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Shock and Vibration Profile for MEF IAS/TCAC PIP

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Abstract

The Marine Expeditionary Force Intelligence Analysis System (MEF IAS) and the Technical Control and Analysis Center Product Improvement Program (TCAC PIP) are command, control, and intelligence systems developed by the Marine Corps Systems Command and built around a common core system. The development strategy behind the MEF IAS and TCAC PIP is to reduce the total cost of these systems. The major savings will be in life-cycle management costs, by fielding the two different systems to two different organizations within the Marine Corps that share (extensively) a common support structure. This common core system is an M-1097 high-mobility multipurpose wheeled vehicle (HMMWV) (heavy variant) carrying a computer and communications system mounted in a standard integrated command post shelter (SICPS).

This report analyzes the results of tests performed during late 1994 and early 1995. These road tests, rail impact tests, and transit drop tests helped develop a general testing profile that can be applied to future upgrades of the MEF IAS and TCAC PIP. The same technique of using a common core system and individual component testing can be applied to the fielding of entirely new systems. The cost savings of such an approach are significant.

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Introduction

The Marine Expeditionary Force Intelligence Analysis System (MEF IAS) and the Technical Control and Analysis Center Product Improvement Program (TCAC PIP) are command, control, and intelligence (C^2I) systems developed by the Marine Corps Systems Command and built around a common core system. This common core system is an M-1097 high-mobility multipurpose wheeled vehicle (HMMWV) (heavy variant) carrying a computer and communications system mounted in a standard integrated command post shelter (SICPS). The core equipment mounted in the shelter includes computers and associated peripherals, modems, and encryption equipment. Supplied with each vehicle/shelter is a tent that is suitable for connection to the shelter, a number of workstations, and a set of support equipment consisting of tables, chairs, and lights.

The concept behind the development strategy of the MEF IAS and TCAC PIP is one that will reduce the total cost of these systems. While there are savings in design, development, and testing, the major savings will be in life cycle management costs. This savings is achieved by fielding the two different systems to two different organizations within the Marine Corps that share (extensively) a common support structure. This commonality can be found in areas ranging from training to spares inventory.

This core system will be fielded in three variants. The MEF IAS is a two-vehicle system. Each of the two MEF IAS variants contains a slightly different set of peripherals and will be issued with an M101A3 general cargo trailer. The TCAC PIP contains yet a slightly different set of computer peripherals and will be fielded with radios for both voice and data communication. These radios will be mounted in a rack that is a part of the core system. The TCAC PIP will also be fielded with an M101A3 general cargo trailer. The load out for this item will, however, be slightly different than that of the MEF IAS trailer. In each of these three variants, over 85 percent of the components are identical.

The Army Research Laboratory (ARL) has been involved in the design, engineering, and testing of these systems since 1992. During late 1994 and early 1995, a number of mechanical tests were run on the low-rate initial production (LRIP) version of the MEF IAS and TCAC PIP. The prime contractor, in accordance with a government-approved test plan, executed some of the tests at commercial facilities. The government executed some of the tests at the Aberdeen Test Center in Aberdeen, Maryland. Those tests included road tests, rail impact tests, and transit drop tests. All tests were performed in accordance with MIL-STD-810E.[1]

In this report, we analyze the results of those tests to develop a general testing profile that can be applied to future upgrades of the MEF IAS and TCAC PIP. The profile to be developed will enable developers to perform component tests rather than full system tests when minor upgrades are

[1]Military Standard, *Environmental Test Methods and Engineering Guidelines*, MIL-STD-810E (14 July 1989).

made to the fielded systems. The same technique of using a common core system and individual component testing can be applied to the fielding of entirely new systems. The cost savings of such an approach are significant.

Procedure

We needed to develop a profile that would be the worst case of the test data for the entire interior of the shelter. We developed this profile by calculating the power spectral density (PSD) of each time response for each accelerometer from the Munson road test data (random vibration) for each channel of each test. Next, we assembled the peak response of the interior by enveloping all of the responses for the interior of the shelter. Once the PSD was enveloped, we compared the resulting PSD with MIL-STD-810E and made the final component testing recommendations.

A similar approach was also taken for the shock data. From the time response of the static drop and rail impact tests, we calculated the shock response spectrum (SRS) for each location and then enveloped the responses to find the worst-case response within the shelter. The final SRS profile was then compared with MIL-STD-810E.

The assumption was made that any new components would be mounted to the existing system in such a way as not to further amplify the response of the components. It was also assumed that the components would be installed in the existing equipment racks.

Results

Shock

We investigated the shock test results first. The results from both the rail impact (table 1*) and the static drop tests (table 2) were considered in the shock analysis. The SRS for each location inside the shelter was calculated and then assembled into a single matrix for each of the three orthogonal directions (vertical, longitudinal, and transverse). Only the locations inside the shelter were considered for the analysis. The locations consisted of channels 17 to 34 for the rail impact tests (table 3) and channels 11 to 28 for the static drop tests (table 4). The plots of the test results are shown in appendix A, figures A-1 through A-27. The maximum values are the solid lines, and the dotted lines represent the individual responses for each interior location. Following this analysis, we assembled the peak response and plotted the results as shown in figures 1 to 3. Figure 1 is the vertical orientation, figure 2 is the longitudinal orientation, and figure 3 is the transverse orientation.

**Tables and figures appear at the end of the main body of text (pp. 5 ff).*

The LRIP rail impact testing consisted of four tests conducted on the TCAC PIP variant at Aberdeen Proving Ground (APG), Maryland. Combat Systems Test Activity (CSTA) performed the tests in November 1995. The four tests are detailed in table 1. The 30 channels that were instrumented during the rail impact testing are shown in table 3.

The LRIP static drop testing consisted of five tests conducted on the TCAC PIP variant at APG. CSTA performed the tests in November 1995. The five tests are detailed in table 2. Table 4 shows the 24 channels that were instrumented during the static drop testing.

Vibration

We next analyzed the vibration test results. The results from the Munsun road tests (table 5) were considered in this analysis. Both the MEF IAS and TCAC PIP variants were tested, and the results were analyzed separately for each variant. The PSD for each location inside the shelter was calculated and then assembled into a single matrix for each of the three orthogonal directions (vertical, longitudinal, and transverse). Only the locations inside the shelter were considered for the analysis. The locations consisted of channels 1 to 12 for road runs 1 through 9 (table 6), and channels 1 to 12 for road runs 12 through 19 (table 7). The plots of these test results are shown in appendix B, figures B-1 through B-33. The maximum values are the solid lines, and the dotted lines represent the individual responses for each interior location. Following this analysis, we assembled the peak responses for each variant and plotted the results as shown in figures 4 to 9. Figure 4 is the vertical orientation of the MEF IAS, figure 5 is the longitudinal orientation, and figure 6 is the transverse orientation. Similarly, figure 7 is the vertical orientation of the TCAC PIP, figure 8 is the longitudinal orientation, and figure 9 is the transverse orientation.

The PSD results were verified using the following relationship:

$$\sigma^2 = \left\langle x^2\,(t)_{rms} \right\rangle \equiv \int_0^\infty S(f)_{rms}\,df$$

$$\sim \sum_{\Delta f} S(f)_{rms}\,\Delta f \quad .$$

The LRIP Munsun road testing consisted of 19 tests (11 were analyzed) conducted on the TCAC PIP and MEF IAS variants at Hughes Road Test Facility, California. Honeywell performed the tests in October 1994. The 11 tests are detailed in table 5. Tables 6 and 7 show the 12 channels that were instrumented during the road testing.

Conclusion

A comparison of the test results from this analysis with the profiles from MIL-STD-810E shows that generally the profiles from MIL-STD-810E (fig. 10–13) are more rigorous than the test data. In some instances, however, the actual environment is more severe than the MIL-STD-810E profiles. It should be noted that MIL-STD-810E is suggested input if no data are available and that the profiles in MIL-STD-810E are for inputs to an entire system and not for individual components.

The SRS plots shown in figures 1 to 3 should be used to test any components that need to be installed in the MEF IAS or TCAC PIP. If the components pass these tests, then it is reasonable to assume that the components would survive within the system during a complete system test.

The PSD plots shown in figures 4 to 6 should be used to define tests for any components that may be installed in the MEF IAS. If the components pass these tests, then it is reasonable to assume that the components would survive within the system during a complete system test.

Finally, the PSD plots shown in figures 7 to 9 should be used to define tests for any components that may be installed in the TCAC PIP. If the components pass these tests, then it is reasonable to assume that the components would survive within the system during a complete system test.

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Table 1. Rail impact tests.

Test	Speed (mph)
1	4.0 forward
2	6.2 forward
3	8.2 forward
4	8.0 reverse

Table 2. Static drop tests.

Test	Orientation
1	Flat
2	Front
3	Rear
4	Curbside
5	Roadside

Table 3. Channel locations for rail impact tests (TCAC PIP).

Channel	Orientation	Location
5	Longitudinal	ECU
6	Transverse	ECU
7	Vertical	ECU
8	Transverse	Shelter ECU frame
9	Longitudinal	Shelter ECU frame
10	Vertical	Shelter ECU frame
11	Longitudinal	HMMWV frame
12	Transverse	HMMWV frame
13	Vertical	HMMWV frame
14	Longitudinal	Floor outside
15	Transverse	Floor outside
16	Vertical	Floor outside
17	Longitudinal	CS rear rack
18	Transverse	CS rear rack
19	Vertical	CS rear rack
20	Longitudinal	CS front rack
21	Transverse	CS front rack
22	Vertical	CS front rack
23	Transverse	BOT disk drive
24	Longitudinal	BOT disk drive
25	Vertical	BOT disk drive
26	Longitudinal	Rack near keyboard
27	Transverse	Rack near keyboard
28	Vertical	Rack near keyboard
29	Longitudinal	RS rack printer
30	Transverse	RS rack printer
31	Vertical	RS rack printer
32	Longitudinal	LG printer base
33	Transverse	LG printer base
34	Vertical	LG printer base

ECU = environmental control unit
HMMWV = high-mobility multipurpose wheeled vehicle
CS = curbside
BOT = bottom
RS = roadside
LG = large

Table 4. Channel locations for static drop tests (TCAC PIP).

Channel	Orientation	Location
5	Longitudinal	HMMWV frame
6	Transverse	HMMWV frame
7	Vertical	HMMWV frame
8	Longitudinal	Floor outside
9	Transverse	Floor outside
10	Vertical	Floor outside
11	Longitudinal	CS rear rack
12	Transverse	CS rear rack
13	Vertical	CS rear rack
14	Longitudinal	CS front rack
15	Transverse	CS front rack
16	Vertical	CS front rack
17	Transverse	BOT disk drive
18	Longitudinal	BOT disk drive
19	Vertical	BOT disk drive
20	Longitudinal	Rack near keyboard
21	Transverse	Rack near keyboard
22	Vertical	Rack near keyboard
23	Longitudinal	RS rack printer
24	Transverse	RS rack printer
25	Vertical	RS rack printer
26	Longitudinal	LG printer
27	Transverse	LG printer
28	Vertical	LG printer

Table 5. Munson road tests.

Run	Description	Speed (mph)	Variant
1	Belgian block	20	MEF IAS
3	Spaced bumps	20	MEF IAS
5	Radial washboard	15	MEF IAS
7	Two-inch washboard	10	MEF IAS
9	Six-inch washboard	5	MEF IAS
12	Belgian block	20	TCAC PIP
13	Spaced bumps	20	TCAC PIP
15	Radial washboard	15	TCAC PIP
16	Two-inch washboard	10	TCAC PIP
18	Six-inch washboard	5	TCAC PIP
19	Pot holes	15	TCAC PIP

Table 6. Channel locations for road runs 1–9.

Channel	Orientation	Location
1	Vertical	Left rear corner
2	Vertical	Center plotter
3	Longitudinal	Left front corner
4	Vertical	Center rack
5	Transverse	Right front corner
6	Vertical	Right rear rack
7	Vertical	Right rear corner
8	Vertical	Center under A/C
9	Transverse	Center rack
10	Longitudinal	Center rack
11	Transverse	Right rear rack
12	Longitudinal	Right rear rack

A/C = air conditioner

Table 7. Channel locations for road runs 12–19.

Channel	Orientation	Location
1	Vertical	Left rear corner
2	Longitudinal	A/C compressor top
3	Longitudinal	Left front corner
4	Vertical	Center rack
5	Vertical	Generator engine mount
6	Vertical	Right rear rack
7	Vertical	Right rear corner
8	Vertical	A/C compressor top
9	Transverse	Center rack
10	Longitudinal	Center rack
11	Transverse	Right rear rack
12	Longitudinal	Right rear rack

Figure 1. Shock response spectrum (SRS): vertical envelope.

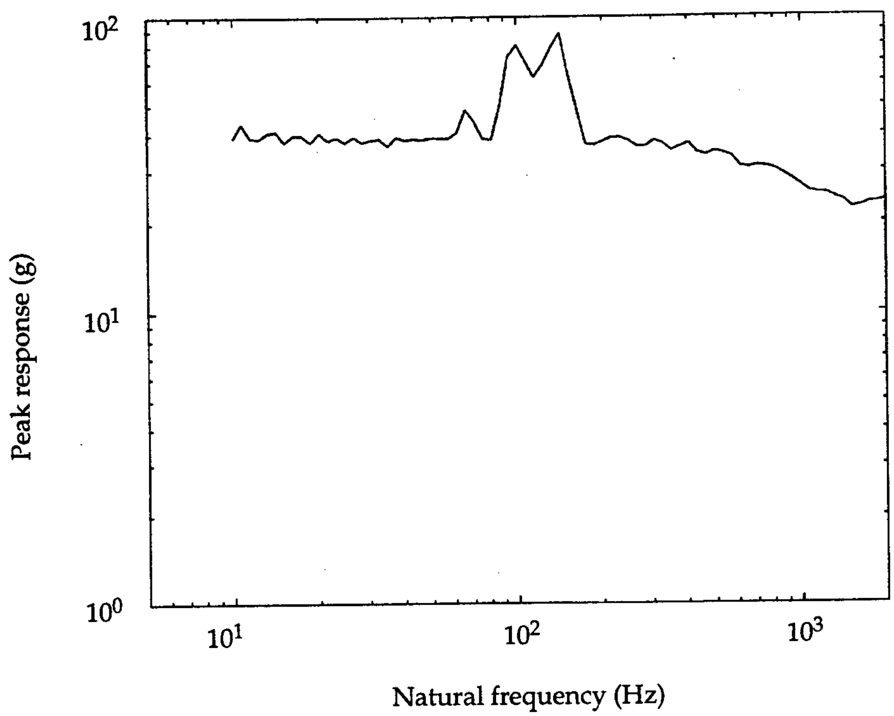
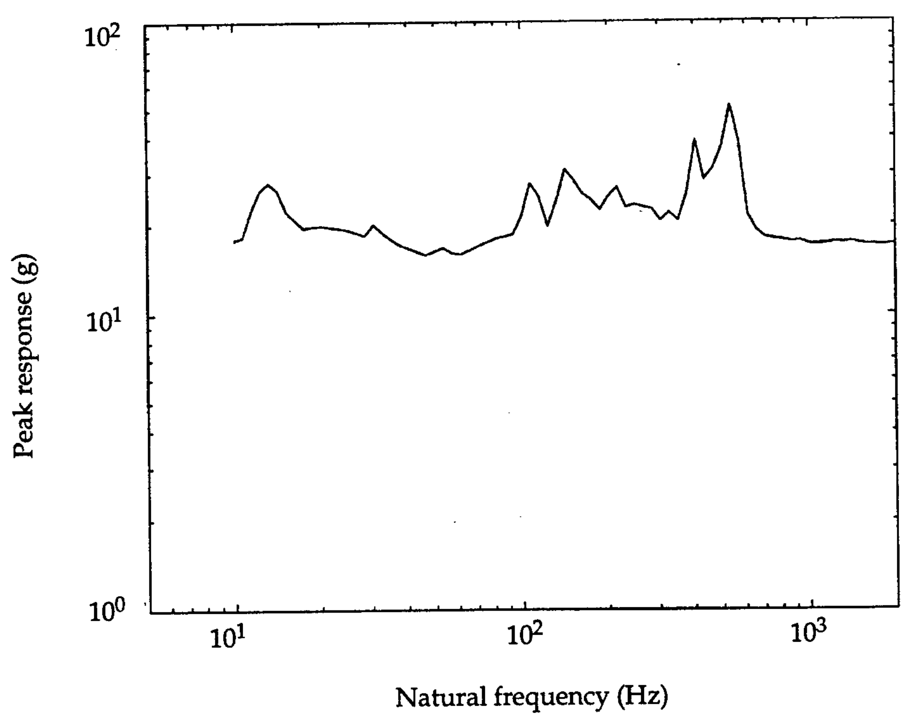


Figure 2. SRS: longitudinal envelope.



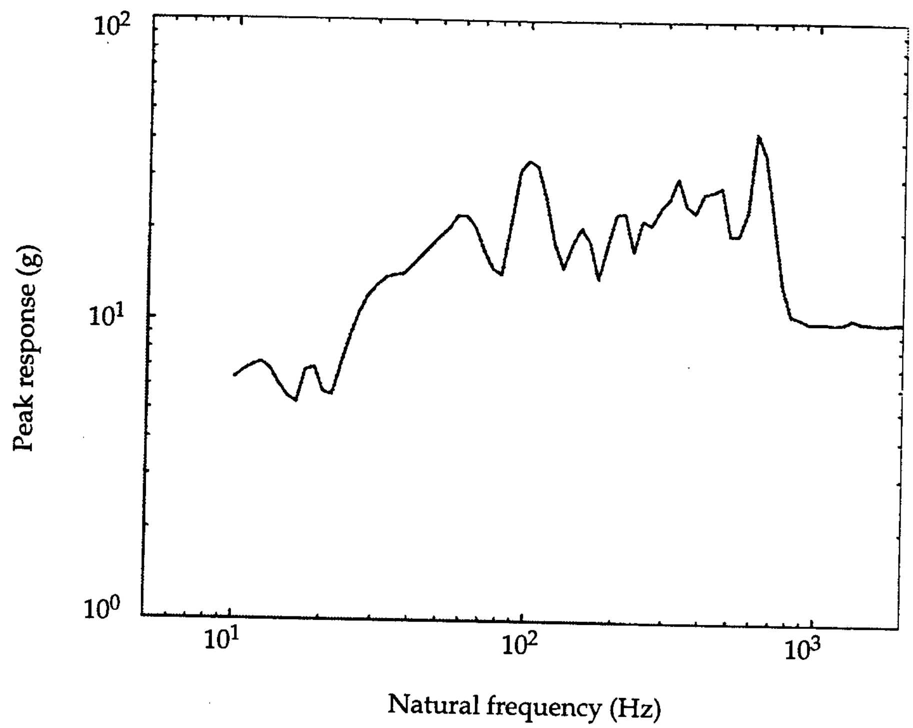


Figure 3. SRS: transverse envelope.

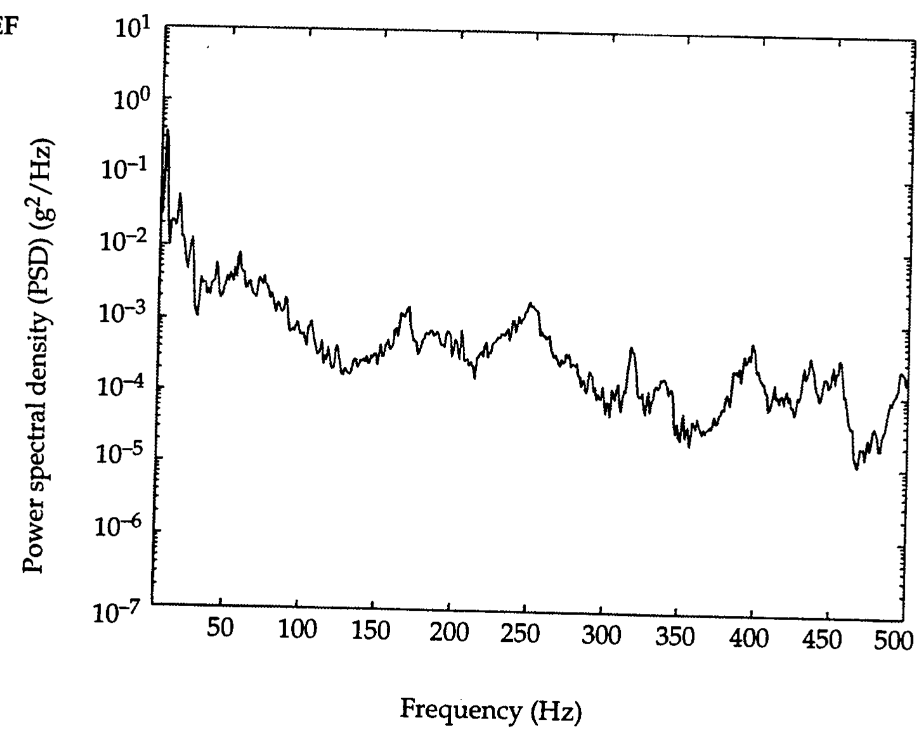


Figure 4. Vertical: MEF IAS—road data.

Figure 5. Longitudinal: MEF IAS—road data.

