8

2/16/79 test

Perryville ~~North~~ South

amcoach wood

concrete

wood

TEST RESULTS REPORT

RIDE QUALITY TESTING OF AN AMCOACH ON WOODEN AND CONCRETE TIE SECTIONS

ENSCO, INC.

23 - Passenger Operations

ENSCO PUB. NO. DOT-FR-80-13

TEST RESULTS REPORT

RIDE QUALITY TESTING OF AN AMCOACH ON WOODEN AND CONCRETE TIE SECTIONS

Contract No. DOT-FR-64113

Task 414.59

November 1979

Prepared for:

DEPARTMENT OF TRANSPORTATION
Federal Railroad Administration
Office of Passenger Systems
400 Seventh Street, S.W.
Washington, DC 20590

Prepared by:

RAIL TRANSPORTATION ENGINEERING DIVISION
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16. Abstract

This report covers the collection of ride quality data on an Amcoach while traveling on wooden and concrete tie sections in the area of Boston, MA and Aberdeen, MD on the Northeast Corridor. The purpose of the test was to compare the ride quality of an Amcoach when riding on wooden and concrete tie sections.

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EXECUTIVE SUMMARY

Ride quality data were collected on an Amcoach while it was traveling over wooden and concrete tie sections on the Northeast Corridor (NEC) in the North (Boston, MA) and in the South (Aberdeen, MD).

Data analysis indicates that ride quality indices such as ISO and W_z do not rate either type of tie section superior to the other. Power spectral density (PSD) plots do show a significant high-frequency vibration while traveling on concrete ties that does not appear when traveling on wooden tie sections.

Noise levels inside the car increased noticeably when the Amcoach went from wooden ties to the concrete tie section but the difference was not as great when the car ran back to wooden ties.

1.0 INTRODUCTION

During the winter of 1978, a cant deficiency test was run to examine the ride quality of an Amcoach while traversing curves at speeds greater than the allowed three-inch-imbalance speed. While this test was being conducted, the test car passed over a section of concrete crossties and questions were raised concerning the difference in ride quality between wooden and concrete tie sections. In an effort to determine which type of crosstie produced the better ride quality, a specific test was designed. This test was run on the concrete tie section around Aberdeen, MD and the wooden tie section south of the concrete tie section. The test car was an Amcoach then being used for the Amtrak disc-brake study. No changes had been made to the trucks or the brakes which would effect truck or car performance.

2.0 DESCRIPTION OF TEST

2.1 PURPOSE

The purpose of this test was to collect vehicle vibration data on an Amcoach while traveling over wooden and concrete tie sections in order to determine the quality of the ride on each type of crosstie.

2.2 DATA COLLECTION

The data collected during this test consisted of vehicle accelerations recorded on analog tape and sound-pressure-level measurements recorded in the test log. The acceleration information was recorded using the FRA/ENSCO Portable Ride Quality Package and sound level information was obtained by using a General Radio, Type 2 sound level meter.

Acceleration information was collected from two tri-axial accelerometer packages with the accelerometers orthogonally oriented as shown in Figure 2-1.

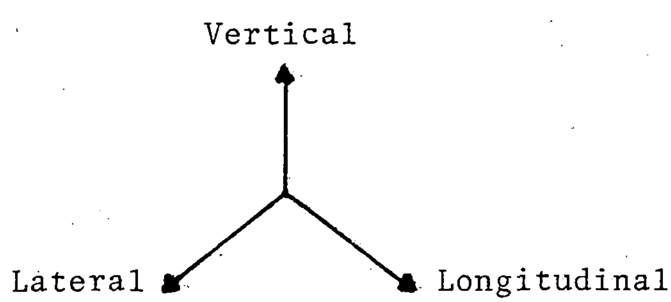


Figure 2-1. Accelerometer Orientation

The accelerometers were checked for proper operation prior to the test. During the test, electrical system checks were made repeatedly to ensure valid data collection.

Sound pressure level measurements were taken during the February test with a General Radio sound-level meter (Type 1565-E). This instrument is capable of making sound-level measurements required under PART 1910.95 "Occupational Noise Exposure" of the Code of Federal Regulations, Chapter XVII Title 29. It has a lead-zinconate-titonate ceramic microphone with filtering networks to achieve A-, B-, or C-weighting. The A-weighting scale discriminates heavily against low-frequency sounds to give an indication that closely correlates with subjective estimates of loudness, annoyance, and speech interference. The C-weighting scale covers a frequency range from 32 Hz to 8 kHz to give an indication of overall sound pressure level. Table 2-1 gives permissible noise exposure limits (per the Federal Code stated above) using the A-scale.

Frequency response characteristics of the A-, B-, and C-scales are shown in Figure 2-2. This figure and Table 2-1 were taken from the instrumentation manual for the 1565-E sound-level meter.

2.3 TEST CONDITIONS

The test consist (southern NEC run) was composed of standard Amcoaches on a revenue run from New York to Washington, DC (Figure 2-3). The test car (Amcoach No. 21058) had restricted entrances and was not used by passengers. This car was instrumented for the Knorr Brake Test and was undergoing an instrument shakedown at the time of the test.

Acceleration data were collected with the acceleration packages securely fastened to the floor in the front and middle of the car (Figure 2-4). The signals were recorded on magnetic tape and individually monitored using a Tektronix oscilloscope.

TABLE 2-1

PERMISSIBLE NOISE EXPOSURES

DURATION PER DAY (HRS)	SOUND LEVEL dB (A) SLOW RESPONSE
8.0	90
6.0	92
4.0	95
3.0	97
2.0	100
1.5	102
1.0	105
0.5	110
<0.25	115

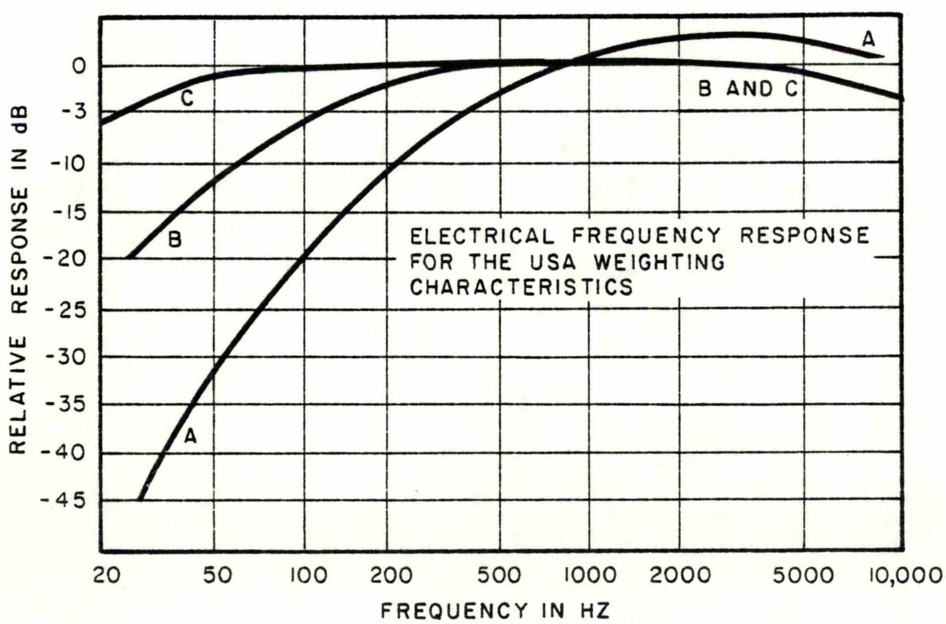


Figure 2-2. A-, B-, and C-Weighted Responses of Sound-Level Meter

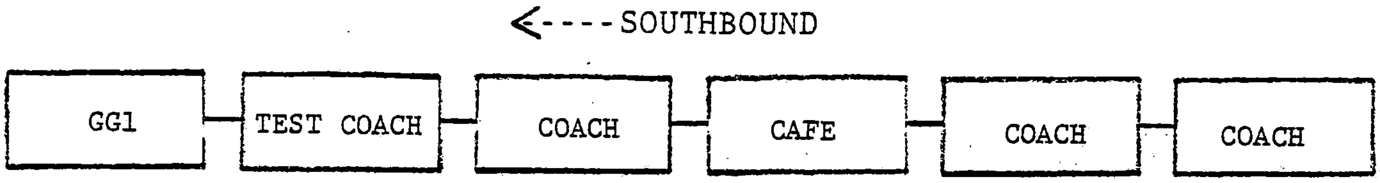


Figure 2-3. Test Consist

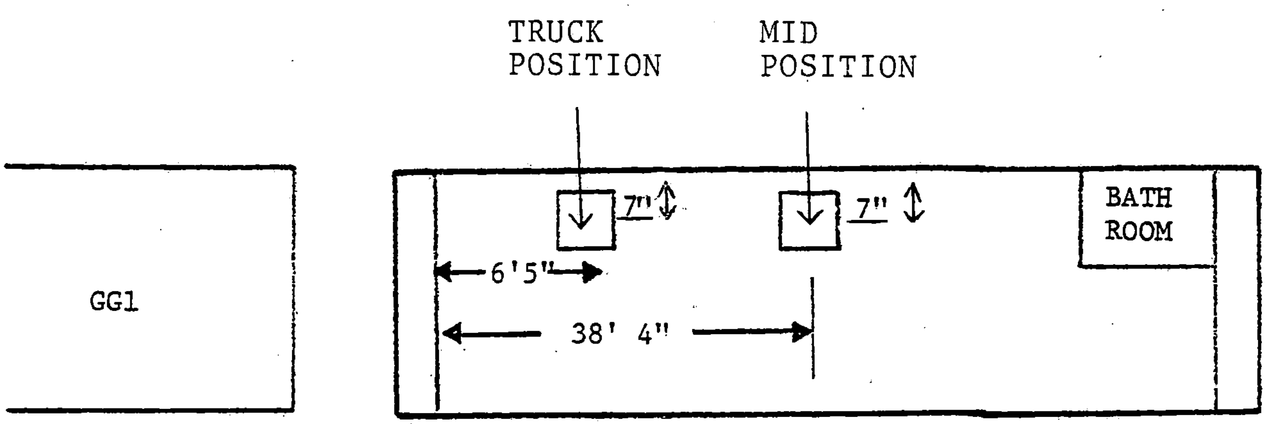


Figure 2-4. Accelerometer Locations in Test Coach (February Test)

Sound level measurements were collected with the sound level meter held in the position shown in Figure 2-5. The meter was held 33 inches above the floor which corresponds closely with the height of a passenger's ear while the passenger is seated. The measurements were made using the meter in the slow response mode. (The test run was conducted 16 February 1979.)

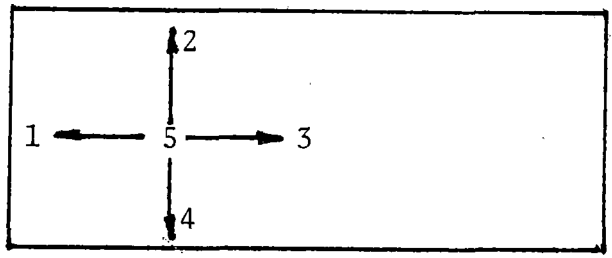


Figure 2-5. Sound Level Measurement

2.4 INSTRUMENTATION

A portable data collection system, referred to as the Portable Ride Quality Package (Figure 2-6) was used to collect data during the test run. The system consists of a magnetic tape recorder, a signal conditioning and coding unit, and two accelerometer packages. Each accelerometer contains three orthongonally-mounted linear accelerometers with full scale readings of ±1.0 g.

The signal conditioning and coding unit converts the current output of each accelerometer to a proportional signal voltage suitable for recording. The unit provides metering for signal monitoring and calibration. This unit also contains batteries, and associated charging and regulator circuits which provide power to the system if ac power is not available. The magnetic tape recorder accommodates eight channels of data. Six channels are used for recording accelerometer signals. The seventh channel is used for a multiplex recording of two external data signals, an internally generated digital annotation, and a reference signal. A channel is also provided for voice annotation.

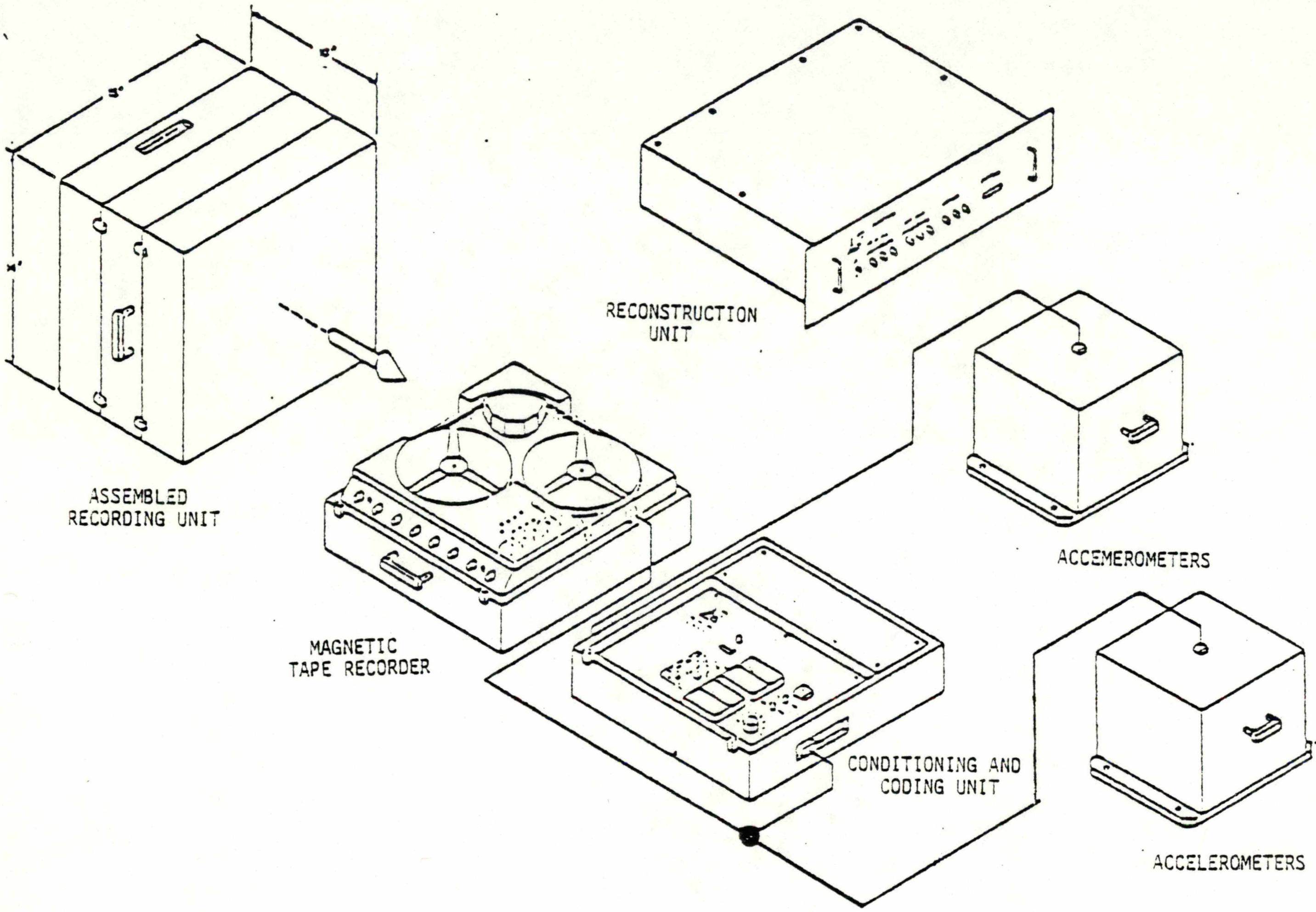


Figure 2-6. Portable Ride Quality System

3.0 RESULTS

3.1 RIDE QUALITY

The accelerometer data from both the northern and southern Northeast Corridor runs were reduced using the standard ride quality data reduction routines. Tables 3-1 and 3-2 summarize the results from the computer runs shown in Appendices A and B.

The northern NEC test results show that the concrete crossties produced a better ride than the adjacent wooden crossties. The exposure time for lateral accelerations over the truck is much greater for concrete crossties than wooden crossties. The exposure time for lateral accelerations in the center of the car is greater for wooden crossties than concrete crossties. The lateral ride on concrete crossties was still quite good. Therefore, the overall ride on concrete crossties is considered to be better. A comparison of the exposure times for vertical accelerations yields a similar reversal between both tie sections.

The southern NEC test results show the ride to be slightly better while traversing concrete ties than wooden ties. The ISO exposure time for the lateral accelerations on concrete ties at the middle of the car is significantly larger than the exposure time while on wooden crossties.

It should be repeated that during the southern NEC run, the test car was immediately behind a GG1. Past experience has shown that this position in the train generally provides a more severe ride than other train positions.

Although the ISO and W_z rating schemes show that the ride on this section of concrete crossties was better than the ride

TABLE 3-1

NORTHERN NORTHEAST CORRIDOR RIDE QUALITY TEST RESULTS

Location	Accelerometer	Wooden Crossties		Concrete Crossties	
		Exposure Time	Center Frequency	Exposure Time	Center Frequency
ISO Reduced Comfort					
Truck	Lateral	5.5 Hours	2.0 Hz	10.2 Hours	2.5 Hz
Truck	Vertical	+12.4 Hours	1.6 Hz	10.3 Hours	12.5 Hz
Truck	Longitudinal	24.0 Hours	1.0 Hz	24.0 Hours	1.0 Hz
Middle	Lateral	+16.2 Hours	2.0 Hz	12.5 Hours	2.0 Hz
Middle	Vertical	7.9 Hours	8.0 Hz	23.1 Hours	6.3 Hz
Middle	Longitudinal	24.0 Hours	1.0 Hz	24.0 Hours	1.0 Hz
Alternate ISO					
Truck	Lateral	3.1 Hours		+4.4 Hours	
Truck	Vertical	4.7 Hours		+5.4 Hours	
Middle	Lateral	+6.5 Hours		5.6 Hours	
Middle	Vertical	4.1 Hours		+7.2 Hours	
Wz Rating					
Truck	Lateral	2.12 Hours	Fair-Good	+2.09 Hours	Fair-Good
Truck	Vertical	2.15 Hours	Fair-Good	+2.00 Hours	Good
Middle	Lateral	+1.98 Hours	Good-Sup.	2.01 Hours	Fair-Good
Middle	Vertical	2.15 Hours	Fair-Good	+1.89 Hours	Good-Sup.

around south of Boston

TABLE 3-2

SOUTHERN NORTHEAST CORRIDOR RIDE QUALITY TEST RESULTS

Location	Accelerometer	Wooden Crosstie		Concrete Crosstie	
		Exposure Time	Center Frequency	Exposure Time	Center Frequency
ISO Reduced Comfort					
Truck	Lateral	2.5 Hours	1.0 Hz	4.2 Hours	1.0 Hz
Truck	Vertical	5.5 Hours	1.3 Hz	8.7 Hours	10.0 Hz
Truck	Longitudinal	24.0 Hours	1.0 Hz	24.0 Hours	1.0 Hz
Middle	Lateral	6.7 Hours	1.6 Hz	-12.2 Hours	2.0 Hz
Middle	Vertical	4.5 Hours	8.0 Hz	+ 4.7 Hours	8.0 Hz
Middle	Longitudinal	24.0 Hours	1.0 Hz	24.0 Hours	1.0 Hz
Alternate ISO					
Truck	Lateral	1.1 Hours		+ 1.8 Hours	
Truck	Vertical	2.1 Hours		+ 3.1 Hours	
Middle	Lateral	3.6 Hours		- 5.7 Hours	
Middle	Vertical	2.7 Hours		+ 2.8 Hours	
Wz Rating					
Truck	Lateral	2.49 Hours	Fair - Good	+2.30 Hours	Fair-Good
Truck	Vertical	2.53 Hours	Adequate- Fair	3.27 Hours	Fair-Good
Middle	Lateral	2.19 Hours	Fair - Good	+2.06 Hours	Fair-Good
Middle	Vertical	2.32 Hours	Fair - Good	+2.23 Hours	Fair-Good

So. of Perryville

on the adjacent section of wooden ties, the power spectral density plots of the data show high frequency characteristics for the concrete ties which do not appear on the wooden crossties (Figure 3-1). These high frequency components do not have a large effect on the ride quality ratings, however, high input frequencies could have adverse effects on truck components by accelerating or causing fatigue cracks or failures.

3.2 SOUND LEVEL MEASUREMENTS

Sound level measurements were collected with the instrumentation and procedures previously described. Table 3-3 summarizes the data.

