Designation: D 1596 – 97

Standard Test Method for Dynamic Shock Cushioning Characteristics of Packaging Material[1]

1. Scope

1.1 This test method covers a procedure for obtaining dynamic shock cushioning characteristics of packaging materials through acceleration-time data achieved from dropping a falling guided platen assembly onto a motionless sample. This test method does not address any effects or contributions of exterior packaging assemblies.

1.2 The data acquired may be used for a single point or for use in developing a dynamic cushion curve for the specific material being tested. Such data may be used for comparison among different materials at specific input conditions, or qualifying materials against performance specifications. Caution should be used when attempting to compare data from different methods or when using such data for predicting in-package performance. Depending upon the particular materials of concern, correlation of such data (from among differing procedures or for predicting in–package performance) may be highly variable.

NOTE 1—Alternative and related method for possible consideration is Test Method D 4168.

1.3 The values stated in inch-pound units are to be regarded as the standard. The SI units given in parentheses are for information only.

1.4 *This standard does not purport to address all of the safety problems, 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.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 996 Terminology of Packaging and Distribution Environments[2]

D 4168 Test Method for Transmitted Shock Characteristics of Foam-in-Place Cushioning Materials[2]

D 4332 Practice for Conditioning Containers, Packages, or Packaging Components for Testing[2]

E 105 Practice for Probability Sampling of Materials[3]

E 122 Practice for Choice of Sample Size to Estimate a Measure of Quality for a Lot or Process[3]

3. Terminology

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

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *acceleration*—the rate of change of velocity of a body with respect to time, measured in in./s^2(m/s^2).

3.2.2 *displacement*—the magnitude of movement of a body, point, or surface from a fixed reference point, measured in inches (metres).

3.2.3 *dynamic cushion curve*— a graphic representation of dynamic shock cushioning or transmitted shock (in *G*'s) over a variety of static loading conditions (psi or kg/square m) for a specific cushioning material thickness (or structure) at a specific equivalent free fall drop height.

3.2.3.1 Such representations can encompass the average response readings in *G*'s of a number of drops, the average of drops, two to five for each test phase, or represent a single, specific drop number in a drop sequence (that is, first or third drop data).

3.2.4 *equivalent free-fall drop height*—the calculated height of free fall in vacuum required for the dropping platen to attain a measured or given impact velocity.

3.2.5 *equivalent free-fall impact velocity*—the calculated impact velocity of the dropping platen if it were to free fall in a vacuum from a specific test drop height.

3.2.6 *platen drop height*—the actual drop height of the test machine platen required to obtain an equivalent free fall impact velocity.

3.2.7 *reaction mass*—a mass, consisting of the impact surface and any other rigidly attached mass that reacts in an opposing manner to the forces produced during the impact of the dropping platen on the impact surface.

3.2.8 *static loading*—the applied mass in pounds (kilograms) divided by the area, measured in square inches (metres) to which the mass is applied (lbs/in.^{2} or kg/m^2). Sometimes referred to as static stress loading.

3.2.9 *velocity*—the rate of change of position of a body in a specified direction with respect to time, measured in inches per

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[2] *Annual Book of ASTM Standards*, Vol 15.09.

[3] *Annual Book of ASTM Standards*, Vol 14.02.

second (metre per second).

3.3 *Symbols: Symbols:*

3.3.1 *g*— symbol for the acceleration due to the effects of the earth's gravitational pull. While somewhat variable, it is usually considered a constant of value 386 in./s^2 or (9.8 m/s^2).

3.3.2 *G*—symbol for the dimensionless ratio between an acceleration in length per time squared units and the acceleration of gravity in the same units.

4. Summary of Test Method

4.1 An apparatus having a guided dropping platen capable of having variable mass, inputs a dynamic force into a test specimen placed on a rigid impact surface at a predetermined impact velocity that equates to a free fall drop height. An accelerometer rigidly mounted to the dropping platen and connected to a data acquisition system records the shock experienced (acceleration-time history) during the impact on the test specimen. By changing the variables, such as impact velocity, static loading (dropping platen mass), and the number of test impacts for any given test, dynamic shock cushioning characteristics (cushion curves) of the packaging material can be developed.

5. Significance and Use

5.1 Dynamic cushioning test data obtained by this test method are applicable to the cushioning material and not necessarily the same as obtained in a package. In addition to the influence of the package, the data can also be affected by the specimen area, thickness, loading rate, and other factors.

6. Apparatus

6.1 *Testing Machine*:

6.1.1 Any guided vertical drop testing system that will produce test conditions conforming to the requirements specified in this section is acceptable. The system shall consist of a rigid flat faced dropping platen, a rigid flat impact surface whose face is parallel to the dropping platen face.

NOTE 2—Lack of rigidity can cause undesirable vibrations in the apparatus that are recorded in the acceleration-time curve. This condition has also been a suspected cause for discontinuities in dynamic data where the mass of the dropping platen is varied at constant height. The existence of flexing in the apparatus often can be verified with aid of high-speed video and subsequently corrected.