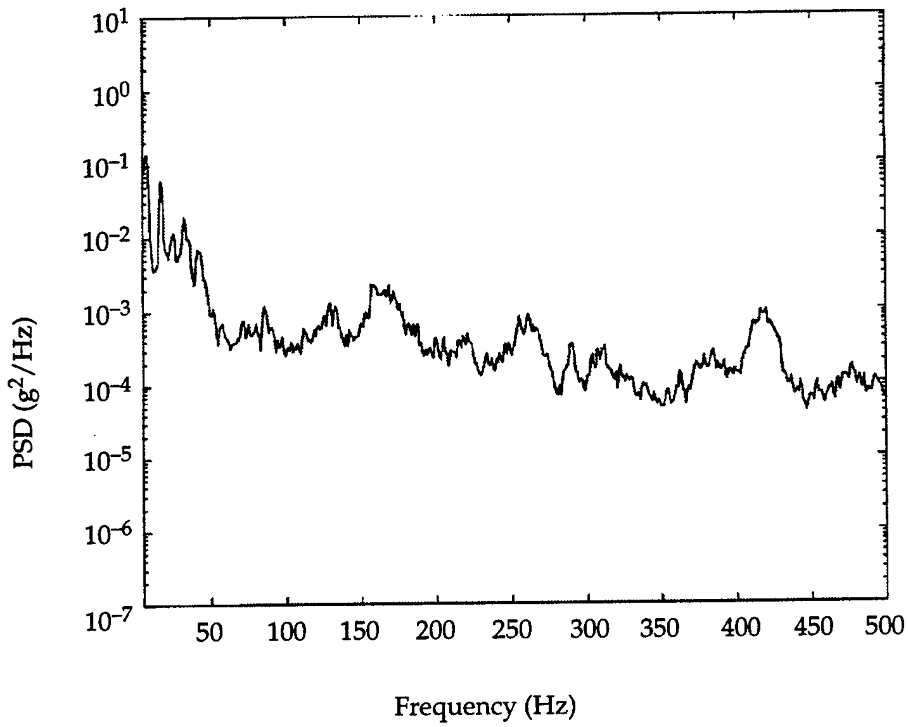


Figure 6. Transverse: MEF IAS—road data.

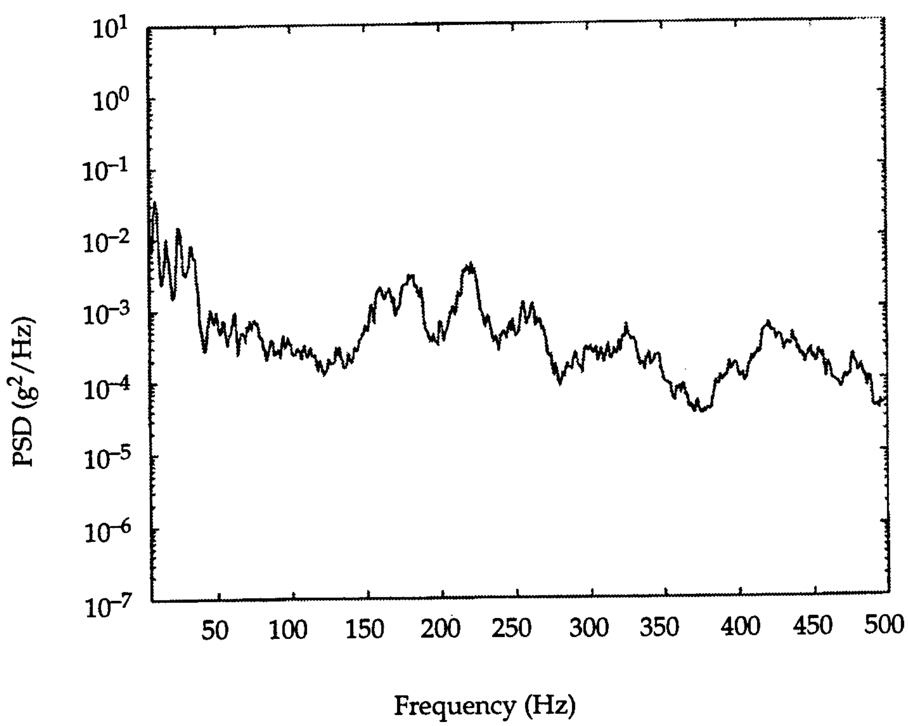


Figure 7. Vertical: TCAC PIP—road data.

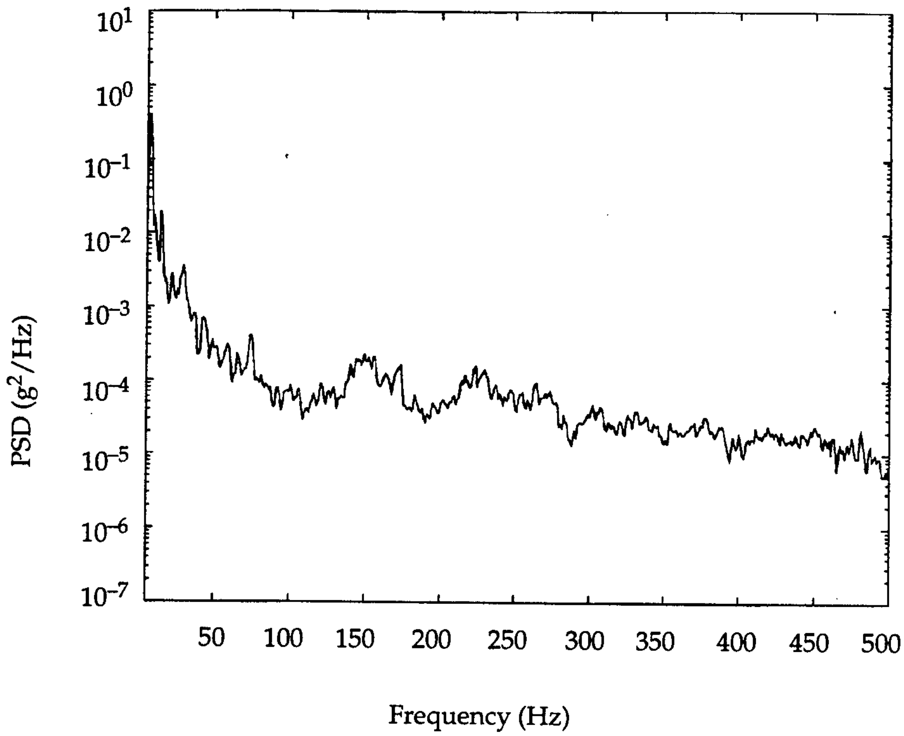


Figure 8. Longitudinal: TCAC PIP—road data.

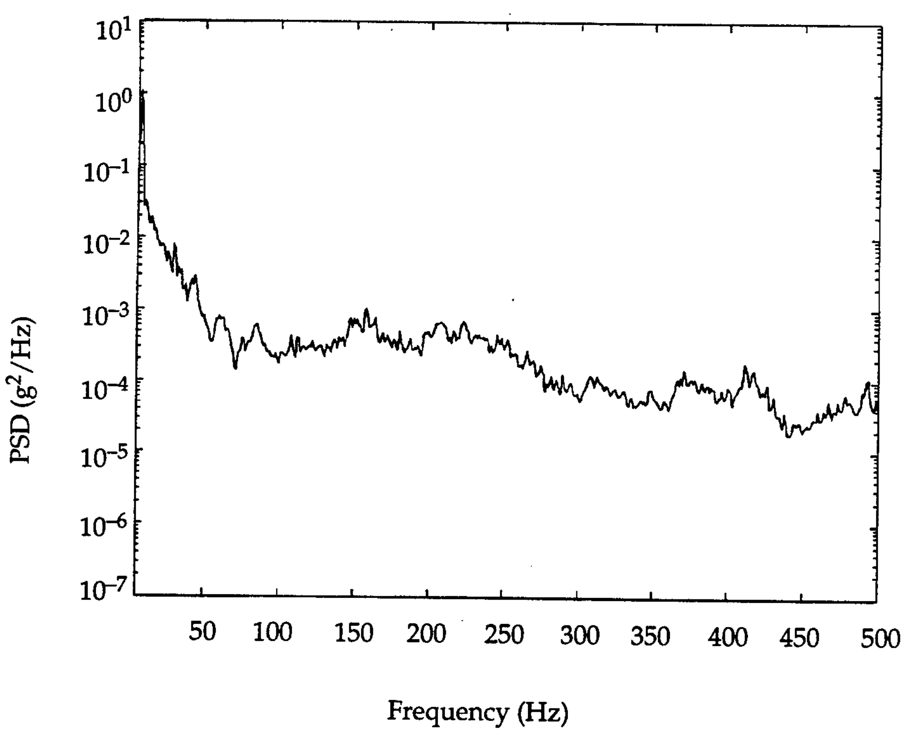


Figure 9. Transverse: TCAC PIP—road data.

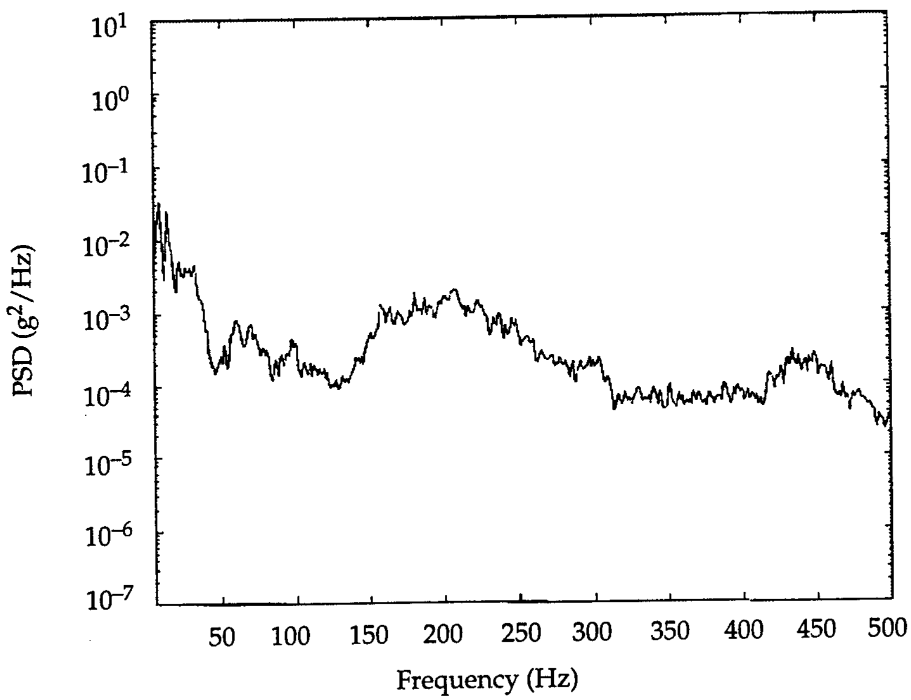
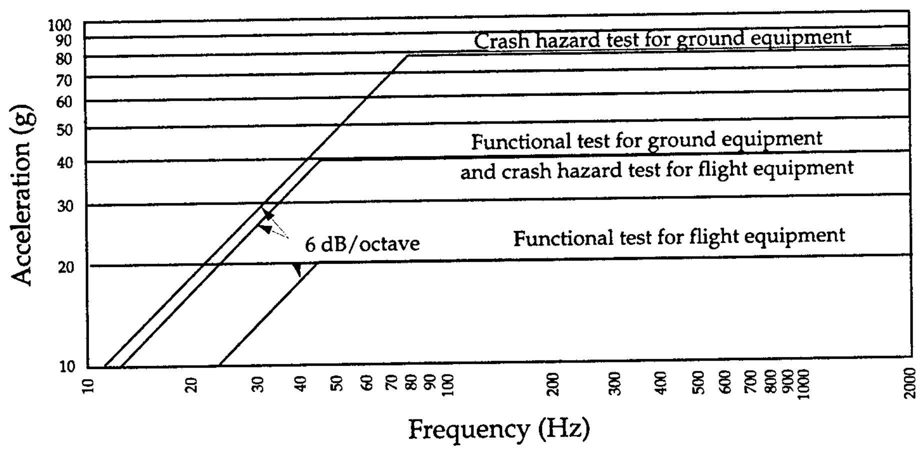
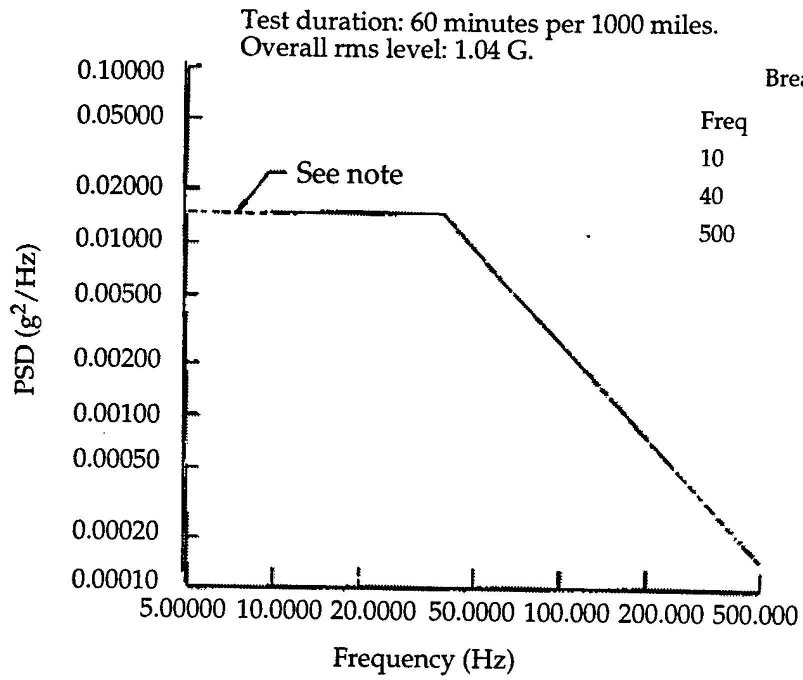


Figure 10. MIL-STD-810E: shock spectrum.



Test procedure	Peak acceleration (g)	T_E (ms)	Crossover frequency (Hz)
Functional test for flight equipment	20	6–9	45
Functional test for ground equipment	40	6–9	45
Crash hazard test for flight equipment	40	6–9	45
Crash hazard test for ground equipment	75	3.5–5	80

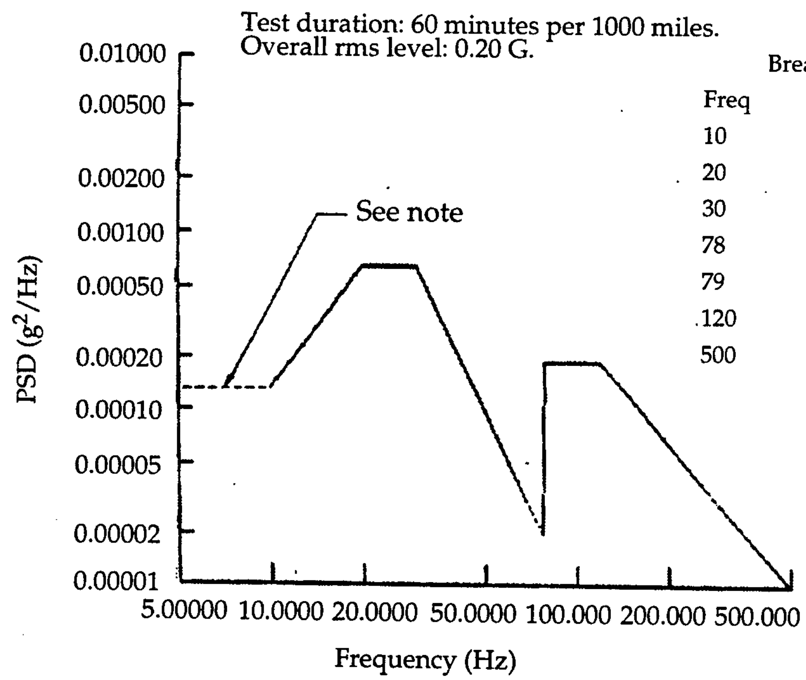
Figure 11. MIL-STD-810E vibration spectrum: overall rms level = 1.04 G.



Breakpoints

Freq	PSD value
10	0.01500
40	0.01500
500	0.00015

Figure 12. MIL-STD-810E vibration spectrum: overall rms level = 0.20 G.

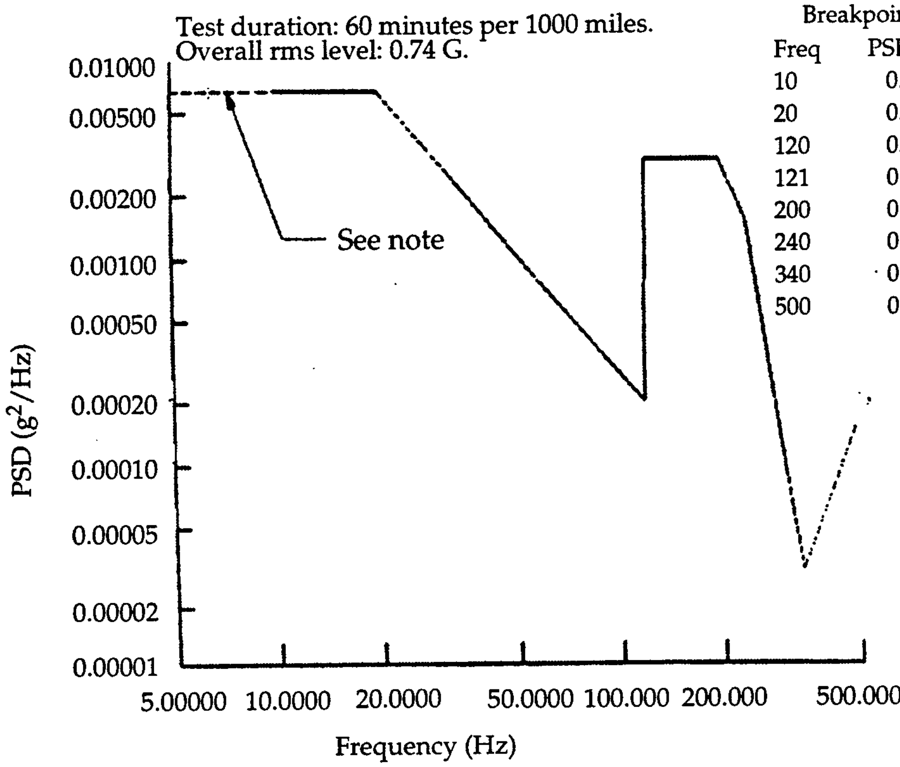


Breakpoints

Freq	PSD value
10	0.00013
20	0.00065
30	0.00065
78	0.00002
79	0.00019
120	0.00019
500	0.00001

Note: If the test item is resonant below 10 Hz, extend the curve to the lowest resonant frequency.

Figure 13. MIL-STD-810E vibration spectrum: overall rms level = 0.74 G.



Breakpoints

Freq	PSD value
10	0.00650
20	0.00650
120	0.00020
121	0.00300
200	0.00300
240	0.00150
340	0.00003
500	0.00015

Note: If the test item is resonant below 10 Hz, extend the curve to the lowest resonant frequency.

Appendix A. Plots of Shock Test Results

These plots show the results of shock tests on the Marine Expeditionary Force Intelligence Analysis System (MEF IAS) and the Technical Control and Analysis Center Product Improvement Program (TCAC PIP) command, control, and intelligence (C^2I) systems. The maximum values are the solid lines, and the dotted lines represent the individual responses for each interior location.

Figure A-1. Rail 1 SRS: vertical envelope.

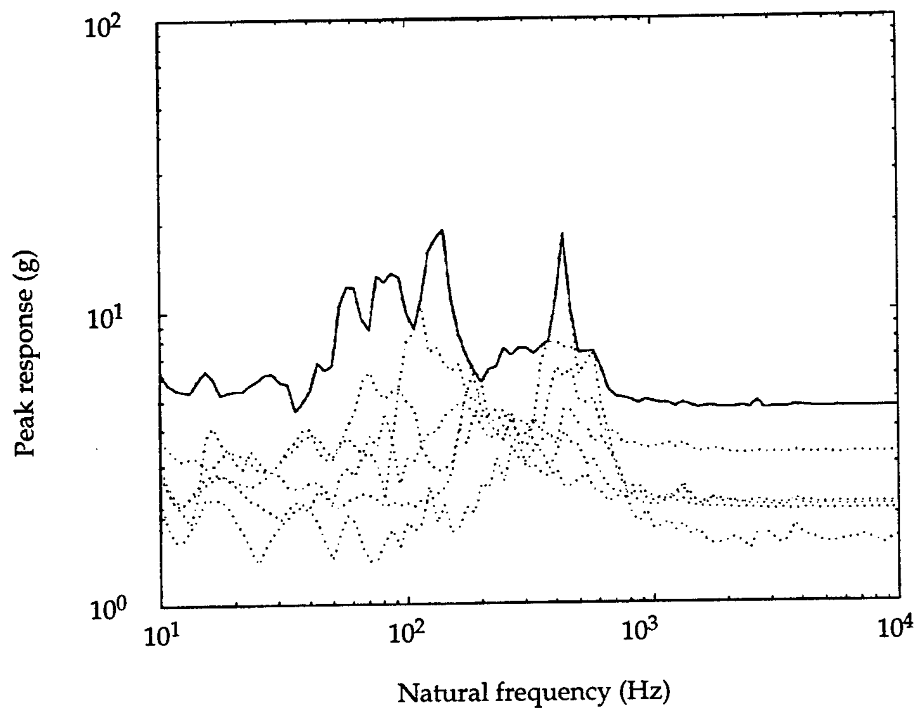


Figure A-2. Rail 2 SRS: vertical envelope.

