CHANGE NOTICES ARE NOT CUMULATIVE AND SHALL BE RETAINED UNTIL SUCH TIME AS THE ENTIRE STANDARD IS REVISED.

MIL-STD-810B
NOTICE -1

20 OCTOBER 1969

# MILITARY STANDARD

## ENVIRONMENTAL TEST METHODS

This Notice should be filed in front of Military Standard MIL-STD-810B dated 15 June 1967.

TO ALL ACTIVITIES:

1. The following pages of this standard have been revised and supersede the pages listed:

| New Pages | Date | Superseded pages | Date |
|---|---|---|---|
| 513.1 through 513.1-6 | 20 October 1969 | 513-1 through 513-4 | 15 June 1967 |
| 514.1 through 514.1-30 | 20 October 1969 | 514-1 through 514-24 | 15 June 1967 |
| 515.1 through 515.1-6 | 20 October 1969 | 515-1 through 515-5 | 15 June 1967 |
| 516.1 through 516.1-10 | 20 October 1969 | 516-1 through 516-8 | 15 June 1967 |
| 517.1 through 517.1-11 | 20 October 1969 | 517-1 through 517-4 | 15 June 1967 |

2. Retain this Notice and insert before table of contents.

FSC MISC

# METHOD 513.1

## ACCELERATION

1. Purpose. - The acceleration test is performed to determine if equipment is constructed to withstand expected steady state stresses and to insure that performance degradations or malfunctions will not be produced by the simulated service acceleration environment other than gravity. Procedure I is the structural test and Procedure II is the operational test.

2. Apparatus. - Either of two facilities may be utilized for acceleration tests: a centrifuge, or a track and rocket sled facility. A centrifuge of adequate size is recommended for all structural and most operational tests because of the convenience and ease of control. However, the performance of space oriented equipment, such as gyros, space control platforms, etc., are difficult to test on a centrifuge, even when a counter-rotating fixture is employed. A rocket sled run is advantageous where strictly linear acceleration is required.

3. Procedures. - The test item shall be subjected to both the structural and the operational test, unless otherwise specified.

3.1 Mounting of test item. - Direction of forward acceleration is always considered to be the direction of the vehicle acceleration and equipment shall be oriented accordingly,using its normal mounting means. For centrifuges,the location of the test item (with reference to the G level established for the test) shall normally be determined by a measurement from the rotational center of the centrifuge to the geometric center of the test item. Should any point of the test item nearest the center of the centrifuge experience less than 90 percent of the specified G level, the test item shall be moved outward on a radius of the centrifuge or the speed of rotation shall be increased until not less than 90 percent of the specified G level is obtained. Caution: If the furthest end of the test item experiences more than 110 percent of the desired G level at the geometric center (while the nearest end experiences 90 percent or under), then the test item may be tested using a lower speed and a larger radius centrifuge arm. For large test specimens exceptions should be made to allow for maximum gradient based on the existing availability of large centrifuges in commercial or Government test facilities.

3.1.1 Test item orientation (centrifuge). - When a centrifuge is used to attain the required acceleration levels, the test item shall be oriented as follows:

| | |
|---|---|
| Fore: | Front or forward end of test item shall face toward center of centrifuge. |
| Aft: | Reverse item 180 degrees from the "fore" position. |
| Up: | Top of specimen shall face toward center of centrifuge. |
| Down: | Reverse item 180 degrees from the "up" position. |
| Lateral: | Each side (right, left) in turn shall face toward center of centrifuge. |

3.2 Test level determination. - The G level to be applied to the test item is contingent on two factors: The direction of forward acceleration level (A) of the vehicle, and the orientation of the test item within the vehicle.

Where: A = The highest possible known or unknown forward acceleration of a vehicle in which equipment is to be mounted. (A) shall never be less than one G level.

Instructions for selection of test levels for Procedure I from table 513.1-I, and for Procedure II from table 513.1-II are as follows:

| Forward accel. of vehicle | Orientation of test item in vehicle | Test level |
|---|---|---|
| Known | Known | Substitute known acceleration A in forward acceleration column of appropriate vehicle category, and use given multiplying factors to attain test level for indicated directions. |
| Known | Unknown | Substitute known acceleration A in forward acceleration column of appropriate category, and use largest given multiplying factor to attain test level for all directions. |
| Unknown | Known | Select most probable level from those given in forward acceleration column of appropriate category, and use given multiplying factors to attain test level for required direction. |
| Unknown | Unknown | Select most probable level from those given in forward acceleration column of appropriate category, and use largest given multiplying factor to attain test level for all directions. |

3.3 Procedure I. Structural test. - The test item shall be installed on the acceleration apparatus in accordance with section 3, General Requirements, paragraph 3.2.2, by its normal mounting means. The G level shall be determined in accordance with 3.2, and shall be applied while the test item is nonoperating.

3.3.1 Performance of test. - The G level determined for the test shall be applied along at least three mutually perpendicular axes in two opposite directions along each axis. The test time duration in each direction shall be at least 1 minute following centrifuge stabilization. On centrifuges, a test time of 1 minute is usually sufficient to determine structural soundness (proper operation); however, the test time may be increased. Test times for other apparatus will probably be shorter, depending upon the type of apparatus. At the conclusion of the test, the test item shall be operated and the results compared with the data obtained in accordance with section 3, General Requirements, paragraph 3.2.1. The test item shall then be inspected as specified in section 3, General Requirements, paragraph 3.2.4.

3.4 Procedure II. Operational test. - The test item shall be installed on the acceleration apparatus in accordance with section 3, General Requirements, paragraph 3.2.2, by its normal mounting means. The G level shall be determined in accordance with 3.2, and shall be applied while the test item is operating.

TABLE 513.1-I. G levels for structural test (Procedure I)

| Vehicle category | Forward acceleration A 1/ | Test level | | | | |
|---|---|---|---|---|---|---|
| | | Direction of vehicle acceleration (see figure 513.1-1) | | | | |
| | | Fore | Aft | Up | Down | Lateral (two directions) |
| Airplanes | 2.0 | 1.5 x A | 4.5 x A | 6.75 x A | 2.25 x A | 3.0 x A |
| Helicopters | 2.0 | 1.5 x A | 1.5 x A | 5.25 x A | 2.25 x A | 3.0 x A |
| Manned aerospace vehicles | 6.0 to 12.0 | 1.5 x A | 0.5 x A | 2.25 x A | 0.75 x A | 1.0 x A |
| Air launched missiles | 9.0 to 30.0 | 1.5 x A | 0.5 x A | 2.25 x A | 0.75 x A | 1.0 x A |
| Ground launched missiles | 6.0 to 30.0 | 1.5 x A | 0.5 x A | 1.0 x A | 1.0 x A | 1.0 x A |

1/ Levels in this column shall be used when forward acceleration is unknown. When the forward acceleration of the vehicle is known, that level shall be used for (A).

TABLE 513.1-II. G levels for operational test (Procedure II)

| Vehicle category | Forward acceleration A 1/ | Test level | | | | |
|---|---|---|---|---|---|---|
| | | Direction of vehicle acceleration (see figure 513.1-1) | | | | |
| | | Fore | Aft | Up | Down | Lateral (two directions) |
| Airplanes | 2.0 | 1.0 x A | 3.0 x A | 4.5 x A | 1.5 x A | 2.0 x A |
| Helicoptors | 2.0 | 1.0 x A | 1.0 x A | 3.5 x A | 1.5 x A | 2.0 x A |
| Manned aerospace vehicles | 6.0 to 12.0 | 1.0 x A | 0.33 x A | 1.5 x A | 0.5 x A | 0.66 x A |
| Air launched missiles | 9.0 to 30.0 | 1.0 x A | 0.33 x A | 1.5 x A | 0.5 x A | 0.66 x A |
| Ground launched missiles | 6.0 to 30.0 | 1.0 x A | 0.33 x A | 0.66 x A | 0.66 x A | 0.66 x A |

1/ Levels in this column shall be used when forward acceleration is unknown. When the forward acceleration of the vehicle is known, that level shall be used for (A).

3.4.1 Performance of test.- The G level determined for the test shall be applied along at least three mutually perpendicular axes in two opposite directions along each axis. The test time duration in each direction shall be at least 1 minute following centrifuge stabilization. A test time of 1 minute is usually sufficient to determine proper operation; however, the test time may be increased. This test time applies to centrifuge apparatus only. Other apparatus may require modification of the above test time duration. The test item shall be operated before, during and at the conclusion of each test, and the results compared with the data obtained in accordance with section 3, General Requirements, paragraph 3.2.1. The test item shall then be inspected as specified in section 3, General Requirements, paragraph 3.2.4.

4. Summary.- The following details shall be specified in the equipment specification or test plan.

(a) Procedure number if both procedures are not required (see 3).
(b) Pretest data required (section 3, General Requirements, paragraph 3.2.1).
(c) Test level and test time (see 3.3 and 3.4).
(d) Length of time required for operation and measurements.

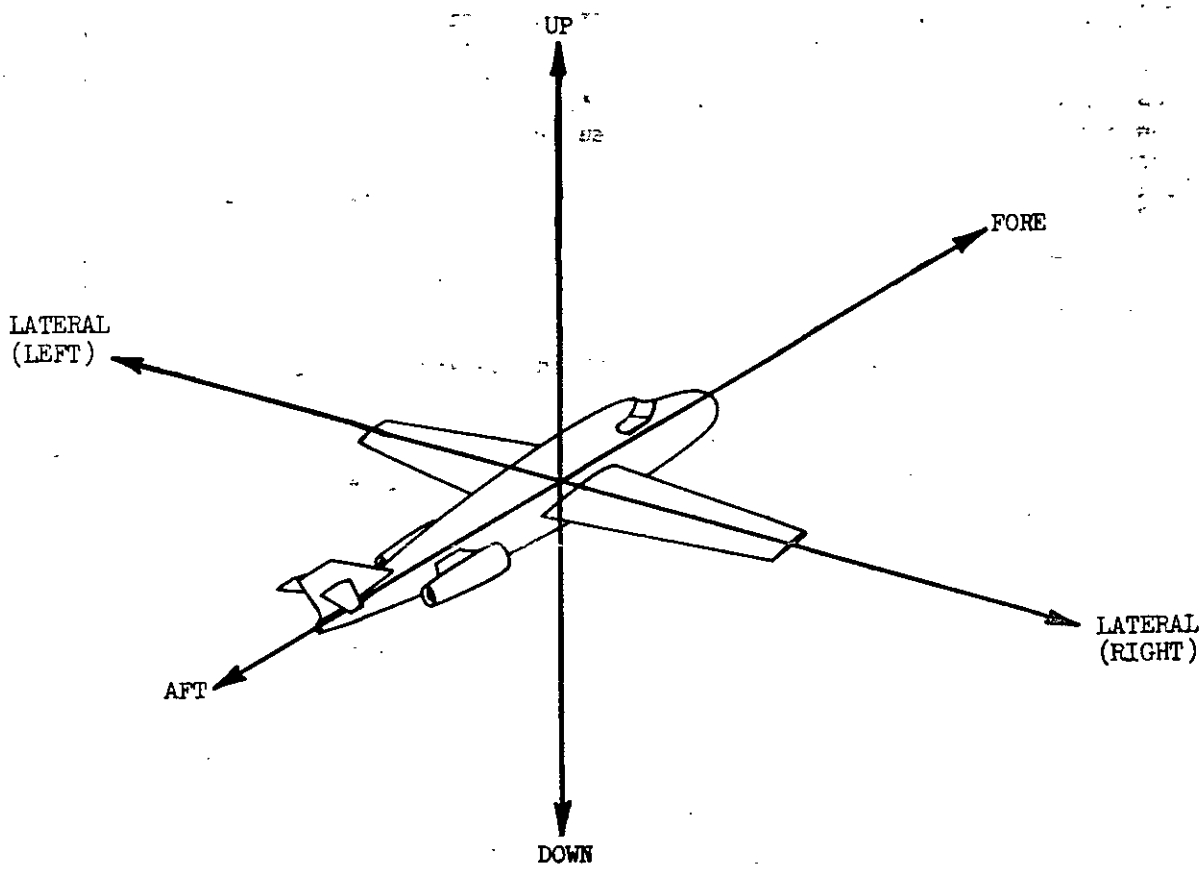



FIGURE 513.1-1. Direction of vehicle acceleration

METHOD 514.1

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 charts, tables 514.1-I through 514.1-VII, 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. The tables are divided into two major sections. Section A, "Test procedure and time schedule chart," specifies the tests to be imposed on the equipment and the test time schedule for each test. Section(s) B(C),"Curve selection chart," specifies the vibration test curves applicable to that particular equipment category and application. Guidance for selection of the vibration test for an item is as follows:

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

(b) Proceed to the applicable table corresponding to equipment category (a) through (h) or 4.17 for category (i) equipment. Select a procedure from the table based on the following equipment mounting configuration:

(1) Without vibration isolators

(2) With vibration isolators

(3) Tied down

(4) Loose

(c) For all procedures except IX, XI, and XIII, select the applicable test level curve(s) from tables 514.1-I through 514.1-VII in accordance with 3.3 based on:

(1) Listed selection criteria

(2) Detailed knowledge of the specific equipment environment

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

(a) Equipment installed in airplanes and helicopters (see table 514.1-I and figure 514.1-1)

(b) Equipment installed in airplanes, excluding helicopters (see table 514.1-II and figure 514.1-2)

(c) Equipment installed in helicopters (see table 514.1-III and figure 514.1-3)

(d) Equipment installed in air launched missiles (see table 514.1-IV and figure 514.1-4)

(e) Equipment installed in ground launched missiles (see table 514.1-V and figure 514.1-5)

(f) Equipment installed in ground vehicles (see table 514.1-VI and figure 514.1-6)

(g) Equipment transported by common carrier, land or air (see table 514.1-VII and figure 514.1-7)

(h) Ground equipment, excluding category f (for transportation test, see category g)

(i) Shipboard and amphibious equipment or when a ship is the common carrier (see 4.17)

3.2 Applicable tests. - For any given equipment category, all tests listed beside the selected procedure for the applicable equipment mounting configuration in tables 514.1-I through 514.1-VII shall be performed unless otherwise specified. For example, referring to table 514.1-IV section A, for testing equipment category (d) when Procedure III is selected, there are four parts with four different test levels indicated by the test curves. Tests indicated by "X" in all four parts shall be performed to evaluate equipment installed in an air launched missile for both the captive and flight phase.

3.3 Selection of test curves. - A curve shall be selected using tables 514.1-I through 514.1-VII 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 section(s) B(C) of tables 514.1-I through 514.1-VII. Applicable test curves for each equipment category are shown on figures 514.1-1 through 514.1-7. In some instances, several curves are shown for one equipment category. When the equipment, due to its application, may be subjected to more than one level of particular type of vibration, the curve representing the most severe level shall be selected.

3.4 Examples of procedure selection. - The equipment specification or test plan shall identify which tests are to be imposed on the equipment by specifying the applicable procedure and test curve(s) when applicable. Tables 514.1-I through 514.1-VII and figures 514.1-1 through 514.1-7 are arranged to accommodate this identification.

3.4.1 Example No. 1. - Select the test conditions for equipment to be used in the following application.

Category: Equipment installed in airplane (jet engine at rear of fuselage)

Equipment location: Forward half of fuselage

Equipment mounting: On vibration isolated panel

Referring to table 514.1-II, the above identification specifies the following test conditions:

Procedure I

Part 1 (curve J)

Part 2 (curve AR)

Part 1 specifies a resonance search, resonance dwell and sinusoidal vibration cycling to the level of curve J from figure 514.1-2 within the time schedule specified for part 1 on table 514.1-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 of curve AR from figure 514.1-2 within the time schedule specified for part 2 from table 514.1-II.

3.4.2 Example No. 2. - Select the test conditions for equipment to be used in the following application:

Category: Equipment installed in air launched missile (missile thrust/weight ratio 15/1 and carried on airplane wing of jet airplane with wing mounted engines).

Equipment location: Equipment in missile booster section

Equipment mounting: Without vibration isolators (hard mounted)

Referring to table 514.1-IV, the above identification specifies the following test conditions:

Procedure II

Part 1 - Captive phase (curve H)

Part 2 - Flight phase (curve R)

Part 3 - Flight phase (curve AJ)

Part 1 specifies a resonance search, resonance dwell, and sinusoidal cycling to the level of curve H from figure 514.1-4 within the time schedule specified for part 1 of procedure II on table 514.1-IV. These tests are followed by part 2, a sinusoidal cycling test to the level of curve R from figure 514.1-4 within the time schedule specified for part 2 of procedure II on table 514.1-IV. Next, part 3, a random vibration test, shall be performed to the level of curve AJ from figure 514.1-4 within the time schedule specified for part 3 of procedure II on table 514.1-IV.

4. Test procedures. - The basis for selecting a test procedure (Procedure I through XII) for a particular equipment category shall be according to 3. A procedure consists of all tests indiated by an "X" under the "Applicable tests" column of tables 515.1-I through 514.1-VII to the right of the procedure number with the duration of the test as specified under the column entitled "Test time schedules (per axis)". The vibration environment, specified by the curve selected from tables 514.1-I through 514.1-VII in accordance with 3, shall be applied to each of the three mutually perpendicular axes of the test item. 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. 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 shall be abbreviated accordingly. At the conclusion of the test, the test item shall be operated and the results shall be compared with the data obtained in accordance with section 3, General Requirements, paragraph 3.2.1. At the conclusion of each test, the test item then shall be inspected in accordance with section 3, General Requirements, paragraph 3.2.4.

4.2 Mounting techniques. - In accordance with section 3, General Requirements, paragraph 3.2.2, the test item shall be attached to the vibration exciter table by its normal mounting means 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 undesirable responses in the test

setup. Whenever possible, the test load shall be distributed uniformly on the vibration exciter table in order to minimize effects of unbalanced loads. Vibration amplitudes and frequencies shall be measured by techniques that will not significantly affect test item input control or response. The input control sensing device(s) shall be rigidly attached to the vibration table or to the intermediate structure, if used, at or as near as possible to the attachment point(s) of the test item.

