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23 May 1975

TECHNICAL EVALUATION DEPARTMENT

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ANALYSIS OF FLIGHT DATA FOR DEEPWELL SYSTEM

INSTALLED IN EP-3E AIRCRAFT

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NAVAL AVIONICS FACILITY

INDIANAPOLIS, INDIANA 46218

ESL-169
23 May 1975

Environmental Sciences Branch
Test Report

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ANALYSIS OF FLIGHT DATA FOR DEEPWELL SYSTEM INSTALLED IN EP-3E AIRCRAFT

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PREFACE

Naval Avionics Facility, Indianapolis (NAFI) was contacted by NAVAIR regarding the acquisition of flight data for two components, Tape Recorder RD-375/ALR-60 and Magnetic Drum Memory, MU-600/ALR-60, of the Deepwell System installed in the EP-3E Aircraft. It was suspected that failures, which were occurring during shipment and in-flight operation, were the result of a vibration and/or shock environment. The Environmental Sciences Branch 443 was requested by the NAFI Program Manager D/905 to acquire the necessary data during Flight Tests at NAS Fallon, Nevada during the period of 11 through 15 November 1974.

The data were obtained for analysis during the Flight Tests of the Deepwell System installed in EP-3E Aircraft G6 (Bureau No. 150505) to determine magnitudes of the vibration and/or shock responses and also the flight conditions that resulted in the most severe responses. The results obtained from the data analysis will be used to suggest possible corrective actions relative to the failures being incurred by the components.

In conjunction with the acquisition of the vibration and/or shock data, the Environmental Sciences Branch 443 was also requested by the NAVAIR representative for the Deepwell Program at NAS Moffett Field, to measure acoustic noise levels at the Secure Communications Station, Position 18. Since the equipment for measuring the acoustic noise levels was available, acoustic noise level measurements were obtained at various locations throughout the interior of the aircraft in addition to the requested location.

Analysis of the flight data was performed during the interim of November 1974 to April 1975. This analysis was interrupted two separate times for the purpose of acquiring additional vibration data in the laboratory for the Deepwell and ARIES Programs and three separate times for the purpose of analyzing data and preparing reports relative to the two programs. The additional vibration data were obtained during special laboratory evaluations of the Tape Recorder, RD-375/ALR-60 (refer to Environmental Sciences Branch 443 Report ESL-157 dated 14 March 1975) and the ARIES Lower Rotary Joint Assembly (refer to Environmental Sciences Branch 443 Report ESL-162 dated 31 March 1975). The third report concerns the Analysis of the Vibration Environment for ARIES installed on EP-3E Aircraft (refer to Environmental Sciences Branch 443 Report ESL-163 dated 11 April 1975).

This report describes the data acquisition methods, data analysis procedures, results obtained from the analysis of the flight data, the comparison of the Flight Test results with the data obtained for the

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Tape Recorder during the special laboratory evaluation, and recommendations for corrective action to alleviate the present failures.

Funds for conducting the acquisition and analysis of the flight data were provided by NAFI Job Order 1652-1.

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I. CONCLUSIONS

1. The mechanical damages being incurred by the Tape Recorder, RD-375/ALR-60, during flight operation and shipment are primarily the result of the transport "banging" into both the case and front cover of Tape Recorder. This "banging" is attributed to the "softness" of the internal isolators that support the transport and their inability to restrain the deflection of the transport within the allotted space when the Tape Recorder experiences the low frequency vibration and the rather low level shock environment encountered during the flight operations. Although not measured, it is the opinion that the shock environment encountered during shipment would be even more severe than that experienced in field service.

2. From the special laboratory evaluation of the Tape Recorder, reported in Environmental Sciences Branch 443 Report ESL-157 dated 14 March 1975, it was concluded that either the Tape Recorder was not qualified to the applicable vibration specification or the production units do not reflect the design of the unit qualified. Analysis of the flight data supports this conclusion and suggests the same may be true for the applicable shock requirement.

3. Analysis of the data obtained for both the Tape Recorder, RD-375/ALR-60, and Magnetic Drum Memory, MU-600/ALR-60, indicate the following.

a. The "softness" of the internal isolators that support the Recorder transport results in the transport experiencing resonance frequencies at both 8 and 17 Hz, with the 8 Hz resonance being the most severe.

b. The sinusoidal and random responses transmitted from the aircraft to the transport are generally attenuated by the isolator system of the transport above 200 Hz.

c. Although it is reported that failures of the Magnetic Drum Memory are occurring during flight, the vibration, both sinusoidal and random, transmitted from the aircraft to the Magnetic Drum Memory and the resultant responses of the Magnetic Drum Memory do not appear to be of sufficient magnitude to cause either mechanical damage or electrical malfunctions. However, it is possible that the Magnetic Drum Memory is particularly susceptible to this vibration. Moreover, the 30 Hz vibration that occurs as a result of the rotation of the Drum could contribute to possible problems, particularly since this results in significant vibration responses being experienced by the Drum Memory. This could also explain a reported instance of the Magnetic Drum Memory failing while operating not mounted in the aircraft.

4. The acoustic noise levels measured at the Secure Communications Station of EP-3E Aircraft G-6 (Bureau No. 150505) are of sufficient amplitudes (92 and 95 dBA) to warrant further investigation of all the EP-3E Aircraft relative to the acoustic noise environment and compliance with the requirements of the Occupational Safety and Health Act (OSHA) of 1970. OSHA requirements state that at the above mentioned acoustic noise levels, personnel can not be exposed for more than 6 and 4 hours per an 8-hour period, respectively. Therefore, since a normal mission is 8-12 hours and in some instances may be longer, personnel situated in the Secure Communications Station are subjected to acoustic noise levels, provided no protective equipment is supplied, for a period of time which exceeds the OSHA requirements.

II. RECOMMENDATIONS

1. Since the Tape Recorder RD-375/ALR-60 is incurring mechanical damage, that has been attributed to the "softness" of the internal isolators, during both field operations and shipment, it is recommended that either the internal isolators, which support the transport in the case, be replaced by a "stiffer" isolation system (one with a higher resonant frequency), and/or a method be implemented to restrain the movement of the transport, either by snubbing or "locking out" the internal isolators, during shipment and during take-off and landing. It should be noted that any effort to resolve the problems attributed to the "softness" of the internal isolators may result in uncovering other problems currently masked by the isolator problem. In particular, as pointed out in the report of the special laboratory evaluation of the Tape Recorder, the Card Cage Assembly may need some modification if the isolator resonant frequency is increased substantially.

2. Inasmuch as initial qualification of the Tape Recorder to the applicable environmental requirements is very vague, it is suggested that prior to any modification effort, a production unit be subjected to the recommended vibration and shock exposures detailed in this report to identify the problem areas and provide a basis from which to begin the modification. Then, after the modification, it is recommended that the modified Tape Recorder be subjected to the vibration and shock requirements detailed in this report to verify the adequacy of the modifications.

3. Since there is a considerable amount of self-induced vibration on the Magnetic Drum Memory, which is unrelated to the in-flight environment, it is recommended that this self-induced vibration be investigated as a possible cause for the failures that are being experienced by the unit. In addition, it is suggested that the

Magnetic Drum Memory be investigated for susceptibility to in-flight vibration and shock environments, even though these levels are extremely low. This investigation could be performed by subjecting the Magnetic Drum Memory to the requirements specified in this report.

4. Since the acoustic noise levels measured at the Secure Communications Station are of sufficient magnitude to limit exposure to a 4-hour period and since these levels were measured during in-flight operation and excluded take-off and landing, for which the levels would probably increase, it is recommended that protective equipment be provided for personnel assigned to that station. In addition, it is suggested that acoustic noise levels be measured during all flight conditions for a complete mission to insure that personnel assigned to other stations aboard the EP-3E Aircraft are not being exposed to excessive acoustic noise levels.

III. BACKGROUND INFORMATION

Failures, encountered during both shipment and in-flight operation, have occurred in the past and are presently occurring to the Tape Recorders, RD-375/ALR-60, herein referred to as Recorder, located at Stations 10-14 of the Deepwell System. Also, failures have occurred to the Magnetic Drum Memory, MU-600/ALR-60, herein referred to as Drum Memory, located at Station 11 of the Deepwell System. These continuing failures resulted in the Environmental Sciences Branch 443 being requested to acquire data during Flight Tests at NAS Fallon, Nevada.

Subsequent to the acquisition of data during Flight Tests for the components mentioned above, a special evaluation was performed in the laboratory on the Recorder. The results of that evaluation are detailed in Environmental Sciences Branch 443 Report ESL-157 dated 14 March 1975. This special evaluation revealed that the tape transport experienced excessive movement due to the "softness" of the internal isolators and this excessive movement combined with insufficient clearance between the tape transport and case results in the tape transport impacting with both the front panel and back of the case. Thus, the failures are occurring as a result of those impacts which also cause some degree of mechanical degradation.

Also, it was concluded that the Recorder was not originally qualified to the correct vibration specification or the production units do not reflect the design of the unit qualified. The manufacturer's spec sheet for the Recorder specifies that the Recorder is qualified to the vibration requirements of MIL-E-5400, Curve II (0.01 inch D.A. from 5 to 63 Hz and 2g from 63 to 500 Hz). This implies the Recorder must be mounted on external isolators when used in a field application, which is the case when the Recorder is mounted in the aircraft. However, when external isolators are added, the applicable vibration requirement becomes Curve I of MIL-E-5400 (0.08 inch D.A. from 5 to 10 Hz, 0.42g from 10 to 15 Hz, 0.036 inch D.A. from 15 to 74 Hz, and 10g from 74 to 500 Hz) and not Curve II, unless some relaxation is provided by the procuring activity.

Thus, the low frequency vibration input is increased by 3.6 to 8 times. Since the lowest isolator resonance is 8-10 Hz, this results in the tape transport colliding with the case because the clearance between the tape transport and case is less than the input displacement. Consequently, if the appropriate vibration requirement was imposed, the problems being encountered with the mechanical damage of the Recorder should have been discovered and corrective action implemented during the qualification effort. Apparently, this did not occur; therefore, it is assumed that either the Recorder was

incorrectly qualified in regards to the vibration requirement or the production units do not reflect the design of the qualified unit.

Also, the manufacturer's spec sheet does not list any requirement relative to the shock environment. Thus, it is questionable if the Recorder was ever subjected to a Shock Test. Again, if the Recorder was exposured to the applicable shock environment, many of the problems being experienced in the field should have been uncovered in the qualification effort or the production units do not reflect the design of the qualified unit.

IV. DISCUSSION

A. TEST DESCRIPTION

Environmental data - vibration, shock, and acoustic noise, were obtained during Flight Tests for the Deepwell System installed in EP-3E Aircraft G-6 (Bureau No. 150505) at NAS Fallon, Nevada during the period of 11-15 November 1974. These Flight Tests were performed in conjunction with the calibration runs for the Deepwell System. The vibration and/or shock data were acquired during two different flights for the flight conditions of take-off (when possible), flying on the calibration runs, and landing (when possible). Also, acoustic noise levels were obtained during the second flight at various locations of the aircraft interior.

B. DATA ACQUISITION

Instrumentation provided to acquire the vibration and/or shock data for the Recorders, located at Stations 10-14, and Drum Memory, located at Station 11 of the Deepwell System, (refer to Figures I and II of APPENDIX A for the general location) during the Flight Tests included: (a) 13 triaxial accelerometers, with the response of only six accelerometers recorded simultaneously; (b) six charge amplifiers, located at Position 28, operating on 115 V.A.C., 60 Hz power from the aircraft electrical system; and (c) two portable instrumentation recorders, location at Position 28, operating on 115 V.A.C., 60 Hz power from the aircraft electrical system, with each recorder having three FM channels for recording data and one direct channel for voice. The mounting locations and monitoring axes for the triaxial accelerometers are illustrated in Figures II and III of APPENDIX A.

In addition to the instrumentation equipment previously described, a General Radio Precision Sound-Level Meter and Analyzer, Type 1933, with an 1/2-inch microphone having a flat random-incidence response was utilized to support the acquisition of the requested acoustic noise data. The acoustic noise data were acquired only during high altitude flight and, although the main area of concern centered around the Secure Communications Station, Position 18, acoustic noise data were also acquired at several locations throughout the interior of the aircraft.

C. DATA ANALYSIS

1. Procedure

Analysis of the data obtained during Flight Tests for the Deepwell Program required the usage of six different analysis techniques. These different techniques were necessary to insure

that a thorough analysis of the acquired data was performed. A brief description for each of the analysis techniques is detailed below.

a. Averaged Time History - This type of analysis provides an overall view of broadband acceleration levels as a function of time, thus assuring that the portion of data selected for the remaining analysis exhibits the most significant response levels. To perform this type of analysis for the data acquired from the Deepwell Flight Tests, approximately 100 graphs were obtained. A typical Averaged Time History Analysis is illustrated in Figure I of APPENDIX B.

b. Time Domain Analysis - This type of analysis allows for an analysis of short, selected samples of data, based on the results of the Averaged Time History Analysis and provides an output of instantaneous levels which is a representation of the actual selected data. Because of the nature of the response data, this analysis was only performed to illustrate certain characteristics of the data, thus a small number of graphs were obtained. Typical Time Domain Analyses are illustrated in Figures II and III of APPENDIX B.

c. Frequency Domain Analysis - This type of analysis provides a power spectral density (PSD) of selected portions of data. This technique allows assessing the frequency dependence of the measured responses. It provides a method of observing the amplitudes and frequencies of any responses present. Frequency Domain Analysis was accomplished using a 1.6 Hz filter and 2 to 32 averages (corresponding to statistical degrees of freedom of 4 to 64, respectively) depending on the flight condition over the frequency range of 1.6 to 200 Hz. Also to observe responses above 200 Hz, a 16 Hz filter and 2 to 32 averages were used over the frequency range of 16 to 2000 Hz. Approximately 180 graphs were obtained to perform this analysis. A typical Frequency Domain Analysis is illustrated in Figure IV of APPENDIX B.

d. Transfer Function Analysis - This type of analysis requires two responses (one response is used as an input and the second response as an output) for providing a result which displays the relationship of the output response with respect to the input response. A Coherence Function is used in conjunction with the Transfer Function. The Coherence Function establishes the validity of the resultant Transfer Function. That is, since the optimum Coherence between two responses is one, any deviation from one would indicate that the accuracy of the Transfer Function is less, thus indicating that possibly the two responses are being excited by separate sources. However, some discretion is necessary in interpreting the Coherence Function results. Approximately 150 Transfer and Coherence Function graphs were obtained for this analysis. Typical Transfer and Coherence Functions are illustrated in Figures V and VI, respectively, of APPENDIX B.

e. Histogram Analysis - This type of analysis was performed to determine the amplitude content of certain responses. That is, to determine whether certain responses, as observed during the previous analysis techniques, were the result of a sinusoidal or random type of vibration. As can be seen in the typical Histogram Analysis, illustrated in Figure VII of APPENDIX B, both types of responses are present. Approximately 40 Histograms were obtained for the purpose of establishing the presence of sinusoidal components.

As can be seen from the above discussion, analysis of the data was complex and required the acquisition of approximately 450 graphs to perform the required analysis of the flight data. Since the number of acquired graphs is large, all of the graphs are not included in this report. Only those graphs which help to explain the flight environment and were necessary to support the discussion, herein, are included.

2. Results

a. General - The analysis of the data obtained during the Flight Tests indicates that the most significant information occurs

below 200 Hz, thus the discussion presented herein, concentrates on that data only with occasional comments regarding data above 200 Hz. The analysis provided the following information relative to the Deepwell System and the Secure Communications Station.

(1) The predominate frequencies of the aircraft (68 and 136 Hz) are noticeable on the framework which supports the Deepwell equipment and on the equipment during certain flight conditions. However, in both cases the response levels are very low in magnitude.

(2) Take-off and landing are the most severe flight conditions for the Recorder. Take-off produces the maximum vibration levels for the Drum Memory; however, operation of the Drum Memory in non-flight conditions also produces significant vibration levels (refer to (6) below).

(3) The natural resonances of the internal isolators that support the Recorder transport are in the frequency range of 8 to 10 Hz. Also, responses at 17 Hz are present during certain flight conditions, although it could not be determined from the data whether the 17 Hz component was being generated by the aircraft or the Recorder transport[1].

(4) The most severe environment during the Flight Test appears to be a shock exposure that occurs as a result of runway roughness, pitch applied to props during take-off, in-flight turbulence, touchdown, and reverse pitch applied to props after touchdown. Although not measured as a part of this effort, it is anticipated that the shock exposure encountered during shipment is more severe than that encountered during flight operations. This shock exposure during shipment could be the result of improper packaging, excessive movement of the Recorder transport, and rough handling encountered in shipping.

(5) As a result of the softness of the internal isolators, the low frequency responses experienced by the case, and transmitted from the case to the transport, are amplified. An average of the flight data for the major resonance at 8 Hz and the secondary resonance at 17 Hz resulted in an amplification of 3.4, with the maximum amplification several times more severe than this.

(6) The Drum Memory, by operating at 1800 rpm, generates a 30 Hz resonance which results in an amplification of

[1] A special laboratory evaluation of the Recorder was performed subsequent to the acquisition of the flight data. During this evaluation, resonances were measured on the front panel of the Recorder transport in the 8 to 10 Hz frequency range and also at 17 Hz. The details of the evaluation are presented in Environmental Sciences Branch 443 Report ESL-157 dated 14 March 1975.

approximately 4.5 between the top of the isolators (location 11) and the top of the Drum Memory (location 12). Thus, a significant portion of the vibration experienced by the Drum Memory is not related to the flight environment, but instead is a result of the operation of the unit. This implies that the vibration experienced by the Drum Memory while operating in a non-flight status is nearly as severe as that encountered in flight. Consequently, failures of the Drum Memory are possibly unrelated to the in-flight vibration environment.

(7) The resonance conditions experienced by the Recorders are being predominantly excited by random responses and shocks as opposed to sinusoidal responses. That is, the responses that are exciting the resonance frequencies of the Recorders are not pure sinusoidal as was the case for the special laboratory evaluation reported in Environmental Sciences Branch Report ESL-157. Even though the input responses between flight operations and the special laboratory evaluation for the Recorder are different, the results are similar. That is, the acceleration responses when converted to equivalent displacement, especially for the flight conditions of take-off and landing, are consistent with those measured during the special laboratory evaluation.

(8) The acoustic noise levels measured at the Secure Communications Station are of sufficient magnitude to warrant concern.

The summary of results presented in the above discussion is of general nature with details of these results being discussed in the following paragraphs.

b. Vibration/Shock Environment

The Transfer Function, Coherence Function, and Frequency Domain Analysis, previously discussed, were utilized to perform the major part of the analysis. Although the Transfer Function provides a method of observing the relationship between two responses, because of the complex nature of the Recorder responses, especially those obtained from the Recorder transport, the Transfer Function may not be completely accurate. To provide a general idea of what is occurring during flight operations, Table I lists the maximum Transfer Functions which result in the most severe conditions that occur between the case of the Recorder and the front panel of the Recorder transport and between the top of the isolators for the Drum Memory and the top of the Drum Memory.

Table I

Transfer Functions Resulting in the Most Severe Vibration Conditions

Sta. No.	Axis	Freq. (Hz)	Case of Recorder and Front Panel of Recorder Transport Trans. Funct.	Case of Recorder and Front Panel of Recorder Transport Coherence	Top of Drum Memory Isolator and Top of Drum Memory Trans. Funct.	Top of Drum Memory Isolator and Top of Drum Memory Coherence
10	X	8	5.5	0.9	-	-
11	Z	30	-	-	1.5	0.98
12	X	8	3.0	0.85	-	-
14	X	8	3.6	0.7	-	-

The Transfer Functions listed in Table I represent the most severe condition as determined by an amount of equivalent displacement, which is estimated from the complex frequency spectrum (containing random and sinusoidal components) by assuming a pure sinusoid at the frequency of concern with the same RMS g level as calculated from the PSD. In the case of the Drum Memory, the calculated displacement is exact because the major 30 Hz resonance is a sinusoidal signal caused by the Drum rotation as previously discussed. It should be noted that although the Transfer Function of 1.5 obtained between Drum Memory Isolators and Drum Memory is not a maximum value (an amplification of 4.5 was previously discussed), the equivalent displacements are greater, thus creating a more severe condition.

As can be seen in Table I, the response measured on the Recorder transport contains an 8 Hz component, while the Drum Memory experiences the most severe condition at the self generated resonance of 30 Hz. A more complete view showing the relationship between the equipment frame (locations 1, 4, and 8), Recorder case (locations 2, 5, and 7) and Recorder transport (locations 3, 6, and 9) along with the relationship between the equipment frame (location 10), top of the Drum Memory isolators (location 11), and top of the Drum Memory (location 12) during all flight conditions is presented by the Tables of Transfer and Coherence Functions detailed in APPENDIX C (refer to APPENDIX A for definition of the location numbers).

These tables also include equivalent input displacements and, by applying the Transfer Function, providing a good Coherence Function was obtained, the resultant estimated displacement can be determined. For example, at Station 12 during the flight condition of landing, at touchdown, an equivalent displacement of 0.06 inch D.A. was obtained for the Recorder case. Applying the Transfer Function

(3.0) results in the Recorder transport experiencing an equivalent displacement of 0.18 inch D.A. This flight condition along with take-off resulted in equivalent displacements that were consistent with the displacements obtained during the special laboratory evaluation of the Recorder detailed in Environmental Sciences Branch 443 Report ESL-157.

However, the Transfer and Coherence Functions do not provide the complete analysis. As shown by the typical Time Domain Analysis graph detailed in Figure II of APPENDIX B, the results obtained during take-off are definitely caused by a shock environment. Figure II of APPENDIX B is an eight-second sample during take-off with a shock exposure being observed that approaches an instantaneous peak shock level of 6.5g. To observe that instantaneous shock peak more thoroughly, an expanded view is presented in Figure III of APPENDIX B. This expanded view was obtained from the eight-second sample and starts at 4.559 seconds and ends at 4.599 seconds, making the expanded view 40 milliseconds in duration. This view shows that the shock peak is approximately 4 milliseconds in duration and 6.5g in amplitude.

Another method to illustrate the relationship between the equipment frame, Recorder case, and Recorder transport, and also the relationship between the equipment frame, top of Drum Memory isolators, and top of the Drum Memory, is by composite graphs. The composite graphs are power spectral density (PSD) graphs obtained from the Frequency Domain Analysis. Each composite graph contains the responses for one axis, one location, all applicable flight conditions. Thus, the response for any one location for all flight conditions can be observed. In addition, by comparing composite graphs, it can be observed how different locations respond to the various flight conditions.

c. Acoustic Noise Environment

In conjunction with the previously discussed flight data acquisition, Mr. Jim Hurley, NAVAIR representative for the Deepwell Program at NAS Moffett Field, requested that acoustic noise levels be measured at the Secure Communications Station #18, to determine how the acoustic noise level/exposure time, measured at that location, compared with the acoustic noise level/exposure time requirements established by the Occupational Safety and Health Act (OSHA) of 1970. Acoustic noise level measurements were also obtained at other stations throughout the interior of the EP-3E Aircraft G6 (Bureau No. 150505). Table II details these locations and the acoustic noise level (A weighting) obtained. It should be noted that the levels detailed in Table II represent only the data which was obtained during the flight condition of flying at altitude. Therefore, it is suspected that during take-off and landing the levels would increase in amplitude.