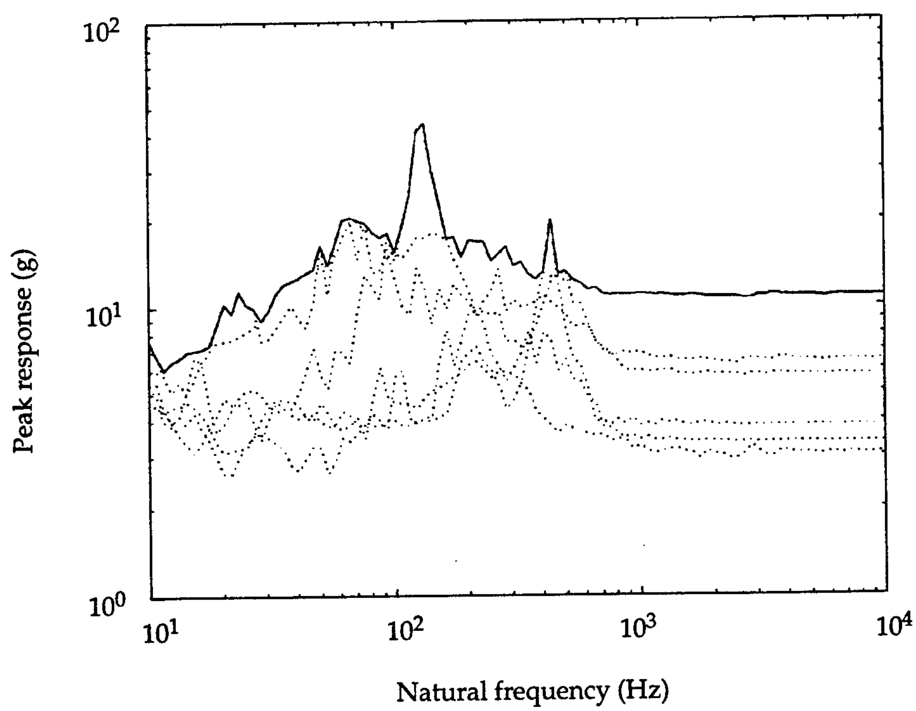


Figure A-3. Rail 3 SRS: vertical envelope.

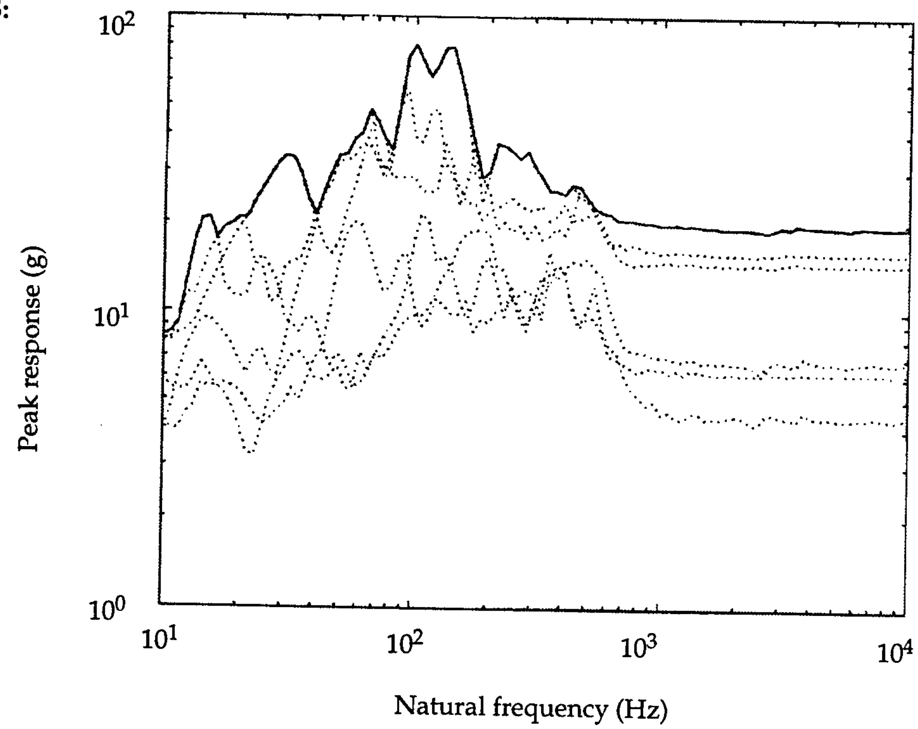


Figure A-4. Rail 4 SRS: vertical envelope.

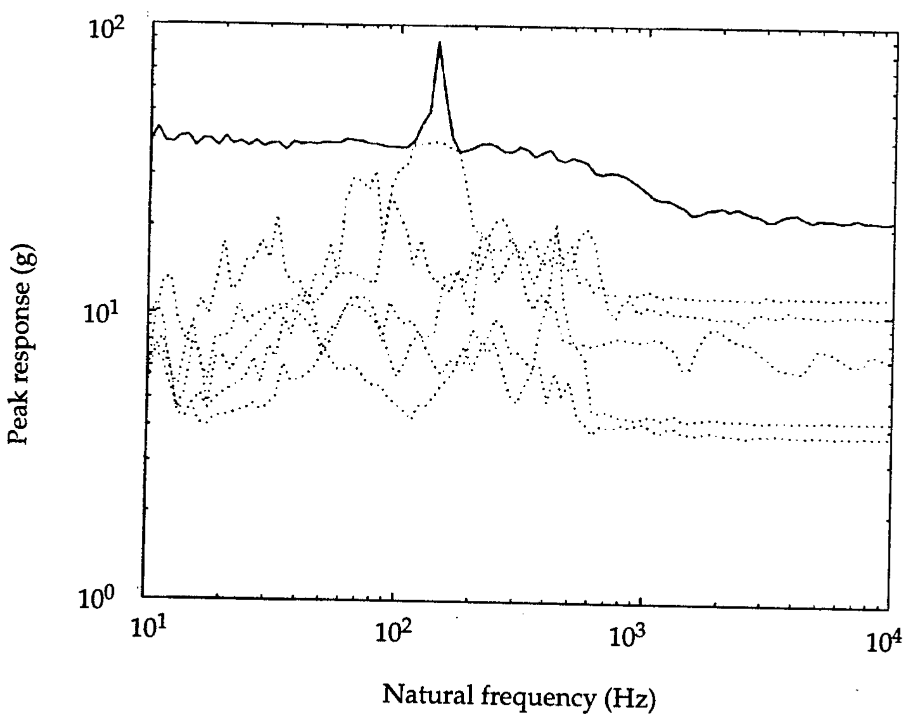


Figure A-5. Drop 1 SRS: vertical envelope.

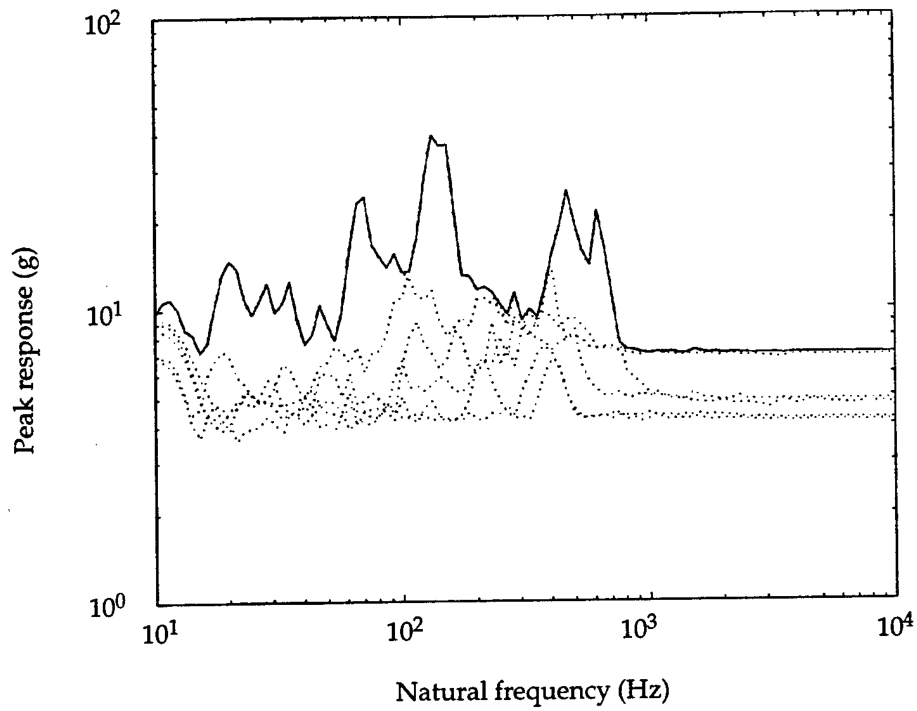


Figure A-6. Drop 2 SRS: vertical envelope.

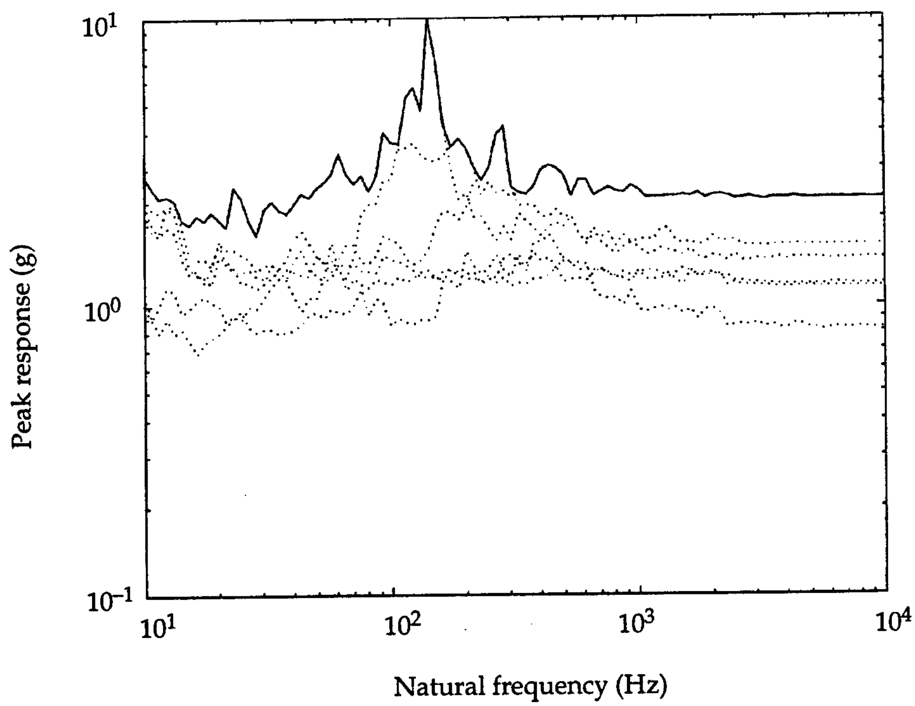


Figure A-7. Drop 3 SRS: vertical envelope.

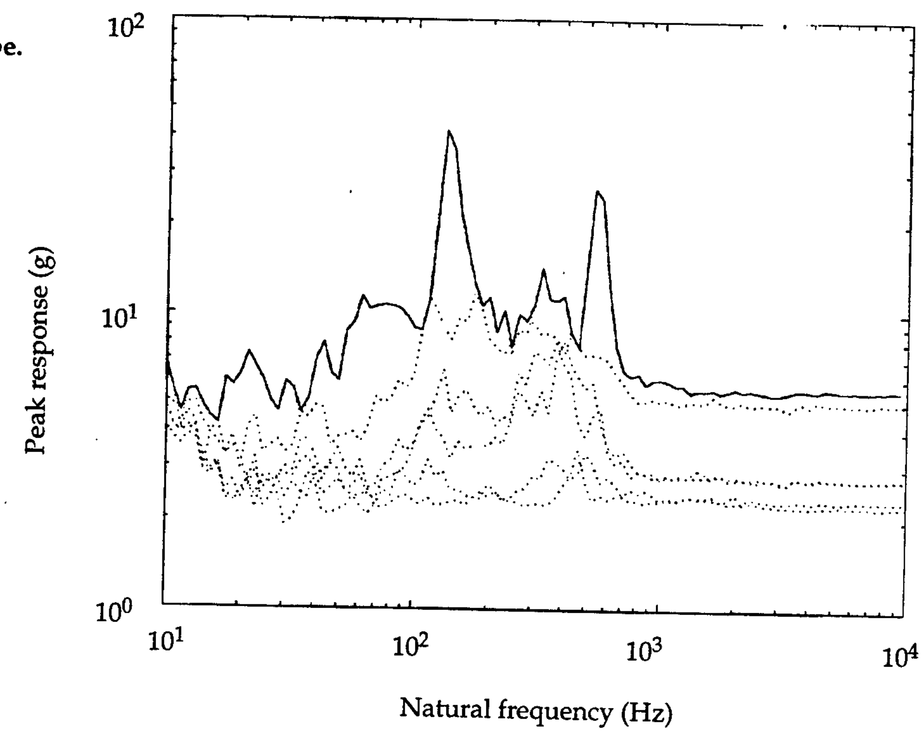


Figure A-8. Drop 4 SRS: vertical envelope.

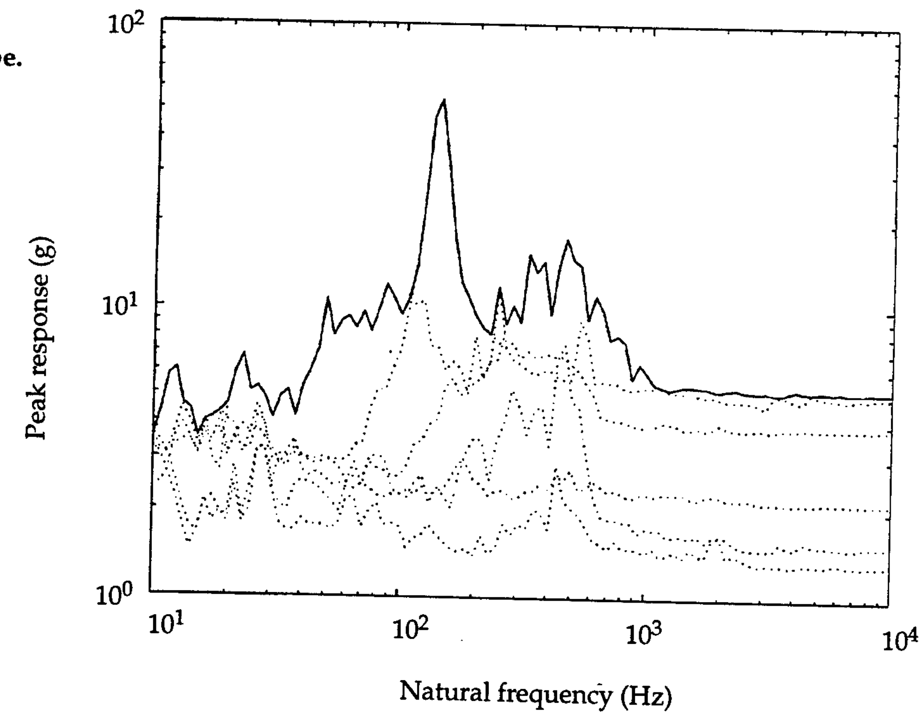


Figure A-9. Drop 5 SRS: vertical envelope.

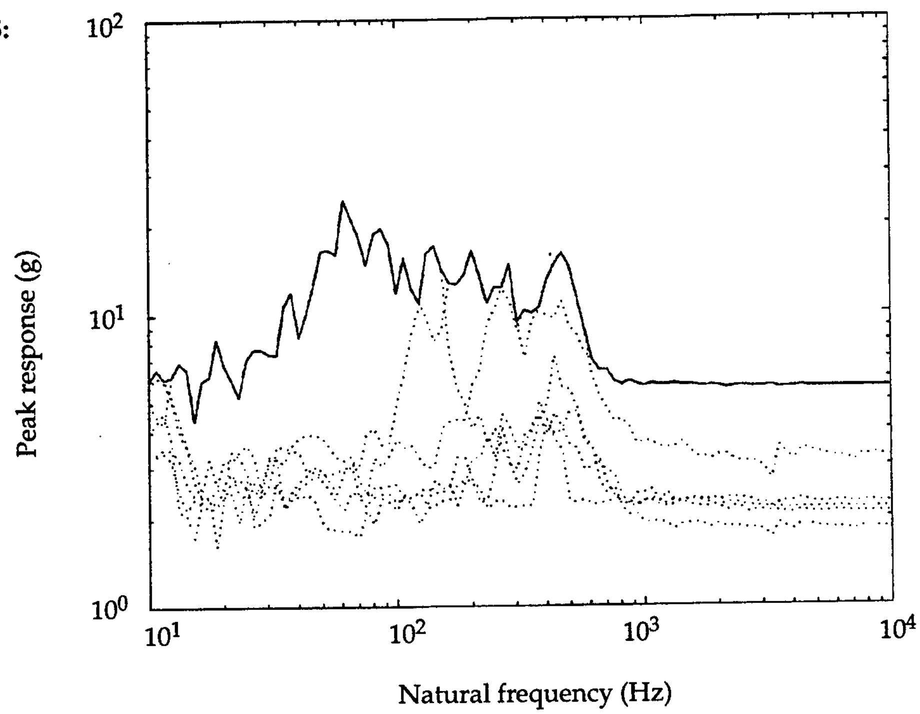


Figure A-10. Rail 1 SRS: longitudinal envelope.

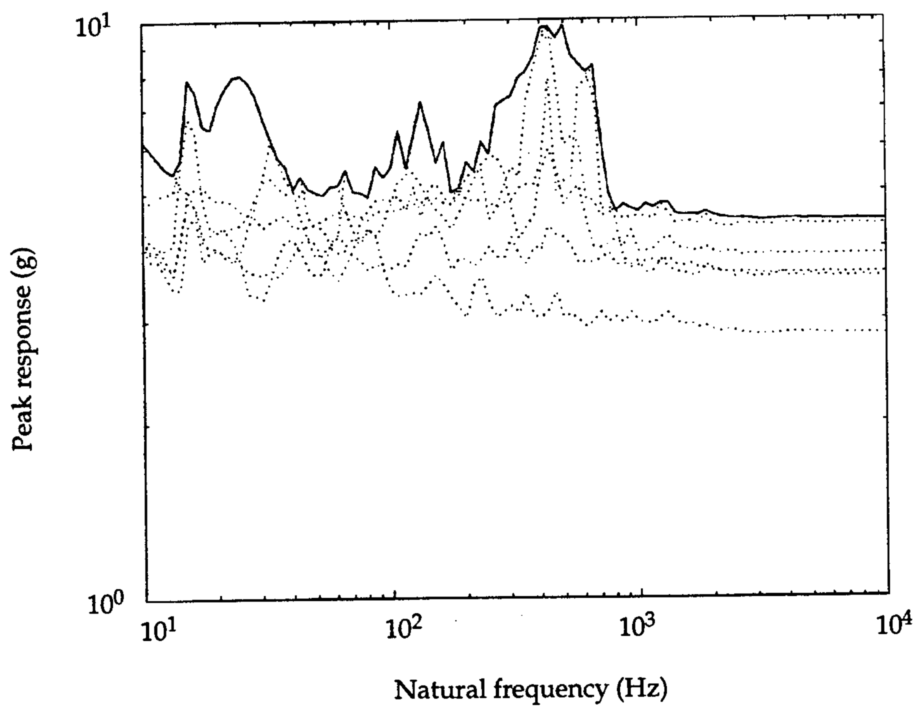


Figure A-11. Rail 2 SRS: longitudinal envelope.

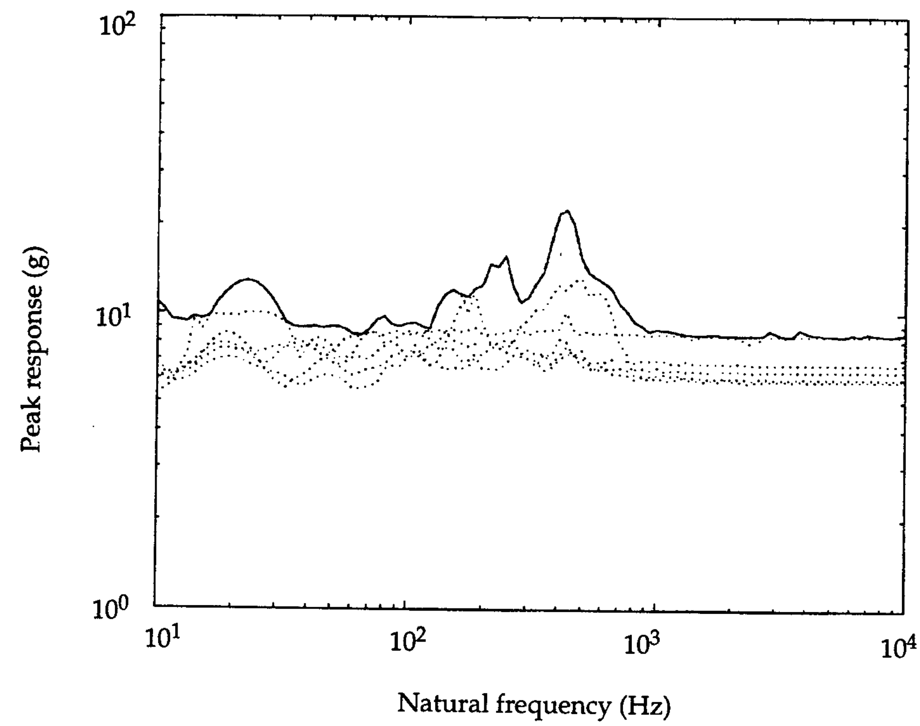


Figure A-12. Rail 3 SRS: longitudinal envelope.

