Bendix
Aerospace Systems Division

ALSEP Array E Engineering Model
Subpackage No. 2
Design Limit Vibration Test Results

NO.	REV. NO.
ATM-1090	

PAGE 1 OF ____

DATE 3/20/72

This technical memorandum represents the engineering vibration test report for EEM Subpackage No. 2.

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TABLE OF CONTENTS

		Page
1.0	Introduction	4
2.0	Test Article	4
3.0	Test Description	4
4.0	Instrumentation	4
5.0	Results	4
6.0	Conclusion	6
7.0	References	7

LIST OF TABLES

Table	Title	Page
1	EEM-SP2 Hardware	8
2	EEM-SP2 Design Limit Vibration Test Levels	9
3	EEM-SP2 Instrumentation	10
4	EEM-SP2 Vibration Response Values	11

LIST OF FIGURES

Figure	Title	Page
1	EEM-SP2 (Photo)	12
2	EEM-SP2 Instrumentation	13
3-7	Alsep SP2 Vibration Test Levels	14-18
8-16	RTG Response Data	19-27
17-25	LEAM Response Data	28-36
26-34	AAM Response Data	37-45
35-43	HFE Electronics Response Data	46-54
44-52	HFE Probe Response Data	55-63

1.0 Introduction

The Array E Subpackage No. 2 engineering model (EEM-SP2) was subjected to the ALSEP specified design limit vibration levels. The primary purpose of the test was to verify the structural integrity of the system and to verify that the component environments are consistent with component specifications given in reference 1.

2.0 Test Article

The EEM Subpack 2 consists primarily of EEM and modified Qual D components. A detail breakdown of the major components is given in Table I. The individual experiments and components mount to the basic pallet and the HFE subpallet. A photograph of Subpack 2 is shown in Figure 1.

3.0 Test Description

EEM Subpack 2 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. Accelerometers were mounted on the subpack in order to obtain response data at the individual experiment attachment points. Additional information with respect to the test plan is contained in reference 2.

4.0 Instrumentation

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

5.0 Results

Response data is given for each of the three orthogonal axes for the individual components - the RTG, LEAM, AAM, HFE electronics, and HFE probe. Response envelopes giving g-peak and power spectral

density values due to sine and random inputs are shown. For the LEAM and the AAM segmented straight line curves are superimposed on each of the response envelopes which represent specification levels to which the individual components are designed and tested (Ref. I). Solid curves represent response for which 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 (e.g., response in x-direction due to input in y-direction). For the RTG, HFE probe, and HFE electronics response data is shown in the same manner. However, since original specification levels for the RTG and HFE are no longer applicable, the response data for these must be compared to the qualification vibration levels of each component. These levels were recorded at the component attachment points during the Qual SA, Qual B, and/or Qual C tests.

Table 4 is included to summarize the maximum g-peak and g-rms values for each of the individual components due to sine and random testing.

Figures 8-16 show response levels for RTG due to sinusoidal, launch and boost random, and lunar descent random inputs. A maximum response of 11.5 g-peak at 63 Hz due to sine input is shown in Figure 8. Figures 9 & 10 show the Y & Z sine response. Figures 11-16 show the power spectral density levels for the random environments. Levels are generally low across the frequency band except at about 1500 Hz where a spike exists.

Figures 17-25 show response levels for the LEAM due to the different input environments. Figure 17 shows a maximum x-axis sinusoidal response of 15.0 g-peak at 65 Hz, whereas the spec level limit (Ref. 1) is 9.0g. Figures 18 & 19 show Y & Z sine response to be in good agreement with spec levels. Response levels due to launch and boost and lunar descent random vibration levels are shown in Figure 20-25. These response levels are in good agreement with the spec levels across the frequency band.

Figures 26-34 show response levels for the AAM due to the sine and random vibration environments. Response levels are consistent with spec levels (Ref. 1) for all three input axes and all three input environments.

Figures 35-43 show response levels for the HFE electronics. The sine response in Figure 35 shows a maximum x-response of 23.0 g-peak at 60 Hz. Figures 36 & 37 show a maximum Y & Z response level of 8.0

g-peak due to cross axis input. The response levels due to launch and boost and lunar descent random inputs are shown in Figures 38-43. The response levels across the frequency band are similar having a high power spectral density in the lower frequency range and a low power spectral density in the high frequency range. The response data should be compared with previous arrays for proper interpretation.

Figures 44-52 show response levels for the HFE probe. In general the response levels are similar to the HFE electronics. The sine response in Figure 44 shows a maximum X-response of 23.0 g-peak at 65 Hz. Response levels under 9.0 g-peak are seen in Figures 45 & 46 for the Y & Z directions. The response levels due to launch and boost and lunar descent random inputs are shown in Figures 44-52. Much like the HFE electronics the response levels across the frequency band are higher in the low frequency range and lower in the high frequency range. Again this response data should be compared with previous arrays for proper interpretation.

6.0 Conclusion

Vibration testing of Array E engineering model of Subpack 2 was completed on 22 July 71. Individual component response levels were ascertained for the RTG, LEAM, AAM, HFE electronics, & HFE probe, due to the design limit vibration levels as specified for ALSEP.

For the RTG a maximum X-response of 11.5 g-peak at 63 Hz due to sine input was seen. This compares with a g-peak of 5.2 at 43 Hz in previous arrays. The power spectral density levels for the random environments are generally low across the frequency band except at about 1500 Hz where a spike exists. Except for these two excursions the response levels are in fairly good agreement with those from the previous arrays.

For the LEAM the response levels are generally in good agreement with the specification levels across the frequency band for both sinusoidal and random tests. The only exception is a maximum X-axis sinusoidal response of 15.0 g-peak at Hz, whereas the specification level (Ref. 1) is 9.0 g-peak.

For the AAM the response levels for both the sinusoidal and random vibration environments are entirely consistent with specification levels (Ref. 1) for all three axes and all three input environments.

For both the HFE electronics and the HFE probe the maximum response was found to be 23.0 g-peak at about 60 Hz along the x-axis. The response levels due to the random input were similar having a high power spectral density in the lower frequency range and a desirable low power spectral density in the high frequency range. The above sine response of 23.0 g-peak at 60 Hz compares to 7 g-peak at 52 Hz for Qual D - SP 2 tests.

The increase in amplitude during the X-axis sinusoidal vibration for the RTG, LEAM, & HFE components is due primarily to the additional mass on EEM-SP2 relative to Qual D-SP2 and secondary effects due to over used rubber grommets. It has been demonstrated in reference 4 pertaining to the HFE that this combination probably caused a non-linear spring behavior and lower damping of the system resulting in the frequency shift with an increase in amplitude at resonance.

Recommendations have been made to (1) stiffen the pallet in the X-direction and (2) to replace all used silicone rubber grommets with new ones. This combination will increase the natural frequency and insure maximum damping resulting in decreased amplitude.

It is concluded then that the basic structural integrity of the system has been verified and, with the above recommendations, the component environments should be entirely consistent with the test level component specifications and previous component qual levels.

7.0 References

1. ATM-964, "ALSEP Array E Component Non-Operating Vibration Specifications 2/2/71".

2. BxA Letter No. 9712-331 "ALSEP Array E EEM Vibration Test Plan" 4/27/71.

3. BxA Letter No. 9712-383, "EEM Instrumentation Plan for Vibration Testing", 6/10/71.

4. BxA Letter No. 9712-631 "HFE Vibration Environment-EEM Subpack No. 2", 10/18/71.

TABLE I

EEM SUBPACK II HARDWARE

Pallet	Qual D (modified)
HFE subpallet	Qual D (modified)
LEAM subpallet	EEM
Tools & carry bar	EEM
Gimbal and container	Qual D
RTG	Qual D (Simulator)
HFE	DVT (SN-1)
LEAM	EEM (Dynamic Simulator)

TABLE 2

EEM SUBPACK II VIBRATION TESTS - DESIGN LIMIT LEVELS

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

TABLE 3

EEM/SP-2 INSTRUMENTATION

Location No.	Acc. Nos.	Location	Accelerometers	Response Dir.
α	1, 2, 3	Sunshield, near RTG brkt. and strut brkt.	3	x, y, z
γ	4, 5, 6	Carrier near right rear LEAM brkt. (on hat sect.)	3	x, y, z
β	7, 8, 9	Carrier, near rear AAM brkt.	3	x, y, z
δ	10	Carrier, near right fwd. LEAM brkt.	1	input-axis
A	11, 12, 13	Upper left HFE brkt, . top	3	x, y, z
B	14	Lower right HFE brkt., top	1	input-axis
F	15, 16, 17	Left HFE probe brkt	3	x, y, z
G	18	Right HFE probe brkt	1	input-axis

TABLE 4

EEM SP 2 VIBRATION RESPONSE VALUES

RESPONSE		INPUT								
		Sinusoidal			Launch & Boost Random			Lunar Descent Random		
		X	Y	Z	X	Y	Z	X	Y	Z
RTG 1-2-3	X	11.9	1.0	1.0	6.0	3.2	6.4	4.5	3.0	5.4
	Y	1.0	1.7	0.2	4.5	5.8	7.5	3.8	4.2	6.6
	Z	3.0	0.2	0.3	5.5	3.8	6.8	3.8	2.8	6.0
LEAM 4-5-6	X	15.5	1.3	1.1	5.8	3.6	3.0	3.5	3.0	3.1
	Y	1.7	1.7	0.4	3.2	4.2	3.4	2.2	3.3	3.0
	Z	2.0	0.3	3.6	4.2	2.8	2.2	2.8	2.4	1.8
AAM 7-8-9	X	2.8	2.1	1.9	5.2	3.8	2.5	2.3	3.2	1.9
	Y	1.1	1.6	0.3	3.1	4.0	1.5	2.3	3.2	___
	Z	0.4	0.3	2.8	4.2	2.8	2.3	N.D.	2.3	1.6
HFE Elect. 11-12-13	X	23.5	1.3	3.6	1.6	1.0	1.0	1.4	0.8	< 1
	Y	7.5	3.4	1.1	1.4	0.8	< 1	1.1	0.7	< 1
	Z	7.5	0.8	4.9	N.D.	0.7	N.D.	0.9	0.2	N.D.
HFE Probe 15-16-17	X	23.5	3.0	2.5	1.5	1.6	< 1	1.6	1.5	< 1
	Y	9.0	4.6	1.0	1.2	0.8	1.0	1.0	0.8	< 1
	Z	5.0	2.2	1.8	0.3	0.8	< 1	0.8	0.7	< 1

NOTE: SINE LEVELS ARE G-PEAK VALUES.
RANDOM LEVELS ARE G (RMS) VALUES.

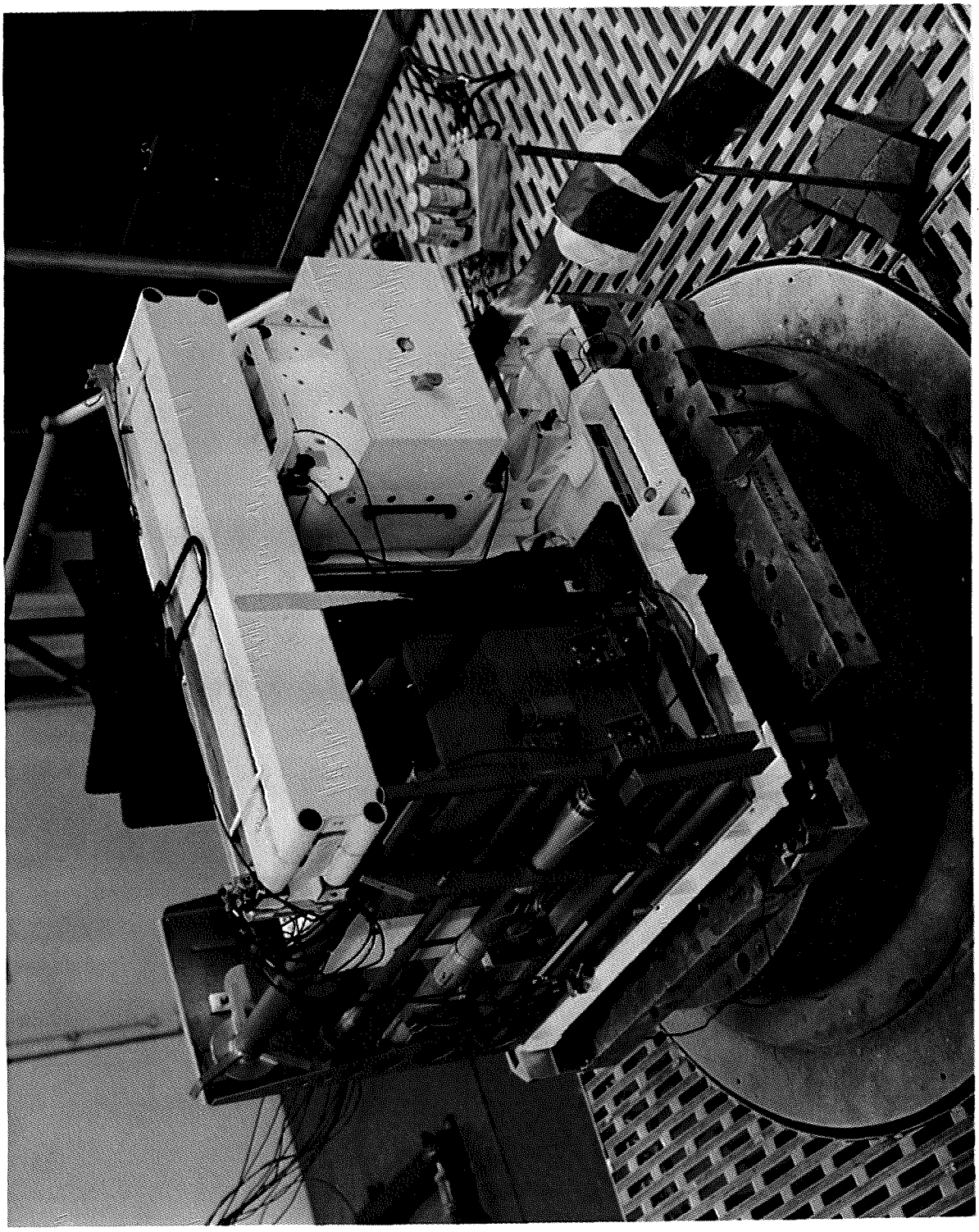


Figure 1 - EEM - SP2

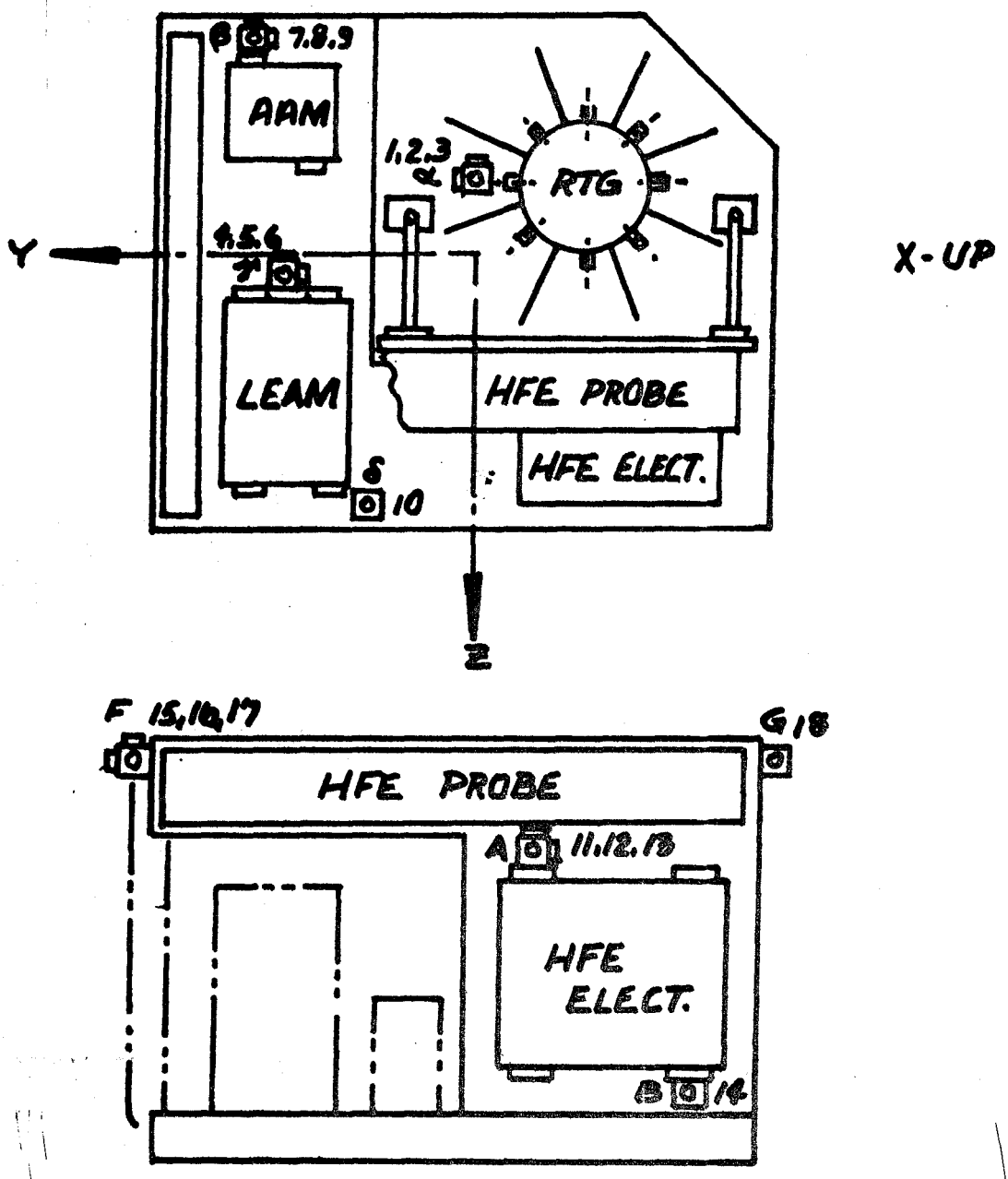


Figure 2 EEM-SP 2 Instrumentation

DESIGN LIMIT LEVEL

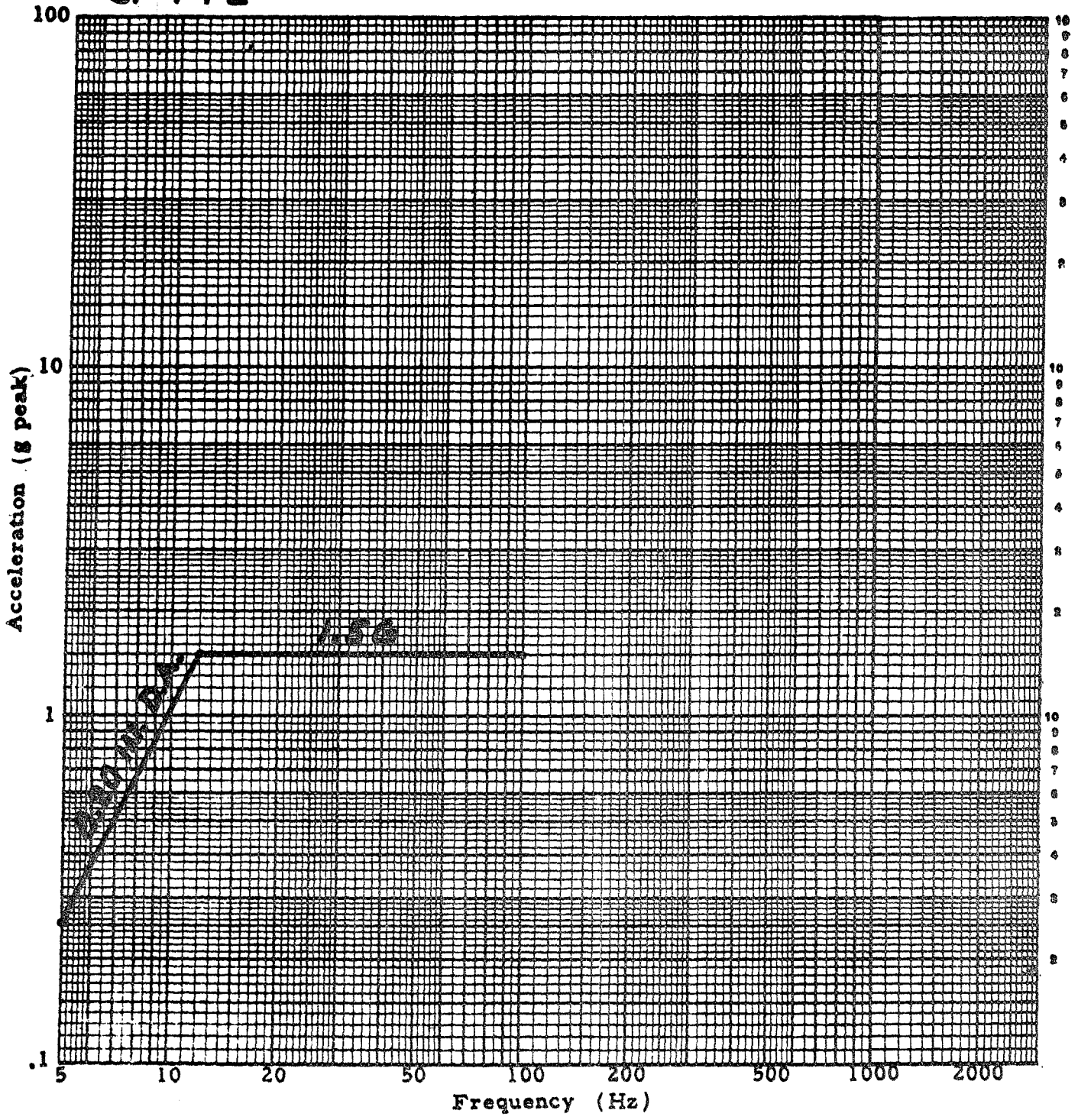
SINUSOIDAL VIBRATION

Axis: X, Y, Z

Sweep Rate: 3 OCT/MIN.

SWEEP: 5-100-5 HZ

SP-1 & 2



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DESIGN LIMIT LEVEL L&B

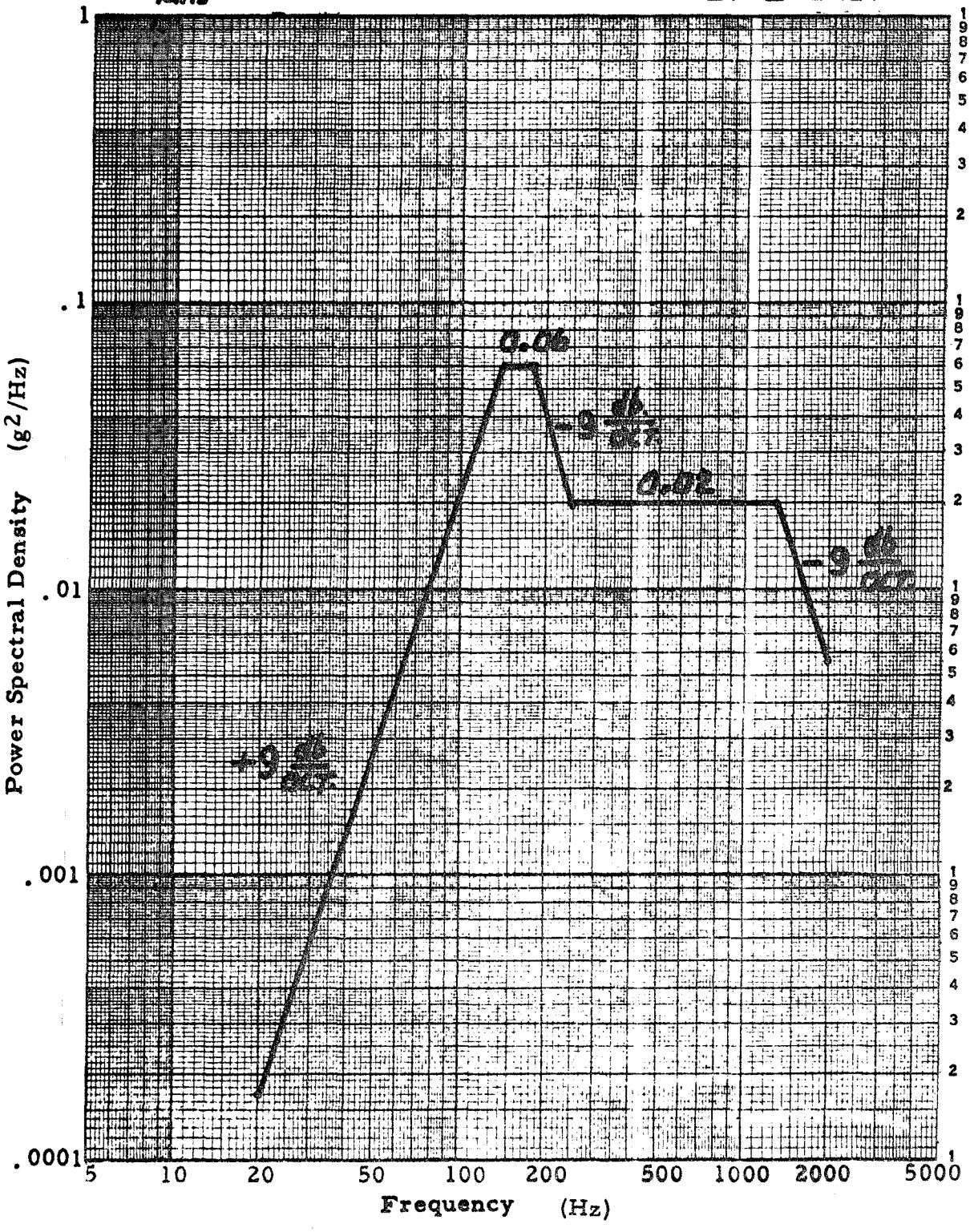
RANDOM VIBRATION SPECTRUM

Axis: X

Duration: 1.0 MIN.

