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Standard Test Methods for Vibration (Vertical Linear Motion) Test of Products[1]

This standard is issued under the fixed designation D3580; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 These test methods cover the determination of resonances of unpackaged products and components of unpackaged products by means of vertical linear motion at the surface on which the product is mounted for test. Two alternate test methods are presented:

Test Method A—Resonance Search Using Sinusoidal Vibration, and
Test Method B—Resonance Search Using Random Vibration.

NOTE 1—The two test methods are not necessarily equivalent and may not produce the same results. It is possible that tests using random vibration may be more representative of the transport environment and may be conducted more quickly than sine tests.

1.2 This information may be used to examine the response of products to vibration for product design purposes, or for the design of a container or interior package that will minimize transportation vibration inputs at these critical frequencies, when these products resonances are within the expected transportation environment frequency range. Since vibration damage is most likely to occur at product resonant frequencies, these resonances may be thought of as potential product fragility points.

1.3 Information obtained from the optional dwell test methods may be used to assess the fatigue characteristics of the resonating components and for product modification. This may become necessary if the response of a product would require design of an impractical or excessively costly shipping container.

1.4 These test methods do not necessarily simulate the vibration effects that the product will encounter in its operational or in-use environment. Other, more suitable test procedures should be used for this purpose.

1.5 Test levels given in these test methods represent the correlation of the best information currently available from research investigation and from experience in the use of these test methods. If more applicable or accurate data are available, they should be substituted.

1.6 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* See Section 6 for specific precautionary statements.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D996 Terminology of Packaging and Distribution Environments
D4332 Practice for Conditioning Containers, Packages, or Packaging Components for Testing
D4728 Test Method for Random Vibration Testing of Shipping Containers
E122 Practice for Calculating Sample Size to Estimate, With Specified Precision, the Average for a Characteristic of a Lot or Process

2.2 *Military Standard:*

MIL-STD 810, Method 514 Vibration[3]

3. Terminology

3.1 *Definitions*—For definitions of terms used in these test methods, see Terminology D996.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *decade*—the interval of two frequencies having a basic frequency ratio of 10 (1 decade = 3.322 octaves).

3.2.2 *decibel (dB)*—a logarithmic expression of the relative values of two quantities. For relative power measurements, the dB value equals 10 times the base-10 logarithm of the ratio of the two quantities, that is, $dB = 10 \log_{10} \{P1/P2\}$.

3.2.3 *mean-square*—the time average of the square of the function.

[1] These test methods are under the jurisdiction of ASTM Committee D10 on Packaging and are the direct responsibility of Subcommittee D10.13 on Interior Packaging.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from Defense Printing Service Detachment Office, Bldg. 4D, NPM-DODSSP, 700 Robbins Ave., Philadelphia, PA 19111–5094.

3.2.4 *octave*—the interval of two frequencies having a basic frequency ratio of 2 (1 octave = 0.301 decade).

3.2.5 *overall g rms*—the square root of the integral of power spectral density over the total frequency range.

3.2.6 *power spectral density (PSD)*—a term used to quantify the intensity of random vibration in terms of mean-square acceleration per unit of frequency. The units are g^2/Hz (g^2/cycles/s). Power spectral density is the limiting mean square value in a given rectangular bandwidth divided by the bandwidth, as the bandwidth approaches zero.

3.2.7 *random vibration*—oscillatory motion which contains no periodic or quasiperiodic constituent.

3.2.8 *random vibration magnitude*—the root-mean–square of the power spectral density value. The instantaneous magnitudes of random vibration are not prescribed for any given instant in time, but instead are prescribed by a probability distribution function, the integral of which over a given magnitude range will give the probable percentage of time that the magnitude will fall within that range.

3.2.9 *resonance*—for a system undergoing forced vibration, the frequency at which any change of the exciting frequency in the vicinity of the exciting frequency, causes a decrease in the response of the system.

3.2.10 *root-mean-square (rms)*—the square root of the mean-square value. In the exclusive case of a sine wave, the rms value is 0.707 times the peak.

3.2.11 *sinusoidal vibration*—periodic motion whose acceleration versus time waveform has the general shape of a sine curve, that is, y = sine x.

3.2.12 *sinusoidal vibration amplitude*—the maximum value of a sinusoidal quantity. By convention, acceleration is typically specified in terms of zero-to-peak amplitude, while displacement is specified in terms of peak-to-peak amplitude.

3.2.13 *transmissibility*—the ratio of the measured acceleration amplitude at a point of interest in the product to the measured input acceleration amplitude of the test surface of the apparatus.

3.2.14 *vertical linear motion*—motion occurring essentially along a straight vertical line, with no significant horizontal or off-axis components.

4. Significance and Use

4.1 Products are exposed to complex dynamic stresses in the transportation environment. The determination of the resonant frequencies of the product may aid the packaging designer in determining the proper packaging system to provide adequate protection for the product, as well as providing an understanding of the complex interactions between the components of the product as they relate to expected transportation vibration inputs.