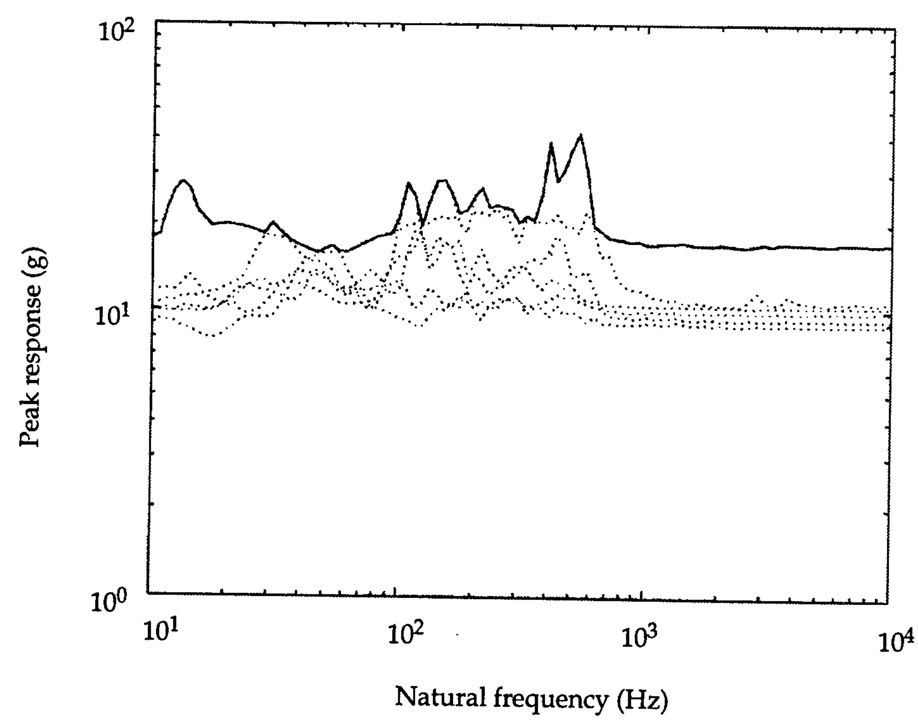


Figure A-13. Rail 4 SRS: longitudinal envelope.

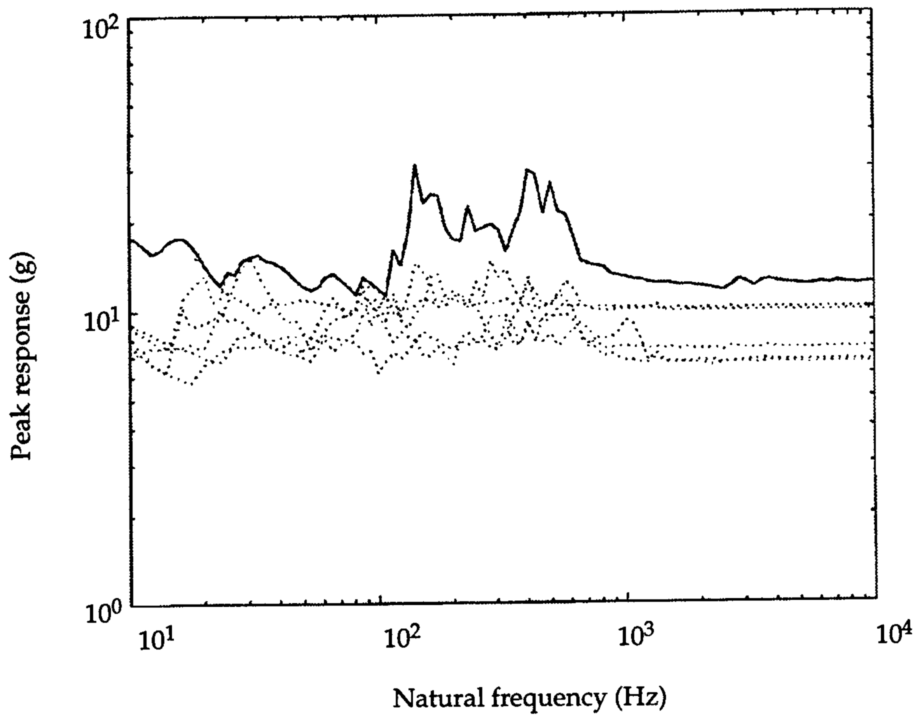


Figure A-14. Drop 1 SRS: longitudinal envelope.

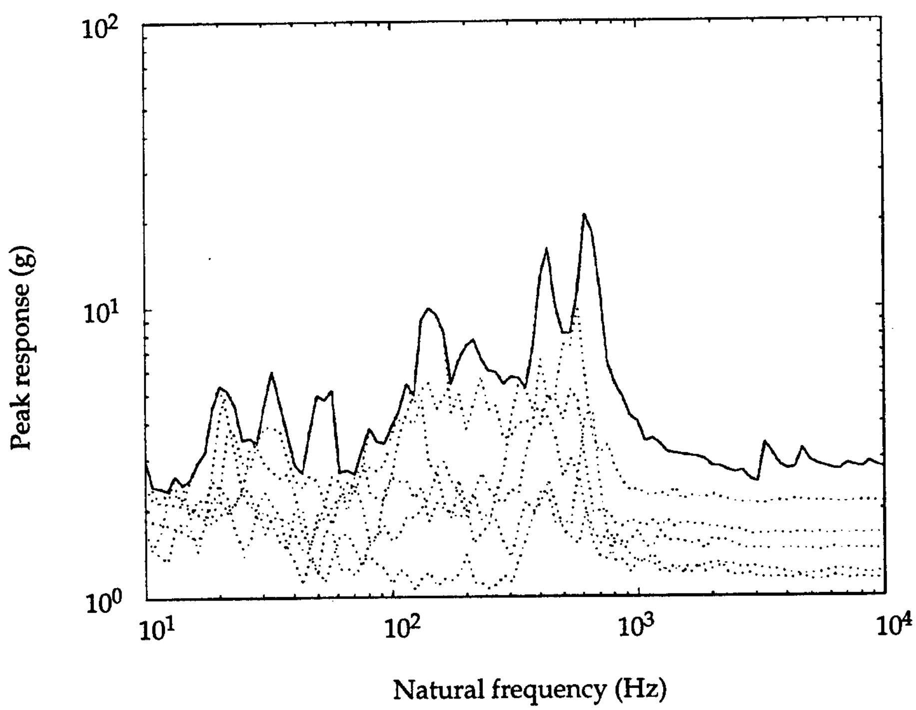


Figure A-15. Drop 2 SRS: longitudinal envelope.

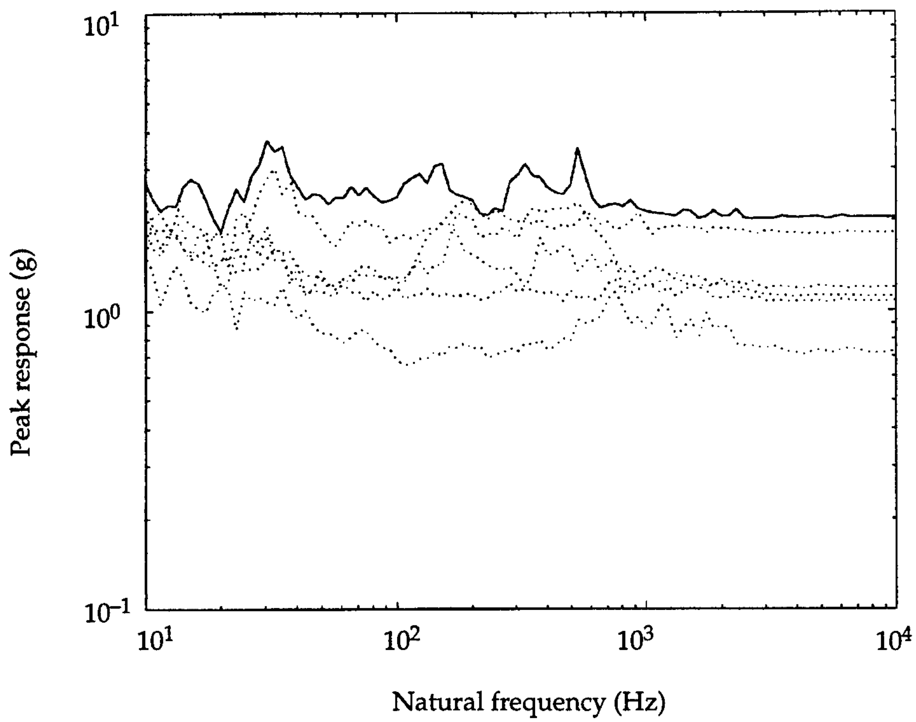


Figure A-16. Drop 3 SRS: longitudinal envelope.

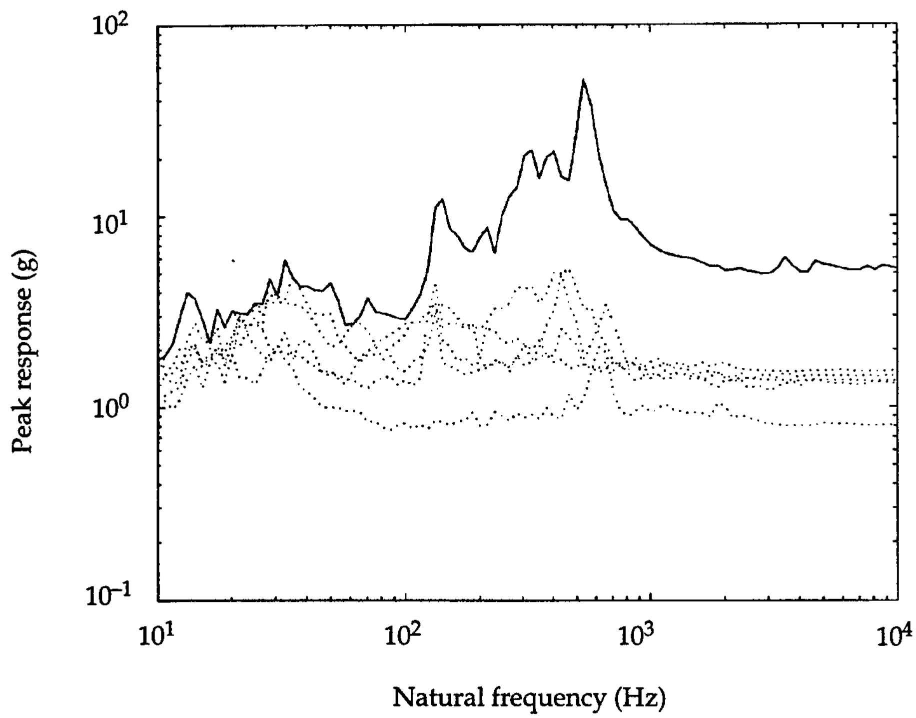


Figure A-17. Drop 4 SRS: longitudinal envelope.

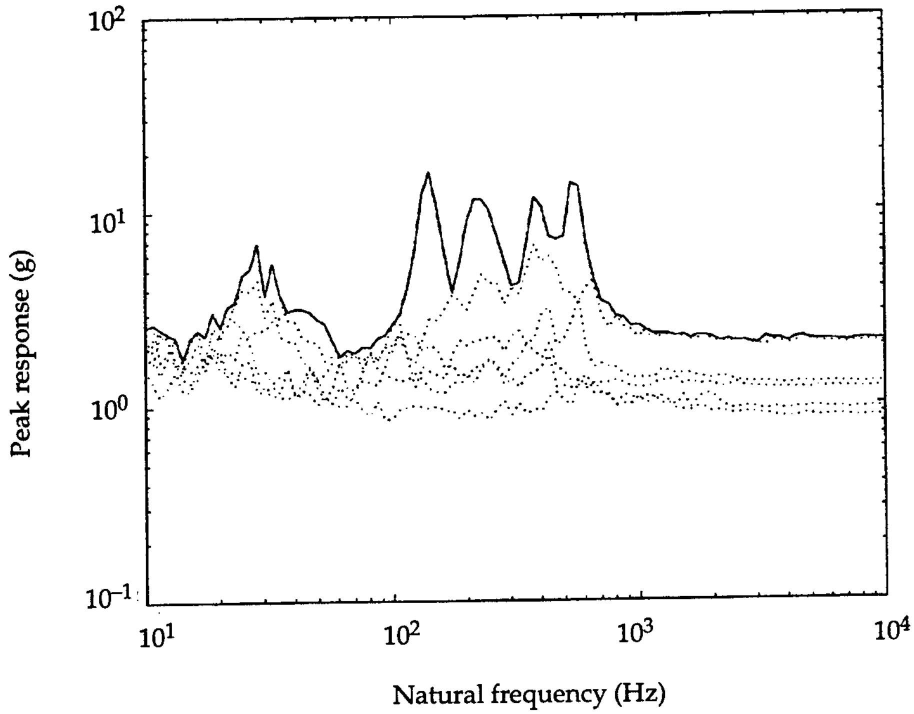


Figure A-18. Drop 5 SRS: longitudinal envelope.

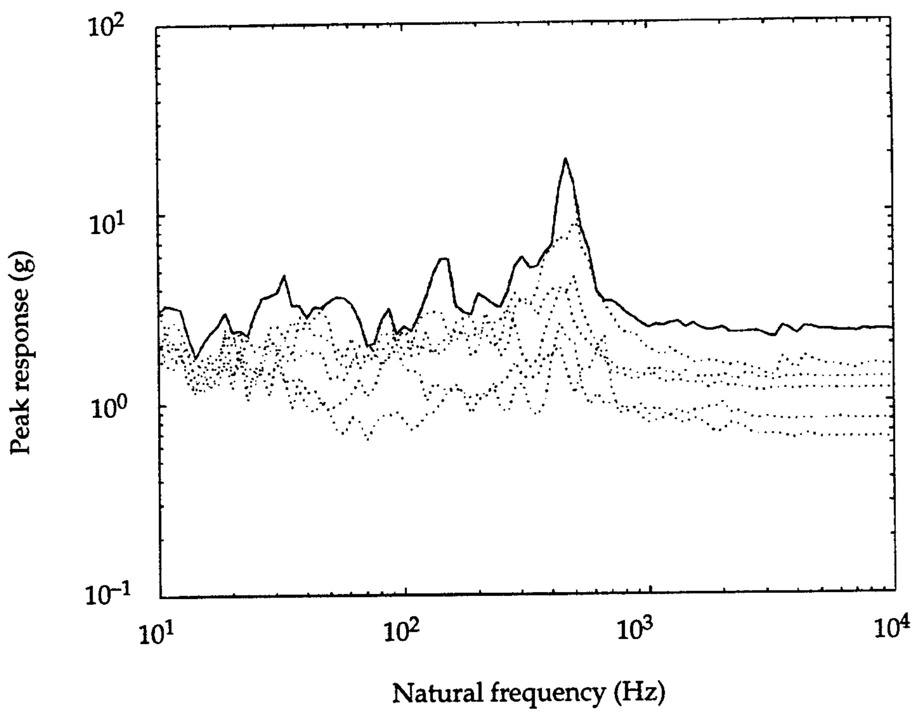


Figure A-19. Rail 1 SRS: transverse envelope.

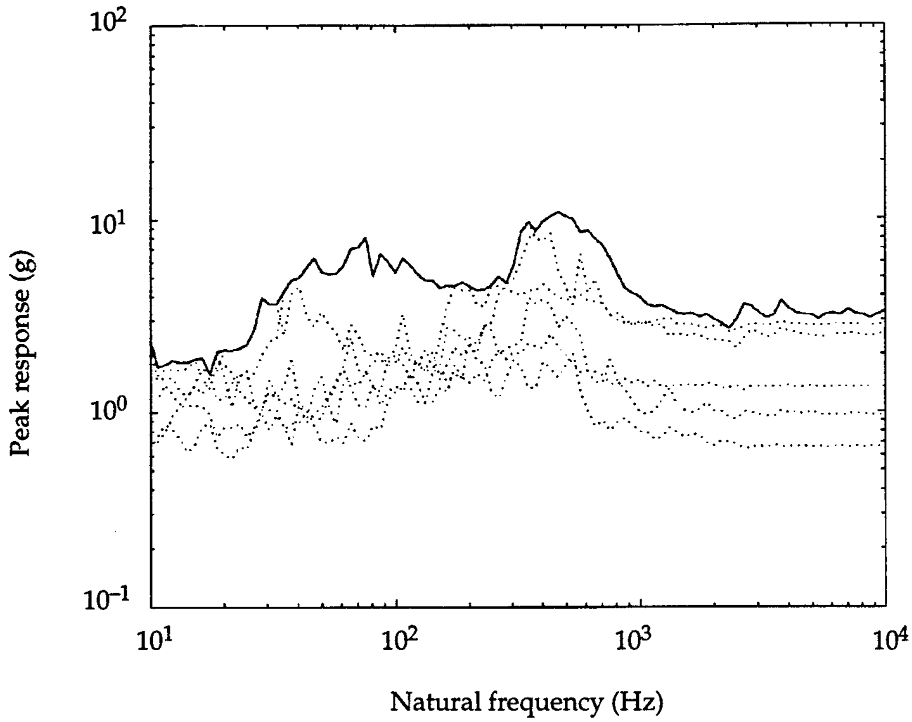


Figure A-20. Rail 2 SRS: transverse envelope.

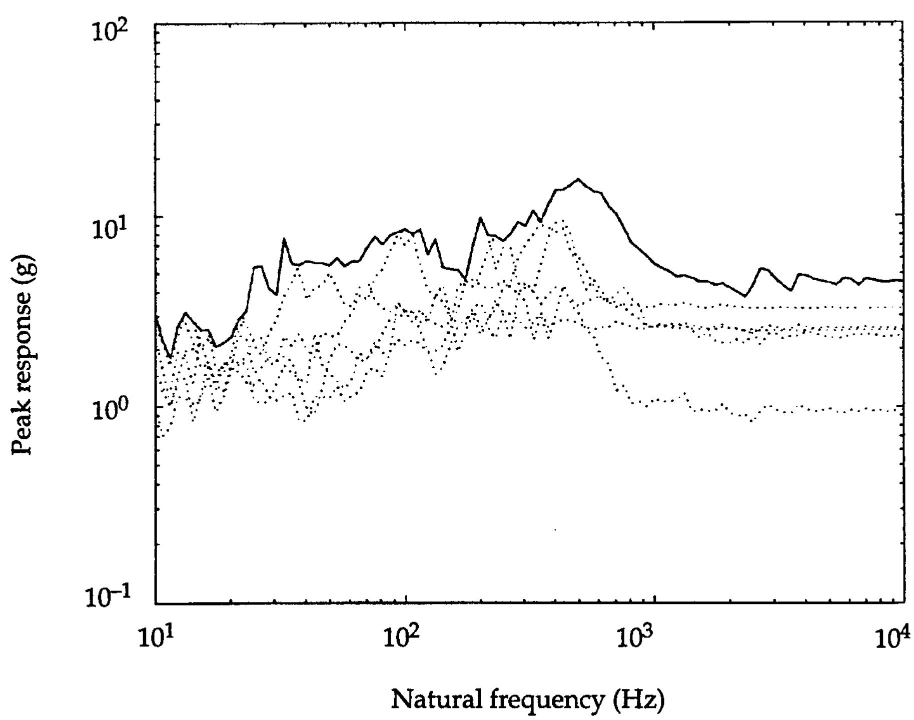


Figure A-21. Rail 3 SRS: transverse envelope.

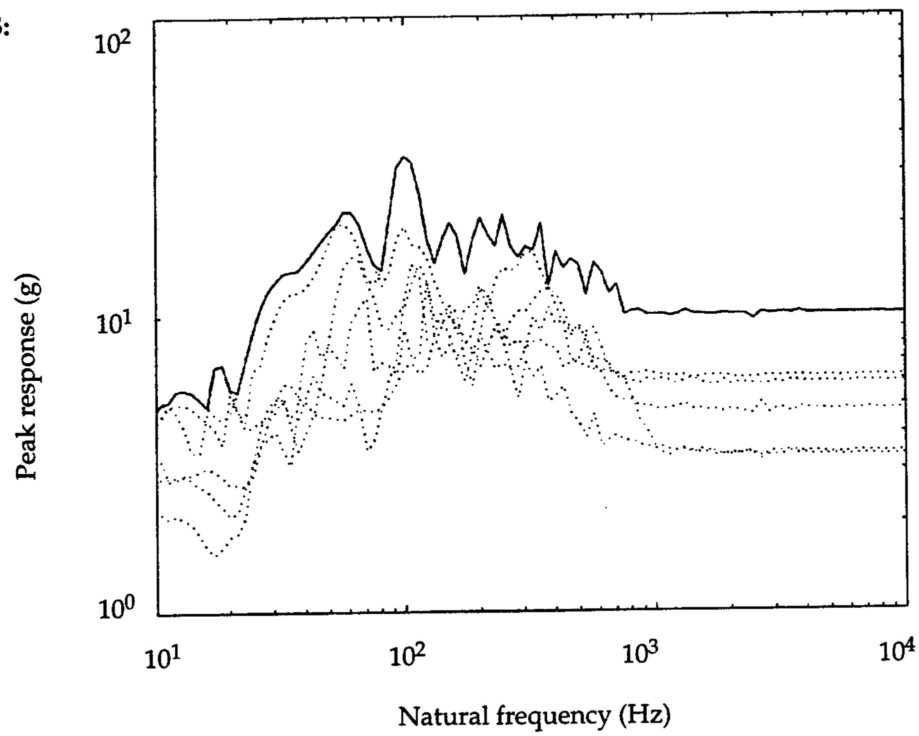
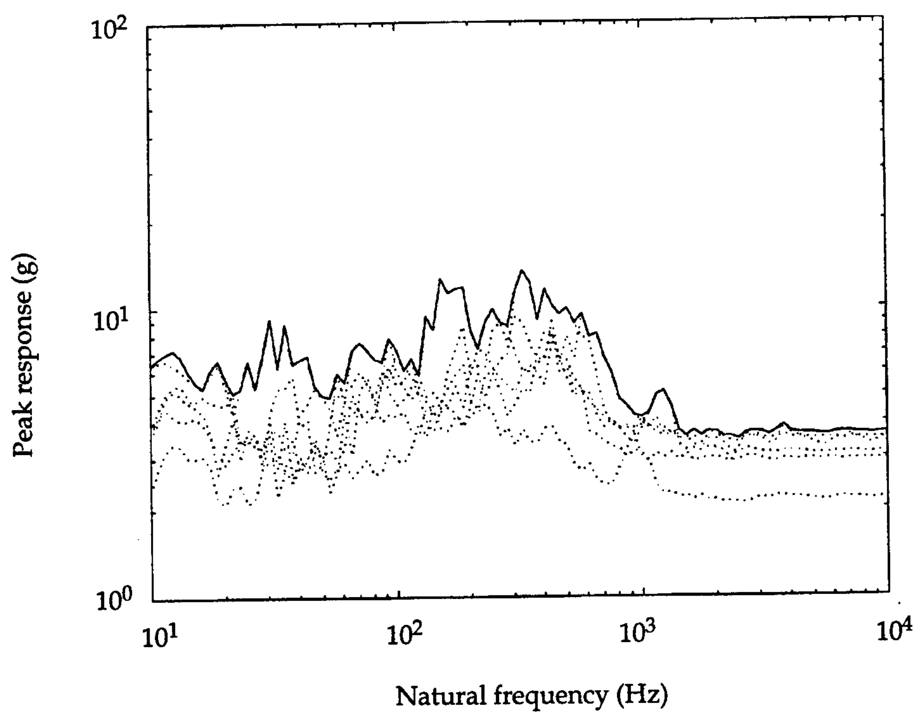


Figure A-22. Rail 4 SRS: transverse envelope.