6.1.2 The dropping platen should have provisions for firmly mounting additional mass to adjust its total mass to a desired value. Its mass may be determined by consideration of the static loading of the items the dynamic test is simulating. Various testing systems will have different ranges of testing capability, both for drop height and static loadings.

6.1.3 All dropping platens are influenced by guide system friction and air resistance. The significance of these effects varies with the type of apparatus and the mass on the dropping platen. For this reason, the equivalent free fall impact velocity of the dropping platen is equated to a free fall drop height rather than an actual platen drop height. (*Example*—Using the formula in 11.2, a 30 in. (0.7 m) free fall is equated to a 152 in./s (3.9 m/s) impact velocity of the dropping platen.)

6.2 *Reaction Mass*:

6.2.1 The testing machine shall be attached to a reaction mass. The reaction mass shall be sufficiently heavy and rigid so that not more than 2 % of the impact acceleration is lost to the reaction mass while conducting dynamic tests. The rigid impact surface should be in intimate contact with the reaction mass so that the two bodies move as one (surface preparation or grouting may be required). This performance may be verified by using shock sensors, one located on the dropping platen and one on the impact surface or on the reaction mass immediately next to the impact surface to measure the acceleration levels. The ratio of the measured impact acceleration of the reaction mass divided by the measured acceleration of the dropping platen shall be equal to or less than 2 %.

6.2.2 As an alternative to measuring the acceleration level of the reaction mass for each test condition, the reaction mass is acceptable if it is 50 times the maximum mass of the dropping platen. Neither the depth nor the width of such a mass shall be less than half the length.

6.3 *Instrumentation and Shock Sensors*:

6.3.1 Instrumentation is required to measure the impact velocity to an accuracy of ±2 % of the true value.

6.3.2 Accelerometers, signal conditions, and data storage apparatus are required to monitor acceleration versus time histories. The instrumentation systems shall have the following minimum properties:

6.3.2.1 Frequency response range from 2 Hz or less to at least 1000 Hz.

6.3.2.2 Accuracy reading to be within ±5 % of the actual value.

6.3.2.3 Cross axis sensitivity less than 5 % of full scale.

7. Sampling

7.1 The choice of sampling plans for materials depends on the purpose of the testing. Practice E 105 is recommended.

7.2 The number of test specimens for each condition of test (for example, static loading) depends on the desired degree of precision and the availability of materials. Practice E 122 and many statistical tests provide excellent guidance on the choice of sample size. It is recommended that at least three replicate test specimens be used for each initial test condition. Then, depending on the accuracy and degree of certainty required, this sample size may be increased or decreased.

7.3 Randomization of test specimens from the sample of material and randomization of the order of testing are recommended. This may be accomplished by the use of random number tables, lottery, or other accepted procedures of randomization.

8. Test Specimens

8.1 Test specimens shall be right square prisms or other configuration as desired with the maximum length and width dimensions less than the corresponding drop platen dimensions. It is recommended that the minimum length and width dimensions be 4 by 4 in. (101.6 by 101.6 mm). Because pneumatic effects and buckling properties of cushioning materials may be influenced by size and shape of the specimen, 8 by 8 in. (203.2 by 203.2 mm) specimens are recommended whenever possible. When comparing data for different cushions, identically shaped specimens should be used.

NOTE 3—Not all test apparatus are able to provide static loadings across the usable range of all possible materials to be tested. For this reason it is important to prominently note the sizes of specimens tested in the test report.

9. Conditioning

9.1 Materials, such as cellulosic materials, that undergo changes in physical properties as the temperature and the relative humidity to which they are exposed are varied need to be preconditioned in accordance with Practice D 4332. For polymeric cushions, condition test specimens prior to test for a sufficient length of time to essentially achieve and maintain equilibrium in accordance with any requirements. In the absence of other requirements, use standard conditioning atmosphere of 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 2 % relative humidity.

10. Procedure

10.1 *Dimensions*—Determine measurements for area calculations with an apparatus yielding values accurate to 0.01 in. (0.3 mm).

10.2 *Thickness*—Load top surface of conditioned specimen as furnished or cut, to 0.025 psi (17.55 kg/m ^{2}). (*Example*—Specimen size of 8 by 8 in. (203.2 by 203.2 mm) = 64 in.^{2} (41290 mm^2); 64 in.^{2} × 0.025 psi (41290 mm^2 ÷ (1 × 10^6) × 17.55 kg/m^2 = a load of 1.6 lb (0.725 kg).) After a 30 s interval, and while the specimen is still under 0.025 psi (17.55 kg/m^2) load, measure the thickness to the nearest 0.01 in. (0.3 mm) at the specimen top surface geometric center. As an alternative procedure, average the thickness measurements taken at the four corners of the specimen. Record this value as the specimen thickness. For odd shapes report where measurements were taken.

10.3 *Area and Mass*— Measure the top surface area of the specimen with apparatus yielding values accurate to 1⁄32 in. or 1 mm. Measure the mass of the specimen with apparatus yielding values accurate to 30 g.

