INTERNATIONAL TEST OPERATIONS PROCEDURES

9 September 2002

1. All currently ratified ITOP's are changed as follows:

a. US Standard Form 298, Report Documentation Page (when used). Change Block 12a to read as follows: "Distribution limited to NATO nations; September 2002. Other requests for this document shall be referred to Sponsoring/Monitoring Agency as shown in block 9, above."

b. Ratification Sheet, distribution statement. Replace the first sentence as follows: "Distribution limited to NATO nations."

c. Page 1. Replace the distribution statement as follows: "Distribution limited to NATO nations."

2. The proponent for this change is the FR/GE/UK/US International Test and Evaluation Steering Committee.

3. After posting the changes, attach this change sheet in the front of each ITOP for reference purposes.

FRANCE
Date:

GERMANY
Date:

UNITED KINGDOM
Date:

UNITED STATES
Date:

INTERNATIONAL TEST OPERATIONS PROCEDURE

25 January 1999

CHANGE 1
ITOP 1-2-601
AD No. B238288

FR/GE/UK/US LABORATORY VIBRATION SCHEDULES

ITOP 1-2-601, 23 April 1998, is changed as follows:

1. Remove pages and insert attached revised pages as indicated below:

Remove pages	Insert pages
B-8, Figure B-4	B-8, Figure B-4
B-9, Figure B-5	B-9, Figure B-5
B-10, Figure B-6	B-10, Figure B-6

2. The proponent of this change is the Commander, U.S. Army Test and Evaluation Command, ATTN: AMSTE-TM-T, Aberdeen Proving Ground, Maryland 21005-5055.

3. After posting the changes, file this change sheet in the front of the ITOP for reference purposes.

CLAUDE BERTHOMMIER
DGA/DCE/ETBS
Bourges, France

WOLFGANG MUELLER vom HOFE
WTD91-440
Meppen, Germany

GURMIT S. CHANA
DERA Shoeburyness
United Kingdom

WOLFGANG H.R. SCHMIDT
HQ TECOM/APG/MD
United States

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	23 April 1998	Final

4. TITLE AND SUBTITLE

FR/GE/UK/US International Test Operations Procedure (ITOP)
1-2-601 Laboratory Vibration Schedules

5. FUNDING NUMBERS

WU A 268445

6. AUTHOR(S)

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Commander
U.S. Army Aberdeen Proving Ground
ATTN: STEAC-TE-I
Aberdeen Proving Ground, MD 21005-5059

8. PERFORMING ORGANIZATION REPORT NUMBER

ITOP 1-2-601

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Commander
U.S. Army Test and Evaluation Command
ATTN: AMSTE-TM-T
Aberdeen Proving Ground, MD 21005-5055

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

Same as item 8

11. SUPPLEMENTARY NOTES

Defense Technical Information Center (DTIC), AD No.: B238288
This ITOP supersedes FR/GE/UK/US ITOP 1-2-601, 19 October 1992.

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Distribution limited to FR/GE/UK/US Government agencies only; Foreign Government Information, July 1997.
Other requests for this document shall be referred to Sponsoring/Monitoring Agency as shown in block 9, above.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This ITOP describes two types of vibration tests conducted in the laboratory: first, a mission/field secured-cargo test to simulate the transportation of Army materiel as secured cargo during logistical shipments; and second, an application -induced vibration test to simulate the tactical-vibration environment experienced by equipment installed in/on ground vehicles or helicopters. Through application of these tests the design and fabrication of the test item are evaluated for conformance with requirements documents. The tests apply to ammunition (including close-support rockets and missiles), electronic equipment, mechanical equipment, and optical equipment.

14. SUBJECT TERMS

Ammunition	Helicopters	Transportability
Cargo	Installed equipment	Vibration environment
Ground vehicles	Munitions	Vibration test

15. NUMBER OF PAGES

90

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED			SAR

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std 239-18
298-102

REFERENCE FILE

International Test Operations Procedure
Internationales Erprobungsverfahren
Procedure Internationale d'Essais

Ratification Agreement For:

ITOP No: 1-2-601 **23 April 1998**

Laboratory Vibration Schedules

Abstract: This ITOP describes two types of vibration tests conducted in the laboratory: first, a mission/field secured-cargo test to simulate the transportation of Army materiel as secured cargo during logistical shipments; and second, an application -induced vibration test to simulate the tactical-vibration environment experienced by equipment installed in/on ground vehicles or helicopters. Through application of these tests the design and fabrication of the test item are evaluated for conformance with requirements documents. The tests apply to ammunition (including close-support rockets and missiles), electronic equipment, mechanical equipment, and optical equipment.

The following principal national representatives of Working Group of Experts 2.1 agree this document to be acceptable.

Ratifying Nations		
FRANCE	Signature:	Date: 23 April 1998
	ICT G. Cagnin, DEA/DCE/ETC4/ETBS, BP 712, 18015 Bourges Cedex, France	
GERMANY	Signature:	Date: 23 April 1998
	LBDir. Wolfgang Müller vom Hofe, WTD 91-440, 49707 Meppen Germany	
UNITED KINGDOM	Signature:	Date: 23 April 98
	Dr. Gurmit S. Chana, DERA T&E Ranges, Shoeburyness, Essex, SS3 9SR, UK	
UNITED STATES	Signature:	Date: 23 April 1998
	Mr. Wolfgang H.R. Schmidt, HQ TECOM, AMSTE-TM-T APG MD 21005-5055 USA	

In principal ITOPs are intended for official use in the governments or authorized agents of the governments of France, Germany, the United Kingdom and the United States, i.e., the participants of the Four-Nation MOU relating to the mutual acceptance of Test and Evaluation, 5 December 1983. This ITOP may be released to other nations provided permission to do so has been granted by each signatory nation. Formal prior notification is required and a 30 day silent procedure is to be observed.

Supersedes: ITOP 1-2-601, 19 October 1992.

Classification: UNCLASSIFIED

No. of Pages: 89

INTERNATIONAL TEST OPERATIONS PROCEDURE

*International Test Operations Procedure (ITOP) 1-2-601 — 23 April 1998
AD No. B238288

FR/GE/UK/US LABORATORY VIBRATION SCHEDULES

			Page
PARAGRAPH	1.	SCOPE	2
	2.	FACILITIES AND INSTRUMENTATION	2
	2.1	Facilities	2
	2.2	Instrumentation	2
	3.	REQUIRED TEST CONDITIONS	3
	3.1	Inspection and Packing	3
	3.2	Selection of Vibration Schedules	3
	3.3	Test Controls	4
	4.	TEST PROCEDURES	6
	4.1	Field/Mission Secured Cargo	6
	4.2	Equipment Installed in Ground Vehicles	8
	4.3	Equipment Installed Within and External to Helicopters	10
	5.	DATA REQUIRED	13
	6.	PRESENTATION OF DATA	13
APPENDIX	A.	BACKGROUND/SELECTION OF SCHEDULES	A-1
	B.	WHEELED- AND TRACKED-VEHICLE SECURED CARGO VIBRATION	B-1
	C.	VEHICLE AMMUNITION-RACK VIBRATION	C-1
	D.	TRACKED VEHICLE INSTALLED-EQUIPMENT VIBRATION	D-1
	E.	HELICOPTER VIBRATION	E-1
	F.	LOAD-RATING FACTOR	F-1
	G.	REFERENCES	G-1

This International Test Operations Procedure results from an agreement among the Republic of France, the Federal Republic of Germany, the United Kingdom of Great Britain and Northern Ireland, and the United States. Any ratifying nation may issue supplemental test information to amplify or clarify procedures, but in no case will such information contravene the provisions of this ITOP. Revisions to this ITOP require the approval of all the ratifying nations. If a ratifying nation must deviate from a provision of this ITOP due to constraints such as available facilities, national regulations or instrumentation accuracies, the test methods used will be described in the test report and the rationale for the deviation will be provided upon request. However, such deviation may cause nonacceptance of the test data by other nations.

In principal ITOP's are intended for official use by the Governments or authorized agents of the Governments of France, Germany, the United Kingdom of Great Britain and Northern Ireland, and the United States, i.e., the participants of the Four-Nation MoU on Mutual Acceptance of Test and Evaluation, dated 5 December 1983.

This ITOP may be released to other nations provided permission to do so has been granted by each signatory nation. Formal prior notification of the ITOP signatory nations is required and a 30-day silence procedure is to be observed.

*This ITOP supersedes ITOP 1-2-601, dated 19 October 1992.

1. SCOPE.

a. This ITOP describes two types of vibration tests conducted in the laboratory: first, a mission/field secured-cargo test to simulate the transportation of Army materiel as secured cargo during logistical shipments; and second, an application-induced vibration test to simulate the tactical-vibration environment experienced by equipment installed in/on ground vehicles or helicopters. Through application of these tests the design and fabrication of the test item are evaluated for conformance with requirements documents. The tests apply to ammunition (including close-support rockets and missiles), electronic equipment, mechanical equipment, and optical equipment.

b. No attempt is made to address the vibration environments for equipment installed in fixed-wing aircraft, missiles, and ships (marine environment). Information on these environments can be obtained from MIL-STD-810E[a**].

c. An explanation of the vibration test is contained in Appendix A. Background information and techniques used for developing laboratory vibration test schedules from field data are contained in ITOP 1-1-050[1].

d. The laboratory vibration test schedules for field/mission secured cargo in Appendix B apply to general types of cargo and were developed from data acquired on cargo vehicles that were loaded to 75% of rated payload. For the special circumstances that arise in transporting unique items that load a vehicle above or below the 75% level, load-rating factors have been established and are described in Appendix F.

e. ITOP 1-2-601 is a dynamic document. Measurements are continually being made. Schedules will be added as they become available for other vehicles. Forward newly-developed schedules and data for immediate inclusion in this ITOP.

2. FACILITIES AND INSTRUMENTATION.

2.1 Facilities.

Item	Requirements
Temperature chamber	To be able to condition test item to temperatures ranging from 63 °C to -51 °C, and relative humidity from 5% to 95%.
X-ray facility	As required
Vibration test facility	As required

2.2 Instrumentation.

Devices for Measuring	Requirements
Temperature	± 2 °C

** Superscript letters/numbers correspond to those in Appendix G, References.

3. REQUIRED TEST CONDITIONS.

3.1 Inspection and Packing.

a. Item is to be tested in packaged condition.

(1) Draw a randomly selected sample of packages from each test lot.

(2) Open each and examine systematically (using nondestructive techniques as applicable). If evidence of a nonstandard condition is found, examine the entire lot.

(3) Record the following information:

(a) Identification data, including lot number and nomenclature.

(b) Size and weight.

(c) Evidence of damage or looseness of bindings.

(4) Photograph any test item damage.

(5) Pack the test item (or repack if necessary) to ensure that it is tested in the identical package used for field deployment.

b. If the item is to be tested in an unpackaged condition.

(1) Inspect each item (using nondestructive techniques as applicable), and reject those which are damaged.

(2) Record the following information:

(a) Identification data, including the lot number and nomenclature.

(b) Size and weight.

(c) Evidence of damage as determined visually or by the applicable nondestructive test method.

(d) Operational check (as applicable) and record of same.

(3) Photograph any test item damage.

3.2 Selection of Vibration Schedules.

The vibration environment is divided into two major categories: logistical and tactical vibration. Most equipment will be subject to vibration induced by a carrying platform (aircraft, truck, etc.) in its intended application. In order for these vibration environments to be considered applicable to a given materiel item, the item should either be intended for use within a category as a mission requirement or expected to spend a significant portion of its service life exposed to the environment as a consequence of its deployment, storage, or use.

It is important to note that under these guidelines, most materiel will experience exposure to both logistical and tactical vibration environments. Schedules are provided for exposure of a specific test item to the various combinations of cargo and platform environments that could be experienced. Appendix A provides guidance to be used in selecting the appropriate combination of schedules.

3.3 Test Controls.

a. Vibration tolerances. The acceleration power spectral density of the test control signal shall not deviate from the specified requirements by more than ±3 dB over the entire test frequency range. Deviations of -6 dB in the test control signal, however, may be granted for frequencies greater than 500 Hz due to fixture resonance, test item resonance, or facility limitations. The cumulative bandwidth over which this reduction shall be allowed cannot be greater than 5% of the test frequency range (see Fig. 1). In no case shall the acceleration power spectral density be more than 6 dB below the specified requirements. When the test cannot be controlled within +3 dB from the specified requirements, a risk of an overtest could exist; however, and the test may continue only after discussion/concurrence with the test sponsor. The risk is to assume no overtesting is occurring; test results are valid, and appropriate corrective action will be taken in accordance with the nature of the test. The rms level of the vibration test, however, shall not deviate more than ±10% from the required level. Tolerance levels in terms of dB are defined as:

$$dB = 10 \log \frac{W_1}{W_0}$$

where W_1 is the measured acceleration power spectral density in g^2/Hz units. The term W_0 defines the specified level in g^2/Hz units.

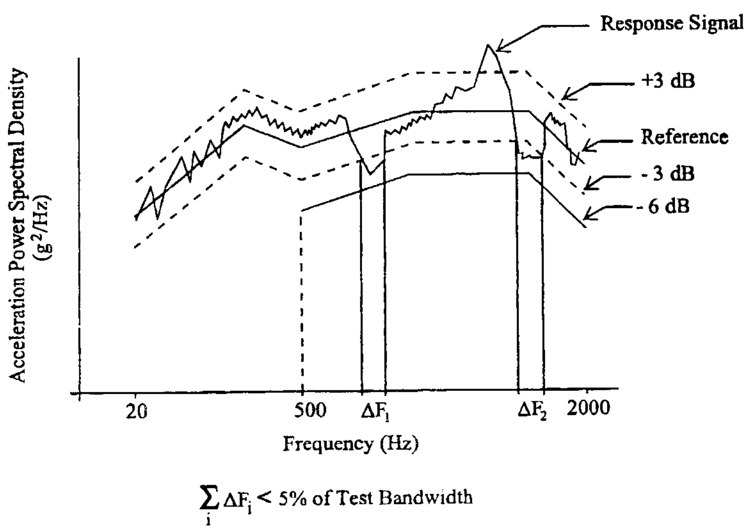


Figure 1. Example of Acceptable Performance Within Tolerance.

If confirmation of these tolerances is required an analysis system providing at least 100 statistical degrees of freedom can be used. The analysis performed by digital control systems under normal conditions is usually sufficient. When additional analysis is required to verify control, the analyzer system shall have at least four filters included between the -3 dB points of the lowest spectral peak of interest. The resolution filters shall have skirts which attenuate at least -40 dB/octave, and the filter side lobes shall not be above the -18 dB/ octave shape.

b. Response characterization. Response characterization is an engineering process in which empirical data are used to define the structural response of equipment or test fixtures to applied vibration. Response characterizations may either use broadband-random or swept-sine excitation. They are performed for reasons which include but are not limited to the following:

(1) Identifying critical vibration modes, especially when there is concern over the coincidence of these modes with induced excitation frequencies occurring in service operation.

(2) Evaluating fixture/test item interactions to ensure reasonable materiel behavior representative of known or expected service-induced responses.

(3) Determining appropriate locations for test control instrumentation.

NOTE: Response characterizations should ultimately be performed at realistic vibration conditions since equipment structure nonlinearities normally render characterizations at other levels inconclusive.

c. Test axes. Unless otherwise stated in a specific procedure or requirements document, this method prescribes excitation in the three major orthogonal axes of the item being tested. Excitation is directed along each axis, one axis at a time. Multiaxis-input test techniques are an acceptable alternative; however, specific test schedules must be generated to utilize such control techniques.

d. Input control versus response-defined control. Input control is the traditional approach to vibration testing. Ideally, this form of testing should represent the input from the carrying platform into the materiel on the platform. This is the type of control used for the field/mission secured-cargo environment test and the application-induced environment test associated with ground vehicles. This type of control, however, should not be used when the item's mass loading significantly alters the platform behavior.

The data utilized to develop the vibration schedules presented for both secured-cargo and application exposures were taken at a point which is the input to the test item. In the case of secured cargo, the data are the input from the bed of the carrying platform to the base of the cargo. In the platform application, the data are the input from the carrying platform to the ammunition rack or through the attachment points of the test item when testing materiel other than ammunition. The input-control vibration testing performed in the laboratory, therefore, shall be controlled from the same location.

NOTE: If field data are to be used in place of the schedules provided, the control point for the vibration test must correspond to the locations utilized for acquiring the field data.

Response-defined testing uses an essentially undefined input and, instead, tries to achieve an item's structural response representative of that anticipated or measured in service. This type of control is generally used for the helicopter environment in the application-induced environment test. There may be occasions during input control when it is essential to limit the vibration response of one or more components on the test item. Under these conditions a combination of input and response control should be utilized.

e. Test duration. Test duration is given along with test levels on each schedule to accomplish the test purpose. Usually vibration criteria are written in terms of total time at a given level and implemented as a continuous exposure. Service exposure, however, is usually made up of a series of discrete or short-term events. Thus, when application of continuous vibration could result in unrealistic structural, isolator, or other heat build-up effects, vibration should be applied for short periods representative of service conditions. Vibration periods should be alternated with vibration-off periods of sufficient length to allow heat dissipation.

The vibration schedules presented in this ITOP have been derived from field measurements from the transportation and/or application environment. The levels and test durations of these schedules were developed to establish test exposures considered to be representative of this field exposure. The overall schedule may reflect the use of exaggerated test levels to establish laboratory test durations which are compressed in time in relation to the duration of the field transport.

This process incorporates the accepted equivalent-damage theory (fatigue damage can be accelerated by increasing the stress level and reducing the number of stress applications). This is only applicable as long as the failure mechanism is assumed to be fatigue. If it is required or determined necessary to further reduce the test duration of the provided test schedules, conservatism (additional severity) may be added to the random spectra and periodic components of the schedules. This operation must be applied by utilizing the equivalent-damage theory. Caution must be applied to ensure that the resulting exaggerated test schedules do not contain levels which are significantly beyond peak, short-duration levels of the field exposure.

f. Combined temperature-vibration test. To expose materiel to realistic service stresses, a combined temperature-vibration test may be necessary. The high and low temperatures that materiel is expected to endure while being transported are usually specified in the requirements documents in terms of certain climatic categories in NATO STANAG 2895[b] and MIL-STD-210C.[c] A low temperature of -51 °C (category C3) will be assumed unless otherwise specified in the requirements documents. A temperature of 63 °C is usually adequate to cover all of the hot and warm climates (categories A1 through B3). Though air temperatures in boxcars, for example, may exceed 63 °C at times, the insulating properties of the packages, the thermal lag of the test item, and the relatively short occurrences of such temperatures argue in favor of limiting tests to 63 °C. For safety evaluation of ammunition and for other items of materiel requiring laboratory vibration testing at extreme temperatures, the test items are preconditioned as a group to achieve the prescribed temperature, and this temperature is maintained throughout the period of vibration. Sufficient temperature-conditioning time must be allowed to ensure complete temperature stabilization (MIL-STD-810E), unless ambient conditions are being used.

4. TEST PROCEDURES.

4.1 Field/Mission Secured Cargo.

The secured-cargo test is conducted to ensure that the test item in its shipping configuration is safe to transport and will not be adversely affected by the vibration environment to which it may be exposed. The field/mission transportation environment is defined in Appendix A along with maximum reasonable distances of travel.

Under these conditions, the packaging shall be part of the test setup; therefore, the packaged item will be securely fastened to the vibration fixture in its normal shipping orientation. Unpackaged items normally shipped unpackaged will be securely fastened to the vibration fixture, also in the normal shipping orientation.

The fixture used for this controlled-input vibration test consists of a flat table which provides restraints and tiedowns representative of those to be used during actual transport. Excitation should be applied through the three major axes. The item is not operated during this test.

The laboratory vibration test schedules given in Appendix B apply to general cargo and were derived from data acquired on cargo vehicles that were loaded to 75% of rated payload. The rationale for this procedure is given in reference 1. For special items of secured cargo that would load a vehicle above or below the 75% capacity, rating factors have been established as described in Appendix F. These factors increase or decrease the test schedule amplitudes as the special-cargo load weight varies.

4.1.1 Testing of Ammunition. It is necessary to determine the performance damage of the items following vibration testing by comparison with established baseline data. One method is to compare the performance of the test items exposed to vibration to the performance of other items from the same lot which have not been so exposed. Another method is to compare the vibrated item's performance against established performance standards. The method for establishment of the performance criteria will not be addressed in this ITOP.

a. Method.

(1) Select the number of samples required by the test plan, and inspect each visually and radiographically. Follow up by performing other nondestructive test inspections as required.

(2) Package the inspected samples in shipping containers as they would be sent from the depot.

(3) Condition the high temperature samples to 63 °C and low temperature samples to -51 °C, unless otherwise specified in the requirements documents.

(4) Mount the packaged sample in its normal shipping orientation on the vibration table. Utilize restraints and tiedowns which secure the package to the table so that it receives the input motion of the exciter. Steel banding is an acceptable mechanism for such tiedown. The test will be conducted in three axes, defined as:

(a) Vertical axis - direction of motion of the shaker perpendicular to the plane area of the base or bottom of the package.

(b) Longitudinal axis - direction of motion of the shaker parallel to the base and through the longitudinal axis of the package.

(c) Transverse axis - direction of motion of the shaker is the same as for the longitudinal axis but with the test item rotated 90° from its longitudinal-axis position.

(5) The vibration schedule for each axis of the test item shall be selected from Appendix B. The selection of which curve to use shall be based upon a typical mission/field transportation scenario. Appendix A provides information on the use of each curve as related to types of vehicles utilized for this transport.

(6) For tests which utilize the schedules in Appendix B, the time durations per axis are given in Table B-1 in terms of minutes per expected distance of transportation. Again a typical mission/field transportation scenario must be developed to determine the extent of travel anticipated for the specific test item. Unless the scenario is given, use the information provided in Appendix A.

(7) For special circumstances involving ammunition that is known to be sensitive to the vibration environment, a safety factor may be introduced by increasing the amplitudes of the schedules in Appendix B by values up to a maximum of 38%. This upper limit on the safety factor is based on the fact that the peak (worst-case) vibration amplitudes of the vehicle field data are generally 38% higher than the average-plus-standard deviation field data that were used to develop the schedules.

(8) Following the vibration exposure, visually examine the test item for damage to the packaging and ammunition for exudation, abrasions, disassembly, etc. Re-inspect the test item performing nondestructive tests similar to the pretest inspections. (See NOTE 1 below.)

(9) The test samples can be exposed to additional sequential environmental testing or fired for accumulation of performance data.

b. Data required. Record the following test conditions:

(1) Results of pre- and post-vibration inspections.

(2) Potential safety hazards.

(3) Mission/field transportation scenario developed for determining test schedules and durations.

(4) Vibration schedules selected.

(5) Test temperatures.

(6) Orientation of the test item during vibration.

(7) Test duration.

(8) Acquisition of performance data and comparison to baseline data or conduct of additional testing shall be accomplished in accordance with established test plans or other TOPs/ITOPs. (See NOTE 2 below.)

NOTE 1: Vibration exposure may damage the test ammunition. The damaged item will be fired (or functioned) if it is judged that an immediate safety hazard will not be created and that troops in the field would have overlooked or considered the damage negligible and fired (or functioned) the item.

NOTE 2: Most vibration tests of munitions involve exposure to a series of sequential environmental tests representative of the environments encountered in service applications. Other documents, such as ITOP 1-1-050, stipulate the nature and extent of the sequential testing along with other testing conditions as related to chamber pressure and weapon characteristics.

4.1.2 Testing of Items Other Than Ammunition.

a. Method.

(1) Inspect the test item, and perform all operational checks at ambient temperature. Establish baseline data for performance standards either from measurements or requirements documents.

(2) Precondition the test samples to storage and transit temperatures. Unless otherwise specified, condition half the samples at 63 °C and the other half at -51 °C.

(3) Mount the item in its transportation configuration on the table utilizing restraints and tiedowns which secure the package to the table so that it receives the input motion of the exciter. Steel banding is acceptable for tiedown during actual transport. The transport configuration shall incorporate shipping containers or packaging as defined in paragraph 4.1. Excitation should be applied through the three axes (longitudinal, transverse, and vertical).

(4) From a typical mission/field transportation scenario, determine the appropriate vehicle(s) and distance(s) expected for secured-cargo transport. Select the appropriate schedule(s) and test duration(s) from Appendix B, and conduct the vibration test.

(5) After completion of test exposure, inspect the test item; operate at ambient, upper and lower operating temperature, and compare performance with pretest baseline data.

b. Data required. Record the following test conditions:

(1) Performance values before and after vibration tests.

(2) Results of pre- and post-vibration inspections.

(3) Potential safety hazards.

(4) Mission/field transportation scenario developed for determining test schedules and durations.

(5) Vibration schedules selected.

(6) Test temperatures.

(7) Orientation of the test item during vibration.

(8) Test duration.

4.2 <u>Materiel Installed in Ground Vehicles</u>.

In addition to secured-cargo transportation, most military materiel will be exposed to vibration environments due to its intended application in service. Radios, electronic equipment, optical devices, and other electromechanical devices are mounted in/on various racks, panels, and other locations in/on vehicles. This materiel is then subjected to the vibration environment in/on the vehicle for either the lifetime of the vehicle or the service life of the installed materiel.

4.2.1 Ammunition Tests. Ammunition installed in tanks, self-propelled artillery, and other vehicles must be safe to carry in the ready racks of the vehicle in which it is stowed, and there must be no degradation in its performance. This tactical vibration environment is related to the vehicle stowage location and expected distance of transport. Information on vibration schedules and distances can be obtained in Appendix A. The test must be developed from a service scenario which addresses vehicle, installation location, travel distance, and type of road traversed. If available, the operational mode summary/mission profile and service life can be extracted from the user requirements documents to tailor the service scenario to user expectations. Any items such as obturator bands, lifting plugs, or rotating band covers that fall off the ammunition or are damaged while undergoing testing, shall not be replaced during the remainder of the test, to include the performance tests.

a. Method.

(1) The tactical vibration test usually follows the secured-cargo vibration test, and the samples used are drawn from those used for the secured-cargo test, generally half from the high temperature test portion and half from the low temperature test portion.

(2) Inspect the samples visually and radiographically, and perform other nondestructive test examinations as required.

(3) Precondition the test samples to the desired temperature. Unless otherwise specified, the high temperature will be 63 °C and the low temperature will be -51 °C.

(4) Place the samples into the vibration fixture simulating the configuration, attitude, and restraint of the appropriate ammunition ready rack. The vibration fixture shall be designed by utilizing racks, panels, and platform structures of the vehicle to minimize introduction of unrepresentative response to the samples. If actual racks are not available, locally fabricated racks that adequately simulate actual racks may be used.

Note: When using simulated racks with samples which are not rigidly secured in the rack, great care must be taken when choosing control locations and associated test levels. The transfer function between the energy input to the actual rack and worst case response in the rack should be identified and utilized in the decision making process. Further investigation may be required to properly identify the appropriate interface between test item and test fixture.

(5) Select the vibration schedule for each axis (vertical, transverse, and longitudinal) of the test item from Appendix C.

(6) For tests which utilize the schedules in Appendix C, the time durations per axis are given in Table C-1 in terms of minutes per expected distance of transportation. Again, a typical mission/field transportation scenario must be developed to determine the extent of travel anticipated for the specific test item. Unless the scenario is given, use the information provided in Appendix A.

(7) Following vibration testing, re-examine the test items visually, radiographically, and by other nondestructive means as required.

(8) Conduct performance testing as required, and compare post-vibration exposure performance with established baseline data.

NOTE: The vibration level is controlled from one or more accelerometers mounted at or near the attachment point between the item or rack and test fixture. If more than one accelerometer is used for control, the response of these accelerometers shall be averaged when used in the feedback control loop. The notes in paragraph 4.1.lb also apply to this test.

b. Data required. Same as paragraph 4.1.1b.

4.2.2 Other Equipment. The test item (radio, telescope, air conditioner, etc.) must be able to withstand the vibration induced by the vehicle in which it is installed for the expected life of the vehicle or the life of the test item, if different.

The vibration test for such materiel shall be based upon the expected stress level intended for the materiel at the installed location on/within the vehicle. The selection of the vibration schedule and test duration shall be made in accordance with information provided in Appendix A. The vehicle and distance shall be determined from development of a transport scenario.

a. Method.

(1) Select an item for test.

(2) Inspect the test item and perform all operational checks according to the technical manual or test plan requirements. The test item must be in acceptable operating condition prior to exposure to vibration tests. All failures and/or shortcomings revealed during operational checks must be repaired or components replaced prior to vibration exposure.

(3) Install the test item into a vibration fixture which has been designed with sufficient structural rigidity to transmit the designed vibration levels. This fixture shall incorporate the actual vehicle mounting structure, as far as practical, to allow the test item to respond to the laboratory excitation in a manner more closely related to the application environment. Orient the item in the fixture/structure in the same manner as the application configuration. Perform a response-characterization test of the test item (if required) as defined in paragraph 3.3b.

(4) Complete the test at ambient temperature unless otherwise stipulated.

(5) The vibration schedule for each axis (vertical, transverse, and longitudinal) of the test item shall be selected from Appendix D.

(6) For tests which utilize the schedules in Appendix D, the time durations per axis are given in Table D-1 in terms of minutes per expected distance of transportation. Again a typical mission/field transportation scenario must be developed to determine the extent of travel anticipated for the specific test item. Unless the scenario is given, use the information provided in Appendix A.

(7) Conduct the vibration test in each of three mutually orthogonal axes.

(8) Following vibration testing in each axis, perform the appropriate checks listed below:

(a) Inspect for visual damage and/or loosened components.

(b) Operate equipment at ambient temperatures.

b. Data required. Record the following test conditions:

(1) Performance values before and after vibration tests.

(2) Results of pre- and post-vibration inspections.

(3) Potential safety hazards.

(4) Mission/field transportation scenario developed for determining test schedules and durations.

(5) Vibration schedules selected.

(6) Test temperatures.

(7) Orientation of the test item during vibration.

(8) Test duration.

(9) Response characteristics of test item (if measured).

4.3. Materiel Installed Within and External to Helicopters.

This test is conducted to ensure that the test item will be able to withstand the vibration environment of the helicopter in which it is installed for the expected life of the helicopter or life of the test item, if different. This exposure is in addition to the exposure the test item would have experienced in secured-cargo transportation. The vibration environment of the helicopter is broken down into two areas: the first is materiel installed as external stores, which are attached to the wings or pylons of a helicopter; the second is materiel installed within the helicopter in racks, panels, or on/in other aircraft structures.

For testing purposes, the aircraft can be divided into three zones. The zones are defined in terms of the rotating aircraft components which produce dominant vibration sources in the region of the aircraft. (See Fig. E-1.) All equipment locations included within a vertical projection of the main rotor disk should use the source frequencies of the main rotor. For materiel to be located within a horizontal projection of the tail rotor, use the source frequencies of the tail rotor. All material located on drive-train components such as gear boxes and drive shafts should use the source frequencies of that drive-train component (i.e., gear mesh frequency, shaft rotational speed, etc.).

An obvious requirement for helicopter materiel is the avoidance of the item's natural resonant frequency at or near the frequency of the helicopter source vibration affecting that region of the aircraft where the materiel is to be installed. The response characterization of the test item shall be determined as defined in paragraph 3.3b. The resonant frequencies and transmissibilities shall be determined before and after exposure to the test vibration environment. Significant changes in resonant properties must be thoroughly evaluated and shall be considered as an item failure if structural changes are identified even though the item still functions to specification levels.

4.3.1 Materiel Installed Within Helicopters. This test is conducted to determine the capability of equipment installed within helicopters to withstand the expected vibration stresses.

a. Method.

(1) Select an item for test.

(2) Perform a visual inspection for damage, and perform all operational checks according to the technical manual. The test item must be in acceptable operating condition prior to exposure to vibration tests. All failures and/or shortcomings revealed during operational checks must be repaired or components replaced prior to vibration exposure.

(3) Install the test item into a vibration fixture which has been designed with sufficient rigidity to transmit the desired vibration excitation. This fixture shall incorporate actual aircraft mounting structure, as far as practical, to allow the test item to respond to the laboratory environment. Orient the test item in the fixture in the same orientation as the application configuration.

(4) Perform a response characterization test of the test item. Identify the test-item resonant frequencies and transmissibilities. These structural properties can be determined by applying vibration excitations as detailed in paragraph 3.3b.

(5) Establish a life cycle profile for the test item. This profile must identify the helicopter(s) in which the test item will be installed, hours of expected operation, hours of expected operation between maintenance inspections, typical flight profiles, and any other operational properties or limitations which would affect test level or duration. Make a determination whether the test item is to be mounted on vibration isolators or hard mounted in its application environment.

(6) If flight-worthiness (structural-survivability) testing is required and no field data are available, a 1-hour-per-axis exposure at the levels and spectra given in Appendix E is suggested. For operational capability and functional testing, appropriate vibration schedules and test durations shall be developed from the measured application environment associated with the life profile.

(7) Determine and select location(s) of accelerometer(s) to be used for controlling the vibration levels based upon the type of test exposure desired. If the test levels are based upon item response, attach the accelerometer(s) to the test item; for platform input, locate the accelerometer(s) on the fixture near the attachment point between fixture and item. If more than one accelerometer is used for control, the response of these accelerometers shall be averaged in the feedback control loop.

(8) Perform the vibration test in each of the three mutually perpendicular axes and at ambient temperatures (unless otherwise specified).

(9) Operate the test item during exposure to laboratory vibration excitations. Care must be exercised in evaluating operational capability and performance when the test item is exposed to the vibration test levels.

(10) Following the vibration test, perform the actions listed below:

(a) Post-test response characterization determinations for comparison to pre-test measurements.