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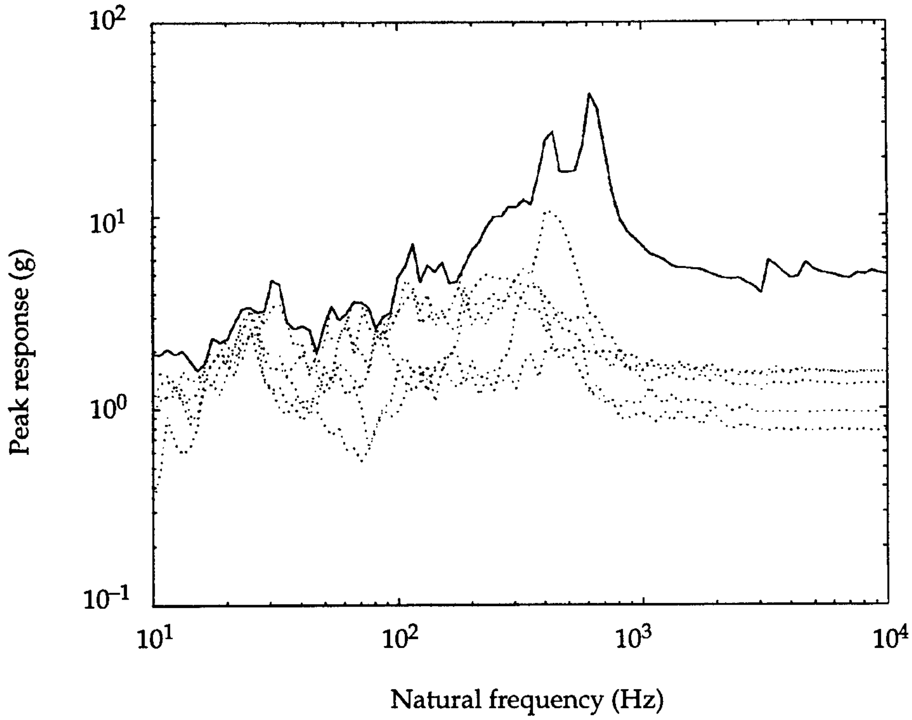


Figure A-24. Drop 2 SRS: transverse envelope.

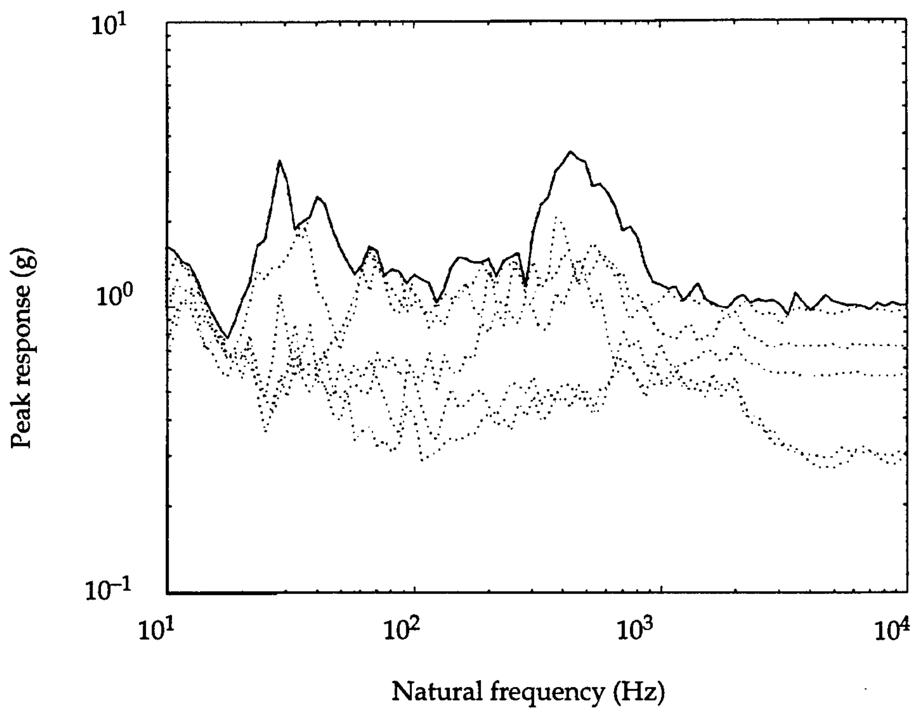


Figure A-25. Drop 3 SRS: transverse envelope.

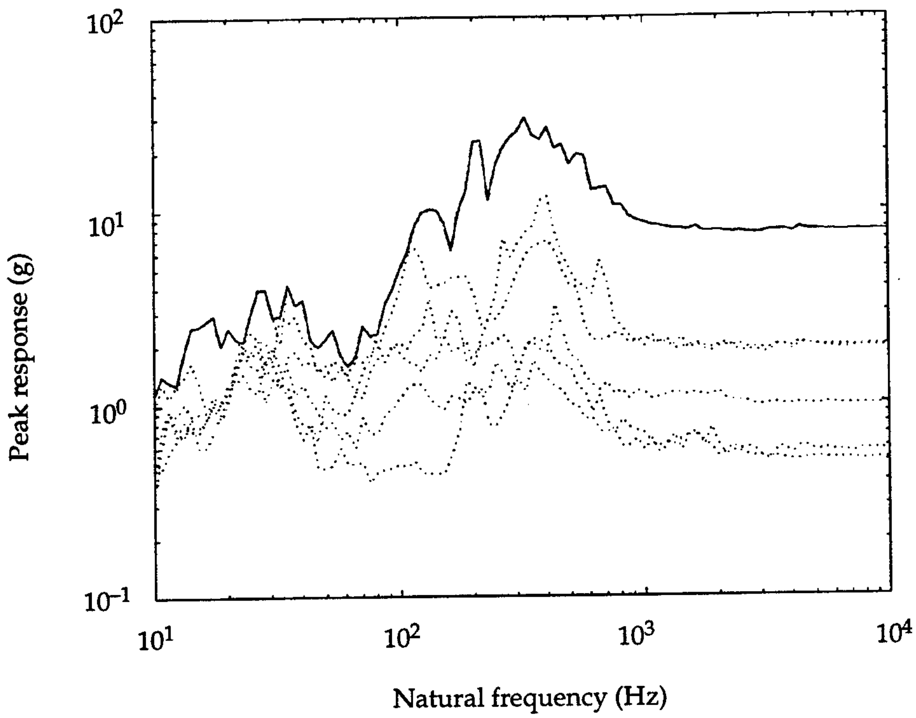


Figure A-26. Drop 4 SRS: transverse envelope.

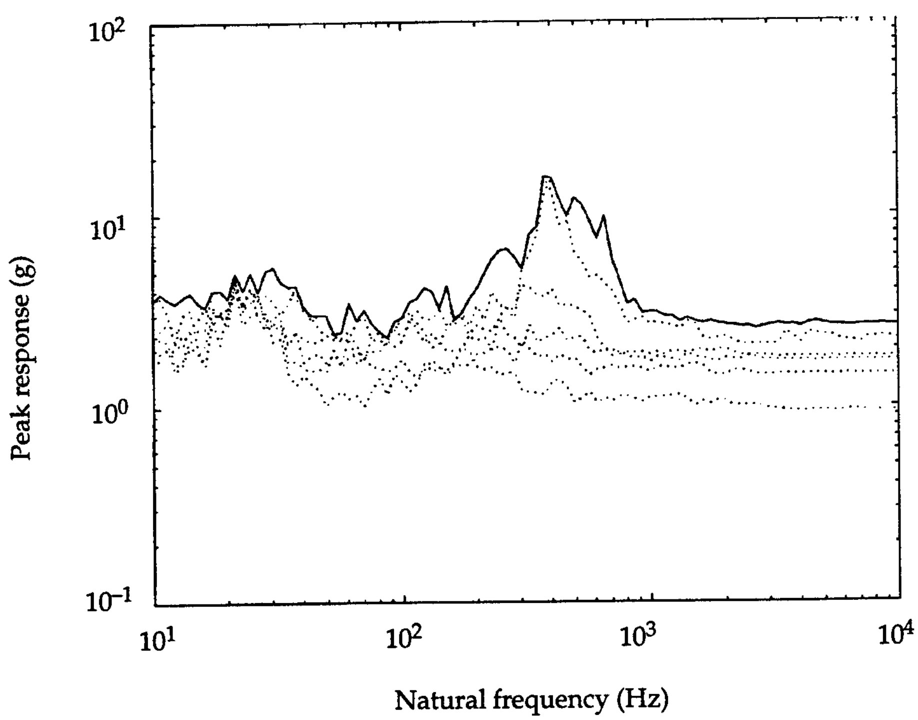
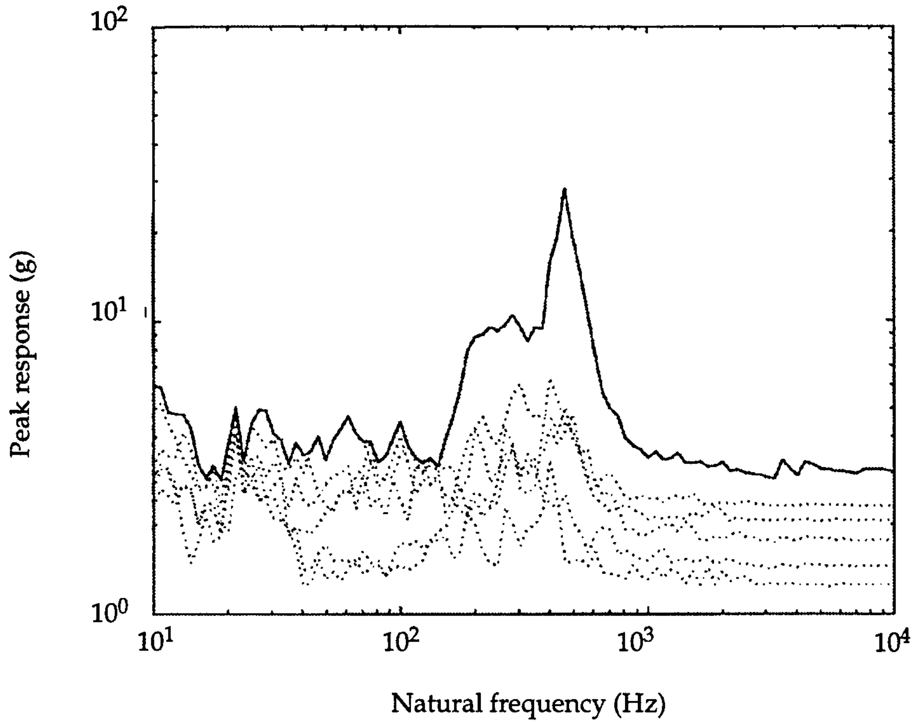


Figure A-27. Drop 5 SRS: transverse envelope.



Appendix B. Plots of Vibration Test Results

These plots show the results of vibration tests on the Marine Expeditionary Force Intelligence Analysis System (MEF IAS) and the Technical Control and Analysis Center Product Improvement Program (TCAC PIP) command, control, and intelligence (C^2I) systems. The maximum values are the solid lines, and the dotted lines represent the individual responses for each interior location.

Figure B-1. Vertical: IAS—Belgian block at 20 mph (ROAD001).

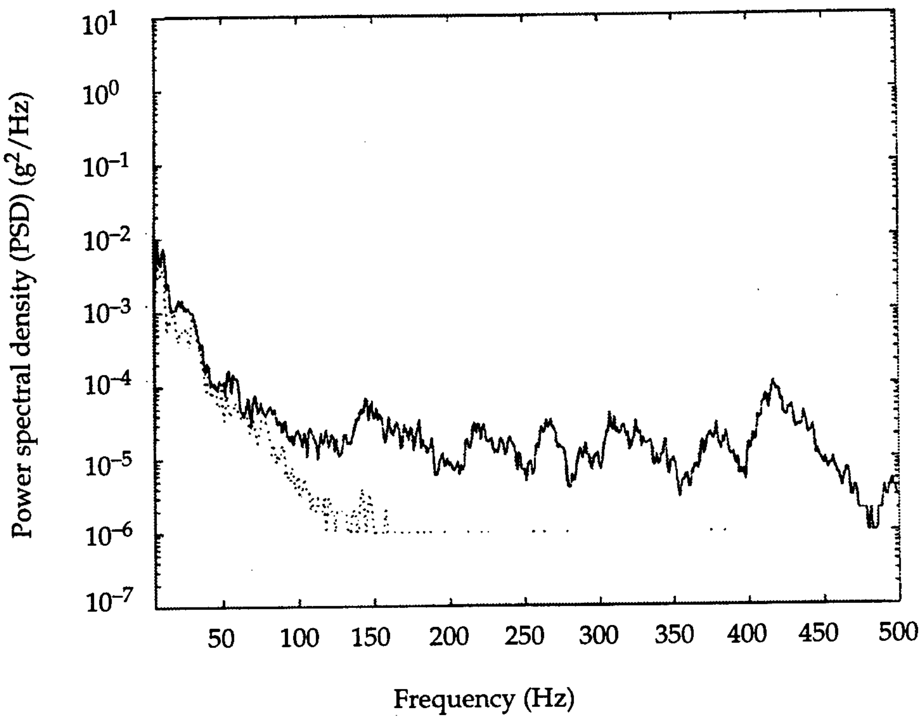


Figure B-2. Vertical: IAS—spaced bumps at 20 mph (ROAD003).

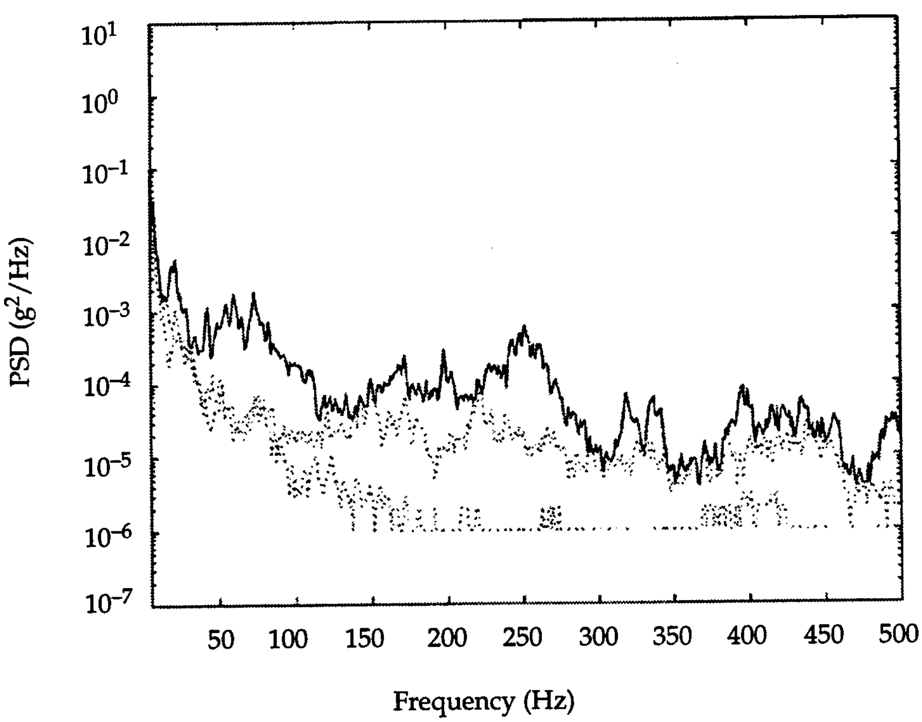


Figure B-3. Vertical: IAS—radial washboard at 15 mph (ROAD005).

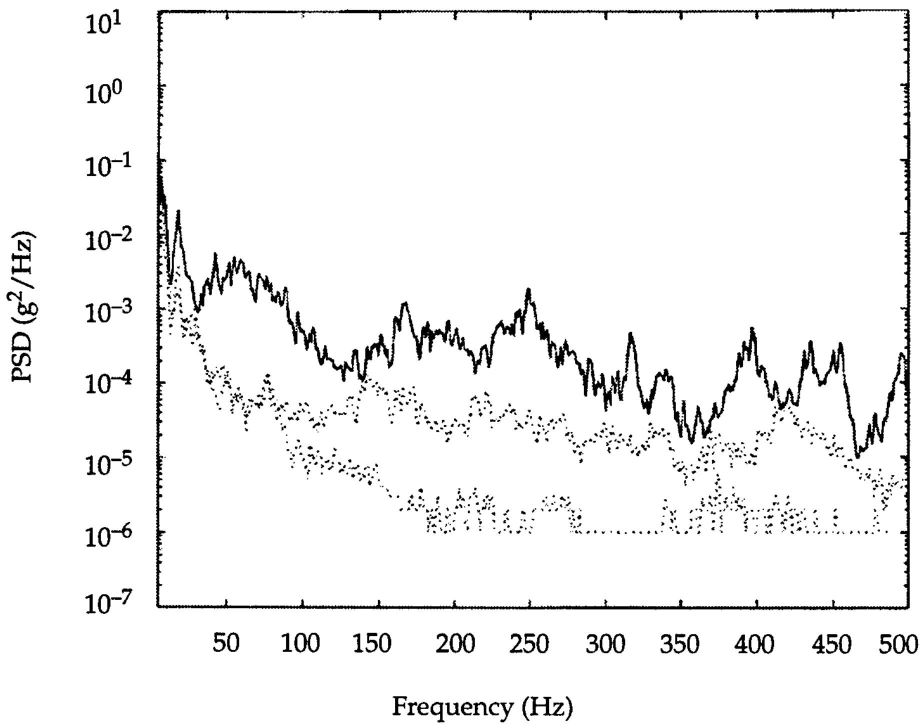


Figure B-4. Vertical: IAS—two-inch washboard at 10 mph (ROAD007).

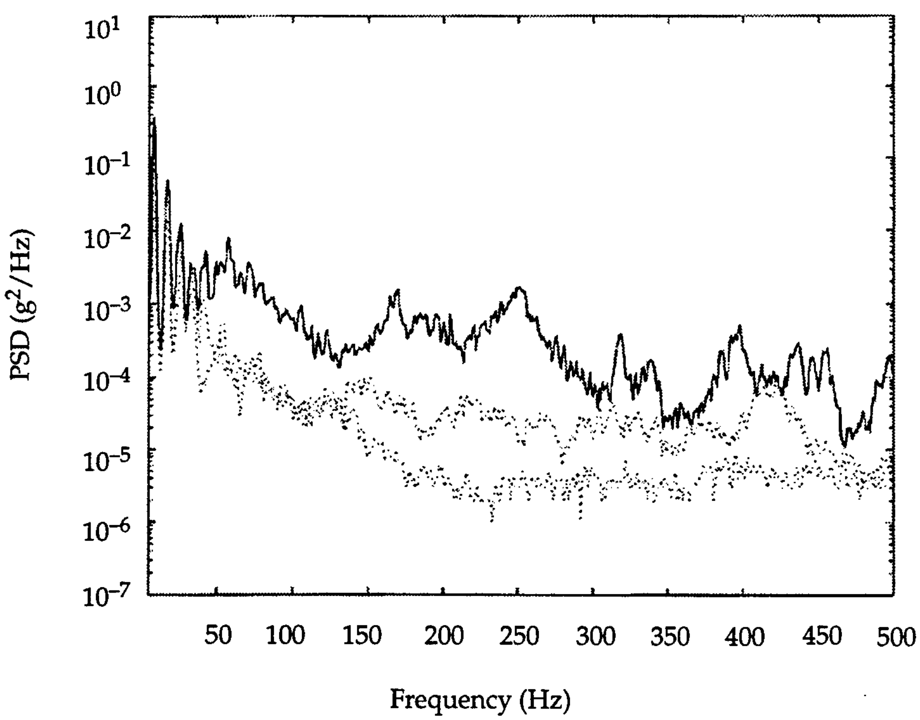


Figure B-5. Vertical: IAS—six-inch washboard at 5 mph (ROAD009).