Table II

Acoustic Noise Levels in EP-3E
Aircraft G6 (Bureau No. 150505)

Location of Measurement	Acoustic Noise Level (dBA)
Station #14	82
Station #10	83
Station #16	90
Station #5	87
Station #18 (Aft Equipment De-energized)	92
Station #18 (AN/APS-20 and All Equipment except Teletype Energized)	95

In addition to obtaining the A weighting acoustic noise levels of Table II, octave band analysis was performed for the same locations and conditions as indicated in Table II. This analysis indicates the major low frequency component is the 68 Hz signal generated by the aircraft engines, which results in a low frequency "throbbing" affect most noticeable in the forward area of the aircraft, but is also evident throughout the entire aircraft. The acoustic noise level for each of the center frequencies for the octave band analysis is available upon request.

The 95 dBA level measured at Station #18 includes not only the 68 Hz signal mentioned above, but also includes high frequency components in the 4 to 16 KHz range, which are generated by the blower fan when the AN/APS-20 is energized. It should be noted that the acoustic noise levels measured at Station #18 were obtained without the teletype energized. The levels could be expected to increase with the teletype in operation.

Inasmuch as the acoustic noise levels were obtained under set conditions and since the nature of an actual flight entails varying conditions, it is suggested that the acoustic noise levels can best be measured relative to an actual flight, with the varying conditions, by using a type of noise dosimeter, such as a General Radio Model 1944. This instrument would accumulate the total acoustic noise exposure that any individual is exposed to for the entire flight or it could be used to determine the acoustic noise exposure for a given location during an entire flight. NAFI has some of these units and associated equipment for readout and could assist NAVAIR in determining acoustic noise levels in the fleet.

D. RECOMMENDED VIBRATION AND SHOCK REQUIREMENTS

For assurance that equipment to be used in field operations will survive the field environment and provide satisfactory performance characteristics, it is necessary to subject the equipment to environmental exposures, that are representative of the field environment, during the qualification test effort. In many cases, the field environmental data are not available so the environmental exposures performed in the laboratory are obtained from specifications (such as MIL-E-5400, MIL-STD-810, etc.) which may or may not simulate the actual field environment. As discussed in the BACKGROUND INFORMATION, the Recorder has reportedly been qualified to a vibration requirement in accordance with MIL-E-5400, Curve II. In addition to the applicability of this requirement being questioned, it is unfortunate that this requirement does not adequately simulate the field environment, in particular the low frequency vibration. Thus, the simulated laboratory tests failed to uncover the design weaknesses. Also, qualification of the Recorder to a specific shock requirement is uncertain.

Therefore, to insure that the Recorders will function properly during field operation, vibration requirements, as well as shock requirements, are being proposed that reflect the actual field environment. These proposed requirements were obtained under flight conditions of take-off, in-flight, and landing. Because no turbulence was encountered during these Flight Tests, data were not obtained for this flight condition; however, it is anticipated that the vibration and shock environments encountered as a result of in-flight turbulence would not be more severe than those recorded for take-off or landing. These requirements were derived using the data obtained from the case of the Recorder; therefore, the Recorder is to be hard-mounted (without the external isolators) to verify compliance with the proposed requirements.

Inasmuch as the severity of the vibration environment experienced by the Recorder is dependent on the flight condition, with the most severe occurring during take-off and landing, and, coincidentally, satisfactory operation of the Recorder is not required during take-off and landing (it must just survive these exposures), two vibration test spectrums are proposed for the qualification of the Recorder. The first, detailed in APPENDIX E, Figure I, is applicable for simulating the vibration environment encountered during take-off and landing. For this exposure, the Recorder is not required to comply with any performance requirements during application of the vibration, but must operate satisfactorily after the exposure. This is based on the fact the Recorder need not be performing its required function during take-off and landing. The second, detailed in APPENDIX E, Figure II, is for simulating the in-flight vibration environment. For this exposure, the Recorder must comply with the applicable

performance requirements while the unit is being vibrated, since the Recorder must perform its assigned task during in-flight operation. The recommended test procedure for performing the vibration exposures is also included in APPENDIX E.

Since the Recorder is subjected to a shock environment during both field operation and shipment, a shock requirement is recommended to insure satisfactory operation when subjected to the shock exposure. The recommended shock requirement for qualification of the Recorder is in accordance with MIL-T-5422F, Paragraph 4.3.2.1.

Since the vibration and shock environments experienced by the Drum Memory during flight operations are rather mild, the requirements of MIL-E-5400, using Curve II for the vibration, should be sufficient for qualifying the Drum Memory with the external isolators removed.

Satisfactory results from exposure to the recommended vibration and shock requirements, under the conditions stated, should provide a high degree of assurance that the units will also operate satisfactorily during field service. However, any problems encountered by the Recorder during these simulated environments should not be taken lightly in that their probability of occurring during fleet operation would be very high.

APPENDIX A

Drawings Showing Aircraft Layout, Deepwell Stations and Accelerometer Locations

Figure I - Aircraft Layout

Figure II - Deepwell Stations Showing Accelerometer Locations and Axes

Figure III - Magnetic Drum Memory Located at Station 11, Showing Accelerometer Locations and Axes

Figure I - Aircraft Layout

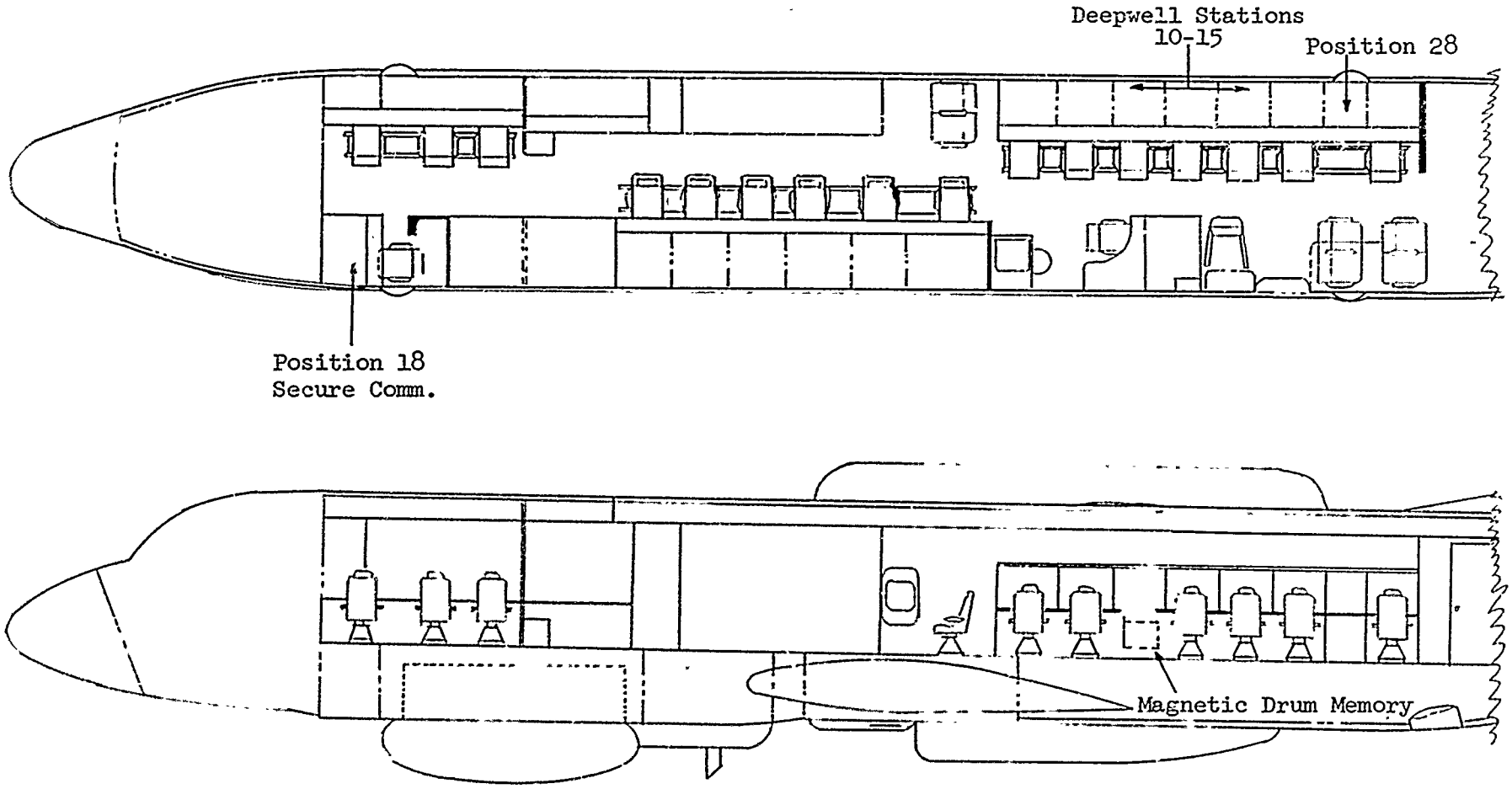
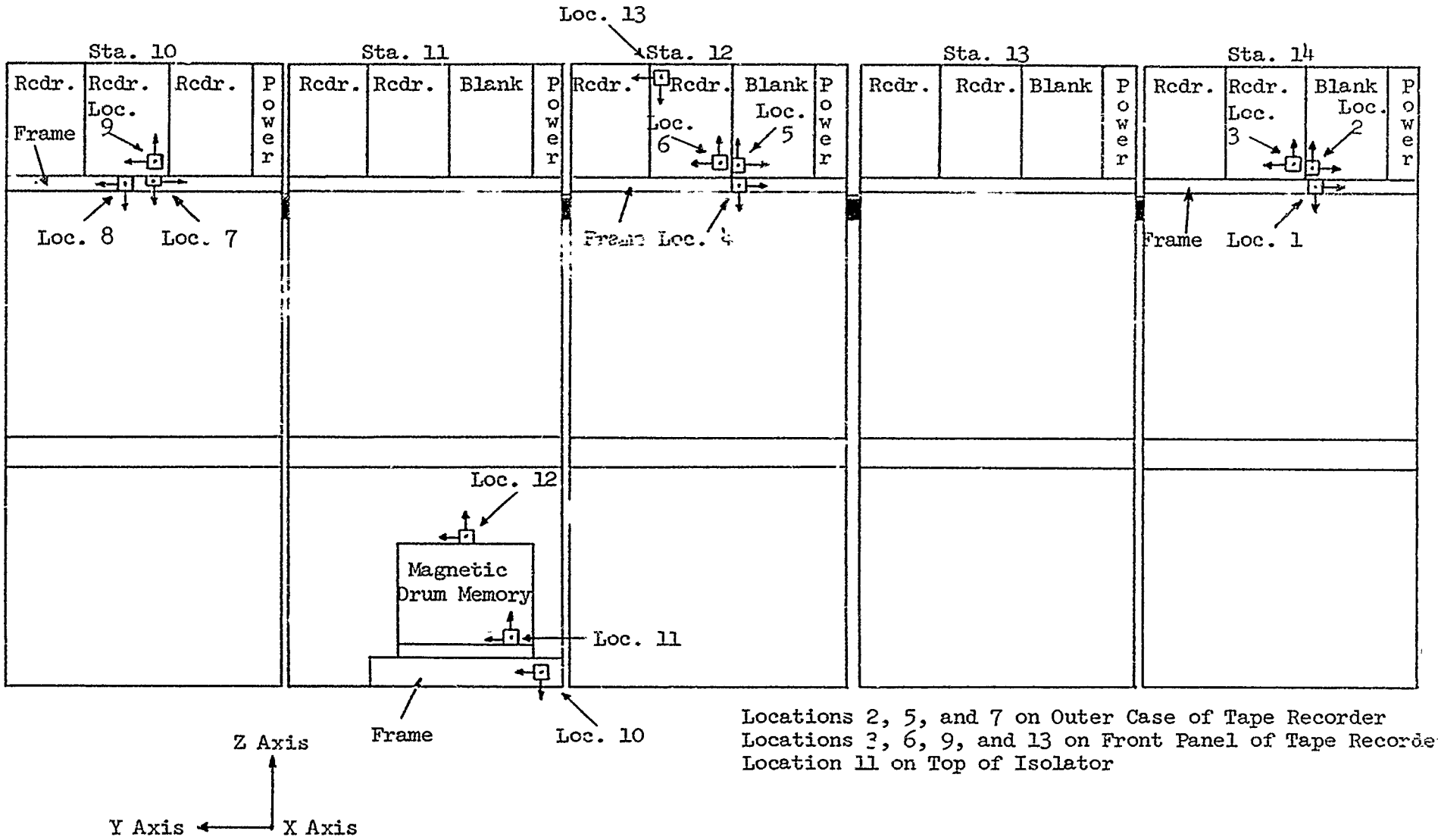
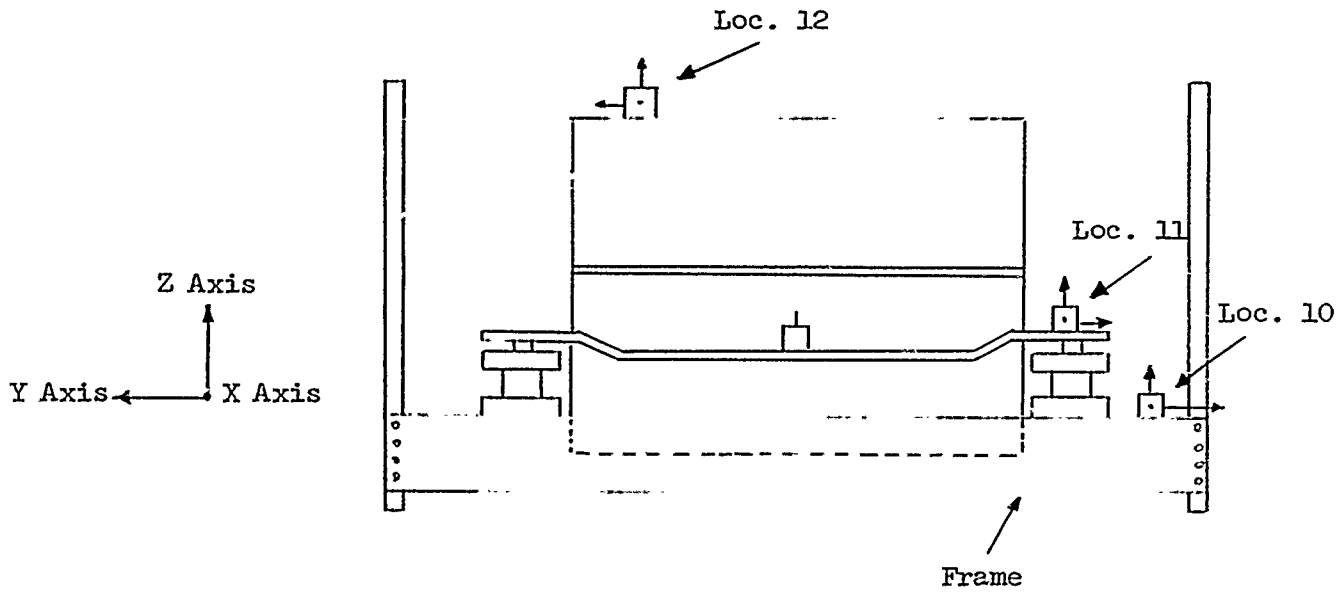


Figure II - Deepwell Stations Showing Accelerometer Locations and Axes



Locations 2, 5, and 7 on Outer Case of Tape Recorder
Locations 3, 6, 9, and 13 on Front Panel of Tape Recorder
Location 11 on Top of Isolator

Figure III - Magnetic Drum Memory Located at
Station 11 Showing Accelerometer Locations and Axes



APPENDIX B

Typical Analysis Graphs

Figure I - Typical Averaged Time History Analysis

Figure II - Typical Time Domain Analysis

Figure III - Typical Time Domain Analysis (Expanded)

