METHOD 514.2

VIBRATION

1. PURPOSE. The vibration test is performed to determine if equipment is constructed to withstand expected dynamic vibrational stresses and to insure that performance degradations or malfunctions will not be produced by the service vibration environment. Tests specified herein are established for equipment which may be used in a variety of military applications.

2. APPARATUS. Vibration equipment with required instrumentation.

3. GENERAL. The vibration test tables and figures provide a convenient means of summarizing test procedures to be specified in the equipment specification or test plan according to various military applications. Each table title refers to the applicable category of the equipment to be tested. Guidance for selecting a test is as follows:

a. Determine equipment category (or categories) in accordance with 3.1.

b. Proceed to the designated table(s) and figure(s) corresponding to the applicable equipment category. Select a test based on the table instructions, procedure, and figure designated.

3.1 Equipment category. For purposes of this test method, equipment is categorized according to the vehicle in which it will be installed or transported as follows:

Category	Description	Procedure	Table	Figure
a	Equipment installed in airplanes and helicopters. An equipment intended for both aircraft and helicopters should be qualified for each installation in turn.	--	514.1-I (discontinued)	514.1-1 (discontinued)
b.1	Equipment installed in propellor airplanes and equipment mounted directly to engines including jet engines.	I	514.2-II	514.2-2
b.2	Equipment installed in jet airplanes except for jet engine mounted equipment.	IA	514.2-IIA	514.2-2A

c	Equipment installed in helicopters	I	514.2-III	514.2-3
d.1	Equipment installed in external stores carried on airplanes	IIA	514.2-IV	514.2-4
d.2	Assembled external stores carried on airplanes	IIB	514.2-IV	514.2-4A
d.3	Assembled externally carried stores for helicopters	IIC	514.2-IVA	514.2-4B, 4C, 4D, 4E, 4F
e	Equipment installed in ground launched missiles	V, VI or VII as applicable	514.2-V	514.2-5
f	Equipment installed in ground vehicles	VIII	514.2-VI	514.2-6
g	Equipment transported as cargo	X, XI	514.2-VII	514.2-7
h	Ground equipment, excluding category f. (For transportation see category g.)	--	--	--
i	Shipboard and amphibious equipment or when a ship is the common carrier (see 4.6.13)	--	--	--

3.2 Applicable tests. For any given equipment category, all tests listed beside the selected procedure for the applicable equipment mounting configuration in the tables shall be performed unless otherwise specified. For example, referring to table 514.2-V section A, for testing equipment category e when procedure VI is selected, there are three parts with different test levels indicated by the test curves. Tests indicated by (X) in all three parts shall be performed to evaluate equipment with isolators.

3.3 Selection of test curves. A curve shall be selected from the tables and figures or by making a detailed analysis of the expected vibration environment within the particular vehicle involved. A primary consideration is the equipment location with respect to predominant vibration sources such as high intensity noise of jet and rocket exhausts, aerodynamic excitation including atmospheric wind and turbulence, and unbalance of rotating

parts. Additional factors to be considered shall include attenuation or amplification and filtering by structural members. Guidance for selecting vibration curves with respect to equipment location or application is given in the tables. Applicable test curves for each equipment category are shown on the figures.

3.4 Procedure selection. The equipment specification or test plan shall identify which tests are to be imposed on the equipment by specifying the applicable procedure, table, figure, and test curve.

3.4.1 Example. Select the test conditions for equipment to be used in the following application:

Category: Equipment installed in a propellor airplane

Equipment location: Forward half of fuselage

Equipment mounting: On vibration isolated panel

Referring to table 514.2-II, the above identification specifies the following test conditions:

Procedure I

Part 1 (curve C)

Part 2 (curve B)

Part 1 specifies a resonance search, resonance dwell and sinusoidal vibration cycling to the level of curve C from figure 514.2-2 within the time schedule specified for part 1 on table 514.2-II. Next, with vibration isolators removed in accordance with note 2, part 2 is performed the same as part 1 but to the test level or curve B from figure 514.2-2 within the time schedule specified for part 2 from table 514.2-II.

4. PROCEDURES. The basis for selecting a test procedure for a particular equipment category shall be according to 3. The vibration environment, specified by the curve selected from applicable tables in accordance with 3, shall be applied to each of the three mutually perpendicular axes of the test item. (For assembled external stores, see procedure IIB.) The entire sequence of tests may be accomplished for any one axis before changing to the next axis. The transverse motion at the input monitoring point(s) shall be minimized, and should be limited to 100 percent of the input motion except that reaction machines shall be balanced to reduce transverse motion ±10 percent.

4.1 Test item operation. Unless otherwise specified, the test item shall be operated during application of vibration (resonance search, resonance dwell, cycling, and random vibration) so that functional effects caused by these tests may be evaluated. Procedure IA, IIA and IIB provide for a functional vibration test and an endurance vibration test. The test item shall meet performance requirements as specified in the detail equipment specification and General Requirements, 3.2 while the functional vibration test levels are being applied. When a test item performance test is required during vibration and the time required for the performance test is greater than the duration of the vibration test, the performance test may be abbreviated accordingly. The test item shall be operated and inspected and the results shall be obtained in accordance with General Requirements, 3.2

4.2 Mounting techniques. The test item shall be attached by its normal mounting means, either directly to the vibration exciter or transition table, or by means of a rigid fixture capable of transmitting the vibration conditions specified herein. Precautions shall be taken in the establishment of mechanical interfaces to minimize the introduction of extraneous responses in the test setup. The test load shall be distributed as uniformly as possible on the vibration exciter table in order to minimize effects of unbalanced loads. The input control sensing device(s) shall be rigidly attached to the vibration table, or fixture if used, as near as possible to the attachment point(s) of the test item. Additional vibration sensors shall be located in or on the test item to determine resonant frequencies and amplification factors. Locations to be selected should include main structure, printed circuit boards, large components, and modules, where practicable. The sensor sizes and weights shall be limited so that their effect on the dynamic responses being measured is minimal. For sinusoidal vibration, when necessary for obtaining uniform results, a tracking filter should be used in the vibration exciter control feedback loop prior to the servo input.

4.3 Combined temperature-vibration test. Tests shall be performed under room ambient conditions unless a high or low temperature vibration test is specified, in which case the temperature extremes and time duration also shall be as specified in the equipment specification.

4.5 Common test techniques

4.5.1 Sinusoidal vibration tests. The vibration shall be applied along each of three mutually perpendicular axes of the test item. The vibratory acceleration levels or double amplitudes of the specified test curve shall be maintained at the test item mounting points. When necessary for obtaining uniform results, a tracking filter should be used in the exciter control feedback loop prior to the servo input. When specified, for

sinusoidal resonance search, resonance dwell, and cycling tests of items weighing more than 80 pounds mounted in airplanes, and missiles, the vibratory accelerations shall be reduced 1g for each 20-pound increment over 80 pounds. Acceleration derating shall apply only to the highest test level of the selected curve, but in no case shall the derated test level be less than 50 percent of the selected curve (see note 1 of the applicable table). When the input vibration is measured at more than one control point, the control signal shall be the average of all the accelerometers unless otherwise specified. For massive test items, fixtures and large force exciters, it is recommended that the input control level be an average of at least three or more inputs.

4.5.1.1 Resonance search. Resonant frequencies of the equipment shall be determined by varying the frequency of applied vibration slowly through the specified range at reduced test levels but with sufficient amplitude to excite the item. Sinusoidal resonance search may be performed using the test level and cycling time specified for sinusoidal cycling test, provided the resonance search time is included in the required cycling test time of 4.5.1.3.

4.5.1.2 Resonance dwell. The test item shall be vibrated along each axis at the most severe resonant frequencies determined in 4.5.1.1. Test levels, frequency ranges, and test times shall be in accordance with the applicable conditions from the tables and figures for each equipment category. If more than four significant resonant frequencies are found for any one axis, the four most severe resonant frequencies shall be chosen for the dwell test. If a change in the resonant frequency occurs during the test, its time of occurrence shall be recorded and immediately the frequency shall be adjusted to maintain the peak resonance condition. The final resonant frequency shall be recorded.

4.5.1.3 Cycling. The test item shall be vibrated along each axis in accordance with the applicable test levels, frequency range, and times from the applicable tables and figures. The frequency of applied vibration shall be swept over the specified range logarithmically in accordance with figure 514.2-10. The specified sweep time is that of an ascending plus a descending sweep and is twice the ascending sweep time shown on figure 514.2-10 for the specified range.

4.5.2 Random vibration test. The test item shall be subjected to random vibration along each of three mutually perpendicular axes according to the specified curve. Test times shall be according to the applicable schedule from the tables. The instantaneous random vibration acceleration peaks may be limited to three times the rms acceleration level. The power spectral density of the test control signal shall not deviate from the specified requirements by more than +100,-30 percent (+3, -1.5 dB) below 500 Hz

and +100, -50 percent (±3 dB) between 500 Hz and 2,000 Hz except that deviations as large as +300, -75 percent (±6 dB) shall be allowed over a cumulative bandwidth of 100 Hz maximum, between 500 and 2,000 Hz.

Tolerance levels in terms of dB are defined as:

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

Where W_1 = measured acceleration power spectral density in G^2/Hz units. The term W_0 defines the specified level in G^2/Hz units. Confirmation of these tolerances shall be made by use of an analysis system providing statistical accuracies corresponding to a bandwidth-time constant product, BT = 50, minimum. Specific analyzer characteristics shall be as specified below or equivalent, subject to the BT = 50, minimum limitation.

a. On-line, contiguous filter, equalization/analysis system having a bandwidth as follows:

B = 25 Hz, maximum between 20 and 200 Hz

B = 50 Hz, maximum between 200 and 1,000 Hz

B = 100 Hz, maximum between 1,000 and 2,000 Hz

b. Swept frequency analysis systems characterized as follows:

(1) Constant bandwidth analyzer.

(a) Filter bandwidth as follows:

B = 25 Hz, maximum between 20 to 200 Hz

B = 50 Hz, maximum between 200 to 1,000 Hz

B = 100 Hz, maximum between 1,000 to 2,000 Hz

(b) Analyzer averaging time = T = 2 RC = 1 second, minimum, where T = True averaging time and RC = analyzer time constant

(c) Analysis sweep rate (linear) = $R = \frac{B}{4RC}$ or $\frac{B^2}{8}$ (Hz/second) maximum, whichever is smaller.

(2) Constant percentage bandwidth analyzer

(a) Filter bandwidth = pf_c = one-tenth of center frequency maximum, ($0.1f_c$) where p = percentage and f_c = analyzer center frequency

(b) Analyzer averaging time = $T = \frac{50}{pf_c}$, minimum

(c) Analysis sweep rate (logarithmic) = $R = \frac{pf_c}{4RC}$ or $\frac{(pf_c)^2}{8}$

(Hz/second), maximum, whichever is smaller.

c. Digital power spectral density analysis system employing quantization techniques providing accuracies corresponding to the above approach.

Accelerometer(s) employed for test level control shall be mounted in accordance with 4.2. Where more than one accelerometer is employed for test level control, the power average of the several accelerometer signals shall be used as the test level signal control.

4.6 Procedures

4.6.1 Procedure I. Equipment installed in airplanes or helicopters. (Category b.1 or c.)

4.6.1.1 Part 1. For category b.1 equipment, proceed the same as in 4.5.1.1, 4.5.1.2, and 4.5.1.3. The test levels and time durations shall be as specified in table 514.2-II and figure 514.2-2. For category c equipment, proceed the same as in 4.5.1.3 only. The test levels and time schedules shall be as specified in table 514.2-III and figure 514.2-3.

4.6.1.2 Part 2. For category b.1 equipment, test items normally provided with vibration isolators shall be vibrated in accordance with 4.5.1.1, 4.5.1.2, and 4.5.1.3 with the vibration isolators removed but including any other required holding devices. The test levels and time durations shall be as specified in table 514.2-II and figure 514.2-2. For category c equipment, proceed the same as in 4.5.1.3 only with the vibration isolators removed but including any other holding devices. The test levels and time schedules shall be as specified in table 514.2-III and figure 514.2-3.

4.6.2 Procedure IA. Random vibration test for equipment installed in jet airplanes. (Not for turboprop aircraft or jet powered helicopters.) The random vibration environment which occurs at equipment locations in jet aircraft stems from four principal sources:

a. Turbulent aerodynamic airflow along external surfaces of the aircraft structure.

b. Jet engine noise impinging on aircraft structure.

c. Gun blast pressure impinging on aircraft structure from high speed repetitive firing of installed guns.

d. General aircraft motions caused by such factors as runway roughness, landing, and gusts.

