Designation: D4577 – 05 (Reapproved 2010)

Standard Test Method for Compression Resistance of a Container Under Constant Load[1]

This standard is issued under the fixed designation D4577; 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 is designed to determine the resistance of a shipping container to a vertically applied constant load for either a specified time or to failure. The test method may also be used for palletized or unitized load configurations.

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 whoever uses this standard to consult and 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]

D642 Test Method for Determining Compressive Resistance of Shipping Containers, Components, and Unit Loads

D644 Test Method for Moisture Content of Paper and Paperboard by Oven Drying (Withdrawn 2010)[3]

D685 Practice for Conditioning Paper and Paper Products for Testing

D996 Terminology of Packaging and Distribution Environments

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

D4442 Test Methods for Direct Moisture Content Measurement of Wood and Wood-Base Materials

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 *Definitions*—General definitions for the packaging and distribution environments are found in Terminology D996.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *load*—the force applied to a body, lbf or N.

3.2.2 *constant load*—a load that is invariable or unchanging

3.2.3 *static load*—an imposed stationary force, constant in magnitude, direction, and sense

4. Significance and Use

4.1 In the distribution system for many products there is a phase wherein the packaged product may be stored for a period of time in a manner such that one or more containers are superimposed one upon the other. The bottom package is thus continually stressed with a constant load.

4.2 This test method subjects a container, empty or filled, to a predetermined static load, and to specified atmospheric conditions, if required.

5. Apparatus

5.1 The testing apparatus shall be capable of imposing a constant load on the test specimen and may be hydraulically, pneumatically, or mechanically activated. A test apparatus employing dead weights to impose the constant load may be used, as in Fig. 1 and Fig. 2. Compression machines may also be used, as in Fig. 3 and Fig. 4, and shall contain two platens, or suitable framework and fixturing, one stationary and one movable in the vertical direction. The movable platen may be swiveled (floating) or fixed and should have proper mechanical, pneumatic, or hydraulic linkages to permit top-to-bottom loading. If the floor where the test is to be conducted is subject to severe vibration, it may be necessary to vibration-isolate the test apparatus. The test device should have a timer for measuring the period of time required to cause container failure and means such as a dial indicator to measure box deformation (inches or millimetres) while under load, or an autographic recording device that records load and deformation over a period of time.

5.2 *Closing Equipment for Fiberboard Boxes*—When empty boxes are to be tested, suitable closing facilities such as sealing

[1] This test method is under the jurisdiction of ASTM Committee D10 on Packaging and is the direct responsibility of Subcommittee D10.21 on Shipping Containers and Systems - Application of Performance Test Methods.

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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] The last approved version of this historical standard is referenced on www.astm.org.

FIG. 1 Containers Under Constant Load of Dead Weights Imposed by Other Containers

boards and proper adhesive for closing the flaps of box specimens shall be used. See Test Method D642.

5.3 *Conditioning Apparatus*—Adequate facilities shall be provided to maintain a conditioned atmosphere of temperature and humidity as required for the purpose of the test.

5.4 *Miscellaneous Equipment*—Drying oven, scales, knife, saws, etc., for use in determination of the moisture content or for making other supplementary tests of the materials from which the containers are made. When testing unit loads, it is recommended that an empty pallet be placed on top of the unit load test specimen to achieve conditions similar to actual use.

6. Safety Precautions

6.1 Performance of a test should never be considered without regard to safety. Some apparent precautions against injuries are:

6.1.1 Care and caution should be observed while placing the shipping container filled or unfilled on the testing apparatus.

6.1.2 The testing apparatus should have load arrestors or safety interlocks to prevent complete crushing of the container after initial failure.

