9 | 8 | 1.6 |
| 3A1/T2 | | | | | | | | 9 | 8 | 1.6 |
| 3A2/T1 | | | | | | | | 14 | 8 | 1.6 |
| 3A2/T2 | | | | | | | | 14 | 8 | 1.6 |
| 3A16/T1 | | | | | | | | 13 | 8 | 1.6 |
| 3A16/T2 | | | | | | | | 13 | 8 | 1.4 |
| 3A12/T1 | | | | | | | | 8 | 7 | 1.4 |
| 3A17/T2 | | | | | | | | 8 | 7 | 1.4 |
| 3A18/T1 | | | | | | | | 7 | 6 | 1.2 |
| 3A18/T2 | | | | | | | | 7 | 6 | 1.2 |
| 3A19/T1 | | | | | | | | 22 | 9 | 1.8 |
| 3A16/T2 | | | | | | Questionable | 1 | 22 | 9 | 0.18 |
| 3A20/T1 | | | | | | | | 13 | 8 | 1.6 |
| 3A20/T2 | | | | | | | | 13 | 8 | 1.6 |
| 3A21/T1 | | | | | | | | 7 | 6 | 1.2 |
| 3A21/T2 | | | | | | | | 7 | 6 | 1.2 |
| 3A22/T1 | | | | | | | | 11 | 8 | 1.6 |
| 3A22/T2 | | | | | | | | 11 | 8 | 1.6 |
| 3A23/T1 | | | | | | | | 34 | 10 | 2.0 |
| 3A23/T2 | | | | | | | | 34 | 10 | 0.2 |
| 3A24/T1 | | | | | | | 10 | 6 | 5 | 1.0 |
| 3A24/T2 | | | | | | | | 6 | 5 | 1.0 |
| 3A25/T1 | | | | | | | | 5 | 4 | 0.8 |
| 3A25/T2 | | | | | | | | 5 | 4 | 0.8 |
| 3A26/T1 | | | | | | | | 6 | 5 | 1.0 |
| 3A26/T2 | | | | | | | | 6 | 5 | 1.0 |
| 3A27/T1 | | | | | | | | 3 | 2 | 0.4 |
| 3A27/T2 | | | | | | | | 3 | 2 | 0.4 |
| 3A4/T1 | | | | | | | | 40 | 10 | 2.0 |

QUALITY RATING FOR SECTION

I.B.1

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 3A4/T2 | Al. Block | 1250 | 2 | | 10 | ------- | 10 | 40 | 10 | 2.0 |
| 3A5/T1 | | | | | | | | 19 | 9 | 1.8 |
| 3A5/T2 | | | | | | | | 19 | 9 | 1.8 |
| 3A6/T1 | | | | | | | | 22 | 9 | 1.8 |
| 3A6/T2 | | | | | | | | 22 | 9 | 1.8 |
| 3A7/T1 | | | | | | | | 34 | 10 | 2.0 |
| 3A7/T2 | | | | | | | | 34 | 10 | 2.0 |
| 3A8/T1 | | | | | | | | 30 | 10 | 2.0 |
| 3A8/T2 | | | | | | | | 30 | 10 | 2.0 |
| 3A9/T1 | | | | | | | | 41 | 10 | 2.0 |
| 3A9/T2 | | | | | | | | 41 | 10 | 2.[illegible] |
| 3A10/T1 | | | | | | | | 9 | 8 | 1.6 |
| 3A10/T2 | | | | | | | | 9 | 8 | 1.6 |
| 3A11.T2 | | | | | | | | 13 | 8 | 1.6 |
| 3A13/T1 | | | | | | | | 25 | 9 | 1.8 |
| 3A13/T2 | | | | | | | | 25 | 9 | 1.8 |
| 3A14/T1 | | | | | | | | 38 | 10 | 2.0 |
| 3A14/T2 | | | | | | | | 38 | 10 | 2.0 |

QUALITY RATING FOR SECTION

I.B.2

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 3A1* | | 10 K | 8 | | 10 | | 10 | 12 | 8 | 6.4 |
| 3A1** | | 1250 | 2 | | | | | 12 | 8 | 1.6 |
| 3A2* | | 10 K | 8 | | | | | 4 | 3 | 2.4 |
| 3A2** | | 1250 | 2 | | | | | 4 | 3 | 0.6 |
| 3A16* | | 10 K | 8 | | | | | 20 | 9 | 7.2 |
| 3A16** | | 1250 | 2 | | | | | 20 | 9 | 1.8 |
| 3A17* | | 10 K | 8 | | | | | 31 | 10 | 8.0 |
| 3A17** | | 1250 | 2 | | | | | 31 | 10 | 2.0 |
| 3A18* | | 10 K | 8 | | | | | 18 | 8 | 6.4 |
| 3A18** | | 1250 | 2 | | | | | 18 | 8 | 1.6 |
| 3A19* | | 10 K | 8 | | | | | 15 | 8 | 6.4 |
| 3A19** | | 1250 | 2 | | | | | 15 | 8 | 1.6 |
| 3A20* | | 10 K | 8 | | | | | 26 | 9 | 7.2 |
| 3A20** | | 1250 | 2 | | | | | 26 | 9 | 1.8 |
| 3A21* | | 10 K | 8 | | | | | 6 | 5 | 4.0 |
| 3A21** | | 1250 | 2 | | | | | 6 | 5 | 1.0 |
| 3A22* | | 10 K | 8 | | | | | 7 | 6 | 4.8 |
| 3A22** | | 1250 | 2 | | | | | 7 | 6 | 1.2 |
| 3A23* | | 10 K | 8 | | | | | 5 | 4 | 3.2 |
| 3A23** | | 1250 | 2 | | | | | 5 | 4 | 0.8 |
| 3A24* | | 10 K | 8 | | | | | 5 | 4 | 3.2 |
| 3A24** | | 1250 | 2 | | | | | 5 | 4 | 0.8 |
| 3A26* | | 10 K | 8 | | | | | 31 | 10 | 8.0 |
| 3A26** | | 1250 | 2 | | | | | 31 | 10 | 2.0 |
| 3A4* | Al. Block | 10 K | 8 | | 10 | | 10 | 76 | 10 | 8.0 |
| 3A4** | | 1250 | 2 | | | | | 76 | 10 | 2.0 |
| 3A5* | | 10 K | 8 | | | | | 56 | 10 | 8.0 |
| 3A5** | | 1250 | 2 | | | | | 56 | 10 | 2.0 |
| 3A6* | | 10 K | 8 | | | | | 31 | 10 | 8.0 |
| 3A6** | | 1250 | 2 | | | | | 31 | 10 | 2.0 |

QUALITY RATING FOR SECTION

I.B.2

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 3A7* | Al. Block | 10 K | 8 | | 10 | | 10 | 18 | 8 | 6.4 |
| 3A7** | | 1250 | 2 | | | | | 18 | 8 | 1.6 |
| 3A8* | | 10 K | 8 | | | | | 25 | 9 | 7.2 |
| 3A8** | | 1250 | 2 | | | | | 25 | 9 | 1.8 |
| 3A9* | | 10 K | 8 | | | | | 22 | 9 | 7.2 |
| 3A9** | | 1250 | 2 | | | | | 22 | 9 | 1.8 |
| 3A10* | | 10 K | 8 | | | | | 8 | 7 | 5.6 |
| 3A10** | | 1250 | 2 | | | | | 8 | 7 | 1.4 |
| 3A11* | | 10 K | 8 | | | | | 12 | 8 | 6.4 |
| 3A11** | | 1250 | 2 | | | | | 12 | 8 | 1.6 |
| 3A13* | | 10 K | 8 | | | | | 47 | 10 | 3.0 |
| 3A13** | | 1250 | 2 | | | | | 47 | 10 | 2.0 |
| 3A14* | | 10 K | 8 | | | | | 22 | 9 | 7.2 |
| 3A14** | | 1250 | 2 | | | | | 22 | 9 | 1.8 |
| 3A25* | | 10 K | 8 | | | | | 4 | 3 | 2.4 |
| 3A25** | | 1250 | 2 | | | | | 4 | 3 | 0.6 |
| 3A27* | | 10 K | 8 | | | | | 6 | 5 | 4.0 |
| 3A27** | | 1250 | 2 | | | | | 6 | 5 | 1.0 |

* Analyzed analog
** Analyzed digital

QUALITY RATING FOR SECTION

I.B.3

| Measm't Number | | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3A1 | 15' | | 100 1250 | 2 | End. 2225 | 10 | -------- | 10 | 1.5 | 0 | 0 |
| | 35' | | | | | | | | 4 | 3 | 0.6 |
| | 50' | | | | | | | | 7 | 6 | 1.2 |
| 3A2 | 15' | | | | | | | | 2 | 1 | 0.2 |
| | 35' | | | | | | | | 5 | 4 | 0.8 |
| | 50' | | | | | | | | 5 | 4 | 0.8 |
| 3A4 | 15' | | | | | | | | 4 | 3 | 0.6 |
| | 35' | | | | | | | | 6 | 5 | 1 |
| | 50' | | | | | | | | 5 | 4 | 0.8 |
| 3A5 | 15' | | | | | | | | 5.5 | 4 | 0.8 |
| | 35' | | | | | | | | 5 | 4 | 0.8 |
| | 50' | | | | | | | | 5 | 4 | 0.8 |
| 3A6 | 15' | | | | | | | | 4 | 3 | 0.6 |
| | 35' | | | | | | | | 5 | 4 | 0.8 |
| | 50' | | | | | | | | 6 | 5 | 1 |
| 3A7 | 15' | | | | | | | | 5 | 4 | 0.8 |
| | 35' | | | | | | | | 6 | 5 | 1 |
| | 50' | | | | | | | | 5 | 4 | 0.8 |
| 3A8 | 15' | | | | | | | | 5.5 | 4 | 0.8 |
| | 35' | | | | | | | | 9 | 7 | 1.4 |
| | 50' | | | | | | | | 12 | 8 | 1.6 |
| 3A9 | 15' | | | | | | | | 3 | 2 | 0.4 |
| | 35' | | | | | | | | 11 | 8 | 1.6 |
| | 50' | | | | | | | | 11 | 8 | 1.6 |
| 4A10 | 15' | | | | | | | | 3 | 2 | 0.4 |
| | 35' | | | | | | | | 6 | 5 | 1 |
| | 50' | | | | | | | | 10 | 8 | 1.6 |
| 3A11 | 15' | | | | | | | | 5 | 4 | 0.8 |
| | 35' | | | | | | | | 8 | 7 | 1.4 |
| | 50' | | | | | | | | 7 | 6 | 1.2 |

QUALITY RATING FOR SECTION

I.B.3

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 3A13 15' | | 100 1250 | 2 | End. 2225 | 10 | -------- | 10 | 6 | 5 | 1 |
| 35' | | | | | | | | 8 | 7 | 1.4 |
| 50' | | | | | | | | 5 | 4 | 0.8 |
| 3A14 15' | | | | | | | | 5 | 4 | 0.8 |
| 35' | | | | | | | | 7 | 6 | 1.2 |
| 50' | | | | | | | | 4 | 3 | 0.6 |
| 3A15 15' | | | | | | | | 2 | 1 | 0.2 |
| 35' | | | | | | | | 10 | 8 | 1.6 |
| 50' | | | | | | | | 12 | 8 | 1.6 |
| 3A17 15' | | | | | | | | 4 | 3 | 0.6 |
| 35' | | | | | | | | 12 | 8 | 1.6 |
| 50' | | | | | | | | 7 | 6 | 1.2 |
| 3A18 15' | | | | | | | | 2 | 1 | 0.2 |
| 35' | | | | | | | | 15 | 8.5 | 1.7 |
| 50' | | | | | | | | 9 | 7 | 1.4 |
| 3A19 15' | | | | | | | | 6 | 5 | 1 |
| 35' | | | | | | | | 12 | 8 | 1.6 |
| 50' | | | | | | | | 7 | 6 | 1.2 |
| 3A20 15' | | | | | | | | 5 | 4 | 0.8 |
| 35' | | | | | | | | 13 | 8 | 1.6 |
| 50' | | | | | | | | 9 | 7 | 1.4 |
| 3A21 15' | | | | | | | | 3 | 2 | 0.4 |
| 35' | | | | | | | | 10 | 8 | 1.6 |
| 50' | | | | | | | | 8 | 6 | 1.2 |
| 3A22 15' | | | | | | | | 4 | 3 | 0.6 |
| 35' | | | | | | | | 13 | 8 | 1.6 |
| 50' | | | | | | | | 27 | 9.5 | 1.9 |
| 3A23 15' | | | | | | | | 8 | 6 | 1.2 |
| 35' | | | | | | | | 10 | 8 | 1.6 |
| 50' | | | | | | | | 12 | 8 | 1.6 |

QUALITY RATING FOR SECTION

I.B.3

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 3A24 15' | | 100 1250 | 2 | End. 2225 | 10 | ----------- | 10 | 5 | 4 | 0.8 |
| 35' | | | | | | | | 14 | 8.5 | 1.7 |
| 50' | | | | | | | | 11 | 8 | 1.6 |
| 3A25 15' | | | | | | | | 2 | 1 | 0.2 |
| 35' | | | | | | | | 6 | 5 | 1 |
| 50' | | | | | | | | 9 | 7 | 1.4 |
| 3A26 15' | | | | | | | | 2 | 1 | 0.2 |
| 35' | | | | | | | | 9 | 7 | 1.4 |
| 50' | | | | | | | | 17 | 8.5 | 1.7 |
| 3A27 15' | | | | | | | | 3 | 2 | 0.4 |
| 35' | | | | | | | | 10 | 8 | 1.6 |
| 50' | | | | | | | | 6 | 5 | 1 |
| 3A1 15' | | | | | | | | 3 | 2 | 0.4 |
| 35' | | | | | | | | 15 | 8.5 | 1.7 |
| 50' | | | | | | | | 7 | 6 | 1.2 |
| 3A2 15' | | | | | | | | 4 | 3 | 0.6 |
| 35' | | | | | | | | 10 | 8 | 1.6 |
| 50' | | | | | | | | 6 | 5 | 1 |
| 3A4 15' | | | | | | | | 6 | 5 | 1 |
| 35' | | | | | | | | 28 | 9.5 | 1.9 |
| 50' | | | | | | | | 4 | 3 | 0.6 |
| 3A5 15' | | | | | | | | 8 | 6 | 1.2 |
| 35' | | | | | | | | 23 | 9 | 1.8 |
| 50' | | | | | | | | 12 | 8 | 1.6 |
| 3A6 15' | | | | | | | | 6 | 5 | 1 |
| 35' | | | | | | | | 12 | 8 | 1.6 |
| 50' | | | | | | | | 9 | 7 | 1.4 |
| 3A7 15' | | | | | | | | 9 | 7 | 1.4 |
| 35' | | | | | | | | 22 | 9 | 1.8 |
| 50' | | | | | | | | 6 | 5 | 1 |

