TEST REPORT: VIBRATION TESTING OF THE ELECTRON/PROTON SPECTROMETER STRUCTURAL TEST UNIT

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(NASA-CR-128699) TEST REPORT: VIBRATION TESTING OF THE ELECTRON/PROTON SPECTROMETER STRUCTURAL TEST UNIT (Lockheed Electronics Co.) 42 p HC $4.25 CSCL 14B G3/14 Unclas 62705

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Details of illustrations in this document may be better studied on microfiche

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Introduction

The Structural Test Unit of the Electron-Proton Spectrometer is tested to the random vibration spectra shown in Appendix A and to a sinusoidal resonant search to comply with the requirements of the Verification Plan for Electron-Proton Spectrometer, LEC Document EPS-435.

The test item consists of mass simulated electronic and P/C boards mounted in a flight type electronic housing, detectors, and their shields within an outer housing. The arrangement, center of gravity, and weight were as proposed for flight units.

Testing

On 28th June 1971, the test item was taken to the NASA vibration test facility at Building 49, Manned Spacecraft Center to be subjected to the random vibration criteria shown in Appendix A. The corresponding axes of the instrument are shown in Figure 1. The basic arrangement of the test item is shown in Figure 2.

Testing was started in the 'R' axis of the test article. After approximately 30 seconds at the full nominal level in this axis, a failure of the thermal insulation bushes between the baseplate and the electronics package mounting screws occurred and the testing was aborted. Appendix B reports on this failure and the corrective action taken.

On 2nd July 1971, the test article was returned to Building 49 and subjected to the 'R' axis random vibration criteria. Approximately 40 seconds into the test, the screws securing the baseplate and electronics housing to the outer housing failed and the test was aborted.

At this point in time, an intensive investigation of the design approach was undertaken; this is discussed in Appendix C, together with the corrective action taken.

To provide additional data for the above mentioned investigation, the failed test article was repaired and subjected to the sinusoidal resonant search on the 12th July 1971. The results of this search are shown in Appendix D.

On the 13th August 1971, the modified Structural Test Unit incorporating vibration isolators between the outer housing and electronics package (see Figures 3 and 4) and utilizing actual P/C boards (whose structural responses were monitored) within the electronics package was taken to Building 15, NASA/MSC and subjected to the sinusoidal resonant search. The results of this test are shown in Appendix D.

On 18th August 1971, the same modified Structural Test Unit was subjected to the 'R' axis random vibration criteria. The unit satisfactorily completed both the nominal vibration level and the 10 second burst 4 dB above the nominal level. It should be noted that the system in Building 49 is not capable of reaching the full 64 g rms level for the 10 second burst with the test fixture and article mounted upon it. The level reached was 55 g rms, at which point the control system consistently shut down.

On the 10th September 1971, the test item was subjected to the 'X' and 'T' axes random vibration criteria. The unit satisfactorily completed testing in both these axes.

Results

The results of the sinusoidal resonant search are given in Appendix D.

The random vibration typical response levels for the electronics and P/C boards on the modified test unit are shown in Figure 5. Prior response levels of the hard-mounted electronics package are also shown for comparison.

Input vibration spectra for the R, X, and T axes are shown in Figures 6, 7 and 8, 9, 10, and 11. Response Spectra are shown in Figures 12 and 22. Comments on unusual responses are presented in Appendix E.

Conclusion

The test responses shown in Figure 5 are considered to be satisfactory for survival of the detectors and electronics. Deflections, as far as could be judged by eye, appear to be within predicted values, hence, it is considered that the revised design provides a solution to the vibration problem that will allow the electronics package to be qualified to the vibration levels imposed on the EPS.

The results of the resonant search indicate that the natural frequency range of the vibration isolators is so dominant, and their attenuation so effective, that no significant resonance is seen on the electronics package and its inherent parts.

Appendix A

Vibration Criteria

APPENDIX 'A'

R-Axis

20 to 125 Hz	+12 dB/oct increase
125 to 500 Hz	2.0 g^2/Hz
500 to 670 Hz	-9 dB/oct decrease
670 to 1100 Hz	0.8 g^2/Hz
1100 to 2000 Hz	-9 dB/oct decrease

X-Axis

20 to 75 Hz	+6 dB/oct increase
75 to 175 Hz	0.085 g^2/Hz
175 to 300 Hz	+6 dB/oct increase
300 to 1000 Hz	0.25 g^2/Hz
1000 to 2000 Hz	-6 dB/oct decrease

T-Axis

20 to 100 Hz	+6 dB/oct increase
100 to 440 Hz	0.04 g^2/Hz
440 to 600 Hz	+18 dB/oct increase
660 to 900 Hz	0.3 g^2/Hz
900 to 2000 Hz	-12 dB/oct decrease

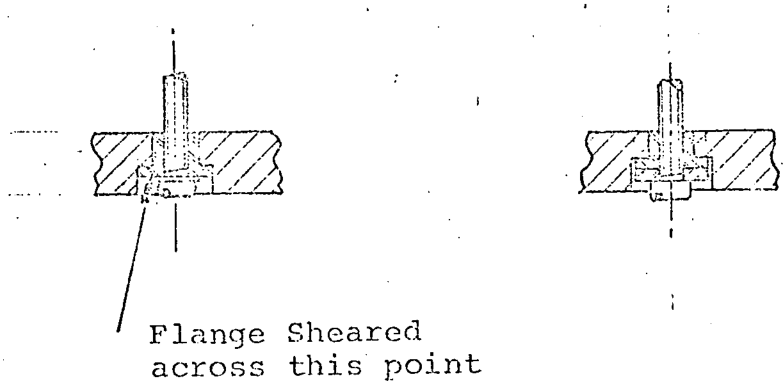
For each of the above axes, duration is 140 seconds plus 10 seconds at 4 dB above the nominal.

Appendix B

Thermal Insulation Bushing Failure

APPENDIX 'B'

Investigation of the failure of the insulating bushes showed that conventional washers had been fitted under the screws, rather than the special large washers required. (See 'a' and 'b' below)



(a) (b)

As can be seen, these standard washers placed the flange of the bushings in shear (for which they were not designed) and this was the primary mode of failure.

Corrective action taken was to reassemble the unit with the correct special washers under the heads of the screws. Some additional mounting screws were added, to reduce the loading on the bushings.

Appendix C

Failure Investigation

APPENDIX C

The failure of the screws securing the baseplate to the outer housing lead to an intensive investigation of the design and the loading upon it. Perusal of the vibration data obtained showed that the levels upon the structure were higher than had been anticipated, overloading the screws and causing loosening and failure.

While every effort was being expended to strengthen the 'hard-mounted' electronics design, it became increasingly clear that the P/C boards would be subjected to levels of vibration that would seriously reduce the confidence level in their operating satisfactorily after vibration. Hence, an alternative approach was instigated, investigating the possibility of utilizing vibration isolators to reduce the vibration levels seen by the instrument.

However, it became clear that it was not satisfactory to mount the instrument off the spacecraft structure by isolators, as this required extensive modification of the spacecraft interface. To minimize this impact on the interface with North American Rockwell/Downey, it was decided that any isolation used must remain within the basic envelope of the package, and that the outer housing and mounting flange would remain 'hard-mounted' with the electronics package mounted to this structure via the vibration isolators. The resultant arrangement is shown in Figure 3.

During this phase, LEC was first made aware of the requirement to control the internal pressure of the Service Module during the initial launch phase; this places the underside of the housing under pressure and had to be taken into account. Additionally, information was made available regarding the shock environment that also had to be taken into account in selecting the isolators.

A more detailed view of the instrument is given in Figure 4, showing the mounting arrangement adopted. It can be seen that this had very little impact on the electronics housing arrangement. This modified design was then fabricated, assembled and submitted to testing.

The original hard-mounted design had been prepared on the basis of the vibration levels given for the original EPS location on the MDA, and the unit had been completely designed before the change of location to the Service Module. Only minimal modifications were made at that time, to keep the impact to the schedule low.

Appendix D

Sinusoidal Resonant Search

APPENDIX D

A 3.6 g sinusoidal resonant search, from 5 - 2000 Hz at a sweep rate of 1 octave/minute conducted on the original EPS Structural Test Unit yielded the results shown in Fig. 23 for the 'R' axis. This indicates the following resonant frequencies:

Mounting flange:	200 Hz, 370 Hz
Baseplate:	420 Hz
Data Processor:	300 Hz, 460 Hz
L. V. Power Supply:	460 Hz
Heater Control:	460 Hz, 1200 Hz
Temp. Monitor:	420-460 Hz, 900-1650 Hz
Amplifier:	200 Hz, 460 Hz, 1100 Hz, 1400 Hz
Pre-Amplifier:	460 Hz
H. V. Power Supply: (Det. Bias Supply)	200 Hz, 550 Hz, 1100 Hz
Detector Mounting Plate:	370 Hz

In the 'X' and 'T' axes, accelerometers mounted on the printed circuit boards were measuring cross-axes responses, and resonances were not clearly established. However, the audible indications of response were much quieter in these axes. In the 'X' axis, a sharp peak in audible noise at 290 Hz was traced to the outer housing; similarly, in the 'T' axis at 290 Hz, there was a sharp peak again attributable to the outer housing.

Minor resonance in the electronics package existed over the range of 380 - 420 Hz and at 925 Hz and 1370 Hz in the 'X' axis, and over the range of 350 - 420 Hz, 670 - 800 Hz and 1150 - 1200 Hz in the 'T' axis.

Examination of the results of these resonant sweeps confirmed that the responses in the 'R' axis were the most critical, and this was considered in the investigation mentioned in Appendix 'C'.

As mentioned in the body of this report the modified Structural Test Unit was resubmitted to a resonant search. The test article was exposed to a 3.8 g peak, 5 - 2000 Hz sinusoidal sweep at 1 octave/minute in the 'R' axis. Responses were as follows:

Baseplate: 30 g @ 280 Hz, 15 g @ 360 Hz, 7 g @ 620 Hz, 7 g @ 750 Hz, 7 g @ 990 Hz, 10 g @ 1220 Hz, and 15 g @ 1500 Hz.

Mounting Flange: No significant resonant response.

Electronics Package: 13.8 g @ 51 Hz (Amplification of 3.6).

The response of the electronics package ranged between 25 - 80 Hz and then beyond this there was no significant response-which is as would be expected from the vibration isolators. On the printed circuit boards, no significant resonant responses were noted below 1500 Hz. However at 1500 Hz and 1800 Hz, significant response levels were noted.

After several investigative runs to determine the cause of this, it was discovered that the fixture and mounting plate resonated at these points. The control accelerometer appeared to be mounted at a node and had given no indication of this resonant situation. Based on this finding, it was considered that the responses at 1500 and 1800 Hz were not true responses to the 3.8 g peak input.

Based on a comparison of the 'R' axis resonant search data with the data from the original Structural Test Unit, it was decided that no significant purpose would be achieved by running resonant searches in the 'X' and 'T' axes, hence the unit was not tested in these axes. From previous data, the only part to significantly respond would be the outer housing.

Appendix E
Comments on Vibration Response

APPENDIX E

Comments on Random Vibration results.

Many of the P.S.D. plots showing the response of various parts of the EPS to the random vibration input show a number of 'spikes', particularly in the 1000 - 2000 Hz range. An attempt was made to account for these spikes, the results of which are stated below.

In Figures 12 through 19, spikes occur at approximately the following frequencies:

1100, 1150, 1200, 1300, 1400, 1500, 1550, 1700, 1750, 1800, 1900, 1950, 2100 Hz.

Spikes below .01 g^2/Hz have been ignored as providing no significant energy input.

The 1100 Hz spikes appear to be in response to some resonance in the top plate (Figure 19).

1150 Hz appears to be a resonant frequency for the Discriminator PC boards (Figure 17).

1200 Hz appears to be a resonant frequency of the Amplifier PC boards (Figure 15) possibly combined with a 'standing wave' effect in the isolators.

1300 Hz appears to be another top plate resonance, with possibly some excitation of the Discriminator boards.

1400 Hz appears to be a prime resonance of the top plate, also exciting the Temperature Monitor PC board (Figure 16).

1500 - 1550 Hz is due to resonance in the shaker system.