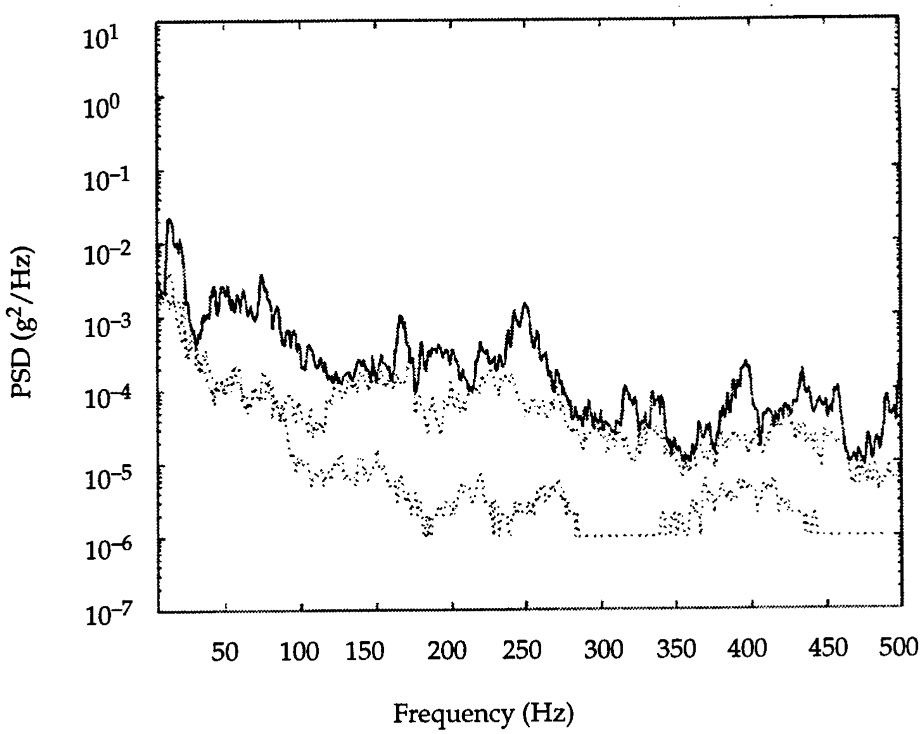


Figure B-6. Vertical: TCAC—Belgian block at 20 mph (ROAD012).

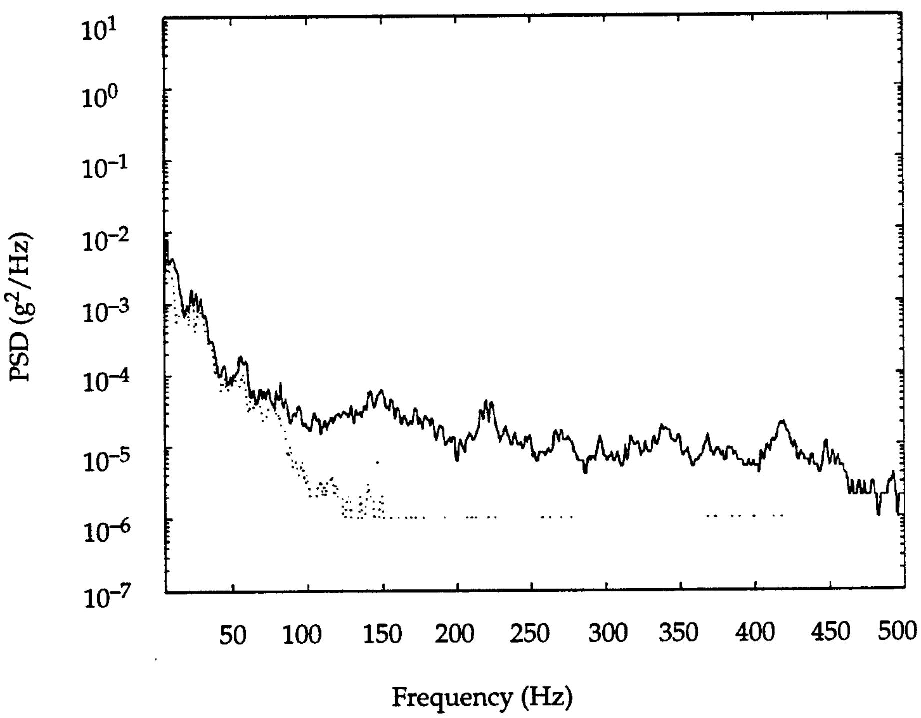


Figure B-7. Vertical: TCAC—spaced bumps at 20 mph (ROAD013).

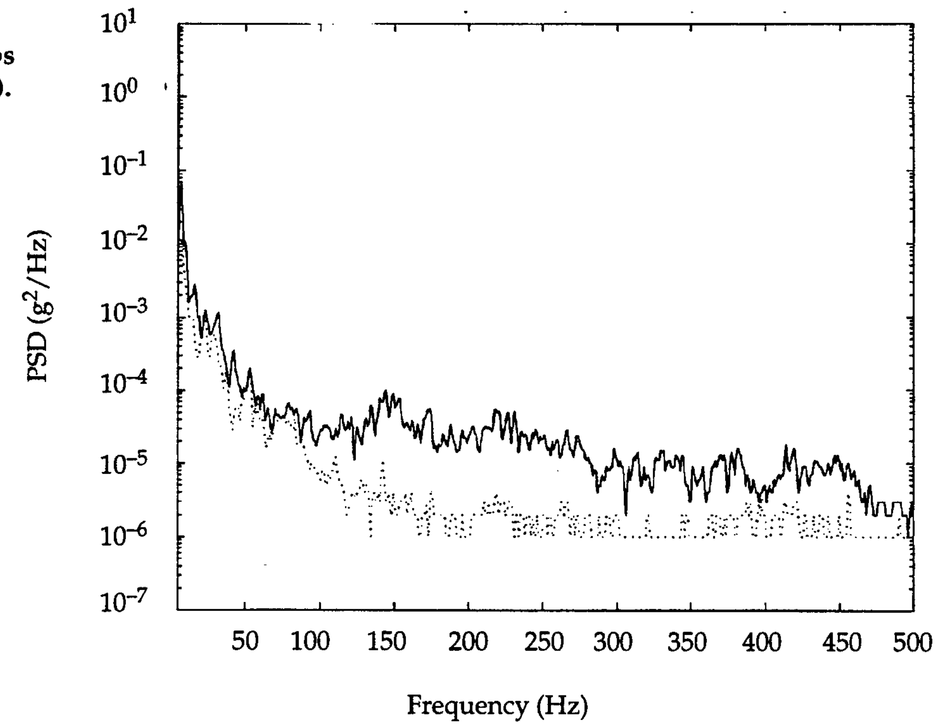


Figure B-8. Vertical: TCAC—radial washboard at 15 mph (ROAD015).

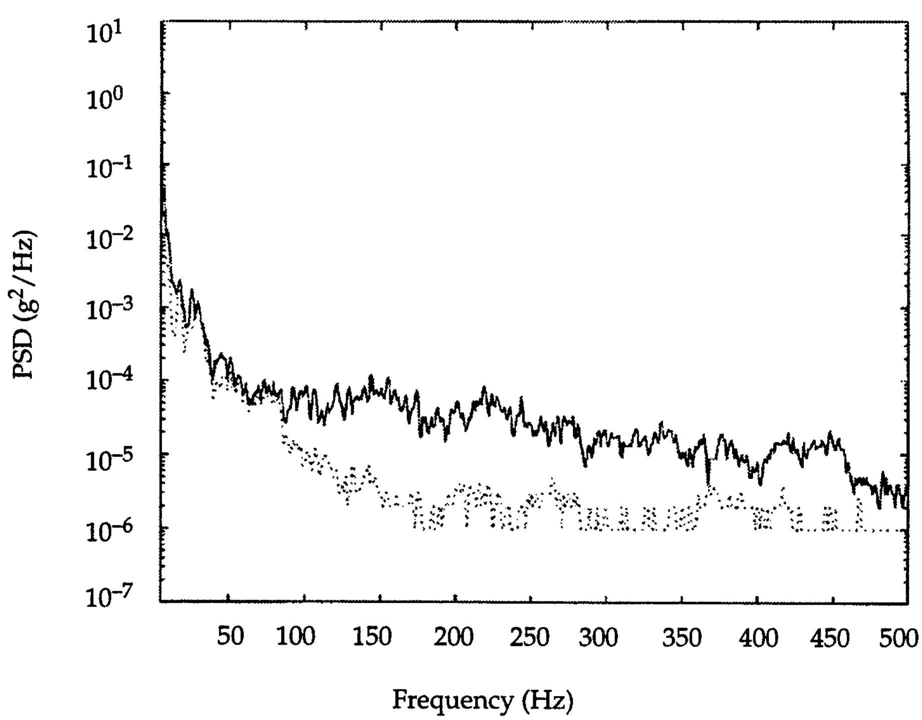


Figure B-9. Vertical: TCAC—two-inch washboard at 10 mph (ROAD016).

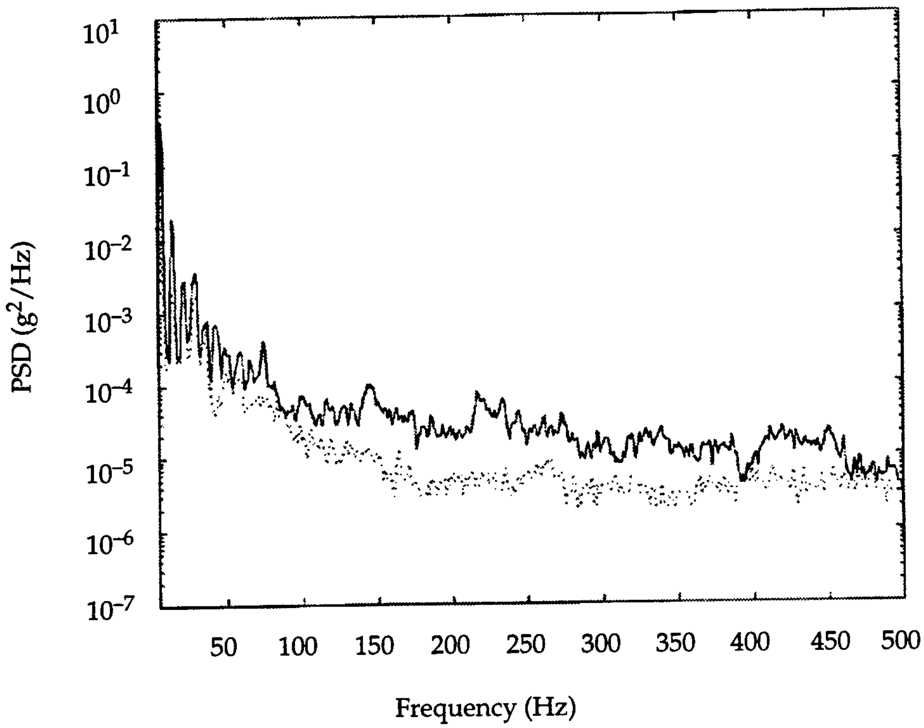


Figure B-10. Vertical: TCAC—six-inch washboard at 5 mph (ROAD018).

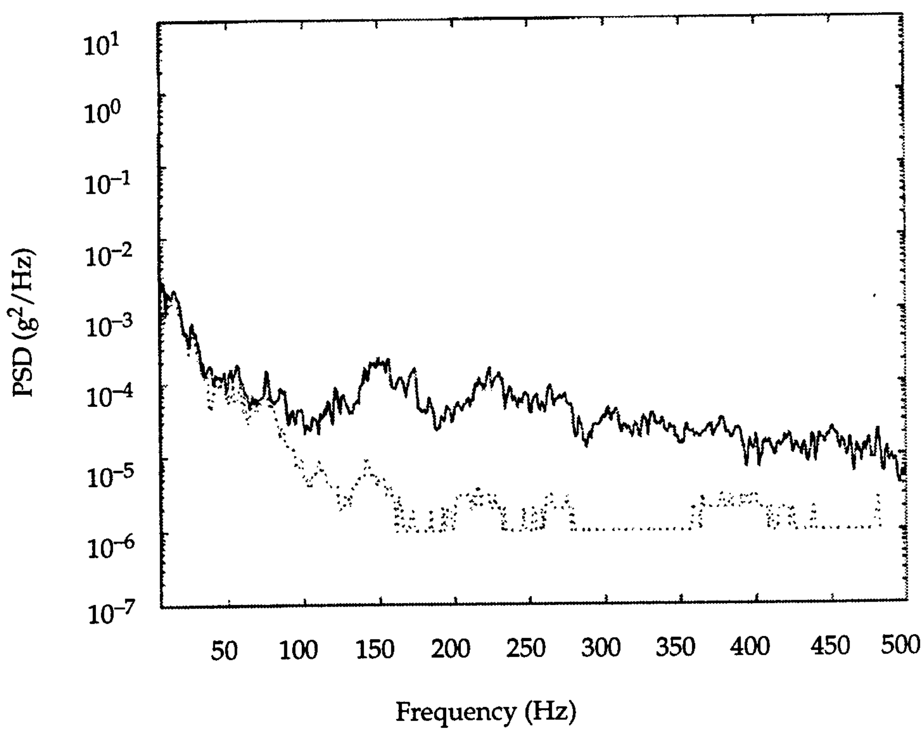


Figure B-11. Vertical: TCAC—pot holes at 15 mph (ROAD019).

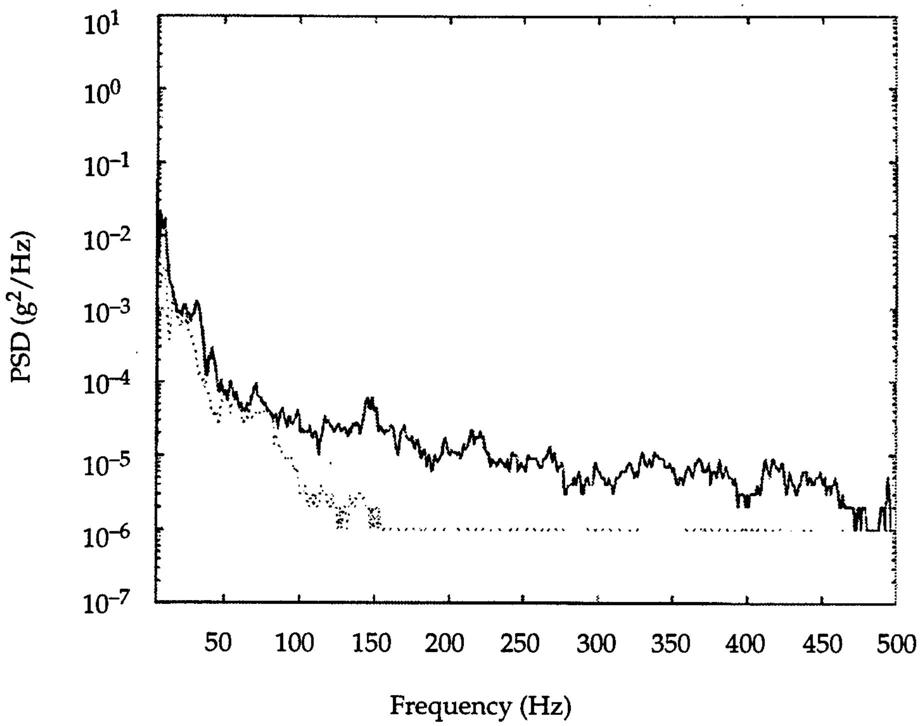


Figure B-12. Longitudinal: IAS—Belgian block at 20 mph (ROAD001).

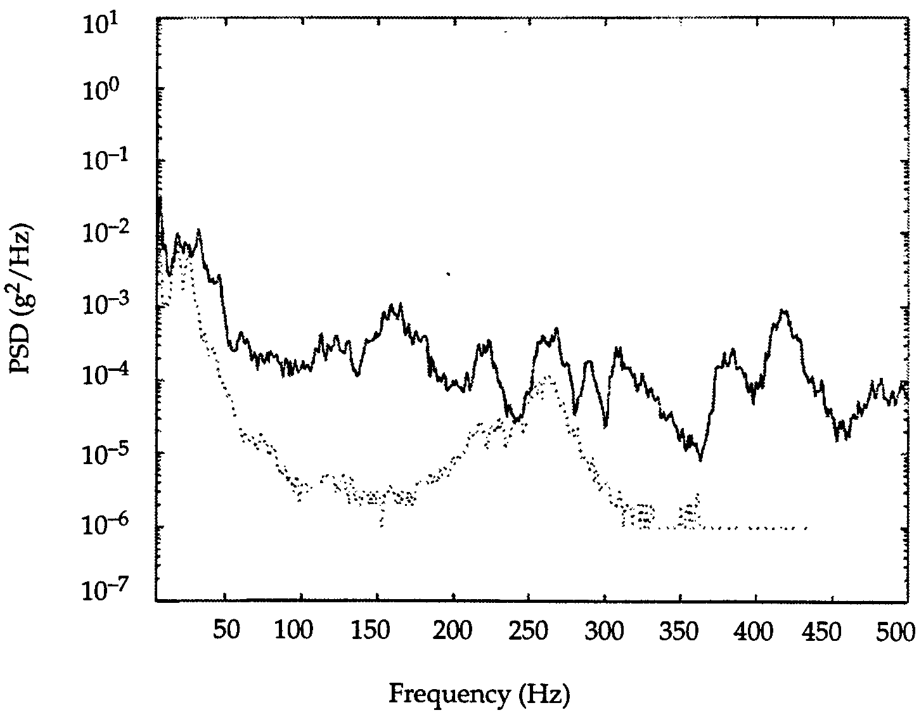


Figure B-13. Longitudinal: IAS—spaced bumps at 20 mph (ROAD003).

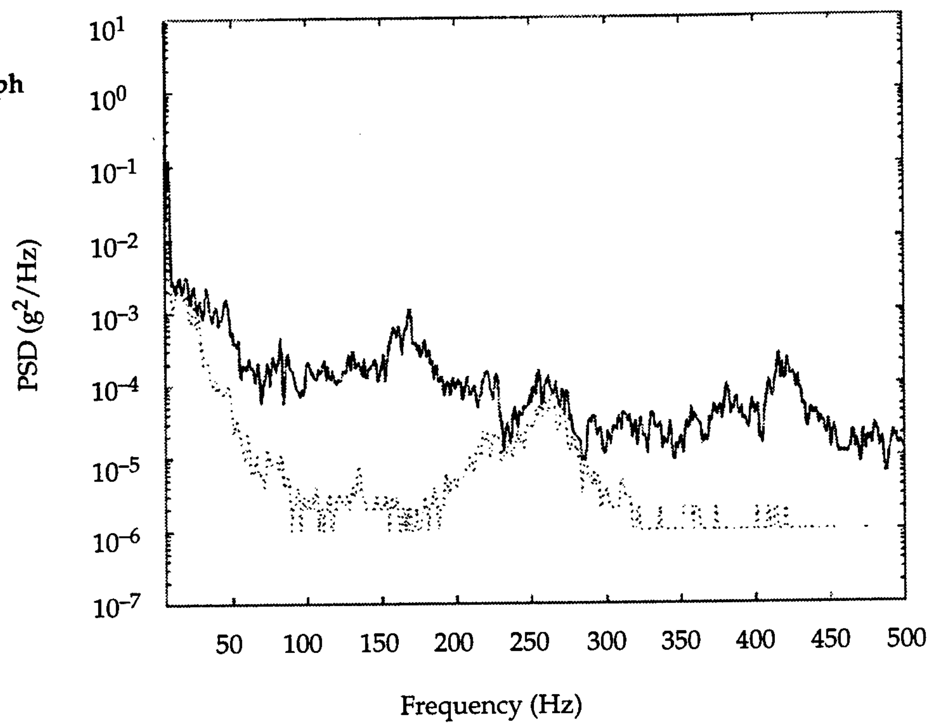


Figure B-14. Longitudinal: IAS—radial washboard at 15 mph (ROAD005).

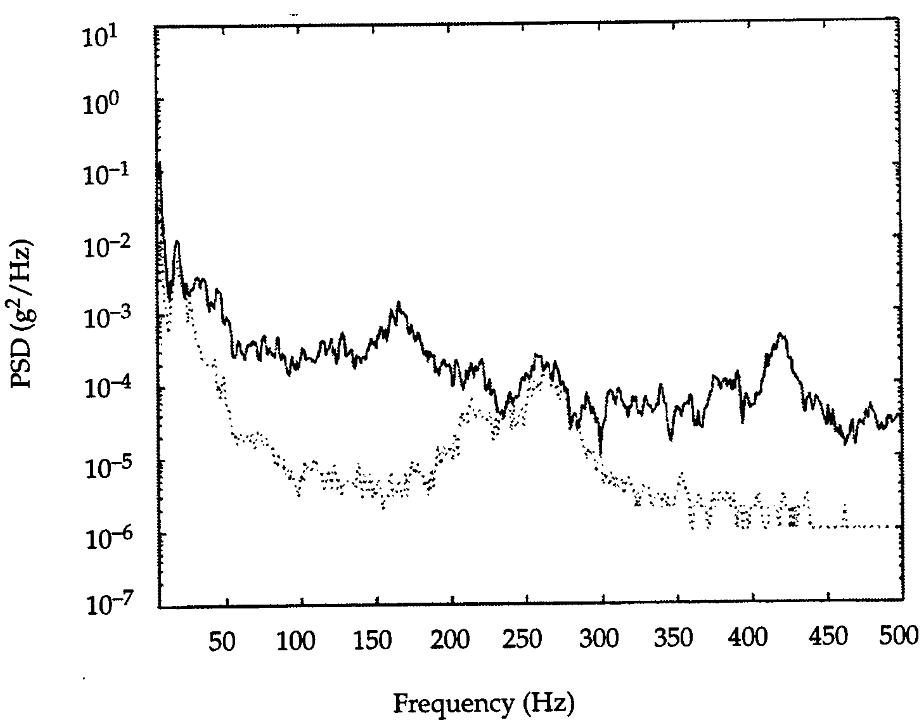


Figure B-15. Longitudinal: IAS—two-inch washboard at 10 mph (ROAD007).