QUALITY RATING FOR SECTION

I.B.3

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 3A8 15' | | 100 1250 | 2 | End. 2225 | 10 | --------- | 10 | 10 | 8 | 1.6 |
| 35' | | | | | | | | 29 | 10 | 2 |
| 50' | | | | | | | | 7 | 6 | 1.2 |
| 3A9 15' | | | | | | | | 10 | 8 | 1.6 |
| 35' | | | | | | | | 17 | 8.5 | 1.7 |
| 50' | | | | | | | | 7 | 6 | 1.2 |
| 3A10 15' | | | | | | | | 6 | 5 | 1 |
| 35' | | | | | | | | 14 | 8.5 | 1.7 |
| 50' | | | | | | | | 8 | 6 | 1.2 |
| 3A11 15' | | | | | | | | 6 | 5 | 1 |
| 35' | | | | | | | | 17 | 8.5 | 1.7 |
| 50' | | | | | | | | 5.5 | 4 | 0.8 |
| 3A13 15' | | | | | | | | 11 | 8 | 1.6 |
| 35' | | | | | | | | 43 | 10 | 2 |
| 50' | | | | | | | | 9 | 7 | 1.4 |
| 3A14 15' | | | | | | | | 12 | 8 | 1.6 |
| 35' | | | | | | | | 42 | 10 | 2 |
| 50' | | | | | | | | 7 | 6 | 1.2 |
| 3A16 15' | | | | | | | | 4 | 3 | 0.6 |
| 35' | | | | | | | | 40 | 10 | 2 |
| 50' | | | | | | | | 7 | 6 | 1.2 |
| 3A17 15' | | | | | | | | 4 | 3 | 0.6 |
| 35' | | | | | | | | 17 | 8.5 | 1.7 |
| 50' | | | | | | | | 16 | 8.5 | 1.7 |
| 3A18 15' | | | | | | | | 5 | 4 | 0.8 |
| 35' | | | | | | | | 19 | 9 | 1.8 |
| 50' | | | | | | | | 6 | 5 | 1 |
| 3A19 15' | | | | | | | | 7 | 6 | 1.2 |
| 35' | | | | | | | | 37 | 10 | 2 |
| 50' | | | | | | | | 12 | 8 | 1.6 |

QUALITY RATING FOR SECTION

I.B.3

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 3A20 15' | | 100 1250 | 2 | End. 2225 | 10 | -------- | 10 | 7 | 6 | 1.2 |
| 35' | | | | | | | | 32 | 10 | 2 |
| 50' | | | | | | | | 4 | 3 | 0.6 |
| 3A21 15' | | | | | | | | 5 | 4 | 0.8 |
| 35' | | | | | | | | 25 | 9.5 | 1.9 |
| 50' | | | | | | | | 22 | 9 | 1.8 |
| 3A22 15' | | | | | | | | 5 | 4 | 0.8 |
| 35' | | | | | | | | 68 | 10 | 2 |
| 50' | | | | | | | | 8 | 6 | 1.2 |
| 3A23 15' | | | | | | | | 5 | 4 | 0.8 |
| 35' | | | | | | | | 35 | 10 | 2 |
| 50' | | | | | | | | 25 | 9.5 | 1.9 |
| 3A24 15' | | | | | | | | 6 | 5 | 1 |
| 35' | | | | | | | | 32 | 10 | 2 |
| 50' | | | | | | | | 12 | 8 | 1.6 |
| 3A25 15' | | | | | | | | 3 | 2 | 0.4 |
| 35' | | | | | | | | 37 | 10 | 2 |
| 50' | | | | | | | | 5 | 4 | 0.8 |
| 3A26 15' | | | | | | | | 3 | 2 | 0.4 |
| 35' | | | | | | | | 26 | 9.5 | 1.9 |
| 50' | | | | | | | | 7 | 6 | 1.2 |
| 3A27 15' | | | | | | | | 4 | 3 | 0.6 |
| 35' | | | | | | | | 21 | 9 | 1.8 |
| 50' | | | | | | | | 12 | 8 | 1.6 |

QUALITY RATING FOR SECTION

I.C.1

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | No Block | 500 10K | 8 | End. 2220C | 10 | 2 events | 10 | 12 | 8 | 6.4 |
| 2 | | | | | | poor data | 1 | N/A | 5* | .4 |
| 3 | | | | | | --------- | 10 | 3 | 1 | .8 |
| 4 | | | | | | 2 events | 10 | 3 | 1 | .8 |
| 5 | | | | 2225 | | --------- | 10 | 6 | 5 | 4.0 |
| 6 | | | | | | --------- | 10 | 6 | 5 | 4.0 |
| 7 | | | | | | | | 5 | 4 | 3.2 |
| 8 | | | | | | | | 6 | 5 | 4.0 |
| 9 | | | | | | | | 15 | 8 | 6.[illegible] |
| 10 | | | | | | | | 5 | 4 | 3.2 |
| 11 | | | | 2220C | | | | 4 | 3 | 2.4 |
| 12 | | | | 2225 | | | | 8 | 6 | 4.8 |
| 13 | | | | 2225 | | | | 30 | 10 | 8.0 |
| 14 | Al. Block | | | 2225 | | | | 12 | 8 | 6.4 |
| 15 | | | | 2225 | | | | 12 | 8 | 6.4 |
| 16 | | | | 2225 | | | | 25 | 9 | 7.2 |
| 17 | | | | 2225 | | | | 12 | 8 | 6.4 |
| 18 | | | | 2220C | | | | 10 | 8 | 6.4 |
| 19 | | | | 2220C | | | | 15 | 8 | 6.4 |
| 20 | | | | 2225 | | | | 25 | 9 | 7.2 |

QUALITY RATING FOR SECTION

I.C.2

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 4 | Al. Block | 10-10K | 8 | End. 2225 | 10 | --------- | 10 | N/A | 5* | 4.0 |
| 6 | Al. Block | | | | | | | N/A | 5* | 4.0 |
| 7 | No Block | | | | | | | N/A | 5* | 4.0 |
| 9 | Al. Block | | | | | | | 25 | 9.5 | 7.6 |
| 10 | Al Block | | | | | | | 30 | 10 | 8.0 |
| 14 | Al Block | | | | | | | N/A | 5* | 4.0 |
| 20 | No Block | | | | | | | N/A | 5* | 4.0 |
| 22 | No Block | | | | | | | 20 | 9 | 7.2 |
| 23 | Al Block | | | | | | | N/A | 5* | 4.0 |
| 24 | No Block | | | | | | | N/A | 5* | 4.0 |
| 25 | No Block | | | | | | | 20 | 9 | 7.2 |

QUALITY RATING FOR SECTION
I.C.3

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| All Measurements | Al Block | 0-5K | 4 | End. 2225 | 10 | ------- | 10 | --------- | 5* | 2.0 |

QUALITY RATING FOR SECTION

II.A.1

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| All Measurements | | 5000 | 4 | Endevco 2225 | 10 | -------- | 10 | -------- | 5* | 2* |

QUALITY RATING FOR SECTION

II.E.1

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 Long -7 | Al Block | 10,000 | 8 | Endevco 2225 | 10 | -------- | 10 | 23 | 9 | 7.2 |
| -8 | | | | | | | | 21 | 9 | 7.2 |
| -11 | | | | | | | | 20 | 9 | 7.2 |
| -12 | | | | | | | | 28 | 9 | 7.2 |
| 1 Lat. -7 | | | | | | | | 14 | 8 | 6.4 |
| -8 | | | | | | | | 14 | 8 | 6.4 |
| -11 | | | | | | | | 16 | 8 | 6.4 |
| -12 | | | | | | | | 24 | 9 | 7.2 |
| 1 Vert. -7 | | | | | | | | 21 | 9 | 7.2 |
| -8 | | | | | | | | 26 | 9 | 7.2 |
| -11 | | | | | | | | 24 | 9 | 7.2 |
| -12 | | | | | | dc shift | 5 | 31 | 10 | 4 |
| 2 Long -7 | | | | | | | 10 | 20 | 9 | 7.2 |
| -8 | | | | | | | | 41 | 10 | 8 |
| 2 Lat. -7 | | | | | | | | 9 | 7 | 5.6 |
| -8 | | | | | | | | 18 | 8 | 6.4 |
| 2 Vert. -7 | | | | | | | | 6 | 5 | 4 |
| -8 | | | | | | | | 12 | 8 | 6.4 |
| 3 Long -7 | | | | | | | | 15 | 8 | 6.4 |
| -8 | | | | | | | | 34 | 10 | 8 |
| -12 | | | | | | | | 28 | 9 | 7.2 |
| 3 Lat. -7 | | | | | | | | 20 | 9 | 7.2 |
| -8 | | | | | | | | 30 | 10 | 8 |
| -12 | | | | | | | | 31 | 10 | 8 |
| 3 Vert. -7 | | | | | | | | 16 | 8 | 6.4 |
| -8 | | | | | | | | 31 | 10 | 8 |
| -12 | | | | | | | | 26 | 9 | 7.2 |
| 4 Long -7 | | | | | | | | 6 | 5 | 4 |
| -8 | | | | | | | | 16 | 8 | 6.4 |

QUALITY RATING FOR SECTION

II.B.1

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Lat. -7 | Al Block | 10,000 | 8 | Endevco 2225 | 10 | ------- | 10 | 7 | 6 | 4.8 |
| -8 | | | | | | | | 17 | 8 | 6.4 |
| 4 Vert.-7 | | | | | | | | 6 | 5 | 4 |
| -8 | | | | | | | | 15 | 8 | 6.4 |
| 5 Long.-7 | | | | | | | | 11 | 8 | 4.6 |
| -8 | | | | | | | | 26 | 9 | 7.2 |
| 5 Lat. -7 | | | | | | | | 6 | 5 | 4 |
| -8 | | | | | | | | 14 | 8 | 6.4 |
| 5 Vert.-7 | | | | | | | | 8 | 6 | 4.8 |
| -8 | | | | | | | | 22 | 9 | 7.2 |
| 6 Long.-7 | | | | | | | | 18 | 8 | 6.4 |
| -8 | | | | | | | | 40 | 10 | 8 |
| -12 | | | | | | | | 55 | 10 | 8 |
| 6 Lat. -7 | | | | | | | | 7 | 6 | 4.8 |
| -8 | | | | | | | | 11 | 8 | 6.4 |
| -12 | | | | | | | | 21 | 9 | 7.2 |
| 6 Vert.-7 | | | | | | | | 14 | 8 | 6.4 |
| -8 | | | | | | | | 28 | 9 | 7.2 |
| -12 | | | | | | | | 30 | 10 | 8 |
| 7 Long.-7 | | | | | | | | 16 | 8 | 6.4 |
| -8 | | | | | | | | 30 | 10 | 8 |
| 7 Lat. -7 | | | | | | | | 14 | 8 | 6.4 |
| -8 | | | | | | | | 32 | 10 | 8 |
| 7 Vert.-7 | | | | | | | | 20 | 9 | 7.2 |
| -8 | | | | | | | | 41 | 10 | 8 |
| 8 Long.-7 | | | | | | | | 9 | 7 | 5.6 |
| -8 | | | | | | | | 21 | 9 | 7.2 |
| -12 | | | | | | | | 18 | 8 | 6.4 |

QUALITY RATING FOR SECTION
II.B.1

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 8 Lat. -7 | Al Block | 10,000 | 8 | Endevco 2225 | 10 | ------- | 10 | 8 | 7 | 5.6 |
| -8 | | | | | | | | 14 | 8 | 6.4 |
| -12 | | | | | | | | 12 | 8 | 6.4 |
| 8 Vert.-7 | | | | | | | | 12 | 8 | 6.4 |
| -8 | | | | | | | | 27 | 9 | 7.2 |
| -12 | | | | | | | | 25 | 9 | 7.2 |
| 11 Long-9 | | | | | | block fell off | 5 | 16 | 8 | 3.2 |
| -10 | | | | | | | 5 | 24 | 9 | 3.6 |
| 11 Tang -9 | | | | | | | 5 | 8 | 6 | 2.4 |
| -10 | | | | | | | 5 | 31 | 10 | 4 |
| 11 Rad. -9 | | | | | | | 5 | 47 | 10 | 4 |
| -10 | | | | | | | 5 | 42 | 10 | 4 |
| 12 Long.-9 | | | | | | | 10 | 6 | 5 | 4 |
| -10 | | | | | | | | 19 | 8 | 6.4 |
| -11 | | | | | | | | 27 | 9 | 7.2 |
| 12 Tan. -9 | | | | | | | | 18 | 8 | 6.4 |
| -10 | | | | | | | | 14 | 8 | 6.4 |
| -11 | | | | | | | | 25 | 9 | 7.2 |
| 12 Rad. -9 | | | | | | | | 25 | 9 | 7.2 |
| -10 | | | | | | | | 15 | 8 | 6.4 |
| -11 | | | | | | exceeded cabr | 5 | 57 | 10 | 4 |
| 13 Long.-9 | | | | | | | 10 | 11 | 8 | 6.4 |
| -10 | | | | | | | | 30 | 10 | 8 |
| -11 | | | | | | | | 19 | 8 | 6.4 |
| -12 | | | | | | | | 28 | 9 | 7.2 |

QUALITY RATING FOR SECTION
II.B.1

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 13 Tan. -9 | Al Block | 10,000 | 8 | Endevco 2225 | 10 | --------- | 10 | 37 | 10 | 8 |
| -10 | | | | | | | | 25 | 9 | 7.2 |
| -11 | | | | | | | | 39 | 10 | 8 |
| -12 | | | | | | | | 28 | 9 | 7.2 |
| 13 Rad. -9 | | | | | | exceeded cabr | 8 | 47 | 10 | 6.4 |
| -10 | | | | | | | 10 | 40 | 10 | 8 |
| -11 | | | | | | | | 41 | 10 | 8 |
| -12 | | | | | | exceeded cabr | 6 | 56 | 10 | 4.8 |
| 14 Long.-9 | | | | | | | 10 | 12 | 8 | 6.4 |
| -10 | | | | | | | | 25 | 9 | 7.2 |
| -11 | | | | | | | | 18 | 8 | 6.4 |
| -12 | | | | | | | | 23 | 9 | 7.2 |
| 14 Tan. -9 | | | | | | exceeded cabr | 0 | 80 | 10 | 0 |
| -10 | | | | | | | 10 | 24 | 9 | 7.2 |
| -11 | | | | | | | | 26 | 9 | 7.2 |
| -12 | | | | | | dc shift | 5 | 25 | 9 | 3.6 |
| 14 Rad. -9 | | | | | | | 10 | 27 | 9 | 7.2 |
| -10 | | | | | | | | 27 | 9 | 7.2 |
| -11 | | | | | | | | 20 | 9 | 7.2 |
| -12 | | | | | | | | 25 | 9 | 7.2 |