Figure IV - Typical Frequency Domain Analysis

Figure V - Typical Transfer Function Analysis

Figure VI - Typical Coherence Function Analysis

Figure VII - Typical Histogram Analysis

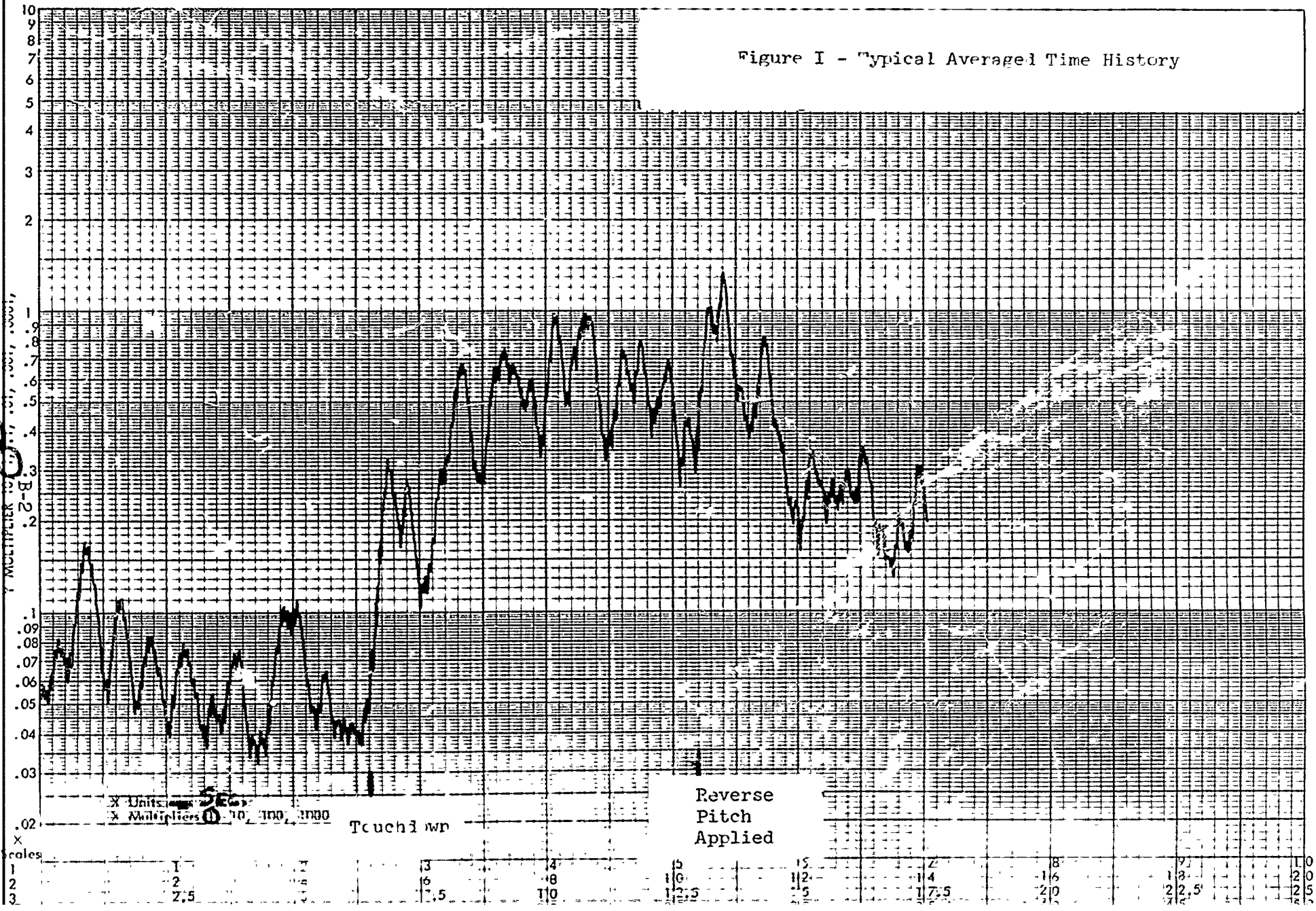


Figure I - Typical Averaged Time History

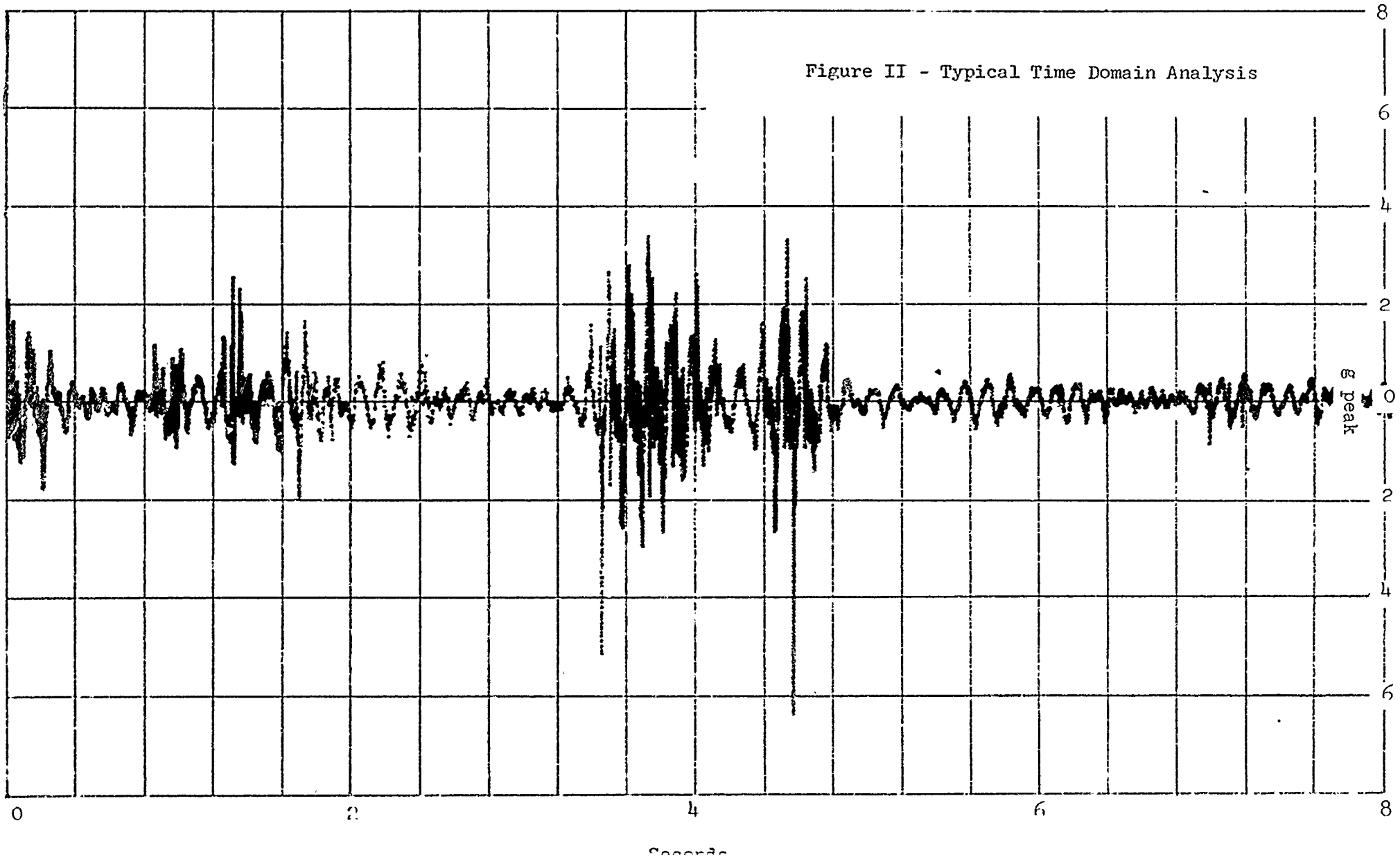


Figure II - Typical Time Domain Analysis

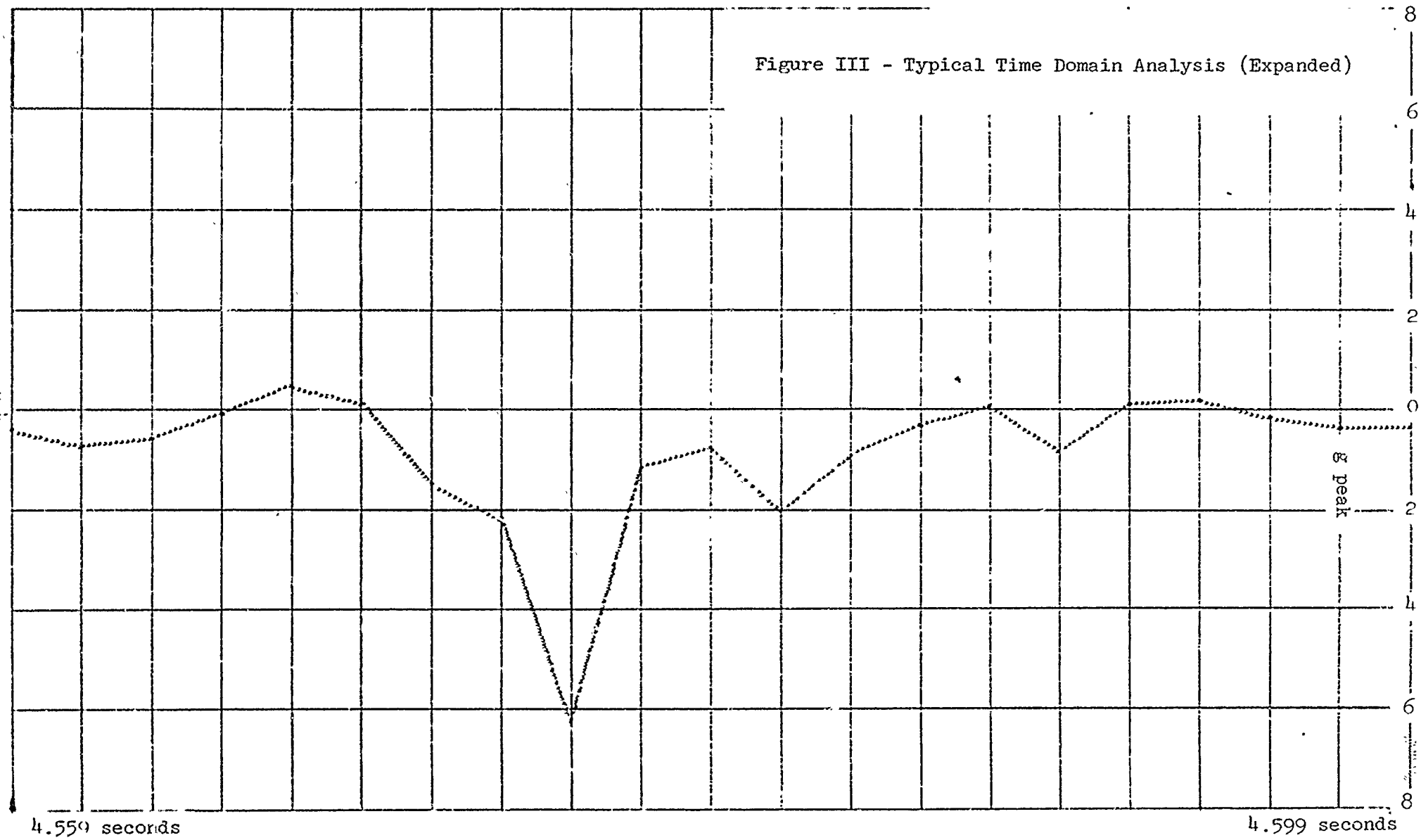
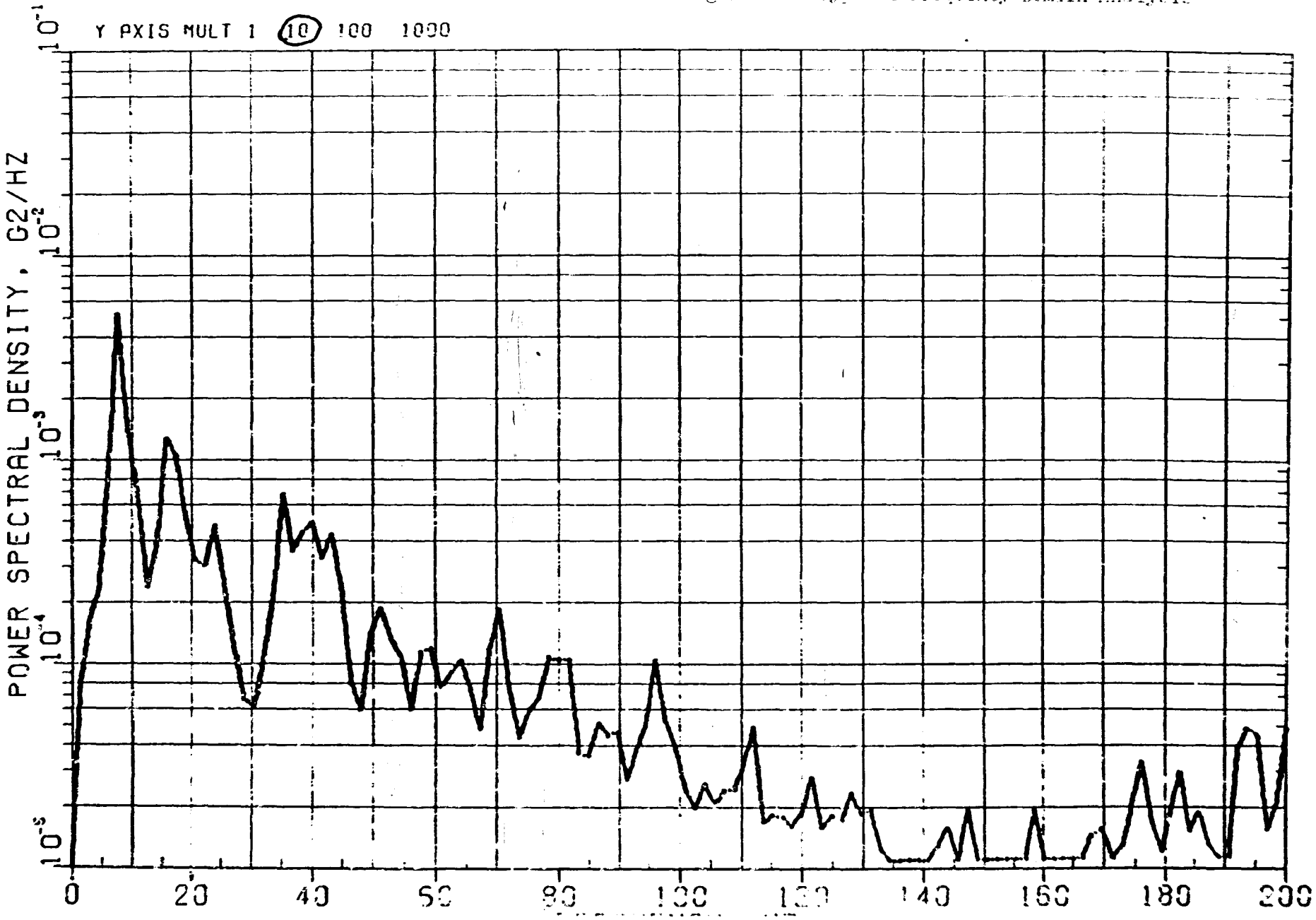


Figure III - Typical Time Domain Analysis (Expanded)

Figure IV - Typical Frequency Domain Analysis



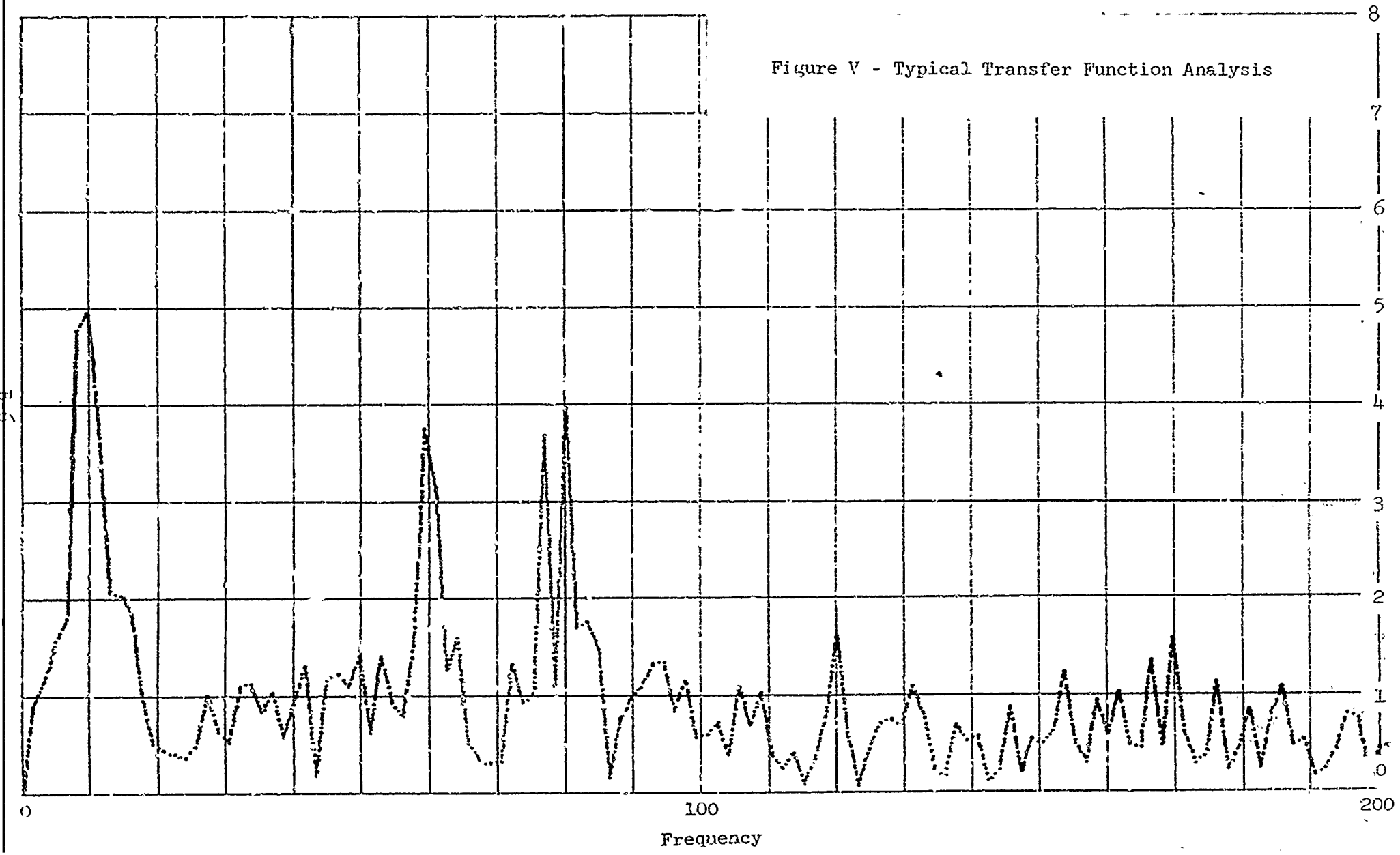


Figure V - Typical Transfer Function Analysis

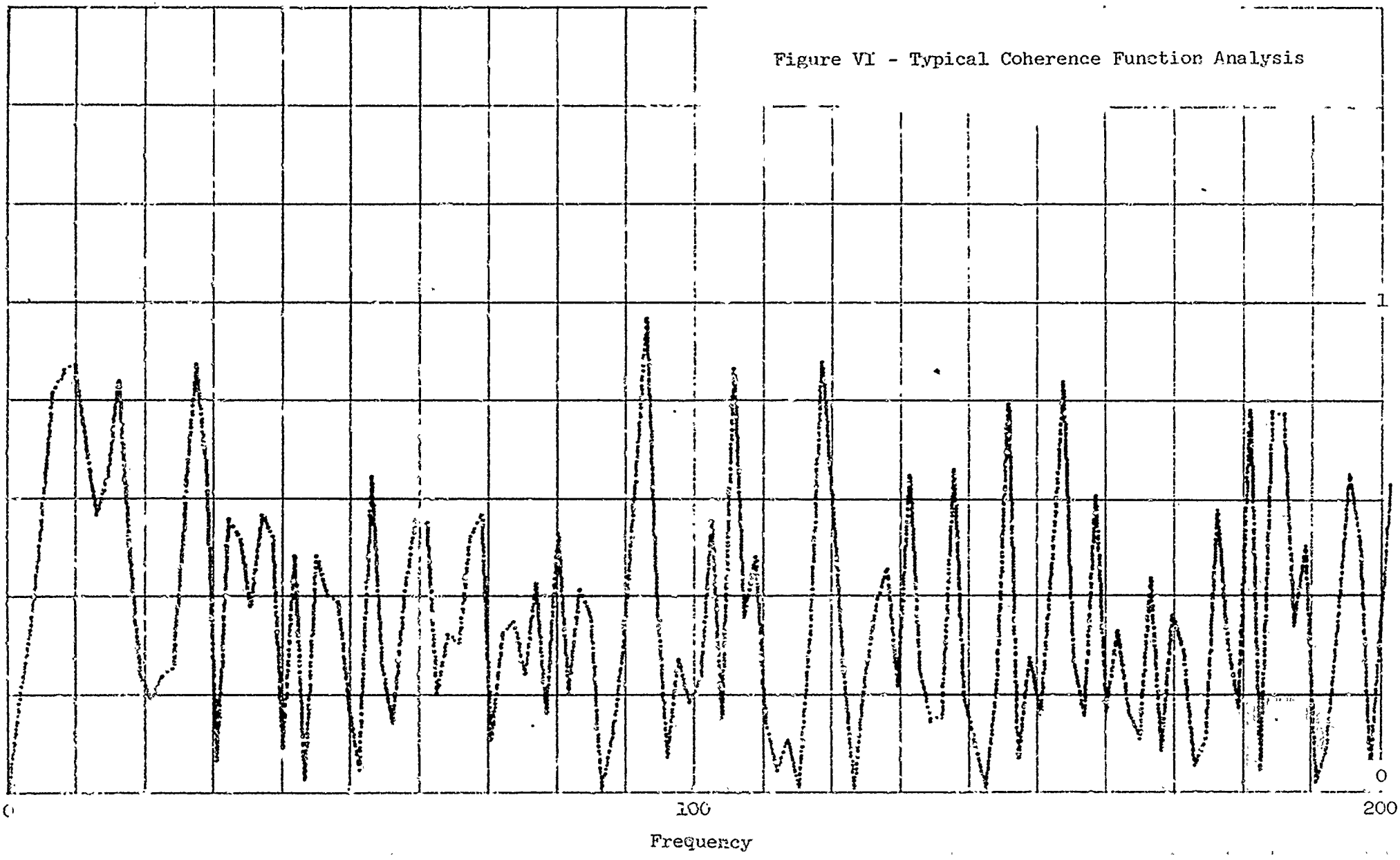


Figure VI - Typical Coherence Function Analysis

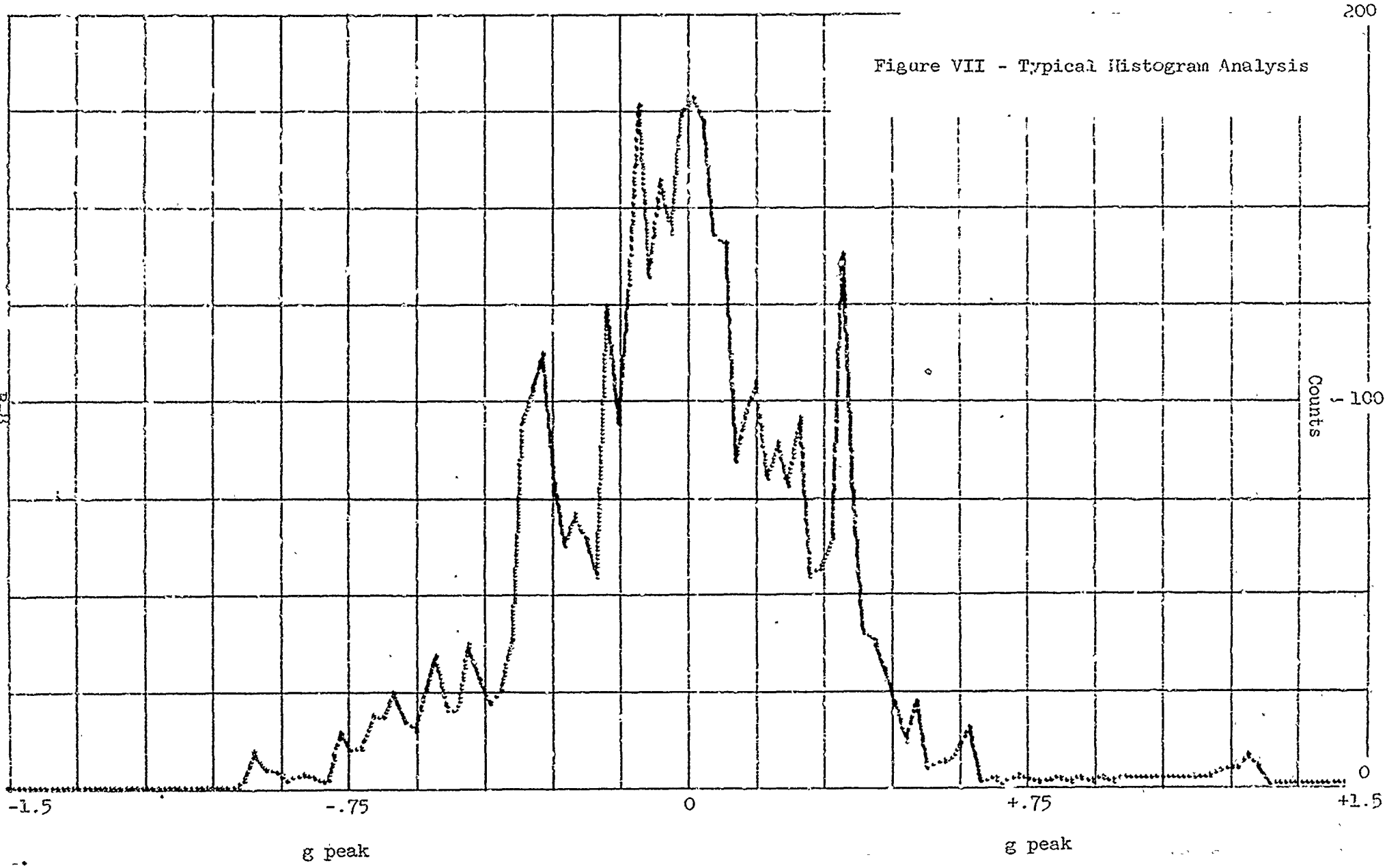


Figure VII - Typical Histogram Analysis

APPENDIX C

Tables of Transfer and Coherence Functions

Table I - Transfer and Coherence Functions for Station 10

Table II - Transfer and Coherence Functions for Station 11

Table III - Transfer and Coherence Functions for Station 12

Table IV - Transfer and Coherence Functions for Station 14

Table I - Transfer and Coherence Functions for Station 10

Take-off

Axis	Freq. (Hz)	Equipment Frame and Case of Recorder				Case of Rcdr. & Front Panel of Rcdr. Transport			
		Transfer Function	Coherence Function	Resp. Level (Frame)(g^2/Hz)	Displ.* (Frame) in. D.A.)	Transfer Function	Coherence Function	Resp. Level (Case)(g^2/Hz)	Displ.* (Case) in. D.A.)
X	8	1.0	0.95	0.004	0.03	5.5	0.9	0.004	0.03
Y	8(28)	(.75)	(0.8)	(0.0005)	(0.001)	4.0	0.43	0.00015	0.007
Z	8(12)	(1.2)	(0.8)	(0.0016)	(0.0095)	4.8	0.85	0.003	0.028

Flying

Axis	Freq. (Hz)	Equipment Frame & Case of Recorder				Case of Rcdr. & Front Panel of Rcdr. Transport			
		Transfer Function	Coherence Function	Resp. Level (Frame)(g^2/Hz)	Displ.* (Frame) in. D.A.)	Transfer Function	Coherence Function	Resp. Level (Case)(g^2/Hz)	Displ.* (Case) in. D.A.)
X	8	1.0	0.9	0.00012	0.006	5.2	0.7	0.00012	0.006
Y	8	-	-	-	-	14	0.42	0.000005	0.0012
Z	8	0.8	0.9	0.00009	0.006	4.0	0.7	0.00007	0.005

Landing - Touchdown (T), Reverse Pitch (RP) Applied to Props

Axis	Freq. (Hz)	Equipment Frame and Case of Recorder				Case of Rcdr. & Front Panel of Rcdr. Transport			
		Transfer Function	Coherence Function	Resp. Level (Frame)(g^2/Hz)	Displ.* (Frame) in. D.A.)	Transfer Function	Coherence Function	Resp. Level (Case)(g^2/Hz)	Displ.* (Case) in. D.A.)
X(T)	8(17)	(1.1)	(0.7)	(0.002)	(0.0055)	6.5	0.9	0.0006	0.012
Y(T)	8	2.6	0.6	0.0003	0.009	3.0	0.5	0.0026	0.028
Z(T)	8(17)	(1.5)	(0.6)	(0.0015)	(0.0048)	5.0	0.95	0.0015	0.022
X(RP)	8	1.0	0.95	0.0035	0.03	4.0	0.9	0.0035	0.03
Y(RP)	8	-	-	-	-	3.5	1.0	0.00009	0.006
Z(RP)	8(17)	(1.6)	(0.9)	(0.0025)	(0.006)	5.3	0.95	0.0015	0.022

