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Standard Test Method for Random Vibration Testing of Shipping Containers[1]

This standard is issued under the fixed designation D4728; 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 random vibration testing of filled shipping units. Such tests may be used to assess the performance of a container with its interior packing and means of closure in terms of its ruggedness and the protection that it provides the contents when subjected to random vibration inputs.

1.2 This test method provides guidance in the development and use of vibration data in the testing of shipping containers.

NOTE 1—Sources of supplementary information are listed in the Reference section (**1-11**).[2]

1.3 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.* Specific safety hazard statements are given in Section 6.

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

D996 Terminology of Packaging and Distribution Environments

D4169 Practice for Performance Testing of Shipping Containers and Systems

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

D7386 Practice for Performance Testing of Packages for Single Parcel Delivery Systems

2.2 *ISO Standards:*

ISO 13355 Packaging—Complete, filled transport packages and unit loads—Vertical random vibration test[4]

2.3 *ISTA Standards:*[5]

ISTA Procedure 1G Packaged-Products 150 lb (68 kg) or Less (Random Vibration)

ISTA Procedure 3A Packaged-Products for Parcel Delivery System Shipment 70 kg (150 lb) or Less

ISTA Procedure 3H Products or Packaged-Products in Mechanically Handled Bulk Transport Containers

3. Terminology

3.1 *Definitions:*

3.1.1 *General*—Definitions for the packaging and distribution environments are found in Terminology D996.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *bandwidth*—the difference, in Hz, between the upper and lower limits of a frequency band. For the purposes of this test method, the bandwidth may be considered equivalent to the frequency resolution of a spectrum analysis.

3.2.2 *closed-loop*—a condition of control where the input may be modified over time by the effect of the output or response of the system.

3.2.3 *decibel (dB)*—ten times the base 10 logarithm of a ratio of two power like quantities that is, a PSD. Two PSD levels that have a ratio of 2.0 differ by 3 dB. Two PSD levels that have a ratio of 0.5 differ by −3 dB.

3.2.4 *equalization*—adjustment or correction of the amplitude characteristics of an electronic control signal throughout a desired frequency range to maintain a desired vibration output spectrum and level.

3.2.5 *equalizer*—instrumentation used to conduct equalization.

3.2.6 *mean-square*—the time average of the square of a function.

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[1] This test method is under the jurisdiction of ASTM Committee D10 on Packaging and is the direct responsibility of Subcommittee D10.21 on Shipping Containers and Systems - Application of Performance Test Methods.

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[2] The boldface numbers in parentheses refer to the list of references at the end of this test method.

[3] 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.

[4] Available from International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, http://www.iso.org.

[5] Available from International Safe Transit Association (ISTA), 1400 Abbot Road, Suite 160, East Lansing, MI 48823-1900, http://www.ista.org.

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

3.2.8 *periodic vibration*—an oscillation whose waveform repeats at equal increments of time.

3.2.9 *power spectral density (PSD)*—an expression 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 limit of the mean square amplitude in a given rectangular band divided by the bandwidth, as the bandwidth approaches zero.

3.2.10 *random vibration*—an oscillation whose instantaneous amplitude is not prescribed for any given instant in time. The instantaneous amplitudes of a random vibration are prescribed by a probability distribution function, the integral of which over a given amplitude range will give the probable percentage of time that the amplitude will fall within that range. Random vibration contains no periodic or quasi-periodic constituent. If random vibration has instantaneous magnitudes that occur according to the Gaussian distribution, it is called "Gaussian random vibration." Gaussian random vibration has the property that the rms level is equal to the standard deviation, or 1 sigma, and that the amplitude will fall within 3 sigma, or 3 times the rms level, 99.7 % of the time.

3.2.11 *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 peak value.

3.2.12 *sigma drive signal clipping*—a condition where the maximum amplitude of the drive or output signal to a vibration system is limited to a sigma value, or multiple of the rms value. For drive clipping at the 3 sigma level, the maximum amplitude will not exceed 3 times the rms value.

3.2.13 *sinusoidal vibration*—a periodic oscillation having a sinusoidal waveform of only one frequency.

3.2.14 *spectrum*—a definition of the magnitude of the frequency components within a specified *frequency range*.

3.2.15 *statistical degrees of freedom (DOF)*—as related to PSD calculation, the degrees of freedom is a measure of the statistical accuracy of the PSD estimation. The number of DOF is determined by the analysis bandwidth (frequency resolution) and total time of the sample (determined by frequency resolution and number of averages). It is defined by the formula DOF = $2BT$, where B is the analysis bandwidth in Hz, and T is the total record length in seconds.

3.2.16 *transfer function*—the dynamic relationship between output and input. In terms of a vibration system, it is the ratio of output response to a constant input over a defined frequency *range*.

4. Significance and Use

4.1 Shipping containers are exposed to complex dynamic stresses in the distribution environment. Approximating the actual damage, or lack of damage, experienced in real life may require subjecting the container and its contents to random vibration tests. In this way, many product and container resonances are simultaneously excited.

4.2 Resonance buildups during random vibration tests are less intense than during sinusoidal resonance dwell or sweep tests. Therefore, unrealistic fatigue damage due to resonance buildup is minimized.

4.3 Random vibration tests should be based on representative field data. When possible, confidence levels may be improved by comparing laboratory test results with actual field shipment effects. Refer to Practice D4169 for recommended random vibration tests. (See Appendix X1 and Appendix X2 for related information.)

4.4 There is no direct equivalence between random vibration tests and sinusoidal vibration tests. Equivalent tests between sine and random, in a general sense, are difficult to establish due to nonlinearities, damping and product response characteristics.

4.5 Vibration exposure affects the shipping container, its interior packing, means of closure, and contents. This test allows analysis of the interaction between these components. Design modification to one or all of these components may be used to achieve optimum performance in the shipping environment.

4.6 Random vibration tests may be simultaneously performed with transient or periodic data to simulate known stresses of this type, that is, rail joints, pot holes, etc.

4.7 Random vibration may be conducted in any axis (vertical or horizontal) or in any package orientation. However, different test levels may be utilized for each axis depending on the field environment that is to be simulated.

5. Apparatus

5.1 *Vibration Test System*—The vibration test system (shaker) shall have a vibration table of sufficient strength and rigidity so that the applied vibrations are essentially uniform over the entire test surface when loaded with the test specimen. The vibration table shall be supported by a mechanism capable of producing single axis vibration inputs at controlled levels of continuously variable amplitude throughout the desired range of frequencies. Suitable fixtures and guides to restrict undesired movement of the test specimens shall be provided.

5.2 *Electronic Controls*—Controls shall provide the capability of generating vibration system drive inputs necessary to produce the desired power spectral density at the table surface adjacent to the test specimen.

5.2.1 *Closed Loop–Automatic Equalization*—A closed loop controller is required, which allows the operator to enter desired PSD data. The controller automatically generates equalized vibration test system drive signals to achieve the desired PSD thus maintaining closed loop control. The equalized drive signals automatically compensate for specimen and vibration test system characteristics. Typical systems include an analog to digital converter for conditioning feedback signals, a digital to analog converter to produce drive signals, a digital processor with real time analysis capability, random vibration control software programs, a graphics display terminal, printer, and a data storage unit.

NOTE 2—Random vibration systems typically create a drive signal that