QUALITY RATING FOR SECTION

II.B.1

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 15 Long.-9 | Al Block | 10,000 | 8 | Endevco 2225 | 10 | --------- | 10 | 48 | 10 | 8 |
| -10 | | | | | | | | 24 | 9 | 7.2 |
| -11 | | | | | | | | 20 | 9 | 7.2 |
| -12 | | | | | | | | 22 | 9 | 7.2 |
| 15 Tan. -9 | | | | | | | | 7 | 6 | 4.8 |
| -10 | | | | | | | | 30 | 10 | 8 |
| -11 | | | | | | | | 21 | 9 | 7.2 |
| -12 | | | | | | | | 19 | 8 | 6.4 |
| 15 Rad. -9 | | | | | | | | 4 | 3 | 2.4 |
| -10 | | | | | | | | 23 | 9 | 7.2 |
| -11 | | | | | | | | 19 | 8 | 6.4 |
| -12 | | | | | | | | 21 | 9 | 7.2 |
| 16 Long.-9 | | | | | | | | 5 | 4 | 3.2 |
| -10 | | | | | | | | 27 | 9 | 7.2 |
| -11 | | | | | | | | 17 | 8 | 6.4 |
| 16 Tan. -9 | | | | | | | | 4 | 3 | 2.4 |
| -10 | | | | | | | | 20 | 9 | 7.2 |
| -11 | | | | | | | | 20 | 9 | 7.2 |
| 16 Rad. -9 | | | | | | | | 6 | 5 | 4 |
| -10 | | | | | | | | 20 | 9 | 7.2 |
| -11 | | | | | | | | 17 | 8 | 6.4 |
| 17 Long.-9 | | | | | | | | 7 | 6 | 4.8 |
| -10 | | | | | | | | 23 | 9 | 7.2 |
| -11 | | | | | | | | 19 | 8 | 6.4 |
| -12 | | | | | | | | 23 | 9 | 7.2 |
| 17 Tan. -9 | | | | | | | | 4 | 3 | 2.4 |
| -10 | | | | | | | | 16 | 8 | 6.4 |
| -11 | | | | | | | | 15 | 8 | 6.4 |
| -12 | | | | | | | | 19 | 8 | 6.4 |

QUALITY RATING FOR SECTION

II.B.1

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 17 Rad. -9 | Al Block | 10,000 | 8 | Endevco 2225 | 10 | --------- | 10 | 5 | 4 | 3.2 |
| -10 | | | | | | | | 18 | 8 | 6.4 |
| -11 | | | | | | | | 16 | 8 | 6.4 |
| -12 | | | | | | | | 20 | 9 | 7.2 |
| 18 Long.-9 | | | | | | | | 3 | 2 | 1.6 |
| -10 | | | | | | | | 13 | 8 | 6.4 |
| -11 | | | | | | | | 23 | 9 | 7.2 |
| 18 Tan. -9 | | | | | | | | 3 | 2 | 1.6 |
| -10 | | | | | | | | 11 | 8 | 6.4 |
| -11 | | | | | | | | 22 | 9 | 7.2 |
| 18 Rad. -9 | | | | | | | | 3 | 2 | 1.6 |
| -10 | | | | | | | | 10 | 8 | 6.4 |
| -11 | | | | | | | | 20 | 9 | 7.2 |
| 1 Long -1 | | | | | 10 | block fell off | 5 | 40 | 10 | 4 |
| -2 | | | | | 1 | block fell off exceeded cabr | 5 | 44 | 10 | 4 |
| -3 | | | | | 1 | exceeded cabr | 6 | 48 | 10 | 4.8 |
| 1 Lat. -1 | | | | | 10 | block fell off | 5 | 35 | 10 | 4 |
| -2 | | | | | 10 | block fell off | 5 | 47 | 10 | 4 |
| -3 | | | | | 10 | --------- | 10 | 33 | 10 | 8 |
| 1 Vert. -1 | | | | | 10 | block fell off | 5 | 45 | 10 | 4 |
| -2 | | | | | 10 | block fell off | 5 | 45 | 10 | 4 |
| -3 | | | | | 10 | dc shift | 5 | 48 | 10 | 4 |

6

QUALITY RATING FOR SECTION

II.B.1

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 2 Long. -1 | Al Block | 10,000 | 8 | Endevco 2225 | 10 | Block fell off | 5 | 35 | 10 | 4 |
| -2 | | | | | 10 | block fell off | 5 | 42 | 10 | 4 |
| -3 | | | | | 10 | ---------- | 10 | 42 | 10 | 8 |
| 2 Lat. -1 | | | | | 10 | block fell off | 5 | 20 | 9 | 3.6 |
| -2 | | | | | 10 | block fell off | 5 | 24 | 9 | 3.6 |
| -3 | | | | | 10 | ---------- | 10 | 17 | 8 | 6.4 |
| 2 Vert. -1 | | | | | | block fell off | 5 | 12 | 8 | 3.2 |
| -2 | | | | | | block fell off | 5 | 16 | 8 | 3.2 |
| -3 | | | | | | ---------- | 10 | 23 | 9 | 7.2 |
| 3 Long. -1 | | | | | | ---------- | 10 | 38 | 10 | 8 |
| -2 | | | | | | ---------- | 10 | 45 | 10 | 8 |
| -3 | | | | | | block fell off | 5 | 38 | 10 | 4 |
| 3 Lat. -1 | | | | | | ---------- | 10 | 33 | 10 | 8 |
| -2 | | | | | | ---------- | 10 | 46 | 10 | 8 |
| -3 | | | | | | block fell off | 5 | 40 | 10 | 4 |
| 3 Vert. -1 | | | | | | ---------- | 10 | 30 | 10 | 8 |
| -2 | | | | | | ---------- | 10 | 10 | 8 | 6.4 |
| -3 | | | | | | block fell off | 5 | 30 | 10 | 4 |
| 4 Long. -1 | | | | | | ---------- | 10 | 7 | 6 | 4.8 |
| -2 | | | | | | ---------- | 10 | 15 | 8 | 6.4 |
| -3 | | | | | | ---------- | 10 | 15 | 8 | 6.4 |

QUALITY RATING FOR SECTION
II.B.1

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 4 Lat. -1 | Al Block | 10,000 | 8 | Endevco 2225 | 10 | ---------- | 10 | 15 | 8 | 6.4 |
| -2 | | | | | | ---------- | 10 | 28 | 9 | 7.2 |
| -3 | | | | | | ---------- | 10 | 30 | 10 | 8 |
| 4 Vert. -1 | | | | | | ---------- | 10 | 14 | 8 | 6.4 |
| -2 | | | | | | ---------- | 10 | 32 | 10 | 8 |
| -3 | | | | | | ---------- | 10 | 28 | 9 | 7.2 |
| 5 Long. -1 | | | | | | ---------- | 10 | 31 | 10 | 8 |
| -2 | | | | | | ---------- | 10 | 40 | 10 | 8 |
| -3 | | | | | | ---------- | 10 | 35 | 10 | 8 |
| 5 Lat. -1 | | | | | | ---------- | 10 | 19 | 8 | 6.4 |
| -2 | | | | | | ---------- | 10 | 27 | 9 | 7.2 |
| -3 | | | | | | ---------- | 10 | 25 | 9 | 7.2 |
| 5 Vert. -1 | | | | | | | 10 | 30 | 10 | 8 |
| -2 | | | | | | | 10 | 43 | 10 | 8 |
| -3 | | | | | | | 10 | 41 | 10 | 8 |
| 6 Long. -1 | | | | | | block fell off | 5 | 30 | 10 | 4 |
| -2 | | | | | | ---------- | 10 | 75 | 10 | 8 |
| -3 | | | | | | | 10 | 46 | 10 | 8 |
| 6 Lat. -1 | | | | | | block fell off | 5 | 31 | 10 | 4 |
| -2 | | | | | | ---------- | 10 | 18 | 8 | 6.4 |
| -3 | | | | | | ---------- | 10 | 17 | 8 | 6.4 |
| 6 Vert. -1 | | | | | | block fell off | 5 | 28 | 9 | 3.6 |
| -2 | | | | | | --------- | 10 | 40 | 10 | 8 |
| -3 | | | | | | --------- | 10 | 37 | 10 | 8 |

QUALITY RATING FOR SECTION
II.B.1

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 2 Lat. -4 | Al Block | 10,000 | 8 | Endevco 2225 | 8 | block fell off | 5 | 18 | 8 | 3.2 |
| 5 | | | | | | | 10 | 19 | 8 | 6.4 |
| 6 | | | | | | | 10 | 17 | 8 | 6.4 |
| 2 Vert. -4 | | | | | | block fell off | 5 | 25 | 9 | 3.6 |
| 5 | | | | | | | 10 | 22 | 9 | 7.2 |
| 6 | | | | | | | 10 | 18 | 8 | 6.4 |
| 3 Long. -4 | | | | | | | 10 | 40 | 10 | 8 |
| 5 | | | | | | | 10 | 56 | 10 | 8 |
| 6 | | | | | | | 10 | 35 | 10 | 8 |
| 3 Lat. -4 | | | | | | | 10 | 38 | 10 | 8 |
| 5 | | | | | | | 10 | 54 | 10 | 8 |
| 6 | | | | | | | 10 | 40 | 10 | 8 |
| 3 Vert. -4 | | | | | | | 10 | 35 | 10 | 8 |
| 5 | | | | | | | 10 | 35 | 10 | 8 |
| 6 | | | | | | | 10 | 33 | 10 | 8 |
| 4 Long. -4 | | | | | | | 10 | 20 | 9 | 7.2 |
| 5 | | | | | | | 10 | 18 | 8 | 6.4 |
| 6 | | | | | | | 10 | 15 | 8 | 6.4 |
| 4 Lat. -4 | | | | | | | 10 | 25 | 9 | 7.2 |
| 5 | | | | | | | 10 | 23 | 9 | 7.2 |
| 6 | | | | | | | 10 | 22 | 9 | 7.2 |
| 4 Vert. -4 | | | | | | | 10 | 26 | 9 | 7.2 |
| 5 | | | | | | | 10 | 24 | 9 | 7.2 |
| 6 | | | | | | | 10 | 24 | 9 | 7.2 |
| 5 Long. -4 | | | | | | | 10 | 34 | 10 | 8 |
| 5 | | | | | | | 10 | 33 | 10 | 8 |
| 6 | | | | | | | 10 | 26 | 9 | 7.2 |
| 5 Lat. -4 | | | | | | | 10 | 23 | 9 | 7.2 |
| 5 | | | | | | | 10 | 22 | 9 | 7.2 |

QUALITY RATING FOR SECTION

II.B.1

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 5 Lat. -6 | Al Block | 10,000 | 8 | Endevco 2225 | 10 | -------- | 10 | 18 | 8 | 6.4 |
| 5 Vert. -4 | | | | | | | 10 | 35 | 10 | 8 |
| 5 | | | | | | | 10 | 38 | 10 | 8 |
| 6 | | | | | | | 10 | 44 | 10 | 8 |
| 6 Long. -4 | | | | | | | 10 | 48 | 10 | 8 |
| 5 | | | | | | | 10 | 46 | 10 | 8 |
| 6 | | | | | | block fell off | 5 | 39 | 10 | 4 |
| 6 Lat. -4 | | | | | | | 10 | 16 | 8 | 6.4 |
| 5 | | | | | | | 10 | 13 | 8 | 6.4 |
| 6 | | | | | | block fell off | 5 | 15 | 8 | 3.2 |
| 6 Vert. -4 | | | | | | | 10 | 34 | 10 | 8 |
| 5 | | | | | | | 10 | 32 | 10 | 8 |
| 6 | | | | | | block fell off | 5 | 26 | 9 | 3.6 |
| 7 Long. 4 | | | | | | | 10 | 50 | 10 | 8 |
| 5 | | | | | | | 10 | 52 | 10 | 8 |
| 6 | | | | | | | 10 | 42 | 10 | 8 |
| 7 Lat. -4 | | | | | | | 10 | 28 | 9 | 7.2 |
| 5 | | | | | | | | 33 | 10 | 8 |
| 6 | | | | | | | | 32 | 10 | 8 |
| 7 Vert. -4 | | | | | | | | 35 | 10 | 8 |
| 5 | | | | | | | | 30 | 10 | 8 |
| 6 | | | | | | | | 30 | 10 | 8 |
| 8 Long. -4 | | | | | | | | 13 | 8 | 6.4 |
| 5 | | | | | | | | 14 | 8 | 6.4 |
| 6 | | | | | | | | 14 | 8 | 6.4 |
| 8 Lat. -4 | | | | | | | | 25 | 9 | 7.2 |

QUALITY RATING FOR SECTION

II.B.1

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 3 Long. -13 | Al Block | 10,000 | 8 | Endevco 2225 | 10 | Poor surface | 10* | 25 | 9 | 7.2 |
| -14 | | | | | | | 10 | 36 | 10 | 8 |
| -15 | | | | | | | 10 | 36 | 10 | 8 |
| 3 Lat. -13 | | | | | | Poor surf- | 10* | 20 | 9 | 7.2 |
| -14 | | | | | | | 10 | 48 | 10 | 8 |
| -15 | | | | | | exceeded cabr. | 8 | 58 | 10 | 6.4 |
| 3 Vert. -13 | | | | | | Poor surface | 10* | 31 | 10 | 8 |
| -14 | | | | | | | 10 | 27 | 10 | 8 |
| -15 | | | | | | | 10 | 48 | 10 | 8 |
| 4 Long.-13 | | | | | | Poor surface | 10* | 25 | 9 | 7.2 |
| -14 | | | | | | | 10 | 35 | 10 | 8 |
| -15 | | | | | | | 10 | 45 | 10 | 8 |
| 4 Lat. -13 | | | | | | Poor surface | 10* | 34 | 10 | 8 |
| -14 | | | | | | | 10 | 44 | 10 | 8 |
| -15 | | | | | | | 10 | 48 | 10 | 8 |
| 4 Vert.-13 | | | | | | Poor surface | 10 | 29 | 9 | 7.2 |
| -14 | | | | | | | 10 | 53 | 10 | 8 |
| -15 | | | | | | | 10 | 60 | 10 | 8 |
| 5 Long.-13 | | | | | | Poor surface | 10* | 42 | 10 | 8 |
| -14 | | | | | | | 10 | 64 | 10 | 8 |
| -15 | | | | | | | 10 | 41 | 10 | 8 |
| 5 Lat. -13 | | | | | | Poor surface | 10* | 30 | 10 | 8 |
| -14 | | | | | | | 10 | 46 | 10 | 8 |
| -15 | | | | | | | 10 | 45 | 10 | 8 |

