Standard Test Method for
Creep Properties of Package Cushioning Materials[1]

This standard is issued under the fixed designation D 2221; 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.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This test method covers the determination of creep properties of package cushioning materials. It is applicable to materials available in bulk, sheet, or molded form used for the cushioning of articles during storage, handling, and shipment.

1.2 *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:*
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 Calculating Sample Size to Estimate, With a Specified Tolerable Error, the Average for a Characteristic of a Lot or Process[3]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *creep*—the deformation of a material occurring with time and due to an externally applied constant stress. For cushioning materials specifically, it may be defined as the change in thickness of a cushion under static compressive load over a period of time.

3.1.2 *permanent set*—the permanent change in thickness of an unloaded cushion as a result of an applied compressive load for any given time interval and any given unloaded recovery time period.

4. Summary of Test Method

4.1 The test apparatus consists of a suitable testing device having a base plate and a guided movable platen which can be loaded with weights. The loaded movable platen is placed on a cushion to simulate static compressive loading of cushioning material in actual packaging. By measuring the change in thickness of the loaded cushion with time, creep properties of the cushioning material can be obtained.

5. Significance and Use

5.1 This test method determines the extent and nature of cushion thickness change under static load. Creep data obtained by this test method are applicable to the cushion under the conditions of the particular test and are not necessarily the same as obtained in a complete pack in actual packaging environments. Data may be affected by magnitude of static load, specimen area, shape, and thickness, by varying ambient conditions of temperature, humidity, by friction in the movable platen guide system, and by actual cushion thickness. Vibration in the vicinity of the test fixtures may also influence data results.

6. Apparatus

6.1 *Movable, Guided Platen*, capable of being weighted to achieve the desired loading along with a base to support the sample throughout the duration of the test. Two such assemblies are shown in Fig. 1 and Fig. 2.

6.2 *Static Load Box Fixture* (Fig. 1), consisting of a movable guided platen and an outer box that shall act as the guide and the base plate for supporting the sample.

6.2.1 *Base Plate (Outer Box)*, may be constructed of ¾ in. (19.0 mm) minimum white pine and fabricated to reduce swelling which may occur at high humidity. A flat rigid plate of appropriate dimensions is placed on the inside bottom surface and used as the base plate. The plate can be made of a material such as aluminum, steel, rigid plastic sheeting or glass.

6.2.2 *Movable Guided Platen (Inner Box)*, may be loaded with weights (for example, lead shot or molded lead weights), and fabricated in the same manner as described in 6.2.1. A flat rigid plate similar to that described in 6.2.1 is placed between the top of the test specimen and the movable platen and serves as a reference for measuring the height of the specimen.
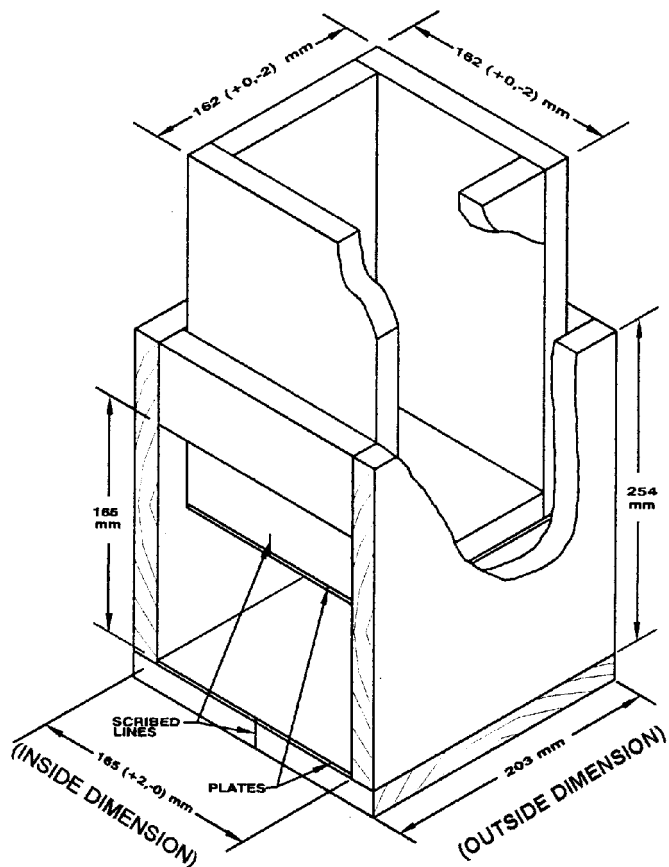
6.2.3 Two means of measurement, two position and four position, may be utilized. A micrometer or steel rule capable of measurement to 0.01 in. (0.3 mm) shall be utilized.

