Designation: D3332 – 99 (Reapproved 2016)

Standard Test Methods for
Mechanical-Shock Fragility of Products, Using Shock Machines[1]

This standard is issued under the fixed designation D3332; 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 determination of the shock fragility of products. This fragility information may be used in designing shipping containers for transporting the products. It may also be used to improve product ruggedness. Unit or consumer packages, which are transported within an outer container, are considered to be the product for the purposes of these test methods. Two test methods are outlined, as follows:

1.1.1 Test Method A is used first, to determine the product's critical velocity change.

1.1.2 Test Method B is used second, to determine the product's critical acceleration.

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 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

D2463 Test Method for Drop Impact Resistance of Blow-Molded Thermoplastic Containers

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

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

D5112 Test Method for Vibration (Horizontal Linear Motion) Test of Products

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

E680 Test Method for Drop Weight Impact Sensitivity of Solid-Phase Hazardous Materials

3. Terminology

3.1 *Definitions*—General definitions for packing and distribution are found in Terminology D996.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *acceleration of gravity (g)*—386.1 in./s^2 (9.806 m/s^2).

3.2.2 *critical acceleration (A$_c$)*—the maximum-faired acceleration level for a minimum velocity change of 1.57 ΔV_c (see 9.3), above which product failure (or damage) occurs. A product usually has a different critical acceleration for each direction in which it is tested.

3.2.3 *critical velocity change (V$_c$)*—the velocity change (see 9.2) below which product failure is unaffected by shock-pulse maximum-faired acceleration or waveform. A product usually has a different critical velocity change for each direction in which it is tested.

3.2.4 *damage*—product failure that occurs during a shock test. Damage can render the product unacceptable because it becomes inoperable or fails to meet performance specifications when its appearance is unacceptably altered, or some combination of these failure modes occurs.

3.2.5 *damage boundary*—See Annex A3.

3.2.6 *fairing*—The graphical smoothing of the amplitude of a recorded pulse still containing high frequency components even though electronic filtering may have been performed. This amplitude is used to evaluate the basic recorded pulse features with respect to the specified pulse. (see Figs. A1.1 and A2.1)

3.2.7 *shock pulse programmer*—a device used to control the parameters of the acceleration versus time shock pulse generated by a shock test machine.

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

4. Significance and Use

4.1 These test methods are intended to provide the user with data on product shock fragility that can be used in choosing optimum-cushioning materials for shipping containers or for product design modification.

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 the stresses 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 the shock pulses given in 9.2 and 9.3. Drop height control shall be provided to permit reproducibility within ±0.25 in. (±6 mm).

5.1.3 The machine shall be equipped to produce shock pulses at the carriage as specified in 9.2 and 9.3.

5.1.4 Means shall be provided to arrest the motion of the carriage after impact to prevent secondary shock.

5.2 *Instrumentation:*

5.2.1 *Acceleration*—An accelerometer, signal conditioner, and data storage apparatus are required to record acceleration-time histories. The accelerometer shall be attached rigidly to the base structure of the product or to the fixture, at or near a point at which the fixture is fastened to the carriage. If the fixture is sufficiently rigid to not distort the shock pulse imparted to the product, the accelerometer may be mounted on the carriage. In some cases, when a product contains heavy resiliently supported masses that will distort the shock pulses severely, it may be necessary to precalibrate the shock machine. The accelerometer is fastened to the carriage in this case, and a rigid mass weighing the same as the product is subjected to a series of shock pulses. The instrumentation system shall have sufficient response to permit measurements in the following ranges.

5.2.1.1 *Test Method A*—5 Hz or less to at least 1000 Hz.

5.2.1.2 *Test Method B*—1 Hz or less to at least 330 Hz.

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

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

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

6. Precautions

6.1 These test methods may produce severe mechanical responses in the test specimen. Operating personnel must

therefore remain alert to potential hazards and take necessary safety precautions. The test area should be cleared prior to each impact. The testing of hazardous material or products may require special precautions that must be observed. Safety equipment may be required, and its use must be understood before starting the test.

7. Sampling

7.1 Sampling procedures and the number of test specimens depend on the specific purposes and needs of the testing. Sample size determination based on Practice E122 or other established statistical procedures is recommended.

8. Conditioning

8.1 If temperature and humidity conditioning is required for the product being tested, refer to Practice D4332 for standard conditioning procedures. Unless otherwise specified, conduct all tests with the same conditions prevailing.