TABLE 3-3
ACTUAL SOUND LEVEL MEASUREMENTS

Speed	Tie Section	Position	Sound Pressure Level		
			dB(A)	dB(B)	dB(C)
≈80 mph	Wooden	1	73	84	96
		2	74	85	96
		3	73	84	96
		4			
		5			
≈80 mph	Concrete	1	79	89	98
		2	78	88	97
		3	77	86	97
		4	78	87	97
		5	78	88	98
≈80 mph	Wooden	1	73	84	96
		2	74	85	96
		3	73	84	96

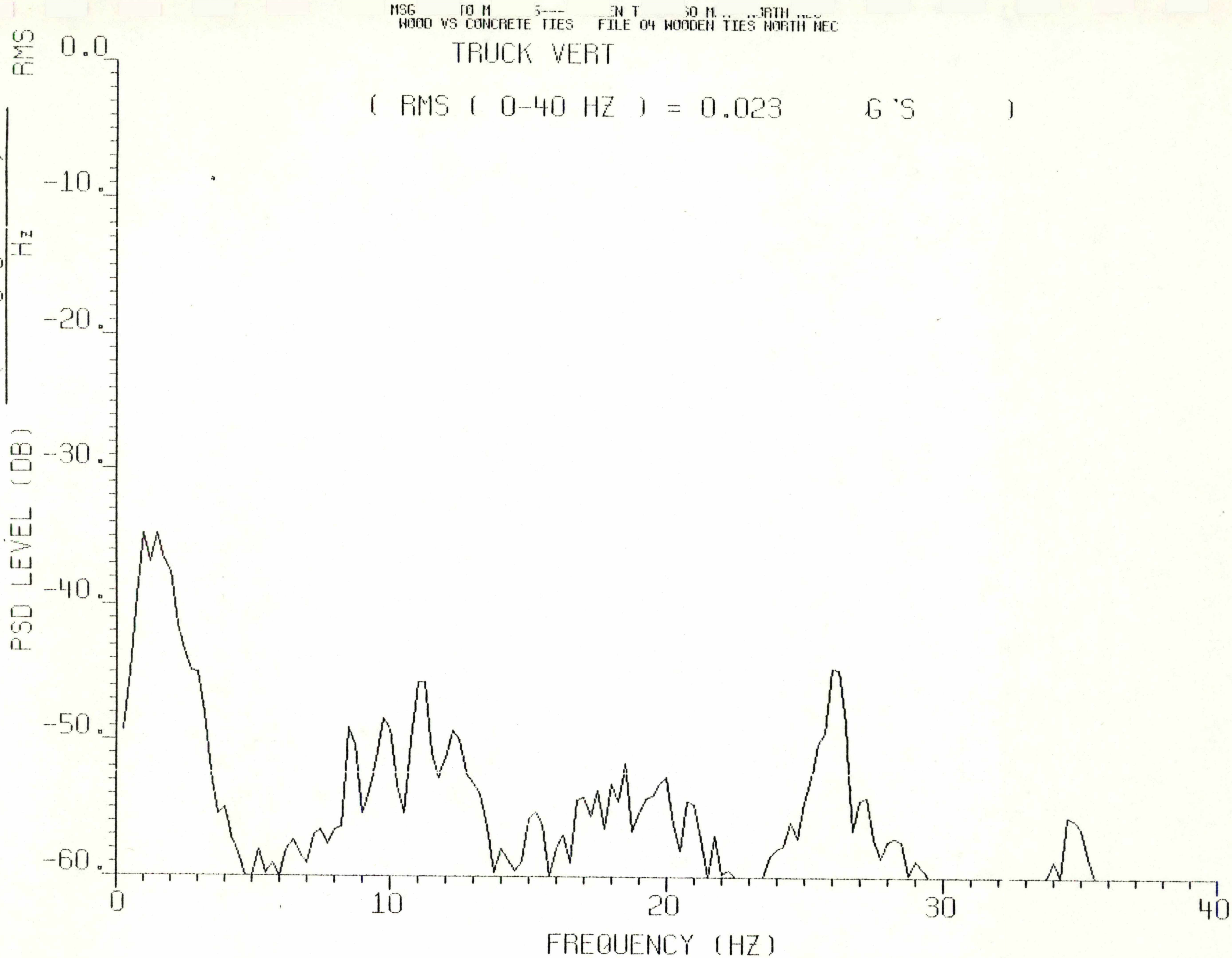


Figure 3-1(a). Power Spectral Density for Wooden Ties

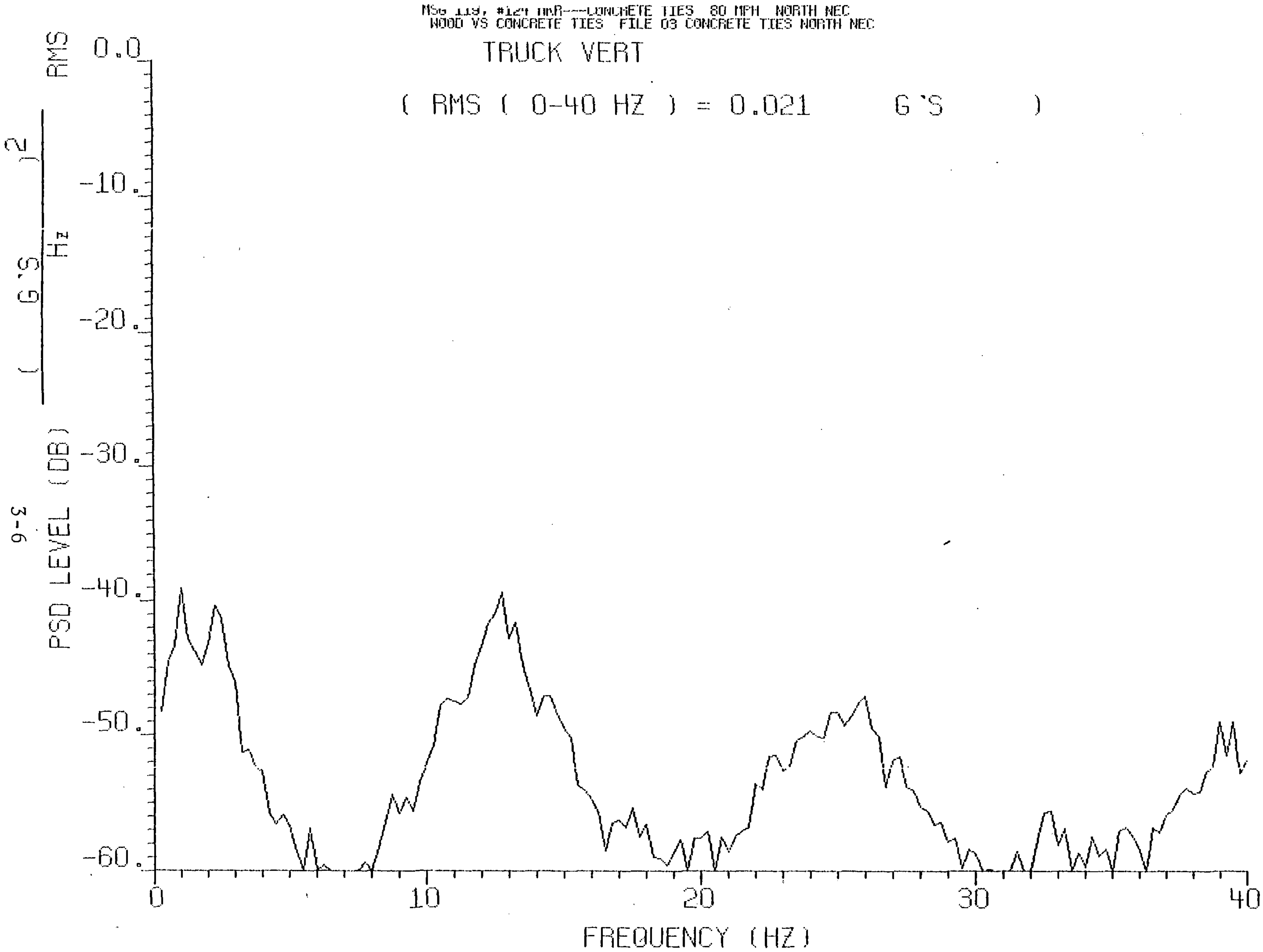


Figure 3-1(b). Power Spectral Density for Concrete Ties

Note that the sound pressure levels for measurements one, two and three are generally 4 to 6 dB higher for concrete ties than wooden ties. Additionally, note that the dB(C) level is substantially higher than the dB(A) level for both wooden and concrete tie sections.

Since the C level reading is several dB higher than the A and B levels, the noise is probably under 600 Hz.

4.0 CONCLUSIONS

The test shows that both sections of concrete ties produced a better ride than the adjacent sections of wooden ties. The detailed scores were not consistent between the northern and southern test but the concrete ties did provide a better overall ride than the wooden ties. The sound level test, however, indicated that there was a significant increase in noise when the car ran over the concrete tie sections.

The other significant difference in the data was the higher amplitude of 20 to 30 Hertz vibration during the northern test. The higher frequency vibration for wood and concrete tie sections are not as different for the Aberdeen test zone (southern zone). Both the wood and concrete data show relatively high amplitude vibrations at 8 to 14 Hz and at 27 Hz. The southern test was made during a very cold period. Therefore, the difference in the relative response could be associated with track stiffness.

5.0 REFERENCES

1. Owings, R. P., Adair, J.W., "Rohr Turboliner Ride Quality Test", Contract DOT-FR-64113, Publication No. DOT-FR-77-01, ENSCO, Inc., 1976.

2. Peterson Arnold, P.G. and Gross Ervin E. Jr., "Handbook of Noise Measurement," Eighth Edition, 1978 by Genrad, Inc.

APPENDIX A

TEST LOGS

PASSENGER LOG

TEST #: ____________ TITLE: RIDE QUALITY TESTING AMCOACH ON WOODEN AND CONCRETE TIE SECTIONS

NAME & TITLE (PLEASE PRINT)	COMPANY	DATE
E. J. Lombardi	AMTRAK	16 February 1979
M. A. Nicolay	ENSCO, INC.	16 February 1979
J. G. Berglund	ENSCO, INC.	16 February 1979
R. E. Scofield	ENSCO, INC.	16 February 1979

DATE 2/16/79

TIME 12 30 PM

OPERATOR BERGLUN

PORTABLE RIDE QUALITY PACKAGE

USER CHECK LIST

1. Initial Set-up - Checkout

[X] a. Ensure that the record amplifier boards are inserted with proper filters in their respective positions in the tape recorder. FM record boards are located in channels 1 through 6. A direct record board is placed in channel 7. Rep 1/SW remains the same.

[X] b. Tape speed is 1 7/8 ips. Make sure tape is threaded properly and tape is usable.

[X] c. Connect all cables. Plug in 115v AC line if battery is not used.

[X] d. Check if battery is fully charged by pressing Batt on recorder. Indicator should show a value to the + side of 0. Make sure recorder is on.

[X] e. Switch monitor function to ±15v and ±7 1/2v. Reading should be full scale on all four locations. If reading is not full scale, internal problems exist or battery is dead.

[X] f. Set-up accelerometers in place using directional axis located on instrumentation.

[X] g. Reset message number to 0. Turn memory on. Enable display, when pressed, will display the present message unit.

2. Initial Test

After each and every re-location of the accelerometer package an operational check of each channel must be performed. This can be accomplished by the following procedure:

a. Activate "Record" and "Play" buttons on the tape recorder. ✓

b. Select the particular channel to be checked on the monitor function switch (roll, pitch, etc.). ✓

c. Physically rotate the accelerometer package in the particular axis being tested and observe any fluctuations on the signal monitor. If there are fluctuations present, the accelerometer package is operating properly for that axis.

d. Repeat steps (2) and (3) for each channel.

[X] Roll / Vert	[X] Pitch / Long.	[X] Yaw / Lat	[X] Vert.	[X] Long.	[X] Lat.

(Circle appropriate description).

3. Calibration

a. Switch recorder on (record, play). Record test ID, i.e., test number, date, location, purpose, etc., on voice channel. Enter message unit 1.

b. Position the SW/reproduce channel selector on the tape recorder to the channel to be calibrated (#1, #2, etc.).

c. Position the monitor function switch to the specific channel to be calibrated (roll, pitch, etc.). Update message number. Message numbers 2 through 7 should indicate calibration signal. Use voice channel to record what accelerometers are being calibrated, etc.

d. Press the calibration switch to +cal, hold for 3 seconds, switch to -cal, hold for one second, then release.

e. Repeat this procedure for all six channels until all calibration signals are recorded.

TIME						
≈100	[✓] Roll / Vert	[✓] Pitch / Long.	[✓] Yaw / Lat	[✓] Vert.	[✓] Long.	[✓] Lat.
	QUICK CAL AT STATION					
___	[ ] Roll / Vert	[ ] Pitch / Long.	[ ] Yaw / Lat	[ ] Vert.	[ ] Long.	[ ] Lat.
___	[ ] Roll / Vert	[ ] Pitch / Long.	[ ] Yaw / Lat	[ ] Vert.	[ ] Long.	[ ] Lat.

4. Data Collection

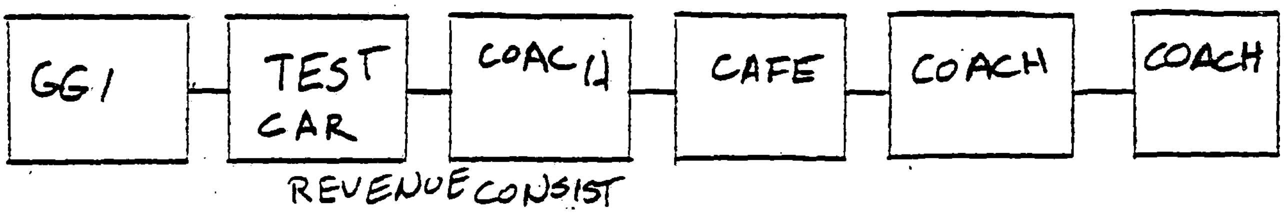
a. Activate "Record" and "Play" buttons on the tape recorder. Enter message number for beginning of test data.

b. Enter additional message numbers, vocal comments, etc., for points of interest, milepost numbers, speed, etc.

c. One can visually monitor the accelerations. By selecting the appropriate channel on the monitor function switch, the output will be displayed on the signal monitor. In addition, by switching the position of the SW/reproduce channel selector on the tape recorder, the output is displayed on the SW/reproduce channel meter. A scale factor of 10 can be activated to produce a more sensitive reading.

d. When the data is fully collected, turn recorder off. After disengaging cables, turn off memory and pack up unit.

CONSIST



PERSONNEL PRESENT: BERGLUND
SCOFIELD
NICOLAY

POSITION OF PACKAGE: FRONT & MIDDLE

MESSAGES

1. Calibration & check-out
2. Turn off recorder
3. Turn on Cal.
4. Package D - Start Cal. Vertical
5. " - Start Cal. Longitudinal
6. " - Start Cal. Lateral
7. Package F - Start Cal. Vertical
8. " - Start Cal. Longitudinal
9. " - Start Cal. Lateral
10. Turn off recorder
11. Check-out
12. Turn off recorder
13. Turn on recorder
14. Blank
15. Perryville
16. HIT CAL
17. Wooden Tie
18. Blank
19. Blank
20. Blank
21. Concrete Ties
22. Blank
23. Blank
24. Blank
25. Blank
26. Blank
27. Underpass
28. Concrete pipe plant
29. Blank - speed approx. 0
30. Blank - speed approx. 0
31. Blank
32. Blank
33. Wooden ties
34. Bridge
35. Blank
36. Blank
37. Blank
38. Slowing down
39. Turn off recorder
40. Comparison data
41. Blank
42. Blank
43. Blank
44. Turn off recorder
45. Post-Test Calibration
46.
47.
48.
49.
50.

APPENDIX B

SOUND LEVEL MEASUREMENTS

SOUND LEVEL READINGS

1565B SOUND LEVEL METER

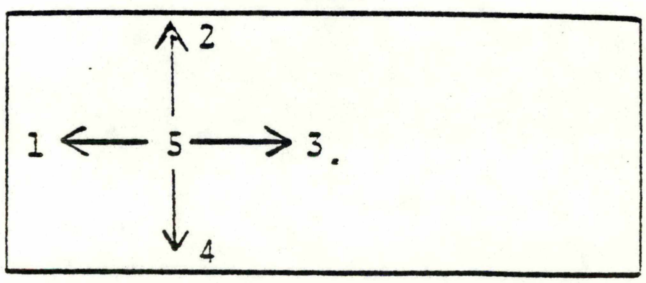
TYPE OF INSTRUMENT 2 DATE 2-16-79

OPERATOR: SCOFIELD SCRIBE: Nicolay TIME 1514 HRS

(SLOW RESPONSE)

	POSITION	DB(A)	DB(B)	DB(C)
Wooden Tie Section	2	73	84	96
	4	74	85	96
	3	73	84	96
	4			
	5			
Concrete Tie Section	2	78	88	97
	4	78	87	97
	3	77	86	97
	1	79	89	98
	5	78	88	98

AMCOACH



←----Microphone direction

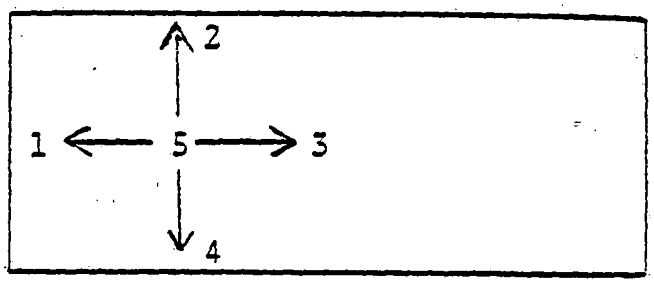
SOUND LEVEL READINGS

TYPE OF INSTRUMENT 1565B Sound Level Meter 2 DATE 2-16-79

OPERATOR SCOFIELD SCRIBE NICOLAY TIME 1518 HRS

	POSITION	DB(A)	DB(B)	DB(C)
Wooden Tie Section	1	77	85	97
	2	78	86	97
	3	76	84	97
	4		TOO SLOW	
	5			
Concrete Tie Section	1			
	2			
	3			
	4			
	5			

AMCOACH



◄----Microphone direction

APPENDIX C

DATA REDUCTION

STANDARD RIDE QUALITY DATA REDUCTION PACKAGE

A standard ride quality software package has been developed to reduce the data collected with the ride quality instrumentation. The output of this data reduction package consists of 22 pages of summaries, graphic estimates and plots. The output includes:

- Probability density estimates and plots.
- Distribution function estimates and plots.
- One-third octave band RMS levels.
- The ISO ride quality exposure time for the reduced comfort criteria.
- Power spectral density levels and plots.
- Cepstrum plots for PSD levels.
- RMS levels.

The format of the output is explained below.

Pages 1 and 2 describe the probability density estimate. The probability density is a function of the number of data location bins, the total number of samples and the channel scale factor. This page has twelve columns, two for each channel. The first column of each channel gives a specified voltage setting which corresponds to an acceleration level. The second column of each channel gives the value of the probability associated with each bin. The heading for each of these six channels is an alphanumeric input and can include both the channel number and a short description of what data were recorded on the channel. The heading shown at the top of each page is analphanumeric input applicable to points of interest (such as type of test, date and location of test, number of scans and record numbers). The units are g's for linear acceleration channels and radians/second/second for rotational acceleration channels. At the end of Page 2, the standard deviation of the six channels is given. The standard deviations of the data are given in engineering units (such as g's and radians/second/second) based on the scale factor for each channel. The scale factor relates the voltage level of the measured engineering units (g/volt). The data are digitized at a rate of 128 Hz and one second of data is recorded per record. Thus, the number of scans (data points) corresponds to the number of records times the digitizing rate. This value is also shown at the top of Page 1.

Pages 3 and 4 contain the distribution function estimate. Again, two columns are given for each channel, with column one corresponding to a voltage setting and column two to an estimate of the distribution function.

For ride quality data analysis, one-third octave band filtering provides a correspondence to the International Standards Organization (ISO) standards for determining the quality of the ride. Pages 5 and 6 of the standard Ride Qualtiy Data Analysis Package give the RMS acceleration for the filtered data. For center frequencies ranging from 1 Hz to 31.5 Hz, results are given for longitudinal, lateral, vertical, roll, pitch and yaw accelerations. For each band, the mean is reported (expected value - EV) along with the mean plus or minus one standard deviation (UB - upper band, LB - lower band).

The one-third octave band filtered results for ride comfort are shown on Page 7. For center frequencies ranging from 1.0 to 31.5 Hz, time limits for reduced comfort are given for longitudinal, lateral and vertical accelerations. In addition, a summary section reports the minimum exposure limits along with the frequencies at which it occurs.

Pages 8 through 10 give the power spectral density level (PSD) in dB, which corresponds to a given frequency. These levels are printed for each channel and for frequencies from 0.25 to 40.0 Hz.

Page 11 is a short summary of the results. First, a description of the test run is given. Then, for the linear acceleration channels, the following information is given:

- Standard deviation.
- 95 percentile level.
- 99 percentile level.
- Reduced comfort exposure time.
- Center frequency.
- Alternate exposure time (frequency weighted).

