Designation: D4168 – 95 (Reapproved 2015)

Standard Test Methods for Transmitted Shock Characteristics of Foam-in-Place Cushioning Materials[1]

This standard is issued under the fixed designation D4168; 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 determine the shock-absorbing characteristics of foam-in-place packaging materials.

1.2 *Test Method A* uses a free-fall package drop test apparatus.

1.3 *Test Method B* uses a shock-test apparatus.

1.4 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.

1.5 *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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D996 Terminology of Packaging and Distribution Environments

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

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

D5487 Test Method for Simulated Drop of Loaded Containers by Shock Machines

3. Terminology

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

3.2 *Definitions:*

3.2.1 *acceleration*—the rate of change of velocity of a body with respect to time, measured in inches per second per second (metres per second per second).

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

3.3 *Definitions of Terms Specific to This Standard:*

3.3.1 *equivalent free-fall height*—the calculated height of free fall in a vacuum required for a falling body to attain a measured or given impact velocity.

3.3.2 *foam-in-place cushioning material*—a material that is formed by dispensing chemical components which react and expand to produce a foam cushioning material in a container or mold.

3.3.3 *free rise core density*—the density of a foam sample taken from the interior of a bun of foam (without skin) that was produced under unrestricted (free-rise) conditions in pounds per cubic foot (kilograms per cubic metre).

3.3.4 *static loading*—the applied mass in pounds (kilograms) divided by the area, measured in square inches (square metres) to which the mass is applied in pounds per squares inches (kilograms per square metre).

3.3.5 *velocity change*—the sum of the impact velocity and any rebound velocity.

3.4 *Symbols:*

3.4.1 *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/s (9.8 m/s/s).

4. Summary of Test Methods

4.1 The test methods consist of using the cushioning material to be tested to support a weighted test block inside a package. The complete package is subjected to drops or controlled shocks and the accelerations transmitted to the test block are measured.

4.2 Either Test Method A or B may be used. However, the two methods will not necessarily give the same result.

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[1] These test methods are under the jurisdiction of ASTM Committee D10 on Packaging and are the direct responsibility of Subcommittee D10.13 on Interior Packaging.

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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.

5. Significance and Use

5.1 Data obtained by these methods may be used to determine the transmitted shock cushioning characteristics of foam-in-place packaging materials. These data allow design of cushioning systems that can provide adequate and efficient use of foam for protection of goods during a distribution life-cycle.

5.2 These methods, in contrast to other methods that usually test only the cushioning foam, are designed to evaluate foam-in-place cushioning materials in a manner in which the foam-in-place packaging material is used. In particular, the method includes simultaneous use of a plastic film, the foam, and the box usually used in this method of packaging. See Fig. 1.

6. Apparatus

6.1 *Test Method A:*

6.1.1 The free-fall drop test apparatus shall conform to the requirements as described in Test Method D5276.

6.2 *Test Method B:*

6.2.1 The shock test apparatus shall conform to the requirements as described in Test Method D5487.

6.3 *Instrumention and Shock Sensors*—Accelerometers, signal conditioners, and data storage apparatus are required to monitor acceleration versus time histories at various points on the test apparatus and test specimen. The instrumentation systems shall have the following minimum properties:

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

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

6.3.3 Cross-axis sensitivity less than 5 % of full scale.

6.4 *Test Block:*

6.4.1 The test block shall have a rigid square bottom face of not less than 8 in. (203 mm) on a side. Its height shall be a minimum of half the bottom square dimension and a maximum of the full bottom square dimension.

6.4.2 The test block shall include provisions for firmly mounting ballast weight to adjust its total weight to a desired value.

6.4.3 An accelerometer mounting attachment shall be provided near the center of gravity of the block. The block shall be designed and constructed to be as rigid as possible and to minimize motion of the various components.

6.4.4 A recommended configuration is shown in Fig. 2. Also, it is suggested that the box weight be evenly distributed about the center of the bottom face of the test block.

