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Standard Test Method for Simulated Drop of Loaded Containers by Shock Machines[1]

This standard is issued under the fixed designation D5487; 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 general procedures of using shock machines to replicate the effects of vertical drops of loaded shipping containers, cylindrical containers, and bags and sacks.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

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.*

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:*[2]

D996 Terminology of Packaging and Distribution Environments

D999 Test Methods for Vibration Testing of Shipping Containers

D3332 Test Methods for Mechanical-Shock Fragility of Products, Using Shock Machines

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

D5276 Test Method for Drop Test of Loaded Containers by Free Fall

E122 Practice for Calculating Sample Size to Estimate, With Specified Precision, the Average for a Characteristic of a Lot or Process

3. Terminology

3.1 General terms for packaging and distribution environments are found in Terminology D996.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *critical element*—the most fragile component of the test specimen.[3]

3.2.2 *shock pulse programmer*—a device used to control the parameters of the shock pulse and shape of the pulse generated by the shock test machine.

3.2.3 *shock test machine drop height*—the distance through which the carriage of the shock test machine free falls before striking the shock pulse programmer.

3.2.4 *velocity*—the rate of change of position of a body in a specified direction with respect to time, measured in inches per second or metres per second.

4. Significance and Use

4.1 Shipping containers and the interior packaging materials are used to protect their contents from the hazards encountered in handling, transportation, and storage. Shock is one of the more troublesome of these hazards. Free-fall drop testing, while easy to perform, often understresses the test specimen by subjecting it to drops which are not perpendicular to the dropping surface.

NOTE 1—For example, testing has shown that non-perpendicular drops, 2° off perpendicularity, result in 8 % lower acceleration into the test specimen resulting from the impact energy dispersing in several axes.[4]

4.1.1 Controlled shock input by shock machines provides a convenient method for evaluating the ability of shipping containers, interior packaging materials, and contents to withstand shocks. Simulated free-fall drop testing of package systems, which have critical elements, has produced good

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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] Robert E. Newton, Fragility Assessment Theory and Test Procedures, U. Naval Postgraduate School, Monterey, California.

[4] Fiedler, Robert M. and Fanfu Li, *A Study of the Effects of Impact Angles on the Shock Levels Experienced by Packaged Products*, MTS Systems Corporation. On file at ASTM. Request RR:D10-1008.

results where the frequency of the shock pulse is at least three times that of the package system's natural frequency.

4.2 As in most mechanical shock test procedures, fixturing of the package on the shock test machine may have significant influence on the test results. Typically, packages will be firmly held on the table by securing some type of cross member(s) across the top of the package. Care should be taken that any pressure resulting from such fixturing should be minimal, particularly when the container being tested is corrugated or some other similar material.

4.2.1 In cases where low-acceleration, long-duration responses are anticipated, any fixturing can potentially influence packaged item response and can possibly alter any correlation between this test method and free-fall drop testing. Where such correlation is desired, the package can be tested without it being fixed directly to the table. Note that in such circumstances, the shipping container can vigorously rebound from the table and can, if not otherwise controlled, present a safety problem for operators. Fixing the shipping container to the shock machine table is most often recommended for safety and convenience, but accuracy and precision of this test method should not be compromised by such fixturing.

NOTE 2—A rigid package system with a natural frequency above 83 Hz requires a shock pulse shorter than the 2-ms (nominal) duration currently available with many of today's shock machines:

$$f_s = 1 \text{ cycle}/\left(d_s \times 2\right)$$

$$f_s = 1 \text{ cycle}/(0.002 \times 2) = 250 \text{ Hz}$$

$$f_p = f_s/3$$

$$f_p = 250 \text{ Hz}/3 = 83 \text{ Hz}$$

where:

d_s = shock pulse duration, s,
f_s = shock pulse frequency, Hz, and
f_p = package system frequency, which may be determined by Test Methods D999.

Similarly, a shock machine using an input shock pulse duration of 3 ms would only be effective with package system frequencies below 56 Hz.