5. Apparatus

5.1 *Vibration Test Machine*—The machine shall consist of a flat horizontal test surface of sufficient strength and rigidity such that the applied vibrations are essentially uniform over the entire test surface when loaded with the test specimen. The test surface shall be driven to move only in vertical linear motion throughout the desired range of amplitudes and frequencies.

5.1.1 *Sinusoidal Control*—The frequency and amplitude of the motion shall be variable, under control, to cover the range specified in 10.4.

5.1.2 *Random Control*—The frequency and amplitudes of motion shall be continuously variable, under control, to achieve the bandwidths, amplitudes, and overall *g* rms values specified in 10.5.

5.2 *Specimen-Mounting Devices*—Devices of sufficient strength and rigidity are required to attach the product securely to the test surface. The mounting devices shall not have significant resonances in the test frequency range. They shall rigidly mount the product in a manner similar to the way in which it will be supported in its shipping container. Relative motion between the test surface and the specimen mounting interface shall not be permitted.

5.3 *Instrumentation:*

5.3.1 Sensors, signal conditioners, filters, and a data acquisition apparatus are required to monitor or record, or both, the accelerations and frequencies at the test surface of the apparatus and at points of interest in the product. The instrumentation system shall have a response accurate to within ±5 % over the test range.

5.3.1.1 For Test Method A, the frequencies and acceleration amplitudes or transmissibilities may be taken either manually or by means of a recording instrument. A stroboscope or video system may be beneficial for visual examination of the specimen under test.

5.3.1.2 For Test Method B, the data acquisition apparatus shall be capable of recording or indicating the transmissibilities between points of interest in the product to the test surface, over the frequency bandwidth specified in 10.5.

6. Hazards

6.1 *Precaution*—These test methods may produce severe mechanical response in the product being tested. Therefore, the means used to fasten the product to the test surface must be of sufficient strength to keep it adequately secured. Operating personnel shall remain alert to potential hazards and take necessary precautions for their safety. Stop the test method immediately if a dangerous condition should develop.

7. Sampling

7.1 Test specimens and number of samples shall be chosen to permit an adequate determination of representative performance. Whenever sufficient products are available, five or more replicate samples should be tested to improve the statistical reliability of the data obtained (see Practice E122).

8. Test Specimens

8.1 The product as intended for packaging shall constitute the test specimen. Sensor(s) may be applied as appropriate to measure data points of interest with the minimum possible alteration of the test specimen. In particular, sensors shall be lightweight and have flexible cables to prevent changing either the effective weight or stiffness of the components to which they are mounted, thereby changing the resonant frequencies of the components. Parts and surfaces of the specimen may be marked for identification and reference. When necessary to observe interior components of the product during tests, holes may be cut in noncritical areas or noncritical panels may be removed.

9. Conditioning

9.1 Condition test specimens before test and maintain in accordance with any requirements. In the absence of other requirements, conditioning in accordance with Practice D4332 is recommended with a standard conditioning atmosphere of 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 2 % relative humidity.

10. Procedure

10.1 Perform the tests in the conditioned environment or immediately upon removal from that environment.

10.2 Attach the test specimen to the test surface, near the center of the apparatus in a manner that will prevent the specimen from leaving or moving across the test surface during vibration. Caution is necessary to avoid excessive pressure or mounting methods that could influence the characteristics of the product.

10.3 Test intensities shall be sufficient to vibrate the product at acceleration and frequency levels that determine if product resonances exist in the expected transportation environment. Experience has shown that most individual transportation environments contain frequencies ranging from 3 to 100 Hz. Acceleration levels sufficient to excite resonance normally range from 0.25 to 0.5 g.

10.4 *Sinusoidal Vibration—Test Method A:*

10.4.1 Sweep the frequency range from 3 to 100 Hz and return using automatic or manual sweep, while maintaining a nearly constant acceleration level.

10.4.2 Select an acceleration level between 0.25 and 0.5 g (zero to peak). Starting at 3 Hz, vary the frequency of vibration at a continuous logarithmic rate of 0.5 to 1 octave/min to 100 Hz and back to 3 Hz. Record any resonant responses of the product, repeat the cycle if necessary.

NOTE 2—For some specific product/environmental combinations, higher frequencies may be required to produce product resonances. For an example, see MIL-STD 810.

10.5 *Random Vibration—Test Method B:*

10.5.1 Start the vibration system such that the PSD levels do not overshoot the desired spectrum during startup. It is recommended that tests be initiated at least 6 dB below full level and incremented in one or more subsequent steps to full test level. Operate at full test level for a time duration long enough for the control system to stabilize and for the data to be averaged sufficiently to represent stable spectrum shapes and levels, usually 3 min or more. This time is dependent upon the characteristics of the vibration test machine and control system, the setup, and the weight and characteristics of the test specimen.