QUALITY RATING FOR SECTION

II.B.1

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 5 Vert.-13 | Al Block | 10,000 | 8 | Endevco 2225 | 10 | Poor surf-ace | 10* | 50 | 10 | 8 |
| -14 | | | | | | Exceeded cabr | 5 | 73 | 10 | 4 |
| -15 | | | | | | | 10 | 36 | 10 | 8 |
| 6 Long.-13 | | | | | | Poor surf-ace | 10* | 18 | 8 | 6.4 |
| -14 | | | | | | Exceeded cabr | 5 | 73 | 10 | 4 |
| -15 | | | | | | | 10 | 37 | 10 | 8 |
| 6 Lat. -13 | | | | | | Poor surf-ace | 10* | 20 | 9 | 7.2 |
| -14 | | | | | | | 10 | 59 | 10 | 8 |
| -15 | | | | | | | 10 | 33 | 10 | 8 |
| 6 Vert.-13 | | | | | | Poor surf-ace | 10* | 24 | 9 | 7.2 |
| -14 | | | | | | Exceeded cabr | 5 | 100 | 10 | 4 |
| -15 | | | | | | | 10 | 51 | 10 | 8 |
| 7 Long.-13 | | | | | | Poor surf-ace | 10* | 43 | 10 | 8 |
| -14 | | | | | | | 10 | 76 | 10 | 8 |
| -15 | | | | | | | 10 | 42 | 10 | 8 |
| 7 Lat. -13 | | | | | | Poor surf-ace | 10* | 39 | 10 | 8 |
| -14 | | | | | | | 9 | 72 | 10 | 7.2 |
| -15 | | | | | | | 10 | 43 | 10 | 8 |
| 7 Vert.-13 | | | | | | Poor surf-ace | 10* | 54 | 10 | 8 |
| -14 | | | | | | Exceeded cahr | 8 | 88 | 10 | 6.4 |

QUALITY RATING FOR SECTION

II.B.1

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 8 Lat. 5 | Al Block | 10,000 | 8 | Endevco 2225 | 10 | ------- | 10 | 28 | 9 | 7.2 |
| 6 | | | | | | | | 26 | 9 | 7.2 |
| 8 Vert. -4 | | | | | | | | 25 | 9 | 7.2 |
| 5 | | | | | | | | 22 | 9 | 7.2 |
| 6 | | | | | | | | 20 | 9 | 7.2 |
| 1 Long.-13 | | | | | | | 10* | 25 | 9 | 7.2 |
| -14 | | | | | | | 10 | 44 | 10 | 8 |
| -15 | | | | | | | 10 | 41 | 10 | 8 |
| 1 Lat. -13 | | | | | | poor surf-ace | 10* | 22 | 9 | 7.2 |
| -14 | | | | | | | 10 | 50 | 10 | 8 |
| -15 | | | | | | | 10 | 52 | 10 | 8 |
| 1 Vert.-13 | | | | | | poor surf-ace | 10* | 29 | 9 | 7.2 |
| -14 | | | | | | | 10 | 46 | 10 | 8 |
| -15 | | | | | | | 10 | 49 | 10 | 8 |
| 2 Long.-13 | | | | | | poor surf-ace | 10* | 25 | 9 | 7.2 |
| -14 | | | | | | | 10 | 35 | 10 | 8 |
| -15 | | | | | | | 10 | 38 | 10 | 8 |
| 2 Lat. -13 | | | | | | poor surf-ace | 10* | 20 | 9 | 7.2 |
| -14 | | | | | | | 10 | 39 | 10 | 8 |
| -15 | | | | | | | 10 | 52 | 10 | 8 |
| 2 Vert.-13 | | | | | | poor surf-ace | 10* | 25 | 9 | 7.2 |
| -14 | | | | | | | 10 | 55 | 10 | 8 |
| -15 | | | | | | | 10 | 40 | 10 | 8 |

QUALITY RATING FOR SECTION
II.B.1

| Meas'm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 7 Vert.-15 | Al Block | 10,000 | 8 | Endevco 2225 | 10 | --------- | 10 | 41 | 10 | 8 |
| 8 Long-13 | | | | | | Poor surface | 10* | 30 | 10 | 8 |
| -14 | | | | | | | 10 | 40 | 10 | 8 |
| -15 | | | | | | | 10 | 46 | 10 | 8 |
| 8 Lat. -13 | | | | | | Poor surface | 10* | 21 | 9 | 7.2 |
| -14 | | | | | | | 10 | 31 | 10 | 8 |
| -15 | | | | | | | 10 | 35 | 10 | 8 |
| 8 Vert.-13 | | | | | | Poor surface | 10* | 30 | 10 | 8 |
| -14 | | | | | | | 10 | 54 | 10 | 8 |
| -15 | | | | | | | 10 | 28 | 9 | 7.2 |
| 1 Long.-16 | | | | | | --------- | 10 | 26 | 9 | 7.2 |
| -17 | | | | | | --------- | 10 | 31 | 10 | 8 |
| -18 | | | | | 8 | | | 32 | 10 | 8 |
| -19 | | | | | 8 | | | 30 | 10 | 8 |
| 1 Lat. -16 | | | | | 10 | | | 20 | 9 | 7.2 |
| -17 | | | | | | | | 18 | 8 | 6.4 |
| -18 | | | | | | | | 21 | 9 | 7.2 |
| -19 | | | | | | | | 25 | 9 | 7.2 |
| 1 Vert.-16 | | | | | | | | 20 | 9 | 7.2 |
| -17 | | | | | | | | 19 | 8 | 6.4 |
| -18 | | | | | | | | 17 | 8 | 6.4 |
| -19 | | | | | | | | 15 | 8 | 6.4 |
| 2 Long.-16 | | | | | | exceeded cabr | 9 | 56 | 10 | 7.2 |
| -17 | | | | | | --------- | 10 | 31 | 10 | 8 |
| -18 | | | | | | --------- | | 33 | 10 | 8 |
| -19 | | | | | | --------- | | 30 | 10 | 8 |

QUALITY RATING FOR SECTION

II.B.1

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 2 Lat.-16 | Al Block | 10,000 | 8 | Endevco 2225 | 10 | --------- | 10 | 31 | 10 | 8 |
| -17 | | | | | | | | 29 | 9 | 7.2 |
| -18 | | | | | | | | 29 | 9 | 7.2 |
| -19 | | | | | | | | 31 | 10 | 8 |
| 2 Vert.-16 | | | | | | | | 27 | 9 | 7.2 |
| -17 | | | | | | | | 28 | 9 | 7.2 |
| -18 | | | | | | | | 28 | 9 | 7.2 |
| -19 | | | | | | | | 25 | 9 | 7.2 |
| 3 Long.-16 | | | | | | | | 60 | 10 | 8 |
| -17 | | | | | | | | 30 | 10 | 8 |
| -18 | | | | | | | | 31 | 10 | 8 |
| -19 | | | | | | | | 28 | 9 | 7.2 |
| 3 Lat. -16 | | | | | | exceeded cabr | 9 | 55 | 10 | 7.2 |
| -17 | | | | | | | 10 | 28 | 9 | 7.2 |
| -18 | | | | | | | | 26 | 9 | 7.2 |
| -19 | | | | | | | | 26 | 9 | 7.2 |
| 3 Vert.-16 | | | | | | exceeded cabr | 6 | 58 | 10 | 4.8 |
| -17 | | | | | | --------- | 10 | 35 | 10 | 8 |
| -18 | | | | | | | 10 | 32 | 10 | 8 |
| -19 | | | | | | | 10 | 32 | 10 | 8 |
| 4 Long.-16 | | | | | | | 10 | 33 | 10 | 8 |
| -17 | | | | | | | 10 | 34 | 10 | 8 |
| -18 | | | | | | | 10 | 33 | 10 | 8 |
| -19 | | | | | | | | 32 | 10 | |
| 4 Lat. -16 | | | | | | | | 35 | 10 | |
| -17 | | | | | | | | 35 | 10 | |
| -18 | | | | | | | | 33 | 10 | |
| -19 | | | | | | | | 32 | 10 | |

QUALITY RATING FOR SECTION

II.B.1

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 4 Vert.-16 | Al Block | 10,000 | 8 | Endevco 2225 | 10 | ---------- | 10 | 31 | 10 | 8 |
| -17 | | | | | | | | 33 | 10 | |
| -18 | | | | | | | | 31 | 10 | |
| -19 | | | | | | | | 19 | 8 | 6.4 |
| 5 Long.-16 | | | | | | | | 55 | 10 | 8 |
| -17 | | | | | | | | 24 | 9 | 7.2 |
| -18 | | | | | | | | 24 | 9 | 7.2 |
| -19 | | | | | | | | 22 | 9 | 7.2 |
| 5 Lat. -16 | | | | | | | | 39 | 10 | 8 |
| -17 | | | | | | | | 41 | 10 | 8 |
| -18 | | | | | | | | 35 | 10 | 8 |
| -19 | | | | | | | | 35 | 10 | 8 |
| 5 Vert. -16 | | | | | | | | 45 | 10 | 8 |
| -17 | | | | | | | | 40 | 10 | 8 |
| -18 | | | | | | | | 43 | 10 | |
| -19 | | | | | | | | 41 | 10 | |
| 6 Long.-16 | | | | | | | | 50 | 10 | |
| -17 | | | | | | | | 62 | 10 | |
| -18 | | | | | | | | 63 | 10 | |
| -19 | | | | | | | | 59 | 10 | |
| 6 Lat. -16 | | | | | | | | 24 | 9 | 7.2 |
| -17 | | | | | | | | 28 | 9 | 7.2 |
| -18 | | | | | | | | 25 | 9 | 7.2 |
| -19 | | | | | | | | 25 | 9 | 7.2 |
| 6 Vert.-16 | | | | | | | | 25 | 10 | 8 |
| -17 | | | | | | | | 46 | 10 | 8 |
| -18 | | | | | | | | 45 | 10 | |
| -19 | | | | | | | | 44 | 10 | |

QUALITY RATING FOR SECTION

II.B.1

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 7 Long.-16 | Al Block | 10,000 | 8 | Endevco 2225 | 10 | --------- | 10 | 49 | 10 | 8 |
| -17 | | | | | | | | 50 | 10 | |
| -18 | | | | | | | | 48 | 10 | |
| -19 | | | | | | | | 50 | 10 | |
| 7 Lat. -16 | | | | | | | | 46 | 10 | 8 |
| -17 | | | | | | | | 50 | 10 | |
| -18 | | | | | | | | 43 | 10 | |
| -19 | | | | | | | | 48 | 10 | |
| 7 Vert.-16 | | | | | | | | 40 | 10 | |
| -17 | | | | | | | | 46 | 10 | |
| -18 | | | | | | | | 41 | 10 | |
| -19 | | | | | | | | 45 | 10 | |
| 8 Long.-16 | | | | | | | | 21 | 9 | 7.2 |
| -17 | | | | | | | | 23 | 9 | |
| -18 | | | | | | | | 23 | 9 | |
| -19 | | | | | | | | 23 | 9 | |
| 8 Lat. -16 | | | | | | | | 21 | 9 | |
| -17 | | | | | | | | 24 | 9 | |
| -18 | | | | | | | | 21 | 9 | |
| -19 | | | | | | | | 20 | 9 | |
| 8 Vert.-16 | | | | | | | | 24 | 9 | |
| -17 | | | | | | | | 26 | 9 | |
| -18 | | | | | | | | 25 | 9 | |
| -19 | | | | | | | | 26 | 9 | |

QUALITY RATING FOR SECTION

II.B.1

| Meas'm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 7 Long. -1 | Al Block | 10,000 | 8 | Endevco 2225 | 10 | -------- | 10 | 13 | 8 | 6.4 |
| -2 | | | | | | | | 38 | 10 | 8 |
| -3 | | | | | | | | 38 | 10 | 8 |
| 7 Lat. -1 | | | | | | | | 10 | 8 | 6.4 |
| -2 | | | | | | | | 28 | 9 | 7.2 |
| -3 | | | | | | | | 26 | 9 | 7.2 |
| 7 Vert. -1 | | | | | | | | 16 | 8 | 6.4 |
| -2 | | | | | | | | 44 | 10 | 8 |
| -3 | | | | | | | | 38 | 10 | 8 |
| 8 Long. -1 | | | | | | | | 10 | 8 | 6.4 |
| -2 | | | | | | | | 22 | 9 | 7.2 |
| -3 | | | | | | | | 22 | 9 | 7.2 |
| 8 Lat. -1 | | | | | | | | 6 | 5 | 4 |
| -2 | | | | | | | | 18 | 8 | 6.4 |
| -3 | | | | | | | | 16 | 8 | 6.4 |
| 8 Vert. -1 | | | | | | | | 11 | 8 | 6.4 |
| -2 | | | | | | | | 30 | 10 | 8 |
| -3 | | | | | | | | 30 | 10 | 8 |
| 1 Long. -4 | | | | | 8 | | 10 | 46 | 10 | 8 |
| -5 | | | | | 10 | | 10 | 38 | 10 | 8 |
| -6 | | | | | 10 | | 10 | 27 | 9 | 7.2 |
| 1 Lat. -4 | | | | | | dc shift | 5 | 40 | 10 | 4 |
| -5 | | | | | | | 10 | 33 | 10 | 8 |
| -6 | | | | | | | 10 | 27 | 9 | 7.2 |
| 1 Vert. -4 | | | | | | | 10 | 31 | 10 | 8 |
| -5 | | | | | | | 10 | 30 | 10 | 8 |
| -6 | | | | | | | 10 | 25 | 9 | 7.2 |
| 2 Long. -4 | | | | | | block fell | 5 | 41 | 10 | 4 |
| -5 | | | | | | off | 10 | 37 | 10 | 8 |
| -6 | | | | | | | 10 | 34 | 10 | 8 |