(b) Inspection for visible damage.

(c) Operational checks for comparison to pre-test measurements.

(d) Measurement/check of all performance parameters.

b. Data required.

(1) Life profile of test item.

(2) Vibration schedule selected.

(3) Test duration.

(4) Response characterization determinations before and after vibration exposure.

(5) Test temperatures.

(6) Results of visual inspections.

(7) Results of operational checks.

(8) Measurements/checks of performance parameters.

4.3.2 Assembled External Stores - Helicopters. This test is conducted to ensure that externally carried stores attached to the wings and pylons of helicopters are capable of withstanding dynamic vibration stresses normally induced by helicopters. The test is applicable to the store structures as well as munitions and materiel installed within stores.

a. Method.

(1) Select the desired number of test items. (Select munitions from lots previously tested as secured cargo.) For store structures such as rocket launchers, accomplish exposure to vibration with the store full of munitions and with the store half full.

(2) Perform a visual inspection for damage, nondestructive-test inspections, and all operational checks according to the technical manual.

NOTE: The test item must be in acceptable operating condition prior to exposure to vibration tests. All failures and/or shortcomings revealed during operational checks or visual or nondestructive inspections must be repaired or components replaced before the vibration test is accomplished.

(3) Mount the test item into a vibration fixture which has been designed to transmit the desired vibration excitation. This fixture shall incorporate an actual aircraft mounting structure, as far as practical, to allow the test item to respond to the laboratory exposure in a manner more closely related to the application environment. Orient the test item in the fixture in the same orientation as the application configuration (e.g., suspension lugs for 2.75-in. rocket launcher in the UP position).

(4) Select the location(s) of the accelerometer(s) to be used for controlling the vibration test levels. The selected location(s) will be either on the store near the forward lug with response control or on the fixture at the interface of the store and fixture for platform input control. If more than one accelerometer is used for control, the response of these accelerometers shall be averaged in the feedback control loop.

(5) Perform a response characterization test of the test item. Identify the test item's resonant frequencies and transmissibilities. These structural properties can be determined by applying a vibration excitation as identified in paragraph 3.3b and measuring the response of the test item at the points of concern. For tests of munitions, conduct this phase only to determine the effect of the munition upon the store structure.

(6) Establish a life cycle profile for the test item. This profile shall include identification of the helicopter(s) upon which the store will be attached, hours of operation, number of expected missions, hours of expected operation or missions between maintenance inspections, typical mission profiles, and any other operational properties or limitations which would affect the test levels or durations of the laboratory test.

(7) If flight worthiness (structural-survivability) testing is required and no field data are available, a 1-hour-per-axis exposure at the levels and spectra given in Appendix E is suggested. For operational capability and functional testing, appropriate vibration schedules and test durations shall be developed from the measured application environment associated with the life profile.

(8) Perform the vibration test in each of the three mutually perpendicular axes and at the temperature stipulated. Unless otherwise specified, the high temperature will be 63 °C and the low temperature will be -51 °C.

(9) Following the vibration test, perform the actions listed below:

(a) Post-test response characterization determinations for comparison with pre-test measurements.

(b) Inspection for visual damage.

(c) Nondestructive test examinations.

(d) Operational checks for comparison with pre-test measurements.

(e) Measurements/checks to all performance parameters.

b. Data required. Record the following test conditions:

(1) Life profile of test item.

(2) Vibration schedule(s) selected.

(3) Test duration.

(4) Response characterization determinations before and after test exposure.

(5) Test temperature(s).

(6) Results of visual and nondestructive inspections.

(7) Results of operations checks.

(8) Results of performance measurements.

5. DATA REQUIRED.

The data required is specified in the individual test paragraphs, 4.1 through 4.3.

6. PRESENTATION OF DATA.

Summarize data obtained during tests using narration, tables, photographs, charts, and graphs as appropriate. Evaluate any damage to ammunition to determine whether firing of the test item would result in a safety hazard to friendly troops, whether the damaged item would have functioned on impact, and whether or not the damaged ammunition could be safely disposed of.

APPENDIX A. BACKGROUND/SELECTION OF SCHEDULES.

1. The Vibration Test.

a. Vibration is an oscillation that describes the motion of a mechanical system. A description of the techniques used for developing laboratory vibration test schedules from field data is contained in ITOP 1-1-050.

b. During transportation, vibration is induced by several factors including the roughness of the medium through which the vehicle travels whether it be air, ground, or sea; the action of the power source whether it be a rocket motor or an engine; irregularities at the interface of the medium and the vehicle related to such features as tires, wheels, wings, and rotors; rotational imbalances; and actions of moving subassemblies.

c. The overall objective of laboratory vibration tests is to produce the same force-dependent damage in a laboratory as the specimen would incur during its life. This is known as equivalent testing. The principal problem is to establish a relationship between the vibratory oscillation and the damage that is introduced into the test specimen by this oscillation. To establish this relationship, first the assumption is made that damage accumulates linearly according to Miner's Theory. Additionally, given that the environment is random, stationary, and ergodic and that the system responds as a simple mechanical oscillator, investigators devised a method for determining an equivalent vibration level that would produce the same damage as that in service. The work of Miner and other investigators is used as the basis for equivalent tests that have been derived based on the measured environment. The severity of the test, i.e., magnitude of acceleration, frequency and time of exposure, must be related to the environment and transport distance of the test item in its intended field use.

d. Vibration testing has proved useful in determining design weakness and in estimating the ability of test items to withstand severe environments. Extensive research has been conducted by private industry, universities, and the Government in an effort to more realistically analyze structural response to vibratory motion and to derive meaningful laboratory vibration tests by analysis.

2. Types of Transportation Environment.

a. During its life cycle, Army materiel transport involves all forms of standard vehicles, both commercial and military. In such cases as shipment by rail, ship, truck/semitrailer, or fixed-wing aircraft, there is no real distinction between the commercial and military vehicle environments for individually packaged or containerized cargo. Transportation by track-layers, helicopter, two-wheeled trailers, and special-purpose vehicles is generally accepted as being uniquely military. Whether the materiel is shipped by commercial or military vehicles is of little relative importance. What is important in arriving at the proper test is determining whether the environment to be simulated is secured cargo, installed materiel, loose cargo, or any combination of these. The forms of transportation may be divided as follows:

(1) Secured cargo. The transportation associated with moving an item, in its logistical package secured to the carrier, by commercial common carrier, military long-range aircraft, ship, rail, or surface military transportation (including truck, tracked cargo carrier, or two-wheeled trailer, as applicable) over improved and unimproved roads. Logistical transportation involves the movement of secured cargo. Secured cargo is defined as equipment tied down or restrained in such a way that its base or attachment points move with the cargo bed.

(2) Installed materiel. This applies to the movement of unpackaged items installed on, or carried in holders by mobile equipment. Examples are ammunition in vehicle ready racks, radios in helicopters, or rockets in their launchers mounted on helicopters. It includes mounted components as well as other equipment (not part of the basic vehicle structure) bolted or otherwise securely fastened to the vehicle, usually remaining attached for the life of the vehicle.

(3) Loose cargo. This includes packaged/unpackaged items placed on the cargo bed of a truck or trailer without any restraints. This form of transportation is covered by the loose-cargo test described in ITOP 4-2-602.[d]

Most items, are tested for both environments in accordance with the vibration test(s) described herein and the loose-cargo test.

b. Vibration levels for rail, ship, and fixed-wing aircraft cargo environments are so low in comparison to the levels existing in land vehicles that they are considered to have negligible additional effect on Army materiel and need not be imposed separately. Testing of an item to the greater amplitude severity of ground vehicles encompasses the damage potential of rail, shipboard, and aircraft (except helicopter) cargo vibration environments.

3. Selection of Vibration Schedules.

The selection of one or two appropriate vibration schedule(s) involves a determination of the types of movements that the materiel in question may encounter.

a. All packable end items transported from the factory to some distribution point or warehouse may be assumed to be carried as secured cargo during logistical transportation. For most end items secured cargo transportation continues to a point where the items are issued to troops. Some items, ammunition in particular, are carried still further after being installed in a major item of equipment such as a tank or helicopter. In all cases the choice of vibration schedules is dependent upon the life cycle of the materiel. With some items, only the secured cargo test is necessary; others require only the installed materiel test, and still others may require both the secured-cargo and the installed materiel tests. Table A-1 provides guidance for a number of Army items.

b. In addition to the vibrations discussed above, an item that is being transported, handled, and carried may also encounter drops, either accidentally or intentionally, as well as other rough treatment. Such events are considered to be shock rather than vibration and are simulated as part of the rough handling tests which include not only drop but a loose cargo test as well, all of which are covered in ITOP 4-2-602. The loose cargo test simulates a condition wherein the item (either in a packaged or unpackaged configuration) is placed in the cargo bed of a vehicle without restraints.

c. For most items, vibration tests are conducted to ensure that the materiel will not suffer degradation in performance from vibration environments likely to be encountered. While this is also true of ammunition, a more important requirement is that ammunition be safe to transport. Thus, for ammunition, the secured cargo vibration test is a part of safety testing, ITOPs 4-2-504(1)[e], (2).[f] For tank and self-propelled artillery ammunition, the installed equipment test (simulation of ammunition in the ready racks) is also part of safety testing.

Table A-1. Vibration Tests For Various Army Items.

Installed Equipment Vibration Test

Test Item	Tactical Vibration Test	Installed in Vehicles	Installed in Helicopter	Externally Mounted on Helicopters
Tank Ammunition	X	X	---	---
Artillery Ammunition	X	X	---	---
Mines, Grenades, Pyrotechnics, etc.	X	X[a]	---	X[a]
Rockets, Missiles	X	X	X	X
Infantry Rockets and Missiles	X	---	---	---
Recoilless Rifle and Mortar Ammunition	X	X[a]	---	---
Small Arms Ammunition	X[a]	X[a]	X[a]	X
Air Conditioners[b]	X[a]	X	---	---
Generators[b]	X	X[a]	---	---
Installed Radios Control Equipment	---	X	X	---
Installed Fire Control Equipment	---	X	X	---
Man Portable Radios and Fire Control Equipment	X	---	---	---

[a]As applicable
[b]Testing is often conducted according to a schedule in the procurement specification for the particular item.

4. Development of Mission/Field Transport Scenario.

The mission/field transport scenario shall address the transportation of Army materiel from the factory to end use. For ground transportation this evaluation must establish a list of types of vehicles to be encountered for each phase of transport, types of terrain which the vehicles will traverse, and expected distance for each phase of transport. The helicopter environment shall require similar analysis as above for ground transportation, with the added phases associated with aircraft flight. These aircraft flight phases shall include development of a list of types of expected aircraft, materiel configuration, and hours of expected flight or number of missions.

a. The schedules developed for secured cargo transportation were derived from the typical mission/field transport scenario shown below:

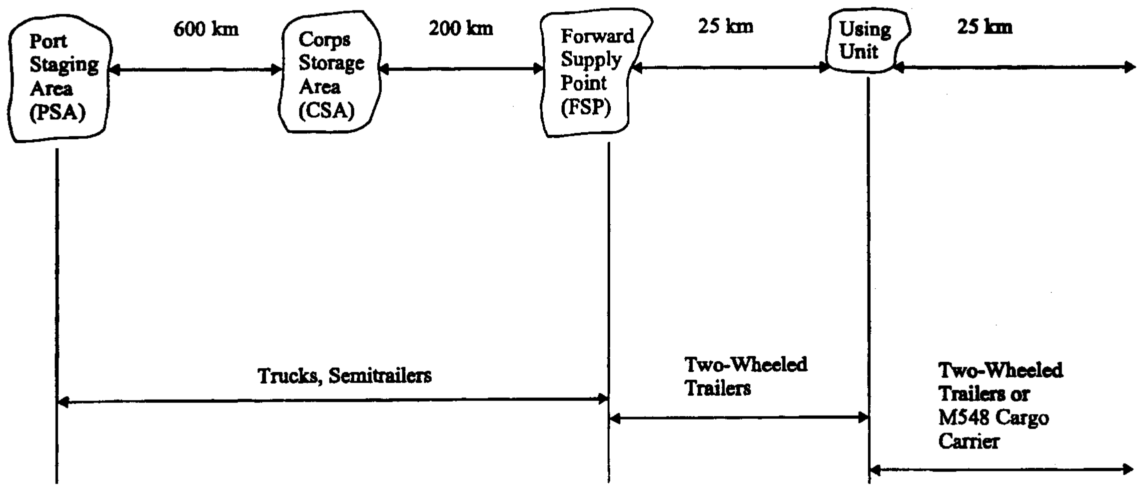


Figure A-1. Transportation, Modes and Distances Traveled in Each Mode for Transporting Materiel from the Port Staging Area to User in the Field.

As seen, the typical mission/field transport scenario starts at the port staging area. The movement prior to this point would include transport by commercial common carrier, military long-range aircraft, ship, and/or railroad. This movement would occur over improved road surfaces or in platforms which have been proven to impose significantly lower vibration levels than those vehicles used for transport from the port staging area to the using unit. The commercial common-carrier platform environment would be significant only if no other ground transportation is to occur after arrival at the port staging area. (For tests of materiel which experience only this type of movement, refer to MIL-STD-810E for appropriate test schedules and durations.)

The typical scenario has established that 800km of transport are expected between the PSA and the forward supply point (FSP). This transport is in trucks and/or semitrailers. The road surfaces will be paved, secondary, and cross-country. These road surfaces are defined as:

PAVED: Concrete, bituminous, or brick-surfaced streets, roads, or highways.

SECONDARY: Prepared, packed-surface roads of stone or other stabilizing material.

CROSS-COUNTRY: Direct point-to-point travel over reasonably virgin terrain where there is a variety of obstacles such as ditches, streams, rock outcrops, shrubs and trees, and other natural barriers.

The movement from the FSP to the user unit and beyond consists of two 25km hauls. Each of these movements can be accomplished by trucks, tracked cargo carriers, or two-wheeled trailers over any of the aforementioned road surfaces. If the cargo will fit within the size restraints of the two-wheeled trailer, this vehicle schedule shall be used since the vibration levels are significantly higher. Materiel that is too large for the two-wheeled trailer will be exposed to the composite wheeled vehicle schedule. The tracked cargo carrier (M548) schedule shall be used for materiel (ammunition) which is known to be hauled in it.

b. The vibration levels used for developing the secured cargo test schedules were obtained from the various vehicles traversing a variety of test courses. Specifically, the wheeled vehicles and trailers were operated over selected courses representing cross country terrain, which is the most severe vibration-producing terrain for these vehicles; the track-laying vehicles were operated on a paved road which is the most severe vibration environment for those vehicles. The actual courses utilized for the cross-country environment were the Belgian Block, Radial Washboard, Spaced Bump, and Two-Inch Washboard; the high speed Three Mile Straightaway Course was used for the paved course.

All of these courses are contained within the Munson and Perryman Areas at the U.S. Army Aberdeen Test Center. Based on information contained in TOP 2-2-506[k], 33% of the scenario cross-country transport distance in wheeled vehicles will be terrain typified by the four Munson courses, and 30% of the scenario distance for tracked vehicles will be on paved surfaces (ref 1).

c. The vibration levels used for developing the installed materiel test schedules were obtained in the same manner as the secured cargo levels, the only difference being the actual locations of the measuring transducer. The installed materiel mileages vary according to vehicle type and materiel and are addressed in Table A-2.

5. Test Durations.

a. Test duration for the secured cargo transportation exposure is again based upon the scenario shown above. The vibration levels for the specific vehicle or class of vehicles is applied for the times given on each schedule (Appendix B). This exposure is representative of the transport distance shown on the scenario.

b. For materiel installed in ground vehicles, the times given on the schedules are representative of the vibration exposure for a given distance of travel. The total distance such installed materiel is required to remain in ground vehicles is usually not specified in the requirements documents. Thus, an estimate of the distance must be made for each item being tested. Determining the equivalent distance to be simulated for installed materiel is complex as it must be based upon the distance expected to be accumulated by the carrying platform. Military tactical wheeled vehicles have an established minimum expected life of 80,000 km without major overhaul or rebuilding. Most sensitive electronic and fire control equipment is installed in vehicles classified as "tactical support equipment" with an established minimum expected life one-half of that established for tactical wheeled vehicles or 40,000 km. Thus, most of the sensitive on-board mounted equipment on wheeled vehicles would be exposed to 40,000 km in the field life span. During rebuilding operations, all vehicle components are removed, inspected, repaired/replaced, and installed on-board equipment is considered as vehicle components.

The minimum established distance between depot overhaul of military combat vehicles, including tracked vehicles, is 9600 km. Again, all components of these vehicles, including fire control equipment, are repaired or replaced during this overhaul. Ammunition is also installed within such vehicles and has a high probability of being carried in the ready rack as long as 30 months (ref i). Table A-2 provides information on the expected distance materiel will be transported in various types of Army vehicles.

Table A-2. Expected Transport Distance For Materiel Installed In Ground Vehicles.

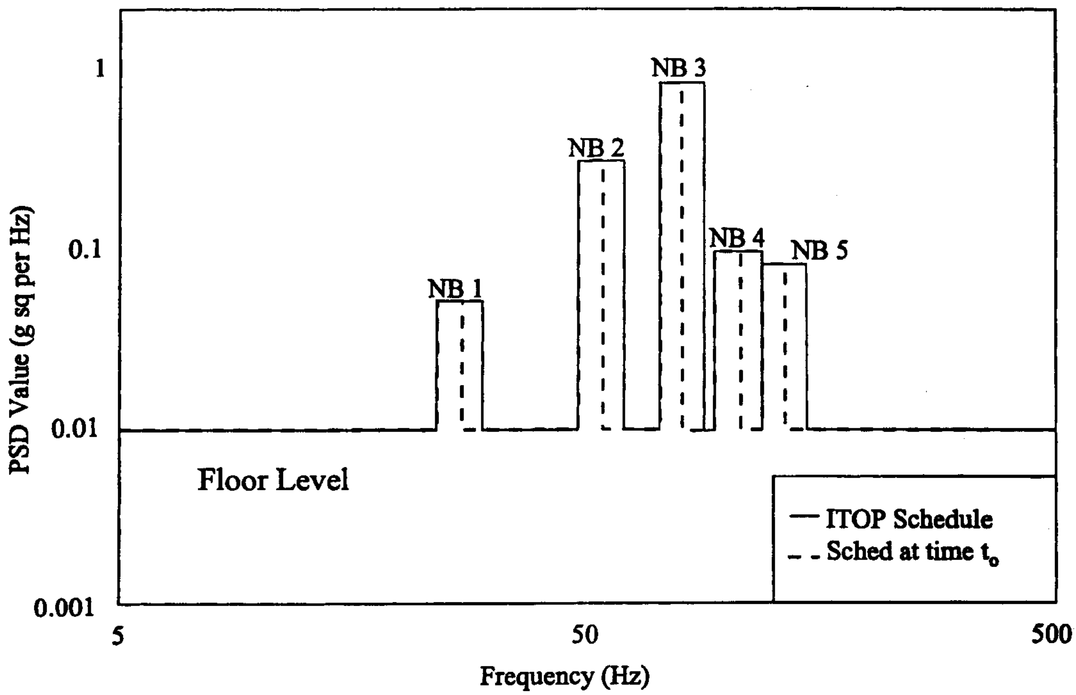
Vehicle	km
AMMUNITION	
Combat tanks	
M60A3	8000
M1	8000
M1A1	8000
Self-propelled Howitzers	
M109A3	7000
OTHER EQUIPMENT	
Tracked vehicles	9600
Wheeled vehicles	40,000

6. Narrowband Random on Random Explanation.

a. The data presented were derived with the bandwidth of the sweeping band always equal to 1/2 of the defined narrowband (see Figure A-2). The center frequency of the sweeping band is swept up or down 1/2 of the defined narrowband such that when the sweeping band center frequency is at its lowest frequency the lower frequency band edge of the sweeping band and the lower band edge of the narrowband coincide. When the center frequency of the sweeping band is at its highest frequency, the upper band edge of the sweeping band and the upper band edge of the narrowband coincide.

b. A sweep is defined as moving the sweeping band up in frequency. Two sweeps is a sweep up in frequency and a sweep down in frequency to the original position. Three sweeps will be an up, down, and an up frequency movement, etc.

c. When it is an option (generally, on newer control systems), the sweep shall be linear rather than logarithmic. Linear sweep best simulates the original intent of simulating tracked vehicle speed changes.



Notes:
A single axis is typically represented by several test phases.
Number of narrow bands may vary.
See definitions in text.

Figure A-2. Typical swept Narrow Band Random-on-Random Test Phase.

APPENDIX B. WHEELED- AND TRACKED-VEHICLE SECURED CARGO VIBRATION.

Figures B-1 through B-3 represent the cargo environment at the cargo bed of a composite of U.S. and German tactical wheeled vehicles. The U.S. vehicles were the M127 12-ton semitrailer, M813 and M814 5-ton trucks, M36 2-1/2-ton truck, CUCV M1009 1-1/2-ton truck, HMMWV M998 1-1/4-ton truck, and HEMTT M985 10-ton truck; the German vehicles included the following trucks: Unimog, 2-ton, MAN 5-ton, MAN 7-ton, MAN 10-ton, and MAN 15-ton. The data used for establishing these spectra were derived from measurements of the vehicles operating at various speeds over specially designed courses representing unimproved road and off-road conditions. Figures B-4 through B-6 represent the cargo environment at the cargo bed of the 1/4-ton M416 and the 1-1/2-ton M105A2 two-wheeled trailers (U.S.), and the German 1-1/2-ton two-wheeled trailer. Figures B-7 through B-15 represent the 10 ton M985 HEMTT (US), 5 ton M813/814 truck (US) and the M998 HMMWV (US). Again the spectra were established from measurements on the two-wheeled trailers operating over the same specially designed courses. These spectra are broadband random with peaks and notches at various discrete frequency bands. The break points of the peaks and notches are given for establishing the spectra shapes. Excitation shall be applied through the three major axes of the test item.

Table B-3 presents the vibration environment at the cargo bed of the M548 tracked vehicle. These spectra were derived from measurements on the vehicle while operating at various speeds on a paved road. The schedules consist of a flat low-level broadband random excitation across the total frequency spectrum with higher level narrowbands of random excitation superimposed on the broadband environment. The narrowbands of random energy are from the track-laying patterns and are vehicle speed related and are swept simultaneously across the total frequency bandwidth of the applicable narrowband at the specified bandwidth and sweep rate. Excitation shall be applied through the three axes as described above. The transport distance and associated test duration given in Table B-1 represent a one-time movement through the transport scenario defined in Figure A-1. A determination of the number of transport scenarios to be simulated must be made during test planning to ensure proper mileage simulation.

The acquisition and processing of data for all the vehicles are documented in References j and m.

During laboratory testing, the vibration control accelerometers should be located on the mounting platform as close as possible to the test load.

Table B1. Time Schedules For Vibration Of Items Transported As Mission/Field Secured Cargo.

Transport mode	Figure #	Page #	Transport Distance-km	Test Duration
Tracked Vehicle	Table B-3	B-4	25	60 minutes per axis
Wheeled Vehicles	Figure B-1	B-5	800	40 minutes per axis
	Figure B-2	B-6	800	40 minutes per axis
	Figure B-3	B-7	800	40 minutes per axis
Two-wheeled Trailers (See NOTE.)	Figure B-4	B-8	50	32 minutes per axis
	Figure B-5	B-9	50	32 minutes per axis
	Figure B-6	B-10	50	32 minutes per axis
M985 HEMTT 10 Ton Truck	Figure B-7	B-11	800	40 minutes per axis
	Figure B-8	B-12	800	40 minutes per axis
	Figure B-9	B-13	800	40 minutes per axis
M813/814 5 Ton Truck	Figure B-10	B-14	800	40 minutes per axis
	Figure B-11	B-15	800	40 minutes per axis
	Figure B-12	B-16	800	40 minutes per axis
M998 HMMWV Cargo Bed	Figure B-13	B-17	800	40 minutes per axis
	Figure B-14	B-18	800	40 minutes per axis
	Figure B-15	B-19	800	40 minutes per axis

NOTE: This is the maximum distance of travel in the two-wheeled trailer from Figure A-1, Appendix A. If the tracked vehicle (M548) is used, this transport distance and corresponding test duration should be reduced by 50 percent.

The actual field vibration levels have been exaggerated in order to reduce the laboratory test times. The individual exaggeration factors used are presented in Tables B-2 and B-3. If the user determines that the selected test times are unacceptable, the actual field levels may be exaggerated to a greater extent using the procedures discussed in ITOP 1-1-050[1].

Table B-2. Test Exaggeration Factors For Vibration Of Items Transported As Mission Field-Secured Cargo.

Transport Mode	Exaggeration Factor
M985 HEMTT	1.85
M813/814	1.85
M998 HMMWV	1.85
Composite Wheeled Vehicle	1.85
Two-wheeled Trailer	1.00
Tracked Vehicle	0.69*

NOTE: If ammunition is destroyed or damaged beyond safe and effective use during test, reduce exaggeration factors and annotate test records.

* Since test time would have been only approximately 4.8 minutes at the exaggeration factor of 1, test time could not be properly accommodated by existing software for narrowband random-on-random type lab test. For additional guidance and background information consult ITOP 1-1-050, Appendix A, page A-6, paragraph 4.c, (1), (2), and (3).

Table B-3. Narrowband Random-On-Random Vibration Program Data For Secured Cargo Transportation, Tracked Vehicle.

					NARROWBAND 1			NARROWBAND 2			NARROWBAND 3			NARROWBAND 4			NARROWBAND 5		
Test Phase	5-500 Hz Floor g²/Hz	No. Sweeps	Overall RMS g	Time min	BW Hz	Ampl g²/Hz	Sweep BW Hz	BW Hz	Ampl g²/Hz	Sweep BW Hz	BW Hz	Ampl g²/Hz	Sweep BW Hz	BW Hz	Ampl g²/Hz	Sweep BW Hz	BW Hz	Ampl g²/Hz	Sweep BW Hz
VERTICAL AXIS																			
V1	.0041	1	1.70	12.0	30-35	.0876	2	60-70	.0405	5	90-105	.0319	7	120-140	..0131	10	150-175	0173	12
V2	.0024	1	1.47	12.0	41-47	.0686	3	82-94	.0759	6	123-141	.0073	9	164-188	.0090	12	205-235	.0173	15
V3	.0059	1	2.74	12.0	53-65	.1480	6	106-130	.0090	12	159-195	.0717	18	212-260	.0363	24	265-325	0655	30
V4	.0043	1	2.86	12.0	71-88	.1389	8	142-176	.0942	17	213-264	.0873	25	284-352	.0378	34	355-440	0078	42
V5	.0068	1	5.85	12.0	94-112	1.6288	9	188-224	.7682	18	282-336	.0787	27	376-448	.0228	36	------	------	--
TRANSVERSE AXIS																			
T1	.0020	1	1.17	12.0	30-35	.0220	2	60-70	.0300	5	9*0-105	.0151	7	120-140	.0073	10	150-175	.0050	12
T2	.0016	1	1.17	12.0	41-47	.0223	3	82-94	.0212	6	123-141	.0105	9	164-188	.0089	12	205-235	.0174	15
T3	.0054	1	2.05	12.0	53-65	.0716	6	106-130	.0325	12	159-195	.0238	18	212-260	.0123	24	265-325	.0153	30
T4	.0039	1	2.51	12.0	71-88	.0722	8	142-176	.1480	17	213-264	.0483	25	284-352	.0097	34	------	------	--
T5	.0032	1	2.90	12.0	94-112	.2826	9	188-224	.1750	18	282-336	.0360	27	376-448	.0127	36	------	------	--
LONGITUDINAL AXIS																			
L1	.0031	1	1.36	12.0	30-35	.0257	2	60-70	.0182	5	90-105	.0074	7	120-140	.0016	10	150-175	.0084	12
L2	.0016	3	.95	12.0	41-47	.0100	3	82-94	.0155	6	------	------	--	------	------	--	------	------	--
L3	.0051	1	2.06	12.0	53-65	.0559	6	106-130	.0306	12	159-195	.0177	18	212-260	.0223	24	265-325	.0204	30
L4	.0038	1	2.28	12.0	71-88	.1196	8	142-176	.0128	17	213-264	.0400	25	284-352	.0284	34	355-440	.0312	42
L5	.0047	1	2.85	12.0	94-112	.1330	9	188-224	.1501	18	282-336	.0582	27	376-448	.0208	36	------	------	--

Exaggeration Factor = .69

Figure B-1. Laboratory Vibration Schedule, Composite Wheeled Vehicle, Vertical Axis.

BREAKPOINTS

FREQ	PSD VALUE
5	.2366
8	.6889
12	.0507
21	.0202
23	.0301
24	.0109
26	.0150
49	.0038
51	.0054
61	.0023
69	.0111
74	.0029
78	.0048
84	.0033
90	.0052
93	.0034
123	.0083
160	.0041
207	.0055
224	.0139
245	.0031
276	.0129
287	.0036
353	.0027
375	.0049
500	.0010

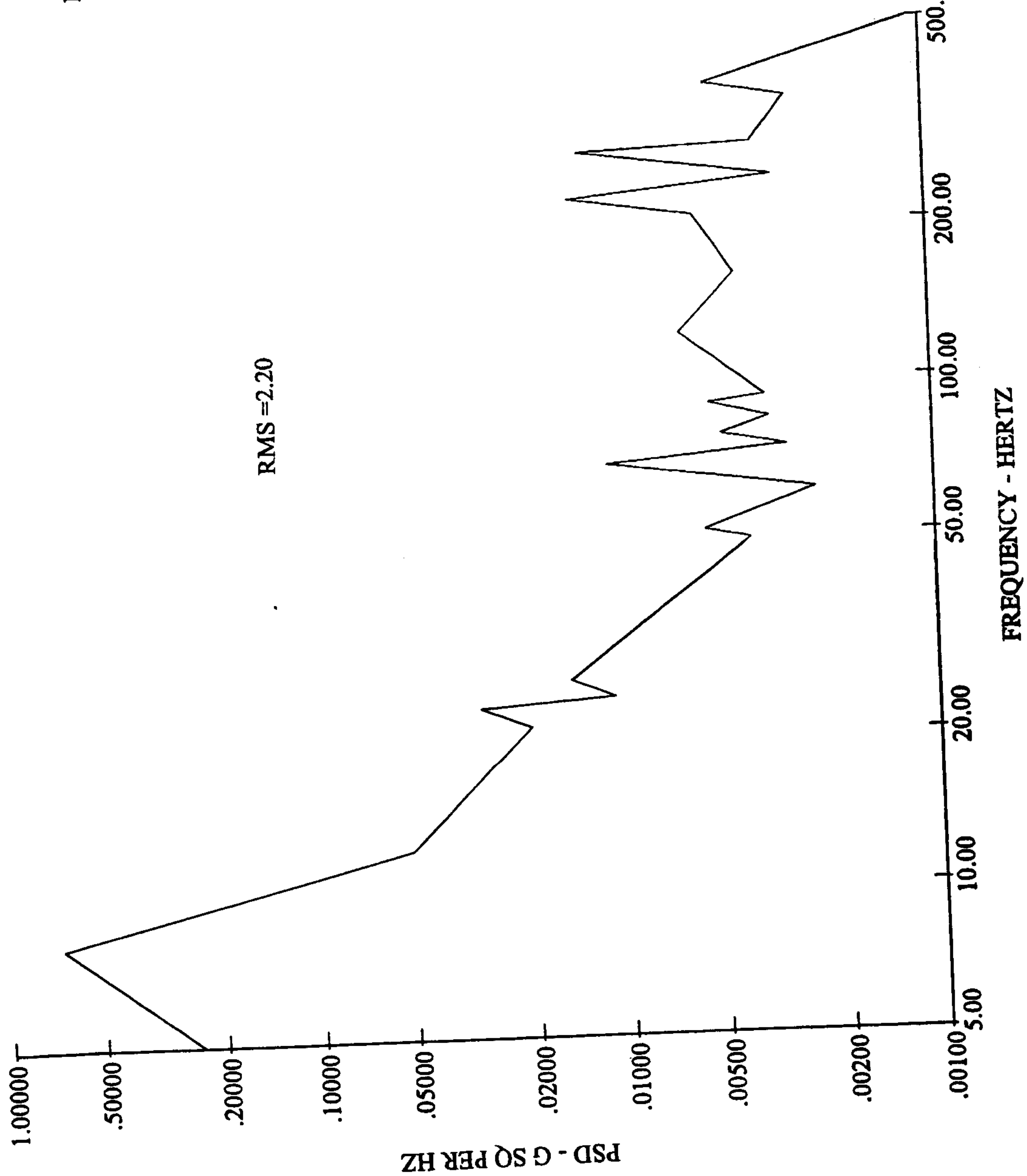


Figure B-2. Laboratory Vibration Schedule, Composite Wheeled Vehicle, Transverse Axis.