6.4.5 Ballast weights are added or removed to achieve the desired static loading on the cushioning material. The accelerometer shall be considered as a portion of the ballast weight.

6.5 *Outer Container,* shall be a regular, slotted container (RSC) corrugated box fabricated with 200 psi (1380 kPa) test "C" flute fiberboard.

7. Sampling

7.1 Because users form their own cushioning materials, it is very important that accurate records be prepared of all physical data pertaining to those materials for later identification. In addition, the specific characteristics of the film used with the cushion shall be recorded. Care must be taken to ensure that samples are of representative quality. It is recommended that all samples be allowed to cure and stabilize after being poured for a minimum period of 24 h before they are tested.

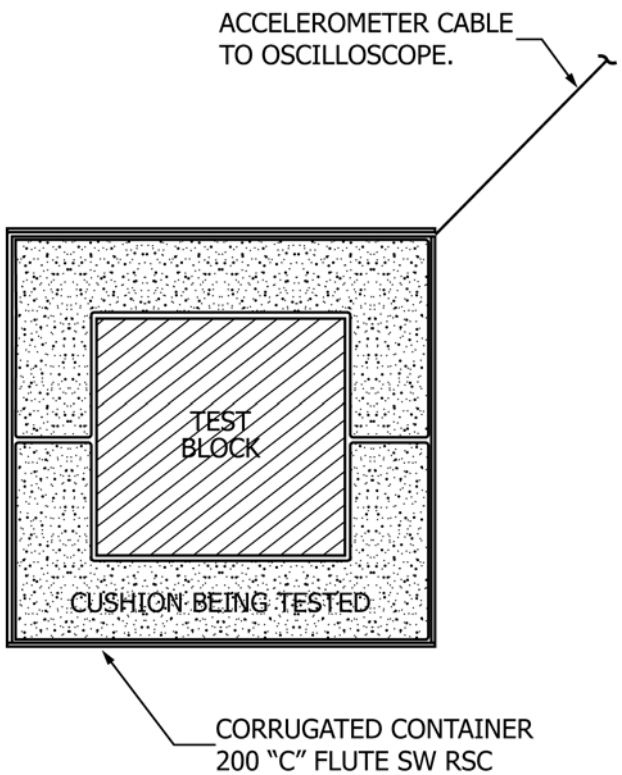

FIG. 1 Specimen Ready For Test

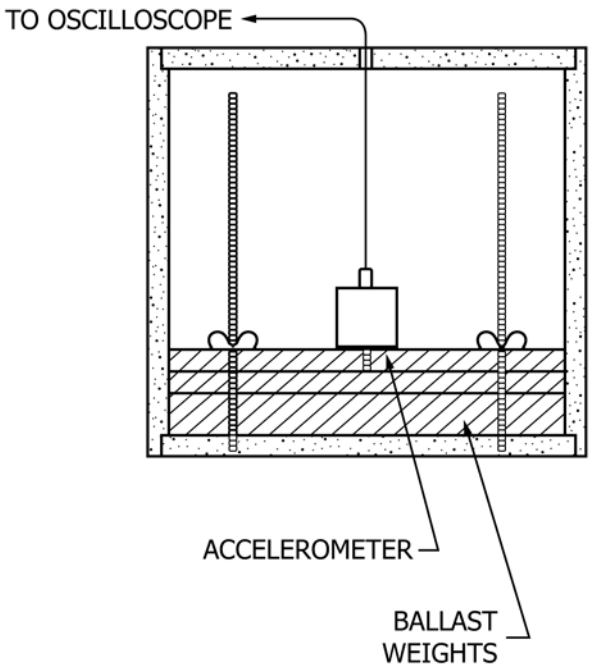

FIG. 2 Test Block

7.2 *Specimens*—If any of the requirements of Sections 7 and 8 are not met, the container and cushioning material shall be discarded and the procedure repeated with new material. Fig. 1 shows a typical specimen assembled and ready for test.