10.5.2 Use one of the spectra from Test Method D4728, a spectrum representative of the expected transportation environment, a flat broadband spectrum, or a spectrum known to be appropriate. It is recommended that the minimum frequency range be from 3 to 100 Hz, the overall amplitude of the spectrum be not less than 0.25 *g* rms, and that the maximum variation in power spectral density over the total frequency range be 30 db or less. Record any resonant responses of the product.

NOTE 3—Spectrum shapes and levels may be important, due to product responses which are nonlinear with variations in amplitude. For some specific product/environmental combinations, higher frequencies or higher-amplitude spectra may be required to produce observable product resonances. For an example, see MIL-STD 810.

10.6 Monitor the amplitude and frequency data sensed on the test surface to ensure that the desired test conditions are produced. Mount the accelerometer to either the top or bottom of the test surface, as close to the test item as possible, or in a location which produces data representative of table motion.

10.7 Monitor the test specimen and its components for any resonant vibrations. Use a stroboscope; sensors and readouts; and visual, auditory, or other means as applicable to determine these resonances. Any resonances with transmissibilities of 2 or greater may be considered significant. For sine testing, the frequency sweep may be interrupted or reversed if necessary for short time periods to identify properly a resonating component.

10.8 Record the frequencies of any resonances and identify the product components that are resonating. For sine testing, if different frequencies are recorded for each resonating component on the upsweep as compared to the downsweep (a typical situation), record both frequencies and the corresponding sweep direction.

10.9 Test the product in each of the potential shipping orientations of concern.

10.10 *Optional Sinusoidal Dwell Test*— Perform a sinusoidal dwell test at each resonant frequency found in 10.8, if it is determined to be within the expected transportation environment, to examine the fatigue characteristics of the resonating components. Dwell time, acceleration level, and damage criteria are to be specified by the user. Adjust the frequency of the vibration as necessary to maintain resonance.

NOTE 4—If no dwell time is specified, a time of 15 min at each resonant frequency is recommended.

10.11 *Optional Random Vibration Test*— Perform a random vibration test to examine the fatigue characteristics of the resonating components and the interactions between them. Test duration, random spectrum, and damage criteria are to be specified by the user. For spectrum examples, see 10.5.2.

NOTE 5—If no test duration is specified, a time of 30 min is recommended.

11. Report

11.1 Report the following information:

11.1.1 Description of the test product in sufficient detail for proper identification.

11.1.2 Identification of the purpose of the test.

11.1.3 A statement of whether sine testing or random testing, or both, were performed.

11.1.3.1 For sine tests, descriptions of the test sequence, the input acceleration level, frequency range swept, and sweep rate.

11.1.3.2 For random tests, descriptions of the test sequence, the input spectrum shape, levels, frequencies, and the test duration.

11.1.4 Descriptions of any deviations from the specified test method.

11.1.5 A statement of the number of test replications, if any.

11.1.6 Identification of apparatus and instrumentation used, including dates of last instrument calibrations, names of manufacturers, and model numbers. Details of any modifications, if known, shall be included.

11.1.7 Method of conditioning.

11.1.8 Results of any prior tests.

11.1.9 Components that displayed resonant vibration and their corresponding frequencies. Any other significant data, including measurements and observations shall be included.

11.1.10 If applicable, identification of components that could be redesigned to eliminate excessive resonant vibration or to change the resonant frequency.

11.1.11 Transmissibilities, when measured, shall be reported.

11.1.12 If applicable, a description of shipping container characteristics desirable for vibration protection of the product.

12. Precision and Bias

12.1 *Precision*—An interlaboratory study has been conducted.[4] This study evaluated resonant responses of a blower assembly by six laboratories. A total of 52 tests were conducted on the test item with vibration inputs based on sine sweep, random truck vibration, random rail vibration, random air vibration, and broadband or flat random signals. The fixturing and accelerometer location were identical for all tests.

12.1.1 The first significant resonant response was on a relatively simple spring-mass system in the test item. It was identified by all 52 tests with an average of 28.2 Hz. The observed responses showed varying transmissibilities, but the resonant frequencies were essentially identical for all types of input signals. The within-laboratory standard deviation was about 1 Hz. The between-laboratory standard deviation was about 1 Hz. Other products with broader or less prominent primary resonances may have higher within- and between-laboratory variability.

12.1.2 Higher-frequency resonances, when identified, had a similar precision as the first significant response. However, about 10 % of the tests did not identify two other resonances identified by the other 90 % of the tests. In addition, some other frequencies were identified as resonances in about half of the tests. These inconsistencies usually are not of great concern because cushioning designed to attenuate vibration at the lowest-frequency resonance would also attenuate vibrations at the higher resonances.

12.2 *Bias*—The procedures in these test methods have no bias because the identification of resonant frequencies is defined only in terms of these test methods.

13. Keywords

13.1 dwell test; fatigue characteristics; random; resonances; sinusoidal; vibration

[4] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D10-1011.