The tests outlined in this procedure consider all of these environments and require design to the most severe of these. These tests are preferred for use with equipment in jet aircraft in lieu of the sinusoidal tests of procedure I, table 514.2-II, figure 514.2-2, except for jet engine mounted equipment. For equipment mounted directly to aircraft jet engines, use procedure I. To determine an equipment specific random vibration test, compute functional and endurance test levels for aerodynamic induced and for jet engine induced vibration from table 514.2-IIA and figure 514.2-2A. Use the more severe of the two functional levels as the equipment's functional test, and the more severe of the two endurance levels (on an equal time, T, basis) for the equipment's endurance test.

4.6.2.1 Performance of test. The individual equipment test item shall be subjected to broadband random vibration excitation. The power spectral density tolerances of applied vibration shall be according to 4.5.2. The test item shall be attached to the vibration exciter according to 4.2. Equipment hard mounted in service shall be hard mounted to the test fixture. Equipment isolated in service shall use service isolators when mounted on the test fixture. If service isolators cannot be made available during the qualification test, isolators shall be provided with characteristics such that the isolator/equipment resonant frequencies shall be between 20 Hz and 45 Hz with resonant amplification ratio between 3 and 5. Vibration shall be applied sequentially along each of the three orthogonal axes of the test item. Two test levels are required, a functional level and an endurance level. For each axis, one half of the functional test shall be conducted first, then the endurance test, followed by the second half of the functional test. The equipment shall perform according to the equipment specification operating requirements in accordance with General Requirements, 3.2 during the functional testing. The acceleration power spectral density (G^2/Hz) of applied vibration, as measured on the test fixture at mounting points of the test item, shall be according to table 514.2-IIA and figure 514.2-2A. The functional and endurance test time durations and other test conditions shall be determined from the test level equations and other parameter values from table 514.2-IIA.

4.6.2.2 Equipment with isolators. Equipment designed for operational installation on vibration isolators shall also be subjected to a minimum rigidity endurance test with the isolators removed. This test shall be conducted according to part 2, procedure 1, table 514.2-II, and curve AR of figure 514.2-2. At the conclusion of this test the equipment shall provide specified performance, in accordance with General Requirements, 3.2.

4.6.2.3 References

a. Dreher, J.F., "Aircraft Equipment Random Vibration Test Criteria Based on Vibrations Induced by Turbulent Airflow Across Aircraft External Surfaces," Shock and Vibration Bulletin No. 43 (part 3, pp 127-139), NRL, Wash., DC, June 1973.

b. Wafford, J.H., and Dreher, J.F., "Aircraft Equipment Random Vibration Test Criteria Based on Vibration Induced by Jet and Fan Engine Exhaust Noise," Shock and Vibration Bulletin No. 43 (part 3, pp 141-151), NRL, Wash., DC, June 1973.

c. Earls, D.L., "Technical Progress on New Vibration and Acoustic Tests," for proposed MIL-STD-810C entitled, Environmental Test Methods, Journal of Environmental Sciences, pp 22-32, July/August 1973.

4.6.3 Procedure II. This procedure includes tests for three applications:

a. Individual equipment items designed for installation in external stores carried on airplanes

b. Assembled external stores carried on airplanes

c. Assembled external stores carried on helicopters

These tests apply to such stores as air launched missiles, bombs, dispensers, instrument pods and rocket launchers (see equipment categories d.1, d.2 and d.3 as applicable).

4.6.3.1 Procedure IIA. Equipment installed in external stores carried on airplanes.

4.6.3.1.1 Test conditions. The individual equipment test item (designed for installation in an external store) shall be subjected to broadband random vibration excitation. The power spectral density tolerances of applied vibration shall be according to 4.5.2. The test item shall be attached to the vibration exciter according to 4.2. Vibration shall be applied sequentially along each of the three orthogonal axes of the test item.

4.6.3.1.2 Captive flight. Two test levels are required, a functional level and an endurance level. For each axis, one-half of the functional test shall be conducted first, then the endurance test, followed by the second-half of the functional test. The equipment shall perform according to the equipment specification operating requirements in accordance with General Requirements, 3.2 during the functional testing. The acceleration power spectral density (G^2/Hz) of applied vibration, as measured on the test fixture at mounting points of the test item, shall be according to table 514.2-IV and figure 514.2-4 except as noted below. The functional and endurance test time durations and other test conditions shall be determined from the test level requirements and other parameter values from table 514.2-IV. If the computed functional and endurance (T=1) test levels (W_2) are less than 0.04 G^2/Hz, use W_2 = 0.04 G^2/Hz and T = 1 for the endurance test.

4.6.3.1.3 Free flight functional test. For stores that are deployed by separation from the aircraft (free flight) such as bombs and missiles, a free flight functional test shall be conducted in addition to the captive flight tests of 4.6.3.1.2. The equipment shall perform according to the equipment specification operating requirements in accordance with General Requirements, 3.2 during the functional testing. 4.6.3.1.1, 4.6.3.1.2, table 514.2-IV, and figure 514.2-4 shall be used to determine the test procedures, levels and frequency spectra for the free flight test except as noted below. In this case, factors A_1, A_2, and (N/3T) shall be set equal to one. The value of q shall be the maximum value attainable during free flight. The duration of this functional test, per axis, shall equal the maximum free flight time expected at maximum q, but not less than 30 seconds. In the event that all free flight functional checks are made during the captive functional test and the captive functional test levels are larger than or equal to those derived here (4.6.3.1.3), no free flight functional test is required.

NOTE: Items marked DISCONTINUED refer to items of the superseded issue of MIL-STD-810 including notices thereto.

4.6.3.1.4 References

a. Dreher, J. F., Lakin, E. D., Tolle, E. A., "Vibracoustic Environment and Test Criteria for Aircraft Stores During Captive Flight," Shock and Vibration Bulletin No. 39, Supplement, (pp 15-40), NRL, Wash., DC, April 1969.

b. Dreher, J. F., "Effects of Vibration and Acoustical Noise on Aircraft/Stores Compatibility," Proc. Aircraft Store Compatibility Symp., Vol. 6, pp 245-272, Eglin AFB, Florida, November 1969.

c. Piersol, A. G., "Vibration and Acoustic Test Criteria for Captive Flight of Externally Carried Aircraft Stores," AFFDL-TR-71-158, Wright-Patterson AFB, Ohio, December 1971.

d. Burkhard, A., "Captive Flight Acoustic Test Criteria for Aircraft Stores," Shock and Vibration Bulletin No. 43, Part 3 (pp 113-126), NRL, Wash., DC., June 1973.

4.6.3.2 Procedure IIB. Assembled externally carried airplane stores

4.6.3.2.1 Purpose. This vibration test is performed to determine that the assembled store as a system is constructed to withstand and perform in the expected dynamic environment. The nature of this test is to simulate the lower frequency vibratory environment of the store by application of vibratory energy at discreet points. To insure that the vibratory test levels reflect the inflight vibratory levels, the selection of the test points and vibration input levels are determined by the response of the store. Procedure II of Method 515.2, acoustic testing for assembled externally carried aircraft stores, shall also be conducted to simulate the higher frequency distributed aerodynamically induced vibratory environment. Acoustic testing is not required if the minimum value of f_o of 4.6.3.2.3 is greater than 1,200 Hz. Procedure IIA of this method shall be used when individual equipment items such as fuzes, electronic equipment, etc., need to be tested separately from the whole store.

4.6.3.2.2 Accelerometer placement. Accelerometers to monitor the vibratory response of the store shall be mounted on two relatively hard points or rings within the store: one in the nose section and one in the aft section. For stores such as bombs with nonintegral tail cones, the aft section mounting point shall be in the aft most section of the main body of the store. At each mounting point or ring, two accelerometers shall be mounted - one in the vertical and one in the lateral plane. (Longitudinal direction is along the axis of the store. The vertical direction shall be considered as perpendicular to the longitudinal axis and contained in a plane passing through the mounting lugs.)

4.6.3.2.3 Test levels. The test frequency spectrum for each store mounted monitoring accelerometer shall be determined from figure 514.2-4A and the values of table 514.2-IV. Generally, the test spectrum for the forward accelerometers will be different from that of the aft accelerometers. Test levels for both a functional and endurance test shall be determined. The value of f_o used in figure 514.2-4A for this test shall be defined as follows:

$f_o = (t/R^2) \times 10^5 + 100$ Hz for stores with circular or elliptical cross-sections

f_o = 500 Hz for all other cross-sections

t = local store average skin thickness where radius, R, is measured--inches

R = one-half the average of major and minor external diameters (inches) of the elliptical cross-section (for a cylindrical section use local average radius; for conical section use smallest f_o calculated using geometry within 1 foot of accelerometer mounting point)

NOTE: If calculated $f_o \leq 1,200$ Hz, use 2,000 Hz
Acceptable range for $t/R^2 = .001 \leq t/R2 \leq .02$
If calculated values fall outside these limits, use these limit values.

4.6.3.2.4 Test setup. The store shall be mounted and tested with its longitudinal axis horizontal and positioned so that its mounting lugs are on top of the store using 4.6.3.2.4a or, as an alternate, 4.6.3.2.4b, depending on the facilities available.

a. Mounting method. The store shall be suspended from a structural frame by means of its normal mounting lugs using hooks and sway braces which simulate the operational mounting apparatus. The test setup shall be such that the rigid body modes (translation and rotation) of vibration for the store/frame/suspension system are between 5-20 Hz. Vibration shall be applied to the store by means of a rod or other suitable mounting device running from a vibration shaker to a relatively hard structurally supported point on the surface of the store.

b. Alternate mounting method. The store shall be hard mounted directly to the shaker, using its normal mounting lugs and a suitable fixture. The stiffness of the mounting fixture shall be such that its induced resonant frequencies are as high as possible but none are below one-third of any f_o frequency.

4.6.3.2.5 Determination of resonance response peaks. Vibration shall be applied at an input level sufficient to excite vibratory responses within the store. The frequencies at which significant resonance response peaks occur shall be identified for each store mounted accelerometer using no greater than a 10 percent constant percentage bandwidth analysis. A resonance response peak shall have at least a 6 dB amplification of input level to be considered significant. This shall be done for both vertically and laterally applied vibration.

4.6.3.2.6 Captive flight test. The following procedure shall be performed so that both the lateral and vertical directions are tested to their respective test levels. Separate testing for each direction shall be required unless one test is able to excite both directions simultaneously to their respective test levels. Two test levels are required, a functional level and an endurance level. For each axis, one-half of the functional test shall be conducted first then the endurance test followed by second half of functional test. The equipment shall perform according to the equipment specification operating requirements during functional testing.

4.6.3.2.6.1 Part 1. Random vibration shall be applied to the store using an input spectrum shape of the store mounted forward accelerometer, but at an input level 6 dB down from the calculated response level of the forward accelerometer. The input random vibration level shall then be peaked or notched in those portions of the frequency range where significant resonance response peaks were identified in 4.6.3.2.5. The peaking and notching of the input spectrum shall be such that the significant resonance response peaks of each store mounted accelerometer in the direction of applied vibration shall be equal to or greater than their respective test levels calculated in 4.6.3.2.3 and figure 514.2-4A. When using the test setup of 4.6.3.2.4a, different attachment locations for the shaker to the store may be tried to determine an optimum point so that both ends of the store are simultaneously tested to their respective test levels.

4.6.3.2.6.2 Part 2. The response of the accelerometers in the direction perpendicular to the store mounted accelerometers which were used to establish the test spectrum shall be compared to their levels specified in 4.6.3.2.3. For each frequency where the response of a (the) perpendicular accelerometer(s) is above their specified levels the following procedure may be used.

4.6.3.2.6.3 Part 3. Calculate at each of these frequencies a ratio of specified to observed levels for each accelerometer which was in the direction of vibration and those perpendicular accelerometer(s) which have excessive levels. These ratios shall be averaged so that an average value is determined for each frequency. The input vibration spectrum shall be adjusted so that at each of these frequencies their respective average value shall be equal to unity. The duration of the functional and endurance test is given in table 514.2-IV and the test levels for each test are determined in 4.6.3.2.3.

4.6.3.2.7 Free flight functional test. For stores that are deployed by separation from the aircraft (free flight) such as bombs and missiles, a free flight functional test shall be conducted in addition to the captive flight tests of 4.6.3.2.6. The equipment shall perform according to the equipment specification operating requirements as specified in General Requirements, 3.2 during the functional testing. Use 4.6.3.2.6, table 514.2-IV, and figure 514.2-4A to determine the test procedures, levels and frequency spectra for the free flight test except as noted below.