QUALITY RATING FOR SECTION
II.B.2

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| S1 A1 | A1 Block | 1OK | 8 | END2225 | 10 | Exceeded Cal. | 5 | 40 | 10 | 4.0 |
| S2 A1 | | | | | | | 10 | 21 | 9 | 7.2 |
| S3 A1 | | | | | | | 10 | 23 | 9 | 7.2 |
| S1 A2 | | | | | | | 10 | 32 | 10 | 8.0 |
| S2 A2 | | | | | | | 10 | 25 | 9 | 7.2 |
| S3 A2 | | | | | | | 10 | 27 | 9 | 7.2 |
| S1 A3 | | | | | | dc Shift | 5 | 35 | 10 | 4.0 |
| S2 A3 | | | | | | | 10 | 18 | 8 | 6.4 |
| S3 A3 | | | | | | | | 25 | 9 | 7.2 |
| S1 A4 | | | | | | | | 70 | 10 | 8.0 |
| S2 A4 | | | | | | | | 40 | 10 | 8.0 |
| S3 A4 | | | | | | | | 40 | 10 | 8.0 |
| S1 A5 | | | | | | | | 16 | 8 | 6.4 |
| S2 A5 | | | | | | | | 12 | 8 | 6.4 |
| S3 A5 | | | | | | | | 11 | 8 | 6.4 |
| S1 A6 | | | | | | | | 43 | 10 | 8.0 |
| S2 A6 | | | | | | | | 13 | 8 | 6.4 |
| S3 A6 | | | | | | | | 25 | 9 | 7.2 |
| S1 A7 | | | | | | | | 22 | 9 | 7.2 |
| S2 A7 | | | | | | | | 16 | 8 | 6.4 |
| S3 A7 | | | | | | | | 10 | 8 | 6.4 |
| S1 A8 | | | | | | | | 43 | 10 | 8.0 |
| S2 A8 | | | | | | | | 46 | 10 | 8.0 |
| S3 A8 | | | | | | | | 40 | 10 | 8.0 |
| S1 A9 | | | | | | | | 13 | 8 | 6.4 |
| S2 A9 | | | | | | | | 15 | 8 | 6.4 |
| S3 A9 | | | | | | | | 13 | 8 | 6.4 |
| S1 A10 | | | | | | | | 30 | 10 | 8.0 |

QUALITY RATING FOR SECTION

II.B.2

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| S2 A10 | A1 Block | 10K | 8 | END2225 | 10 | dc Shift | 10 | 27 | 9 | 7.2 |
| S3 A10 | | | | | | | | 20 | 9 | 7.2 |
| S1 A11 | | | | | | | | 54 | 10 | 8.0 |
| S2 A11 | | | | | | | | 19 | 9 | 7.2 |
| S3 A11 | | | | | | | | 41 | 10 | 8.0 |
| S1 A12 | | | | | | | | 70 | 10 | 8.0 |
| S2 A12 | | | | | | | | 39 | 10 | 8.0 |
| S3 A12 | | | | | | | | 33 | 10 | 8.0 |
| S1 A13 | | | | | | | | 33 | 10 | 8.0 |
| S2 A13 | | | | | | | | 25 | 9 | 7.2 |
| S2 A13 | | | | | | | | 28 | 9 | 7.2 |
| S1 A14 | | | | | | | | 29 | 10 | 8.0 |
| S2 A14 | | | | | | | | 24 | 9 | 7.2 |
| S3 A14 | | | | | | | | 25 | 9 | 7.2 |
| S1 A15 | | | | | | | | 28 | 9 | 7.2 |
| S2 A15 | | | | | | | | 23 | 9 | 7.2 |
| S3 A15 | | | | | | | | 30 | 10 | 8.0 |
| S1 A16 | | | | | | | | 126 | 10 | 8.0 |
| S2 A16 | | | | | | | | 70 | 10 | 8.0 |
| S3 A16 | | | | | | | | 20 | 9 | 7.2 |
| S1 A17 | | | | | | Exceeded Cal. | 5 | 46 | 10 | 4.0 |
| S2 A17 | | | | | | | 10 | 23 | 9 | 7.2 |
| S3 A17 | | | | | | | | 11 | 8 | 6.4 |
| S1 A18 | | | | | | | | 88 | 10 | 8.0 |
| S2 A18 | | | | | | | | 43 | 10 | 8.0 |
| S3 A18 | | | | | | | | 26 | 8 | 6.4 |
| S1 A19 | | | | | | | 10 | 46 | 10 | 8.0 |
| S2 A19 | | | | | | | 10 | 30 | 10 | 8.0 |

QUALITY RATING FOR SECTION
II.B.2

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| S3 A19 | Al Block | 10K | 8 | END2225 | 10 | Exceeded Cal. | 10 | 35 | 10 | 8.0 |
| S1 A20 | | | | | | Loose Accel. | 2 | 34 | 10 | 1.6 |
| S2 A20 | | | | | | | 10 | 28 | 9 | 7.2 |
| S3 A20 | | | | | | | | 33 | 10 | 8.0 |
| S1 A21 | | | | | | | | 23 | 9 | 7.2 |
| S2 A21 | | | | | | | | 15 | 8 | 6.4 |
| S3 A21 | | | | | | | | 15 | 8 | 6.4 |
| S1 A22 | | | | | | Exceeded Cal. | 6 | 62 | 10 | 4.8 |
| S2 A22 | | | | | | | 10 | 35 | 10 | 8.0 |
| S3 A22 | | | | | | dc Shift | 5 | 66 | 10 | 4.0 |
| S1 A23 | | | | | | dc Shift | 5 | 53 | 10 | 4.0 |
| S2 A23 | | | | | | | 10 | 23 | 9 | 7.2 |
| S3 A23 | | | | | | dc Shift | 2 | 39 | 10 | 1.6 |
| S1 A24 | | | | | | dc Shift | 5 | 83 | 10 | 4.0 |
| S2 A24 | | | | | | | 10 | 130 | 10 | 8.0 |
| S3 A24 | | | | | | dc Shift | 2 | 64 | 10 | 1.6 |
| S4 A1 | | | | | | | 10 | 22 | 9 | 7.2 |
| S5 A1 | | | | | | | | 19 | 9 | 7.2 |
| S6 A1 | | | | | | | | 13 | 8 | 6.4 |
| S4 A2 | | | | | | | | 23 | 9 | 7.2 |
| S5 A2 | | | | | | | | 26 | 9 | 7.2 |
| S6 A2 | | | | | | | | 12 | 8 | 6.4 |
| S4 A3 | | | | | | | | 24 | 9 | 7.2 |
| S5 A3 | | | | | | | | 17 | 8 | 6.4 |
| S6 A3 | | | | | | | | 8 | 7 | 5.6 |
| S4 A4 | | | | | | | | 24 | 9 | 7.2 |

QUALITY RATING FOR SECTION
II.B.2

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| S5 A4 | Al Block | 10K | 9 | END2225 | 10 | dc Shift | 10 | 37 | 10 | 8.0 |
| S6 A4 | | | | | | | | 26 | 9 | 7.2 |
| S4 A5 | | | | | | | | 10 | 8 | 6.4 |
| S5 A5 | | | | | | | | 17 | 8 | 6.4 |
| S6 A5 | | | | | | | | 14 | 8 | 6.4 |
| S4 A6 | | | | | | | | 22 | 9 | 7.2 |
| S5 A6 | | | | | | | | 20 | 9 | 7.2 |
| S6 A6 | | | | | | | | 16 | 8 | 6.4 |
| S4 A7 | | | | | | | | 27 | 9 | 7.2 |
| S5 A7 | | | | | | | | 9 | 8 | 6.4 |
| S6 A7 | | | | | | | | 39 | 10 | 8.0 |
| S4 A8 | | | | | | | | 11 | 8 | 6.4 |
| S5 A8 | | | | | | | | 15 | 8 | 6.4 |
| S6 A8 | | | | | | | | 14 | 8 | 6.4 |
| S4 A9 | | | | | | | | 20 | 9 | 7.2 |
| S5 A9 | | | | | | | | 11 | 8 | 6.4 |
| S6 A9 | | | | | | | | 17 | 8 | 6.4 |
| S4 A10 | | | | | | | | 19 | 9 | 7.2 |
| S5 A10 | | | | | | | | 23 | 9 | 7.2 |
| S6 A10 | | | | | | | | 26 | 9 | 7.2 |
| S4 A11 | | | | | | | | 18 | 8 | 6.4 |
| S5 A11 | | | | | | | | 11 | 8 | 6.4 |
| S6 A11 | | | | | | | | 21 | 9 | 7.2 |
| S4 A12 | | | | | | | | 48 | 10 | 8.0 |
| S5 A12 | | | | | | | | 40 | 10 | 8.0 |
| S6 A12 | | | | | | | | 45 | 10 | 8.0 |
| S4 A13 | | | | | | | | 15 | 8 | 6.4 |
| S6 A13 | | | | | | | | 17 | 8 | 6.4 |
| S4 A14 | | | | | | | | 24 | 9 | 7.2 |

QUALITY RATING FOR SECTION
II.B.2

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| S6 A14 | A1 Block | 10K | 8 | END2225 | 10 | dc Shift | 10 | 19 | 9 | 7.2 |
| S4 A15 | | | | | | | | 23 | 9 | 7.2 |
| S6 A15 | | | | | | | | 15 | 8 | 6.4 |
| S4 A16 | | | | | | | | 12 | 8 | 6.4 |
| S6 A16 | | | | | | | | 25 | 9 | 7.2 |
| S4 A17 | | | | | | | | 7 | 6 | 4.8 |
| S6 A17 | | | | | | | | 16 | 8 | 6.4 |
| S4 A18 | | | | | | | | 9 | 8 | 6.4 |
| S6 A18 | | | | | | | | 55 | 10 | 8.0 |
| S4 A19 | | | | | | | | 21 | 9 | 7.2 |
| S6 A19 | | | | | | | | 46 | 10 | 8.0 |
| S4 A20 | | | | | | | | 19 | 9 | 7.2 |
| S6 A20 | | | | | | | | 24 | 9 | 7.2 |
| S4 A21 | | | | | | | | 12 | 8 | 6.4 |
| S6 A21 | | | | | | | | 14 | 8 | 6.4 |
| S4 A22 | | | | | | | | 11 | 8 | 6.4 |
| S6 A22 | | | | | | | | 34 | 10 | 8.0 |
| S4 A23 | | | | | | | | 45 | 3 | 2.4 |
| S6 A23 | | | | | | dc Shift | 5 | 51 | 10 | 4.0 |
| S4 A24 | | | | | | | 10 | 13 | 8 | 6.4 |
| S6 A24 | | | | | | dc Shift | 5 | 73 | 10 | 4.0 |
| S7 A1 | | | | | | | 10 | 7 | 6 | 4.8 |
| S8 A1 | | | | | | | | 16 | 8 | 6.4 |
| S9 A1 | | | | | | | | 23 | 9 | 7.2 |
| S7 A2 | | | | | | | | 11 | 8 | 6.4 |
| S8 A2 | | | | | | | | 22 | 9 | 7.2 |
| S9 A2 | | | | | | | | 30 | 10 | 8.0 |
| S7 A3 | | | | | | | | 8 | 7 | 5.6 |
| S8 A3 | | | | | | | | 20 | 9 | 7.2 |

QUALITY RATING FOR SECTION
II.B.2

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| S9 A3 | A1 Block | 10K | 8 | END2225 | 10 | dc Shift | 10 | 18 | 8 | 6.4 |
| S7 A4 | | | | | | | | 28 | 9 | 7.2 |
| S8 A4 | | | | | | | | 47 | 10 | 8.0 |
| S9 A4 | | | | | | | | 54 | 10 | 8.0 |
| S7 A5 | | | | | | | | 20 | 9 | 7.2 |
| S9 A5 | | | | | | | | 13 | 8 | 6.4 |
| S7 A6 | | | | | | | | 12 | 8 | 6.4 |
| S8 A6 | | | | | | | | 40 | 10 | 8.0 |
| S9 A6 | | | | | | | | 32 | 10 | 8.0 |
| S7 A7 | | | | | | | | 17 | 8 | 6.4 |
| S8 A7 | | | | | | | | 25 | 9 | 7.2 |
| S9 A7 | | | | | | | | 22 | 9 | 7.2 |
| S7 A8 | | | | | | | | 25 | 9 | 7.2 |
| S8 A8 | | | | | | | | 36 | 10 | 8.0 |
| S9 A8 | | | | | | | | 34 | 10 | 8.0 |
| S7 A9 | | | | | | | | 7 | 6 | 4.8 |
| S8 A9 | | | | | | | | 18 | 8 | 6.4 |
| S9 A9 | | | | | | | | 24 | 9 | 7.2 |
| S7 A10 | | | | | | | | 10 | 8 | 6.4 |
| S8 A10 | | | | | | | | 22 | 9 | 7.2 |
| S9 A10 | | | | | | | | 26 | 9 | 7.2 |
| S7 A11 | | | | | | | | 15 | 8 | 6.4 |
| S8 A11 | | | | | | | | 19 | 9 | 7.2 |
| S9 A11 | | | | | | | | 25 | 9 | 7.2 |
| S7 A12 | | | | | | | | 28 | 9 | 7.2 |
| S8 A12 | | | | | | | | 37 | 10 | 8.0 |
| S9 A12 | | | | | | | | 53 | 10 | 8.0 |
| S7 A13 | | | | | | | | 9 | 8 | 6.4 |
| S8 A13 | | | | | | | | 23 | 9 | 7.2 |

QUALITY RATING FOR SECTION
II.B.2

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| S9 A13 | Al Block | 10K | 8 | END2225 | 10 | dc Shift | 10 | 22 | 9 | 7.2 |
| S7 A14 | | | | | | | | 12 | 8 | 6.4 |
| S8 A14 | | | | | | | | 25 | 9 | 7.2 |
| S9 A14 | | | | | | | | 23 | 9 | 7.2 |
| S7 A15 | | | | | | | | 6 | 7 | 5.6 |
| S8 A15 | | | | | | | | 24 | 9 | 7.2 |
| S9 A15 | | | | | | | | 26 | 9 | 7.2 |
| S7 A16 | | | | | | | | 34 | 10 | 8.0 |
| S8 A16 | | | | | | | | 50 | 10 | 8.0 |
| S9 A16 | | | | | | | | 54 | 10 | 8.0 |
| S7 A17 | | | | | | | | 39 | 10 | 8.0 |
| S8 A17 | | | | | | | | 18 | 8 | 6.4 |
| S9 A17 | | | | | | | | 31 | 10 | 8.0 |
| S7 A18 | | | | | | Exceeded Cal. | 8 | 50 | 10 | 6.4 |
| S8 A18 | | | | | | | 10 | 35 | 10 | 8.0 |
| S9 A18 | | | | | | Exceeded Cal. | 8 | 70 | 10 | 6.4 |
| S7 A19 | | | | | | | 10 | 10 | 8 | 6.4 |
| S8 A19 | | | | | | | | 36 | 10 | 8.0 |
| S9 A19 | | | | | | | | 42 | 10 | 8.0 |
| S7 A20 | | | | | | | | 22 | 9 | 7.2 |
| S8 A20 | | | | | | | | 41 | 10 | 8.0 |
| S9 A20 | | | | | | | | 42 | 10 | 8.0 |
| S7 A21 | | | | | | | | 16 | 8 | 6.4 |
| S8 A21 | | | | | | | | 28 | 9 | 7.2 |
| S9 A21 | | | | | | | | 28 | 9 | 7.2 |
| S7 A22 | | | | | | | | 24 | 9 | 7.2 |
| S8 A22 | | | | | | | | 23 | 9 | 7.2 |