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 specified.

4.4 Combined sinusoidal cycling and random vibration test. - The sinusoidal cycling and random vibration tests shall normally be performed separately. If analyses of actual or predicted data indicate a simultaneous sinusoidal and random vibration environment, the procedure for a combined test shall be specified.

4.5 Common test techniques. -

4.5.1 Sinusoidal vibration tests. - The vibration shall be applied along each of the 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 specified, for sinusoidal resonance search, resonance dwell, and cycling tests of items weighing more than 80 pounds mounted in airplanes, helicopters, and missiles, the vibratory accelerations shall be reduced +/-1 g 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 applicable table 514.1-I through 514.1-V). For equipment weighing over 100 pounds and transported by aircraft, resonance search, resonance dwell, and cycling tests may be frequency and acceleration derated (see notes 1 and 2 of table 514.1-VII). When packaged items are always grouped together on mechanized loading platforms or pallets, acceleration and frequency derating may be based on the total load on the pallet. 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 preformed 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 tables 514.1-I through 514.1-V and figures 514.1-1 through 514.1-7 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 tables 514.1-I through 514.1-VII and figures 514.1-1 through 514.1-7. The frequency of applied vibration shall be swept over the specified range logarithmically in accordance with figure 514.1-10. The specified sweep time is that of an ascending plus a descending sweep and is twice the ascending sweep time shown on figure 514.1-10 for the specified range. Linear sweep rates may be substituted for the logarithmic sweep rate. When linear sweep rates are used, the total frequency range shall be divided into logarithmic frequency bands having similar time intervals such that each time interval is the time of ascending plus a descending sweep for the corresponding band. The sum of these time intervals shall equal the sweep time specified for the applicable frequency range. The linear sweep rate for each band is then determined by dividing each bandwidth in cps by one-half the sweep time in minutes for each band. The logarithmic frequency bands may be readily determined from figure 514.1-10. The frequency bands and linear sweep rates shown in table 514.1-IX shall be used for the 2 (or 5) to 500 cps and 5 to 2,000 cps frequency ranges. For test frequency ranges of 100 cps or less, no correction of the linear sweep rate is required.

4.5.2 Random vibration test. - The test item shall be subjected to random vibration along each of three mutually perpendicular axes according to one specified curve AE through AP from the applicable figure 514.1-4 or 514.1-5. Test times shall be according to the applicable schedule from tables 514.1-IV or 514.1-V. 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 +40, -30 percent (+/-1.5 dB) below 500 cps and +100, -50 percent (+/-3 dB) between 500 cps and 2,000 cps, except that deviations as large as +300, -75 percent (+/-6 dB) shall be allowed over a cumulative bandwidth of 100 cps, maximum, between 500 and 2,000 cps.

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 $G^2$/cps units. The term $W_0$ defines the specified level in $G^2$/cps 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.

(a) On-line, contiguous filter, equalization/analysis system having a bandwidth = B = 50 cps, maximum.

(b) Swept frequency analysis systems characterized as follows:

1. Constant bandwidth analyzer.

a. Filter bandwidth as follows:
B = 20 cps, maximum between 20 to 200 cps
B = 50 cps, maximum between 200 to 2,000 cps

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 $\frac{B^2}{8}$, (cps/second) maximum, whichever is smaller.

2. Constant percentage bandwidth analyzer.

a. Filter bandwidth=$pf_c$=one-third octave maximum (.23 $f_c$) 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 $\frac{(pf_c)^2}{8}$ (cps/second), maximum, whichever is smaller.

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

The composite G-rms test level shall not be less than the value given on figure 514.1-4 or 514.1-5 for each test curve. Accelerometer(s) employed for test level control shall be mounted in accordance with 4.1. 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 Procedure I. -

4.6.1 Part 1. - Proceed the same as in 4.5.1.1, 4.5.1.2, and 4.5.1.3. The test level shall be according to one specified curve C through H, J, L, M, Z, AS, or AT from figures 514.1-1, 514.1-2, or 514.1-3 as applicable for that equipment category. Test time schedules shall be as specified for part 1 of Procedure I in the applicable table.

4.6.2 Part 2. - 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 level shall be according to one specified curve B or AR from figures 514.1-1, 514.1-2, or 514.1-3 as applicable for that equipment category. Test time schedules shall be as specified for part 2 of Procedure I in the applicable table.

4.7 Procedure II. -

4.7.1 Part 1. - Proceed the same as in 4.5.1.1, 4.5.1.2, and 4.5.1.3. The test level shall be according to one specified curve C, D, H, or J from figure 514.1-4. Test time schedules shall be as specified for part 1 of Procedure II as shown in table 514.1-IV.

4.7.2 Part 2. - Proceed the same as in 4.5.1.3. The test level shall be according to one specified curve P, Q, R, or S from figure 514.1-4. Test time schedules shall be as specified for part 2 of Procedure II as shown in table 514.1-IV.

4.7.3 Part 3. - Proceed the same as in 4.5.2. The test level shall be according to one specified curve AF through AK from figure 514.1-4. Test time schedules shall be as specified for part 3 of Procedure II as shown in table 514.1-IV.

4.8 Procedure III. -

4.8.1 Part 1. - Test items normally provided with vibration isolators shall be vibrated with the isolators in place as in 4.5.1.1, 4.5.1.2, and 4.5.1.3. The test level shall be according to one specified curve C, D, H, or J from figure 514.1-4. Test time schedules shall be as specified for part 1 of Procedure III as shown on figure 514.1-IV.

4.8.2 Part 2. - 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 level shall be according to one specified curve B or AR from figure 514.1-4. Test time schedules shall be as specified for part 2 of Procedure III as shown in table 514.1-IV.

4.8.3 Part 3. - Next, vibration isolators shall be replaced and the test item vibrated again as in 4.5.1.3. The test level shall be in according to one specified curve P, Q, R, or S from figure 514.1-4. Test time schedules shall be as specified for part 3 of Procedure III as shown in table 514.1-IV.

4.8.4 Part 4. - With vibration isolators in place, proceed the same as in 4.5.2. The test level shall be according to one specified curve AF through AK from figure 514.1-4. Test time schedules shall be as specified for part 4 of Procedure III as shown in table 514.1-IV.

4.9 Procedure IV. -

4.9.1 Part 1. - Proceed the same as in 4.5.1.1, 4.5.1.2, and 4.5.1.3. The test level shall be according to one specified curve B or AR from figure 514.1-4. Test time schedules shall be as specified for part 1 of Procedure IV as shown in table 514.1-IV.

4.9.2 Part 2. - Proceed the same as in 4.5.1.3. The test level shall be according to curve N from figure 514.1-4. Test time schedules shall be as specified for part 2 of Procedure IV as shown in table 514.1-IV.

4.9.3 Part 3. - Proceed the same as in 4.5.2. The test level shall be according to curve AE from figure 514.1-4. Test time schedules shall be as specified for part 3 of Procedure IV as shown in table 514.1-IV.

4.10 Procedure V. -

4.10.1 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 figure 514.1-5. Test time schedules shall be as specified for part 1 of Procedure V as shown in table 514.1-V.

4.10.2 Part 2. - Proceed the same as in 4.5.2. The test level shall be according to one specified curve AE through AP from figure 514.1-5. Test time schedules shall be as specified for part 2 of Procedure V as shown in table 514.1-V.

4.11 Procedure VI. -

4.11.1 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 514.1-5. Test time schedules shall be as specified for part 1 of Procedure VI as shown in table 514.1-V.

4.11.2 Part 2. - Test items normally provided with 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 514.1-5. Test time schedules shall be as specified for part 2 of Procedure VI as shown in table 514.1-V.

4.11.3 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 514.1-5. Test time schedules shall be as specified for part 3 of Procedure VI as shown in table 514.1-V.

4.12 Procedure VII. -

4.12.1 Part 1. - Proceed the same as in 4.5.1.3. Test levels shall be according to curve N from figure 514.1-5. Test time schedules shall be as specified for part 1 of Procedure VII as shown in table 514.1-V.

4.12.1 Part 2. - Proceed the same as in 4.5.2. Test levels shall be according to curve AE from figure 514.1-5. Test time schedules shall be as specified for part 2 of Procedure VII as shown in table 514.1-V.

4.13 Procedure VIII. - Proceed the same as in 4.5.1.1, 4.5.1.2, and 4.5.1.3. Test levels shall be according to one specified curve V, W, or Y from figure 514.1-6. Test time schedules shall be as specified in Procedure VIII as shown in table 514.1-VI. Time schedule A shall be used for general tests when the vehicle (in which the equipment is to be mounted) or its mileage schedule is not known. Time schedule B is to be used for more realistic testing when the vehicle is known. When test item resonances below 5 cps are measured or expected the test curves shall be extended to 2 cps and the sweep time shall be 18 minutes (2-500-2 cps).

4.14 Procedure IX. -

4.14.1 Part 1. - Proceed the same as in 4.5.1.1. The test level shall be applied over a frequency range of 10 to 55 cps and at a vibratory displacement of not less than 0.030 inches, double amplitude. The vibratory frequency shall be changed in discrete steps of 1 cps and maintained at least 10 seconds at each frequency. Where possible, fixturing shall be such that resonances within the test item can be observed and measured. Subassemblies may be tested separately, provided they are secured to the vibration exciter in a manner similar to that used to mount them in the test item. Vibration isolators, if any, of the test item shall be blocked during the test. The test item shall have no resonances in the frequency range of 10 to 55 cps that exceed twice the amplitude of applied vibration. This criteria applies for equipment designed to operate with or without vibration isolators.

4.14.2 Part 2, bounce, vehicular. -

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

4.14.22 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 sixpenny 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.

4.14.2.3 Performance of test. -

Step 1 - Secure the test item to the vehicular, or simulated, adapter plate in accordance with section 3, General Requirements, paragraph 3.2.2, and place on the package tester with the constraints outlined in 4.14.2.2(b). If the test item weighs over 200 pounds, an approved simulated adapter plate 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 +/-2.5 g'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 cps 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 10 g'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 the test item and compare the results with the data obtained in accordance with section 3, General Requirements, paragraph 3.2.1. Then inspect the test item as specified in section 3, General Requirements, paragraph 3.2.4.

4.15 Procedure X. - Proceed the same as in 4.5.1.1, 4.5.1.2, and 4.5.1.3. The test level shall be according to specified curve(s) AV, AW, AX, AY, AA and AQ from figure 514.1-7 as applicable. Test time schedules shall be as specified for Procedure X as shown in table 514.1-VII. When test item resonances below 5 cps are measured or expected the test curves shall be extended to 2 cps.

4.16 Procedure XI. -

4.16.1 Part 1. - Proceed the same as in part 1 of Procedure IX.

4.16.2 Part 2, bounce, loose cargo. -

4.16.2.1 Purpose.- To determine that the equipment, as prepared for field use, shall be capable of withstanding the vibrations normally induced during transportation as loose cargo. Equipment in this class is normally transported in a shipping case, transit case, or combination case.

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

4.16.2.3 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 sixpenny 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 note more than 2 inches in a direction parallel to the axes of the shafts, a distance more than sufficient to insure the test item will not rebound from fence to fence.

4.16.2.4 Performance of test. - The test item, as secured in its shipping case, 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 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 the results compared with the data obtained in accordance with section 3, General Requirements, paragraph 3.2.1. The test item shall then be inspected as specified in section 3, General Requirements, paragraph 3.2.4. 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.

4.17 Procedure XII. - For shipboard and amphibious equipment or when a ship is the common carrier, the vibration test shall be in accordance with Type 1 of MIL-STD-167.

4.18 Procedure XIII.

4.18.1 Part 1. - Proceed the same as in part 1 of Procedure IX.

4.18.2 Part 2, bounce, system shelter assemblage.

4.18.2.1 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.

4.18.2.2 Performance of test. - The system shelter assemblage shall be driven five times over the 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. (See 4.1.)

| | |
|---|---|
| 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 |
| Single corrugations (4-inch to 6-inch waves) | 20 mph |
| Any short sections between the above sections | 20 mph |

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

(a) Procedure number (see 3).

(b) Pretest data required (section 3, General Requirements, paragraph 3.2.1).

(c) Curve selection (see 3.3).

(d) Acceleration or frequency derating of selected curve, if required (see 4.5.1).

(e) Nonoperation of equipment during test, if desired (see 4.1).

(f) Limitation of transverse motion (see 4).

(g) Temperature extremes and test time durations (see 4.3).

(h) Procedure for combining sinusoidal and random vibration, if applicable (see 4.4).

(i) Total vehicle mileage (see table 514.1-VI).

(j) Total land transportation mileage (see time schedule in table 514.1-VII).

TABLE 514.1-I

A. Test procedure and time schedule chart for equipment installed in airplanes and helicopters – equipment category (a)

| Equipment mounting configuration | Procedure number | Procedure part number | Applicable tests (see 4 for test procedures) | | | Test time schedule (per axis) | | | | Curve (note 1) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 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 (4.5.1.3) | Sweep time 5-500-5 cps | Sweep time 5-2000-5 cps | |
| Without vibration isolators | I | 1 | X | X | X | 30 min | 3-hrs-less dwell time | 15 min | 20 min | M,Z,AS,AT |
| With vibration isolators (note 2) | I | 1 | X | X | X | 30 min | 3-hrs-less dwell time | 15 min | 20 min | M,Z,AS,AT |
| | | 2 | X | X | X | 10 min | 30 min | 15 min | 20 min | B,AR |
| Normally with vibration isolators but tested without isolators | I | 2 | X | X | X | 10 min | 30 min | 15 min | 20 min | B,AR |

Note 1: For sinusoidal vibration resonance tests and cycling tests of items mounted in airplanes and 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. 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. (Part 1). The isolators then shall be removed, and the test item rigidly mounted and subjected to the test level indicated. (Part 2).

B. Curve selection chart for category (a) equipment

| Selection criteria | Curve (for freq. to 500 cps) | Curve (for freq. to 2000 cps such as jet aircraft) |
|---|---|---|
| Equipment designed for both helicopter and airplane applications when the location in the airplane is in the forward half of fuselage or in wing areas of airplanes with engines at rear of fuselage. | M | AS |
| Equipment designed for both helicopter and airplane applications when the location in the airplane is in the rear half of the fuselage or in wing areas of airplanes with wing or front mounted engines or other equipment or engine locations not specifically mentioned for other curves. | Z | AT |
| 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 |

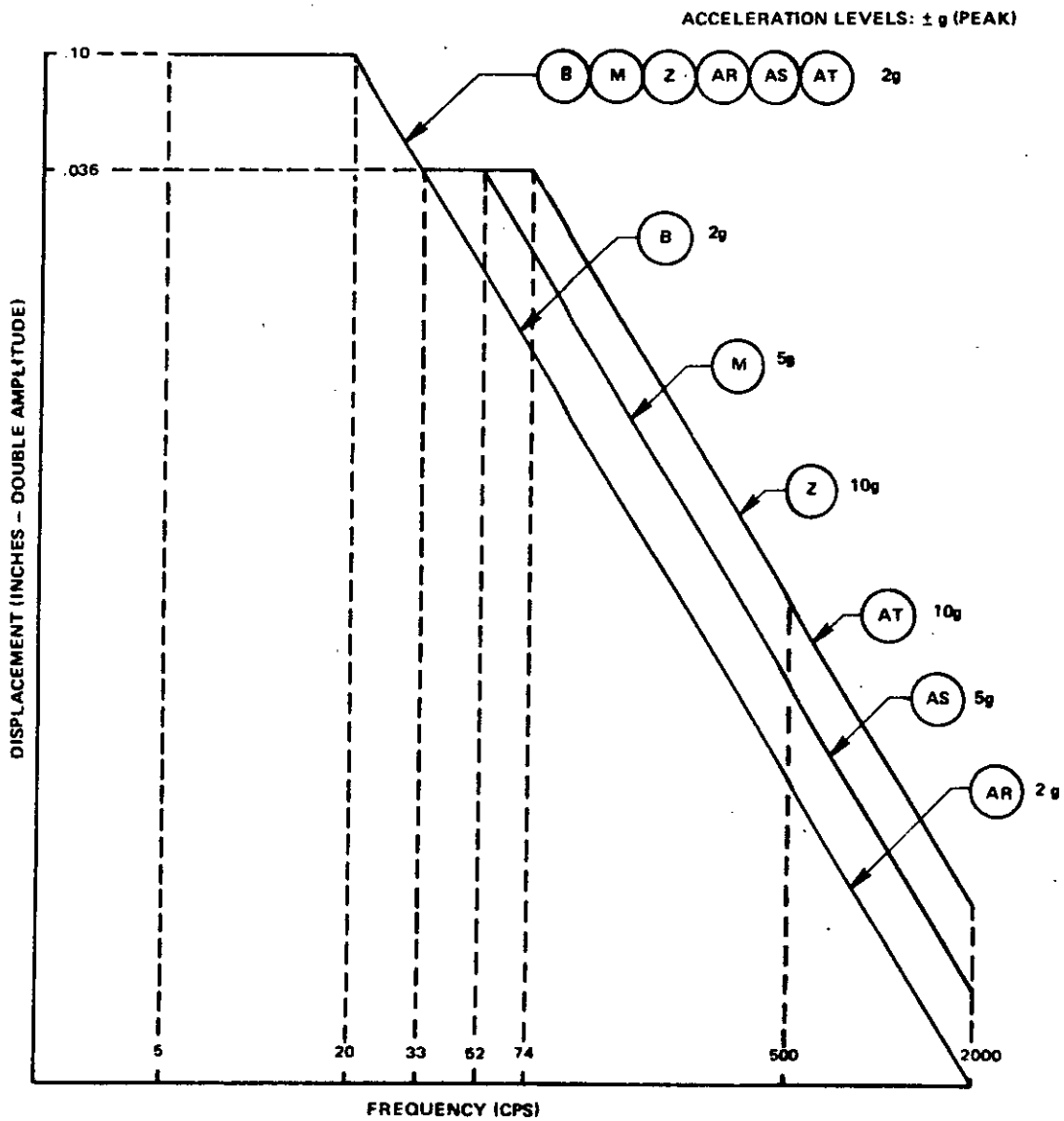



*FIGURE 514.1–1. Vibration test curves for equipment installed in airplanes and helicopters – equipment category (a)*