In this case, factors A_1, A_2, and (N/3T) shall be set equal to one. The value of q shall be the maximum value attainable during free flight. The duration of this functional test, per axis, shall equal the maximum free flight time expected at maximum vibration level, but not less than 30 seconds. In the event that all free flight functional checks are made during the captive functional test and the captive functional test levels are larger than or equal to those derived here (4.6.3.2.7), no free flight functional test is required.

4.6.3.2.8 References

a. Dreher, J. F.; Lakin, E. D.; Tolle, E. A.; "Vibracoustic Environment and Test Criteria for Aircraft Stores During Captive Flight," Shock and Vibration Bulletin No. 39, Supplement (pp 15-40), NRL, Wash., DC, April 1969.

b. Dreher, J. F., "Effects of Vibration and Acoustical Noise on Aircraft/Stores Compatibility," Proc. Aircraft Store Compatibility Symp., Vol. 6, pp 245-272, Eglin AFB, Florida, November 1969.

c. Piersol, A. G., "Vibration and Acoustic Test Criteria for Captive Flight of Externally Carried Aircraft Stores," AFFDL-TR-71-158 Wright-Patterson AFB, Ohio, December 1971.

4.6.3.3 Procedure IIC, assembled externally carried stores for helicopters

4.6.3.3.1 Purpose. To determine that externally carried stores attached to the wings and pylons of helicopters (with a main rotor speed of 324 rpm, two blades, such as UH-1B, UH-1C, AH-1G, etc) are capable of withstanding expected dynamic vibrational stresses normally induced by the helicopter during flight conditions and to qualify the equipment for service life. If the equipment normally operates while being carried by the helicopter, then the equipment is expected to operate satisfactorily during the vibration test. For helicopters other than the above, use values of frequencies and g levels applicable to the helicopter on which that item is to be mounted.

NOTE: This procedure is only applicable to the operating phase of the equipment and does not include the common carrier transportation phase.

4.6.3.3.2 Test fixture. A rigid test fixture shall be designed for attaching the test item to the vibration exciter in all three axes with the mounting lugs in the up position. The test item shall be attached to the fixture by its normal mounting means (e.g., suspension lugs for 2.75-inch FFAR launchers). The vibration levels shall be controlled from an accelerometer mounted at or near the attachment point on the test item.

4.6.3.3.3 Cycling test. The test item shall be subjected to vibration cycling in each of three orthogonal axes. The frequency of applied vibration shall be cycled at a logarithmic rate between the frequency limits and at the vibratory acceleration levels as shown on figure 514.2-4B. The cycling period and rate shall be determined from table 514.2-IVA.

4.6.3.3.4 Dwell test. The test item shall be subjected to vibration dwell in each of three orthogonal axes. The dwell test shall be conducted at the four frequencies and at the vibratory acceleration levels as shown on figures 514.2-4D, 514.2-4E, 514.2-4F for the particular weight of the test item. (The minimum acceleration level shall be 0.5g for all dwell tests.) The dwell period at each frequency shall be determined from curve A of figure 514.2-4C.

NOTE: For test items such as rocket launchers, which are flown to the target area loaded and come back empty, it is recommended that one-half of the cycling test be applied to a loaded launcher and the other half be applied to an empty launcher.

4.6.4 Procedure III (Former 4.8 DISCONTINUED). (See equipment categories d.1 and d.2.)

4.6.5 Procedure IV (Former 4.9 DISCONTINUED). (See equipment categories d.1 and d.2.)

4.6.6 Procedure V. Equipment installed in ground launched missiles (without vibration isolators, equipment category e.)

4.6.6.1 Part 1. Proceed the same as in 4.5.1.3. The test level shall be according to one specified curve P through U from table 514.2-V and figure 514.2-5. Test time schedules shall be as listed for part 1 of procedure V as specified in table 514.2-V.

4.6.6.2 Part 2. Proceed the same as in 4.5.2. The test level shall be according to one specified in curve AE through AP from table 514.2-V and figure 514.2-5. Test time schedules shall be as listed for part 2 of procedure V as specified in table 514.2-V.

4.6.7 Procedure VI. Equipment installed in ground launched missiles (with vibration isolators, equipment category e.)

4.6.7.1 Part 1. Test items normally provided with vibration isolators shall be vibrated with the isolators in place as in 4.5.1.3. Test levels shall be according to one specified curve P through U from figure 514.2-5. Test time schedules shall be as listed for part 1 of procedure VI as specified in table 514.2-V.

4.6.7.2 Part 2. Test items normally provided wi"h vibration isolators shall be vibrated in accordance with 4.5.1.3 with the vibration isolators removed but including any other required holding devices. Test levels shall be according to curve N from figure 514.2-5. Test time schedules shall be as listed for part 2 of procedure VI as specified in table 514.2-V.

4.6.7.3 Part 3. With vibration isolators in place, proceed the same as in 4.5.2. Test levels shall be according to one specified curve AE through AP from figure 514.2-5. Test time schedules shall be as listed for part 3 of procedure VI as specified in table 514.2-V.

4.6.8 Procedure VII (Former 4.12). Equipment installed in ground launched missiles. (Isolated equipment, tested without isolators, equipment category e.)

4.6.8.1 Part 1. Proceed the same as in 4.5.1.3. Test levels shall be according to curve N from figure 514.2-5. Test time schedules shall be as listed for part 1 of procedure VII as specified in table 514.2-V.

4.6.8.2 Part 2. Proceed the same as in 4.5.2. Test levels shall be according to curve AE from figure 514.2-5. Test time schedules shall be as specified for part 2 of procedure VII as specified in table 514.2-V.

4.6.9 Procedure VIII (Former 4.13). Equipment installed in ground vehicles (equipment category f). Proceed the same as in 4.5.1.3. Test levels shall be according to one specified curve V, W, or Y from figure 514.2-6. Test time schedules shall be as specified in procedure VIII as specified in table 514.2-VI. When test item resonances below 5 Hz are measured or expected the test curves shall be extended to 2 Hz and the sweep time shall be 18 minutes (2-500-2 Hz); 15 minutes (2-200-2 Hz).

4.6.10 Procedure IX (Former 4.14)

4.6.10.1 Part 1 (Former 4.14.1) DISCONTINUED

4.6.10.2 Part 2, bounce, vehicular

4.6.10.2.1 Apparatus. A package tester capable of 1 inch (double amplitude) displacement and of suitable capacity for testing military equipment.

4.6.10.2.2 Test conditions

a. Cover the test bed of the package tester with a panel of 1/2-inch plywood, with the grain parallel to the drive chain. Secure the plywood with six-penny nails, with top of heads flush with, or slightly below the surface. Space nails at 6-inch intervals around all four edges. If the distance between either pair of fences is greater than 24 inches, the plywood shall also be nailed at 3-inch intervals in a 6-inch square at the center of the test area.

b. Using suitable wooden fences, constrain the vehicular, or simulated, adapter plate to a horizontal motion of not more than 2 inches in any lateral direction.

4.6.10.2.3 Performance of test

Step 1 - Prepare the test item in accordance with General Requirements, 3.2, securing the test item to the vehicular, or simulated, adapter plate and placing on the package tester with the constraints outlined in 4.6.10.2.2. If the test item weighs over 200 pounds, simulated adapter plate approved by the procuring agency shall be used.

Step 2 - Attach an accelerometer as close as possible to the point of test item attachment to record the shock transmitted to the test item.

Step 3 - Adjust the package tester, shafts in phase and table operating in a vertical linear mode, to a speed such that the average value of the random acceleration peaks shall be 7.5 ±2.5g's. Measure this input with an accurate measuring or recording system at the output of a band pass filter. The filter band pass shall be 0.2 to 100 Hz and the attenuation slope shall be 12 to 18 dB per octave at the 3-dB down point. Due to the random nature of the input, pulses greater than 10g's can be expected to occur, however, if they are infrequent, they need not be used in calculating the average. Perform the test for a total of 3 hours. At the end of each 3/4-hour period, rotate the adapter plate and test item 90 degrees each time in the same direction.

Step 4 - At the end of the 3-hour period, operate and inspect the test item in accordance with General Requirements, 3.2. Then inspect the test item as specified in General Requirements, 3.2.

4.6.11 Procedure X (Former 4.15). Equipment transported as secured cargo. Proceed the same as in 4.5.1.3 with the unpackaged test item secured to the vibrator table. The test level and time schedules shall be in accordance with figure 514.2-7 and table 514.2-VII. The test item will not be operated during vibration.

4.6.12 Procedure XI (Former 4.16). Equipment transported as loose cargo.

4.6.12.1 Part 1 (Former 4.16.1) DISCONTINUED

4.6.12.2 Part 2, bounce, loose cargo

4.6.12.2.1 Purpose. To determine that the equipment, as prepared for field use, shall be capable of withstanding the vibrations normally induced during combat transportation as loose cargo. Equipment in this class is normally transported in a transit case, combination case, or special container from which it is removed just prior to use, e.g., ammunition or missiles.

4.6.12.2.2 Apparatus. A package tester capable of 1 inch (double amplitude) displacement and of suitable capacity for testing military equipment.

4.6.12.2.3 Test conditions. The test bed of the package tester shall be covered with a panel of 1/2-inch plywood, with the grain parallel to the drive chain. The plywood shall be secured with six-penny nails, with top of heads flush with or slightly below the surface. Nails shall be spaced at 6-inch intervals around all four edges. If the distance between either pair of fences is greater than 24 inches, the plywood shall also be nailed at 3-inch intervals in a 6-inch square at the center of the test area. Using suitable wooden fences, constrain the test item to a horizontal motion of not more than 2 inches in a direction parallel to the axes of the axes of the shafts, a distance more than sufficient to insure the test item will not rebound from fence to fence. For large items, care should be taken to avoid potential air-cushioning effects which may exist between the surface of the package tester and the test item.

4.6.12.2.4 Performance of test. The test item, as secured in its transit case, or combination case, or as otherwise prepared for field transportation, shall be placed on the package tester within the constraints outlined above. The test item will not be operated during vibration. The package tester shall be operated in the synchronous mode with the shafts in phase. (In this mode any point on the bed of the package tester will move in a circular path in a vertical plane perpendicular to the axes of the shafts.) The package tester shall be operated at 1-inch double amplitude and 284 rpm ±2 rpm for a total of 3 hours. At the end of each 1/2-hour period, turn the test item to rest on a different face, so that at the end of the 3-hour period the test item will have rested on each of its six faces (top, bottom, sides, and ends). At the end of the 3-hour period, the test item shall be operated and inspected and results obtained in accordance with General Requirements, 3.2. The package tester shall be operated in the vertical linear mode (straight up and down in the vertical plane) instead of in the synchronous mode when one of the following conditions occurs:

a. Bouncing of the test item is very severe and presents a hazard to personnel.

b. Forward and rear oscillations cannot be reduced. When operated in the vertical linear mode, wooden fences shall be placed on all four sides of the test item to constrain its motion to not more than 2 inches in either direction.

4.6.13 Procedure XII. For shipboard and amphibious equipment or when a ship is the common carrier, the vibration test shall be in accordance with type I of MIL-STD-167.

4.6.14 Procedure XIII. Transportation vibration test for system, van or shelter assemblage.

4.6.14.1 Part 1. DISCONTINUED

4.6.14.2 Part 2, bounce, system shelter assemblage

4.6.14.2.1 Purpose. To insure that the system shelter assemblage shall be capable of withstanding the vibrations normally induced during transportation. The system shelter assemblage may consist of equipment mounted in a truck or trailer, or equipment mounted in a shelter which is then mounted on a truck or trailer.

4.6.14.2.2 Performance of test. The tire pressure of the van or shelter transport vehicle shall be adjusted for tactical (off-road) cross-country service. The system shelter assemblage shall be driven five times over sections of the Munson Test Course at the Aberdeen Proving Ground, Aberdeen, Maryland, or approved equal, in the following order and at the specified speeds:

Coarse washboard (6-inch waves spaced 72 inches apart)	5 mph
Belgian block	20 mph
Radial washboard (2-inch to 4-inch waves)	15 mph
Two-inch washboard	10 mph
Three-inch spaced bump	20 mph

5. SUMMARY. The following details shall be as specified in the equipment specification or test plan:

a. Equipment category, applicable table, procedure, figure, and test curve (see 3).

b. Pretest data required (General Requirements, 3.2).

c. Failure criteria

d. Weight of test item when acceleration derating of selected curve is required (see 4.5.1 and table 514.2-IIA, note 6).

e. Temperature extremes and temperature test time durations (see 4.3).

f. Total vehicle mileage for category f equipment (see table 514.2-VI).

g. Necessary parameters for calculating test levels for equipment categories 6.2, d.1 and d.2.