BREAKPOINTS

FREQ	PSD VALUE
5	.1344
7	.1075
8	.1279
14	.0366
16	.0485
17	.0326
19	.0836
23	.0147
116	.0008
145	.0013
164	.0009
201	.0009
270	.0051
298	.0021
264	.0099
375	.0019
394	.0073
418	.0027
500	.0016

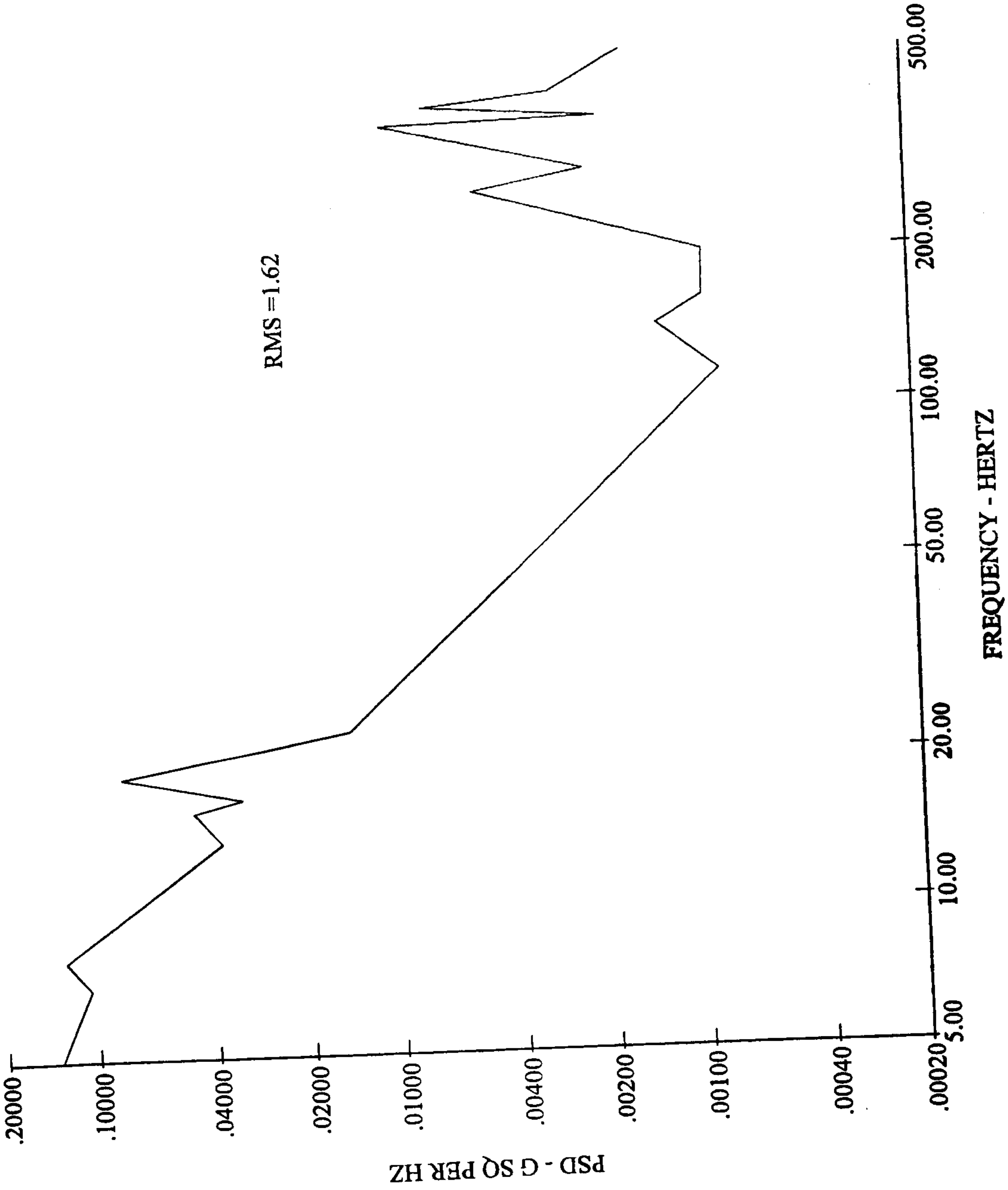
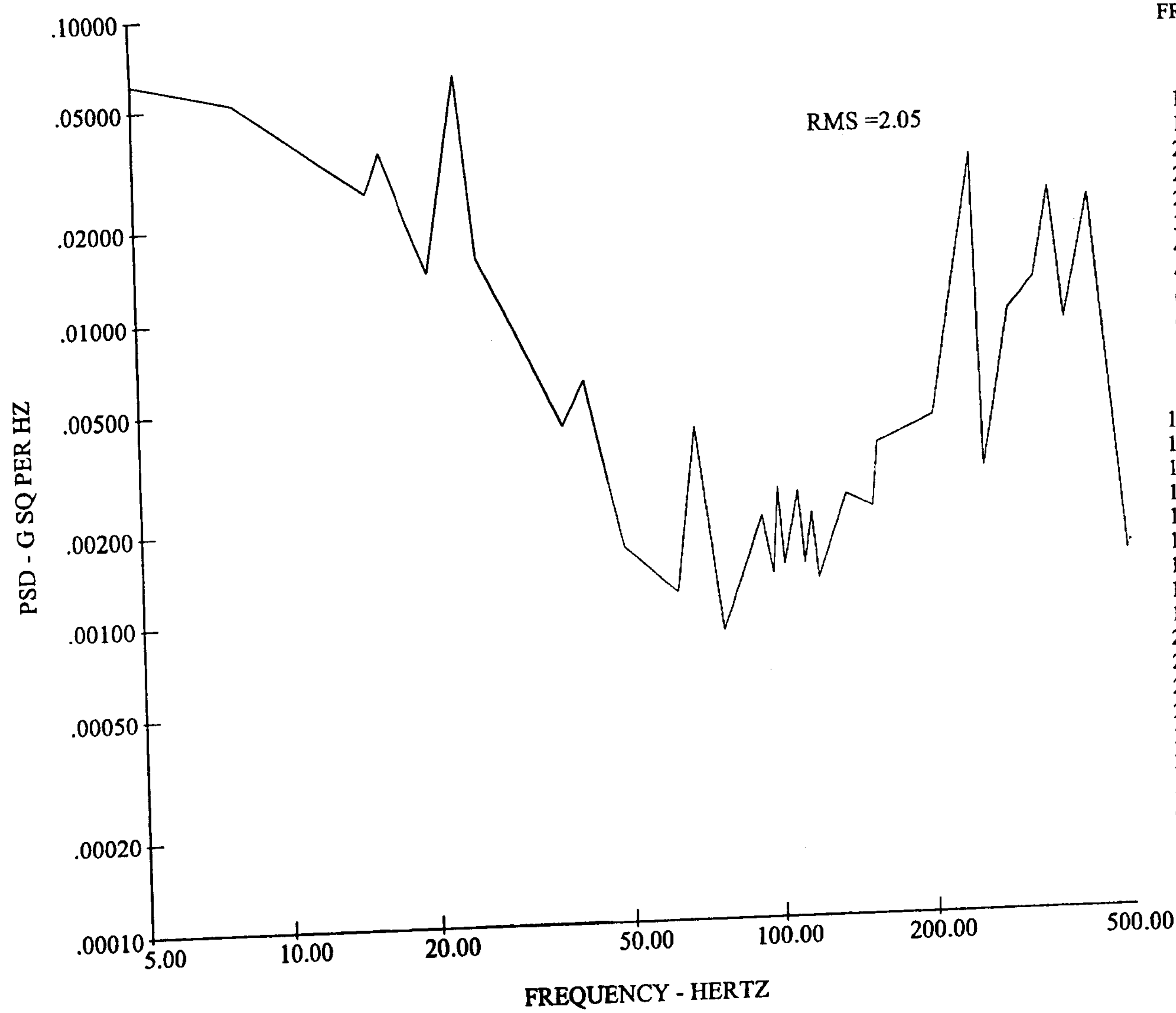


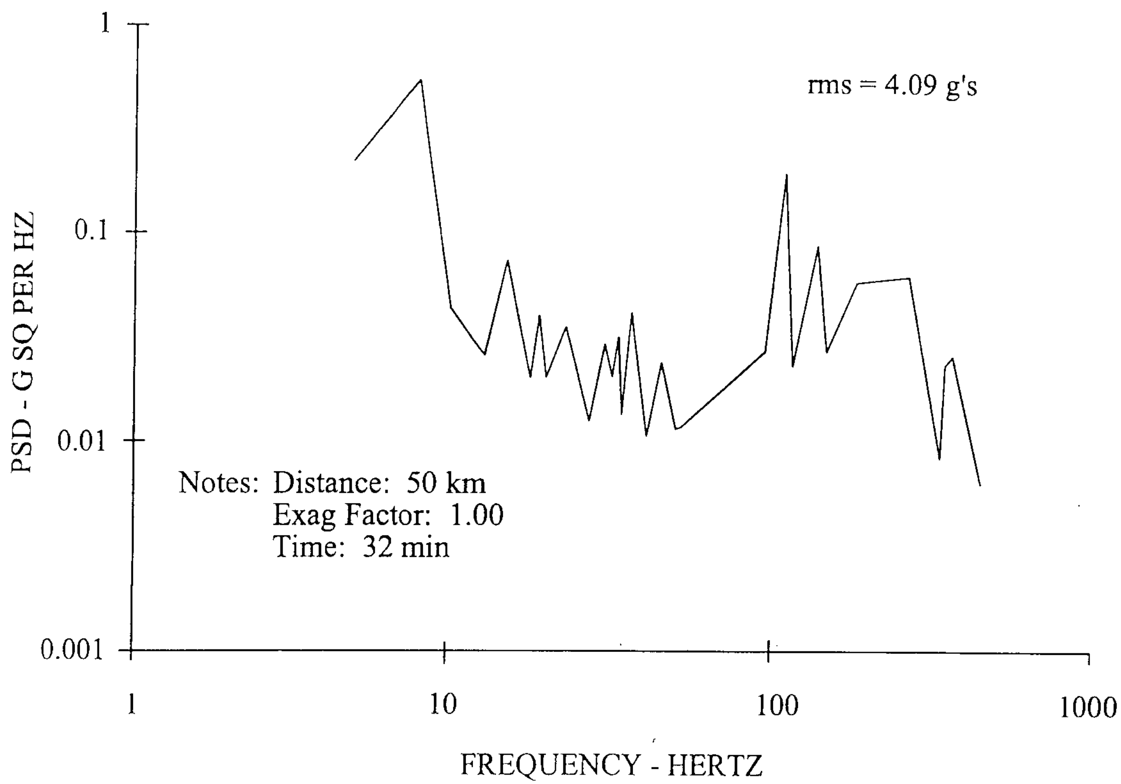
Figure B-3. Laboratory Vibration Schedule, Composite Wheeled Vehicle, Longitudinal Axis.



BREAKPOINTS

FREQ	PSD VALUE
5	.0593
8	.0499
15	.0255
16	.0344
20	.0134
23	.0608
25	.0148
37	.0040
41	.0059
49	.0016
63	.0011
69	.0040
78	.0008
94	.0020
98	.0013
101	.0025
104	.0014
111	.0024
114	.0014
117	.0020
121	.0012
139	.0024
155	.0021
161	.0034
205	.0042
247	.0303
257	.0027
293	.0092
330	.0116
353	.0231
379	.0083
427	.0220
500	.0014

Figure B-4. Laboratory Vibration Schedule, Composite GE/US 2-Wheeled Trailer, Vertical Axis.



BREAKPOINTS

FREQ	PSD VALUE
5	.22520
8	.55080
10	.04370
13	.02530
15	.07350
18	.02000
19	.04021
20	.02000
23	.03580
27	.01230
30	.02860
32	.02000
33	.03136
34	.01330
36	.04160
41	.01030
45	.02410
51	.01140
95	.02660
109	.19240
116	.02300
138	.08687
147	.02660
185	.06030
262	.06340
330	.00830
343	.02270
360	.02530
444	.00639
500	.00170

Figure B-5. Laboratory Vibration Schedule, Composite GE/US 2-Wheeled Trailer, Transverse Axis.

BREAKPOINTS

FREQ	PSD VALUE	FREQ	PSD VALUE
5	.04740	106	.00330
6	.03030	108	.00453
7	.07610	111	.00325
13	.01300	148	.00300
15	.03350	163	.00539
16	.01370	175	.00230
21	.01020	235	.00130
23	.02680	262	.00282
25	.00900	265	.00250
28	.00900	317	.00160
30	.01370	326	.00570
34	.00550	343	.00090
37	.00810	384	.00180
46	.00390	410	.00080
51	.00680	462	.00200
55	.00420	500	.00070

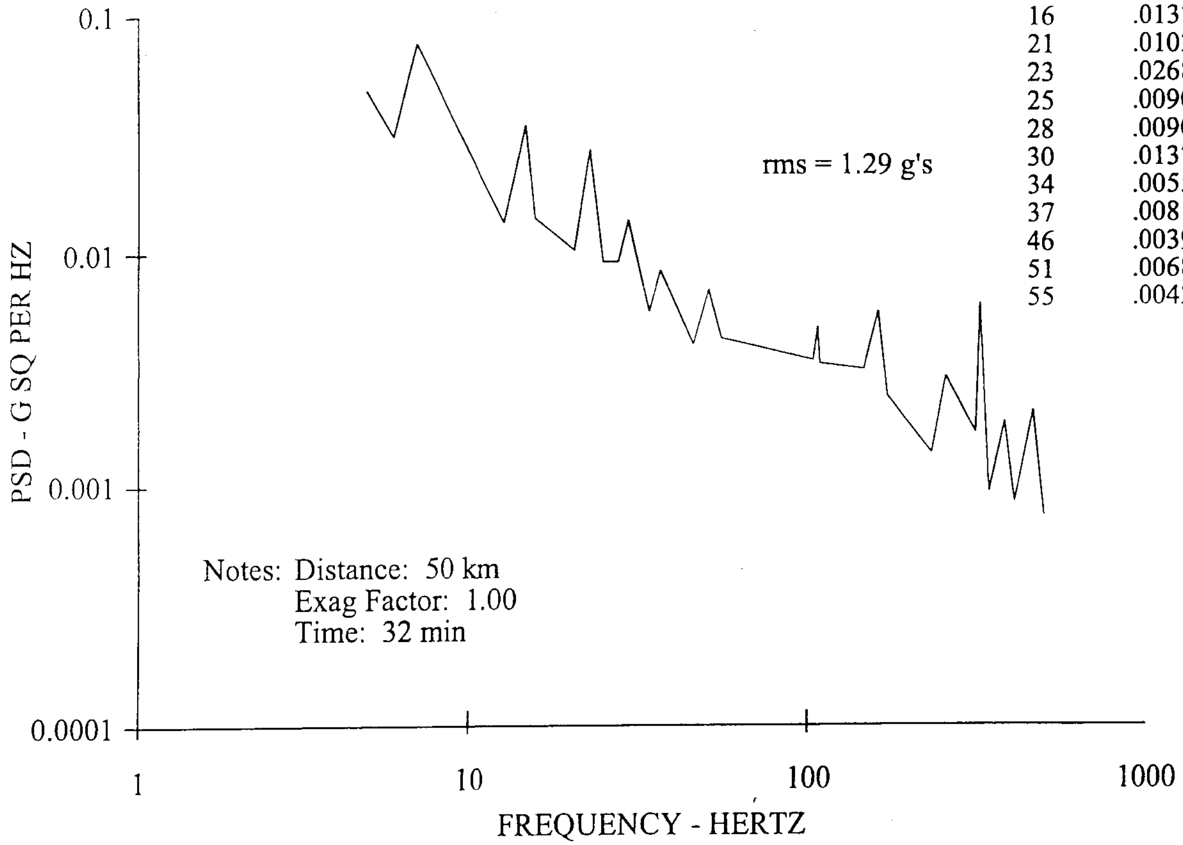
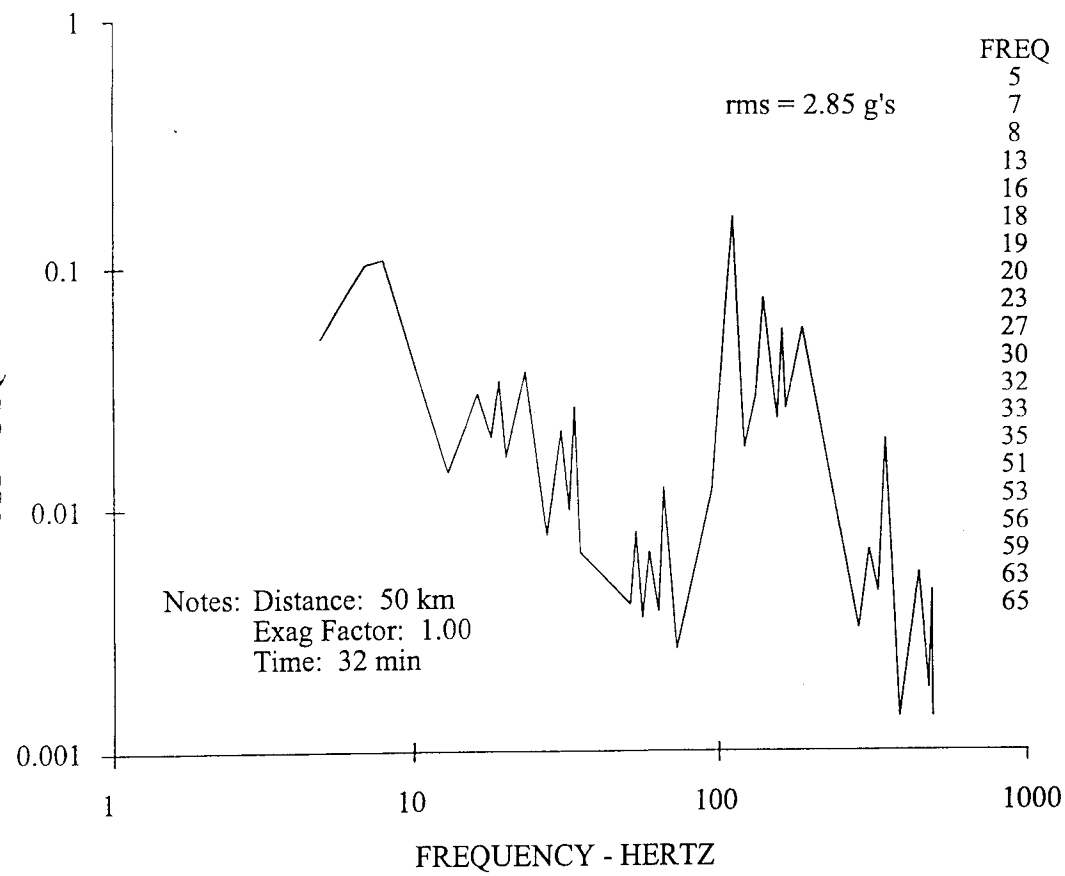


Figure B-6. Laboratory Vibration Schedule, Composite GE/US 2-Wheeled Trailer, Longitudinal Axis.



BREAKPOINTS

FREQ	PSD VALUE	FREQ	PSD VALUE
5	.05214	73	.00260
7	.10456	93	.01174
8	.11020	109	.16354
13	.01400	120	.01800
16	.03030	132	.03200
18	.02000	138	.07384
19	.03418	153	.02360
20	.01600	158	.05490
23	.03780	164	.02610
27	.00790	185	.05770
30	.02080	257	.00615
32	.01000	280	.00320
33	.02666	304	.00680
35	.00650	323	.00445
51	.00400	343	.01929
53	.00808	386	.00139
56	.00350	444	.00543
59	.00663	476	.00180
63	.00374	490	.00456
65	.01265	500	.00140

Figure B-7. Laboratory Vibration Schedule, M985 HEMTT 10 Ton Truck Vertical Axis.

BREAKPOINTS

FREQ	PSD VALUE
6	.1055
10	.0097
12	.0527
15	.0029
22	.0009
25	.0047
27	.0007
32	.0007
37	.0033
43	.0005
47	.0005
49	.0008
54	.0002
57	.0004
60	.0002
62	.0003
65	.0002
78	.0002
81	.0004
87	.0002
92	.0003
117	.0004
125	.0002
138	.0004
182	.0002
189	.0003
233	.0003
350	.0008
408	.0005
500	.0002

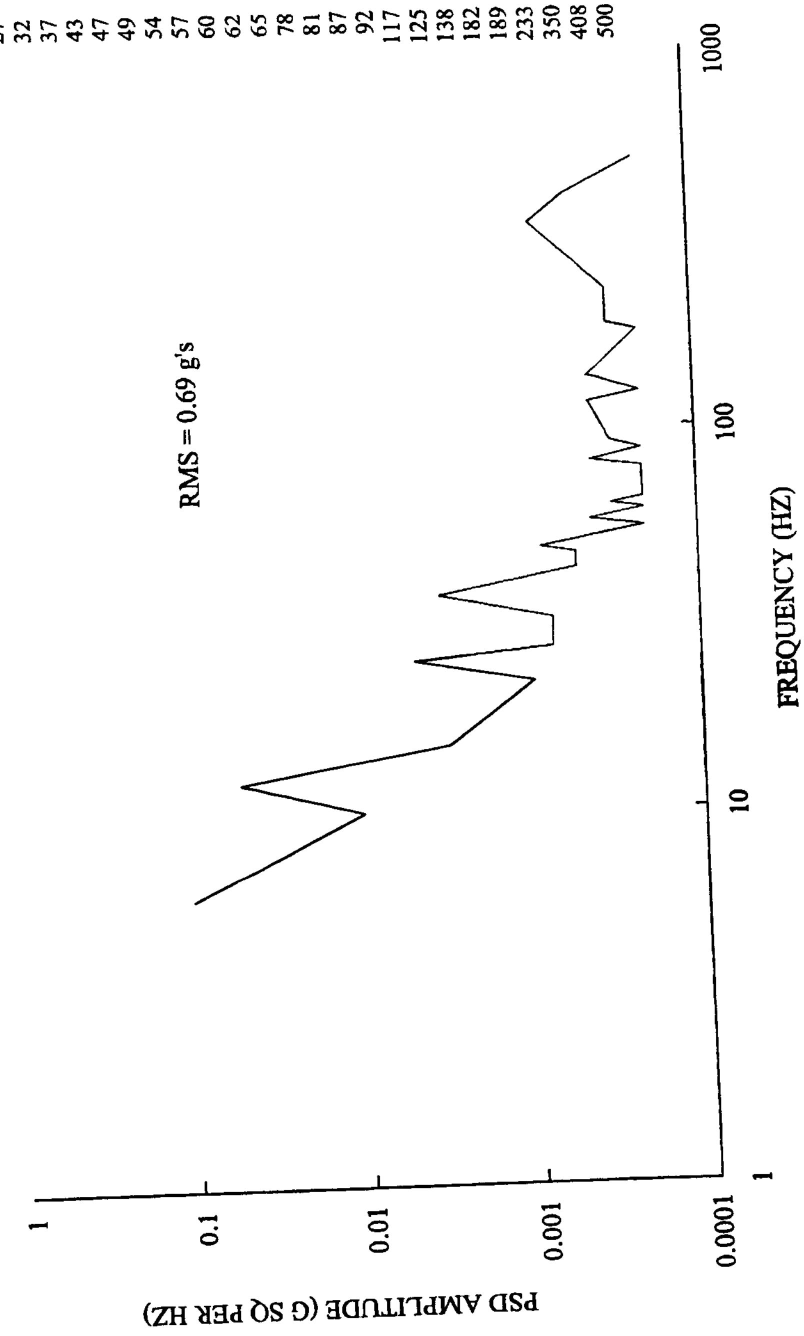


Figure B-8. Laboratory Vibration Schedule M985 HEMTT 10 Ton Truck Transverse Axis.

BREAKPOINTS

FREQ	PSD VALUE
6	.0777
10	.0104
12	.0902
15	.0032
17	.0018
19	.0025
21	.0013
25	.0039
28	.0004
32	.0004
37	.0022
44	.0003
50	.0007
54	.0002
60	.0003
66	.0001
69	.0003
76	.0001
81	.0002
88	.0001
113	.0002
128	.0001
193	.0002
247	.0001
287	.0003
307	.0001
330	.0003
382	.0001

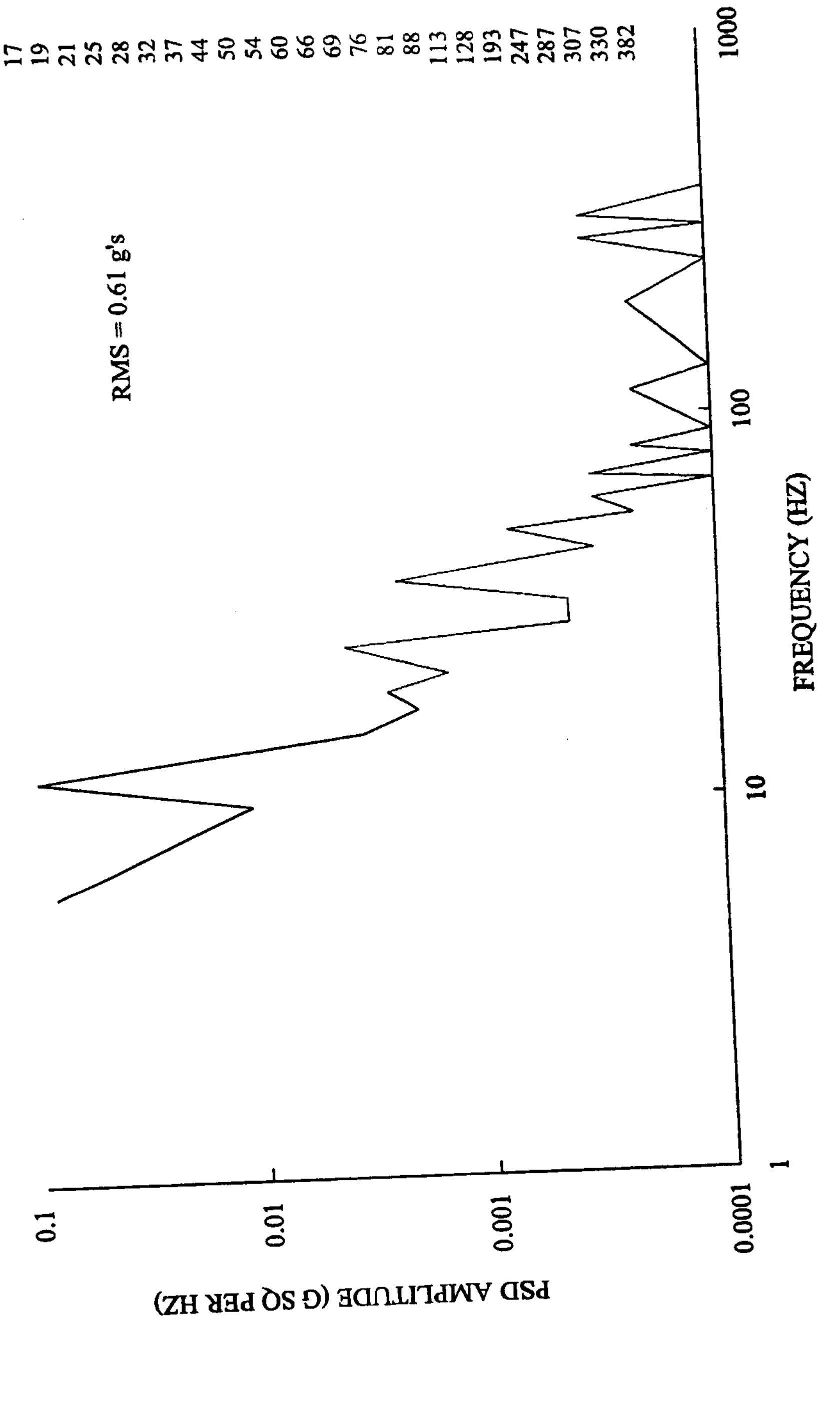
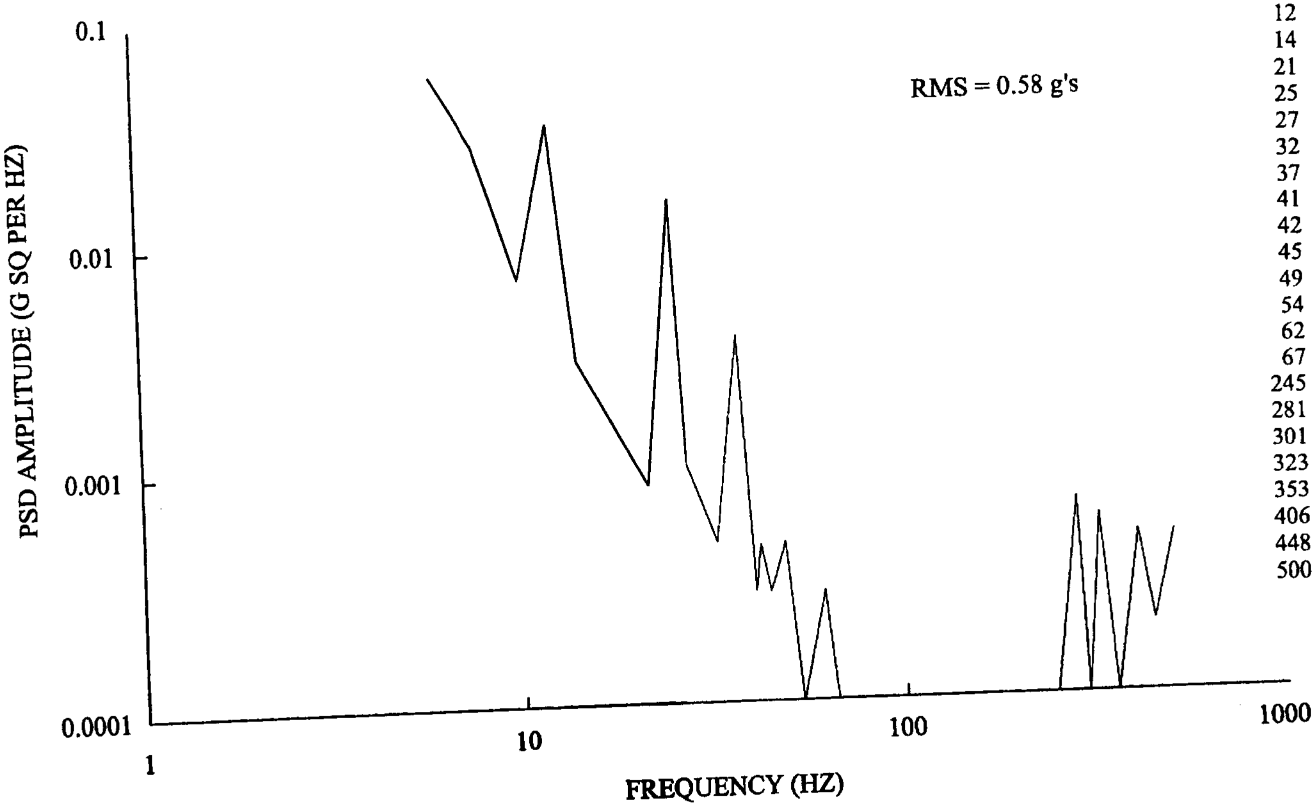


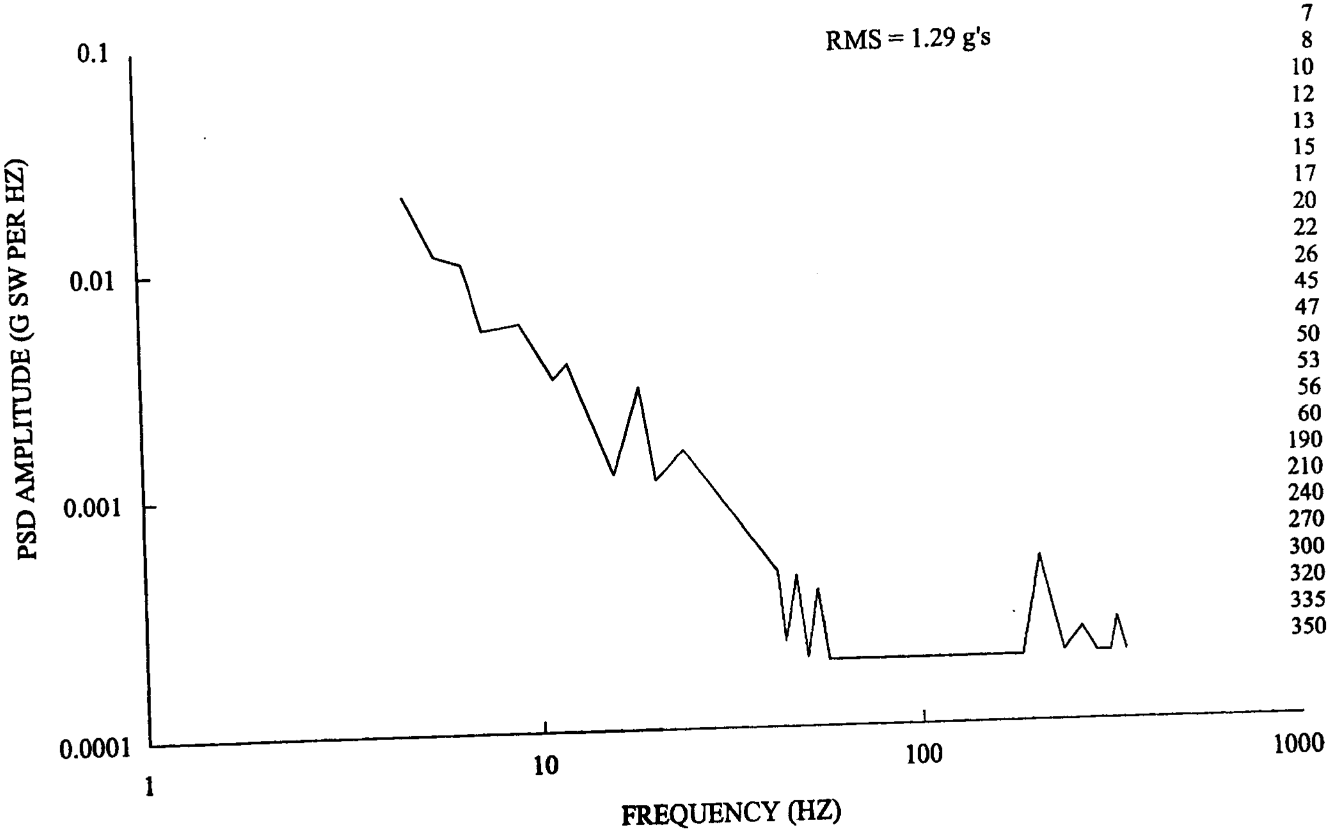
Figure B-9. Laboratory Vibration Schedule, M985 HEMTT 10 Ton Truck Longitudinal Axis.