Cepstrum plots of power spectral density in one-third octave bands are given on Page 12. These plots indicate the amount of change in each one-third octave band over a period of time.

Plots of the probability density estimate and the distribution function estimate are given on Pages 13 and 14. These graphs are plotted as a function of acceleration level.

Power spectral densities are presented on Pages 15 through 20. The x-axis is a frequency axis which varies from 0 to 40 Hz. The y-axis prints out the power spectral density (PSD) level in dB relative to 1 g (RMS) squared per Hertz RMS. The plots are titled as to which channel is represented and what phase of testing is represented. In addition, the RMS level, computed by summing up the PSD levels, is given.

On the next pages, a time history of the RMS acceleration level is given for each of the channels. Page 21 gives a description of the channels and the scale factors used in the plots. Page 22 gives the RMS plots which are useful in determining relative amplitudes and an overall profile of the parameters being recorded.

A flow chart of the processing is shown in Figure C-1.

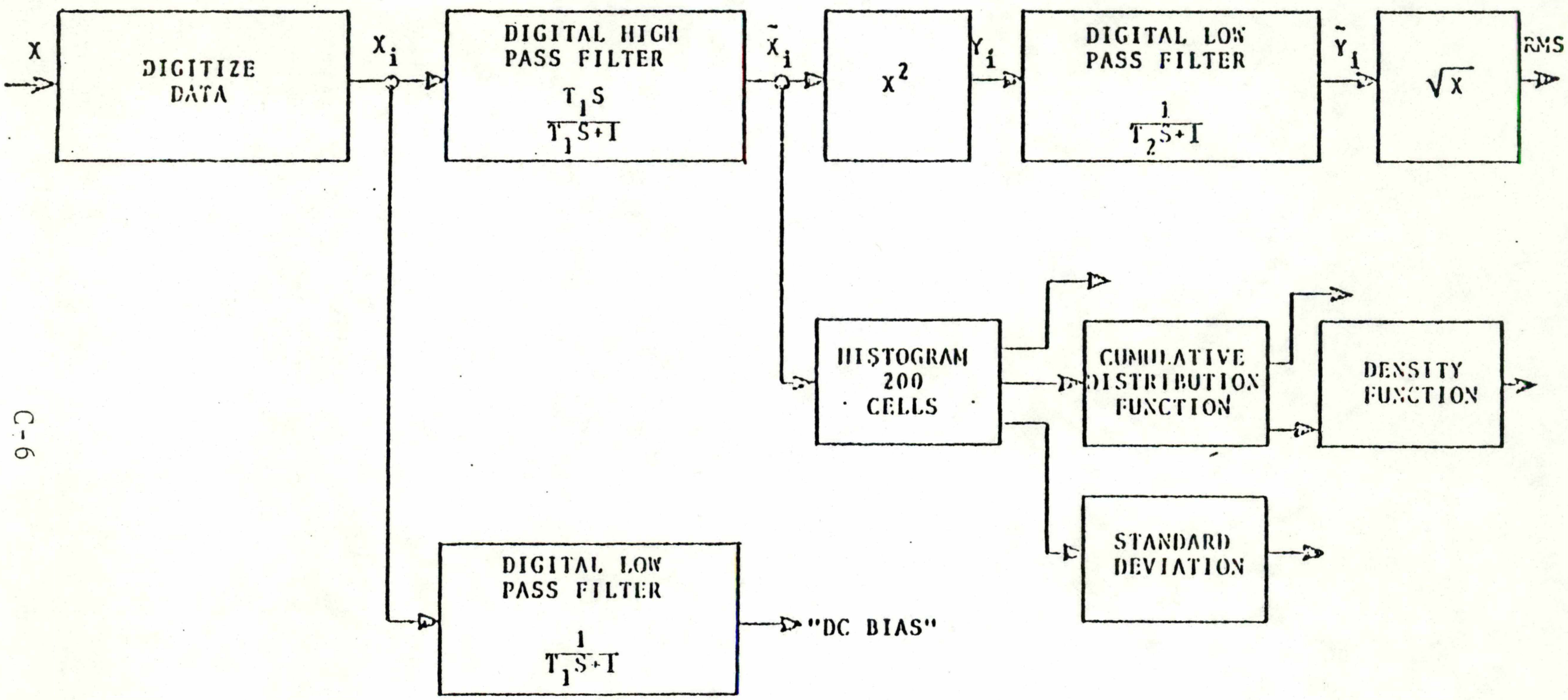


Figure C-1. Block Diagram for Data Reduction (One Channel)

APPENDIX D

ISO STANDARDS

ISO STANDARDS

One method of evaluating the ride quality of a vehicle from acceleration environment data is to use the International Organization for Standardization Standard 2631. This standard, entitled "Guide for the Evaluation of Human Response to Vehicle-Body Vibration," presents three criteria for evaluating ride quality:

- The preservation of working efficiency (fatigue-decreased proficiency boundary).
- The preservation of health or safety (exposure limits).
- The preservation of comfort (reduced comfort boundary).

Based on each criterion, two sets of amplitude-frequency curves are defined. One curve is for the longitudinal (foot to head direction) acceleration, and the second curve is for the transverse (back to front or side-to-side direction) acceleration. For each amplitude-frequency curve, a set of boundaries is defined and denoted by exposure times. The tolerable acceleration level increases with decreasing exposure time. The limits for transverse acceleration as a function of frequency for various exposure times (for the fatigue-decreased proficiency criteria) are shown in Figure D-1. Similar curves for the longitudinal directions are shown in Figure D-2.

For the set of curves associated with the "exposure limit" criteria, a factor of 2 (or 6 dB) times the values shown in the curve is introduced. Correspondingly, a factor 1:3.15 (or -10 dB) is introduced to obtain the set of curves, for the "reduced comfort" criteria.

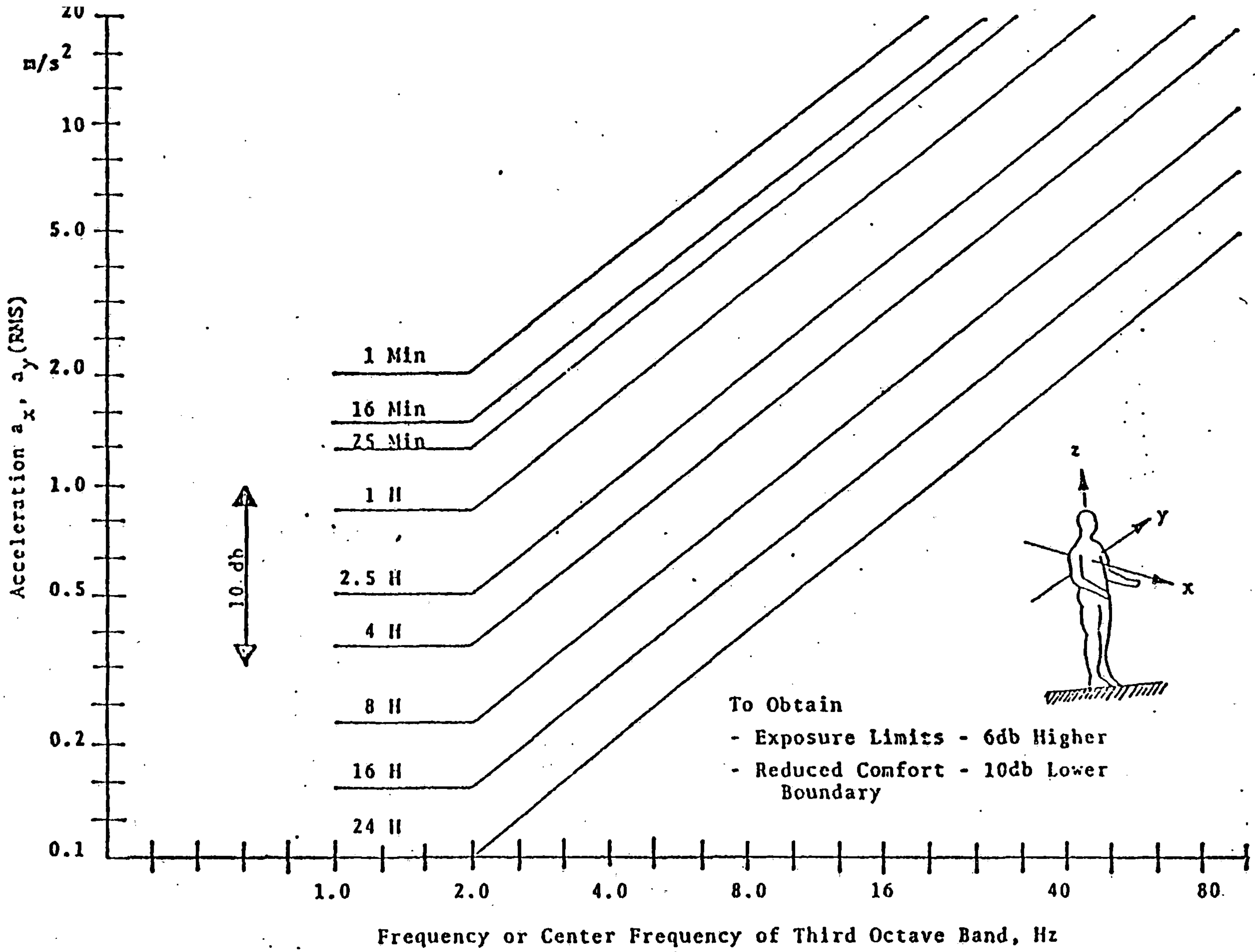


Figure D-1. Transverse Acceleration Limits as a Function of Frequency and Exposure Time (Fatigue-Decreased Proficiency Boundary)

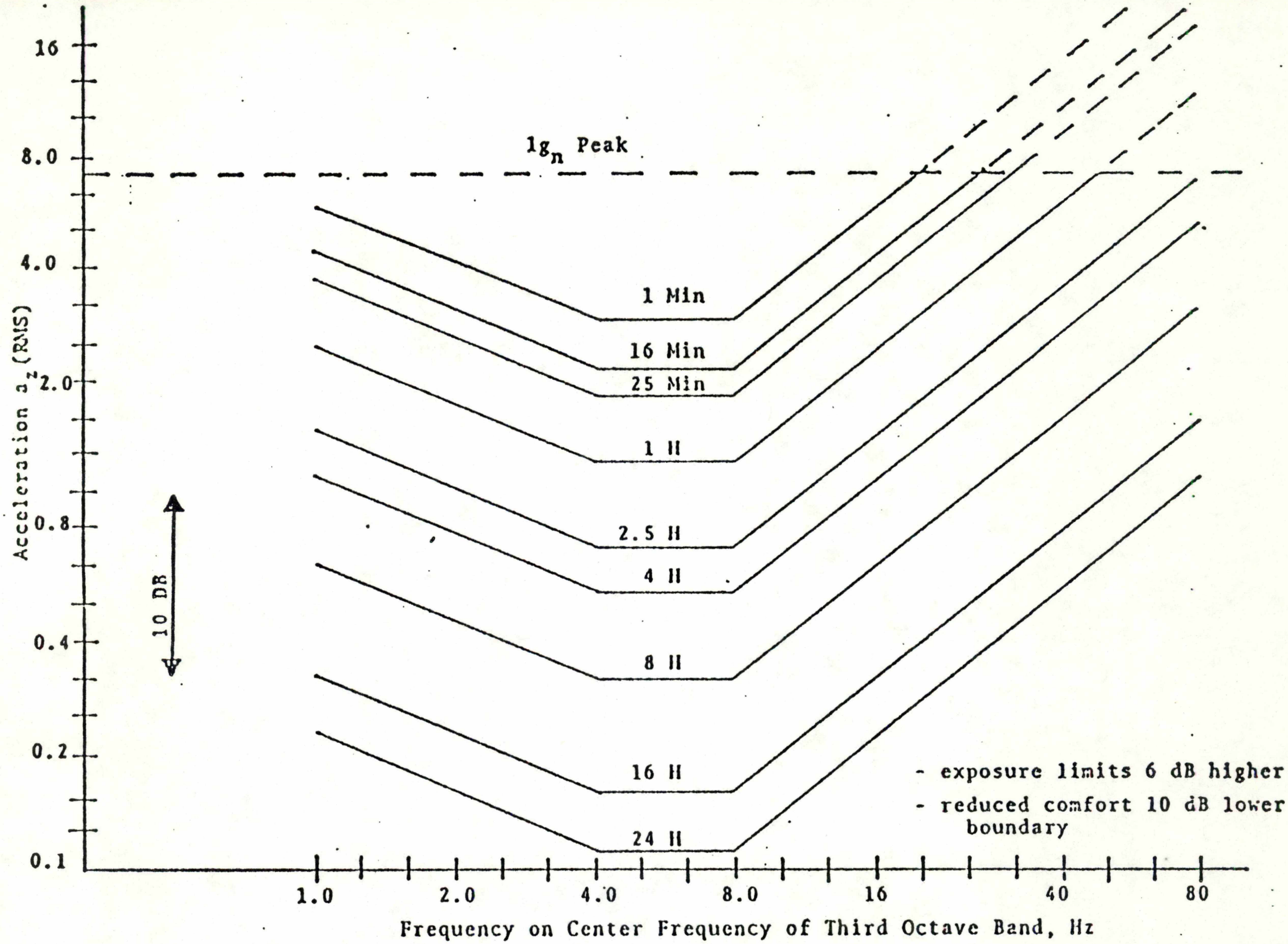


Figure D-2. Longitudinal Acceleration Limits as a Function of Frequency and Exposure Time (Fatigue-Decreased Proficiency Boundary)

These curves are defined for a sinusoidal acceleration signal. In practice, this form of acceleration is not likely to occur, and one-third octave band filtering is defined as the appropriate method for applying the standard for random or broad-band vibration data.

The standard is defined for the frequency level from 1 Hz to approximately 90 Hz. A set of 20 one-third octave band filters is required to cover this frequency band. The one-third octave band filtering provides an RMS acceleration level for each of the 20 filters. The standard is used to convert each RMS acceleration level to exposure time. The minimum exposure time from the 20 bands is taken as the description of the ride. For instance, the "reduced comfort" criteria would be used to evaluate a passenger vehicle. The ISO standard provides a means of assigning a single number (say five hours) to the ride based on the acceleration environment. The exposure time is a daily exposure time (i.e., exposure per 24-hour period).

Much of the ride quality data which has been processed has been presented in PSD form. This is a narrow band, constant band-width type of processing as compared to one-third octave band processing appropriate for the ISO standard. However, the ISO standard can be converted to an equivalent PSD form. The procedure for converting the ISO standard to PSD form is to assume that the allowable "power" (i.e., the RMS value squared) is distributed uniformly over the band covered by each one-third octave band filter.

The allowable PSD level from the ISO standard is given by:

$$\text{PSD level} = (A_{RMS}^{2})/\text{bandwidth}$$

Since the bandwidth of the one-third octave band filter is proportional to the center frequency of the filter, the expression becomes:

$$\text{PSD level} = (A_{RMS}{}^2)/0.231\ f_c;\ \frac{g^2{}_{RMS}}{Hz}$$

The PSD level is usually given in dB form, so the expression becomes:

$$\text{PSD level (dB)} = 10LOG_{10}(A_{RMS}{}^2)/0.231\ f_c)$$

$$= 20LOG_{10}A_{RMS} - 10LOG_{10}0.231 - 10LOG_{10}f_c$$

Table D-1 gives the PSD levels for the fatigue-decreased proficiency boundary and a four-hour exposure time. To change criteria and/or exposure time, the factors given in Table D-2 and Table D-3 are to be used. Figures D-3 and D-4 show the ISO standard translated to PSD form for the three criteria and the longitudinal and transverse direction.

One convenient method of applying the PSD form of the ISO standard is to make transparent overlays for use directly with PSD plots. The exposure time can be found directly from the PSD and the overlay.

TABLE D-1

FATIGUE-DECREASED PROFICIENCY BOUNDARY FOUR FOUR-HOUR EXPOSURE TIME

F_c (Hz)	A_z (RMS) (M/sec^2)	$20Log_{10}A_z$ (dB)	$-10Log_{10}F_c$ (dB)	PSD Level (Z-Direction)	A_x, A_y (M/sec^2)	$20Log_{10}A_x$ (dB)	PSD level (X- and Y- Directions
1	1.06	+ 0.51	0	-13	0.36	- 8.87	-22.4
1.25	0.95	- 0.44	- 1	-15	0.36	- 8.87	-23.4
1.6	0.85	- 1.4	- 2	-16.9	0.36	- 8.87	-24.4
2.0	0.75	- 2.5	- 3	-19	0.36	- 8.87	-25.4
2.5	0.67	- 3.5	- 4	-21	0.45	- 6.94	-24.4
3.15	0.60	- 4.4	- 5	-22.9	0.56	- 5.04	-23.5
4.0	0.53	- 5.5	- 6	-25	0.71	- 2.97	-22.5
5.0	0.53	- 5.5	- 7	-26	0.90	- 0.92	-21.0
6.3	0.53	- 5.5	- 8	-27	1.12	+ 0.98	-20.5
8.0	0.53	- 5.5	- 9	-28	1.40	+ 2.92	-19.6
10.0	0.67	- 3.5	-10	-27	1.80	+ 5.10	-18.4
12.5	0.85	- 1.4	-11	-25.9	2.24	+ 7.00	-17.5
16.0	1.06	+ 0.51	-12	-25	2.80	+ 8.94	-16.6
20.0	1.32	+ 2.41	-13	-24.1	3.55	+11.00	-15.5
25.0	1.70	+ 4.6	-14	-22.9	4.50	+13.10	-14.4
31.5	2.12	+ 6.5	-15	-22	5.60	+15.00	-13.5
40.0	2.65	+ 8.5	-16	-21	7.10	+17.00	-12.5
50.0	3.35	+10.5	-17	-20	9.00	+19.10	-11.4
63.0	4.25	+12.5	-18	-19	11.20	+21.00	-10.5
80.0	5.30	+14.5	-19	-18	14.00	+22.90	- 9.6

TABLE D-2

ADJUSTMENTS TO PSD LEVEL FOR Z-DIRECTION

EXPOSURE LIMITS		+ 6 dB
FATIGUE-DECREASED PROFICIENCY		0 dB
REDUCED COMFORT BOUNDARY		-10 dB
	<u>HOURS</u>	
EXPOSURE TIME	24	-13.5 dB
	16	-10.4 dB
	8	- 4.5 dB
	4	0 dB
	2.5	+ 2.5 dB
	1.0	+ 6.9 dB

TABLE D-3

ADJUSTMENTS TO PSD LEVEL FOR X- AND Z-DIRECTIONS

EXPOSURE LIMITS		+ 6 dB
FATIGUE-DECREASED PROFICIENCY		0 dB
REDUCED COMFORT BOUNDARY		-10 dB
	<u>HOURS</u>	
EXPOSURE TIME	24	-10.8 dB
	16	- 7.5 dB
	8	- 3.8 dB
	4	0 dB
	2.5	+ 3.0 dB
	1.0	+7.57 dB