10.4 *Dynamic Test*— Center the test specimen on the impact surface face and prepare the dropping platen to strike the cushion on its top surface area. Then impact the specimen with a series of five drops at a predetermined static loading and impact velocity in the dynamic tester, allowing a minimum of 1 min between drops. When testing under special conditions, if possible, return specimen to the special condition between drops. Do not allow specimen to be out of the special condition for more than 30 min. As an alternative, condition test specimens in the chamber. Place testing machine in chamber, check impact velocity of dropping platen. Test at temperature, with recording instrumentation outside of chamber. Take a complete acceleration-time record for each drop and measure the impact velocity of the platen just before impact to ensure it is representative of the impact velocity equated to the desired free drop height. To obtain dynamic data of a general nature for a given cushion, it is necessary to repeat the five test drops on a new specimen varying some condition of test such as static loading, impact velocity, or cushion thickness. As an option, upon the completion of the five drops measure the final thickness of the specimen in accordance with the procedure outlined in 10.2 to determine dynamic set.

11. Calculation

11.1 Calculate the density of a test specimen as follows:

$$\text{Inch-pound units } D = (3.81 \times M)/(L_1 \times L_2 \times T) \quad (1)$$

$$(\text{Metric}) D = ((1 \times 10^6) \times M)/(L_1 \times L_2 \times T)$$

where:
D = density, lb/ft^3(kg/m^3),
M = mass of specimen, grams,
L_1 = length of specimen, in. (mm),
L_2 = width of specimen, in. (mm), and
T = original thickness of specimen, in. (mm).

11.2 Equate an impact velocity to a free fall drop height or vice versa as follows:

$$h = V_i^2/2\,g \text{ (solving for free fall drop height)} \quad (2)$$

$$V_i = \sqrt{2\,gh} \text{ (solving for impact velocity)}$$

where:
h = free fall drop height, in. (m),
V_i = measured impact velocity, in./s (m/s), and
g = acceleration due to gravity, 386 in./s^2(9.8 m/s^2).

11.3 Calculate the dynamic set as follows:

$$\text{Dynamic set, \%} = [(T - F)/T] \times 100 \quad (3)$$

where:
T = original thickness of specimen, in. (mm), and
F = thickness of specimen after test, in. (mm).

12. Report

12.1 Report the following information:
12.2 A description of cushioning material tested,
12.2.1 Name of manufacturer,
12.2.2 Generic name of material,
12.2.3 Date of cushion manufacture, if known,
12.2.4 Date and method of cushion fabrication, if known,
12.3 Number of specimens tested and date of test,
12.3.1 The size and shape of the specimens, and
12.3.2 The original thickness of the specimen.
12.3.2.1 *Optional*—The final thickness in inches (millimetres) and the resultant dynamic set in percent.
12.3.3 The density of each specimen in pounds per cubic foot (kg/m^3) as specified by the manufacturer or if unknown, as calculated by the method shown in Section 11.
12.4 Conditioning parameters.
12.5 Identification of apparatus and instrumentation used, including dates of last instrument calibrations, manufacturer's names and model numbers. Details of any modifications thereto, if known, shall be included.
12.5.1 State method of verification of proper reaction mass; measurement or mass ratio.
12.6 The dropping platen mass, in pounds (kilograms), and the static loading on the specimen, in lb/in.^{2}(kg/m^2), for each test condition,
12.6.1 The impact velocity and equivalent free fall drop height for each test sequence ($h = V_i^2/2\,g$),
12.6.2 A representative sample of the acceleration-time curve for each phase of the testing, along with a reading of the acceleration amplitude for each drop, and
12.6.3 *Optional*—A best fit dynamic shock cushion curve

can be plotted with a minimum of five points using a french curve, drawing spline, or by use of a mathematical curve fitting analysis.

12.7 Descriptions of any deviations from the specified test method.

13. Precision and Bias

13.1 *Precision*—An interlaboratory program has been conducted by the National Institute of Packaging, Handling, and Logistics Engineers (NIPHLE) and the Air Force Packaging Technology and Engineering Facility (AFPTEF). This program is documented under AFPTEF Report Number 96–R-03.

13.2 *Repeatability*—The within laboratory repeatability standard deviation for one type of elastomeric pad ranged from 1 to 4 g's, 1 to 5 % of the average value. Other cushion systems may have different repeatability standard deviations. When repeated tests include the variability between replicate cushion samples, this variability is expected to increase.

13.3 *Reproducibility*—The between laboratory reproducibility standard deviation for one type of elastomeric pad ranged from 5 to 15 g's, 9 to 18 % of the mean. This depends on the type and loading of the cushion and on the type of equipment used by the laboratories.

13.4 *Bias*—This procedure has no bias because the cushioning characteristics are defined in terms of this test method without an accepted reference material.

14. Keywords

14.1 cushion curves; cushioning materials; dynamic shock characteristics; guided platen method