9. Procedure

9.1 Mount the product to be tested on the carriage of the shock test machine. The product should be supported by a fixture similar in shape and configuration to the cushion that will support the product in its shipping container. The fixture should be as rigid as possible so as not to distort the shock pulse imparted to the product. Fasten the fixture and product securely to the carriage so that it will not leave the surface of the carriage during the shock test.

NOTE 1—The points at which the fixture supports the product are very important because the dynamic response of the product is influenced strongly by the location of these support points

NOTE 2—If the orientation of the product can change during handling impacts, a test may be required for each of the directions in which the input shock can occur. Multidirectional tests are recommended since most products have different fragilities in different orientations.

9.2 *Test Method A—Critical Velocity Change Shock Test:*

9.2.1 *Scope*—This test method is used to determine the critical velocity change (V_c) portion of the damage boundary plot of a product.

9.2.1.1 To ensure that the components of a product only respond to the velocity change of the pulse, a shock pulse having any waveform and a duration (T_p) not longer than 3 ms should be used to perform this test. Pulse durations as short as 0.5 ms may be required when testing small, very rigid products (see Note 3). Shock pulse waveform is not limited since the critical velocity portion of the damage boundary is unaffected by shock pulse shape. Since they are relatively easy to control, shock pulses having a half sine shock waveform are normally used.

NOTE 3—In general: $T_p \leq 167 / f_c$

where:

T_p = maximum shock test machine pulse duration in ms, and
f_c = component natural frequency in Hz.

For example, a component of a product with a natural frequency below 56 Hz can be effectively tested on a shock machine with a 3 ms duration pulse. If the component natural frequency is higher, the pulse duration must be shorter. A 2 ms duration pulse can be used on a component with a natural frequency up to 83 Hz.

9.2.2 *Procedure:*

9.2.2.1 Set the shock test machine so that the shock pulse produced has a velocity change below the anticipated critical velocity change of the product.

9.2.2.2 Perform one shock test.

9.2.2.3 Examine or functionally test the product, or do both, to determine whether damage due to shock has occurred.

9.2.2.4 If no damage has occurred, set the shock test machine for a higher velocity change and repeat the shock test. Acceptable increment size is influenced strongly by the product being tested. For example, an increment of 5 in./s (0.13 m/s) may be appropriate for most products but unacceptable for high-value products.

9.2.2.5 Repeat 9.2.2.2 – 9.2.2.4, with incrementally increasing velocity change, until product damage occurs. This point is shown as Test No. 7 in Fig. A3.1.

9.2.2.6 Common practice is to define the critical velocity change (V_c) as the midpoint between the last successful test and the test that produced failure. Depending on the purpose of the test, use of the last successful test point before failure may be considered as a more conservative estimate of (V_c).

9.3 *Test Method B—Critical Acceleration Shock Test:*

9.3.1 *Scope*—This test method is used to determine the critical acceleration (A_c) portion of the damage boundary plot of a product.

9.3.1.1 When the critical acceleration of a product is known, package cushioning materials can be chosen to protect it.

9.3.1.2 If no cushioning materials are to be used in the package, it may be unnecessary to perform this test. Only the critical velocity change test may suffice in this case.

9.3.1.3 Trapezoidal shock pulses are normally used to perform this test. Although a true square wave shock pulse is most desirable in theory, it is not possible to obtain infinitely short rise and fall times. On the basis of much testing experience, it has been determined that rise and fall times (see Fig. A2.1) of 1.8 ms, or less, are required. Longer rise and fall times cause the critical acceleration line of the damage boundary curve to deviate from the horizontal, introducing errors into the test results. For the same reason, waveforms having faired shapes that are not trapezoidal should not be used for this test. Their use would cause the critical acceleration line of the damage boundary curve to vary widely as a function of velocity change. For example, if a half sine shock pulse waveform is used, a deeply scalloped critical acceleration line is produced and the test data become meaningless.

9.3.2 *Procedure:*

9.3.2.1 Set the shock test machine so that it will produce a trapezoidal shock pulse having a velocity change of at least 1.57 times as great as the critical velocity change determined in Test Method A (9.2). A factor of 2 or more is normally used for an added safety margin. This is required to avoid the rounded intersection of the critical velocity change and critical acceleration lines. Maximum-faired acceleration level of the first shock pulse should be below the anticipated failure level of the product.