8. Preparation of Test Specimens

8.1 *Modified Free-Rise Bottom Cushion Fabrication (Option 1):*

8.1.1 Dispense a layer of the foam-in-place cushioning material into the bottom of the box. Place the barrier film over the foam; then position the test block such that the foam will rise to a depth equal to the thickness to be tested. Alternatively, a dummy test block jig referenced to the top of the box may be used to ensure the correct position of the test block. The sides of the foam cushion shall be 3 in. (76 mm) thick and should come up about half of the depth of test block. Care must be taken to dispense a proper amount of foam in order that the cushion samples are of representative quality, are not overly densified, and are free of large voids. See Fig. 3.

8.2 *Premolded Bottom Cushion Fabrication (Option 2):*

8.2.1 The bottom cushion may be premolded outside of the outer container by using a wooden mold having the inside dimensions of the outer container, and including an insert in the bottom that duplicates the size and shape of the test block. The sides of the foam cushion shall be 3 in. (76 mm) thick and should come up to half of the depth of the test block. Care must be taken to dispense a proper amount of foam in order that the cushions are of representative quality and have the desired molded density. (See 12.3.2 and Fig. 4)

9. Test Machine

9.1 *Shock Test Apparatus Set-Up:*

9.1.1 Calculate the required carriage velocity change using the following equation:

$$\Delta V = \sqrt{2\,gh} \tag{1}$$

where:

ΔV = required velocity change, in./s (m/s),
g = acceleration of gravity, in./s^2 (m/s^2), and
h = desired equivalent freefall drop height, in. (m).

9.1.2 Following the recommendations of the shock machine manufacturer, adjust the machine to produce a shock pulse of not greater than 3 ms total duration and a velocity change equal to that calculated in 9.1.1.

9.1.3 Rigidly mount an accelerometer or velocity-measuring instrumentation such as optical sensors on the carriage to measure this velocity change.

9.1.4 Secure the test specimen to the shock table carriage in such a way to ensure a flat impact of the test specimen.

NOTE 1—Instrumentation to mesaure the velocity change of the shock table is required. This may be a device that integrates the area electronically under the shock pulse wave form. 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. See Annexes A1 and A2 of Test Method D3332 for a more complete discussion.

NOTE 2—Equivalent drop height determined in 9.1.1 for the shock test machine will not be necessarily the same as free-fall drop height. For a more complete discussion of the relationship, refer to Test Method D3332.

10. Conditioning

10.1 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.

10.2 *Conditioning Apparatus*—In those cases where special atmospheric conditions may be required, provide adequate