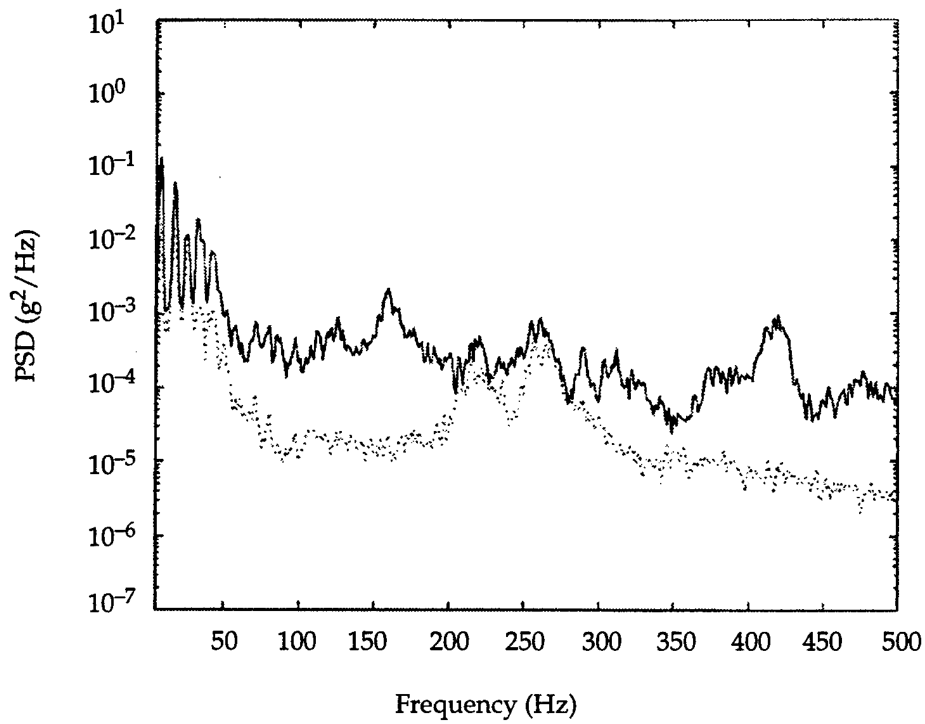


Figure B-16. Longitudinal: IAS—six-inch washboard at 5 mph (ROAD009).

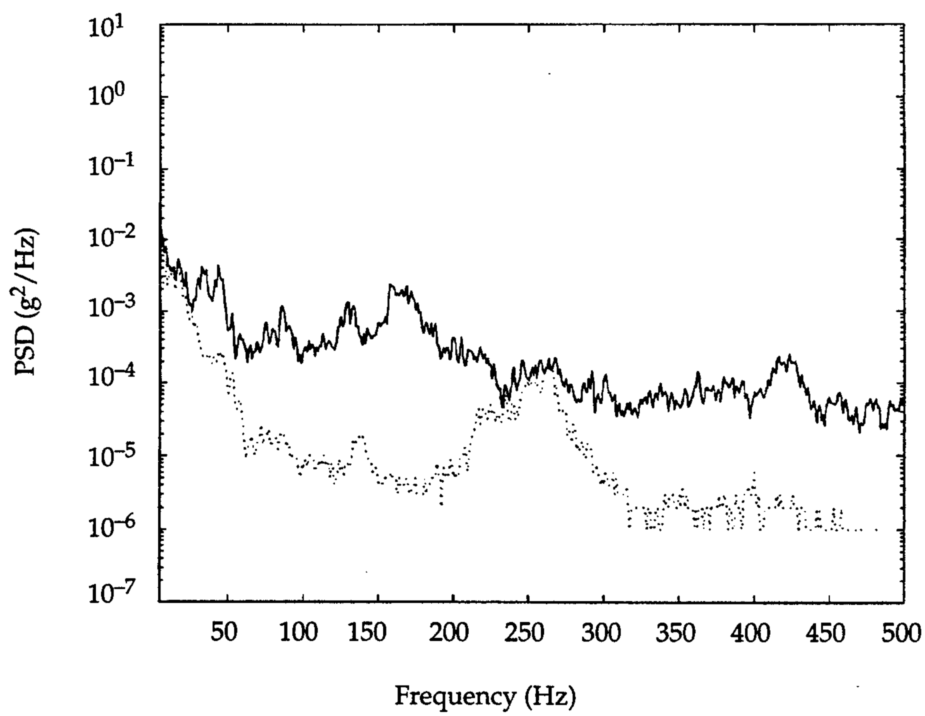


Figure B-17.
Longitudinal: TCAC—
Belgian block at
20 mph (ROAD012).

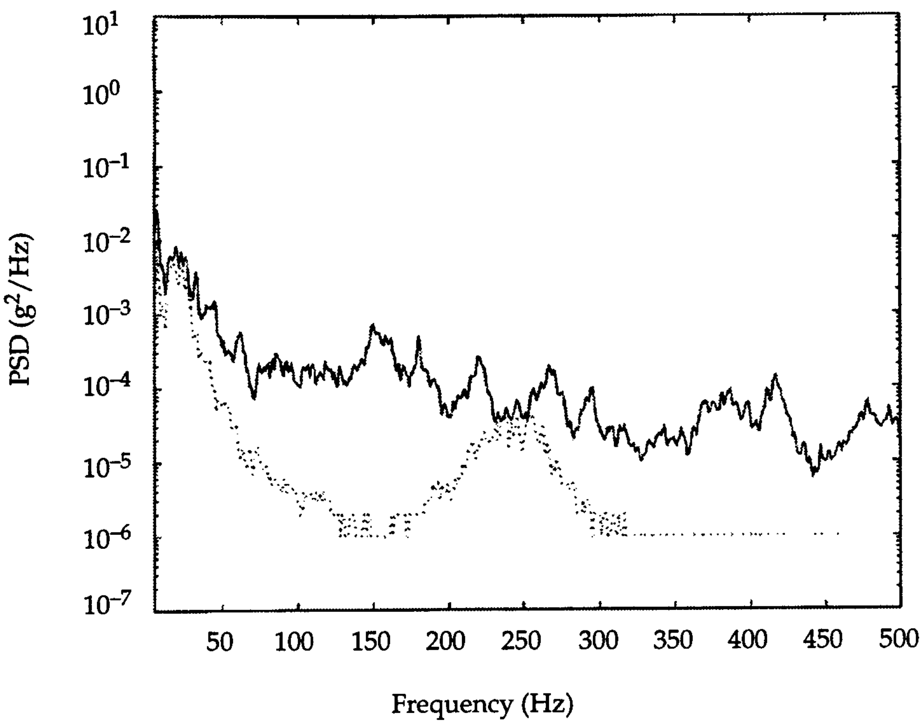


Figure B-18.
Longitudinal: TCAC—
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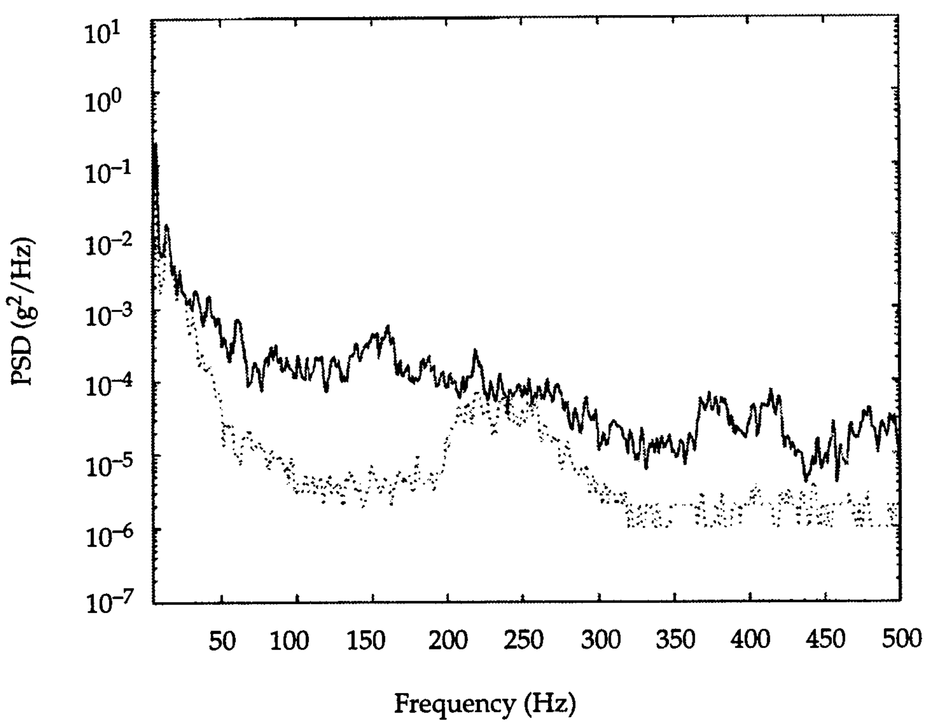


Figure B-19. Longitudinal: TCAC—radial washboard at 15 mph (ROAD015).

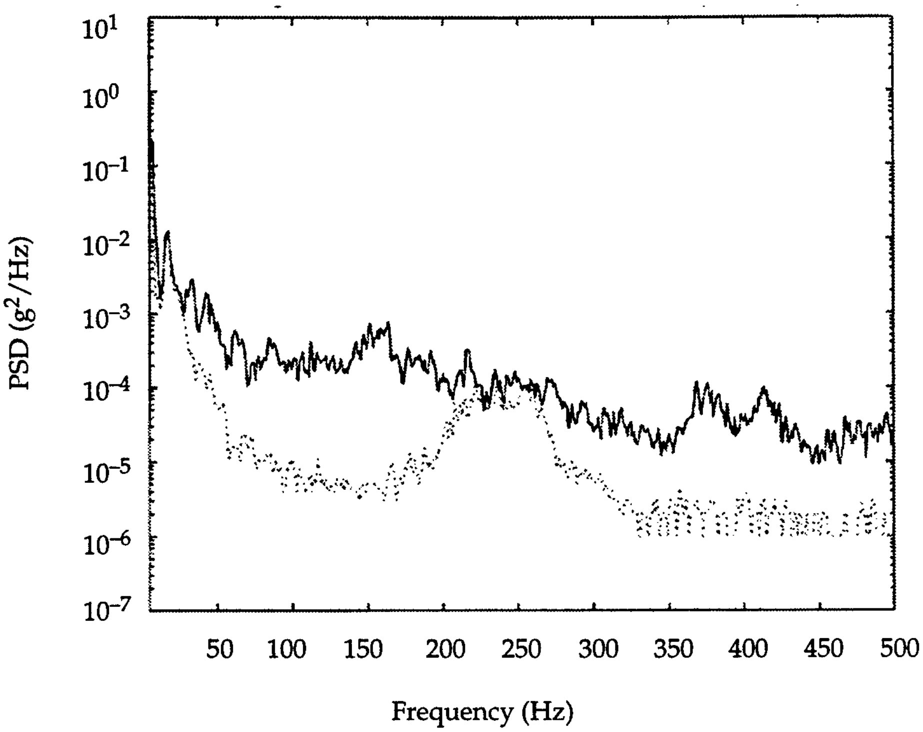


Figure B-20. Longitudinal: TCAC—two-inch washboard at 10 mph (ROAD016).

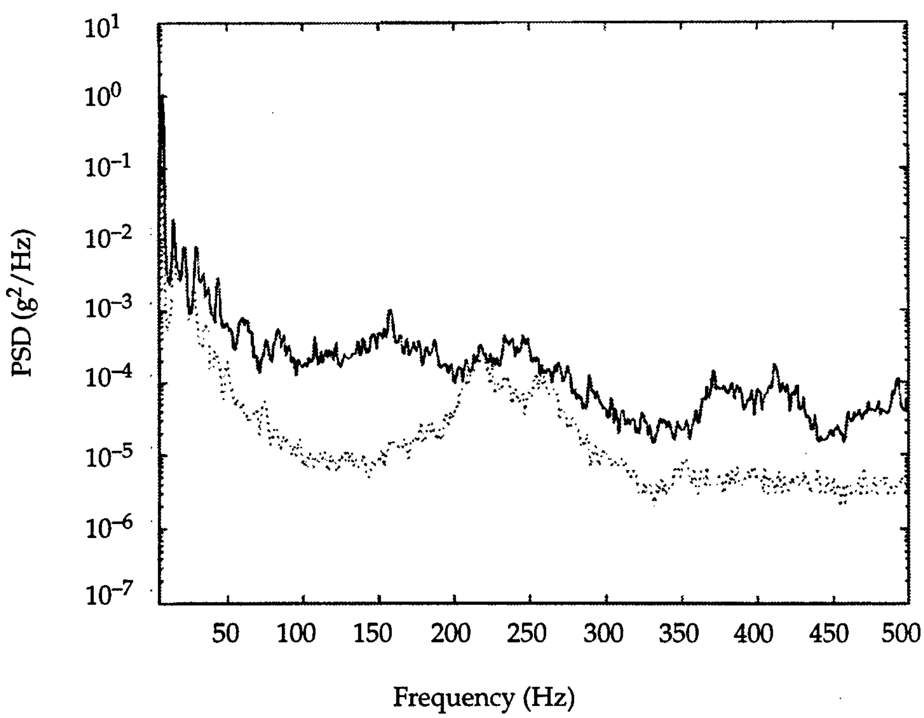


Figure B-21. Longitudinal: TCAC—six-inch washboard at 5 mph (ROAD018).

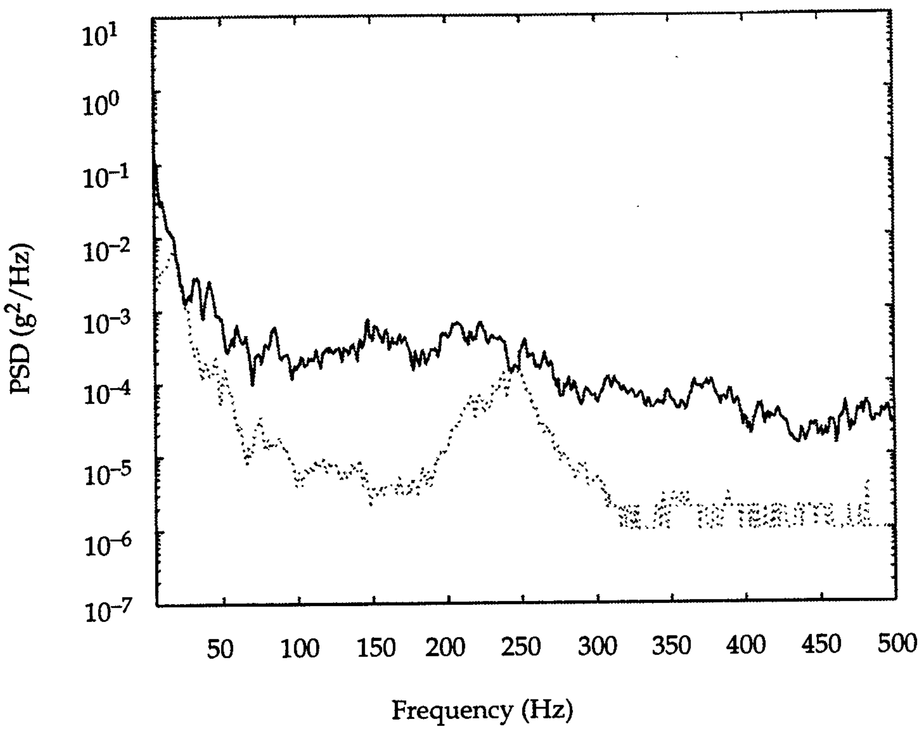


Figure B-22. Longitudinal: TCAC—pot holes at 15 mph (ROAD019).

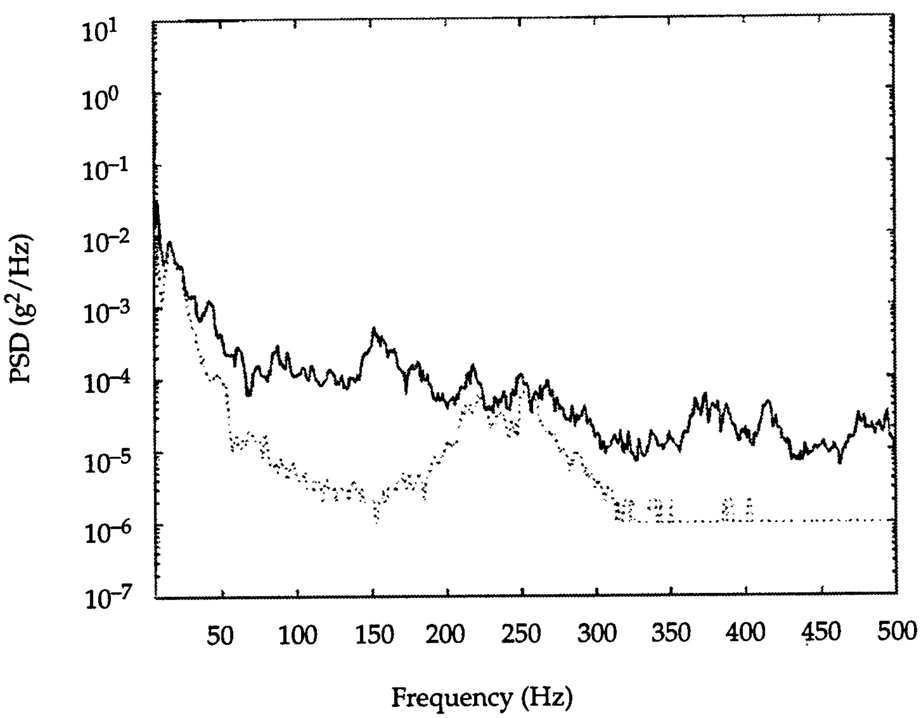


Figure B-23.
Transverse: IAS—
Belgian block at
20 mph (ROAD001).

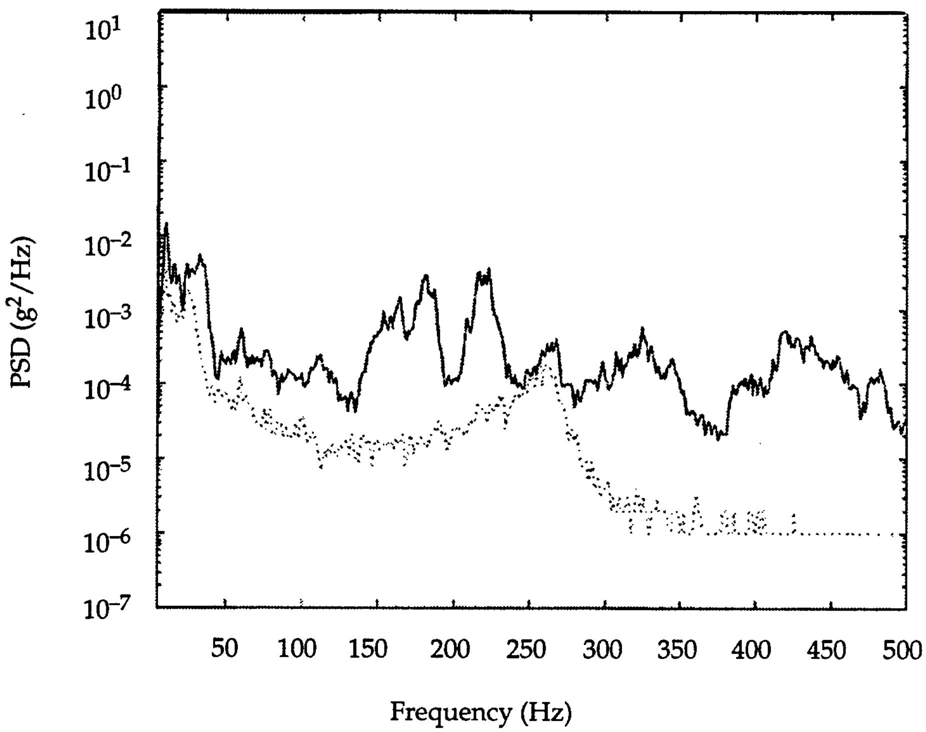


Figure B-24.
Transverse: IAS—
spaced bumps at
20 mph (ROAD003).

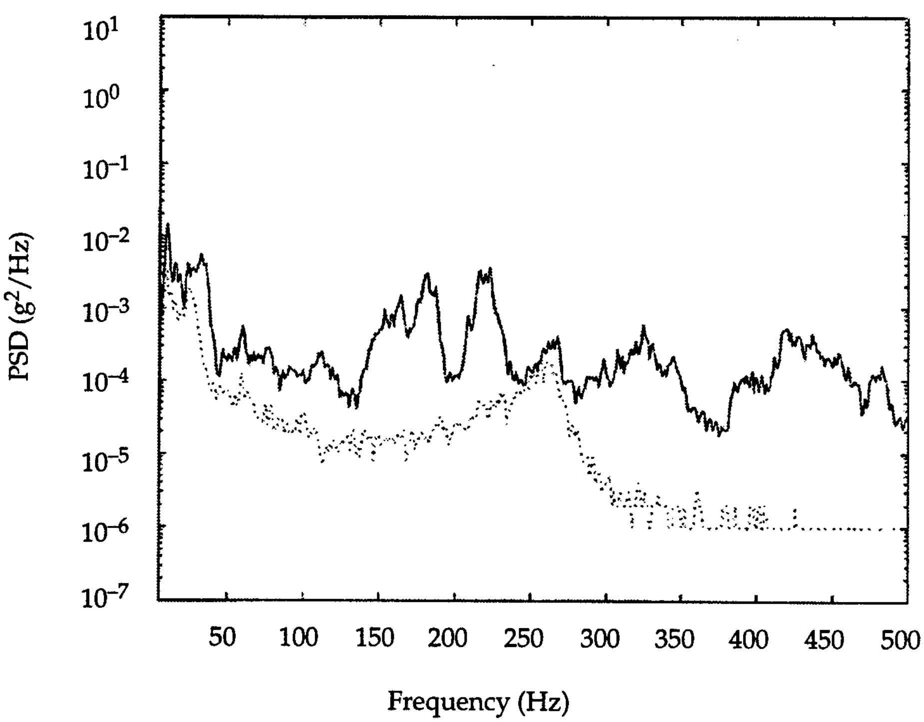


Figure B-25. Transverse: IAS—radial washboard at 15 mph (ROAD005).