BREAKPOINTS

FREQ	PSD VALUE
6	.0577
8	.0267
10	.0073
12	.0351
14	.0031
21	.0009
25	.0159
27	.0011
32	.0005
37	.0040
41	.0003
42	.0005
45	.0003
49	.0005
54	.0001
62	.0003
67	.0001
245	.0001
281	.0007
301	.0001
323	.0006
353	.0001
406	.0005
448	.0002
500	.0005

Figure B-10. Laboratory Vibration Schedule, M813/814 5 Ton Truck Vertical Axis.



BREAKPOINTS

FREQ	PSD VALUE
5	.22200
6	.12025
7	.11100
8	.05550
10	.05920
12	.03330
13	.03885
15	.02035
17	.01203
20	.02960
22	.01110
26	.01573
45	.00444
47	.00222
50	.00426
53	.00185
56	.00370
60	.00185
190	.00185
210	.00500
240	.00185
270	.00241
300	.00185
320	.00185
335	.00259
350	.00185

Figure B-11. Laboratory Vibration Schedule, M813/814 5 Ton Truck Transverse Axis.

BREAKPOINTS

FREQ	PSD VALUE
5	.02220
6	.01665
7	.02405
8	.02405
9	.01850
12	.00555
13	.00925
14	.00740
16	.00370
22	.02035
26	.00370
28	.00463
33	.00204
35	.00370
41	.00093
60	.00111
80	.00056
100	.00019

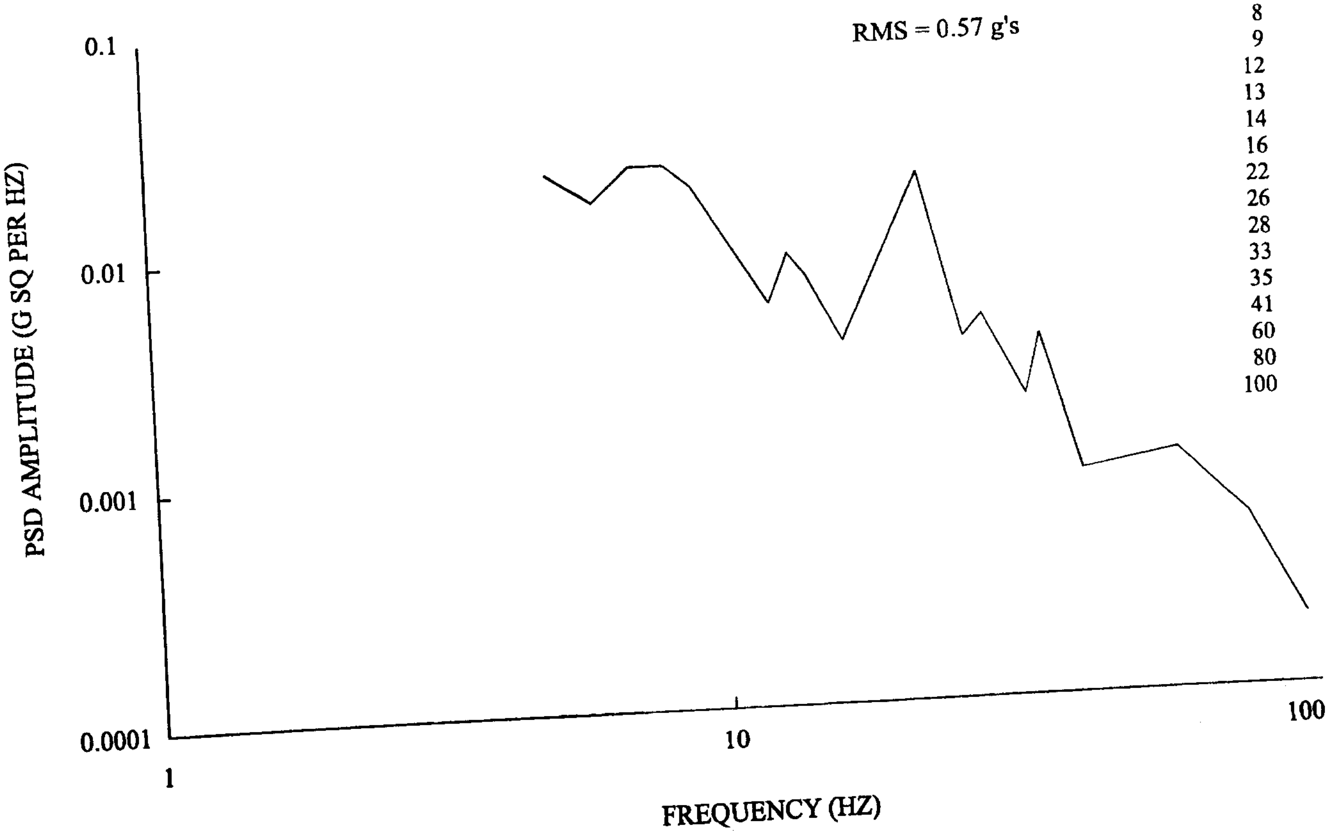


Figure B-12. Laboratory Vibration Schedule, M813/814 5 Ton Truck Longitudinal Axis.

BREAKPOINTS

FREQ	PSD VALUE
5	.01110
6	.00740
7	.01480
11	.00166
13	.01110
14	.00925
16	.00185
19	.00555
24	.00148
26	.00592
29	.00148
32	.00296
38	.00166
42	.00093
44	.00129
60	.00037
80	.00018
100	.00018
150	.00046
170	.00028
210	.00185
250	.02775
270	.00185
290	.00925
320	.00370
350	.00555
450	.00056
470	.00093
500	.00037

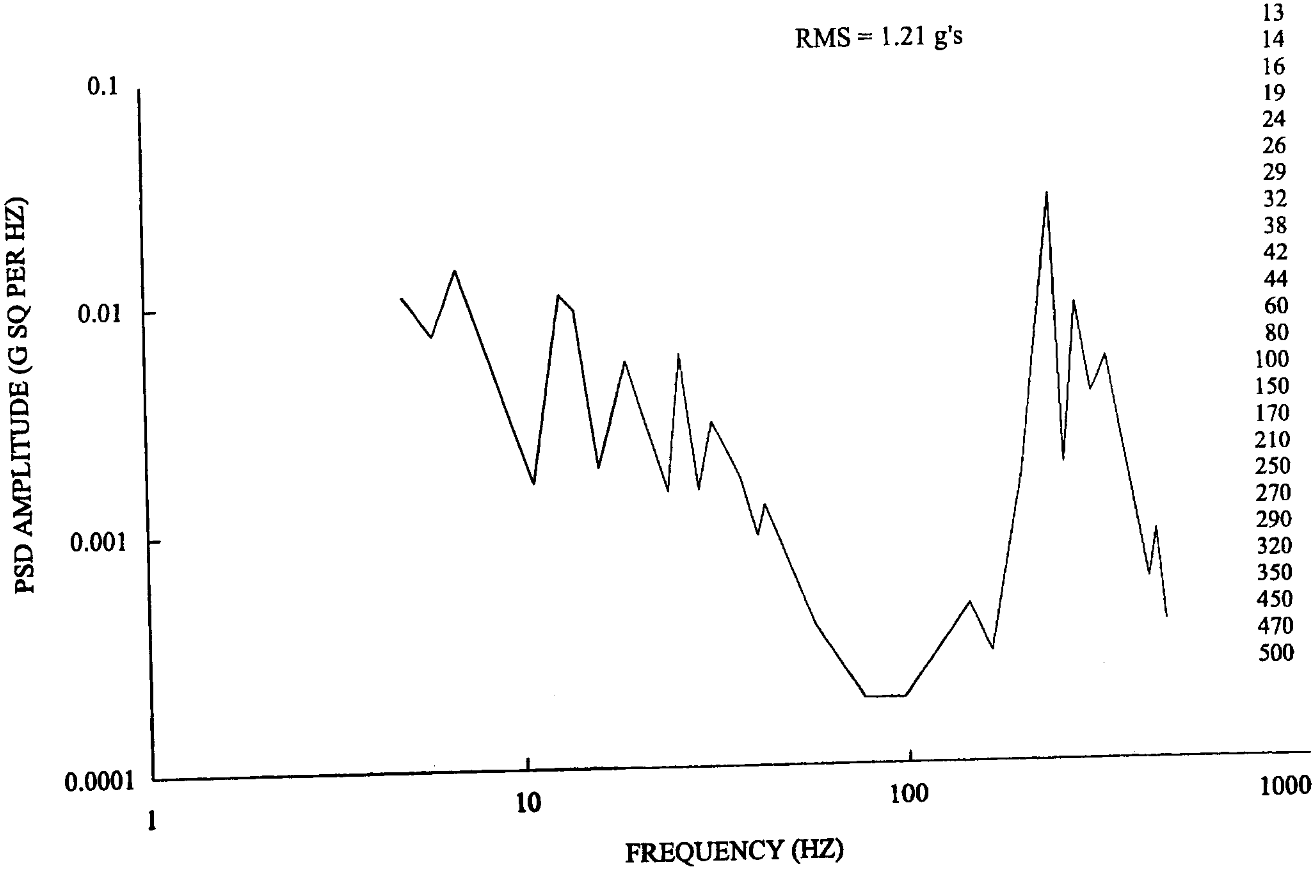
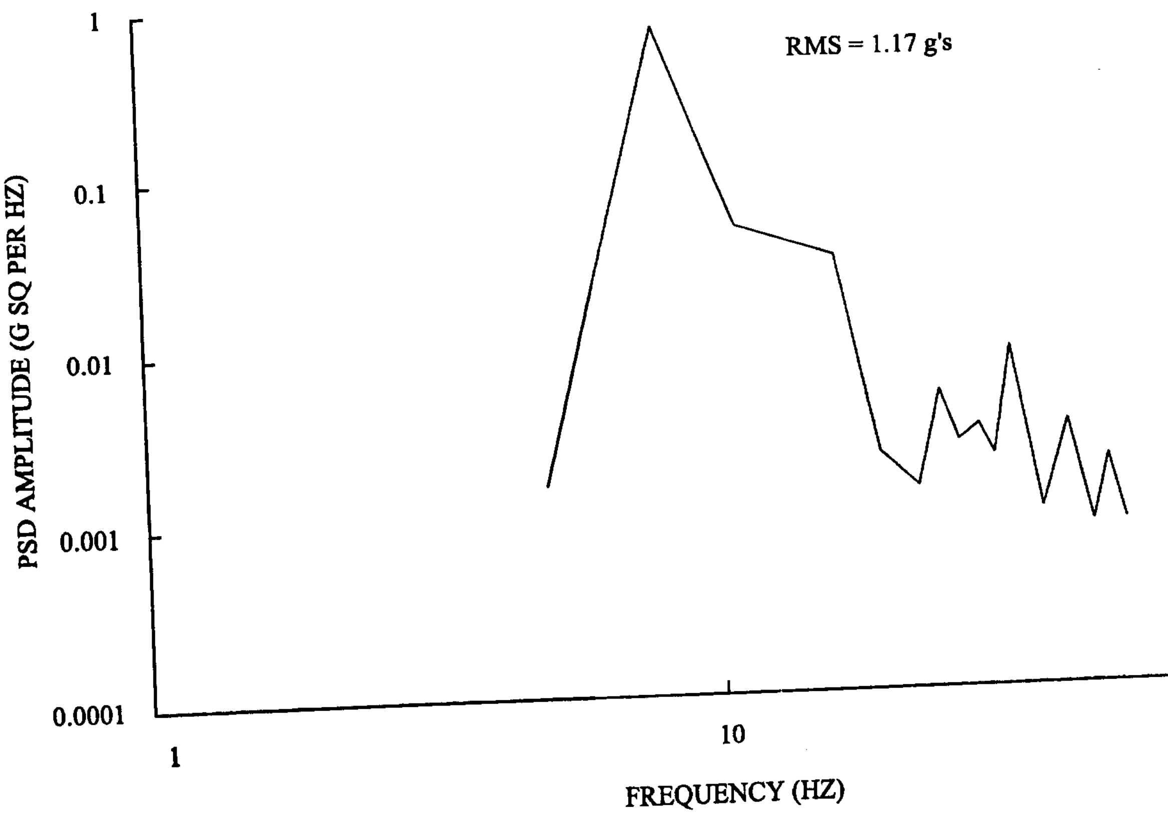


Figure B-13. Laboratory Vibration Schedule, M998 HMMWV Cargo Bed Vertical Axis.



BREAKPOINTS

FREQ	PSD VALUE
5	.00159
8	.70413
11	.04692
16	.03001
19	.00211
22	.00131
24	.00477
26	.00239
28	.00298
30	.00191
32	.00888
36	.00092
40	.00305
44	.00076
47	.00185
50	.00076

Figure B-14. Laboratory Vibration Schedule, M998 HMMWV Cargo Bed Transverse Axis.

BREAKPOINTS

FREQ	PSD VALUE
5	.00115
8	.04549
10	.00975
12	.01380
14	.00779
15	.01859
21	.00092
24	.00289
29	.00107
32	.00226
36	.00031
39	.00057
44	.00017
47	.00067
53	.00007
56	.00019
60	.00007
65	.00013
71	.00006
74	.00015
78	.00006
88	.00013
99	.00006
105	.00011
108	.00006

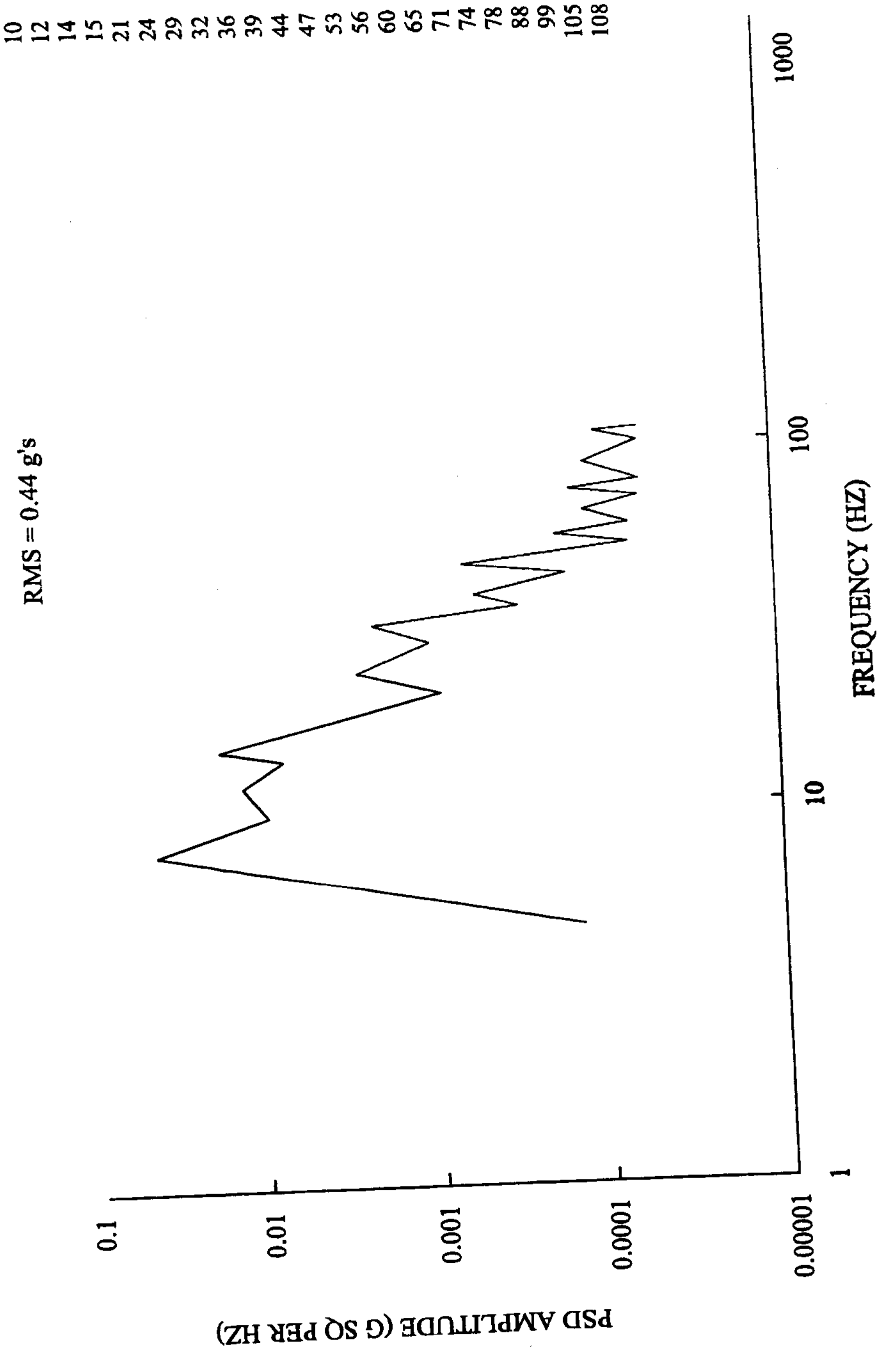
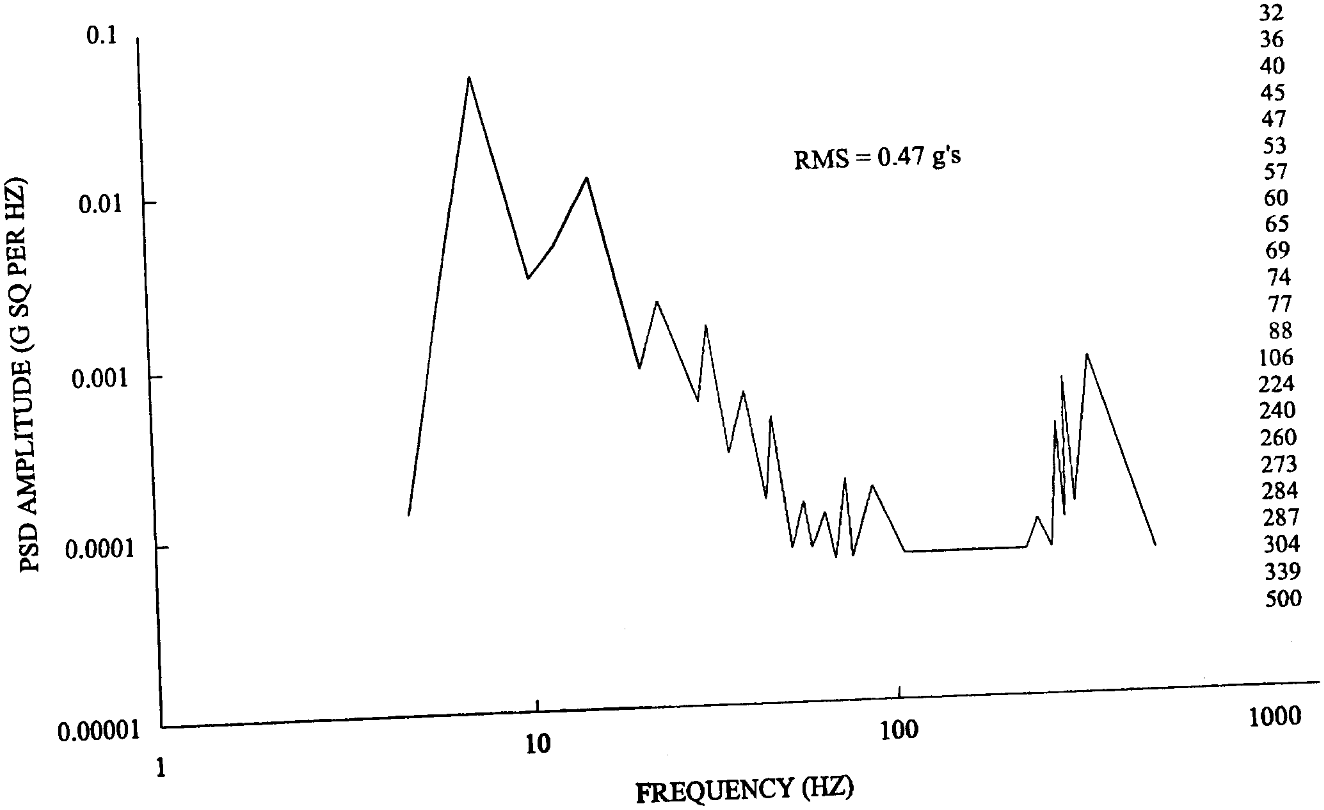


Figure B-15. Laboratory Vibration Schedule, M998 HMMWV Cargo Bed Longitudinal Axis.



BREAKPOINTS

FREQ	PSD VALUE
5	.00013
8	.04549
11	.00289
13	.00451
16	.01104
21	.00081
24	.00203
30	.00050
32	.00144
36	.00024
40	.00057
45	.00013
47	.00041
53	.00007
57	.00013
60	.00007
65	.00011
69	.00006
74	.00017
77	.00006
88	.00015
106	.00006
224	.00006
240	.00009
260	.00006
273	.00031
284	.00009
287	.00057
304	.00011
339	.00078
500	.00006

APPENDIX C. VEHICLE AMMUNITION-RACK VIBRATION.

Tables C-2 and C-3 represent the most severe vibration environments for 120mm and 105mm tank ammunition, respectively. The 120mm ammunition vibration schedules are for the Wegmann hull rack which is the current rack used in the M1A1 vehicle. The 105mm ammunition schedule describes the vibration environment of the M1 Abrams and the German Leopard 1 tanks. The vertical axis data represents the environment at the input to the Leo 1 hull rack in which the rounds are mounted vertically (base down). The transverse and longitudinal axes data represent the M1 Abrams hull rack in which the rounds are mounted horizontally. Therefore, 105mm tank ammunition will be tested base-down in the three-round Leo 1 hull rack according to the vertical axis schedule from Table C-3 and horizontally in the M1 hull rack according to the transverse and longitudinal schedules of the same table. These spectra were derived from measurements on the vehicles while operating at various speeds on a paved road. Excitation shall be applied through the three major axes of the test samples. The schedules consist of a flat low level broadband random excitation across the total frequency spectrum with higher level narrowbands of random excitation superimposed on the broadband environment. The narrowbands of random energy are from the track-laying patterns, are vehicle speed related, and are swept simultaneously across the total frequency bandwidth of the applicable narrowband at the specified bandwidth and sweep rate.

Table C-4 represents the ammunition bustle rack environment of the M109A3 howitzer and Table C-5 represents the ammunition deck rack environment of the same vehicle. The deck rack environment has been determined to be the worst vibration environment for 155mm projectiles; however, certain 155mm projectiles will not physically fit into the deck rack and thus are carried in the bustle rack. In these instances, the projectiles will be tested in the bustle rack. Additionally, Table C-6 represents the input vibration environment to the rounds carried on the sponson, and Table C-7 represents the input vibration environment to the 155mm propelling charges in the M109A3 howitzer. The excitation, spectra content, and origin of the environment are the same as described above.

The following is a list of the accelerometer locations used during the development of test schedules for ammunition racks. It serves as a guide for determining the location of vibration control accelerometers during laboratory testing.

120mm Ammunition - M1A1 Tank, Wegmann hull rack

Hull deck, curb side, front shock mount
Hull deck, road side, front shock mount
Hull deck, curb side, rear shock mount
Hull deck, road side, rear shock mount

105 Ammunition - M1 Tank, hull rack, horizontal orientation

Hull deck, curb side, front, at attachment
Hull deck, road side, front, at attachment

105mm Ammunition - Leopard 1 Tank, hull rack, vertical orientation

Hull deck, 3-round rack

155mm Projectiles - M109A3 Self-Propelled Howitzer (SPH) bustle rack

Bustle rack, bottom rear, road side
Bustle rack, sidewall, rear, curb side
Bustle rack, sidewall, rear, road side
Bustle rack, top, rear, center
Bustle rack, bottom, front, center
Bustle rack, sidewall, front, curb side
Bustle tack, sidewall, front, road side
Bustle rack, top, front, center

155mm Projectiles - M109A3 SPH deck rack

Vehicle deck, input to rack, rear, curb side
Vehicle deck, input to rack, front, curb side
Vehicle deck, input to rack, rear, road side

155mm Propelling Charges M109A3 SPH sponson

Vehicle road side, sponson, right side, center
Vehicle road side, sponson, left side, rear

155mm Ammunition - M109A3 SPH sponson

Vehicle curb side, sponson, right side, front
Vehicle curb side, sponson, right side, rear

Table C-1. Test Duration Times - Installed Equipment - Ammunition.

Mode of Transport	Table	Transport Distance-km	Test Duration (per axis)
M1A1 Tank (ammunition hull rack)	C-2	8000	225 min*
M1 and Leo 1 Tanks (ammunition hull racks)	C-3	8000	225 min*
M109A3 SPH (ammunition bustle rack)	C-4	7000	191.25 min*
M109A3 SPH (ammunition deck rack)	C-5	7000	191.25 min*
M109A3 SPH (ammunition on sponson)	C-6	7000	191.25 min*
M109A3 SPH (propelling charges)	C-7	7000	191.25 min*

*The test duration for each of 3 axes are based on 45 minutes of laboratory vibration being equivalent to 1600km of vehicle transport.

The actual field vibration levels have been exaggerated in order to reduce the laboratory test times. The individual exaggeration factors used are presented in Tables C-2 through C-7. If the user determines that the selected test times are unacceptable, the actual field levels may be exaggerated to a greater extent using the procedures discussed in ITOP 1-1-050[1].

Table C-2. Narrowband Random-On-Random Vibration Program Data For 120MM Ammunition Transported In M1A1 Tank Wegmann Hull Rack.

					NARROWBAND 1			NARROWBAND 2			NARROWBAND 3			NARROWBAND 4			NARROWBAND 5		
Test Phase	5-500 Hz Floor g^2/Hz	No. Sweeps	Overall RMS g	Time min	BW Hz	Ampl g^2/Hz	Sweep BW Hz	BW Hz	Ampl g^2/Hz	Sweep BW Hz	BW Hz	Ampl g^2/Hz	Sweep BW Hz	BW Hz	Ampl g^2/Hz	Sweep BW Hz	BW Hz	Ampl g^2/Hz	Sweep BW Hz
VERTICAL AXIS																			
V1	.0021	4	1.16	56.3	33-41	.0037	4	66-82	.0098	8	99-123	.0044	12	132-164	.0084	16	165-205	.0072	20
V2	.0028	3	1.76	56.3	46-56	.0219	5	92-112	.0091	10	138-168	.0779	15	184-224	.0173	20	230-280	.0081	25
V3	.0029	2	1.72	56.3	60-74	.0340	7	120-148	.0217	14	180-222	.0364	21	240-296	.0111	28	300-370	.0058	35
V4	.0034	1	2.56	56.3	80-100	.0550	10	160-200	.1093	20	240-300	.0413	30	320-400	.0150	40	400-500	.0163	50
TRANSVERSE AXIS																			
T1	.0024	4	1.23	56.3	33-41	.0179	4	66-82	.0050	8	99-123	.0024	12	132-164	.0052	16	165-205	.0118	20
T2	.0028	4	1.86	56.3	46-56	.0246	5	92-112	.0106	10	138-168	.0917	15	184-224	.0300	20	------	----	--
T3	.0029	2	1.81	56.3	60-74	.0239	7	120-148	.0312	14	180-222	.0531	21	240-296	.0088	28	300-370	.0050	35
T4	.0031	1	2.64	56.3	80-100	.0671	10	160-200	.1627	20	240-300	.0310	30	320-400	.0163	40	400-500	.0081	50
LONGITUDINAL AXIS																			
L1	.0020	4	1.09	56.3	33-41	.0106	4	66-82	.0032	8	99-123	.0020	12	132-164	.0037	16	165-205	.0086	20
L2	.0021	4	1.56	56.3	46-56	.0223	5	92-112	.0066	10	138-168	.0575	15	184-224	.0223	20	------	----	--
L3	.0024	2	1.58	56.3	60-74	.0195	7	120-148	.0235	14	180-222	.0396	21	240-296	.0056	28	300-370	.0034	35
L4	.0026	1	2.42	56.3	80-100	.0444	10	160-200	.1546	20	240-300	.0245	30	320-400	.0091	40	400-500	.0069	50

Exaggeration factor = 2.0.

Table C-3. Narrowband Random-On-Random Vibration Program Data For 105MM Ammunition Transported In M1 And Leo 1 Tank Hull Racks.

Test Phase	5-500 Hz Floor g^2/Hz	No. Sweeps	Overall RMS g	Time min	NARROWBAND 1 BW Hz	NARROWBAND 1 Ampl g^2/Hz	NARROWBAND 1 Sweep BW Hz	NARROWBAND 2 BW Hz	NARROWBAND 2 Ampl g^2/Hz	NARROWBAND 2 Sweep BW Hz	NARROWBAND 3 BW Hz	NARROWBAND 3 Ampl g^2/Hz	NARROWBAND 3 Sweep BW Hz	NARROWBAND 4 BW Hz	NARROWBAND 4 Ampl g^2/Hz	NARROWBAND 4 Sweep BW Hz	NARROWBAND 5 BW Hz	NARROWBAND 5 Ampl g^2/Hz	NARROWBAND 5 Sweep BW Hz
VERTICAL AXIS																			
V1	.0018	5	1.14	37.5	28-34	.0050	3	56-68	.0018	6	84-102	.0856	9	112-136	.0131	12	140-170	.0151	15
V2	.0044	3	1.75	37.5	39-45	.0167	3	78-90	.0525	6	117-135	.0343	9	156-180	.0230	12	195-225	.0085	15
V3	.0099	2	2.89	37.5	50-56	.0539	3	100-112	.0773	6	150-168	.2523	9	200-224	.0227	12	250-280	.0475	15
V4	.0101	2	3.01	37.5	61-73	.1056	6	122-146	.0930	12	183-219	.0909	18	244-292	.0212	24	305-365	.0354	30
V5	.0093	1	2.58	37.5	78-84	.2614	3	156-168	.1894	6	234-252	.0223	9	312-336	.0111	12	390-420	.0131	15
V6	.0190	1	4.39	37.5	89-101	.1635	6	178-202	.6485	12	267-303	.1012	18	------	------	--	------	------	--
TRANSVERSE AXIS																			
T1	.0009	5	.76	45.0	14-28	.0103	7	28-59	.0059	14	------	------	--	------	------	--	------	------	--
T2	.0012	3	.95	45.0	33-41	.0337	4	66-82	.0050	8	99-123	.0030	12	132-164	.0050	16	165-205	.0046	20
T3	.0013	2	1.12	45.0	46-56	.0299	5	92-112	.0175	10	138-168	.0101	15	184-224	.0086	20	230-280	.0028	25
T4	.0020	2	2.04	45.0	60-74	.0701	7	120-148	.0956	14	180-222	.0349	21	240-296	.0224	28	300-370	.0056	35
T5	.0039	1	2.96	45.0	79-97	.1227	9	158-194	.1330	18	237-291	.0457	27	316-388	.0625	36	395-485	.0081	45
LONGITUDINAL AXIS																			
L1	.0015	5	.92	45.0	14-28	.0101	7	28-56	.0042	14	------	------	--	------	------	--	------	------	--
L2	.0019	3	1.16	45.0	33-41	.0278	4	66-82	.0046	8	99-123	.0036	12	132-164	.0076	16	165-205	.0100	20
L3	.0020	2	1.47	45.0	46-56	.0278	5	92-112	.0217	10	138-168	.0131	15	184-224	.0275	20	230-280	.0088	25
L4	.0031	2	2.75	45.0	60-74	.0558	7	120-148	.1020	14	180-222	.0432	21	240-296	.0520	28	300-370	.0617	35
L5	.0045	1	3.98	45.0	79-97	.2687	9	158-194	.1249	18	237-291	.0862	27	316-388	.1426	36	395-485	.0466	45

Exaggeration factor = 2.0.

Table C-4. Narrowband Random-On-Random Vibration Program Data For 155MM Projectile Transported In The Bustle Rack Of The M109A3 Self-Propelled Howitzer.

Test Phase	5-500 Hz Floor g^2/Hz	No. Sweeps	Overall RMS g	Time min	NARROWBAND 1 BW Hz	Ampl g^2/Hz	Sweep BW Hz	NARROWBAND 2 BW Hz	Ampl g^2/Hz	Sweep BW Hz	NARROWBAND 3 BW Hz	Ampl g^2/Hz	Sweep BW Hz	NARROWBAND 4 BW Hz	Ampl g^2/Hz	Sweep BW Hz	NARROWBAND 5 BW Hz	Ampl g^2/Hz	Sweep BW Hz
VERTICAL AXIS																			
V1	.0030	4	1.71	47.8	24-42	.0976	9	48-84	.0361	18	------	------	--	------	------	--	------	------	--
V2	.0069	3	3.23	47.8	48-60	.5202	6	96-120	.2647	12	144-180	.0334	18	192-240	.0219	24	------	------	--
V3	.0157	2	4.61	47.8	66-84	.3852	9	132-168	.4237	18	198-252	.1074	27	264-336	.0249	36	------	------	--
V4	.0131	2	3.07	47.8	90-108	.1846	9	180-216	.0669	18	270-324	.0300	27	------	------	--	------	------	--
TRANSVERSE AXIS																			
T1	.0020	8	1.35	47.8	18-36	.0948	9	------	------	--	------	------	--	------	------	--	------	------	--
T2	.0044	6	1.96	47.8	42-54	.2153	6	84-108	.0366	12	------	------	--	------	------	--	------	------	--
T3	.0074	2	2.45	47.8	63-78	.1563	7	126-156	.0300	15	189-234	.0241	22	252-312	.0118	32	315-390	.0169	37
T4	.0106	1	2.95	47.8	84-108	.1175	12	168-216	.0239	24	252-324	.0290	36	336-432	.0349	48	------	------	--
LONGITUDINAL AXIS																			
L1	.0051	10	2.00	47.8	18-24	.0843	3	36-48	.2108	6	------	------	--	------	------	--	------	------	--
L2	.0027	3	1.77	47.8	36-48	.1764	6	72-96	.0420	12	108-144	.0103	18	144-192	.0091	24	------	------	--
L3	.0042	2	2.45	47.8	58-72	.1605	7	116-144	.0152	14	174-216	.0474	21	232-288	.0239	28	290-360	.0386	35
L4	.0047	1	2.73	47.8	80-106	.1001	13	160-212	.0468	26	240-318	.0534	39	320-424	.0217	52	------	------	--

The exaggeration factor was 2.0.