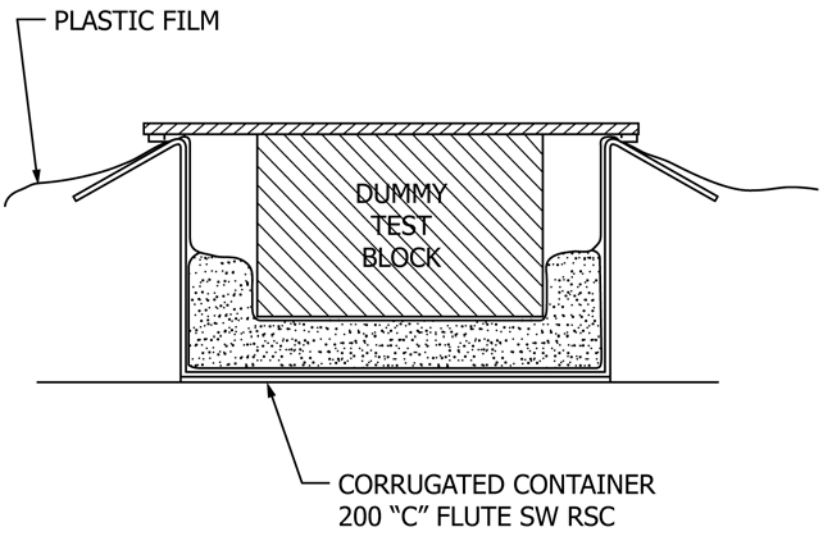

FIG. 3 Bottom Cushion Fabrication

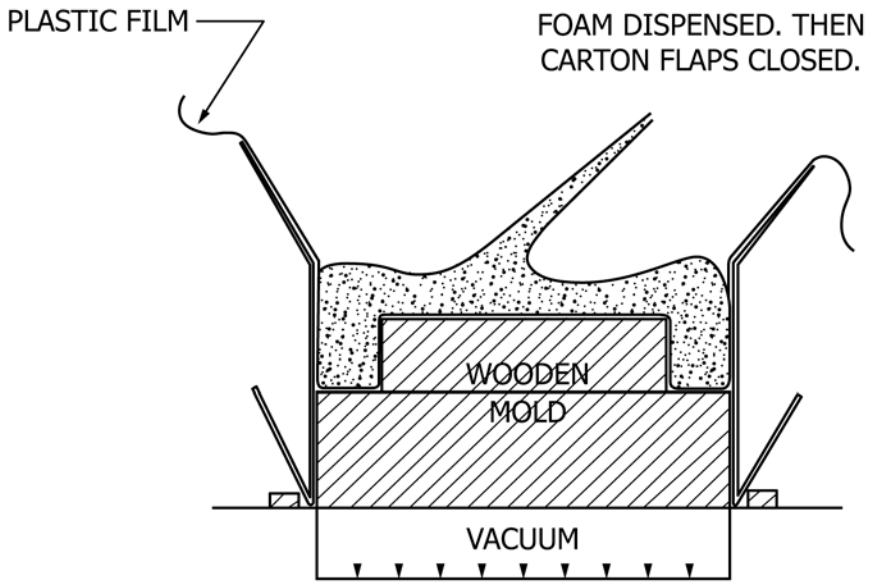

FIG. 4 Bottom Cushion Fabrication

facilities for conditioning the test specimens to the desired humidity and temperature prior to test.

11. Procedure

11.1 *Test Specimen Assembly:*

11.1.1 Assemble the test block with the weight adjusted to achieve the desired static load.

11.1.2 Insert the test cushion into the corrugated container.

11.1.3 Place the test block into the cavity of the test cushion with care.

11.1.4 Add the top cushion.

11.1.4.1 For Option 1, modified free-rise bottom cushion, add a layer of plastic film, then dispense the foam-in-place cushioning material to form the top cushion. The sides of the top cushion should extend down about one half of the depth of the test block to mate with the sides of the bottom cushion.

11.1.4.2 For Option 2, premolded bottom cushion, the top cushion shall also be premolded as discussed in 8.2.

11.1.5 Close the box securely. See Fig. 1.

11.1.6 Take proper care to ensure that the accelerometer leads are arranged so as not to interfere with a free fall.

11.2 *Test Method A Free-Fall Drop Test:*

11.2.1 Set the release mechanism to support the test specimen at the desired drop height.

11.2.2 Place the test specimen on the release mechanism support. The center of gravity of the supported face shall be centered on the supporting mechanism.

11.2.3 Operate the machine in accordance with the manufacturer's instructions to produce a flat drop within ±2° as defined in Test Method D5276.

11.2.4 Repeat for a total of five drops at the chosen test conditions with the box positioned so that the weight rests on the test cushion as shown in Fig. 1 throughout the entire test.

11.2.4.1 There shall be a minimum of 1 min between the sequential drops.

11.2.4.2 The time interval between the drops shall not be excessive in order not to affect adversely the test specimen preconditioning.

11.2.5 The maximum number of drops to be conducted with one sample of the cushioning material is five. If more tests are to be run at different drop heights or static loadings, for example, use new samples.

11.3 *Test Method B, Shock Test:*

11.3.1 Securely fasten the properly prepared test specimen to the carriage of the shock test machine. Attach the input pulse-monitoring accelerometer to the carriage as closely as possible to the outer container. Properly connect the test block acceleration measuring channels.