Table 514.2-II. Test Procedure and Time Schedule Chart for Equipment Installed in Propeller Airplanes - Equipment Category b.1

A. Procedure Selection and Time Schedule Chart

Equipment mounting configuration	Procedure number	Procedure part number	Applicable tests (see 4 for test procedures)			Test time schedule (per axis)				Fig. 514.2-2
			Resonance search (4.5.1.1)	Resonance dwell (4.5.1.2)	Sinusoidal cycling (4.5.1.3)	Dwell time at each resonance (4.5.1.2)	Sinusoidal cycling time	Sweep time 5-500-5 Hz	Sweep time 5-2000-5 Hz	Curve 1/
Without vibration isolators	1	1	X	X	X	30 min	3 hrs less dwell time	15 min	20 min	C, D, E, F G, H, J, or L
With vibration isolators 2/	1	1	X	X	X	30 min	3 hrs less dwell time	15 min	20 min	C, D, E, F, G, J, H, or L
		2	X	X	X	10 min	50 min	15 min	20 min	B, AR
Normally with vibration isolators but tested without isolators	1	2	X	X	X	30 min	3 hrs less dwell time	15 min	20 min	B, AR

1/ For sinusoidal vibration resonance tests and cycling tests of item mounted in airplanes and weighing more than 80 pounds, the vibratory accelerations shall be reduced by 1g for each 20-pound increment of weight over 80 pounds. Acceleration derating shall apply only to the highest test level of the selected test curve, however, the vibratory acceleration shall in no case be less than 50 percent of the specified curve level.

2/ Test items of equipment normally provided with vibration isolators first shall be tested with the isolators in place (part 1). The isolators then shall be removed, and test item rigidly mounted and subjected to the test level indicated (part 2).

B. Curve Selection Chart for Category b.1 Equipment

Selection criteria	Fig. 514.2-2 Curve (for freq. to 500 Hz)	Fig. 514.2-2 Curve (for freq. to 2000 Hz for jet engines)
Equipment installed on vibration isolated panels or racks when the panel or rack is not available for test or when the equipment is tested with isolators removed as specified by the applicable procedure.	B	AR
Equipment in forward half of fuselage or equipment in wing areas of airplanes with engines at rear of fuselage.	C	J
Equipment in rear half of fuselage or equipment in wing areas of airplanes with wing or front mounted engines or other equipment of engine locations not specifically mentioned for other curves.	D	H
Equipment located in the engine compartments or engine pylons of airplanes.	E	G
Equipment mounted directly on airplane engines.	F	L

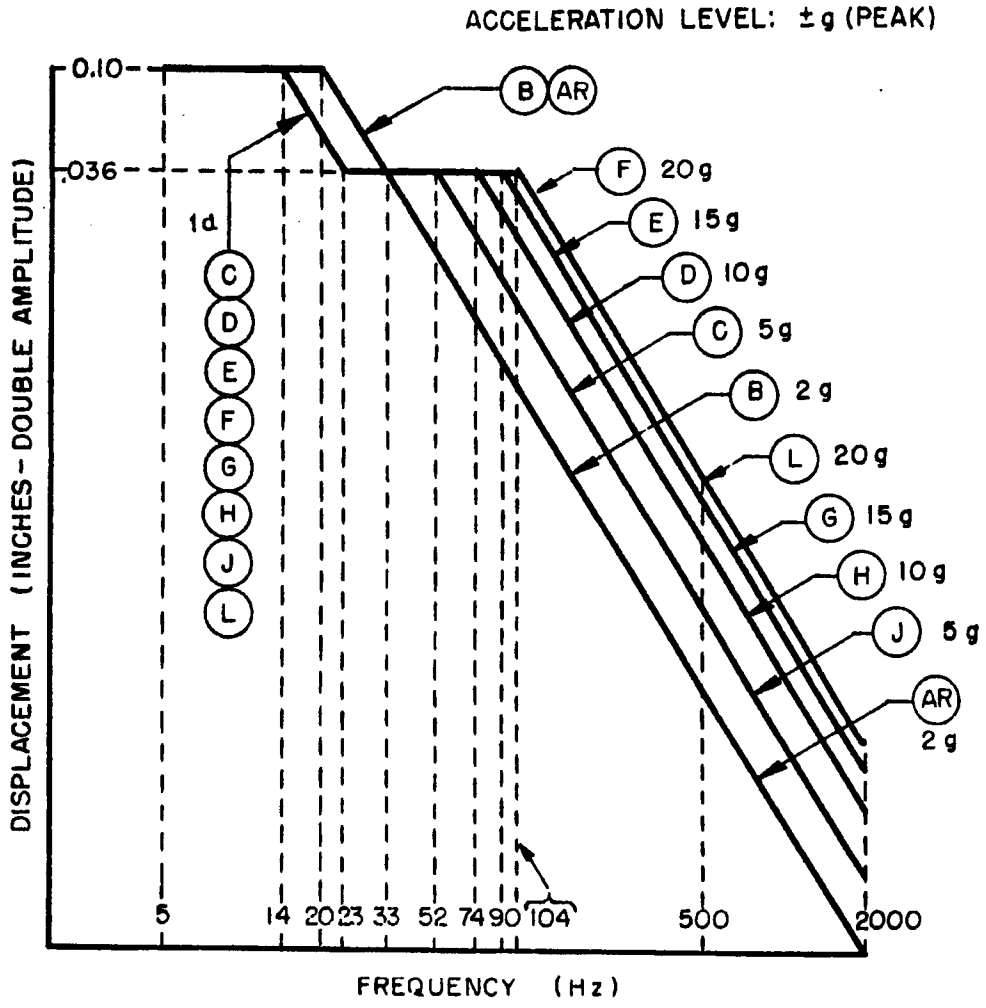
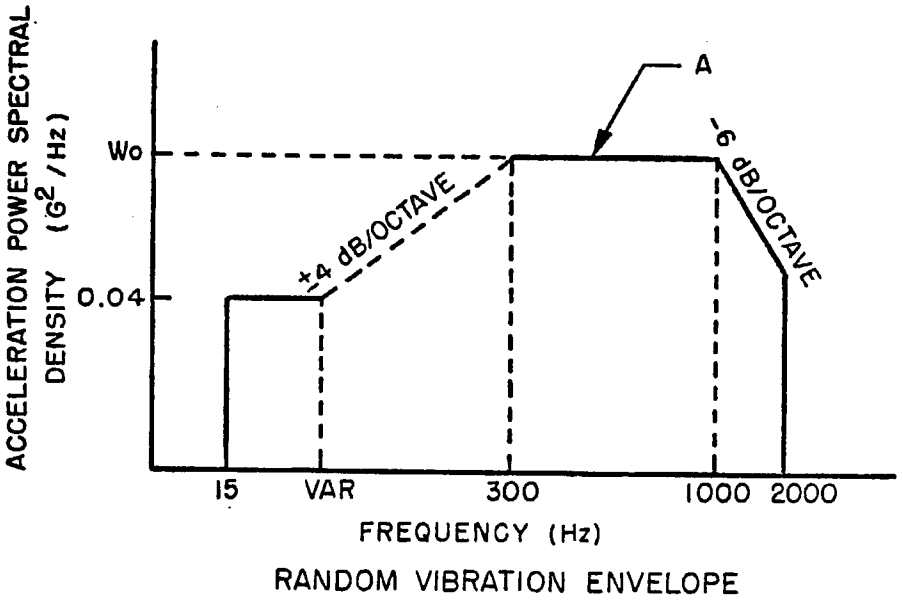


Figure 514.2-2. Vibration Test Curves for Equipment Installed in Airplanes, Excluding Helicopters, Equipment Category b.1.

Table 514.2-IIA. Random Vibration Test Criteria for Jet Aircraft Equipment, Category b.2

Criteria	Notes
Aerodynamic induced vibration (curve A, figure 514.2-2A) Functional test level 1/, 6/ $W_o = K(q)^2$ Endurance test level 2/, 3/, 6/ $W_o = K(q)^2\ (N/3T)^{1/4}$	1. Functional test time shall be 1 hour per axis. 2. Use $W_o = 0.04\ g^2/hz$ if calculated endurance test level values are less than 0.04 g2/hz, T = 1. 3. If one hour (T = 1) endurance test level is ≤ functional test level, no endurance test is required except according to Note 2. 4. If aircraft has more than one engine, W_o shall be the sum of the individually computed values for each engine. 5. For equipment weighing more than 80 pounds, the vibration W_o level may be reduced according to Curve B, Figure 514.2-2A. 6. For $70° < \theta \leq 180°$, use $\theta = 70°$ to compute W_o. 7. For engines with afterburners, use W_o which is 4 times larger than W_o computed using maximum V_c and V_f without afterburner.
Jet engine noise induced vibration (curve A, figure 514.2-2A) Functional test level 1/, 4/, 6/, 7/, 8/ $W_o = (0.48\ \cos^2\theta/R)[D_c(V_c/1850)^3 + D_f(V_f/1850)^3]$ Endurance test level 2/, 3/, 4/, 6/, 7/, 8/ $W_o = (0.48\ \cos^2\theta/R)[D_c(V_c/1850)^3 + D_f(V_f/1850)^3]\ (N/10T)^{1/4}$	
Gunblast induced vibration (see method 519)	
Definitions	
$K = 2.7 \times 10^{-8}$ for cockpit equipment and equipment attached to structure in compartments adjacent to external surfaces that are smooth, free from discontinuities. $K = 14 \times 10^{-8}$ for equipment attached to structure in compartments adjacent to or immediately aft of external surfaces having discontinuities (cavities, chins, blade antennas, speed brakes, etc.) and equipments in wings, pylons, stabilizers, and fuselage aft of trailing edge wing root. q = 1200 psf or maximum aircraft q, whichever is less. N = maximum number of anticipated service missions for equipment or carrying aircraft ($N \geq 3$). T = test time per axis, hours ($T \geq 1$). D_c = engine core exhaust diameter, feet (for engines without fans, use maximum exhaust diameter). D_f = engine fan exhaust diameter, feet. R = minimum distance between center of engine aft exhaust plane and the center of gravity of installed equipment, feet. V_c = engine core exhaust velocity, feet per sec (for engines without fans, use maximum exhaust velocity without afterburner). V_f = engine fan exhaust velocity, feet per sec. θ = angle between R line and engine exhaust axis, degrees, aft vectored.	



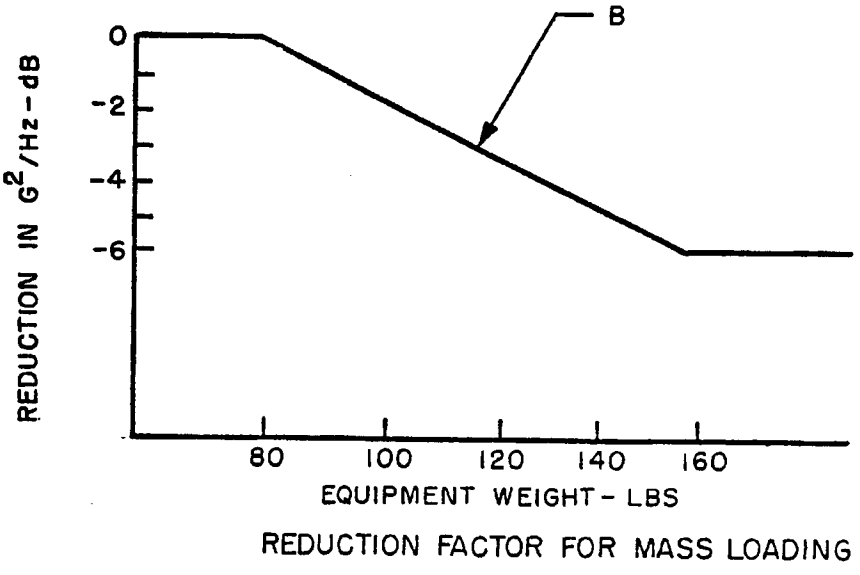


Figure 514.2-2A. Random Vibration Test Curve and Mass Loading Reduction Factor for Jet Aircraft Equipment.

TABLE 514.2-III
Test procedure and time schedule chart for equipment installed in helicopters-equipment category (c)

Equipment mounting configuration	Procedure number	Procedure part number	Test time schedule (per axis)		Fig. 514.2-3 Curve (note 1)
			Sinusoidal cycling (4.5.1.3)	Sweep Time (Note 3)	
Without vibration isolators	1	1	3 hrs	36 min	M
With vibration isolators (note 2)	1	1	3 hrs	36 min	M
		2	30 min	30 min	B
Normally with vibration isolators but tested without isolators	1	2	30 min	30 min	B

Note 1: For sinusoidal vibration cycling tests of items mounted in helicopters and weighing more than 80 pounds, the vibratory accelerations shall be reduced by 1 g for each 20-pound increment of weight over 80 pounds. Acceleration derating shall apply only to the highest test level of the selected test curve. However, the vibratory acceleration shall in no case be less than 50 percent of the specified curve level.