*An Equivalent Sinusoidal Value Calculated from the PSD's

Table II - Transfer and Coherence Functions for Station 11

Take-off

Axis	Freq. (Hz)	Equipment Frame & Top of Drum Memory Isolators				Top of Drum Memory Isolators & Top of Drum Memory			
		Transfer Function	Coherence Function	Resp. Level (Frame) (g)	Displ.* (Frame) in. D.A.)	Transfer Function	Coherence Function	Resp. Level (Isolators)(g)	Displ.* (Isol.) in. D.A.)
X	12	5.0	0.8	0.00015	0.0033	1.1	1.0	0.0025	0.012
Y	-	-	-	-	-	-	-	-	-
Z	-	-	-	-	-	-	-	-	-

Flying

Axis	Freq. (Hz)	Equipment Frame & Top of Drum Memory Isolators				Top of Drum Memory Isolators & Top of Drum Memory			
		Transfer Function	Coherence Function	Resp. Level (Frame) (g)	Displ.* (Frame) in.D.A.)	Transfer Function	Coherence Function	Resp. Level (Isolators)(g)	Displ.* (Isol. in.D.A.)
X	12 (30)	2.8	0.7	0.00006	0.0006	(2.0)	(1.0)	(0.0003)	(0.0007)
Y	30	3.0	0.2	0.0000006	-	4.5	0.95	0.00008	0.0003
Z	30	11.0	0.8	0.00003	-	1.5	0.98	0.004	0.0022

Flying (No Landing Data)

Axis	Freq. (Hz)	Equipment Frame & Top of Drum Memory Isolators				Top of Drum Memory Isolators & Top of Drum Memory			
		Transfer Function	Coherence Function	Resp. Level (Frame) (g)	Displ.* (Frame in.D.A.)	Transfer Function	Coherence Function	Resp. Level (Isolators)(g)	Displ.* (Frame in.D.A.)
X	950	3.5	0.6	0.0000003	-	3.5	0.7	0.00008	-
Y	1580	-	-	-	-	7.0	0.7	0.000006	-

*An Equivalent Sinusoidal Value Calculated from the PSD's

Table III - Transfer and Coherence Functions for Station 12

Take-off

Axis	Freq. (Hz)	Equipment Frame and Case of Recorder				Case of Rcdr. & Front Panel of Rcdr. Transport			
		Transfer Function	Coherence Function	Resp. Level (Frame) (g^2/Hz)	Displ.* (Frame) (in.D.A.)	Transfer Function	Coherence Function	Resp. Level (Case) (g^2/Hz)	Displ.* (Case) (in.D.A.)
X	8	2.0	1.0	0.008	0.044	1.3	0.9	0.032	0.090
Y	8	-	-	-	-	1.8	1.0	0.0009	0.015
Z	10	1.2	0.95	0.0001	0.0037	4.5	0.8	0.00014	0.0038

Flying

Axis	Freq. (Hz)	Equipment Frame and Case of Recorder				Case of Rcdr. & Front Panel of Rcdr. Transport			
		Transfer Function	Coherence Function	Resp. Level (Frame) (g^2/Hz)	Displ.* (Frame) (in.D.A.)	Transfer Function	Coherence Function	Resp. Level (Case) (g^2/Hz)	Displ.* (Case) (in.D.A.)
X	8	2.3	0.8	0.0001	0.0055	1.7	0.7	0.0005	0.012
Y	-	-	-	-	-	-	-	-	-
Z	8	1.2	0.95	0.00003	0.00027	3.0	0.9	0.00004	0.0027

Landing - Touchdown (T), Reverse Pitch (RP) Applied to Props

Axis	Freq. (Hz)	Equipment Frame and Case of Recorder				Case of Rcdr. & Front Panel of Rcdr. Transport			
		Transfer Function	Coherence Function	Resp. Level (Frame) (g^2/Hz)	Displ.* (Frame) (in.D.A.)	Transfer Function	Coherence Function	Resp. Level (Case) (g^2/Hz)	Displ.* (Case) (in.D.A.)
X(T)	8	2.0	0.95	0.0035	0.029	3.0	0.85	.014	0.060
Y(T)	17	2.0	1.0	0.0002	0.0085	3.0	1.0	0.0007	0.0145
Z(T)	-	-	-	-	-	-	-	-	-
X(RP)	8	3.0	0.95	0.003	0.026	1.4	0.75	0.027	0.075
Y(RP)	-	-	-	-	-	-	-	-	-
Z(RP)	-	-	-	-	-	-	-	-	-

*An Equivalent Sinusoidal Value Calculated from the PSD's

Table IV - Transfer and Coherence Functions for Station 14

Axis	Freq. (Hz)	Equipment Frame and Case of Recorder				Case of Rcdr. & Front Panel of Rcdr. Transport			
		Transfer Function	Coherence Function	Resp. Level (Frame)(g^2/Hz)	Displ.* (Frame) (in.D.A.)	Transfer Function	Coherence Function	Resp. Level (Case)(g^2/Hz)	Displ.* (Case) (in.D.A.)
X	8	1.2	0.8	0.002	0.024	3.6	0.66	0.003	0.030
Y	-	-	-	-	-	-	-	-	-
Z	-	-	-	-	-	-	-	-	-

Flying

Axis	Freq. (Hz)	Equipment Frame and Case of Recorder				Case of Rcdr. & Front Panel of Rcdr. Transport			
		Transfer Function	Coherence Function	Resp. Level (Frame)(g^2/Hz)	Displ.* (Frame) (in.D.A.)	Transfer Function	Coherence Function	Resp. Level (Case)(g^2/Hz)	Displ.* (Case) (in.D.A.)
X	8	1.3	0.6	0.00007	0.004	2.5	0.7	0.0001	0.006
Y	8	1.2	0.3	0.000003	-	5.2	0.65	0.000035	0.003
Z	8(17)	(1.0)	(0.95)	(0.00009)	(0.0013)	2.5	0.8	0.00018	0.0072

Landing (No Landing Data)

*An Equivalent Sinusoidal Value Calculated from the PSD's

APPENDIX D

Composite PSD Graphs

Enclosure (1) - Composite PSD Graphs for Station 10

Enclosure (2) - Composite PSD Graphs for Station 11

Enclosure (3) - Composite PSD Graphs for Station 12

Enclosure (4) - Composite PSD Graphs for Station 14

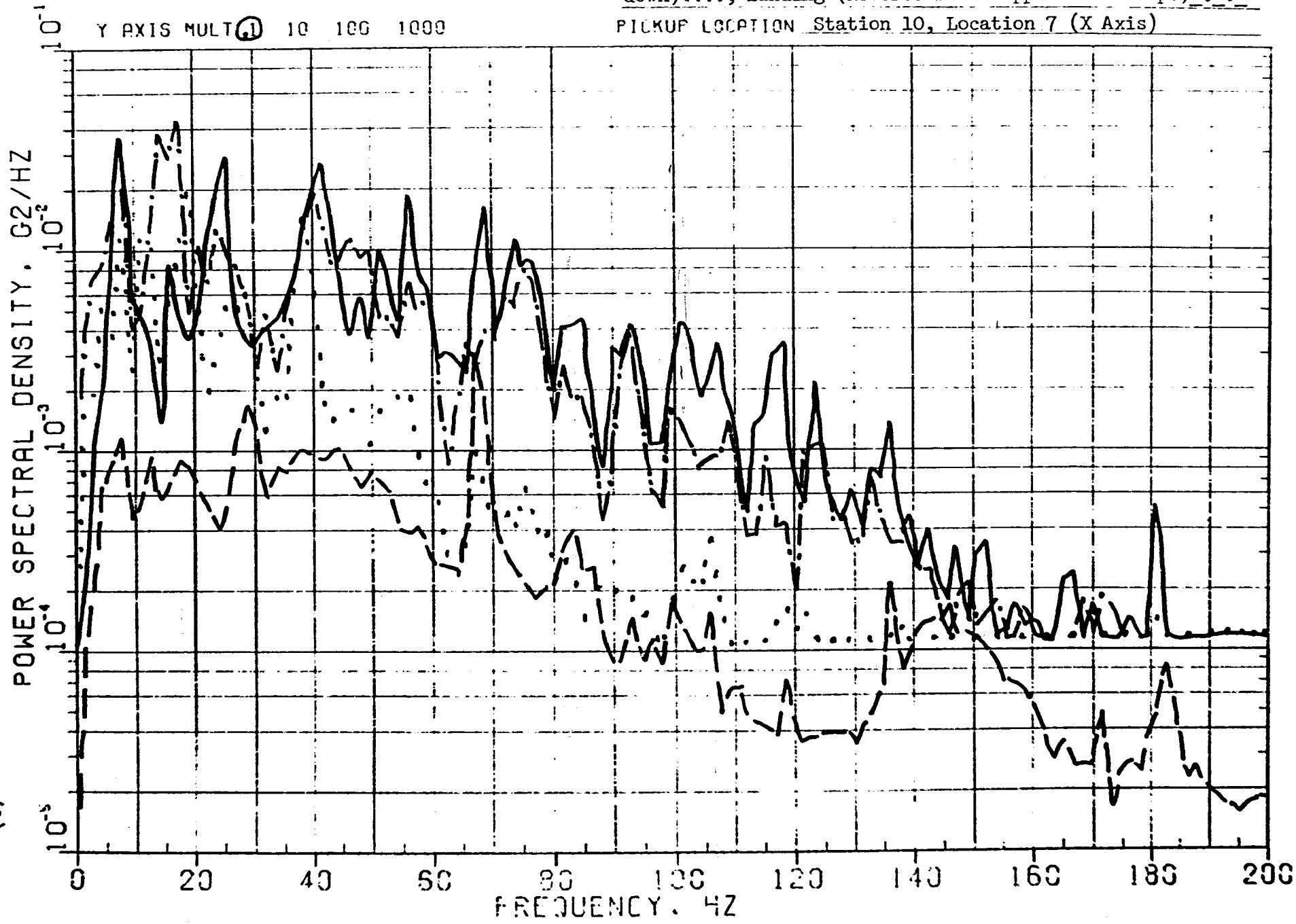
BANDWIDTH 1.6 HZ

DEG. OF FREEDOM -

TEST TITLE Composite PSD Graph TEST DATE 11/13/74-11/15/74

TEST CONDITION Take-off ____, Flying ____, Landing (Touch-down)...., Landing (Reverse Pitch Applied to Props) _._._

PICKUP LOCATION Station 10, Location 7 (X Axis)



Enclosure (1)
Page 1 of 9

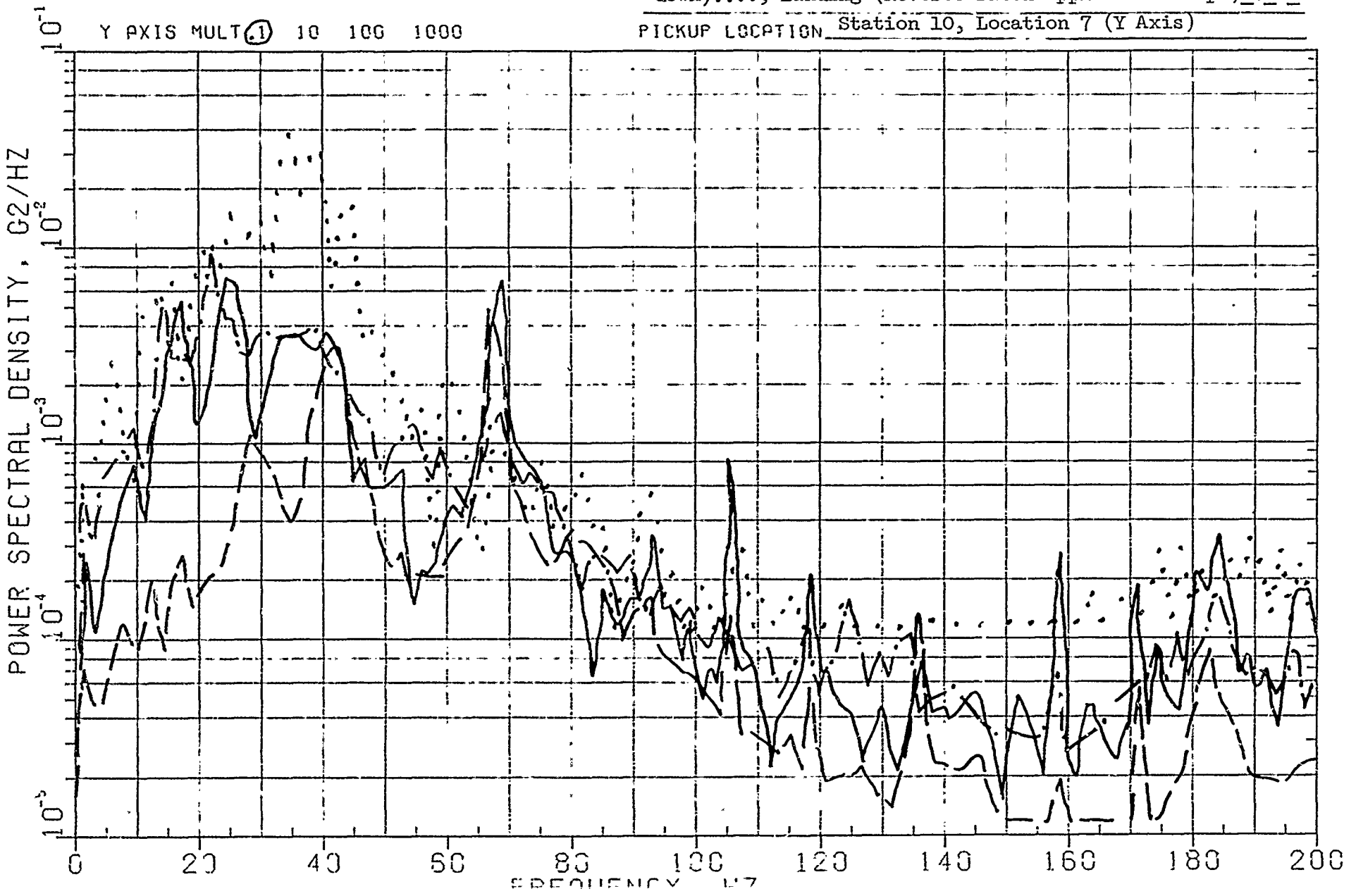
BANDWIDTH 1.6 HZ

DEG. OF FREEDOM -

TEST TITLE Composite PSD Graph TEST DATE 11/13/74-11/15/74

TEST CONDITION Take-off ____, Flying _ _ _, Landing (Touch-down)...., Landing (Reverse Pitch Applied to Props) _.._.._

PICKUP LOCATION Station 10, Location 7 (Y Axis)



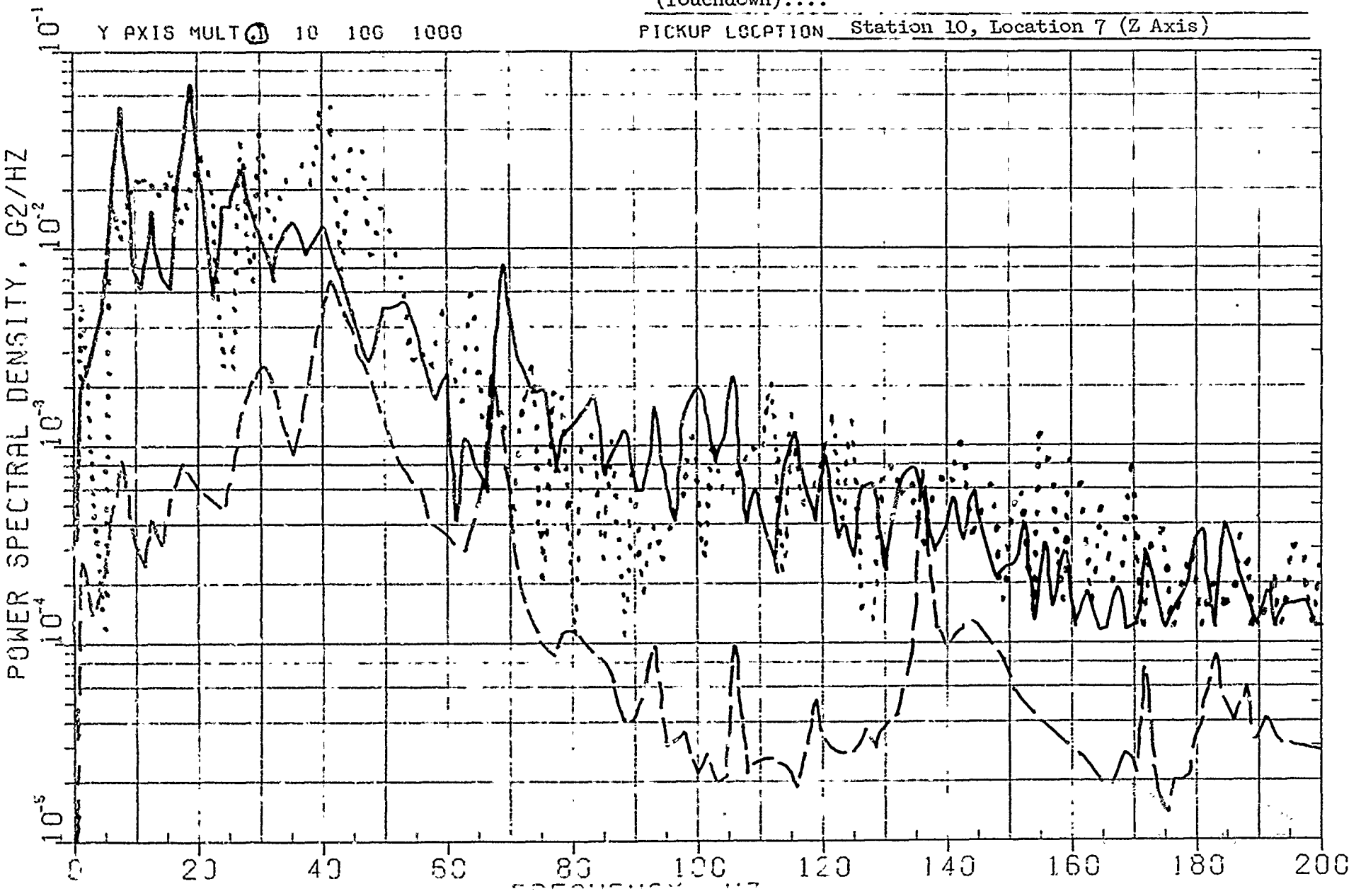
BANDWIDTH 1.6 HZ

DEG. OF FREEDOM -

TEST TITLE Composite PSD Graph TEST DATE 11/13/74-11/15/74

TEST CONDITION Take-off, Flying, Landing (Touchdown)....

PICKUP LOCATION Station 10, Location 7 (Z Axis)



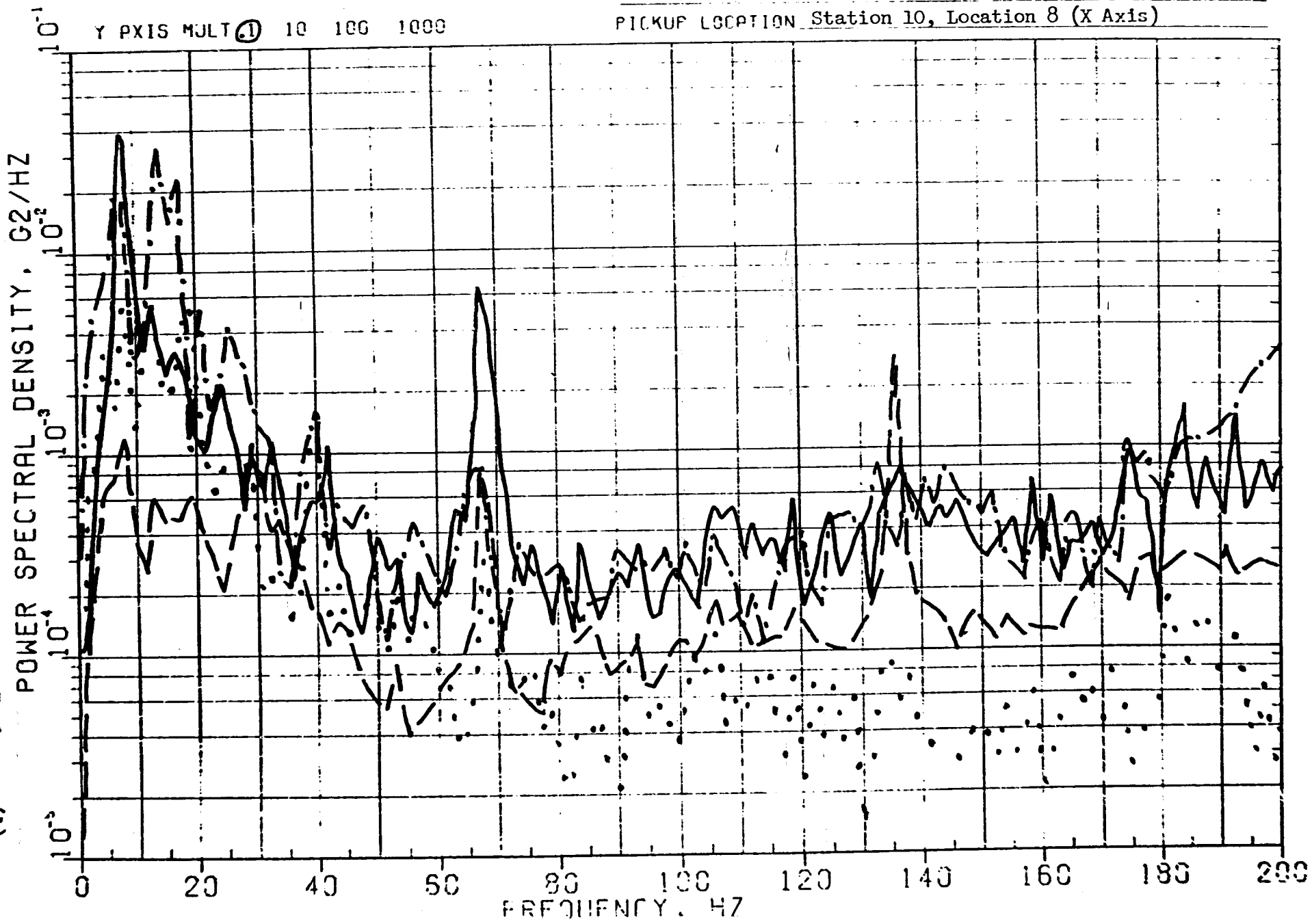
BANDWIDTH 1.6 HZ

DEG. OF FREEDOM -

TEST TITLE Composite PSD Graph TEST DATE 11/13/74-11/15/74

TEST CONDITION Take-off ___, Flying _ _ _, Landing (Touch-down)...., Landing (Reverse Pitch Applied to Props) _._._