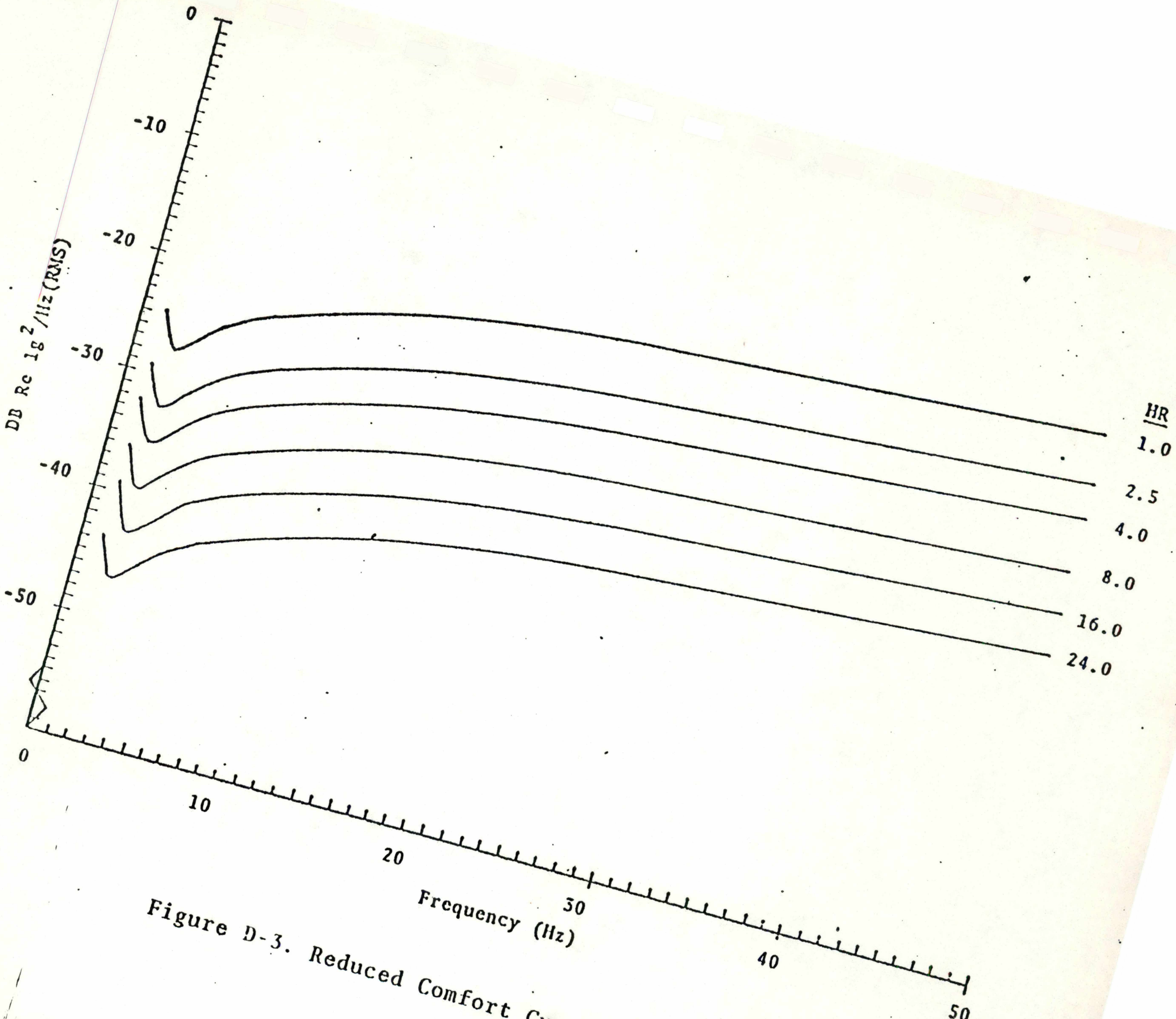


Figure D-3. Reduced Comfort Curves (Lateral)

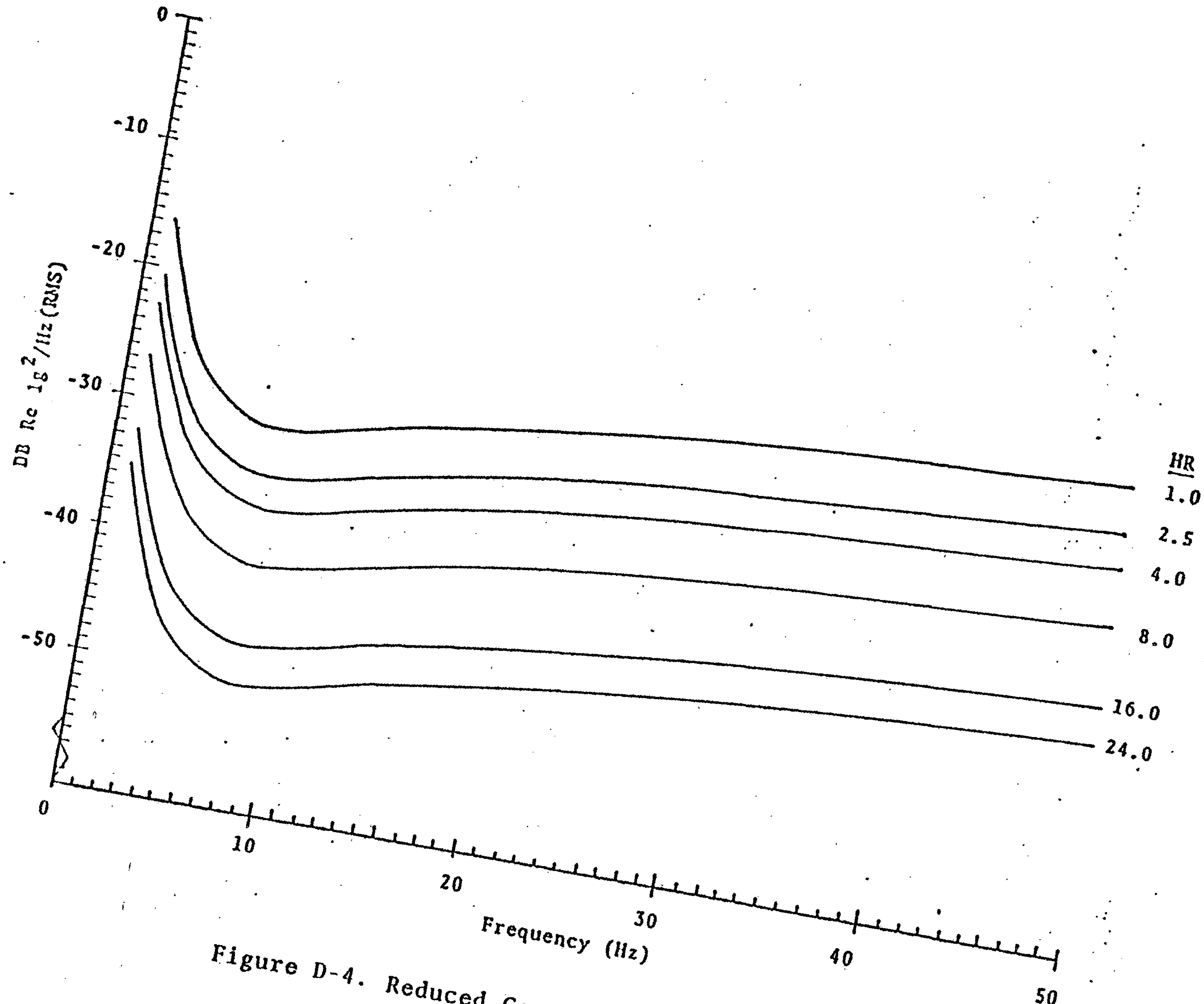


Figure D-4. Reduced Comfort Curves (Vertical)

APPENDIX E

TEST PLANNING DOCUMENT

Contract DOT-FR-64113
(Task 414.59)

TEST PLAN
RIDE QUALITY TESTING OF AN AMCOACH ON WOODEN AND CONCRETE CROSSTIE SECTIONS
IN SUPPORT OF TEST REQUEST RX-

Submitted by:

ENSCO, INC.
R. Scofield, Program Manager

Date

Concurrence by:

FRA

Date

Approved by:

FRA

Date

Distribution:

FRA
R. Scharr
C. Gannett
M. Mitchell

ENSCO
B. Scofield
R. Hendrickson
R. Owings
R. Avant
M. Nicolay

NECPO
L. Thompson

AMTRAK

I. PURPOSE

The purpose of this test is outlined as follows:

- To collect vehicle vibration data on an Amcoach car travelling over wooden and concrete tie sections.

- To compare vehicle vibration data between the wooden and concrete tie sections.

- To measure noise levels within the Amcoach over wooden and concrete tie sections.

II. TEST ZONE

The test zone shall be Northeast Corridor track between Washington, DC and New York City, NY. The concrete tie section to be tested is at Aberdeen, MD.

III. TEST PROCEDURES

Vehicle vibration data will be collected on the test Amcoach using the FRA Portable Ride Quality Package.

The accelerometer packages will be located in the positions shown in Figure E-1. Noise level measurements will be made with the instrument held at the level of the Amcoach seat headrests and in the middle of the passenger aisle. To reduce the noise-level-contamination caused by the recording equipment, the sound measurements should be done at the end of the car opposite the recorders (refer to Appendix B).

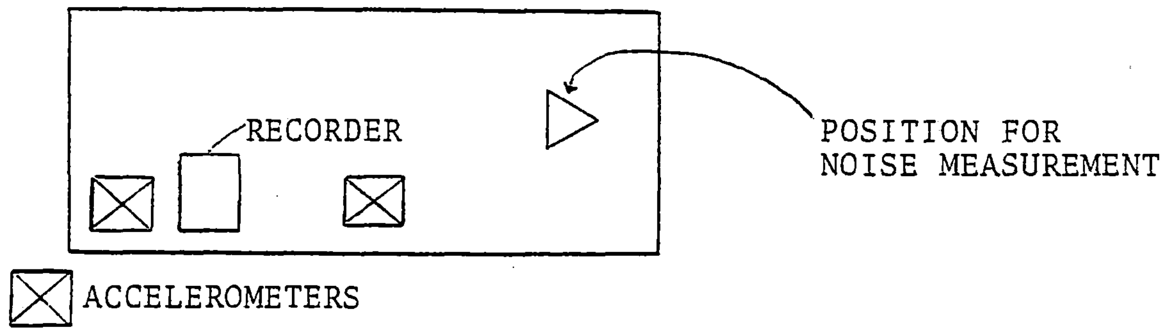


Figure E-1. PRQ Accelerometer Positions

Vehicle vibration data will be collected during a wooden tie section prior to the concrete tie section, during travel through the concrete tie section, and on a wooden tie section after the concrete tie section. This will allow the analyst to compare different wooden tie sections, thereby allowing a more general evaluation of the track input to the car caused by wooden ties.

IV. TEST SCHEDULE

The test schedule will be as follows:

- Three hours prior to train departure from Union Station, Washington, DC, ENSCO personnel must be onboard for preliminary calibrations.

- During the run between Washington and the Beltway Station, comparison data from the PRQ accelerometer packages will be collected. Both accelerometer packages will be side-by-side.

- The train will run a conventional Metroliner time schedule between Wilmington and Baltimore. An Amtrak representative will call out mileposts, track changes, track numbers and train speed over the car's PA system.

- At New York, the PRQ packages will be post-calibrated.

V. TEST INSTRUMENTATION

The instrumentation will include the following:

- Portable ride quality package C.
- Two linear tri-axial accelerometer packages.
- Junction Box
- Six-channel strip chart recorder.
- Necessary cabling to record signals.
- Noise level meter.

VI. SPECIAL INSTRUCTIONS

- Data will be collected during the tests as specified by the on-site ENSCO Test Director.

- Data will be recorded at the locations specified in the test plan. Should there be a request from either FRA or Amtrak to perform additional testing, the tests will be at additional cost and with the condition that the original test zones are given first priority.

- The accelerometer packages will be screwed down into the floor to prevent unwanted movement.

- A complete test log will be maintained for all data collected. A copy of the log format is shown in Appendix A.

- Power requirements for this test are: 110 VAC power in the test Amcoach.

- Data analysis requires a minimum of two minutes of continuous data taken at constant train speed. Experience has shown that ten-minute segments of constant speed operation are desirable to ensure that two minute segment free of electromagnetic interference are obtained.

VII. SPECIAL EQUIPMENT

A six-channel strip chart recorder will be used.

VIII. DATA REDUCTION

The ride quality data shall be analyzed by ENSCO, INC. Analysis shall include, but not be limited to:

- ISO exposure time for test zones.
- W_z rating for test zones.
- Comparison of PSD levels between wooden and concrete tie sections.

IX. REPORT PREPARATION

A test events report will be prepared within ten working days following completion of the test. A Test Results Report will be prepared within 60 working days following completion of the test.

X. AREAS OF RESPONSIBILITY

1. FRA responsibility will be:
   - To approve documentation for test.
   - To approve data reduction format.
   - To approve use of the FRA Portable Ride Quality Equipment.

2. Amtrak responsiblity will be:
   - To supply test Amcoach.
   - To run test consist.
   - To provide a crewman to call out milepost, track number, speed, etc. to ENSCO personnel.
   - To provide track information concerning type of track (bolted, welded) and crosstie type.

3. ENSCO responsiblity will be:
   - To collect and record ride quality data.
   - To reproduce and analyze data.
   - To submit a Test Events Report.
   - To submit a Test Results Report.

XI. SAFETY

A copy of the Safety Manual for FRA test cars will be carried onboard by the ENSCO Test Director and will be read by all ENSCO personnel involved in the test. The ENSCO on-site test director or delegate will act as safety officer alternate during the test and must perform all duties as outlined in the Safety Manual.

All ENSCO personnel are expected to work in a safe manner and are required to notify the safety office if any safety hazards or potential safety hazards exist.

If an accident occurs which involves any personel injury, however minor, the safety office must be made aware of the injury immediately.

XII. INFORMATION SOURCES

	Phone
Richard Scharr, FRA	202/426-9665
Gannett, Clifford, FRA	202/426-9665
Scofield, Robert, ENSCO (Project Engineer)	703/960-8500

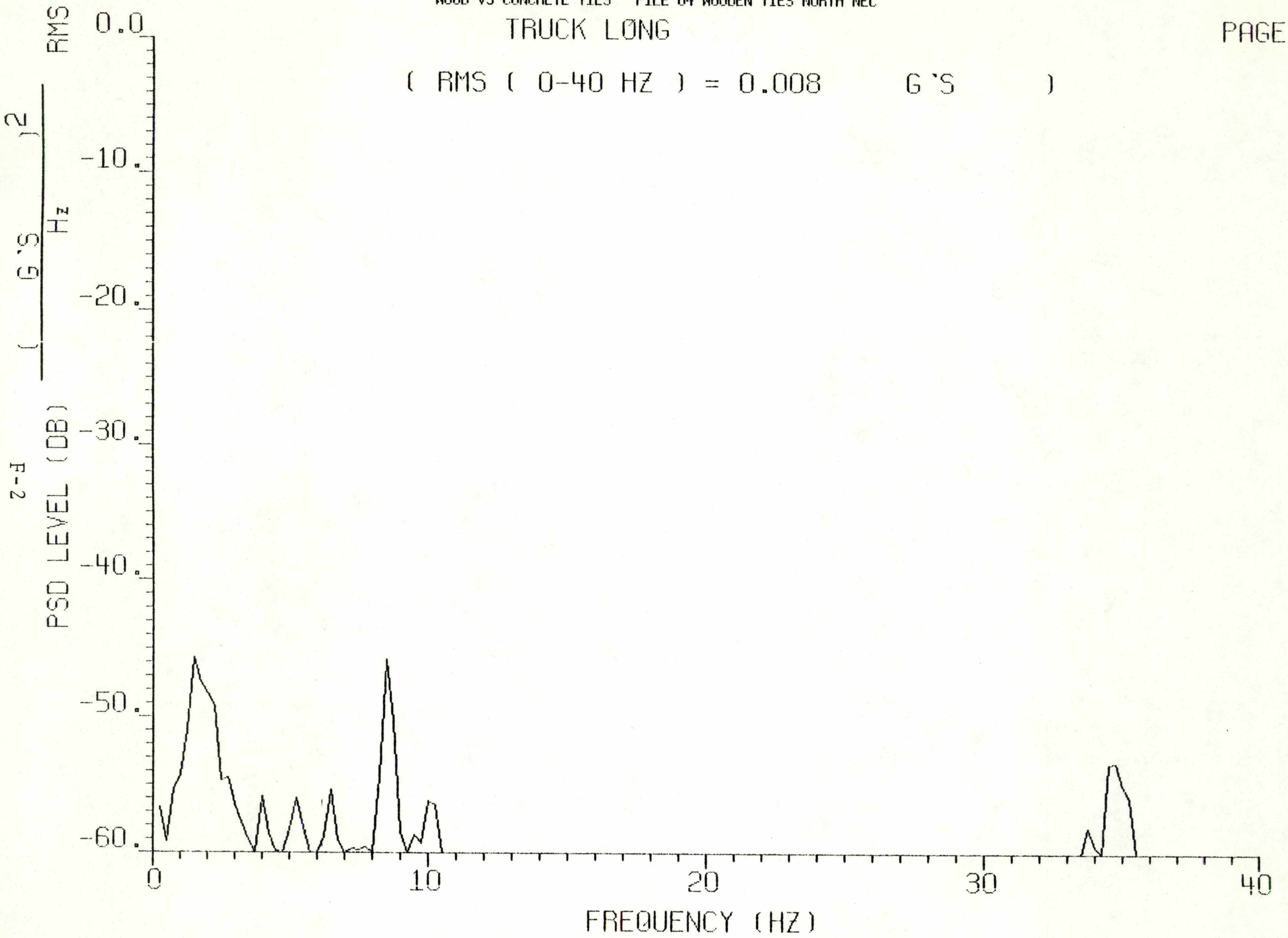
APPENDIX F

PSD PLOTS
NORTHERN NORTHEAST CORRIDOR
WOODEN TIES-CONCRETE TIES

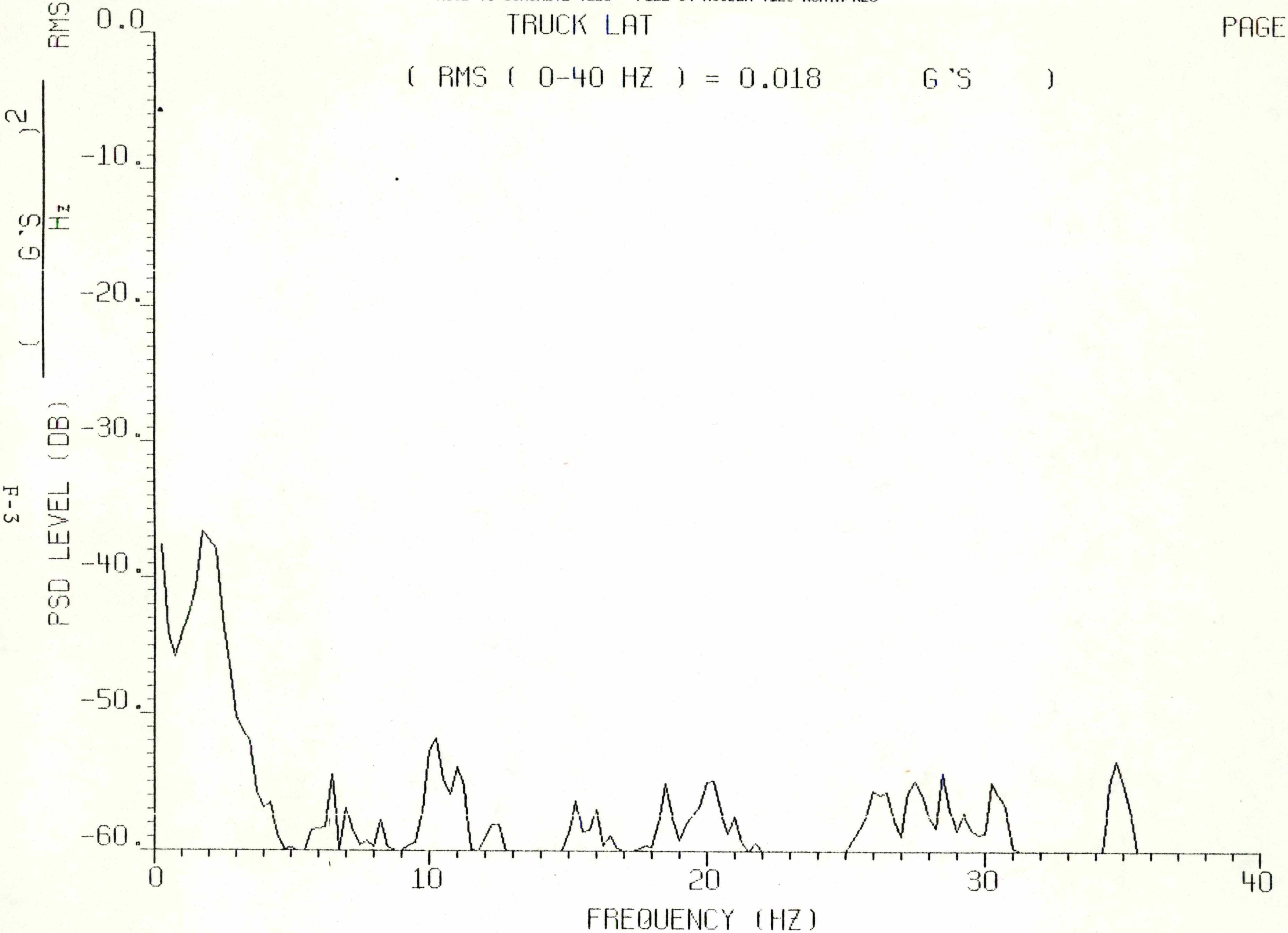
MSG 132 TO MSG 135----WOODEN TIES 60 MPH NORTH NEC
WOOD VS CONCRETE TIES FILE 04 WOODEN TIES NORTH NEC

TRUCK LONG

(RMS (0-40 HZ) = 0.008 G'S)