QUALITY RATING FOR SECTION II.B.2

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| S9 A22 | Al Block | 10K | 8 | END2225 | 10 | Exceeded Cal. | 10 | 28 | 9 | 7.2 |
| S7 A23 | | | | | | | | 22 | 9 | 7.2 |
| S8 A23 | | | | | | | | 31 | 10 | 8.0 |
| S9 A23 | | | | | | | | 41 | 10 | 8.0 |
| S7 A24 | | | | | | | | 30 | 10 | 8.0 |
| S8 A24 | | | | | | | | 44 | 10 | 8.0 |
| S9 A24 | | | | | | | | 36 | 10 | 8.0 |

QUALITY RATING FOR SECTION

II.B.3

| Meas'<br>Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 1-BL-1 | Al. Block | 10K | 8 | Endevco 2225 | 10 | ---------- | 10 | 60 | 10 | 8.0 |
| 2 | | | | | | | | 56 | 10 | 8.0 |
| 5 | | | | | | | | 32 | 10 | 8.0 |
| 3 | | | | | | | | 31 | 10 | 8.0 |
| 4 | | | | | | | | 40 | 10 | 8.0 |
| 1-WL-1 | | | | | | | | 60 | 10 | 8.0 |
| 2 | | | | | | | | 42 | 10 | 8.0 |
| 5 | | | | | | | | 21 | 9 | 7.2 |
| 3 | | | | | | | | 22 | 9 | 7.2 |
| 4 | | | | | | | | 53 | 10 | 8.0 |
| 1-Vert.-1 | | | | | | | | 80 | 10 | 8.0 |
| 2 | | | | | | | | 53 | 10 | 8.0 |
| 5 | | | | | | | | 37 | 10 | 8.0 |
| 3 | | | | | | | | 25 | 9 | 7.2 |
| 4 | | | | | | exceeded calbr | .5 | 52 | 10 | 4 |
| 2-BL-1 | | | | | | | 10 | 15 | 8 | 6.4 |
| 2 | | | | | | | 0 | 80 | 10 | 0 |
| 6 | | | | | | | 10 | 73 | 10 | 8.0 |
| 2-WL-1 | | | | | | | | 17 | 8 | 6.4 |
| 2 | | | | | | | | 80 | 10 | 8.0 |
| 6 | | | | | | | | 84 | 10 | 8.0 |
| 7 | | | | | | | | 76 | 10 | 8.0 |
| 2-Vert.-1 | | | | | | | | 9 | 8 | 6.4 |
| 2 | | | | | | | | 43 | 10 | 8.0 |
| 6 | | | | | | exceeded cabr | 2 | 110 | 10 | 1.6 |
| 7 | | | | | | | 10 | 76 | 10 | 8.0 |
| 3-BL-5 | | | | | | | | 10 | 8 | 6.4 |
| 3-WL-5 | | | | | | | | 11 | 8 | 6.4 |
| 3-Vert-5 | | | | | | | | 19 | 9 | 7.2 |

QUALITY RATING FOR SECTION
II.B.3

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 4-BL-5 | Al. Block | 10K | 8 | End. 2225 | 10 | -------- | 10 | 18 | 8 | [illegible].4 |
| 4-BL-3 | | | | | | exceeded cabr | 0 | 95 | 10 | 0 |
| 4 | | | | | | | 10 | 23 | 9 | 7.[illegible] |
| 4-WL-3 | | | | | | | | 31 | 10 | 8.0 |
| 4 | | | | | | | | 32 | 10 | 8.0 |
| 4-[illegible]L-5 | | | | | | | | 33 | 10 | 8.0 |
| 4-Vert-5 | | | | | | | | 20 | 9 | 7.2 |
| 4-Vert-3 | | | | | | | | 35 | 10 | 8.0 |
| 4 | | | | | | | | 33 | 10 | 8.0 |
| 5-BL-1 | | | | | | | 10 | 80 | 10 | 8.0 |
| 2 | | | | | | | | 24 | 9 | 7.2 |
| 5-BL-3 | | | | | | | | 57 | 10 | 8.0 |
| 5-WL-3 | | | | | | | | 40 | 10 | 8.0 |
| 5-WL-1 | | | | | | | | 65 | 10 | 8.0 |
| 2 | | | | | | | | 27 | 9 | 7.2 |
| 5-Vert-1 | | | | | | | | 42 | 10 | 8.0 |
| 2 | | | | | | | | 28 | 9 | 7.2 |
| 5-Vert-3 | | | | | | | | 60 | 10 | 8.0 |
| 6-BL-1 | | | | | | | | 26 | 9 | 7.2 |
| 2 | | | | | | | | 65 | 10 | 8.0 |
| 6-BL-5 | | | | | | | | 30 | 10 | 8.0 |
| 6 | | | | | | | | 75 | 10 | 8.0 |
| 7 | | | | | | | | 65 | 10 | 8.0 |
| 6-WL-1 | | | | | | | | 30 | 10 | 8.0 |
| 2 | | | | | | | | 70 | 10 | 8.0 |
| 6-WL-5 | | | | | | | | 31 | 10 | 8.0 |
| 6 | | | | | | | | 90 | 10 | 8.0 |
| 7 | | | | | | | | 72 | 10 | 8.0 |

QUALITY RATING FOR SECTION

II.B.3

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 6-Vert-1 | Al Block | 10K | 8 | End. 2225 | 10 | -------- | 10 | 50 | 10 | 8.0 |
| 2 | | | | | | | | 30 | 10 | 8.0 |
| 5 | | | | | | | | 53 | 10 | 8.0 |
| 6 | | | | | | | | 47 | 10 | 8.0 |
| 7 | | | | | | | | 44 | 10 | 8.0 |
| 7-BL-4 | | | | | | | | 64 | 10 | 8.0 |
| 7-WL-4 | | | | | | | | 63 | 10 | 8.0 |
| 7-Vert-4 | | | | | | | | 90 | 10 | 8.0 |
| 8-BL-4 | | | | | | | | 28 | 9 | 7.2 |
| 8-WL-4 | | | | | | | | 35 | 10 | 8.0 |
| 8-Vert-4 | | | | | | | | 26 | 9 | 7.2 |
| 9-BL-7 | | | | | | | | 19 | 9 | 7.2 |
| 9-WL-7 | | | | | | | | 22 | 9 | 7.2 |
| 9-Vert-7 | | | | | | | | 19 | 9 | 7.2 |
| 10-BL-3 | | | | | | | | 30 | 10 | 8.0 |

QUALITY RATING FOR SECTION
II.B.3

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 10-WL-3 | Al Block | 10K | 8 | End. 2225 | 10 | -------- | 10 | 31 | 10 | 8.0 |
| 10-Vert-3 | | | | | | | | 20 | 9 | 7.2 |
| 11-BL-7 | | | | | | | | 26 | 9 | 7.2 |
| 11-WL-7 | | | | | | | | 28 | 9 | 7.2 |
| 11-Vert-7 | | | | | | | | 29 | 10 | 8.0 |
| 12-BL-6 | | | | | | | | 31 | 10 | 8.0 |
| 12-WL-6 | | | | | | | | 48 | 10 | 8.0 |
| 12-Vert-6 | | | | | | | | 57 | 10 | 8.0 |
| 13-BL-6 | | | | | | | | 56 | 10 | 8.0 |
| 13-WL-6 | | | | | | | | 75 | 10 | 8.0 |
| 13-Vert-6 | | | | | | | | 84 | 10 | 3.0 |

QUALITY RATING FOR SECTION
III.B.1

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 1-1 | Al Block | 10K | 8 | End. 2225 | 10 | -------- | 10 | 31 | 10 | 8.0 |
| 2-2 | | | | | | | | 12 | 8 | 6.4 |
| 3 | | | | | | | | 21 | 9 | 7.2 |
| 3-1 | | | | | | | | 43 | 10 | 8.0 |
| 2 | | | | | | | | 13 | 8 | 6.4 |
| 3 | | | | | | | | 22 | 9 | 7.2 |
| 4-2 | | | | | | | | 9 | 8 | 6.4 |
| 3 | | | | | | | | 19 | 9 | 7.2 |
| 5-1 | | | | | | | | 30 | 10 | 8.0 |
| 2 | | | | | | | | 13 | 8 | 6.4 |
| 3 | | | | | | | | 28 | 9 | 7.2 |
| 6-1 | | | | | | | | 8 | 7 | 5.6 |
| 2 | | | | | | | | 14 | 8 | 6.4 |
| 3 | | | | | | | | 21 | 9 | 7.2 |
| 7-1 | | | | | | | | 25 | 9 | 7.2 |
| 2 | | | | | | | | 17 | 8 | 6.4 |
| 3 | | | | | | | | 18 | 8 | 6.4 |
| 8-2 | | | | | | | | 24 | 9 | 7.2 |
| 3 | | | | | | | | 23 | 9 | 7.2 |
| 9-1 | | | | | | | | 35 | 10 | 8.0 |
| 2 | | | | | | | | 24 | 9 | 7.2 |
| 3 | | | | | | | | 20 | 9 | 7.2 |
| 10-1 | | | | | | | | 6 | 5 | 4.0 |
| 2 | | | | | | | | 40 | 10 | 8.0 |
| 3 | | | | | | | | 22 | 9 | 7.2 |
| 11-1 | | | | | | | | 13 | 8 | 6.4 |
| 2 | | | | | | | | 5 | 4 | 3.2 |
| 3 | | | | | | | | 15 | 8 | 6.4 |
| 12-1 | | | | | | | | 6 | 5 | 4.0 |
| 2 | | | | | | | | 8 | 7 | 5.6 |

QUALITY RATING FOR SECTION

III.B.1

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 12-3 | Al Block | 10K | 8 | End. 2225 | 10 | -------- | 10 | 16 | 8 | 6.4 |

QUALITY RATING FOR SECTION

III.B.2

| Meass't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Al Block | 7K | 6 | End. 2225 | 10 | --------- | 10 | 25 | 9 | 5.4 |
| 2 | | | | | | | | 18 | 8 | 4.8 |
| 3 | | | | | | | | 23 | 9 | 5.4 |
| 4 | | | | | | | | 18 | 8 | 4.8 |
| 5 | | | | | | | | 11 | 8 | 4.8 |
| 6 | | | | | | | | 6 | 5 | 2.0 |
| 7 | | | | | | | | 8 | 7 | 4.2 |
| 8 | | | | | | | | 8 | 7 | 4.2 |
| 9 | | | | | | | | 10 | 8 | 4.8 |
| 10 | | | | | | | | 9 | 8 | 4.8 |
| 11 | | | | | | | | 9 | 8 | 4.8 |
| 12 | | | | | | | | 6 | 5 | 3.0 |

QUALITY RATING FOR SECTION

III.B.3

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 11X | on Al Block | 20-1250 | 2 | Endevco 2221C | 10 | dc shift | 8 | 10 | 8 | 1.3 |
| 16X | | | | | | -------- | 10 | 6 | 5 | 1.0 |
| 16Y | | | | | | -------- | | 20 | 9 | 1.8 |
| 35X | | | | | | -------- | | 10 | 8 | 1.6 |
| 35Y | | | | | | -------- | | 10 | 8 | 1.6 |
| 35Z | | | | | | -------- | | 8 | 6 | 1.2 |
| 49Y | | | | | | -------- | | 20 | 9 | 1.8 |
| 49Z | | | | | | -------- | | 20 | 9 | 1.8 |
| 58X | | | | | | dc shift | 8 | 20 | 9 | 1.4 |
| 58Y | | | | | | -------- | 10 | 10 | 8 | 1.6 |
| 58Z | | | | | | dc shift | 8 | 40 | 10 | 1.6 |
| 73X | | | | | | -------- | 10 | 30 | 10 | 2.0 |
| 73Y | | | | | | -------- | | 10 | 8 | 1.6 |
| 90X | | | | | | dc shift | 8 | 30 | 10 | 1.6 |
| 90Y | | | | | | dc shift | 9 | 10 | 8 | 1.4 |
| 100X | | | | | | -------- | 10 | 5 | 4 | 0.8 |
| 100Y | | | | | | dc shift | 8 | 5 | 4 | 0.6 |
| 100Z | | | | | | dc shift | 9 | 8 | 6 | 1.1 |
| 106X | | | | | | dc shift | 8 | ? | 5* | 0.8* |
| 106Z | | | | | | -------- | 10 | 10 | 8 | 1.6 |
| 121X | | | | | | dc shift | 8 | 6 | 5 | 0.8 |
| 121Y | | | | | | dc shift | 8 | 8 | 5 | 1.0 |
| 121Z | | | | | | -------- | 10 | 8 | 6 | 1.2 |

QUALITY RATING FOR SECTION

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 7 | | 1000+ | 1.5 | Endevco 2225 | 10 | -------- | 10 | 40 | 10 | 1.5 |
| 8 | | | | | | dc shift | 8 | 30 | 10 | 1.2 |
| 9 | | | | | | -------- | 10 | 60 | 10 | 1.5 |
| 10 | | | | | | -------- | 10 | 15 | 8 | 1.2 |
| 11 | | | | | | dc shift | 8 | 45 | 10 | 1.2 |
| 12 | | | | | | -------- | 10 | 48 | 10 | 1.5 |

QUALITY RATING FOR SECTION

III.C.2

| Measr't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 3L | | 2000 | 2 | End. 2221 | 10 | -------- | 10 | 6 | 5 | 1 |
| 3R | | | | | | | | 30 | 10 | 2 |
| 4L | | | | | | | | 20 | 9 | 1.8 |
| 4R | | | | | | | | 30 | 10 | 2 |
| 5L | | | | | | | | 40 | 10 | 2 |
| 5R | | | | | | | | 25 | 9.5 | 1.9 |
| 6L | | | | | | | | 30 | 10 | 2 |
| 6R | | | | | | | | 35 | 10 | 2 |
| 7L | | | | | | | | 4 | 3 | 0.6 |
| 8L | | | | | | | | 10 | 8 | 1.6 |
| 9L | | | | | | | | 10 | 8 | 1.6 |
| 9R | | | | | | | | 12 | 8 | 1.6 |
| 11L | | | | | | | | 20 | 9 | 1.8 |
| 11R | | | | | | | | 13 | 8 | 1.6 |

QUALITY RATING FOR SECTION
III.C.3

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 1* | Mounted directly to structure with dental cememt and cement on studs all measurements | 20-1250 | 2 | Endevco 2225 | 10 | ---------- | 10 | 7 | 6 | 1.2 |
| 2* | | | | | | | | 10 | 8 | 1.6 |
| 3* | | | | | | | | 30 | 10 | 2 |
| 4* | | | | | | | | 25 | 10 | 2 |
| 5 | | | | | | | | 30 | 10 | 2 |
| 6 | | | | | | | | 65 | 10 | 2 |
| 7 | | | | | | | | 55 | 10 | 2 |
| 8 | | | | | | | | 13 | 8 | 1.6 |

* These accelerometers exhibit a slight dc shift which is not appreciable enough to alter the rating.

