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Standard Test Method for Vibration (Horizontal Linear Motion) Test of Products[1]

This standard is issued under the fixed designation D5112; 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 This test method covers the determination of resonances of unpackaged products and components by means of horizontal linear motion applied at the surface on which the product is mounted. For vertical vibration testing of products see Test Method D3580. Two alternate test methods are presented:

1.1.1 *Test Method A*—Resonance Search Using Sinusoidal Vibration, and

1.1.2 *Test Method B*—Resonance Search Using Random Vibration.

NOTE 1—These two test methods are not necessarily equivalent and may not produce the same results.

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 the critical frequencies, when these product resonances are within the expected transportation environment frequency range. Since vibration damage is most likely to occur at product resonant frequencies, these may be thought of as potential product fragility points.

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

1.4 This test method does not necessarily simulate vibration effects the product will encounter in operating or end-use environments. Other, more suitable test procedures should be used for this purpose.

1.5 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.6 *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.* For specific precautionary statements, see Section 6.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D996 Terminology of Packaging and Distribution Environments

D3580 Test Methods for Vibration (Vertical Linear Motion) Test of Products

D4332 Practice for Conditioning Containers, Packages, or Packaging Components for Testing

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 810E, Method 514, Vibration[3]

3. Terminology

3.1 *Definitions*—For definitions of terms used in this test method, 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, $dB = 10 \log_{10} [P_1/P_2]$.

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

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

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

[1] This test method is under the jurisdiction of ASTM Committee D10 on Packaging and is 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 Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

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

3.2.7 *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.

3.2.8 *random vibration*—oscillatory motion which contains no periodic or quasi-periodic constituent.

3.2.9 *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.

3.2.10 *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.

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

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

3.2.13 *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.

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

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, either horizontal, vertical or both, aids the package designer in determining the proper packaging system to provide adequate protection of 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,* consisting 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 horizontal linear motion throughout the desired range of amplitudes and frequencies.

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

5.1.2 *Random Control*—The frequency and amplitude 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,* of sufficient strength and rigidity to attach the product securely to the test surface. The resonant frequency of the mounting devices shall be, at a minimum, twice that of the high end of the intended test range for the product. The device(s) shall support 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 test mounting interface shall not be permitted.

5.3 *Instrumentation:*

5.3.1 Sensors, signal conditioners, filters, and 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.

NOTE 2—Strain gage type accelerometers may be required to monitor the product, control the test system, or both.

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. Safety Precautions

6.1 **Warning—**This test method 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 must remain alert to potential hazards and take necessary precautions for their safety. Stop the test immediately if a dangerous condition should develop.

7. Sampling

7.1 Test specimens and the 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 Specimen

8.1 The product as intended for packaging shall constitute the test specimen. Sensor(s) may be applied as appropriate to measure data at 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 the interior components of the product during testing, holes may be cut in noncritical areas, or noncritical panels may be removed.

9. Conditioning

9.1 Condition test specimens prior to testing and maintain them in accordance with any specific requirements applicable to the item being tested. In the absence of other specific requirements, conditioning in accordance with Practice D4332 is recommended (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 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 mounting methods that cause excessive stress or strain that could alter the response 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 frequency range of the transportation environment. Typical products may exhibit resonant frequencies ranging from 1.0 to 100 Hz. Acceleration levels sufficient to excite resonance normally range from 0.1 to 0.5 g.

10.4 *Sinusoidal Vibration—Test Method A:*

10.4.1 Select an acceleration level between 0.1 and 0.5 g (zero-to-peak). Sweep the frequency range from 1 to 100 Hz, starting at 1 Hz and varying the frequency of the vibration at a continuous logarithmic rate of 0.5 to 1.0 octaves/min to 100 Hz and back to 1 Hz using either automatic or manual sweep, while maintaining a nearly constant acceleration level.

10.4.2 Select an acceleration level between 0.1 and 0.5 g (zero-to-peak). Starting at 1 Hz, vary the frequency of the vibration at a continuous logarithmic rate of 0.5 to 1.0 octaves/min to 100 Hz and back to 1 Hz. Record any resonant responses of the product, repeating the cycle if necessary.

NOTE 3—Low frequency vibration requires a long stroke. It may be necessary to reduce the acceleration level inputs at low frequencies in order to stay within the stroke capabilities of the test equipment. This can be accomplished by dividing the test into two or more frequency ranges with different input acceleration levels. Response levels from different input acceleration levels may result in different transmissibilities.

NOTE 4—Frequencies above and below the frequency range from 1.0 to 100 Hz may be necessary or desirable for some products.

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 a spectrum representative of the expected transportation environment or a flat broadband spectrum. It is recommended that the minimum frequency range be from 1 to 100 Hz, the overall *g* rms be not less than 0.2, 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 5—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 acceleration and frequency data sensed on the test surface to ensure that the desired test conditions are produced. Mount the accelerometer, in the direction of motion, as close as possible to the test specimen 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; 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 in order to properly identify 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 6—If no dwell time is specified, a time of 15 min at each resonant frequency is recommended.

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

NOTE 7—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 specimen, 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 date of last calibration, manufacturers' names, model numbers, and serial numbers. Details of any known modifications thereto shall be included.

11.1.7 Method of conditioning.

11.1.8 Results of any prior tests of this product.

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 recorded.

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

12. Precision and Bias

12.1 With the exception of axis of the test and slightly lower starting points for both frequency and acceleration, the precision and bias for this standard are essentially as specified in Test Method D3580.

13. Keywords

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

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