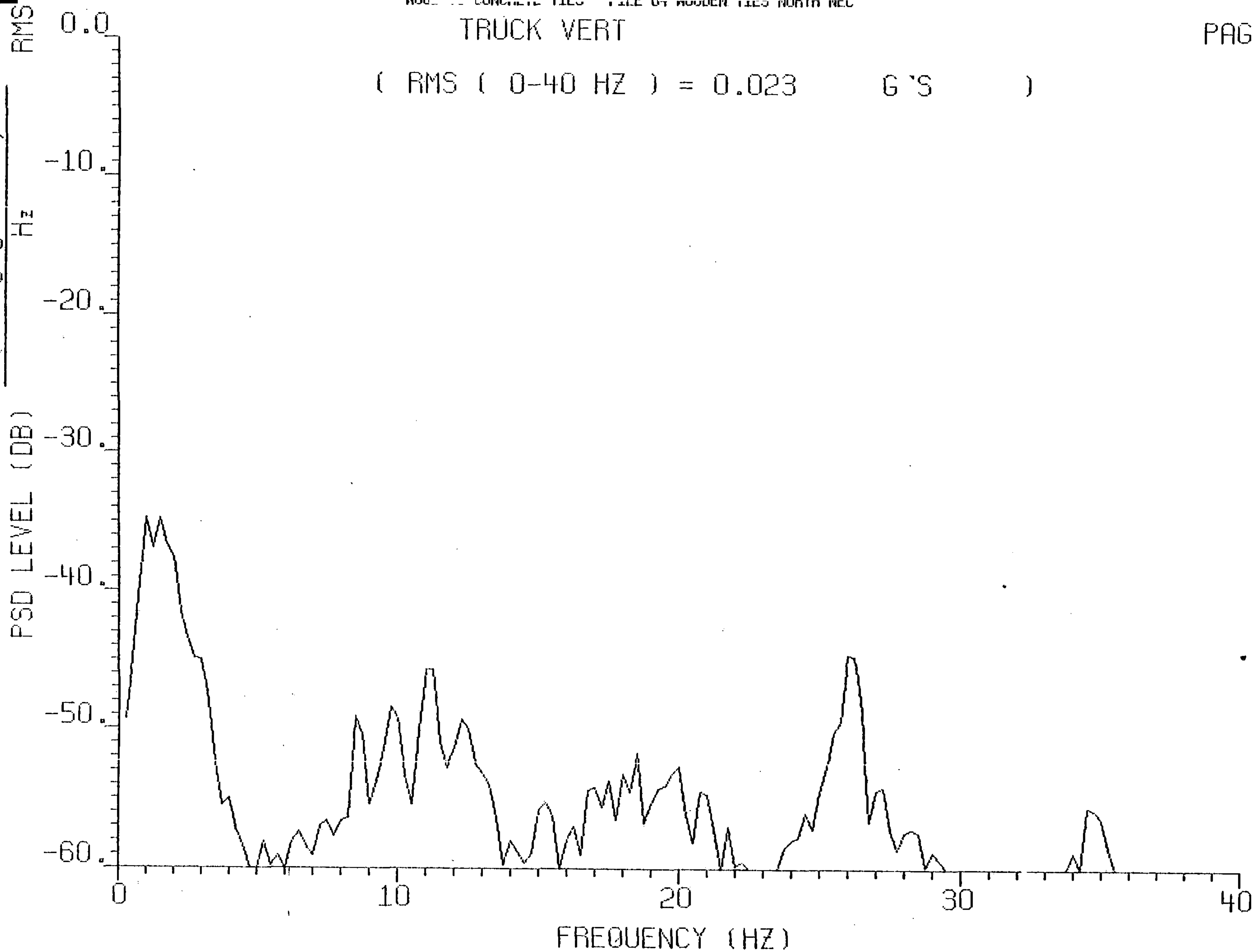


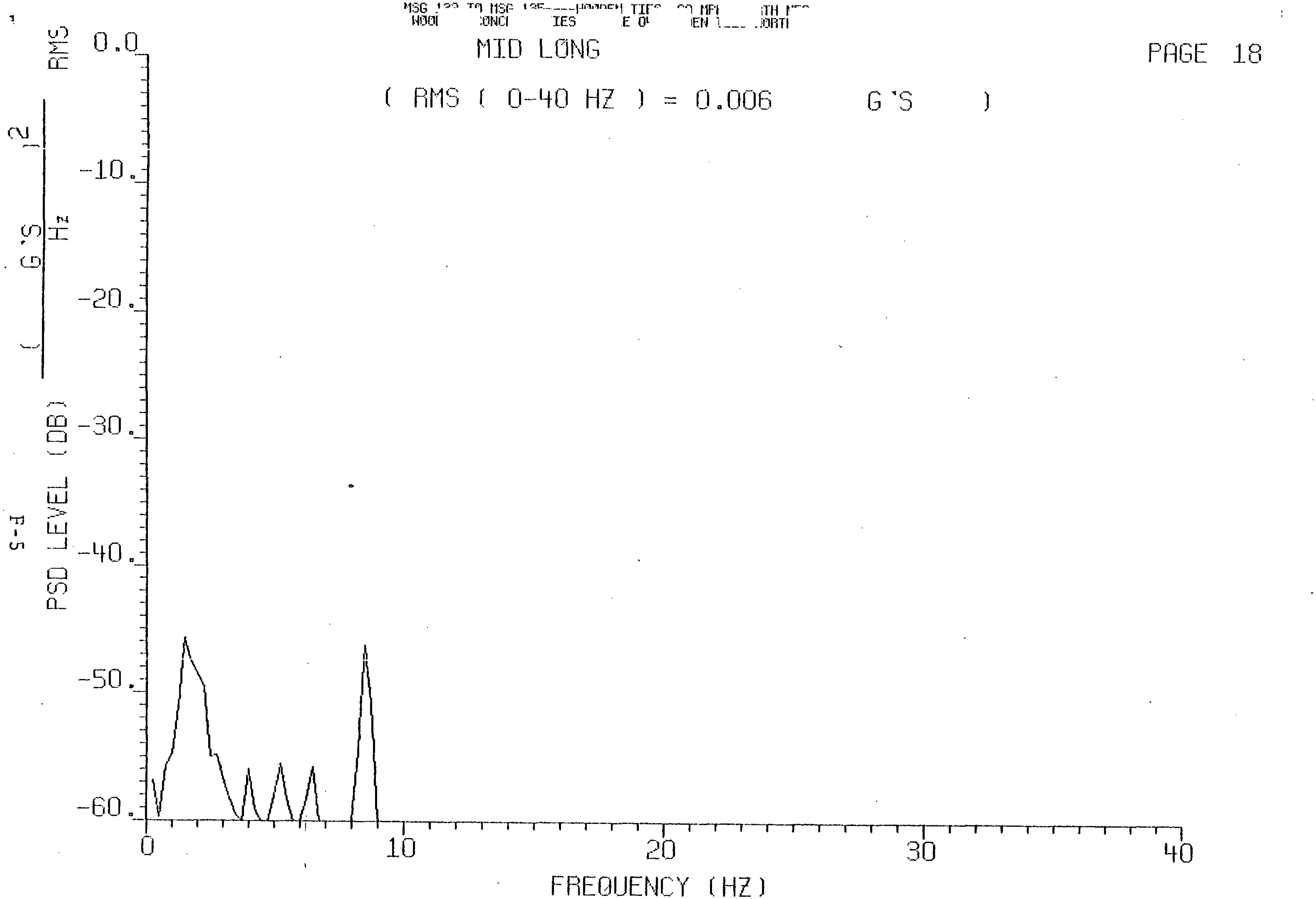
MSG 132 TO MSG 135----WOODEN TIES 60 MPH NORTH NEC
WOOD VS CONCRETE TIES FILE 04 WOODEN TIES NORTH NEC



TRUCK VERT

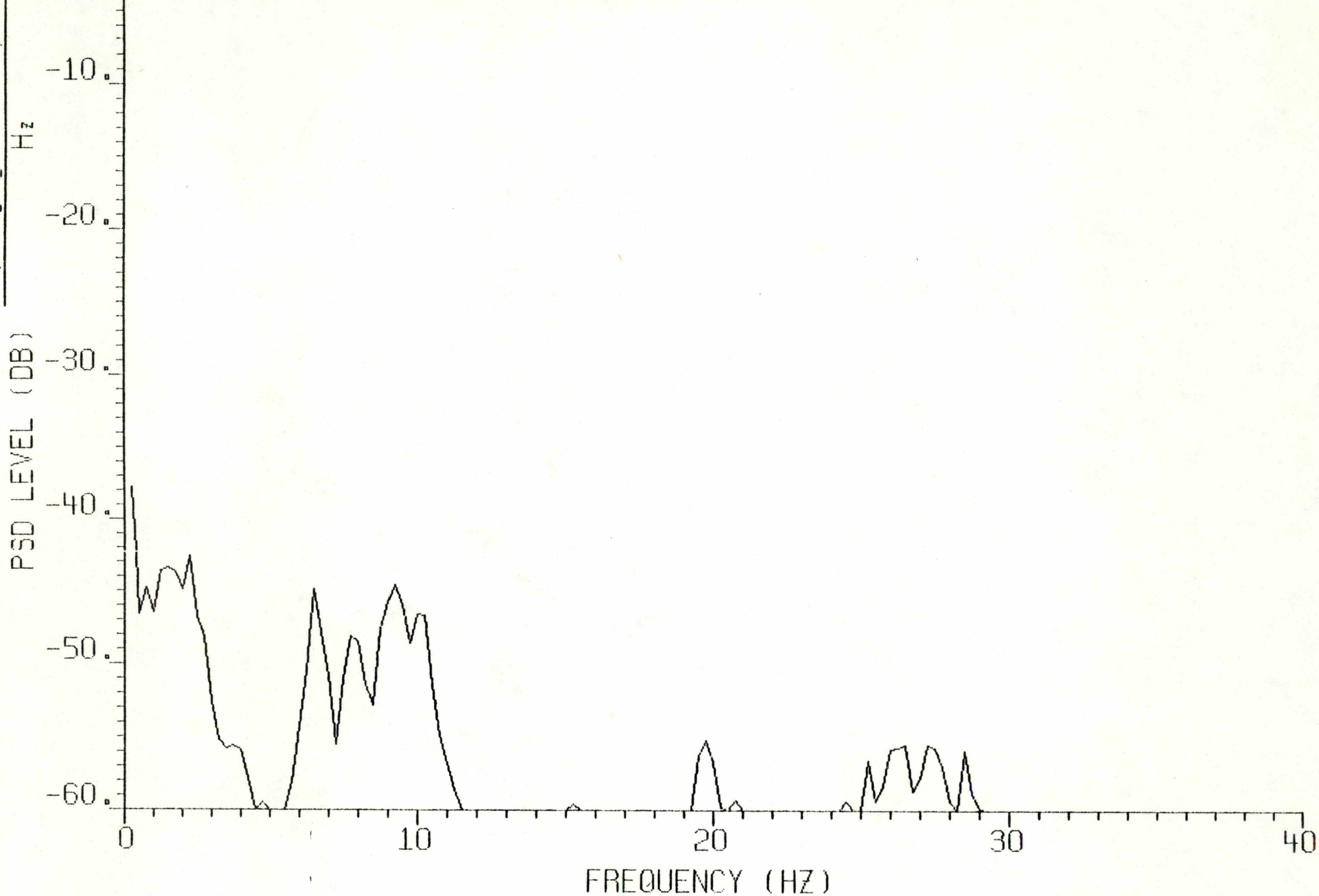
(RMS (0-40 HZ) = 0.023 G'S)

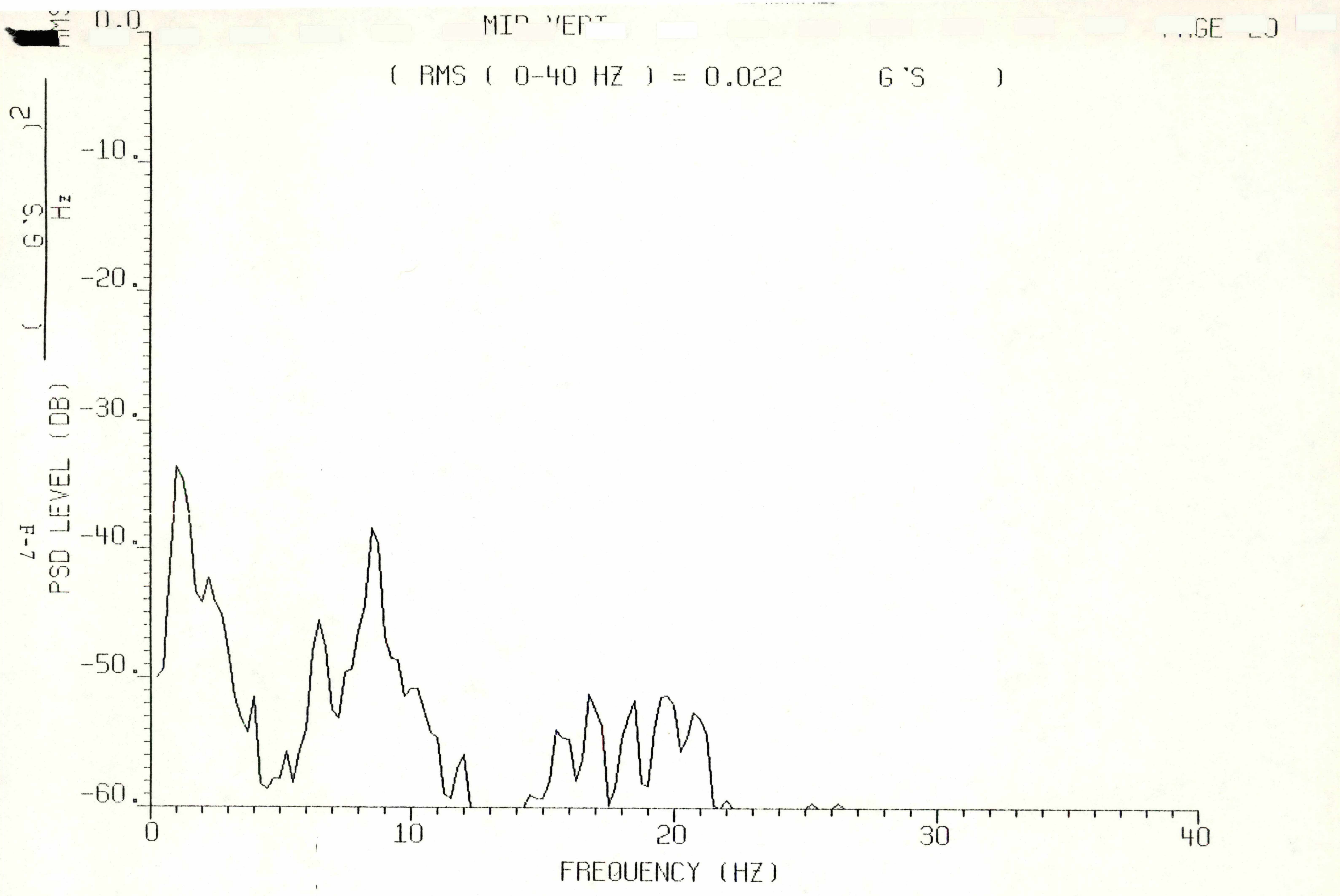



MID LONG
(RMS (0-40 HZ) = 0.006 G'S)
PSD LEVEL (DB) (G'S/Hz)² RMS
0.0
-10.
-20.
-30.
-40.
-50.
-60.
0
10
20
30
40
FREQUENCY (HZ)

MID LAT

(RMS (0-40 HZ) = 0.015 G'S)





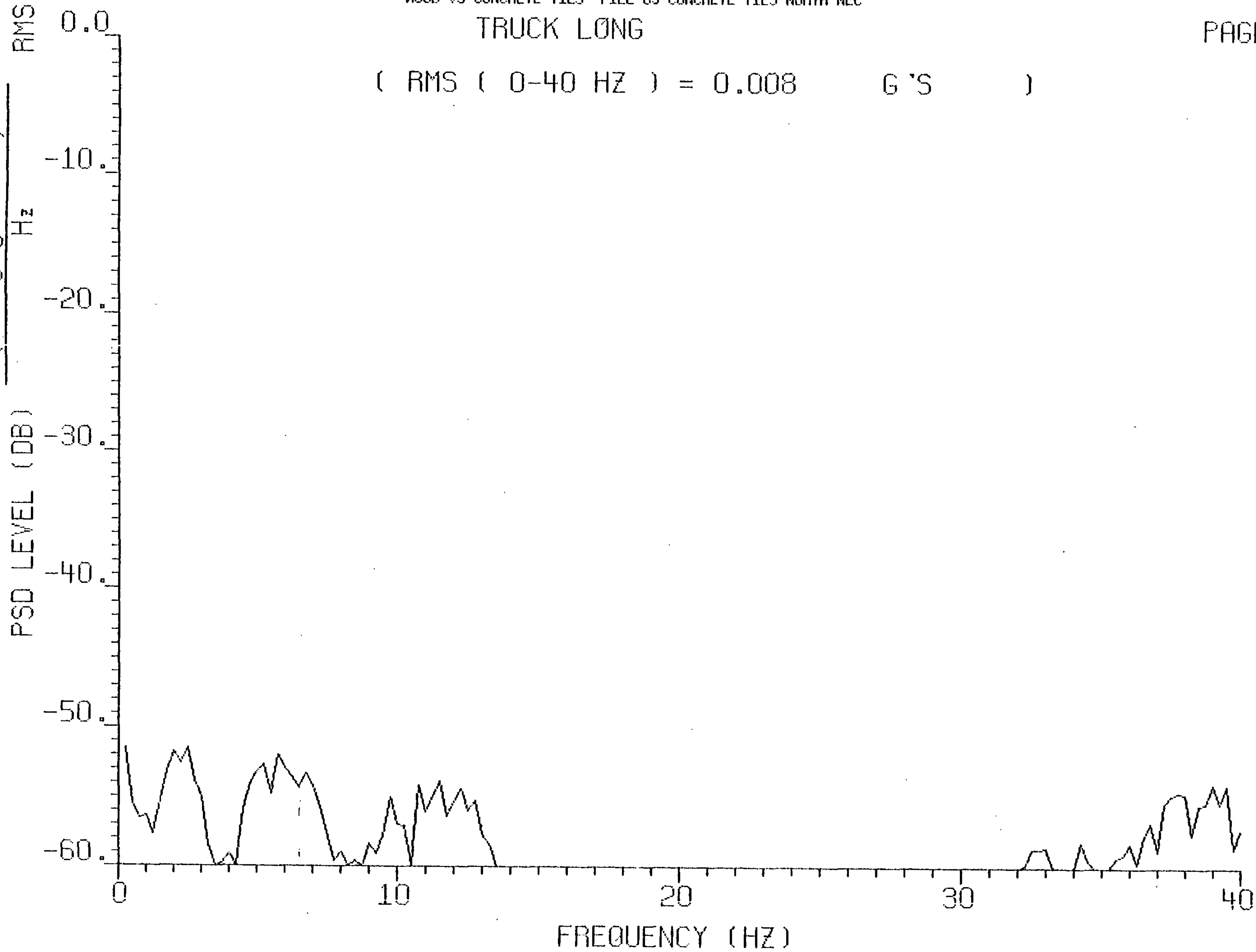
MIᴾ VEPT
(RMS (0-40 HZ) = 0.022 G'S)
...GE
PSD LEVEL (DB)
(G'S)^2 / Hz
0.0
-10.
-20.
-30.
-40.
-50.
-60.
0
10
20
30
40
FREQUENCY (HZ)