QUALITY RATING FOR SECTION

IV.A.1

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 1A pitch-1 | | 5000 | 4 | | 10 | None | 10 | -------- | 5* | 2* |
| 1A roll -5 | | | | | | | | | | |
| 2 pitch -1 | | | | | | | | | | |
| 2 pitch -5 | | | | | | | | | | |
| 2 roll -1 | | | | | | | | | | |
| 2 roll -5 | | | | | | | | | | |
| 2 yaw -1 | | | | | | | | | | |
| 2 yaw -5 | | | | | | | | | | |
| 3 roll -1 | | | | | | | | | | |
| 3 roll -5 | | | | | | | | | | |
| 3 pitch -5 | | | | | | | | | | |
| 3 yaw -1 | | | | | | | | | | |
| 3 yaw -5 | | | | | | | | | | |
| 1X pitch-5 | | | | | | | | | | |
| 1X yaw -5 | | | | | | | | | | |
| 1B pitch-5 | | | | | | | | | | |
| 3B yaw -5 | | | | | | | | | | |
| 5B pitch-5 | | | | | | | | | | |
| 6 yaw -1 | | | | | | | | | | |
| 6 roll -1 | | | | | | | | | | |
| 7 pitch -1 | | | | | | | | | | |
| 7 roll -1 | | | | | | | | | | |
| 7 yaw -1 | | | | | | | | | | |
| 9 roll -1 | | | | | | | | | | |
| 9 yaw -1 | | | | | | | | | | |
| 1A-1 | | | | | | | | | | |
| 2 pitch -1 | | | | | | | | | | |

QUALITY RATING FOR SECTION

IV.A.2

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 1C -4 | | 5000 | 4 | | 10 | None | 10 | ------ | 5* | 2* |
| 1C2 -5 | | | | | | | | | | |
| 1C2 -6 | | | | | | | | | | |
| 2 roll -2 | | | | | | | | | | |
| 2 roll -3 | | | | | | | | | | |
| 2 pitch -2 | | | | | | | | | | |
| 2 pitch -3 | | | | | | | | | | |
| 2 yaw -2 | | | | | | | | | | |
| 2 yaw -3 | | | | | | | | | | |
| 3 roll -2 | | | | | | | | | | |
| 3 roll -3 | | | | | | | | | | |
| 3 yaw -3 | | | | | | | | | | |
| 3B yaw -4 | | | | | | | | | | |
| 5 roll -2 | | | | | | | | | | |
| 5 roll -3 | | | | | | | | | | |
| 5 roll -4 | | | | | | | | | | |
| 5 roll -5 | | | | | | | | | | |
| 5 pitch -2 | | | | | | | | | | |
| 5 pitch -3 | | | | | | | | | | |
| 5 pitch -5 | | | | | | | | | | |
| 5 yaw -4 | | | | | | | | | | |
| 6 roll -2 | | | | | | | | | | |
| 6 roll -3 | | | | | | | | | | |
| 6 yaw -2 | | | | | | | | | | |
| 7 roll -2 | | | | | | | | | | |
| 7 roll -3 | | | | | | | | | | |
| 7 roll -4 | | | | | | | | | | |
| 7 roll -5 | | | | | | | | | | |
| 7 roll -6 | | | | | | | | | | |

QUALITY RATING FOR SECTION

IV.A.2

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 7 pitch -2 | | 5000 | 4 | | 10 | None | 10 | --------- | 5* | 2* |
| 7 pitch -3 | | | | | | | | | | |
| 7 pitch -5 | | | | | | | | | | |
| 7 pitch -6 | | | | | | | | | | |
| 7 yaw -2 | | | | | | | | | | |
| 7 yaw -3 | | | | | | | | | | |
| 7 yaw -6 | | | | | | | | | | |
| 7B roll -5 | | | | | | | | | | |
| 7B roll -6 | | | | | | | | | | |
| 7B pitch-5 | | | | | | | | | | |
| 7B pitch-6 | | | | | | | | | | |
| 7B yaw -5 | | | | | | | | | | |
| 7B yaw -6 | | | | | | | | | | |
| 9 roll -2 | | | | | | | | | | |
| 9 roll -3 | | | | | | | | | | |
| 9 roll -4 | | | | | | | | | | |
| 9 pitch -2 | | | | | | | | | | |
| 9 pitch -3 | | | | | | | | | | |
| 9 yaw -3 | | | | | | | | | | |
| 9A roll -4 | | | | | | | | | | |
| 9A roll -5 | | | | | | | | | | |
| 9A pitch-4 | | | | | | | | | | |
| 9A pitch-5 | | | | | | | | | | |
| 9B roll -5 | | | | | | | | | | |
| 9A yaw -4 | | | | | | | | | | |
| 9B pitch-5 | | | | | | | | | | |
| 9B yaw -5 | | | | | | | | | | |
| 11 roll -6 | | | | | | | | | | |
| 11 pitch-6 | | | | | | | | | | |
| 11 yaw -6 | | | | | | | | | | |

## QUALITY RATING FOR SECTION

IV.A.3

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 1B -2 | | 5000 | 4 | | 10 | None | 10 | --------- | 5* | 2* |
| 1B -3 | | | | | | | | | | |
| 1B -4 | | | | | | | | | | |
| 2 pitch -3 | | | | | | | | | | |
| 2 pitch -4 | | | | | | | | | | |
| 2 roll -3 | | | | | | | | | | |
| 2 roll -4 | | | | | | | | | | |
| 3 roll -2 | | | | | | | | | | |
| 3 roll -3 | | | | | | | | | | |
| 3 roll -4 | | | | | | | | | | |
| 3 yaw -2 | | | | | | | | | | |
| 3 yaw -3 | | | | | | | | | | |
| 3 yaw -4 | | | | | | | | | | |
| 5 pitch -4 | | | | | | | | | | |
| 5 roll -2 | | | | | | | | | | |
| 5 roll -3 | | | | | | | | | | |
| 5 yaw -3 | | | | | | | | | | |
| 6 pitch -4 | | | | | | | | | | |
| 6 roll -3 | | | | | | | | | | |
| 7 pitch -4 | | | | | | | | | | |
| 7 yaw -4 | | | | | | | | | | |
| 9 pitch -4 | | | | | | | | | | |
| 9 yaw -3 | | | | | | | | | | |
| 10 roll -3 | | | | | | | | | | |
| 10 roll -4 | | | | | | | | | | |

QUALITY RATING FOR SECTION

IV.A.4

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 1B -1 | | 5000 | 4 | | 10 | None | 10 | ------- | 5* | 2* |
| 2 roll -1 | | | | | | | | | | |
| 3 roll -1 | | | | | | | | | | |
| 3 yaw -1 | | | | | | | | | | |
| 10 roll-1 | | | | | | | | | | |
| 1B -1 | | | | End. 2225 | | | | | | |
| 1B -2 | | | | | | | | | | |
| 1B -5 | | | | | | | | | | |
| 1B -6 | | | | | | | | | | |
| 2 pitch-5 | | | | | | | | | | |
| 2 pitch-6 | | | | | | | | | | |
| 2 roll -1 | | | | | | | | | | |
| 2 roll -2 | | | | | | | | | | |
| 2 roll -5 | | | | | | | | | | |
| 2 roll -6 | | | | | | | | | | |
| 3 roll -1 | | | | | | | | | | |
| 3 roll -2 | | | | | | | | | | |
| 3 roll -5 | | | | | | | | | | |
| 3 roll -6 | | | | | | | | | | |
| 3 yaw -1 | | | | | | | | | | |
| 3 yaw -5 | | | | | | | | | | |
| 3 yaw -6 | | | | | | | | | | |
| 5 pitch-5 | | | | | | | | | | |
| 5 roll -5 | | | | | | | | | | |
| 5 yaw -5 | | | | | | | | | | |
| 6 roll -5 | | | | | | | | | | |
| 6 yaw -5 | | | | | | | | | | |
| 7 roll -5 | | | | | | | | | | |
| 7 yaw -5 | | | | | | | | | | |
| 9 roll -5 | | | | | | | | | | |

QUALITY RATING FOR SECTION

IV.A.4

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 9 yaw -5<br>10 roll-5<br>10 roll-6 | | 5000 | 4 | | 10 | None | 10 | -------- | 5* | 2* |

QUALITY RATING FOR SECTION

IV.B.2

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| B3 | Al Block | 8K | 6 | ---------------- | 10 | ---------- | 10 | 62 | 10 | 6.0 |
| F4 | No Block | 8K | 6 | | | | | 180 | 10 | 6.0 |
| SS4A | No Block | 7.5K | 6 | | | | | ? | 5* | 3.0* |
| AS1 | No Block | 15K | 9 | | | | | 128 | 10 | 9.0 |
| F1 | No Block | 20K | 10 | | | | | 70 | 10 | 10.0 |
| F3 | No Block | 20K | 10 | | | | | 76 | 10 | 10.0 |
| F4A | No Block | 20K | 10 | | | | | 68 | 10 | 10.0 |
| B1A | Al Block | 20K | 10 | | | | | 49 | 10 | 10.0 |
| B2A | Al Block | 20K | 10 | | | | | 40 | 10 | 10.0 |
| B3A | Al Block | 20K | 10 | | | | | 65 | 10 | 10.0 |
| B4 | Al Block | 9K | 7 | | | | | ? | 5* | 3.5* |
| B5 | Al Block | 9K | 7 | | | | | ? | 5* | 3.5* |
| B6 | Al Block | 9K | 7 | | | | | 12 | 8 | 5.6 |
| BB1 | Al Block | 20K | 10 | | | | | 20 | 9 | 9.0 |
| BB2 | Al Block | 20K | 10 | | | | | 18 | 9 | 9.0 |
| BB3 | Al Block | 20K | 10 | | | | | 70 | 10 | 10.0 |
| 1C4 | No Block | 15K | 9 | | | | | 55 | 10 | 9.0 |
| 3T3 | No Block | 15K | 9 | | | | | 45 | 10 | 9.0 |
| MC4 | No Block | 20K | 10 | | | | | 13 | 8 | 8.0 |

QUALITY RATING FOR SECTION

IV.B.1

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| MC4 | No Block | 20K | 10 | ------------- | 10 | ---------- | 10 | 58 | 10 | 10.0 |
| 1C4 | No Block | 15K | 10 | | | | | 45 | 10 | 9.0 |
| 3T3 | No Block | 15K | 9 | | | | | 54 | 10 | 9.0 |
| SS6A | No Block | 7.5K | 6 | | | | | 37 | 10 | 6.0 |
| AS1 | No Block | 15K | 9 | | | | | 64 | 10 | 9.0 |
| BB3 | Al Block | 20K | 10 | | | | | 70 | 10 | 10.0 |
| SS5A | No Block | 7.5K | 6 | | | | | 28 | 9 | 5.4 |
| BB1 | Al Block | 20K | 10 | | | | | 80 | 10 | 10.0 |
| BB2 | Al Block | 20K | 10 | | | | | 84 | 10 | 10.0 |
| B5 | Al Block | 9K | 7 | | | | | 30 | 10 | 7.0 |
| B6 | Al Block | 9K | 7 | | | | | 20 | 9 | 6.3 |
| B3A | Al Block | 20K | 10 | | | | | 47 | 10 | 10.0 |
| B4 | Al Block | 9K | 7 | | | | | 23 | 9 | 6.3 |
| B1A | Al Block | 20K | 10 | | | | | 42 | 10 | 10.0 |
| 32A | Al Block | 20K | 10 | | | | | 44 | 10 | 10.0 |
| M67-1 F4A | No Block | 20K | 10 | | | | | 16 | 8 | 8.0 |
| M67-2 F4A | No Block | 20K | 10 | | | | | 120 | 10 | 10.0 |
| M67-1 F3 | No Block | 20K | 10 | | | | | 70 | 10 | 10.0 |
| M67-2 F3 | No Block | 20K | 10 | | | | | 66 | 10 | 10.0 |
| M67-1 F1 | No Block | 20K | 10 | | | | | ? | 5* | 5.0* |
| M67-2 F1 | No Block | 20K | 10 | | | | | 100 | 10 | 10.0 |
| M67-1 F4 | No Block | 8K | 6 | | | | | 53 | 10 | 6.0 |
| M67-2 F4 | No Block | 8K | 6 | | | | | ? | 5* | 3.0* |
| M67-1 B3 | Al Block | 8K | 6 | | | | | 50 | 10 | 6.0 |
| M67-2 B3 | Al Block | 8K | 6 | | | | | 110 | 10 | 6.0 |

QUALITY RATING FOR SECTION

IV.B.3

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Descriptior | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| M67-1 B3 | Al Block | 8K | 6 | ------------ | 10 | -------- | 10 | 84 | 10 | 6.0 |
| M67-2 B3 | Al Block | 8K | 6 | | | | | 82 | 10 | 6.0 |
| M67-1 F1 | No Block | 20K | 10 | | | | | 13 | 8 | 8.0 |
| M67-2 F1 | No Block | 20K | 10 | | | | | 21 | 9 | 9.0 |
| M67-1 F3 | No Block | 20K | 10 | | | | | 13 | 8 | 8.0 |
| M67-2 F3 | No Block | 20K | 10 | | | | | 20 | 9 | 9.0 |
| M67-1 F4A | No Block | 20K | 10 | | | | | 10 | 8 | 8.0 |
| M67-2 F4A | No Block | 20K | 10 | | | | | 13 | 8 | 8.0 |
| M67-1 B2A | Al Block | 20K | 10 | | | | | 120 | 10 | 10.0 |
| M67-2 B3A | Al Block | 20K | 10 | | | | | 85 | 10 | 10.0 |
| B4 | Al Block | 9K | 7 | | | | | 36 | 10 | 7.0 |
| B5 | Al Block | 9K | 7 | | | | | 44 | 10 | 7.0 |
| B6 | Al Block | 9K | 7 | | | | | 107 | 10 | 7.0 |
| BB2 | Al Block | 20K | 10 | | | | | 8 | 7 | 7.0 |
| BB3 | Al Block | 20K | 10 | | | | | 34 | 10 | 10.0 |
| SS4A | No Block | 7.5K | 6 | | | | | 35 | 10 | 6.0 |
| SS5A | No Block | 7.5K | 6 | | | | | 40 | 10 | 6.0 |
| SS6A | No Block | 7.5K | 6 | | | | | 23 | 9 | 5.4 |
| AS1 | No Block | 15K | 9 | | | | | 35 | 10 | 9.0 |
| 3T3 | No Block | 15K | 9 | | | | | 41 | 10 | 9.0 |
| 1C4 | No Block | 15K | 9 | | | | | 18 | 8 | 7.2 |
| MC4 | No Block | 20K | 10 | | | | | 25 | 9 | 9.0 |