9.3.2.2 Perform one shock test.

9.3.2.3 Examine the recorded shock pulse to be certain the desired maximum-faired acceleration and velocity change were obtained.

9.3.2.4 Examine or functionally test the product, or do both, to determine whether damage due to shock has occurred.

9.3.2.5 If no damage has occurred, set the shock test machine for a higher maximum-faired acceleration level. Be certain that the velocity change of subsequent shock pulses is maintained at or above the level determined in 9.3.2.1. Acceptable increment size is influenced strongly by the product being tested. For example, an increment of 5 g may be appropriate for most products but unacceptable for high-value products.

NOTE 4—See shock machine manufacturer recommendations for setting acceleration levels because this procedure is specific to the type of programmer.

9.3.2.6 Repeat 9.3.2.2 – 9.3.2.5, with incrementally increasing maximum-faired acceleration, until product damage occurs. This point is shown as Test No. 14 in Fig. A3.1. Common practice is to define the critical acceleration (A_c) as the midpoint between the last successful test and the test that produced failure. Depending on the purpose of the test, use of the last successful test point before failure may be considered as a more conservative estimate of (A_c).

10. Report

10.1 Report the following information:

10.1.1 Reference to these test methods, noting any deviations from the test method.

10.1.2 Complete identification of the product being tested, including type, manufacturer's code numbers, general description of configuration, and its pretest condition.

10.1.3 Method of mounting the product on the carriage of the shock test machine.

10.1.4 Type of instrumentation used and critical settings thereof.

10.1.5 Recordings of the shock pulses that caused product damage.

10.1.6 Record of shock test machine drop height for each shock pulse that caused product damage.

10.1.7 Record of damage, including a photograph of product damage, if visible.

10.1.8 Record of waveform, maximum-faired acceleration, pulse duration, and velocity change of the shock pulses.

10.1.9 Record of conditioning used.

10.1.10 Plots of damage boundaries of the product.

10.1.11 If multiple products are used, record of the sampling methods, average or median test levels, and standard deviations.

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[3] describes an interlaboratory test program of three types of items (in packages) for a critical velocity change shock test. The repeatability standard deviations were 6.7, 14.7, and 21.5 in./s (0.17, 0.37, and 0.55 m/s).

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[3] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D10-1004. Contact ASTM Customer Service at service@astm.org.

Other items may have more or less variability. The between-laboratory or reproducibility standard deviation was 5.7 in./s (0.15 m/s).

11.2 *Bias*—No justifiable statement can be made on the bias of these test methods since a true value cannot be established by an accepted referee method.

12. Keywords

12.1 fragility; products; shock; shock machine

ANNEXES

(Mandatory Information)

A1. HALF-SINE SHOCK PULSE VELOCITY CHANGE, USING INTEGRATING INSTRUMENTATION

A1.1 *Integrating Instrumentation*—Integrate the area under the curve from the point at which the acceleration level first leaves the zero axis in a positive direction to the point at which the acceleration next returns to zero (see Fig. A1.1).
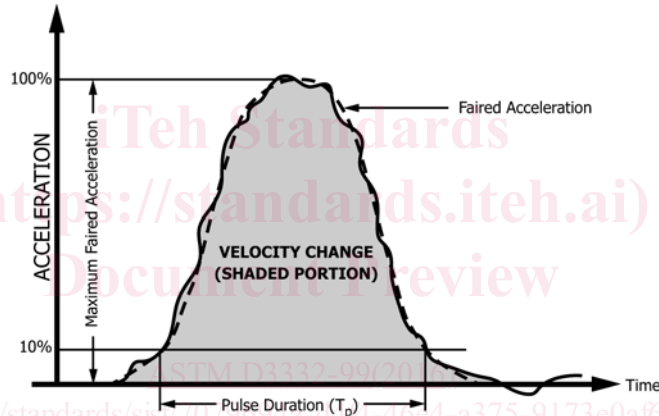

FIG. A1.1 Half-Sine Shock Pulse Diagram

A2. TRAPEZOIDAL SHOCK PULSE VELOCITY CHANGE USING INTEGRATING INSTRUMENTATION

A2.1 *Integrating Instrumentation*—Integrate the area under the curve from the point at which the acceleration level first leaves the zero axis in a positive direction to the point at which the level next returns to zero (Fig. A2.1).