PICKUP LOCATION Station 10, Location 8 (X Axis)



Enclosure (1)
Page 4 of 9

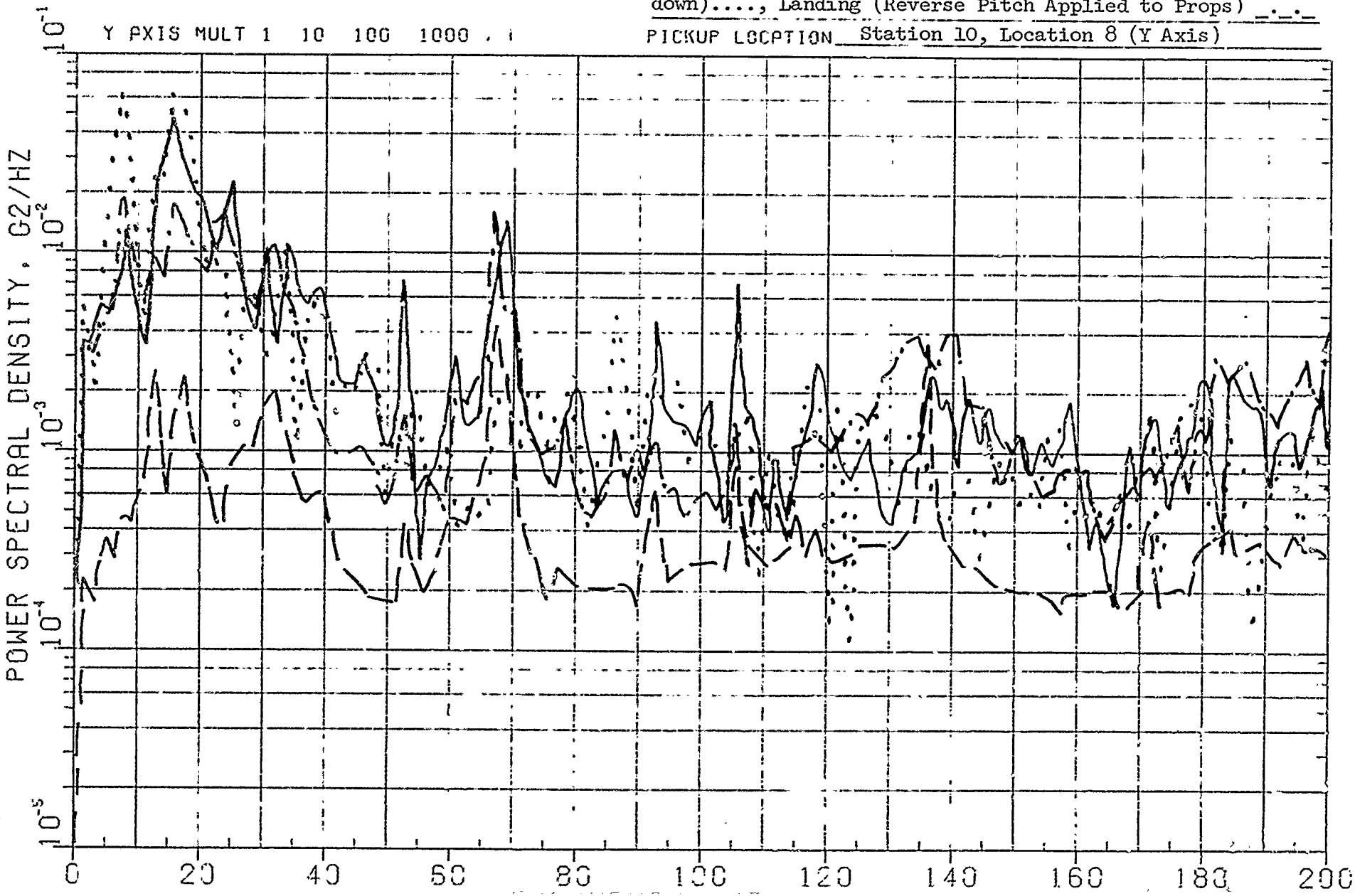
BANDWIDTH 1.6 HZ

DEG. OF FREEDOM -

TEST TITLE Composite PSD Graph TEST DATE 11/13/74-11/15/74

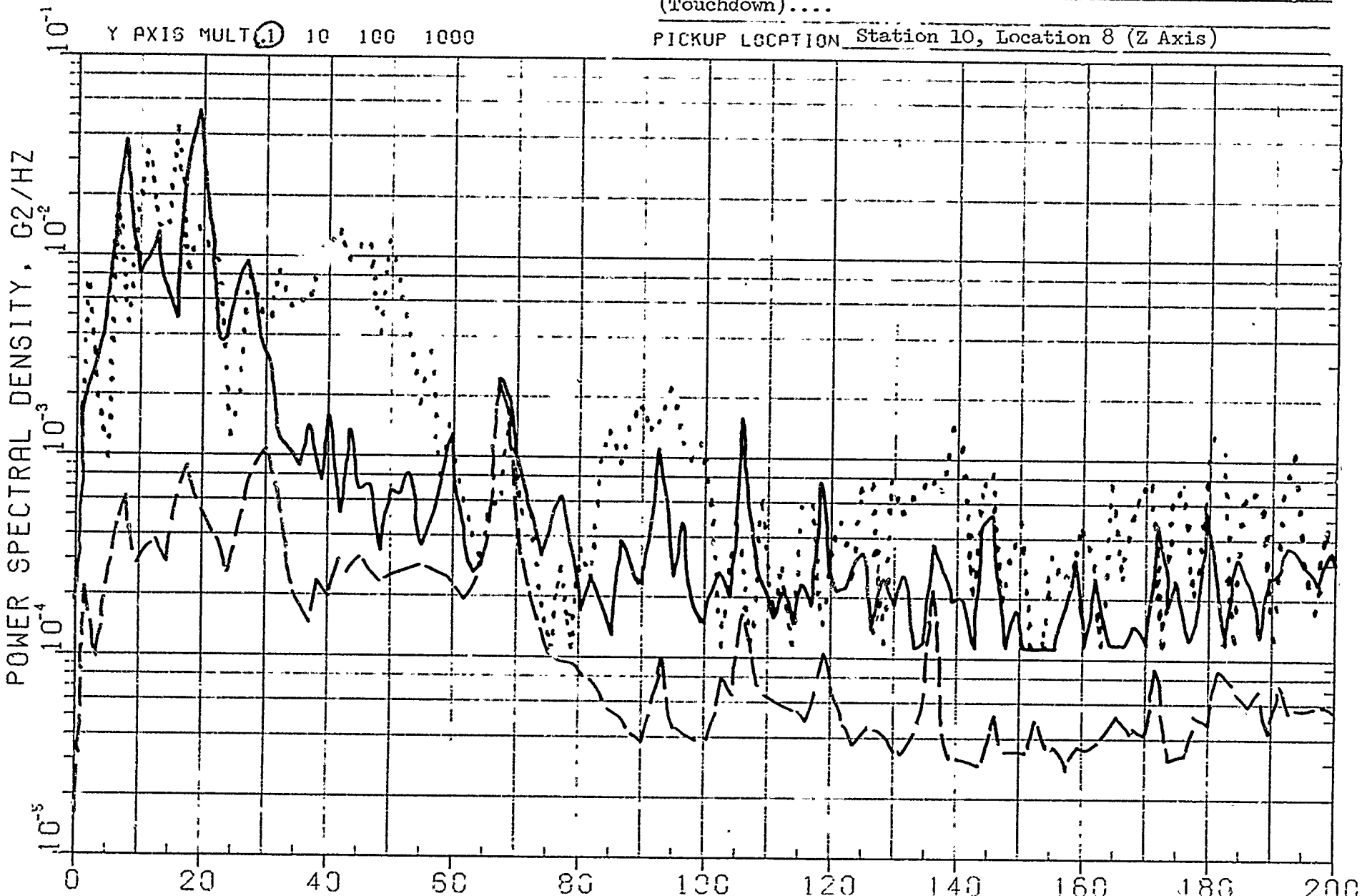
TEST CONDITION Take-off ____, Flying _ _ _, Landing (Touch-down)...., Landing (Reverse Pitch Applied to Props) _._._

PICKUP LOCATION Station 10, Location 8 (Y Axis)



BANDWIDTH 1.6 HZ
DEG. OF FREEDOM -

TEST TITLE Composite PSD Graph TEST DATE 11/13/74-11/15/74
TEST CONDITION Take-off ____, Flying _ _ _, Landing (Touchdown)....
PICKUP LOCATION Station 10, Location 8 (Z Axis)



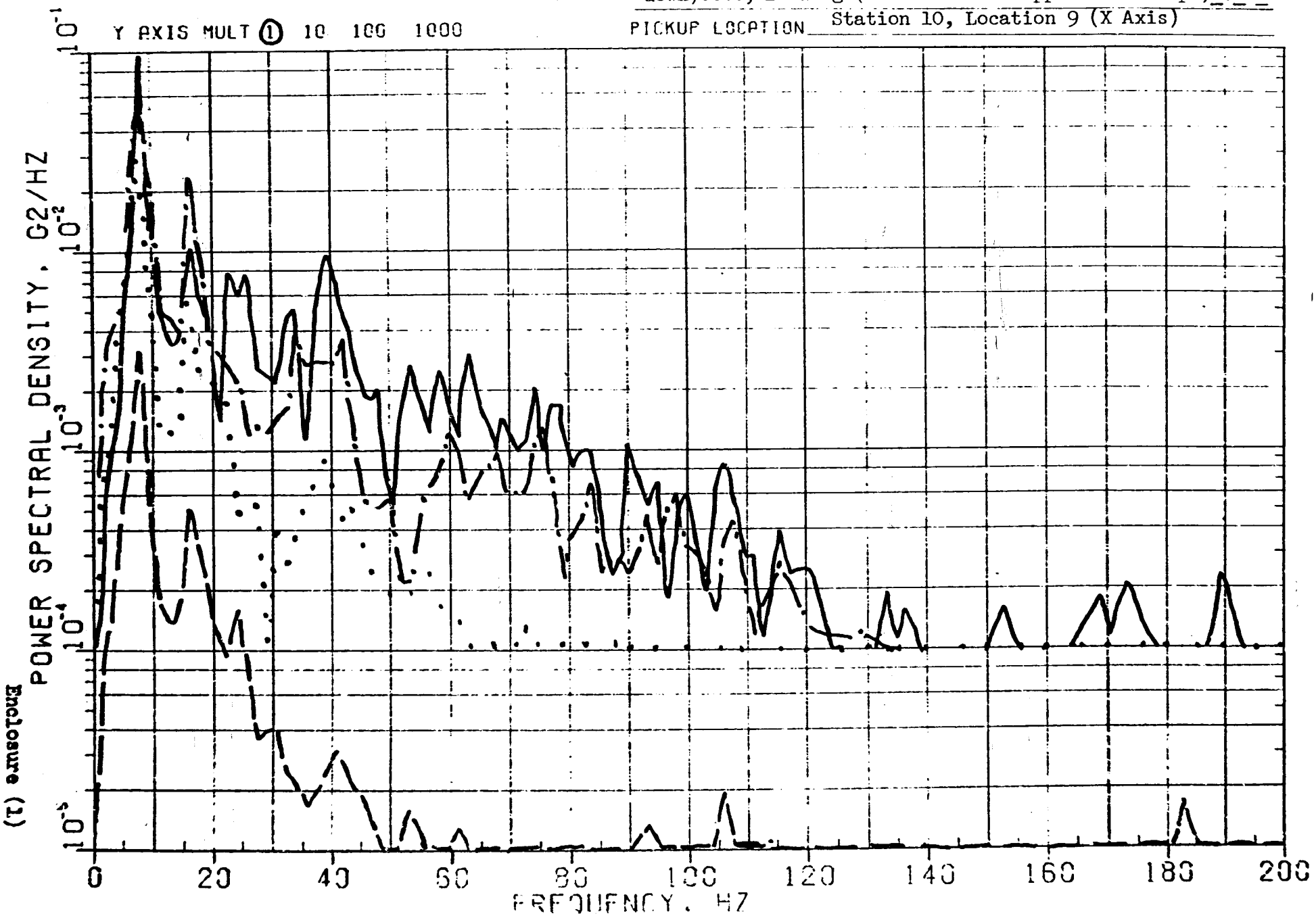
BANDWIDTH 1.6 HZ

DEG. OF FREEDOM -

TEST TITLE Composite PSD Graph TEST DATE 11/13/74-11/15/74

TEST CONDITION Take-off ___, Flying _ _ _, Landing (Touch-down)...., Landing (Reverse Pitch Applied to Props) _._._

PICKUP LOCATION Station 10, Location 9 (X Axis)



Enclosure (1)
Page 7 of 9

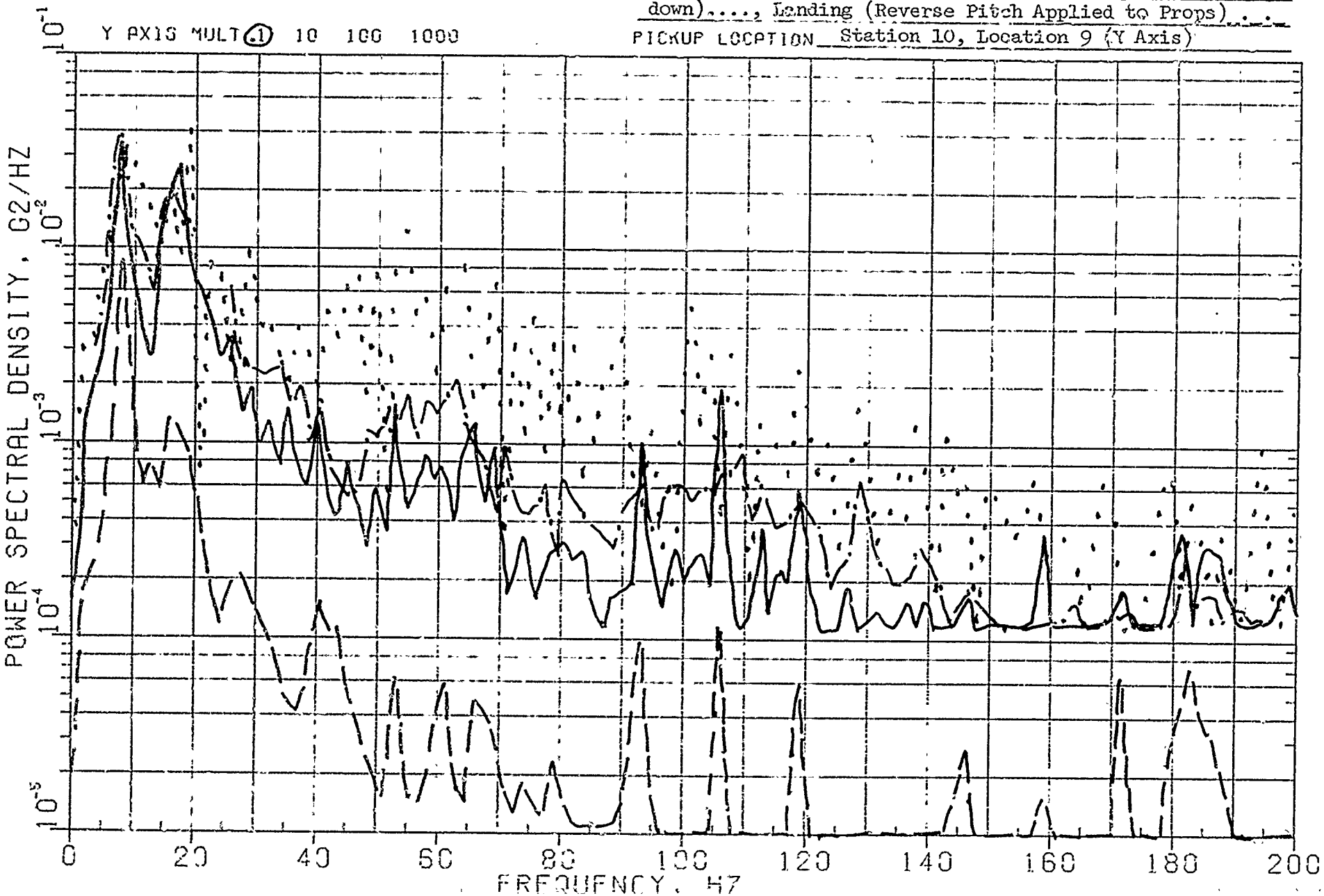
BANDWIDTH 1.6 HZ

DEG. OF FREEDOM -

TEST TITLE Composite PSD Graph TEST DATE 11/13/74-11/15/74

TEST CONDITION Take-off , Flying , Landing (Touch-down)...., Landing (Reverse Pitch Applied to Props)....

PICKUP LOCATION Station 10, Location 9 (Y Axis)

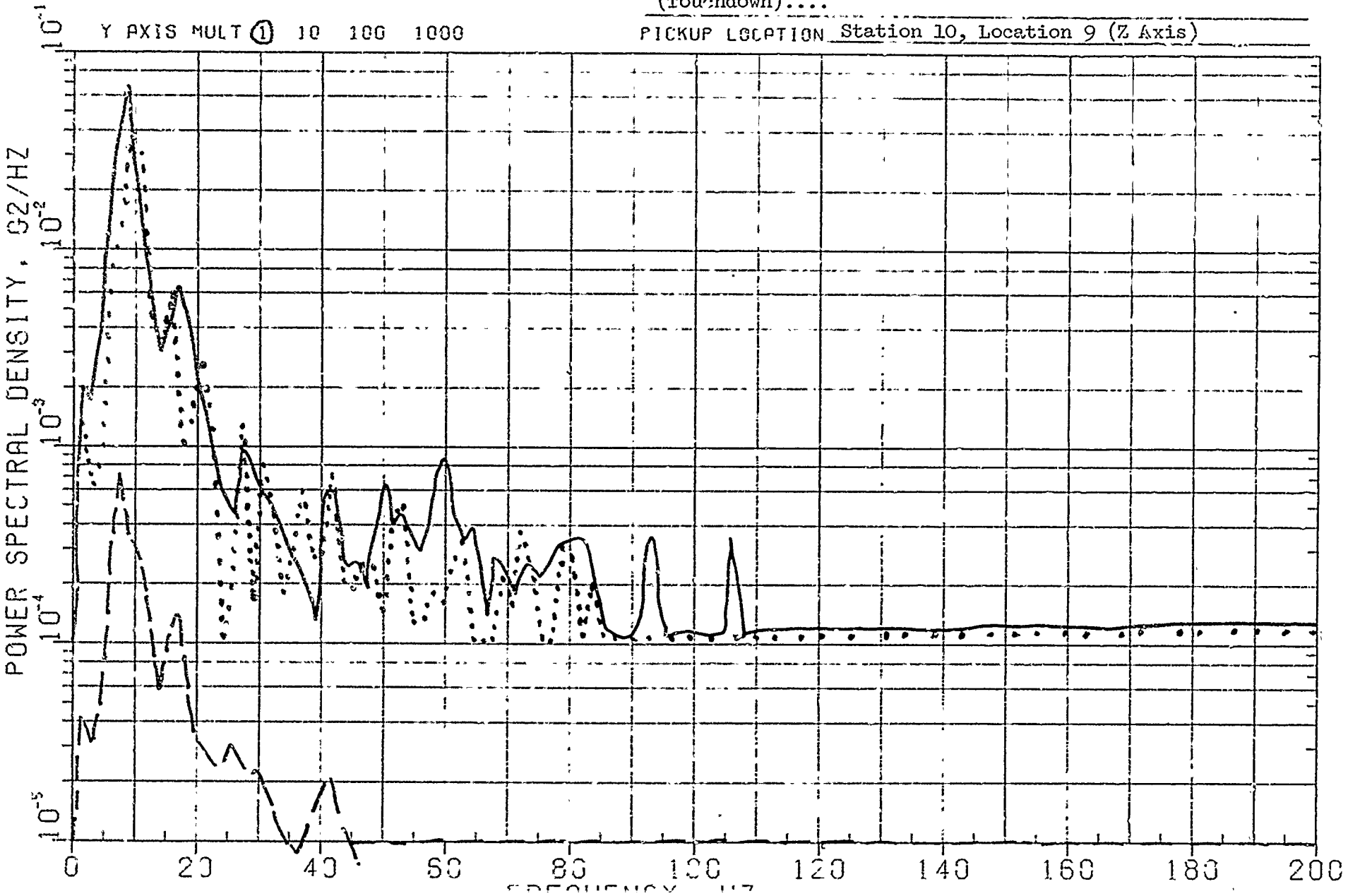


BANDWIDTH 1.6 HZ
DEG. OF FREEDOM -

TEST TITLE Composite PSD Graph TEST DATE 11/13/74-11/15/74
TEST CONDITION Take-off, Flying, Landing (Touchdown)....