Note 2: Test items of equipment normally provided with vibration isolators first shall be tested with the isolators in place.

Note 3: Sweep for curve M is 5-2000-5Hz, curve B is 5-500-5 Hz.

B. Curve selection chart for category (c) equipment

Selection criteria	Curve
Equipment designed for installation without vibration isolators	M
Equipment installed on vibration isolated panels or racks when the panel or rack is not available for test or when the equipment is tested with the isolators removed as specified by the applicable procedure.	B

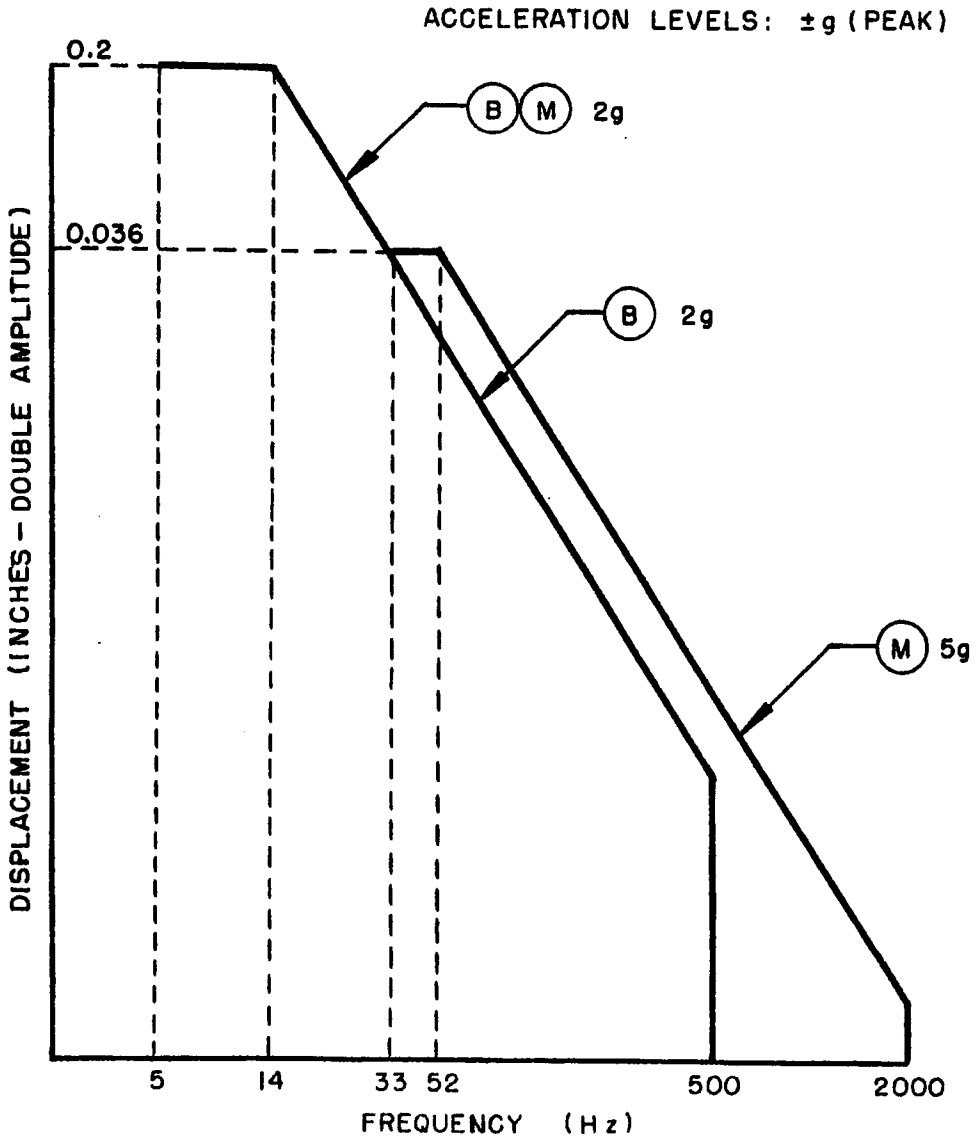


Figure 514.2-3. Vibration Test Curves for Equipment Installed in Helicopters, Equipment Category c.

Table 514.2-IV. Vibration Criteria for External Stores Carried on Airplanes - Categories d.1 and d.2

Parametric Equations for Figure 514.2-4 and 514.2-4A

Eq (1)[1, 2]: $W_1 = (5)(10^{-5})\ (N/5T)^{1/4}(A_1)(B_1)(C_1)(D_1)(E_1)g^2/Hz$

Eq (2)[1, 2]: $W_2 = (5)(10^{-5})(q/\rho)^2(N/5T)^{1/4}(A_2)(B_2)(C_2)(D_2)(E_2)g^2/Hz$

Eq (3)[3, 4]: $f_1 = 10^5\ (t/R^2)Hz$

Eq (4)[3, 4]: $f_2 = f_1 + 1000$ Hz

Location, Configuration, Special Adjustments

	Factor A_1	Factor A_2
TER (tri-ejection rack, cluster mount)	1	2
MER (multiple ejection rack, cluster mount)	2	4
Single station	1	1

	B_1	B_2
Aft half of air fired missiles	1[1]	4[2]
Aft half of all other stores	1	2
Forward half of all stores	1	1

	C_1	C_2
Blunt nosed stores, single station and TER	2	4
Blunt nosed stores, MER	1	2
All other stores	1	1

	D_1	D_2
Free fall munitions with nonintegral finned sheet metal tail cones	8	16
Air fired missiles	1	1
All other stores	4	4

	E_1	E_2
Firebombs (jelly filled)	1/2	1/4
All other conditions	1	1

Representative parameter values to be used for captive flight when specific parameters are not available

Store Type	Max q	ρ	N Endurance	T Endurance	f_1 (Hz)	f_2 (Hz)
Missile, air to ground	1600	100	3	None	500	1500
Missile, air to air	1600	100	100	1	500	1500
Instrument pod	1800	50	500	1	500	1500
Dispenser (reusable)	1200	50	50	1	200	1200
Demolition bomb	1200	120	3	None	125	2000
Fire bomb	1200	40	3	None	100	1100

Definitions

q = maximum flight dynamic pressure in lbs/ft^2 (see note 1).

ρ = average store weight density in lbs/ft^3 (total weight ÷ total volume)

t = local store average skin thickness where R is measured (inches)

R = one-half the average of the major and minor diameters (inches) for a store with an ellipitical cross-section (for cylindrical sections use local geometry; for conical sections use smallest f_1 calculated using geometry within one foot of equipment mounting point; for cast irregular shaped cross-section, R shall be one-half the longest inscribed cord; for monocoque irregular cross-section f_1 = 300 Hz).

N = maximum number of anticipated service missions (functional test, N = 3; endurance test, N = ≥ 3).

T = test time per axis in hours (functional test, T = 1; endurance test, T ≥ 1).

Notes

1. For endurance test, q = 1200 psf or maximum q, whichever is less. For functional test, q = 1800 lbs/ft^2 or maximum q, whichever is less.
2. If functional test level is equal to or larger than the endurance test level when T = 1, no endurance test is required, except as noted in 4.6.3.1.2.
3. Free fall stores with tail fins, used f_1 = 125 Hz; $f_2 = 10^5(t/R^2) + 1000$ Hz.
4. For general use fuzes which can be used in several stores; use W_1 = .01 g^2/Hz; W_2 = 0.15 g^2/Hz; f_1 = 100 Hz; f_2 = 1000 Hz. T = 30 min/axis.
5. Acceptance range for parameter values: $40 \leq \rho \leq 150$, $.001\ t/R^2 \leq .02$. If calculated values fall outside these limits, use these limit values.

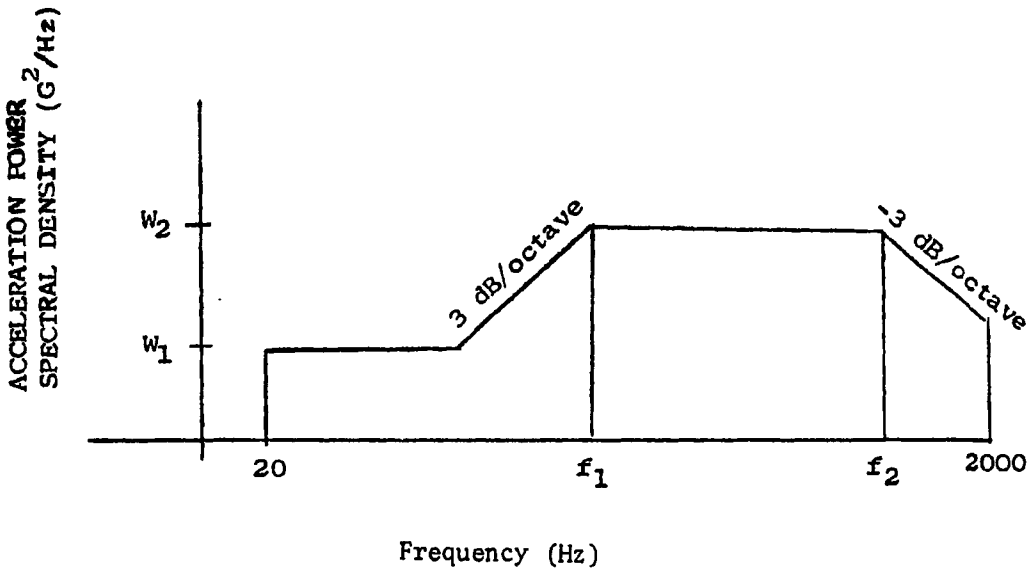
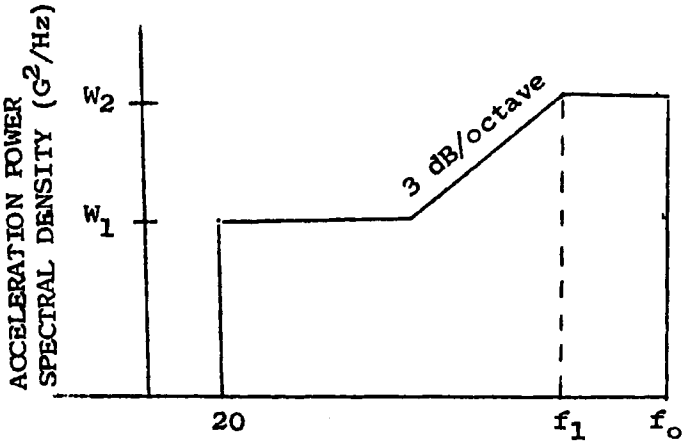


Figure 514.2-4. Vibration Test Levels for Equipment Installed in External Stores Carried on Airplanes



Use table 514.2-IV and 4.6.3.2.3 for parameter values.