F-7

MSG 119, #124 MKR---CONCRETE TIES 80 MPH NORTH NEC
WOOD VS CONCRETE TIES FILE 03 CONCRETE TIES NORTH NEC

TRUCK LØNG

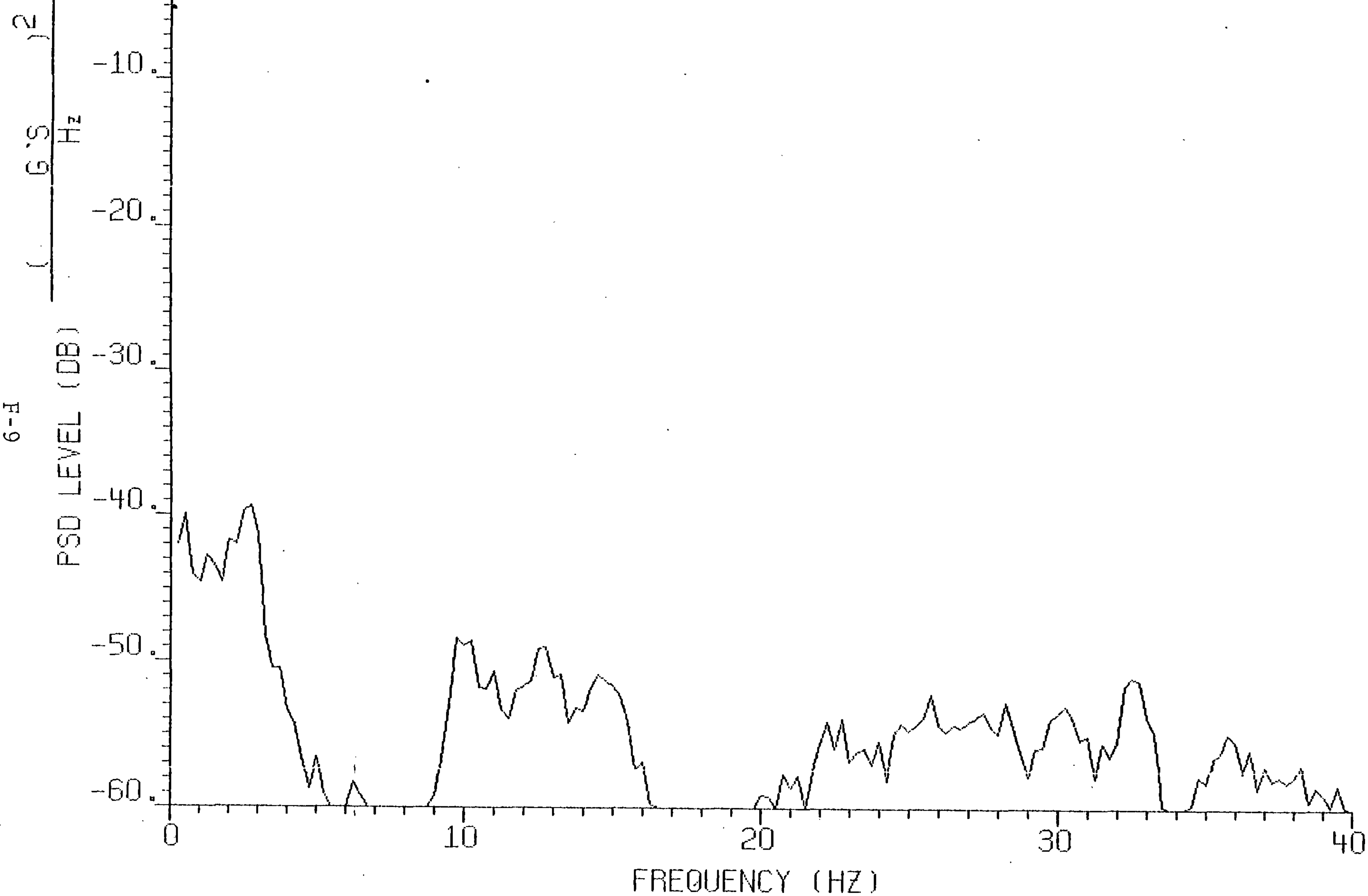
(RMS (0-40 HZ) = 0.008 G'S)



MSG 119, #124 MKR---CONCRETE TIES 80 MPH NORTH NEC
WOOD VS CONCRETE TIES FILE 03 CONCRETE TIES NORTH NEC

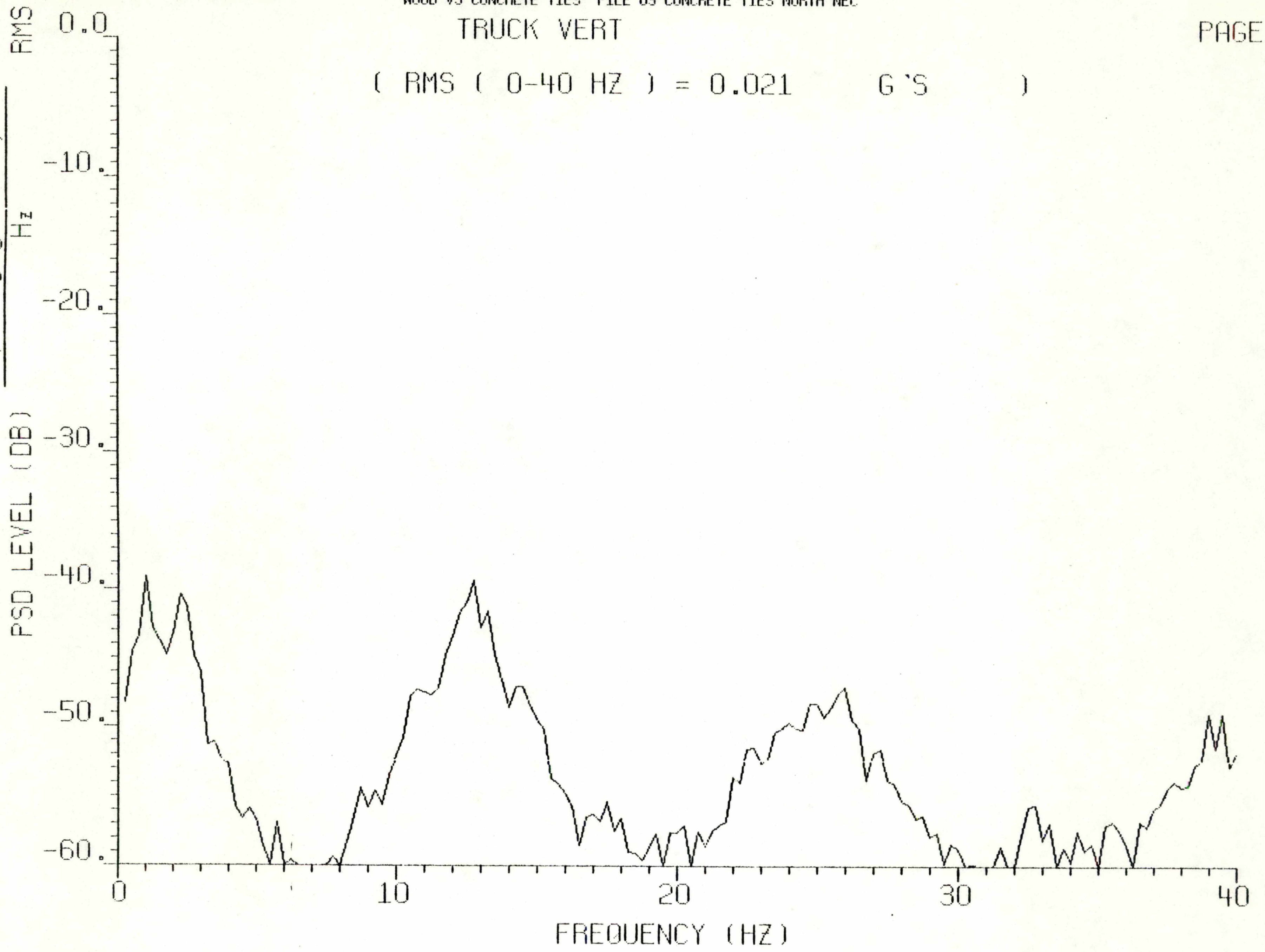
TRUCK LAT

(RMS (0-40 HZ) = 0.018 G'S)

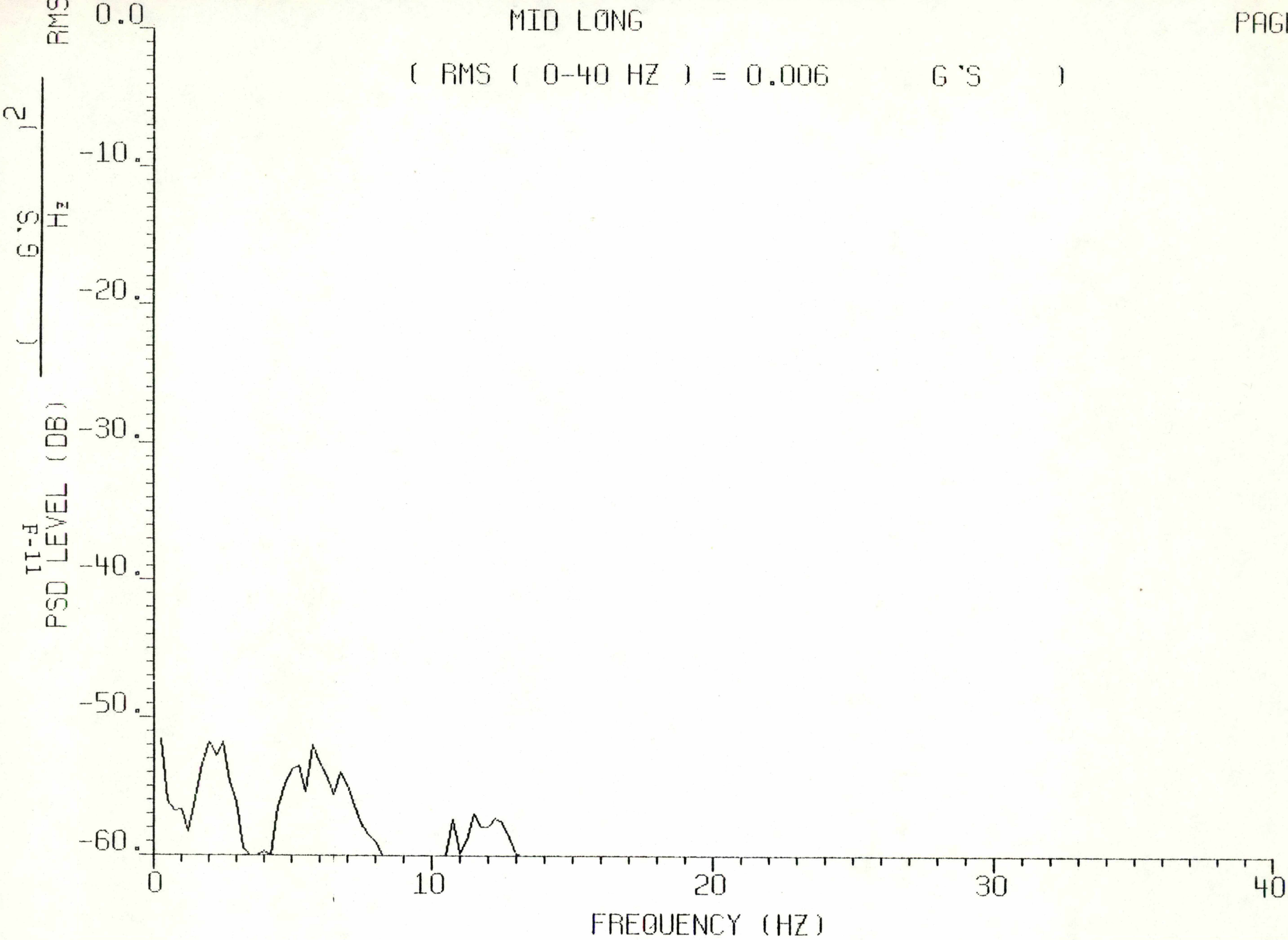


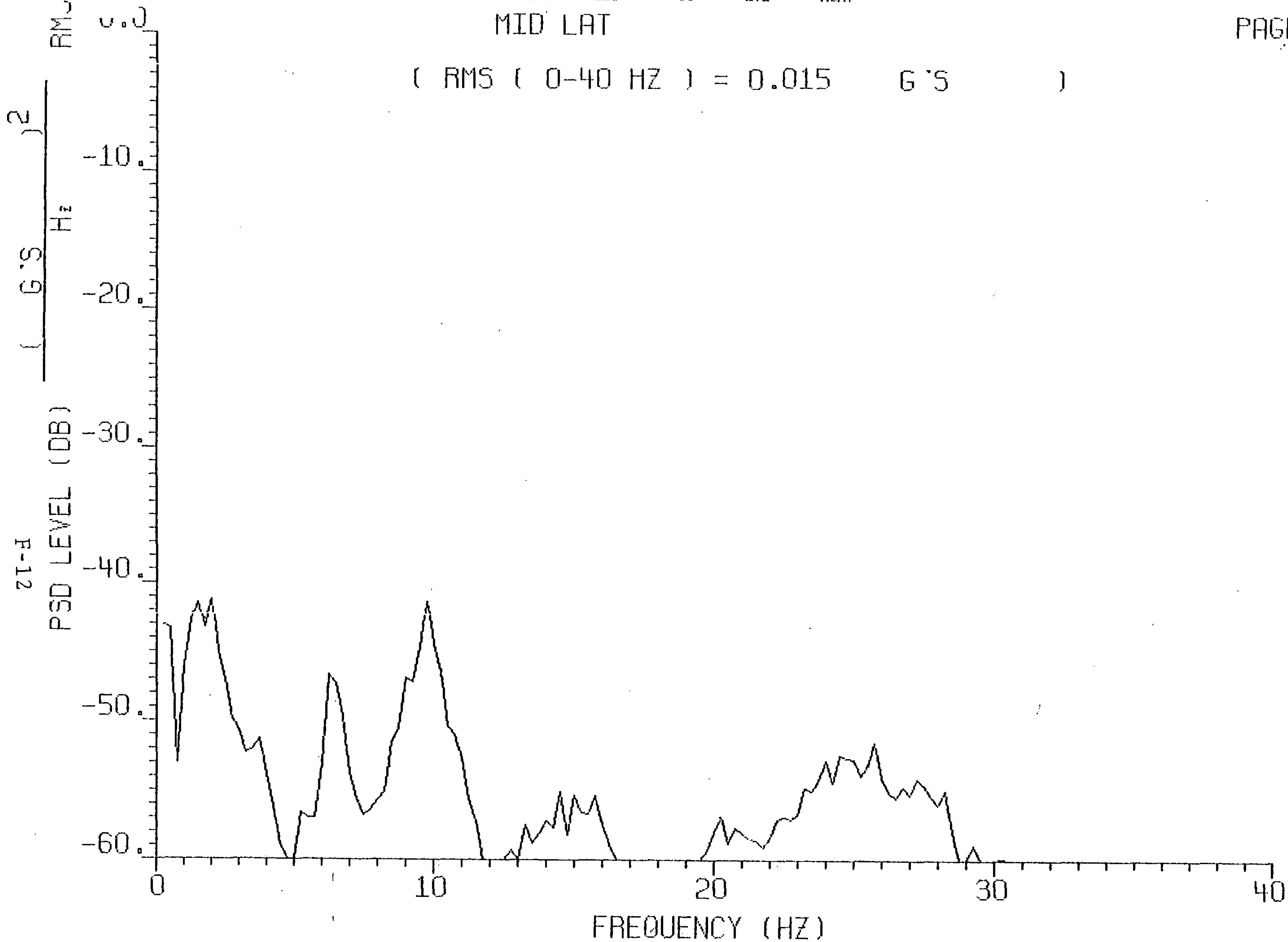
TRUCK VERT

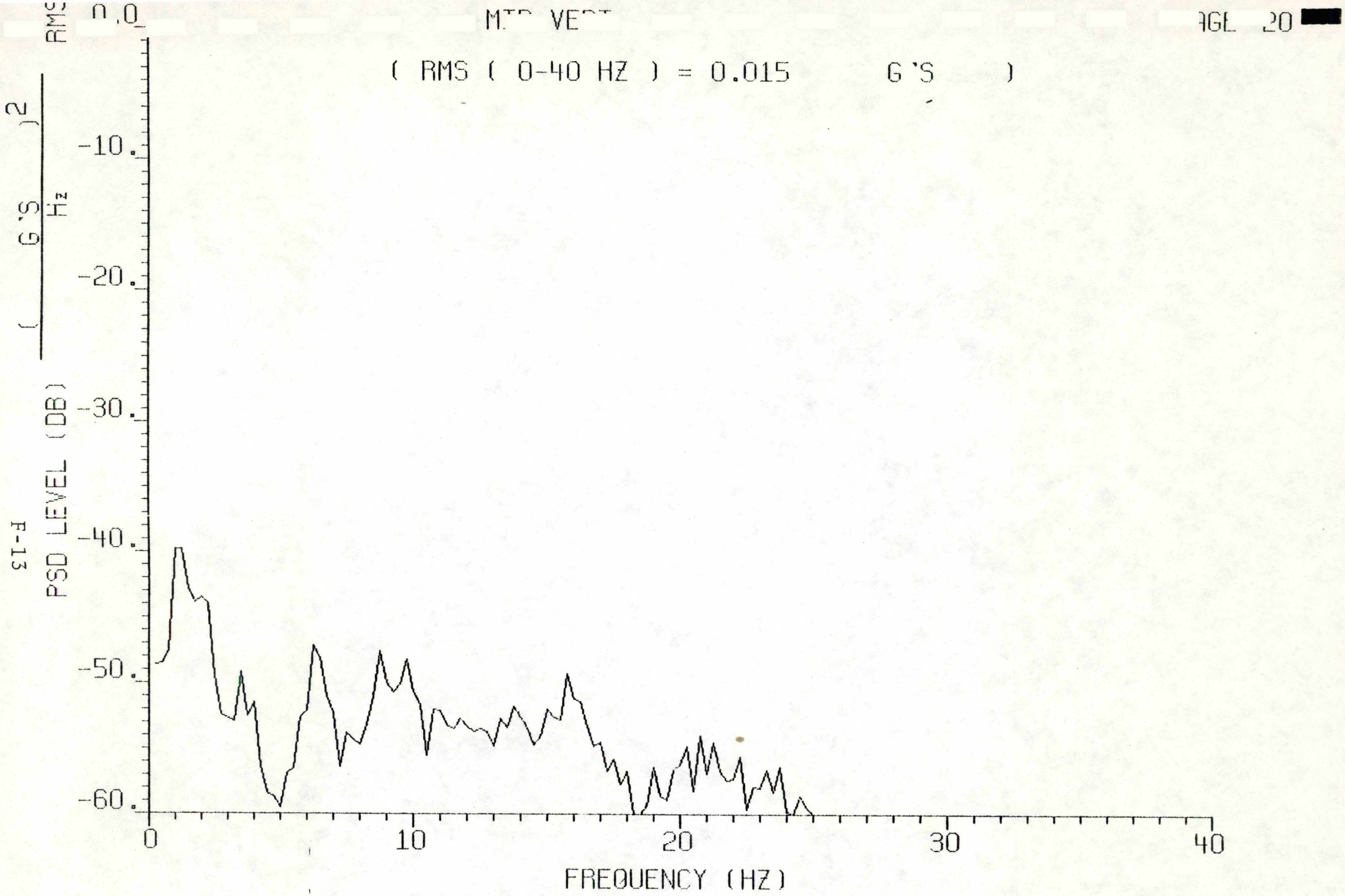
(RMS (0-40 HZ) = 0.021 G'S)



MSG #12 --CO E TI O NF RTH
WOOL TO CONCRETE TIES FILE OS CONCRETE TIES NORTH NEC




MID LAT
(RMS (0-40 HZ) = 0.015 G'S)
PSD LEVEL (DB) (G'S / Hz)²
0.0
-10.
-20.
-30.
-40.
-50.
-60.
0
10
20
30
40
FREQUENCY (HZ)

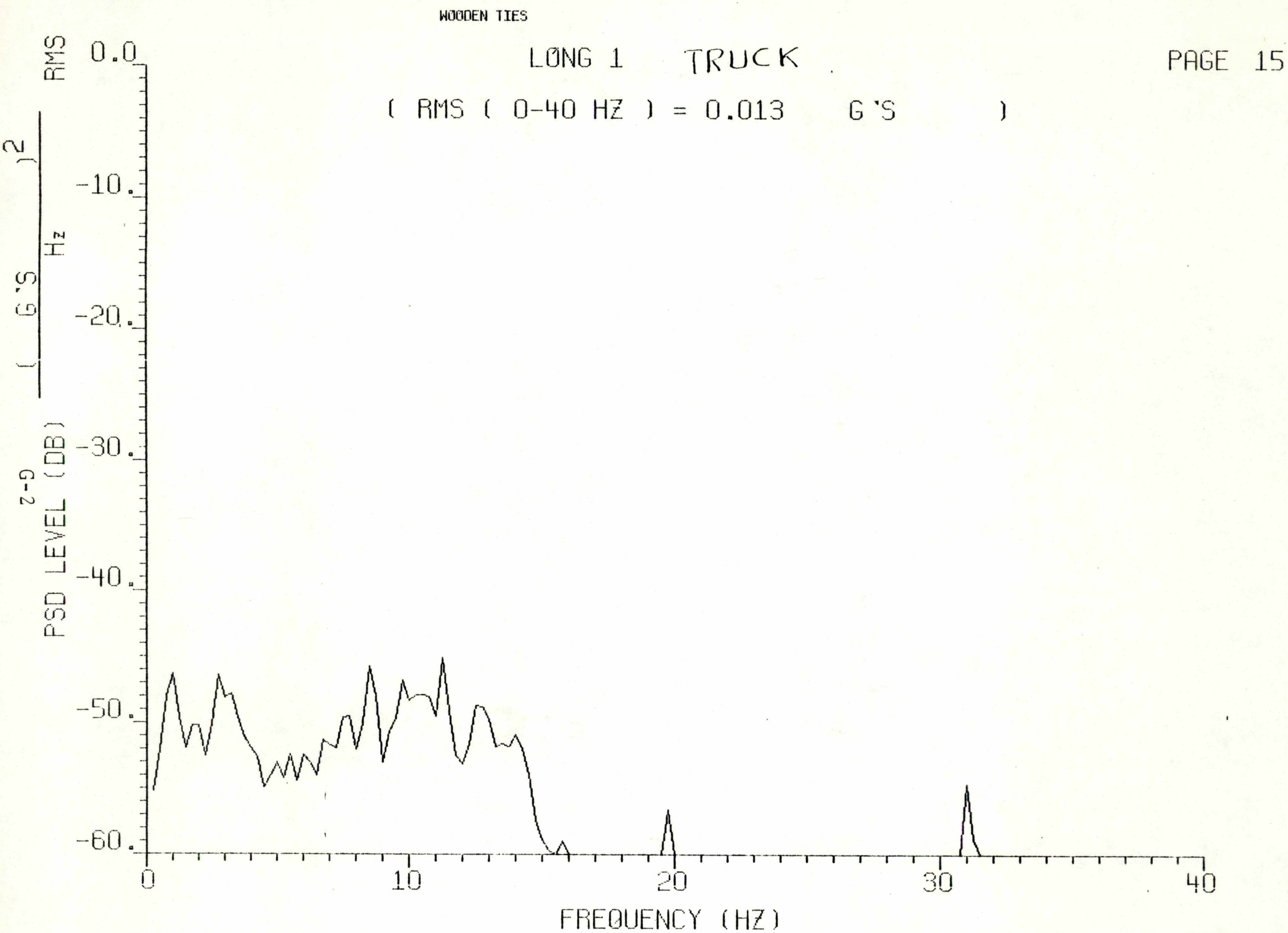


MTR VERT
(RMS (0-40 HZ) = 0.015 G'S)
AGE 20
RMS
(G'S)² / Hz
PSD LEVEL (DB)
0.0
-10.
-20.
-30.
-40.
-50.
-60.
0
10
20
30
40
FREQUENCY (HZ)