Y AXIS MULT (1) 10 100 1000

PICKUP LOCATION Station 10, Location 9 (Z Axis)



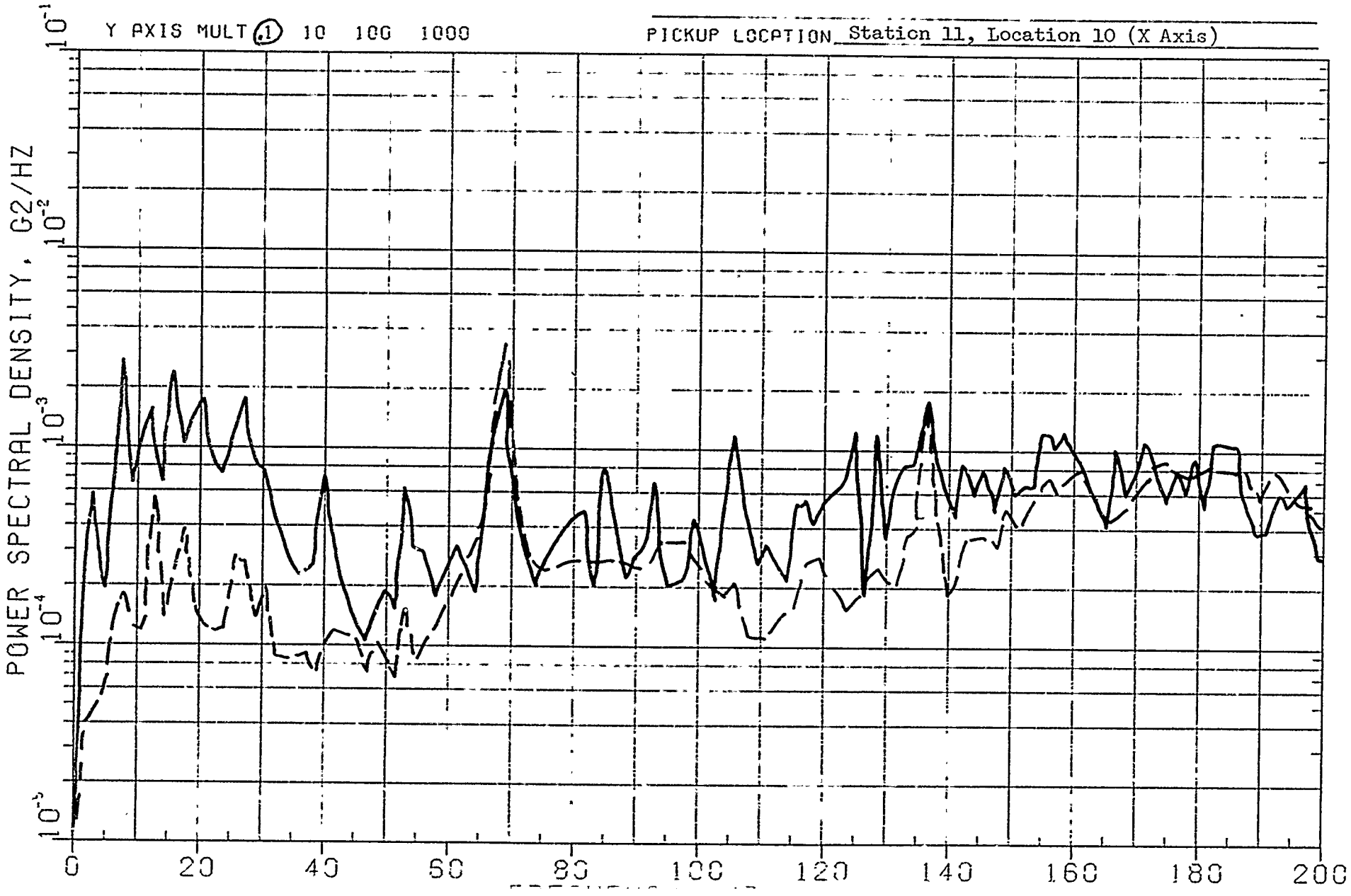
BANDWIDTH 1.6 HZ

DEG. OF FREEDOM -

TEST TITLE Composite PSD Graph TEST DATE 11/13/74-11/15/74

TEST CONDITION Take-off, Flying

PICKUP LOCATION Station 11, Location 10 (X Axis)



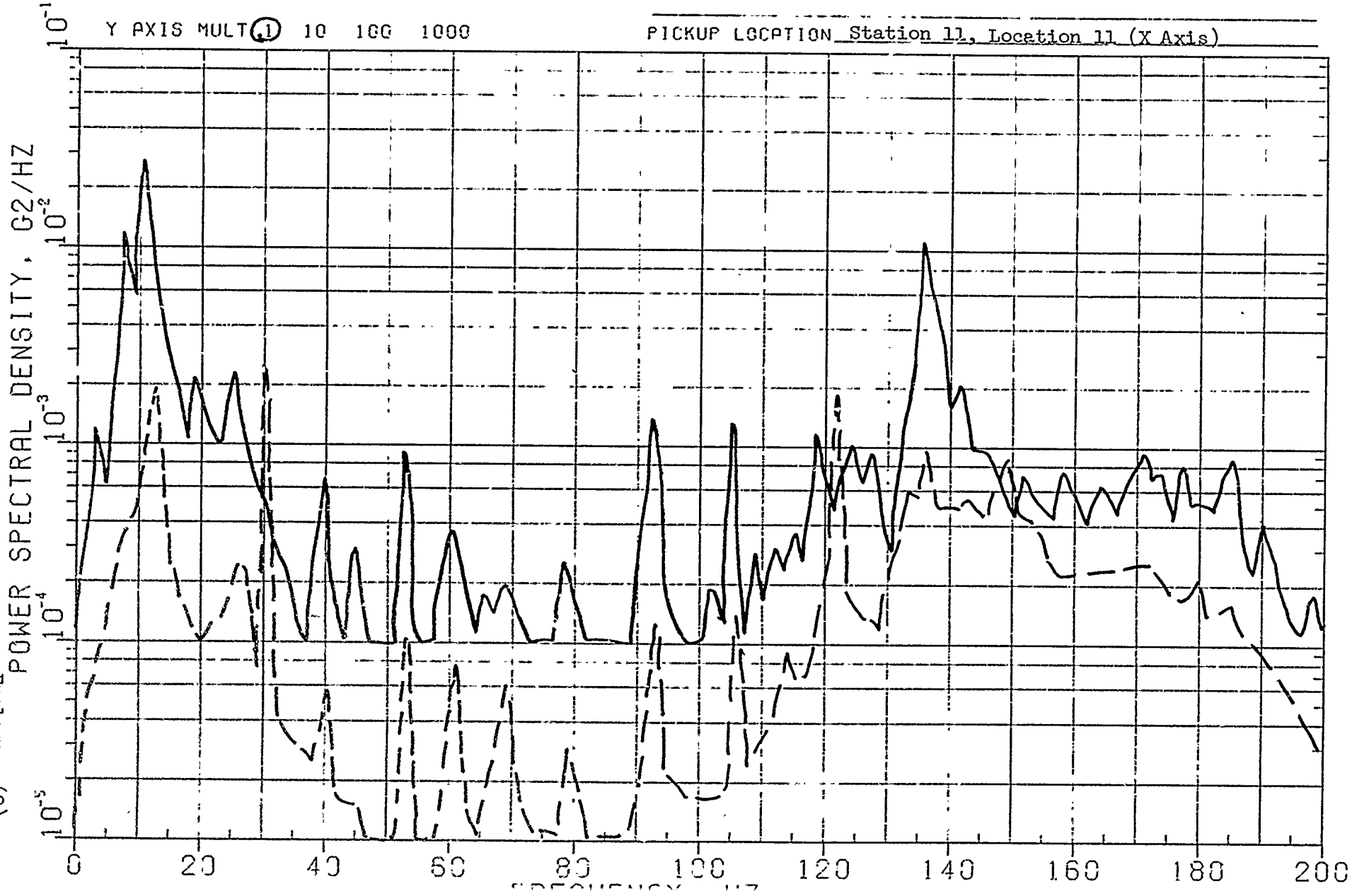
Enclosure (2)
Page 1 of 3

BANDWIDTH 1.6 HZ
DEG. OF FREEDOM -

TEST TITLE Composite PSD Graph TEST DATE 11/13/74-11/15/74
TEST CONDITION Take-off, Flying

Y AXIS MULT (.1) 10 100 1000

PICKUP LOCATION Station 11, Location 11 (X Axis)

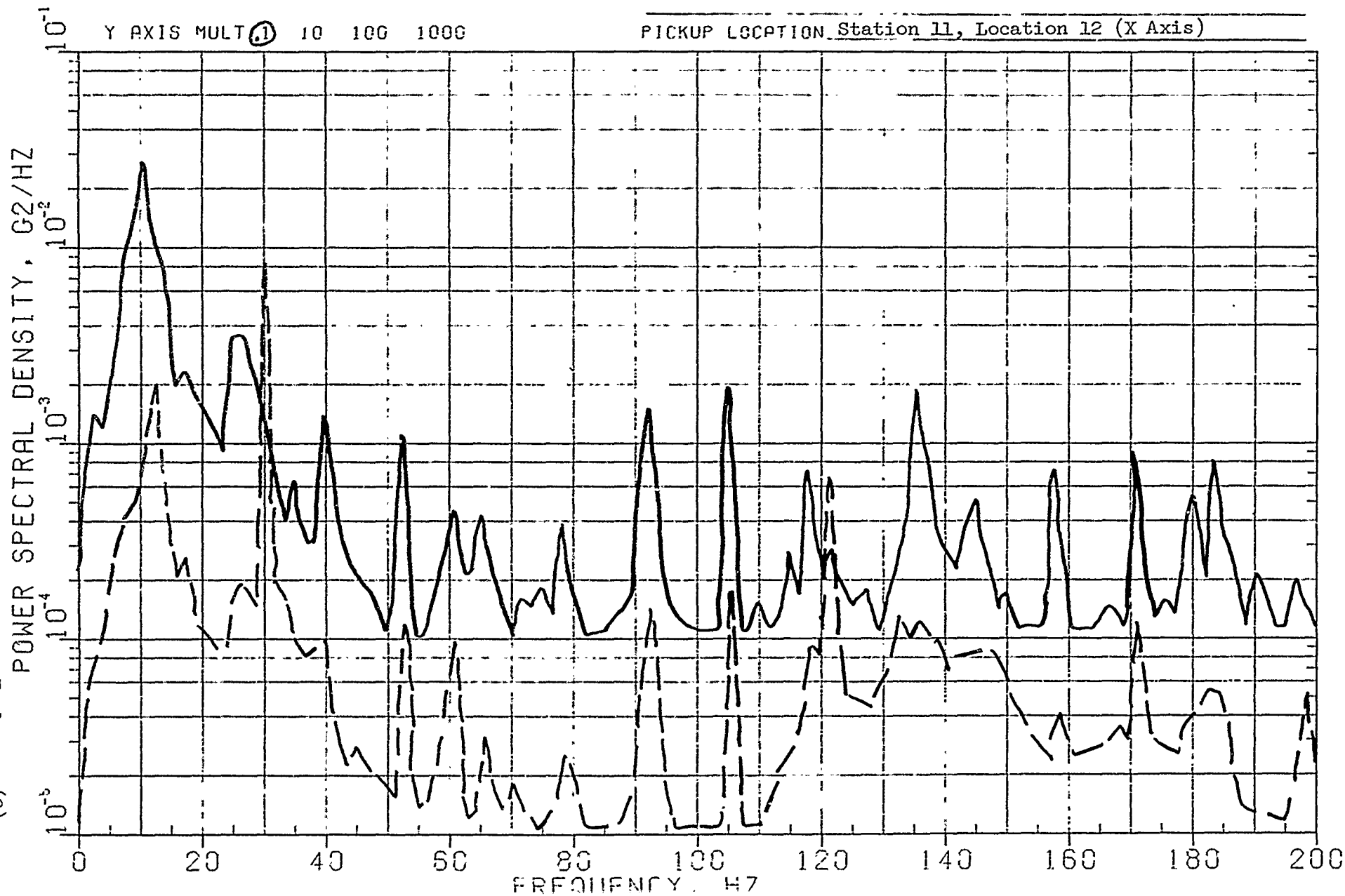


Enclosure (2)
Page 2 of 3

BANDWIDTH 1.6 HZ
DEG. OF FREEDOM -

TEST TITLE Composite PSD Graph TEST DATE 11/13/74-11/15/74
TEST CONDITION Take-off, Flying

PICKUP LOCATION Station 11, Location 12 (X Axis)



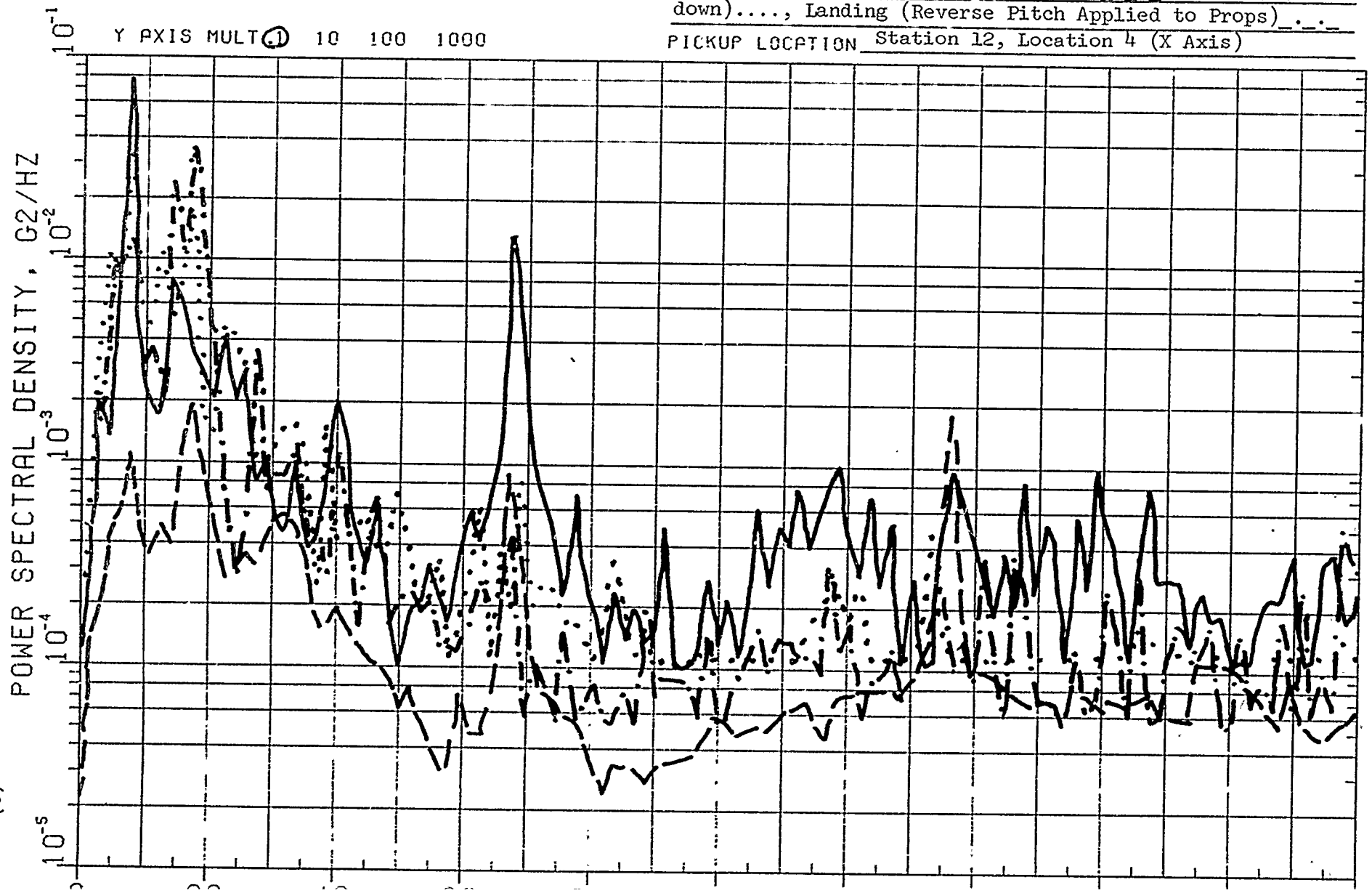
BANDWIDTH 1.6 HZ

DEG. OF FREEDOM -

TEST TITLE Composite PSD Graph TEST DATE 11/13/74-11/15/74

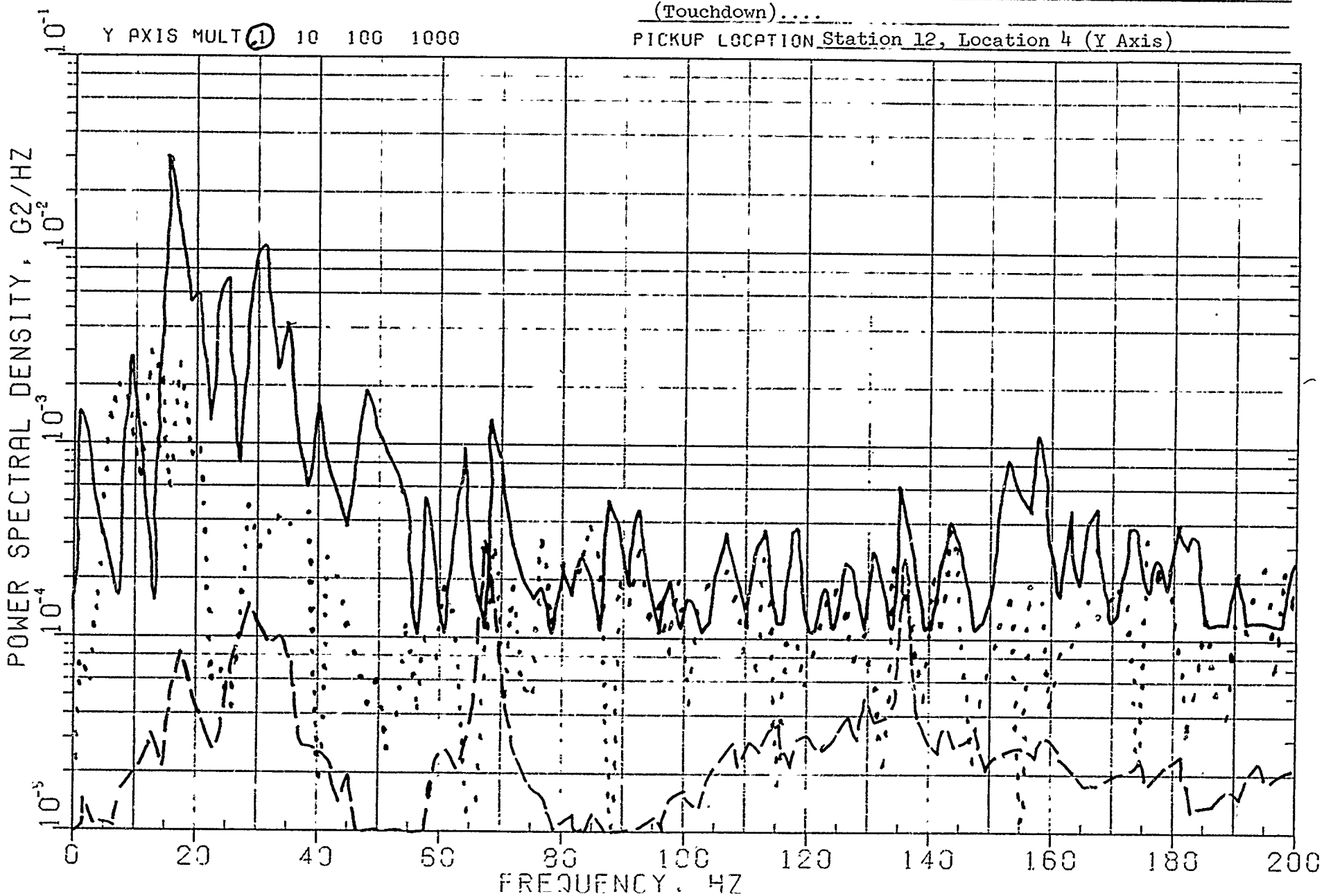
TEST CONDITION Take-off, Flying, Landing (Touch-down)...., Landing (Reverse Pitch Applied to Props)

PICKUP LOCATION Station 12, Location 4 (X Axis)



BANDWIDTH 1.6 HZ
DEG. OF FREEDOM -

TEST TITLE Composite PSD Graph TEST DATE 11/13/74-11/15/74
TEST CONDITION Take-off, Flying, Landing (Touchdown)....
PICKUP LOCATION Station 12, Location 4 (Y Axis)

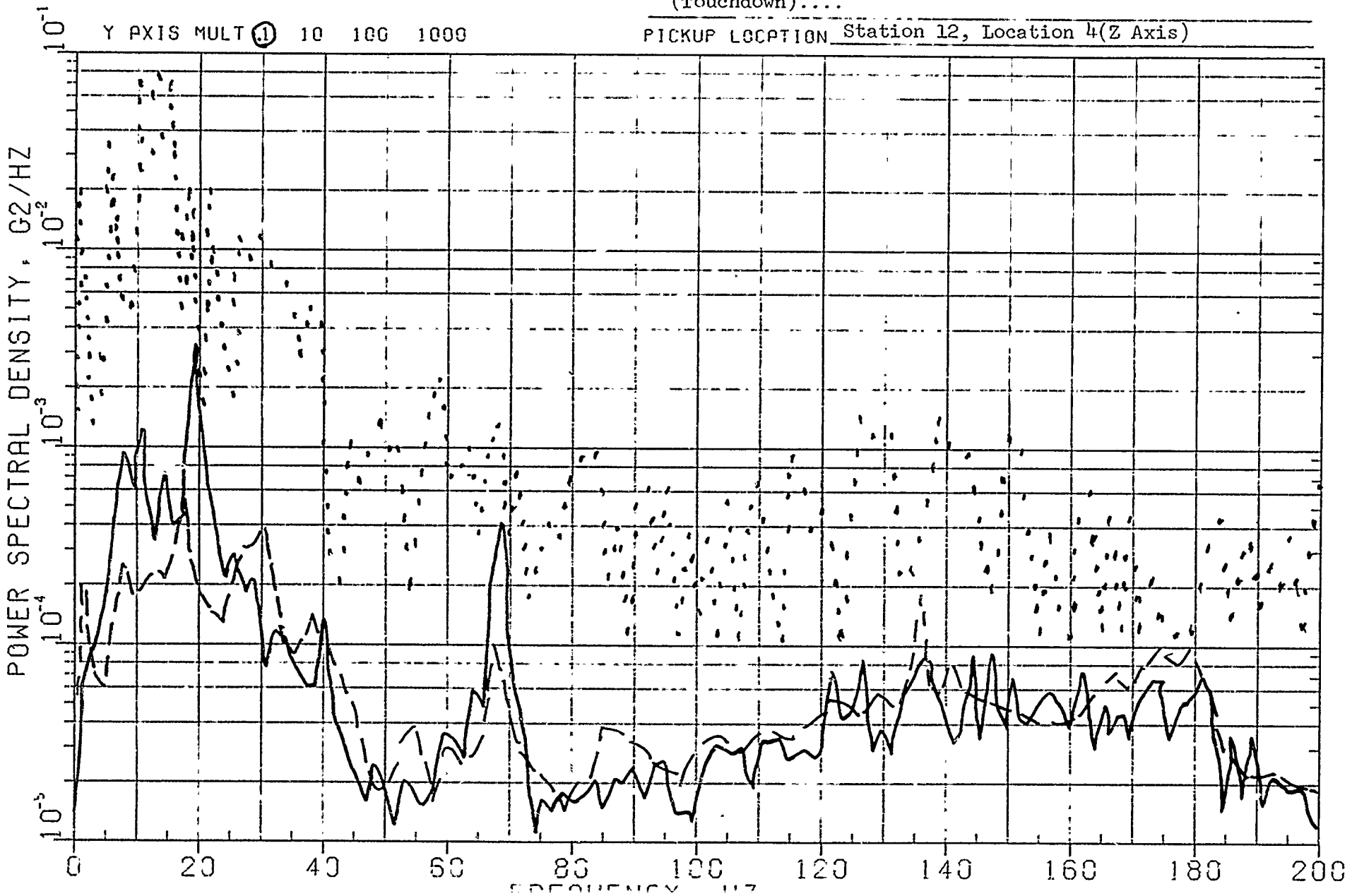


BANDWIDTH 1.6 HZ
DEG. OF FREEDOM -

TEST TITLE Composite PSD Graph TEST DATE 11/13/74-11/15/74
TEST CONDITION Take-off , Flying , Landing (Touchdown)....