TABLE 514.1-II

A. Test procedure and time schedule chart for equipment installed in airplanes – equipment category (b)

| Equipment mounting configuration | Procedure number | Procedure part number | Applicable tests (see 4 for test procedures) | | | Test time schedule (per axis) | | | | Curve (note 1) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 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 cps | 5-2000-5 cps | |
| Without vibration isolators | I | 1 | X | X | X | 30 min | 3 hrs-less dwell time | 15 min | 20 min | C,D,E,F, G,H,J,orL |
| With vibration isolators (note 2) | I | 1 | X | X | X | 30 min | 3 hrs-less dwell time | 15 min | 20min | C,D,E,F, G,J,H,orL |
| | | 2 | X | X | X | 10 min | 30 min | 15 min | 20 min | B,AR |
| Normally with vibration isolators but tested without isolators | I | 2 | X | X | X | 10 min | 30 min | 15 min | 20 min | B,AR |

Note 1: For sinusoidal vibration resonance tests and cycling tests of items mounted in airplanes 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. 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. (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) equipment

| Selection criteria | Curve (for freq. to 500 cps) | Curve (for freq. to 2000 cps such as jet aircraft) |
|---|---|---|
| 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 or engine locations not specifically mentioned for other curves | D | H |
| Equipment located in the engine compartments or pylons of airplanes | E | G |
| Equipment mounted directly on airplane engines | F | L |

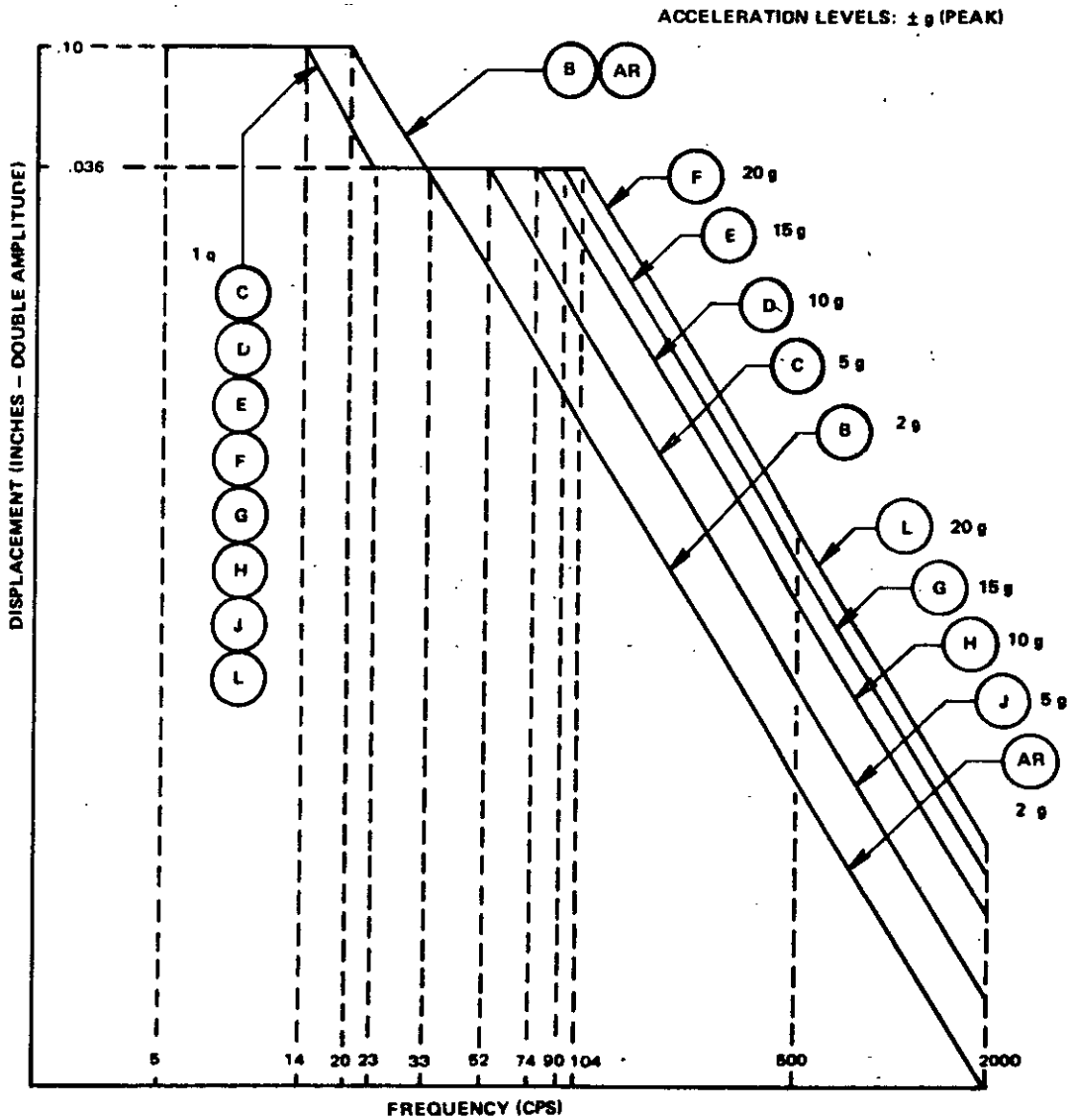



*FIGURE 514.1–2. Vibration test curves for equipment installed in airplanes, excluding helicopters – equipment category (b)*

TABLE 514.1-III

A. Test procedure and time schedule chart for equipment installed in helicopters – equipment category (c)

| Equipment mounting configuration | Procedure number | Procedure part number | Applicable Tests (see 4 for test procedures) | | | Test time schedule (per axis) | | | Curve (note 1) |
|---|---|---|---|---|---|---|---|---|---|
| | | | 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 (4.5.1.3) | Sweep time 5-500-5 cps | |
| Without vibration isolators | I | 1 | X | X | X | 30 min | 3 hrs-less dwell time | 15 min | M |
| With vibration isolators (note 2) | I | 1 | X | X | X | 30 min | 3 hrs-less dwell time | 15 min | M |
| | | 2 | X | X | X | 10 min | 30 min | 15 min | B |
| Normally with vibration isolators but tested without isolators | I | 2 | X | X | X | 10 min | 30 min | 15 min | B |

Note 1: For sinusoidal vibration resonance tests and 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. 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. (Part 1). The isolators then shall be removed, and the test item rigidly mounted and subjected to the test level indicated. (Part 2)

B. Curve selection chart for category (c) equipment

| Selection criteria | Curve |
|---|---|
| Equipment designed for helicopter applications only | 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 |

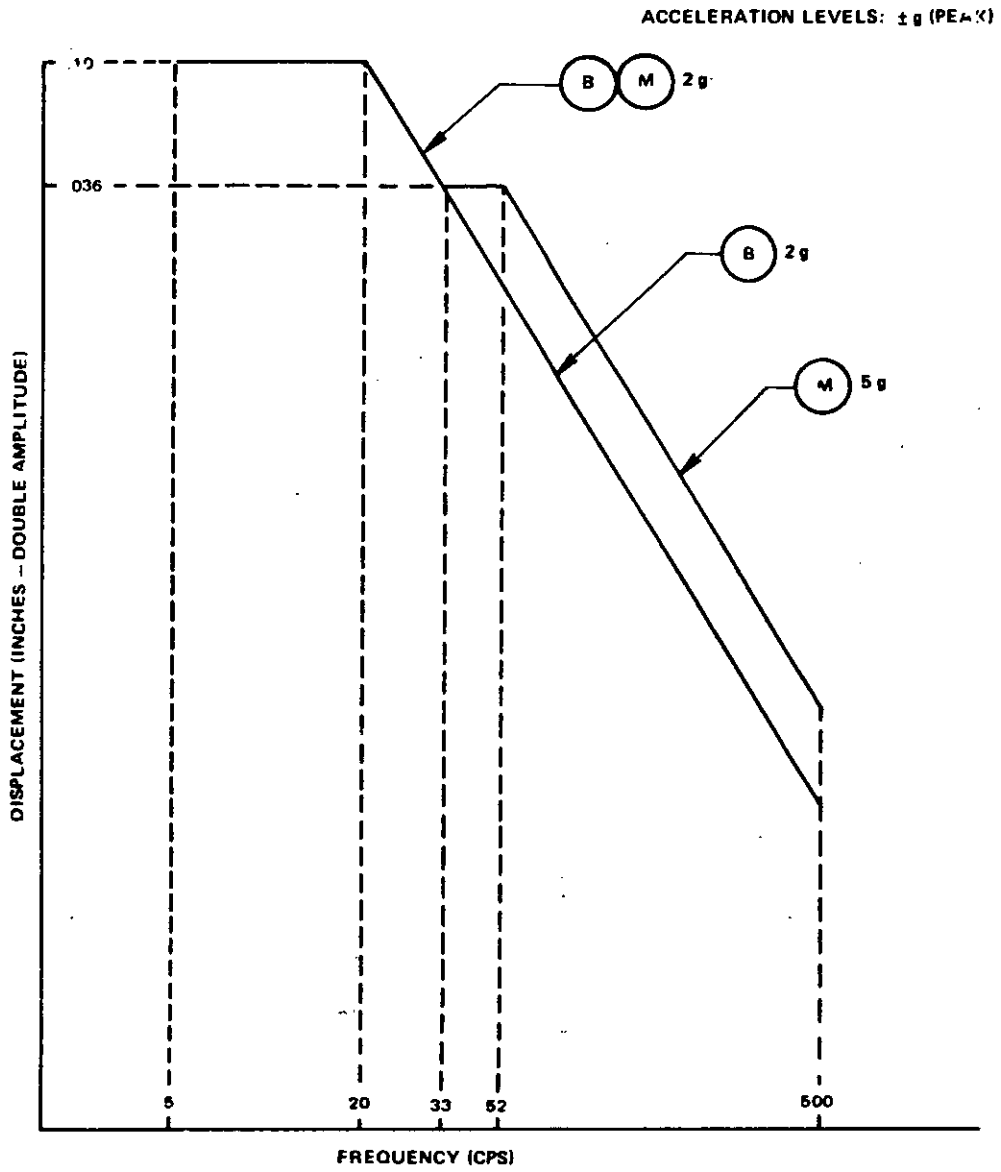



*FIGURE 514.1–3. Vibration test curves for equipment installed in helicopters – equipment category (c)*

TABLE 514.1-IV

A. Test procedure and time schedule chart for equipment installed in air launched missiles - equipment category (d)

| Equipment mounting configuration | Procedure number | Procedure part number | Applicable tests (See 4 for test procedures) | | | | Test time schedule (per axis) | | | | | Curve (note 1) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Resonance search (4.5.1.1) | Resonance dwell (4.5.1.2) | Sinusoidal cycling (4.5.1.3) | Random (4.5.2) | Dwell time at each resonance (4.5.1.2) | Sinusoidal cycling time (4.5.1.3) | Sweep time 5-500-5 cps | Sweep time 5-2000-5 cps | Random time | |
| Without vibration isolators | II | 1 (captive) | X | X | X | | 30 min | 2 hrs-less dwell time | 15 min | 20 min | | C,D,H,orJ |
| | | 2(flight) | | | X | | | 30 min | 15 min | 20 min | | P,Q,RorS |
| | | 3(flight) | | | | X | | | | | 30 min | One of AF thru AK |
| With vibration isolators (note 2) | III | 1 (captive) | X | X | X | | 30 min | 2 hrs-less dwell time | 15 min | 20 min | | C,D,HorJ |
| | | 2 (captive) | X | X | X | | 10 min | 30 min | 15 min | 20 min | | B or AR |
| | | 3(flight) | | | X | | | 30 min | 15 min | 20 min | | P,Q,RorS |
| | | 4(flight) | | | | X | | | | | 30 min | One of AF thru AK |
| Normally with vibration isolators but tested without vibration isolators | IV | 1 (captive | X | X | X | | 30 min | 2 hrs-less dwell time | 15 min | 20 min | | B or AR |
| | | 2(flight) | | | X | | | 30 min | 15 min | 20 min | | N |
| | | 3(flight) | | | | X | | | | | 30 min | AE |

B. Curve selection chart for flight phase category (d) equipment

| Equipment location by vehicle section | Approximate thrust to weight ratio or thrust in pounds | Vibration test curves | |
|---|---|---|---|
| | | Sinusoidal | Random |
| Booster | 20/1 or greater | S | AK |
| | 5/1 thru 20/1 | R | AJ |
| | 5/1 or less | Q | AH |
| All except Booster | 15/1 or greater | Q | AG |
| | Less than 15/1 | P | AF |

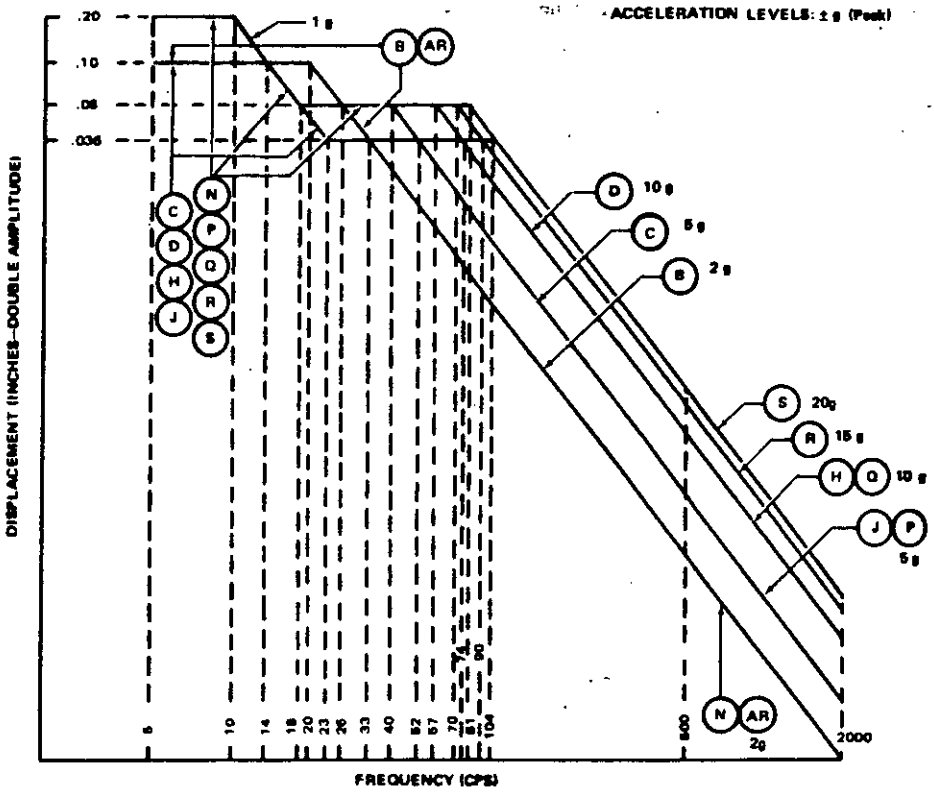
Note 1: For sinusoidal vibration resonance tests and cycling tests of items mounted in missiles and weighing more than 80 pounds, the vibratory acceleration shall be reduced by +/-1 g for each 20-pound increment of weight over 80 pounds. However, the vibratory acceleration shall in no case be less than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

Note 2: Test items of equipment 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. (Parts 3 & 4).

C. Curve selection chart for captive phase category (d) equipment

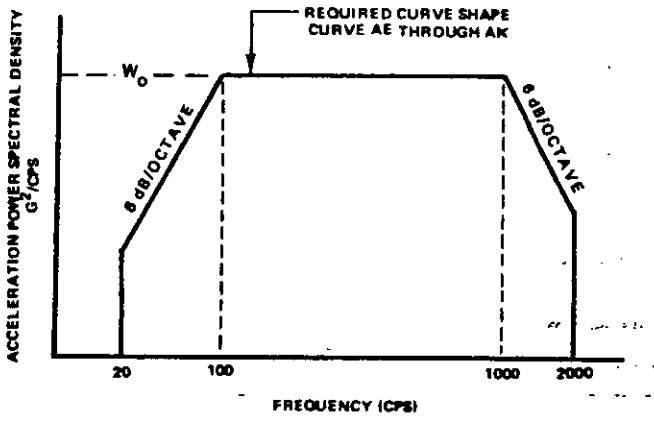
| Selection criteria | Curve (for freq. to 500 cps) | Curve (for freq. to 2000 cps such as jet aircraft) |
|---|---|---|
| Equipment in missiles attached to wing of airplanes with engines in rear of fuselage | C | J |
| Equipment in missiles carried on airplane fuselage or attached to wing in airplanes with wing or front mounted engines. | D | H |
| Equipment in missiles carried on airplanes or helicopters and 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 |

## SINUSOIDAL VIBRATION CURVES




## RANDOM VIBRATION CURVES

### RANDOM VIBRATION ENVELOPE




### RANDOM VIBRATION TEST LEVELS

| TEST CURVE | ACCELERATION POWER SPECTRAL DENSITY $W_o$ (G2/CPS) | 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 |

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 $G^2$/CPS UNITS.