Table C-5. Narrowband Random-On-Random Vibration Program Data For 155MM Projectile Transported In The Deck Racks Of The M109A3 Self-Propelled Howitzer.

Test Phase	5-500 Hz Floor g²/Hz	No. Sweeps	Overall RMS g	Time min	NARROWBAND 1 BW Hz	NARROWBAND 1 Ampl g²/Hz	NARROWBAND 1 Sweep BW Hz	NARROWBAND 2 BW Hz	NARROWBAND 2 Ampl g²/Hz	NARROWBAND 2 Sweep BW Hz	NARROWBAND 3 BW Hz	NARROWBAND 3 Ampl g²/Hz	NARROWBAND 3 Sweep BW Hz	NARROWBAND 4 BW Hz	NARROWBAND 4 Ampl g²/Hz	NARROWBAND 4 Sweep BW Hz	NARROWBAND 5 BW Hz	NARROWBAND 5 Ampl g²/Hz	NARROWBAND 5 Sweep BW Hz
									VERTICAL AXIS										
V1	.0032	6	1.32	38.3	18-24	.0194	3	36-48	.0100	6	54-72	.0103	9	------	------	--	------	------	--
V2	.0096	4	3.02	38.3	36-42	.1262	3	72-84	.2353	6	108-126	.0876	9	144-168	.0910	12	180-210	.0733	15
V3	.0089	2	4.54	38.3	48-60	.5794	6	96-120	.2855	12	144-180	.2445	18	192-240	.1067	24	240-300	.1037	30
V4	.0096	1	4.35	38.3	68-84	.4641	8	136-168	.2240	16	204-252	.1133	24	272-336	.0833	32	340-420	.0663	40
V5	.0098	2	3.36	38.3	90-102	.2038	6	180-204	.2218	12	270-306	.1197	18	360-408	.0418	24	------	------	--
									TRANSVERSE AXIS										
T1	.0052	10	1.62	38.3	18-24	.0173	2	------	------	--	------	------	------	------	------	--	------	------	--
T2	.0052	4	1.89	38.3	36-42	.0632	3	72-84	.0991	6	108-126	.0094	9	144-168	.0052	12	180-210	.0209	15
T3	.0046	2	2.24	38.3	48-60	.0853	6	96-120	.0986	12	144-180	.0312	18	192-240	.0101	24	240-300	.0223	30
T4	.0052	1	2.54	38.3	68-84	.0991	8	136-168	.0317	16	204-252	.0603	24	272-336	.0249	32	340-420	.0235	40
T5	.0052	2	3.25	38.3	90-102	1.0552	6	187-204	.0538	12	270-306	.0349	18	360-408	.0120	24	450-500	.0187	25
									LONGITUDINAL AXIS										
L1	.0018	6	1.03	38.3	18-24	.0194	3	36-48	.0100	6	54-72	.0098	9	------	------	--	------	------	--
L2	.0032	4	1.67	38.3	36-42	.0032	3	72-84	.0482	6	108-126	.0215	9	144-168	.0153	12	180-210	.0446	15
L3	.0046	2	2.41	38.3	48-60	.0281	6	96-120	.0538	12	144-180	.0496	18	192-240	.0275	24	240-300	.0528	30
L4	.0052	1	2.64	38.3	68-84	.0613	8	136-168	.0424	16	204-252	.0295	24	272-336	.0649	32	340-420	.0273	40
L5	.0052	6	1.84	38.3	90-96	.0645	3	180-192	.0595	6	270-288	.0404	9	------	------	--	------	-------	--

Exaggeration factor = 2.0.

Table C-6. Narrowband Random-On-Random Vibration Program Data For 155MM Ammunition Transported On The Sponson Of The M109A3 Self-Propelled Howitzer.

					NARROWBAND 1			NARROWBAND 2			NARROWBAND 3			NARROWBAND 4			NARROWBAND 5		
Test Phase	5-500 Hz Floor g^2/Hz	No. Sweeps	Overall RMS g	Time min	BW Hz	Ampl g^2/Hz	Sweep BW Hz	BW Hz	Ampl g^2/Hz	Sweep BW Hz	BW Hz	Ampl g^2/Hz	Sweep BW Hz	BW Hz	Ampl g^2/Hz	Sweep BW Hz	BW Hz	Ampl g^2/Hz	Sweep BW Hz
VERTICAL AXIS																			
V1	.0022	5	1.22	38.3	36-48	.0420	6	72-96	.0155	12	------	------	--	------	------	--	------	------	--
V2	.0067	4	3.38	38.3	36-42	1.0916	3	72-84	.2673	6	108-126	.2593	9	144-168	.0334	12	180-210	.0524	15
V3	.0096	2	5.54	38.3	48-60	2.2084	6	96-120	.8362	12	144-180	.0416	18	192-240	.0597	24	240-300	.0460	30
V4	.0111	1	7.32	38.3	66-82	1.1492	8	132-164	2.0115	16	198-246	.0777	24	264-328	.1774	32	------	------	--
V5	.0118	1	5.82	38.3	90-108	2.1947	9	180-216	.1052	18	270-324	.1334	27	360-432	.1078	36	------	------	--
TRANSVERSE AXIS																			
T1	.0018	10	.98	38.3	18-24	.0100	3	36-48	.0088	6	------	------	--	------	------	--	------	------	--
T2	.0052	4	2.19	38.3	36-42	.1318	3	72-84	.1507	6	108-126	.0382	9	144-168	.0352	12	180-210	.0253	15
T3	.0074	2	4.02	38.3	48-60	.6917	6	96-120	.1720	12	144-180	.1021	18	192-240	.1563	24	240-300	.0457	30
T4	.0072	2	3.56	38.3	66-78	.4766	6	132-156	.1241	12	198-234	.0792	18	264-312	.0934	24	330-390	.0575	30
T5	.0076	1	5.18	38.3	84-108	.9133	12	168-216	.1748	24	252-324	.1324	36	336-432	.0838	48	------	------	--
LONGITUDINAL AXIS																			
L1	.0012	10	.82	38.3	24-36	.0155	6	------	------	--	------	------	--	------	------	--	------	------	--
L2	.0022	4	1.17	38.3	42-48	.0094	3	84-96	.0251	6	126-144	.0067	9	168-192	.0040	12	210-240	.0058	15
L3	.0026	2	1.56	38.3	54-66	.0460	6	108-132	.0172	12	162-198	.0067	18	216-264	.0098	24	270-330	.0179	30
L4	.0047	1	2.99	38.3	72-90	.0364	9	144-180	.0207	18	216-270	.0179	27	288-360	.1603	36	360-450	.0064	45
L5	.0032	2	1.69	38.3	96-108	.0490	6	192-216	.0310	12	288-324	.0121	18	384-432	.0245	24	------	------	--

Exaggeration factor = 0.69.

Table C-7. Narrowband Random-On-Random Vibration Program Data For 155MM Propelling Charges Transported In The M109A3 Self-Propelled Howitzer.

					NARROWBAND 1			NARROWBAND 2			NARROWBAND 3			NARROWBAND 4			NARROWBAND 5		
Test Phase	5-500 Hz Floor g^2/Hz	No. Sweeps	Overall RMS g	Time min	BW Hz	Ampl g^2/Hz	Sweep BW Hz	BW Hz	Ampl g^2/Hz	Sweep BW Hz	BW Hz	Ampl g^2/Hz	Sweep BW Hz	BW Hz	Ampl g^2/Hz	Sweep BW Hz	BW Hz	Ampl g^2/Hz	Sweep BW Hz
									VERTICAL AXIS										
V1	.0037	3	1.83	38.3	24-36	.1613	6	42-72	.0495	12	72-108	.0047	18	------	------	--	------	------	--
V2	.0053	4	2.74	38.3	42-48	1.0751	3	84-96	.1382	6	126-144	.0120	9	168-192	.0201	12	210-240	.0480	15
V3	.0085	4	3.10	38.3	54-60	.8679	3	108-120	.0374	6	162-180	.0312	9	216-240	.1583	12	270-300	.0528	15
V4	.0103	2	3.17	38.3	66-78	.5529	6	132-156	.0464	12	198-234	.0529	18	264-312	.0317	24	------	------	--
V5	.0103	1	3.44	38.3	84-108	.2031	12	168-216	.0818	24	252-324	.0846	36	------	------	--	------	------	--
									TRANSVERSE AXIS										
T1	.0047	3	2.37	38.3	29-36	.1556	3	58-72	.0605	7	87-108	.1356	10	116-144	.0309	14	145-180	.0398	17
T2	.0066	4	3.43	38.3	42-48	.5715	3	84-96	.1398	6	126-144	.1504	9	168-192	.2819	12	210-240	.0988	15
T3	.0100	2	5.36	38.3	54-66	.7530	6	108-132	.2294	12	162-198	.7143	18	216-264	.0993	24	270-330	.0740	30
T4	.0113	2	6.41	38.3	72-84	1.7997	6	144-168	1.1840	12	216-252	.2055	18	288-336	.2092	24	360-420	.0920	30
T5	.0121	2	5.06	38.3	90-102	1.1329	6	180-204	.6302	12	270-306	.2222	18	360-408	.0821	24	------	------	--
									LONGITUDINAL AXIS										
L1	.0056	5	3.04	47.8	36-42	.7202	3	72-84	.1161	6	108-126	.1504	9	144-168	.0870	12	180-210	0.988	15
L2	.0074	2	5.25	47.8	48-60	.6747	6	96-120	.1352	12	144-180	.5833	18	192-240	.2660	24	240-300	.0677	30
L3	.0111	2	6.16	47.8	66-78	1.4765	6	132-156	.6035	12	198-234	.5570	18	264-312	.2119	24	330-390	.0727	30
L4	.0121	2	7.05	47.8	84-102	1.6440	9	168-204	1.1807	18	252-306	.2158	27	336-408	.0821	36	------	------	--

Exaggeration factor = 2.0.

APPENDIX D. TRACKED VEHICLE INSTALLED EQUIPMENT VIBRATION.

The figures and tables below designate installed equipment vibration at specified areas of tracked vehicles. These spectra were derived from measurements on the vehicles while operating at various speeds on a paved road. Excitation shall be applied through the three major axes of the test samples. Excitation control accelerometers should be located on the test fixture as close as possible to the test item. These schedules consist of a flat low level broadband random excitation across the total frequency spectrum with higher level narrowbands of random excitation superimposed on the broadband environment. The narrowbands of random energy are from the track-laying patterns, are vehicle speed related, and are swept simultaneously across the total frequency bandwidth of the applicable narrowband at the specified bandwidth and sweep rate.

Table D-1. Test Duration Times - Installed Equipment.

The transport distance is 9600km for all vehicles. The test duration is 270 minutes* per axis for all vehicles.

Vehicle/Location	Table
M109A3 Howitzer, SP, 155mm	
Turret	D-2
Walls	D-3
M110A2 Howitzer, SP, 8-inch	
Trunnion	D-4
Deck	D-5
Gun mount	D-6
Driver compartment	D-7
M113A1 Armored Personnel Carrier Sponsons	
Sponsons	D-8
Top	D-9
Deck	D-10
Walls	D-11
Engine compartment	D-12

*The test durations for each of 3 axes are based on 45 minutes of laboratory vibration being equivalent to 1600km of vehicle transport.

Vehicle/Location	Table
M60A3 Tank	
Turret	D-13
Hull	D-14
Leopard 1 Tank	
Hull	D-15
Turret	D-16

The actual field vibration levels have been exaggerated in order to reduce the laboratory test times. The individual exaggeration factors used are presented in Tables D-2 through D-16. If the user determines that the selected test times are unacceptable, the actual field levels may be exaggerated to a greater extent using the procedures discussed in ITOP 1-1-050[1].

Table D-2. Narrowband Random-On-Random Vibration Program Data For Installed Equipment In The Turret Of The M109A3 Self-Propelled Howitzer.

Test Phase	5-500 Hz Floor g^2/Hz	No. Sweeps	Overall RMS g	Time min	NARROWBAND 1 BW Hz	NARROWBAND 1 Ampl g^2/Hz	NARROWBAND 1 Sweep BW Hz	NARROWBAND 2 BW Hz	NARROWBAND 2 Ampl g^2/Hz	NARROWBAND 2 Sweep BW Hz	NARROWBAND 3 BW Hz	NARROWBAND 3 Ampl g^2/Hz	NARROWBAND 3 Sweep BW Hz	NARROWBAND 4 BW Hz	NARROWBAND 4 Ampl g^2/Hz	NARROWBAND 4 Sweep BW Hz	NARROWBAND 5 BW Hz	NARROWBAND 5 Ampl g^2/Hz	NARROWBAND 5 Sweep BW Hz
VERTICAL AXIS																			
V1	.0010	4	1.05	54.0	18-30	.0882	6	36-60	.0081	12	-----	-----	--	-----	-----	--	-----	-----	--
V2	.0024	4	1.80	54.0	36-42	.4914	3	72-84	.0391	6	108-126	.0076	9	144-168	.0275	12	-----	-----	--
V3	.0026	2	1.85	54.0	48-60	.2467	6	96-120	.0319	12	144-180	.0062	18	192-240	.0135	24	-----	-----	--
V4	.0034	1	2.07	54.0	66-96	.1227	15	132-192	.0249	30	198-288	.0074	45	-----	-----	--	-----	-----	--
V5	.0024	1	1.42	54.0	102-126	.0307	12	204-252	.0120	24	306-378	.0024	36	408-500	.0079	48	-----	-----	--
TRANSVERSE AXIS																			
T1	.0022	3	1.29	54.0	18-36	.0585	9	36-72	.0064	18	-----	-----	--	-----	-----	--	-----	-----	--
T2	.0034	3	1.71	54.0	42-48	.1639	3	84-96	.0435	6	126-144	.0128	9	168-192	.0130	12	210-240	.0239	15
T3	.0032	1	1.71	54.0	54-66	.0332	6	108-132	.0223	12	162-198	.0150	18	216-264	.0179	24	270-330	.0152	30
T4	.0040	1	2.31	54.0	72-96	.0457	12	144-192	.0221	24	216-288	.0660	36	288-384	.0076	48	-----	-----	--
T5	.0030	1	1.82	54.0	102-126	.0024	12	204-252	.0647	24	306-378	.0072	36	408-504	.0074	48	-----	-----	--
LONGITUDINAL AXIS																			
L1	.0012	3	.84	54.0	18-36	.0069	9	36-72	.0046	18	-----	-----	--	-----	-----	--	-----	-----	--
L2	.0017	3	1.15	54.0	42-48	.0305	3	84-96	.0143	6	126-144	.0040	9	168-192	.0246	12	210-240	.0037	15
L3	.0022	2	1.27	54.0	54-66	.0679	6	108-132	.0034	12	162-198	.0067	18	216-264	.0032	24	-----	-----	--
L4	.0030	1	1.56	54.0	72-90	.0369	9	144-180	.0229	18	216-270	.0040	27	288-360	.0052	36	360-450	.0069	45
L5	.0022	1	1.43	54.0	96-126	.0157	15	192-252	.0091	30	288-378	.0076	45	384-504	.0072	60	-----	-----	--

Exaggeration factor = 2.0.

Table D-3. Narrowband Random-On-Random Vibration Program Data For Installed Equipment On The Hull Walls Of The M109A3 Self-Propelled Howitzer.

Test Phase	5-500 Hz Floor g²/Hz	No. Sweeps	Overall RMS g	Time min	NARROWBAND 1 BW Hz	NARROWBAND 1 Ampl g²/Hz	NARROWBAND 1 Sweep BW Hz	NARROWBAND 2 BW Hz	NARROWBAND 2 Ampl g²/Hz	NARROWBAND 2 Sweep BW Hz	NARROWBAND 3 BW Hz	NARROWBAND 3 Ampl g²/Hz	NARROWBAND 3 Sweep BW Hz	NARROWBAND 4 BW Hz	NARROWBAND 4 Ampl g²/Hz	NARROWBAND 4 Sweep BW Hz	NARROWBAND 5 BW Hz	NARROWBAND 5 Ampl g²/Hz	NARROWBAND 5 Sweep BW Hz
VERTICAL AXIS																			
V1	.0044	6	1.61	45.0	18-24	.0444	3	36-48	.0044	6	54-72	.0204	9	72-96	.0162	12	-----	-----	--
V2	.0074	4	2.32	45.0	30-36	.0806	3	60-72	.0410	6	90-108	.0657	9	120-144	.0219	12	150-180	.0480	15
V3	.0086	3	3.77	45.0	84-96	.8127	6	168-192	.0121	12	252-288	.2471	18	336-384	.0420	24	-----	-----	--
V4	.0084	2	4.67	45.0	54-66	.3652	6	108-132	.0661	12	162-198	.2657	18	216-264	.2075	24	270-330	.1895	30
V5	.0089	2	5.03	45.0	72-90	.8138	9	144-180	.2323	18	216-270	.2549	27	288-360	.0924	36	-----	-----	--
V6	.0089	1	6.17	45.0	96-126	.8320	15	192-252	.5561	30	288-378	.0969	45	384-500	.0251	58	-----	-----	--
TRANSVERSE AXIS																			
T1	.0120	4	3.71	54.0	34-42	.0223	4	68-84	.1398	8	102-126	.0147	12	136-168	.3751	16	170-210	.0573	20
T2	.0110	2	5.56	54.0	48-60	.2264	6	96-120	.4127	12	144-180	.1834	18	192-240	.5275	24	240-300	.1401	30
T3	.0116	2	4.66	54.0	66-78	.2519	6	132-156	.5437	12	198-234	.1939	18	264-312	.1158	24	330-390	.0904	30
T4	.0113	1	5.35	54.0	84-102	.2394	9	168-204	.4815	18	252-306	.1971	27	336-408	.1249	36	420-500	.0876	40
T5	.0121	2	5.59	54.0	108-126	.5563	9	216-252	.4211	18	324-378	.2959	27	432-500	.1593	34	-----	-----	--
LONGITUDINAL AXIS																			
L1	.0014	10	.86	45.0	24-30	.0169	3	72-84	.0307	6	108-126	.0034	9	144-168	.0135	12	-----	-----	--
L2	.0034	7	1.41	54.0	36-42	.0081	3	96-120	.0100	12	144-180	.0221	18	192-240	.0100	24	240-300	.0054	30
L3	.0032	2	1.53	45.0	48-60	.0207	6	132-156	.0131	12	198-234	.0315	18	264-312	.0128	24	330-390	.0076	30
L4	.0032	2	1.69	45.0	66-78	.0490	6	168-204	.0169	18	252-306	.0110	27	336-408	.0084	36	420-500	.0130	40
L5	.0032	1	1.68	45.0	84-102	.0199	9	216-252	.0466	18	324-378	.0255	27	432-500	.0246	34	-----	-----	--
L6	.0037	2	2.10	45.0	108-126	.0572	9												

Exaggeration factor = 2.0.

Table D-4. Narrowband Random-On-Random Vibration Program Data For Installed Equipment On The Trunnion Of The M110A2 Self-Propelled Howitzer.

Test Phase	5-500 Hz Floor g²/Hz	No. Sweeps	Overall RMS g	Time min	NARROWBAND 1 BW Hz	NARROWBAND 1 Ampl g²/Hz	NARROWBAND 1 Sweep BW Hz	NARROWBAND 2 BW Hz	NARROWBAND 2 Ampl g²/Hz	NARROWBAND 2 Sweep BW Hz	NARROWBAND 3 BW Hz	NARROWBAND 3 Ampl g²/Hz	NARROWBAND 3 Sweep BW Hz	NARROWBAND 4 BW Hz	NARROWBAND 4 Ampl g²/Hz	NARROWBAND 4 Sweep BW Hz	NARROWBAND 5 BW Hz	NARROWBAND 5 Ampl g²/Hz	NARROWBAND 5 Sweep BW Hz
VERTICAL AXIS																			
V1	.0032	7	1.51	54.0	24-36	.0717	6	48-72	.0263	12	-----	-----	--	-----	-----	--	-----	-----	--
V2	.0299	5	7.31	54.0	42-48	2.4285	3	84-96	1.8373	6	126-144	.9756	9	168-192	.5968	12	210-240	.3829	15
V3	.0221	2	7.65	54.0	54-66	.7512	6	108-132	1.7157	12	162-198	.6355	18	216-264	.2226	24	270-330	.2563	30
V4	.0275	2	10.44	54.0	72-90	2.8300	9	144-180	1.9544	18	216-270	1.0022	27	288-360	.2827	36	-----	-----	--
V5	.0050	4	2.22	54.0	96-114	.2151	9	192-228	.0369	18	-----	-----	--	-----	-----	--	-----	-----	--
TRANSVERSE AXIS																			
T1	.0246	7	4.94	67.5	42-48	.4085	3	84-96	.3341	6	126-144	.4016	9	168-192	.3159	12	210-240	.1822	15
T2	.0191	3	6.05	67.5	54-66	.4884	6	108-132	.5501	12	162-198	.3505	18	216-264	.1285	24	270-330	.3323	30
T3	.0241	2	7.76	67.5	72-90	1.0480	9	144-180	.9808	18	216-270	.3409	27	288-360	.1933	36	360-450	.1854	45
T4	.0044	6	1.85	67.5	96-114	.1077	9	192-228	.0221	18	-----	-----	--	-----	-----	--	-----	-----	--
LONGITUDINAL AXIS																			
L1	.0293	7	7.45	67.5	36-42	1.7113	3	72-84	1.1814	6	108-126	.4711	9	144-168	1.2878	12	180-210	.6981	15
L2	.0032	9	1.39	67.5	48-60	.0293	6	96-120	.0183	12	-----	-----	--	-----	-----	--	-----	-----	--
L3	.0342	3	7.59	67.5	66-78	.2431	6	132-156	.9714	12	198-234	1.0473	18	264-312	.3255	24	330-390	.1346	30
L4	.0054	2	2.79	67.5	84-114	.1483	15	168-228	.0811	30	252-342	.0215	45	-----	-----	--	-----	-----	--

Exaggeration factor = 2.0.

Table D-5. Narrowband Random-On-Random Vibration Program Data For Installed Equipment On The Deck Of The M110A2 Self-Propelled Howitzer.

Test Phase	5-500 Hz Floor g^2/Hz	No. Sweeps	Overall RMS g	Time min	NARROWBAND 1 BW Hz	NARROWBAND 1 Ampl g^2/Hz	NARROWBAND 1 Sweep BW Hz	NARROWBAND 2 BW Hz	NARROWBAND 2 Ampl g^2/Hz	NARROWBAND 2 Sweep BW Hz	NARROWBAND 3 BW Hz	NARROWBAND 3 Ampl g^2/Hz	NARROWBAND 3 Sweep BW Hz	NARROWBAND 4 BW Hz	NARROWBAND 4 Ampl g^2/Hz	NARROWBAND 4 Sweep BW Hz	NARROWBAND 5 BW Hz	NARROWBAND 5 Ampl g^2/Hz	NARROWBAND 5 Sweep BW Hz
VERTICAL AXIS																			
V1	.0086	5	2.68	54.0	24-30	.0627	3	48-60	.0580	6	72-90	.0856	9	96-120	.1023	12	120-150	.0514	15
V2	.0332	5	7.40	54.0	36-42	1.1701	3	72-84	.8630	6	108-126	2.2076	9	144-168	.6489	12	180-210	.2355	15
V3	.0177	2	6.62	54.0	48-60	.8503	6	96-120	.4623	12	144-180	.3564	18	192-240	.2534	24	240-300	.4508	30
V4	.0334	2	12.18	54.0	68-84	1.0014	8	136-168	1.2804	16	204-252	.7831	24	272-336	1.0793	32	340-420	1.3497	40
V5	.0320	1	13.23	54.0	92-114	1.6425	11	184-228	.8965	22	276-342	.6735	33	368-456	1.4367	44	460-500	.7516	20
TRANSVERSE AXIS																			
T1	.0091	7	2.50	54.0	30-36	.2088	3	60-72	.0091	6	90-108	.0091	9	120-144	.1063	12	-----	-----	--
T2	.0299	5	5.50	54.0	42-48	.5949	3	84-96	.5447	6	126-144	.7349	9	168-192	.2151	12	210-240	.1711	15
T3	.0231	2	8.25	54.0	54-66	.2660	6	108-132	.1937	12	162-198	.3084	18	216-264	1.3153	24	270-330	.5905	30
T4	.0303	1	10.00	54.0	72-90	.3552	9	144-180	.6218	18	216-270	.6180	27	288-360	.7675	36	360-450	.6735	45
T5	.0327	1	14.20	54.0	96-114	.4503	9	192-228	.4985	18	288-342	.8524	27	384-456	1.4883	36	480-500	2.2304	10
LONGITUDINAL AXIS																			
L1	.0050	7	1.71	54.0	24-36	.0394	6	48-72	.0243	12	-----	-----	--	-----	-----	--	-----	-----	--
L2	.0267	5	5.59	54.0	42-48	.5509	3	84-96	.8962	6	126-144	.7247	9	168-192	.2472	12	210-240	.1838	15
L3	.0185	2	5.72	54.0	54-66	.1802	6	108-132	.6280	12	162-198	.2395	18	216-264	.2525	24	270-330	.2092	30
L4	.0227	1	8.50	54.0	72-90	.4601	9	144-180	.5017	18	216-270	.2465	27	288-360	.4978	36	360-450	.5852	45
L5	.0138	1	5.04	54.0	96-114	.0715	9	192-228	.1047	18	288-342	.2490	27	384-456	.1310	36	480-500	.1428	10

Exaggeration factor = 2.00

Table D-6. Narrowband Random-On-Random Vibration Program Data For Installed Equipment On The Gun Mount Of The M110A2 Self-Propelled Howitzer.

					NARROWBAND 1			NARROWBAND 2			NARROWBAND 3			NARROWBAND 4			NARROWBAND 5		
Test Phase	5-500 Hz Floor g^2/Hz	No. Sweeps	Overall RMS g	Time min	BW Hz	Ampl g^2/Hz	Sweep BW Hz	BW Hz	Ampl g^2/Hz	Sweep BW Hz	BW Hz	Ampl g^2/Hz	Sweep BW Hz	BW Hz	Ampl g^2/Hz	Sweep BW Hz	BW Hz	Ampl g^2/Hz	Sweep BW Hz
VERTICAL AXIS																			
V1	.0017	7	1.04	54.0	24-36	.0183	6	48-72	.0128	12	-----	-----	--	-----	-----	--	-----	-----	--
V2	.0182	5	4.93	54.0	42-48	.4019	3	84-96	.3528	6	126-144	.5447	9	168-192	.3205	12	210-240	.2726	15
V3	.0125	2	4.96	54.0	54-66	.6367	6	108-132	.6391	12	162-198	.2143	18	216-264	.0944	24	270-330	.0627	30
V4	.0147	1	6.77	54.0	72-96	.4788	12	144-192	.7858	24	216-288	.1234	36	288-384	.2347	48	-----	-----	--
V5	.0047	7	1.75	54.0	102-114	.0914	6	204-228	.0233	12	-----	-----	--	-----	-----	--	-----	-----	--
TRANSVERSE AXIS																			
T1	.0303	7	5.55	67.5	36-42	1.0479	3	72-84	.1262	6	108-126	.7384	9	144-168	.2433	12	180-210	.2463	15
T2	.0044	3	2.07	67.5	48-60	.0310	6	96-120	.0378	12	144-180	.0251	18	192-240	.0339	24	240-300	.0195	30
T3	.0331	3	8.97	67.5	66-78	.8721	6	132-156	2.4664	12	198-234	.5855	18	264-312	.7900	24	330-390	.0888	30
T4	.0088	1	6.21	67.5	86-114	1.9514	14	172-228	.1219	28	258-342	.0605	42	344-456	.0394	56	-----	-----	--
LONGITUDINAL AXIS																			
L1	.0281	7	5.72	67.5	42-48	.1040	3	84-96	.3768	6	126-144	.3527	9	168-192	.1196	12	210-240	.8670	15
L2	.0189	3	6.11	67.5	54-66	.4277	6	108-132	1.1609	12	162-198	.0516	18	216-264	.2360	24	270-330	.2180	30
L3	.0233	2	8.01	67.5	72-90	.9363	9	144-180	.9017	12	216-270	.1414	27	288-360	.4952	36	360-450	.2104	45
L4	.0042	6	2.28	67.5	96-114	..3013	9	192-228	.0300	18	-----	-----	--	-----	-----	--	-----	-----	--

Exaggeration factor = 2.0.

Table D-7. Narrowband Random-On-Random Vibration Program Data For Installed Equipment In The Hull Driver Compartment Of The M110A2 Self-Propelled Howitzer.

					NARROWBAND 1			NARROWBAND 2			NARROWBAND 3			NARROWBAND 4			NARROWBAND 5		
Test Phase	5-500 Hz Floor g²/Hz	No. Sweeps	Overall RMS g	Time min	BW Hz	Ampl g²/Hz	Sweep BW Hz	BW Hz	Ampl g²/Hz	Sweep BW Hz	BW Hz	Ampl g²/Hz	Sweep BW Hz	BW Hz	Ampl g²/Hz	Sweep BW Hz	BW Hz	Ampl g²/Hz	Sweep BW Hz
VERTICAL AXIS																			
V1	.0052	9	1.68	54.0	30-36	.0391	3	60-72	.0052	6	90-108	.0201	9	------	------	--	------	------	--
V2	0253	5	5.14	54.0	42-48	.2574	3	84-96	.4282	6	126-144	.4139	9	168-192	.2844	12	210-240	.3028	15
V3	.0175	2	5.62	54.0	54-66	.2413	6	108-132	.2622	12	162-198	.1099	18	216-264	.2019	24	270-330	.4353	30
V4	.0217	1	7.56	54.0	72-90	.1101	9	144-180	.4506	18	216-270	.2908	27	288-360	.3665	36	360-450	.4270	45
V5	.0128	2	3.97	54.0	96-114	.1494	9	192-228	.0661	18	288-342	.1716	27	384-456	.0938	36	------	------	--
TRANSVERSE AXIS																			
T1	.0081	5	2.28	54.0	30-36	.0081	3	60-72	.0081	6	90-108	.0081	9	120-144	.0856	12	150-180	.0264	15
T2	.0233	5	4.57	54.0	42-48	.2035	3	84-96	.0990	6	126-144	.4478	9	168-192	.2204	12	210-240	.1662	15
T3	.0213	2	4.66	54.0	54-66	.1207	6	108-132	.3215	12	162-198	.0623	18	216-264	.1426	24	270-330	.1318	30
T4	.0265	1	8.60	54.0	72-90	.1445	9	144-180	.4487	18	216-270	.3014	27	288-360	.6389	36	360-450	.5300	45
T5	.0287	1	8.29	54.0	96-114	.3548	9	192-228	.2676	18	288-342	.7922	27	384-456	.4408	36	480-570	.2925	10
LONGITUDINAL AXIS																			
L1	.0034	7	1.36	54.0	48-72	.0172	12	------	------	--	------	------	--	------	------	--	------	------	--
L2	.0227	5	4.42	54.0	42-48	.2119	3	84-96	.2254	6	126-144	.2459	9	168-192	.1139	12	210-240	.2498	15
L3	.0160	2	4.09	54.0	54-66	.0617	6	108-132	.1350	12	162-198	.1597	18	216-264	.0811	24	270-330	.1153	30
L4	.0195	1	5.97	54.0	72-90	.2262	9	144-180	.2939	18	216-270	.1536	27	288-360	.1097	36	360-450	.2930	45
L5	.0096	2	3.08	54.0	96-114	.0777	9	192-228	.0629	18	288-342	.0762	27	384-456	.0477	36	------	------	--

Exaggeration factor = 2.0.

Table D-8. Narrowband Random-On-Random Vibration Program Data For Installed Equipment On The Sponsons Of The M113A1 Armored Personnel Carrier.