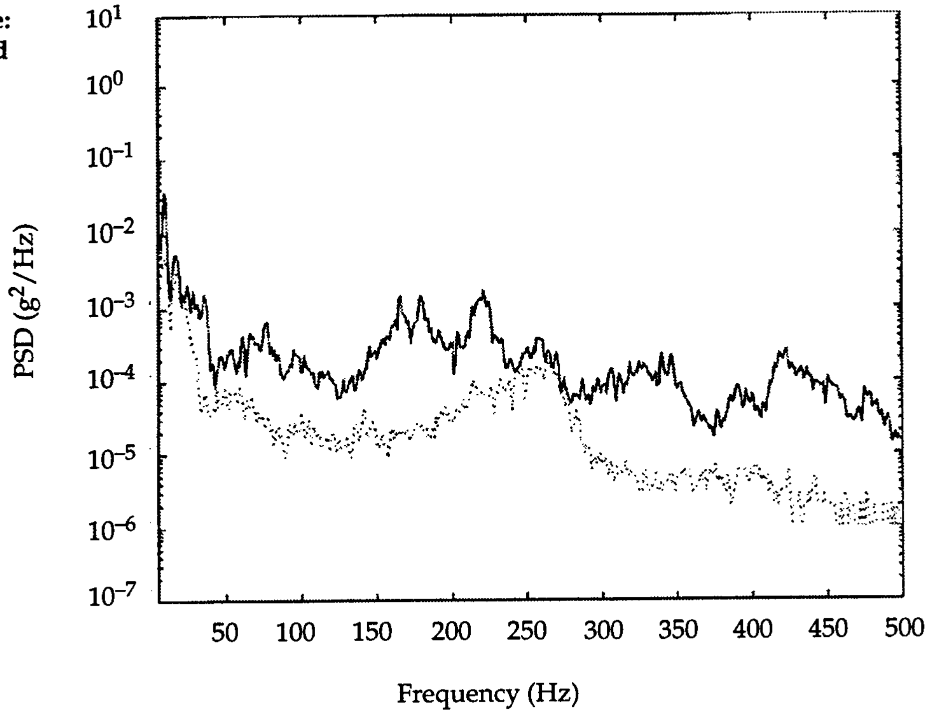


Figure B-26. Transverse: IAS—two-inch washboard at 10 mph (ROAD007).

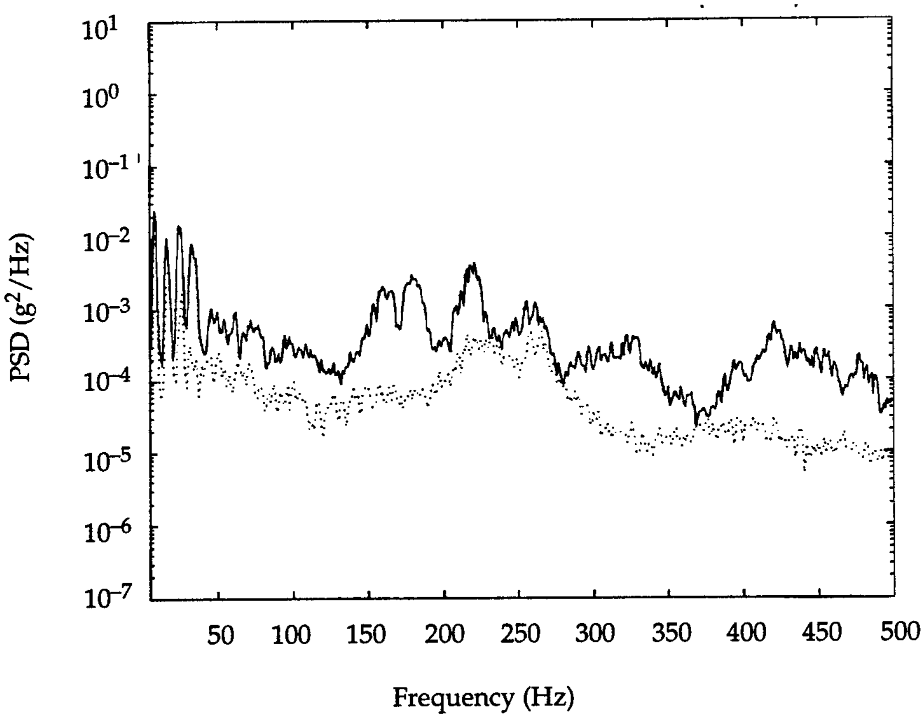


Figure B-27.
Transverse: IAS—
six-inch washboard at
5 mph (ROAD009).

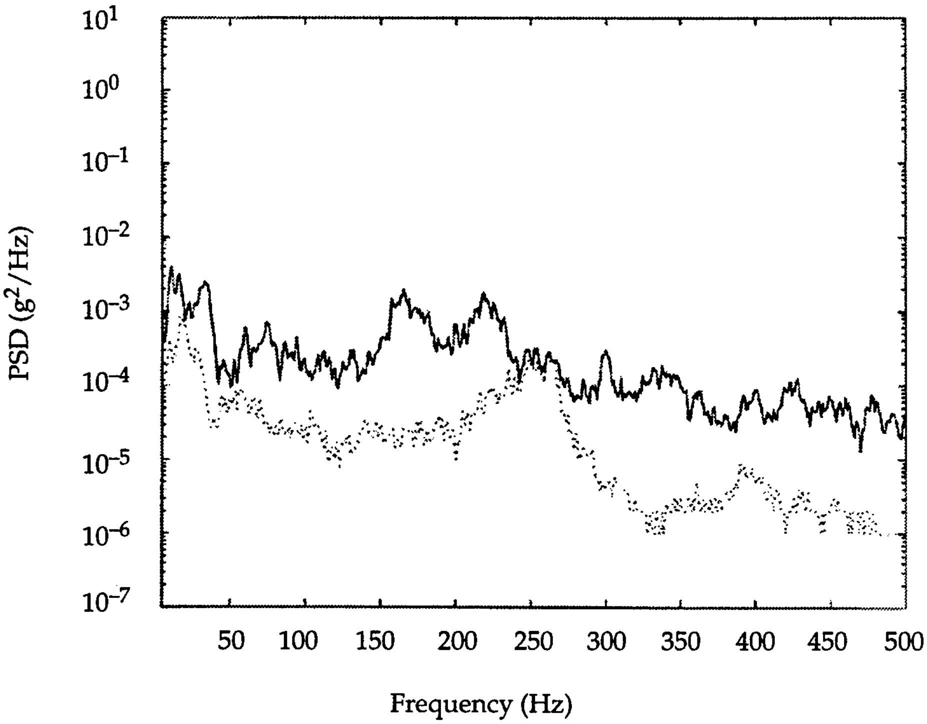


Figure B-28.
Transverse: TCAC—
Belgian block at
20 mph (ROAD012).

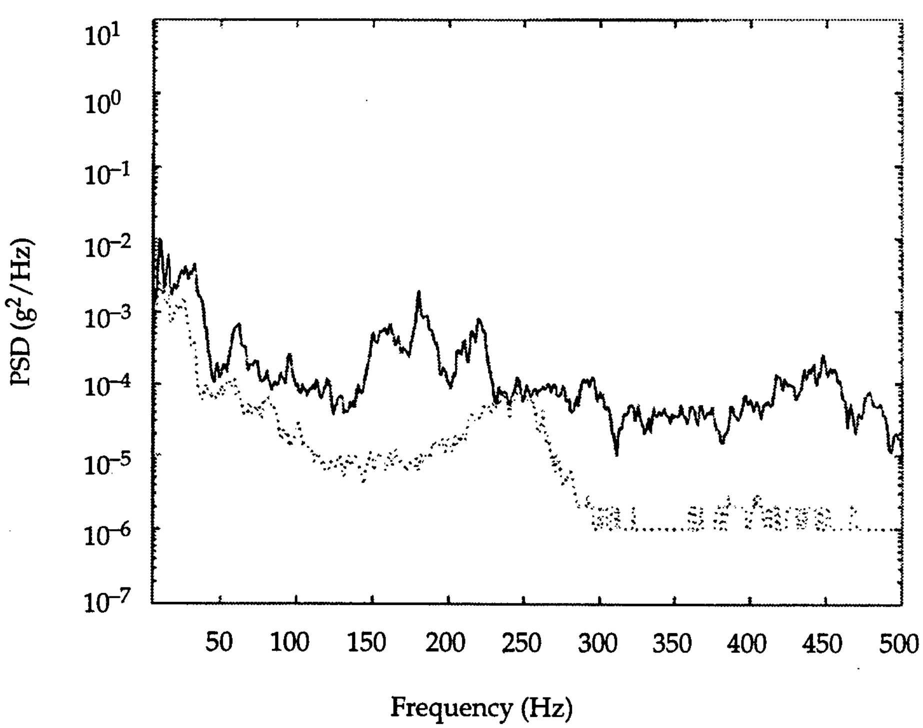


Figure B-29. Transverse: TCAC—spaced bumps at 20 mph (ROAD013).

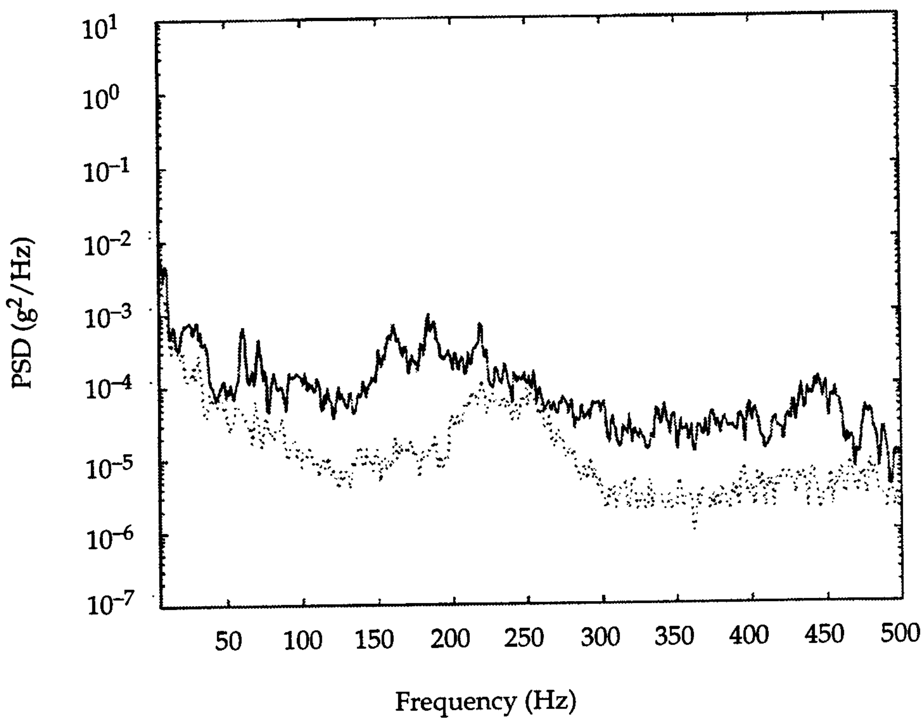


Figure B-30. Transverse: TCAC—radial washboard at 15 mph (ROAD015).

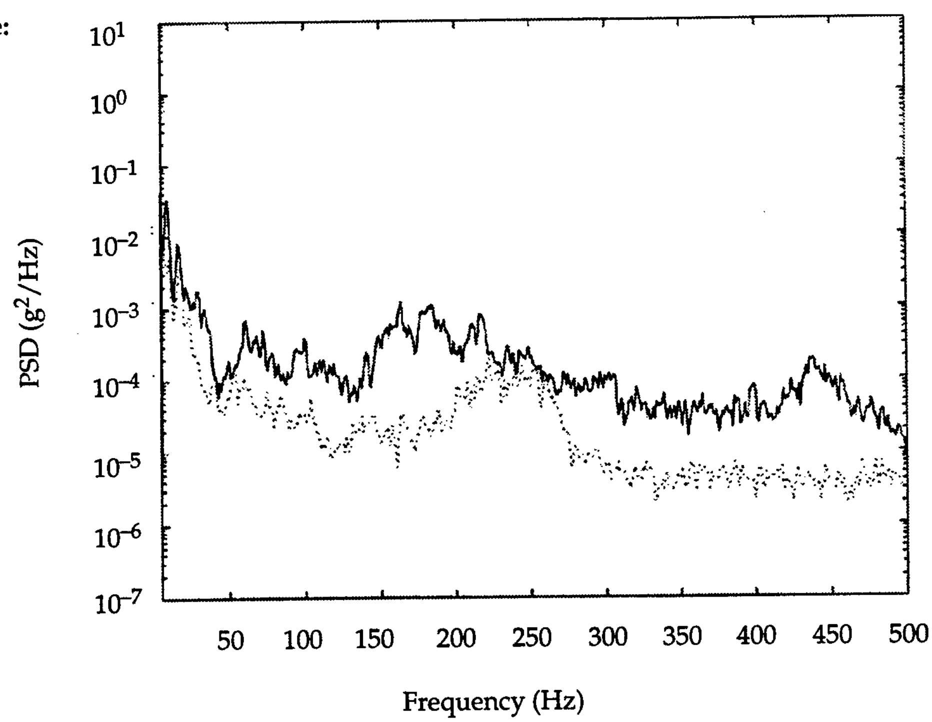


Figure B-31. Transverse: TCAC—two-inch washboard at 10 mph (ROAD016).

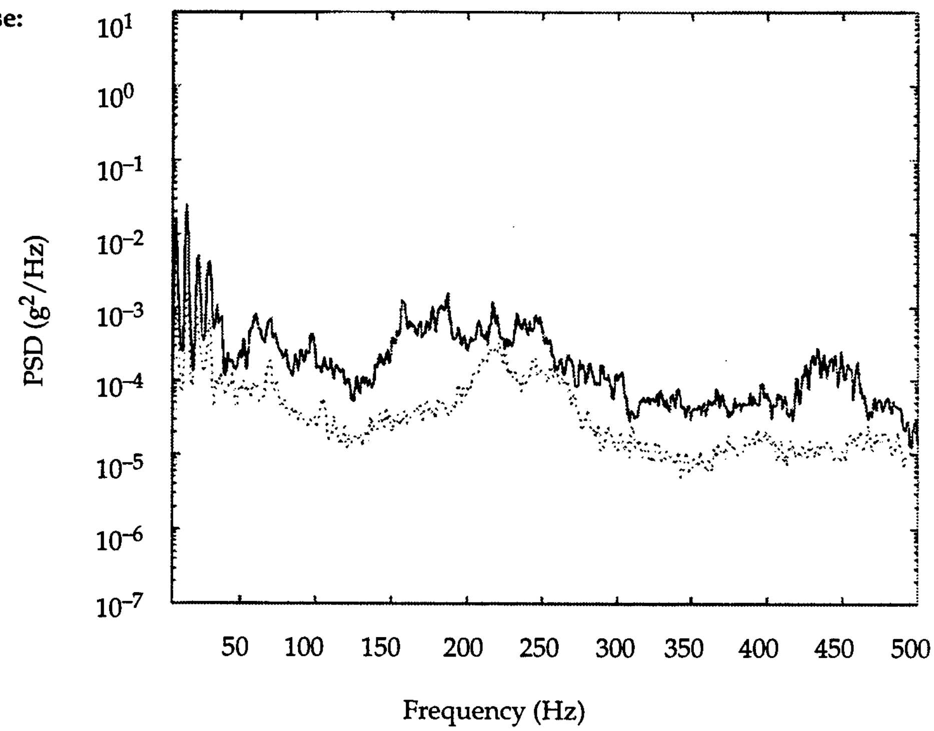


Figure B-32. Transverse: TCAC—six-inch washboard at 5 mph (ROAD018).

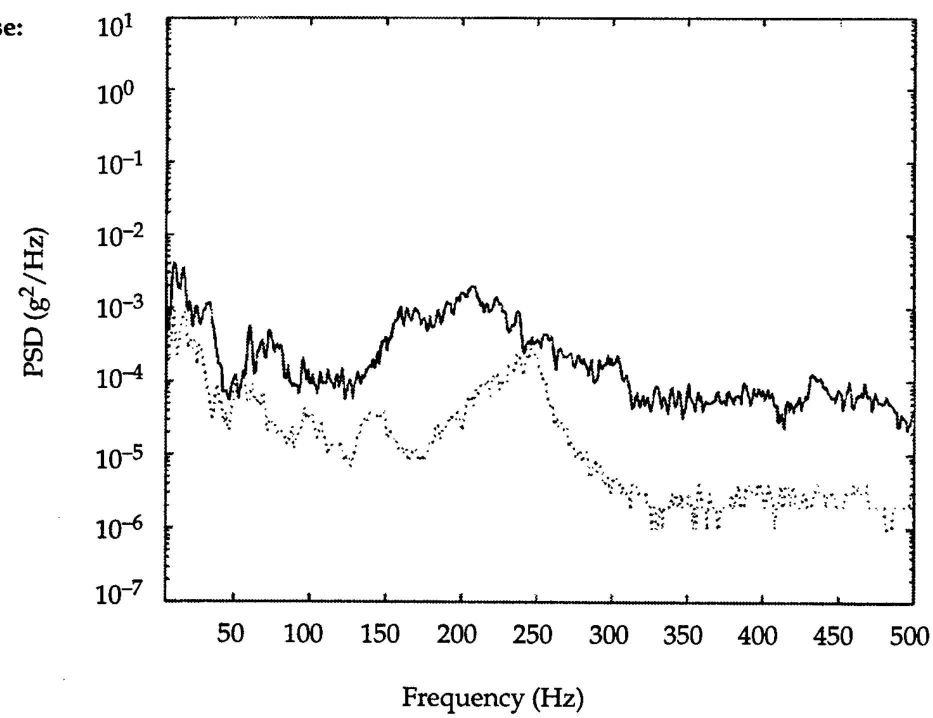
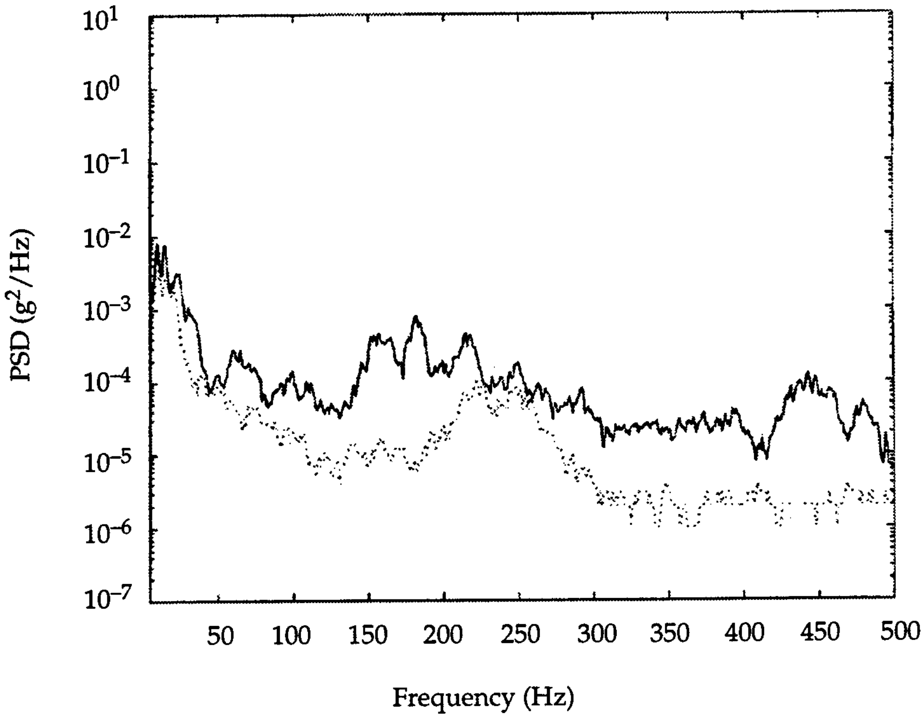


Figure B-33. Transverse: TCAC—pot holes at 15 mph (ROAD019).



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13. ABSTRACT *(Maximum 200 words)*

The Marine Expeditionary Force Intelligence Analysis System (MEF IAS) and the Technical Control and Analysis Center Product Improvement Program (TCAC PIP) are command, control, and intelligence systems developed by the Marine Corps Systems Command and built around a common core system. The development strategy behind the MEF IAS and TCAC PIP is to reduce the total cost of these systems. The major savings will be in life-cycle management costs, by fielding the two different systems to two different organizations within the Marine Corps that share (extensively) a common support structure. This common core system is an M-1097 high-mobility multipurpose wheeled vehicle (HMMWV) (heavy variant) carrying a computer and communications system mounted in a standard integrated command post shelter (SICPS).

This report analyzes the results of tests performed during late 1994 and early 1995. These road tests, rail impact tests, and transit drop tests helped develop a general testing profile that can be applied to future upgrades of the MEF IAS and TCAC PIP. The same technique of using a common core system and individual component testing can be applied to the fielding of entirely new systems. The cost savings of such an approach are significant.

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