*FIGURE 514.1-4. Vibration test curves for equipment installed in air launched missiles – equipment category (d)*

TABLE 514.1-V

A. Test procedure and time schedule chart for equipment installed in ground launched missiles – equipment category (e)

| Equipment mounting configuration | Procedure number | Procedure part number | Applicable tests (see 4 for test procedures) | | Test time schedule (per axis) | | | Curve (note 1) |
|---|---|---|---|---|---|---|---|---|
| | | | Sinusoidal cycling (4.5.1.3) | Random (4.5.2) | Sinusoidal cycling time (4.5.1.3) | Sweep time 5-2000-5 cps | Random time | |
| 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. (note 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 |

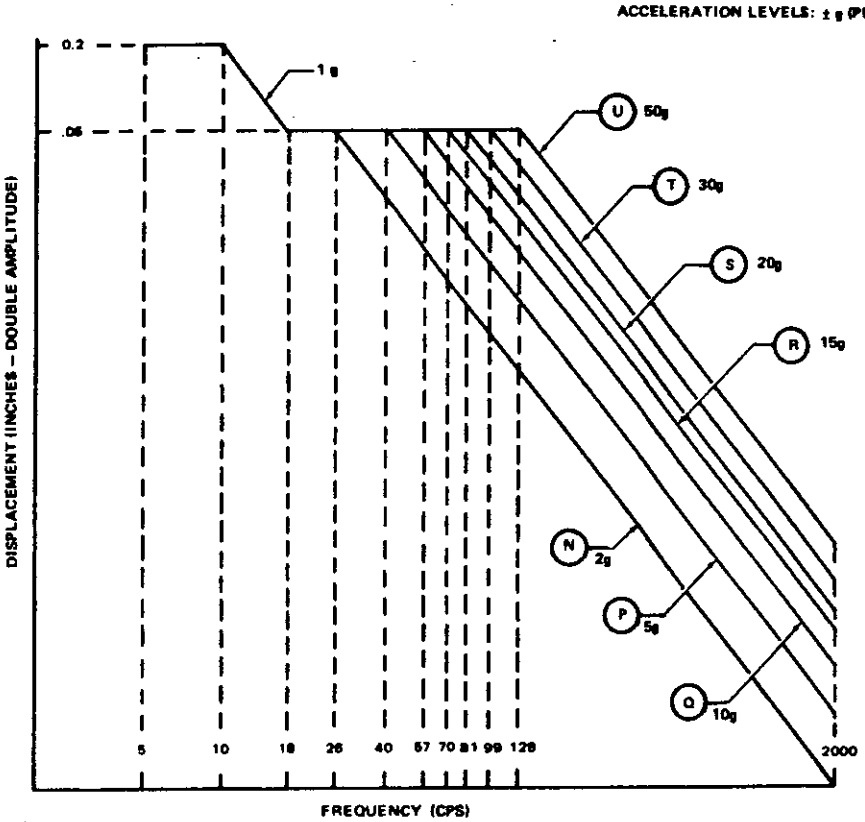
Note 1: For sinusoidal vibration resonance tests and cycling tests of items mounted in missiles and weighing more than 80 pounds, the vibratory accelerations shall be reduced by +/-1 g for each 20-pound increment of weight over 80 pounds. However, the vibratory acceleration shall in no case be less than 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. (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).

B. Curve selection chart for category (e) equipment

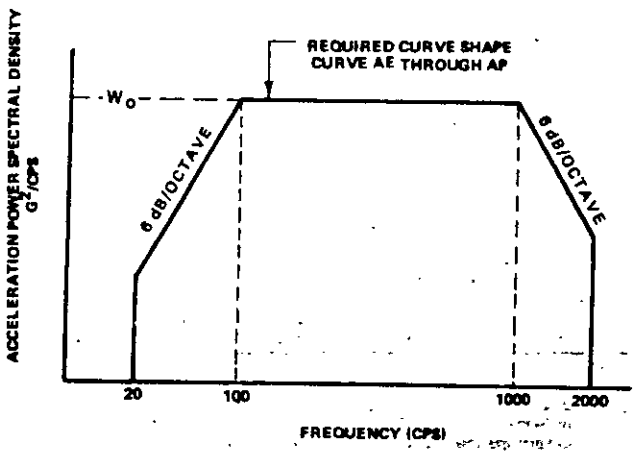
| Equipment location by vehicle section | Approximate thrust to weight ratio or thrust in pounds | Vibration test curves | |
|---|---|---|---|
| | | Sinusoidal | Random |
| All except booster | ALL | P or Q | AE, AF, or AG |
| By individual booster stage | 250,000 lbs. or less | Q or R | AH, AJ, or AK |
| | 250,000 lbs to 500,000 lbs | R or S | AK, AL, or AK |
| | Over 500,000 lbs | T or U | AM, AN, or AP |

## SINUSOIDAL VIBRATION CURVES




## RANDOM VIBRATION CURVES

RANDOM VIBRATION ENVELOPE




RANDOM VIBRATION TEST LEVELS

| TEST CURVE | ACCELERATION POWER SPECTRAL DENSITY $W_o$ ($G^2$/CPS) | COMPOSITE G–RMS MINIMUM |
|---|---|---|
| AE | 0.02 | 5.4 |
| AF | 0.04 | 7.6 |
| AG | 0.08 | 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 $G^2$/CPS UNITS.

*FIGURE 514.1–5. Vibration test curves for equipment installed in ground launched missiles – equipment category (e)*

TABLE 514.1-VI

A. Test procedure and time schedule chart for equipment installed in ground vehicles – equipment category (f)

| Equipment conditions | Procedure number | Procedure part number | Applicable tests (see 4 for test procedures) | | | | Test time schedule (per axis) | | | Curve |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Resonance search (4.5.1.1) | Resonance dwell (4.5.1.2) | Sinusoidal cycling (4.5.1.3) | Bounce vehicular (4.14.2) | Dwell time at each resonance (4.5.1.2) | Sinusoidal cycling time (4.5.1.3) | Sweep time 5-500-5 cps | |
| Vehicle and mileage unknown | VIII | | X | X | X | | Schedule A | | | |
| | | | | | | | 30 min | 3 hrs-less dwell time | 15 min (note 1) | V,W,orY |
| | | | | | | | Schedule B | | | |
| Vehicle known | VIII | | X | X | X | | Dwell 1/6 of cycling time at each resonance (30 min max.) | 20 min/1000 vehicle miles or as determined from vehicle mileage chart | 15 min (Note 1) | V,W,orY |
| To be used only when specified | IX | 1 | X | | | X | See 4.14.1 | | | |
| | | 2 | | | | X | See 4.14.2 | | | |
| | XIII | | | | | See 4.18.2 | | | | |

Note 1: Sweep time shall be 18 minutes if test frequencies go to 2 cps.

B. Curve selection chart for category (f) equipment

| Selection criteria | Curve |
|---|---|
| Wheeled vehicles except two-wheeled trailers | V |
| Tracked vehicles | W |
| Two-wheeled trailers | Y |

C. Vehicle mileage selection chart

| Group | Classification | Total Mileage |
|---|---|---|
| | Trailers, semitrailers, and dollies: | |
| A | Trailers, semitrailers and dollies | 6,000 |
| B | Trailer bodies and equipment | 3,000 |
| C | Electronic and missile systems trailers and semitrailers | 4,000 |
| | Wheeled vehicles: | |
| D | Tactical trucks (See Note) | 25,000 |
| E | Truck bodies, equipment (See Note) | 11,400 |
| F | Light weight, low mileage trucks | |
| | 1 – Sprung type | 4,000 |
| | 2 – Unsprung types | 5,000 |
| G | High flotation vehicles | 4,000 |
| H | Amphibious | 8,400 |
| I | Fire trucks | 5,000 |
| J | Commercial trucks, buses, passenger cars | 35,000 |
| | Tracked Vehicles: | |
| K | Tanks and self-propelled (SP) weapons | 5,000 |
| L | Armored personnel carriers (APC), cargo carriers, missile support vehicles, wreckers, recovery vehicles and cargo tractors (with towed load) | 6,000 |
| M | Engineer combat vehicle (ECF) and engineer assault vehicle, etc | 5,000 |
| N | Engineer crawler tractors – military type | 6,000 |
| O | Amphibious vehicle (LVT type) | 5,000 |
| P | Turret-mounted accessories such as integrally mounted flamethrowers and search lights | 700 |

Note: Unless otherwise specified, when equipment mounted in group D or E vehicles is not part of the basic vehicle structures, the total test mileage for group B or C vehicles, as applicable, shall be used to determine the test time of the time schedule B.

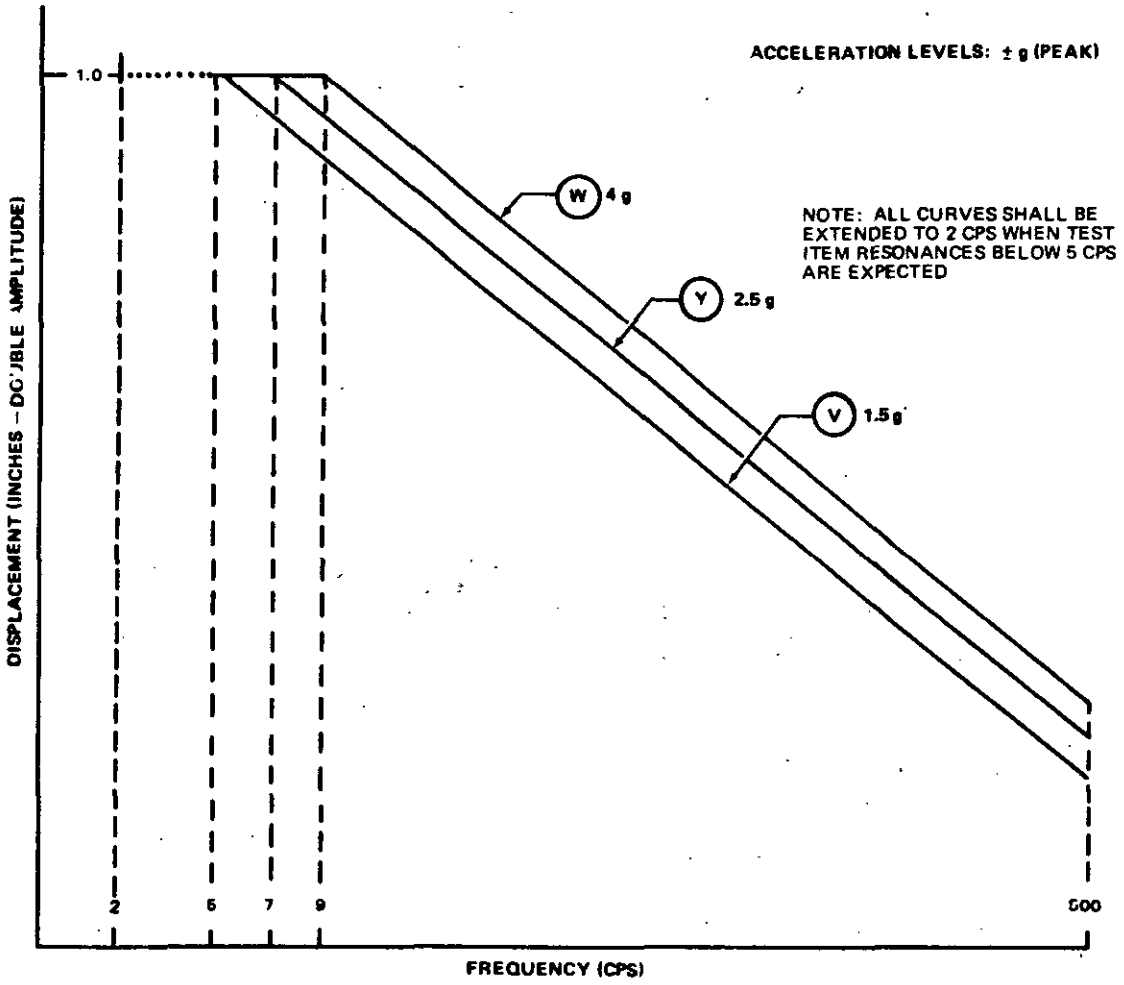



*FIGURE 514.1–6. Vibration test curves for equipment installed in ground vehicles – equipment category (f)*

TABLE 514.1-VII

A. Test procedure and time schedule chart for equipment transported by common carrier, land or air – equipment category (g)

| Equipment conditions | Procedure number | Procedure part number | Applicable tests (see 4 for test procedures) | | | | Time schedule (per axis) | | | | | | Curve (notes 1 and 2) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Resonance search (4.5.1.1) | Resonance dwell (4.5.1.2) | Sinusoidal cycling (4.5.1.3) | Bounce loose cargo (4.16.2) | Dwell time at each resonance (4.5.1.2) | | Sinusoidal cycling time (4.5.1.3) | | Sweep time .5-500-5 cps (note 3) | | |
| | | | | | | | Land | Air | Land | Air | Land | Air | |
| Tied down (notes 4, 6 and 7) | X | | X | X | X | | 2.5 min (note 5) | 10 min (note 5) | 15 min (note 5) | 1 hr. (note 5) | 15 min | 15 min (note 2) | AV, AW, AX, AY, AA or AQ |
| Loose cargo (Note 7) | XI | 1 | X | | | | See 4.16.1 | | | | | | |
| | | 2 | | | | X | See 4.16.2 | | | | | | |

Note 1: For sinusoidal vibration resonance tests and cycling tests of items transported in airplanes and helicopters and weighing more than 100 pounds, the vibratory accelerations shall be reduced by +/-1 g for each 25-pound increment of weight over 100 pounds. Derating shall apply only to the highest test level of curve AY. However, the vibratory acceleration shall in no case be less than 1.5g.

Note 2: For equipment transported in aircraft and weighing more than 100 pounds, the upper frequency limit of curve AY of figure 514.1-7 may be reduced according to the cut-off frequency vs. weight requirement of figure 514.1-9. When a transit case or crate is provided for the item, the case or crate shall be included in the test set-up for acceleration and frequency derating.

Note 3: Sweep time may be as long as 18 minutes if test frequencies go to 2 cps.

Note 4: When testing vibration isolated items, the resonant dwell time shall be broken into 5-minute test periods with 2-minute shut down intervals.

Note 5: Total test time per axis (resonant dwells plus cycling) is 15 minutes per 1000 miles for land transportation or one hour for aircraft transportation. For equipment shipped by both land and air, both tests shall be performed. (The load vehicle cycling time of 15 minutes per 1000 miles per axis is reduced 2.5 minutes per 1000 miles for resonance in that axis, and the aircraft cycling time of 1 hour per axis is reduced 10 minutes for each resonance in that axis. Land transportation times are per 1000 vehicle miles, which may be determined from table 514.1-VIC).

Note 6: Land and air curves for Procedure X shall be cycled separately in accordance with the applicable time schedules. The dwell time for each resonance of non-isolated items shall be determined from the total test time of the applicable curves. For example, if the resonance occurs where the applicable land vehicle curve represents a higher G level, the item shall be tested at each resonance (maximum of four) to the G level of the applicable land vehicle curve with a test time for each resonance equal to 1/6 of the total test time per axis for the land vehicle. Conversely, if the aircraft curve is equal to, or higher than, the land vehicle curve, the item shall be tested for each resonance (maximum of four) to the G level of the aircraft curve with a test time for each resonance equal to 1/6 of the cycling time per axis for aircraft.

Note 7: When a transit case or crate is provided for the test item, the case or crate shall be included in the test setup.

B. Curve selection chart for category (g) equipment

| Selection criteria | | Curve |
|---|---|---|
| Equipment shipped by tracked vehicles | | AV |
| Equipment shipped by truck, semitrailer, or railroad | | AW |
| Equipment shipped by two wheeled trailers | | AX |
| Equipment shipped by aircraft | | AY |
| Mounted items with vibration isolators (Note 1) | Cycling | AA |
| | Resonance dwell | AQ |

Note 1: For vibration isolated items, curves AA and AQ are to be used in the lower frequency range (below 13 and 20 cps, respectively) and a curve appropriate to the mode of transportation (AV, AW, AX, or AY) for higher frequencies.