1700, 1750 and 1800 Hz - no satisfactory explanation has been determined.

1900 - 1950 Hz appears again to be resonance of the top plate.

2100 Hz is system resonance in the shaker.

Spikes on Figures 20, 21 and 22 appear to be from resonance of that particular piece of hardware, excepting the 1500 and 2100 Hz peaks.

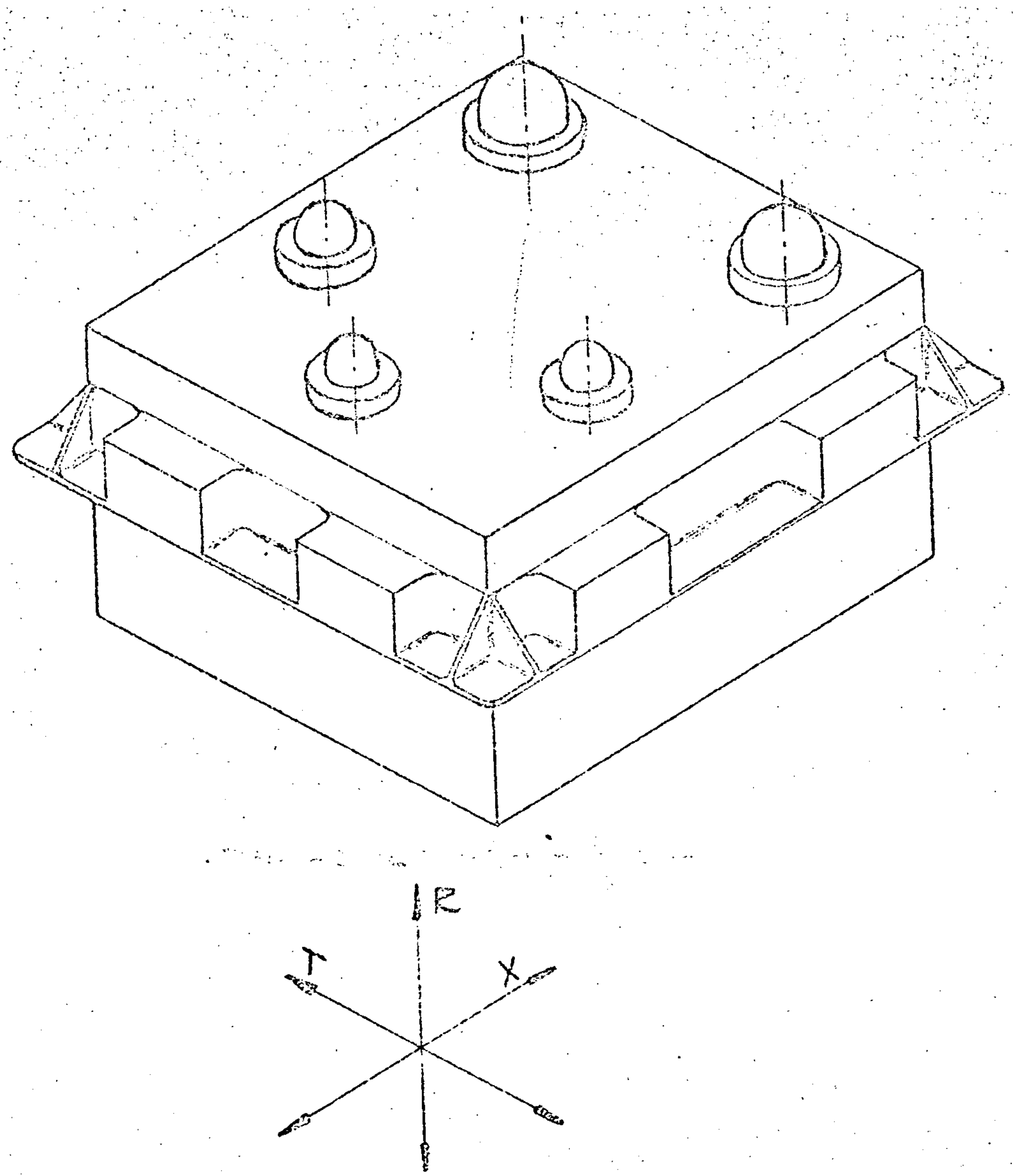


FIG. 1 – INSTRUMENT AXES.

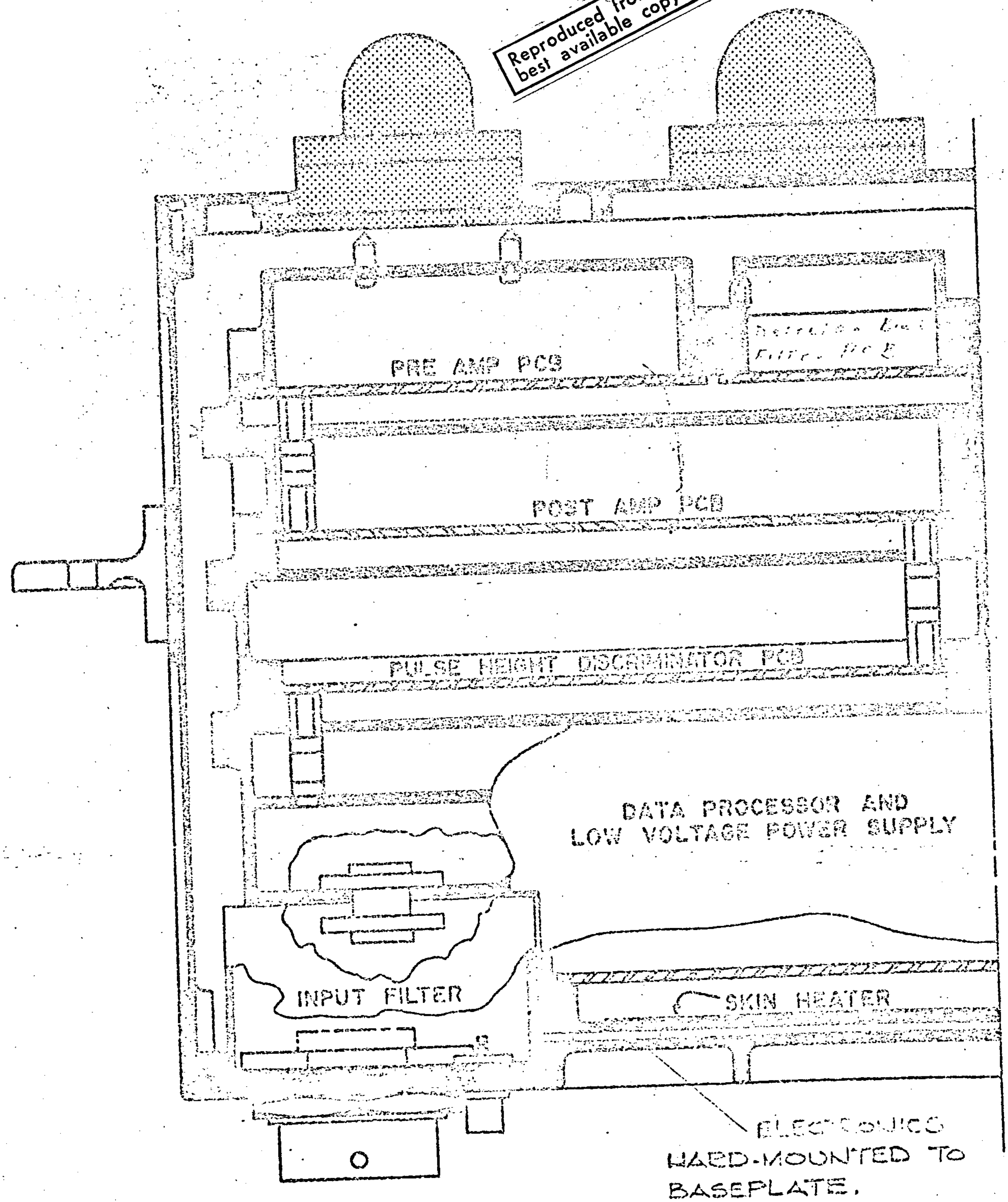


FIG. 2. CROSS SECTION VIEW OF EPS

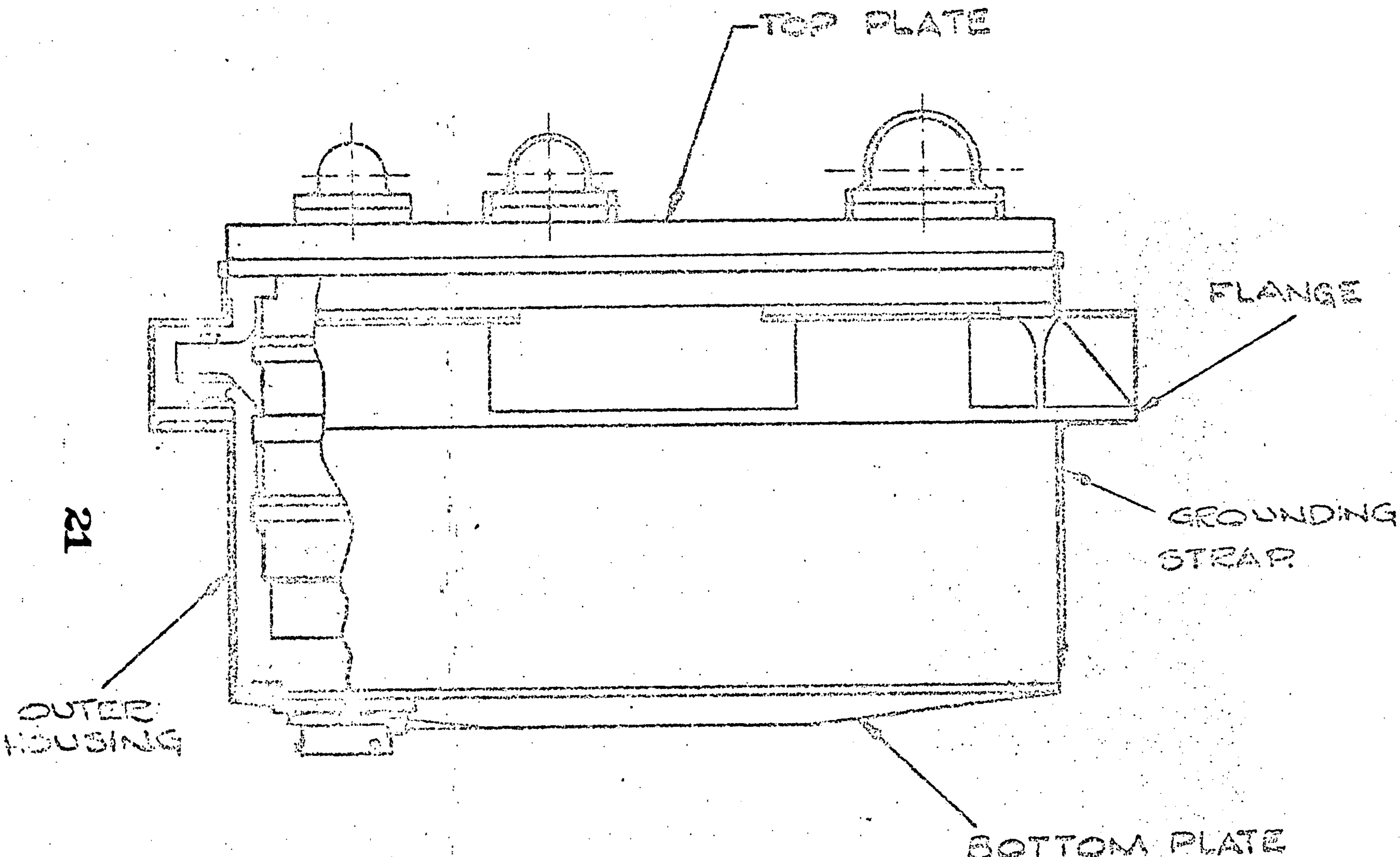


FIG. 3 DIAGRAM OF E.R.S.