$G_{RMS} = 6.0$

SP-2 ONLY



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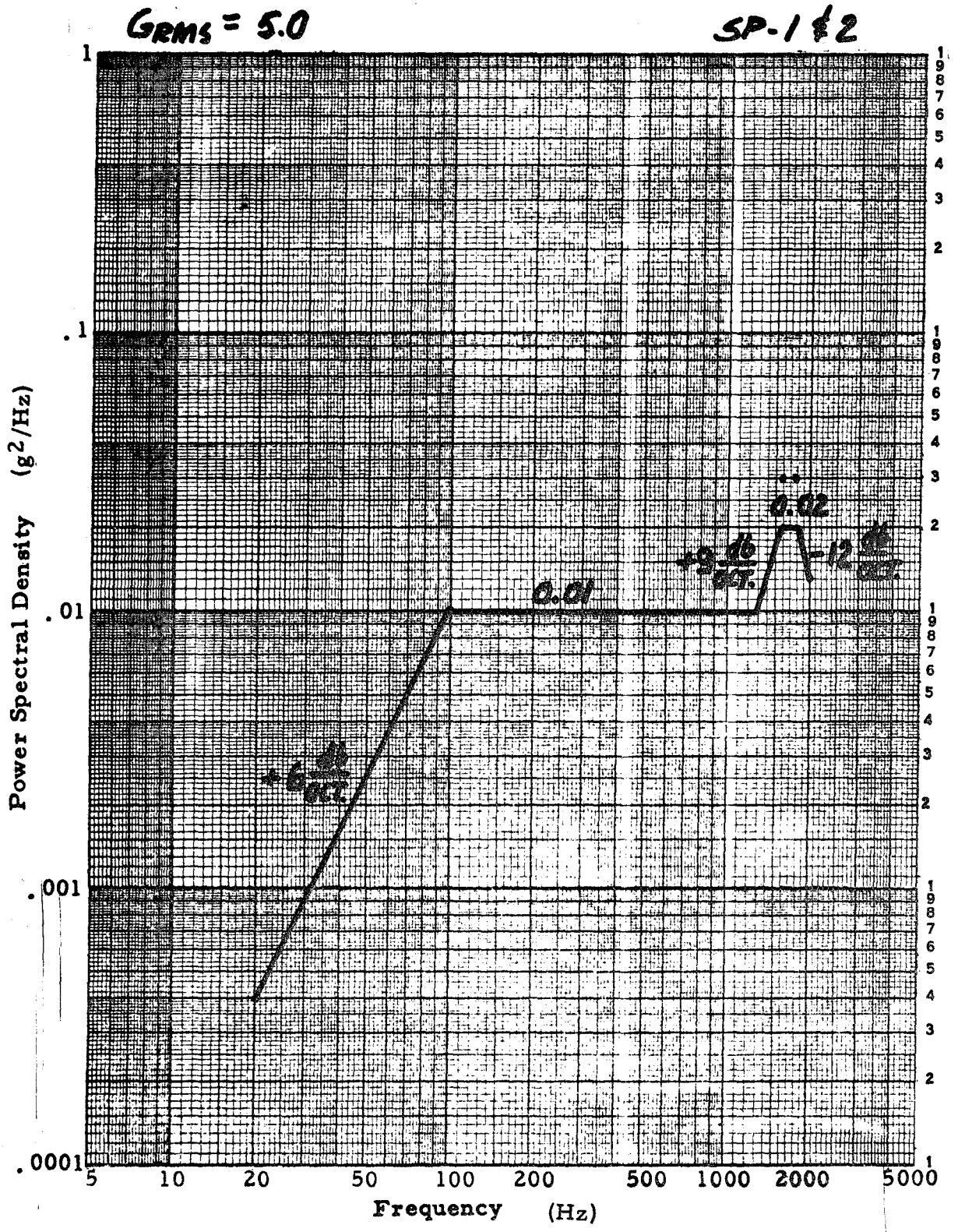
DESIGN LIMIT LEVEL L&B

RANDOM VIBRATION SPECTRUM

Axis: Y

Duration: 1.0 MIN.

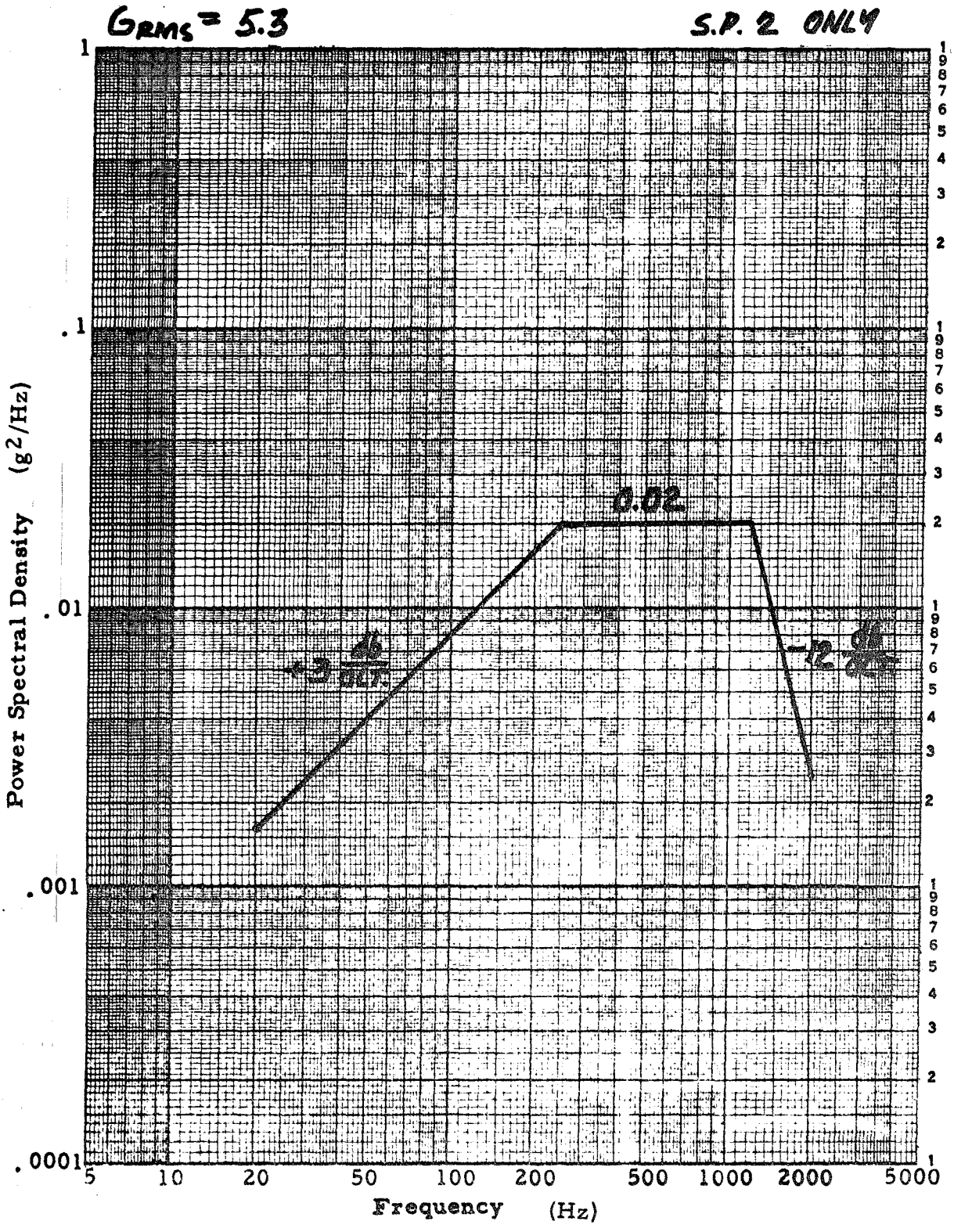


DESIGN LIMIT LEVEL L&B

RANDOM VIBRATION SPECTRUM

Axis: Z

Duration: 1.0 MIN.



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DESIGN LIMIT LUNAR DESCENT

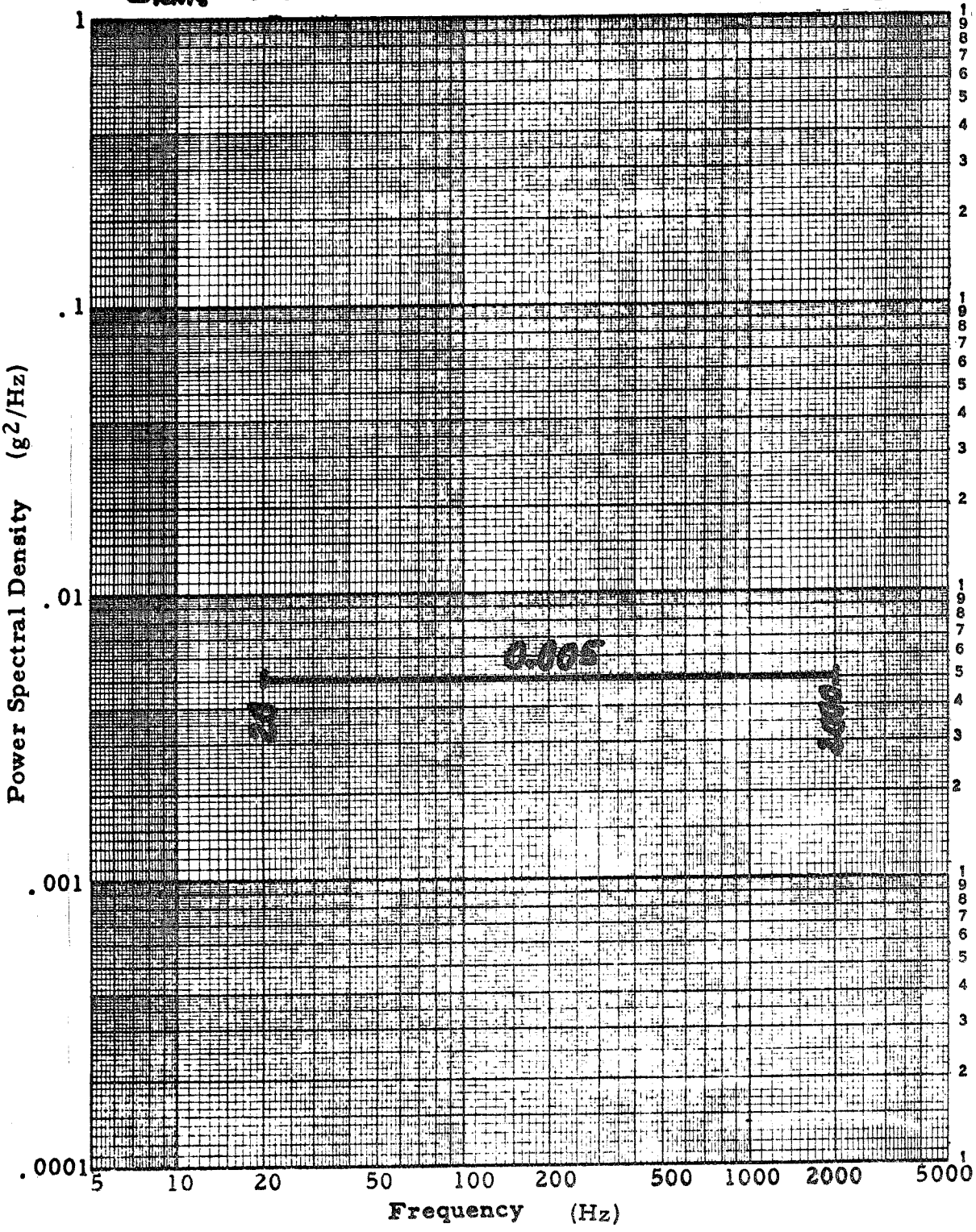
RANDOM VIBRATION SPECTRUM

Axis: X, Y, Z

Duration: 12.5 MIN./AXIS

GRMS = 3.2

SP-1 & 2



ACC. NO 1

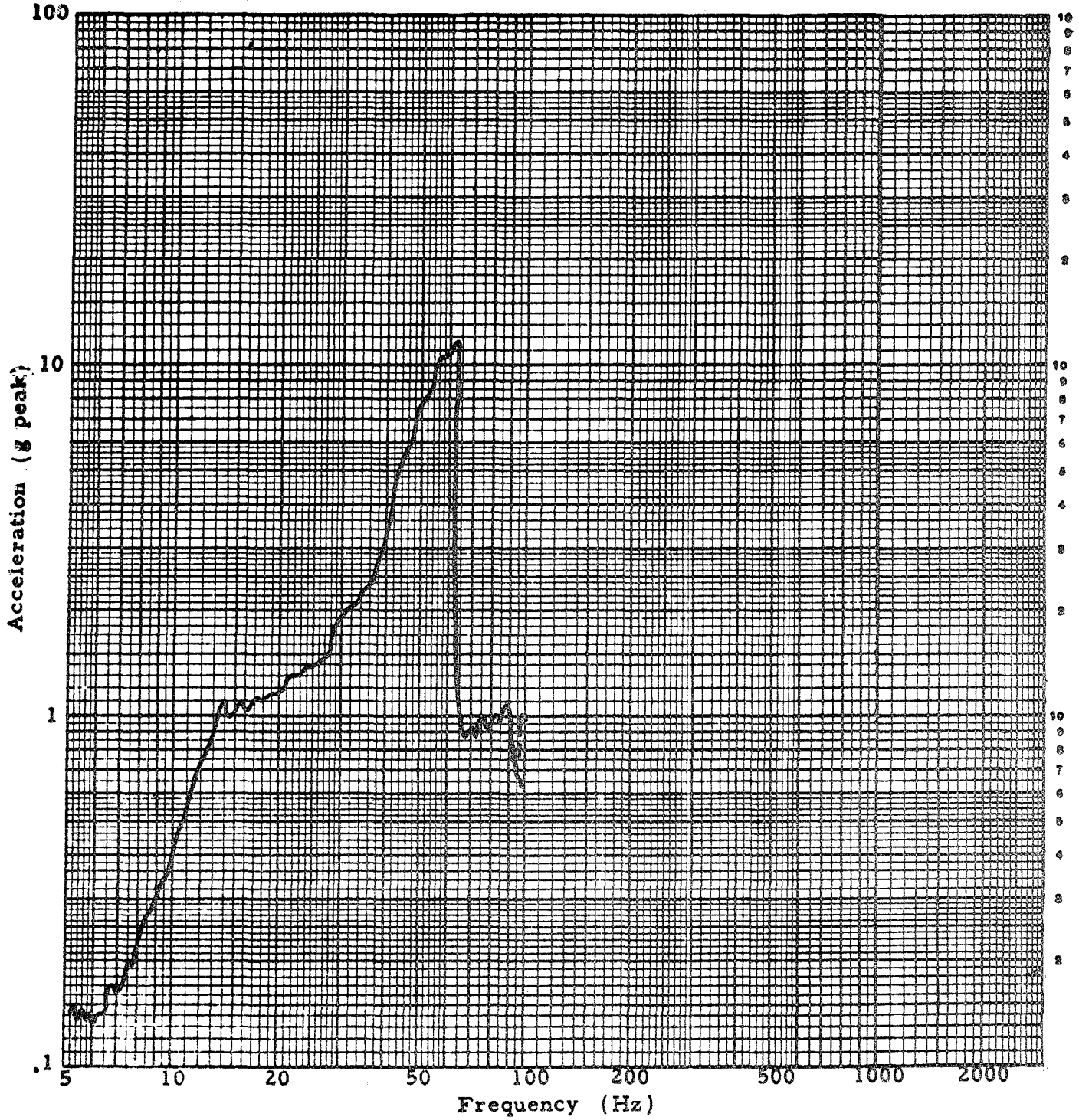
SINUSOIDAL VIBRATION

Axis:

Sweep Rate:

S.D. 2

RTG X RESPONSE



ACC. NO. 2

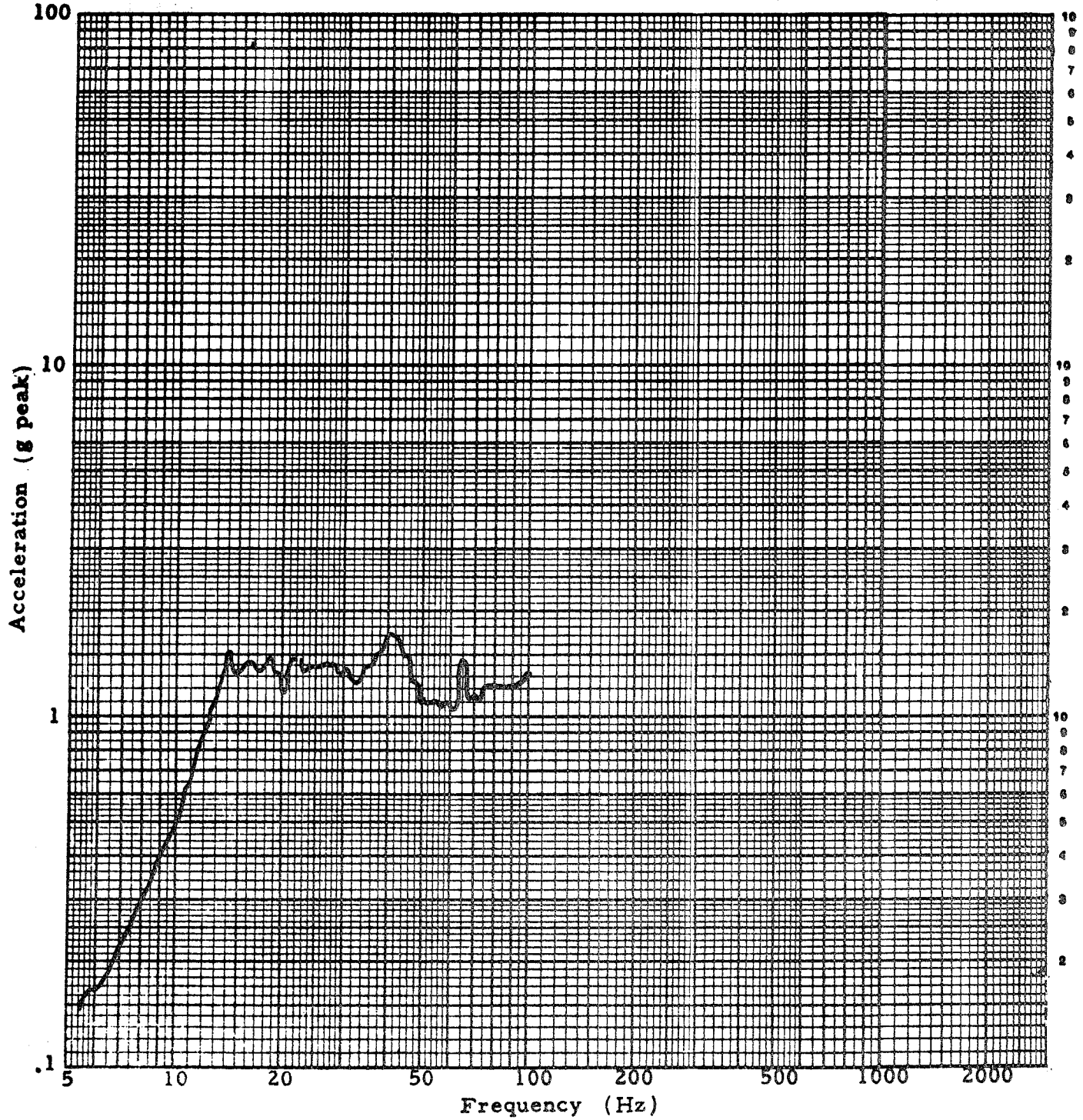
SINUSOIDAL VIBRATION

Axis:

Sweep Rate:

S.P. 2

RTG Y RESPONSE



ACC. NO. 3

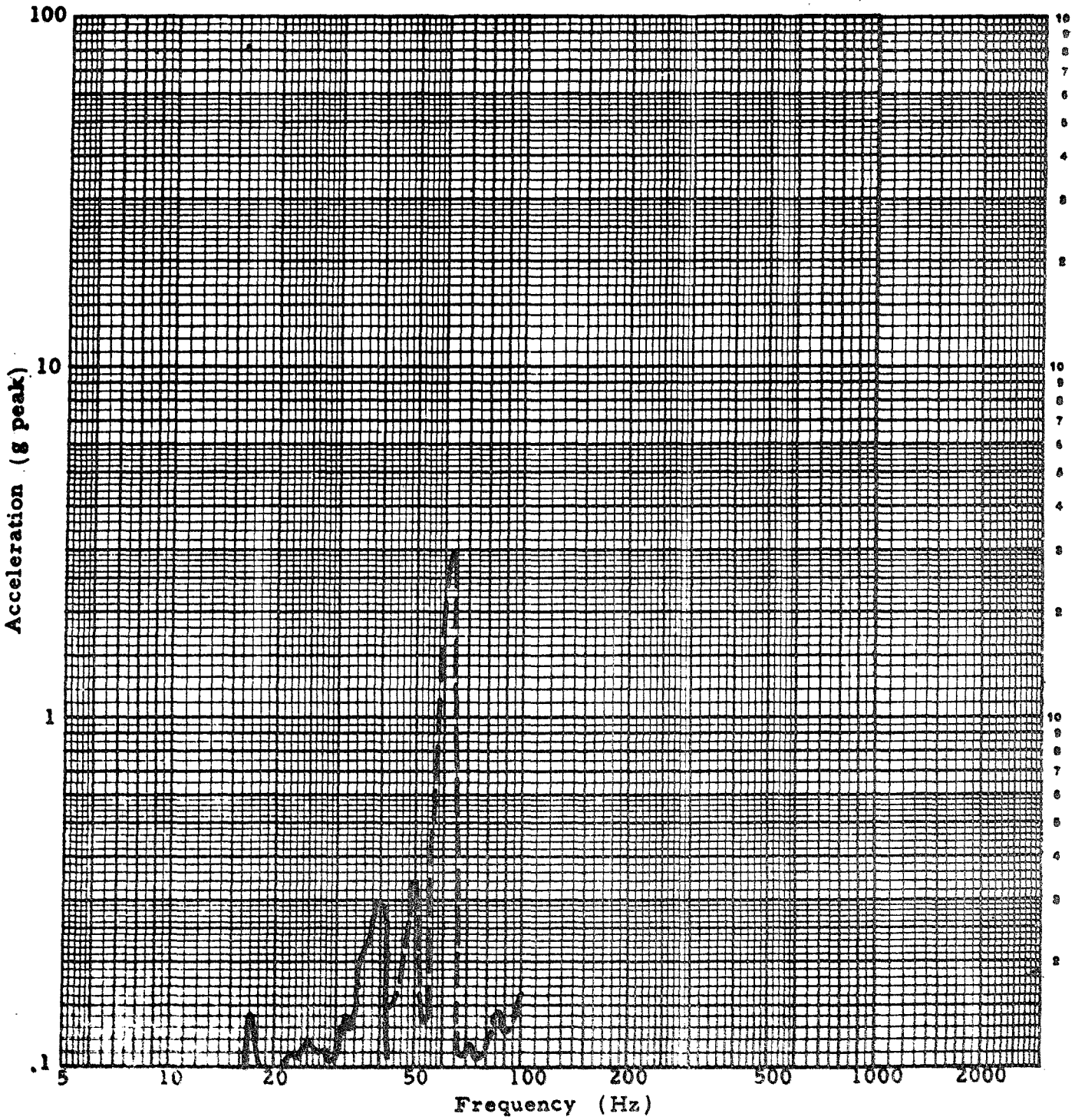
SINUSOIDAL VIBRATION

Axis:

Sweep Rate:

S.P. 2

RTG Z RESPONSE



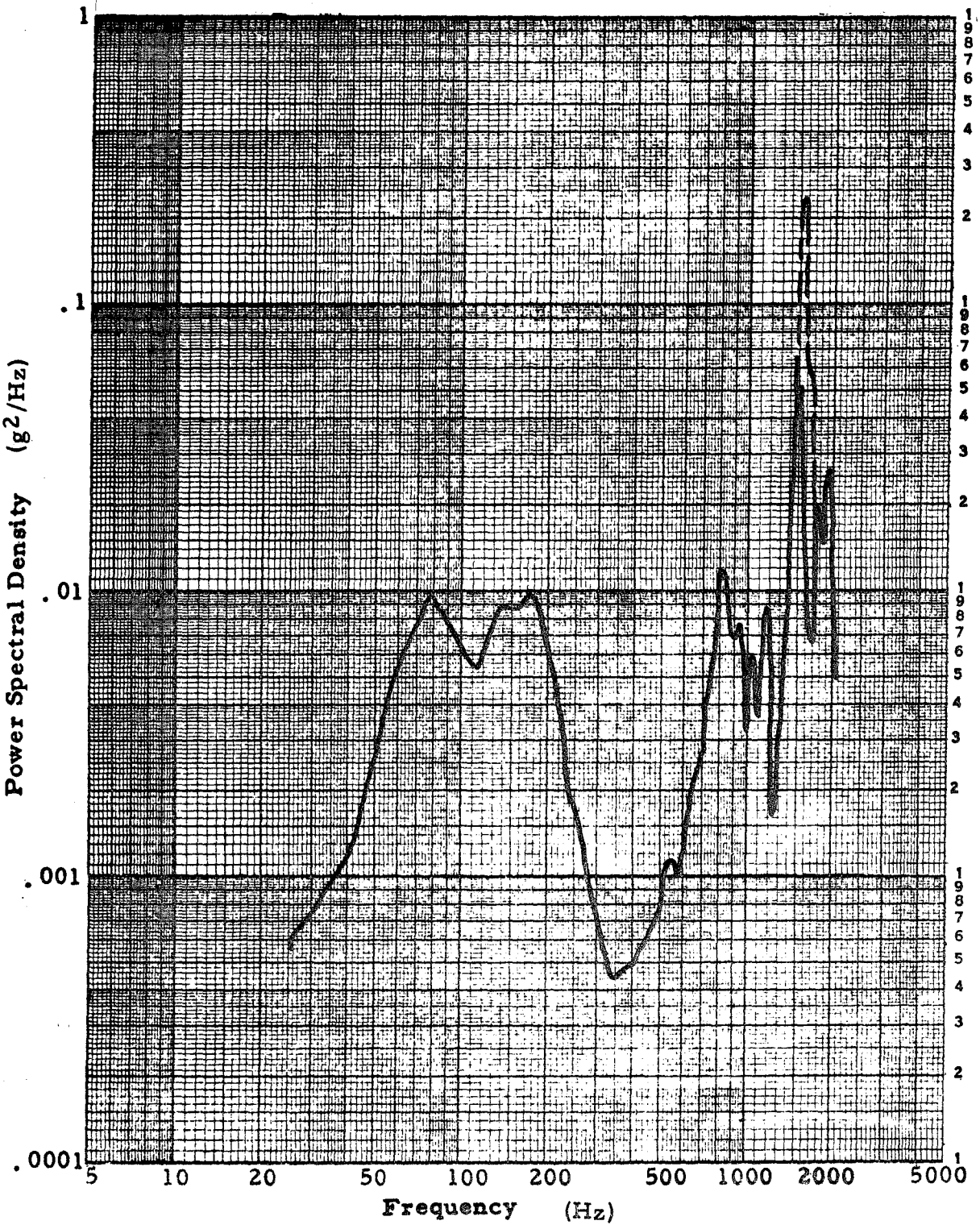
ACL. NO. 1
Axis:

RANDOM VIBRATION SPECTRUM

LAUNCH & BOOST
S.P. 2

Duration:

RTG X RESPONSE



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ACL.NO.2

Axis:

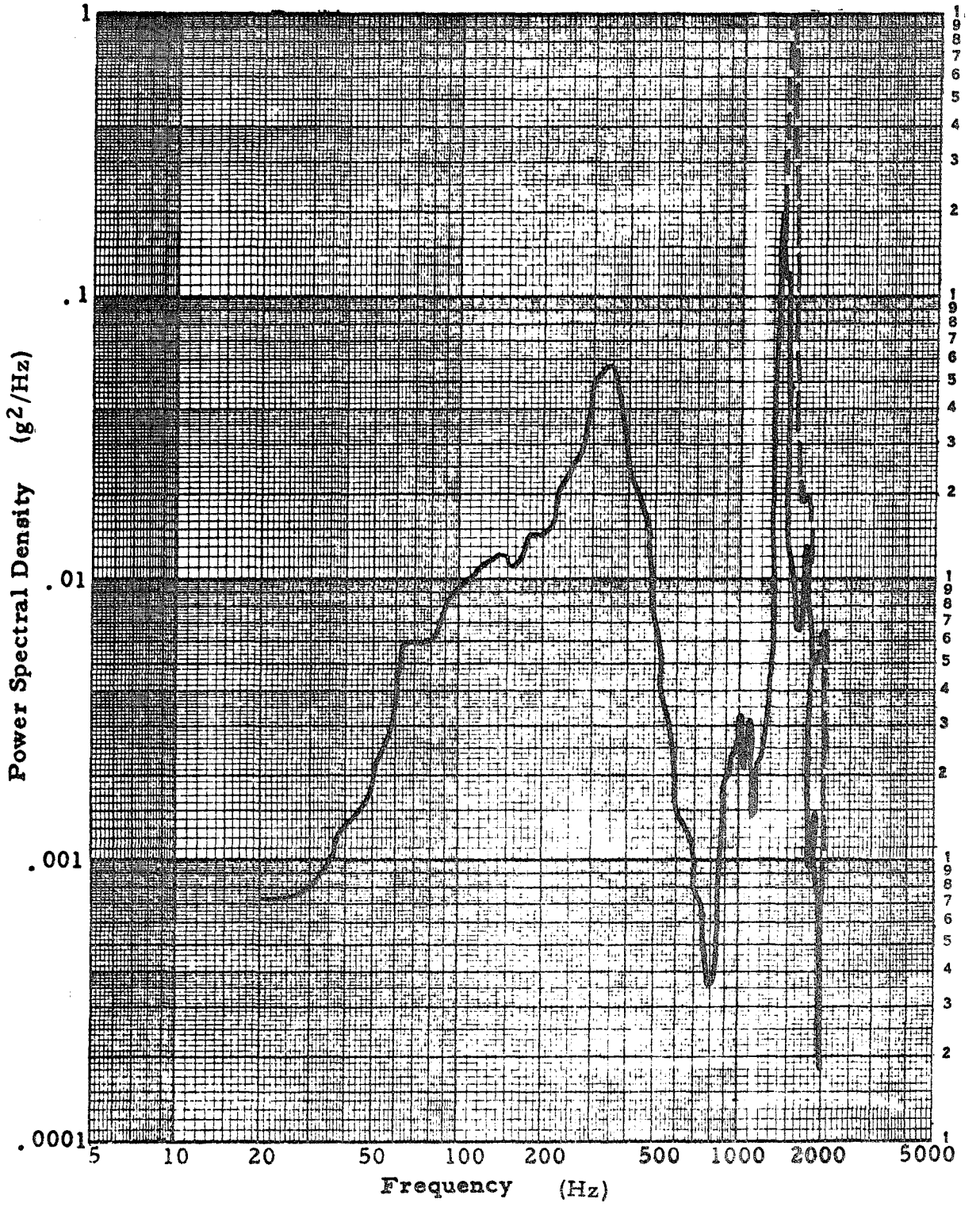
RANDOM VIBRATION SPECTRUM

LAUNCH & BOOST

Duration:

S.P. 2

RTG. Y RESPONSE



ACC. NO. 3
Axis:

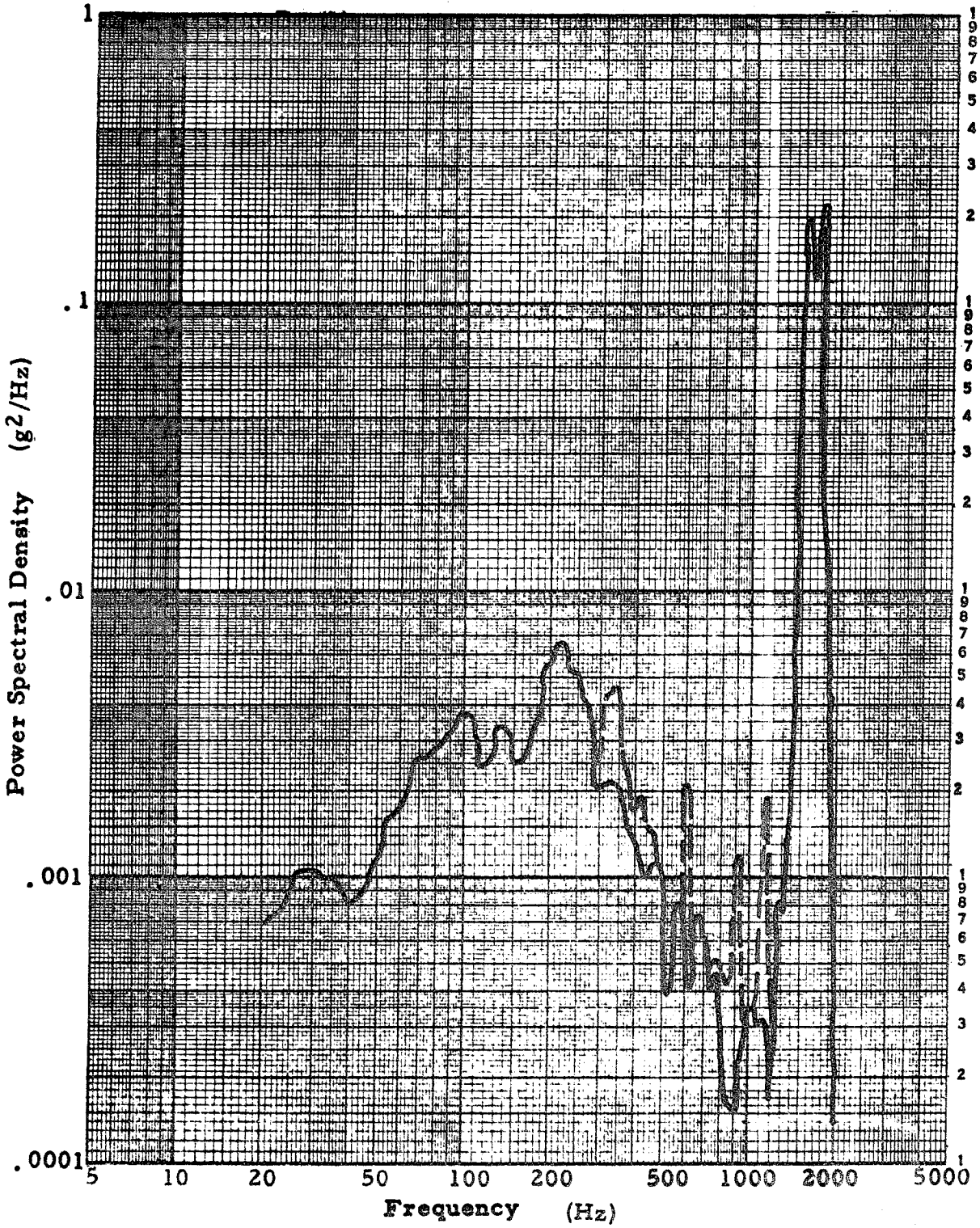
RANDOM VIBRATION SPECTRUM

LAUNCH & BOOST

Duration:

S.P. 2

RTG & RESPONSE



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ACC. NO. 1

Axis:

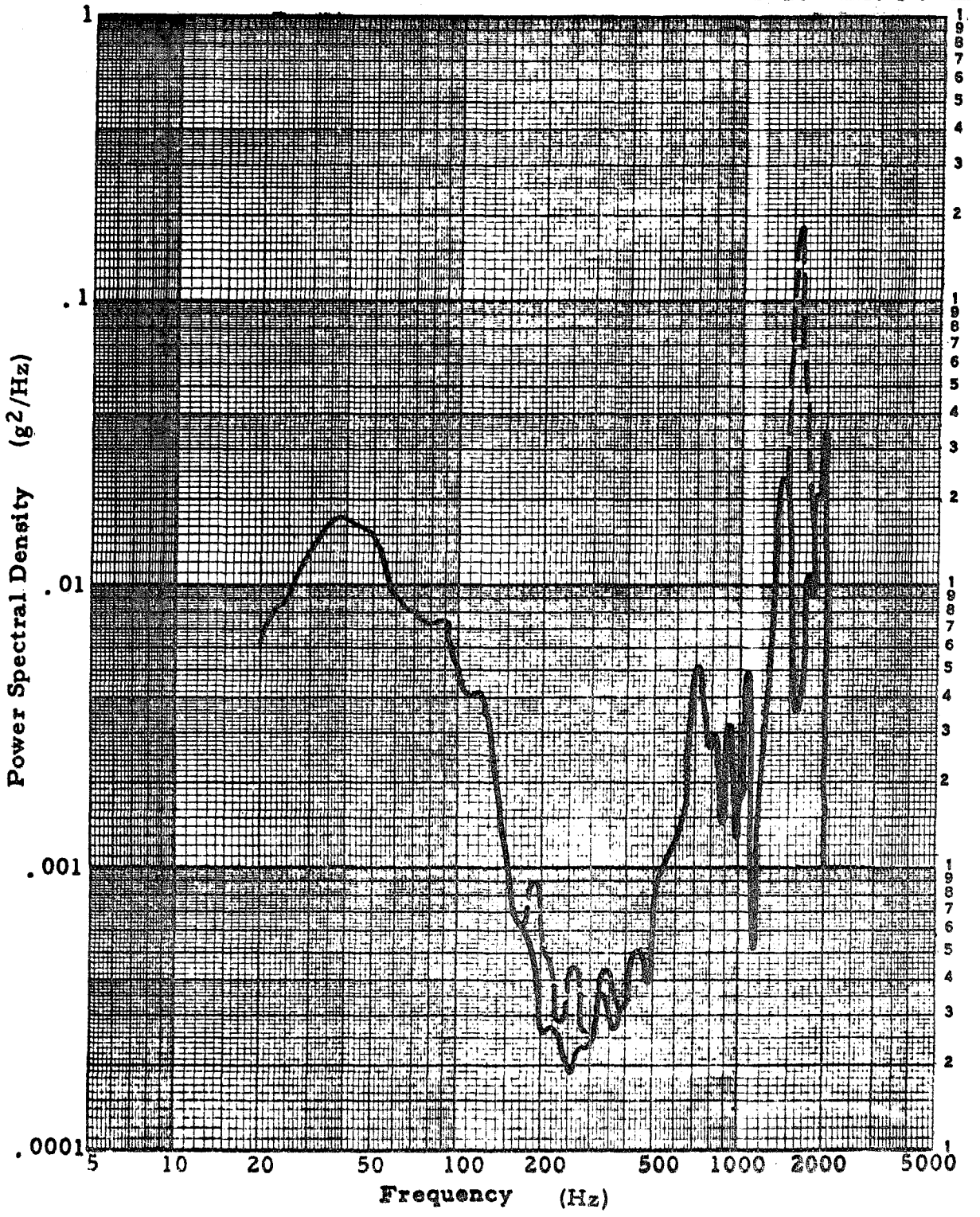
RANDOM VIBRATION SPECTRUM

LUNAR DESCENT

Duration:

S.P. 2

RTG X RESPONSE



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ALL. NO. 2

Axis:

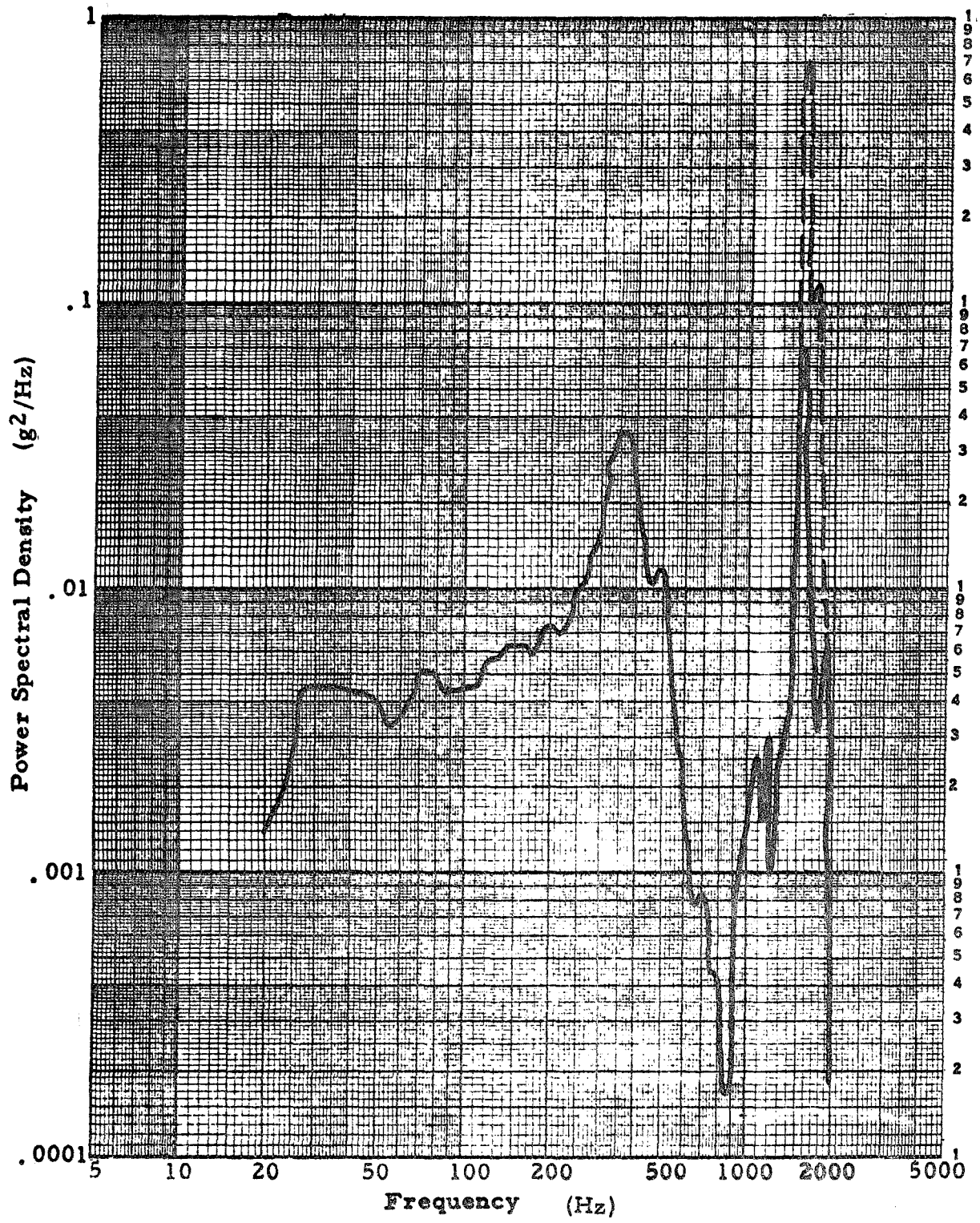
RANDOM VIBRATION SPECTRUM

LUNAR DESCENT

Duration:

S.P. 2

RTG Y RESPONSE



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ALL NO. 3

Axis:

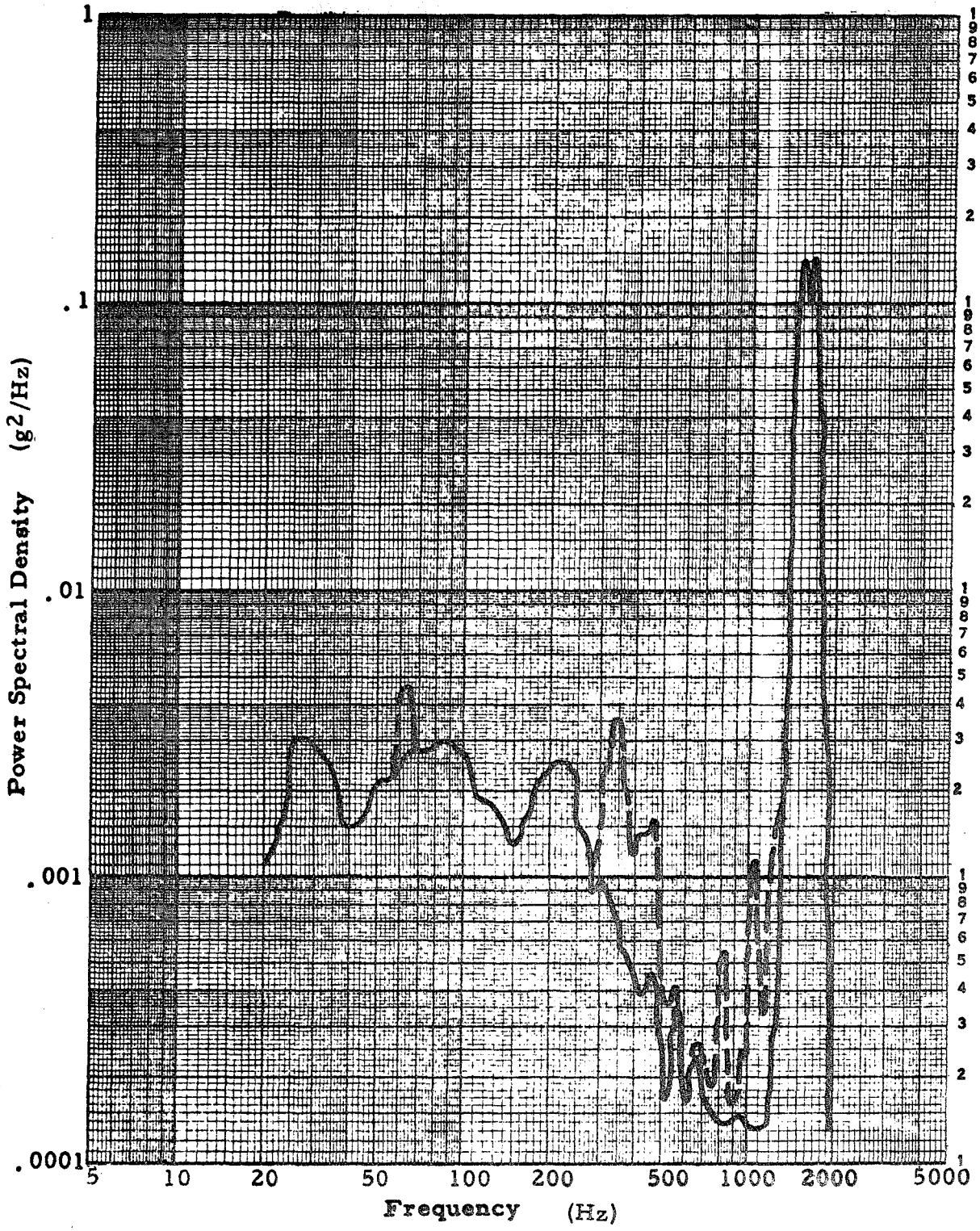
RANDOM VIBRATION SPECTRUM

LUNAR DESCENT

S.P. 2

Duration:

RTG ≥ RESPONSE



ACC. NO. 4

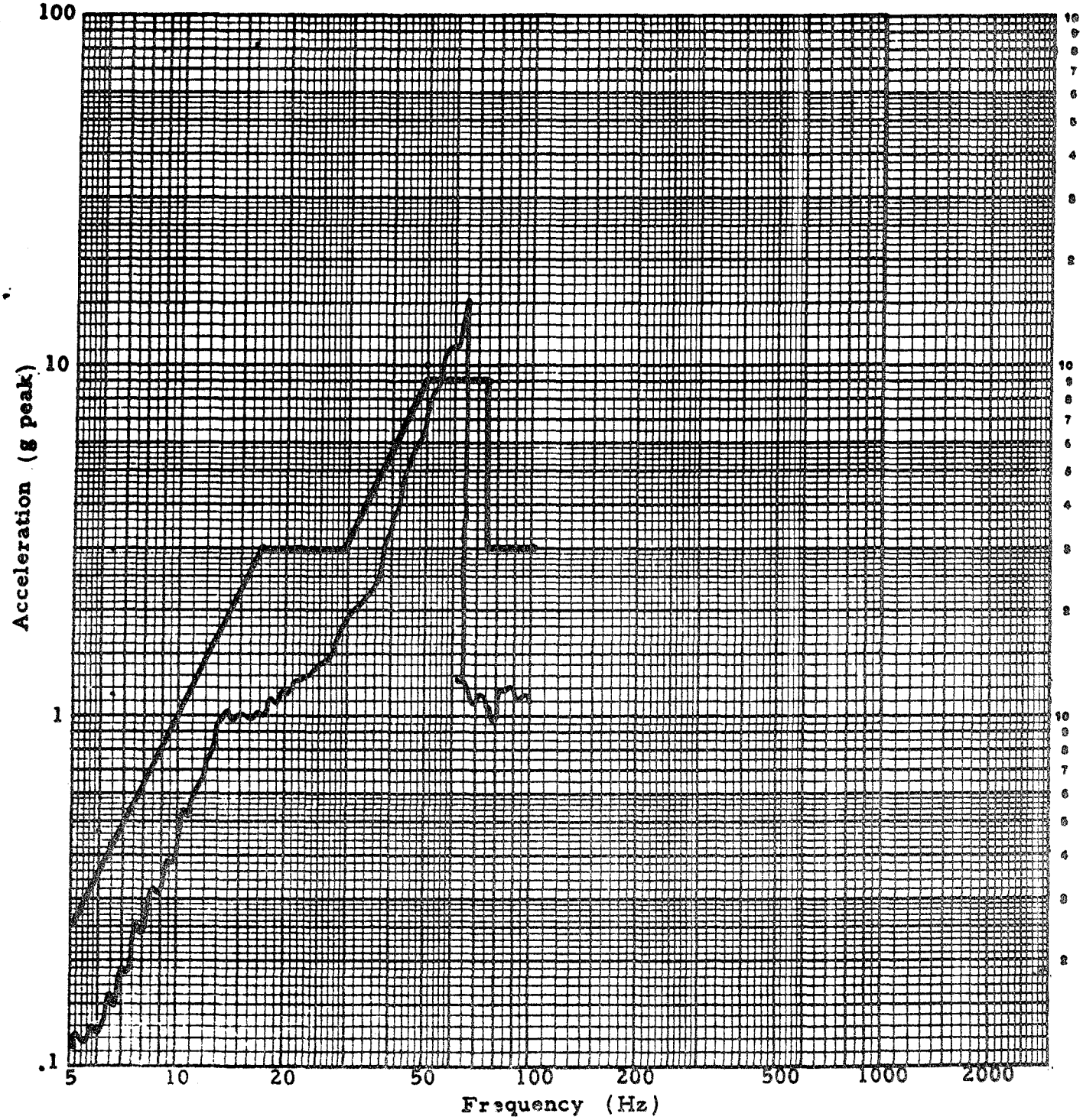
SINUSOIDAL VIBRATION

Axis:

Sweep Rate:

S.P. 2

LEAM X RESPONSE



ACC. NO. 5

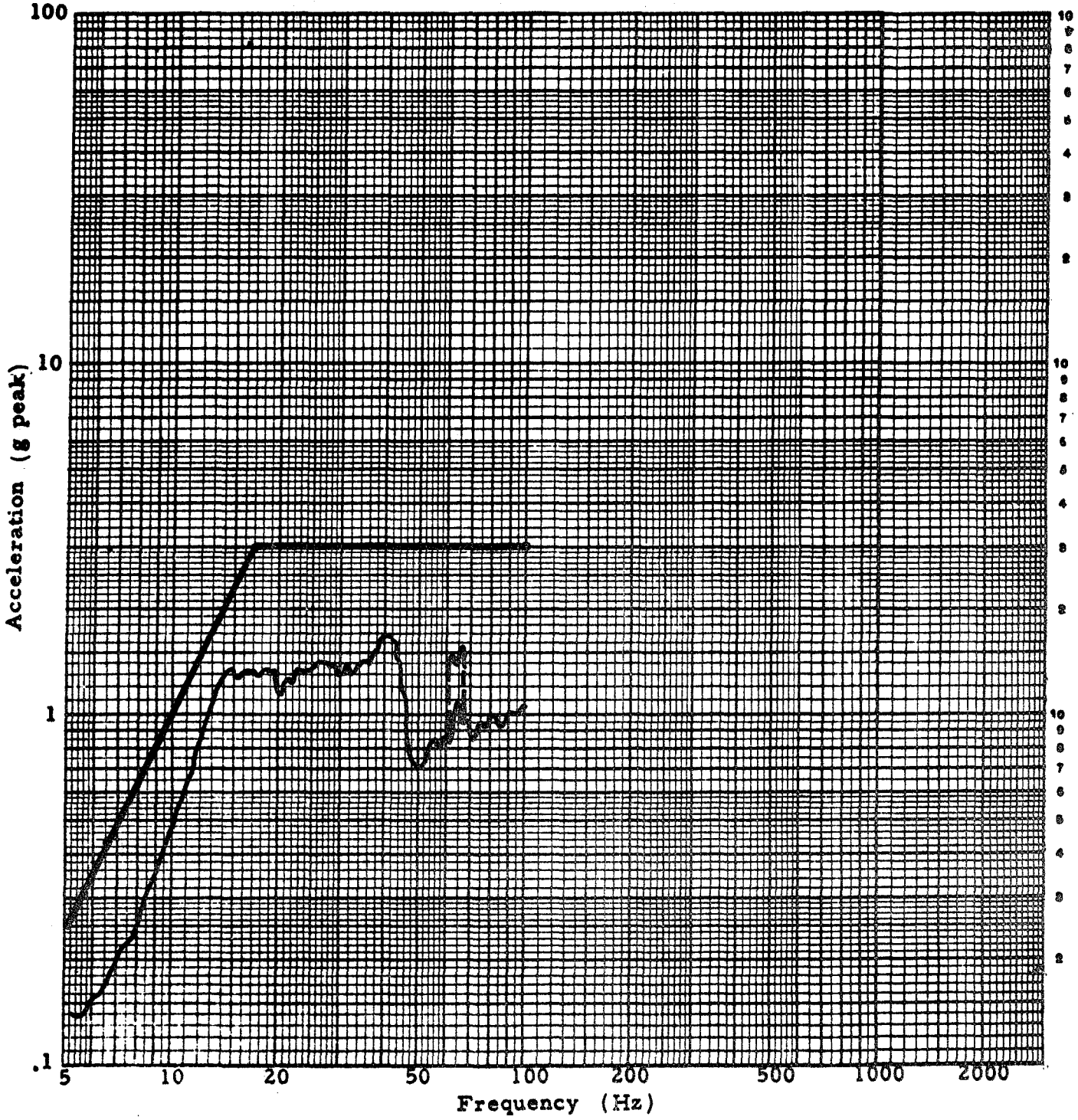
SINUSOIDAL VIBRATION

Axis:

Sweep Rate:

S.P. 2

LEAM Y RESPONSE



ACC. NO. 6

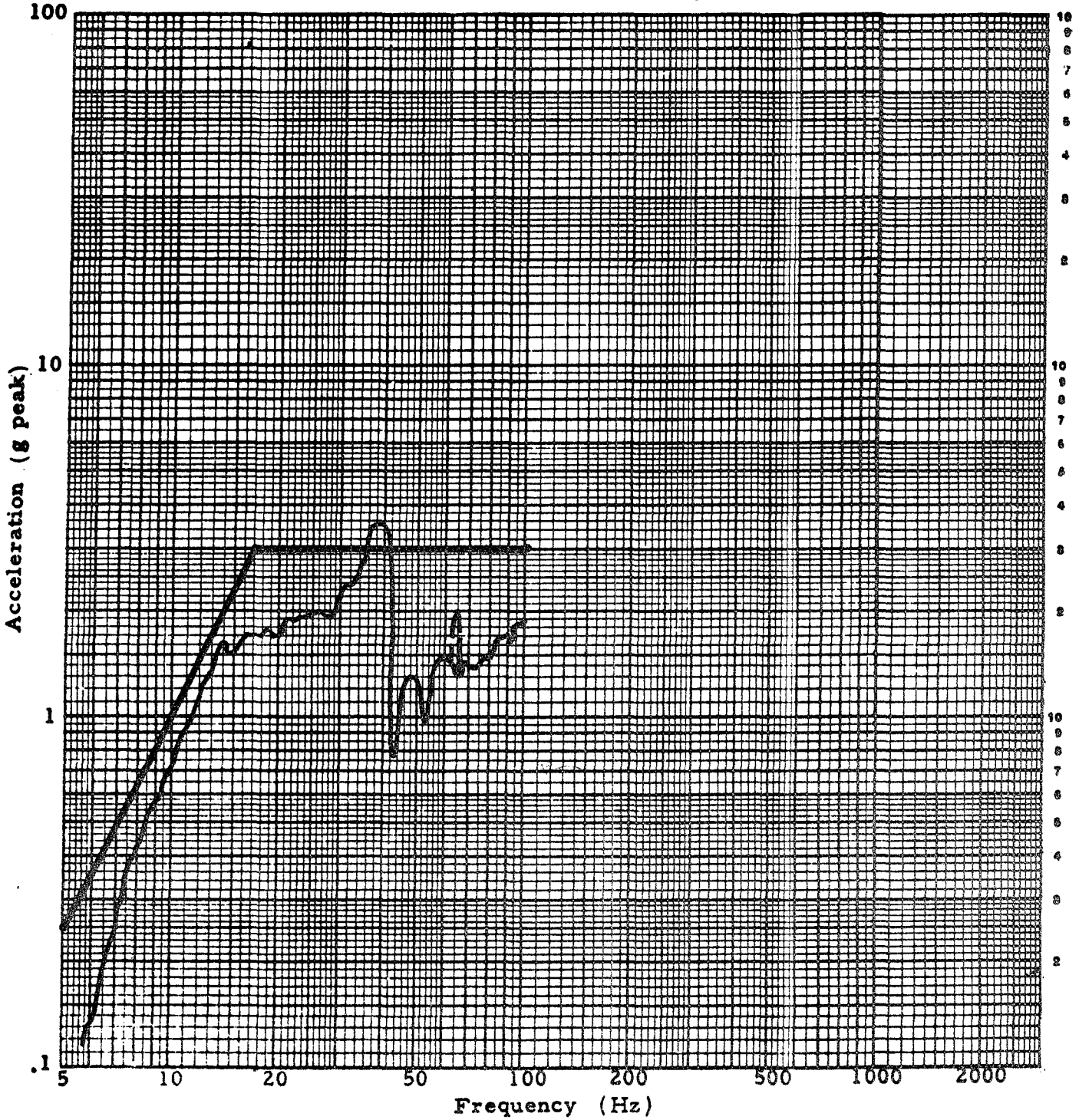
SINUSOIDAL VIBRATION

Axis:

Sweep Rate:

S.P. 2

LEAH Z RESPONSE



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ACC. NO. 4

Axis:

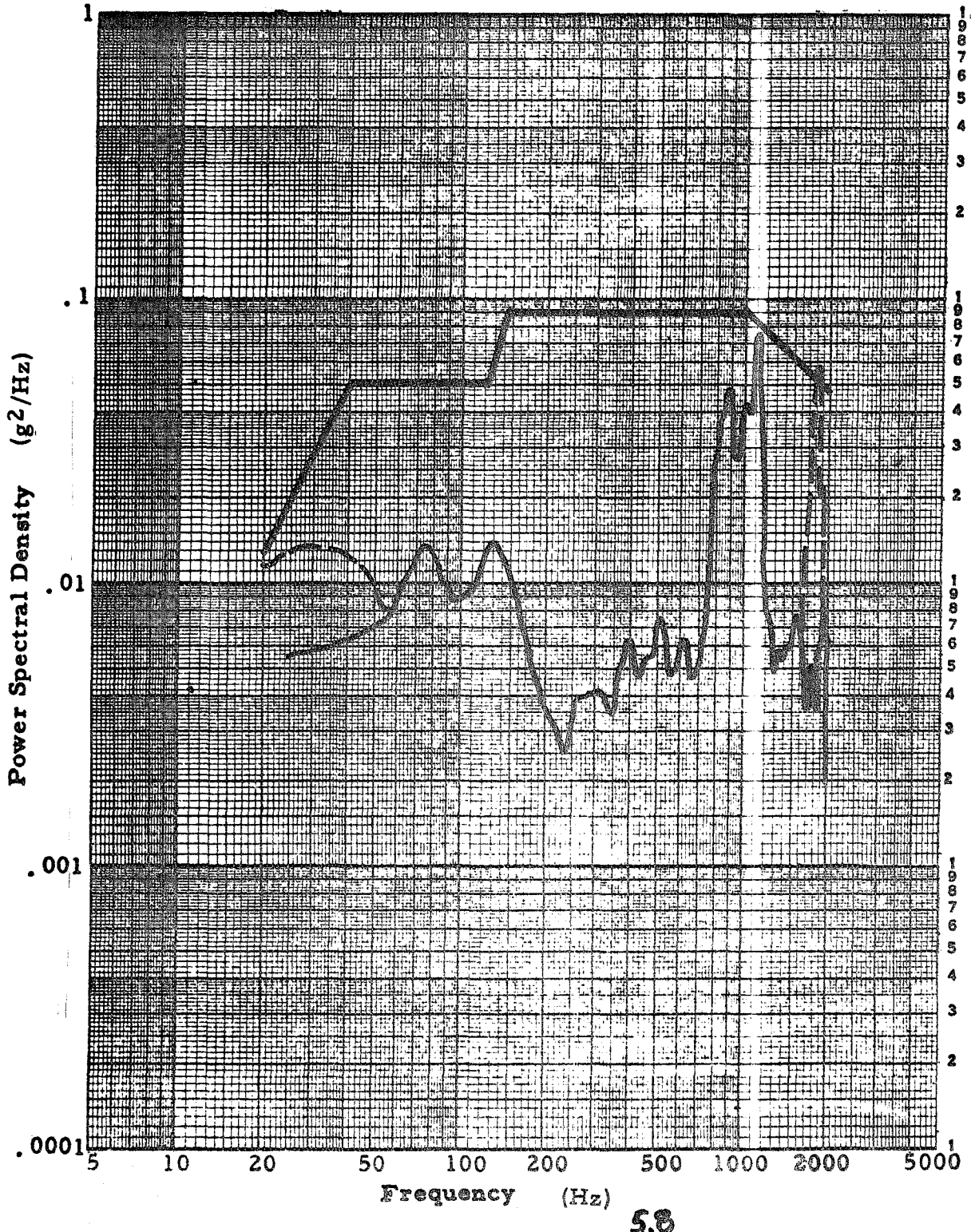
RANDOM VIBRATION SPECTRUM

LAUNCH & BOOST

Duration:

S.P. 2

LEAM X RESPONSE



5.8

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ACC NO. 5

Axis:

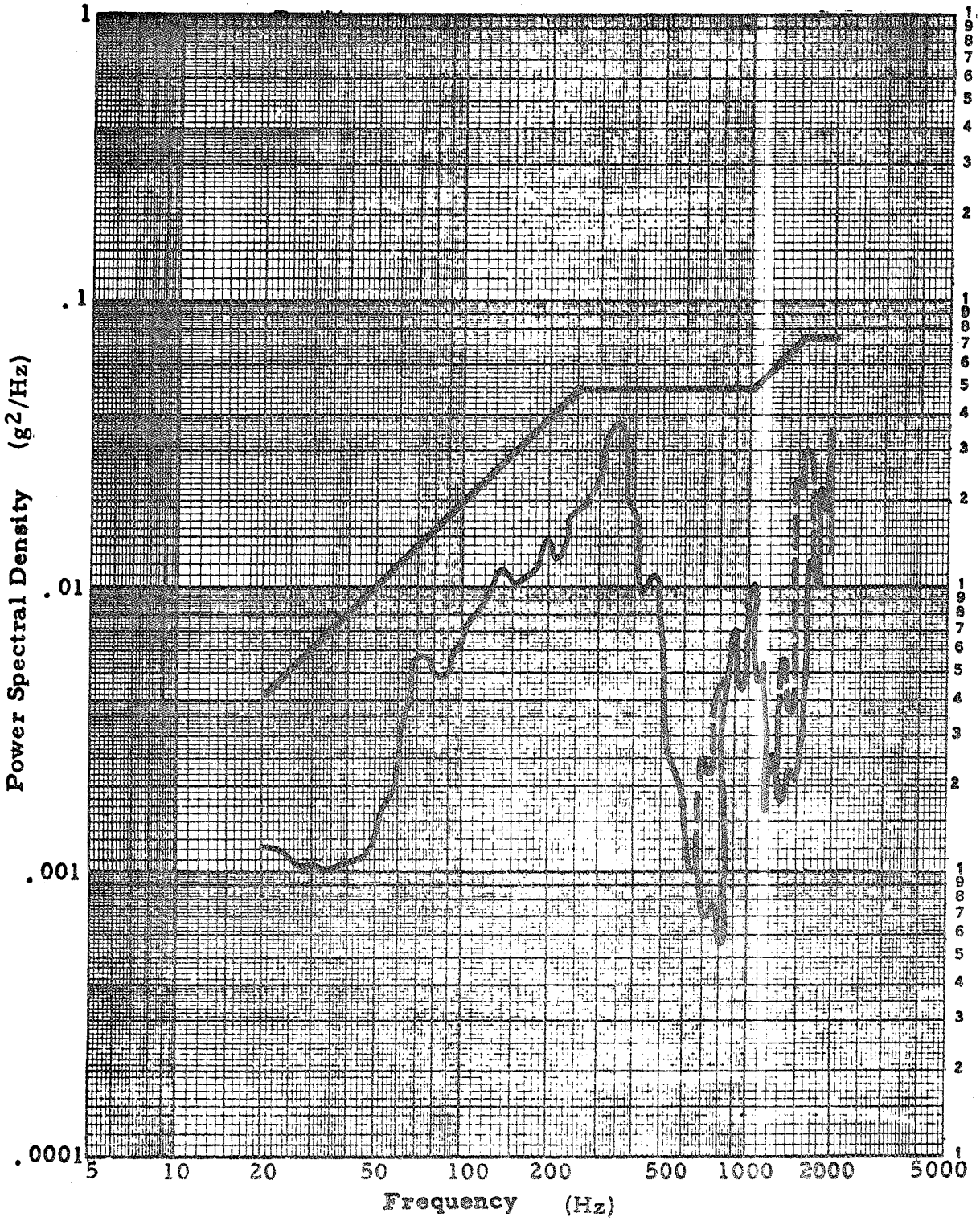
RANDOM VIBRATION SPECTRUM

LAUNCH & BOOST

Duration:

S.P. 2

LEAM Y RESPONSE



ACL. NO. 6

Axis:

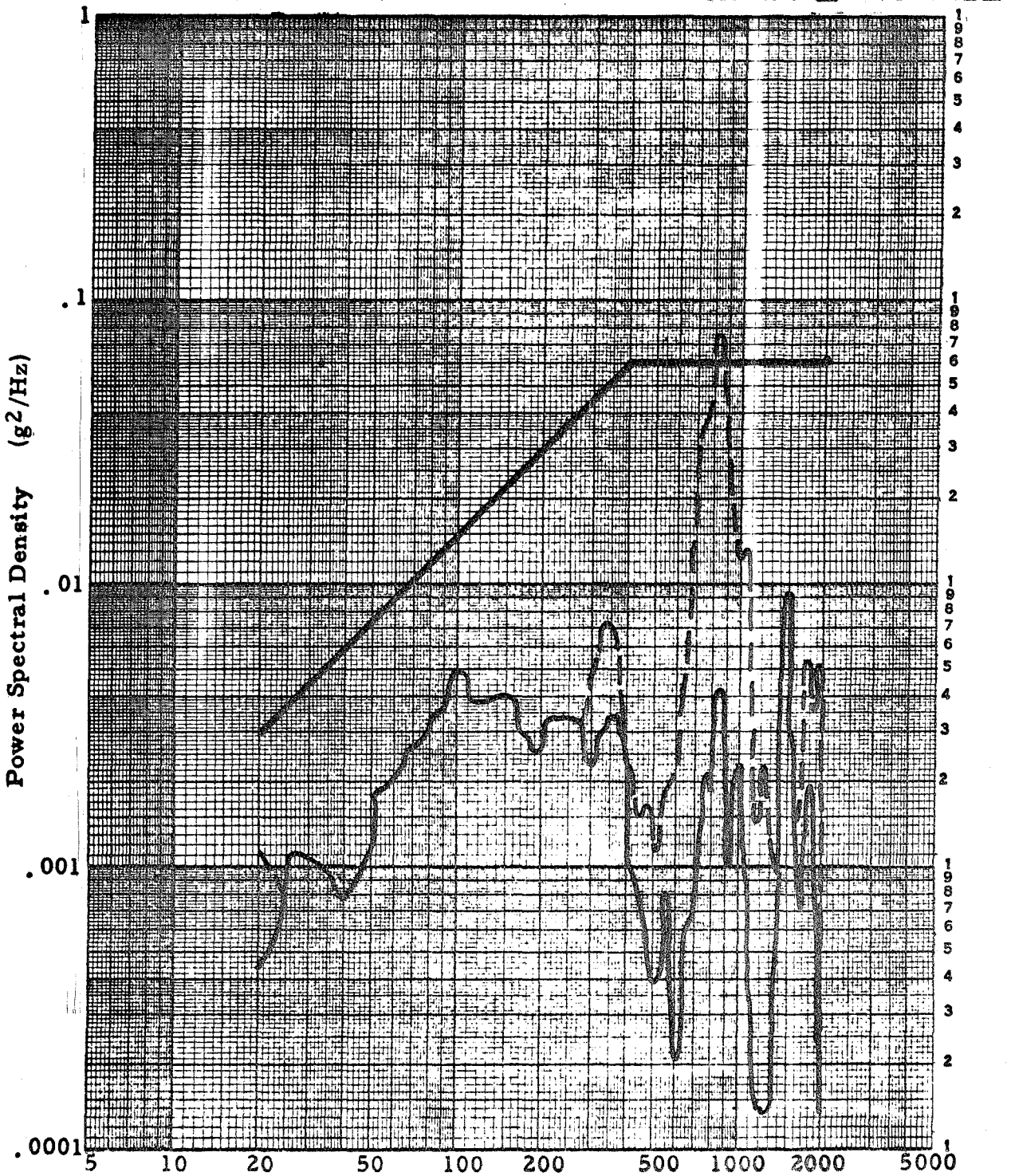
RANDOM VIBRATION SPECTRUM

LAUNCH & BOOST

Duration:

S.P. 2

LEAN 3 RESPONSE



2.2

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ALCM-4

Axis:

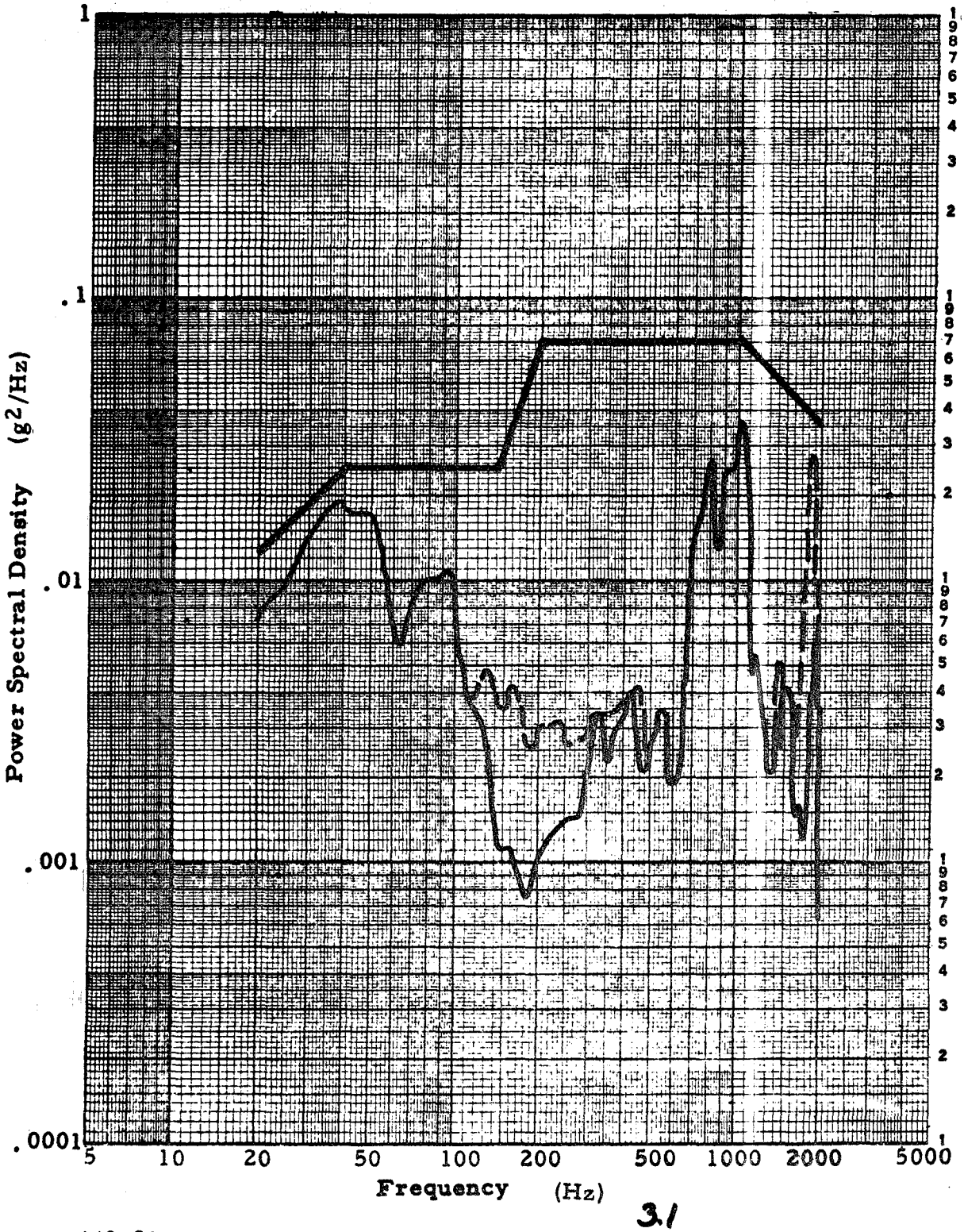
RANDOM VIBRATION SPECTRUM

LUNAR DESCENT

Duration:

S.P. 2

LEAM I RESPONSE



3.1

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ACL. NO. 5

Axis:

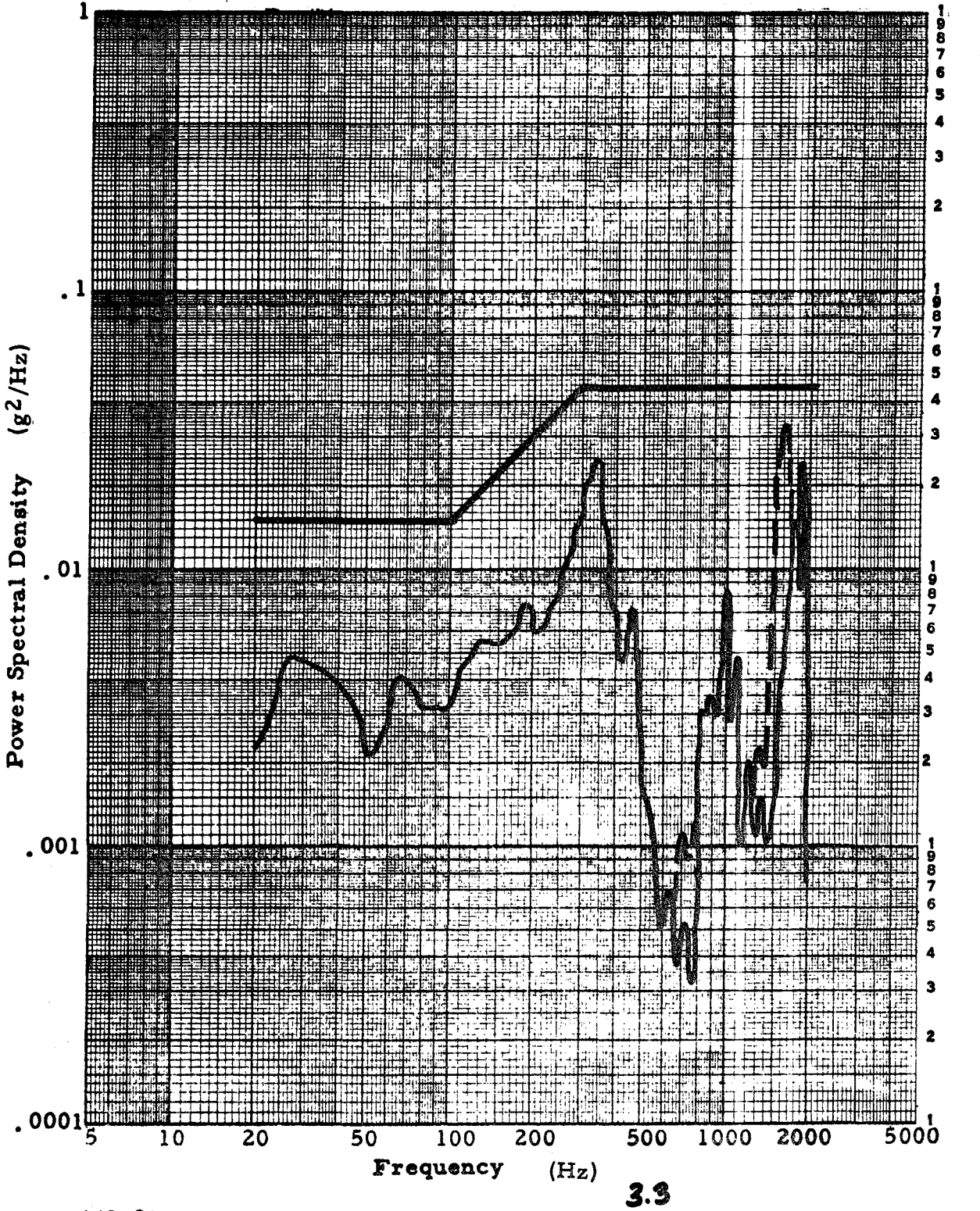
RANDOM VIBRATION SPECTRUM

LUNAR DESCENT

Duration:

S.P. 2

LEAM Y RESPONSE



3.3

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ACL. NO. 6

Axis:

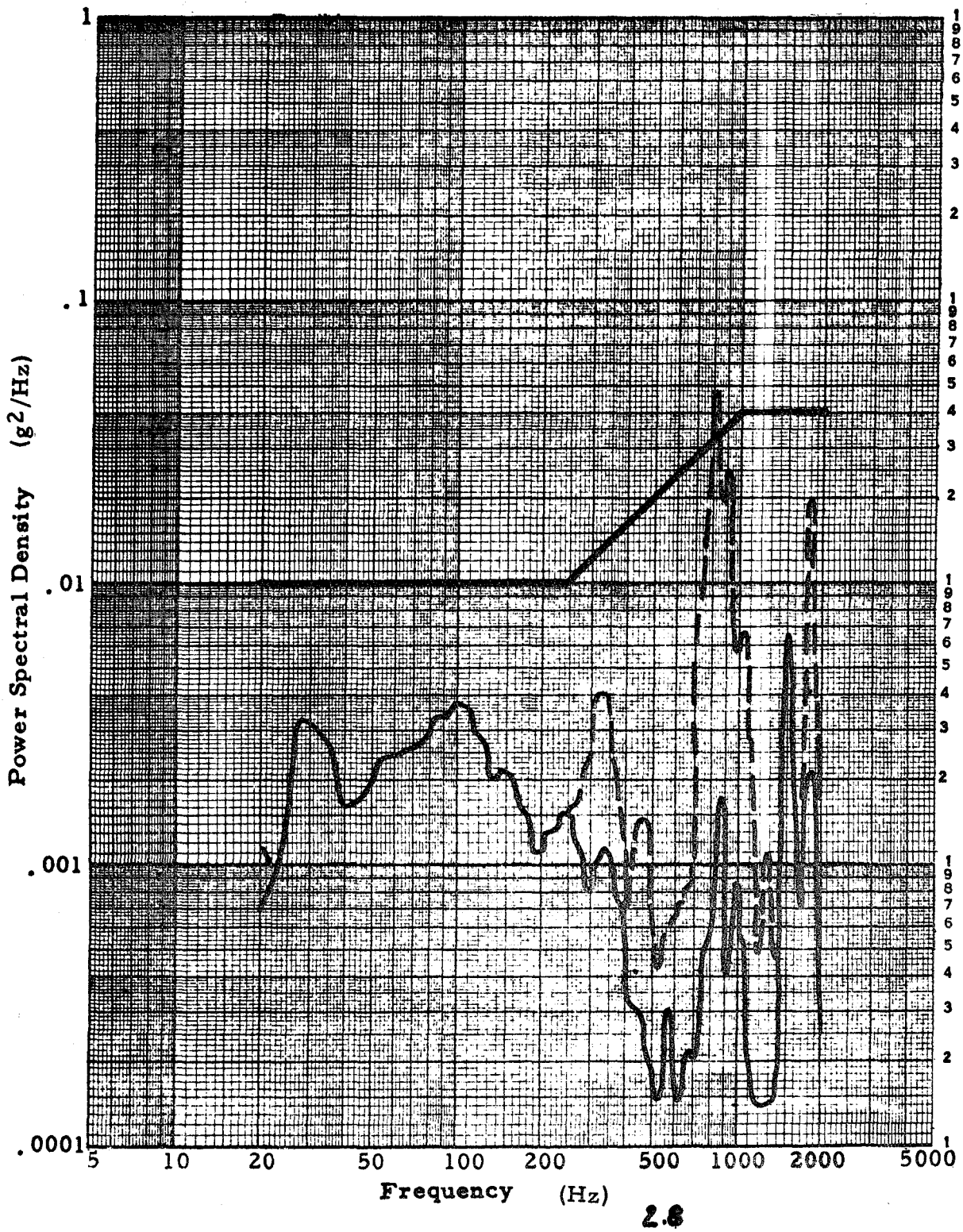
RANDOM VIBRATION SPECTRUM

LUNAR DESCENT

Duration:

S.P. 2

LEAM Z RESPONSE



2.6

ACC. NO. 7

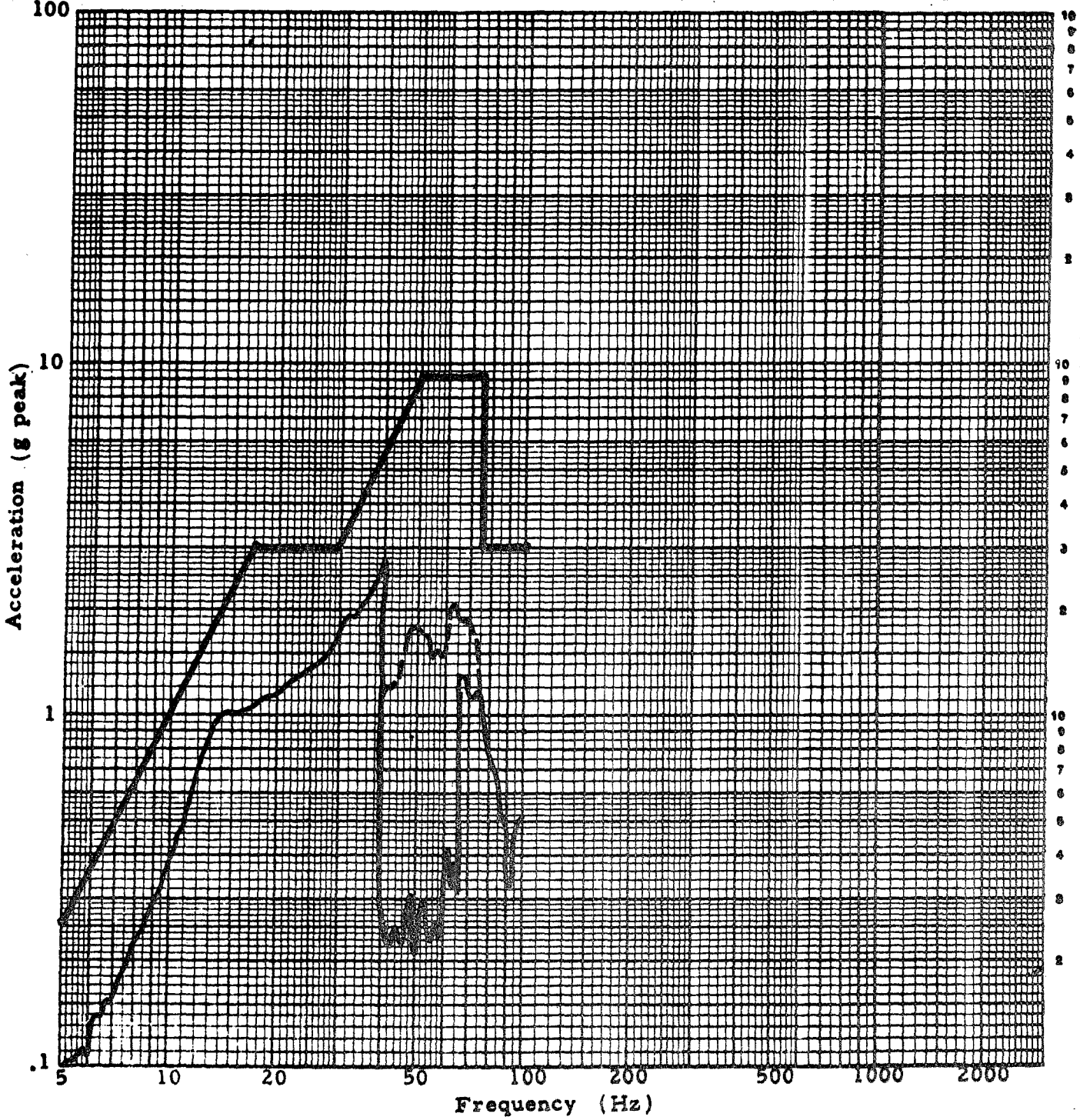
SINUSOIDAL VIBRATION

Axis:

Sweep Rate:

S.P. 2

AAM. X RESPONSE



ACC. NO. 8

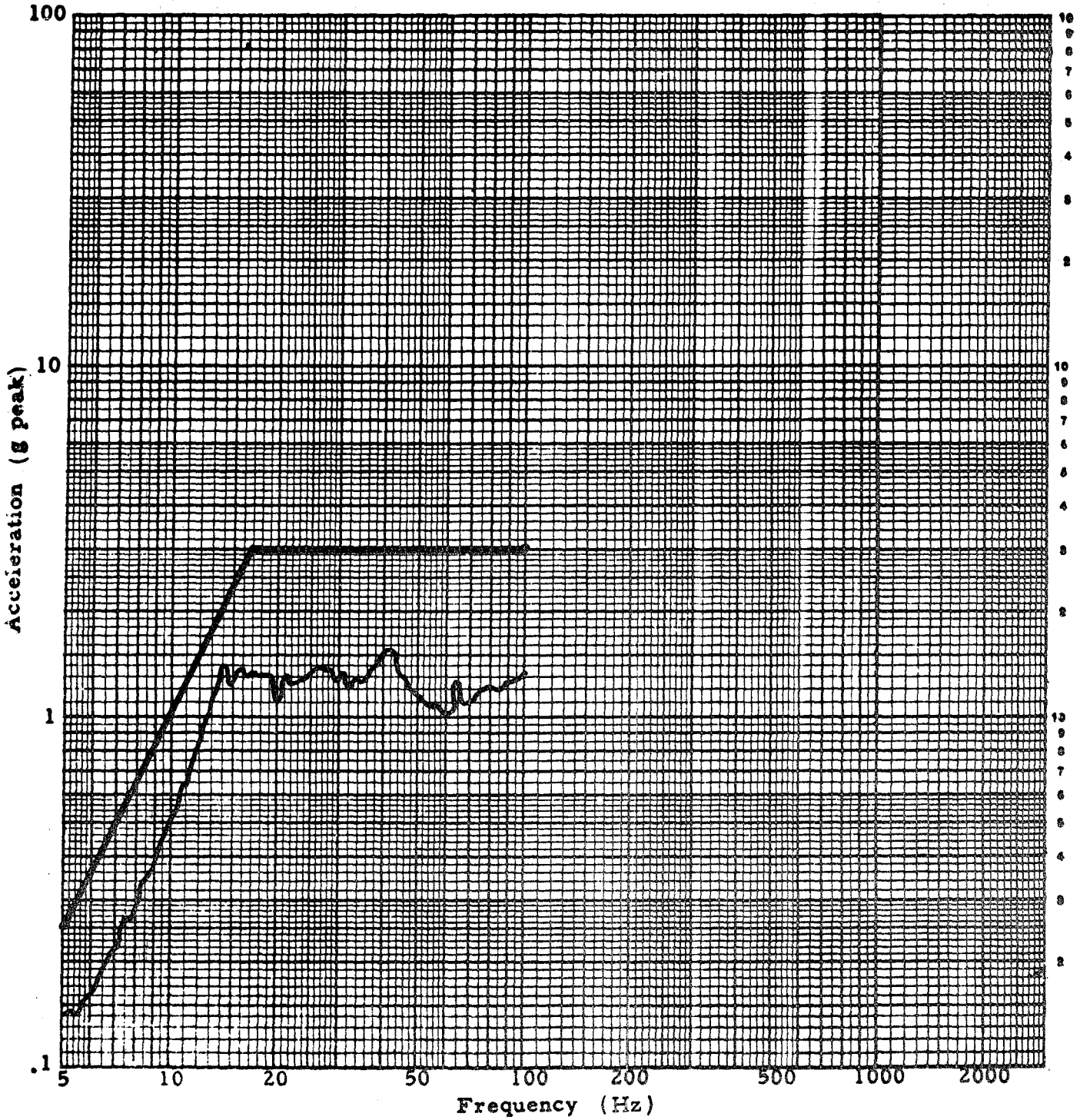
SINUSOIDAL VIBRATION

Axis:

Sweep Rate:

S.P. 2

AAM. Y RESPONSE



ACL. NO. 9

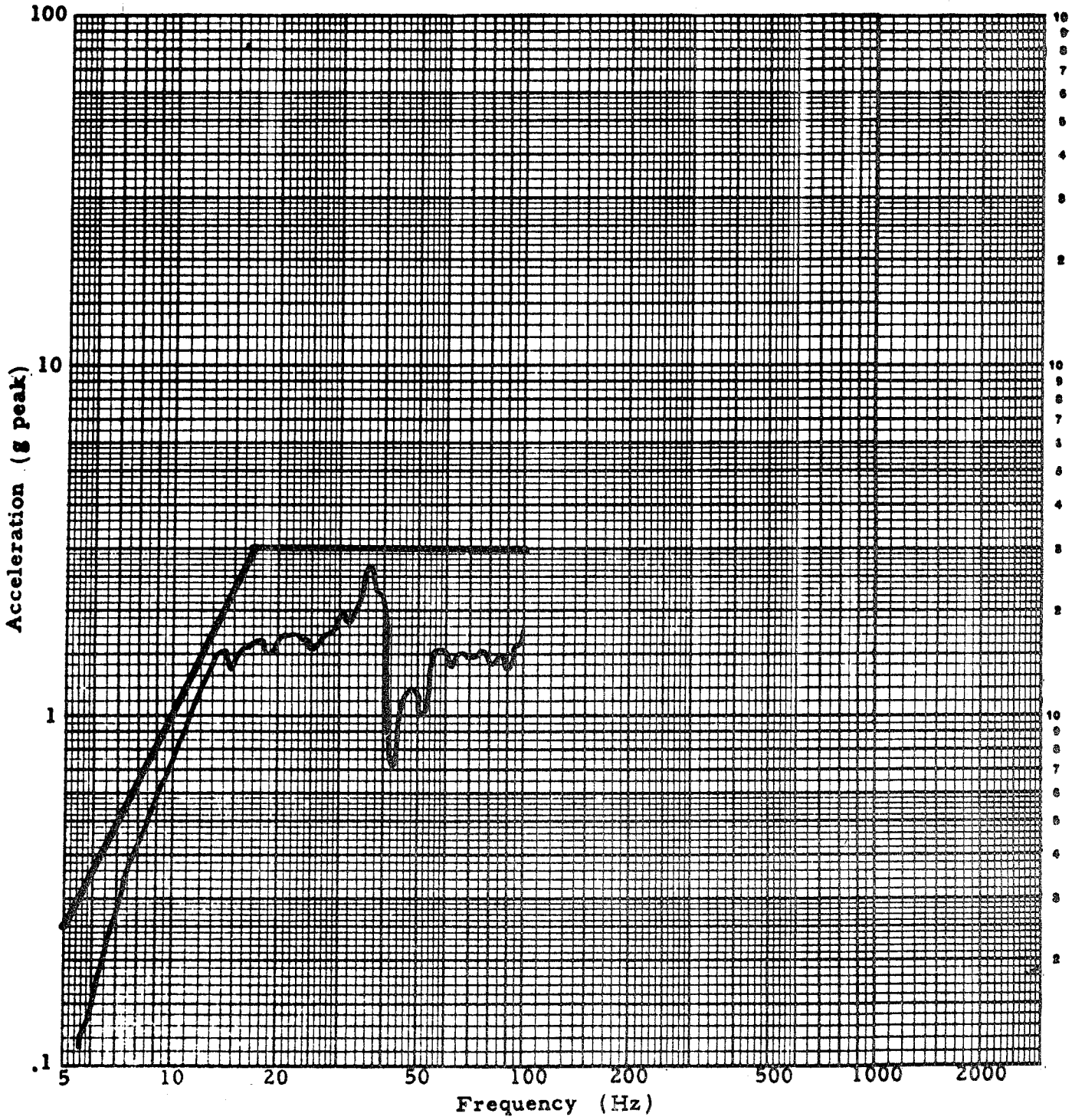
SINUSOIDAL VIBRATION

Axis:

Sweep Rate:

S.P. 2

ARM. Z RESPONSE



ACC. NO. 7

Axis:

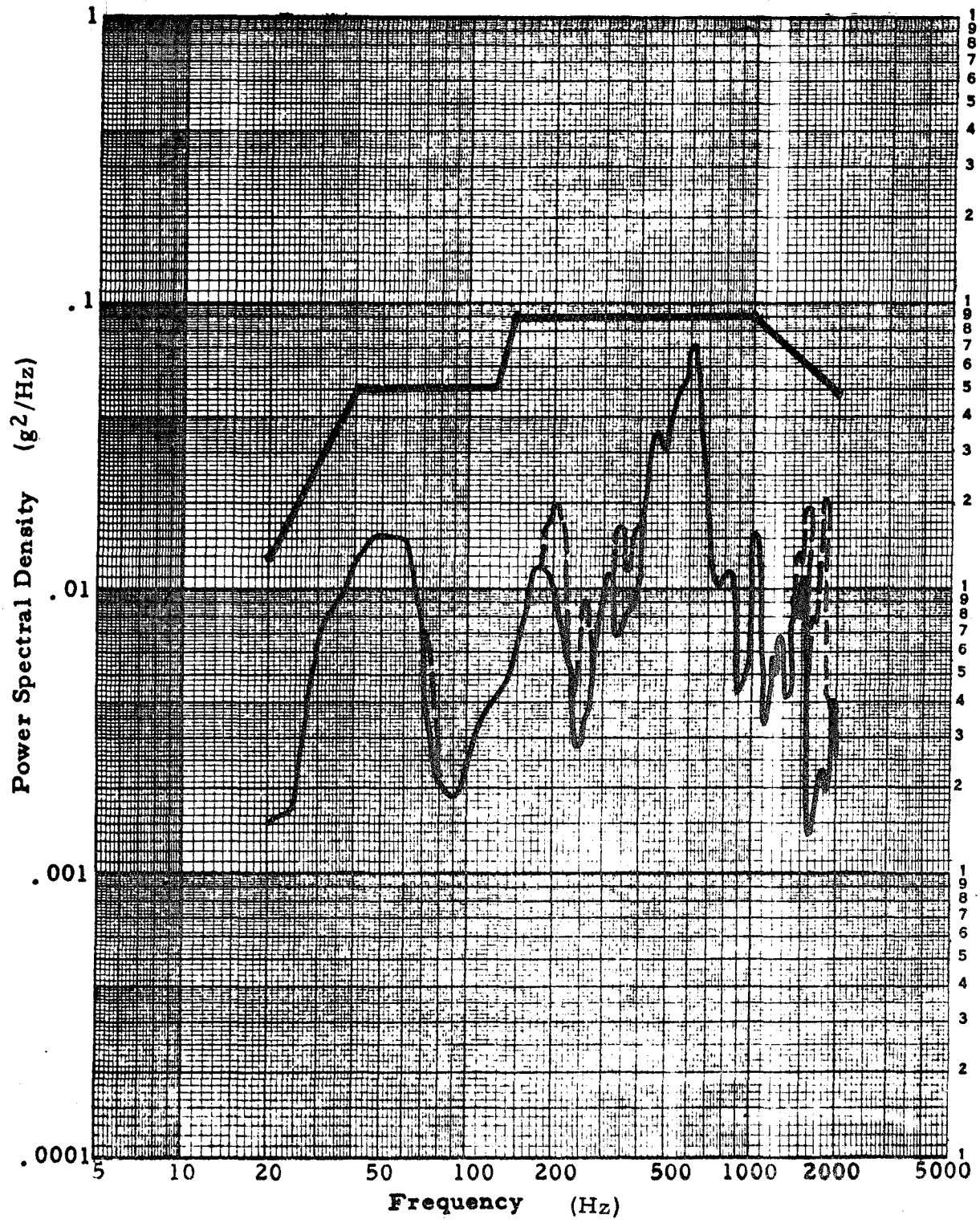
RANDOM VIBRATION SPECTRUM

LAUNCH & BOOST

Duration:

S.P. 2

AAM. X RESPONSE



Bendix Aerospace Systems Division

ACC. NO. 8

Axis:

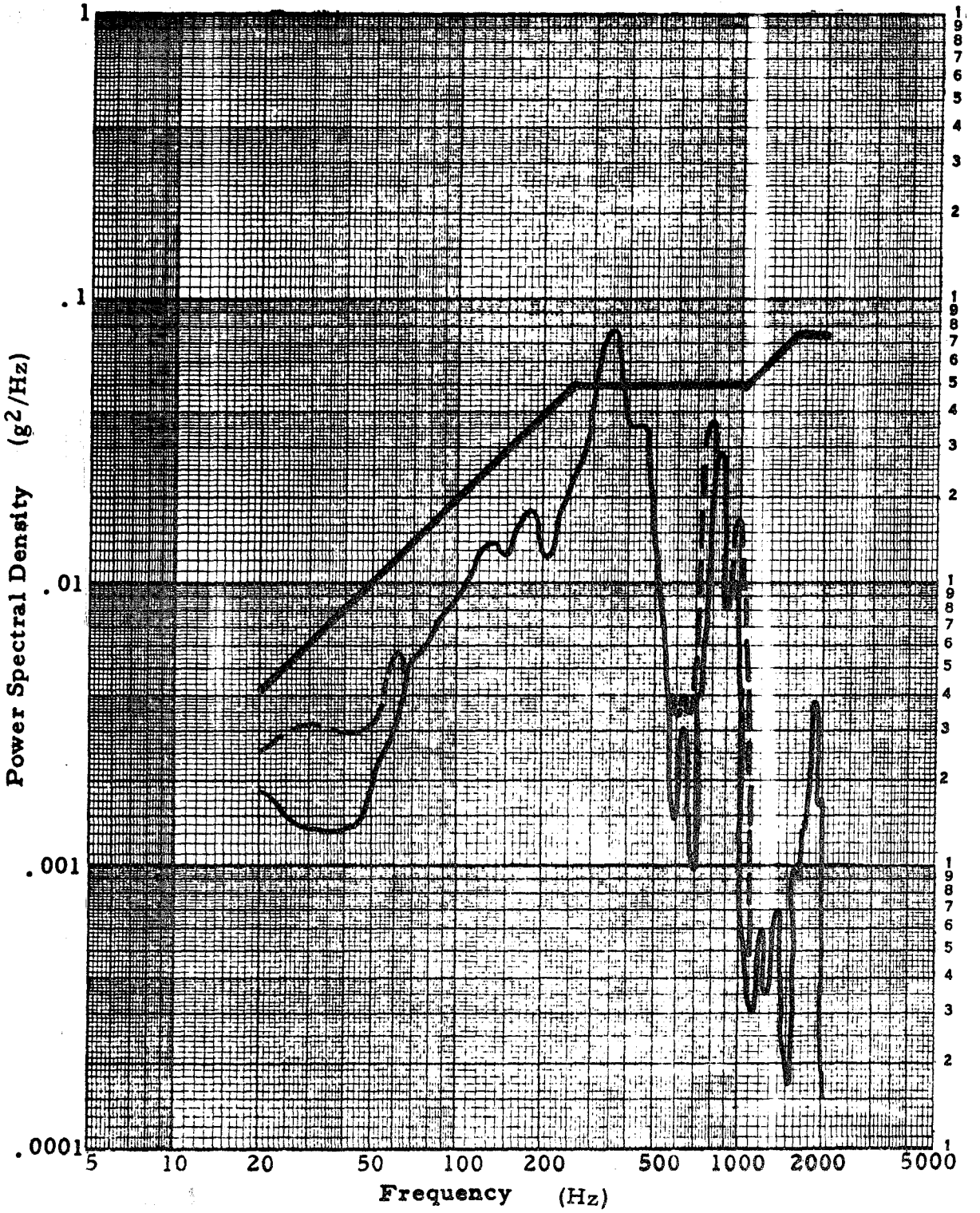
RANDOM VIBRATION SPECTRUM

LAUNCH & BOOST

Duration:

S.P. 2

AAM Y RESPONSE



Bendix Aerospace Systems Division

ACL. NO. 9

Axis:

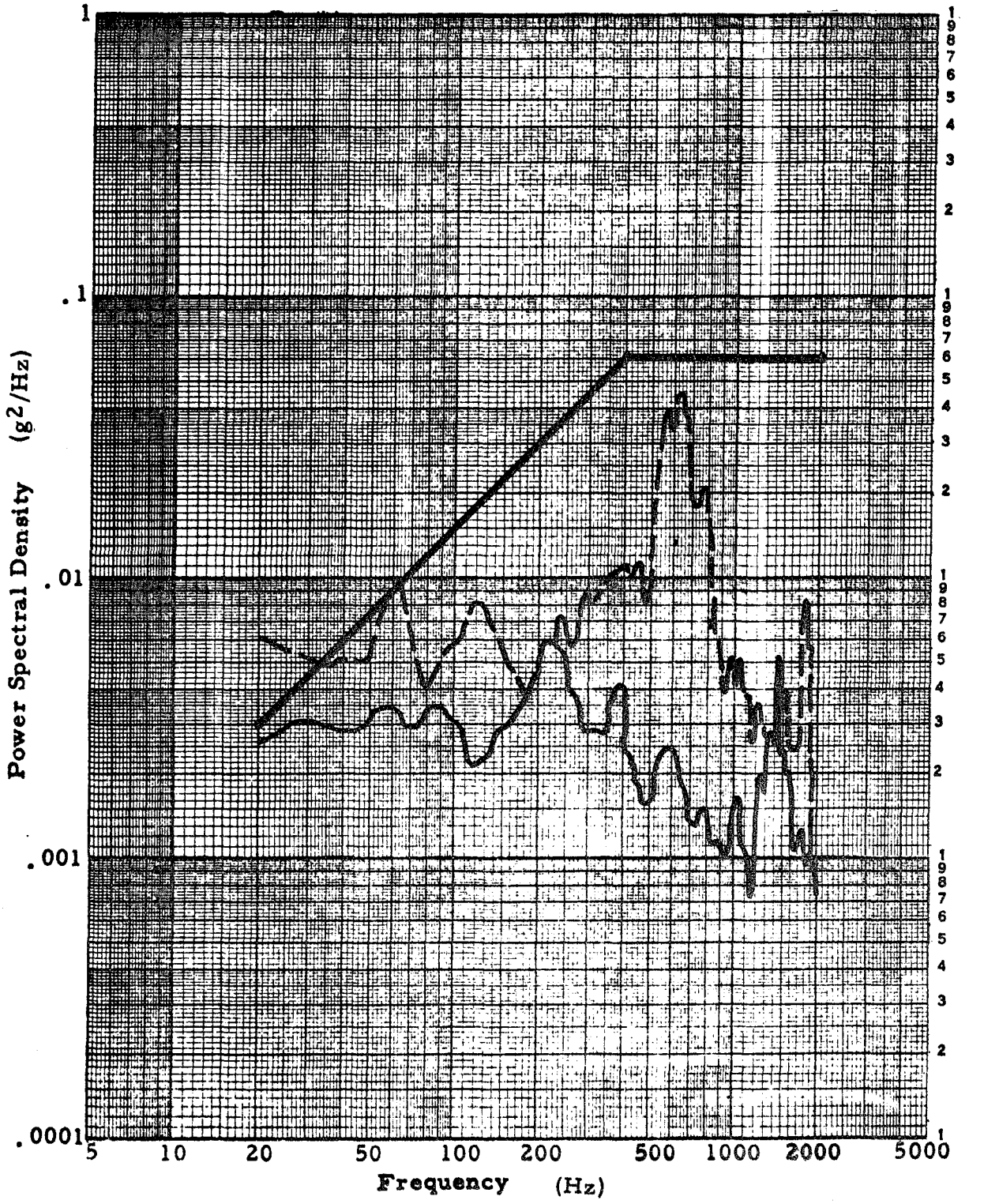
RANDOM VIBRATION SPECTRUM

LAUNCH & BOOST

Duration:

S.P. 2

AAM. Z RESPONSE



ACC. NO. 7

Axis:

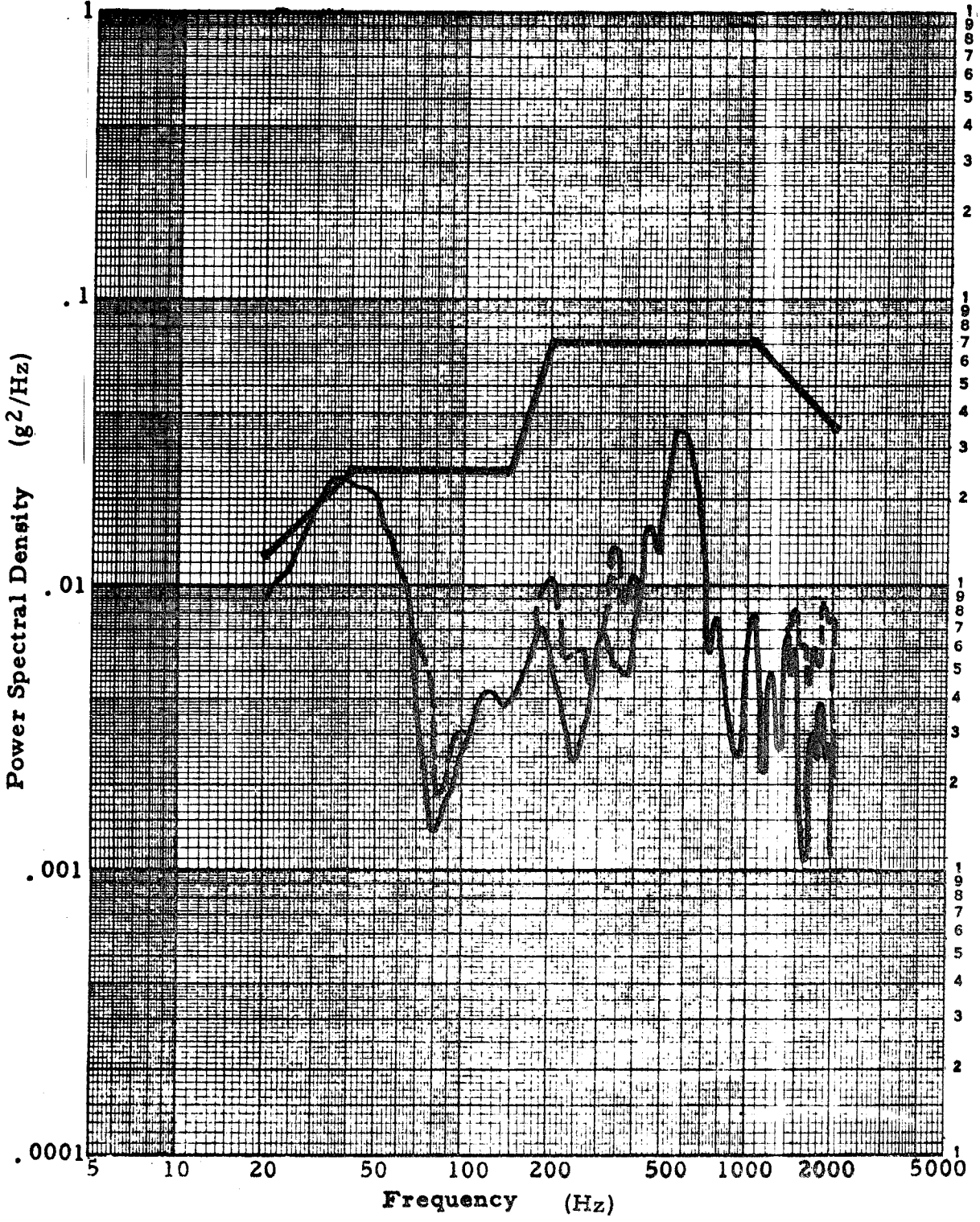
RANDOM VIBRATION SPECTRUM

LUNAR DESCENT

Duration:

S.P. 2

A.A.M. X RESPONSE



Aerospace Systems Division

ACC. NO. 8

Axis:

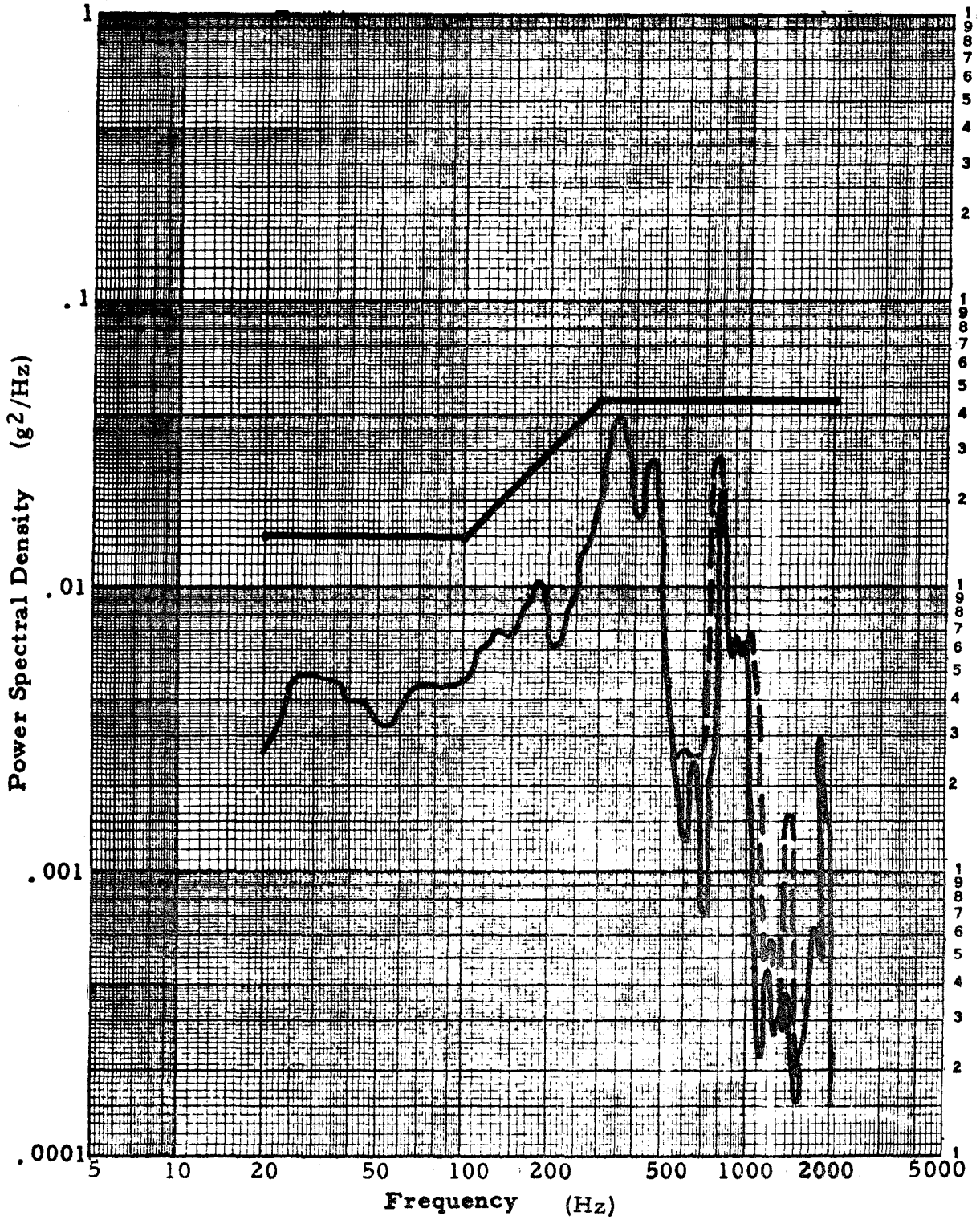
RANDOM VIBRATION SPECTRUM

LUNAR DESCENT

Duration:

S.P. 2

A.A.M. Y RESPONSE



440-91

Aerospace Systems Division

ACC. NO. 9

Axis:

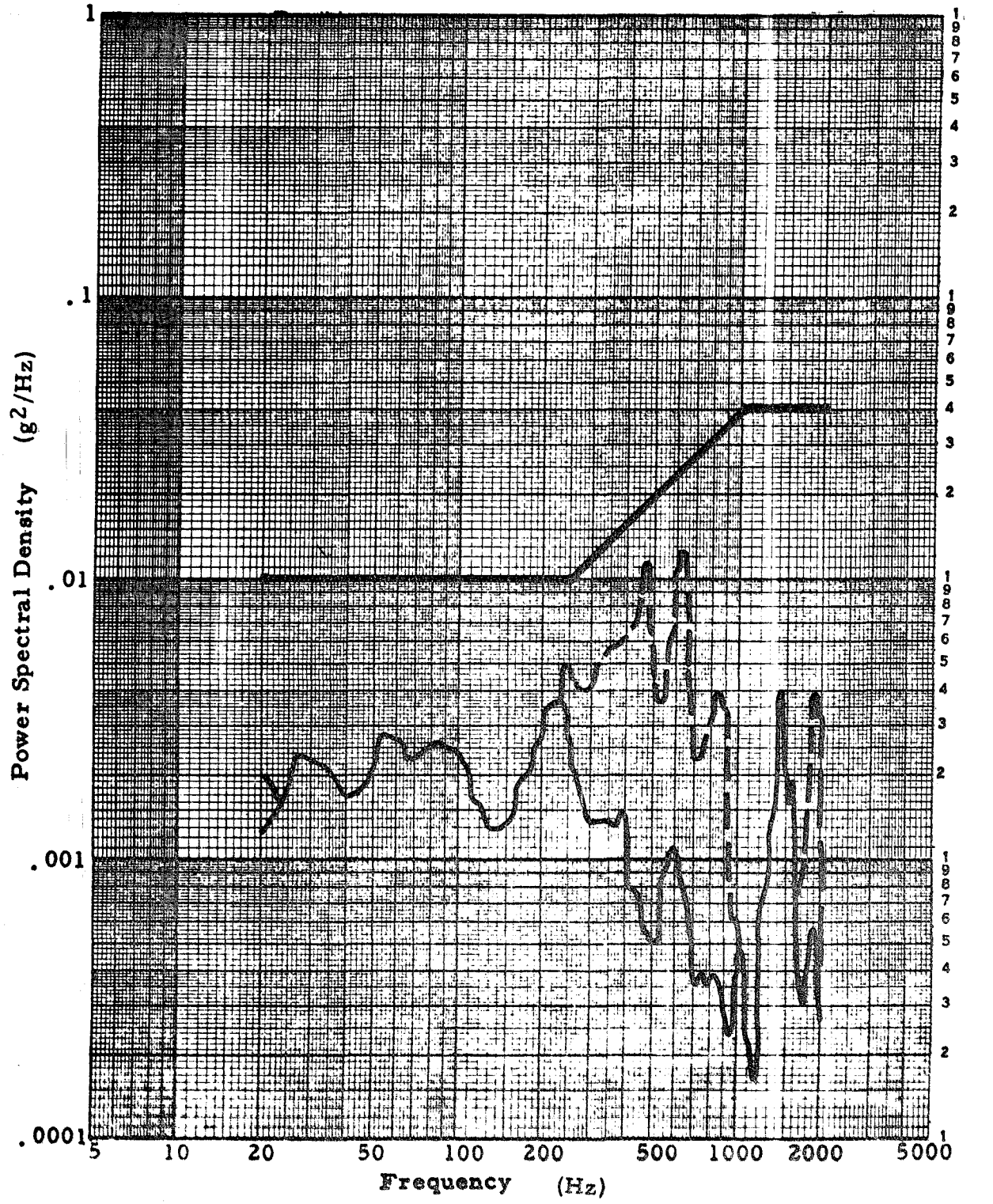
RANDOM VIBRATION SPECTRUM

LUNAR DESCENT

Duration:

S.P. 2

A.A.M. 2 RESPONSE



ACC. NO. 11

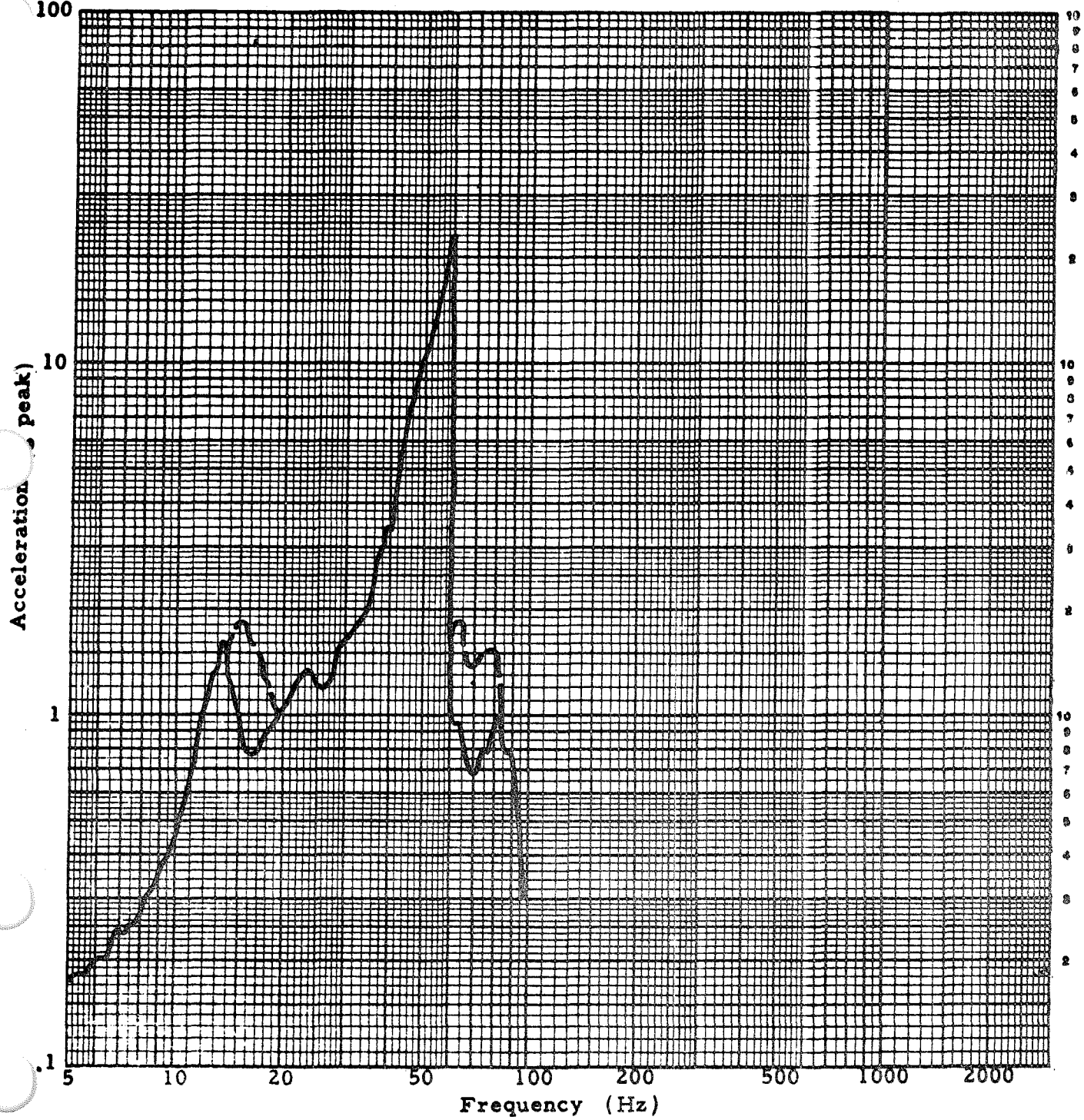
SINUSOIDAL VIBRATION

Axis:

Sweep Rate:

S.P. 2

HFE ELECT. X RESPONSE



ACC. NO. 12

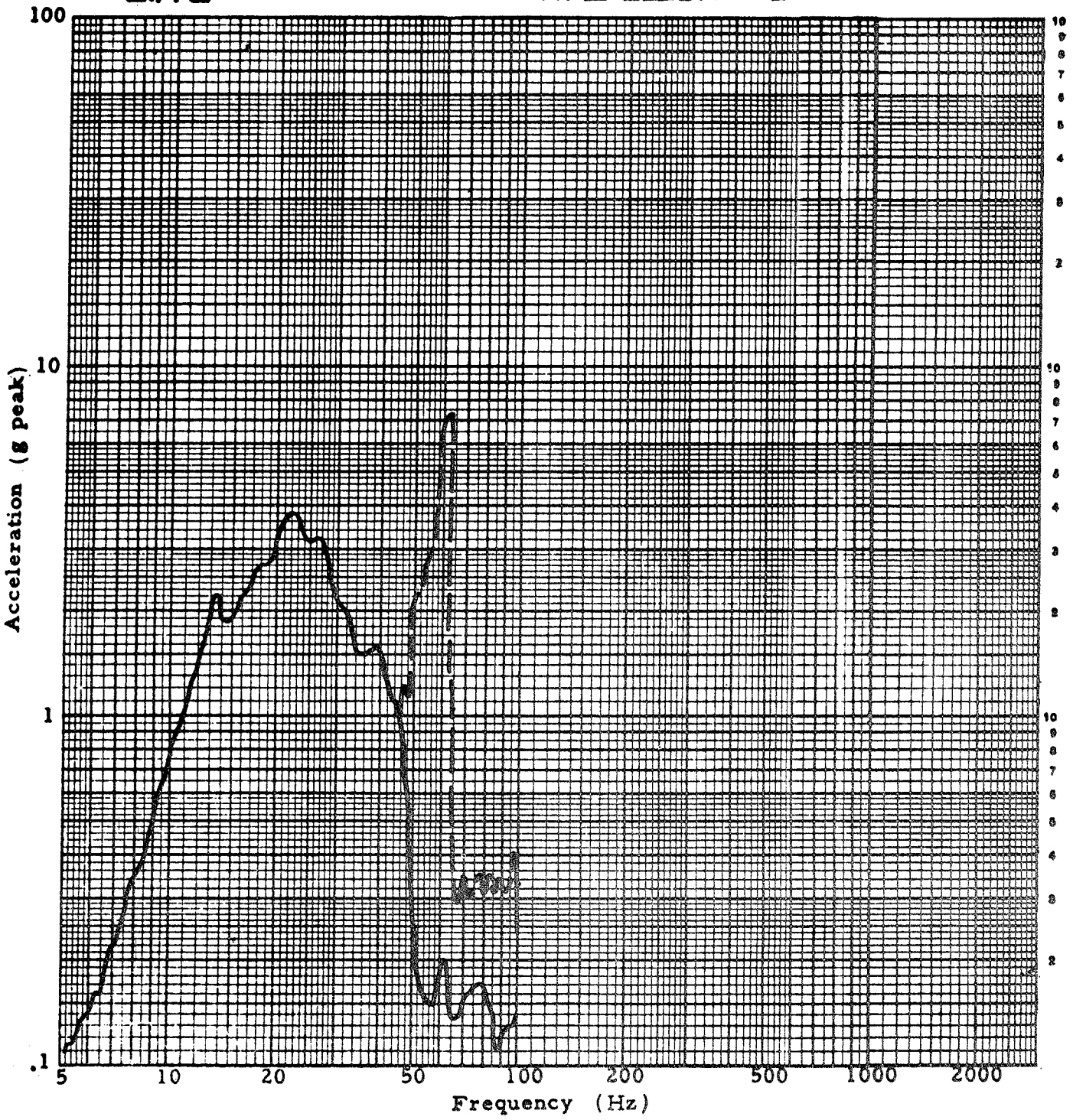
SINUSOIDAL VIBRATION

Axis:

Sweep Rate:

S.P. 2

HFE ELECT. Y RESPONSE



ACC. NO. 13

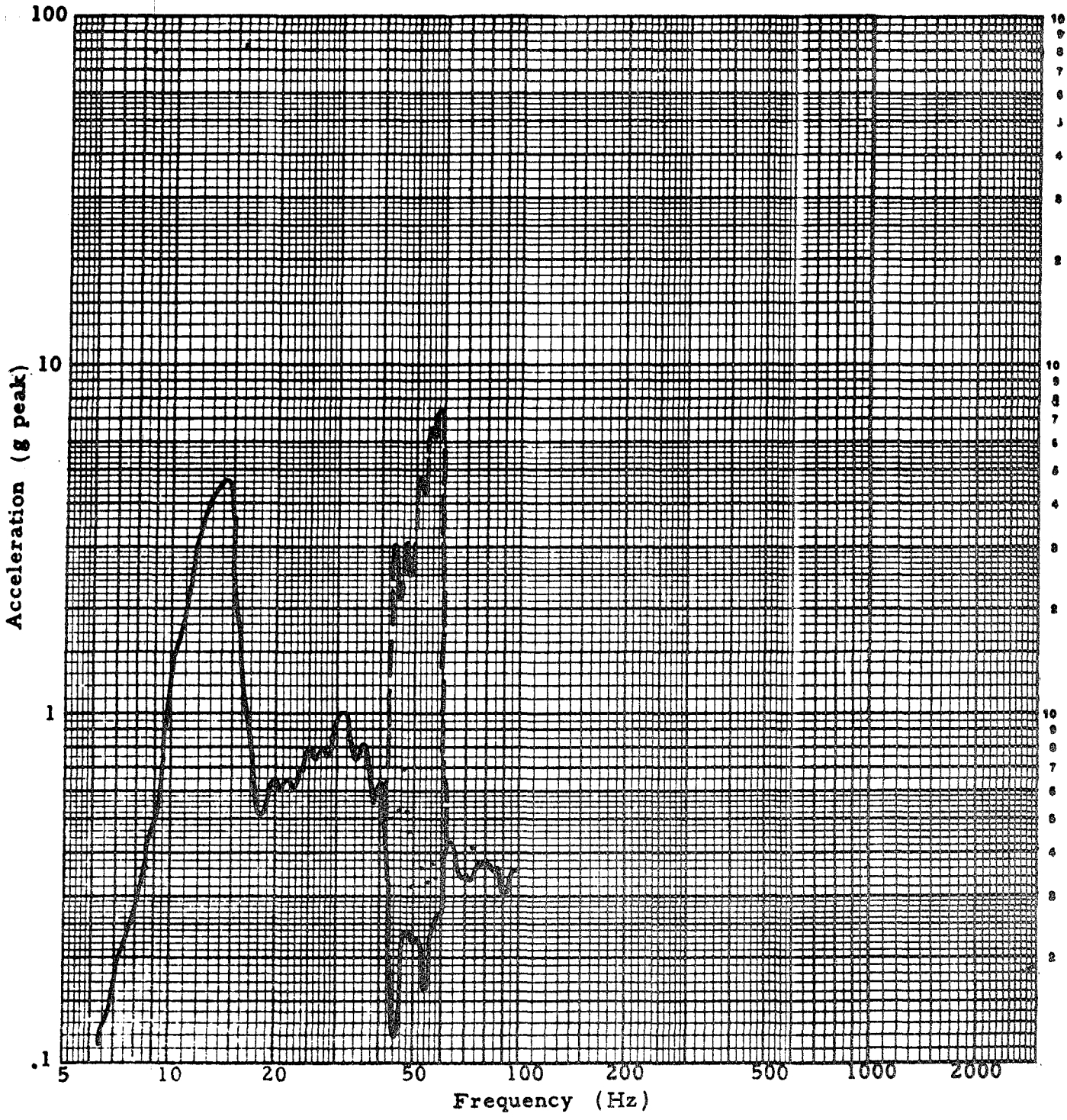
SINUSOIDAL VIBRATION

Axis:

Sweep Rate:

S.P. 2

HFE ELECT. Z RESPONSE



Bendix Aerospace Systems Division

ACC. NO. 11

Axis:

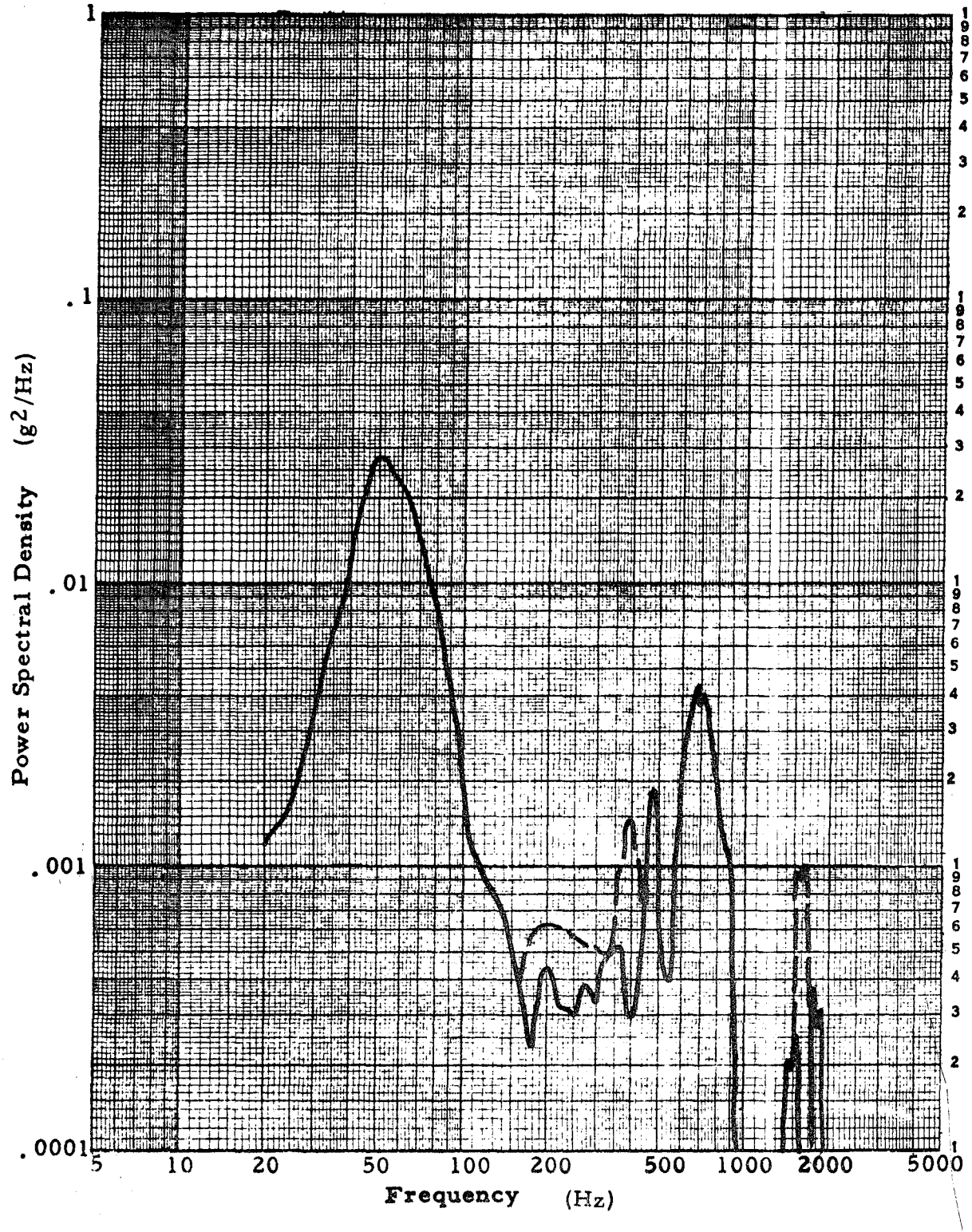
RANDOM VIBRATION SPECTRUM

LAUNCH & BOOST

Duration:

S.P. 2

HFE ELECT X RESPONSE



440-91

Bendix Aerospace Systems Division

ACC. NO. 12

Axis:

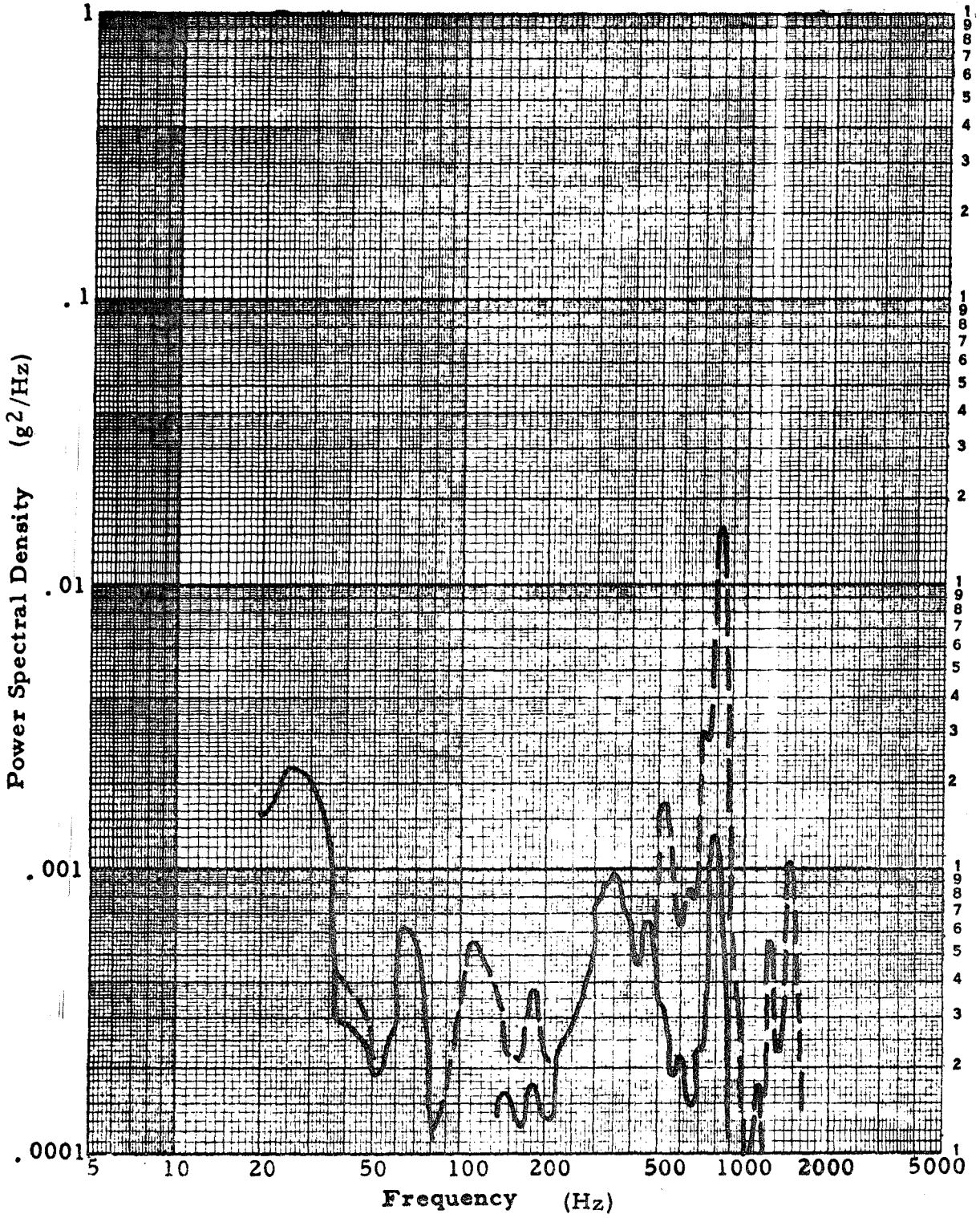
RANDOM VIBRATION SPECTRUM

LAUNCH & BOOST

Duration:

S.P. 2

HFE ELECT. Y RESPONSE



440-91

Bendix Aerospace Systems Division

ACC. NO. 13

Axis:

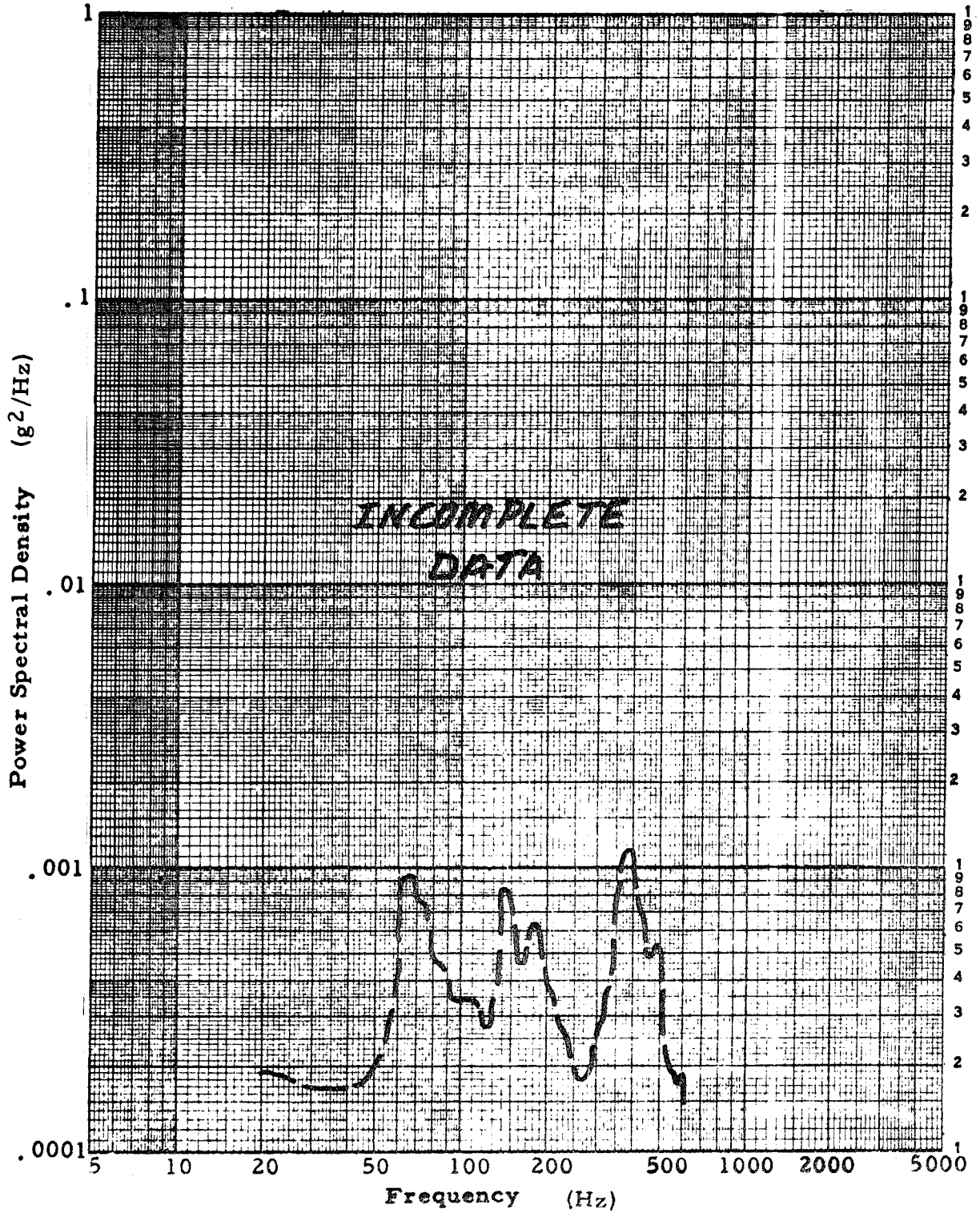
RANDOM VIBRATION SPECTRUM

LAUNCH & BOOST

Duration:

S.P. 2

HFE ELECT. & RESPONSE



Bendix Aerospace Systems Division

ACC. NO. 11

Axis:

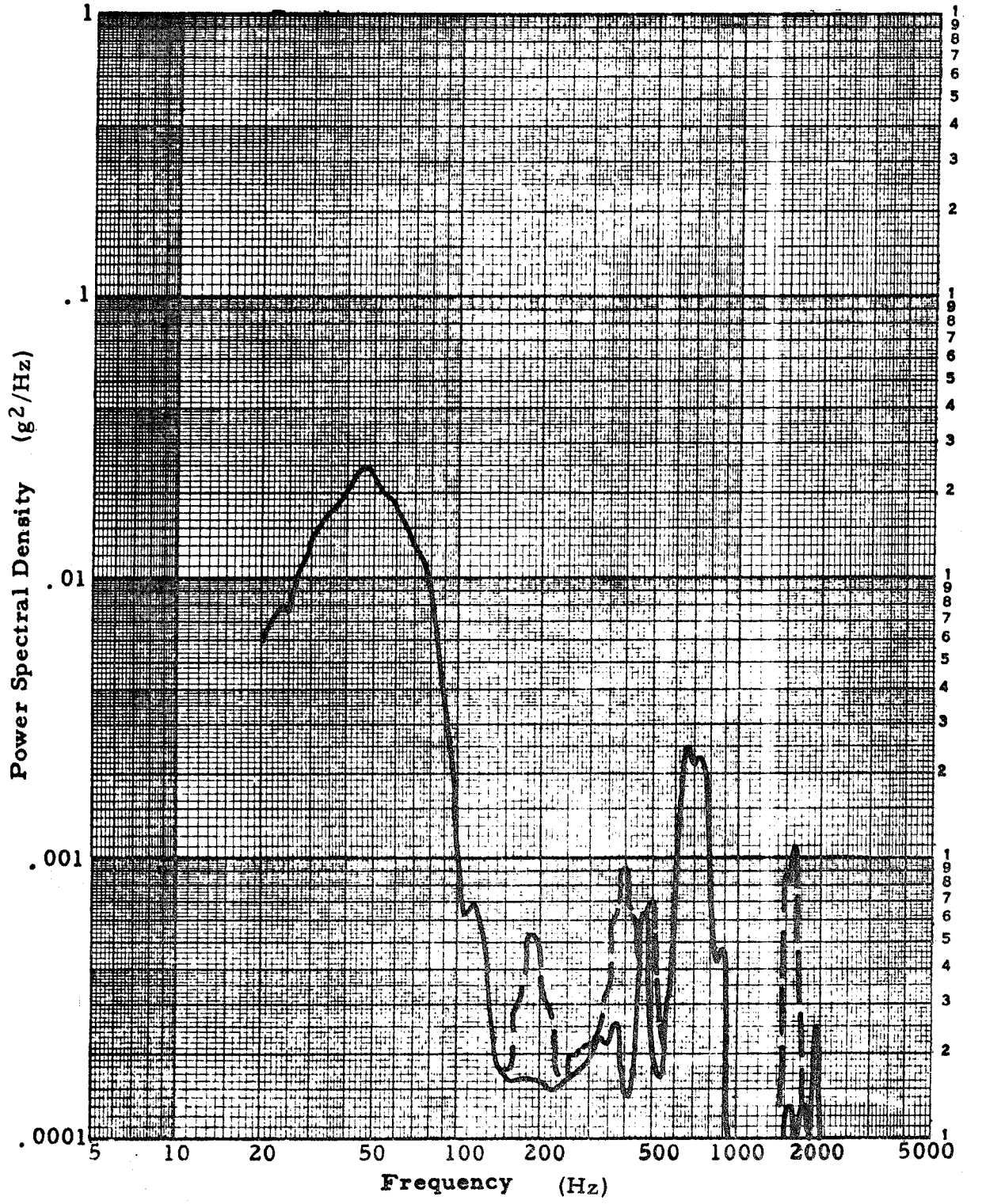
RANDOM VIBRATION SPECTRUM

LUNAR DESCENT

Duration:

S.P. 2

HFE ELECT. X RESPONSE



440-91

Bendix Aerospace Systems Division

ACC. NO. 12

Axis:

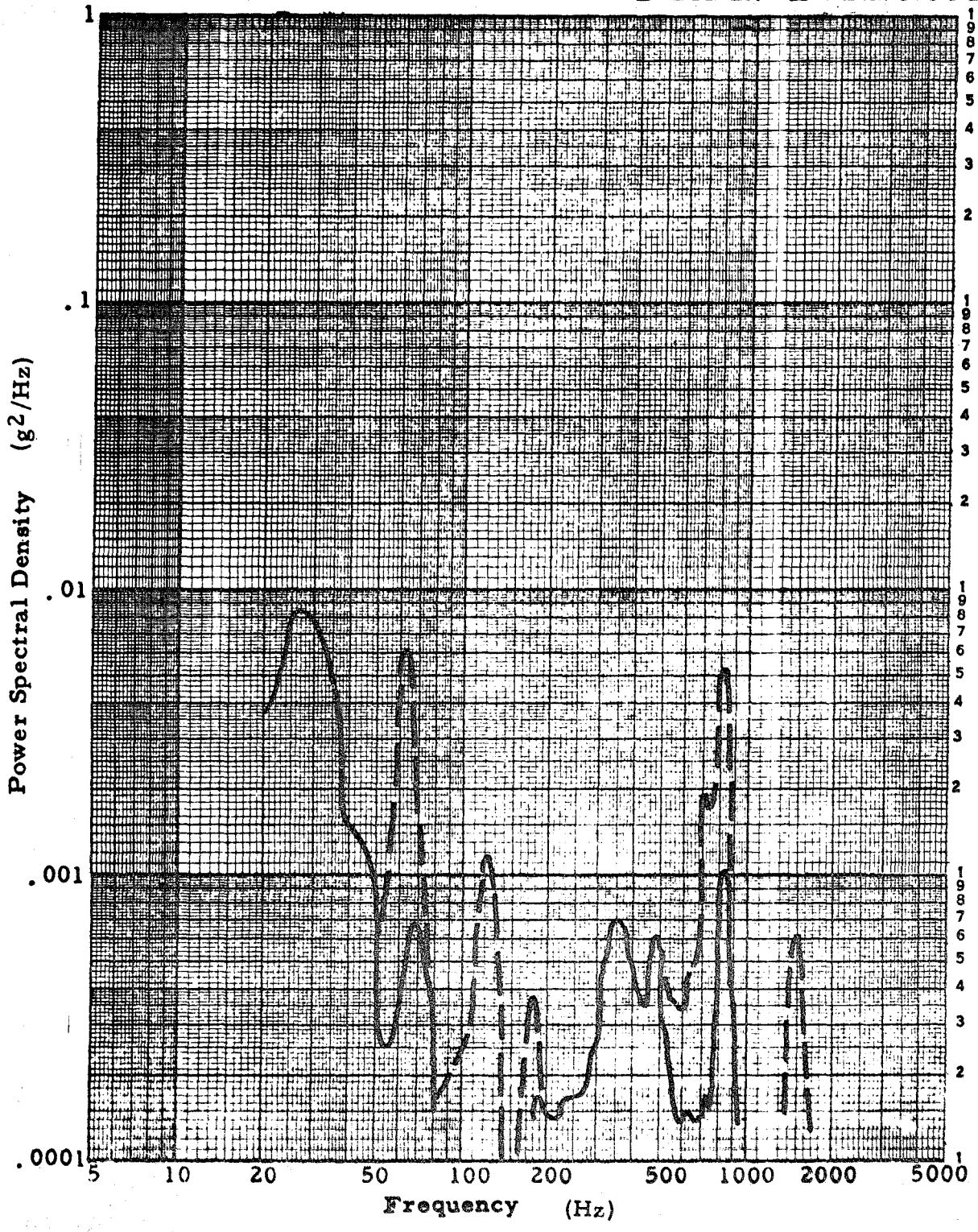
RANDOM VIBRATION SPECTRUM

LUNAR DESCENT

Duration:

S.P. 2

HFE ELECT. Y RESPONSE



440-91

Bendix Aerospace Systems Division

ACC. NO. 13

Axis:

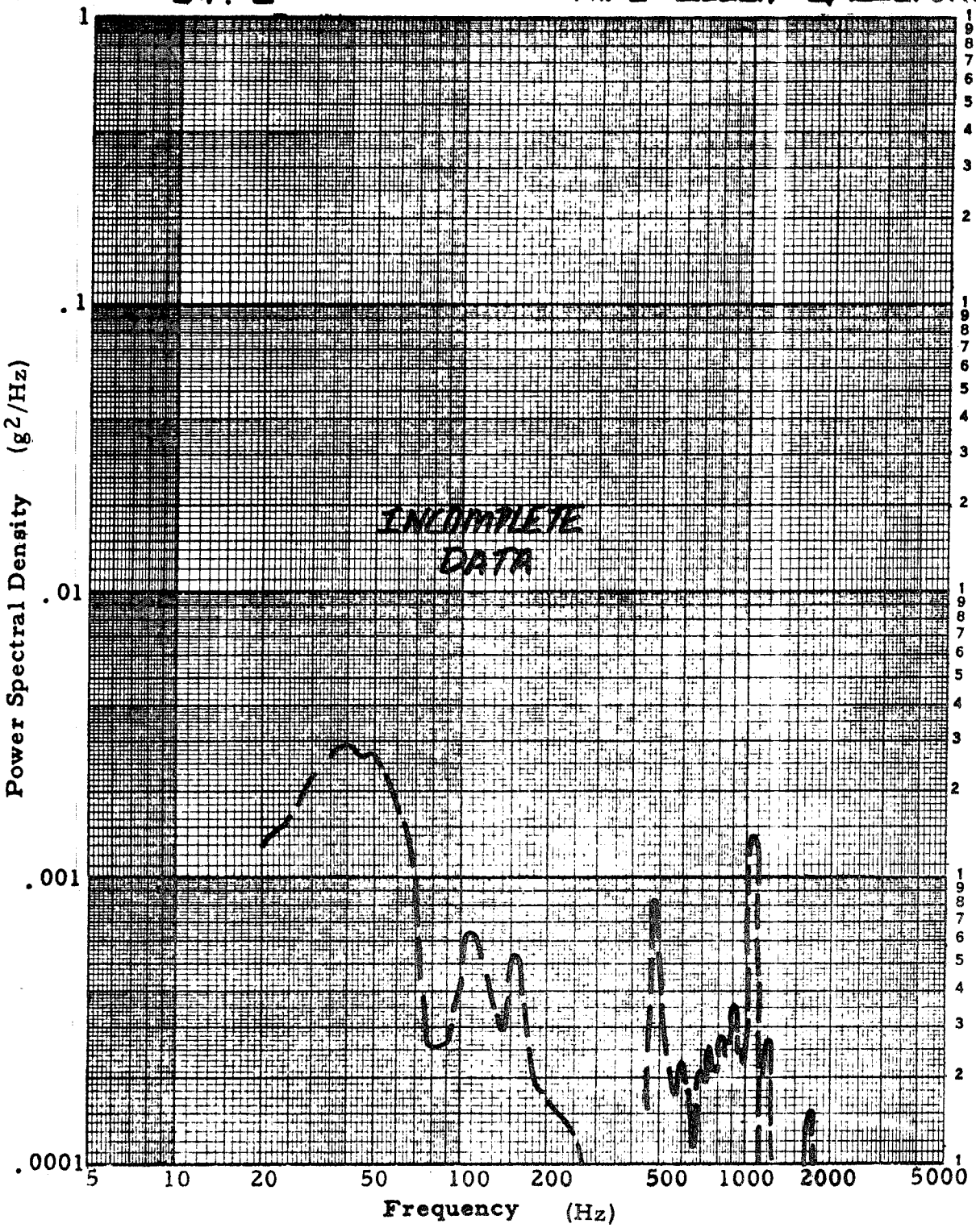
RANDOM VIBRATION SPECTRUM

LUNAR DESCENT

Duration:

S.P. 2

H.F.E. ELECT. 2, RESPONSE



440-91

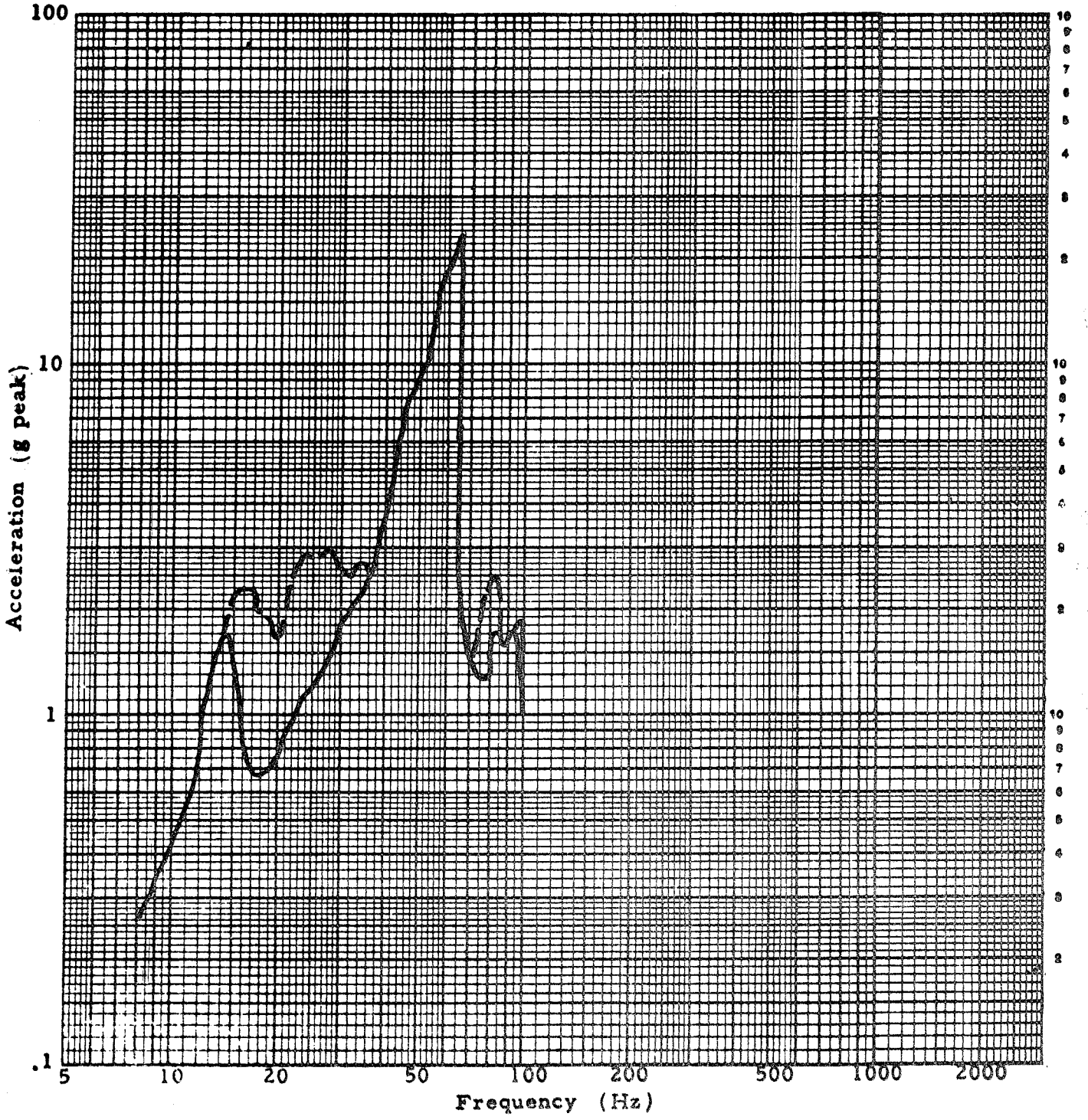
ACC. NO. 15

SINUSOIDAL VIBRATION

Axis:

Sweep Rate:

S.P. 2 H.F.E. PROBE X RESPONSE



ACC. NO. 16

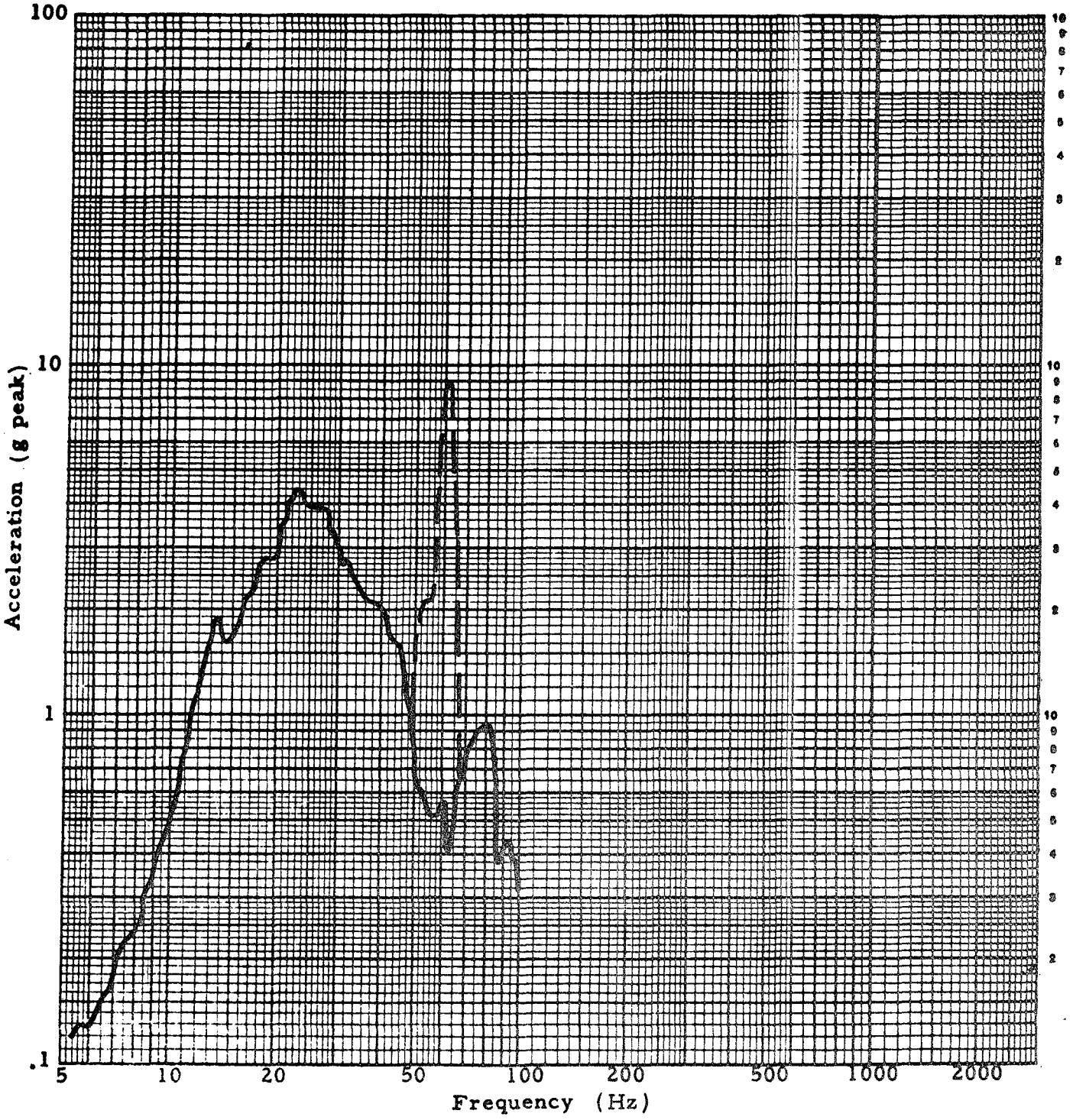
SINUSOIDAL VIBRATION

Axis:

Sweep Rate:

S.P. 2

H.F.E. PROBE Y RESPONSE



ACC. NO. 17

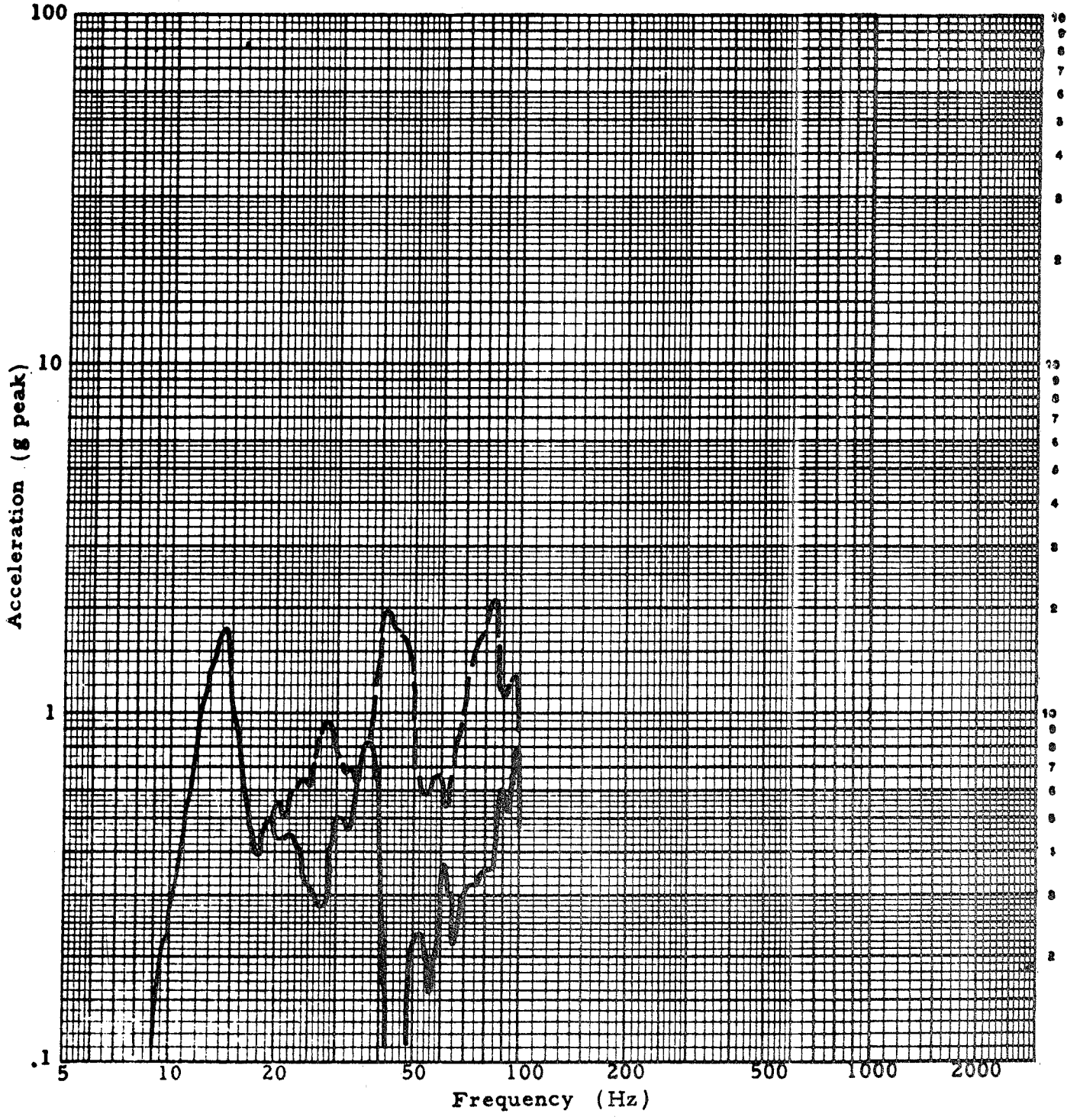
SINUSOIDAL VIBRATION

Axis:

Sweep Rate:

S.P. 2

H.F.E. PROBE 2 RESPONSE



Bendix Aerospace Systems Division

ACC. NO. 15

Axis:

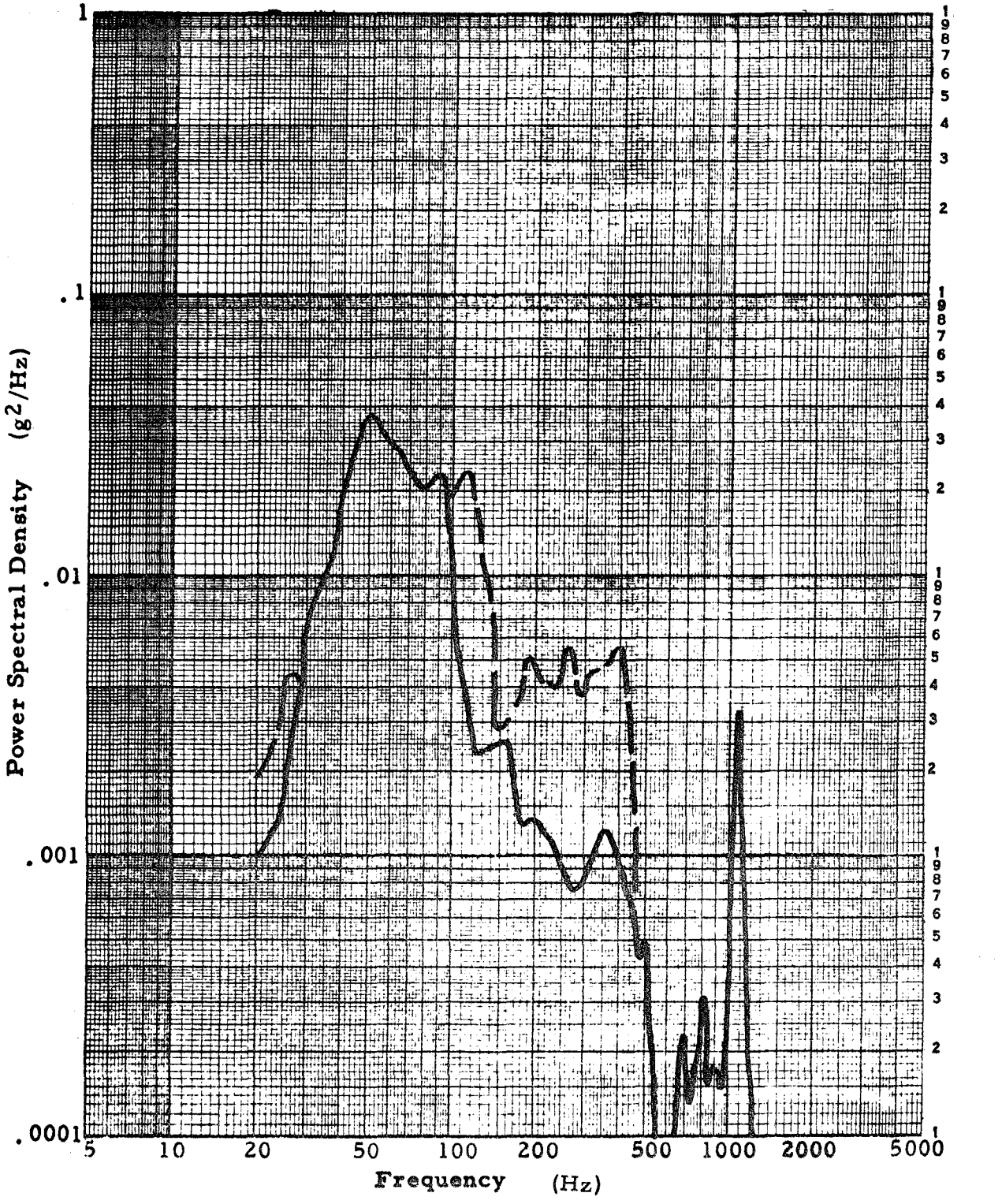
RANDOM VIBRATION SPECTRUM

LAUNCH & BOOST

Duration:

S.P. 2

H.F.E. PROBE X RESPONSE



Bendix Aerospace Systems Division

ACC. NO. 16

Axis:

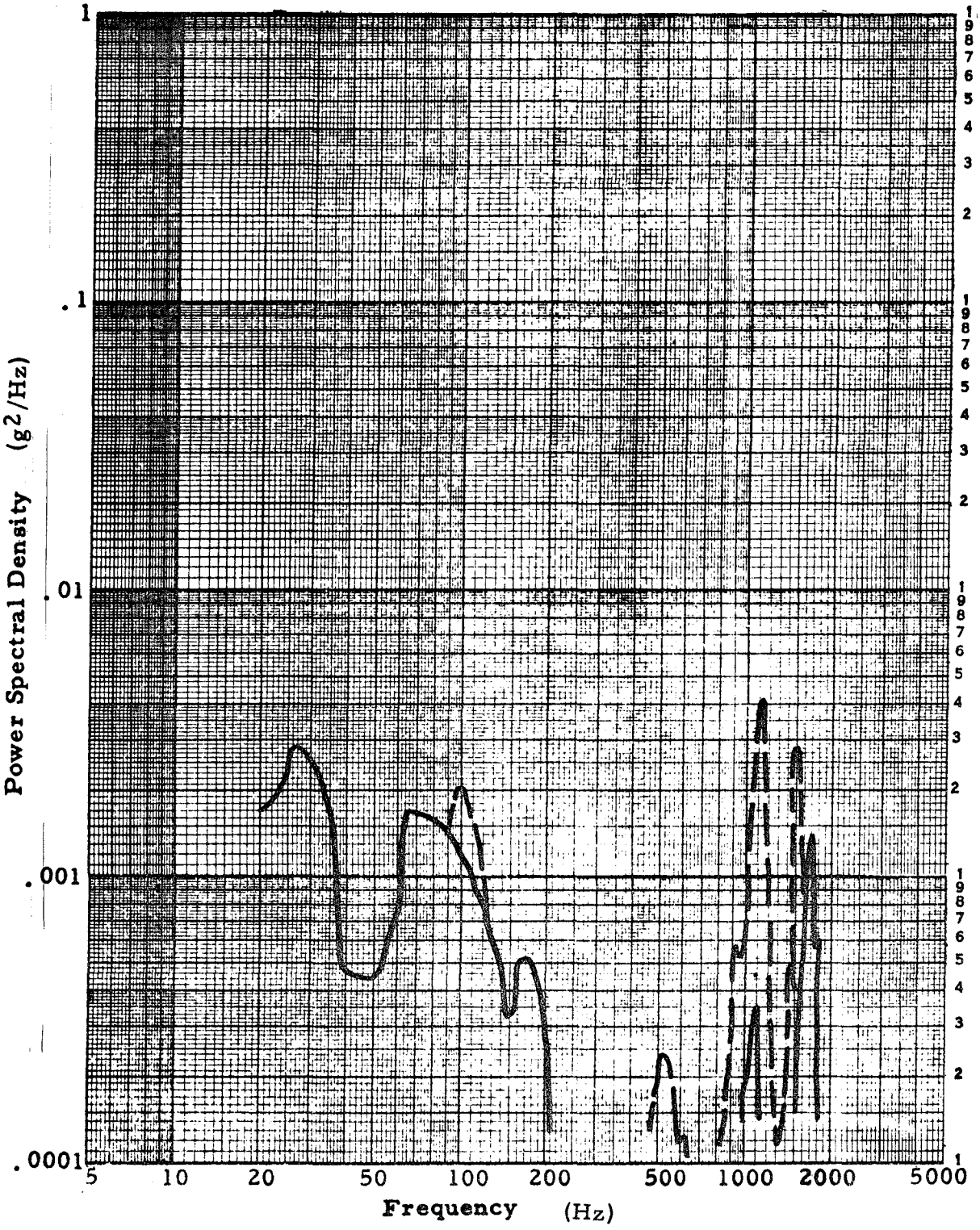
RANDOM VIBRATION SPECTRUM

LAUNCH & BOOST

Duration:

S.P. 2

H.F.E. PROBE Y RESPONSE



Bendix Aerospace Systems Division

ACC. NO. 17

Axis:

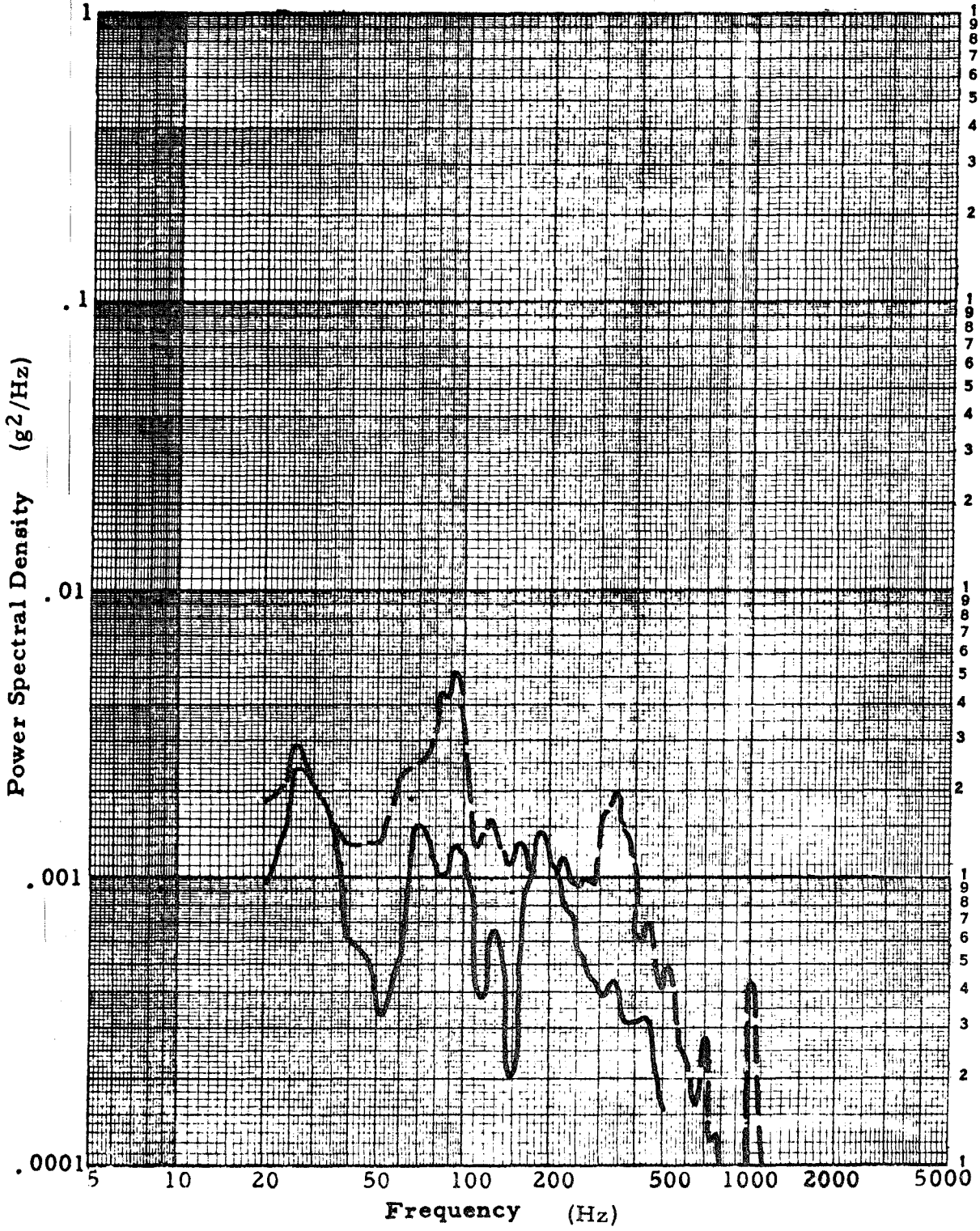
RANDOM VIBRATION SPECTRUM

LAUNCH & BOOST

Duration:

S.P. 2

H.F.E PROBE & RESPONSE



440-91

Bendix Aerospace Systems Division

ACC. NO. 15

Axis:

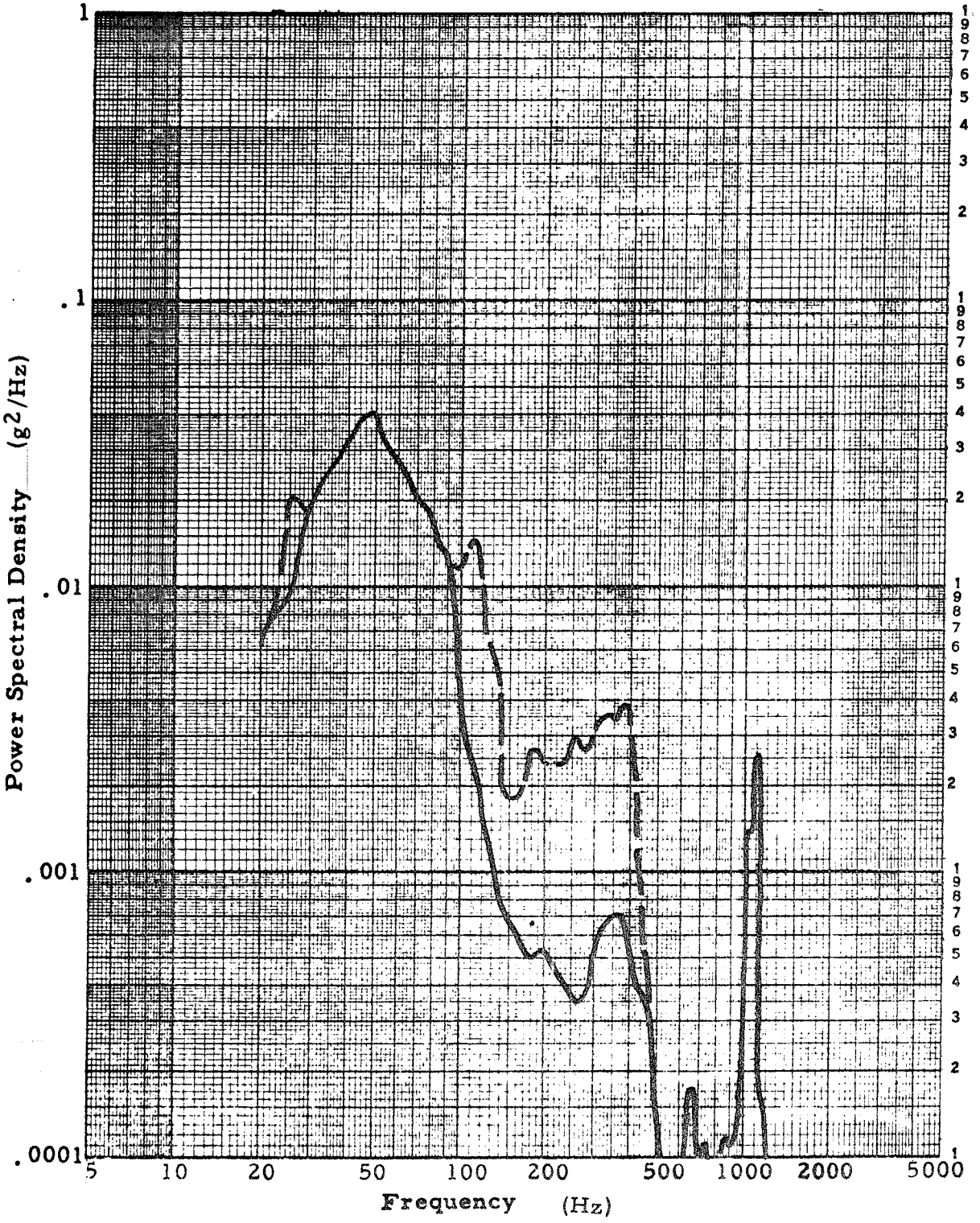
RANDOM VIBRATION SPECTRUM

LUNAR DESCENT

Duration:

S.P. 2

H.F.E. PROBE X RESPONSE



440-91

Bendix Aerospace Systems Division

ACC NO. 16

Axis:

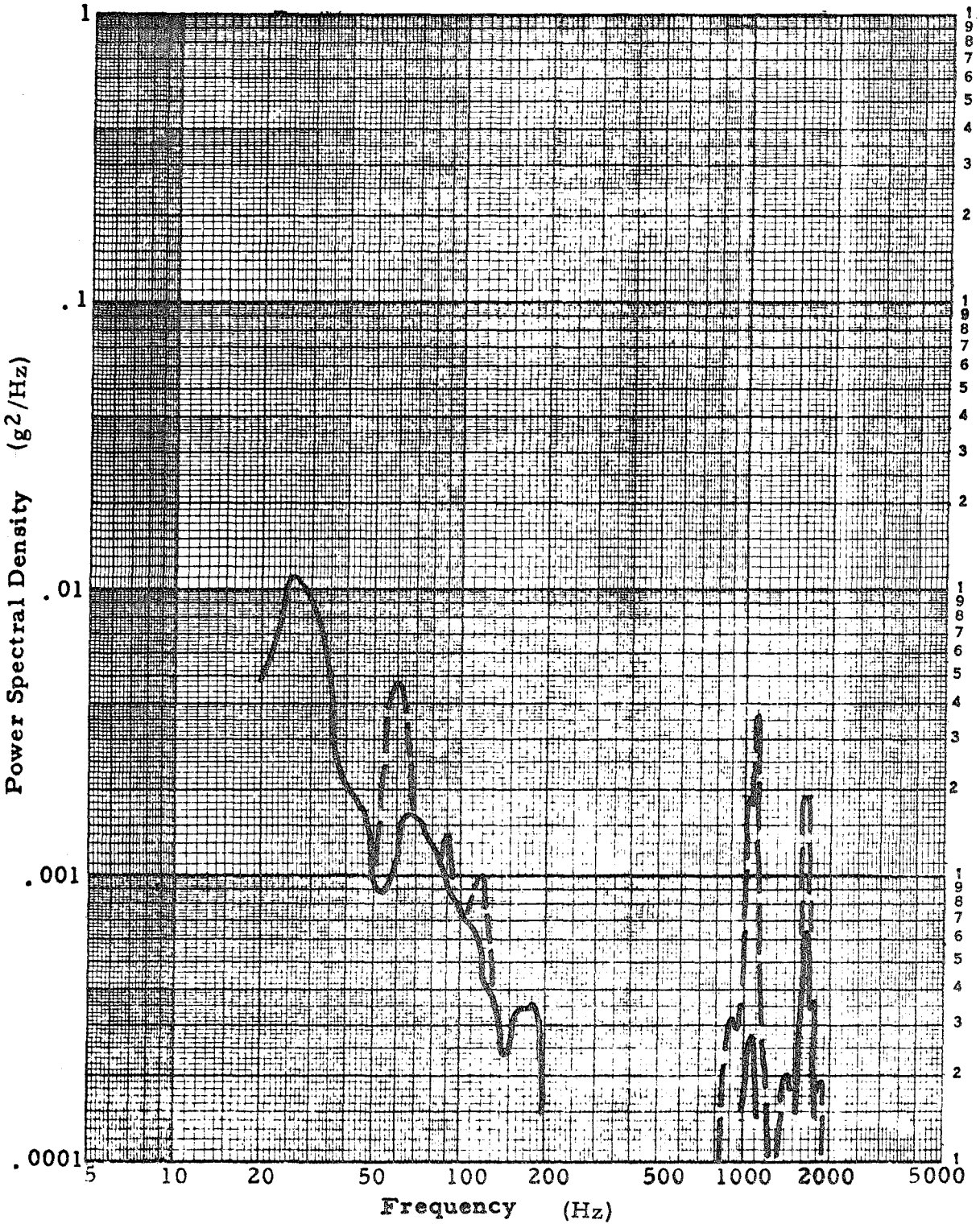
RANDOM VIBRATION SPECTRUM

LUNAR DESCENT

Duration:

S.P. 2

U.F.E. PROBE Y RESPONSE



ACC. NO. M7

Axis:

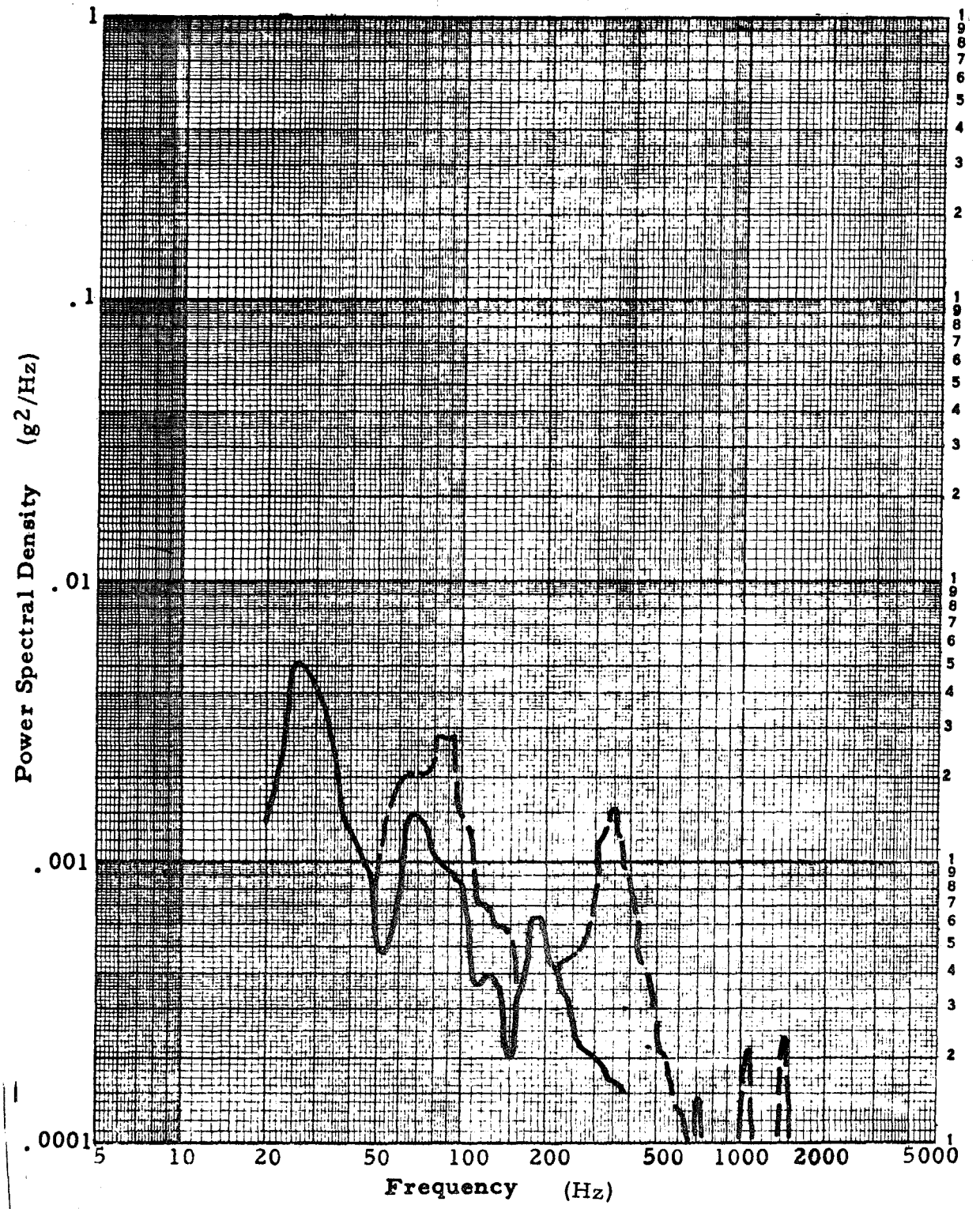
RANDOM VIBRATION SPECTRUM

LUNAR DESCENT

Duration:

S.P.2

H.F.E. PROBE & RESPONSE



440-91