NOTE 1—All dimensions are for reference only and are dependent on the materials tested.

Inside Dimensions of Outer Box
165 (+2,–0) × 165 (+2,–0) × 254 (±3) mm

mm	2	162	165	203	254
in.	0.08	6.37	6.50	8	10

**FIG. 1 Typical Static Load Box Creep Apparatus**

6.2.3.1 *Two Position*—A vertical line, scribed at the center of both (movable and base) flat, rigid plate edges (Fig. 1) serves as location references for specimen thickness measurements (distance between the plates) at various time intervals. Measurements are taken at the vertical scribed lines at both the front and back of the box.

6.2.3.2 *Four Position*—Measurements are taken at the four box corners for specimen thickness measurements (see 6.2.3.1).

6.3 The single point fixture shall consist of a support structure guiding a rod perpendicularly attached to a platen (see Fig. 2).

6.3.1 The support structure shall be constructed in such a manner as to keep the rod and platen perpendicular to the base without binding. The rod shall be attached to the platen so as to limit lateral motion. (The weight of both platen and rod shall be constructed to achieve the minimum static loading for original thickness measurement in 9.2.) Weights may be added to the platen top surface to achieve the desired static loading.

6.3.2 Measurements shall be taken from the top of the rod with a dial micrometer or other similar device capable of measurement to 0.01 in. (0.3 mm).
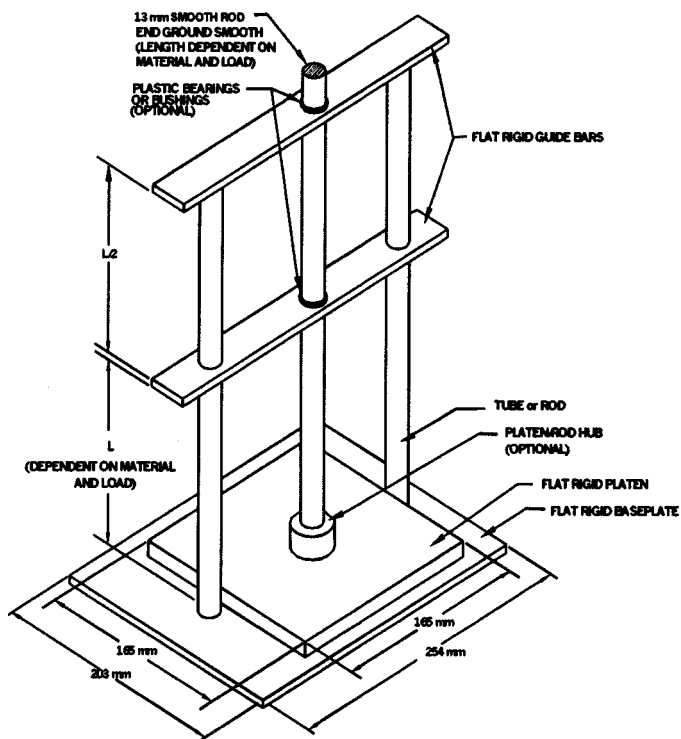
NOTE 1—All dimensions are for reference only and are dependent on the materials tested.

FIG. 2 Typical Single Point Creep Apparatus

6.4 *Flat Rigid Plate*, for measuring specimen thickness (see 9.2) should be constructed to yield a 0.025 psi (0.17 kPa) static load. Plates referenced in 6.2.1 and 6.2.2 used with the static load box may be utilized if constructed to the proper weight required to achieve the desired static load.

7. Test Specimens

7.1 Test specimens shall be right square prisms or right cylinders with the lateral dimensions at least the same as the original thickness, and with minimum dimensions of not less than 2 by 2 by 1 in. (51 by 51 by 25 mm) thick. The preferred size is 6 by 6 by 4 in. (152 by 152 by 102 mm) thick. If the cushioning material, as supplied, is less than 1 in. (25.4 mm) thick, the required thickness may be obtained by using two or more layers of the material. For thin gage materials requiring the stacking of several layers to achieve the desired specimen thickness, interleaving between layers with light weight, non-compressible, flat, rigid plates can help stabilize the stacked specimen. However, the cumulative thicknesses and weights of these plates must be accounted for in all thickness measurements before calculating any values described in Section 10. Specimens with larger areas are recommended whenever possible and may be dictated by the apparatus used to measure creep. Fiber length, pore size, or the nature of a material may also be determining factors regarding specimen size.