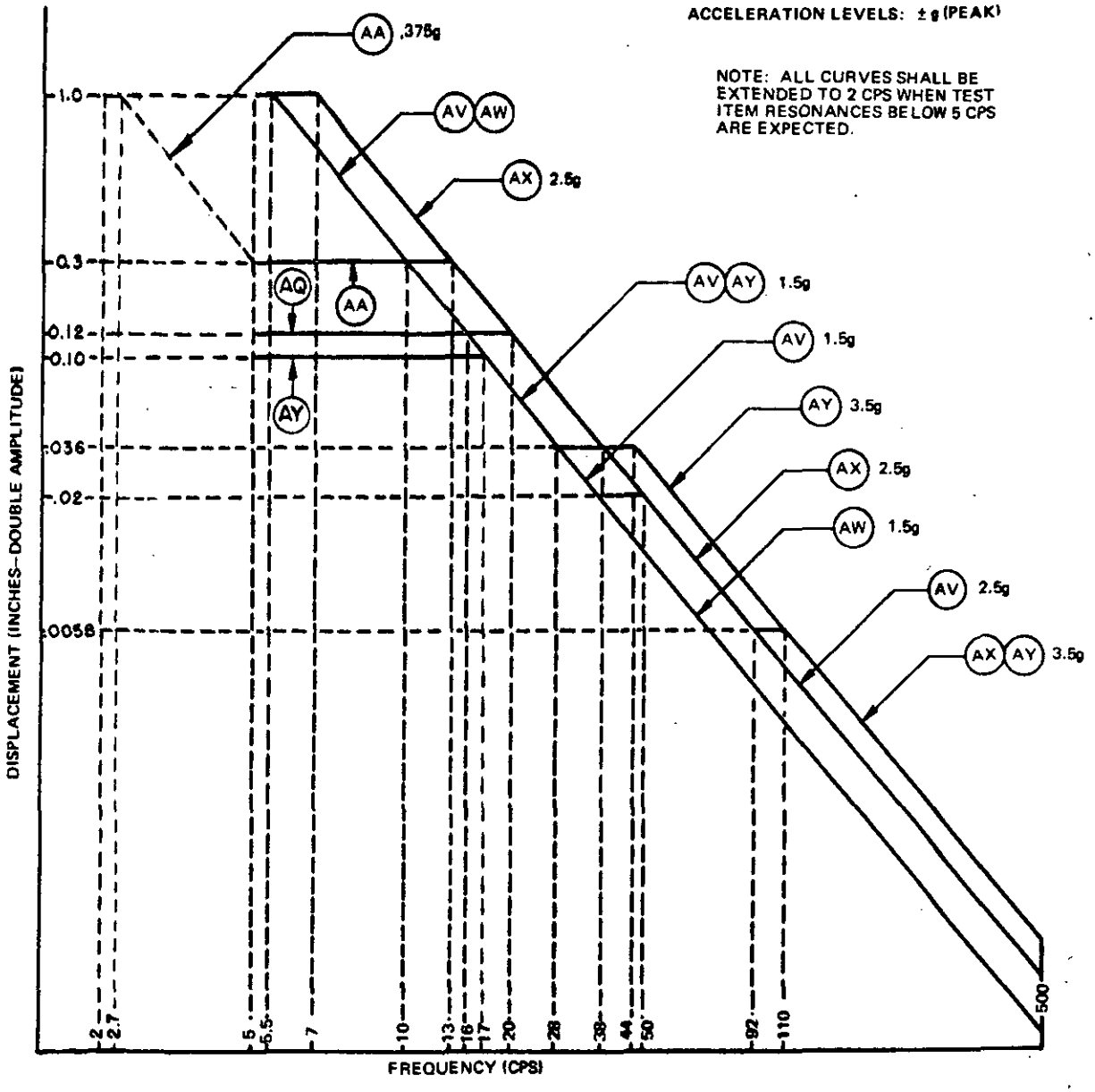



*FIGURE 514.1-7. Vibration test curves for equipment transported by common carrier, land or air – equipment category (g)*

TABLE 514.1-IX
Linear cycling rates

| Total frequency range | Frequency band (cps) | Sweep time in minutes (min-max-min) | Linear cycling rate (cps/min) |
|---|---|---|---|
| 2-500 cps or 5-500 cps as applicable | 2 to 5 | 3 | 2 |
| | 5 to 22.5 | 6 | 5.8 |
| | 22.5 to 110 | 5 | 35 |
| | 110 to 500 | 4 | 195 |
| 5-2000 cps | 5 to 22.5 | 6 | 5.8 |
| | 22.5 to 110 | 5 | 35 |
| | 110 to 500 | 4 | 195 |
| | 500 to 900 | 3 | 267 |
| | 900 to 2,000 | 2 | 1,100 |

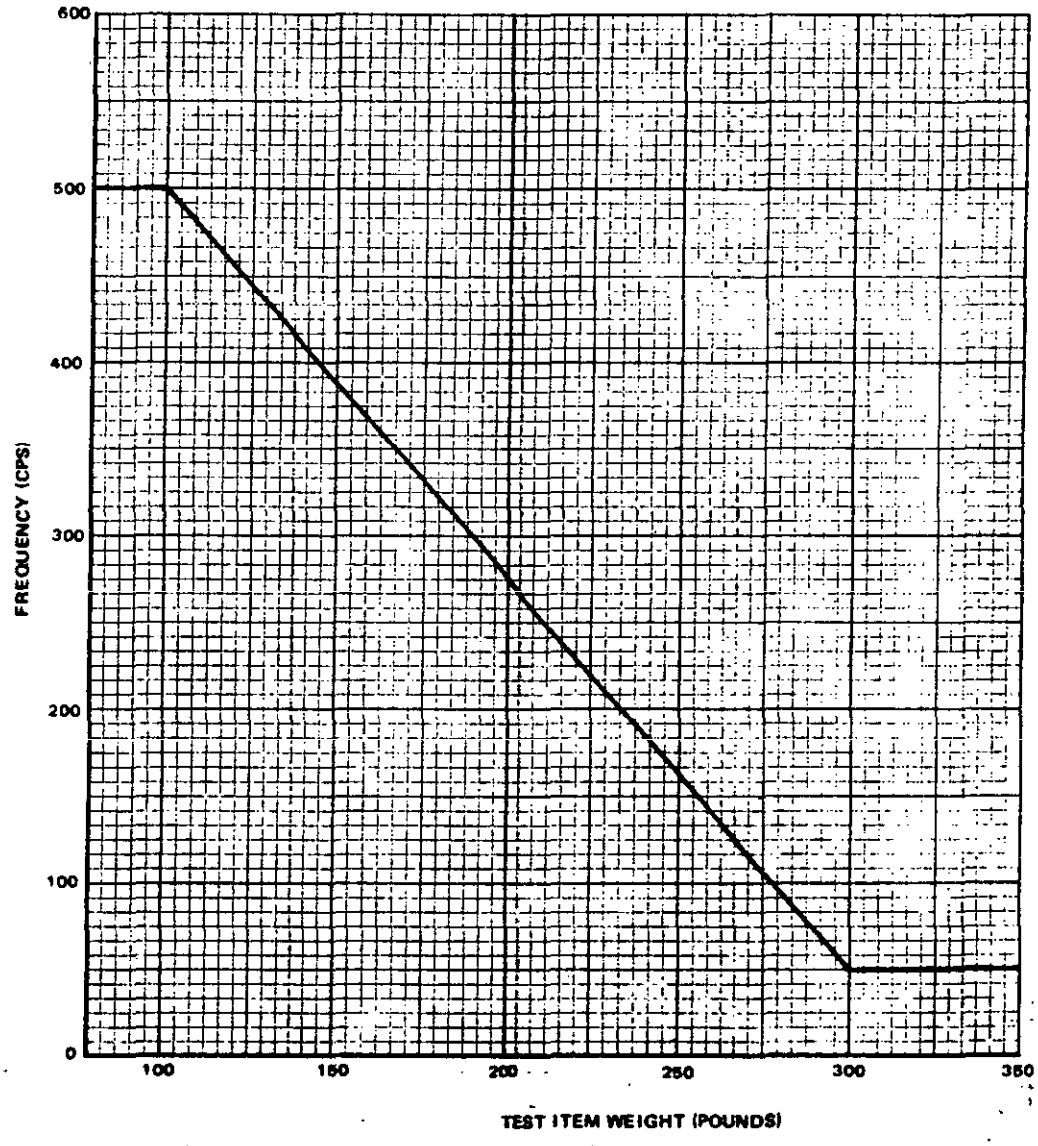



*FIGURE 514.1-9. Cut-off frequency vs weight; equipment shipped by aircraft.*

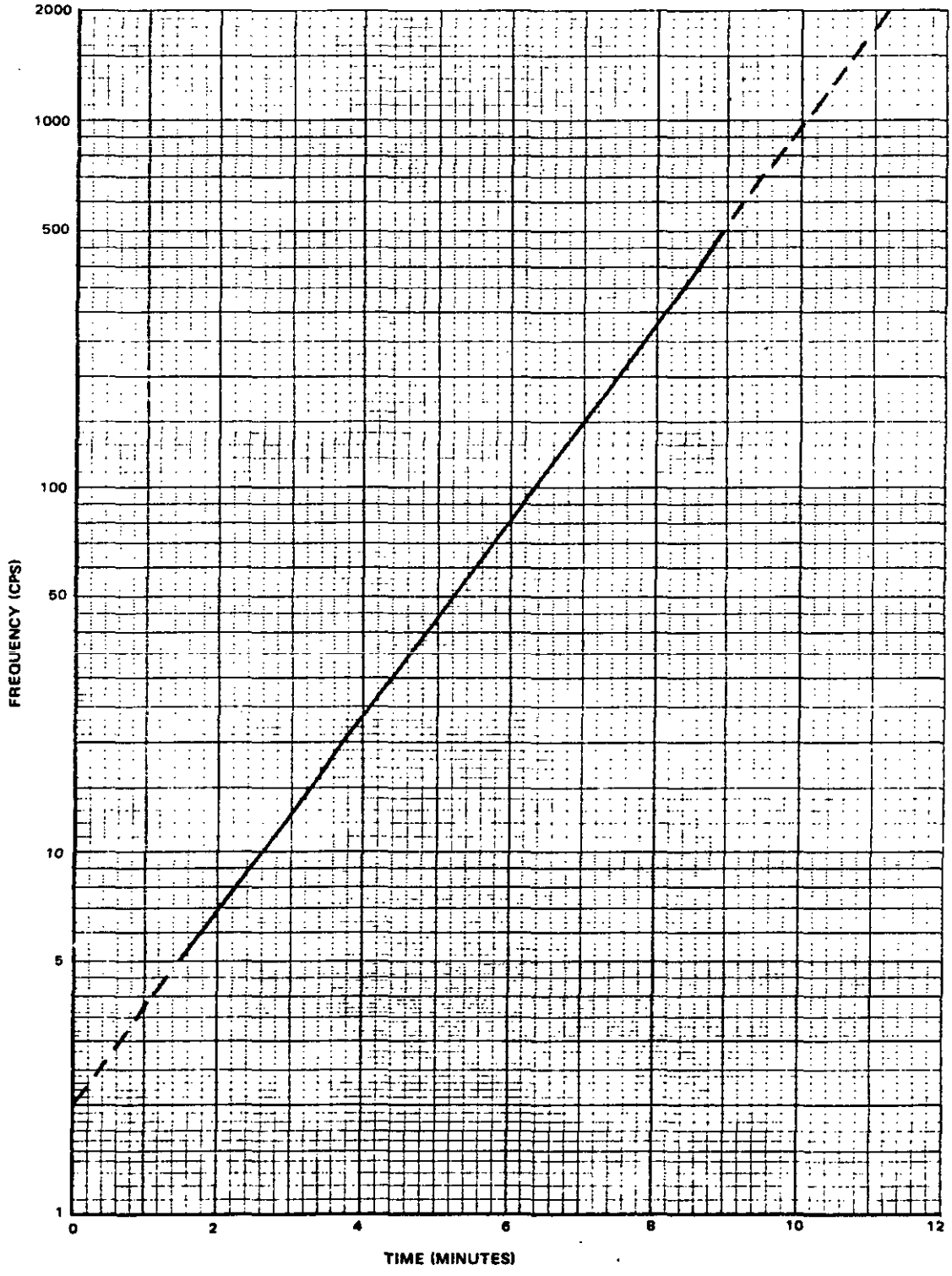



*FIGURE 514.1–10. Logarithmic sweep*

METHOD 515.1

ACOUSTICAL NOISE

1. Purpose. - The acoustical noise test is performed to determine the effects on equipment of acoustic sound fields that are characteristic of aircraft, missile and other high performance vehicles. In general, equipments located in areas where noise levels are 130 dB overall or less will not require testing to noise environments. This method is primarily for use with equipment mounted internal to the vehicle structure, but may also be applicable for use with externally mounted equipment. The acoustical noise test is not a substitute for the conventional sinusoidal or random vibration test.

2. Apparatus. - A reverberation type test chamber, suitable formed and proportioned to produce a diffuse sound field and a uniform sound energy density throughout the enclosure. A noise generator to produce or simulate a broad band noise spectrum. Measuring equipment suitable to accomplish these tests, including an octave band analyzer.

3. Procedure. -

3.1 Definitions and terms. - A comprehensive list of standard terminology is contained in United States of America Standards Institute document S 1.1-1960, titled "Acoustical Terminology (Including Mechanical Shock and Vibration)."

3.2 Criteria for application. - Some equipment is insensitive to acoustic stimulation even at very high levels. Other equipment may respond in a manner that will modify or disrupt the equipment function and in extreme cases mechanical failure may result. Equipment that is sensitive to vibration is usually sensitive to sound field exposure. For this reason a suitable vibration test is often a good indicator of acoustic sensitivity. However, it is possible that high frequency resonances of some responding equipment elements may be overlooked during the vibration test due to the high frequency limitations of the shaker and vibration attenuation of the fixture and the equipment under test. Of importance is the fact that some equipment may possess both sensitive and insensitive characteristics, and it may be difficult to ascertain, before a test is performed, whether the equipment is sensitive to acoustic stimulation. The following criteria are presented as a guide to initially determine whether equipment is sensitive to acoustic stimulation. Such criteria cannot be considered as the only determining factors. The final decision, whether to perform an acoustical noise test, must be supplemented by such additional factors as a description of the characteristics and duration of the end use acoustic environment, the location of the equipment within the vehicle structure, and a consideration of special mounting means or protective enclosures employed for the equipment.

3.2.1 Equipment insensitive to acoustic stimulation. - This equipment is likely to have small surface areas, high mass to area ratios, and high internal damping. Examples are as follows:

(a) High density modules, particularly the solid or encapsulated type.
(b) Modules or packages with solid state elements mounted on small constrained or damped printed circuit boards or matrices.
(c) Valves, hydraulic servo controls, or auxiliary power unit pumps.
(d) Equipment surrounded by heavy metallic castings, particularly those that are potted or are encased within the casting by attenuating media.

3.2.2 Equipment sensitive to acoustic stimulation. - This equipment is normally classified as microphonic or usually having large compliant areas of exposure, low mass to area ratios or low internal damping. Examples are as follows:

(a) Equipment containing microphonic elements with high frequency resonances such as electron tubes, waveguides, klystrons, magnetrons, piezoelectric components, or relays attached to thin plate surfaces.
(b) Equipment containing or consisting of exposed diaphragmatic elements such as pressure sensitive transducers, valves, switches, relays, or flat spiral antenna units.

3.3 Selection of test intensity. - The noise levels are divided into four intensity categories as listed in table 515.1-I. The categories are in order of increasing severity (overall sound pressure level) from A through D. The category should be selected as appropriate for the expected noise level of the end use environment.

TABLE 515.1-I Acoustical noise test category

| Category | Test overall sound pressure level (dB 1/) | Typical applications | | Exposure time (minutes) |
|---|---|---|---|---|
| | | Vehicle | Equipment location | |
| A | 140 | Aircraft | Majority of locations | 30 |
| B | 150 | Aircraft | Near the noise source or in the noise cone, if separated by thin partitions | 30 |
| C | 160 | Aircraft | External stores or open exterior compartments near the noise source or subject to the noise cone environment of any aircraft | 30 |
| | | Rocket | Majority of locations, exclusive of booster or engine compartments | 8 |
| D | 165 | Rocket | Booster or engine compartments, on site launch equipment or externally mounted pods near the noise source | 8 |

1/ Reference $2 \times 10^{-4}$ dynes/cm$^2$.

3.4 Procedure I. -

3.4.1 Test item mounting. - The test item should be softly suspended in the test chamber by means of springs or elastic cord. If a mounting structure is required between the soft suspension and the test item or to hold the soft suspension care must be exercised to assure that no spurious acoustic or vibratory inputs are introduced. The natural frequency of suspension shall be less than 25 cps. The test item shall be exposed on every surface to the sound field by centrally locating it in the test chamber. The test item volume should be no more than 10 percent of the test chamber volume. When the test chamber is rectangular, no major surface of the test item shall be installed parallel to a chamber wall.

3.4.2 Performance of test. -

Step 1 - The overall sound pressure level for the specified test category of table 515.1-I shall be introduced into the test chamber to conform with the octave band spectrum specified on figure 515.1-1 or 515.1-2 1/. The average sound pressure distribution (overall level) should be uniform within -2 to +4 dB of the desired value. The sound pressure field shall be measured without the test item mounted in the test chamber. Measurements shall be made by using a microphone (more than one if desired) to define the sound field within the test volume (central 10 percent of the chamber volume).

1/ Choice of figure 515.1-1 or 515.2-2 is dependent on test equipment availability.

Step 2 - The test item shall be placed in the chamber as specified in 3.4.1. At least three microphones shall be monitored. They shall be located in proximity to each major dissimilar test item surface, at least 18 inches from the test item surface or one-half the distance to the nearest chamber wall, whichever is less. The average overall sound pressure distribution around the test item shall be measured and be uniform within -2 to +4 dB of the desired value. However, for large or irregularly shaped items where this tolerance cannot be achieved, the tolerance shall be ±6 dB. Test times shall be as specified in table 515.1-I. The operation of the test item during the test shall be monitored when and as specified. Following the test and when measurements are made during or following the test, they shall be compared with the data obtained in accordance with section 3, General Requirments, paragraph 3.2.1. At the conclusion of the test, the test item shall be inspected in accordance with section 3, General Requirements, paragraph 3.2.4.

4. Summary. - The following details shall be specified in the equipment specification or test plan.

(a) Pretest data required (section 3, General Requirements, Paragraph 3.2.1).

(b) Test category (see 3.3).

(c) Whether operation during the test is required, and if and how the operation is to be monitored.