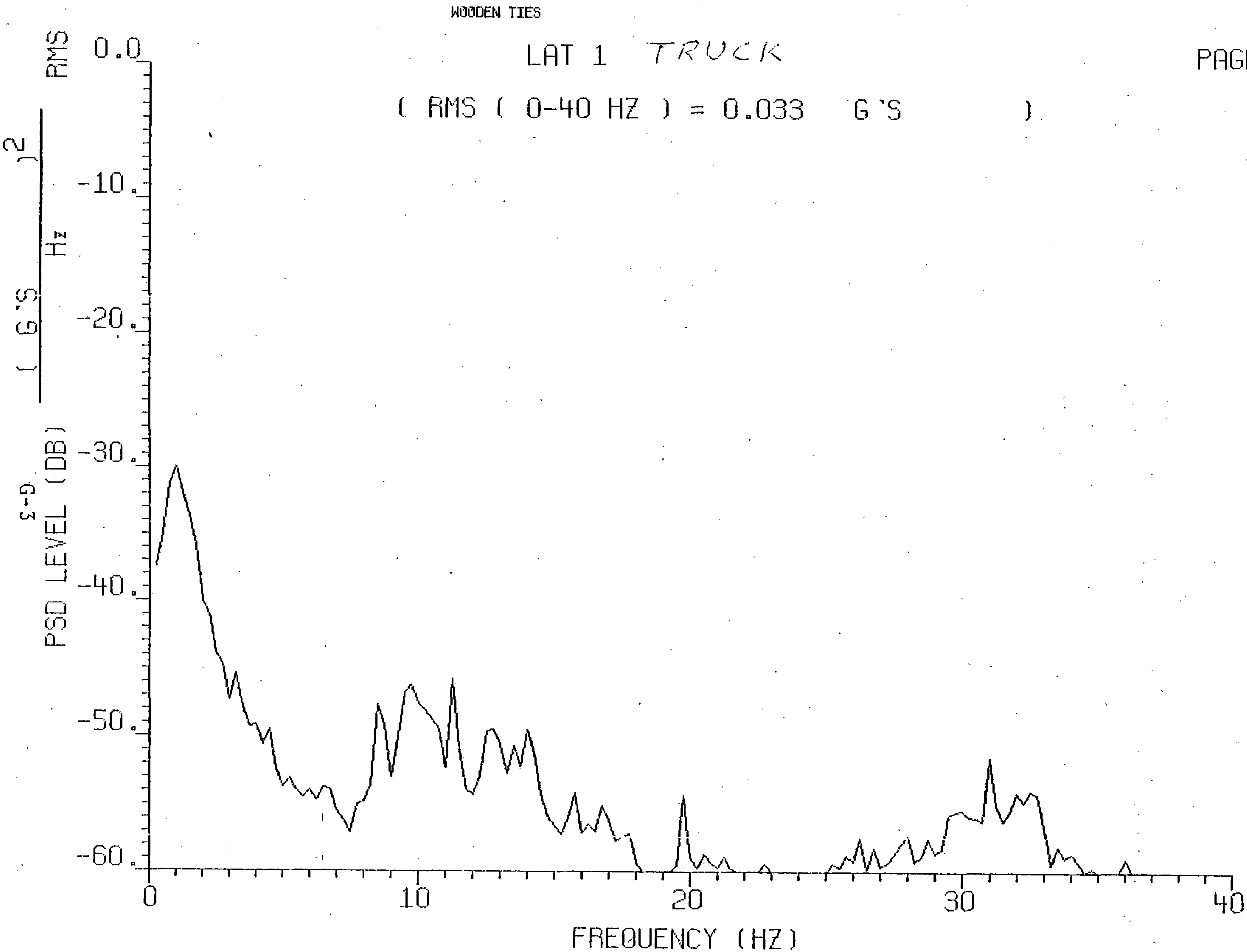
F-13

APPENDIX G

PSD PLOTS
SOUTHERN NORTHEAST CORRIDOR
WOODEN TIES-CONCRETE TIES



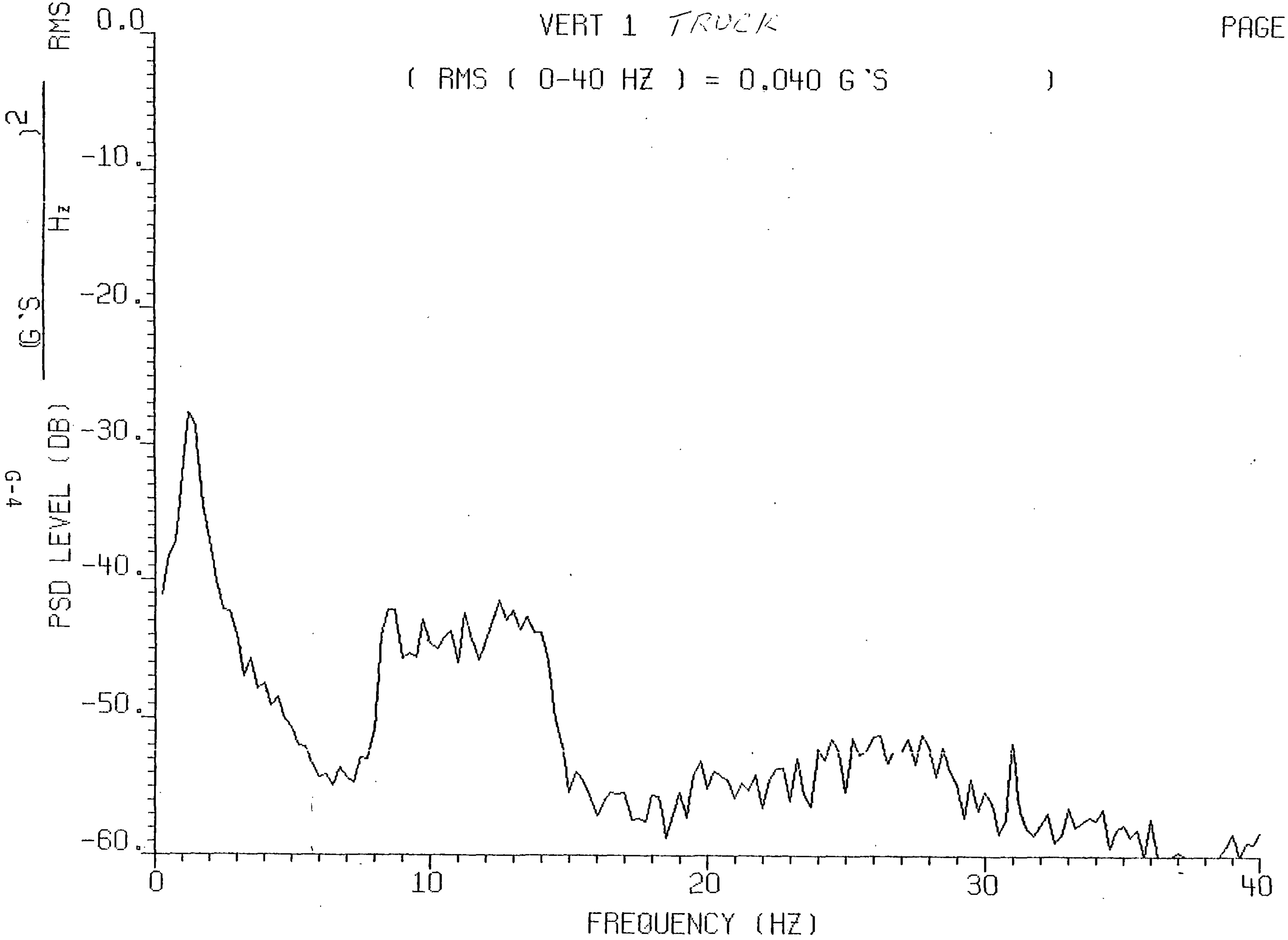
WOODEN TIES
LØNG 1 TRUCK
PAGE 15
(RMS (0-40 HZ) = 0.013 G'S)
0.0
-10.
-20.
-30.
-40.
-50.
-60.
0
10
20
30
40
FREQUENCY (HZ)
PSD LEVEL (DB) (G'S / Hz)^2 RMS
G-2

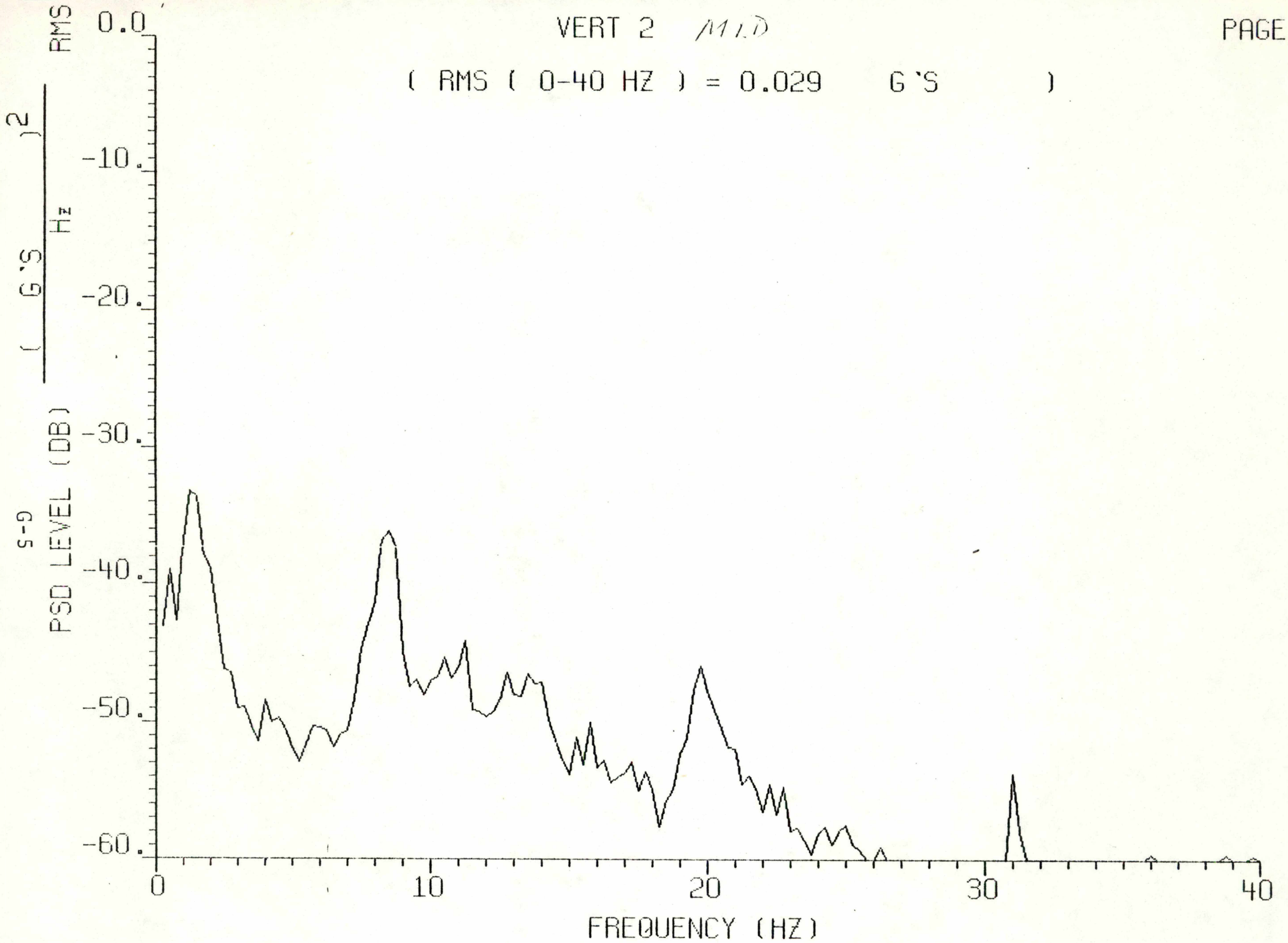

WOODEN TIES
LAT 1 TRUCK
(RMS (0-40 HZ) = 0.033 G'S)
PSD LEVEL (DB)
G-3
(G'S RMS / Hz)²
0.0
-10.
-20.
-30.
-40.
-50.
-60.
0
10
20
30
40
FREQUENCY (HZ)

WOODEN TIES

VERT 1 *TRUCK*

(RMS (0-40 HZ) = 0.040 G'S)

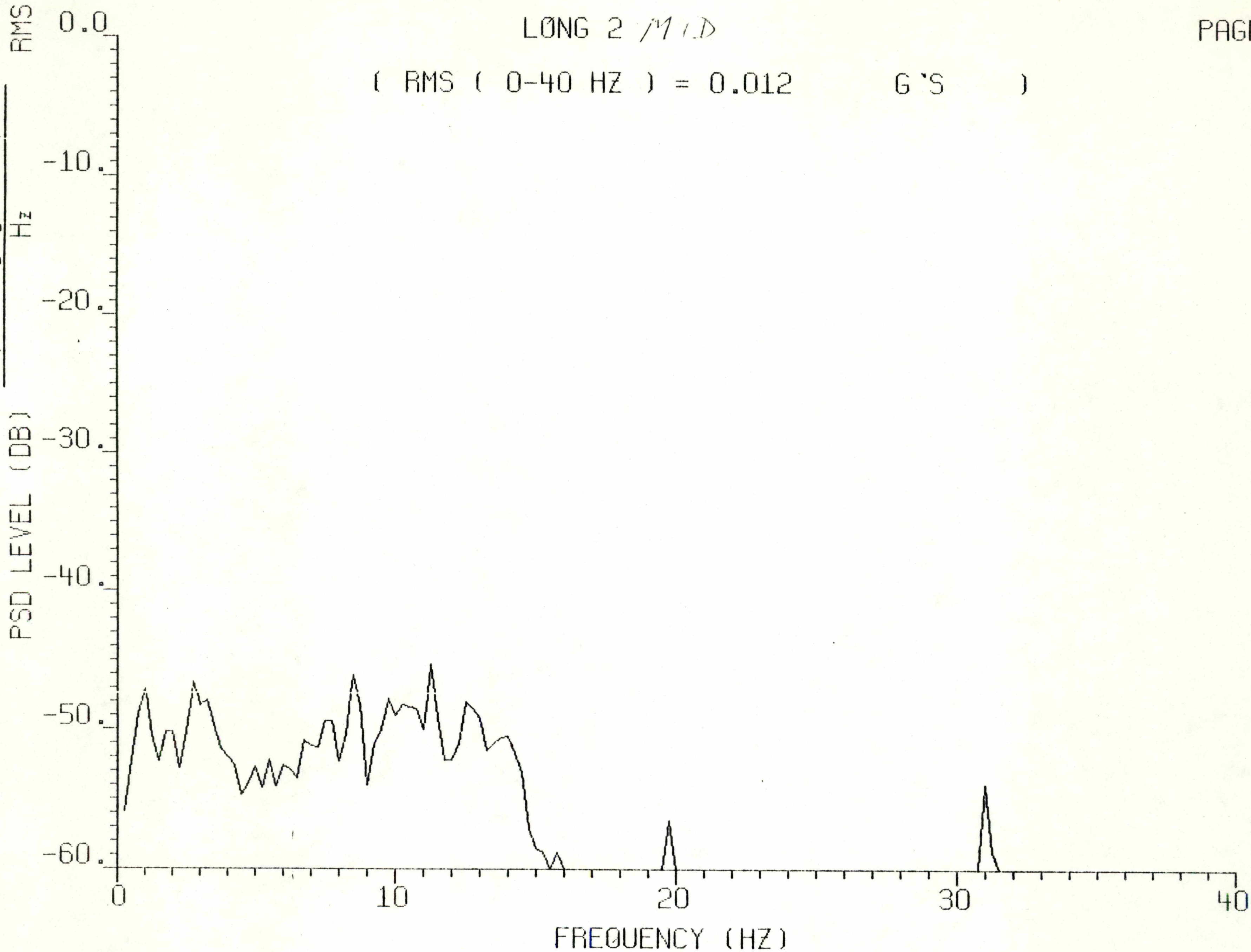



VERT 2 MID
(RMS (0-40 HZ) = 0.029 G'S)
RMS
(G'S)²/Hz
G-S
PSD LEVEL (DB)
0.0
-10.
-20.
-30.
-40.
-50.
-60.
0
10
20
30
40
FREQUENCY (HZ)

WOODEN TIES

LONG 2 MID

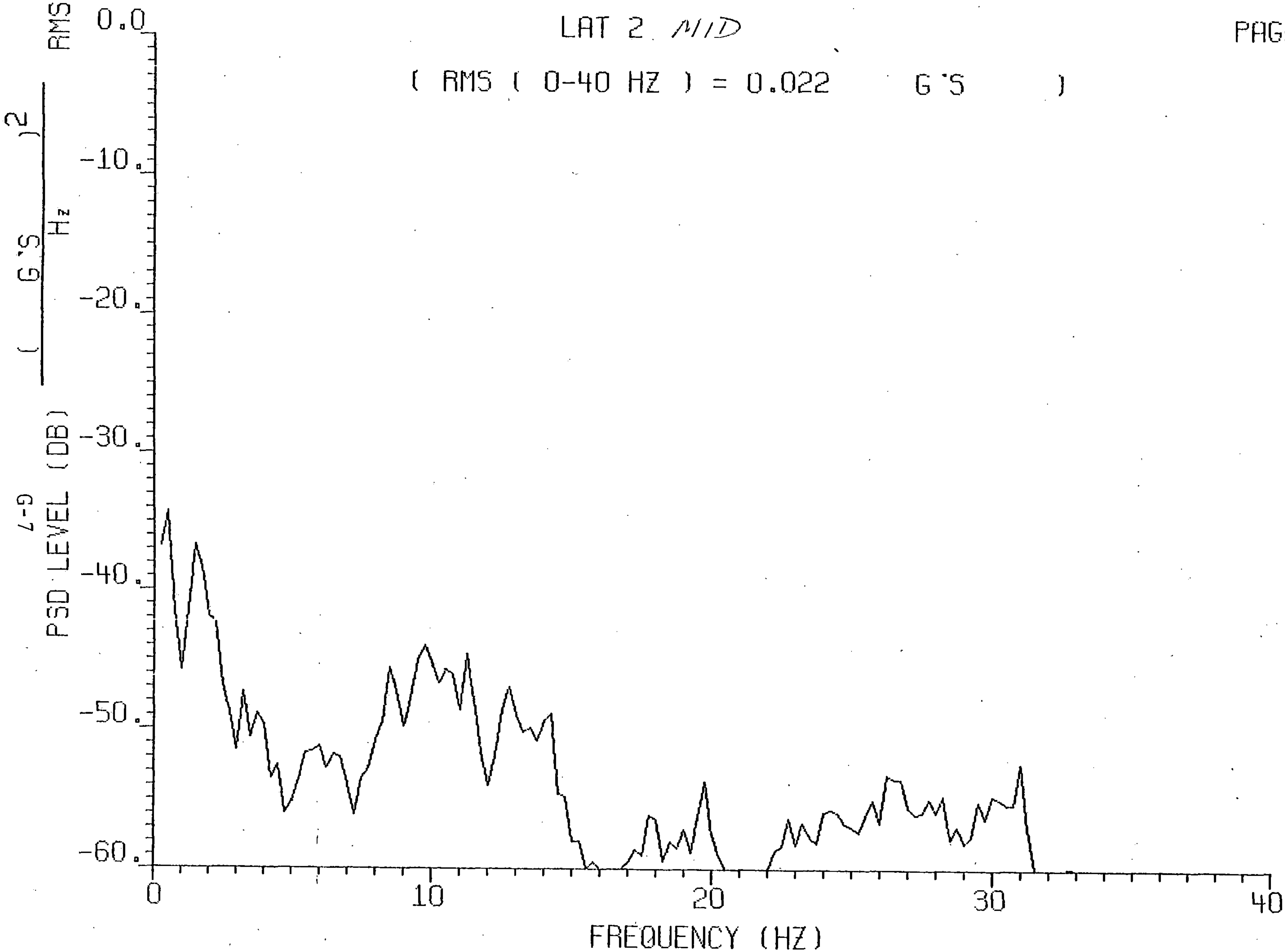
(RMS (0-40 HZ) = 0.012 G'S)