7.2 The number of specimens tested as a sample may vary widely, depending on the intended use of the data. It is recommended that at least four specimens be used for the initial sample of a material. Then, depending on the accuracy and degree of certainty required, this sample size may be

increased or decreased. To ensure better representation of the sample, individual specimens should be selected by systematic randomization. This can be done by assigning a consecutive number to each of the specimens of the sample, and then selecting the specimens which have numbers that correspond to a series drawn by lottery. Sampling procedures for selecting specimens are discussed in Practice E 105. Procedures for determining the number of specimens required for each sample are given in Practice E 122.

8. Conditioning

8.1 Precondition all specimens at any desired condition for a sufficient length of time to essentially achieve equilibrium with the ambient atmosphere. In the absence of more specific requirements, the application of Practice D 4332 is recommended or one of the following procedures may be followed:

8.2 Precondition all specimens at 35 ± 2 % relative humidity at 73.4 ± 3.6°F (23 ± 2°C) maximum for 24 h and then condition and test at 73.4 ± 3.6°F (23 ± 2°C) and 50 ± 2 % relative humidity. The length of conditioning shall be a minimum of 16 h, or until the differences between two successive weights of the specimen determined at 1 h intervals is less than 1 % of the average specimen weight.

8.3 Conduct the test at 73.4 ± 3.6°F (23± 2°C) and 50 ± 5 % relative humidity. If creep is determined at other temperatures, humidities, or both (in accordance with 9.7), conduct only the procedures described in 9.4 to 9.6 at the optional conditions.

9. Procedure

9.1 *Dimensions and Weight*—Determine measurements for area calculations with an apparatus yielding values accurate to 0.01 in. (0.3 mm); for weight, 0.01 lb (4.54 g).

9.2 Load top surface of conditioned specimen (T_o), as furnished or cut, to 0.025 psi (0.17 kPa). Loading shall be applied evenly and gently with a flat, rigid plate (see 6.4). After a 30 s interval, and while the specimen is still under 0.025 psi load; measure the thickness to the nearest 0.01 in. (0.3 mm) at the specimen top surface geometric center (see 6.2.3). As an alternative procedure, average the thickness measurements taken at the four corners of the specimen. Record this value as the original thickness T_o.

9.3 *Preworking (Optional)*—For cushioning applications where a high degree of compressibility and recovery of the cushion is required, a preworking of the creep test specimen prior to loading is recommended. A suggested preworking procedure may consist of compressing the specimen to 65 % of its thickness twice at a rate not to exceed 1 cps. Rest the specimen for a minimum period of 16 h. Following the rest period, record as the preworked thickness, T_p, the thickness of the specimen, as determined in 9.2.

9.4 *Loading of Specimen*—Using either of the fixtures described in Section 6, center the rigid plate on the specimen and apply the desired static load (weight of the rigid plate plus that of the movable platen plus the lead shot or molded weights) evenly and gently to the entire upper surface of each specimen. Start to measure or determine the thickness of the specimen while under load, 60 ± 5 s after the load has been applied. Determine the thickness by averaging the vertical perpendicular distance between the plates using either the two or four position measuring method (see 6.2.3) for the guided platen fixture, or by measuring the height of the rod in the single point fixture. Record this thickness as the initial thickness under load, T_i.

Note 1—Since creep tests are especially sensitive to shock and vibration, select the test apparatus location for a minimum of disturbance. When the test locations are not free from vibration or shock, design the test equipment and mounting so that the specimen is isolated from shock and vibration.

9.5 *Creep Determination*—Measure the distance between the rigid plates of the loaded specimen at any desired time interval (such as at 6 min, 1 h, 24 h, 72 h, 96 h, etc.), after the application of the load. Record this thickness as the deflected thickness under load at the specified interval ($T_{d(\text{time interval})}$, for example, $T_{d(96h)}$).(More frequent readings throughout the duration of the test will provide more complete information on the nature of cushioning creep.) Total test duration will be based on the test materials, the static load being applied, and the intended use of the data. Tests at relatively heavy loadings (as related to the materials under test) may run for considerably shorter time than those run at more reasonable and anticipated loadings. (Intervals for measurements may depend on the load being used, the intended use of the data obtained, and test duration.)

9.6 *Recovery Determination*—At the end of the creep loading test time, remove the test load from the specimen. At three intervals, 30 s, 30 min, and 24 h after removal of the test load, make thickness determinations of the specimen as specified in 9.2. Between these determinations, the test load shall not remain on the specimen. Record as the thickness after recovery period $T_{r(\text{time interval})}$, for example $T_{r(30 \text{ s})}$, $T_{r(30 \text{ min})}$, or $T_{r(24h)}$.

