ASTM INTERNATIONAL

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

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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 vibrational inputs.

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

1.3 Two alternative vibration control techniques are described as follows:

1.3.1 *Method A Closed Loop*—Automatic Equalization (5.2.1, 10.2.1)

1.3.2 *Method B Open Loop*—Data Storage Media (5.2.2, 10.2.2)

NOTE 1—Sources of supplementary information are listed in the Reference section (**1–10**).[2]

1.4 *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.* Specific safety hazard statements are given in Section 6.

2. Referenced Documents

2.1 *ASTM Standards:*

D 996 Terminology of Packaging and Distribution Environments[3]

D 4169 Practice for Performance Testing of Shipping Containers and Systems[3]

D 4332 Practice for Conditioning Containers, Packages or Packaging Components for Testing[3]

2.2 *ISO Standards:*

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

3. Terminology

3.1 *Definitions:*

3.1.1 *General*—Definitions for the packaging and distribution environments are found in Terminology D 996.

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.

3.2.7 *open loop*—a condition of control where the input of a system is preestablished and is not affected by the output or response of the system.

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

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

3.2.10 *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

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density is the limit of the mean square amplitude in a given rectangular band divided by the bandwidth, as the bandwidth approaches zero.

3.2.11 *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.

3.2.12 *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.

3.2.13 *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.

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

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

3.2.16 *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.

3.2.17 *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 D 4169 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. The following methods provide this capability with varying degrees of accuracy and versatility.

5.2.1 *Method A, 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, hard copy printer, and a hard or flexible, or both, disk drive unit.

NOTE 2—Random vibration systems typically create a drive signal that follows the Gaussian distribution. Many systems have a "drive clipping" capability, which is sometimes employed to protect the vibration system or test specimen from high instantaneous amplitudes that might cause damage.

5.2.2 *Method B, Open Loop-Data Storage Media*—Data storage media open loop control systems enable prerecorded equalized PSD data to be produced, as long as the combined transfer function of the specific record/playback device (that is, FM tape, digital tape, floppy disk drive, or CD-ROM drive), vibration system and load configuration was incorporated in

the media's original preparation. Typical systems include a record/playback or playback device, prerecorded data storage media, a means of controlling the overall gain of the vibration system drive signal, and a true rms meter to monitor the overall g rms level of the vibration table. The playback device shall have adequate frequency response and dynamic range to reproduce the vibration spectrum to the tolerances defined in this test method. Ideally, data storage media should be equalized using Method A for each specific test specimen to ensure that the dynamic response of the actual specimen(s) does not cause significant differences between the actual PSD test levels and the desired test levels. Equalization with a very stiff ballast weight equivalent in mass to the test item is sometimes employed as a more practical approach. Exercise caution, however, since the open loop system will not compensate for actual specimen responses.

5.2.3 The digital real time analysis, whether used for Method A or to equalize data storage media for Method B, shall provide a minimum of 60 statistical degrees of freedom, and a maximum analysis bandwidth of 2 Hz.

5.3 *Instrumentation*—Accelerometers, signal conditioners, analyzers, data display, storage devices, and the control techniques described in 5.2 are required to measure and control the PSD levels at the table surface. Instrumentation may also be desirable for monitoring the response of the test specimen(s). The instrumentation system shall have an accuracy of ±5 % throughout the frequency range specified for the test.

6. Safety Precautions

6.1 This test method may produce severe mechanical responses of the test specimen(s). Therefore, fences, barricades, and other restraints must have sufficient strength and must be adequately secured. Operating personnel must remain alert to the potential hazards and take necessary precautions for their safety. Stop the test immediately if a dangerous condition should develop.

7. Test Specimens

7.1 The test specimen shall consist of the container as intended for shipment, loaded with the interior packaging and the actual contents for which it was designed. Blemished or rejected products may be used if the defect will not affect test results and if the defect is documented in the report. Dummy test loads are acceptable if testing the actual product might be hazardous or cost prohibitive. If a dummy load is used, an assessment must be made, after the test is completed, as to whether or not the actual test item would have passed or failed. Sensors and transducers should be applied with minimum possible alteration of the test specimen to obtain data on the container or packaged item. When it is necessary to observe the contents during the test, holes may be cut in noncritical areas of the container.

7.2 Whenever sufficient containers and contents are available, it is highly desirable that replicate tests be conducted to improve the statistical reliability of the data obtained.

8. Calibration and Standardization

8.1 The accuracy of instrumentation and test equipment used to control or monitor the test parameters should be verified prior to conducting each test to ensure that desired test levels and tolerances are maintained.

8.2 The specified PSD data and resulting RMS acceleration level should be based on other test standards, Appendix X1, or derived from actual field measurements or published PSD data made on typical transport vehicles under representative conditions of speed, load, terrain, road surfaces, etc. Field measurements must be accurately recorded with equipment having adequate frequency response and dynamic range to prevent attenuation or noise contamination of the acceleration energy levels. Multiple independent field measurements must be sampled to assure representative test levels. This data must then be reduced to PSD format and equalized for proper control of the vibration system In the absence of specified PSD data it is recommended that the appropriate profile from Fig. X1.1, be used.

8.3 Shaker table input levels to the test specimen provide the only common benchmark for repeatability between various test systems. Therefore, control analysis based on monitoring table motion rather than actual package response is recommended. This table feedback signal is generated by an accelerometer mounted directly to the table. Accelerometer mounting location should be next to the test specimen or directly below it on the underside of the table.

8.4 The shaker's drive signal must be equalized as described in 5.2 to compensate for test specimen dynamics, the test system's transfer function, and the control system's transfer function.

8.4.1 The power spectral density of the random vibration test profile shall not deviate from the specified requirements by more than± 3 dB in any frequency analysis band over the entire test frequency range, except that deviations as large as ±6 dB will be allowed over a cumulative bandwidth of 10 Hz. In addition, the overall g rms level shall not deviate more than ±15 % from the specified level during the test.

8.4.2 The maximum equalizer analysis bandwidth allowed is 2 Hz and the minimum DOF is 60. This applies when running closed loop Method A and when equalizing data storage media for Method B.

8.4.3 For Method B, the recommended time constant for the true rms meter is 1 to 2 s.

8.4.4 The equalizer analysis bandwidth may need to be less than 2 Hz, depending on the slope of the PSD between adjacent breakpoints. Very steep slopes require smaller bandwidths to maintain control to ±3 dB.

8.4.5 If sigma drive signal clipping is used, the clipping level used shall not be less than 3.0 sigma.

9. Conditioning

9.1 Test specimens shall be conditioned prior to test or during test, or both, in accordance with Practice D 4332. When no specific conditioning requirements are given, and container materials are moisture sensitive, a standard conditioning atmosphere of 23± 2°C (73.4 ± 3.6°F) and 50 ± 2 % relative humidity is recommended, for a minimum of 24 h prior to performance of test(s).