Test Phase	5-500 Hz Floor g^2/Hz	No. Sweeps	Overall RMS g	Time min	NARROWBAND 1 BW Hz	NARROWBAND 1 Ampl g^2/Hz	NARROWBAND 1 Sweep BW Hz	NARROWBAND 2 BW Hz	NARROWBAND 2 Ampl g^2/Hz	NARROWBAND 2 Sweep BW Hz	NARROWBAND 3 BW Hz	NARROWBAND 3 Ampl g^2/Hz	NARROWBAND 3 Sweep BW Hz	NARROWBAND 4 BW Hz	NARROWBAND 4 Ampl g^2/Hz	NARROWBAND 4 Sweep BW Hz	NARROWBAND 5 BW Hz	NARROWBAND 5 Ampl g^2/Hz	NARROWBAND 5 Sweep BW Hz
VERTICAL AXIS																			
V1	.0056	4	2.20	45.0	24-30	.1523	3	48-60	.0844	6	72-90	.1025	9	96-120	.0226	12	120-150	.0123	15
V2	.0120	4	3.53	45.0	36-42	.3098	3	72-84	.5120	6	108-126	.0938	9	144-168	.0736	12	180-210	.0908	15
V3	.0132	2	6.05	45.0	48-60	2.9623	6	96-120	.2508	12	144-180	.1737	18	192-240	.1615	24	240-300	.1143	30
V4	.0110	2	5.06	45.0	67-78	2.4820	5	134-156	.1573	11	201-234	.1719	16	268-312	.0613	22	335-390	.0549	27
V5	.0180	1	7.49	45.0	84-102	2.4861	9	168-204	.5375	18	252-306	.3000	27	336-408	.1212	36	420-500	.1134	40
V6	.0208	3	8.95	45.0	108-120	6.7305	6	216-240	1.1798	12	324-360	.6259	18	432-480	.2177	24	------	------	--
TRANSVERSE AXIS																			
T1	.0075	4	2.82	45.0	24-30	.0238	3	48-60	.1397	6	72-90	.2698	9	96-120	.0601	12	120-150	.0358	15
T2	.0149	4	5.39	45.0	36-42	.2406	3	72-84	1.2746	6	108-126	1.0559	9	144-168	.2446	12	180-210	.1039	15
T3	.0152	2	7.93	45.0	48-60	4.2320	6	96-120	1.0347	12	144-180	.4844	18	192-240	.1891	24	240-300	.1900	30
T4	.0124	4	4.46	45.0	66-72	2.9725	3	132-144	.3121	6	198-216	.1896	9	264-288	.0858	12	330-360	.0498	15
T5	.0098	1	11.01	45.0	84-102	10.4347	9	168-204	.3376	18	252-306	.4768	27	336-408	.0833	36	420-500	.0386	40
T6	.0234	3	12.00	45.0	108-120	18.7124	6	216-240	.6378	12	324-360	.6412	18	432-480	.1028	24	------	------	--
LONGITUDINAL AXIS																			
L1	.0010	4	.94	45.0	24-30	.0568	3	48-60	.0174	6	72-90	.0098	9	96-120	.0016	12	120-150	.0030	15
L2	.0020	4	1.43	45.0	36-42	.1525	3	72-84	.0643	6	108-126	.0064	9	144-168	.0149	12	180-210	.0039	15
L3	.0041	2	2.19	45.0	48-60	.1122	6	96-120	.0289	12	144-180	.0765	18	192-240	.0176	24	240-300	.0109	30
L4	.0041	2	1.84	45.0	66-78	.1661	6	132-156	.0118	12	198-234	.0129	18	264-312	.0074	24	330-390	.0057	30
L5	.0073	1	3.27	45.0	84-102	.5564	9	168-204	.0788	18	252-306	.0344	27	336-408	.0127	36	420-500	.0063	40
L6	.0073	3	2.76	45.0	108-120	.5482	6	216-240	.0316	12	324-360	.0316	18	432-480	.0084	24	------	------	--

Exaggeration factor = 2.0.

Table D-9. Narrowband Random-On-Random Vibration Program Data For Installed Equipment On Top Of The M113A1 Armored Personnel Carrier.

	5-500 Hz		Overall		NARROWBAND 1			NARROWBAND 2			NARROWBAND 3			NARROWBAND 4			NARROWBAND 5		
Test Phase	Floor g^2/Hz	No. Sweeps	RMS g	Time min	BW Hz	Ampl g^2/Hz	Sweep BW Hz	BW Hz	Ampl g^2/Hz	Sweep BW Hz	BW Hz	Ampl g^2/Hz	Sweep BW Hz	BW Hz	Ampl g^2/Hz	Sweep BW Hz	BW Hz	Ampl g^2/Hz	Sweep BW Hz
VERTICAL AXIS																			
V1	.0057	4	2.61	45.0	24-30	.3166	3	48-60	.0571	6	72-90	.2471	9	96-120	.0284	12	120-150	.0253	15
V2	.0101	4	3.77	45.0	36-42	.3222	3	72-84	.4779	6	108-126	.1729	9	144-168	.2408	12	180-210	.0902	15
V3	.0136	2	6.04	45.0	48-60	.5418	6	96-120	.5462	12	144-180	.3483	18	192-240	.4488	24	240-300	.1387	30
V4	.0104	2	3.96	45.0	66-78	.5959	6	132-156	.2800	12	198-234	.1679	18	264-312	.0208	24	330-390	.0349	30
V5	.0164	1	7.97	45.0	84-102	4.0698	9	168-204	.8382	18	252-306	.0992	27	336-408	.0621	36	420-500	.0214	40
V6	.0254	3	11.88	45.0	108-120	14.599 0	6	216-240	3.0643	12	324-360	.2433	18	432-480	.0608	24	------	------	--
TRANSVERSE AXIS																			
T1	.0018	4	1.11	45.0	24-30	.0582	3	48-60	.0153	6	72-90	.0105	9	96-120	.0018	12	120-150	.0029	15
T2	.0033	4	1.64	45.0	36-42	.1131	3	72-84	.0460	6	108-126	.0300	9	144-168	.0157	12	180-210	.0095	15
T3	.0049	2	2.75	45.0	48-60	.4060	6	96-120	.0803	12	144-180	.0362	18	192-240	.0390	24	240-300	.0203	30
T4	.0032	3	2.03	45.0	66-78	.3632	6	132-156	.0192	12	198-234	.0104	18	264-312	.0050	24	------	------	--
T5	.0067	2	3.52	45.0	84-102	.7592	9	168-204	.0891	18	252-306	.0368	27	------	------	--	------	------	--
T6	.0063	4	2.58	45.0	108-120	.2799	6	216-240	.1276	12	324-360	.0311	18	------	------	--	------	------	--
LONGITUDINAL AXIS																			
L1	.0017	6	.99	45.0	24-30	.0074	3	48-60	.0042	6	72-90	.0124	9	96-120	.0022	12	------	------	--
L2	.0039	4	1.60	45.0	36-42	.0324	3	72-84	.0626	6	108-126	.0088	9	144-168	.0088	12	180-210	.0105	15
L3	.0043	2	1.97	45.0	48-60	.0394	6	96-120	.0460	12	144-180	.0275	18	192-240	.0224	24	240-300	.0112	30
L4	.0036	2	1.63	45.0	66-78	.0618	6	132-156	.0226	12	198-234	.0113	18	264-312	.0058	24	330-390	.0068	30
L5	.0066	2	3.28	45.0	84-102	.3528	9	168-204	.1764	18	252-306	.0472	27	336-408	.0133	36	------	------	--
L6	.0075	3	3.05	45.0	108-120	.2910	6	216-240	.1969	12	324-360	.0858	18	432-480	.0159	24	------	------	--

The exaggeration factor was 2.0.

Table D-10. Narrowband Random-On-Random Vibration Program Data For Installed Equipment On The Deck Of The M113A1 Armored Personnel Carrier.

					NARROWBAND 1			NARROWBAND 2			NARROWBAND 3			NARROWBAND 4			NARROWBAND 5		
Test Phase	5-500 Hz Floor g²/Hz	No. Sweeps	Overall RMS g	Time min	BW Hz	Ampl g²/Hz	Sweep BW Hz	BW Hz	Ampl g²/Hz	Sweep BW Hz	BW Hz	Ampl g²/Hz	Sweep BW Hz	BW Hz	Ampl g²/Hz	Sweep BW Hz	BW Hz	Ampl g²/Hz	Sweep BW Hz
VERTICAL AXIS																			
V1	.0090	4	3.91	45.0	24-30	.0488	3	48-60	.2881	6	72-90	.7876	9	96-120	.0922	12	120-150	.0783	15
V2	.0154	4	5.80	45.0	36-42	.5468	3	72-84	2.8516	6	108-126	.5710	9	144-168	.1080	12	180-210	.1003	15
V3	.0190	2	6.97	45.0	48-60	1.3670	6	96-120	1.4124	12	144-180	.4079	18	192-240	.2432	24	240-300	.0853	30
V4	.0150	2	6.17	45.0	66-78	2.4200	6	132-156	.8518	12	198-234	.2334	18	264-312	.0632	24	330-390	.0528	30
V5	.0263	1	14.62	45.0	84-102	17.5665	9	168-204	.8421	18	252-306	.3058	27	336-408	.4541	36	420-500	.1437	40
V6	.0311	3	14.41	45.0	108-120	25.374	6	216-240	.9117	12	324-360	.5616	18	432-480	.8734	24	------	------	--
TRANSVERSE AXIS																			
T1	.0041	4	1.74	45.0	24-30	.1118	3	48-60	.0223	6	72-90	.0230	9	96-120	.0143	12	120-150	.0233	15
T2	.0088	4	3.02	45.0	36-42	.3225	3	72-84	.1002	6	108-126	.2736	9	144-168	.0427	12	180-210	.0396	15
T3	.0100	2	4.82	45.0	48-60	1.0548	6	96-120	.2878	12	144-180	.1795	18	192-240	.0939	24	240-300	.1308	30
T4	.0083	2	3.82	45.0	66-78	1.0893	6	132-156	.1479	12	198-234	.0600	18	264-312	.0514	24	330-390	.0203	30
T5	.0138	1	5.90	45.0	84-102	1.9798	9	168-204	.2213	18	252-306	.1805	27	336-408	.0594	36	420-500	.0240	40
T6	.0082	3	7.11	45.0	108-120	5.7063	6	216-240	.6276	12	324-360	.1972	18	432-480	.0718	24	------	------	--
LONGITUDINAL AXIS																			
L1	.0027	4	1.35	45.0	24-30	.0679	3	48-60	.0144	6	72-90	.0240	9	96-120	.0040	12	120-150	.0034	15
L2	.0059	4	2.05	45.0	36-42	.2259	3	72-84	.0543	6	108-126	.0233	9	144-168	.0115	12	180-210	.0137	15
L3	.0067	2	2.57	45.0	48-60	.1404	6	96-120	.0697	12	144-180	.0442	18	192-240	.0201	24	240-300	.0320	30
L4	.0055	2	2.10	45.0	66-78	.1074	6	132-156	.0218	12	198-234	.0333	18	264-312	.0148	24	330-390	.0102	30
L5	.0093	1	3.12	45.0	84-102	.6231	9	168-204	.1252	18	252-306	.0422	27	336-408	.0406	36	420-500	.0248	40
L6	.0104	3	3.89	45.0	108-120	.9753	6	216-240	.1415	12	324-360	.0830	18	432-480	.0646	24	------	------	--

Exaggeration factor = 2.0.

Table D-11. Narrowband Random-On-Random Vibration Program Data For Installed Equipment On The Crew Compartment Walls Of The M113A1 Armored Personnel Carrier.

					NARROWBAND 1			NARROWBAND 2			NARROWBAND 3			NARROWBAND 4			NARROWBAND 5		
Test Phase	5-500 Hz Floor g^2/Hz	No. Sweeps	Overall RMS g	Time min	BW Hz	Ampl g^2/Hz	Sweep BW Hz	BW Hz	Ampl g^2/Hz	Sweep BW Hz	BW Hz	Ampl g^2/Hz	Sweep BW Hz	BW Hz	Ampl g^2/Hz	Sweep BW Hz	BW Hz	Ampl g^2/Hz	Sweep BW Hz
VERTICAL AXIS																			
V1	.0064	4	2.68	45.0	24-30	.2962	3	48-60	.1278	6	72-90	.1955	9	96-120	.0398	12	120-150	.0266	15
V2	.0125	4	4.33	45.0	36-42	.7321	3	72-84	1.0687	6	108-126	.2696	9	144-168	.1037	12	180-210	.0587	15
V3	.0141	2	7.17	45.0	48-60	2.8761	6	96-120	1.0410	12	144-180	.3277	18	192-240	.1882	24	240-300	.1821	30
V4	.0125	2	5.82	45.0	66-78	2.8602	6	132-156	.2816	12	198-234	.1287	18	264-312	.0541	24	330-390	.1570	30
V5	.0202	1	10.43	45.0	84-102	6.8127	9	168-204	1.3442	18	252-306	.2859	27	336-408	.1937	36	420-510	.0314	40
V6	.0250	3	12.63	45.0	108-120	18.5182	6	216-240	1.6032	12	324-360	.8852	18	432-480	.0998	24	------	-----	--
TRANSVERSE AXIS																			
T1	.0113	4	3.26	45.0	24-30	.1763	3	48-60	.1422	6	72-90	.1813	9	96-120	.0845	12	120-150	.1009	15
T2	.0227	4	6.70	45.0	36-42	.5202	3	72-84	.6531	6	108-126	.4183	9	144-168	.6025	12	180-210	1.2154	15
T3	.0330	2	13.63	45.0	48-60	1.8847	6	96-120	.7840	12	144-180	1.5925	18	192-240	4.0892	24	240-300	.8258	30
T4	.0214	2	7.34	45.0	66-78	1.2874	6	132-156	.4257	12	198-234	1.2570	18	264-312	.3104	24	330-390	.0787	30
T5	.0429	1	16.18	45.0	84-102	11.5111	9	168-204	5.9112	18	252-306	1.0630	27	336-408	.1524	36	420-500	.0498	40
T6	.0429	3	15.87	45.0	108-120	10.4740	6	216-240	11.734	12	324-360	1.3871	18	432-480	.1900	24	------	-----	--
LONGITUDINAL AXIS																			
L1	.0043	4	1.65	45.0	24-30	.0720	3	48-60	.0180	6	72-90	.0300	9	96-120	.0084	12	120-150	.0072	15
L2	.0092	4	2.70	45.0	36-42	.2467	3	72-84	.1920	6	108-126	.0332	9	144-168	.0213	12	180-210	.0475	15
L3	.0098	2	3.89	45.0	48-60	.2628	6	96-120	.1436	12	144-180	.1202	18	192-240	.0637	24	240-300	.1398	30
L4	.0098	2	3.82	45.0	66-78	.3640	6	132-156	.0498	12	198-234	.0336	18	264-312	.0840	24	330-390	.1746	30
L5	.0175	2	6.69	45.0	84-102	1.1316	9	168-204	.2252	18	252-306	.5461	27	336-408	.2395	36	------	-----	--
L6	.0202	3	6.70	45.0	108-120	1.0985	6	216-240	.4835	12	324-360	1.2664	18	432-480	.0371	24	------	-----	--

Exaggeration factor = 2.0.

Table D-12. Narrowband Random-On-Random Vibration Program Data For Installed Equipment On The Walls And Sponson Of The Engine Compartment Of The M113A1 Amored Personnel Carrier.

					NARROWBAND 1			NARROWBAND 2			NARROWBAND 3			NARROWBAND 4			NARROWBAND 5		
Test Phase	5-500 Hz Floor g^2/Hz	No. Sweeps	Overall RMS g	Time min	BW Hz	Ampl g^2/Hz	Sweep BW Hz	BW Hz	Ampl g^2/Hz	Sweep BW Hz	BW Hz	Ampl g^2/Hz	Sweep BW Hz	BW Hz	Ampl g^2/Hz	Sweep BW Hz	BW Hz	Ampl g^2/Hz	Sweep BW Hz
										VERTICAL AXIS									
V1	.0046	4	1.87	45.0	24-30	.0373	3	48-60	.0573	6	72-90	.0712	9	96-120	.0124	12	120-150	.0118	15
V2	.0091	4	2.95	45.0	36-42	.1519	3	72-84	.3380	6	108-126	.1030	9	144-168	.0586	12	180-210	.0322	15
V3	.0109	2	4.98	45.0	48-60	1.3120	6	96-120	.5050	12	144-180	.1634	18	192-240	.0497	24	240-300	.0787	30
V4	.0100	2	4.15	45.0	66-78	1.3752	6	132-156	.0881	12	198-234	.0432	18	264-312	.0294	24	330-390	.0790	30
V5	.0165	1	7.70	45.0	84-102	3.2306	9	168-204	.4918	18	252-306	.2326	27	336-408	.1017	36	420-500	.1223	40
V6	.0193	3	7.82	45.0	108-120	5.3995	6	216-240	.7815	12	324-360	.4642	18	432-480	.1112	24	------	-----	--
										TRANSVERSE AXIS									
T1	.0032	4	1.51	45.0	24-30	.0747	3	48-60	.0273	6	72-90	.0231	9	96-120	.0076	12	120-150	.0100	15
T2	.0062	4	2.44	45.0	36-42	.2437	3	72-84	.0966	6	108-126	.0580	9	144-168	.0836	12	180-210	.0210	15
T3	.0070	2	3.76	45.0	48-60	.5248	6	96-120	.3112	12	144-180	.1500	18	192-240	.0484	24	240-300	.0185	30
T4	.0063	2	3.02	45.0	66-78	.5984	6	132-156	.0898	12	198-234	.0690	18	264-312	.0123	24	330-390	.0126	30
T5	.0101	1	5.13	45.0	84-102	1.6349	9	168-204	.2450	18	252-306	.0673	27	336-408	.0330	36	420-500	.0125	40
T6	.0121	3	4.67	45.0	108-120	1.7649	6	216-240	.2714	12	324-360	.0825	18	432-480	.0496	24	------	-----	--
										LONGITUDINAL AXIS									
L1	.0028	4	1.21	45.0	24-30	.0138	3	48-60	.0062	6	72-90	.0055	9	96-120	.0023	12	120-150	.0030	15
L2	.0060	4	1.86	45.0	36-42	.0406	3	72-84	.0219	6	108-126	.0091	9	144-168	.0177	12	180-210	.0185	15
L3	.0066	2	2.67	45.0	48-60	.1042	6	96-120	.0399	12	144-180	.0619	18	192-240	.0177	24	240-300	.0612	30
L4	.0064	2	2.60	45.0	66-78	.0921	6	132-156	.0147	12	198-234	.0134	18	264-312	.0379	24	330-390	.0762	30
L5	.0121	1	4.45	45.0	84-102	.2885	9	168-204	.0876	18	252-306	.2499	27	336-408	.1128	36	420-500	.0107	40
L6	.0140	4	4.34	45.0	108-120	.3588	6	216-240	.2203	12	324-360	.4211	18	------	-----	--	------	-----	--

Exaggeration factor = 2.0.

Table D-13. Narrowband Random-On-Random Vibration Program Data For Installed Equipment In The Turret Of The M60A3 Tank.

Test Phase	5-500 Hz Floor g^2/Hz	No. Sweeps	Overall RMS g	Time min	NARROWBAND 1 BW Hz	NARROWBAND 1 Ampl g^2/Hz	NARROWBAND 1 Sweep BW Hz	NARROWBAND 2 BW Hz	NARROWBAND 2 Ampl g^2/Hz	NARROWBAND 2 Sweep BW Hz	NARROWBAND 3 BW Hz	NARROWBAND 3 Ampl g^2/Hz	NARROWBAND 3 Sweep BW Hz	NARROWBAND 4 BW Hz	NARROWBAND 4 Ampl g^2/Hz	NARROWBAND 4 Sweep BW Hz	NARROWBAND 5 BW Hz	NARROWBAND 5 Ampl g^2/Hz	NARROWBAND 5 Sweep BW Hz
VERTICAL AXIS																			
V1	.0006	10	.61	54.0	20-25	.0139	2.5	40-50	.0088	5	60-75	.0012	7.5	------	-----	--	------	-----	--
V2	.0007	10	.63	54.0	30-35	.0163	2.5	60-70	.0040	5	------	-----	--	------	-----	--	------	-----	--
V3	.0027	3	1.62	54.0	40-50	.0859	5	80-100	.0352	10	120-150	.0193	15	160-200	.0110	20	200-250	.0075	25
V4	.0016	3	1.25	54.0	55-65	.0933	5	110-130	.0265	10	165-195	.0035	15	220-260	.0034	20	275-325	.0019	25
V5	.0016	10	1.01	54.0	70-75	.0732	2.5	140-150	.0105	5	------	-----	--	------	-----	--	------	-----	--
TRANSVERSE AXIS																			
T1	.0004	10	.46	54.0	20-25	.0038	2.5	40-50	.0009	5	60-75	.0005	7.5	------	-----	--	------	-----	--
T2	.0005	10	.51	54.0	30-35	.0015	2.5	60-70	.0016	5	------	-----	--	------	-----	--	------	-----	--
T3	.0010	4	.83	54.0	40-50	.0204	5	80-100	.0085	10	120-150	.0017	15	160-200	.0012	20	------	-----	--
T4	.0012	8	.99	54.0	55-65	.0710	5	110-130	.0052	10	------	-----	--	------	-----	--	------	-----	--
T5	.0013	10	.90	54.0	70-75	.0583	.52	140-150	.0045	5	210-225	.0014	7.5	------	-----	--	------	-----	--
LONGITUDINAL AXIS																			
L1	.0004	10	.47	54.0	20-25	.0067	2.5	40-50	.0026	5	------	-----	--	------	-----	--	------	-----	--
L2	.0005	10	.51	54.0	30-35	.0067	2.5	------	-----	--	------	-----	--	------	-----	--	------	-----	--
L3	.0009	8	.72	54.0	40-50	.0141	5	80-100	.0023	10	------	-----	--	------	-----	--	------	-----	--
L4	.0009	8	.72	54.0	55-65	.0133	5	110-130	.0026	10	------	-----	--	------	-----	--	------	-----	--
L5	.0014	10	.86	54.0	70-75	.0154	2.5	140-150	.0026	5	------	-----	--	------	-----	--	------	-----	--

Exaggeration factor = 2.0.

Table D-14. Narrowband Random-On-Random Vibration Program Data For Installed Equipment In The Hull Of The M60A3 Tank.

Test Phase	5-500 Hz Floor g^2/Hz	No. Sweeps	Overall RMS g	Time min	NARROWBAND 1 BW Hz	NARROWBAND 1 Ampl g^2/Hz	NARROWBAND 1 Sweep BW Hz	NARROWBAND 2 BW Hz	NARROWBAND 2 Ampl g^2/Hz	NARROWBAND 2 Sweep BW Hz	NARROWBAND 3 BW Hz	NARROWBAND 3 Ampl g^2/Hz	NARROWBAND 3 Sweep BW Hz	NARROWBAND 4 BW Hz	NARROWBAND 4 Ampl g^2/Hz	NARROWBAND 4 Sweep BW Hz	NARROWBAND 5 BW Hz	NARROWBAND 5 Ampl g^2/Hz	NARROWBAND 5 Sweep BW Hz
VERTICAL AXIS																			
V1	.0012	10	.78	54.0	20-25	.0029	2.5	40-50	.0017	5	------	-----	--	------	-----	--	------	-----	--
V2	.0018	10	.96	54.0	30-35	.0038	2.5	60-70	.0052	5	90-105	.0020	7.5	------	-----	--	------	-----	--
V3	.0027	3	1.42	54.0	40-50	.0364	5	80-100	.0133	10	120-150	.0144	15	160-200	.0125	20	200-250	.0042	25
V4	.0034	3	1.75	54.0	55-65	.0909	5	110-130	.0231	10	165-195	.0238	15	220-260	.0164	20	275-325	.0109	25
V5	.0042	6	1.70	54.0	70-75	.0984	2.5	140-150	.0470	5	210-225	.0349	7.5	280-300	.0097	10	350-375	.0098	12.5
TRANSVERSE AXIS																			
T1	.0008	10	.65	54.0	20-25	.0029	2.5	40-50	.0029	5	60-75	.0026	7.5	------	-----	--	------	-----	--
T2	.0012	10	.80	54.0	30-35	.0054	2.5	60-70	.0069	5	90-105	.0024	7.5	------	-----	--	------	-----	--
T3	.0018	4	1.26	54.0	40-50	.0696	5	80-100	.0190	10	120-150	.0142	15	160-200	.0024	20	------	-----	--
T4	.0023	3	1.62	54.0	55-65	.1704	5	110-130	.0465	10	165-195	.0125	15	220-260	.0038	20	275-325	.0036	25
T5	.0027	8	1.40	54.0	70-75	.1662	2.5	140-150	.0420	5	210-225	.0047	7.5	280-300	.0031	10	------	-----	--
LONGITUDINAL AXIS																			
L1	.0010	10	.73	54.0	20-25	.0018	2.5	40-50	.0072	5	------	-----	--	------	-----	--	------	-----	--
L2	.0014	6	.86	54.0	30-35	.0103	2.5	60-70	.0032	5	90-105	.0024	7.5	120-140	.0019	10	150-175	.0016	12.5
L3	.0022	3	1.38	54.0	40-50	.0513	5	80-100	.0200	10	120-150	.0247	15	160-200	.0046	20	200-250	.0020	25
L4	.0031	3	1.56	54.0	55-65	.0374	5	110-130	.0463	10	165-195	.0181	15	220-260	.0047	20	275-325	.0041	25
L5	.0035	6	1.46	54.0	70-75	.0407	2.5	140-150	.0506	5	210-225	.0090	7.5	280-300	.0035	10	350-375	.0055	12.5

Exaggeration factor = 2.0.

Table D-15. Narrowband Random-On-Random Vibration Program Data For Installed Equipment In The Hull Of The Leopard 1 Tank.

Test Phase	5-500 Hz Floor g^2/Hz	No. Sweeps	Overall RMS g	Time min	NARROWBAND 1 BW Hz	NARROWBAND 1 Ampl g^2/Hz	NARROWBAND 1 Sweep BW Hz	NARROWBAND 2 BW Hz	NARROWBAND 2 Ampl g^2/Hz	NARROWBAND 2 Sweep BW Hz	NARROWBAND 3 BW Hz	NARROWBAND 3 Ampl g^2/Hz	NARROWBAND 3 Sweep BW Hz	NARROWBAND 4 BW Hz	NARROWBAND 4 Ampl g^2/Hz	NARROWBAND 4 Sweep BW Hz	NARROWBAND 5 BW Hz	NARROWBAND 5 Ampl g^2/Hz	NARROWBAND 5 Sweep BW Hz
VERTICAL AXIS																			
V1	.0008	2	.84	45.0	28-34	.0082	3	56-68	.0086	6	84-102	.0195	9	112-136	.0045	12	140-170	.0023	15
V2	.0020	2	1.38	45.0	39-45	.0342	3	78-90	.0726	6	117-135	.0236	9	156-180	.0069	12	195-225	.0107	15
V3	.0021	2	1.41	45.0	50-56	.0424	3	100-112	.0842	6	150-168	.0207	9	200-224	.0119	12	250-280	.0063	15
V4	.0023	1	1.72	45.0	61-73	.0460	6	122-146	.0411	12	183-219	.0525	18	244-292	.0070	24	305-365	.0047	30
V5	.0031	2	1.67	45.0	78-84	.1422	3	156-168	.0690	6	234-252	.0497	9	312-336	.0042	12	390-420	.0044	15
V6	.0044	1	2.65	45.0	89-101	.3209	6	178-202	.2038	12	267-303	.0287	18	356-404	.0085	24	------	-----	--
TRANSVERSE AXIS																			
T1	.0032	2	1.40	45.0	28-34	.0114	3	56-68	.0194	6	84-102	.0168	9	112-136	.0080	12	140-170	.0077	15
T2	.0073	2	2.16	45.0	39-45	.0174	3	78-90	.0689	6	117-135	.0529	9	156-180	.0128	12	195-225	.0204	15
T3	.0071	2	2.11	45.0	50-56	.0166	3	100-112	.0626	6	150-168	.0343	9	200-224	.0120	12	250-280	.0253	15
T4	.0066	1	2.47	45.0	61-73	.0356	6	122-146	.0833	12	183-219	.0754	18	244-292	.0230	24	305-365	.0102	30
T5	.0078	2	2.40	45.0	78-84	.0690	3	156-168	.2156	6	234-252	.0507	9	312-336	.0116	12	390-420	.0096	15
T6	.0126	1	3.53	45.0	89-101	.2276	6	178-202	.3368	12	267-303	.0584	18	356-404	.0222	24	------	-----	--
LONGITUDINAL AXIS																			
L1	.0008	2	.71	45.0	28-34	.0066	3	56-68	.0029	6	84-102	.0048	9	112-136	.0019	12	140-170	.0025	15
L2	.0016	2	1.18	45.0	39-45	.0537	3	78-90	.0129	6	117-135	.0169	9	156-180	.0114	12	195-225	.0090	15
L3	.0015	2	1.14	45.0	50-56	.0290	3	100-112	.0191	6	150-168	.0139	9	200-224	.0170	12	250-280	.0062	15
L4	.0018	1	1.45	45.0	61-73	.0166	6	122-146	.0267	12	183-219	.0314	18	244-292	.0098	24	305-365	.0053	30
L5	.0023	2	1.36	45.0	78-84	.0822	3	156-168	.0540	6	234-252	.0138	9	312-336	.0046	12	390-420	.0035	15
L6	.0033	1	1.99	45.0	89-101	.1363	6	178-202	.1119	12	267-303	.0151	18	356-404	.0046	24	------	-----	--

Exaggeration factor = 2.0.

Table D-16. Narrowband Random-On-Random Vibration Program Data For Installed Equipment In The Turret Of The Leopard 1 Tank.

					NARROWBAND 1			NARROWBAND 2			NARROWBAND 3			NARROWBAND 4			NARROWBAND 5		
Test Phase	5-500 Hz Floor g²/Hz	No. Sweeps	Overall RMS g	Time min	BW Hz	Ampl g²/Hz	Sweep BW Hz	BW Hz	Ampl g²/Hz	Sweep BW Hz	BW Hz	Ampl g²/Hz	Sweep BW Hz	BW Hz	Ampl g²/Hz	Sweep BW Hz	BW Hz	Ampl g²/Hz	Sweep BW Hz
VERTICAL AXIS																			
V1	.0003	2	.77	45.0	28-34	.0845	3	56-68	.0123	6	84-102	.0089	9	112-136	.0025	12	140-170	.0013	15
V2	.0009	2	1.23	45.0	39-45	.2222	3	78-90	.0372	6	117-135	.0178	9	156-180	.0028	12	195-225	.0012	15
V3	.0005	2	.92	45.0	50-56	.0845	3	100-112	.0387	6	150-168	.0089	9	200-224	.0027	12	250-280	.0013	15
V4	.0009	1	1.14	45.0	61-73	.0844	6	122-146	.0141	12	183-219	.0084	18	244-292	.0024	24	305-365	.0014	30
V5	.0009	5	.86	45.0	78-84	.0778	3	156-168	.0089	6	234-252	.0023	9	------	-----	--	------	-----	--
V6	.0010	1	1.30	45.0	89-101	.1673	6	178-202	.0136	12	267-303	.0023	18	356-404	.0019	24	------	-----	--
TRANSVERSE AXIS																			
T1	.0002	2	.51	45.0	28-34	.0366	3	56-68	.0016	6	84-102	.0014	9	112-136	.0011	12	140-170	.0020	15
T2	.0003	2	.51	45.0	39-45	.0272	3	78-90	.0019	6	117-135	.0009	9	156-180	.0005	12	195-225	.0013	15
T3	.0003	2	.49	45.0	50-56	.0213	3	100-112	.0010	6	150-168	.0006	9	200-224	.0008	12	250-280	.0015	15
T4	.0004	1	.75	45.0	61-73	.0201	6	122-146	.0024	12	183-219	.0067	18	244-292	.0030	24	305-365	.0018	30
T5	.0004	2	.60	45.0	78-84	.0196	3	156-168	.0054	6	234-252	.0066	9	312-336	.0012	12	390-420	.0008	15
T6	.0006	1	.83	45.0	89-101	.0084	6	178-202	.0212	12	267-303	.0053	18	356-404	.0015	24	------	-----	--
LONGITUDINAL AXIS																			
L1	.0006	5	.67	45.0	28-34	.0471	3	56-68	.0024	6	84-102	.0015	9	------	-----	--	------	-----	--
L2	.0011	5	1.07	45.0	39-45	.1934	3	78-90	.0041	6	117-135	.0013	9	------	-----	--	------	-----	--
L3	.0006	5	.67	45.0	50-56	.0471	3	100-112	.0015	6	150-168	.0015	9	------	-----	--	------	-----	--
L4	.0011	2	.91	45.0	61-73	.0433	6	122-146	.0025	12	183-219	.0018	18	------	-----	--	------	-----	--
L5	.0006	5	.58	45.0	78-84	.0117	3	156-168	.0011	6	234-252	.0010	9	------	-----	--	------	-----	--
L6	.0009	2	.79	45.0	89-101	.0243	6	178-202	.0033	12	267-303	.0014	18	------	-----	--	------	-----	--

Exaggeration factor = 2.0.

APPENDIX E. HELICOPTER VIBRATION.

The vibration environment of a helicopter is characterized by broadband random with superimposed strong vibration peaks as depicted in Figure E-2. These peaks are generated by the rotating components, and their levels differ in various zones of the aircraft depending upon the proximity of the source, geometry of the aircraft, and location of the test item, see Figure E-1. The major vibration peaks in the helicopter vibration spectra are usually associated with the major rotating components within that zone of the aircraft such as the main rotor. Since the vibration environment of the equipment is dominated by discrete frequency peaks of vibration, it is logical to use some of these frequencies for exposure in the laboratory test. Normally about four frequencies are chosen for the tests.

The spectra provided in Figure E-2 and suggested functional test levels from Tables E-1 and E-2 are a composite envelope of the highest vibration levels derived from a composite of helicopters. As these schedules represent an extreme worst-case condition, these schedules should only be utilized to establish item structural survivability as required for flight-worthiness testing. The vibration profile of any given helicopter is unique to that helicopter and equipment configuration. To conduct performance evaluation testing of helicopter equipment, actual flight measurements and life cycles for the test items must be measured and established and proper laboratory schedules created.