9.7 *Creep Determinations at Other Temperatures and Humidities (Optional)*—In order to establish data that will simulate actual conditions, it may be necessary to perform creep tests as described, but at varied temperatures or humidities, or both, which can be expected in service. In the absence of more specific requirements, the following procedure is suggested:

9.7.1 Test at − 65 to + 160°F (−54 to 71°C) and from 35 to 95 % relative humidity at 73.4°F (23°C). Use and record other extreme temperatures or humidities, or both as desired, but note that instruments or equipment may not operate at the same efficiency at extreme conditions as at standard conditions.

10. Calculations

10.1 Calculate the density as follows:

$$D = W/(A \times T_o) \tag{1}$$

where:
D = density, lb/ft^3, (g/mm^3),
W = weight of specimen, lb [g (mass)],
A = area of specimen, in.^{2}(mm^2), and
T_o = original thickness of specimen, in. (mm).

10.2 Calculate the static stress for the given loading as follows:

$$\text{Static stress, } = F/A \tag{2}$$

where:

F = load applied, lb [g (mass)], and
A = area of specimen, in.^{2}(mm^2).

10.3 Calculate the initial strain for the given static stress as follows:

$$\text{initial strain, \%} = [(T_o - T_i)/T_o] \times 100 \qquad (3)$$

where:
T_i = initial thickness under load, in. (mm), and
T_o = original thickness, in. (mm).

NOTE 2—Where preworking is utilized, substitute T_p, preworked thickness, for T_o.

10.4 Calculate interval strain based on original thickness as follows:

$$\text{Interval strain, \%} = [(T_o - T_d)/T_o] \times 100 \qquad (4)$$

where:
T_o = original thickness, in. (mm), and
T_d = deflection thickness, at the given time interval in. (mm).

10.4.1 See Note 2.

10.5 Calculate creep based on initial thickness under test load as follows:

$$\text{Creep, at any given time interval, \%} = [(T_i - T_d)/T_i] \times 100 \qquad (5)$$

where:
T_i = initial thickness under load, in. (mm), and
T_d = deflection thickness at the given time interval, in. (mm).

10.6 Calculate set after time intervals as follows:

$$\text{Permanent set, \%} = [(T_o - T_{r(interval)}/T_o] \times 100 \qquad (6)$$

where:
T_o = original thickness, in. (mm), and
$T_{r(interval)}$ = thickness after recovery period, in. (mm).

10.6.1 See Note 2.

11. Report

11.1 Report the following information:

11.1.1 Test fixture used (Guided Platen or Single Point). Note, if dimensions are different than those shown in Fig. 1 or Fig. 2, they should be indicated and described in the test report, along with the dimension L,

11.1.2 Number of specimens tested, origin and description of material, and dates tested,

11.1.3 Method of measurement used (Two position or Four position),

11.1.4 Original thickness of the specimen (T_o), in inches (millimetres), as determined in 9.2, and the area, in square inches (square millimetres), as calculated from measurements determined in 9.1,

11.1.5 Density of each specimen in pounds per cubic foot, (grams per cubic millimetre), as calculated in 10.1 (optional),

11.1.6 Preworking procedure utilized for those materials which are preworked (optional),

11.1.7 Preworked thickness of the preworked specimen, in inches (millimetres), as determined in 9.3 (optional),

11.1.8 Static stress, in pounds per square inch (grams per square millimetres, or killopascals), as calculated in 10.2,

11.1.9 Initial strain as calculated in 10.3, percent,

11.1.10 Initial thickness (T_i) under static load, in inches (millimetres), as determined in 9.4,

11.1.11 Deflection thicknesses, ($T_{d(interval)}$) in inches (millimetres) at time intervals chosen, as determined in 9.5,

11.1.12 Creep, percent, based on the initial thickness under static load, as calculated in 10.5,

11.1.13 Plot of creep determined versus the corresponding time interval,

11.1.14 Thickness after recovery period, ($T_{r(interval)}$) in inches (millimetres), as determined in 9.6,

11.1.15 Set after time interval, in percent, based on the original or preworked thickness (T_o or T_p), as calculated in 10.6,

11.1.16 Detailed description of any deviations from the procedure as specified herein, and

11.1.17 Compilation of data from 11.1.1 to 11.1.16 for any other conditions, as described in 9.7 (optional).

12. Precision and Bias

12.1 Based on limited information from one laboratory, the repeatability standard deviation is approximately 1.3 percentage points, and the 95 % repeatability limit is approximately 3.6 percentage points. This data is based on 72 h average creep of 8.1 %. These are based on specimen sizes of 3½ in. squares, 4 in. squares of 2 in. depth of 3 and 5 psi loadings. The reproducibility of this test is being determined.

13. Keywords

13.1 creep; cushioning materials; initial strain; interval strain; permanent set; single point fixture; static compressive loading; static load box fixture