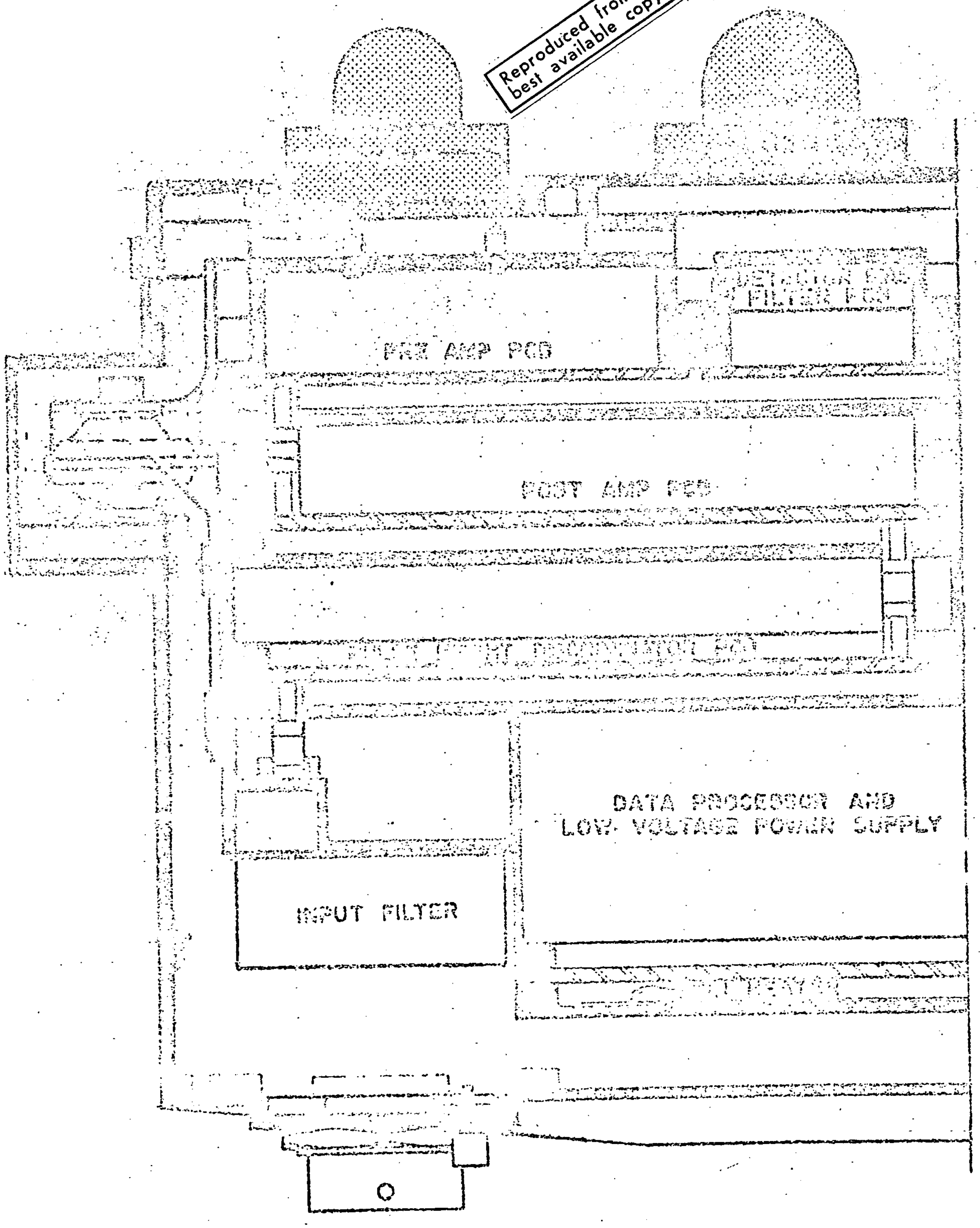


FIG. 4 CROSS SECTION VIEW OF EPS

P.C. BOARD RESPONSES

LOCATION	HARDMOUNTED TO FLANGE G R.M.S.	WITH INTERNAL ISOLATION G. R.M.S.
L.V. POWER SUPPLY	181.9	NO DATA
DATA PROCESSOR	270.4	4.12
DISCRIMINATOR	91.3	16.6
TEMP. MONITOR	118.8	24.9
DETECTOR BIAS SUPPLY	185.9	NO DATA
PRE-AMP	≈ 100	6.9
AMPLIFIER	≈ 100	17.8
HEATER CONTROL	≈ 100	NO DATA
DET. 'A'	217	NO DATA
DET. 'E'	149	6.55

FIG. 5 - COMPARISON OF RESPONSES TO MAX. VIBRATION 'R' AXIS

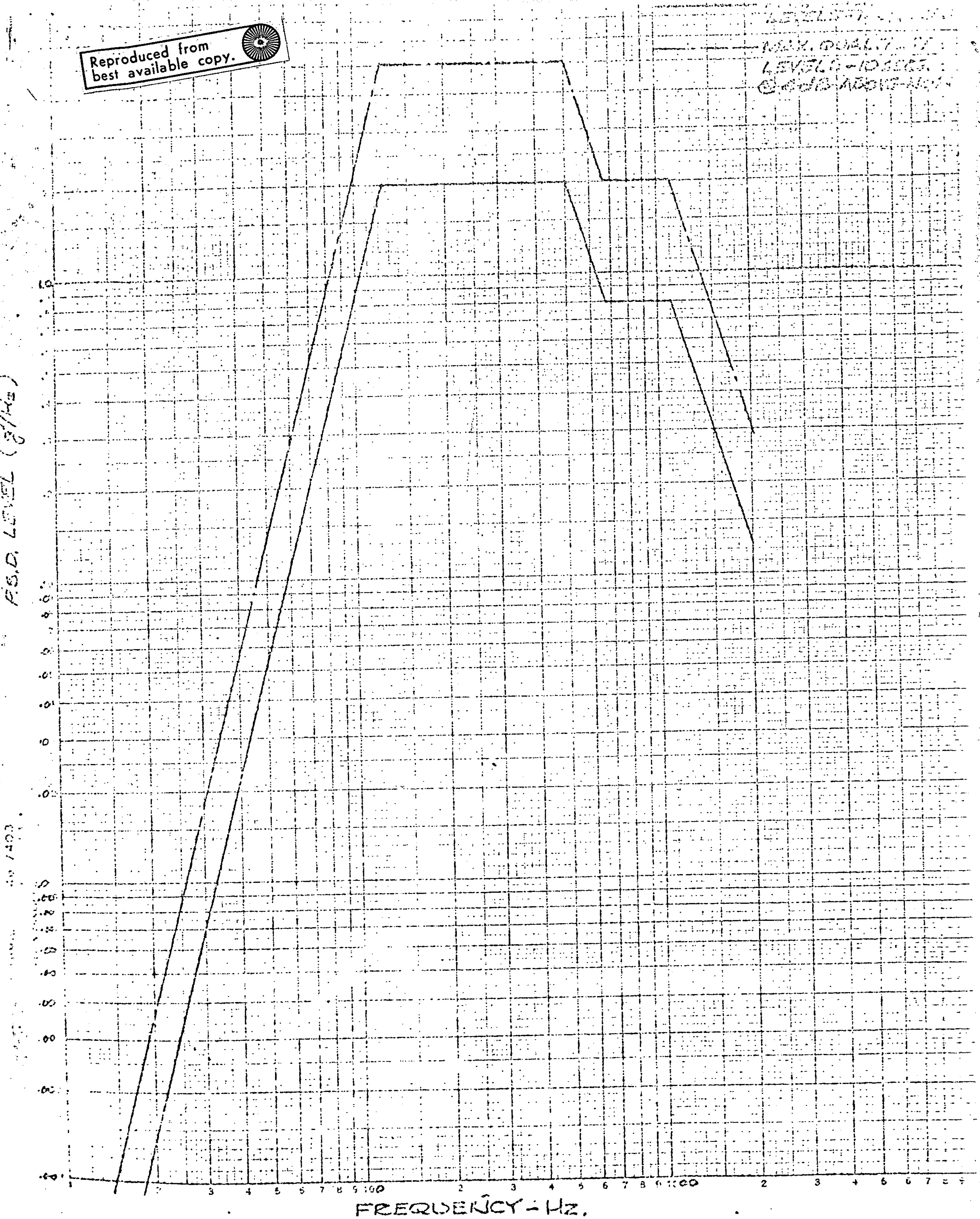


FIG. 6 'B' AXIS

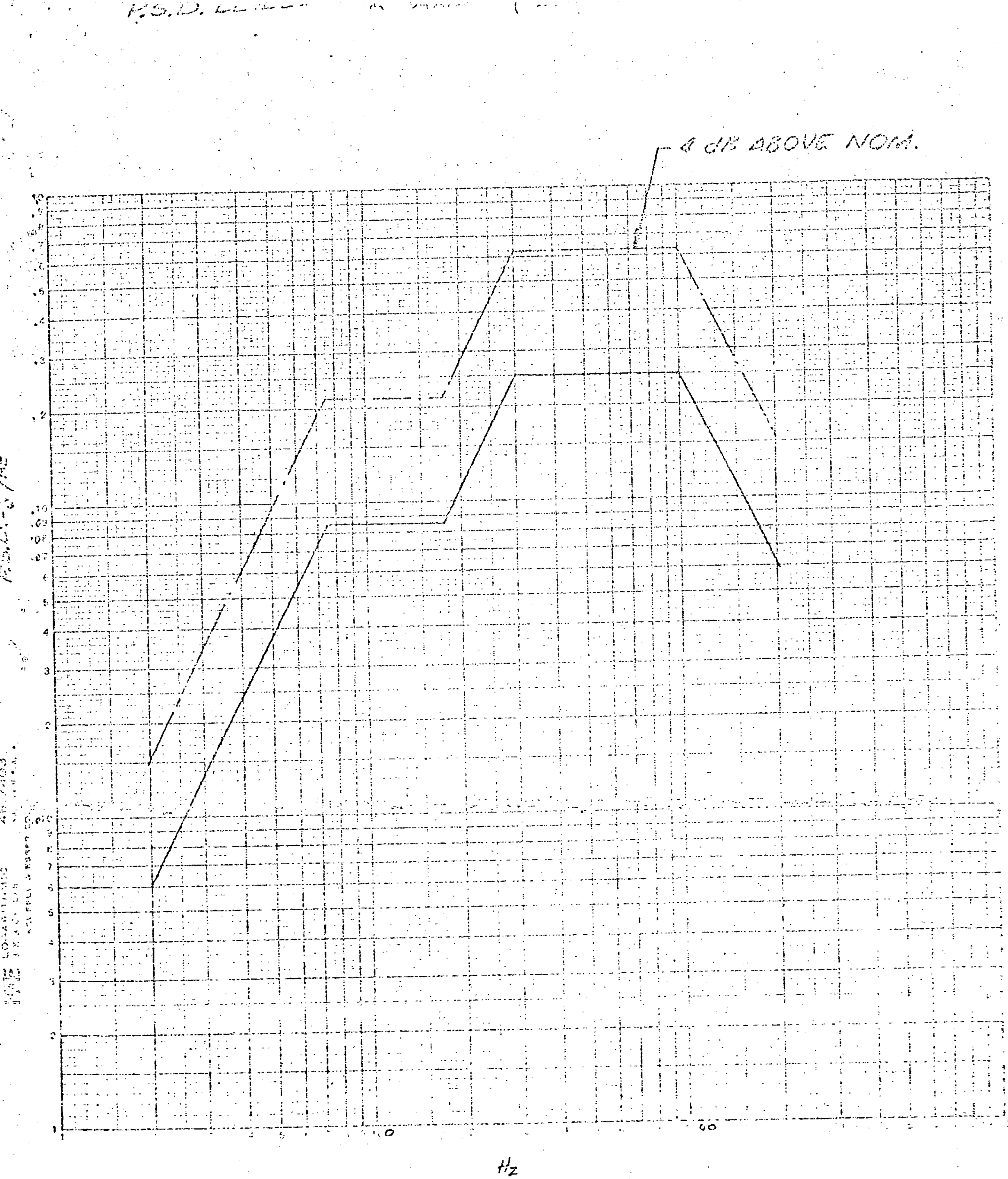


FIG. 7 'X' AXIS.