Figure 514.2-4A. Vibration Test Curve for Assembled External Stores Carried on Airplanes

Table 514.2-IVA. Cycling Period and Rate, and Time Schedule Chart for Externally Carried Stores for Helicopters, Category d.3

Excitation Axis	Sinusoidal cycling (See Test Procedure 4.6.3.3.3)			(See Test Procedure 4.6.3.3.4)					
	Time Schedule		Curve (See figure 514.2-4B)	Test time per dwell	Test Level Curves				
	Sweep time 5-500-5 Hz	Total test time			11 Hz	22 Hz	33 Hz	44 Hz	
Vertical	15 Minutes	See table B	A	See figure 514.2-4C	See figure 514.2-4D				
					VA	VB	VC	VD	
Transverse	15 Minutes	See table B	B	See figure 514.2-4C	See figure 514.2-4E				
					TA	TB	TC	TD	
Longitudinal	15 Minutes	See table B	C	See figure 514.2-4C	See figure 514.2-4F				
					LA	LB	LC	LD	

Table 514.2-IVB. Sinusoidal Cycling Test Time

Number of Missions	Cycling Time per Axis (Minutes)
0-50	30
51-100	60
101-∞	90

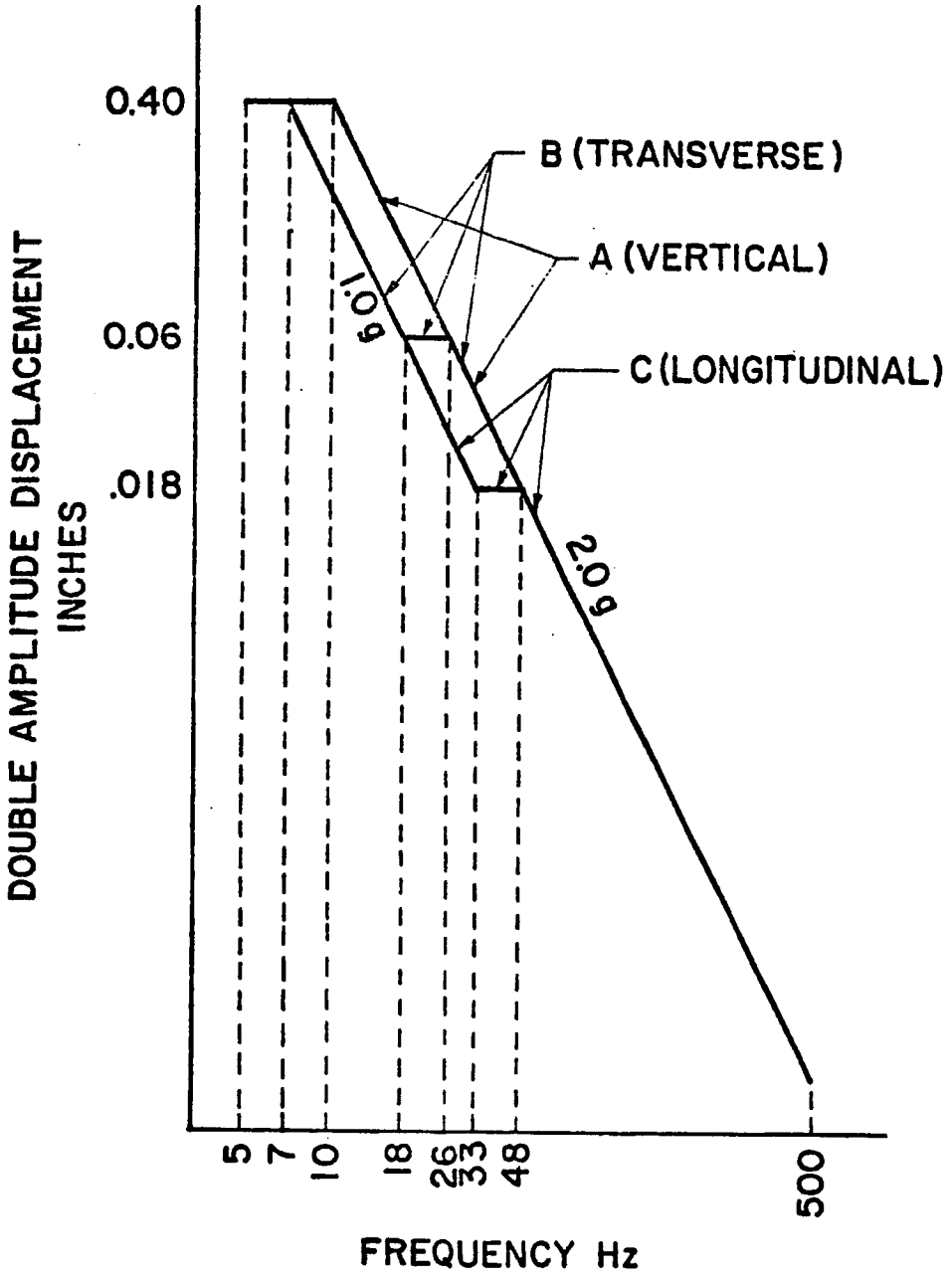


Figure 514.2-4B. Vibration Test Curves for Cycling Test for Externally Carried Stores for Helicopters, Equipment Category d.3.

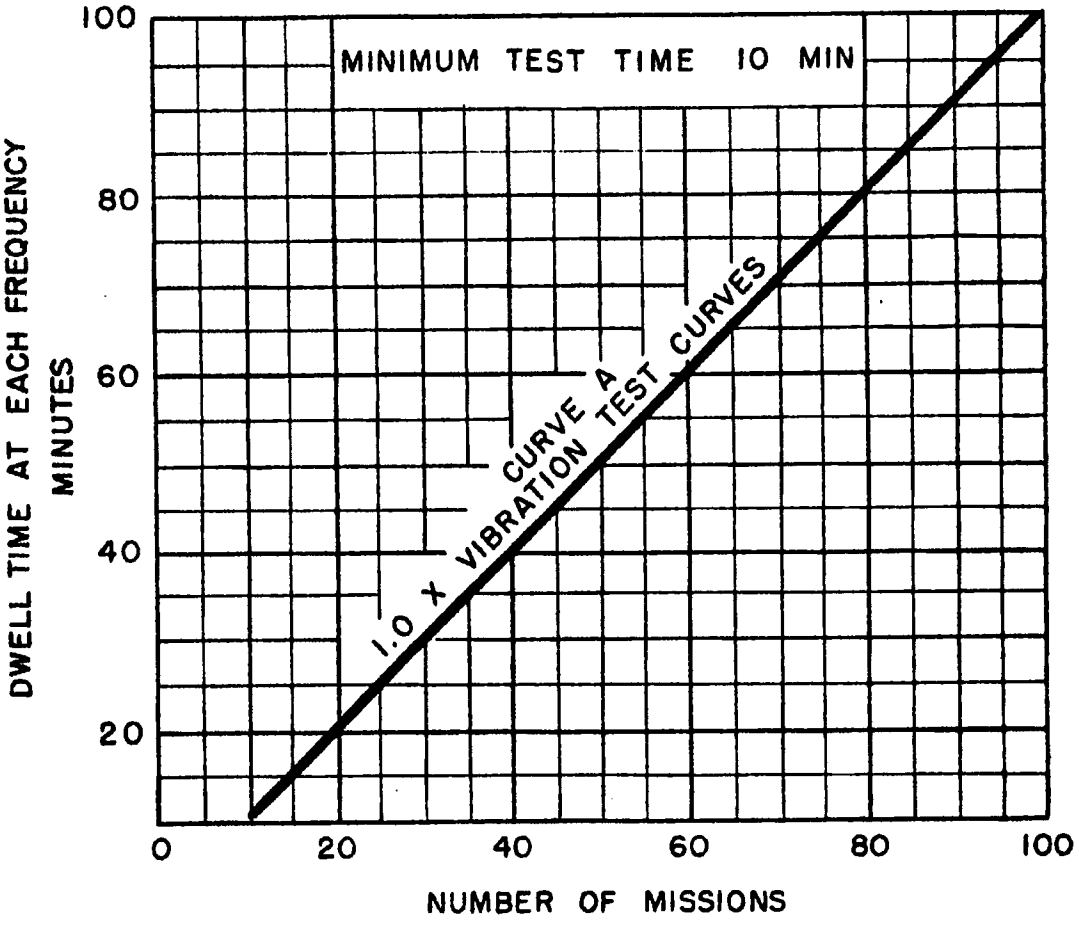


Figure 514.2-4C. Time Curves for Dwell Test for Externally Carried Stores for Helicopters, Equipment Category d.3.

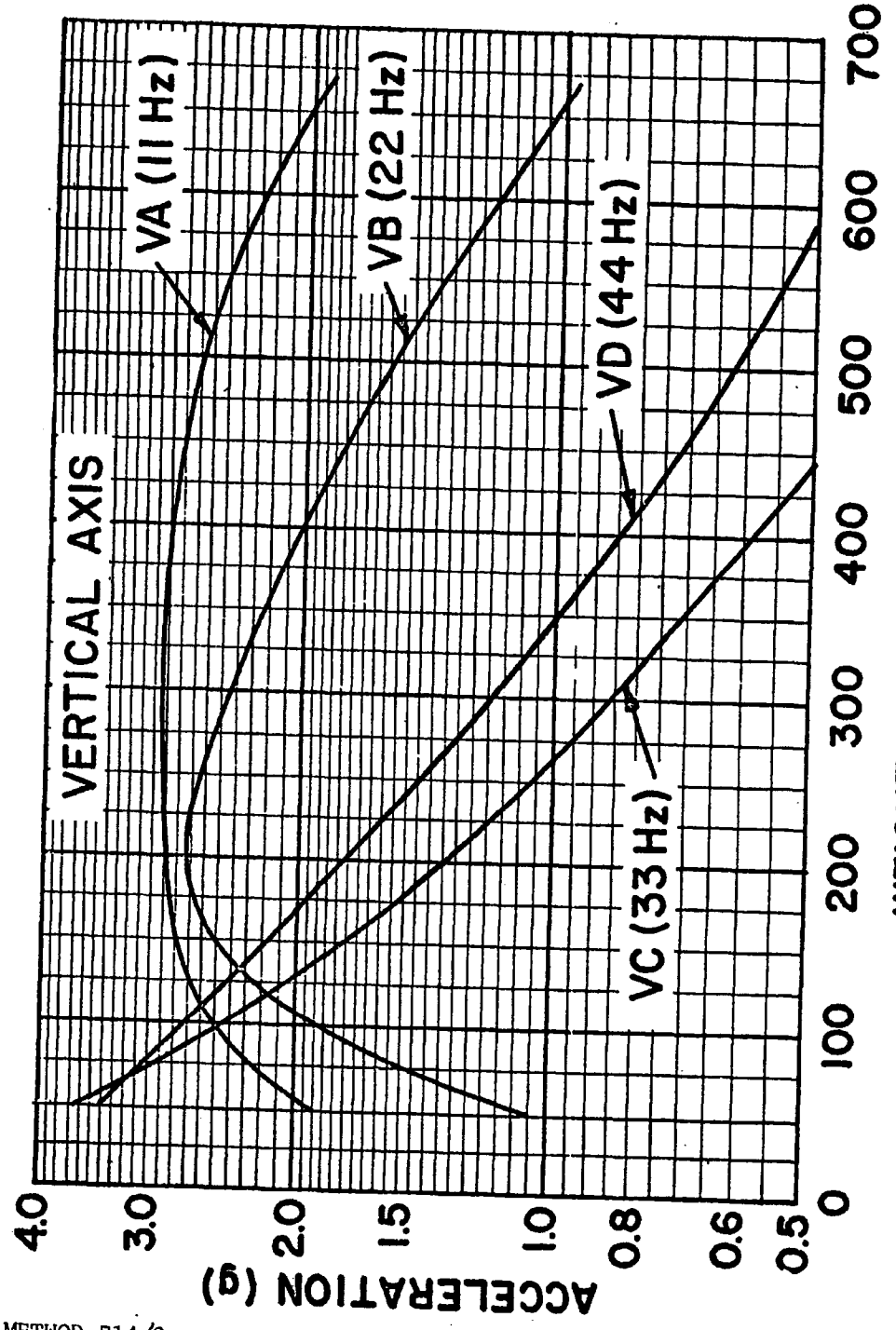


Figure 514.2-4D. Vibration Test Curves for Dwell Tests, Vertical Axis, for Externally Carried Stores for Helicopters, Equipment Category d.3.