5. Apparatus

5.1 *Shock Test Machine:*

5.1.1 The machine shall consist of a flat horizontal test surface (carriage) of sufficient strength and rigidity to remain flat and horizontal under stress developed during the test. The test surface shall be guided to fall vertically without rotation or translation in other directions.

5.1.2 The machine shall incorporate sufficient carriage drop height to produce shock pulses at the carriage as described in 9.1. Drop height control shall be sufficient to control velocity change reproducibility on the table of ±5 %.

5.1.3 Means shall be provided to prevent secondary shocks by stopping the motion of the carriage after impact.

5.2 *Instrumentation:*

5.2.1 *Acceleration*— An accelerometer, a signal conditioner, and a data storage apparatus are required to record velocity change histories. The accelerometer shall be rigidly attached to the carriage. The instrumentation system shall have sufficient response to permit measurements to at least 1000 Hz.

5.2.2 *Accuracy*—Reading to be within ±5 % of the actual value.

5.2.3 *Cross-Axis Sensitivity*—Less than 5 % of the actual value.

5.2.4 *Velocity*—Instrumentation to measure the shock table's velocity change is required. This may be a device which electronically integrates the area under the shock pulse waveform. Alternatively, it can be measured by a photodiode type device which measures the shock table impact and rebound velocity. Calculation which assumes the shock pulse to be a perfect geometric figure usually is grossly inaccurate and should not be used.

6. Sampling, Test Specimens, and Test Units

6.1 The sampling and the number of test specimens depend on the specific purposes and needs of the testing. Sample size determination in accordance with Practice E122 or other established statistical procedures is recommended.

6.2 When the package system's protection characteristics are to be evaluated, construct the packaged system with actual contents as intended.

6.2.1 Where the use of actual contents is prohibitive because of excessive cost or danger, a "dummy" load simulating the contents with respect to dimensions, center of gravity, moment of inertia, product characteristics such as viscosity, etc., may be used with accelerometers or other indicating mechanisms.

6.2.2 Regardless of which procedure is used, close or strap the container, or both, in the same manner that will be used in preparing it for shipment.

6.3 The procedure for identification of the members of the container shall be in accordance with Test Method D5276.

7. Calibration and Standardization

7.1 The accuracy of the test equipment must be verified to ensure reliable test data.

7.2 Verification of calibrations must be performed on a regular basis to ensure compliance with all accuracy requirements established in Section 5. Typically, system verification is performed minimally on an annual basis.

7.2.1 In no case shall the time interval between verification of calibration exceed 18 months.

7.2.2 Regardless of the time interval since the last verification, testing machines shall be verified immediately after functional repairs, relocation, and whenever there is reason to doubt the accuracy.

8. Conditioning

8.1 It is recommended that atmospheres for conditioning be selected from those in Practice D4332. Unless otherwise specified, fiberboard and other paperboard containers shall be preconditioned and conditioned in accordance with the standard atmosphere specified in Practice D4332 and tested in that atmosphere where practical.

8.1.1 If 8.1 is not practical, tests should be conducted within 15 min of removal from the conditioning atmosphere.

9. Procedure

9.1 Set up the shock test machine to produce a haversine or half sine pulse waveform with a pulse duration not longer than 3 ms (Note 2). The measured velocity change (impact + rebound) of the shock machine table should be equivalent to the impact velocity for the chosen free-fall drop height, as calculated using the following formulas:

$$\Delta V_T = V_i$$

where:

V_i	=	$\sqrt{2gh}$,
ΔV_T	=	measured table velocity change,
V_i	=	calculated free fall drop impact velocity,
g	=	acceleration due to gravity, 386.4 in./s^2 (9.806 m/s^2), and
h	=	equivalent free fall drop height, in. (m).