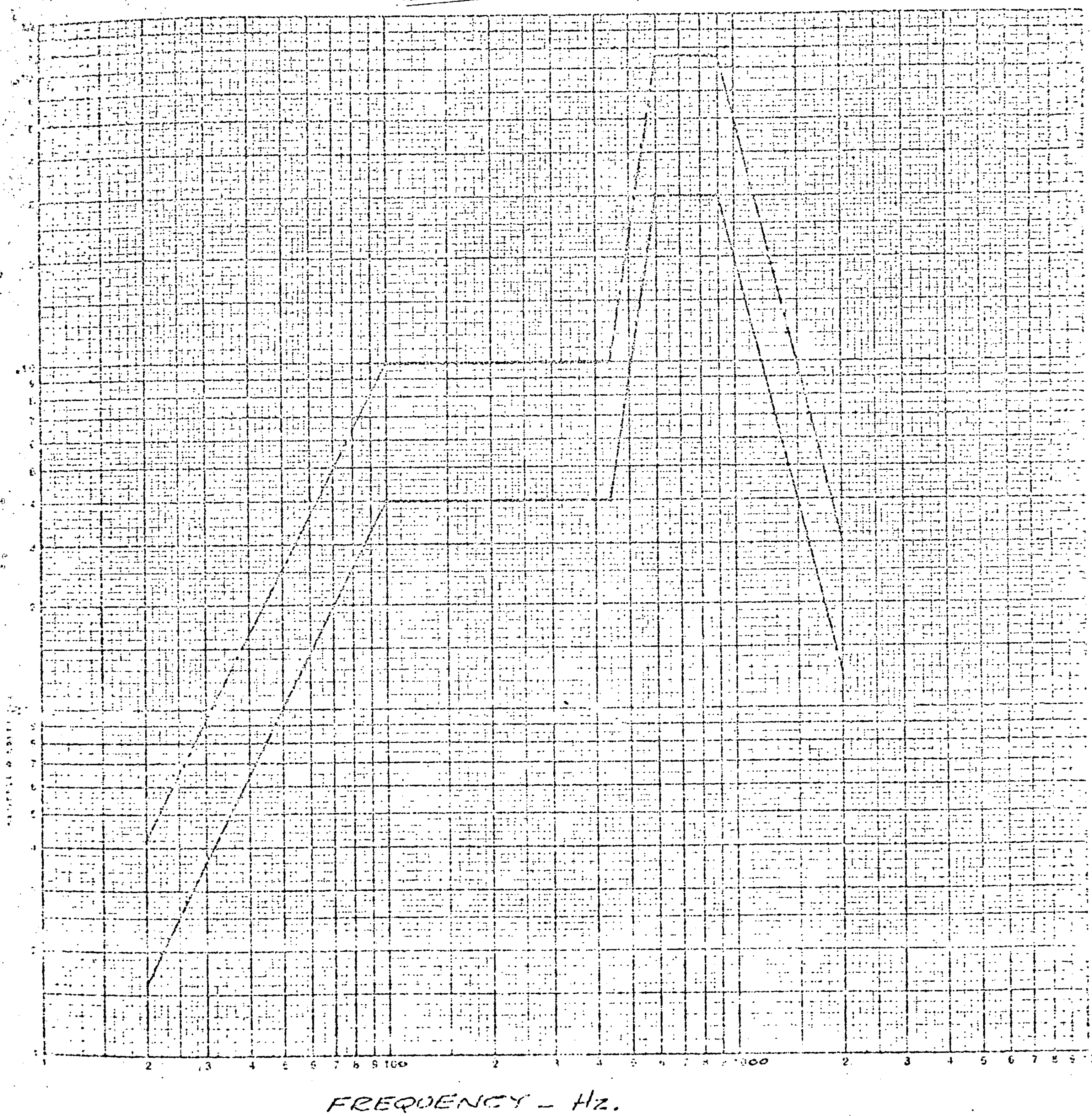
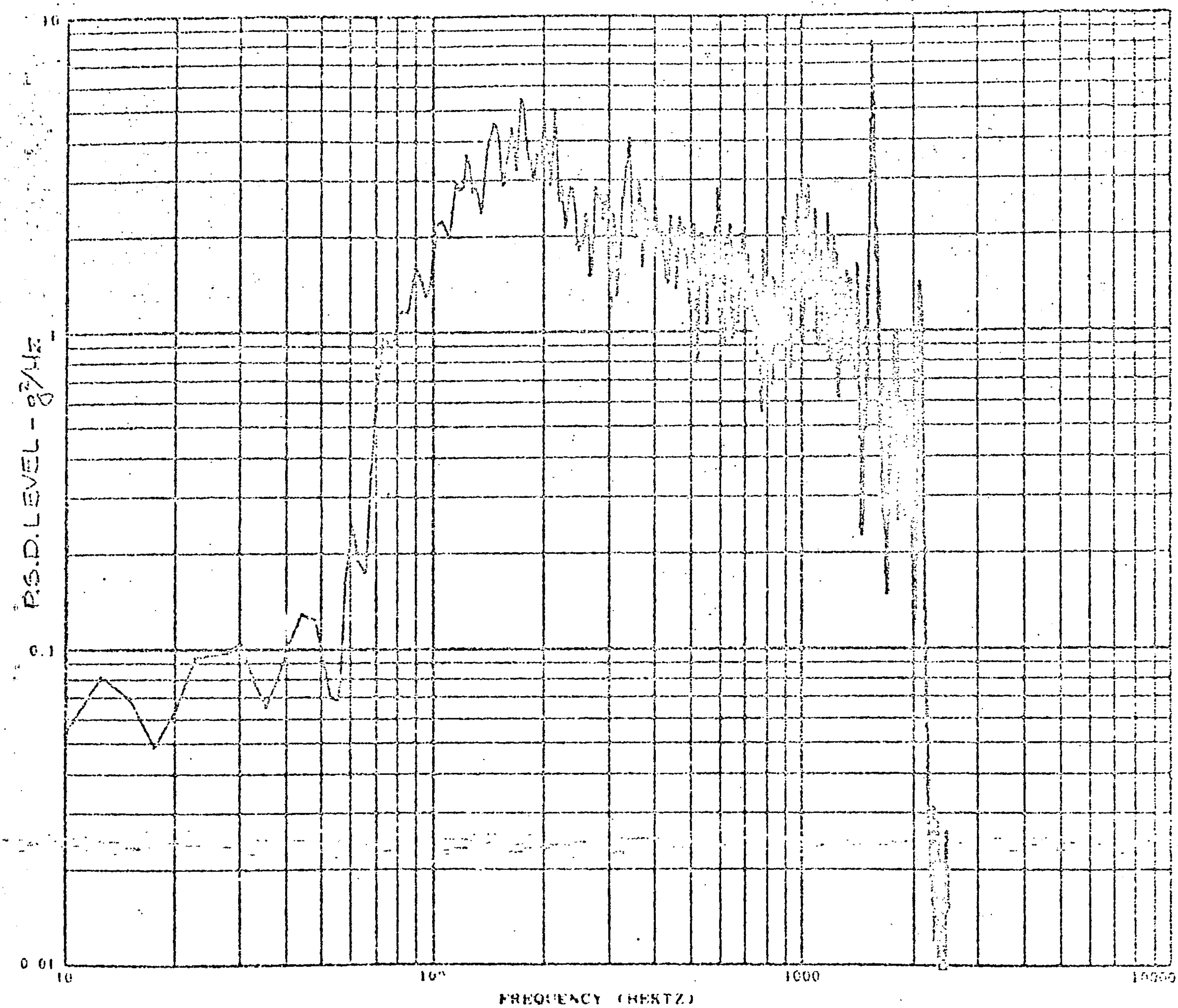
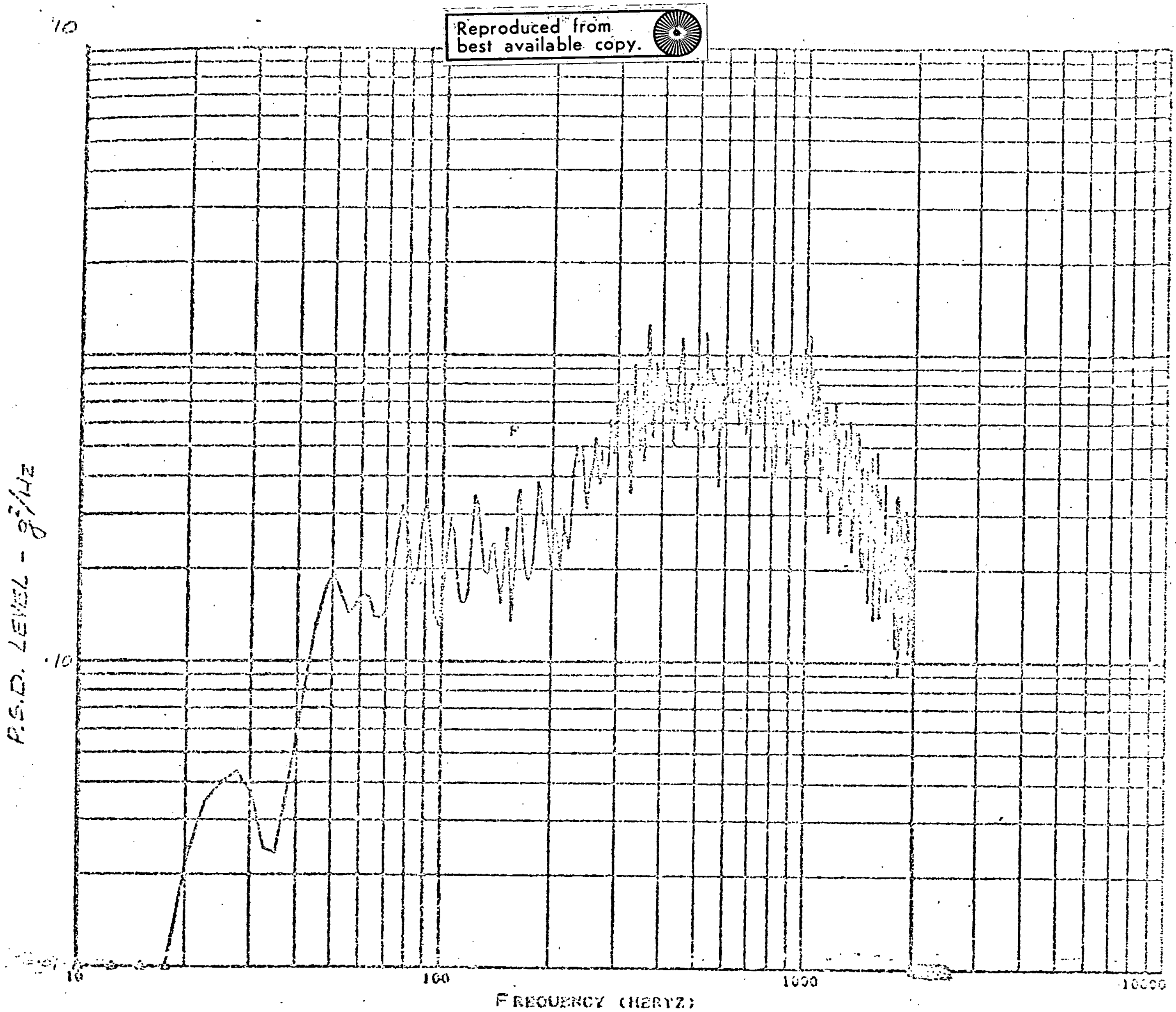


FIG. 8 'T' AXIS.