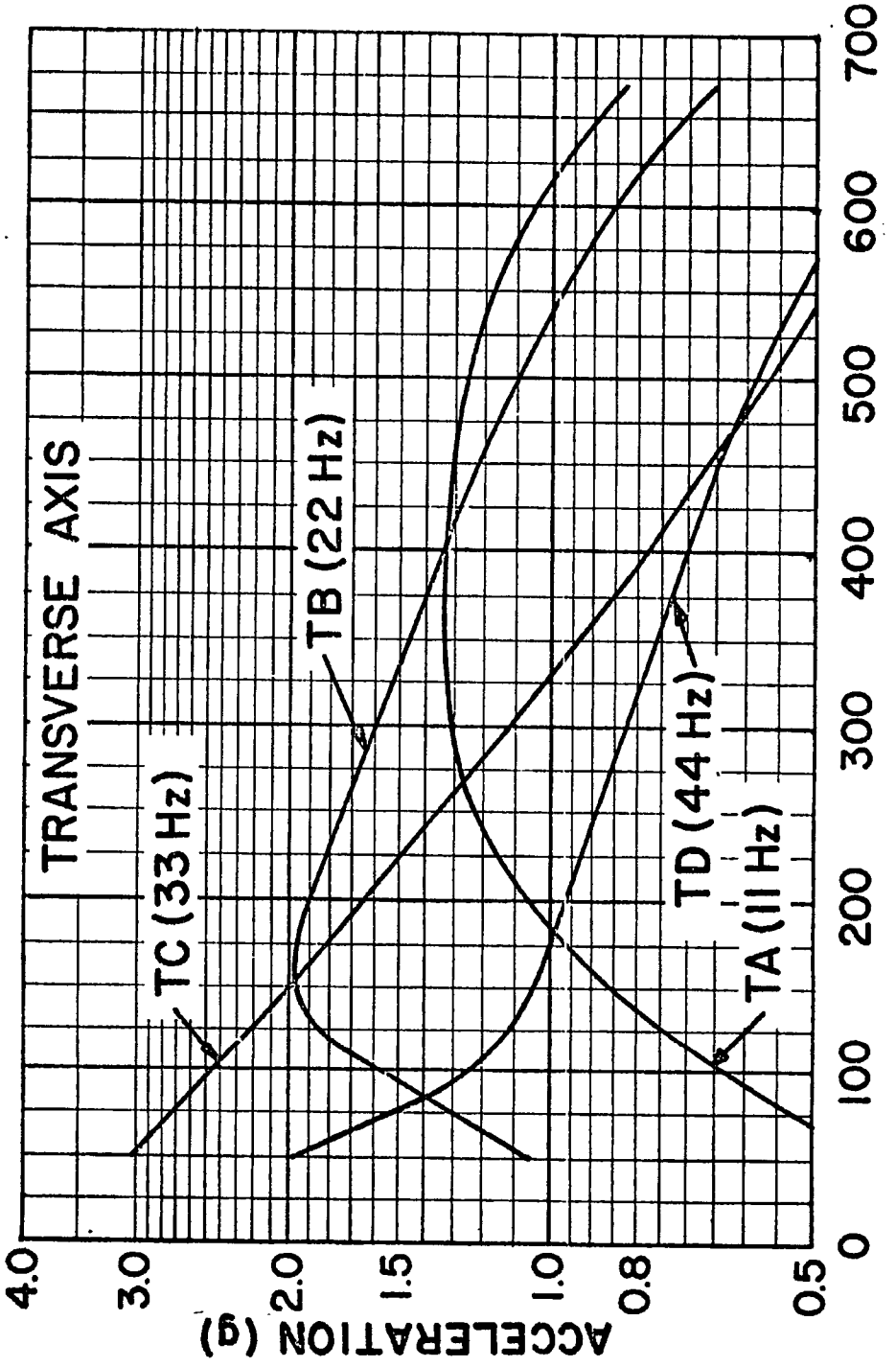


Figure 514.2-4E. Vibration Test Curves for Dwell Tests, Transverse Axis, for Externally Carried Stores for Helicopters, Equipment Category d.3.

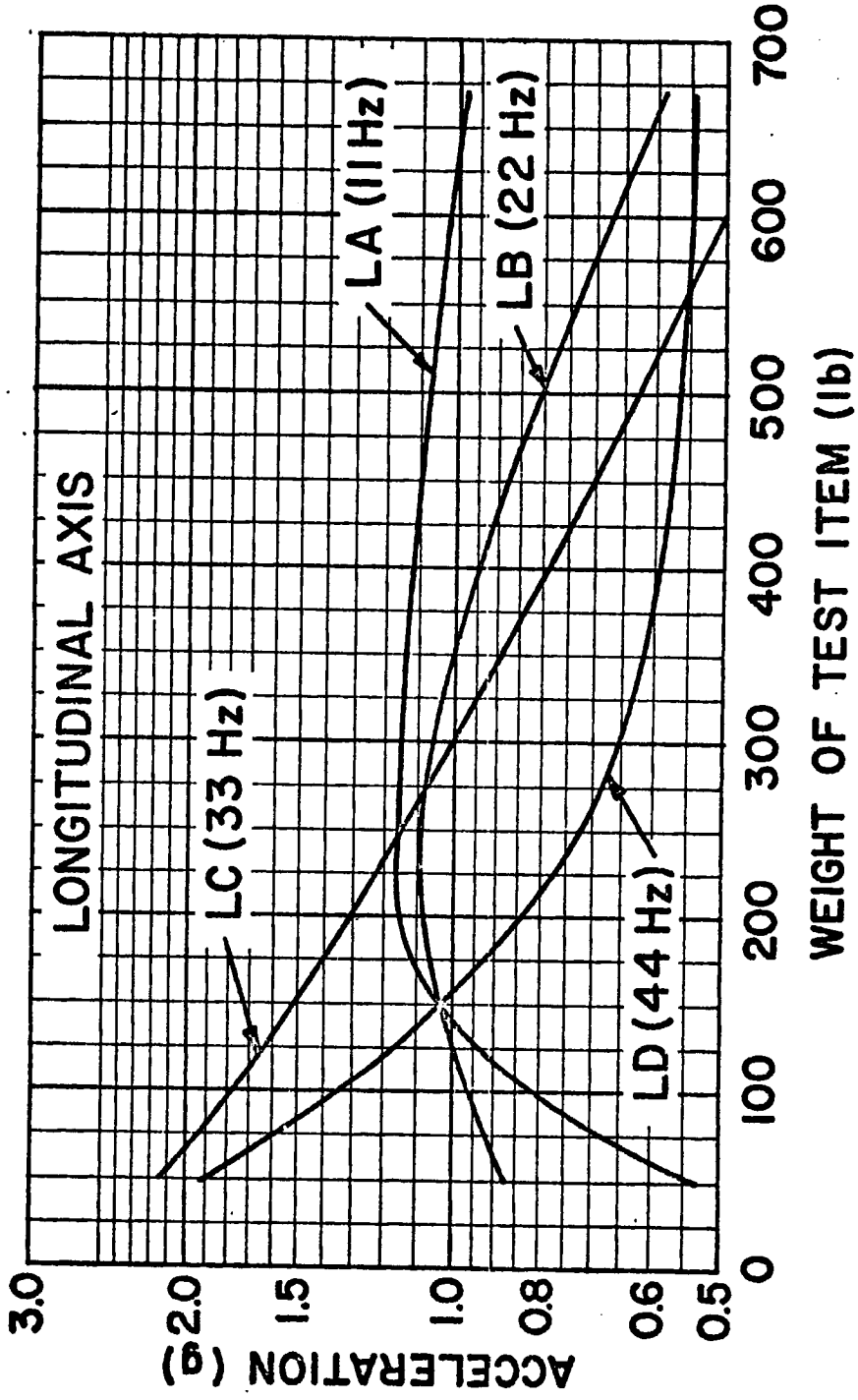


Figure 514.2-4F. Vibration Test Curves for Dwell Tests, Longitudinal Axis, for Externally Carried Stores for Helicopters, Equipment Category d.3.

Table 514.2-V. Test Procedure and Time Schedule Chart for Equipment Installed in Ground Launched Missiles, Equipment Category e.

A. Procedure Selection and Time Schedule Chart

Equipment mounting configuration	Procedure number	Procedure part number	Applicable tests (see 4 for test procedures)		Test time schedule (per axis)			Figure 514.2-V
			Sinusoidal cycling (4.5.1.3)	Random (4.5.2)	Sinusoidal cycling time (4.5.1.3)	Sweep time S-2000-5 Hz	Random time note 3/	Curve 1/
Without vibration isolators	V	1	X		30 min	20 min		One of P thru U
		2		X			30 min	One of AE thru AP
With vibration isolators 2/	VI	1	X		30 min	20 min		One of P thru U
		2	X		30 min	20 min		N
		3		X			30 min	One of AE thru AP
Normally with vib. isolators but tested without isolators	VII	1	X		30 min	20 min		N
		2		X			30 min	AE

1/ For sinusoidal vibration resonance tests and cycling tests of items mounted in missiles and weighing more than 80 pounds, the vibratory accelerations shall be reduced by +1g for each 20-pound increment of weight over 80 pounds. Acceleration derating shall apply only to the highest test level of the selected curve. However, the vibratory acceleration shall in no case be less than 50 percent of the specified curve level.

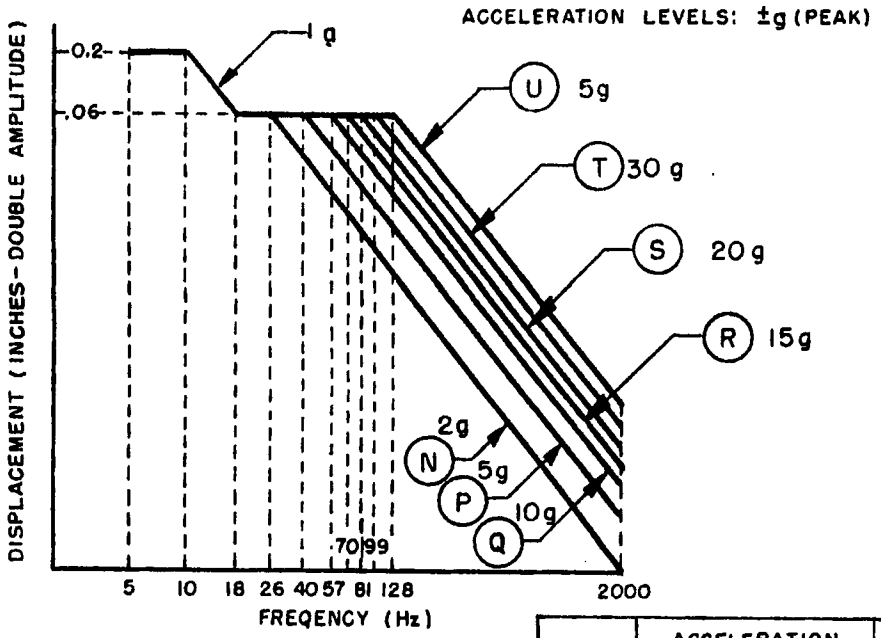
2/ Test items of equipment normally provided with vibration isolators first shall be tested with the isolators in place (part 1). The isolators then shall be removed, and the test item rigidly mounted and subjected to the test level indicated (part 2). Isolators shall be replaced and the test item subjected to the test level indicated (part 3).

3/ When flight distances of missiles are less than 100 miles, the test time is reduced to 5 minutes.

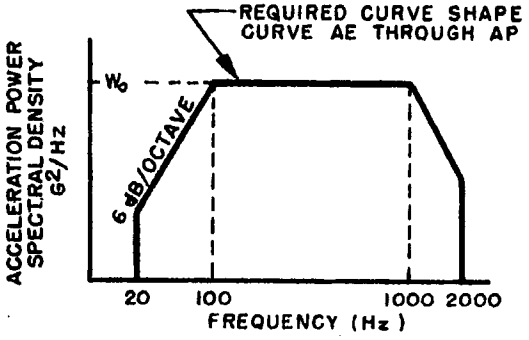
B. Curve Selection Chart for Category e. Equipment

Equipment location by vehicle section	Approximate thrust (power)	Vibration test curves (Figure 514.2-V)	
		Sinusoidal	Random
All except booster	ALL	P or Q	AE, AF, or AG
By individual booster stage	250,000 lbs or less	Q or R	AH, AJ, or AK
	250,000 lbs to 500,000 lbs	R or S	AK, AL, or AM
	Over 500,000	T or U	AM, AN, or AP

SINUSOIDAL VIBRATION CURVES



RANDOM VIBRATION CURVES



RANDOM VIBRATION ENVELOPE

TEST CURVE	ACCELERATION POWER SPECTRAL DENSITY W_0 (G^2/Hz)	COMPOSITE G-RMS MINIMUM
AE	0.02	5.4
AF	0.04	7.6
AG	0.06	9.3
AH	0.10	12.0
AJ	0.20	16.9
AK	0.30	20.7
AL	0.40	23.9
AM	0.60	29.3
AN	1.00	37.9
AP	1.50	46.4