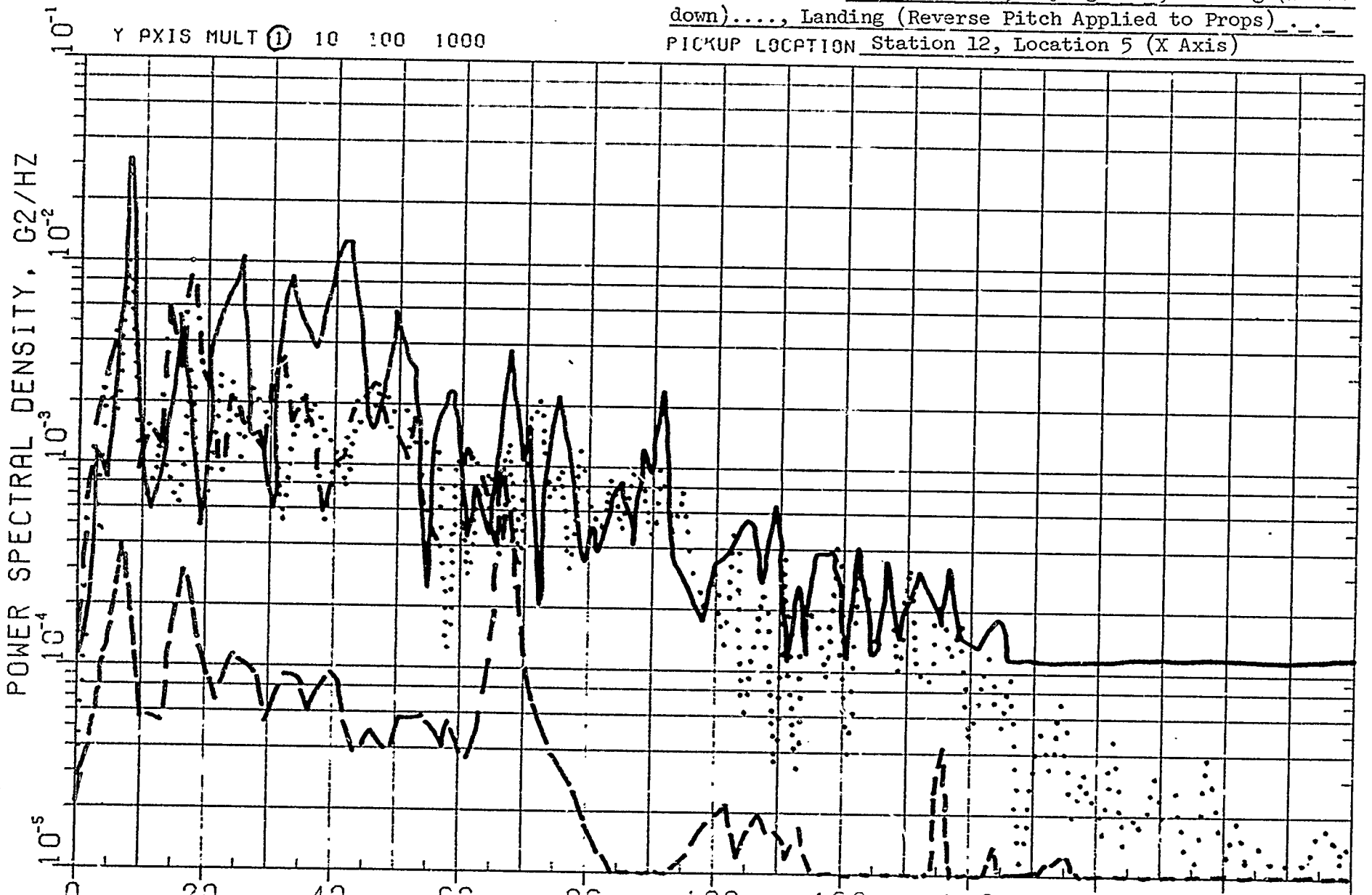
Y AXIS MULT (1) 10 100 1000

PICKUP LOCATION Station 12, Location 4(Z Axis)



BANDWIDTH 1.6 HZ
DEG. OF FREEDOM -

TEST TITLE Composite PSD Graph TEST DATE 11/13/74-11/15/74
TEST CONDITION Take-off, , Flying , Landing (Touch-down)...., Landing (Reverse Pitch Applied to Props)
PICKUP LOCATION Station 12, Location 5 (X Axis)



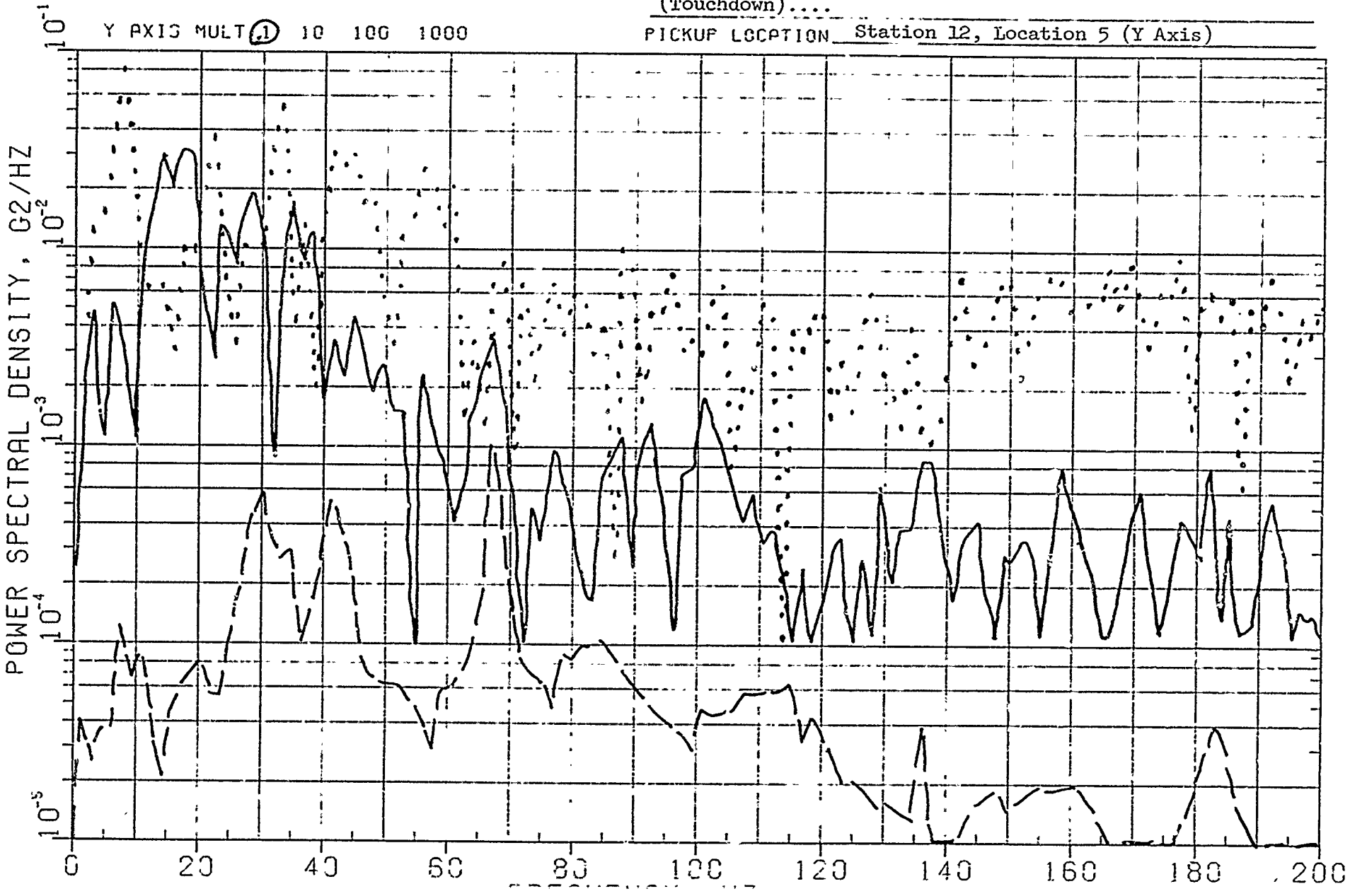
BANDWIDTH 1.6 HZ

DEG. OF FREEDOM -

TEST TITLE Composite PSD Graph TEST DATE 11/13/74-11/15/74

TEST CONDITION Take-off ____, Flying ____, Landing (Touchdown)....

PICKUP LOCATION Station 12, Location 5 (Y Axis)



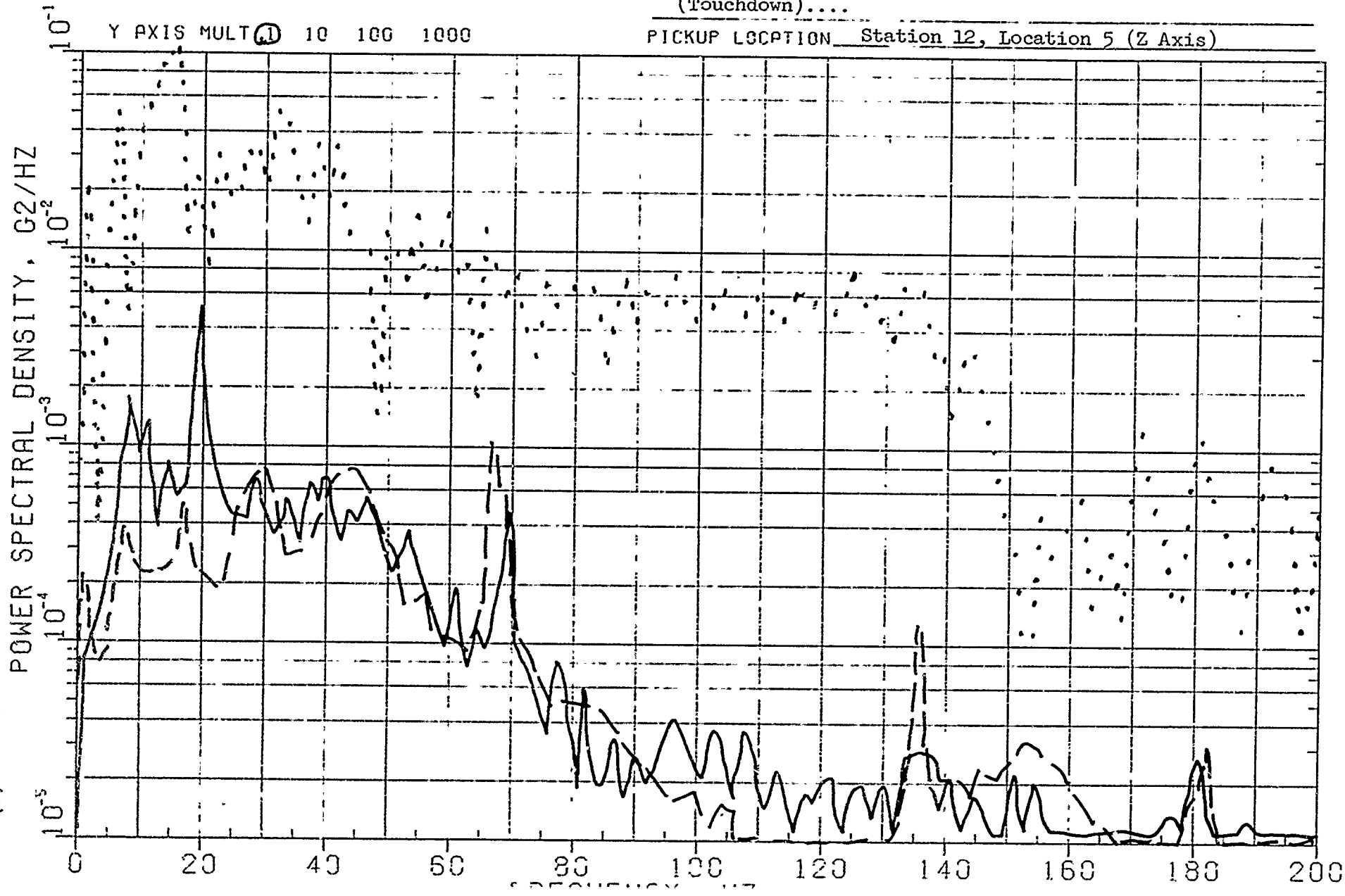
BANDWIDTH 1.6 HZ

DEG. OF FREEDOM -

TEST TITLE Composite PSD Graph TEST DATE 11/13/74-11/15/74

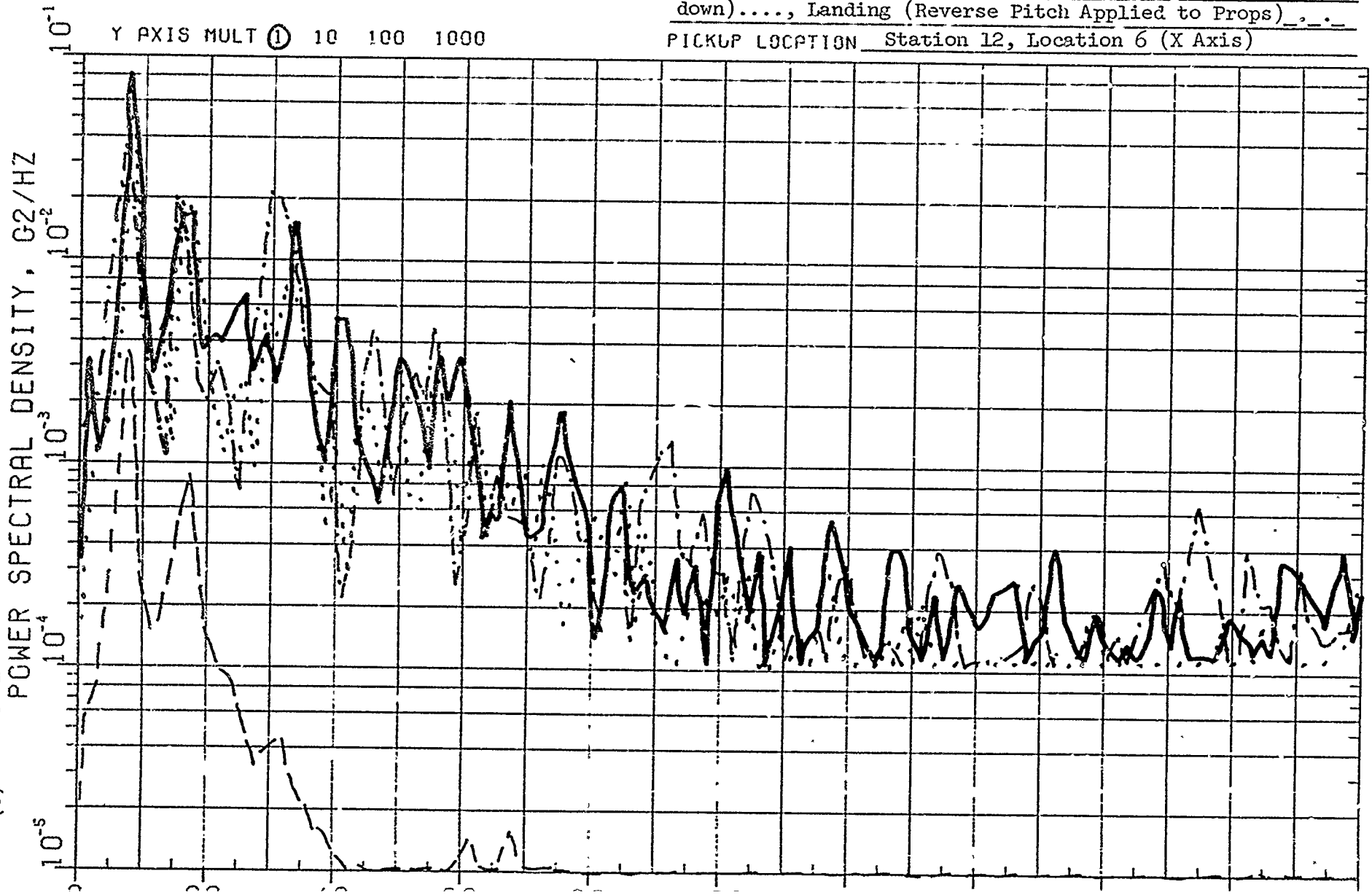
TEST CONDITION Take-off , Flying , Landing (Touchdown)....

PICKUP LOCATION Station 12, Location 5 (Z Axis)



BANDWIDTH 1.6 HZ
DEG. OF FREEDOM -

TEST TITLE Composite PSD Graph TEST DATE 11/13/74-11/15/74
TEST CONDITION Take-off ____, Flying ____, Landing (Touch-down)...., Landing (Reverse Pitch Applied to Props) _._._
PICKUP LOCATION Station 12, Location 6 (X Axis)



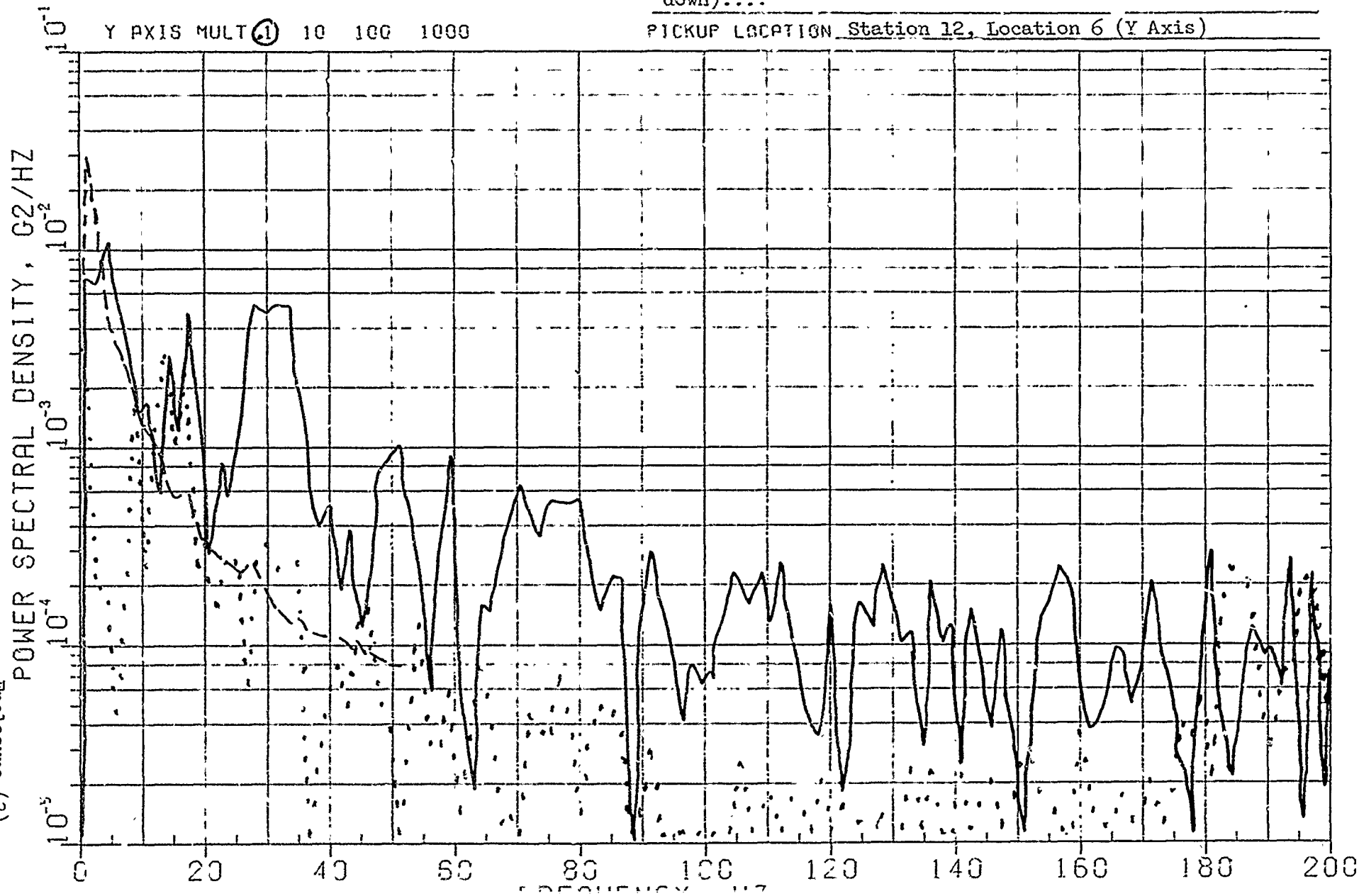
BANDWIDTH 1.6 HZ

DEG. OF FREEDOM "

TEST TITLE Composite PSD Graph TEST DATE 11/13/74-11/15/74

TEST CONDITION Take-off, Flying, Landing (Touch-down)....