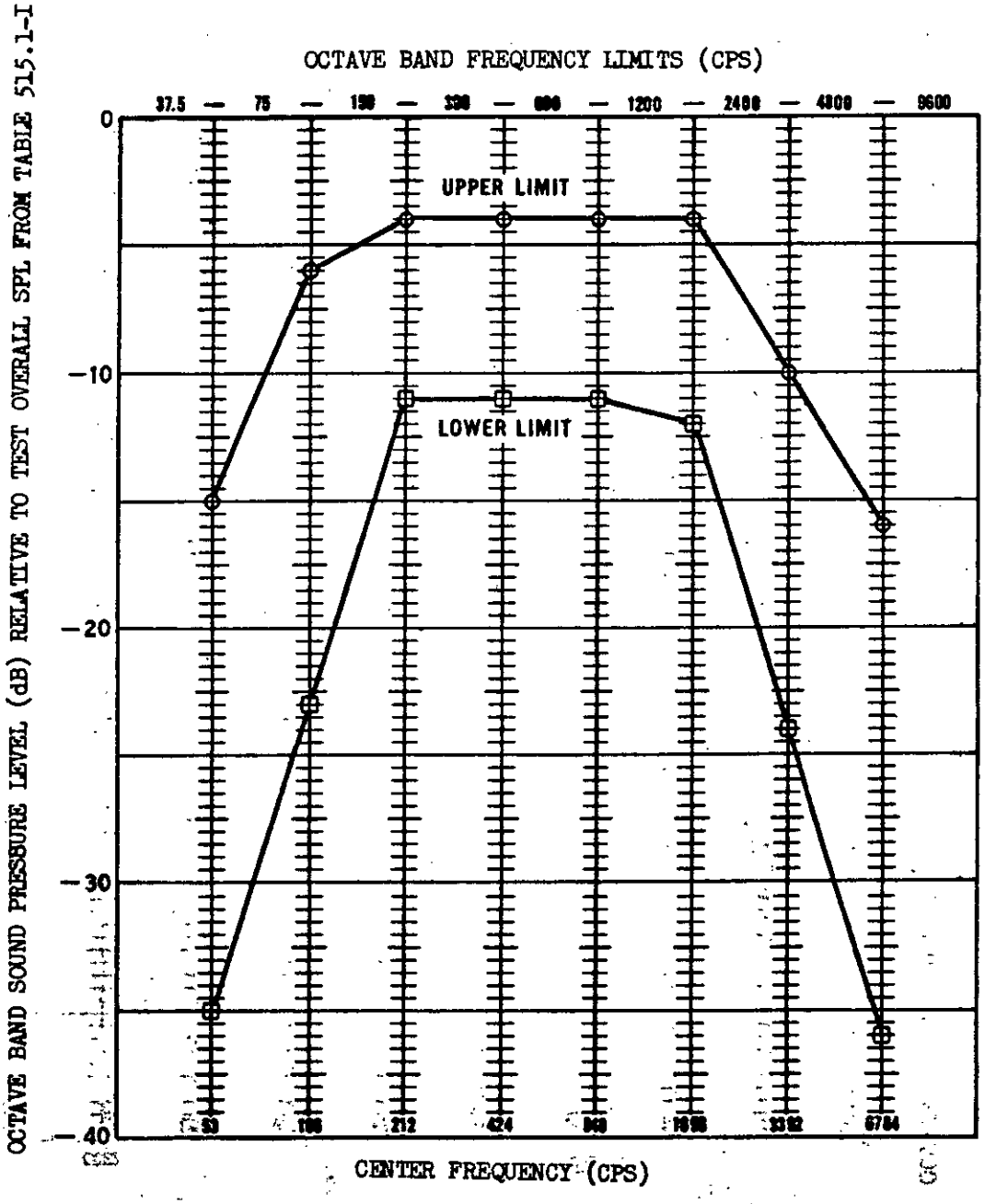



FIGURE 515.1-1. Octave band spectrum for acoustical noise test.
Octave bands conform to ASA Standard Z 24.10 (1953).

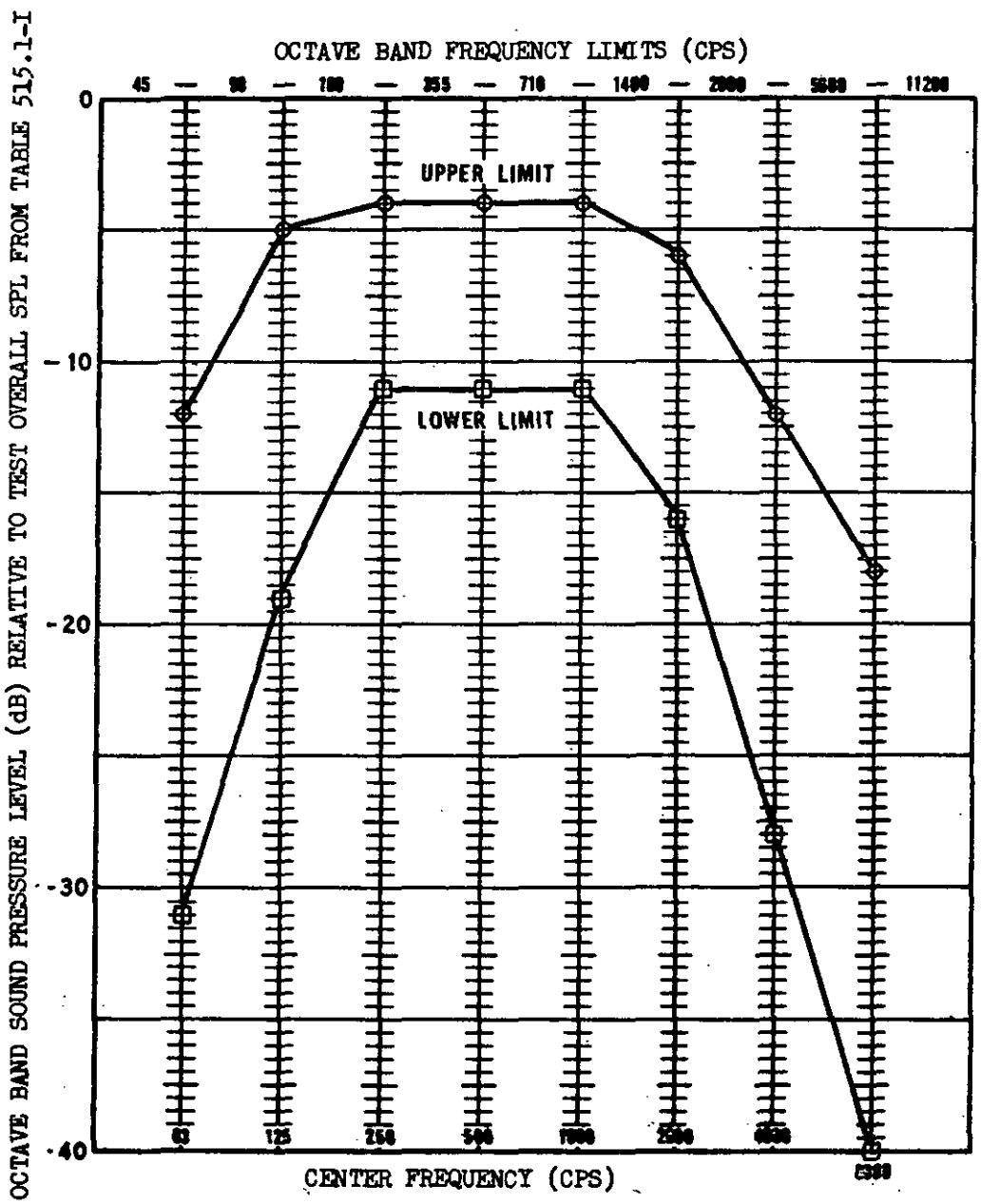



FIGURE 515.1-2. Octave band spectrum for the acoustical noise test. Octave bands conform to ASA Standard S 1.6 (1960).

# METHOD 516.1

## SHOCK

1. Purpose. - The shock test is performed to determine if equipment is constructed to withstand expected dynamic shock stresses and that performance degradations or malfunctions will not be produced by the service shock environment expected in handling, transportation, and service use.

2. Apparatus. -

2.1 Shock machine. - The shock machine utilized for Procedures I, III, and IV shall be capable of producing the specified input shock pulse shown on figure 516.1-1 or 516.1-2. The shock machine may be of the free fall, resilient rebound, nonresilient, hydraulic, compressed gas or other activating types. Apparatus for other procedures are included in the individual procedure.

2.1.1 Shock machine calibration. - The actual test item, a rejected item, or a rigid dummy mass shall be used to calibrate the shock machine for conformance with the specified wave shape. When a rigid dummy mass is used, it shall have the same center of gravity and the same mass as that intended for the test item and shall be installed in a manner similar to that of the test item. (When a rigid dummy mass or rejected item is used for calibration, the waveform during the actual test may be somewhat different from that observed during calibration. The shock machine shall then be calibrated for conformance with the specified waveform. Two consecutive shock applications to the calibration load shall produce waveforms which are all within the tolerance envelope given on figures 516.1-1 and 516.1-2. The calibrating load shall then be removed and the shock test performed on the actual test item. Provided all conditions remain the same, other than the substitution of the test item for the calibrating load, the waveform shall be considered to meet the specified test requirement. The actual test waveform shall be recorded for later use in a failure analysis if the test item fails.

2.2 Instrumentation. - The instrumentation used to measure the input shock pulse, in order to meet the tolerance requirements of the test procedure, shall have the characteristics specified in the following paragraphs.

2.2.1 Frequency response. - The frequency response of the complete measuring system, from the accelerometer through the readout instrument, shall be as specified by figure 516.1-3. Particular care shall be exercised in the selection of each individual instrument of the shock measuring instrumentation system in order to assure compatibility with the prescribed frequency response tolerance.

2.2.2 Accelerometer, piezoelectric. - When a piezoelectric accelerometer is employed as the shock sensor, the fundamental resonant frequency of the accelerometer shall be greater than 14,000 cps (resonant frequencies of 30 kc or higher are recommended). For suitable low frequency response the accelerometer and load (cathode follower, amplifier, or other load) shall have the following characteristics:

$RC > 0.2$

Where R = load resistance (ohms)
C = accelerometer, capacitance plus shunt capacitance of cable and load (farads)

2.2.3 Accelerometer, strain gage. - A strain gage accelerometer may be used, provided the undamped natural frequency is equal to or greater than 1,500 cps with damping approximately 0.64 to 0.70 of critical.

2.2.4 Accelerometer calibration. - The accelerometer shall be dynamically calibrated to the specified accuracy.

2.2.5 Accelerometer mounting. - The monitoring accelerometer shall be rigidly attached to the test item support fixture at or near the attachment point(s) of the test item.

3. Procedures. -

3.1 Shock pulse. - The shock pulses for Procedures I, III, and IV shall be as shown on figure 516.1-1 or 516.1-2 (whichever is specified). All points of the acceleration waveform obtained shall lie within the area enclosed by the tolerance limit lines. It is recommended that the saw tooth shock pulse be used, since its broad frequency spectrum tends to excite all resonant frequencies.

3.2 Mounting of test item. - The test item shall be rigidly attached to the shock machine table for Procedures I, III, and IV, in accordance with section 3, General Requirements, paragraph 3.2.2. Wherever possible, the test load shall be distributed uniformly on the test platform in order to minimize the effects of unbalanced loads.

3.3 Procedure I. Basic design test. - This procedure shall be used for shock testing of equipment assemblies (mechanical, electrical, hydraulic, electronic, etc.) of medium size, including items which mount on vibration isolators and equipment racks. Three shocks in each direction shall be applied along three mutually perpendicular axes of the test item (total of 18 shocks). If the test item is normally mounted on vibration isolators, the isolators shall be functional during the test. The shock pulse shape shall be in accordance with either figure 516.1-1 or 516.1-2, of amplitude a or b and time duration c or d, as specified. The test item shall be operating during the test if required by the equipment specification. At the conclusion of the test, the test item shall be operated and the results compared with the data obtained in accordance with section 3, General Requirements, paragraph 3.2.1. The test item shall then be inspected as specified in section 3, General Requirements, paragraph 3.2.4.

3.4 Procedure II. Transit drop test. -

3.4.1 Purpose. - This procedure shall be used for equipment, in its transit or combination case as prepared for field use, to determine if the equipment is capable of withstanding the shocks normally induced by loading and unloading of equipment. (This is not the logistics shipping environment experienced by shipping containers.)

3.4.2 Test conditions. - The test item shall be in its transit or combination case. For equipment 1,000 pounds or less, the floor or barrier receiving the impact shall be of solid, 2 inches thick, plywood backed by either concrete or a rigid steel frame. For equipment over 1,000 pounds, the floor or barrier shall be concrete or its equivalent.

3.4.3 Performance of test. - Subject the test item to the number and heights of drop as required in table 516.1-I. Upon completion of the test, the test item shall be operated and the results compared with the data obtained in accordance with section 3, General Requirements, paragraph 3.2.1. The test item shall then be inspected as specified in section 3, General Requirements, paragraph 3.2.4.

TABLE 516.1-I. Transit drop test (Procedure II)

| Weight of test item and case | Largest dimensions (inches) | Notes | Height of drop (in.) | No. of drops |
|---|---|---|---|---|
| Under 100 pounds man-packed and man-portable | Under 36 | A | 48 | Drop on each face, edge, and corner |
| | 36 and over | A | 30 | Total of 26 drops |
| 100 to 200 pounds, inclusive | Under 36 | A | 30 | |
| | 36 and over | A | 24 | Drop on each corner |
| Over 200 to 1,000 pounds, inclusive | Under 36 | A | 24 | |
| | 36 to 60 | B | 36 | Total of 8 drops |
| | Over 60 | B | 24 | |
| Over 1,000 pounds | No limit | C | 18 | 4 edgewise drops<br>2 cornerwise drops |

Note A. Drops shall be made from a quick-release hook; or drop tester as made by the L.A.B. Corporation, Skaneateles, New York, or equal. The test item shall be oriented so that upon impact a line from the struck corner or edge to the center of gravity of the case and contents is perpendicular to the impact surface.

Note B. With the longest dimension parallel to the floor, the transit or combination case, with the test item within, shall be supported at the corner of one end by a block 5 inches in height, and at the other corner or edge of the same end by a block 12 inches in height. The opposite end of the case shall then be raised to the specified height at the lowest unsupported corner and allowed to fall freely.

Note C. While in the normal transit position, the case and contents shall be subjected to the edgewise and cornerwise drop test as follows (if normal transit position is unknown, the case shall be oriented such that the two longest dimensions are parallel to the "floor"):

1. Edgewise drop test. One edge of the base of the case shall be supported on a sill 5 to 6 inches in height. The opposite edge shall be raised to the specified height and allowed to fall freely. The test shall be applied once to each edge of the base of the case (total of four drops).

2. Cornerwise drop test. One corner of the base of the case shall be supported on a block approximately 5 inches in height. A block nominally 12 inches in height shall be placed under the other corner of the same end. The opposite end of the case shall be raised to the specified height at the lowest unsupported corner and allowed to fall freely. This test shall be applied once to each of two diagonally opposite corners of the base (total of two cornerwise drops). When the proportions of width and height of the case are such as to cause instability in the cornerwise drop test, edgewise drops shall be substituted. In such instances two more edgewise drops on each end shall be performed (four additional edgewise drops for a total of eight edgewise drops).

3.5 Procedure III. Crash safety test. - This procedure shall be used to determine the structural integrity of equipment mounting means. The test item or dummy load shall be attached by its normal points of attachment. The test item or dummy load shall be subjected to two shocks in each direction along three mutually perpendicular axes of the equipment (total of 12 shocks). The shock pulse shape shall be in accordance with either figure 516.1-1 or 516.1-2, of amplitude a or b and time duration c or d, as specified. There shall be no failure of the mounting attachment and the test item or dummy load shall remain in place and not create a hazard. However, bending and distortion shall be permitted.

3.6 Procedure IV. High intensity test. - This procedure shall be used where high acceleration, short time duration shock excitation results from handling, stage ignition, separation, re-entry, and/or high velocity aerodynamic buffeting experienced by missiles and/or high performance weapon systems. Two shocks shall be applied to the test item in each direction along each of three mutually perpendicular axes (total of 12 shocks). The shock pulse shape shall be in accordance with either figure 516.1-1 or 516.1-2, of amplitude a or b and time duration c or d, as specified. The test item shall be operating during the test if required by the equipment specification. At the conclusion of the test, the test item shall be operated and the results compared with the data obtained in accordance with section 3, General Requirements, paragraph 3.2.1. The test item shall then be inspected as specified in section 3, General Requirements, paragraph 3.2.4.

3.7 Procedure V. Bench handling test. - This procedure shall be used to determine the ability of equipment to withstand the shock encountered during servicing. The chassis and front panel assembly shall be removed from its enclosure, as for servicing, and placed in a suitable position for servicing on a horizontal, solid wooden bench top at least 1-5/8 inches thick. The test shall be performed, as follows, in a manner simulating shocks liable to occur during servicing:

Step 1 - Using one edge as a pivot, lift the opposite edge of the chassis until one of the following conditions occurs (whichever occurs first):

(a) The chassis forms an angle of 45 degrees with the horizontal bench top.

(b) The lifted edge of the chassis has been raised 4 inches above the horizontal bench top.

(c) The lifted edge of the chassis is just below the point of perfect balance.

Let the chassis drop back freely to the horizontal bench top. Repeat, using other practical edges of the same horizontal face as pivot points, for a total of four drops.

Step 2 - Repeat step 1, with the test item resting on other faces until it has been dropped for a total of four times on each face on which the test item could be placed practicably during servicing. The test item shall not be operating during the test. At the conclusion of the test, the test item shall be operated and the results compared with the data obtained in accordance with section 3, General Requirements, paragraph 3.2.1. The test item shall then be inspected as specified in section 3, General Requirements, paragraph 3.2.4.

3.8 Procedure VI. Rail impact test. - This procedure shall be used to determine the effect that impact, due to shipping and other types of transportation, will have on equipment. If an item can be shipped in two orientations, it shall be impacted once in each direction of each orientation at speeds of 8, 9, and 10 miles per hour ±5 percent (total of 12 impacts). If an item can be shipped only in one orientation, it shall be impacted twice in each direction of that orientation at speeds of 8, 9, and 10 miles per hour (a total of 12 impacts).

3.8.1 Apparatus. - The following equipment will be necessary to perform this test:

(a) Three ordinary railroad cars, with standard draft gear couplings.

(b) A prime mover for moving the cars.

(c) A calibrated means to determine that the speed at the time of impact is 8, 9, or 10 mph, within ±5 percent.

(d) Accelerometers and associated circuitry to measure the impact shock, and equipment response, if these measurements are specified.

3.8.2 Performance of test. -

(a) Two cars will act as buffer cars and be located on a level section of track. The air brakes shall be set in the emergency application position on both cars. The total buffer load excluding car weights shall be 140,000 pounds minimum.

(b) The test item shall be mounted on the end of the test car in direct contact with the floor and adquately blocked and secured to prevent any longitudinal, vertical, or lateral movement. Metal banding, or wire, of sufficient size or strength shall be used to provide additional tiedown strength. Positions of the equipment with respect to the test car and whether or not packaging is necessary shall be specified. If loading and tie-downs are not specified, all loading and tie-downs shall be in accordance with recommended practices of the Association of American Railroads.