The schedules provided in Figures E-3, E-4, and E-5 are for the vertical, transverse, and longitudinal axes respectively for the 30mm Ammunition Bay of the AH-64A Apache Helicopter. During laboratory testing, an Apache Helicopter ammunition rack shall be utilized and attached to the exciter. Four test control accelerometers shall be attached to the ammunition bay rack near the four rack mounting points. The control; shall be by extremal averaging control (peak limiting) for the four accelerometers. Control system resolution shall be 3.5 to 4Hz.

The schedules provided in Figures E-6 through E-14 are for the Hydra 70mm Rocket as carried on the AH-64A Apache Helicopter. The schedules were derived from data at the rocket launcher pod fore and aft top positions, and at the rocket pod ejector rack. During laboratory testing, an Apache Helicopter 19-tube rocket launcher pod shall be utilized attached to the ejector rack assembly or simulated hardmount. Two test control accelerometers shall be utilized. One placed at the top front end of the launcher pod and a second placed at the top rear end of the launcher pod. If necessary, control system resolution shall be approximately 1.2Hz. The acquisition and processing for the 30mm ammunition bay on the AH-64A Apache Helicopter and the Hydra 70mm rocket on the AH-64A Apache Helicopter are documented in references n. and o., respectively.

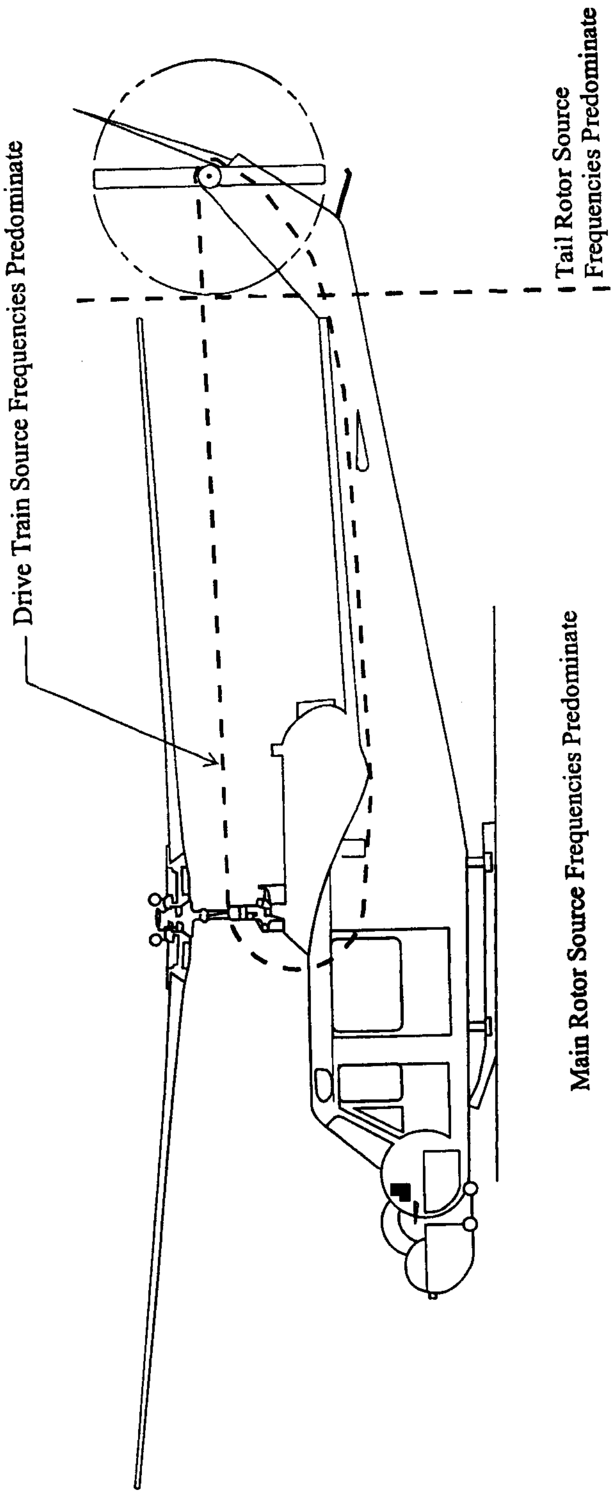
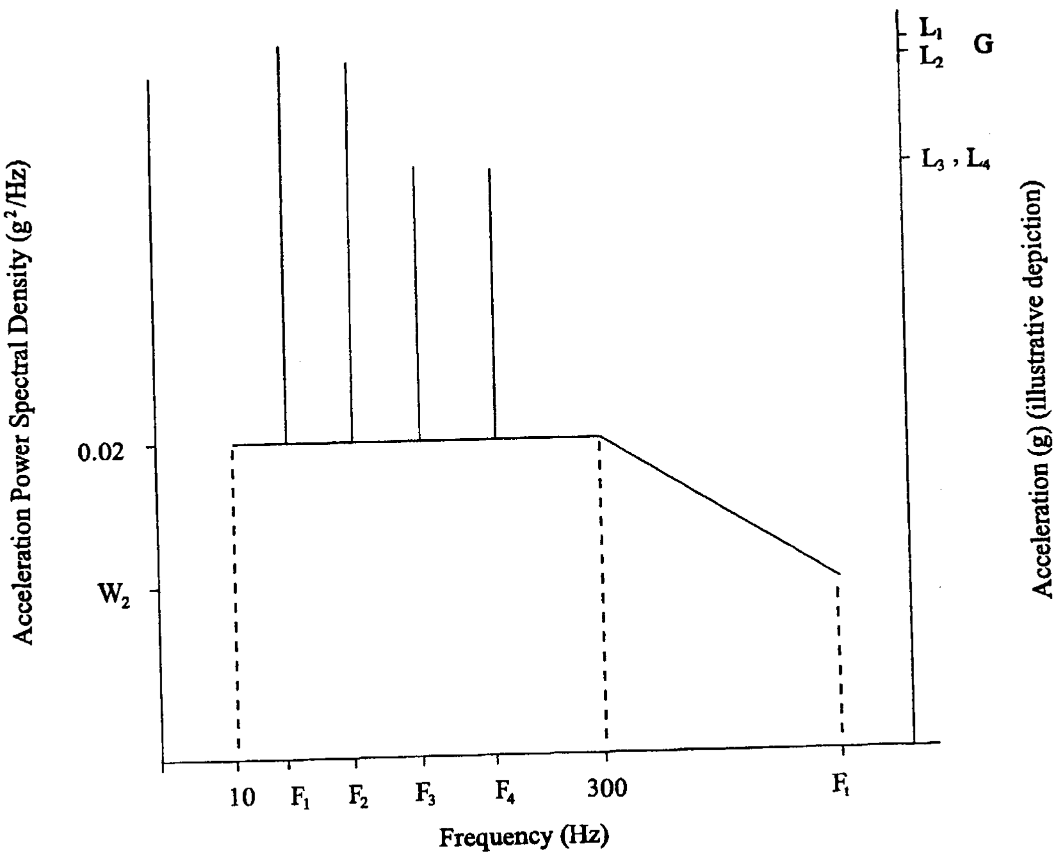


Figure E-1. Zones for rotary-wing aircraft.



Equipment Location	W_2	F_t
General	0.002	500
Instrument panel	0.002	500
External stores	0.002	500
On or near drive-train elements	0.02	2000

Figure E-2. Suggested vibration spectra for flight-worthiness testing of equipment mounted on helicopters. (Use Tables E-1 and E-2 to establish actual spectra levels.)

Table E-1. Suggested Functional Test Levels For Equipment Installed On Helicopters.

Equipment Location	Source Frequency (F_x) Ranges	Peak Vibration Level (Lx) at F_x--g's
General[a]	5-25	0.1 F_x
	25-40	2.5
	40-50	6.5-0.1 F_x
	50-500	1.5
Instrument panel[a]	5-25	0.07 F_x
	25-40	1.75
	40-50	4.55-0.07 F_x
	50-500	1.05
External stores[a]	5-25	0.15 F_x
	25-40	3.75
	40-50	9.75-0.15 F_x
	50-500	2.25
On/near drive-system elements[b]	5-50	0.1 F_x
	50-2000	5 + 0.01 F_x

[a]Fx = source frequency of interest = F_1, F_2, F_3 or F_4.
F_1 = fundamental source frequently.
$F_2 = 2F_1$
$F_3 = 3F_1$
$F_4 = 4F_1$

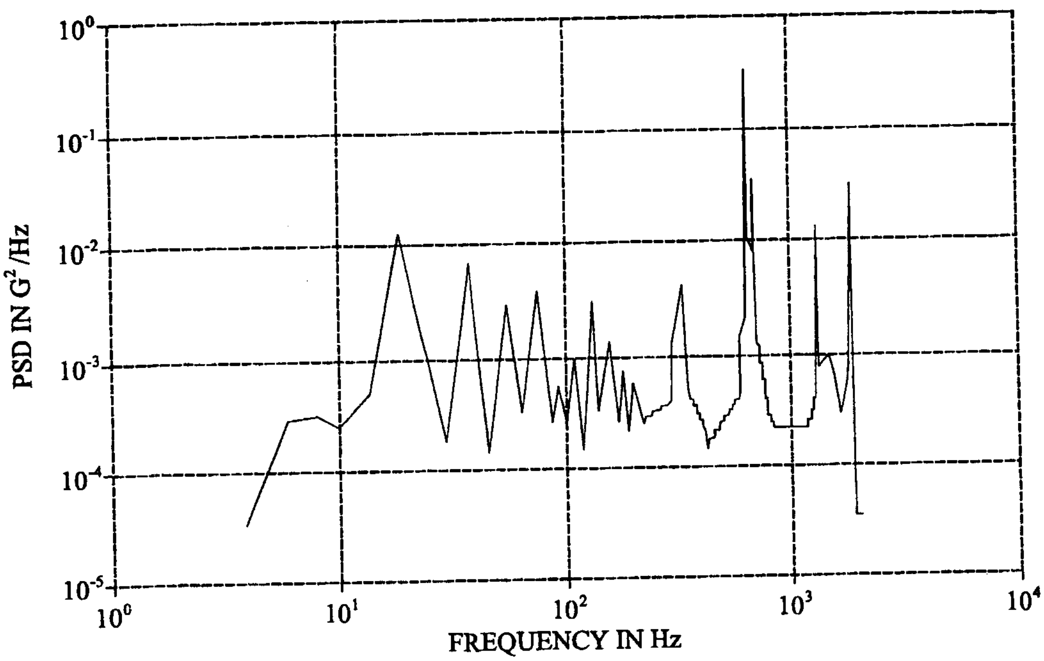
Upon determining values of F_1, F_2, F_3, F_4, select the appropriate source frequency range for each when determining peak vibration levels. The source frequency ranges are not presented in the order F_1 - F_4.

[b]F_1, F_2, F_3, F_4 must be determined from drive-train areas for the particular helicopter. Footnote "a" is then applicable.

Table E-2. Nominal Fundamental Source Frequency.

ROTARY-WING AIRCRAFT	MAIN ROTOR F_1 (Hz)	TAIL ROTOR F_1 (Hz)
OH-3	17	
OH-58A	11.8	40
OH-58	29.3	40
UH-60	17	20
CH-47D	11.3	11.3
CH-47C	12.3	12.3
AH-1	10.8	27.8
UH-1	10.8	27.8
AH-64	19.3	23.4
OH-6	31.9	51.3
CH-54	18.5	14.1
500MD	41	49
Lynx	21.7	32
BO-105	30	

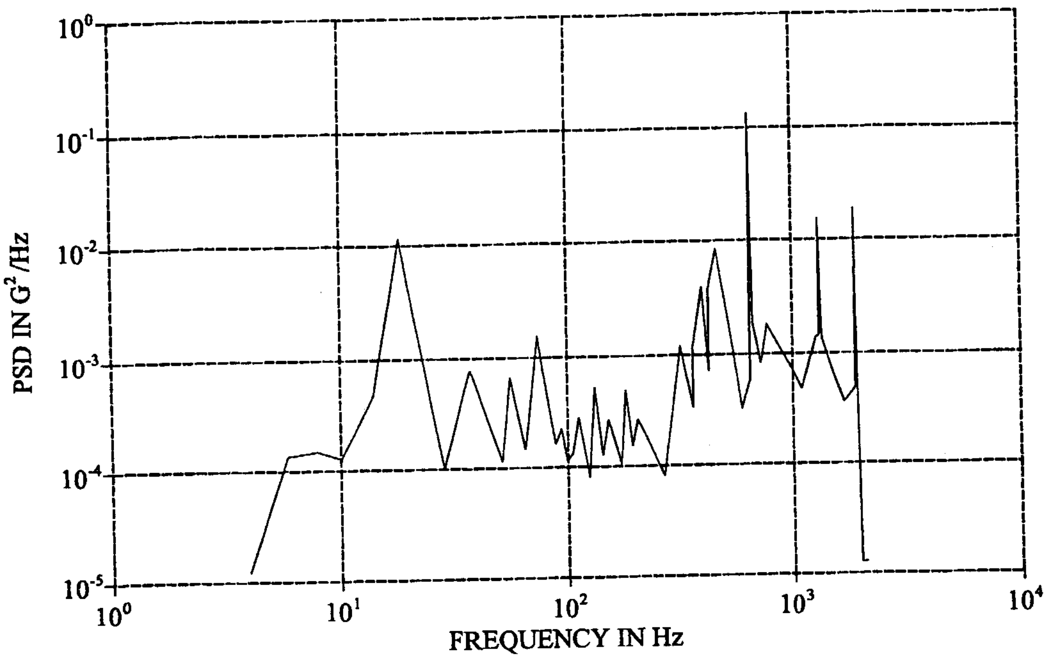
Figure E-3. Laboratory Vibration Schedule, 30-mm Ammunition Bay on Apache Vertical Axis.



RMS = 2.65 TEST TIME = 127 minutes EXAGGERATION FACTOR = 1.00 BREAKPOINTS = 50

FREQ	PSD VALUE	FREQ	PSD VALUE
5	0.00020	223	0.00026
7	0.00038	304	0.00040
10	0.00024	335	0.00416
14	0.00050	357	0.00048
19	0.01061	428	0.00016
31	0.00014	602	0.00044
38	0.00644	642	0.00231
46	0.00014	655	0.34296
57	0.00356	677	0.00704
65	0.00024	698	0.03486
76	0.00356	795	0.00031
89	0.00022	865	0.00021
95	0.00065	1191	0.00021
100	0.00020	1297	0.00045
114	0.00131	1325	0.01240
121	0.00014	1350	0.00069
135	0.00314	1506	0.00098
142	0.00024	1675	0.00030
152	0.00093	1805	0.00059
164	0.00133	1855	0.00097
169	0.00044	1866	0.01424
178	0.00021	1873	0.00690
186	0.00086	1880	0.01483
196	0.00018	1890	0.03014
203	0.00059	1904	0.00997

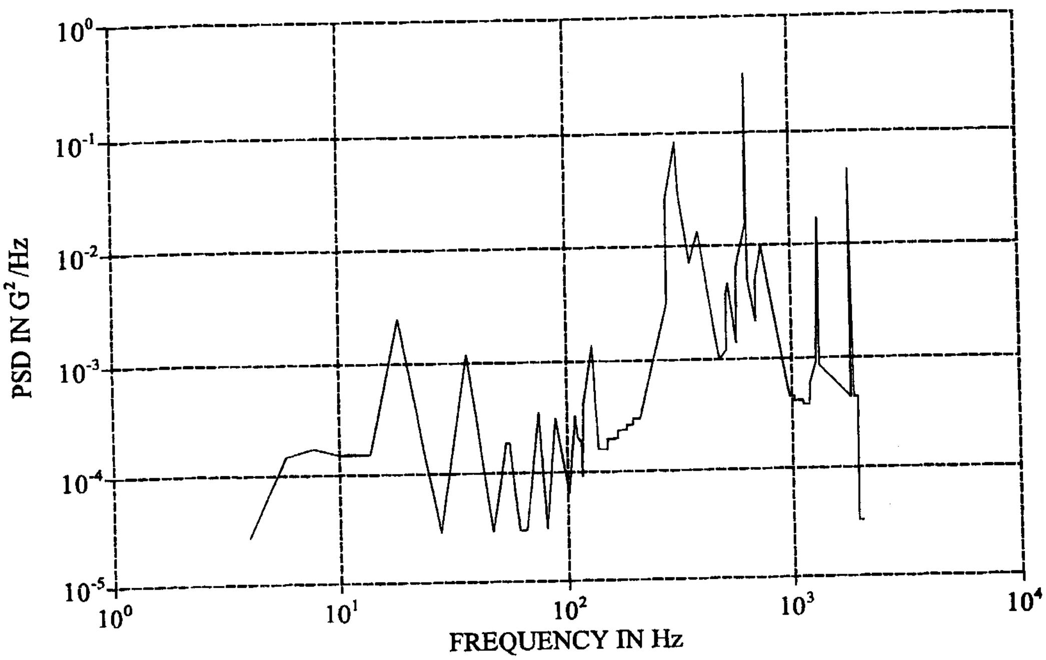
Figure E-4. Laboratory Vibration Schedule, 30-mm Ammunition Bay on Apache Transverse Axis.



RMS = 1.92 TEST TIME = 127 minutes EXAGGERATION FACTOR = 1.00 BREAKPOINTS = 45

FREQ	PSD VALUE	FREQ	PSD VALUE
5	0.00013	273	0.00009
7	0.00018	327	0.00121
10	0.00014	364	0.00029
14	0.00050	405	0.00397
19	0.01061	432	0.00063
29	0.00008	471	0.00893
38	0.00085	595	0.00031
52	0.00013	641	0.00058
58	0.00065	656	0.00695
66	0.00015	662	0.13886
76	0.00158	676	0.00169
89	0.00015	721	0.00079
95	0.00026	769	0.00177
103	0.00011	1093	0.00048
114	0.00029	1297	0.00156
125	0.00008	1325	0.01566
135	0.00057	1339	0.00123
144	0.00011	1658	0.00034
152	0.00028	1844	0.00047
176	0.00009	1884	0.01948
186	0.00057	1904	0.00034
196	0.00016	1925	0.00023
205	0.00028		

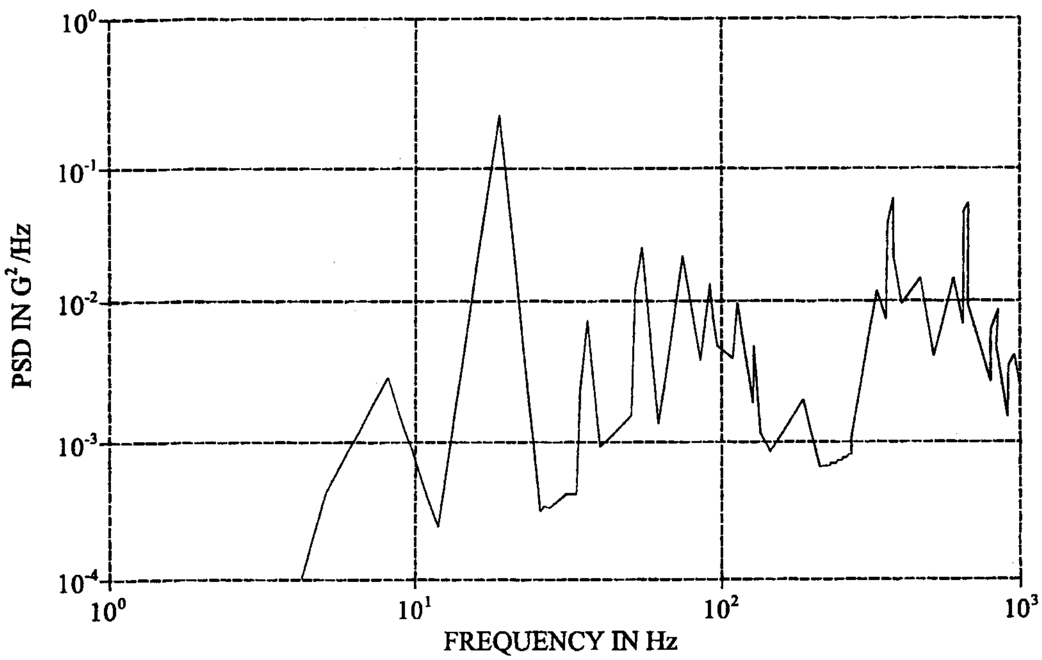
Figure E-5. Laboratory Vibration Schedule, 30-mm Ammunition Bay on Apache Longitudinal Axis.



RMS = 2.98 TEST TIME = 127 minutes EXAGGERATION FACTOR = 1.00 BREAKPOINTS = 39

FREQ	PSD VALUE	FREQ	PSD VALUE
5	0.00014	368	0.00624
7	0.00018	405	0.01259
14	0.00016	486	0.00096
19	0.00230	524	0.00114
28	0.00003	541	0.00429
38	0.00116	595	0.00116
49	0.00003	655	0.01591
57	0.00024	662	0.29807
67	0.00003	669	0.01667
80	0.00048	721	0.00177
86	0.00003	769	0.00936
94	0.00038	1004	0.00039
103	0.00005	1216	0.00033
114	0.00029	1297	0.00088
124	0.00009	1325	0.01518
137	0.00144	1339	0.00073
142	0.00015	1844	0.00037
223	0.00029	1884	0.04053
294	0.00305	1925	0.00034
327	0.08047		

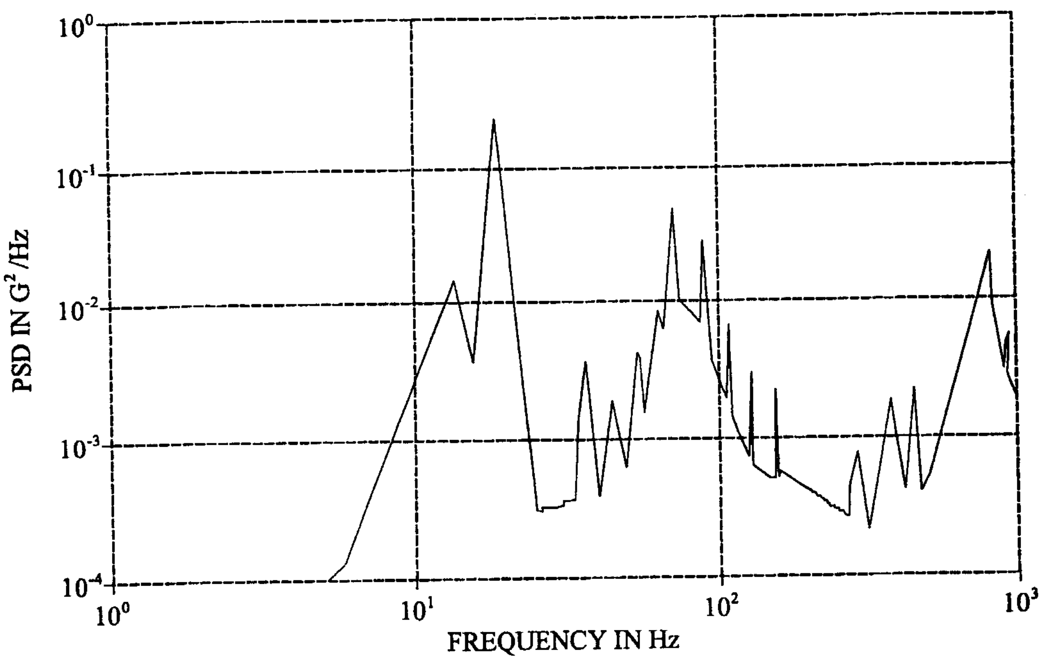
Figure E-6. Laboratory Vibration Schedule, Hydra 70-mm Rocket on Apache Vertical Axis - Launcher Pod Fore Position.



RMS = 2.72 TEST TIME = 127 minutes EXAGGERATION FACTOR = 1.00 BREAKPOINTS = 39

FREQ	PSD VALUE	FREQ	PSD VALUE
5	0.00049	148	0.00086
8	0.00314	192	0.00197
12	0.00028	218	0.00066
19	0.23592	277	0.00080
26	0.00034	336	0.01220
35	0.00051	361	0.00696
38	0.01340	378	0.05711
41	0.00092	403	0.00936
54	0.00171	466	0.01518
57	0.03468	517	0.00385
65	0.00098	607	0.01426
76	0.02173	647	0.00664
88	0.00367	663	0.05184
96	0.01667	680	0.00800
98	0.00510	796	0.00257
113	0.00391	836	0.00911
115	0.00951	920	0.00146
131	0.00146	950	0.00443
134	0.00560	1000	0.00200
138	0.00112		

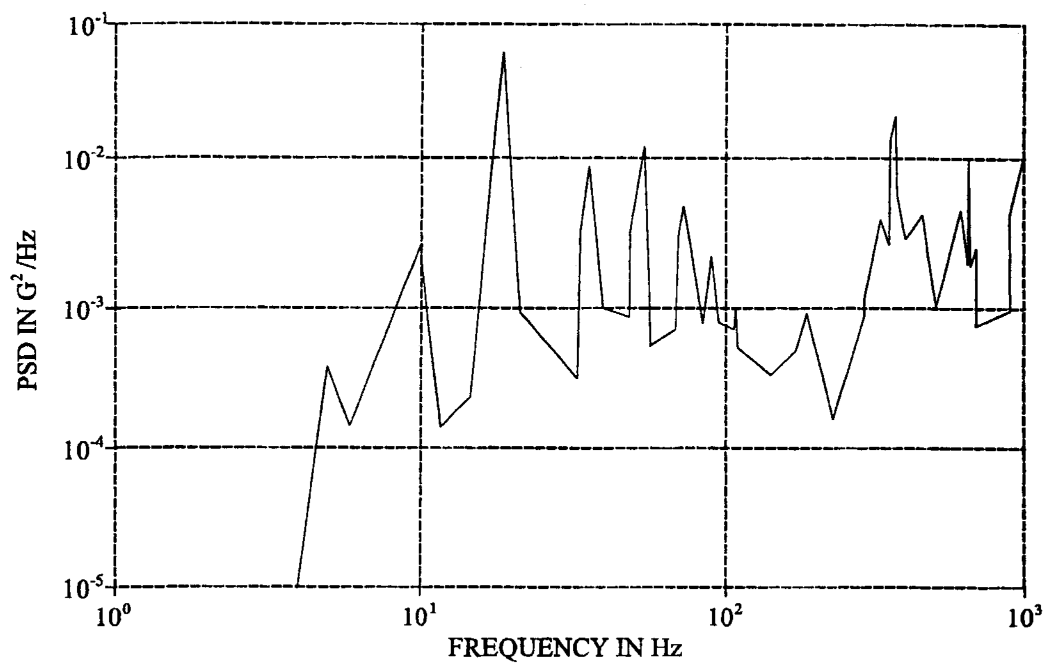
Figure E-7. Laboratory Vibration Schedule, Hydra 70-mm Rocket on Apache Transverse Axis - Launcher Pod Fore Position.



RMS = 2.01 TEST TIME = 127 minutes EXAGGERATION FACTOR = 1.00 BREAKPOINTS = 39

FREQ	PSD VALUE	FREQ	PSD VALUE
5	0.00006	115	0.00801
14	0.01449	118	0.00146
16	0.00367	133	0.00072
19	0.18673	136	0.00345
26	0.00032	138	0.00065
36	0.00040	161	0.00052
38	0.00391	163	0.00269
42	0.00040	166	0.00061
47	0.00206	284	0.00028
52	0.00049	300	0.00081
57	0.00615	328	0.00023
60	0.00142	388	0.00197
67	0.01147	434	0.00040
69	0.00464	470	0.00241
76	0.05450	513	0.00052
79	0.01044	842	0.02073
93	0.00685	935	0.00282
96	0.03109	957	0.00560
99	0.00457	988	0.00216
113	0.00191		

Figure E-8. laboratory Vibration Schedule, Hydra 70-mm Rocket on Apache Longitudinal Axis - Launcher Pod Fore Position.

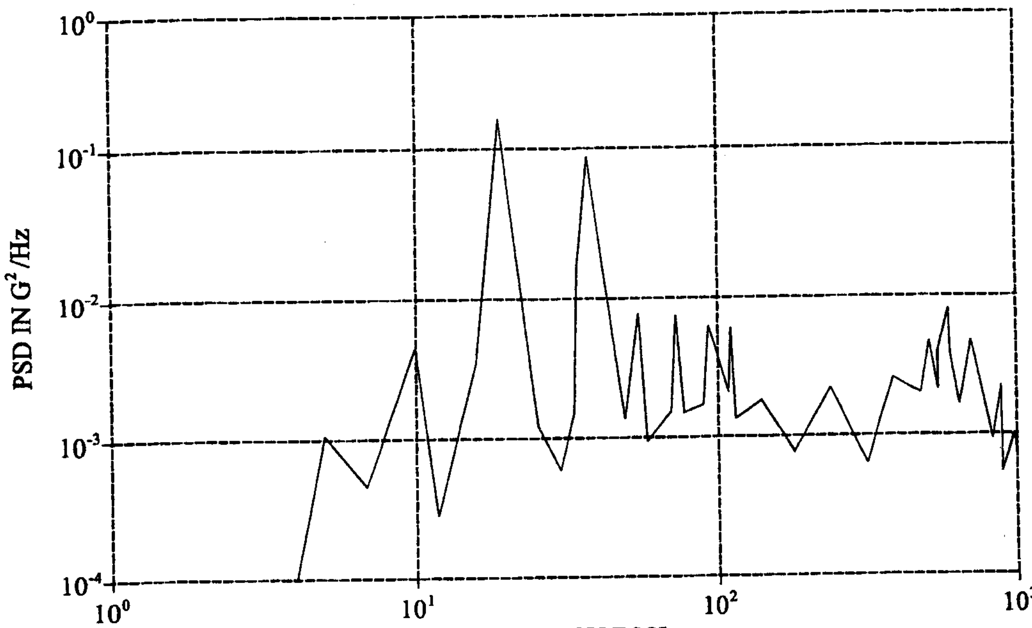


RMS = 1.56 TEST TIME = 127 minutes EXAGGERATION FACTOR = 1.00 BREAKPOINTS = 40

FREQ	PSD VALUE
5	0.00036
6	0.00014
10	0.00239
12	0.00013
16	0.00026
19	0.06202
22	0.00088
35	0.00027
38	0.01623
41	0.00100
52	0.00088
57	0.01727
62	0.00053
73	0.00067
76	0.00489
89	0.00063
96	0.00258
98	0.00078
113	0.00064
115	0.00118

FREQ	PSD VALUE
117	0.00050
148	0.00030
177	0.00046
192	0.00088
236	0.00015
302	0.00089
336	0.00405
361	0.00250
378	0.02050
403	0.00274
466	0.00431
509	0.00109
621	0.00459
652	0.00183
663	0.00985
669	0.00175
706	0.00254
729	0.00075
898	0.00094
988	0.01049

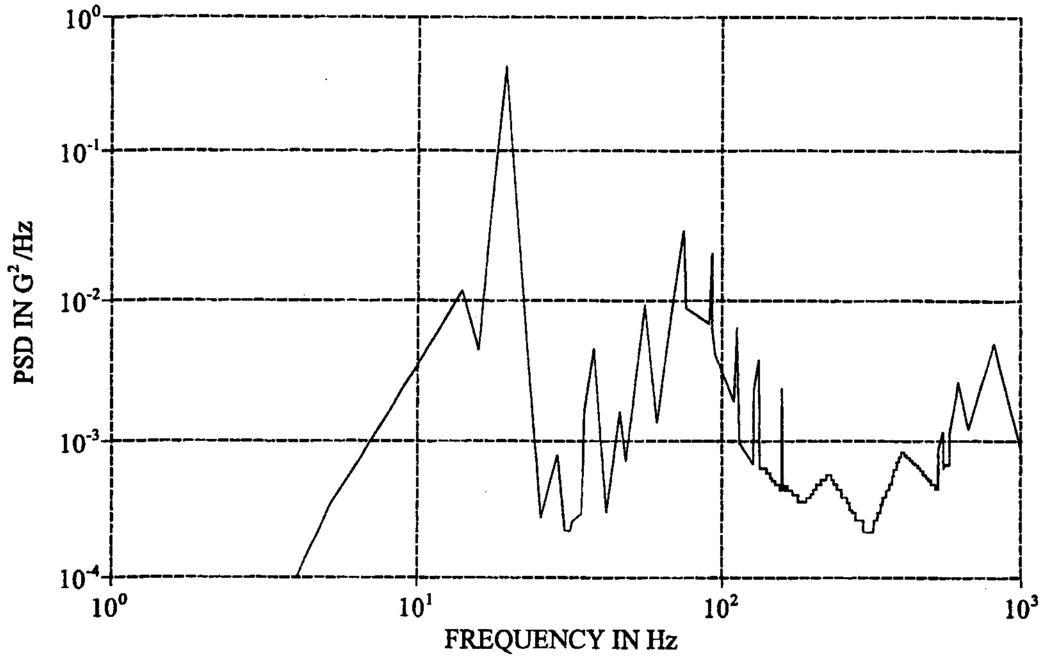
Figure E-9. Laboratory Vibration Schedule, Hydra 70-mm Rocket on Apache Vertical Axis - Launcher Pod Aft Position.