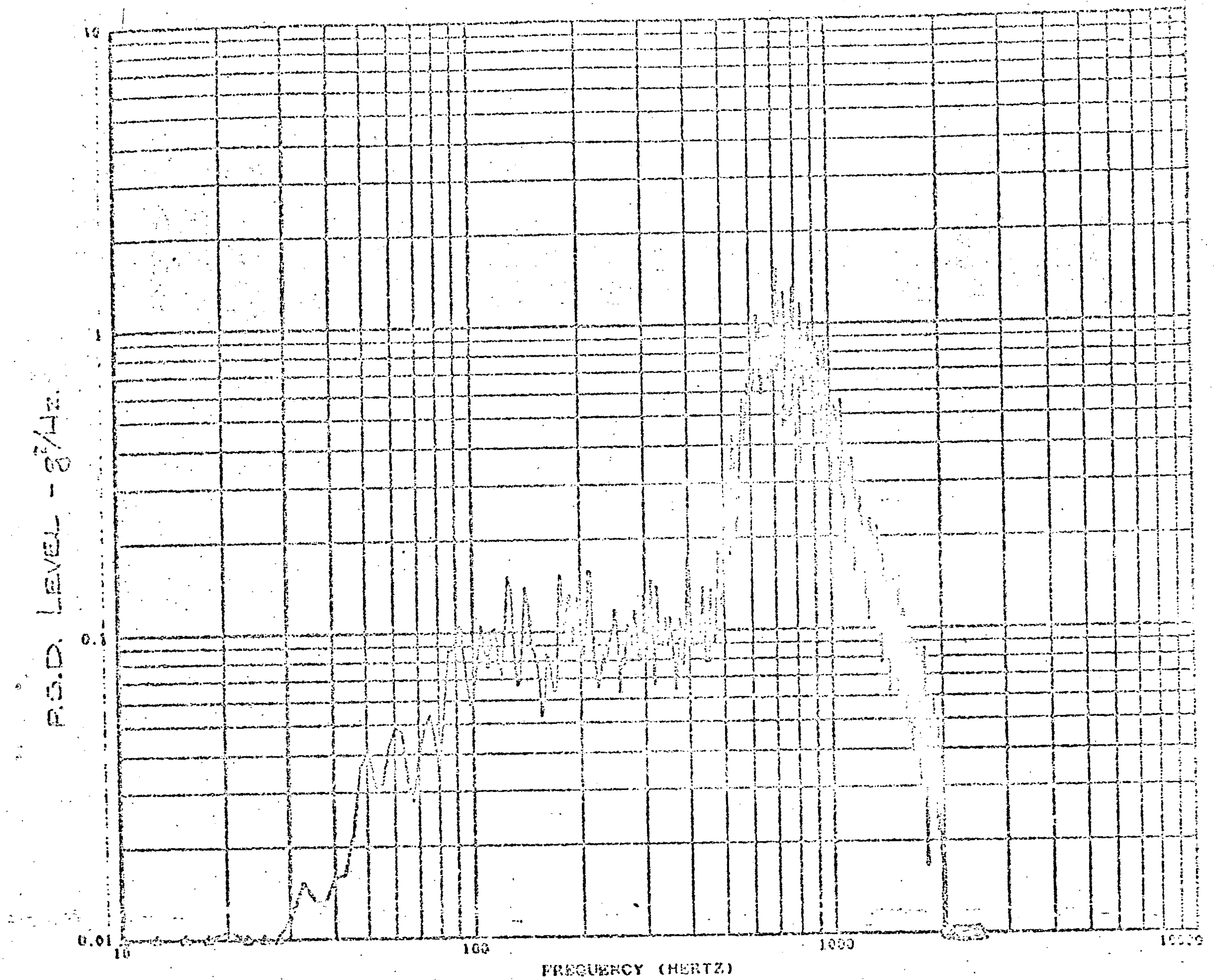
= 54.93 g r.m.s.

FIG. 9 - HIGH LEVEL RANDOM, 'R' AXIS INPUT SPECTRUM



= 30.74 g. r.m.s.

FIG. 10 - HIGH ENERGY RANDOM, 'X' AXIS
INPUT SPECTRUM.



= 22.79 g rms.

FIG. 11 – HIGH ENERGY RANDOM, 'T' AXIS
INPUT SPECTRUM.

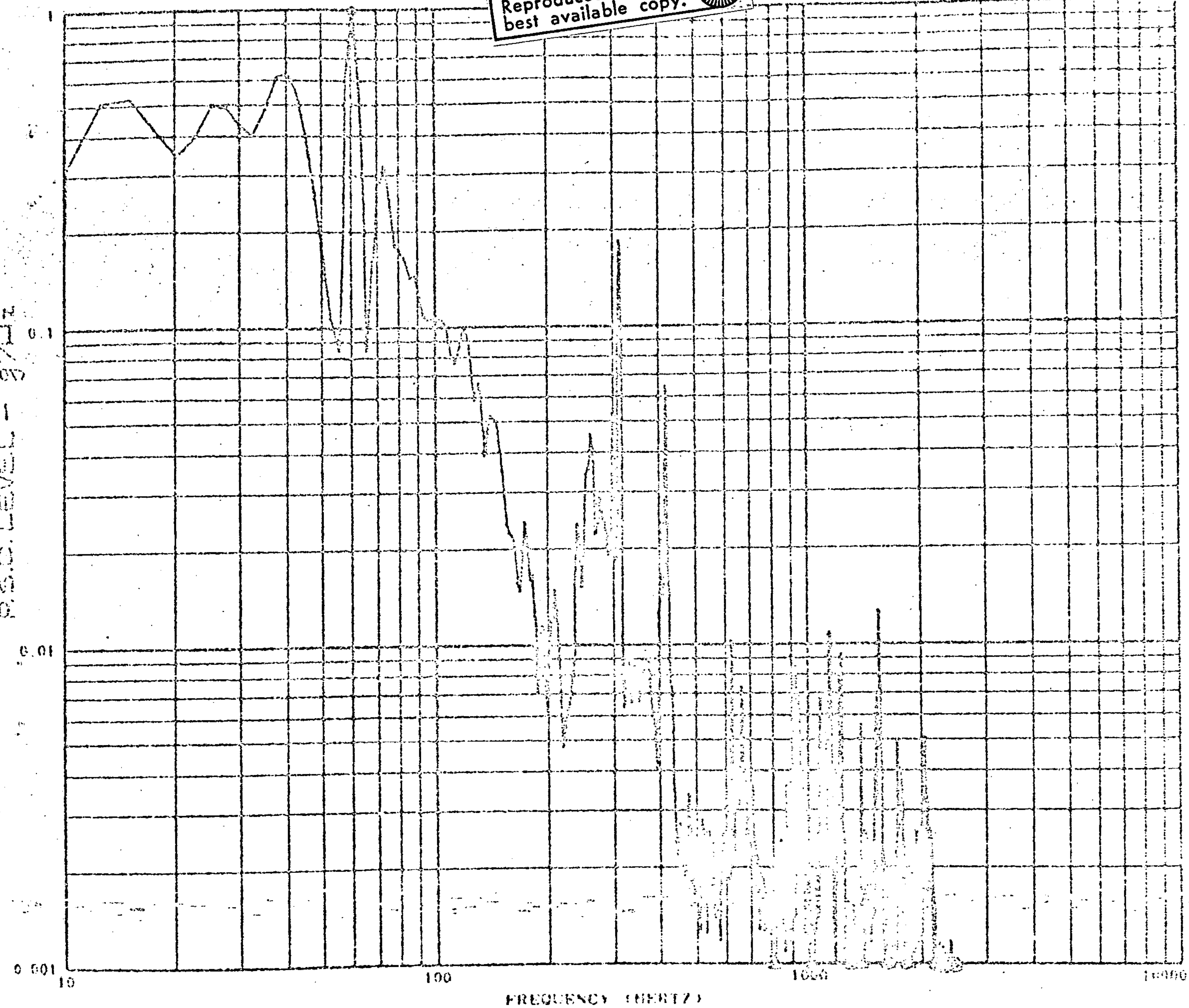
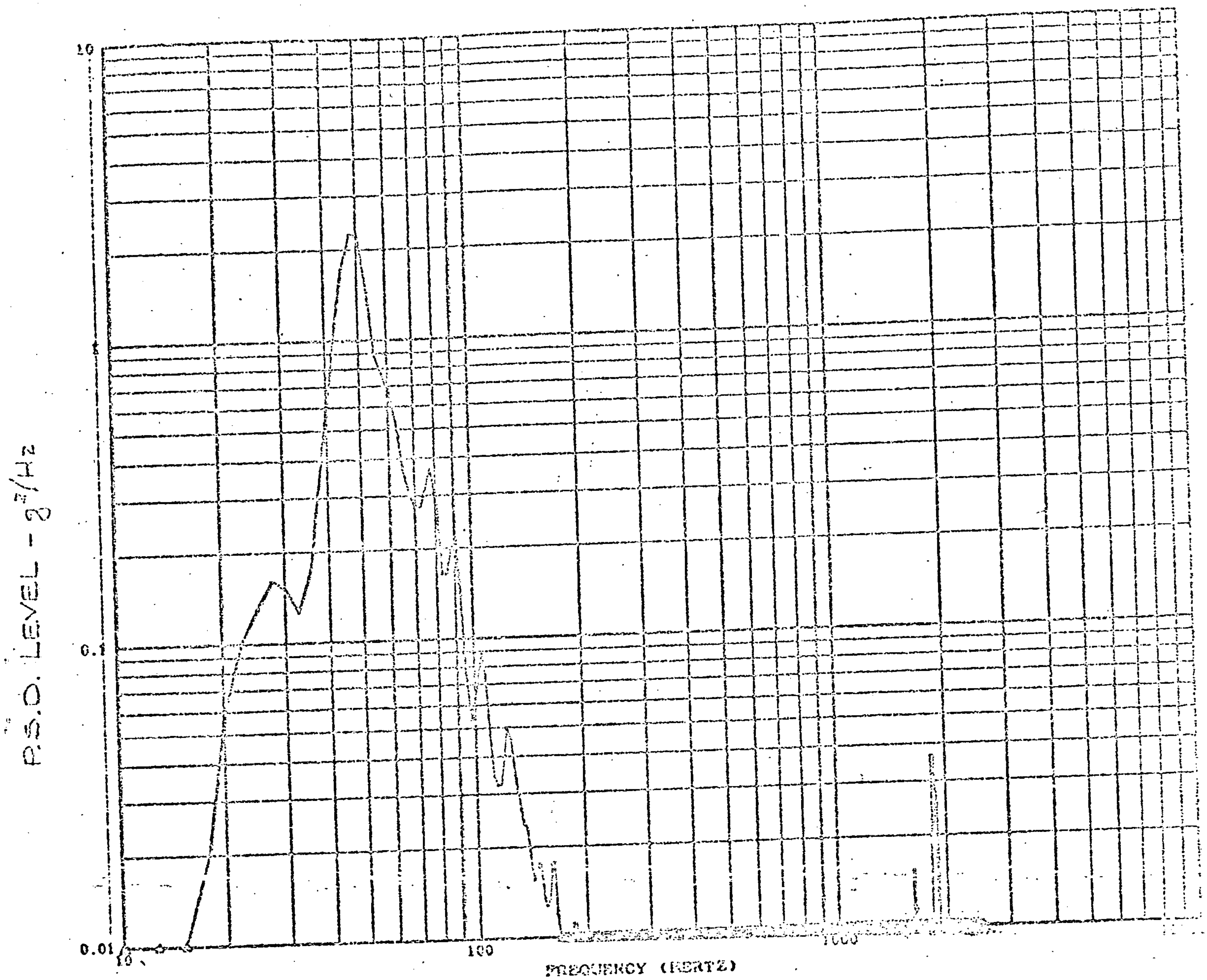
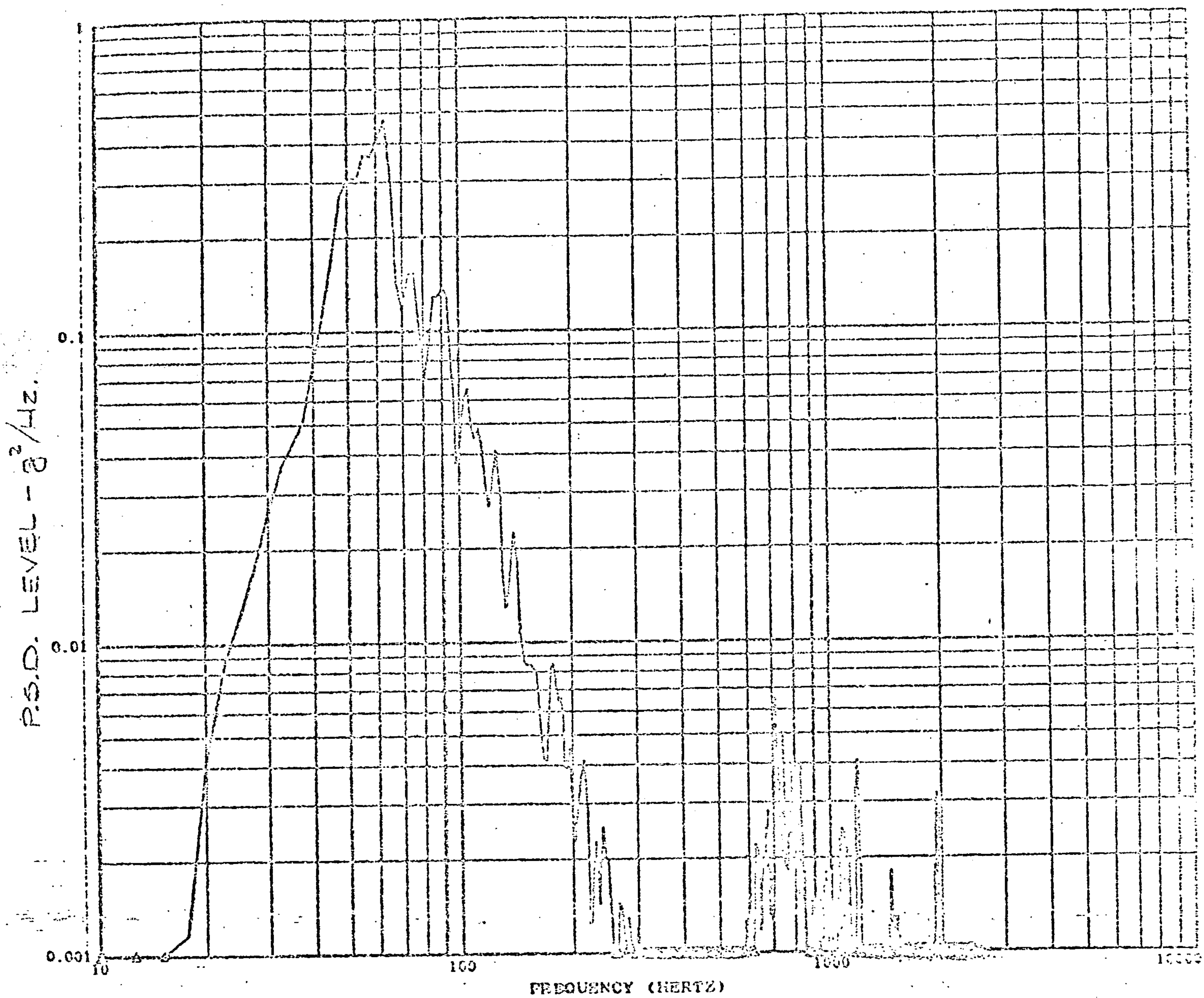