NOTE: COMPOSITE G-rms $= \left[\int_{f_1}^{f_2} W(f)\,df\right]^{1/2}$

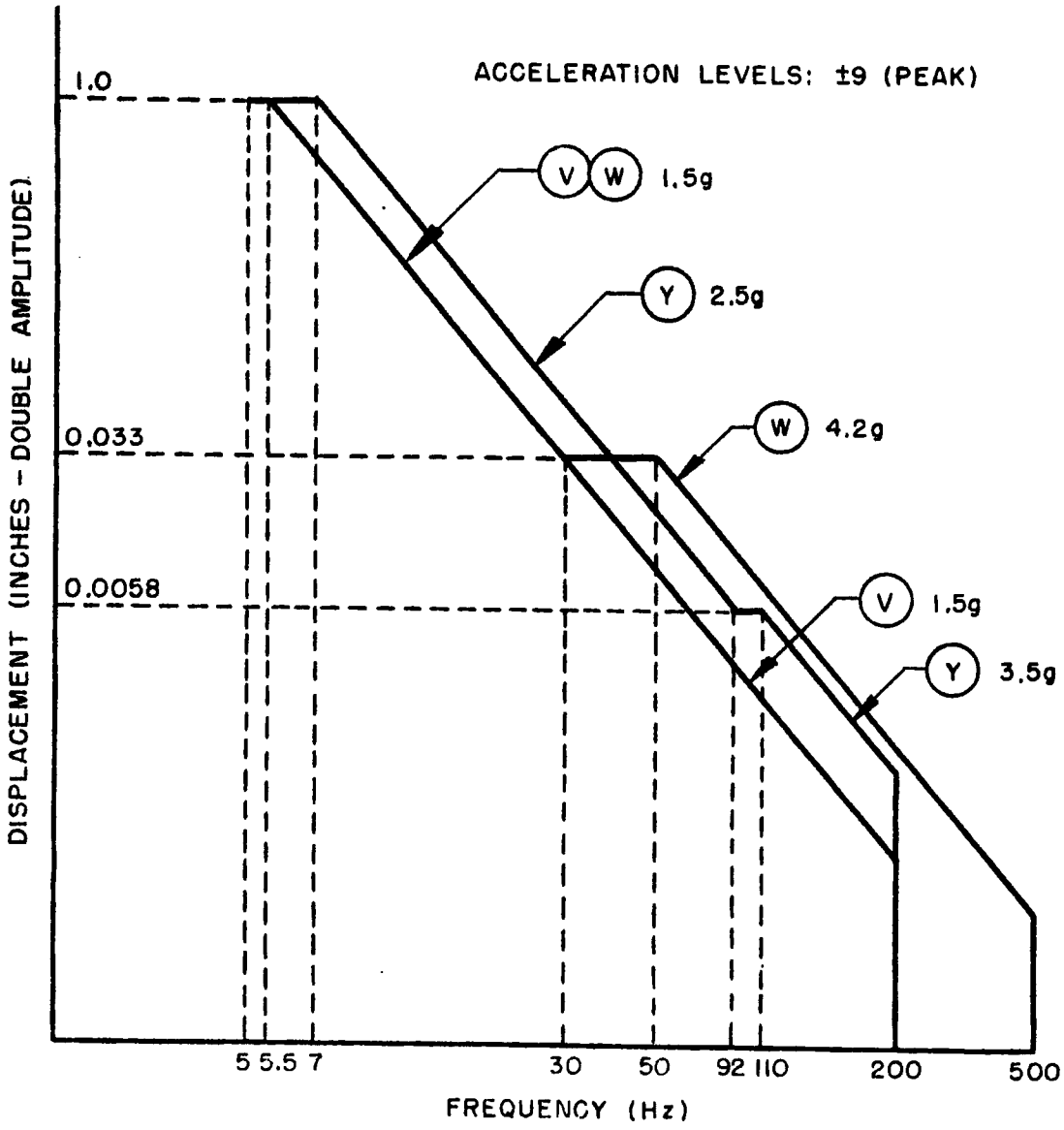
WHERE f_1 AND f_2 ARE THE LOWER AND UPPER TEST FREQUENCY LIMITS RESPECTIVELY
W(f) IS THE ACCELERATION POWER SPECTRAL DENSITY IN G^2/Hz UNITS

Figure 514.2-5. Vibration Test Curves for Equipment Installed in Ground Launched Missiles, Equipment Category e.

Table 514.2-VI. Test Procedure and Time Schedule Chart for Equipment Installed in Ground Vehicles, Equipment Category f

Equipment Conditions	Procedure Number	Procedure Part Number	Applicable Tests		Test Time Schedule (Per Axis)			Curve
			Sinusoidal Cycling (4.5.1.3)	Bounce Vehicular (4.6.10.2)	Sinusoidal Cycling Time (4.5.1.3)	Maximum Cycling Time	Sweep Time	
					Schedule A			
Tracked Vehicles	VIII		X		30 min/1000 miles 2/	3 hours	15 min 5-500-5 Hz 1/	W
					Schedule B			
Wheeled Vehicles	VIII		X		30 min/1000 miles 2/	5-1/2 hours	12 min 5-200-5 Hz 1/	V or Y 3/
Vehicle and Mileage Unknown	VIII		X			3 hours	15 min 5-500-5 Hz 1/	W
To be used only when specified	IX	2		X	see 4.6.10.2			
Vans and shelters	XIII	2		see 4.6.14.2				

1/ Sweep time shall be increased by 3 minutes if test frequencies go to 2 Hz.
2/ Cycling time shall be 30 min/1000 miles or as specified in the equipment specification except that it shall not exceed the maximum specified in table 514.2-VI.
3/ Curve V is for equipment installed in wheeled vehicles except for two-wheeled trailers. Curve Y is for equipment installed in two wheeled trailers.



Note: All curves shall be extended to 2 Hz when test item resonances below 5 Hz are expected

Figure 514.2-6. Vibration Test Curves for Equipment Installed in Ground Vehicles, Equipment Category f.

Table 514.2-VII. Test Procedure and Time Schedule for the Transportation of Cargo, Equipment Category g.

Transport Mode	Procedure	Procedure Part Number	Figure 514.2-7 Curve 5/	Applicable Test	Sweep Time 4/
Rail, air, sea, truck or simitrailer 1/	X		AW	Sinusoidal Cycling for 84 min Per Axis	12 min 5-200-5 HZ
Any of above plus tracked vehicle 2/	X		AV	Sinusoidal Cycling for 84 min Per Axis	12 min 5-200-5 HZ
Any of above plus 2-wheeled trailer 2/	X		AX	Sinusoidal Cycling for 84 min Per Axis	12 min 5-200-5 HZ
Loose Cargo 3/	XI	2	See 4.6.12.2		

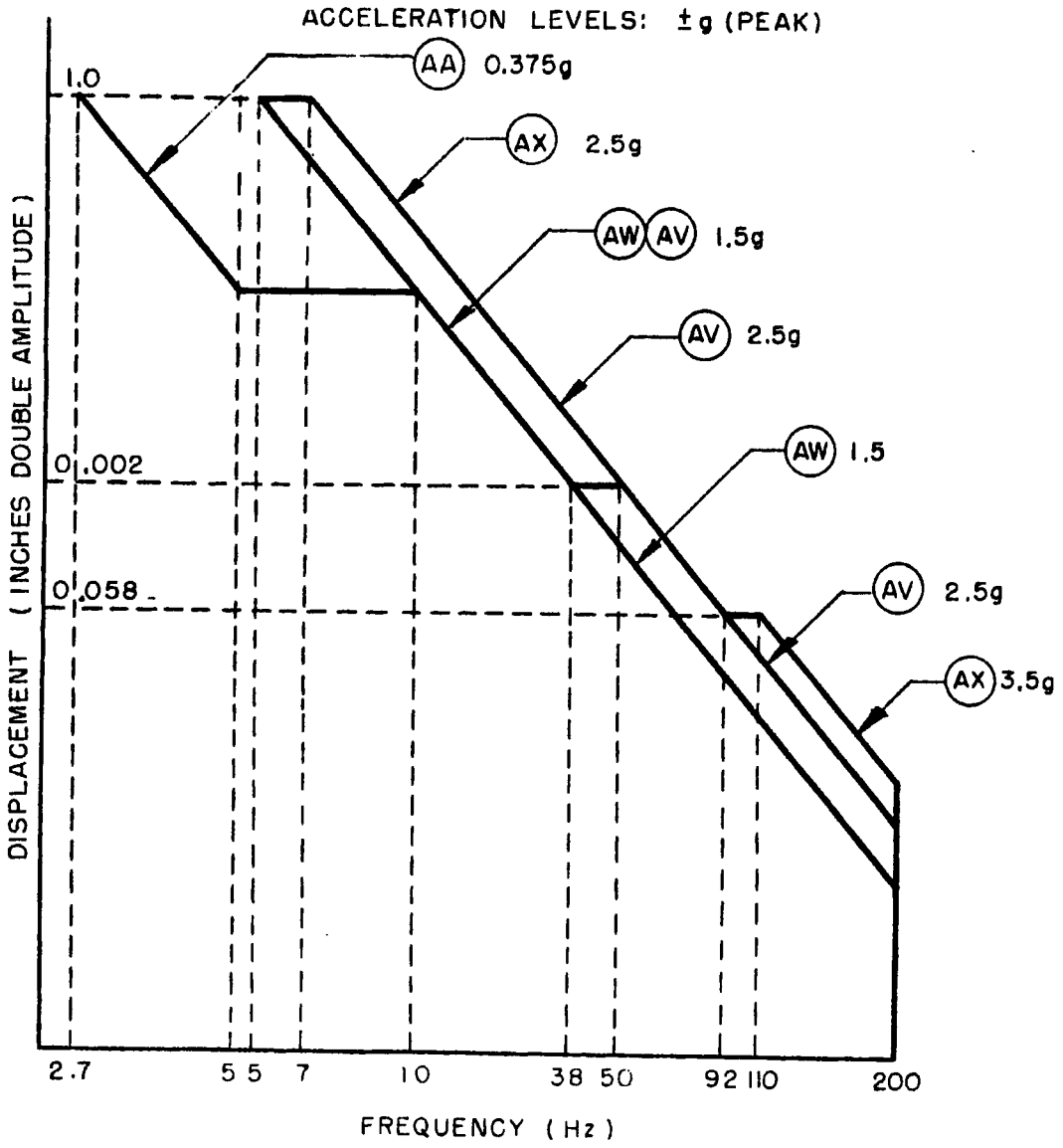
1/ The normal transport of items as secured cargo, with land transport over paved roadways.

2/ The transport of items as secured cargo to include land transport over paved roads, unimproved roads and cross-country terrain.

3/ When transit case or combination case is provided for the test item, the case shall be included in the test setup.

4/ Sweep time may be 15 minutes if test requirements go to 2 HZ.

5/ For vibration isolated items, curve AA is to be used in the lower frequency range (below 13 HZ) and the curve appropriate to the mode of transportation for the higher frequencies.



NOTE: ALL CURVES SHALL BE EXTENDED TO 2 Hz WHEN TEST ITEM RESONANCES BELOW 5 Hz ARE EXPECTED.

Figure 514.2-7. Vibration Test Curves for Equipment Transported as Secured Cargo, Equipment Category g.

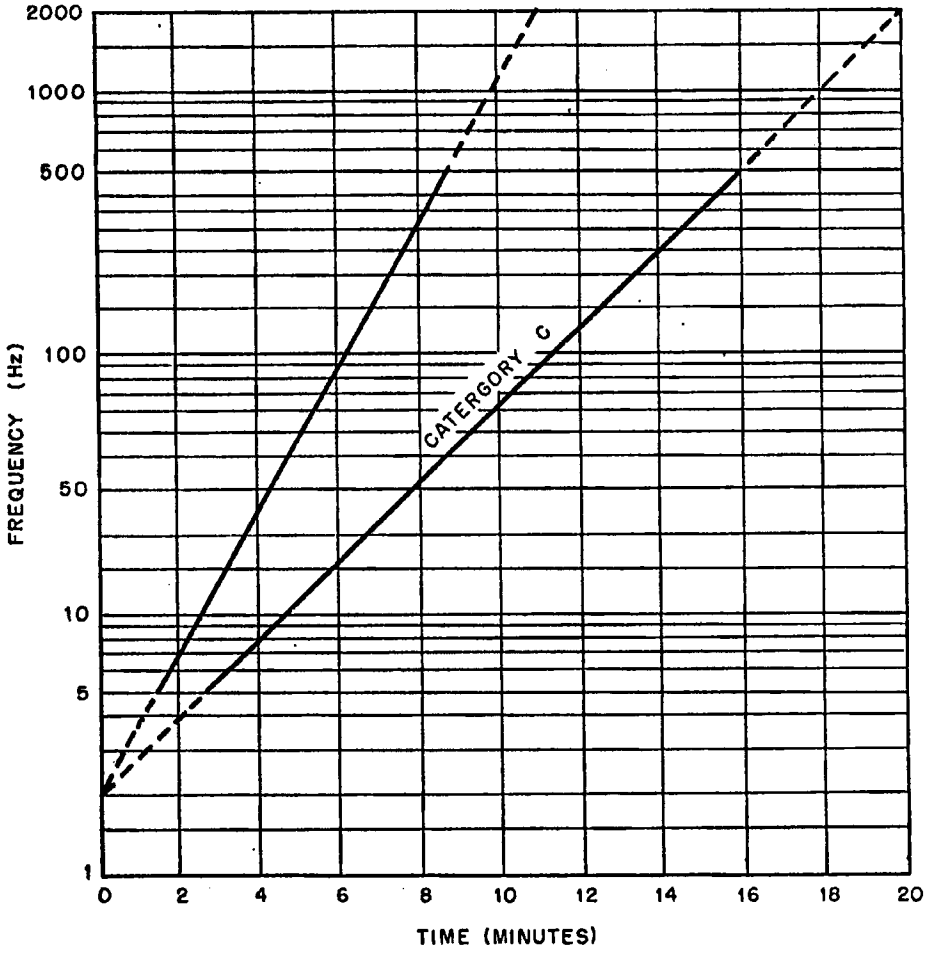


Figure 514.2-10. Logarithmic Sweep