Bendix

Aerospace Systems Division

ALSEP Array E Engineering Model Subpackage No. 1 with LSG - Design Limit Vibration Test Results

NO.	REV. NO.
ATM-1091	

DATE 3/25/72

This technical memorandum represents the engineering vibration test report for EEM Subpackage No. 1 with LSG. In general, test results were quite satisfactory. The capability of the subpack 1 structure to endure specified ALSEP vibration environment without failure or structural deformation was established. In addition it was demonstrated that the component dynamic environments are consistent with specification requirements.

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1.0 INTRODUCTION

The original EEM subpack 1/LSG vibration tests were conducted with the LSG supported by four shock/vibration isolators. Sinusoidal X-axis sweep test results indicated the isolators did not perform as predicted by analysis. Transmissibility at resonance (low frequency) was extremely high (15 instead of 3 as predicted). High frequency response levels were expected to be negligible, but instead were significant and in some cases quite severe.

The isolators were replaced with another set and the X-axis sinusoidal sweep test was repeated. The results were unchanged. Since the response levels with isolators were intolerable, it was decided to replace them with steel bushings (i.e. hardmount the LSG).

The subsequent Array E engineering model (EEM) of Subpack 1, with the LSG hardmounted was then subjected to the design limit vibration levels as specified for ALSEP. The primary purpose of the test was to verify the structural integrity of the system and to establish that the component environments are consistent with component specifications given in references 1 & 2.

2.0 TEST ARTICLE

EEM Subpack 1 and its major components consist primarily of EEM structure, with the exception of a modified EDM primary structure. The CSE and the individual experiments (LSG, LSP, & LMS) were dynamic simulators. A list of the major components is given in Table 1. A photograph of Subpack 1 with the LSG is shown in Figure 1.

3.0 TEST DESCRIPTION

EEM Subpack 1 was subjected to sinusoidal and random vibration tests as outlined in Table 2. The subpack experienced sinusoidal sweep, launch and boost random, and lunar descent random environments in all three axes (X, Y, Z) for a total of nine individual vibration tests. Further information with regards to the test plan is contained in reference 3.

4.0 INSTRUMENTATION

Eighteen accelerometers were mounted to Subpack 1 and monitored during each of the EEM vibration tests. Figure 2 shows a layout of Subpack 1 with the approximate locations of the accelerometers. Additional information regarding locations and response directions is listed in Table 3 and reference 4.

5.0 RESULTS

Response data is given in Figures 8-52 for each of the three orthogonal axes for the LSG, LMS, LSP, and the CSE/Thermal Plate components. Response envelopes giving g-peak and power spectral density values due to the sinusoidal and random inputs are shown. Superimposed on each of the response envelopes are specification levels to which the individual components are designed and tested. Solid curves represent response such that the output is in the same direction as the input (e.g. response in X-direction due to input in X-direction). Dashed lines represent cross axis response data (e.g. response in X-direction due to input in Y-direction). By plotting in this manner a comparison can be made between measured response levels and component specification levels across the frequency bandwidth. Table 4 is included to show the maximum response levels for the individual components. Both g-peak and g(rms) levels due to sinusoidal and random vibration, respectively, are shown.

Figures 8-16 show the response levels for the LSG due to the sinusoidal, launch and boost random, and lunar descent random inputs. Figure 8 shows a maximum X-response of 10.3 g-peak at 58 Hz due to the sinusoidal input. Figures 9 & 10 show the maximum Y and Z sine response to be less than 3.0 g-peak. Figures 11-16 show the power spectral density responses for the random environments. In general these plots show higher power spectral density levels in the lower frequency range tapering to lower power spectral density levels in the higher frequency range. Of course, all response curves agree with the LSG specification levels which have been modified from previous levels as a direct result of this test.

Figures 17-25 show response levels for the LSP due to the different input environments. Figures 17-19 show the sine response levels to be entirely consistent with the specification levels (Ref. 2). A maximum 6.0 g-peak at 55 Hz was seen for the X-direction. Figure 20 shows the X-launch and boost random levels to be within specification level limits except for a peak of 0.10 g^2/Hz at 1000 Hz. Figures 21 and 22 show the Y and Z launch and boost random levels to be entirely consistent with specification limit levels. Figures 23-25 show the lunar descent random levels to be consistent with specification levels except for a spike at 1100 Hz.

Figures 26-34 show response levels for the LMS due to the sine and random vibration environments. Figure 26 shows a maximum X-response of 7.0 g-peak at 60 Hz which is compatible with specification levels. Figures 27 and 28 shows the Y and Z sine response to deviate only slightly from specification levels (Ref. 2). Figures 29-34 show the launch and boost and the lunar descent

random responses to be consistent with specification limit levels except for slight peaks in the X-direction at about 1100 Hz.

Figures 35-52 show the response levels for the CSE/Thermal Plate components. Figures 35-43 pertain to the components near the α location, and Figures 44-52 pertain to the components near the β location as shown in Figure 2. A maximum sine response of 10.5 g-peak at 60 Hz was found in the X-direction. This compares with a specification level of 9.0 g-peak ± 10%. The maximum Y and Z responses of 2.7 g-peak were well within the specification levels. For the launch and boost random vibration environment a few isolated power spectral density peaks as high as .085 g^2/Hz are seen to exceed the specification levels of .025 g^2/Hz in the 300-1300 Hz frequency range for the X and Z response directions. However, these peaks are within the tolerance range as specified for ALSEP random vibration testing. That is, if the above mentioned spikes were experienced by CSE components during a component design limit random vibration test, they would be acceptable. For the Y direction the launch and boost response is consistent with specification levels. For the lunar descent random environment all response levels are entirely consistent with specification levels except for slight excursions at isolated frequencies.

6.0 CONCLUSIONS

Vibration testing of EEM-SP1/LSG was completed 27 August 1971. As stated above the original vibration testing of EEM SP1 was performed with the LSG supported by four shock/vibration isolators resulting in high component response levels. The LSG isolators were then replaced by steel bushings (hardmounted), and then the subpack testing was restarted and completed. The ensuing response levels were significantly lower for all components. In general the individual component response levels due to the specified ALSEP design limit vibration levels were in good agreement with the component specifications. The LSG vibration specification (Reference 1) reflected the results of analysis of a shock mounted system. Hardmounting the LSG would necessitate a specification revision (Reference 5). In order to verify that the experiment would survive the new environment, the engineering model (note: not the EEM-LSG) was subjected to a series of vibration tests which represented the recommended specification revision. The new environment caused no difficulties for the LSG. Hence, the hardmount configuration and corresponding specification change were approved (Reference 6).

For the LSP, LMS, and thermal plate components only minor excursions were seen outside the specification envelopes for the random vibration testing.

Hence it was concluded that the basic structural integrity of the system has been verified, and with the above mentioned modifications to the LSG specifications that the component environments are consistent with the design limit level component specifications.

7.0 REFERENCES

1.	IC 314133	Interface Control Specification for Lunar Surface Grivimeter Experiment Subsystem 4/30/71
2.	ATM-964	ALSEP Array E Component Non-Operating Vibration Specifications 2/2/71
3.	Memorandum No. 9712-311	ALSEP Array E EEM Vibration Test Plan 4/27/71
4.	Memorandum No. 9712-383	EEM Instrumentation Plan for Vibration Testing 6/10/71
5.	Memorandum No. 9712-572	ALSEP Array E Review Meeting
6.	Memorandum No. 984-ME-158	Vibration Spectrum Specification

TABLE 1

EEM SP 1/LSG HARDWARE

Primary Structure	EDM (modified)
Sunshield Assembly	EEM (reworked)
Antenna mast	EEM
Curtain	EEM
Rear curtain retainer	EEM
Thermal plate	EEM
CSE	EEM (dynamic simulator)
LSG	EEM (dynamic simulator)
LSP (geophones)	EEM (dynamic simulator)
LMS	EEM (dynamic simulator)

TABLE 2

EEM SP1/LSG DESIGN LIMIT VIBRATION TEST LEVELS

Test	Axis	Test Levels
Sinusoidal	X	Fig. 3
Random (L&B)	X	Fig. 4
Random (L. D.)	X	Fig. 7
Sinusoidal	Y	Fig. 3
Random (L&B)	Y	Fig. 5
Random (L. D.)	Y	Fig. 7
Sinusoidal	Z	Fig. 3
Random (L&B)	Z	Fig. 6
Random (L. D.)	Z	Fig. 7

TABLE 3

EEM SP-1/LSG INSTRUMENTATION

Loc. No.	Acc. No.	Location	Accelerometers	Response Directi
B	4, 5, 6	LSG Mtg. Platform (Right rear corner)	3	X, Y, Z
C	7	LSG Mtg. Platform (Right fwd. corner)	1	Input-axis
D	8, 9	LSG, Top	2	Y, Z
E	10, 11, 12	LSP Bracket (Left rear)	3	X, Y, Z
F	13, 14, 15	LMS Bracket (Left fwd.)	3	X, Y, Z
α	1, 2, 3	CSE/Thermal Plate (Near Xmtrs.)	3	X, Y, Z
β	16, 17, 18	CSE/Thermal Plate (Near DDP/MUX & C/D)	3	X, Y, Z

TABLE 4

EEM SPI/LSG VIBRATION RESPONSE VALUES

RESPONSE		INPUT								
		Sinusoidal			Launch & Boost Random			Lunar Descent Random		
		X	Y	Z	X	Y	Z	X	Y	Z
LSG 4-5-6	X	10.3	3.4	1.9	2.9	3.2	2.9	2.4	2.4	2.0
	Y	2.5	2.6	0.3	1.2	2.2	1.2	1.2	1.7	0.7
	Z	0.6	0.6	3.3	0.2	0.9	1.2	0.9	0.8	1.0
LSG 8 & 9	X	---	---	---	---	---	---	---	---	---
	Y	16.0	11.0	2.3	3.5	4.8	0.8	3.0	3.8	1.1
	Z	14.5	4.0	7.3	2.3	1.6	2.0	1.7	1.5	2.0
LMS 13-14-15	X	7.3	2.2	1.8	7.0	3.2	2.5	4.4	2.5	2.0
	Y	0.4	4.4	1.3	1.0	2.8	1.3	0.5	2.3	1.0
	Z	6.5	2.1	4.3	5.0	2.0	1.8	3.1	1.6	1.4
LSP 10-11-12	X	6.3	3.0	1.1	5.8	2.8	1.5	3.5	2.2	1.0
	Y	3.5	2.2	3.0	6.0	2.8	1.5	3.2	2.2	1.5
	Z	1.2	N.D.	N.D.	2.8	2.5	2.0	2.7	2.5	1.5

NOTE: Sine levels are G-Peak Values.

Random levels are G (RMS) Values.

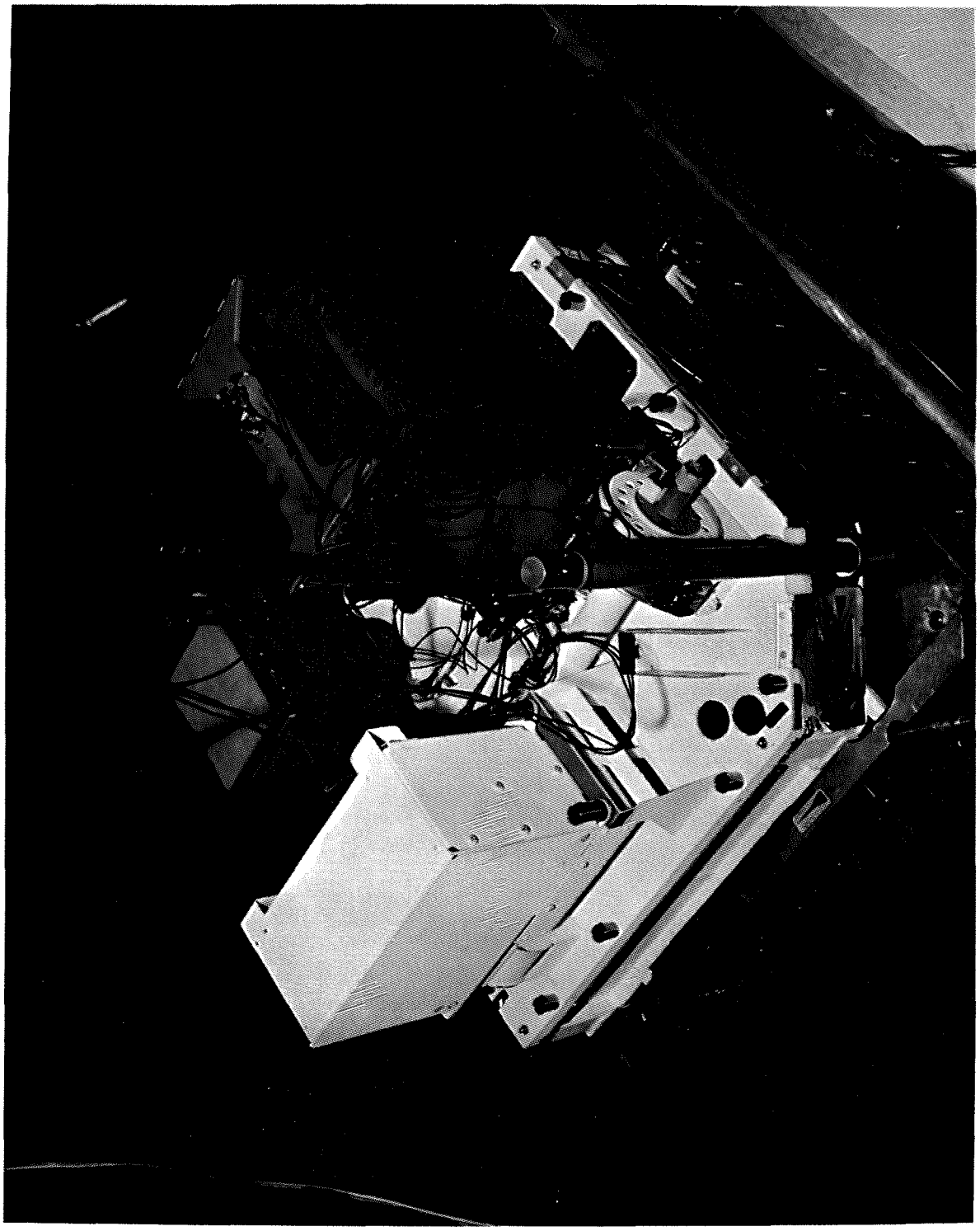


Figure 1 EEM-SP 1/LSG

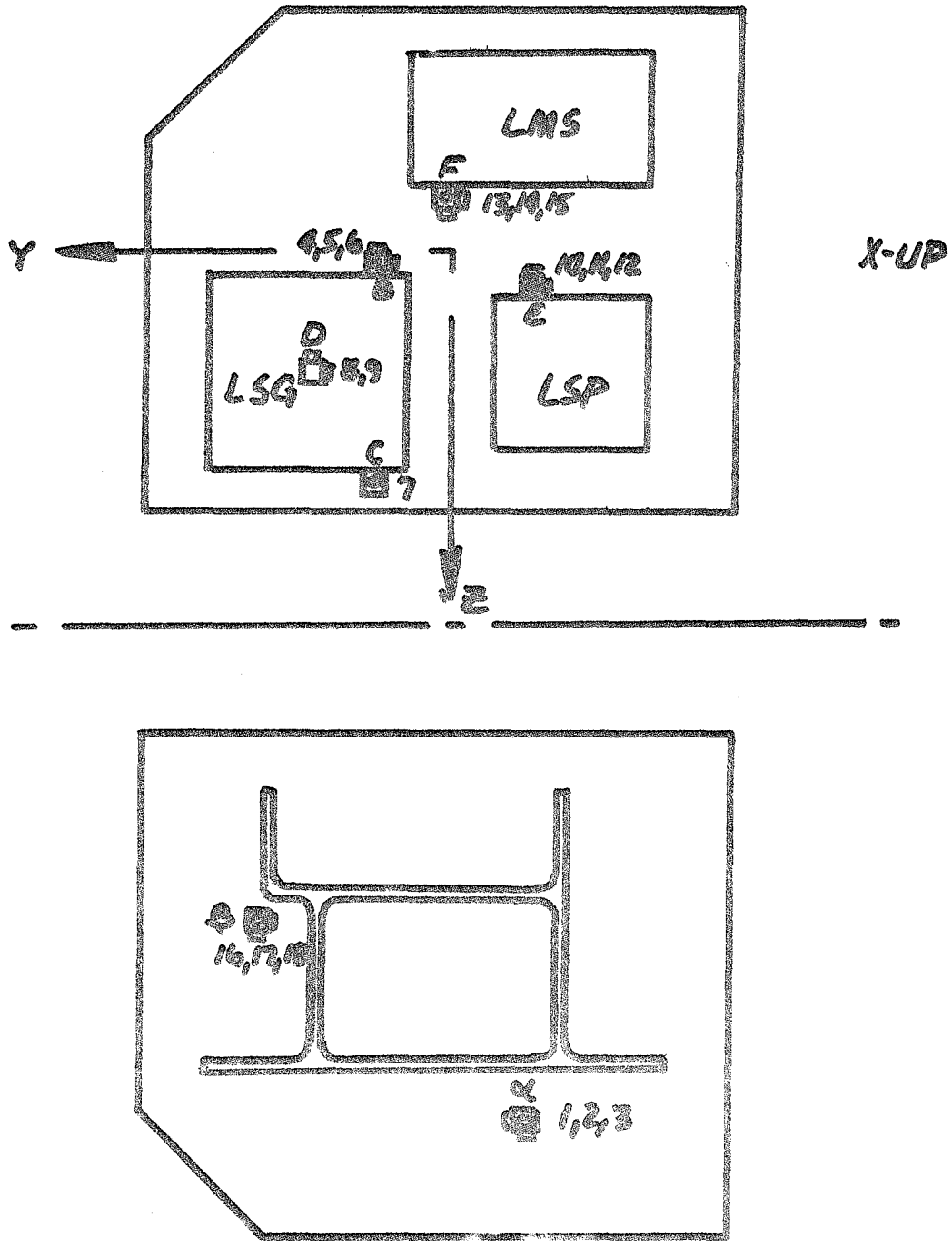


Figure 2 EEM-SP1/LSG Instrumentation

DESIGN LIMIT LEVEL

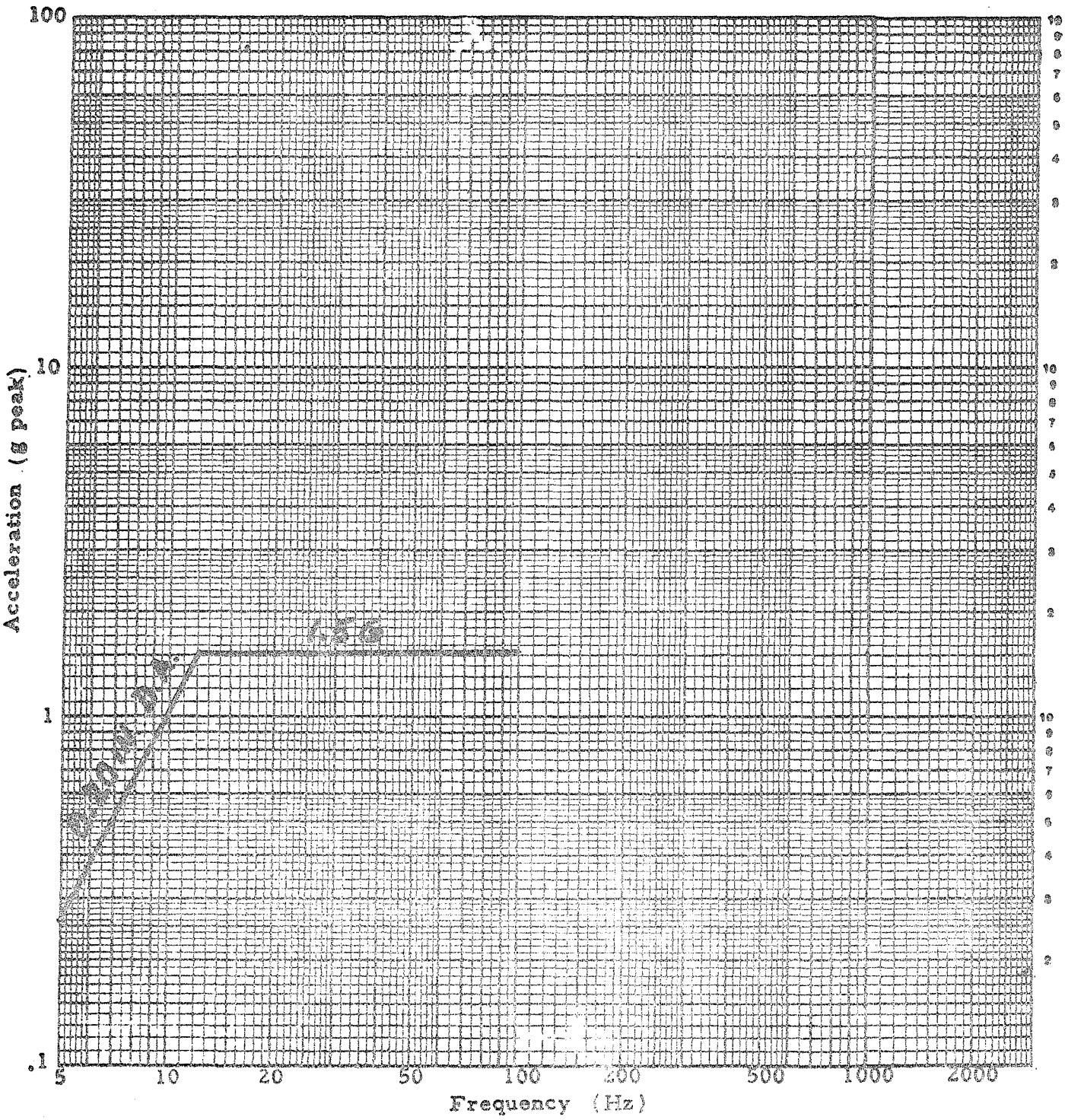
SINUSOIDAL VIBRATION

Axis: X, Y, Z

Sweep Rate: 3 OCT/MIN.

SP-1 & 2

SWEEP: 5-100-5 HZ.



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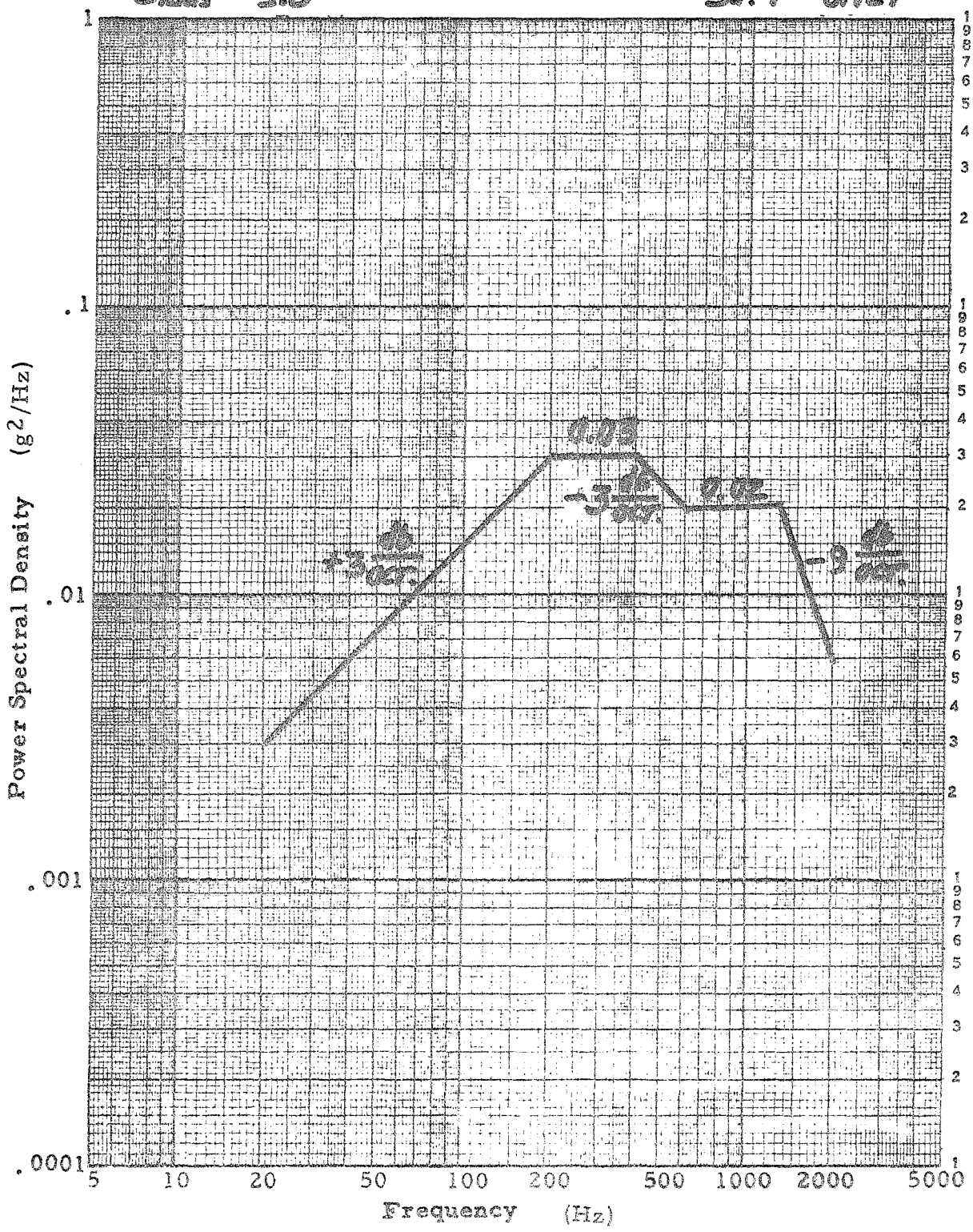
DESIGN LIMIT LEVEL L&B

RANDOM VIBRATION SPECTRUM

Axis: X

Duration: 1.0 MIN.