FIG. 17 - HIGH ENERGY RANDOM, 'R' AXIS.
ELECTRONICS PACKAGE
RESPONSE SPECTRUM.



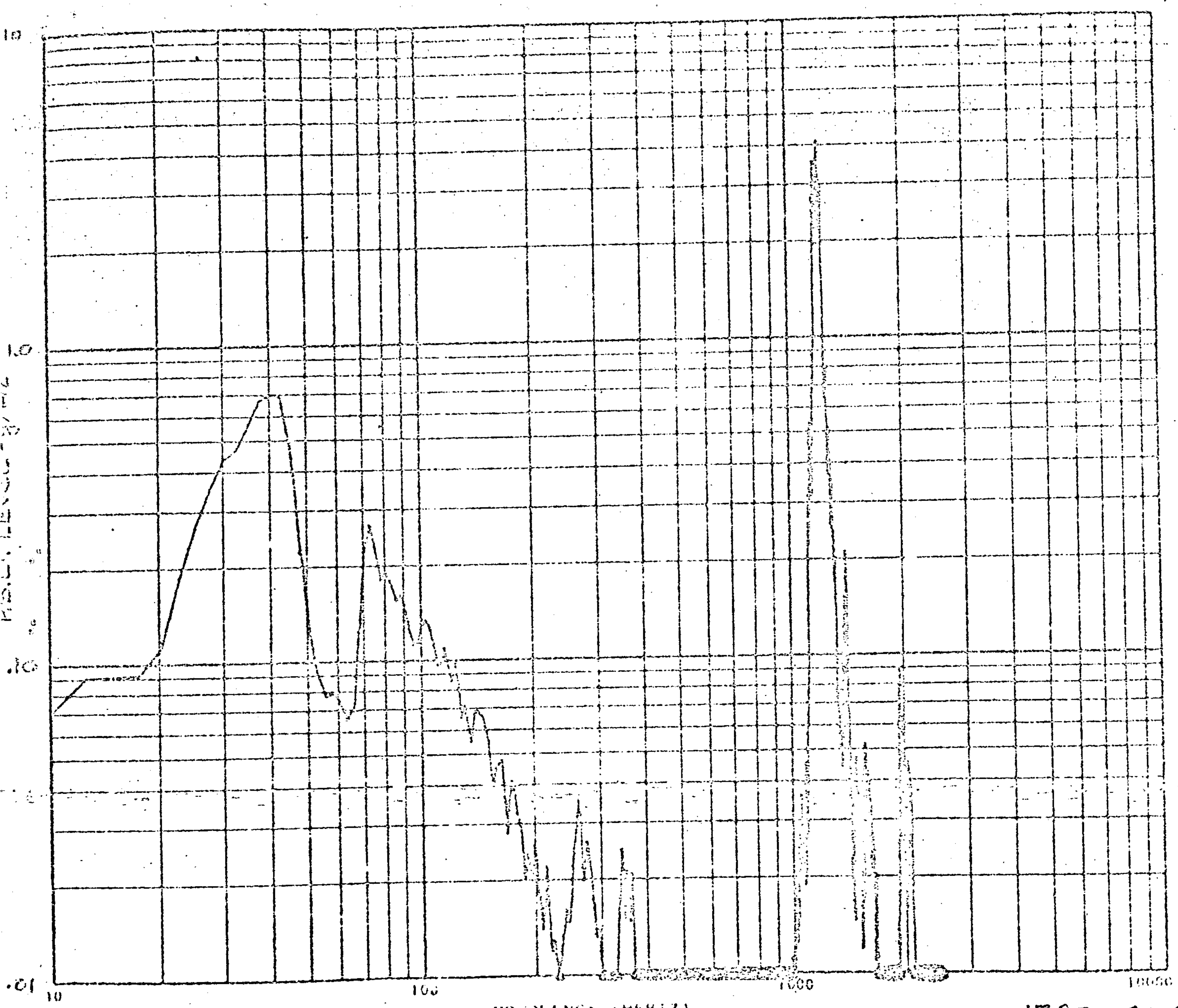
= 7.03 g r.m.s.

FIG.13 HIGH ENERGY RANDOM, 'X' AXIS.
ELECTRONICS PACKAGE
RESPONSE SPECTRUM.



= 4.02 g r.m.s.

FIG. 14 - HIGH ENERGY RANDOM, 'T' AXIS. ELECTRONICS PACKAGE RESPONSE SPECTRUM.



= 17.80 g r.m.s.

FIG. 15 HIGH ENERGY RANDOM, 'R' AXIS

AMPLIFIER P/C BOARD RESPONSE

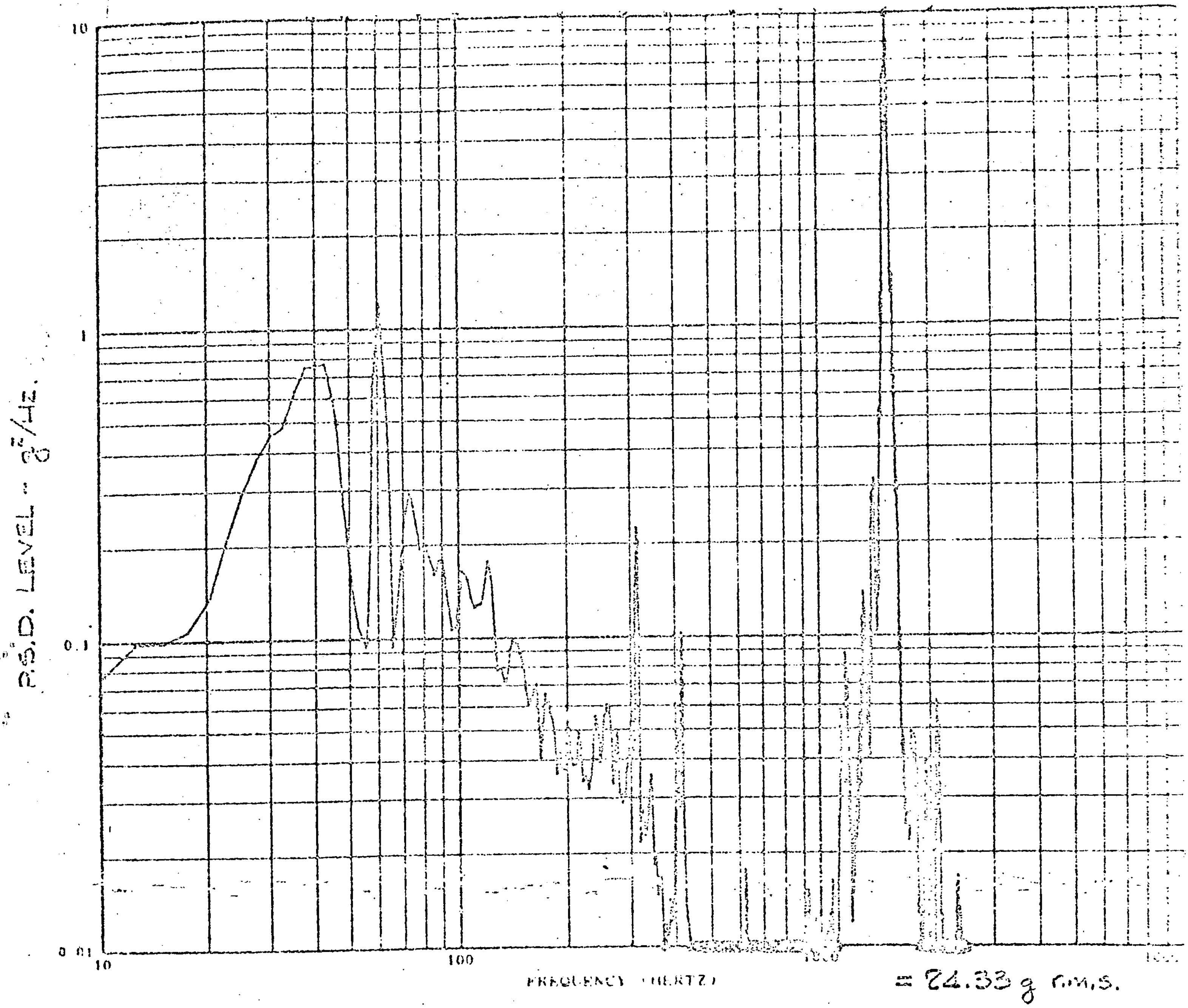


FIG.16. HIGH ENERGY RANDOM, 'R' AXIS
TEMPERATURE MONITOR P/C BOARD RESPONSE.