9.1.1 When rebounding-type shock pulse programmers are used, the shock machine drop height is usually substantially different from the equivalent free-fall drop height. Provision shall be made for determining the velocity change of the shock machine table. The velocity change may be determined by using a photodiode type velocity meter which measures shock machine table velocity change (impact plus rebound). An electronic device which measures acceleration versus time may also be used to record the shock wave pulse. Integrating the area under the curve, either electronically or by other means will result in the total velocity change as a result of the impact (see Fig. 1 in Test Methods D3332).

9.2 *Method A—Unrestrained Test:*

9.2.1 Identify the shipping container members in accordance with Test Method D5276.

9.2.2 Place the shipping container on the center of the shock machine table. Raise the table to the predetermined machine drop height, and release the table. Movement of the specimen should be controlled so that a second impact is prevented. Motorcycle bunge cord netting has been successfully used to prevent test specimens from rebounding from the shock machine table during impact.

NOTE 3—**Warning:** Use caution to prevent injury to the operator and damage to the unit. This test method should not be used if the shipping container is large, bulky, or highly resilient.

9.2.3 Perform one shock test.

9.2.4 Examine or functionally test the product and shipping container to determine if damage has occurred.

9.2.5 Continue shock testing until the required members have been impacted.

NOTE 4—Multiple drops on various members may cause fatigue, a cumulative effect, misleading results, or combinations thereof. In certain instances, it may be beneficial to use multiple samples to determine critical elements.

9.3 *Method B—Restrained Test Method:*

9.3.1 Identify the shipping container faces in accordance with Test Method D5276.

9.3.2 Place the shipping container on the center of the shock machine table. Restrain movement of the loaded container so that the shock pulse is directly transmitted to the test specimen. Raise the table to the predetermined machine drop height and release the table.

9.3.3 Perform one shock test.

9.3.4 Examine or functionally test the product and container to determine if damage has occurred.

9.3.5 Continue shock testing until the required members in accordance with Test Method D5276 have been impacted.

NOTE 5—Multiple drops on various members may cause fatigue, a cumulative effect, misleading results, or combinations thereof. In certain instances, it may be beneficial to use multiple samples to determine critical elements.

10. Report

10.1 Report the following information:

10.1.1 Method, if any, of conditioning the shipping container, the moisture content of the wood, plywood, or fiberboard, if determined, and the results of supplementary tests of the materials from which the specimen is made.

10.1.2 The dimensions of the container under test:

10.1.2.1 Complete structural specifications;

10.1.2.2 Materials used;

10.1.2.3 Description and specifications for blocking and cushioning, if used;

10.1.2.4 Spacing, size, and kind of fasteners;

10.1.2.5 Method of closing and strapping, if any, and

10.1.2.6 Tare and gross masses.

10.1.3 Description of the contents of the shipping container under test.

10.1.4 Description of the apparatus and special instrumentation, if used.

10.1.5 Description of the prescribed test sequence, identifying the member being impacted for each drop (for example, the corner formed by the manufacturer's joint, if applicable, and the number of drops).

10.1.6 Velocity change, free-fall drop height, input shock duration, and the response natural frequency, determined in accordance with Test Methods D999, or its shock duration.

10.1.7 Number of specimens tested per sample.

10.1.8 Detailed record of test on each specimen, including damage to the shipping container and contents, together with any other observation which may assist in correctly interpreting the results or aids in improving the design of the container or the method of packing, blocking, or bracing.

10.1.9 Dates of last calibration of the test equipment and instrumentation.

10.1.10 Statement listing any deviations from this test method.

10.1.11 Complete description of any fixturing used for positioning corner and edge drops.

11. Precision and Bias

11.1 *Precision*—The within-laboratory or repeatability standard deviation is largely dependent on the particular item being tested. A research report[5] describes an interlaboratory test program of three types of items (in packages) for a critical velocity shock test. The repeatability values standard deviations were 6.7, 14.7, and 21.5 in./s (0.17, 0.37, and 0.55 m/s)

[5] R. L. Sheehan, Interlaboratory Study, ASTM Subcommittees D10.15, D10.22, 3M Packaging Systems Division, October 28, 1985.