(c) Impact the test car into the two loaded cars.

(d) Impact shall be made in progressive steps with impacts 8, 9, and 10 miles per hour. The speed just prior to impact shall be measured by electronic or electrical means.

3.9 Related shock tests. -

3.9.1 Missile launch or missile impact. - A test for simulating missile launch, missile impact, hard landings, etc., may be performed by employing a rocket sled test facility, compressed gas ram, or other high acceleration apparatus suitable for performing the required test.

3.9.2 Hardsites. - Equipment located in or at missile hardsites usually demands special tests, however, for some zones, special adaptations of conventional shock machines may be used. For the critical zones, shock tubes, explosion chambers, hydraulic actuators, etc., can be used.

3.9.3 High impact. - Unless otherwise specified, ballistic shock tests and high impact tests shall be performed in accordance with MIL-S-901.

3.9.4 Shipboard equipment. - Shock tests for shipboard equipment shall be performed in accordance with MIL-S-901.

3.9.5 Rough handling for packaged items. - Tests for shipping and handling shall be performed in accordance with MIL-P-116 or FEDERAL STD. NO. 101.

3.9.6 Fuzes and ammunition. - Shock tests for safety and operation of fuzes and ammunition shall be performed in accordance with MIL-STD-331.

3.10 Combined temperature and shock test. - Tests shall be performed at room ambient conditions unless a high or low temperature shock test is required, in which case the temperature extremes shall be as specified.

4. Summary. -

The following details shall be specified in the equipment specification or test plan.

(a) Pretest data required (section 3, General Requirements, paragraph 3.2.1).

(b) Procedure number.

(c) Shock pulse selection, specify shape, peak value, and duration (see 3.1).

(d) Whether the rail impact shock pulse input and test item response are to be measured (see 3.8.1(d)).

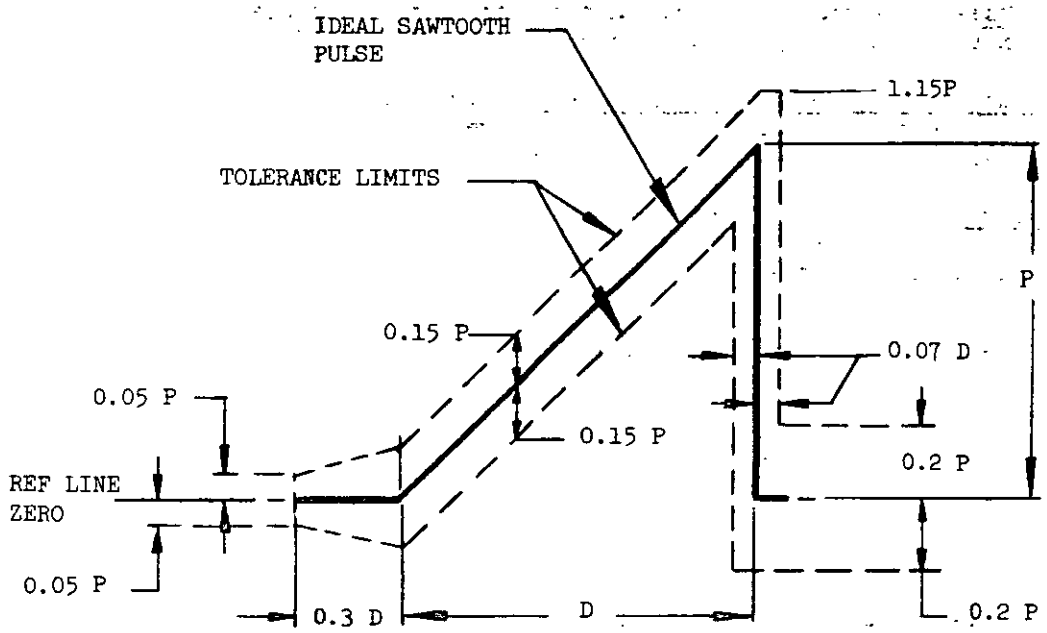
(e) Test item positioning with respect to the test car and whether packaging is necessary for the rail impact test (see 3.8.2(b)).

(f) Temperature extremes (see 3.10).

(g) Filter(s) used shall be identified.

(h) Whether operation during the test is required, mode of such operation, and if and how the operation is to be monitored.

(j) Loading and tie downs (see 3.8.2(b)).



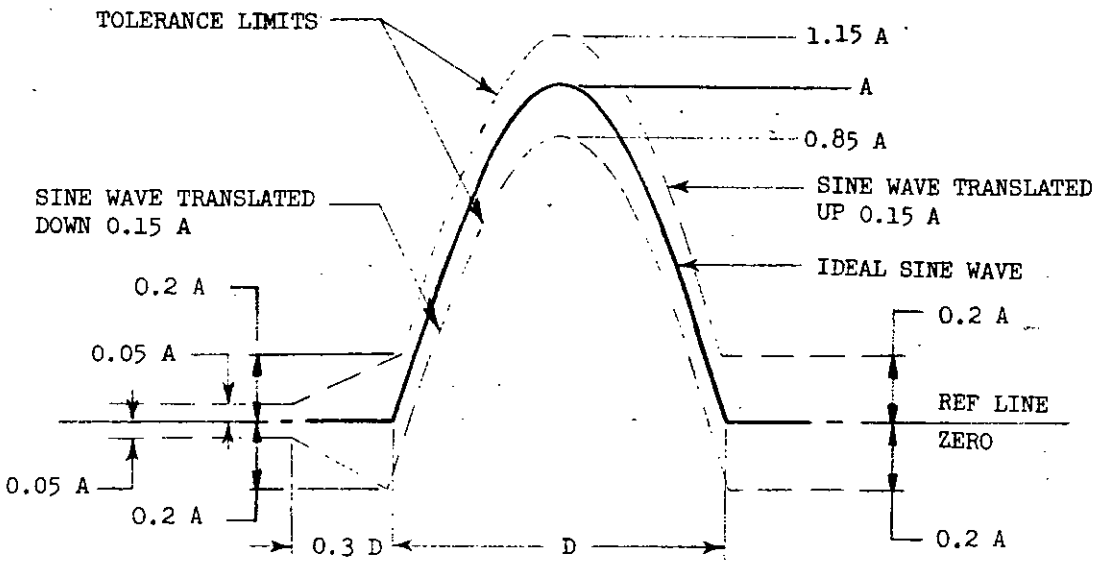

| PROCEDURE | TEST | PEAK VALUE (P) g's | | NOMINAL DURATION (D) ms | |
|---|---|---|---|---|---|
| | | FLIGHT VEHICLE EQUIPMENT (a) | GROUND EQUIPMENT (b) | FLIGHT VEHICLE EQUIPMENT (c) | GROUND EQUIPMENT (d) |
| I | BASIC DESIGN | 20 | 40 2/ | 11 | 18 |
| III | CRASH SAFETY | 40 | 75 | 11 | 11 |
| IV | HIGH INTENSITY | 100 | 100 | 6 | 11 |

NOTES: 1/ SHOCK PARAMETERS (a) AND (c): RECOMMENDED FOR EQUIPMENT NOT SHOCK MOUNTED AND WEIGHING LESS THAN 300 POUNDS.

2/ EQUIPMENT MOUNTED ONLY IN TRUCKS AND SEMITRAILERS MAY USE A 20g PEAK VALUE.

3/ THE OSCILLOGRAM SHALL INCLUDE A TIME ABOUT 3D LONG WITH A PULSE LOCATED APPROXIMATELY IN THE CENTER. THE PEAK ACCELERATION MAGNITUDE OF THE SAWTOOTH PULSE IS P AND ITS DURATION IS D. THE MEASURED ACCELERATION PULSE SHALL BE CONTAINED BETWEEN THE BROKEN LINE BOUNDARIES AND THE MEASURED VELOCITY CHANGE (WHICH MAY BE OBTAINED BY INTEGRATION OF THE ACCELERATION PULSE) SHALL BE WITHIN THE LIMITS OF $V_i \pm 0.1\ V_i$, WHERE $V_i$ IS THE VELOCITY-CHANGE ASSOCIATED WITH THE IDEAL PULSE WHICH EQUALS 0.5 DP. THE INTEGRATION TO DETERMINE VELOCITY CHANGE SHALL EXTEND FROM 0.4D BEFORE THE PULSE TO 0.1D AFTER THE PULSE.

FIGURE 516.1-1. Terminal-peak sawtooth shock pulse configuration and its tolerance limits




| PROCEDURE | TEST | PEAK VALUE (A) g's | | NOMINAL DURATION(D) ms | |
|---|---|---|---|---|---|
| | | FLIGHT VEHICLE EQUIPMENT (a) | GROUND EQUIPMENT (b) | FLIGHT VEHICLE EQUIPMENT (c) | GROUND EQUIPMENT (d) |
| I | BASIC DESIGN | 15 | 40 2/ | 11 | 18 |
| III | CRASH SAFETY | 30 | 75 | 11 | 11 |
| IV | HIGH INTENSITY | 100 | 100 | 6 | 6 |

NOTES: 1/ SHOCK PARAMETERS (a) AND (c): RECOMMENDED FOR EQUIPMENT SHOCK MOUNTED OR WEIGHING 300 POUNDS OR MORE.

2/ EQUIPMENT MOUNTED ONLY IN TRUCKS AND SEMITRAILERS MAY USE A 20g PEAK VALUE.

3/ THE OSCILLOGRAM SHALL INCLUDE A TIME ABOUT 3D LONG WITH A PULSE LOCATED APPROXIMATELY IN THE CENTER. THE ACCELERATION AMPLITUDE OF THE IDEAL HALF SINE PULSE IS A AND ITS DURATION IS D. THE MEASURED ACCELERATION PULSE SHALL BE CONTAINED BETWEEN THE BROKEN LINE BOUNDARIES AND THE MEASURED VELOCITY CHANGE (WHICH MAY BE OBTAINED BY INTEGRATION OF THE ACCELERATION PULSE) SHALL BE WITHIN THE LIMITS $V_i \pm 0.1\ V_i$ WHERE $V_i$ IS THE VELOCITY-CHANGE ASSOCIATED WITH THE IDEAL PULSE WHICH EQUALS $2AD/\pi$. THE INTEGRATION TO DETERMINE VELOCITY CHANGE SHALL EXTEND FROM 0.4D BEFORE THE PULSE TO 0.1D AFTER THE PULSE

FIGURE 516.1-2. Half sine shock pulse configuration and its tolerance limits

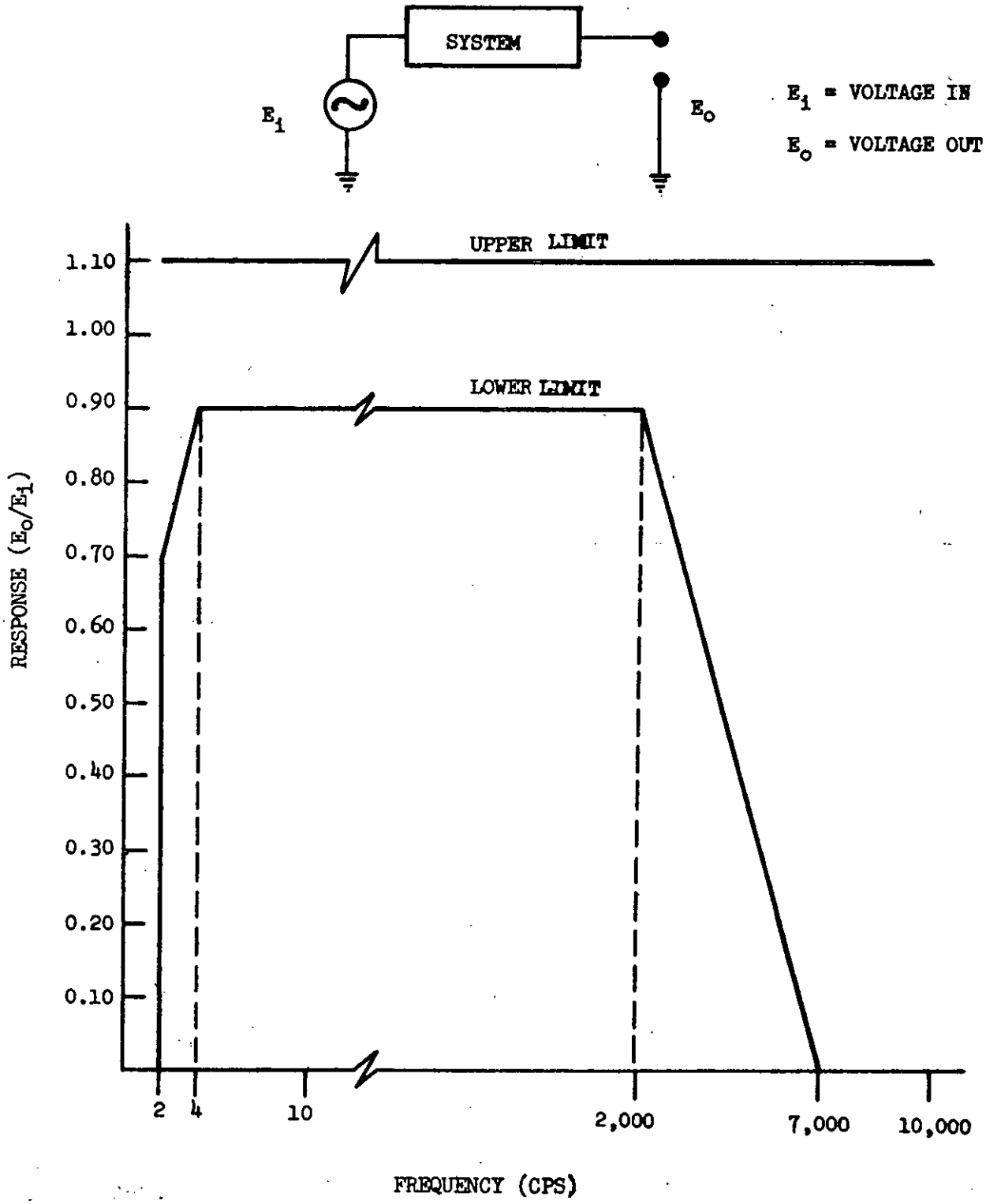



FIGURE 516.1-3 System frequency response

# METHOD 517.1

## SPACE SIMULATION

## (UNMANNED TEST)

1. Purpose.- The tests described herein are intended for the evaluation of space vehicle components, space vehicle subsystems and complete space vehicles including installed equipment.

The space simulation test is performed to determine whether space vehicles, such as satellites, external instrumentation packages, spacecraft, and space stations with associated equipment can withstand the deleterious effects of very low pressures, low temperatures, and solar radiation. Ordinarily, this test will require establishing realistic temperature distribution across and through the test item. Aerodynamic heating is not usually considered a part of this test but may be partially simulated, if so specified, by the application of heat.

The details of a space simulation test depend entirely on the particular environmental condition to be simulated and on the purpose and type of test to be simulated and performed. One of the most significant environments of outer space which must be simulated is that of extremely low pressure. Effects of this environment are the change in convective and conductive heat transfer characteristics. While outer space pressures have been measured as low as $10^{-16}$ Torr it is generally accepted that an operating pressure of $10^{-5}$ Torr is sufficient to avoid convective and gaseous conductive heat transfer and electrical discharge, even though it does not duplicate space conditions in terms of gas material interaction at the surface of the test vehicle. No accurate means exists for calibrating instrumentation to pressures lower than $1 \times 10^{-10}$ Torr, however, it appears that the outer space pressures could be as low as $10^{-16}$ Torr. Pressure levels for various effects simulation are given in table 517.1-I.

Different procedures can be used to simulate the radiant heat transfer effects of the space environment.

1.1 Procedure I utilizes the confining surfaces of the chamber to simulate the cold absorbing nature of space and the radiant heat is provided from a simulated solar spectrum input. Energy collimated within a few degrees of the true solar condition irradiates the test object held in position by a fixed or movable fixture. By a combination of motion or repositioning of the test vehicle and programmed control of the solar source, simulated orbital or space conditions are achieved.

Simulation of reflected solar (albedo) radiation and planetary emitted infrared radiation is generally accomplished by utilizing judiciously located infrared heat sources to prevent undesirable blockage or "shadows".

1.2 Procedure II utilizes the confining surfaces of the chamber to simulate the cold absorbing nature of space and the radiant heat is provided from an infrared source.

TABLE 517.1-II. Average radiation characteristics of planets

| Planet | Incident radiation intensity ($w/m^2$) | Planet reflectivity 1/ | Planet thermal radiation ($w/m^2$) 2/ | Planetary equivalent black body temperature (K°) |
|---|---|---|---|---|
| Earth | 1400 | 0.34 | 213 | 250 |
| Mars | 626 | 0.148 | 134 | 226 |
| Venus | 2740 | 0.67 | 226 | 249 |
| Earth's moon | 1400 | 0.072 | 336 | 284 |

1/ This is the albedo
2/ This is an emissivity function

Performance requirements for a specific test should reference the space simulator classification shown in table 517.1-III.

TABLE 517.1-III. Solar simulator classification

| | Class I | Class II | Class III |
|---|---|---|---|
| Uniformity | ±3% max. | ±5.0% max. | Greater than ±5% |
| Solar subtense angle (whole angle) | ±4° max. | ±8° max. | Greater than ±4° |
| Spectrum | In accordance table IV | 1/ | 2/ |

1/ Calculated effective absorptance within 5% of calculated Johnson solar absorptance.
2/ Calculated effective absorptance within 10% of calculated Johnson solar absorptance.

Temporal variation of intensity in the test volume shall not deviate from the average as listed in table 517.1-III for that class uniformity. Intensity and uniformity measurements shall be made with a sensor which does not exceed 7 $cm^2$ in area and approximates a square or circle in shape.