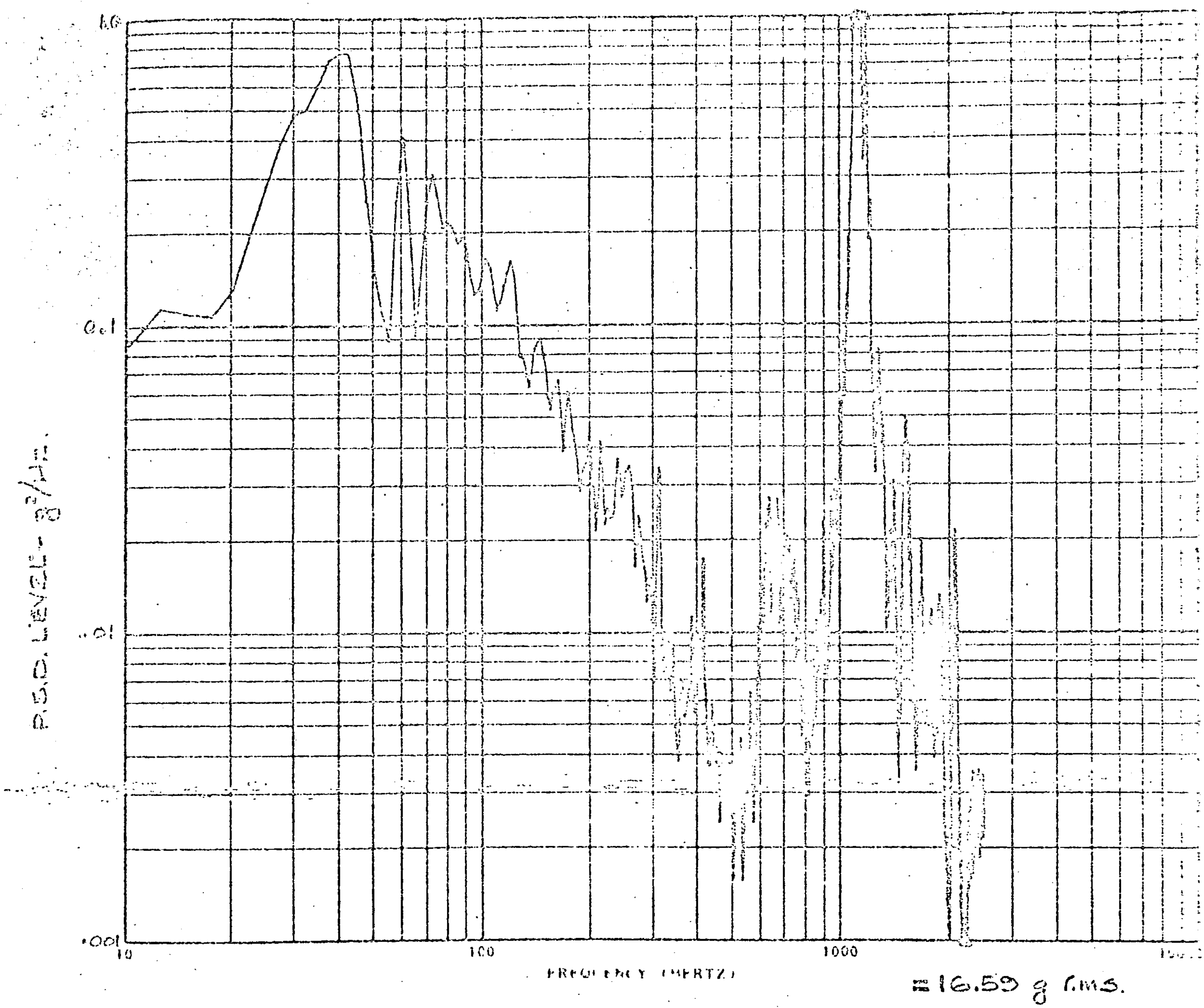


FIG.17 HIGH ENERGY RANDOM, 'R' AXIS

DISCRIMINATOR P/C BOARD RESPONSE

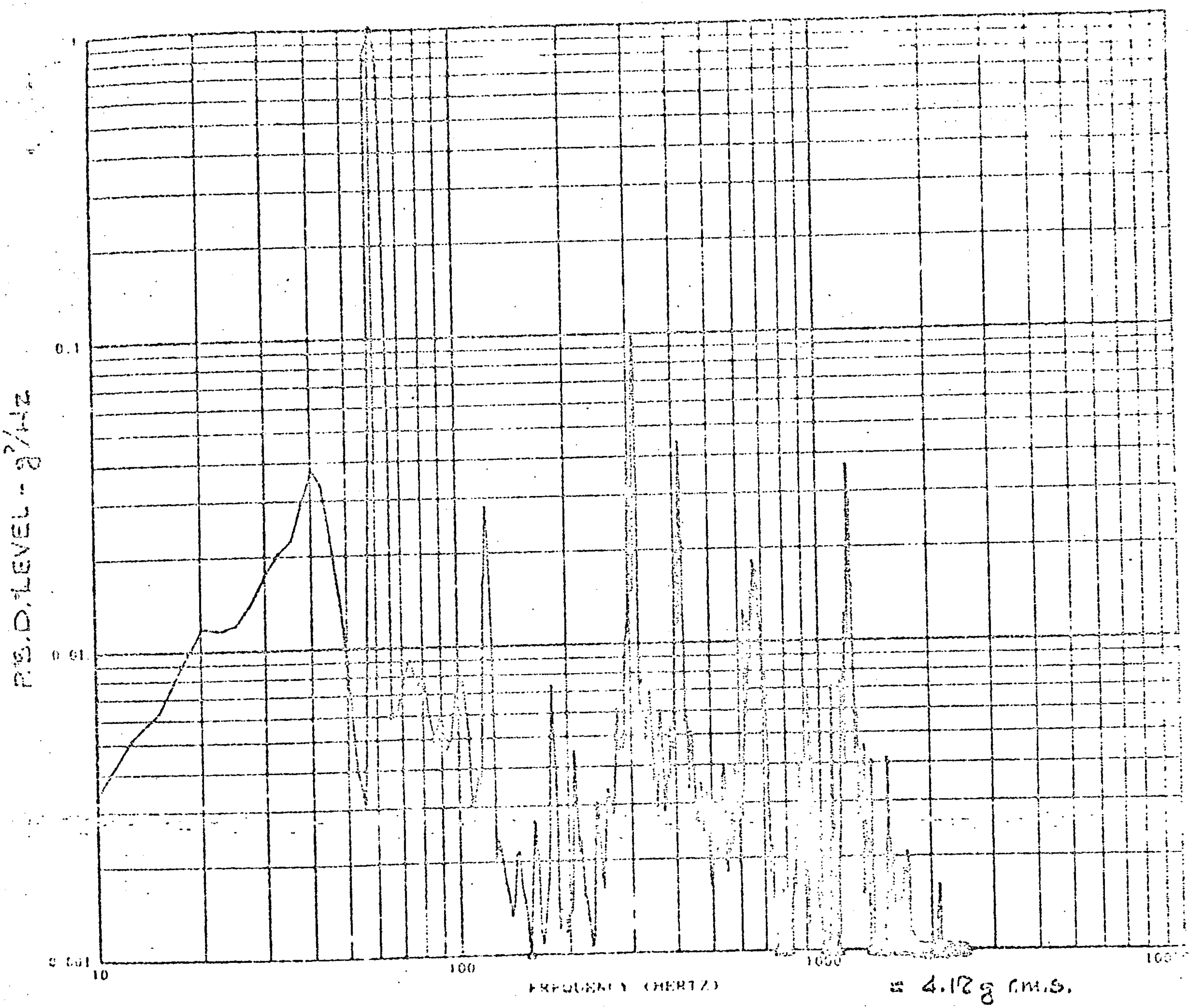
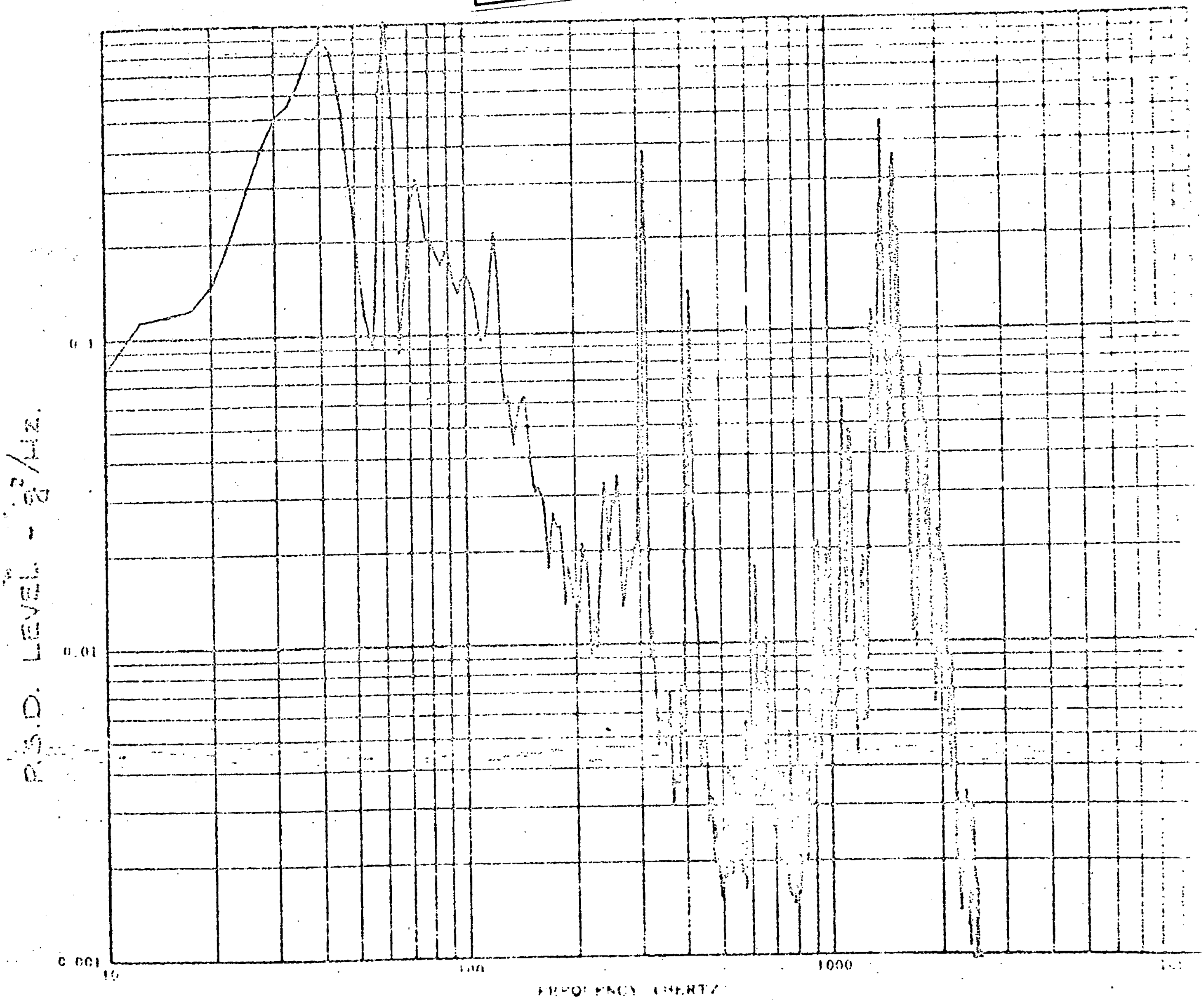


FIG.18 HIGH ENERGY RANDOM, 'R' AXIS
DATA PROCESSOR P/C BOARD RESPONSE.



= 10.32 g r.m.s.