GRMS = 5.8 S.P.-1 ONLY



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DESIGN LIMIT LEVEL L&B

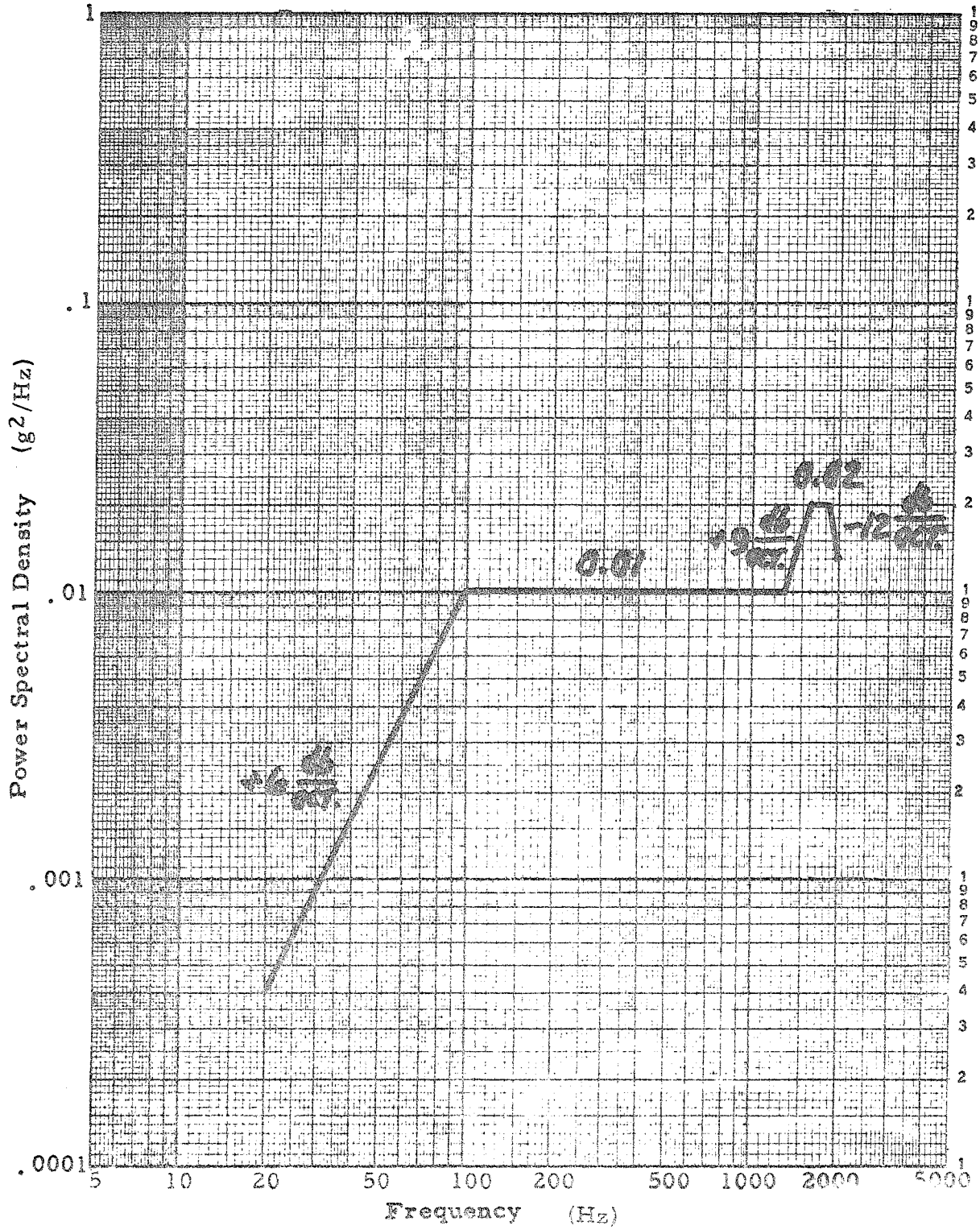
RANDOM VIBRATION SPECTRUM

Axis: Y

Duration: 1.0 MIN.

G_{RMS} = 5.0

SP. 1 & 2



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DESIGN LIMIT LEVEL L&B

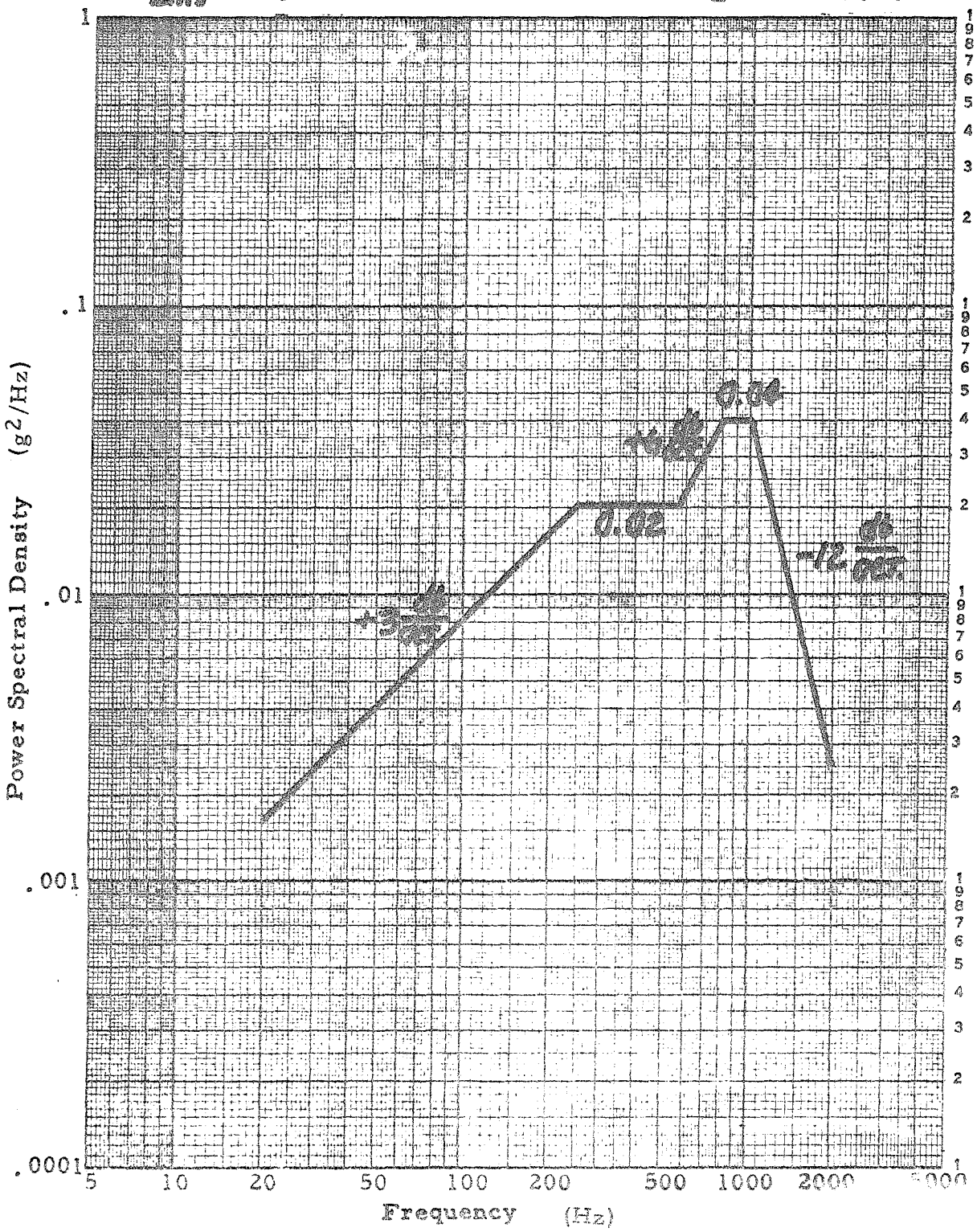
RANDOM VIBRATION SPECTRUM

Axis: Z

Duration: 1.0 MIN.

G_{RMS} = 5.9

S.P.-1 ONLY



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DESIGN LIMIT LUNAR DESCENT

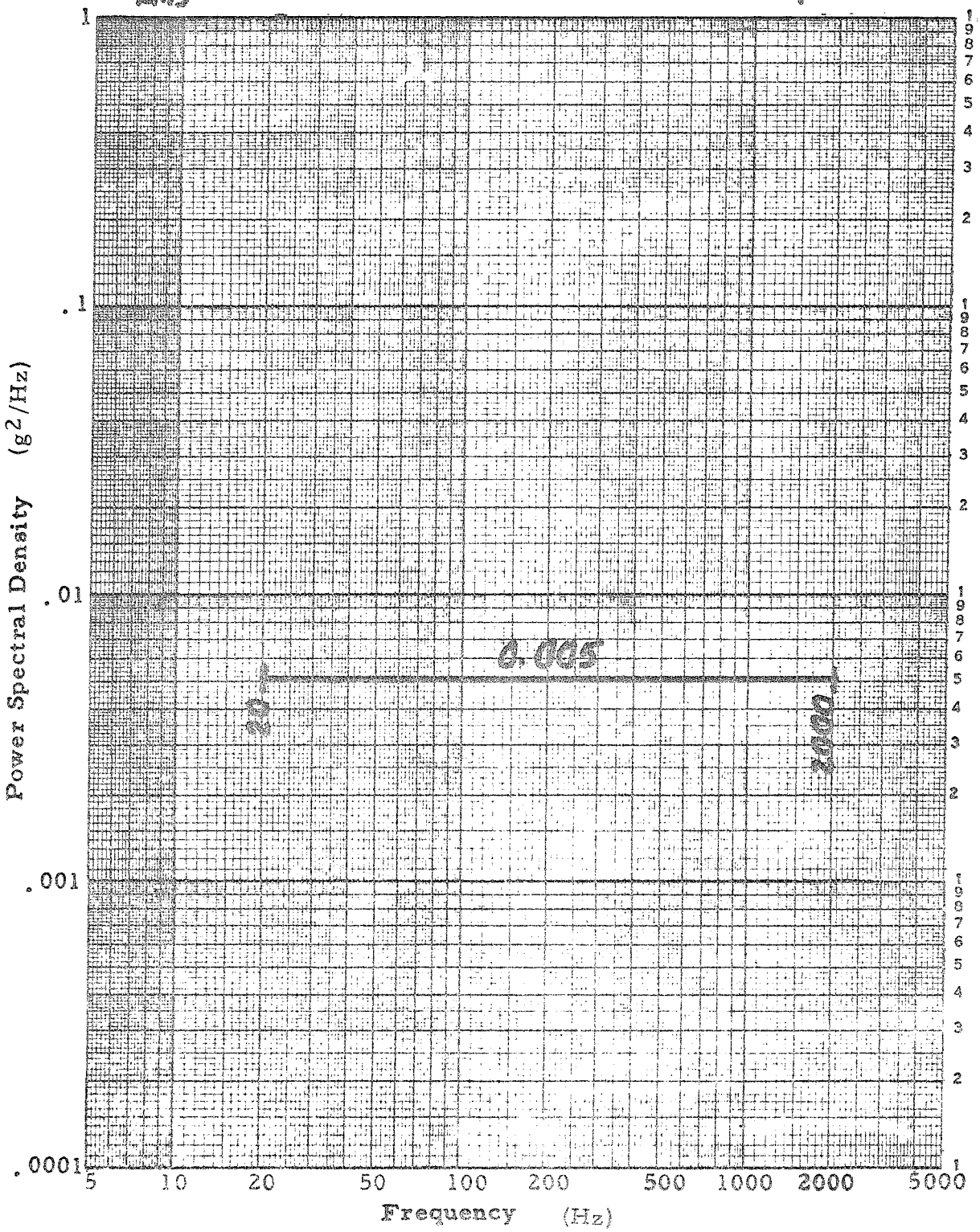
RANDOM VIBRATION SPECTRUM

Axis: X, Y, Z

Duration: 12.5 MIN/AXIS.

G_{RMS} = 3.2

SP-1 & 2



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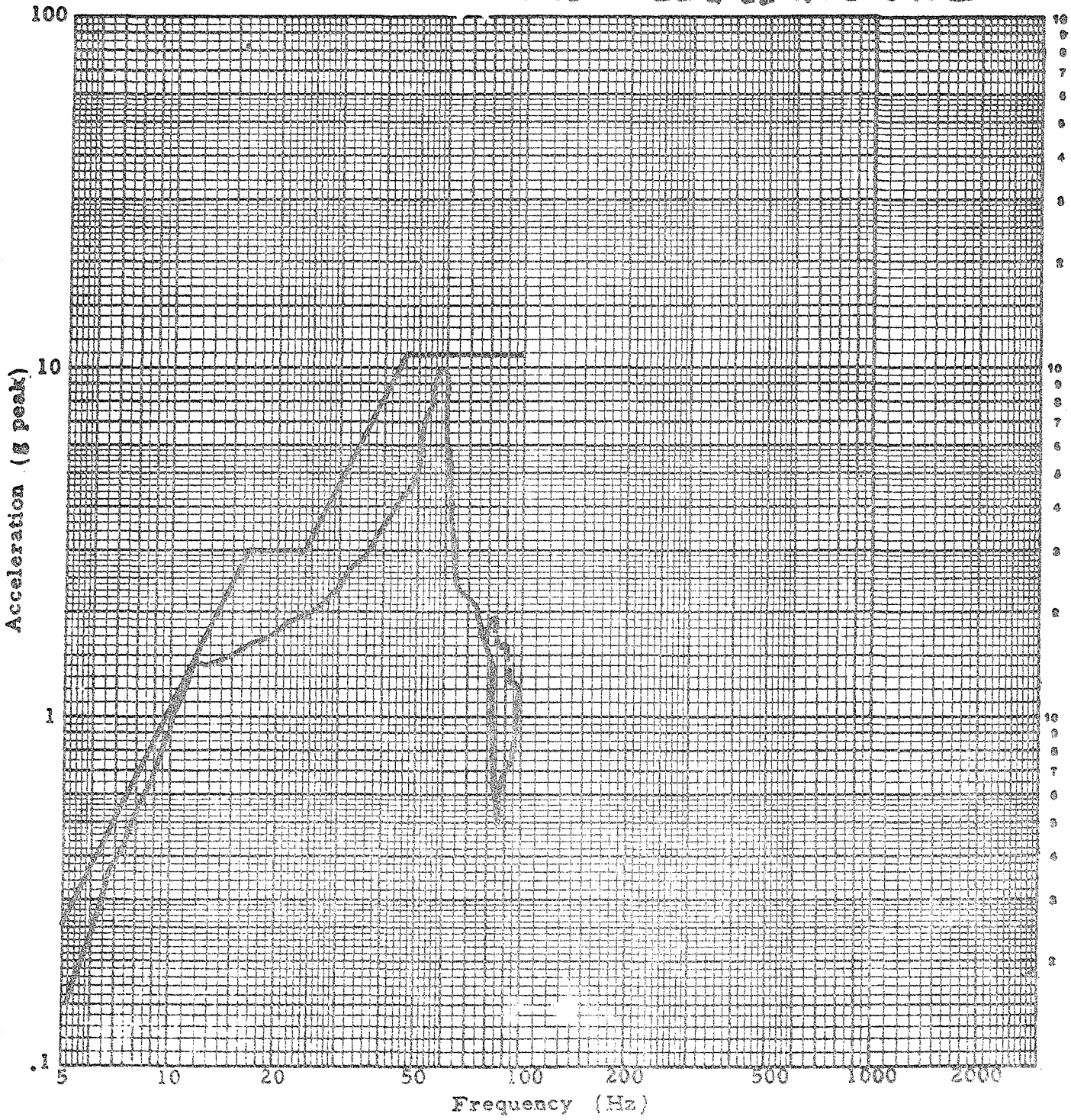
ACC. NO. 4

SINUSOIDAL VIBRATION

Axis:

Sweep Rate:

S.P. 1 W/LSG HARDMOUNTED LSG X RESPONSE



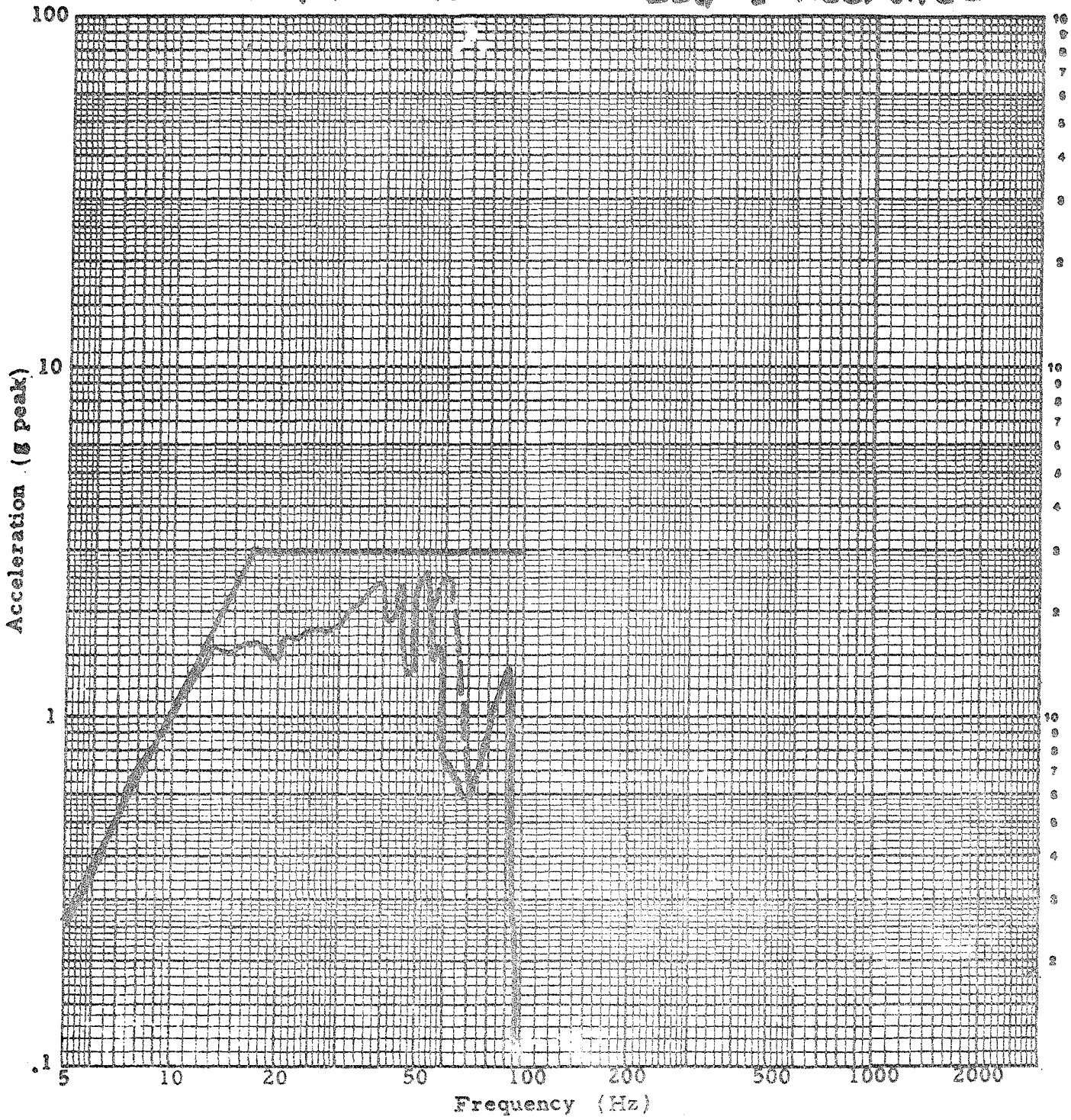
ACC. NO. 5

SINUSOIDAL VIBRATION

Axis:

Sweep Rate:

S.P. 1 W/LSG HARDMOUNTED LSG Y RESPONSE



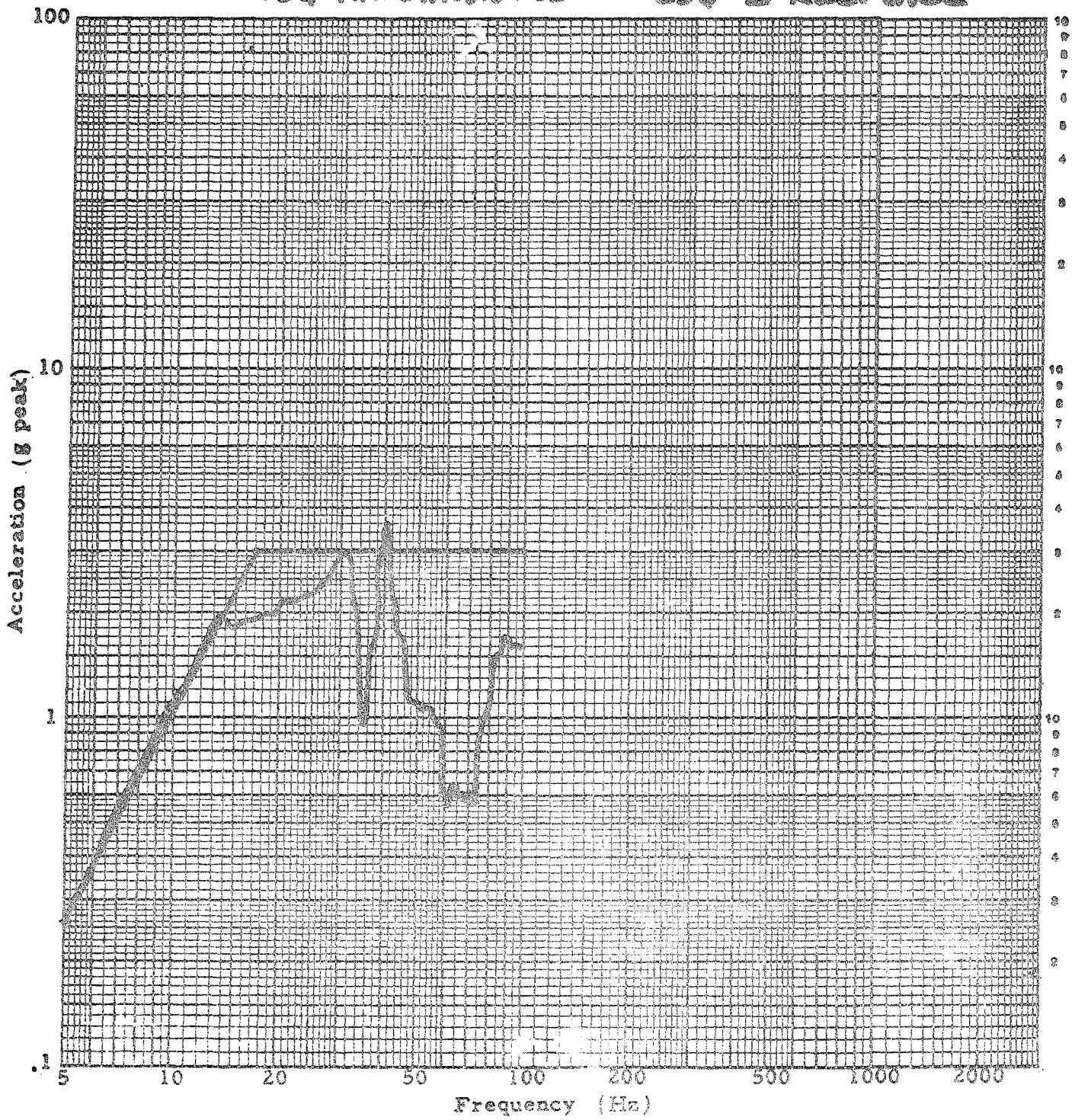
ACC. NO. 6

SINUSOIDAL VIBRATION

Axis:

Sweep Rate:

S.P. 1 W/LSG HARDMOUNTED LSG 3 RESPONSE



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ACC. NO. 4

Axis:

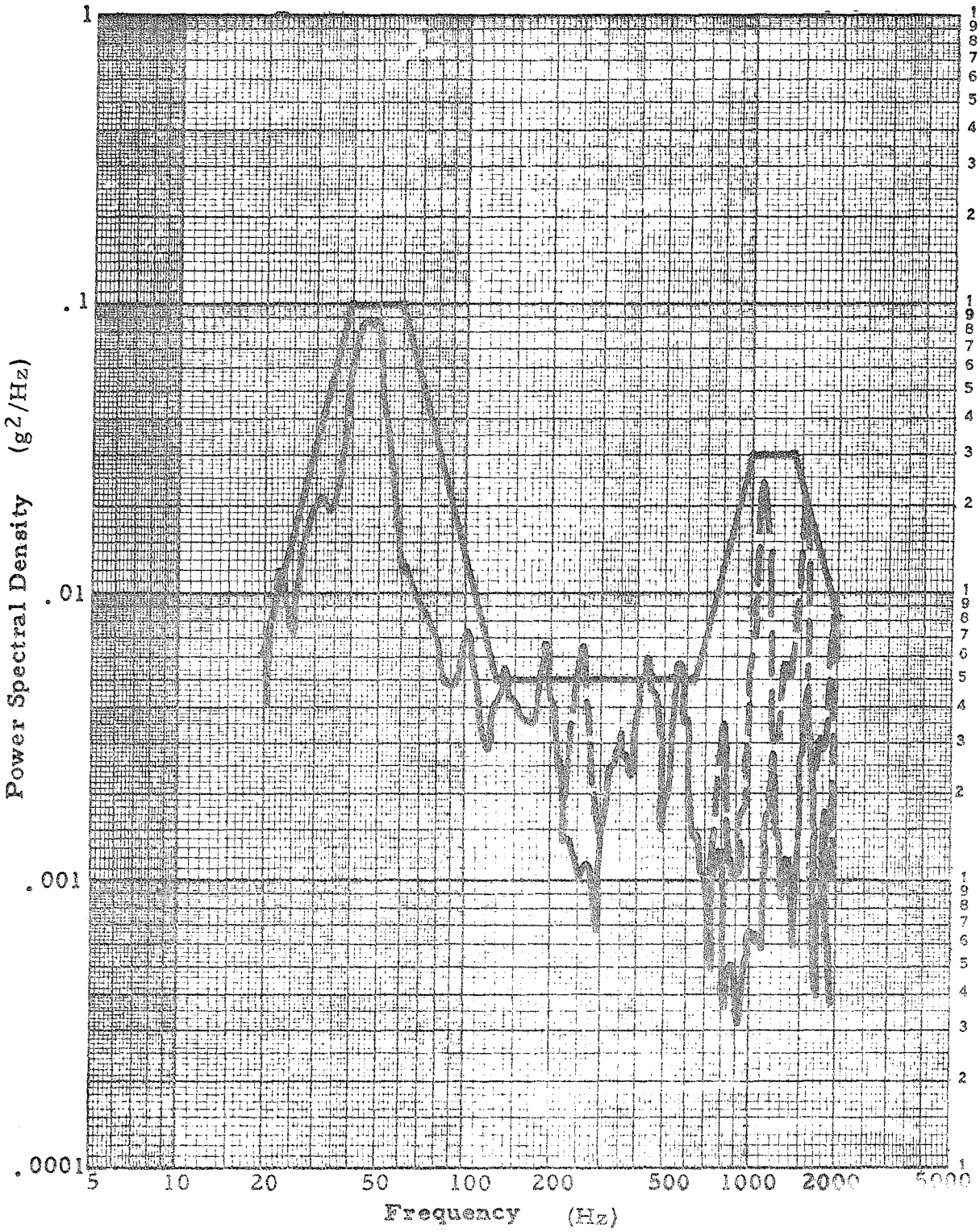
RANDOM VIBRATION SPECTRUM

LAUNCH & BOOST

Duration:

S.P. 1 W/LSG HARDMOUNTED

LSG X RESPONSE



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ACC. NO. 5

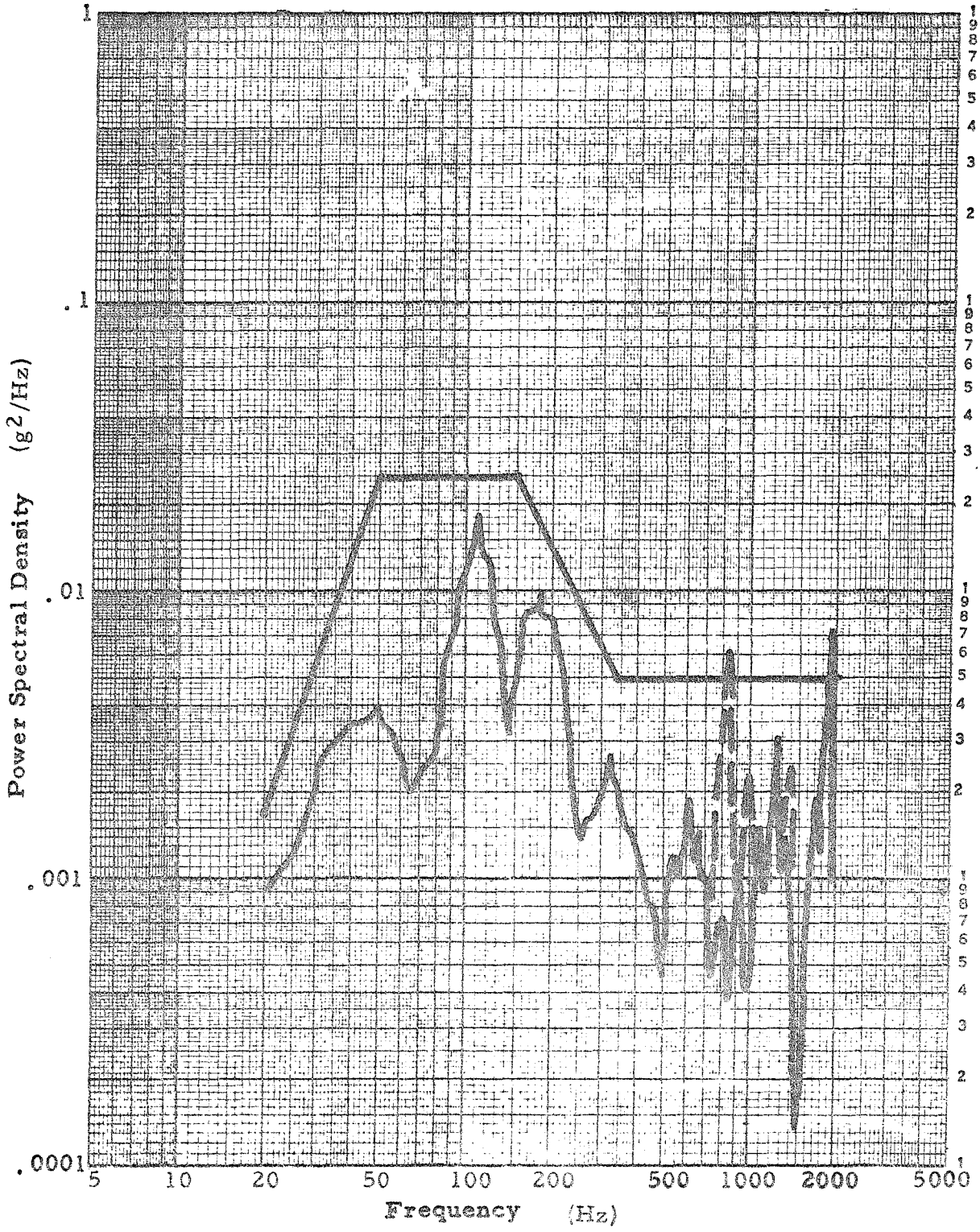
Axis:

RANDOM VIBRATION SPECTRUM

LAUNCH & BOOST

Duration:

S.P. 1 W/LSG HARDMOUNTED LSG Y RESPONSE



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ACC. NO. 6

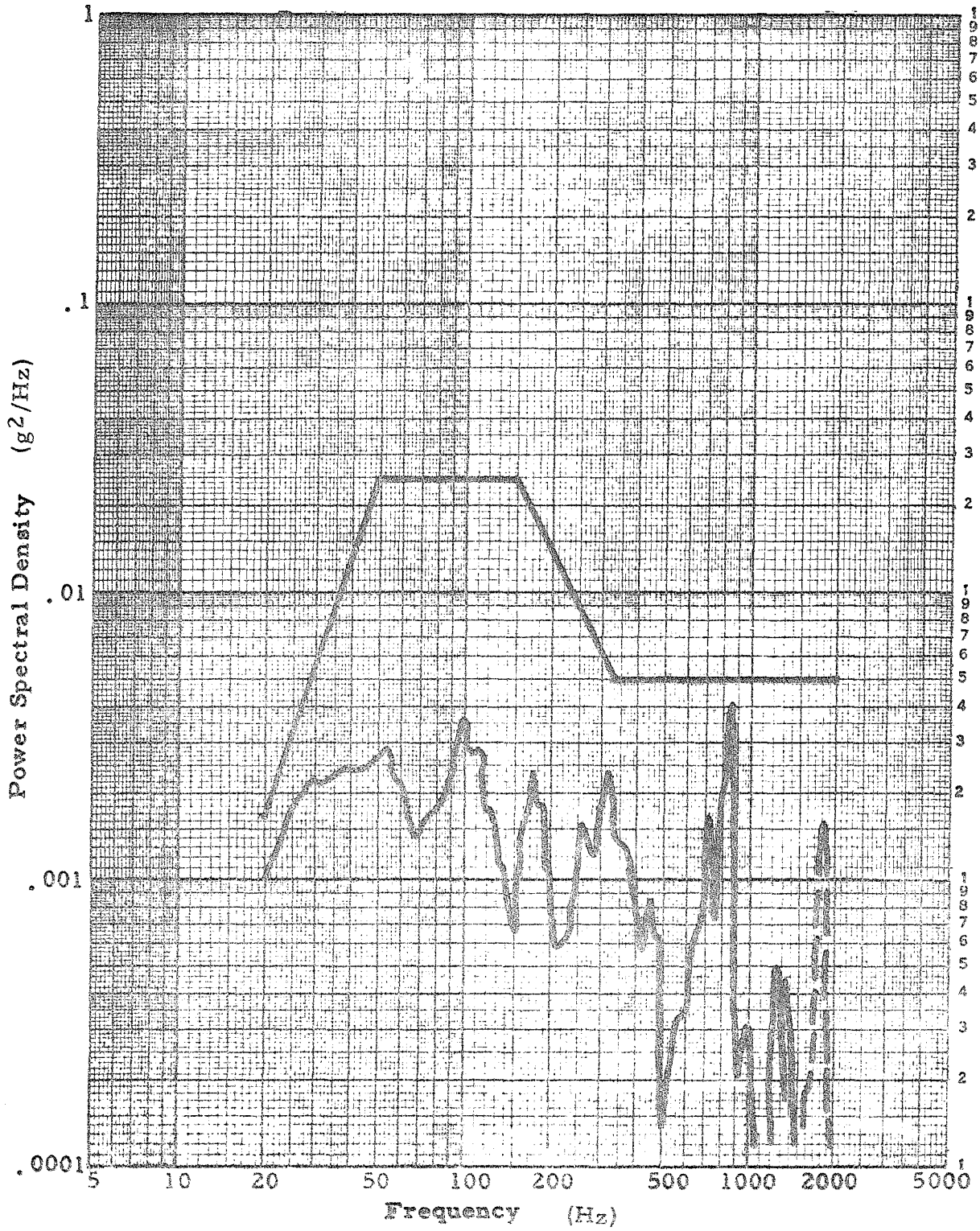
Axis:

RANDOM VIBRATION SPECTRUM

LAUNCH & BOOST

Duration:

S.P. 1 W/LSG HARDMOUNTED LSG & RESPONSE



440-91

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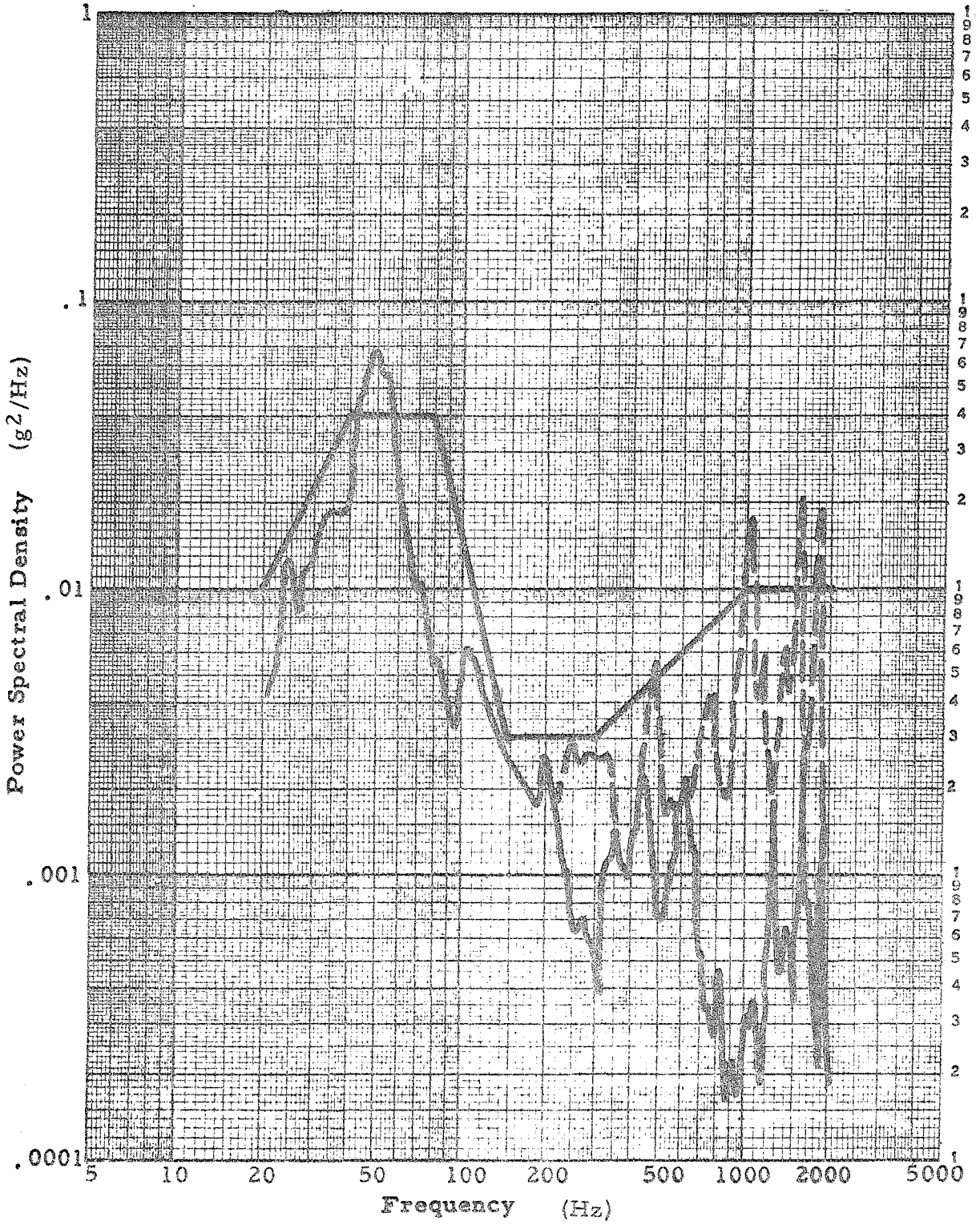
ACC. NO. 4
Axis:

RANDOM VIBRATION SPECTRUM

LUNAR DESCENT

Duration:

S.P. 1 W/LSG HARDMOUNTED LSG X RESPONSE



440-91

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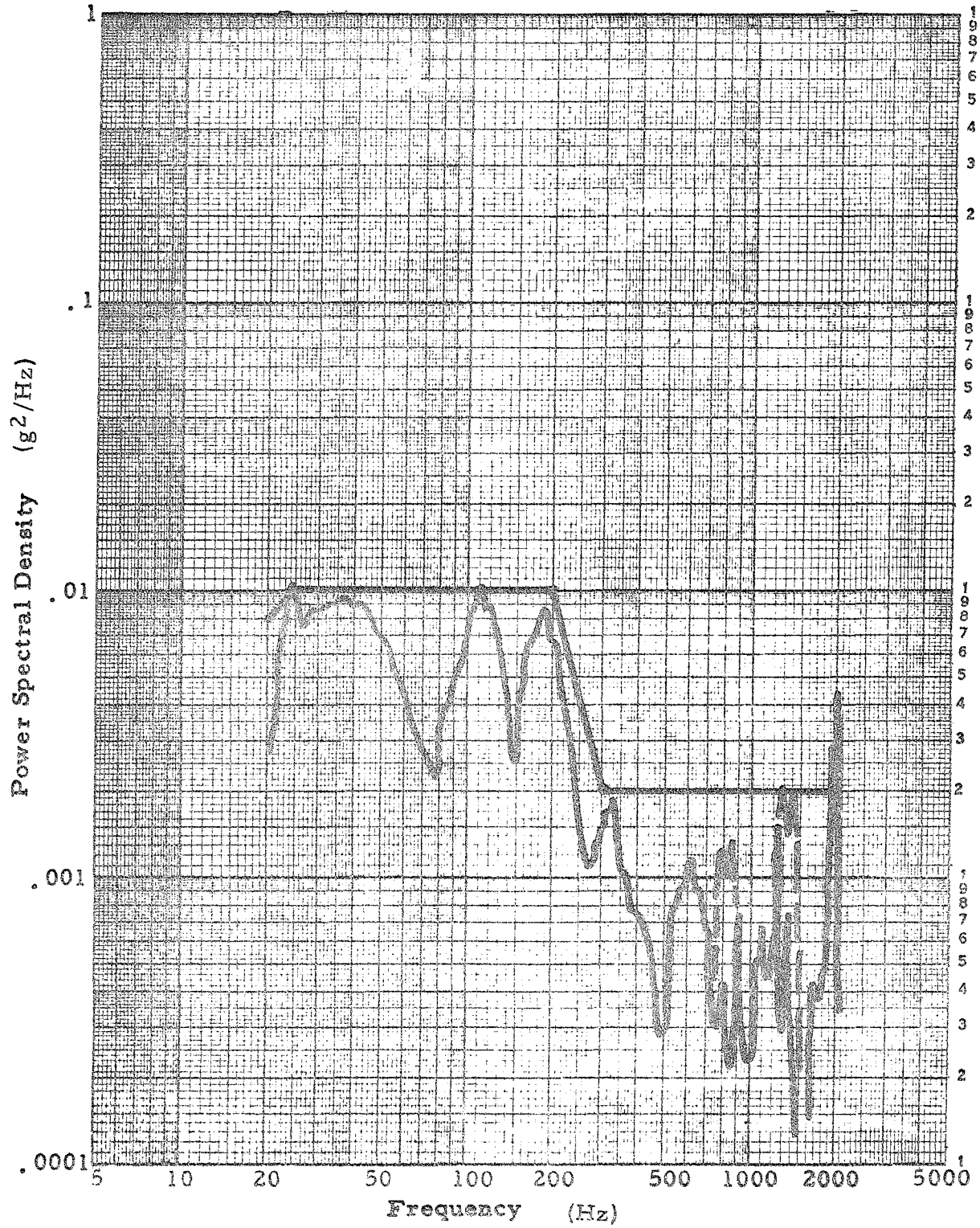
ACC. NO. 5
Axis:

RANDOM VIBRATION SPECTRUM

LUNAR DESCENT

Duration:

S.P. 1 W/LSG HARDMOUNTED LSG Y RESPONSE



440-91

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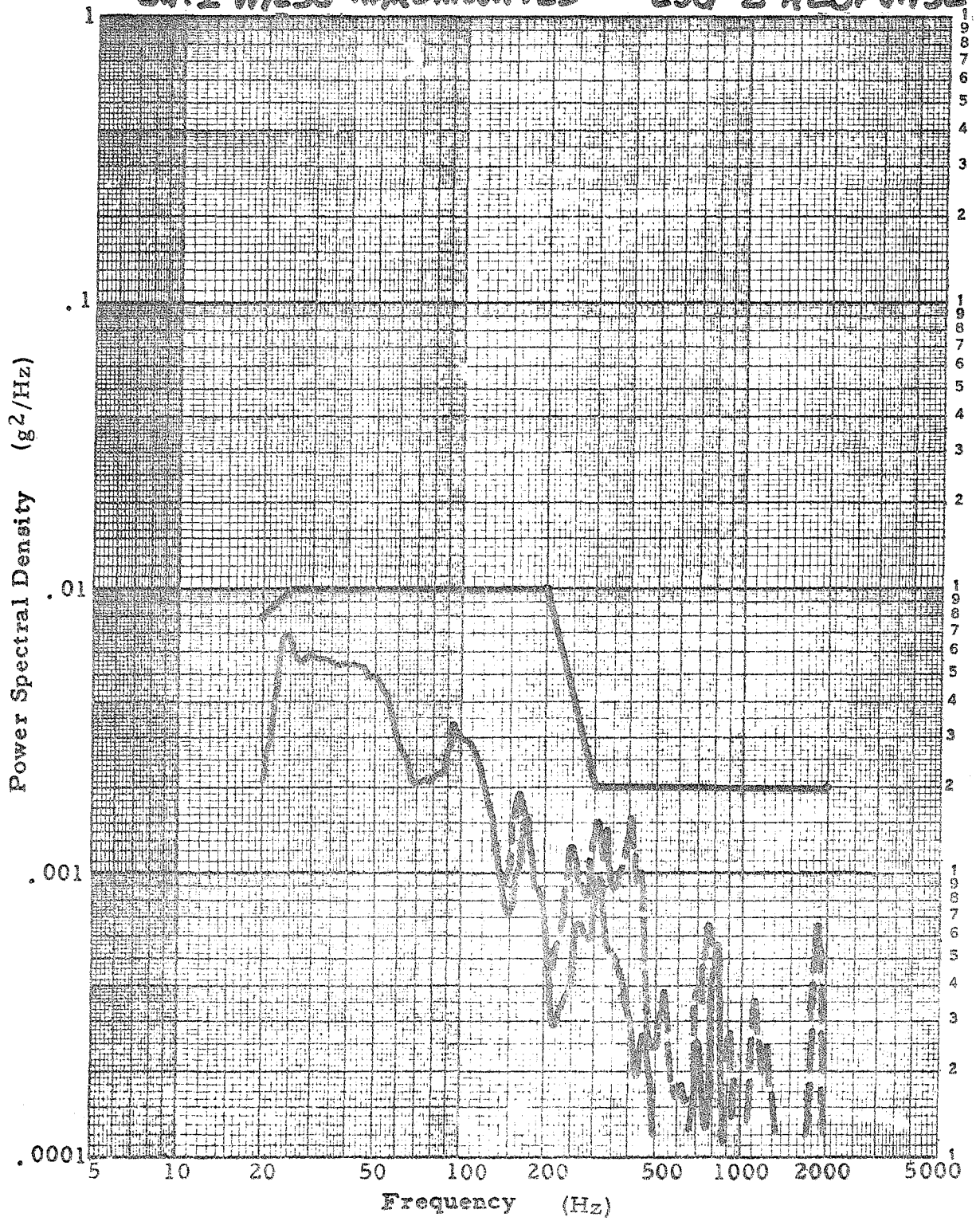
ACC. NO. 6
Axis:

RANDOM VIBRATION SPECTRUM

LUNAR DESCENT

Duration:

S.P. 1 W/LSG HARDMOUNTED LSG Z RESPONSE



440-91

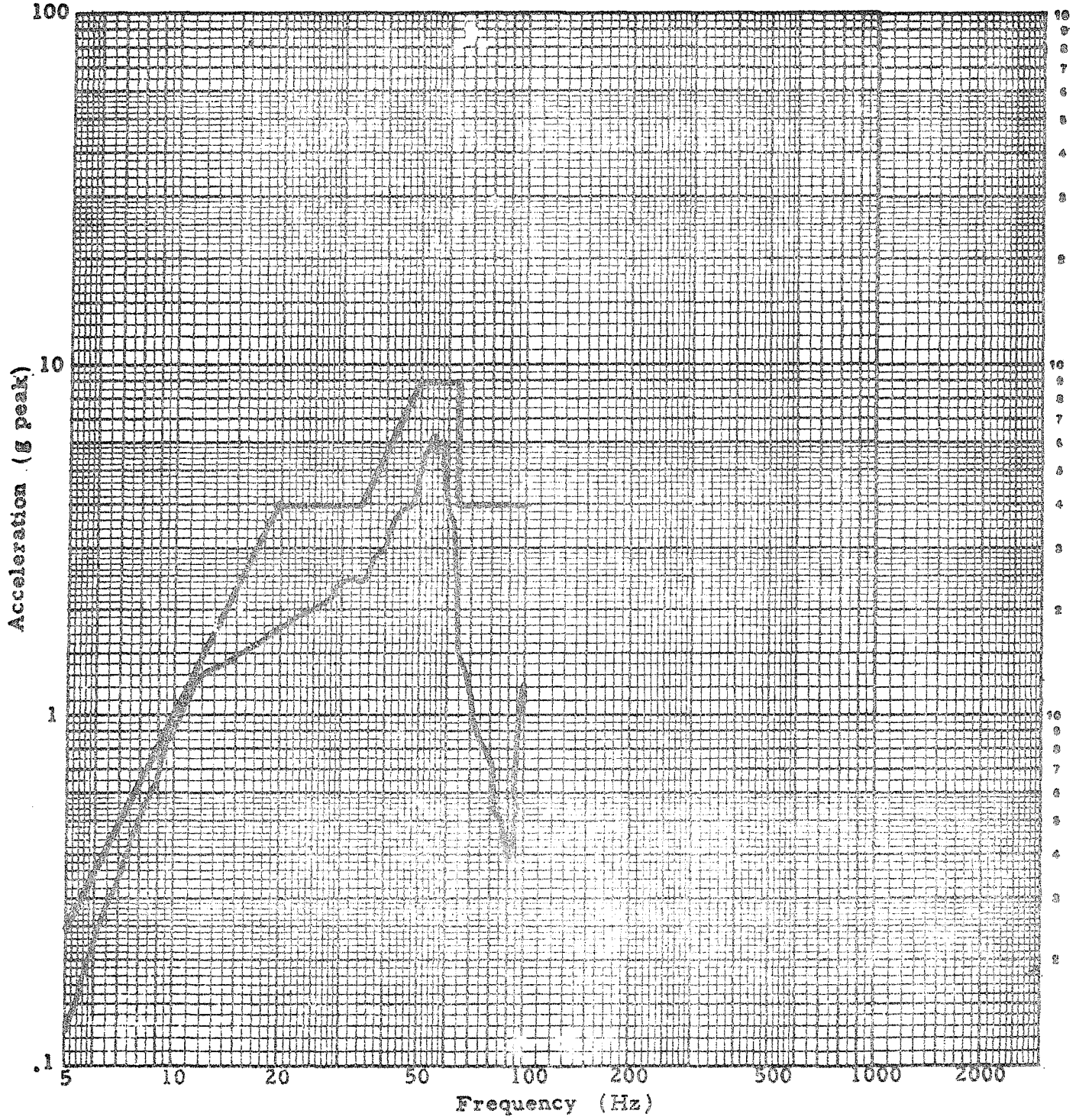
ACC. NO. 10

SINUSOIDAL VIBRATION

Axis:

Sweep Rate:

S.P. 1 W/LSG HARD MOUNTED LSP X RESPONSE



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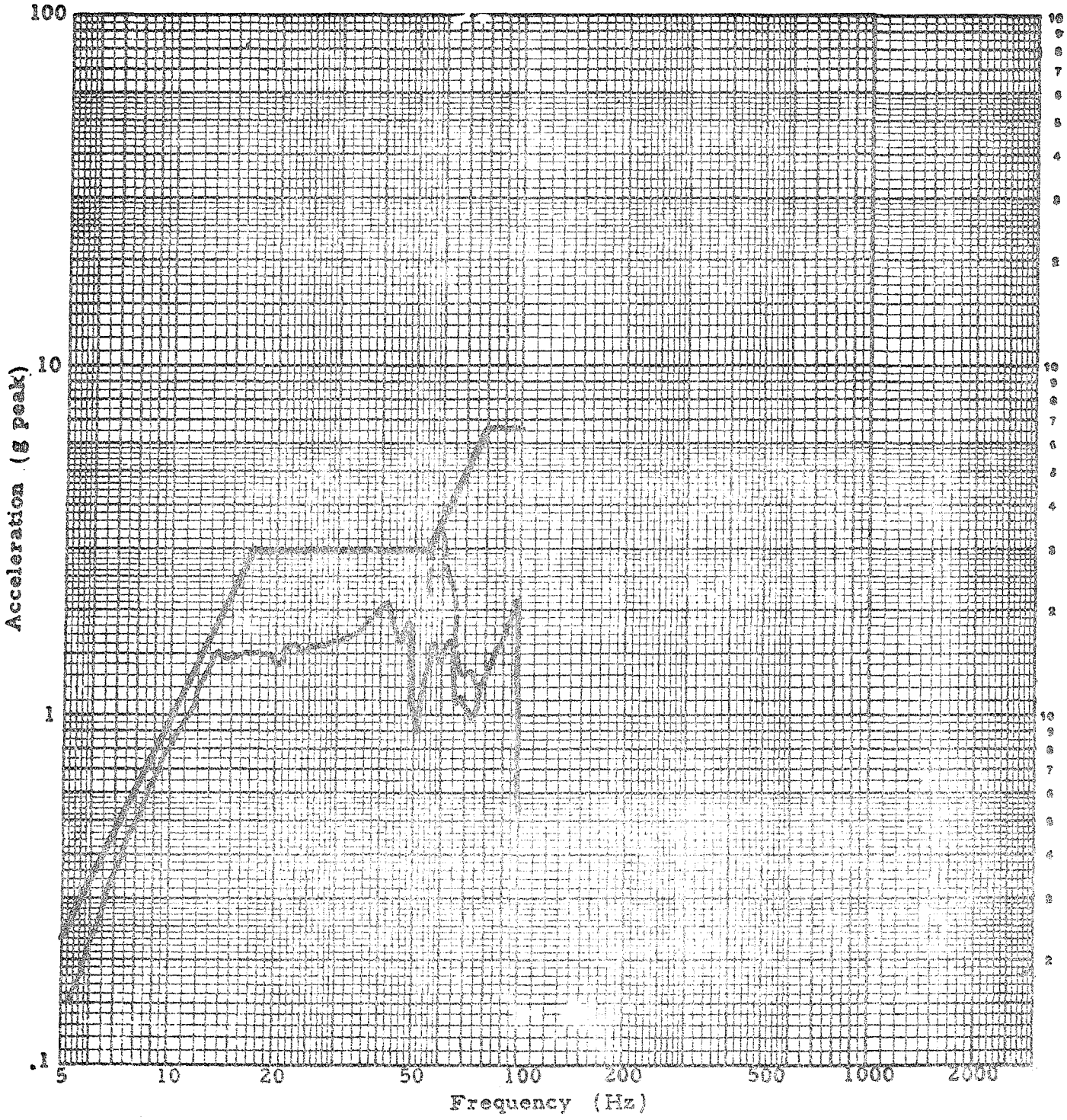
ACC. NO. 11