WOODEN TIES

LAT 2 MID

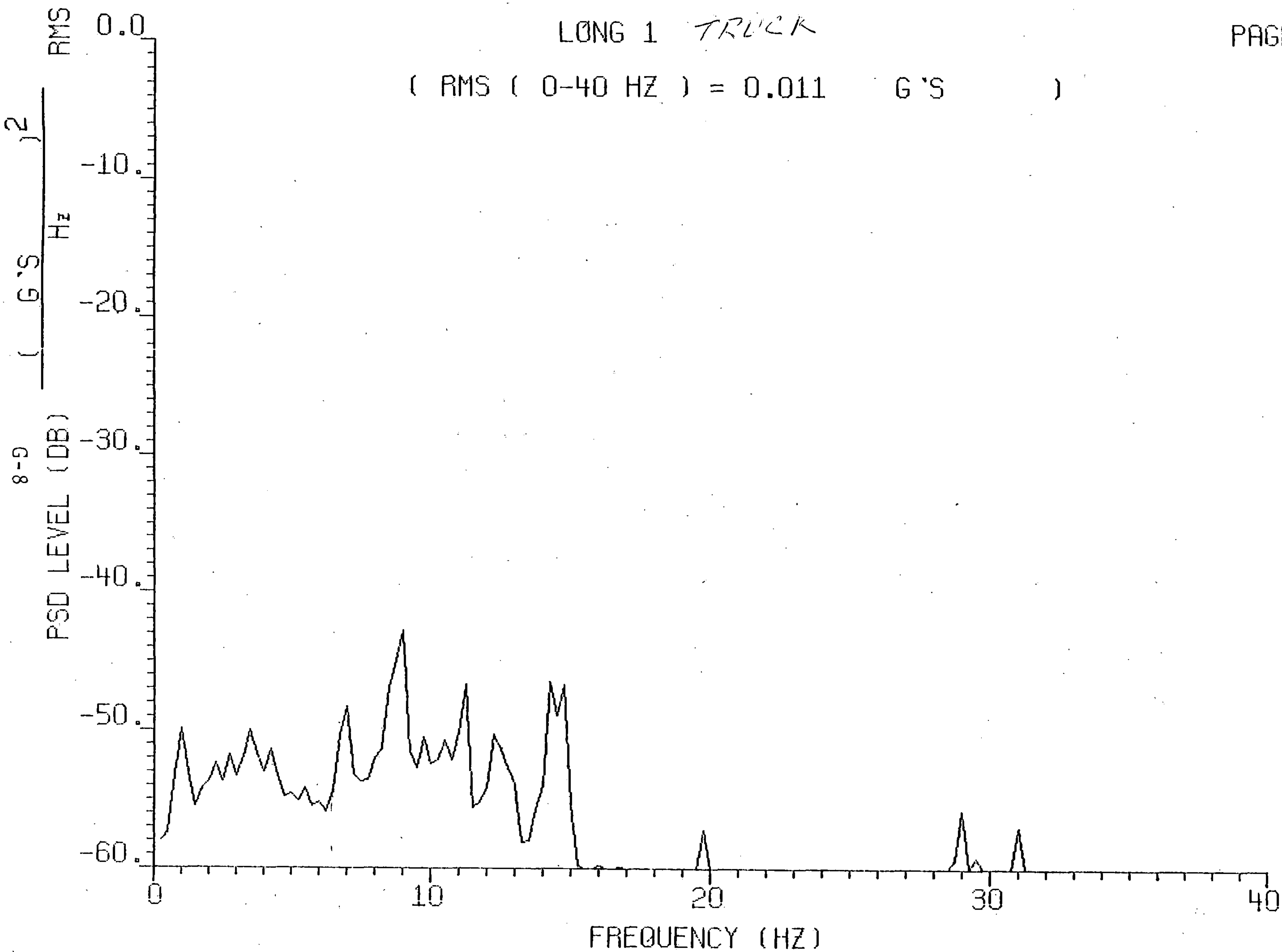
(RMS (0-40 HZ) = 0.022 G'S)



CONCRETE TIES

LØNG 1 TRUCK

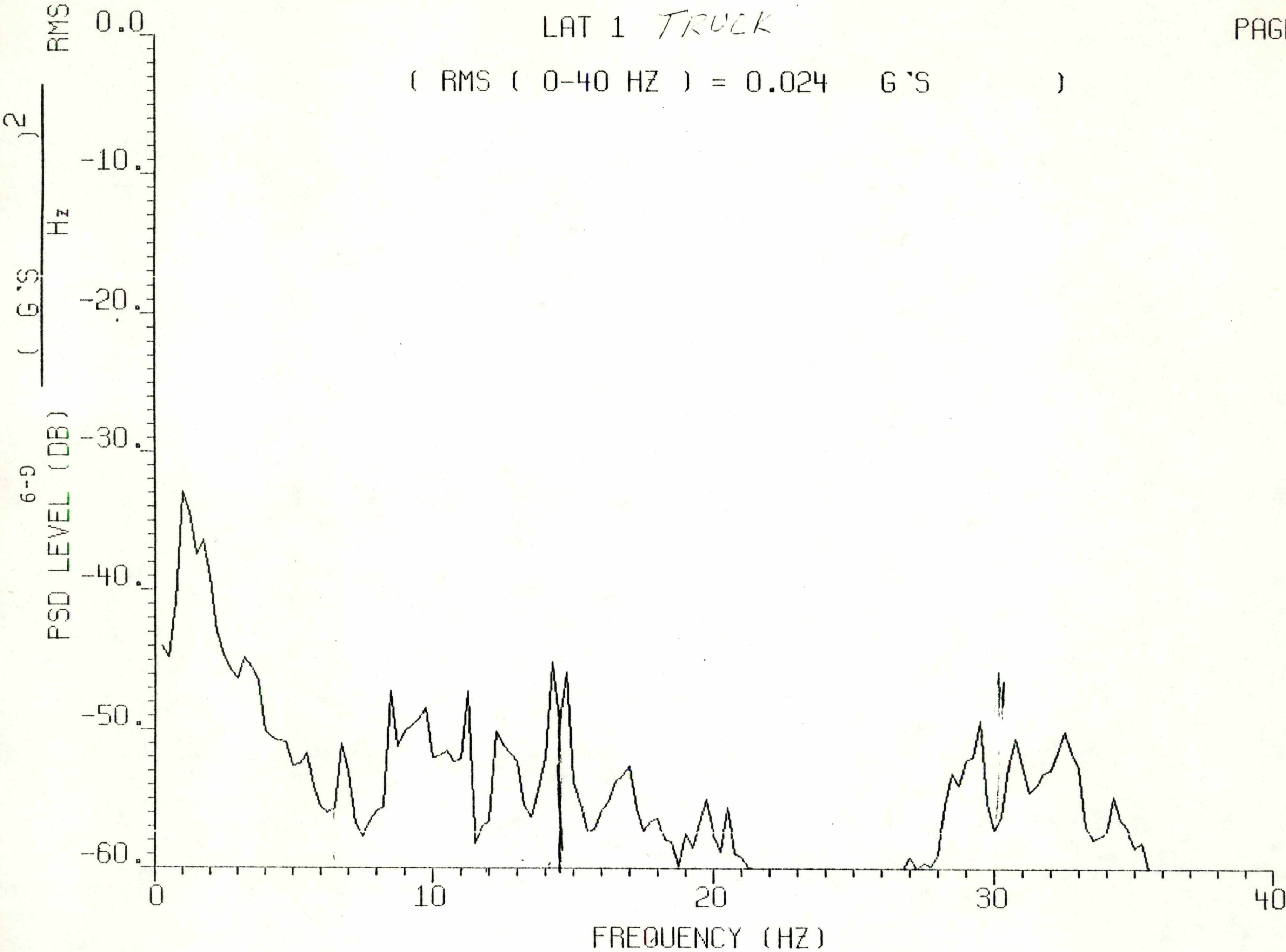
(RMS (0-40 HZ) = 0.011 G'S)



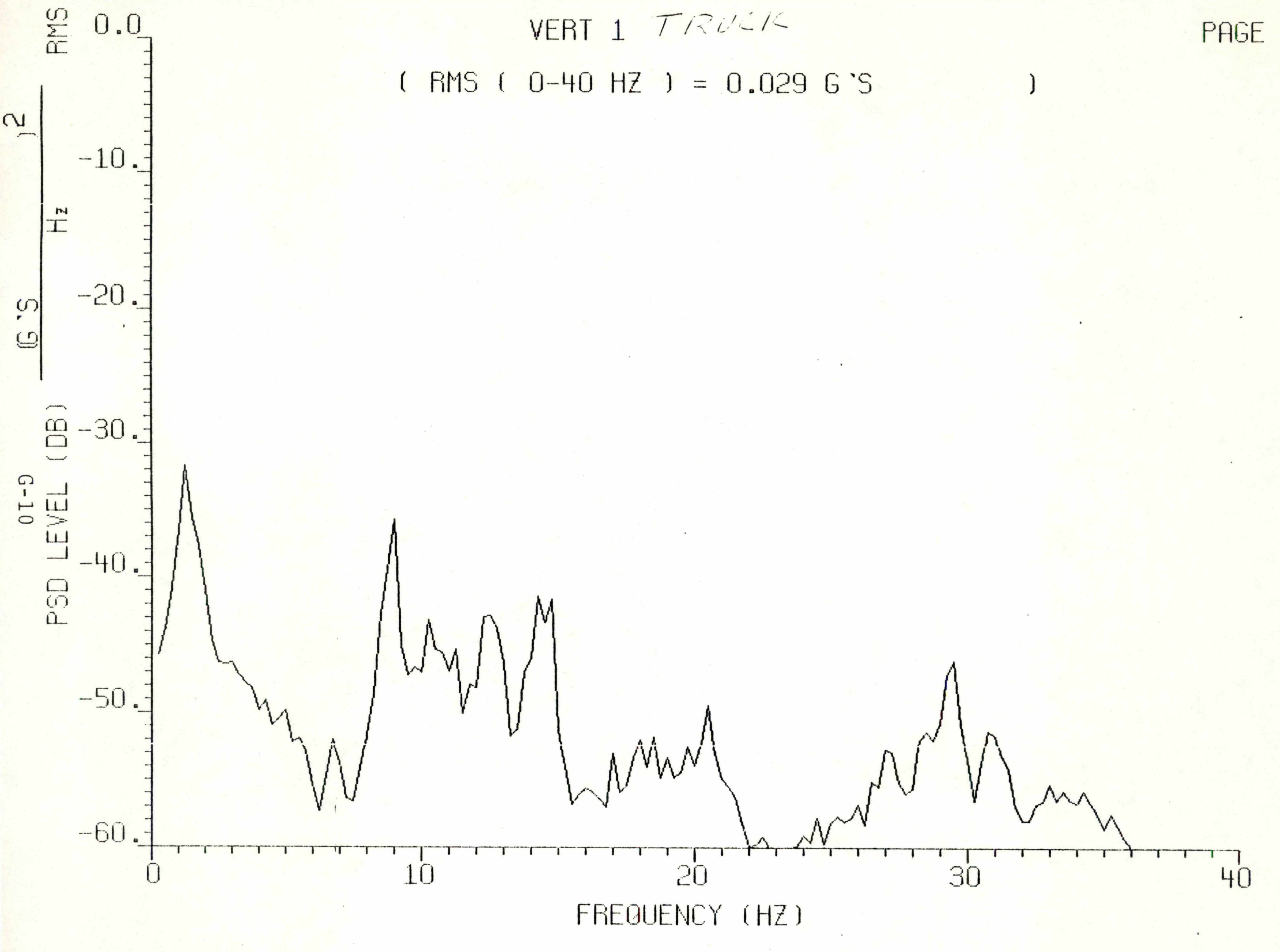
CONCRETE TIES

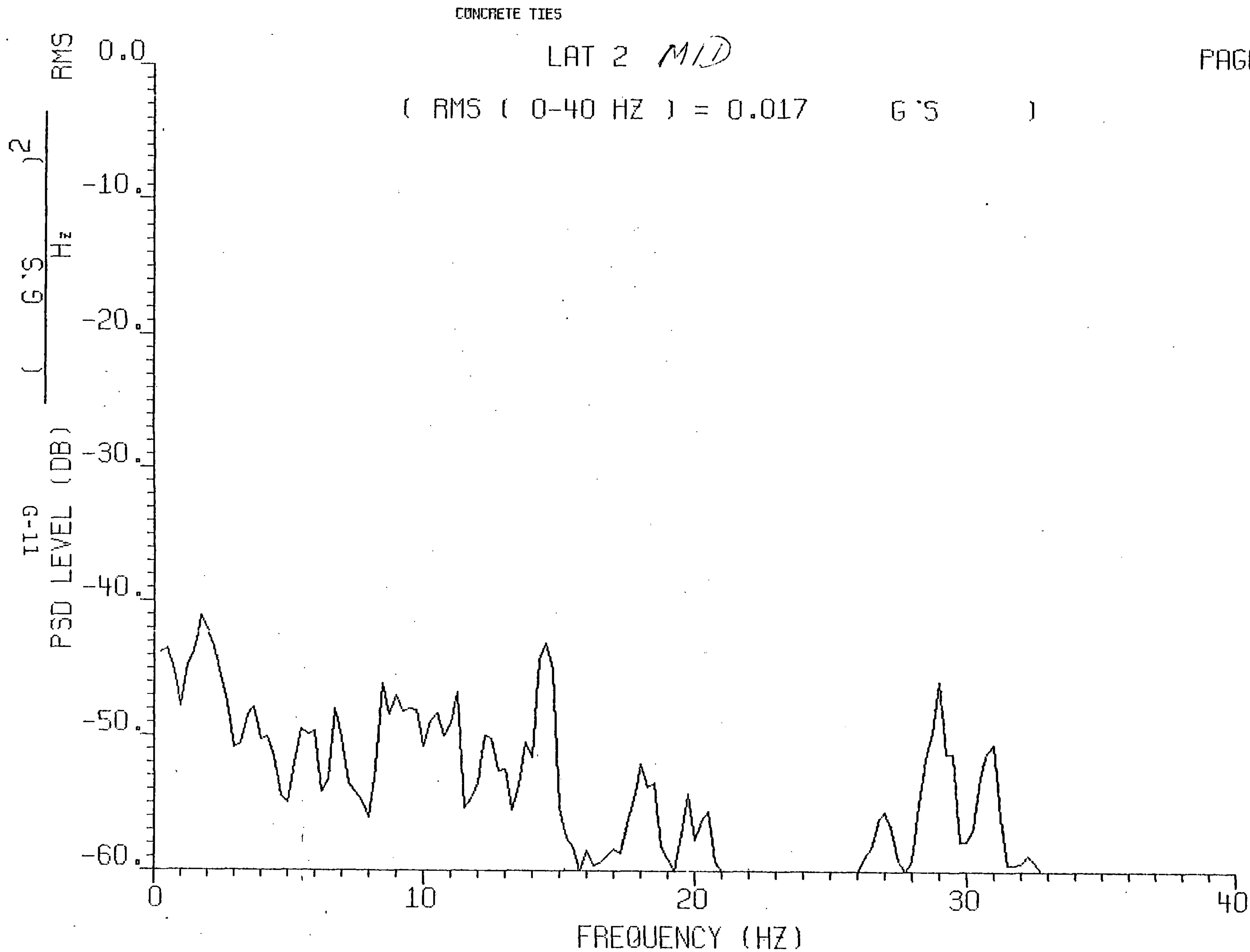
LAT 1 *TRUCK*

(RMS (0-40 HZ) = 0.024 G'S)

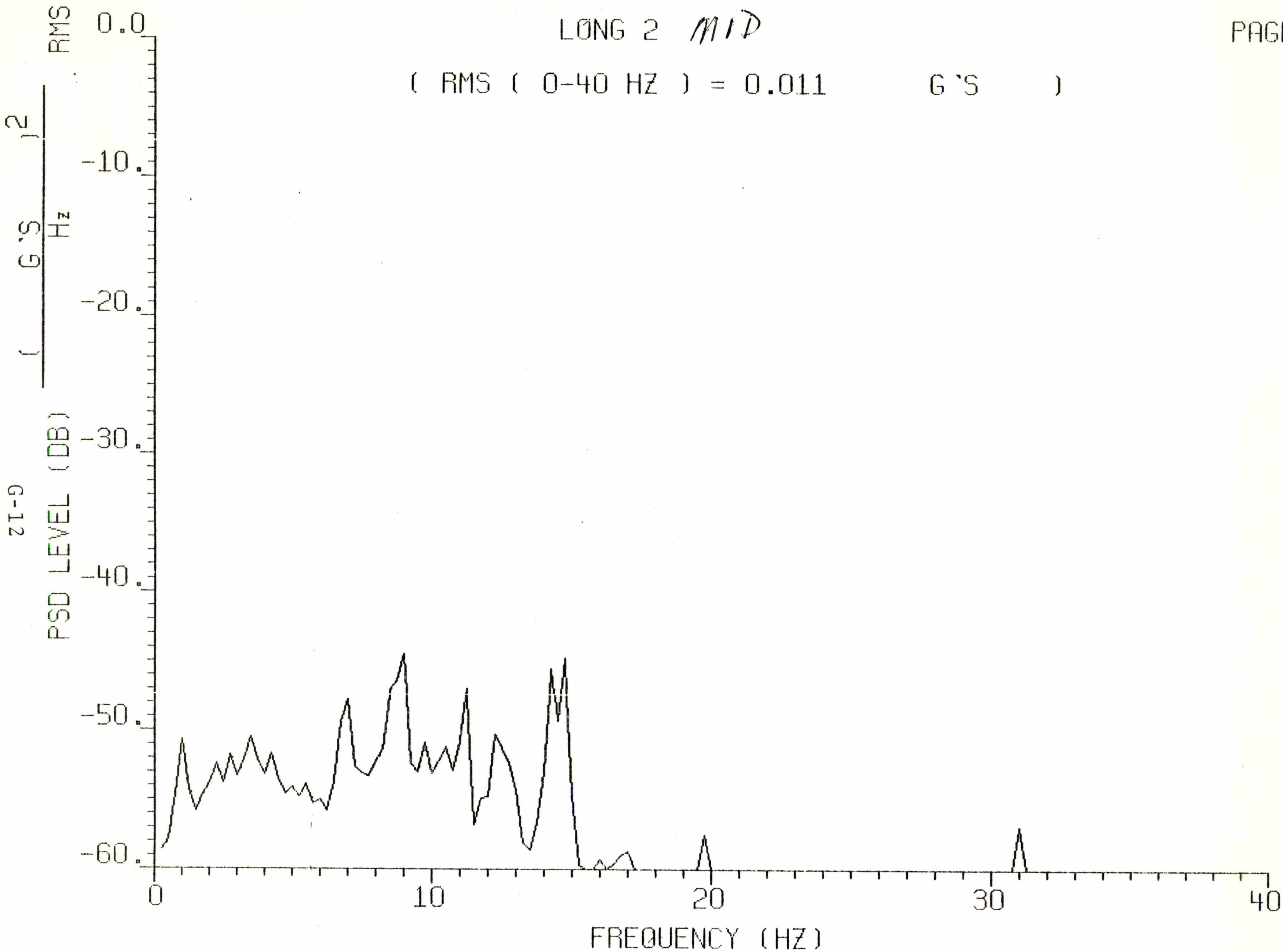


CONCRETE TIES




CONCRETE TIES
LAT 2 MID
(RMS (0-40 HZ) = 0.017 G'S)
RMS
(G'S)^2 / Hz
G-11
PSD LEVEL (DB)
0.0
-10.
-20.
-30.
-40.
-50.
-60.
0
10
20
30
40
FREQUENCY (HZ)

CONCRETE TIES



G-12

Test Results Report, Ride Quality Testing of an
Amcoach on Wooden and Concrete Tie Sectins,
ENSCO, Inc., 1979 -23-Passenger Operations