FIG. 19 HIGH ENERGY RANDOM, 'Z' AXIS
TOP PLATE (CENTER) RESPONSE

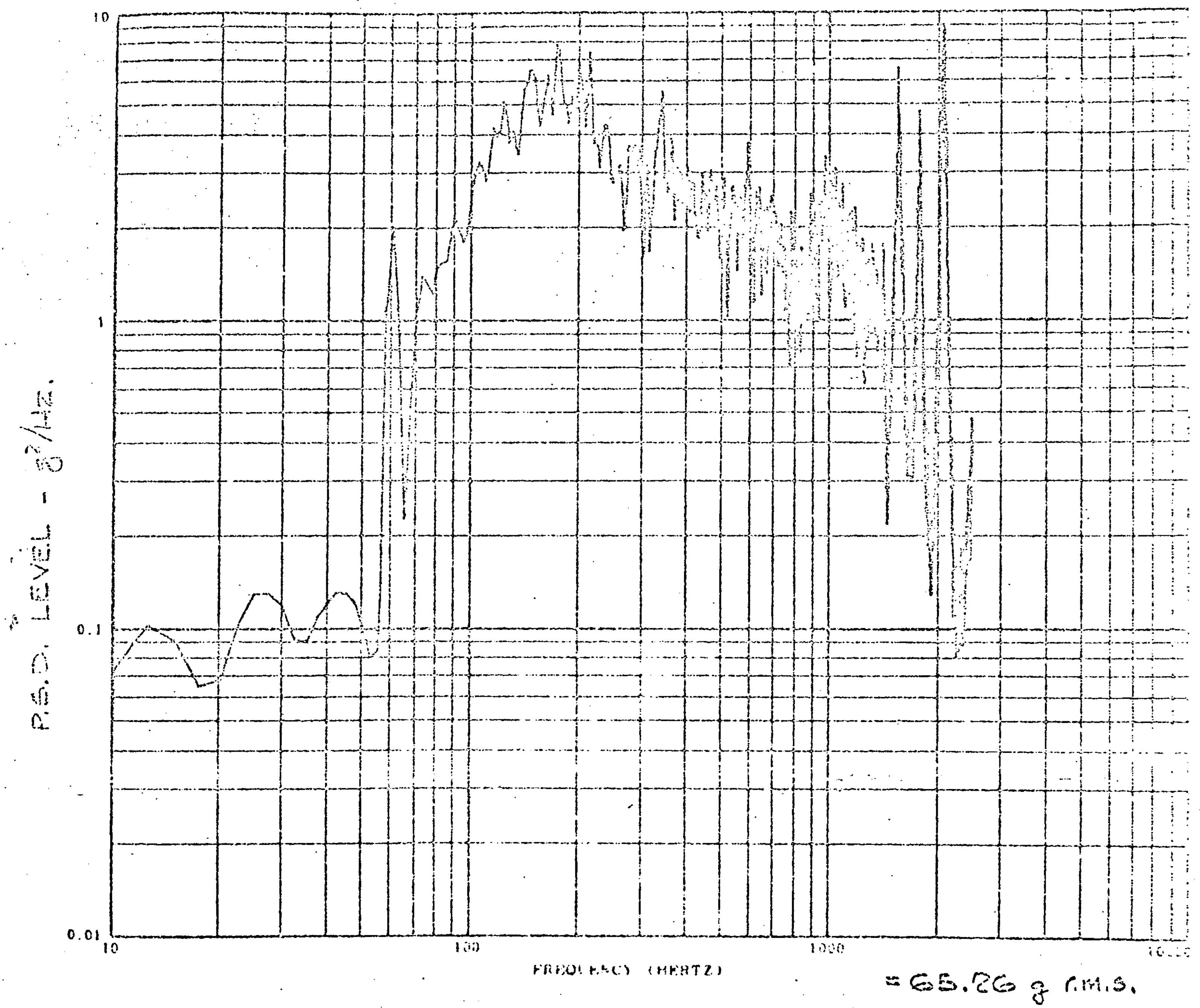
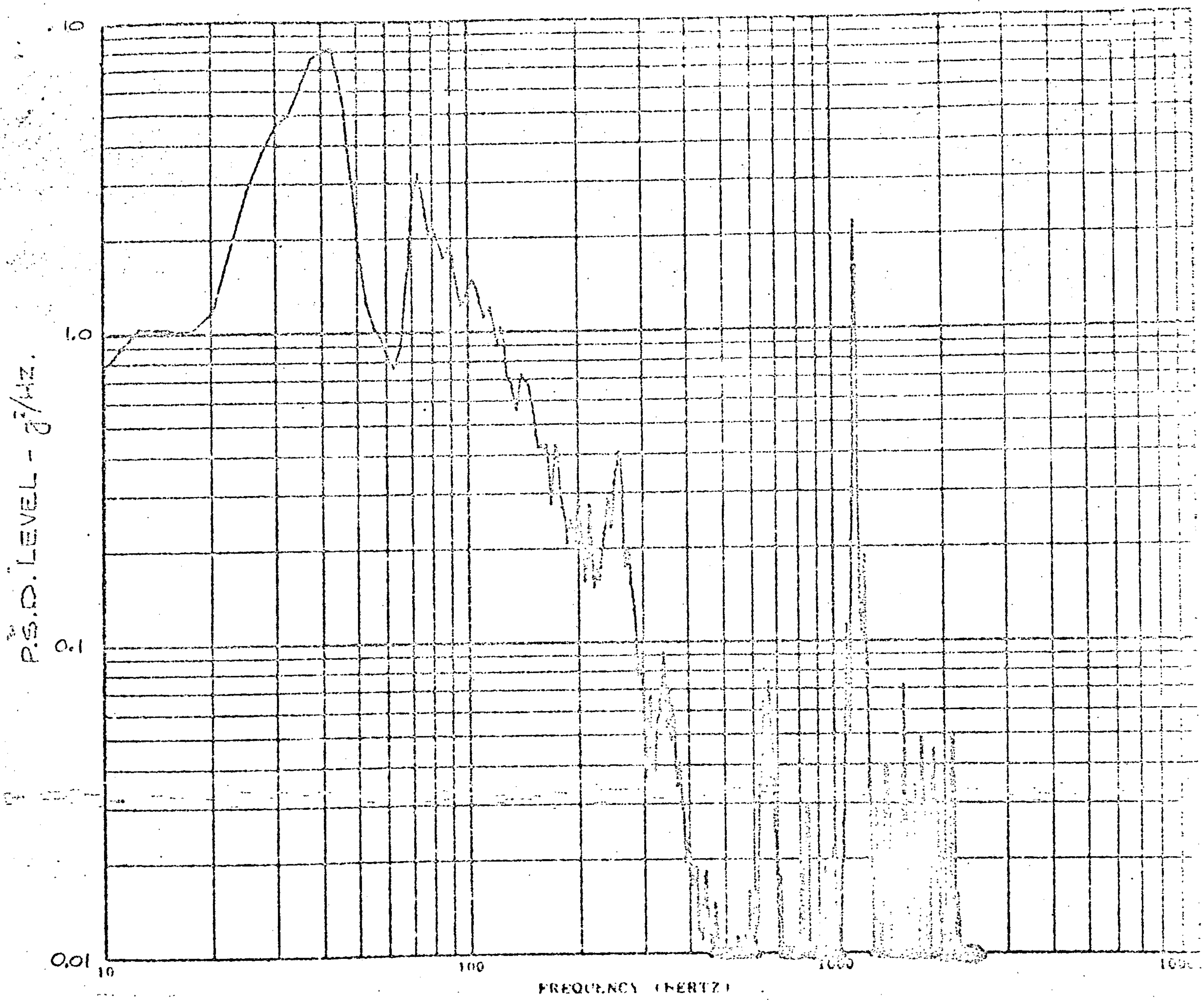


FIG. 20 HIGH ENERGY RANDOM, 'R' AXIS STRUCTURE (FLANGE) RESPONSE.



= 6.55 g r.m.s.

FIG. 21 HIGH ENERGY RANDOM, 'R' AXIS
DETECTOR 'E' ASSEMBLY RESPONSE.

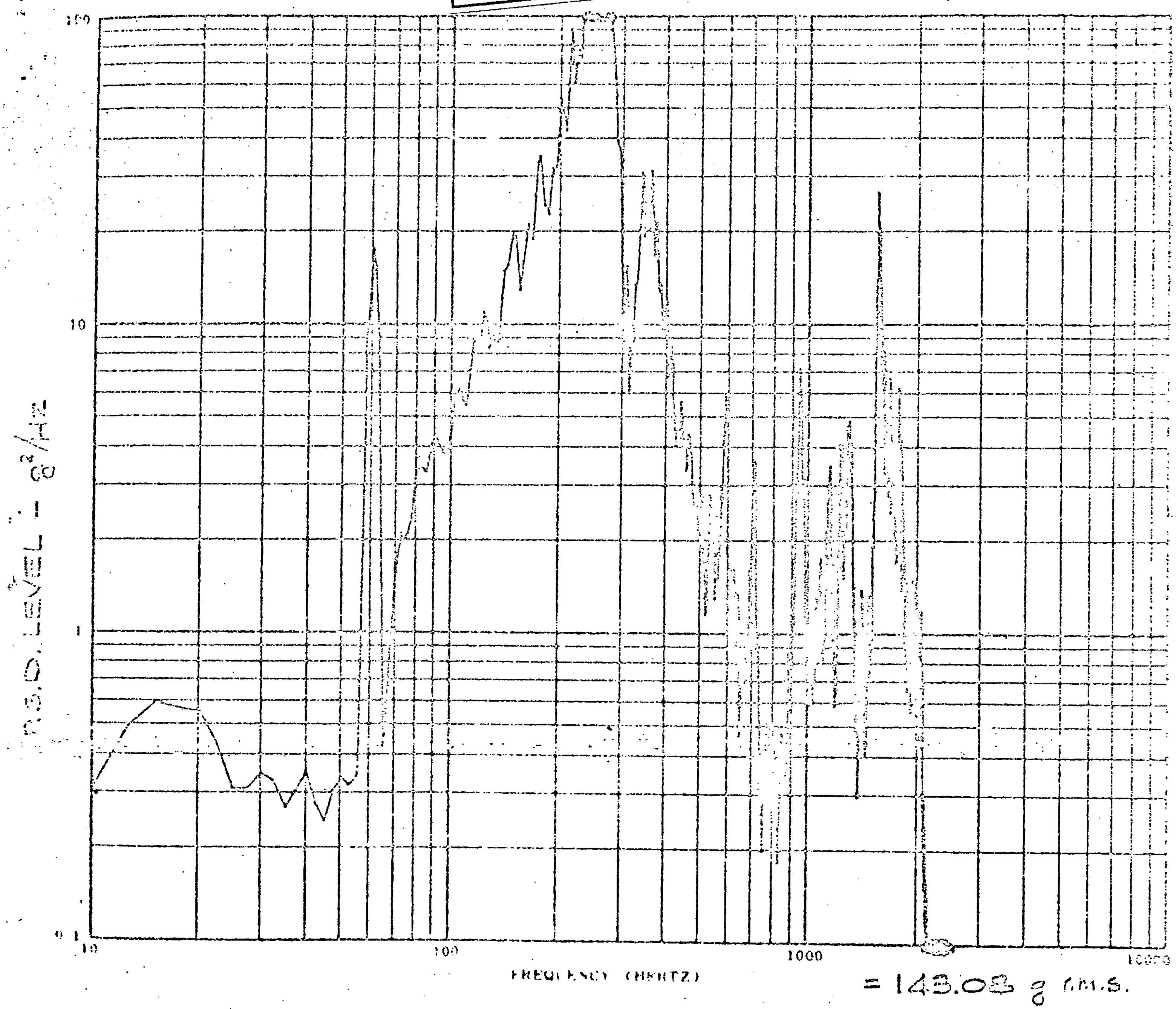


FIG. 22 HIGH ENERGY RANDOM, 'R' AXIS
STRUCTURE (BASEPLATE) RESPONSE.

INPUT = 3.6g

RESPONSE (g)

FREQUENCY, Hz	FLANGE	BASE-PLATE	DATA PROC.	L.V. POWER SUPPLY	HEATER CONTROL	TEMP MONITOR	AMPLIFIER	PRE-AMP.	H.V. POWER SUPPLY	DET. 'A'	DET. 'E'
10	2	5	4		4		4	4		2	2
17	4	5	4		6		5	3		5	5
25	4	5	5		6	4	5	5	6	5	5
160	5	5	8		7	4	6	4	7	7	7
200	9	5	12		10		19		12	30	30
260	4	6	25		7		8		10	20	8
300	4	6	68		9		10	5		8	5
320	4	6							12	9	8
370	9	11				12			27	58	54
420	8	18	35		37	55	34	20	64	7	5
460	8	10	100	100+	32	32	74	20	40	7	4
550	4	5	48	5	16		18	8	27	4	3
700	4	4		4		4			18	12	3
900	5	5	7		14	50	8	3	55	2	4
1100		4	6				16	5	31		
1200		5	5		50		11	3	4		
1280		5	6		6		20	2			
1400		5	2		4		54	3			
1460		5	2		3		30	2			
1650		5	4		11	39	16	3			
1750		5	2		6		15	2			
1850		4							10		

FIG. 23 - SINUSOIDAL RESONANT SEARCH 'R' AXIS.