11.3.2 Operate the machine in accordance with the manufacturer's instructions to produce the acceleration versus time, pulse, as determined in 9.1.

11.3.3 Monitor the carriage accelerometer output to verify that the proper pulse is being obtained.

11.3.4 Repeat for a total of five drops at the chosen test conditions with the box positioned so the weight rests on the test cushion, as shown in Fig. 1, throughout the entire test.

11.3.4.1 There shall be a minimum of 1 min between the sequential drops.

11.3.4.2 The time interval between the drops shall not be excessive in order not to affect adversely the test specimen preconditioning.

11.3.5 The maximum number of impacts to be conducted with one sample of the cushioning material is five. If more tests are to be run at different impact heights or static loadings, for example, use new material.

11.4 *Foam Specimen Weight:*

11.4.1 To determine the foam density when Option 2 (premolded bottom cushion) is used (see 12.3.2), the weight of the bottom cushion is required. At the conclusion of the drop or impact sequence, carefully remove the barrier film from the test cushion and weigh the foam to within 1 % accuracy in pounds (or kilograms).

12. Calculation

12.1 *Drop Height:*

12.1.1 For Test Method A, measure drop height, in inches (or metres).

12.1.2 For Test Method B, calculate equivalent free-fall drop height as $h = \Delta V^2/2g$, in inches (or metres).

12.2 *Static Loading*—Calculate the weight of the test block in pounds (or kilograms) divided by the surface area of the bottom face of the test block in square inches (or square metres).

12.3 *Density:*

12.3.1 For Option 1, modified free rise foam-in-place bottom test cushion, determine the free rise core density of a representative foam sample in pounds per cubic foot (kilograms per cubic metre).

12.3.2 For Option 2, pre-molded bottom cushion:

12.3.2.1 Measure the inside dimensions of the mold used to fabricate the bottom cushion to a 1 % accuracy in inches (millimetres).

12.3.2.2 Determine the inside mold volume in cubic feet (cubic metres) using the inside mold dimensions as determined in 12.3.2.1.

12.3.2.3 Calculate density in pounds per cubic feet (kilograms per cubic metre) by dividing the weight determined in 11.4 by the volume determined in 12.3.2.2.

13. Report

13.1 Report the following information:

13.2 A description of cushioning material tested,

13.2.1 Name of manufacturer,

13.2.2 Generic name of foam, and

13.2.3 Date of cushion fabrication.

13.3 Description of film used, including nominal gage measured.

13.4 Number of specimens tested and date of test.

13.5 Bottom cushion preparation method: modified free rise (Option 1) or pre-molded (Option 2) (see Section 8).

13.6 Test apparatus and procedure used, whether Test Method A (free fall drop test) or Test Method B (shock test).

13.7 Conditioning parameters.

13.8 Drop height in inches (metres) as determined in 12.1.

13.9 Static loading in pounds per square inch (kilograms per square metre) as calculated in 12.2.

13.10 Density in pounds per cubic foot (kilograms per cubic metre) as determined in 12.3.

13.11 The peak *G* at each drop.

13.11.1 Peak duration in milliseconds (optional), and

13.11.2 The acceleration versus time curve (optional).

13.11.3 Filter frequency and filter technique used.

13.12 Detailed description of any deviations from the procedure as specified.

14. Precision and Bias

14.1 *Precision*—Based on limited information from one laboratory, the repeatability standard deviation is about 1.25 *G* for the first drop and 1.6 *G* for the average of drops 2 through 5. Some cushioning materials will have higher or lower variability. Materials which are severely deformed by load and drop height will have more variability in test results.

14.2 *Bias*—The procedure has no bias because the test values are defined in terms of the test methods.

15. Keywords

15.1 cushioning; cushioning material; equivalent free fall drop height; foam-in-place; free fall drop height; modified free rise cushion; pre-molded cushion; static loading; transmitted shock