RMS = 1.63 TEST TIME = 127 minutes EXAGGERATION FACTOR = 1.00 BREAKPOINTS = 36

FREQ	PSD VALUE	FREQ	PSD VALUE
5	0.00111	113	0.00185
7	0.00048	115	0.00664
10	0.00472	118	0.00127
12	0.00029	144	0.00174
17	0.00560	183	0.00076
19	0.16743	240	0.00213
26	0.00121	322	0.00062
31	0.00060	391	0.00249
35	0.00206	481	0.00194
38	0.09259	513	0.00457
51	0.00107	547	0.00194
57	0.01028	592	0.00801
60	0.00092	637	0.00153
73	0.00161	706	0.00457
76	0.00922	829	0.00086
79	0.00146	884	0.00216
93	0.00166	942	0.00060
96	0.00605	981	0.00104

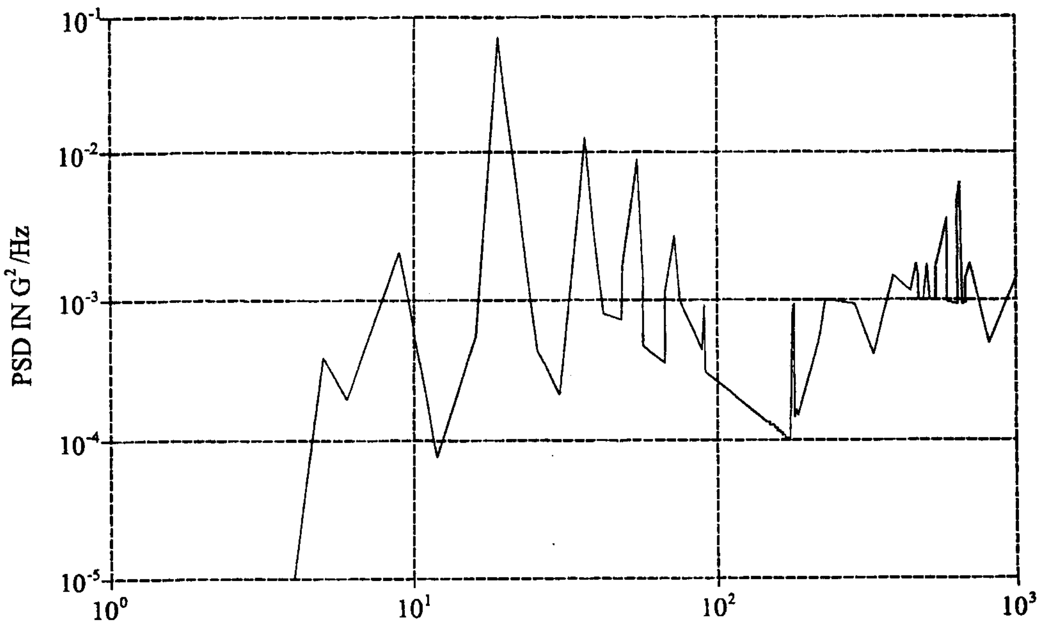
Figure E-10. Laboratory Vibration Schedule, Hydra 70-mm Rocket on Apache Transverse Axis - Launcher Pod Aft Position.



RMS = 1.58 TEST TIME = 127 minutes EXAGGERATION FACTOR = 1.00 BREAKPOINTS = 39

FREQ	PSD VALUE	FREQ	PSD VALUE
5	0.00031	115	0.00730
14	0.01129	118	0.00099
16	0.00416	131	0.00065
19	0.44011	137	0.00423
26	0.00028	139	0.00067
29	0.00082	161	0.00046
31	0.00023	163	0.00257
36	0.00036	166	0.00051
38	0.00450	190	0.00037
43	0.00031	230	0.00061
47	0.00166	315	0.00022
50	0.00048	400	0.00085
57	0.01147	521	0.00046
63	0.00112	542	0.00125
76	0.03868	569	0.00057
78	0.00839	612	0.00261
93	0.00644	652	0.00120
96	0.02461	790	0.00510
99	0.00410	988	0.00081
113	0.00179		

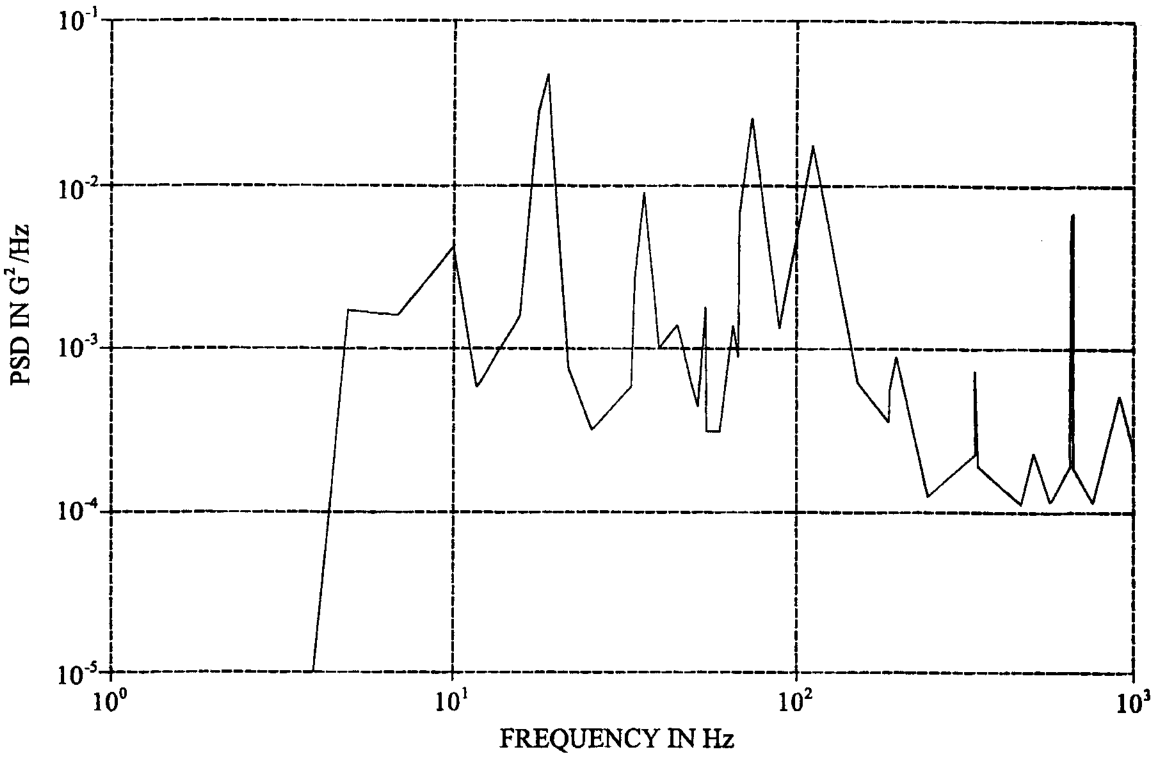
Figure E-11. Laboratory Vibration Schedule, Hydra 70-mm Rocket on Apache Longitudinal Axis - Launcher Pod Aft Position.



RMS = 1.04 TEST TIME = 127 minutes EXAGGERATION FACTOR = 1.00 BREAKPOINTS = 39

FREQ	PSD VALUE	FREQ	PSD VALUE
5	0.00040	187	0.00095
6	0.00020	192	0.00016
9	0.00211	223	0.00046
12	0.00008	238	0.00101
17	0.00083	295	0.00085
19	0.06704	338	0.00038
26	0.00042	394	0.00136
32	0.00018	455	0.00104
38	0.01897	470	0.00169
43	0.00073	489	0.00088
51	0.00067	513	0.00175
57	0.01305	542	0.00065
61	0.00041	592	0.00352
70	0.00033	642	0.00044
76	0.00352	663	0.00637
79	0.00088	679	0.00095
93	0.00038	706	0.00169
96	0.00108	816	0.00046
98	0.00028	981	0.00134
183	0.00010		

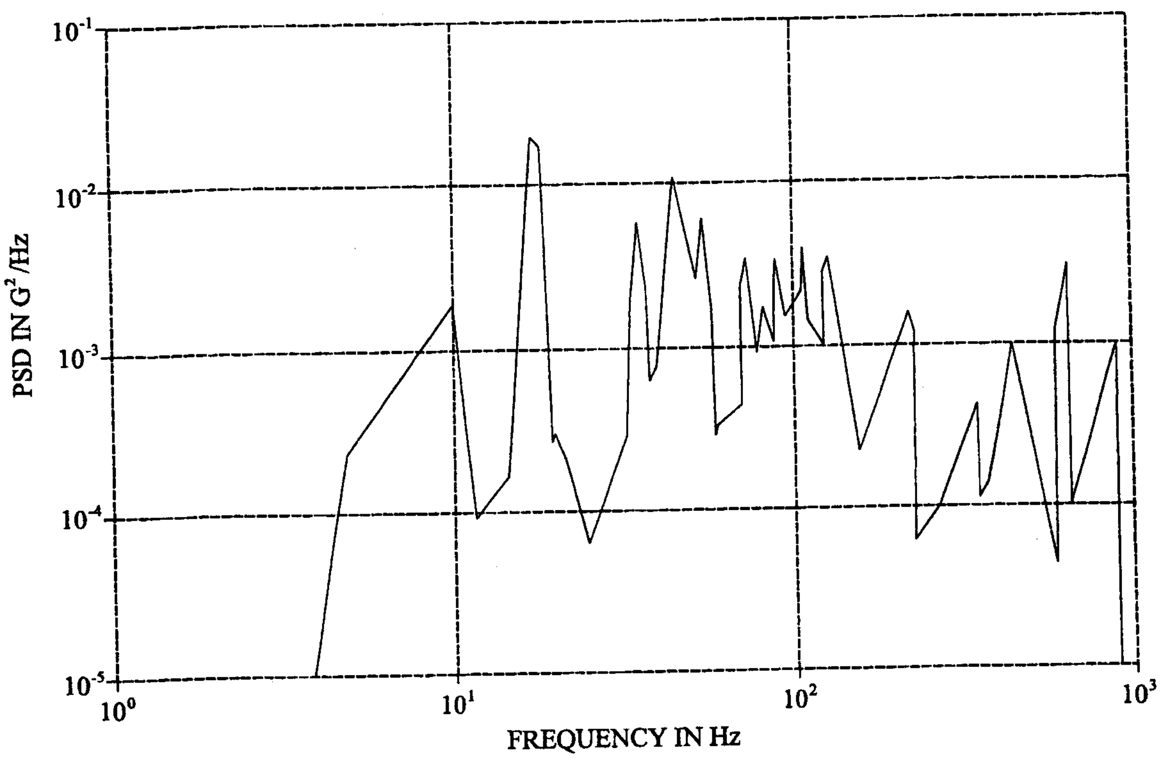
Figure E-12. Laboratory Vibration Schedule, Hydra 70-mm Rocket on Apache
Vertical Axis - Ejector Rack Position.



RMS = 0.99 TEST TIME = 127 minutes EXAGGERATION FACTOR = 1.00 **BREAKPOINTS = 36**

FREQ	PSD VALUE	FREQ	PSD VALUE
5	0.00171	92	0.00123
7	0.00156	115	0.01720
10	0.00429	159	0.00057
12	0.00053	195	0.00032
16	0.00149	203	0.00088
19	0.11339	252	0.00012
22	0.00074	341	0.00022
26	0.00029	347	0.00076
35	0.00058	352	0.00019
38	0.01591	473	0.00011
41	0.00090	509	0.00023
46	0.00138	569	0.00011
54	0.00034	652	0.00019
57	0.00253	663	0.00718
61	0.00026	673	0.00019
67	0.00144	765	0.00011
70	0.00065	912	0.00051
76	0.02539	996	0.00018

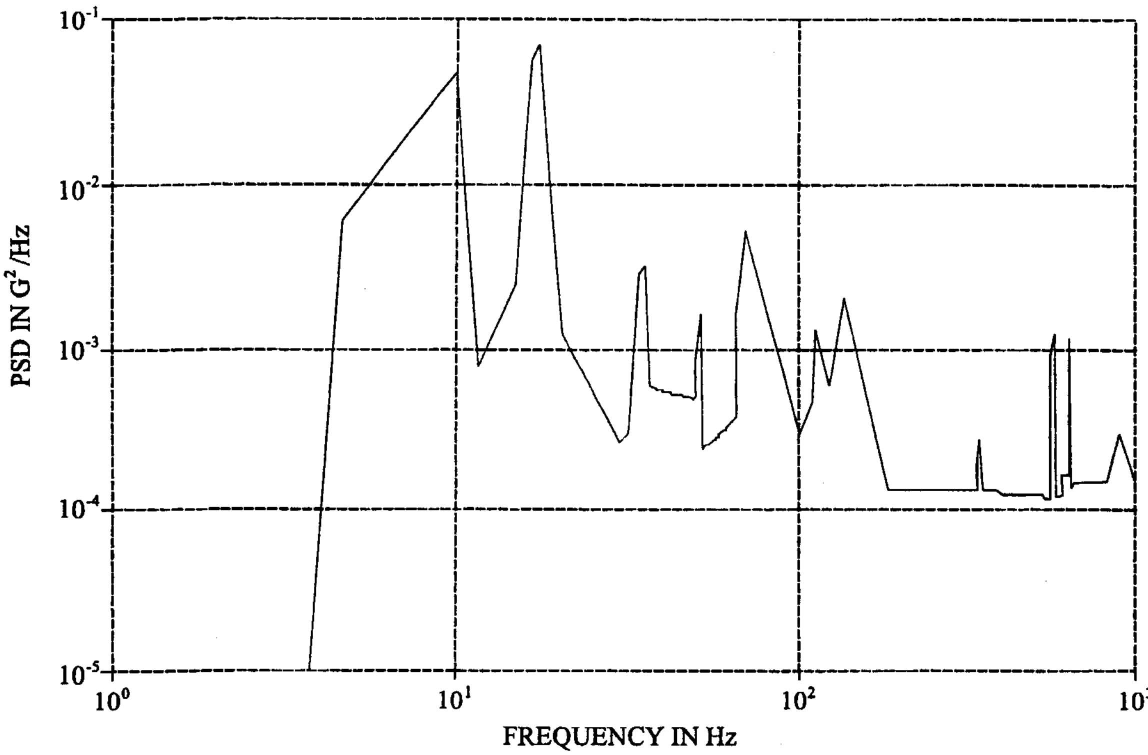
Figure E-13. Laboratory Vibration Schedule, Hydra 70-mm Rocket on Apache Transverse Axis - Ejector Rack Position.



RMS = 0.81 TEST TIME = 127 minutes EXAGGERATION FACTOR = 1.00 BREAKPOINTS = 37

FREQ	PSD VALUE	FREQ	PSD VALUE
5	0.00023	96	0.00412
10	0.00169	97	0.00147
12	0.00009	113	0.00214
16	0.00019	115	0.00452
19	0.07595	117	0.00145
22	0.00022	131	0.00097
26	0.00006	134	0.00331
35	0.00036	162	0.00022
38	0.00955	234	0.00167
41	0.00063	277	0.00010
47	0.01134	364	0.00044
55	0.00207	388	0.00012
57	0.00617	459	0.00106
65	0.00036	612	0.00004
74	0.00046	663	0.00311
76	0.00347	679	0.00011
83	0.00072	920	0.00104
86	0.00180	996	0.00022
93	0.00100		

Figure E-14. Laboratory Vibration Schedule, Hydra 70-mm Rocket on Apache Longitudinal Axis - Ejector Rack Position.



RMS = 0.85   TEST TIME = 127 minutes   EXAGGERATION FACTOR = 1.00   BREAKPOINTS = 33

FREQ	PSD VALUE	FREQ	PSD VALUE
5	0.00615	115	0.00135
10	0.03868	128	0.00054
12	0.00073	136	0.00213
16	0.00234	199	0.00013
19	0.24722	361	0.00013
22	0.00120	372	0.00028
32	0.00025	391	0.00013
35	0.00032	588	0.00012
38	0.00502	607	0.00120
41	0.00054	621	0.00016
54	0.00046	652	0.00016
57	0.00223	663	0.00112
61	0.00027	684	0.00015
71	0.00037	836	0.00015
76	0.00551	912	0.00030
100	0.00033	988	0.00014
113	0.00060		

APPENDIX F. LOAD-RATING FACTOR

The laboratory vibration test schedules for field/mission secured cargo (App B) apply to general types of cargo and were developed from data acquired on cargo vehicles that were loaded to 75% of rated payload. For the special circumstances that arise in transporting unique items (other than general cargo) that load a vehicle above or below the 75% payload, rating factors have been established. Figures F-1 through F-3 are graphic representations of the rating factors for the vehicles used to develop the schedules in Appendix B. The curves were developed using a polynomial least-squares-curve fitting routine. Table F-1 is a list of coefficients for mathematically determining the rating factor for any given special-cargo weight for each category of vehicles using the following formula:

$$Y = A + BX + CX^2$$

where:

Y = load-rating factor.
A, B, C = coefficients from Table F-1.
X = ratio of special-cargo weight to vehicle rated payload in percent.

EXAMPLE: Determine the laboratory vibration schedule in the vertical axis for a special-cargo load weighing 2250 kg to be transported in a 4500-kg cargo truck.

$$X = \frac{2250}{4500} = 50\%$$

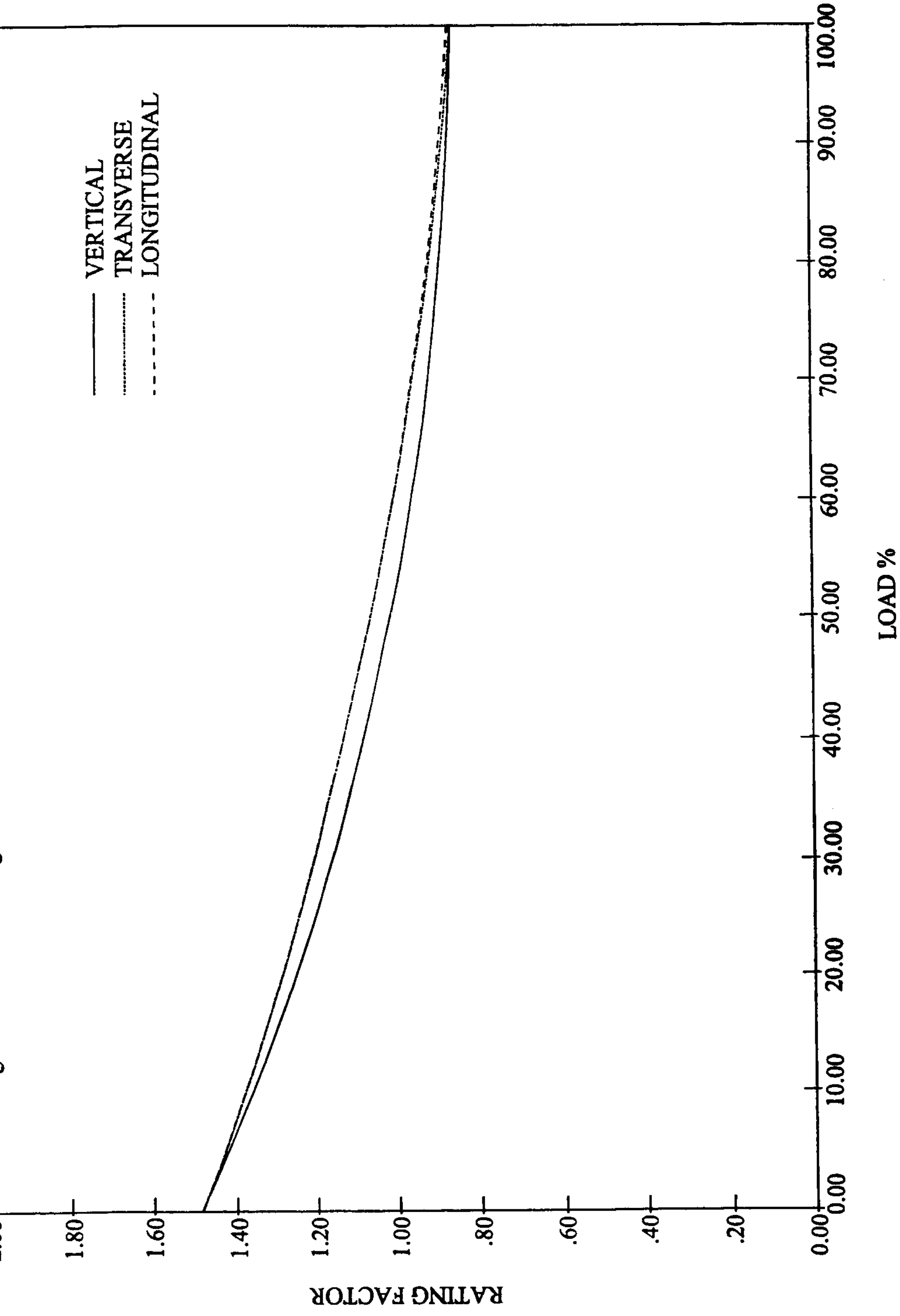
A = 2.3969; B = -0.02915; C = 0.00013 from Table F-1 for combined wheeled-vehicle category.
Y = 2.3969 - 0.02915(50) + 0.00013(2500).
Y = 1.3.

Since the rating factor was developed from overall rms data, multiply the breakpoint PSD values on page B-3 by the rating factor of $(1.3)^2$, and test for the time period specified in Table B-1.

Table F-1. Coefficients Special-Cargo Load-Rating Factor.

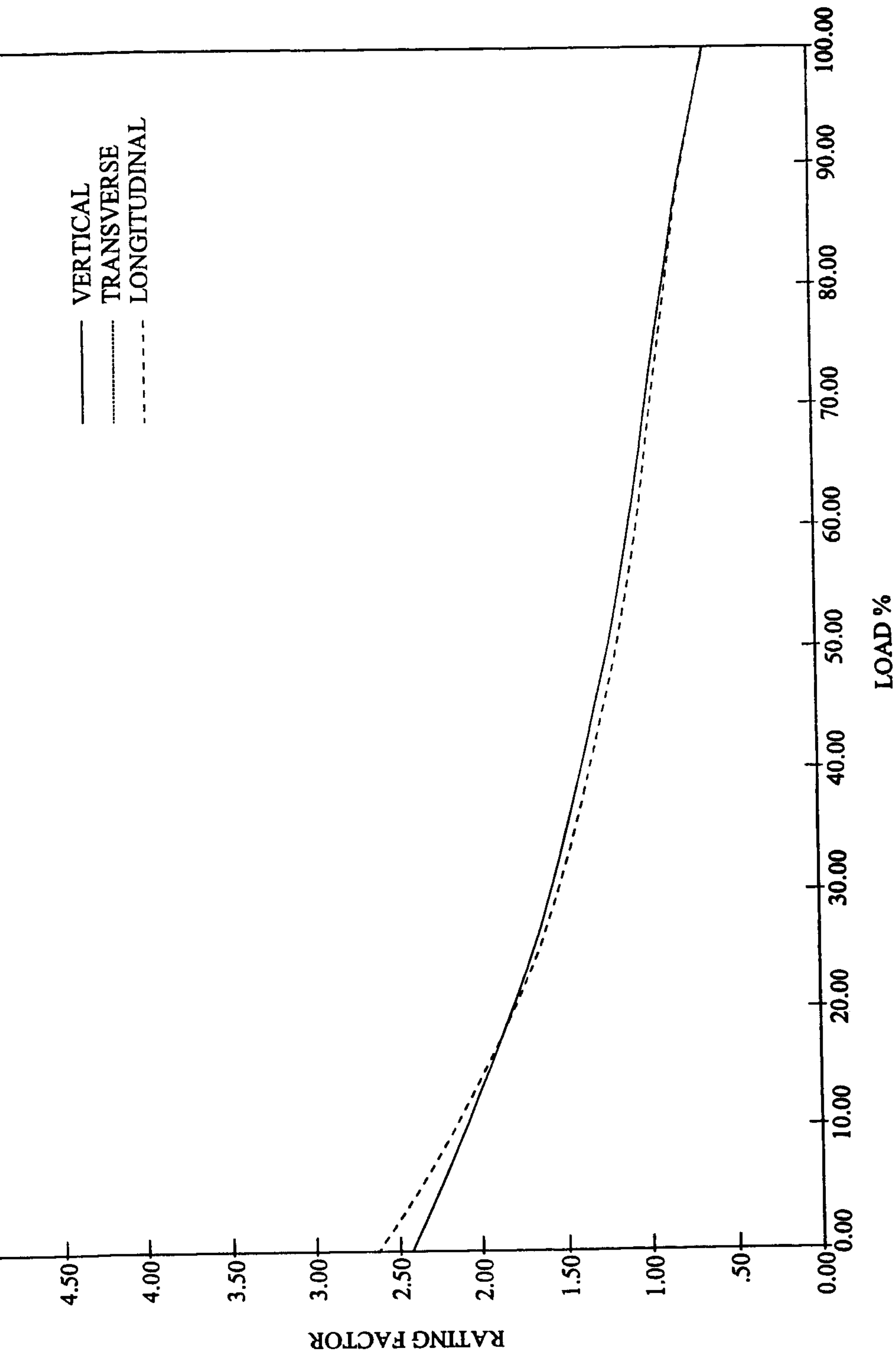
VEHICLE CATEGORY	AXIS	A	B	C
Combined wheeled vehicle	V	2.3969	-0.02915	0.000130
	T	2.4428	-0.03083	0.000145
	L	2.5775	-0.03612	0.000178
Two-wheeled trailer	V	2.1520	-0.02709	0.000137
	T	2.4144	-0.03488	0.000196
	L	2.0054	-0.02595	0.000145
Tracked vehicle	V	1.4823	-0.01225	0.0000647
	T	1.4735	-0.00979	0.0000394
	L	1.4788	-0.01006	0.0000432

Figure F-1. Load-Rating Factor, Tracked Vehicle, 8-Ton, M548.



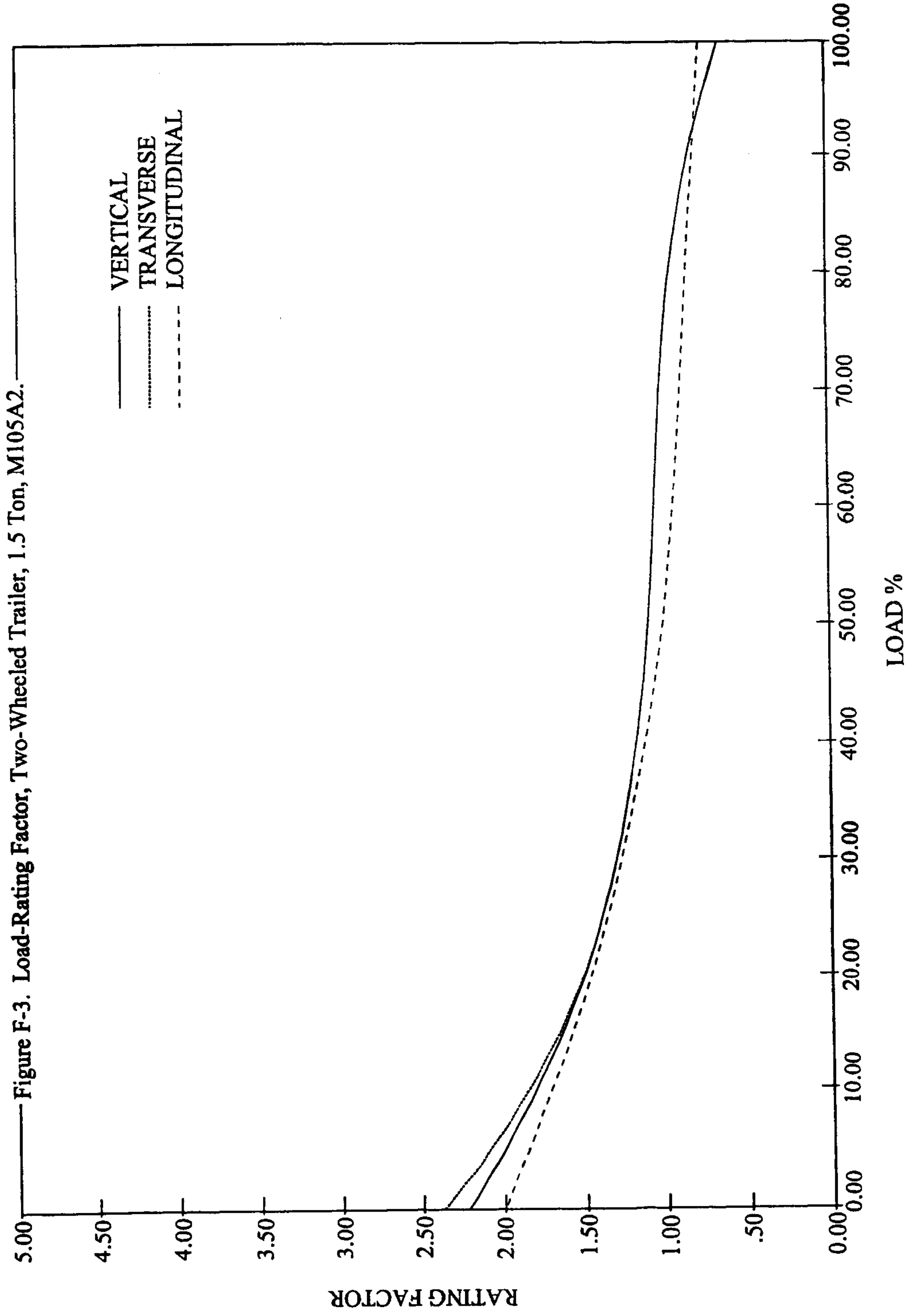
NOTE: Load rating factors can be applied to vertical, transverse, and longitudinal axes.

Figure F-2. Load-Rating Factor, Composite Wheeled Vehicle.



NOTE: Load rating factors can be applied to vertical, transverse, and longitudinal axes.

Figure F-3. Load-Rating Factor, Two-Wheeled Trailer, 1.5 Ton, M105A2.



NOTE: Load rating factors can be applied to vertical, transverse, and longitudinal axes.

APPENDIX G. REFERENCES

NOTE: Each agreeing nation reserves the right not to use the referenced documentation until formal acceptance of the documentation by its country.

1. FR/GE/UK/US ITOP 1-1-050, Development of Laboratory Vibration Test Schedules, 6 June 1997.

FOR INFORMATION ONLY

a. US MIL-STD 810E, Environmental Test Methods and Engineering guidelines, 14 July 1989; Notice 3, 31 July 1995.

b. NATO STANAG 2895 (Draft Edition 1), Extreme Climatic Conditions and Derived Conditions for Use in Defining Design/Test Criteria for NATO Forces Materiel, 15 February 1990.

c. US MIL-STD-210C, Climatic Information to Determine Design and Test Requirements for Military Systems and Equipment, 9 January 1987.

d. FR/GE/UK/US ITOP 4-2-602, Rough Handling Tests, 11 October 1996.

e. FR/GE/UK/US ITOP 4-2-504(1), Safety Testing of Field Artillery Ammunition, 19 Oct 1993.

f. FR/GE/US ITOP 4-2-504(2), Safety Testing of Tank Ammunition, 8 April 1997.

g. The Shock and Vibration Monograph Series, SVM-8, "Selection and Performance of Vibration Tests," The Shock and Vibration Information Center, U.S. Naval Research Laboratory, Washington, D.C.

h. Robinson, J.A., Final Report, Methodology Investigation Cargo Configuration and Restraint in Military Ground Vehicles, TECOM-Project No. 7-CO-RD8-AP1-002; U.S. Amy Aberdeen Proving Ground, Report No. APG-MT-5319, November 1979.

i. Ehlers, E.L. and Cline, H.T., Final Report, Methodology Investigation, Realistic Vehicle Mileages for Installed Equipment in Ground Vehicles, TECOM Project No. T-CO-RD2-AP1-003; U.S. Army Aberdeen Proving Ground, Report No. APG-MT-5804, December 1983.

j. Baily, R.D., Corr, J.R., Final Report, Methodology Investigation, Realistic Test Schedules for Secured Cargo in Military Vehicles, Groups I and II, TECOM Project No. T-CO-RD3-AP1-002; U.S. Army Aberdeen Proving Ground, Report No. APG-MT-5948, January 1984.

k. US TOP 2-2-506, Endurance Testing of Tracked and Wheeled Vehicles, 26 June 1981.

l. FR/GE/UK/US ITOP 2-2-506(1) Tracked-Vehicle Endurance Testing, 15 May 1987.

m. Baily, R.D., Final Report, Methodology Investigation, Realistic Vibration Schedules for Equipment Installed in Military Vehicles, TECOM Project No. 7-CO-R86-APO-003, U.S. Army Aberdeen Proving Ground. Report No. USACSTA 6656, March 1988.

n. Connon, William H. and Dalke, Delon D., Report of the Vibration Test Schedules for the 30-mm Ammunition Bay on the AH-64A Apache Helicopter, TECOM project No. 4-Mu-001-977-003, YPG No. 94-093, DTIC No. B187336, dated June 1994.

o. Dalke, Delon D., Report of the Vibration Test Schedules for the Hydra 70-mm/2.75-Inch Rocket on the AH-64A Apache Helicopter, TECOM Project No. 4-MU-014-000-048, YPG No. 94-006, DTIC AD No. B179007, December 1993.

Forward comments, recommended changes, or any pertinent data which may be of use in improving this publication to one of the following addresses: Commander, U.S. Army Test and Evaluation Command, ATTN: AMSTE-TM-T, Aberdeen Proving Ground, MD 21005-5055, or one of the other participating countries: Direction des Centres d'Expertise et D'Essais, Caserne Sully, 92211 Saint-Cloud Cedex, France; Wehrtechnische Dienststelle fuer Waffen und Munition (WTD 91), Dezernat 440, Postfach 1704, 49707 Meppen, Federal Republic of Germany; or the Range Facility Manager, Ministry of Defence, DERA Test & Evaluation Ranges, Shoeburyness, Essex, SS3 9SR, United Kingdom. Technical information may be obtained from the preparing activity: Commander, U.S. Army Aberdeen Test Center, ATTN: STEAC-TE-I, Aberdeen Proving Ground, MD 21005-5059. Additional copies are available from the Defense Technical Information Center, 8725 John J. Kingman Rd., STE 0944, Fort Belvoir, VA 22060-6218. This document is identified by the accession number (AD No.) printed on the first page.