PICKUP LOCATION Station 12, Location 6 (Y Axis)



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DEG. OF FREEDOM -

TEST TITLE Composite PSD Graph TEST DATE 11/13/74-11/15/74
TEST CONDITION Take-off , Flying , Landing (Touchdown)....
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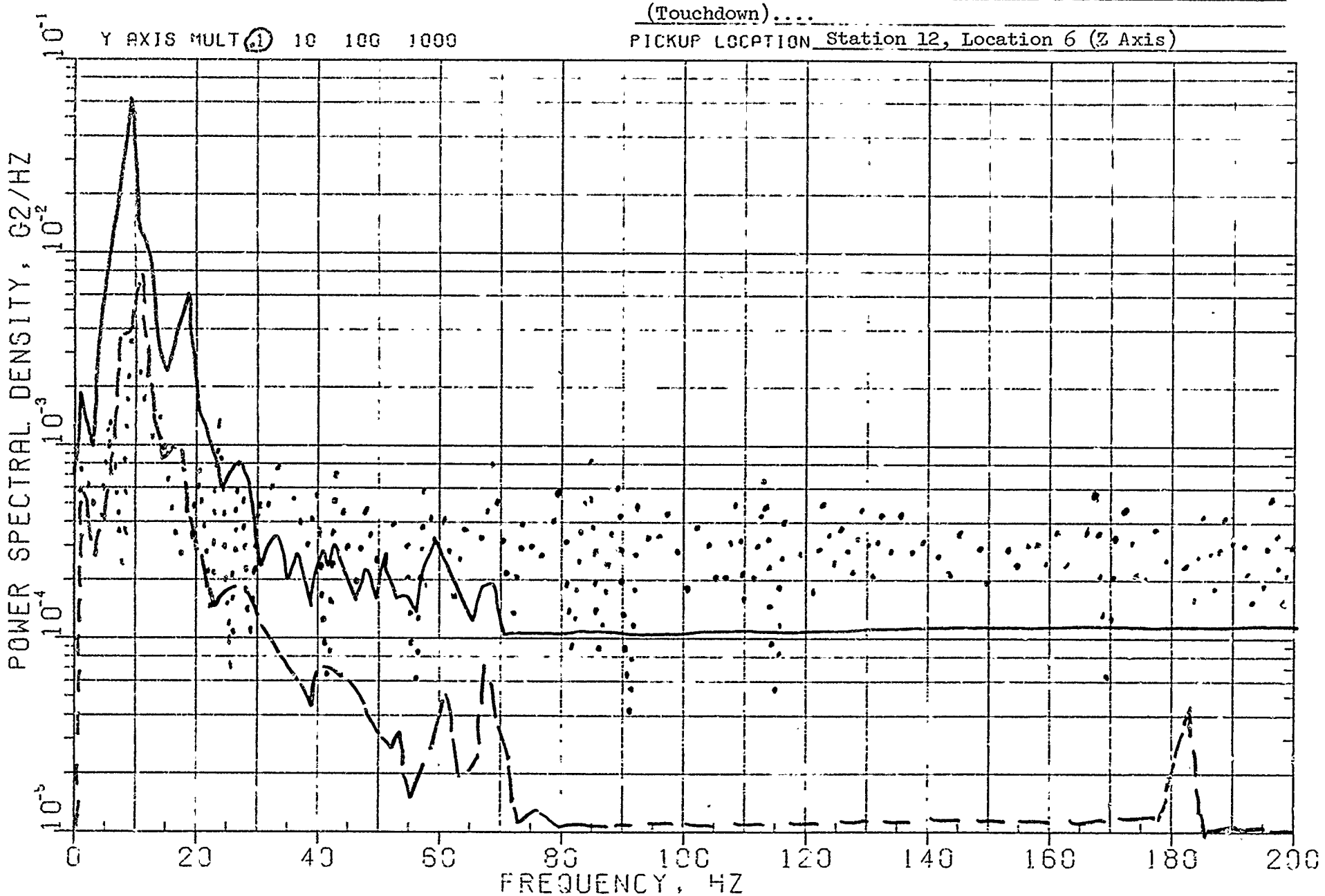

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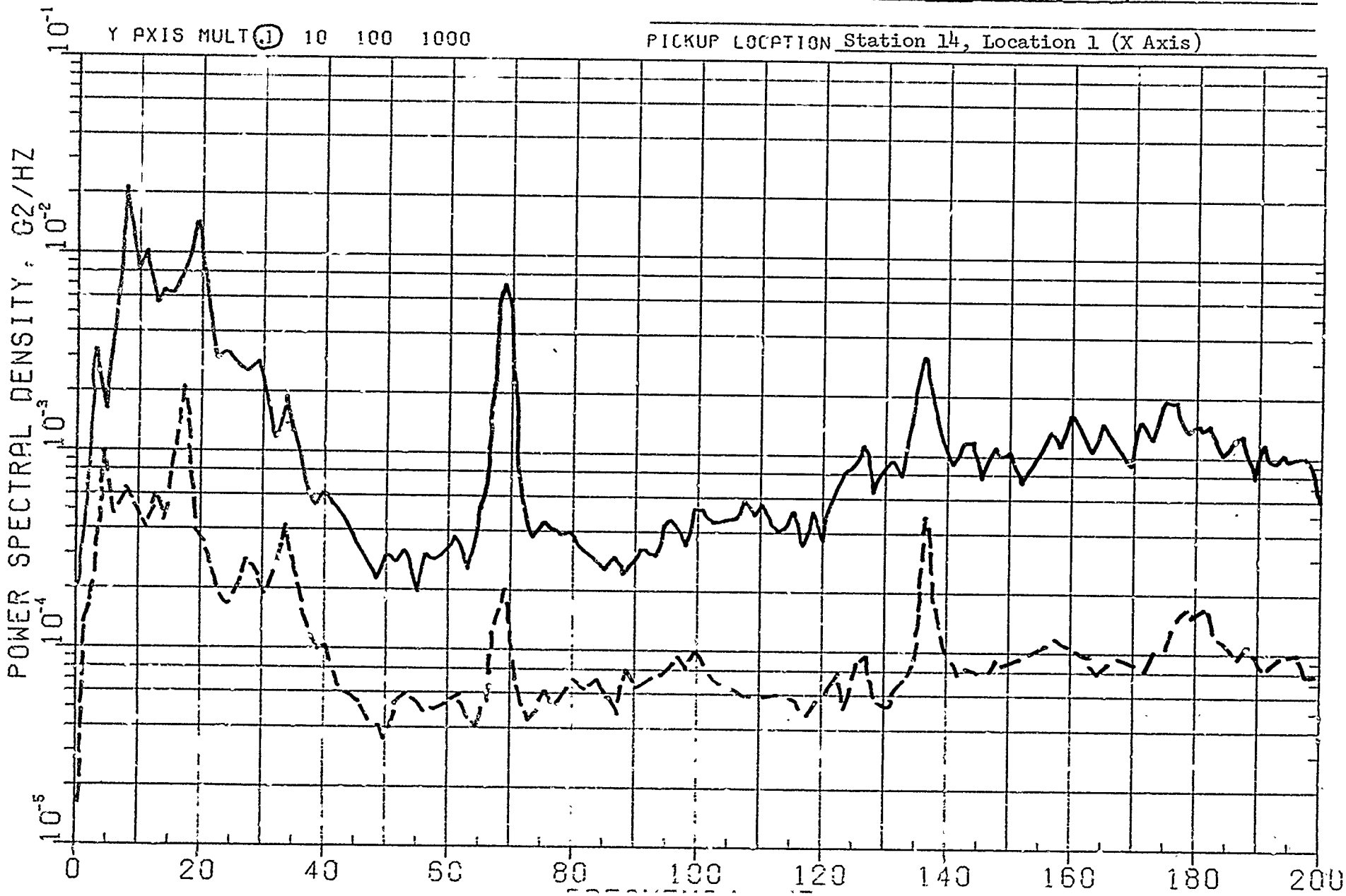
TEST TITLE Composite PSD Graph TEST DATE 11/13/74-11/15/74
TEST CONDITION Take-off , Flying ,

PICKUP LOCATION Station 14, Location 1 (X Axis)

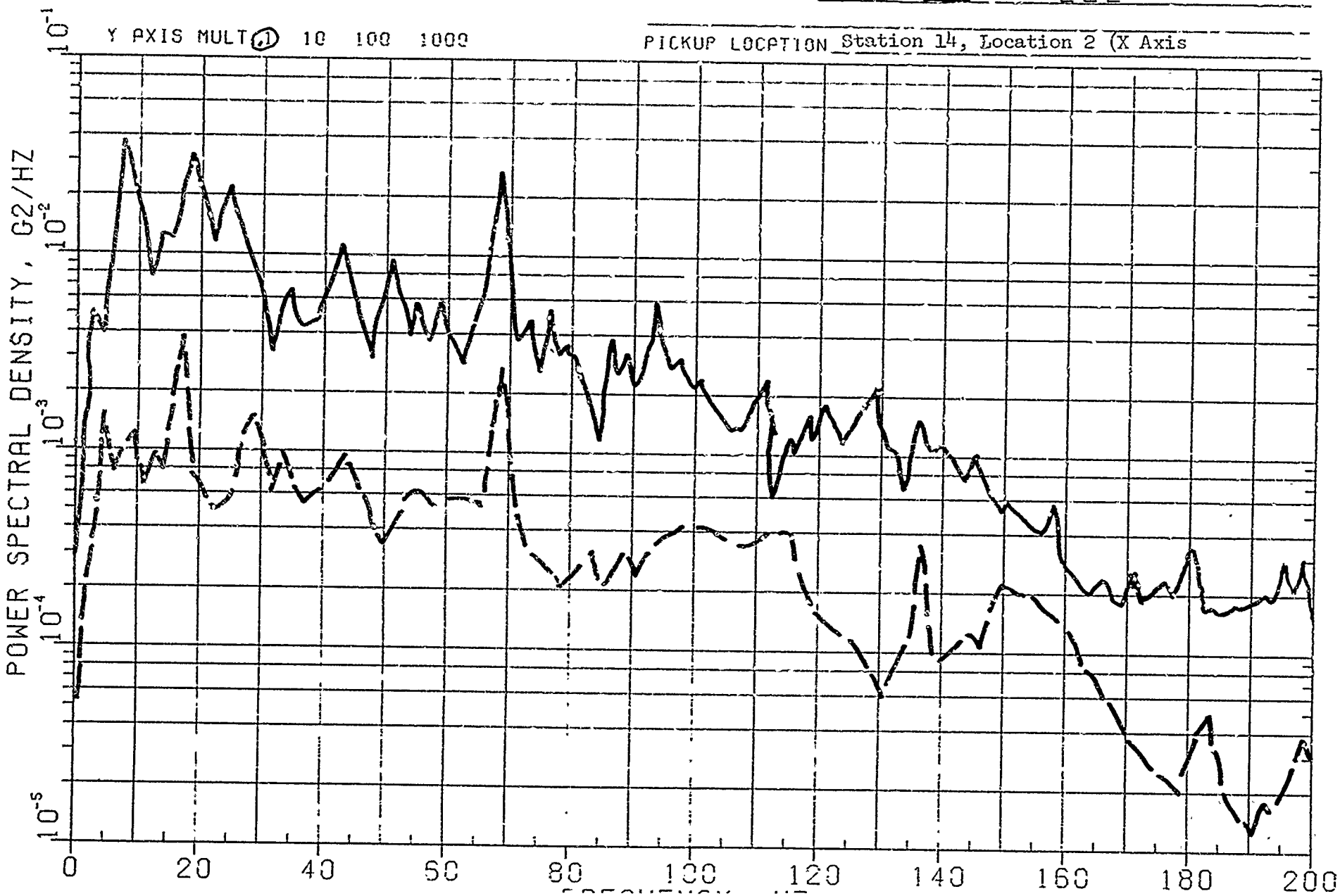


Enclosure (4)
Page 1 of 3

BANDWIDTH 1.6 HZ
DEG. OF FREEDOM -

TEST TITLE Composite PSD Graph TEST DATE 11/13/74-11/15/74
TEST CONDITION Take-off, Flying

PICKUP LOCATION Station 14, Location 2 (X Axis



Enclosure (4)
Page 2 of 3

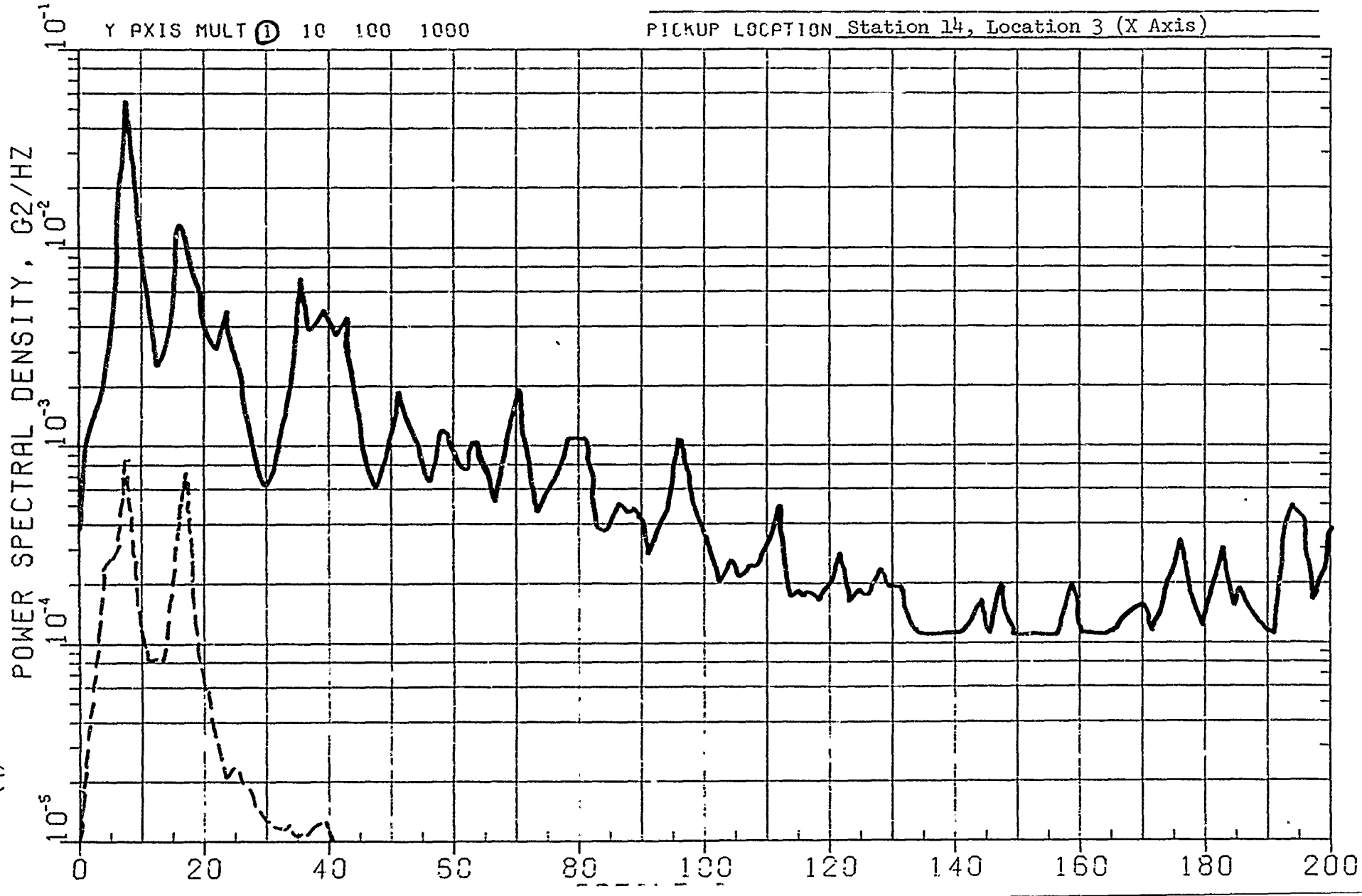
BANDWIDTH 1.6 HZ

DEG. OF FREEDOM -

TEST TITLE Composite PSD Graph TEST DATE 11/13/74-11/15/74

TEST CONDITION Take-off, Flying

PICKUP LOCATION Station 14, Location 3 (X Axis)



APPENDIX E

Recommended Vibration Requirements

Figure I - Recommended Vibration Spectrum for Tape Recorder RD-375/ALR-60 (Take-off and Landing)

Figure II - Recommended Vibration Spectrum for Tape Recorder RD-375/ALR-60 (In-flight)

Recommended Vibration Test Procedure
for Tape Recorder RD-375/ALR-60

a. For simulation of take-off and landing environments - The Tape Recorder shall be subjected to a laboratory Vibration Test in accordance with MIL-T-5422F, Procedure I, Part I, except the applicable curve shall be Figure I detailed herein. For the purpose of this test, the Tape Recorder shall be hard-mounted (without the external isolators) to the vibration exciter. Instrumentation shall be installed throughout the Tape Recorder to identify resonances and insure resonance dwells are performed at the resonant frequency of the internal isolators (for the present configuration this is 8 Hz (major) and 17 Hz (secondary)). The Tape Recorder shall be electrically energized for the duration of the test. It is not required that the Tape Recorder comply with the performance requirements during the vibration exposure; however, at the completion of the vibration exposure, an operational test shall be performed to verify compliance with the performance requirements. No damage shall be incurred as a result of this exposure and the performance of the Tape Recorder shall not be degraded as a result of this exposure.

b. For simulation of in-flight environment - The Tape Recorder shall be subjected to a laboratory Vibration Test in accordance with MIL-T-5422F, Procedure I, Part I, except the applicable curve shall be Figure II detailed herein. For the purpose of this test, the Tape Recorder shall be hard-mounted (without external isolators) to the vibration exciter. Instrumentation shall be installed throughout the Tape Recorder to identify resonances and insure resonance dwells are performed at the resonant frequency of the internal isolators (for the present configuration this is 8 Hz (major) and 17 Hz (secondary)). The Tape Recorder shall be operated and shall comply with the applicable performance requirements during this exposure. Also, no damage shall be incurred as a result of this exposure.

Figure I - Recommended Vibration Spectrum for Tape Recorder RD-375/ALR-60 (Take-off and Landing)

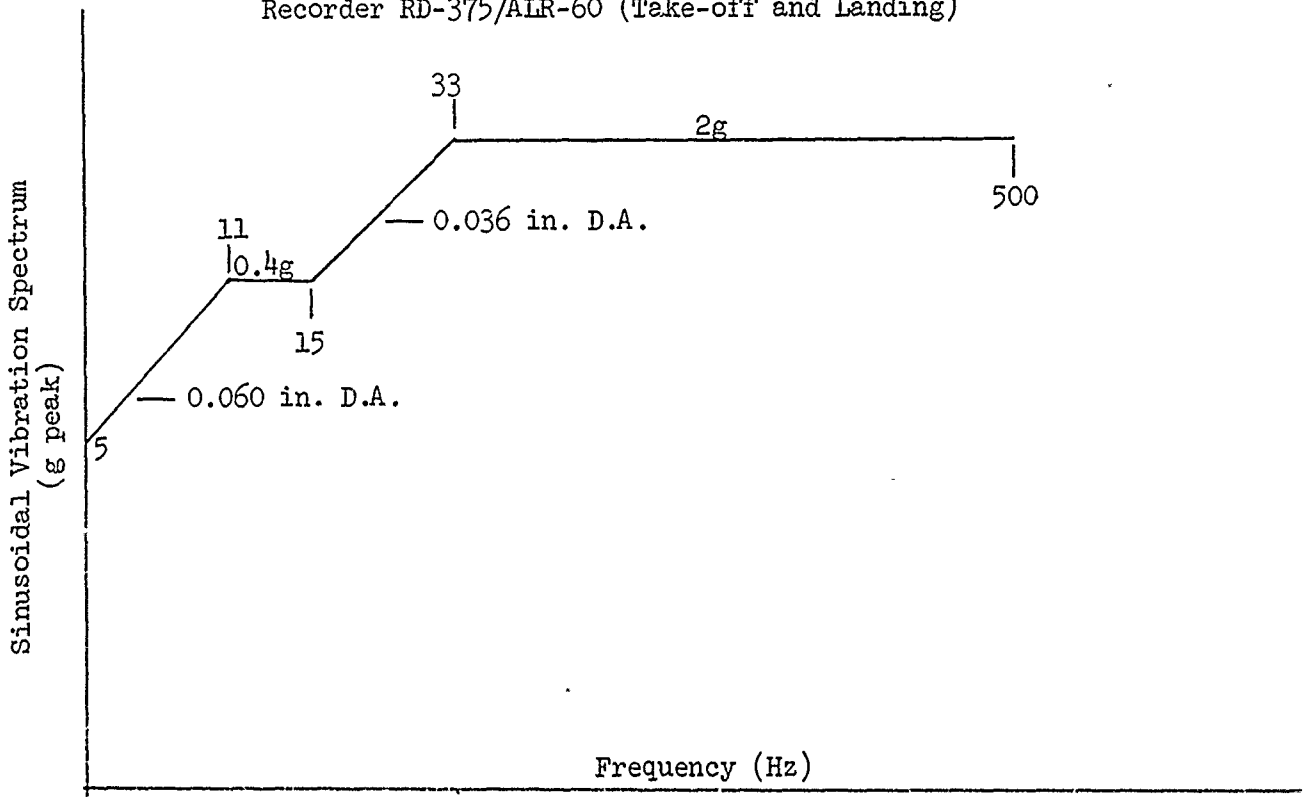
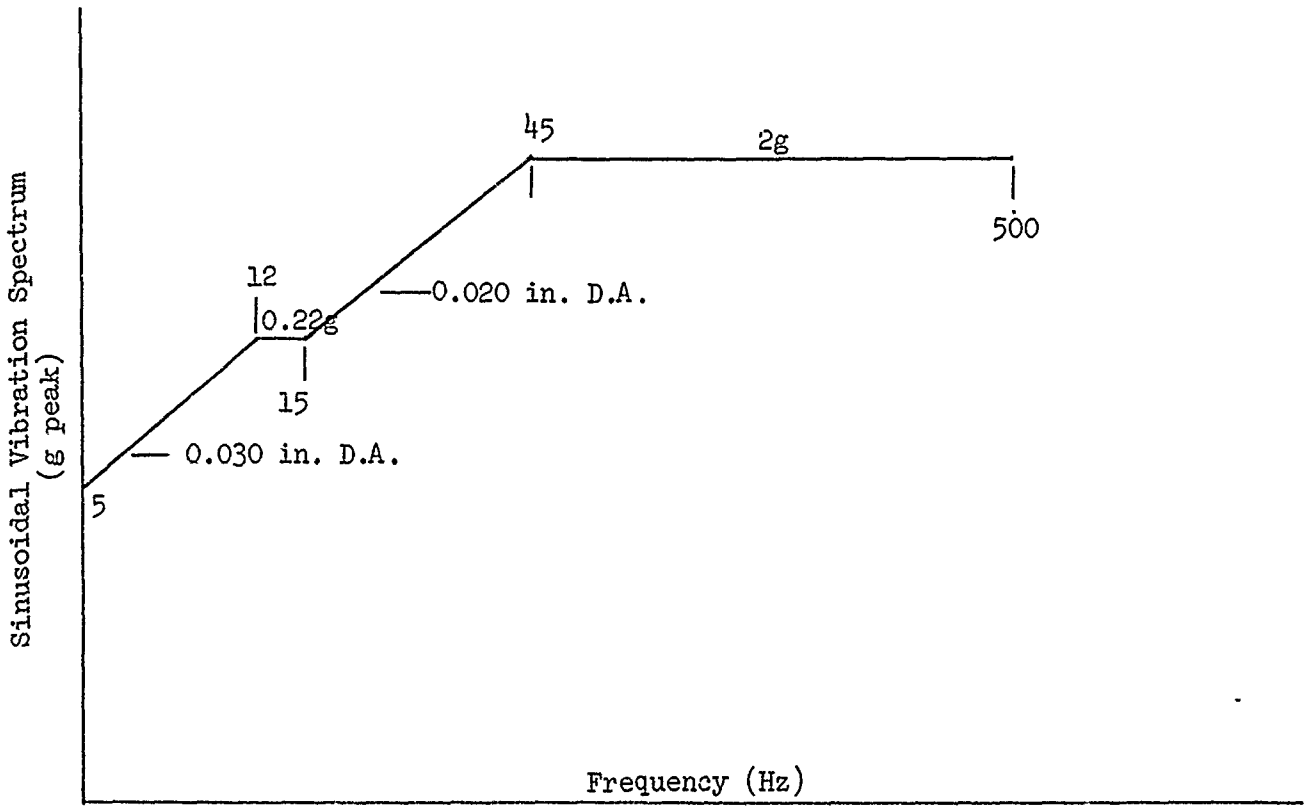


Figure II - Recommended Vibration Spectrum for Tape Recorder RD-375/ALR-60 (In-flight)



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