SINUSOIDAL VIBRATION

Axis:

Sweep Rate:

S.P. 1 W/LSG HARD MOUNTED LSP Y RESPONSE



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ACC. NO. 12

SINUSOIDAL VIBRATION

Axis:

Sweep Rate:

S.P.1 W/LSG HARD MOUNTED LSP & RESPONSE

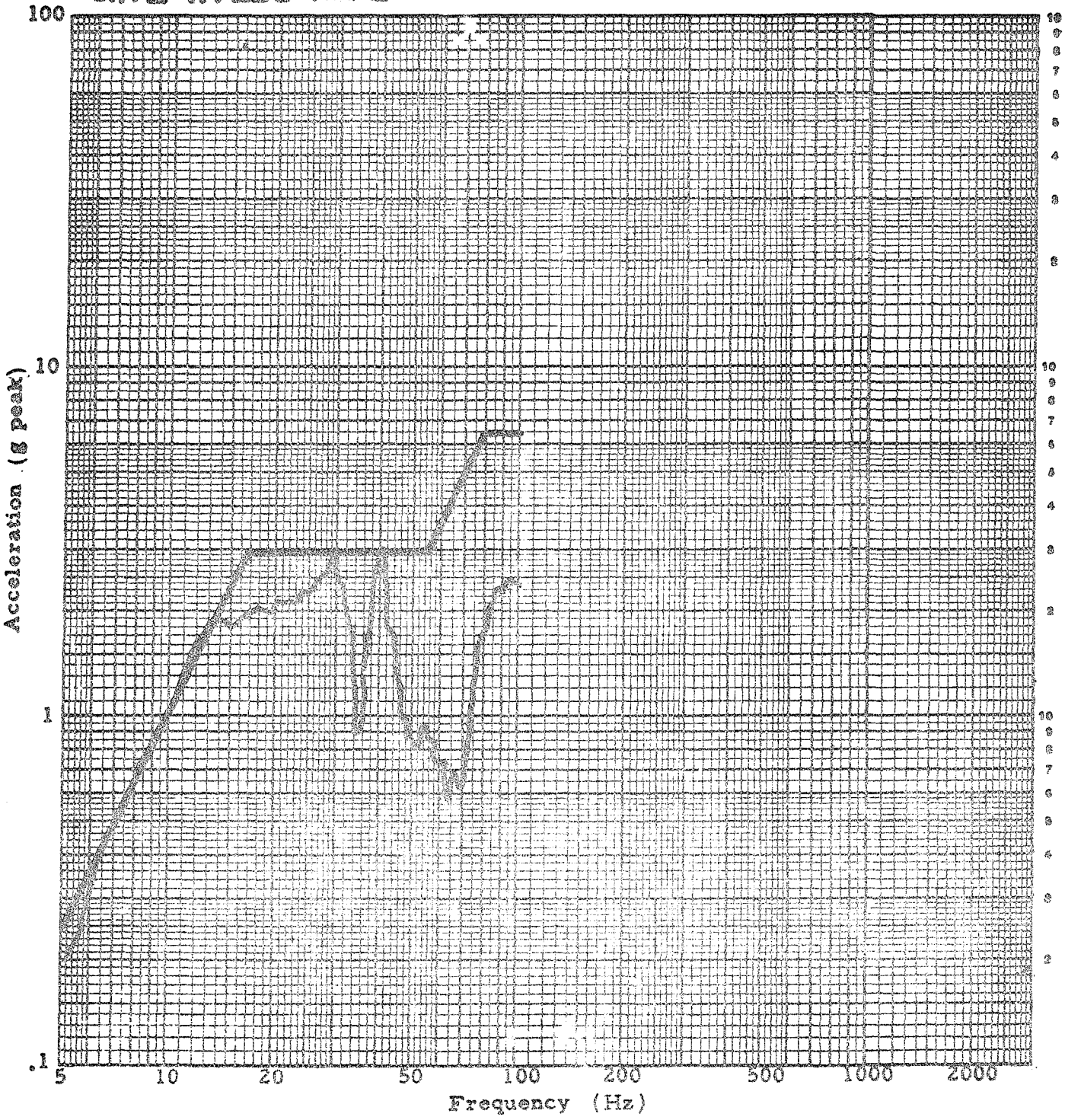

Figure 20

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ACC. NO. 10.

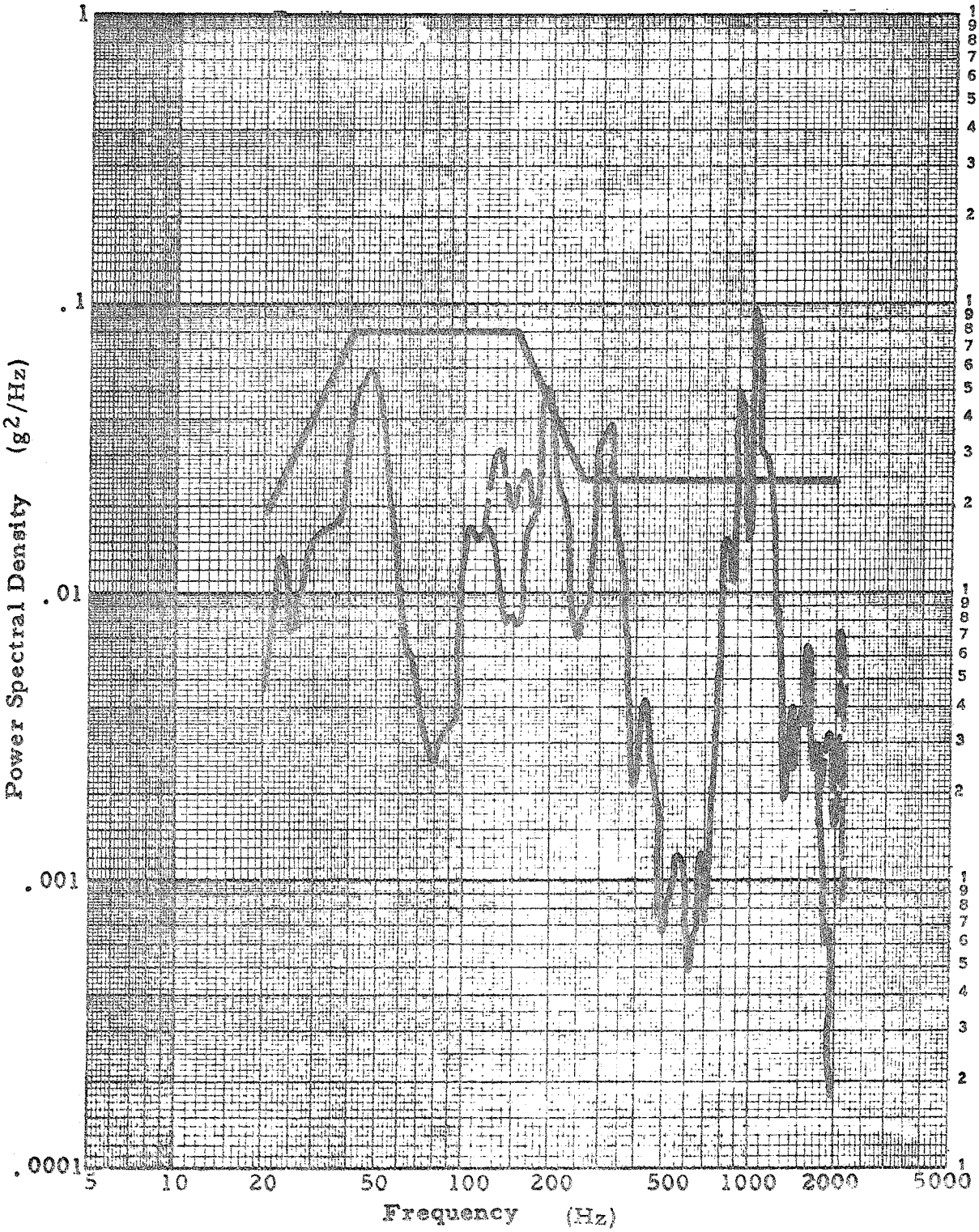
Axis:

RANDOM VIBRATION SPECTRUM

LAUNCH & BOOST

Duration:

S.P. 1 W/LSG HARD MOUNTED LSP X RESPONSE



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ACC. NO. 11
Axis:

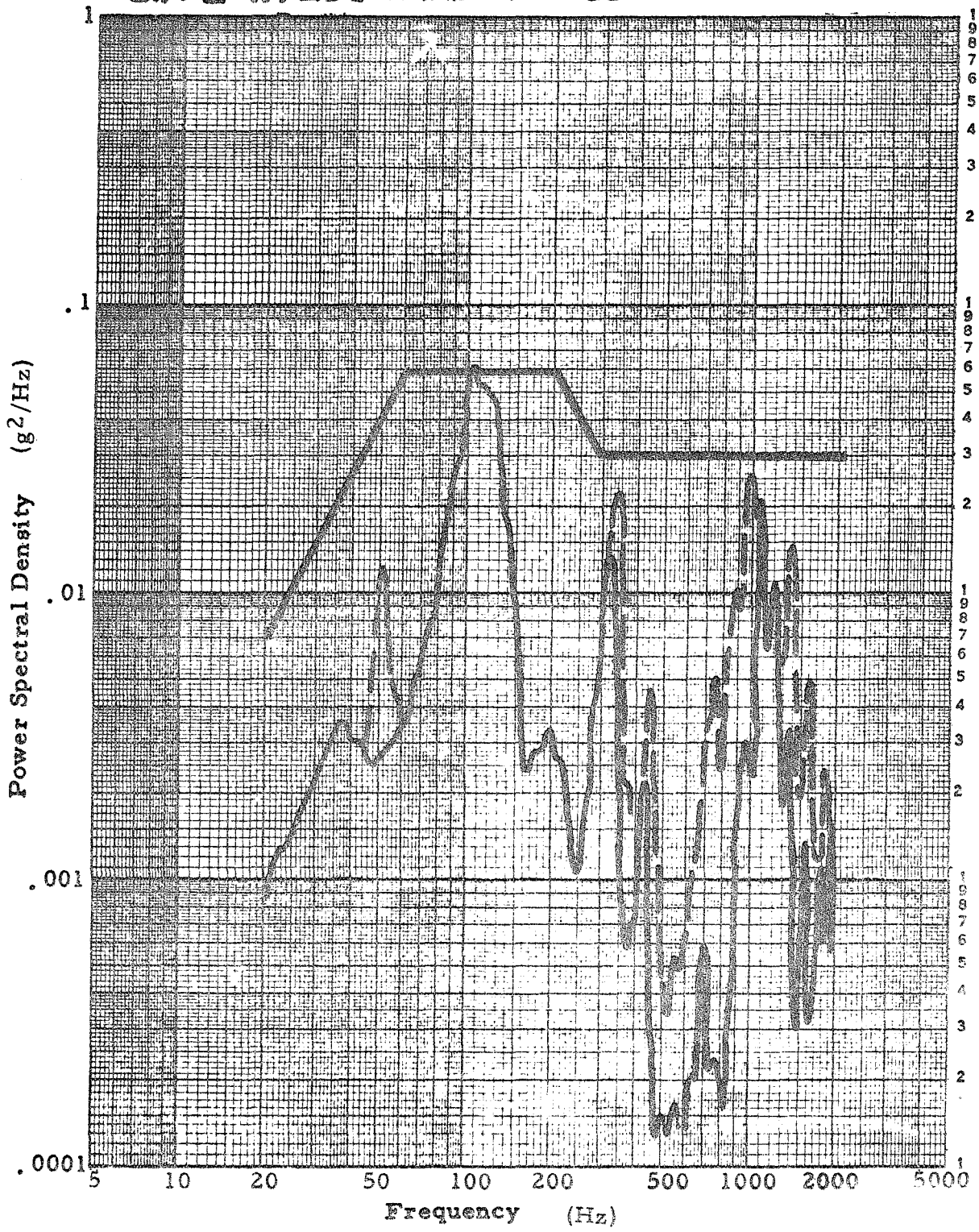
RANDOM VIBRATION SPECTRUM

LAUNCH & BOOST

Duration:

S.P. 1 W/LSG HARD MOUNTED

LSP Y RESPONSE



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ACC. NO. 12

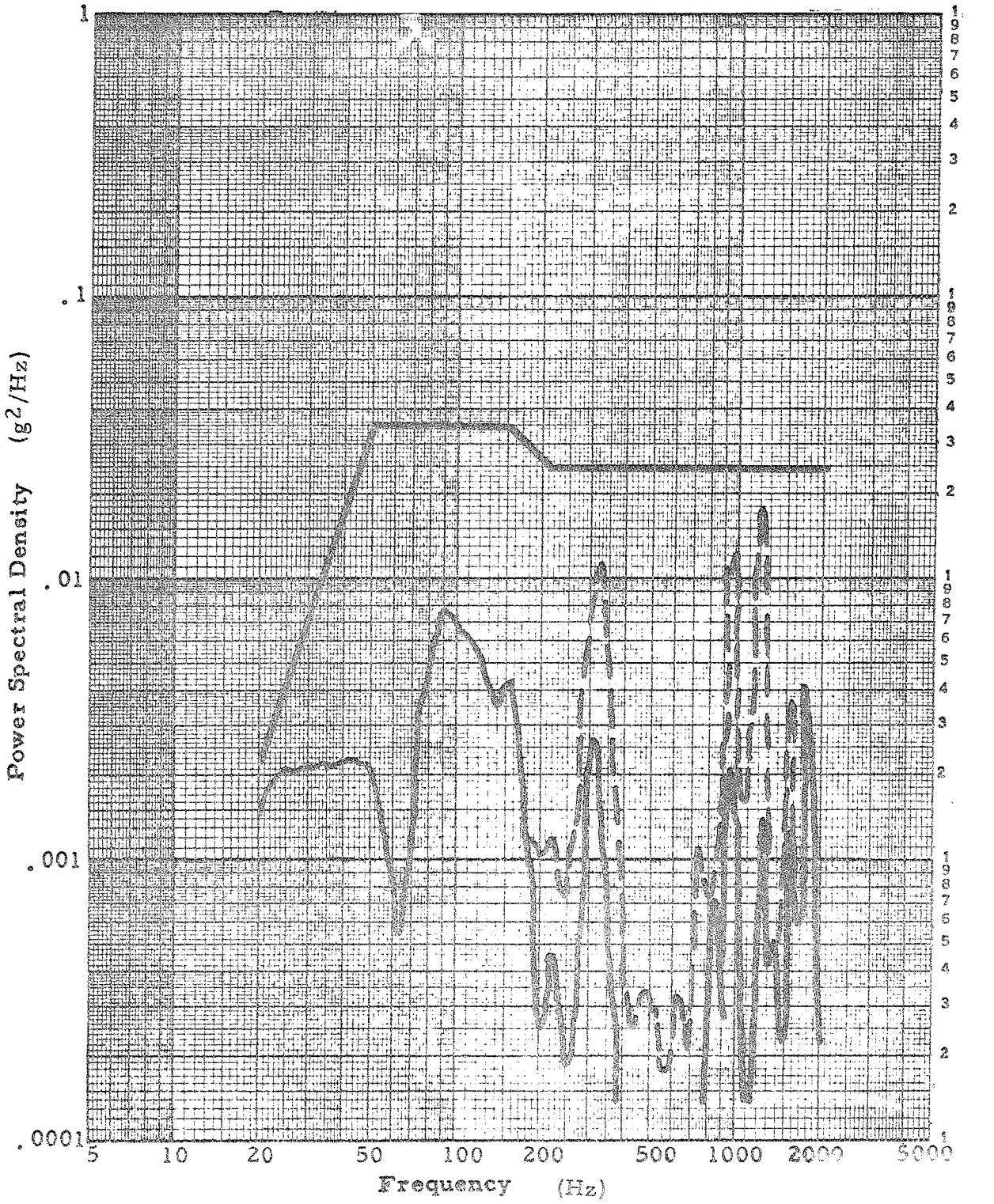
Axis:

RANDOM VIBRATION SPECTRUM

LAUNCH & BOOST

Duration:

S.P. 1 W/LSG HARD MOUNTED LSP 2 RESPONSE



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ACL. NO. 10

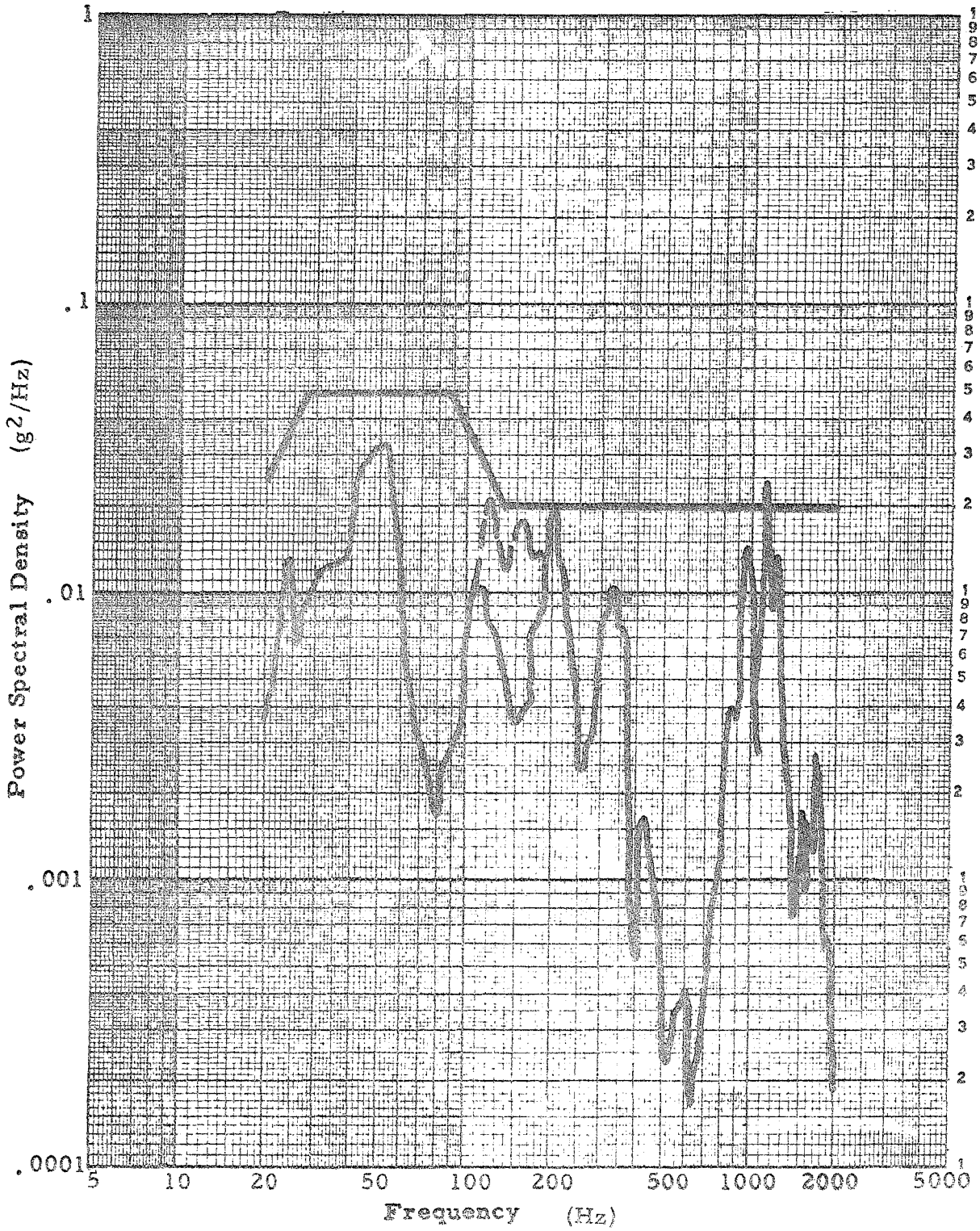
Axis:

RANDOM VIBRATION SPECTRUM

LUNAR DESCENT

Duration:

S.P. 1 W/LSG HARD MOUNTED LSP X RESPONSE

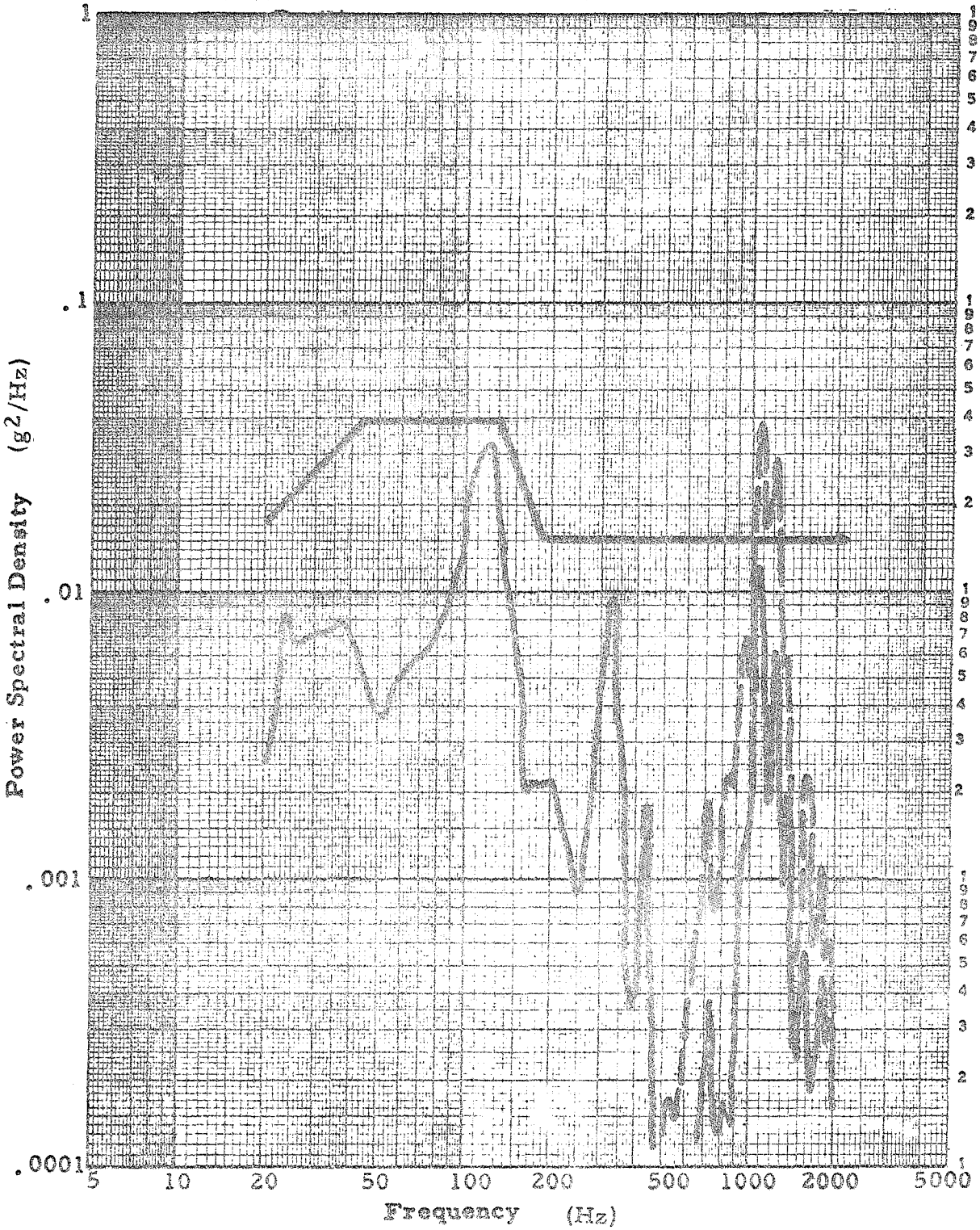


ACC. NO. 11
Axis:

RANDOM VIBRATION SPECTRUM
LUNAR DESCENT

Duration:

S.P. 1 W/LSG HARD MOUNTED LSP Y RESPONSE



Bendix Aerospace Systems Division

ALL. W. 12

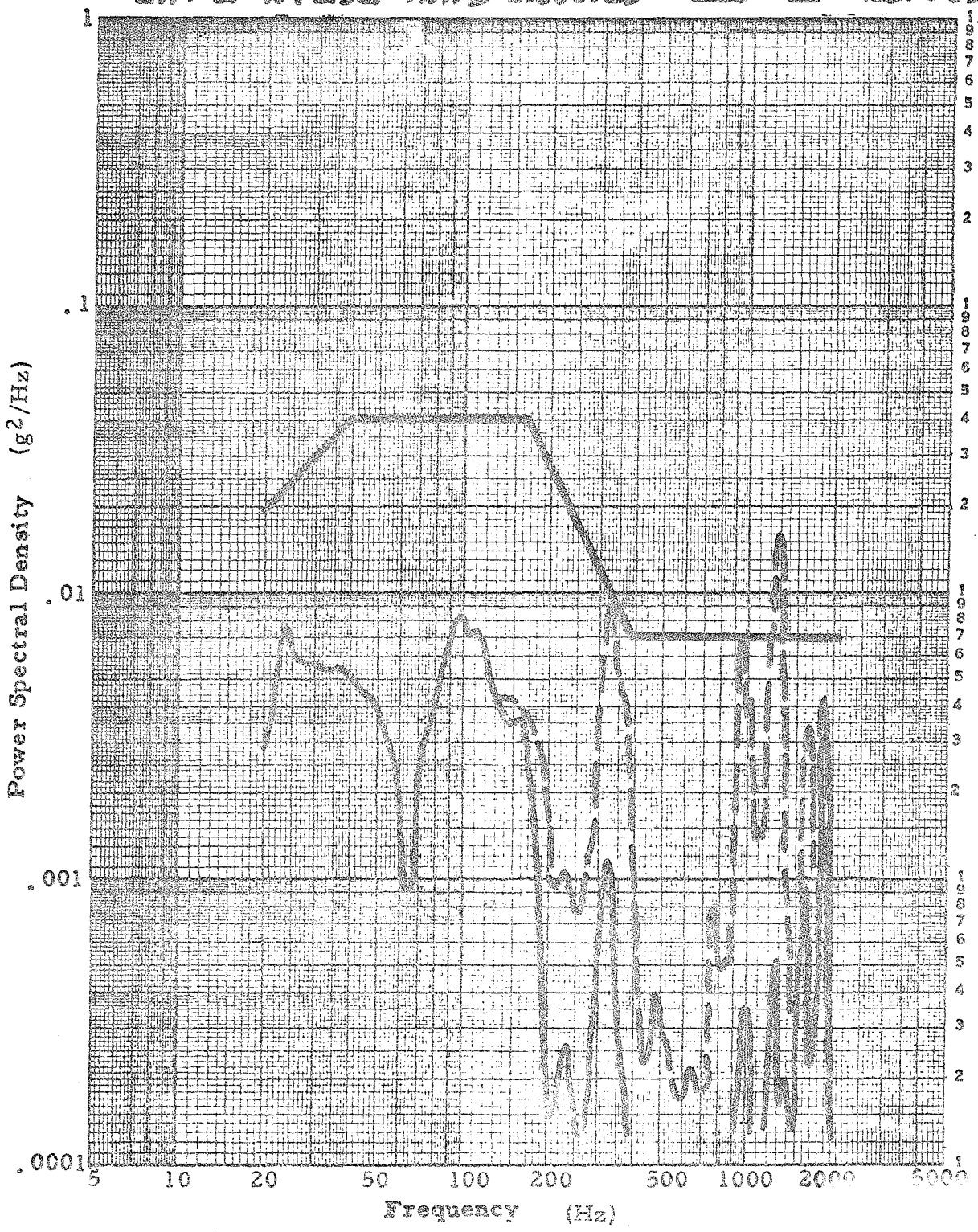
Axis:

RANDOM VIBRATION SPECTRUM

LUNAR DESCENT

Duration:

S.P. 1 W/LSG HARD MOUNTED LSP Z RESPONSE



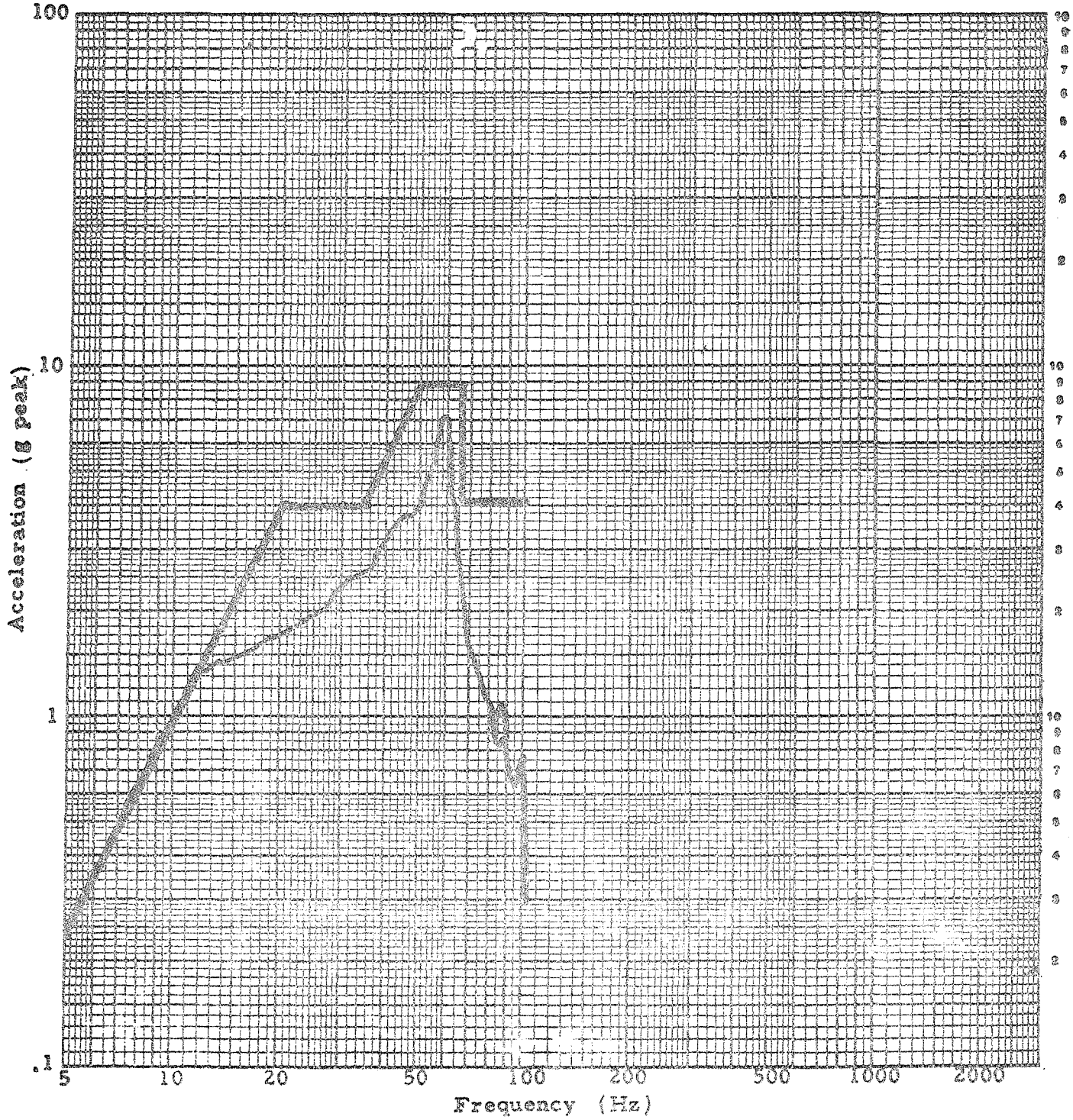
ACC. NO. 13

SINUSOIDAL VIBRATION

Axis:

Sweep Rate:

S.P. 1 W/LSG HARD MOUNTED LMS X RESPONSE



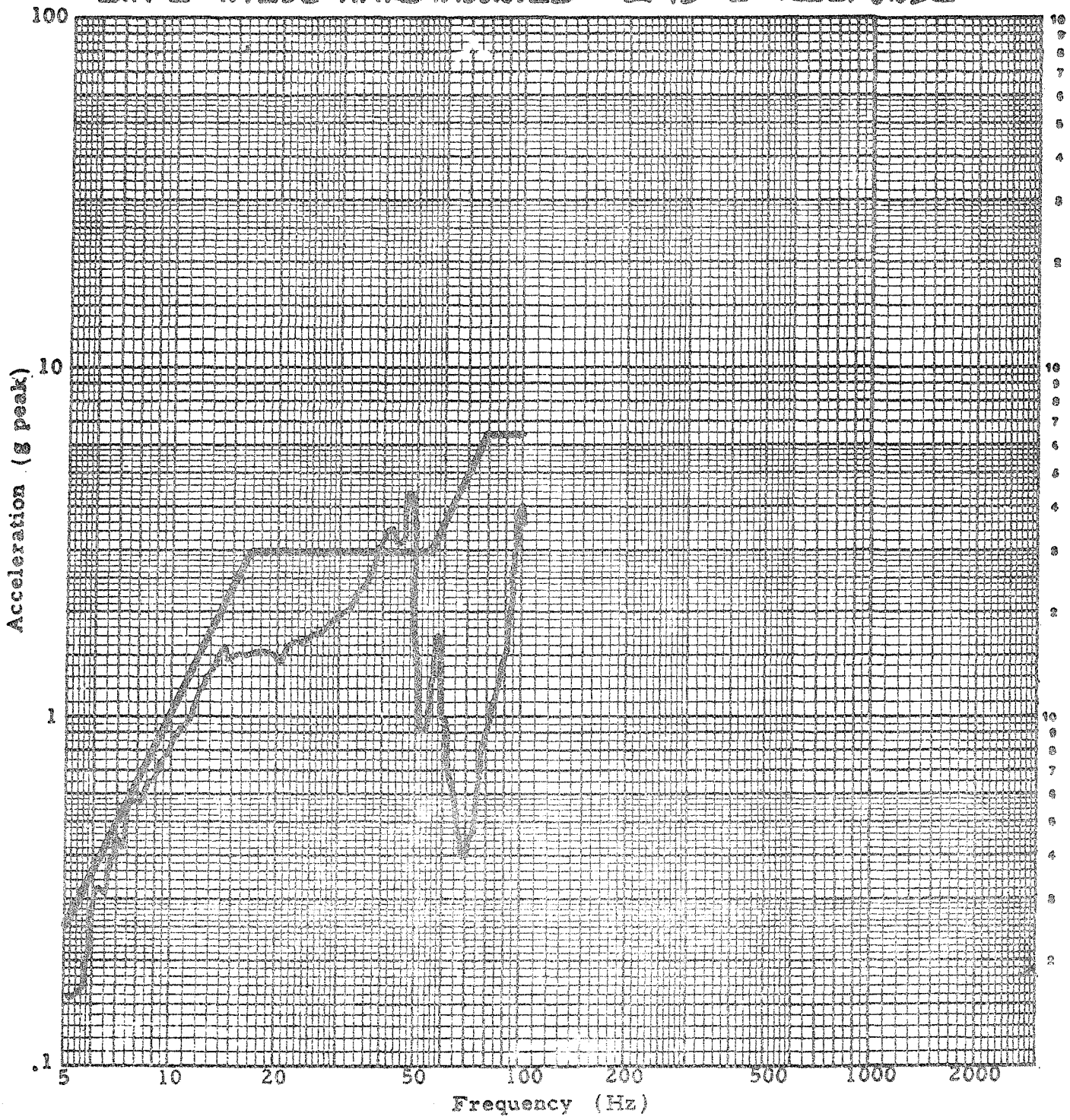
ACC. NO. 14

SINUSOIDAL VIBRATION

Axis:

Sweep Rate:

S.P. L W/LSG HARD MOUNTED LMS Y RESPONSE

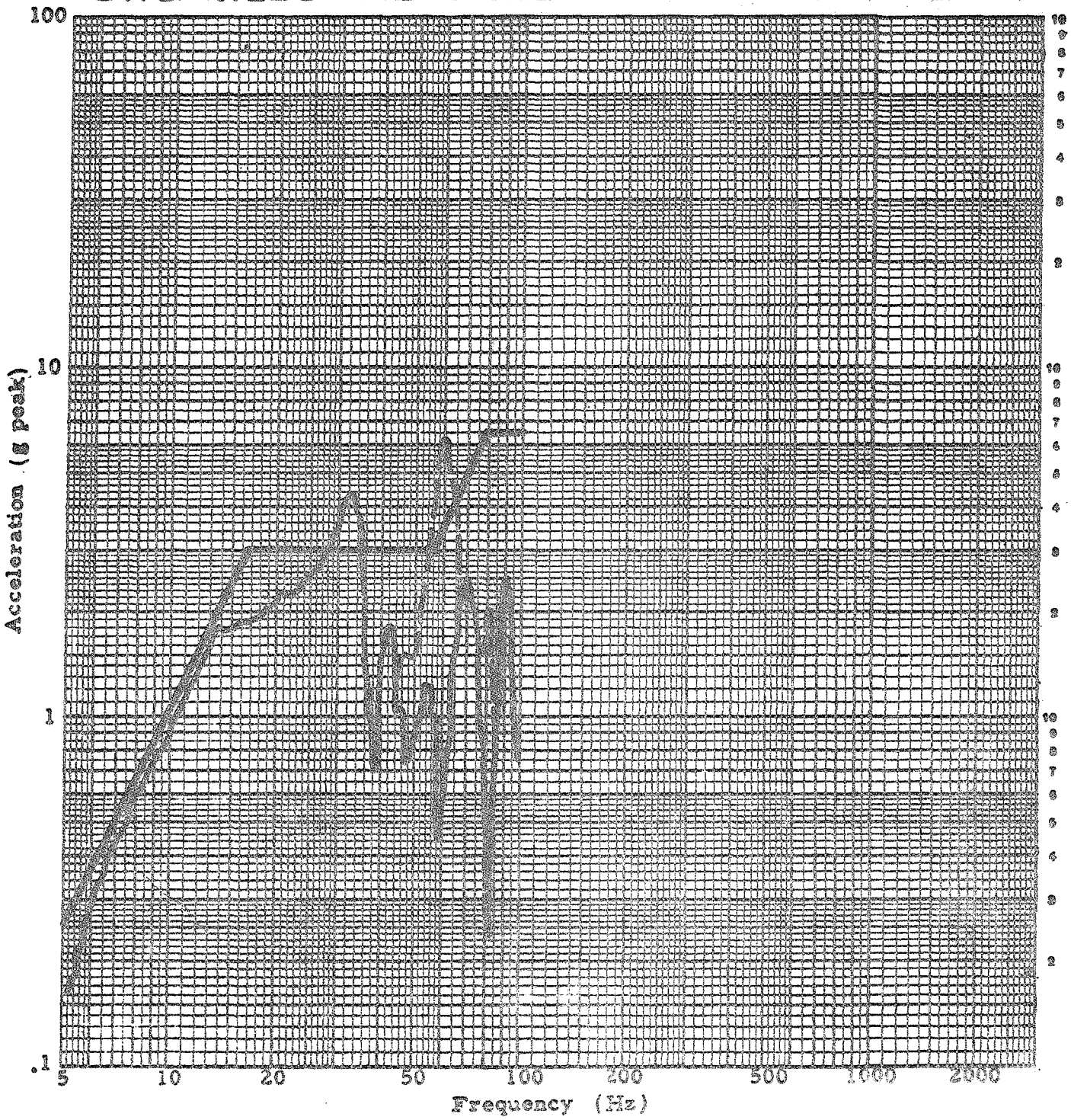


SINUSOIDAL VIBRATION

RCL NO. 15
Axis:

Sweep Rate:

S.P. 1 W/LSG HARDMOUNTED LMS 3 RESPONSE



Aerospace Systems Division

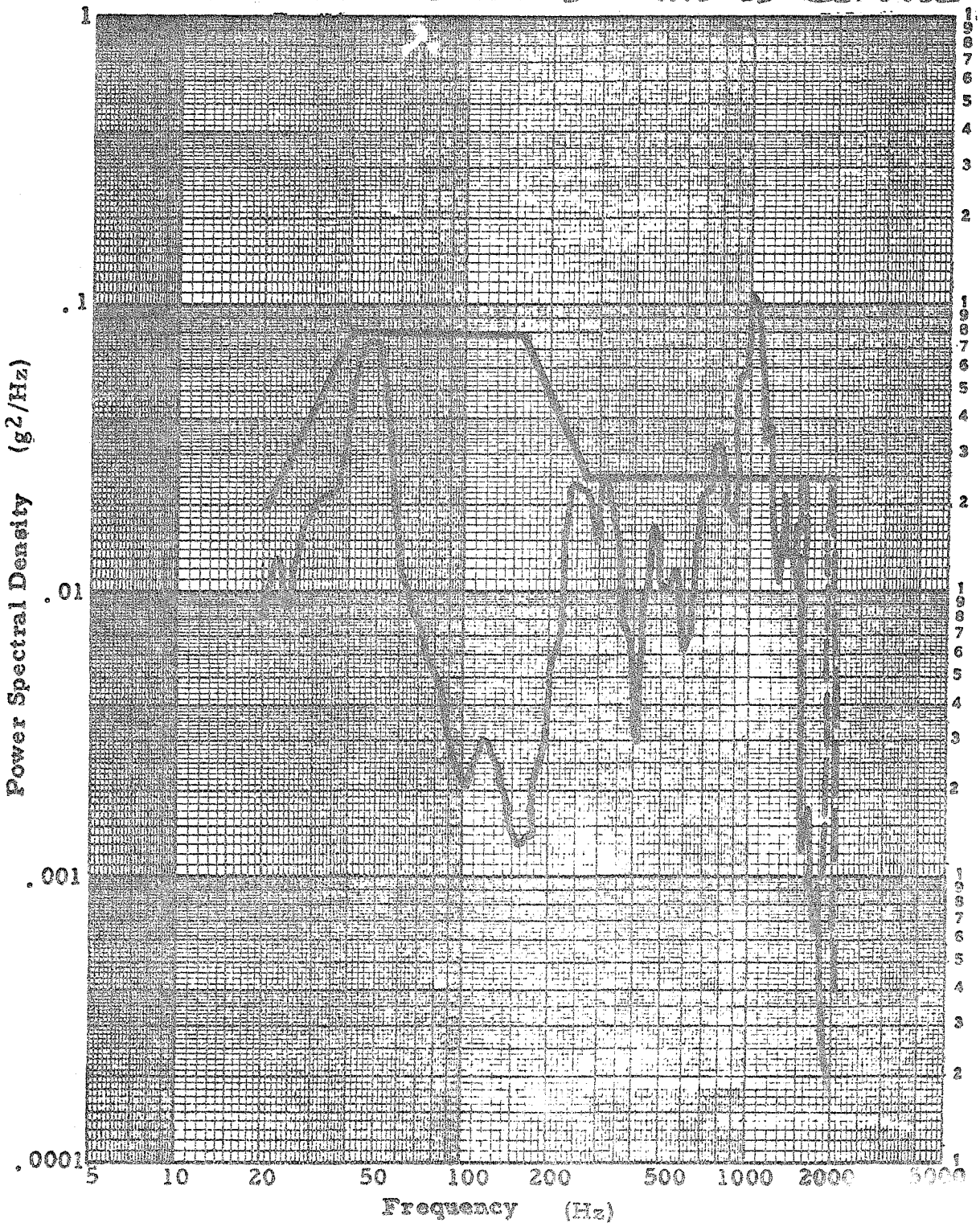
ACL. NO. 13
Axis:

RANDOM VIBRATION SPECTRUM

LAUNCH & BOOST

Duration:

S.P. 1 W/LSG HARMONIUTED LMS X RESPONSE



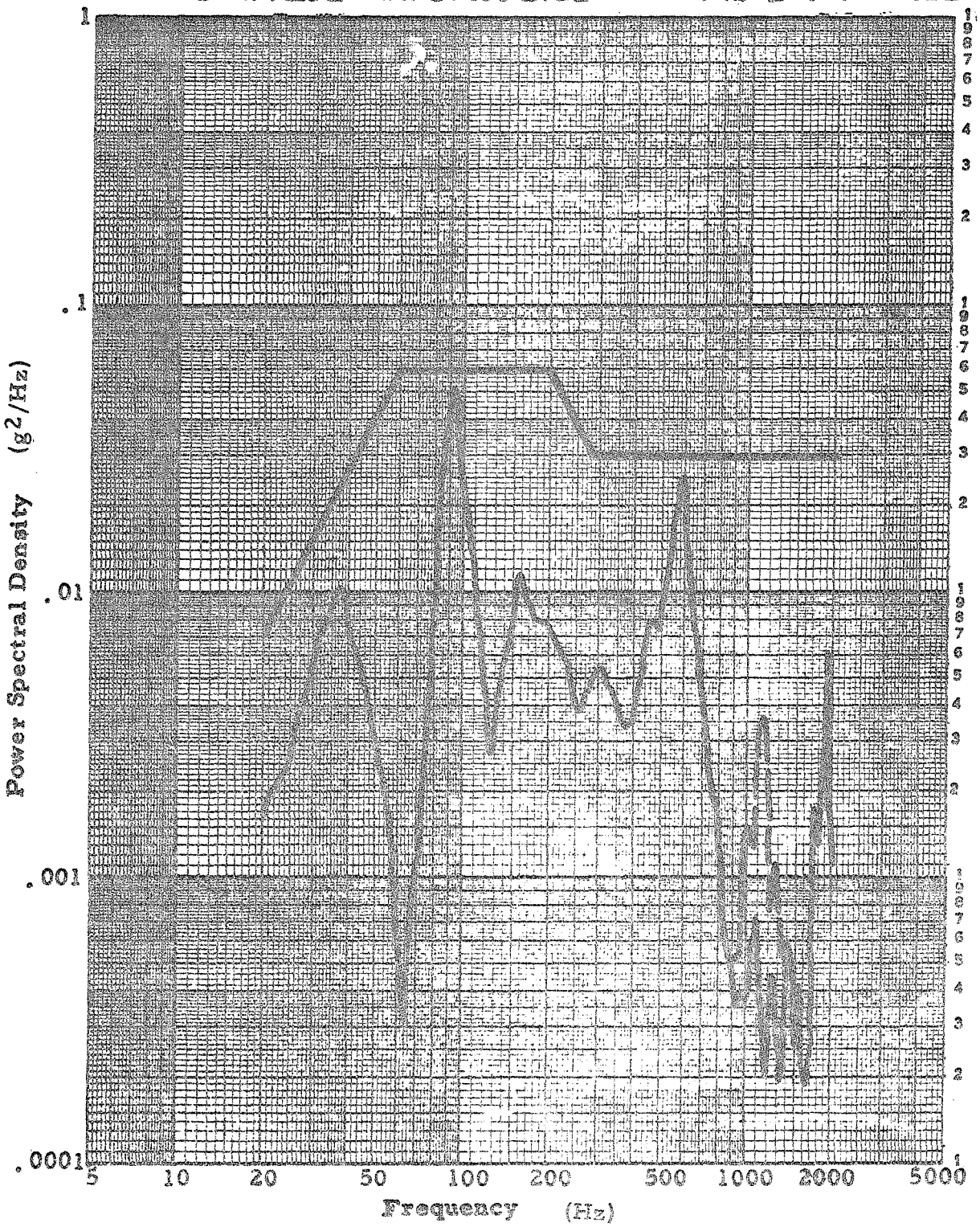
ACC. NO. 14
Axis:

RANDOM VIBRATION SPECTRUM

LAUNCH & BOOST

Duration:

S.P. 1 W/LSG HARDMOUNTED LMS & RESPONSE



Aerospace Systems Division

ALL NO. 15

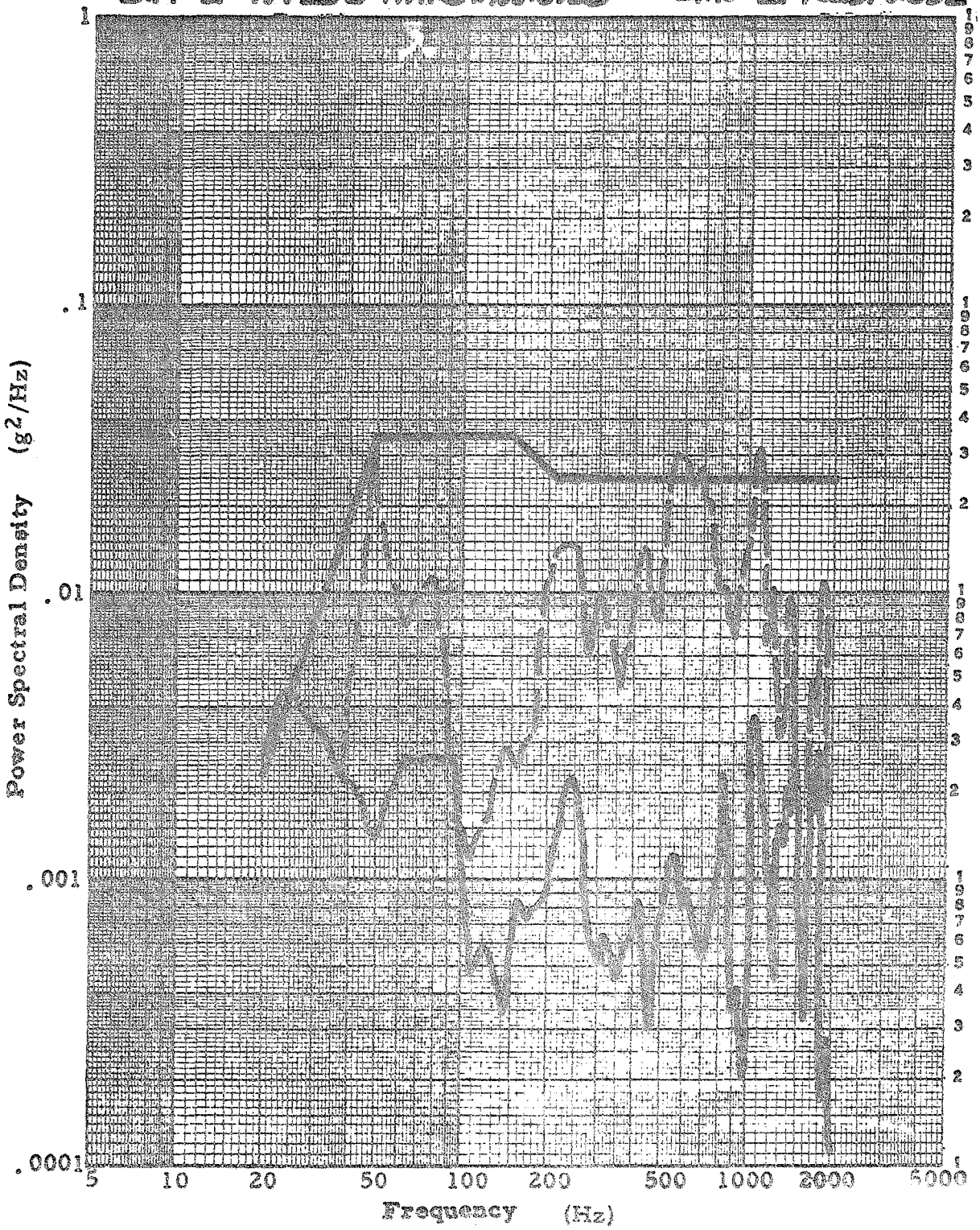
Axis:

RANDOM VIBRATION SPECTRUM

LAUNCH & BOOST

Duration:

S.P. 2 W/LSG HARDMOUNTED LMS 2 RESPONSE



ALL. NO. 13

Axis:

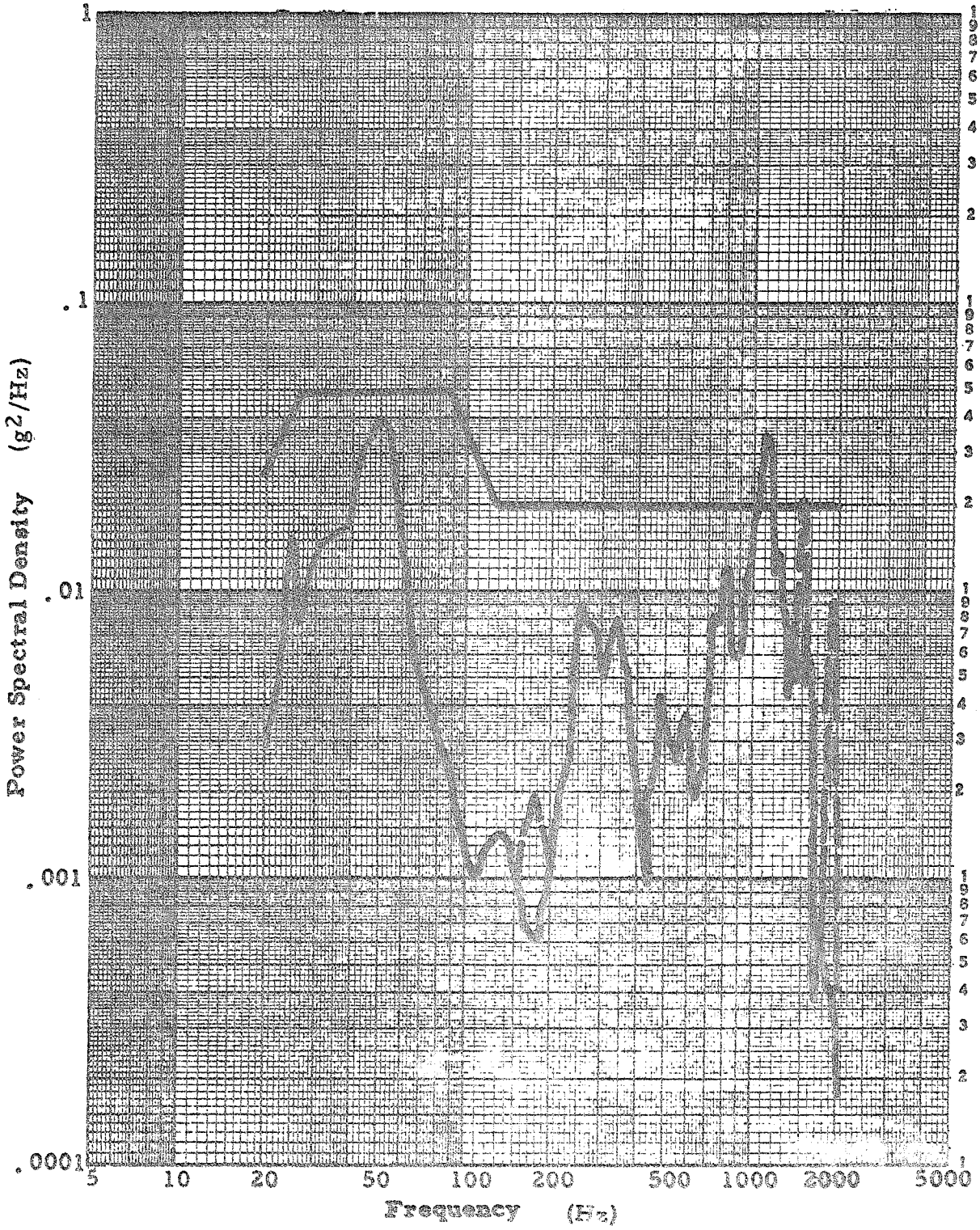
RANDOM VIBRATION SPECTRUM

LUNAR DESCENT

Duration:

S.P. 1 W/LSG HARDMOUNTED

LMS X RESPONSE



Aerospace Systems Division

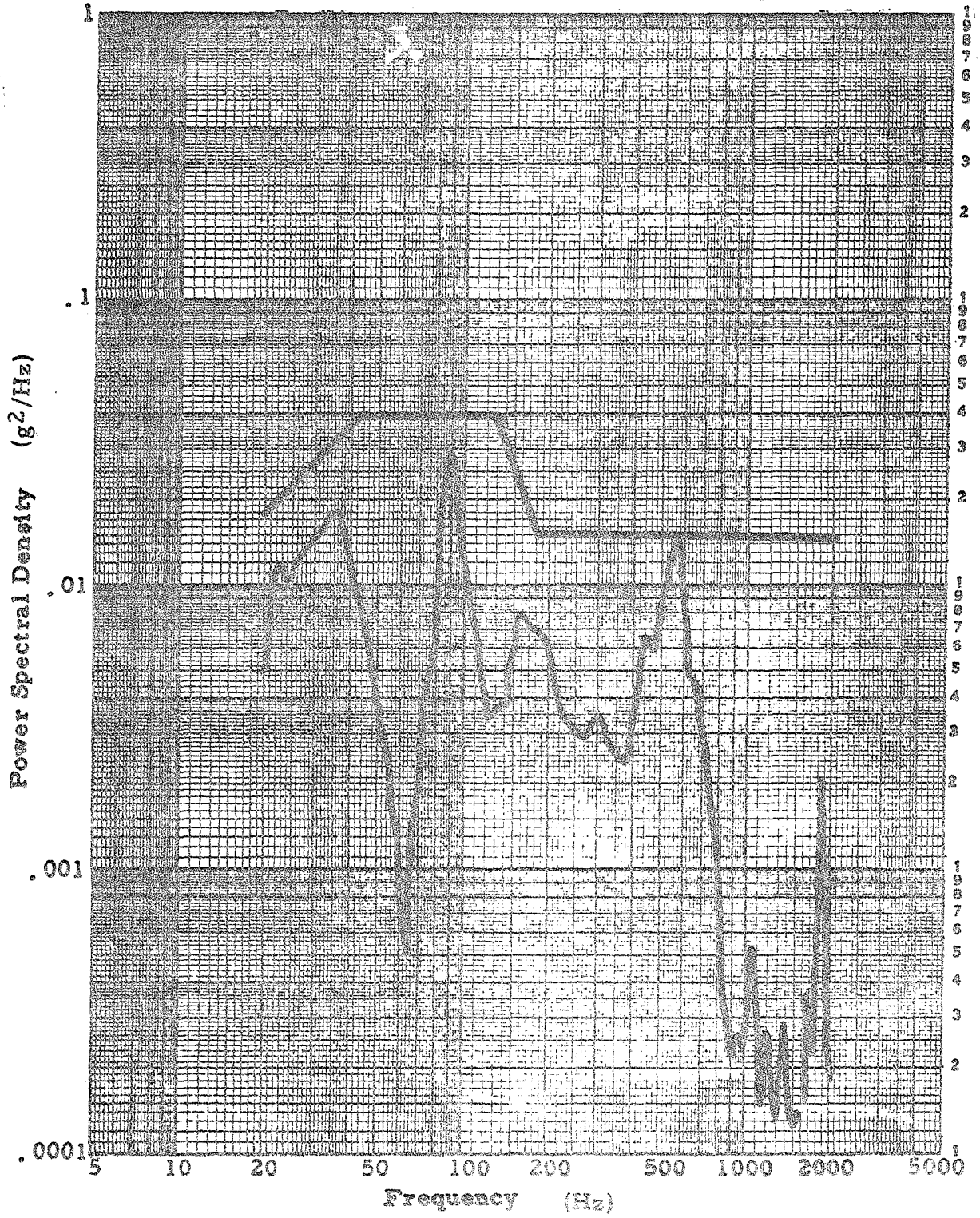
PKG. NO. 14
Axis:

RANDOM VIBRATION SPECTRUM

LUNAR DESCENT

Duration:

S.P. 1 W/LSG HARDMOUNTED LMS Y RESPONSE



ACC. NO. 15

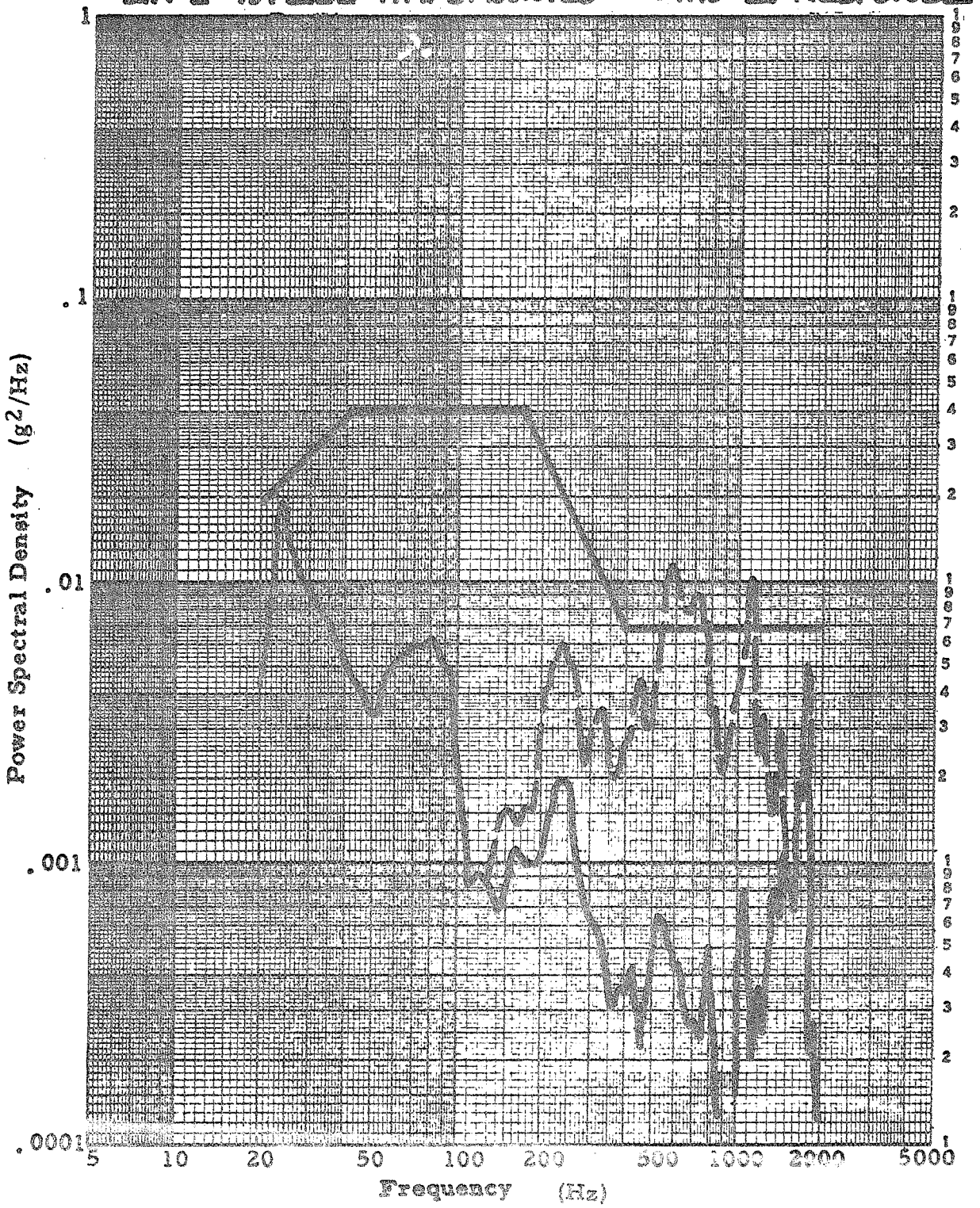
Axis:

RANDOM VIBRATION SPECTRUM

LUNAR DESCENT

Duration:

S.P. 1 W/LSG HARDMOUNTED LMS Z RESPONSE



Bendix Aerospace Systems Division

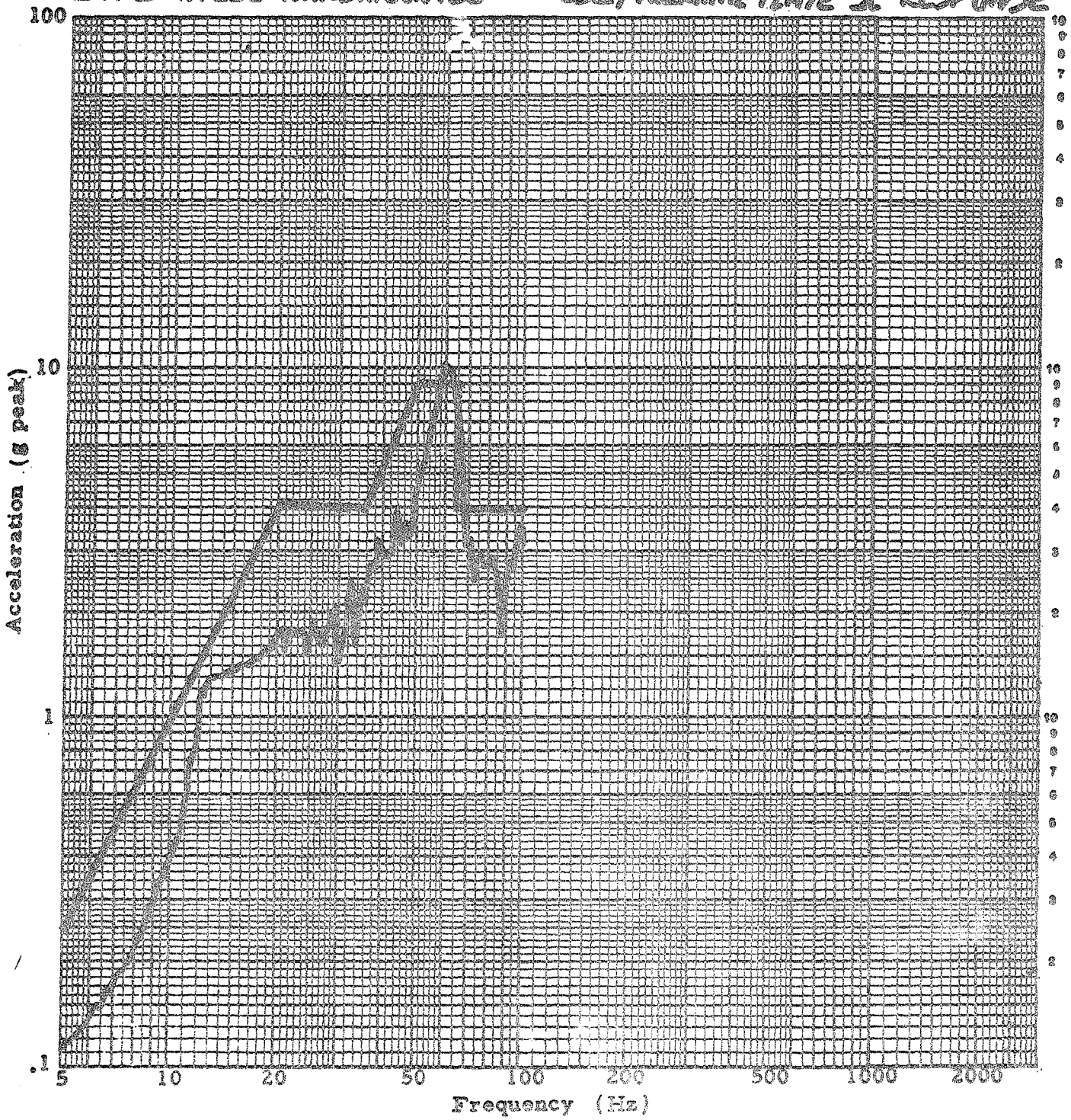
LOCATION α

SINUSOIDAL VIBRATION

Axis:

Sweep Rate:

S.P. 1 W/LSG UNMOUNTED CSE/THERMAL PLATE X RESPONSE



Bendix Aerospace Systems Division

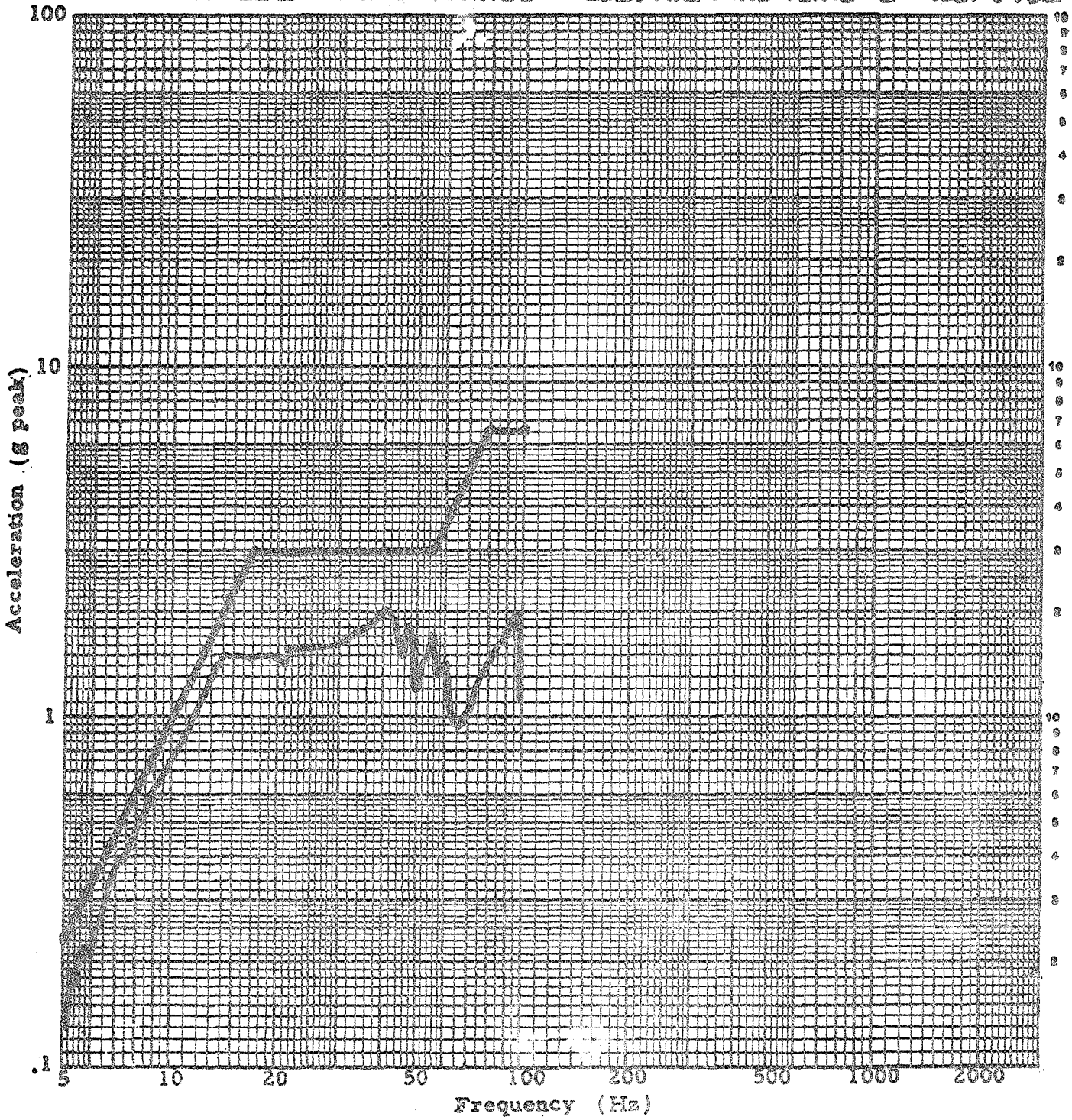
LOCATION α

SINUSOIDAL VIBRATION

Axis:

Sweep Rate:

S.P. 1 W/LSG HARDMOUNTED CSE/THERMAL PLATE Y RESPONSE



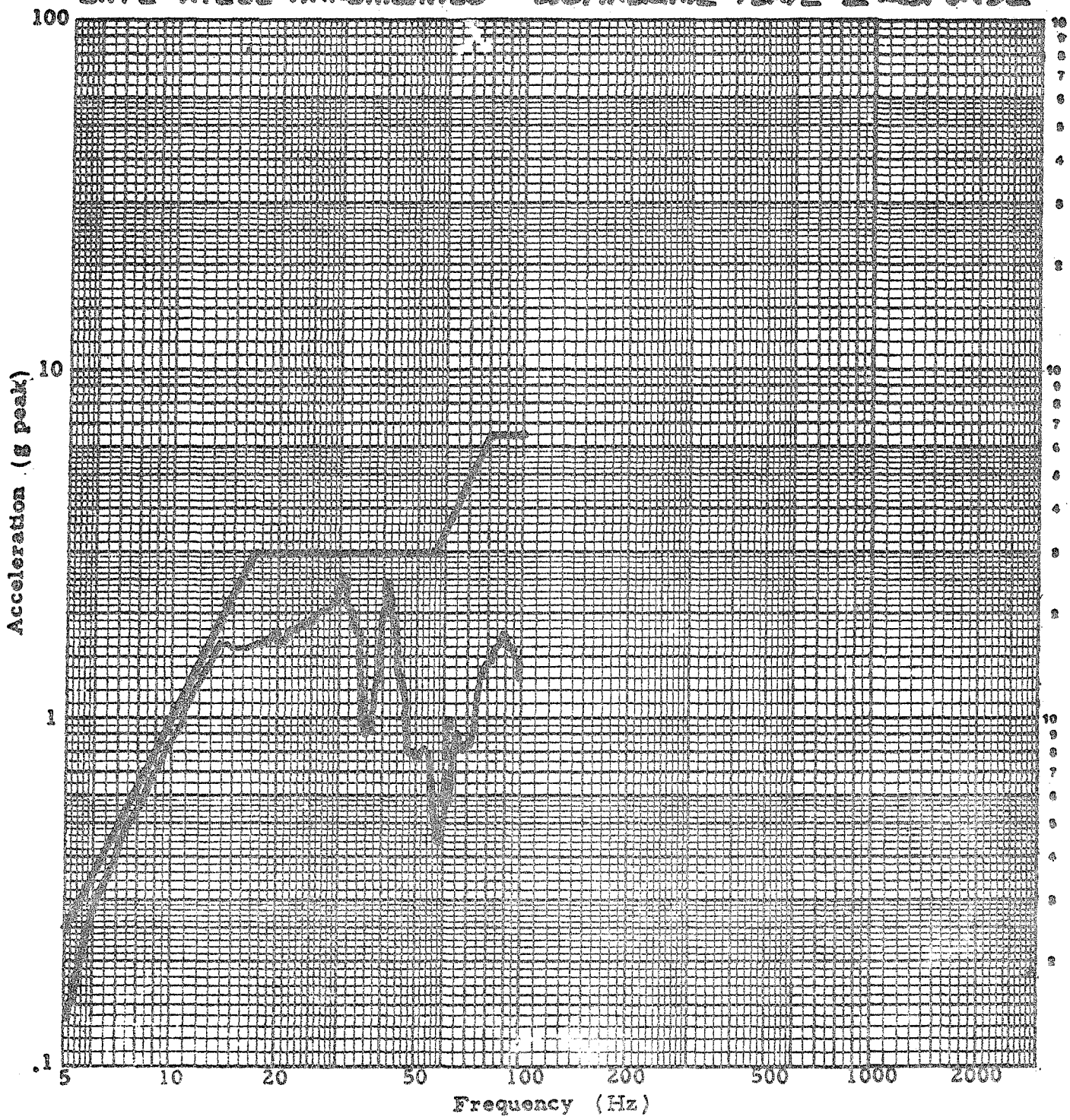
LOCATION 4

SINUSOIDAL VIBRATION

Axis:

Sweep Rate:

S.P. 1 W/LSG HARDMOUNTED CSE/THERMAL PLATE 2 RESPONSE



Aerospace Systems Division

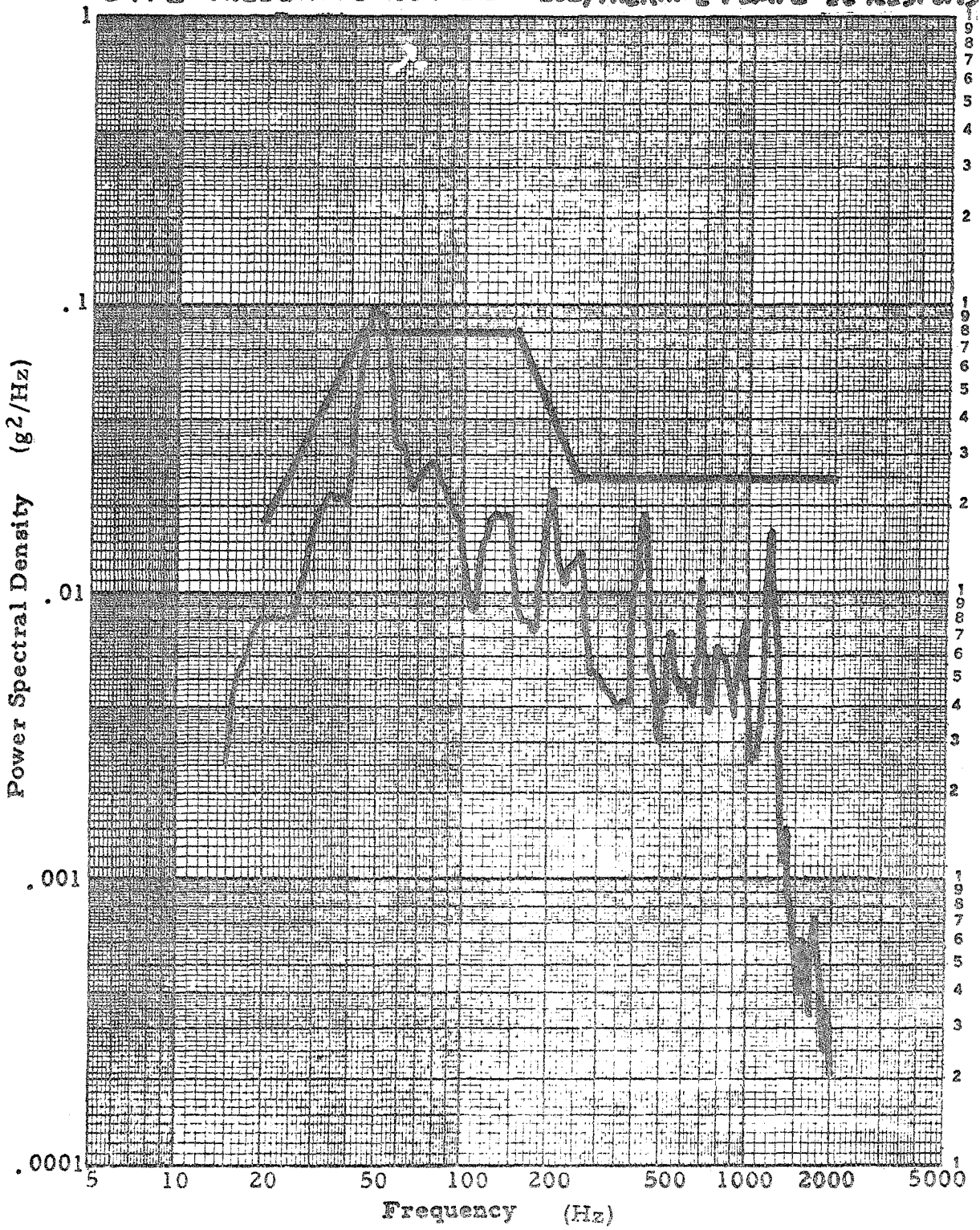
LOCATION α
Axis:

RANDOM VIBRATION SPECTRUM

LAUNCH & BOOST

Duration:

S.P. 1 W/LSG HARDMOUNTED CSE/THERMAL PLATE X RESPONSE



Aerospace Systems Division

LOCATION α

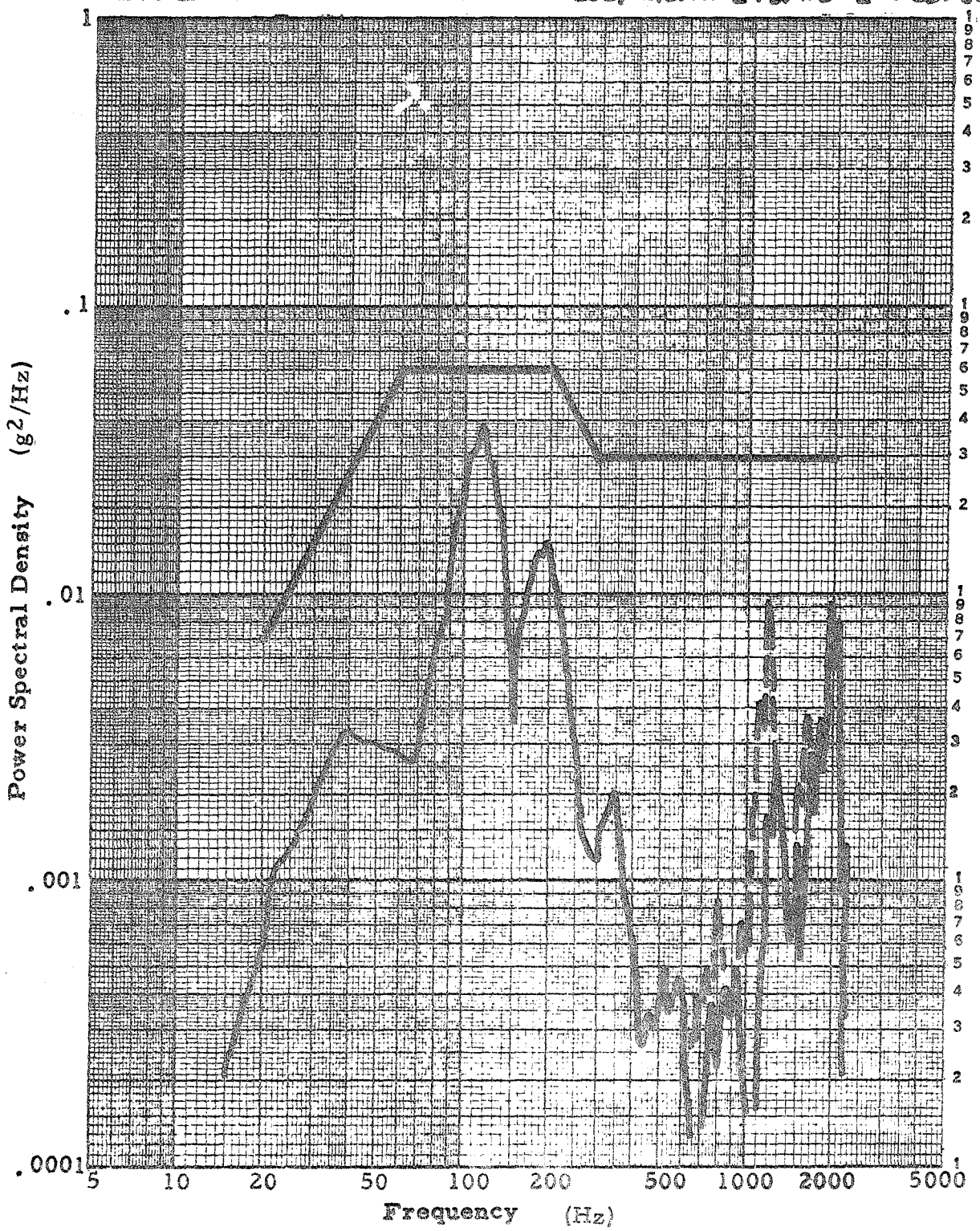
Axis:

RANDOM VIBRATION SPECTRUM

LAUNCH & BOOST

Duration:

S.P. 1 W/LSG HARDMOUNTED CSE/THERMAL PLATE Y RESPONSE



440-91

Bendix Aerospace Systems Division

LOCATION α

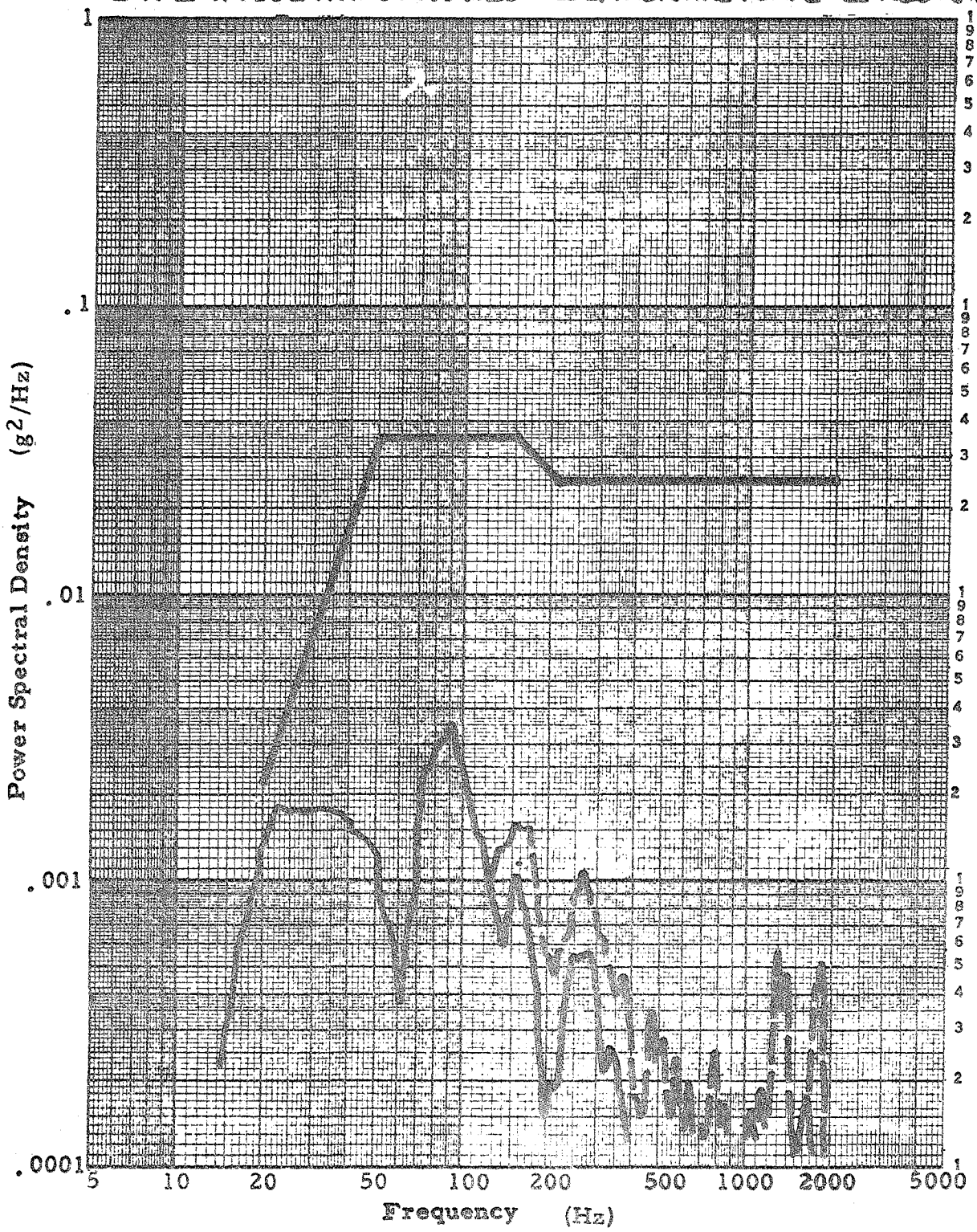
Axis:

RANDOM VIBRATION SPECTRUM

LAUNCH & BOOST

Duration:

S.P. 1 W/LSG HARDMOUNTED CSE/THERMAL PLATE 2 RESPONSE



Aerospace Systems Division

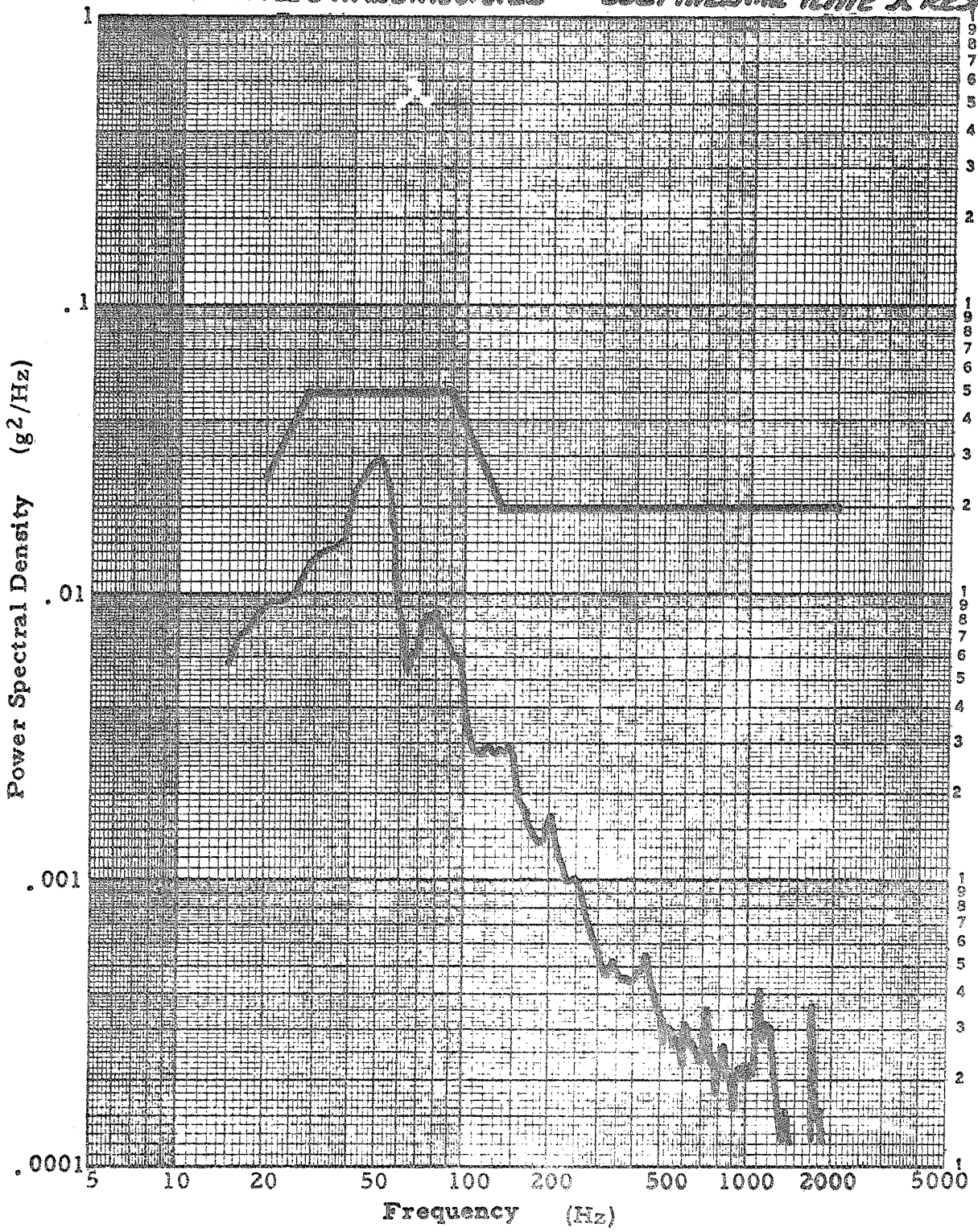
LOCATION α

Axis:

RANDOM VIBRATION SPECTRUM

Duration:

LUNAR DESCENT
S.P. 1 W/LSG HARDMOUNTED CSE/THERMAL PLATE X RESPONSE



440-91

Aerospace Systems Division

LOCATION 4

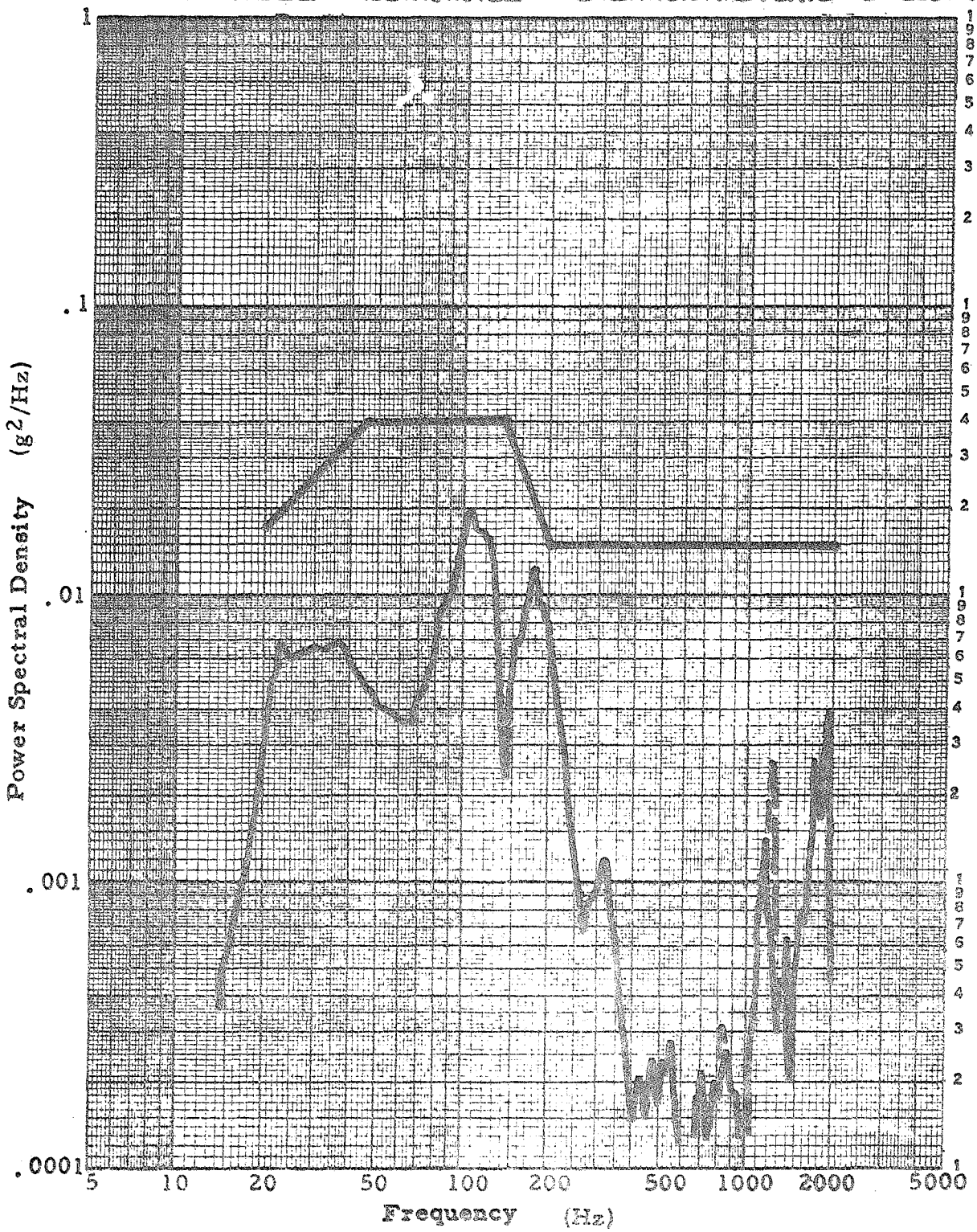
Axis:

RANDOM VIBRATION SPECTRUM

LUNAR DESCENT

Duration:

S.P. 1 W/LSG HARDMOUNTED CSI/THERMAL PLATE Y RESPONSE



440-91

Aerospace Systems Division

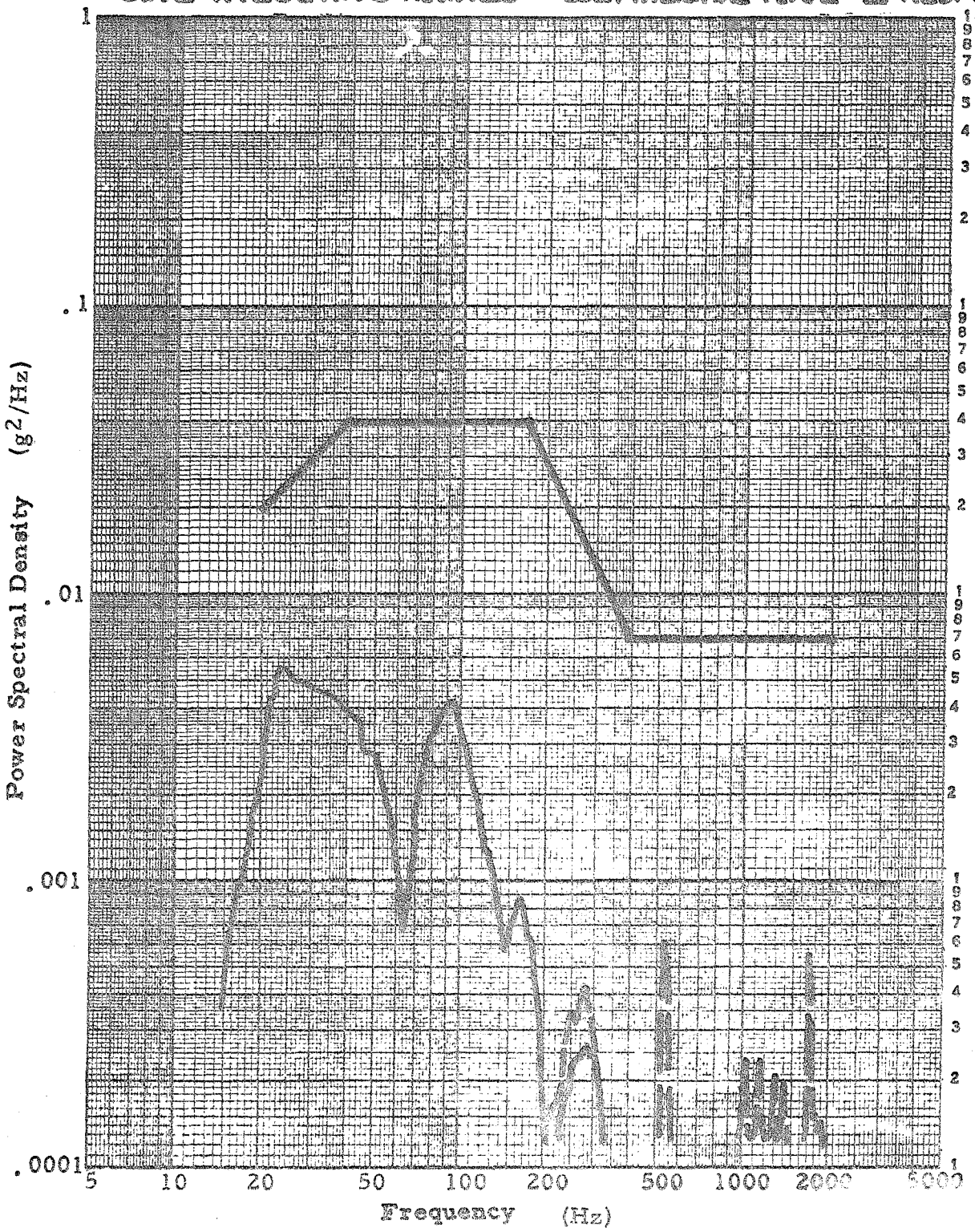
LOCATION α

Axis:

RANDOM VIBRATION SPECTRUM

Duration:

LUNAR DESCENT
S.P.1 W/LSG HARDMOUNTED CSE/THERMAL RATE Z RESPONSE



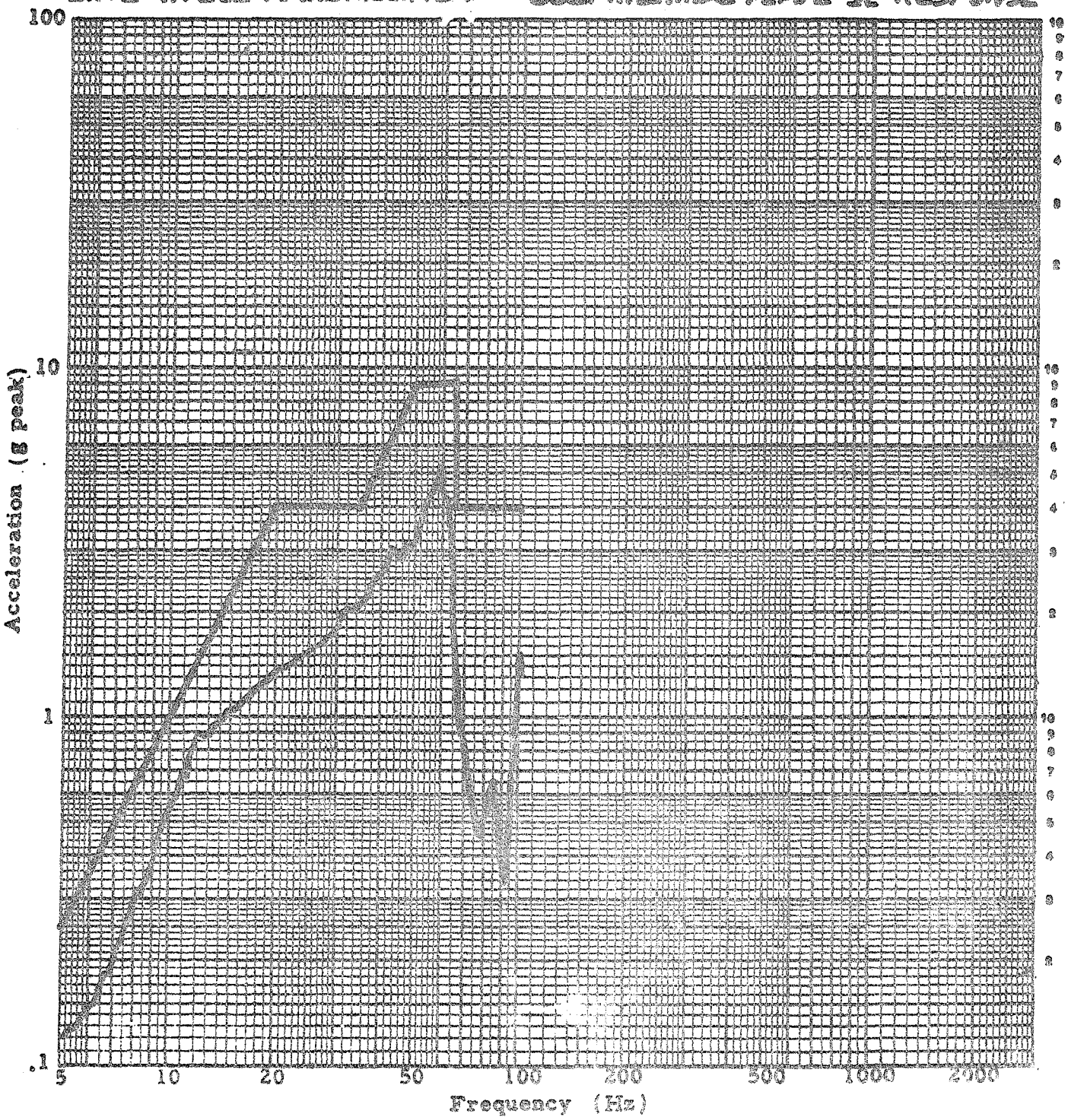
LOCATION B

SINUSOIDAL VIBRATION

Axis:

Sweep Rate:

S.P.1 W/LSG HARDMOUNTED CSE/THERMAL PLATE X RESPONSE



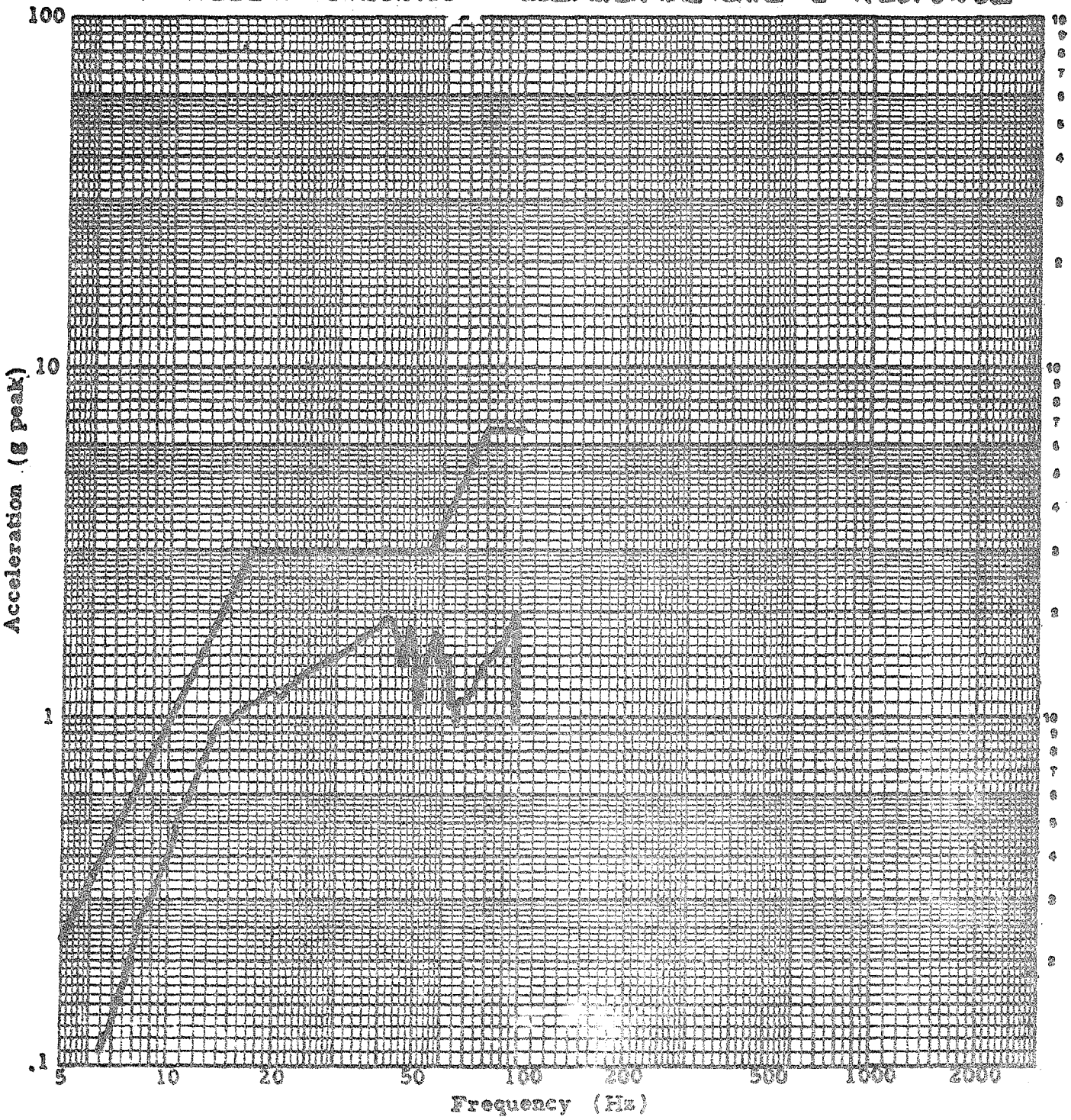
LOCATION 4

SINUSOIDAL VIBRATION

Axis:

Sweep Rate:

S.P. 1 W/LSG HARDMOUNTED CSE/THERMAL PLATE Y RESPONSE



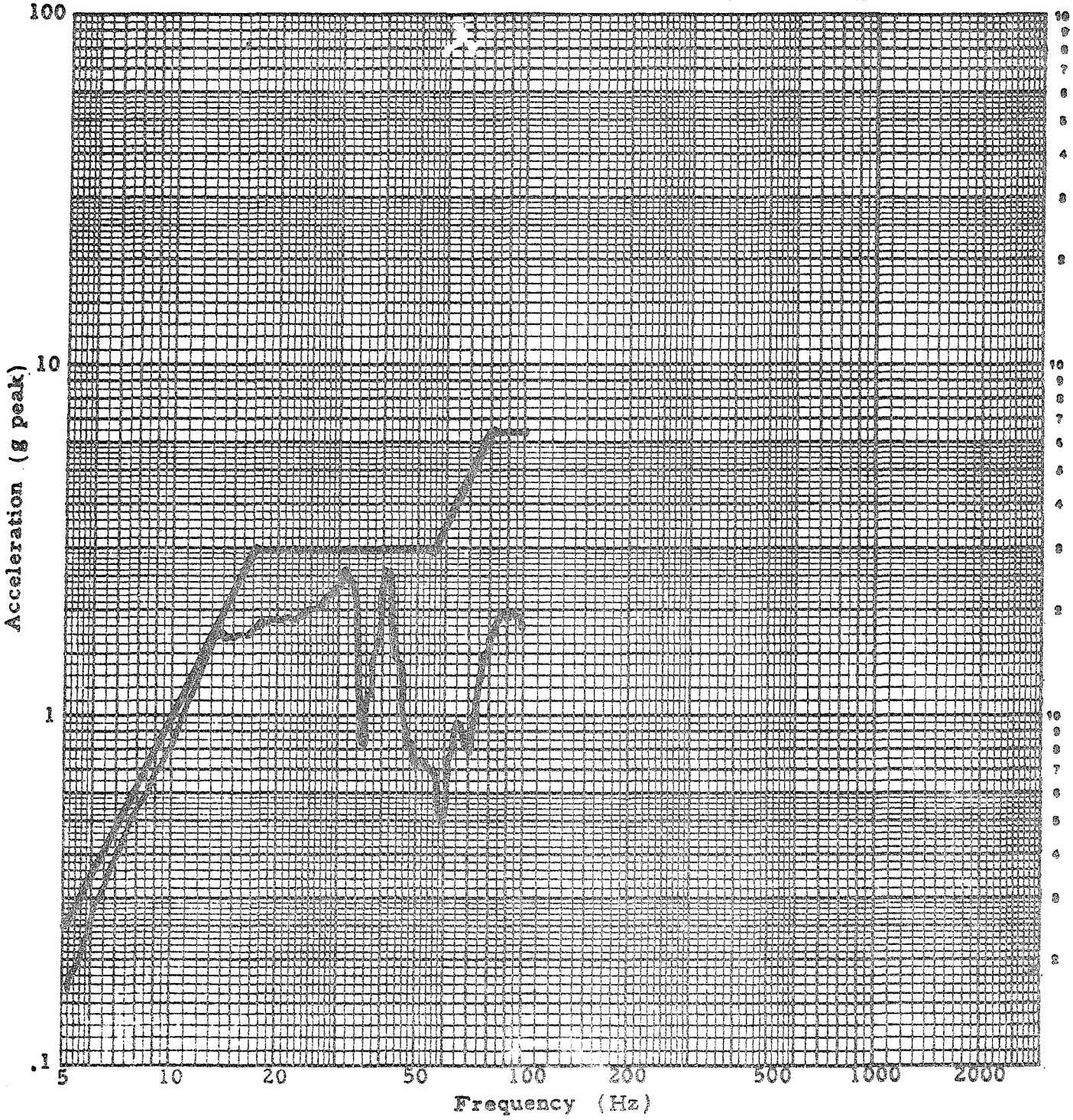
LOCATION B

SINUSOIDAL VIBRATION

Axis:

Sweep Rate:

S.P. 1 W/LSG HARDMOUNTED CSE/THERMAL PLATE Z RESPONSE



Aerospace Systems Division

LOCATION B

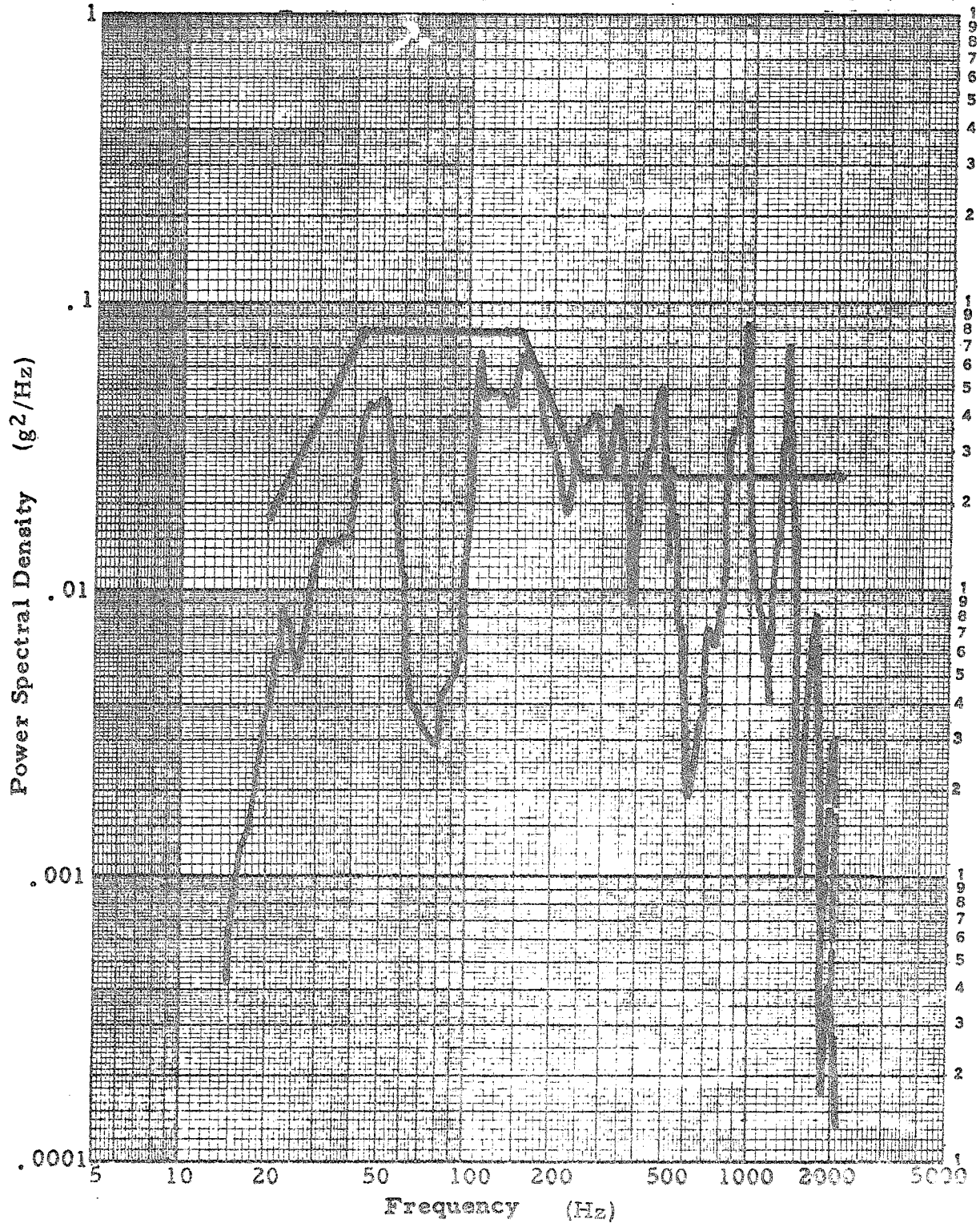
Axis:

RANDOM VIBRATION SPECTRUM

LAUNCH & BOOST

Duration:

S.P. 1 W/LSG HARDMOUNTED CENTERLINE PLATE X RESPONSE



Aerospace Systems Division

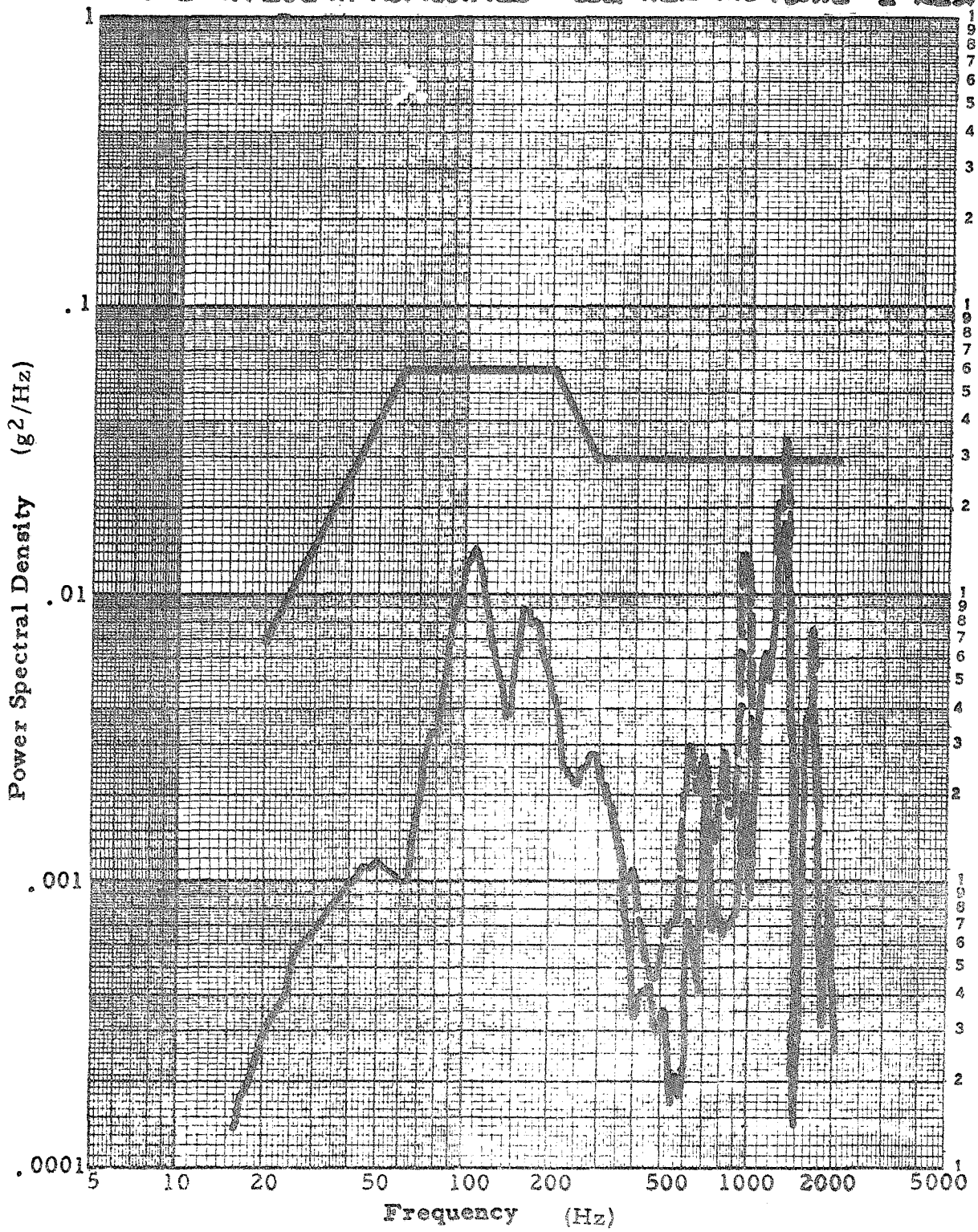
LOCATION B

Axis:

RANDOM VIBRATION SPECTRUM

Duration:

LAUNCH & BOOST
S.P. 1 W/LSG HARDMOUNTED CSE/THERMAL PLATE Y RESPONSE



Bendix Aerospace Systems Division

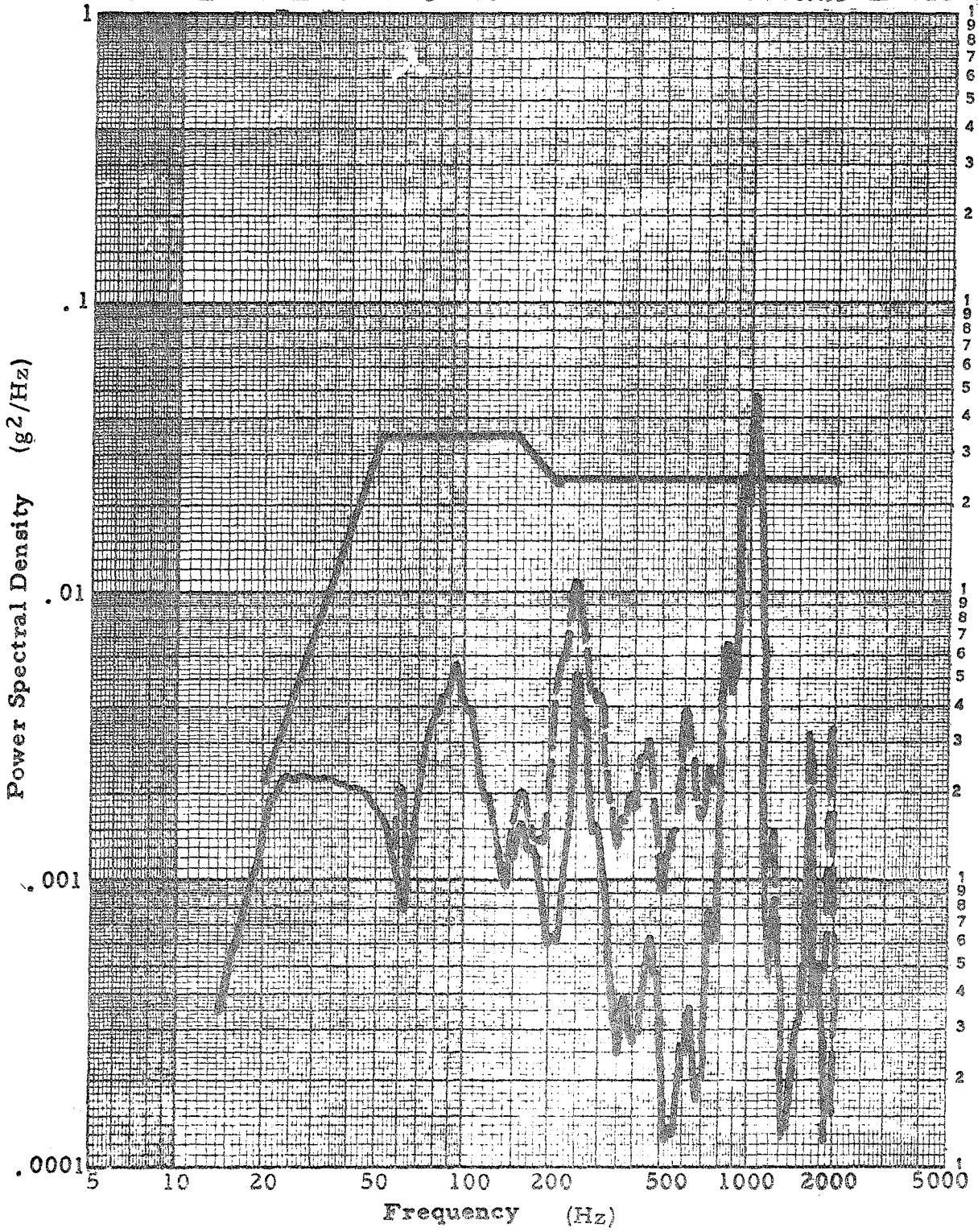
LOCATION B

Axis:

RANDOM VIBRATION SPECTRUM

Duration:

LAUNCH & BOOST
S.P. 1 W/LSG HARD MOUNTED CSE/ALERTING PLATE 2 RESPONSE



Bendix Aerospace Systems Division

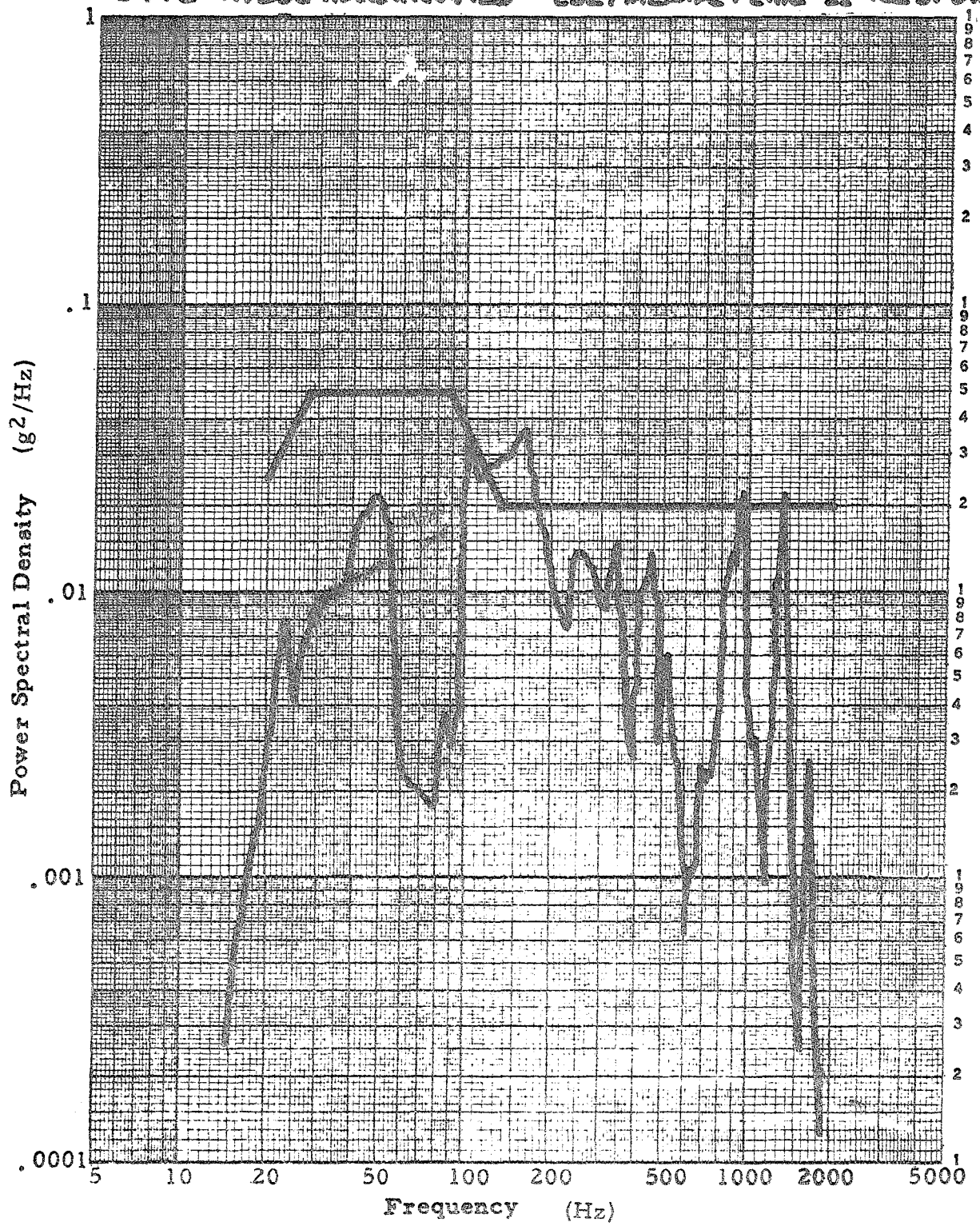
LOCATION B

Axis:

RANDOM VIBRATION SPECTRUM

Duration:

LUNAR DESCENT
S.P. 1 W/LSG HARDMOUNTED CSE/THERMAL PLATE X RESPONSE



Bendix Aerospace Systems Division

LOCATION B

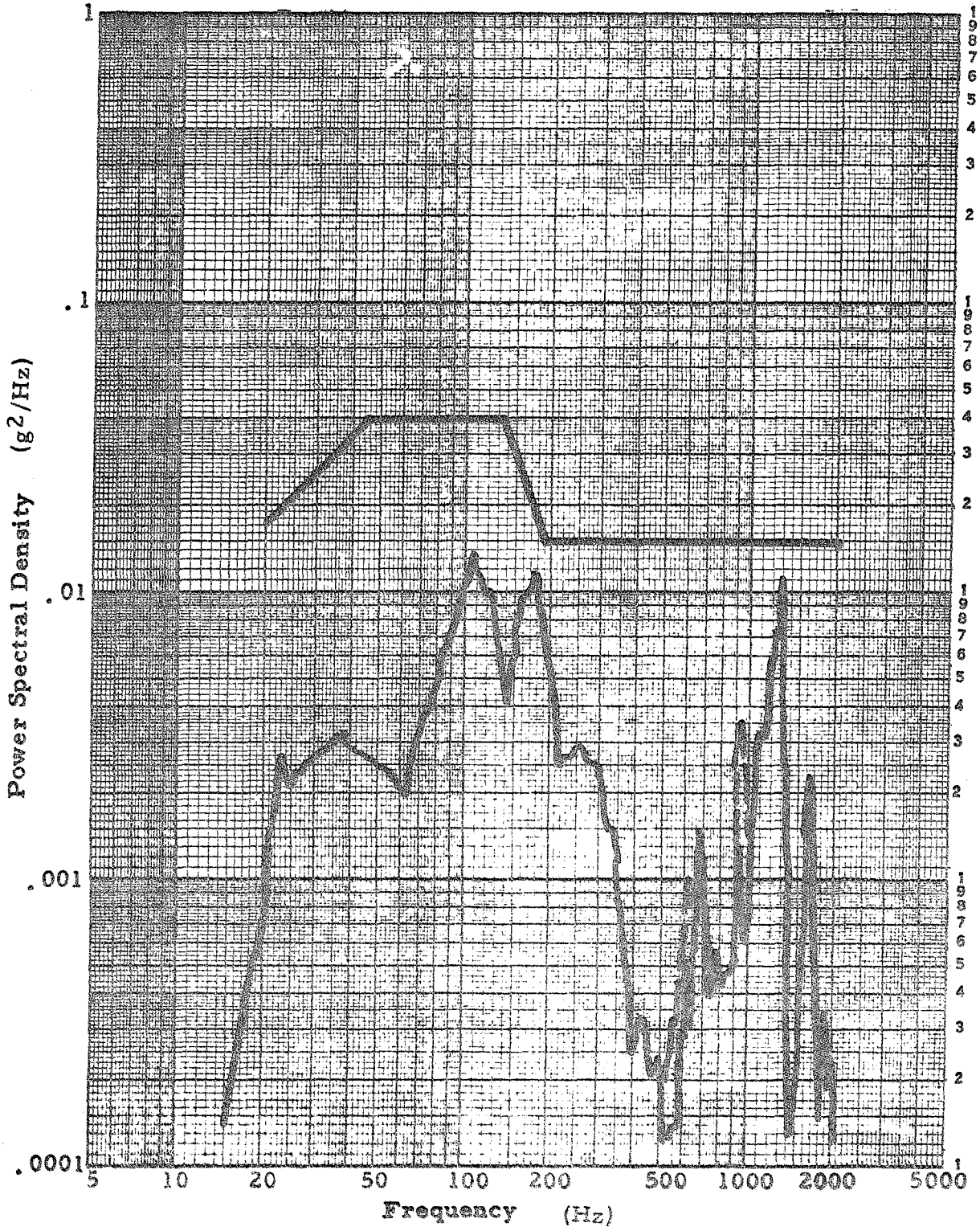
Axis:

RANDOM VIBRATION SPECTRUM

LUNAR DESCENT

Duration:

S.P. 1 W/LSG HARDMOUNTED CSE/THERMAL PLATE Y RESPONSE

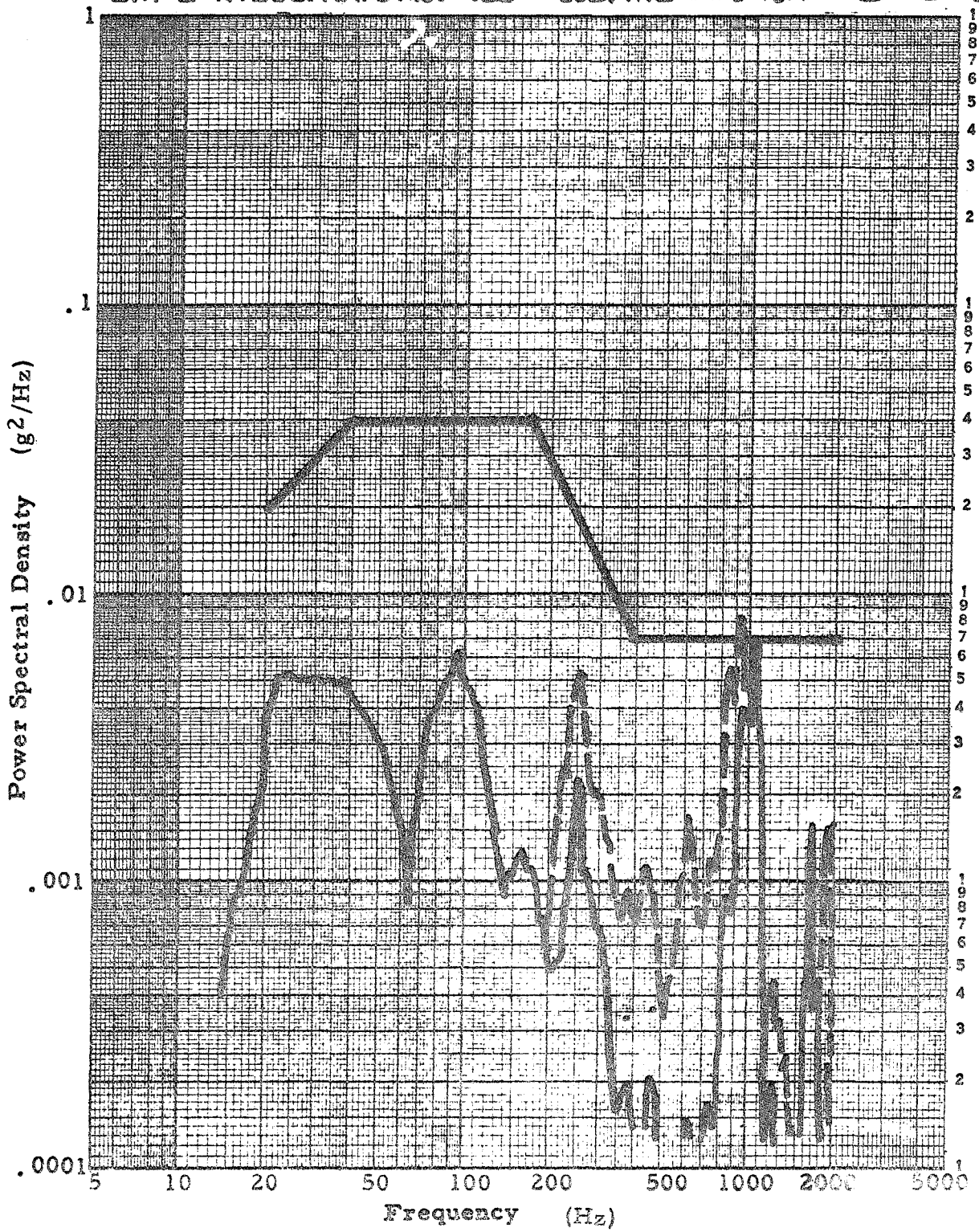


Bendix Aerospace Systems Division

LOCATION B

Axis:

RANDOM VIBRATION SPECTRUM

Duration:

LUNAR DESCENT
S.P. 1 W/LSG. HARDMOUNTED CSE/THERMAL PLATE 2 RESPONSE