It is likely that the spectrum of the simulated radiation will differ in certain wavelength regions from the spectrum of the assumed true solar radiation, listed in table 517.1-IV. Total effective absorptance of the surface of the test item should not differ significantly from the total solar absorptance value if test item temperature errors are to be avoided.

1.3 Procedure III utilizes the confining temperature controlled surfaces of the chamber to force a given calculated temperature on the test object.

1.4 Procedure IV utilizes an infrared source to program heat around the object in zones to simulate orbital skin temperature.

1.5 Procedure V utilizes a conductive temperature controlled surface for mounting internal components to simulate their heat transfer condition.

1.6 Procedure VI utilizes chamber to simulate the pressure effect of space.

1.7 Procedure VII utilizes a cryogenic heat sink plus vehicle heaters.

2. Apparatus. - This section deals with general performance requirements of some apparatus used in space simulation testing. Performance requirements for a specific test should be called out in the equipment specification.

2.1 Thermal vacuum chamber. - The test chamber shall be capable of providing a vacuum of at least $10^{-5}$ Torr with the test item installed. Vacuum gauges shall be calibrated in accordance with ASTM Standard E-295.

Pressure levels recommended for various effects simulation are given in table 517.1-I.

TABLE 517.1-I. Pressure levels for effects simulation

| | |
|---|---|
| Structural | 1 atm to 10 Torr |
| Radiant heat transfer | Below $10^{-5}$ Torr |
| Dielectric strength | Below $10^{-5}$ Torr |
| Material evaporation | To $10^{-7}$ Torr |
| Surface effects | Below $10^{-9}$ Torr |
| | 10-Torr (particular tests are shown in tables 517.1-III and 1-VI) |

2.2 Heat source (radiant). - Heat source systems shall be capable of producing the heating effects of solar energy, planet radiation, and albedo on test specimens within the space simulator.

2.2.1 Solar simulator. - The simulator shall be capable of providing radiant energy corresponding to that of the sun in space. The total solar energy shall be equal to the applicable value of table 517.1-II, column 2. The degree to which the solar environment must be simulated for particular tests is shown in table 517.1-IV.

TABLE 517.1-IV. Solar electromagnetic energy distribution

| Band No. | Percent of total solar irradiance | Wavelength band (angstroms) | Allowable variation of band energy, percent |
|---|---|---|---|
| 1 | 2.6 | 2,500-3,300 | ±50 |
| 2 | 20.8 | 3,300-5,000 | ±25 |
| 3 | 25.5 | 5,000-7,000 | ±10 |
| 4 | 17.3 | 7,000-9,000 | ±10 |
| 5 | 10.8 | 9,000-11,000 | ±15 |
| 6 | 11.2 | 11,000-15,000 | ±20 |
| 7 | 8.3 | 15,000-25,000 | ±30 |

2.2.2 Heat flux simulator.- The thermal effects of the space environment upon a spacecraft may be simulated using radiant energy sources entirely in the infrared (heat) portion of the spectrum under either of the following conditions:

(a) If a piece of equipment is shielded from direct view of sun and planets in flight mode

(b) If a spacecraft or a piece of equipment which is directly viewed by the sun and planets is configured such that a thermal source will supply the same heating effect as a source simulating the spectrum and collimation of the sun would. This would be applicable for an equipment: (1) with a uniform external finish $\alpha/\epsilon$ (Alpha/Epsilon), (2) with no sensitive parts mounted in deep crevices, where the collimation of the radiation would be important, or (3) where the rotational motion in space would be such as to result in effectively uniform solar/planet illumination sufficient to cancel the effects of crevices and non-uniform $\alpha/\epsilon$ surface finishes.

2.2.2.1 Open structure line source. - Quartz lamps, carbon cloth, tungsten wire, strip and tubular heaters, and other similar means may be utilized to simulate the heating effects of solar energy, planet radiation,and albedo on test specimens within cryogenically cooled space simulation chambers. Radiation units and supporting structures shall be designed for minimum blockage area, ease of mounting, low out-gassing, and controllability of radiation intensity.

2.3 Heat sink (radiant). - Both the temperature and emissivity, or blackness, of the cryogenic shrouds are important parameters in simulating the blackness of space. The low temperature reduces the radiation emitted by the walls in accordance with the Stefan-Boltzmann Law, and the high emissivity causes the walls to absorb any radiation impinging upon them rather than reflecting the energy back to the test vehicle. A 100° Kelvin wall with a 0.95 emissivity will simulate the space environment to within 1 percent for a 300° Kelvin vehicle. Radiation can leave the surface of the chamber by either reflection or emission and control of both is necessary to maintain good simulation of the space environment. Total reflected and emitted radiation, exclusive of the solar simulation arriving at the test vehicle shall be less than 50 watts per square meter.

Warm surfaces, such as windows, feed through ports, chamber walls, etc., should be kept to a minimum and should be covered with cooled plates when they are not in use.

2.4 Contamination controls. - Contamination levels shall be controlled and measured to insure that emissivity and absorbtive values are not altered by more than 5% of the initial values of the flight or test hardware from time of acceptance of test article to completion of the test.

3. Preparation for test. -

3.1 Information required. - In preparing the specimen for a test, typical information required is:

(a) Need for simulating planet/moon radiation and albedo.
(b) Rotational modes and attitude orientation, as applicable.
(c) Programming solar radiation in accordance with the mission (considering the day and night orbiting periods plus cislunar and translunar missions).
(d) Equipment operation duty cycles.
(e) Duration of test.
(f) Method for monitoring test item during test.
(g) Operating parameters to be monitored.
(h) Allowable deviation from specified tolerances.
(i) Coupling of radio frequency outputs to dummy loads.
(j) Substitution of power source having volt-ampere characteristics similar to the vehicle's primary power supply.
(k) Emission of fuels and oxidizers.
(l) Statement of reliability and failure criteria.
(m) Peripheral heating and cooling devices to maintain proper conditions of equipment under test until flight conditions are established.
(n) Aerodynamic heating simulation requirement.
(o) Vehicle surface emissivity and absorptivity.
(p) Vehicle thermal balance computations.
(q) Minimum heating conditions (i.e., the coldest condition which is often the most difficult to achieve).
(r) Auxiliary power to supplement power equipment for chamber and equipment under test.
(s) Other applicable requirements.

3.2 Simulator performance parameter validation. - The instrument performance chart, table 517.1-V, indicates the level of performance required of instruments for indicated parameters: absolute accuracy, reproducibility, response time, view angle, discrimination or sensitivity, and miscellaneous items for the evaluation of solar simulation.

3.3 Test duration. - When the intended mission time of the test item is such that the test item will be exposed to low pressure conditions for periods in excess of 24 hours, the test chamber shall be maintained at a pressure of at least $1 \times 10^{-5}$ Torr for not less than 24 hours to properly validate the performance of the test item. Test item with intended flight times of less than 24 hours shall be exposed to low pressure for a time equal to or longer than the actual intended flight time to properly validate the performance of the test item.

TABLE 517.1-V. Solar simulator - instrumentation performance requirements

| Parameter | Absolute accuracy | Repeatability | Response time | Miscellaneous |
|---|---|---|---|---|
| Total irradiance | ±3% | ±1% | 1 min. max. | Spectral sensitivity ±2% for 2500-25,000 Angstrom |
| Irradiance uniformity | N/A | ±1% | 1 min. max. | Scan time must be compatible with response time |
| Solar subtense angle divergence | 1/4° | 1/4° | N/A | Reference to axis of chamber |
| Temporal stability | ±5% | ±5% | 1 sec. | See note 3 |
| Spectral distribution | | | | See note 3 |

Note 1 View angle should be 5 degrees or greater than the solar subtense angle.

Note 2 Temporal stability as used in this standard means the intensity fluctuation of the source where the source is defined in its broadest sense to include the optics. No quantitative value can be given that will serve as a universal stability standard to which all sources must comply. It is self evident that the time constant of the test object or perhaps a local area of interest would have a direct bearing on the resulting criterion. Further, by the broadest interpretation of temporal stability, intensity variations during periods of lamp or electrode replacement must be considered. For the present, it appears appropriate to merely state that the periods of fluctuation must be considerably less than the time constant of the test area of interest.

Note 3 Spectral distribution shall be measured at a carefully defined point in the beam. The bandwidth shall be no longer than that indicated in table 517.1-IV. Bandwidths of 500 Angstrom are preferable. The total area under the spectral curve shall be normalized to 1400 $w/m^2$ for comparison with the Johnson Spectral Curve having equivalent units. The accuracy shall be 1/2 the smallest number in the applicable level of table 517.1-V. Calibration of spectral measuring equipment shall conform to current NBS recommended practices. If some other means of measuring spectral distribution shall be used as a multiple filter radiometer, then proof of its calibration against the same source through use of accurate measurements with a monochromator must be furnished.

4. Procedures. -

4.1 Procedure I - Solar simulation. - The test item shall be subjected to a pressure of $10^{-5}$ Torr or lower in order to virtually eliminate heat transfer by convection. The test item shall initially "see" black coated chamber walls maintained at $\leq 100°K$ in order to simulate the heat sink of space. Simulated solar radiation shall be applied to the test item from the direction corresponding to that of the sun in space.

The test object shall be mounted in the test chamber (apparatus 2.1) having a cryogenic heat sink (apparatus 2.3) and a solar simulator (apparatus 2.2.1). The specimen shall be installed in the test volume on a fixture supported by low heat conduction means. If orbital simulation is required, the fixture shall provide means of motion. Albedo and planetary radiation may be simulated by the use of heat flux sources (apparatus 2.2.2).

Recommended parameters for specific solar test requirements are shown in table 517.1-VI.

TABLE 517.1-VI. Significant parameters for solar simulation

| Parameter | Actual space condition | Thermal tests | Solar cell tests 2/ | Collector type power systems | System tests |
|---|---|---|---|---|---|
| Intensity | $1400 W/M^2$ | 1200-1600 | 1200-1400 | 1200-1400 | 1200-1400 |
| Uniformity 1/ | --- | Class II | Class I | Class III ±10% | ±2 to 5% |
| Solar subtense angle | 32' | Class I | Class III | 1° | Class II |
| Spectral | Assumed NRL curve | ← TABLE 517.1-IV → | | | |
| Cold, black space | $10^{-6}$ watts/$M^2$ | Less than 50 $W/M^{-2}$ received at test article | | | |

1/ In test plane
2/ Near earth orbit

4.1.1 Performance of test. - For the following, refer to Section 3 on General Requirements, paragraph 3.2 of MIL-STD-810.

The test item shall be placed in the test chamber in accordance with General Requirements, Section 3, paragraph 3.2.2. The temperature control surfaces of the test item shall not directly face any abnormal heat source. Any operational performance check shall be accomplished in accordance with General Requirements, Section 3, paragraph 3.2.1. All equipment shall be operated (excluding any propulsion system) and measurements made as specified in the vehicle or equipment specification. The test chamber shall then be reduced to that pressure determined through compliance with 2.1 of this test method and the chamber walls cooled to below 100°K. Thermal energy corresponding to the applicable value and manner of exposure determined through

compliance with 2.2.1 of this method shall then be applied to the test item. The normal rotational mode of the test item along with other requirements and conditions shall then be established and maintained throughout the test. Measurements made during the test shall be compared with the data obtained in accordance with General Requirements, Section 3, paragraph 3.2.1. At the conclusion of the test, the test chamber shall be returned to standard ambient conditions and stabilized and the test item inspected in accordance with General Requirements, Section 3, paragraph 3.2.4.

4.2 Procedure II - Heat flux simulation. - The test object shall be located within the test chamber (apparatus 2.1) having a cryogenic heat sink (apparatus 2.3). A heat flux simulation source (apparatus 2.2.2) shall be provided surrounding the test object and thermally isolated from it. The test object shall be supported by low heat conduction means. The test shall be performed as described in 4.1.1.

4.3 Procedure III - Heat-flux simulation with thermal canister. - The test object shall be located within the test chamber (apparatus 2.1) having a cryogenic heat sink (apparatus 2.3) with a thermal canister (apparatus 2.4.1). The test object shall be mounted within the canister by low heat conduction means. The test shall be performed as described in 4.1.1.

4.4 Procedure IV - Heat flux simulation variable temperature shroud. - The test object shall be located within the test chamber (apparatus 2.1) having a variable temperature shroud (apparatus 2.4.2). The test object shall be mounted within the shroud by low heat conduction means. The test shall be performed as described in 4.1.1.

4.5 Procedure V - Heat flux with conductive source and cryogenic shroud. - The test object shall be located within the test chamber (apparatus 2.1) having a cryogenic heat sink (apparatus 2.3). The test object shall have a conductive source (apparatus 2.5) attached to it and shall be supported by low heat conduction means.

4.6 Procedure VI - Vacuum simulation. - The test object shall be located within the test chamber, (apparatus 2.1). Its volume should be preferably much smaller than chamber volume. All test fixtures should be vacuum compatible.

4.7 Procedure VII - Heat flux simulation with vehicle heaters. - The test object shall be located within the test chamber (apparatus 2.1) having a cryogenic heat sink (apparatus 2.3). The test object shall have vehicle heaters (heater blankets or fluid system) attached to its surface.

5. Definitions.- Terms frequently used in solar simulation in conjunction with thermal vacuum testing are as follows:

(a) Absorptance.- Absorptance is the ratio of the absorbed radiant flux to the incident radiant flux. Total absorptance refers to absorptance measured over all wavelengths. Spectral absorptance refers to absorptance measured at a specified wavelength.

(b) Albedo. - Albedo is the ratio of the amount of electromagnetic radiation reflected by a body to the amount incident upon it. This fraction is often expressed as a percentage, such as 34 percent for earth albedo. The spectrum of reflected energy is generally different from that of the incident radiation.

The definition of albedo, while identical with reflectance, is commonly used in astronomy and meteorology to describe the reflectivity of planetary bodies and their atmospheres to solar radiation.

(c) Black body. - A black body is defined to be a body which absorbs all incident energy. Therefore its absorptance $\alpha$, is equal to 1 for all wavelengths. According to Kirchoff's law, such an object will be a perfect emitter of radiation at all wavelengths.

(d) Collimation angle. - See "Solar beam subtense angle."

(e) Emissivity. - Emissivity is the emittance of a layer of material having an optically smooth surface and of such thickness that there is no change in emissivity with increase in thickness; generally refers to an ideal case, flat surface.

(f) Emissivity (e). - Emissivity is the ratio of the radiant flux emitted by a specimen to that emitted by a black body radiator at the same temperature and wavelength. Generally refers to a specific sample or measurement of a specific sample. Total hemispherical emissivity is the energy emitted over the hemisphere above the emitting element for all wavelengths. Normal emissivity refers to the emissivity normal to the surface to the emitting body.

(h) Radiance. - Radiance is radiant flux emitted in a specified direction per unit projected area of surface, per unit solid angle. The preferred symbol for this quantity is L, and is usually expressed in units of

$$\text{Watts cm}^{-2}\ \text{sr}^{-1}$$

The irradiance (radiant flux density) produced by radiation from the source upon a unit surface area oriented normal to the line between source and receiver, divided by the solid angle subtended by the source at the receiving surface, is equal to source radiance if the receiver to source distance is large relative to the source size.

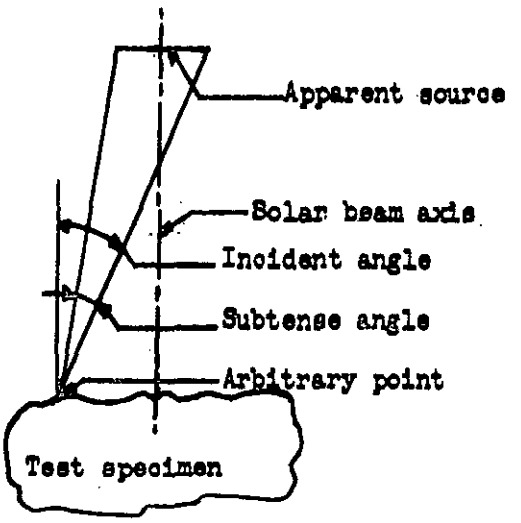
If the radiant source is a perfectly diffuse radiator (that is, emits exactly according to Lamber law), then its radiance is equal to its emittance per unit solid angle.

(i) Radiant energy (Q). - Radiant energy is energy emitted, transferred or received as radiation.

(j) Radiant flux, also, radiant power ($\Phi$). - Radiant flux, also radiant power, is the average radiant energy emitted, transferred or received as radiation per unit time per unit area.

(k) Radiation - infrared. - Infrared radiation is radiation for which the wavelengths are greater than those for visible radiation and less than about 0.1 millimeter.

(l) Solar beam incident angle. - The solar beam incident angle is the angle measured at an arbitrary point in the test volume (see figure below) between the incident rays striking that point and a line parallel to the axis of the solar beam. The angle shall be measured so that 95 percent or more of the solar energy incident at the aforementioned point is included. The maximum incident angle, usually found at the extreme edge of the test volume (or plane), is sometimes referred to as the solar beam divergence angle.




Geometrical relationship of solar subtense and incident angle

(m) Solar beam subtense angle. - The solar beam subtense angle is that angle subtended by the maximum dimension of the apparent source at an arbitrary point on the test specimen. (See figure above). Note: The terms "decollimation angle" and "field angle" are sometimes used for "subtense angle." The term "subtense angle" is preferred. The angle shall be measured so that 90% or more of the simulated solar energy incident at any point in the test volume is received from the apparent source as herein defined.

(n) Solar constant. - "Solar constant" is the rate at which solar radiation is received outside the earth's atmosphere on a surface normal to the incident radiation and at the Earth's mean distance from the Sun.

(o) Solar absorptance. - This relates the absorptance of ($\alpha_s$) a test item irradiated with a solar simulator to the absorptance the test item would experience from the sun.

6. Summary. - The following details shall be specified in the equipment specification.

(a) Pretest data required (Section 3 on General Requirements, paragraph 3.2.1).
(b) All information necessary for the completion of 3.1 (a) through 3.1 (c).
(c) Length of time required for measurements.

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