QUALITY RATING FOR SECTION

IV.B.4

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| B3 | Al Block | 8K | 6 | ------------- | 10 | -------- | 10 | 80 | 10 | 6.0 |
| F4 | No Block | 8K | 6 | | | | | 160 | 10 | 6.0 |
| F4A | No Block | 20K | 10 | | | | | 66 | 10 | 10.0 |
| B1A | Al Block | 20K | 10 | | | | | 67 | 10 | 10.0 |
| B2A | Al Block | 20K | 10 | | | | | 53 | 10 | 10.0 |
| B3A | Al Block | 20K | 10 | | | | | 38 | 10 | 10.0 |
| BB1 | Al Block | 20K | 10 | | | | | 30 | 10 | 10.0 |
| BB2 | Al Block | 20K | 10 | | | | | 21 | 9 | 9.0 |
| BB3 | Al Block | 20K | 10 | | | | | 18 | 9 | 9.0 |
| SS4A | No Block | 7.5K | 6 | | | | | 9 | 8 | 4.8 |
| SS5A | No Block | 7.5K | 6 | | | | | 13 | 8 | 4.8 |
| SS6A | No Block | 7.5K | 6 | | | | | 13 | 8 | 4.8 |
| 1C4 | No Block | 15K | 9 | | | | | 16 | 8 | 7.2 |
| 3T3 | No Block | 15K | 9 | | | | | 40 | 10 | 9.0 |
| MCV1 | No Block | 20K | 10 | | | | | 113 | 10 | 10.0 |
| MCV4 | No Block | 20K | 10 | | | | | 120 | 10 | 10.0 |
| MC4 | No Block | 20K | 10 | | | | | 169 | 10 | 10.0 |

QUALITY RATING FOR SECTION

IV.B.5

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| B3 | Al Block | 8K | 6 | ---------- | 10 | ---------- | 10 | 64 | 10 | 6.0 |
| F4 | No Block | 8K | 6 | | | | | 96 | 10 | 6.0 |
| F3 | No Block | 20K | 10 | | | | | -- | 10 | 10.0 |
| F4A | No Block | 20K | 10 | | | | | 40 | 10 | 10.0 |
| B2A | Al Block | 20K | 10 | | | | | 82 | 10 | 10.0 |
| B3A | Al Block | 20K | 10 | | | | | 56 | 10 | 10.0 |
| BB1 | Al Block | 20K | 10 | | | | | 28 | 9 | 9.0 |
| BB2 | Al. Block | 20K | 10 | | | | | 14 | 8 | 8.0 |
| BB3 | Al Block | 20K | 10 | | | | | 20 | 9 | 9.0 |
| SS4A | No Block | 7.5K | 6 | | | | | 7 | 6 | 3.6 |
| SS5A | No Block | 7.5K | 6 | | | | | 5 | 4 | 2.4 |
| SS6A | No Block | 7.5K | 6 | | | | | 8 | 7 | 4.2 |
| 1C4 | No Block | 15K | 9 | | | | | 11 | 8 | 7.2 |
| 3T3 | No Block | 15K | 9 | | | | | 30 | 10 | 9.0 |
| MCV1 | No Block | 20K | 10 | | | | | -- | 10 | 10.0 |
| MCV4 | No Block | 20K | 10 | | | | | -- | 10 | 10.0 |

QUALITY RATING FOR SECTION

IV.B.6

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| B3 | Al Block | 8K | 6 | ------------ | 10 | ---------- | 10 | 100 | 10 | 6.0 |
| F4 | No Block | 8K | 6 | | | | | 190 | 10 | 6.0 |
| M67-1 F1 | No Block | 20K | 10 | | | | | -- | 10 | 10.0 |
| M67-2 F1 | No Block | 20K | 10 | | | | | 70 | 10 | 10.0 |
| M67-1 F3 | No Block | 20K | 10 | | | | | 23 | 9 | 9.0 |
| M67-2 F3 | No Block | 20K | 10 | | | | | 26 | 9 | 9.0 |
| B4 | Al Block | 9K | 7 | | | | | -- | 10 | 7.0 |
| 3T3 | No Block | 15K | 9 | | | | | 19 | 9 | 8.1 |
| B5 | Al Block | 9K | 7 | | | | | -- | 10 | 7.0 |
| B6 | Al Block | 9K | 7 | | | | | -- | 10 | 7.0 |
| SS4A | No Block | 7.5K | 6 | | | | | 36 | 10 | 6.0 |
| SS5A | No Block | 7.5K | 6 | | | | | 34 | 10 | 6.0 |
| SS6A | No Block | 7.5K | 6 | | | | | 21 | 9 | 5.4 |
| AS2 | No Block | 15K | 9 | | | | | -- | 10 | 9.0 |
| F4A | No Block | 20K | 10 | | | | | 13 | 8 | 8.0 |

QUALITY RATING FOR SECTION

IV.B.7

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| B3 | Al Block | 8K | 6 | -------------- | 10 | -------- | 10 | 28 | 9 | 5.4 |
| F4 | No Block | 8K | 6 | | | | | 100 | 10 | 6.0 |
| F1 | No Block | 20K | 10 | | | | | 38 | 10 | 10.0 |
| F3 | No Block | 20K | 10 | | | | | 47 | 10 | 10.0 |
| F4A | No Block | 20K | 10 | | | | | 102 | 10 | 10.0 |
| B1A | Al Block | 20K | 10 | | | | | 15 | 8 | 8.0 |
| B2A | Al Block | 20K | 10 | | | | | 18 | 8 | 8.0 |
| B3A | Al Block | 20K | 10 | | | | | 20 | 9 | 9.0 |
| BB1 | Al Block | 20K | 10 | | | | | 32 | 10 | 10.0 |
| BB2 | Al Block | 20K | 10 | | | | | 23 | 9 | 9.0 |
| BB3 | Al Block | 20K | 10 | | | | | 20 | 9 | 9.0 |
| AS2 | No Block | 20K | 10 | | | | | 6 | 5 | 5 |
| 1C4 | No Block | 15K | 9 | | | | | -- | 5* | 4.5* |
| 3T3 | No Block | 15K | 9 | | | | | 14 | 8 | 7.2 |
| MCV1 | No Block | 20K | 10 | | | | | 80 | 10 | 10.0 |
| MCV4 | No Block | 20K | 10 | | | | | 18 | 9 | 9.0 |
| MC4 | No Block | 20K | 10 | | | | | 18 | 9 | 9.0 |

QUALITY RATING FOR SECTION

IV.C.1

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| CY490 SD-2 | | 500 | 0.5 | ------------ | 10 | --------- | 10 | 1.5 | 0 | 0 |
| CY500 SD-2 | | 1000 | 1 | | | | | 6 | 5 | 0.5 |
| CY510 SD-2 | | 1000 | 1 | | | | | 8 | 7 | 0.7 |
| CY520 SC-1 SD-2 SC-3 SC-4 | | 1000 | 1 | | | | | 25 | 9 | 0.9 |
| CY530 SC-1 SD-2 | | 1000 | 1 | | | | | 30 | 10 | 1 |
| CA7720 SC-5 SC-6 SC-7 | | 2000 | 2 | | | | | 26 | 9 | 1.8 |
| CA7730 SC-5 SC-6 SC-7 | | 2000 | 2 | | | | | 33 | 10 | 2 |

QUALITY RATING FOR SECTION
IV.C.2

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| CY520 SC-1 SD-2 SC-3 SC-4 | | 1000 | 1 | --------------- | 10 | ---------- | 10 | 4 | 3 | 0.3 |
| CY540 SD-2 | | 1000 | 1 | | | | | 5 | 4 | 0.4 |
| CA7720 SC-5 SC-6 SC-7 | | 2000 | 2 | | | | | 8 | 7 | 1.4 |
| CA7730 SC-5 SC-6 SC-7 | | 2000 | 2 | | | | | 21 | 9 | 1.8 |

QUALITY RATING FOR SECTION

IV.C.3

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| CY490 SD-2 | | 500 | 0.5 | ------------- | 10 | ---------- | 10 | 3 | 2 | 0.1 |
| CY500 SD-2 | | 1000 | 1 | | | | | 11 | 8 | 0.8 |
| CY510 SD-2 | | 1000 | 1 | | | | | 11 | 8 | 0.8 |
| CY520 SC-1 SD-2 SC-3 SC-4 | | 1000 | 1 | | | | | 24 | 9 | 0.9 |
| CY530 SD-2 | | 1000 | 1 | | | | | 33 | 10 | 1 |
| CA7720 SC-5 SC-6 SC-7 | | 2000 | 2 | | | | | 22 | 9 | 1.8 |
| CA7730 SC-5 SC-6 SC-7 | | 2000 | 2 | | | | | 16 | 8 | 1.6 |

QUALITY RATING FOR SECTION

IV.C.4

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| CY520 SC-1 SC-3 SC-4 | | 1000 | 1 | ---------------- | 10 | -------- | 10 | 26 | 9 | 0.9 |
| CY540 SC-1 | | 1000 | 1 | | | | | 30 | 10 | 1 |
| CA7720 SC-5 SC-6 SC-7 | | 2000 | 2 | | | | | 6 | 5 | 1 |
| CA7730 SC-5 SC-6 SC-7 | | 2000 | 2 | | | | | 34 | 10 | 2 |

QUALITY RATING FOR SECTION
IV.C.5

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| CA7720 SC-5 SC-6 SC-7 | | 2000 | 2 | Main Engine Cutoff --------------- | 10 | --------- | 10 | 4 | 3 | 0.6 |
| CA7720 SC-5 SC-6 SC-7 | | 2000 | 2 | Main Engine Cutoff | | | | 3 | 2 | 0.4 |
| CY540 SC-1 | | 1000 | 1 | Landing Gear Extension | | | | 25 | 9 | 0.9 |
| CY520 SC-1 SC-3 SC-4 | | 1000 | 1 | Landing Gear Extension | | | | 28 | 9 | 0.9 |
| CA7720 SC-5 SC-6 | | 2000 | 2 | Landing Gear Extension | | | | 44 | 10 | 2 |
| CA7730 SC-5 SC-6 | | 2000 | 2 | Landing Gear Extension | | | | 36 | 10 | 2 |
| CY520 SC-1 SC-3 | | 1000 | 1 | Landing Gear Lock | | | | 13 | 8 | 0.8 |

QUALITY RATING FOR SECTION

IV.C.5

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| CA7720 SC-5 SC-6 | | 2000 | 2 | Landing Gear Lock ------------- | 10 | --------- | 10 | 6 | 5 | 1 |
| CA7730 SC-5 SC-6 | | 2000 | 2 | Landing Gear Lock | 10 | | 10 | 17 | 8 | 1.6 |

QUALITY RATING FOR SECTION
V.1

| Meas'm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| I-13 | | 10-1000 | 1 | -------------- | 10 | --------- | 10 | ----------- | 5* | 0.5 |
| I-17 | | | | | | | | | | |
| I-18 | | | | | | | | | | |
| II-12 | | | | | | | | | | |
| II-13 | | | | | | | | | | |
| II-17 | | | | | | | | | | |
| II-18 | | | | | | | | | | |

QUALITY RATING FOR SECTION
V.2

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| FM3-11 | | 0-50 | .5 | * | | --------- | 10 | 4 | 3 | 0.15 |
| FM3-12 | | 0-50 | .5 | * | | | | 2 | 1 | 0.05 |
| FM3-13 | | 0-40 | .5 | ** | | | | 3 | 2 | 0.1 |
| FM3-14 | | 0-50 | .5 | * | | | | 3 | 2 | 0.1 |
| FM3-15 | | 0-50 | .5 | * | | | | 7 | 5 | 0.25 |
| FM3-14 | | 0-50 | .5 | * | | | | 20 | 9 | 0.45 |
| FM3-15 | | 0-50 | .5 | * | | | | 30 | 10 | 0.5 |

* Statham strain gage model - A404TC-2

** CEC - strain gage model - 4-290-0001

QUALITY RATING FOR SECTION

V.3

| Measm't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| FM3-11 | Al Block | 30-550 | .5 | ------ | 10 | --------- | 10 | 50 | 10 | .5 |
| FM3-12 | | 30-800 | .8 | | | | | 30 | 10 | .8 |
| FM3-14 | | 30-1700 | 1.7 | | | | | 50 | 10 | 1.7 |
| FM3-15 | | 30-2500 | 2 | | | | | 60 | 10 | 2 |
| FM3-16 | | 30-5000 | 4 | | | | | 55 | 10 | 4 |
| FM3-17 | | 30-5000 | 4 | | | | | 30 | 10 | 4 |
| FM3-11 | | 630 | .6 | | | | | 25 | 9 | 5.4 |
| FM3-12 | | 800 | .8 | | | | | 30 | 10 | .8 |
| FM3-14 | | 1600 | 1.6 | | | | | 30 | 10 | 1.6 |
| FM3-15 | | 2500 | 2 | | | | | 45 | 10 | 2 |
| FM3-16 | | 5000 | 4 | | | | | 30 | 10 | 4 |
| FM3-17 | No Block | 5000 | 4 | | | | | 10 | 8 | 3.2 |

QUALITY RATING FOR SECTION

V.4

| Measn't Number | Instl. Description | System Freq. Resp. (Hz) | $R_1$ | Accelerometer Description | $R_2$ | Anomalies | $R_3$ | Signal/ Noise Ratio | $R_4$ | $R_T$ |
|---|---|---|---|---|---|---|---|---|---|---|
| FM3-10 | Al Block | 550 | .5 | End. 2223 | 10 | ------- | 10 | 36 | 10 | .5 |
| FM3-11 | | 550 | .5 | End. 2223 | 10 | | | 7 | 6 | .3 |
| FM3-12 | | 800 | .8 | End. 2223 | 4 | | | 25 | 9 | .28 |
| FM3-13 | | 1000 | 1 | End. 2223 | 4 | | | 36 | 10 | .4 |
| FM3-A | No Block | 2000 | 2 | End. 2223 | 1 | | | 8 | 7 | .14 |
| FM3-10 | Al Clock | 550 | .5 | End. 2223 | 10 | | | 30 | 10 | .5 |
| FM3-11 | | 550 | .5 | End. 2223 | 8 | | | 40 | 10 | .4 |
| FM3-12 | | 800 | .8 | End. 2223 | 8 | | | 38 | 10 | .64 |
| FM3-13 | | 1000 | 1 | End. 2223 | 8 | | | 32 | 10 | .8 |
| FM3-A | No Block | 2000 | 2 | End. 2223 | 1 | | | 42 | 10 | .2 |

END

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