6.1.3 When using dead weights, caution should be taken when loading and unloading the weights from the apparatus.

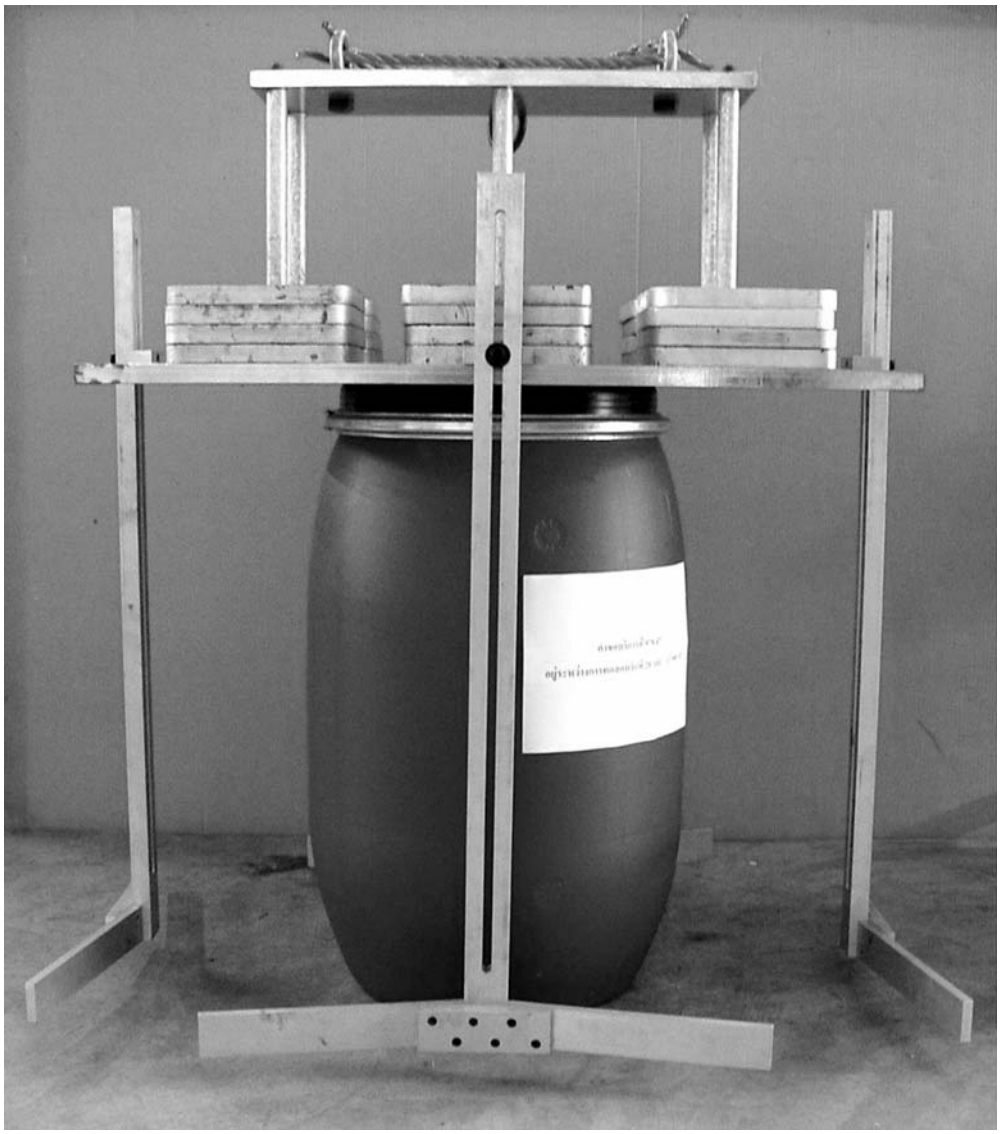


FIG. 2 Container Under Constant Load of Dead Weights

7. Test Specimens and Number of Tests

7.1 The containers being tested shall be complete in all respects. Depending on the purpose of the test, interior packing may or may not be included. No related bracing material within the boxes that will give false results as to sample behavior shall be used. Tests may be made on containers with or without contents as prescribed. Packed containers should be closed and secured in the same manner as will be used in preparing them for shipment (for example, tape, strapping).

7.2 Performance normally should be based on tests of not fewer than five representative specimens of a given size and type of container. For large production runs, lot sampling is advised. Application of Practice E122 is suggested.

7.3 For testing unitized loads, multiple specimens are recommended but a single specimen is permissable.

8. Closing Fiberboard Containers Using Adhesive

8.1 Close the box specimen so as to avoid distortions that may affect its loadbearing ability. The method of preparing the test specimen as described in the Annex of Test Method D642 will accomplish this, but any method that will produce the same results may be used.

9. Conditioning

9.1 When required, the container should be conditioned for the static load test by exposure to fixed or controlled variable conditions of temperature and humidity.

9.1.1 Where applicable, a special atmosphere selected from those specified in Practice D4332 may be used.

9.2 The test container shall be preconditioned in the desired atmosphere for such a time as is necessary to bring the container into equilibrium with that atmosphere and using the techniques given in Practice D685.

10. Acceptance Criteria

10.1 Acceptance criteria must be established prior to testing and should consider the required condition of the product at receipt. The organizations conducting the test may choose any

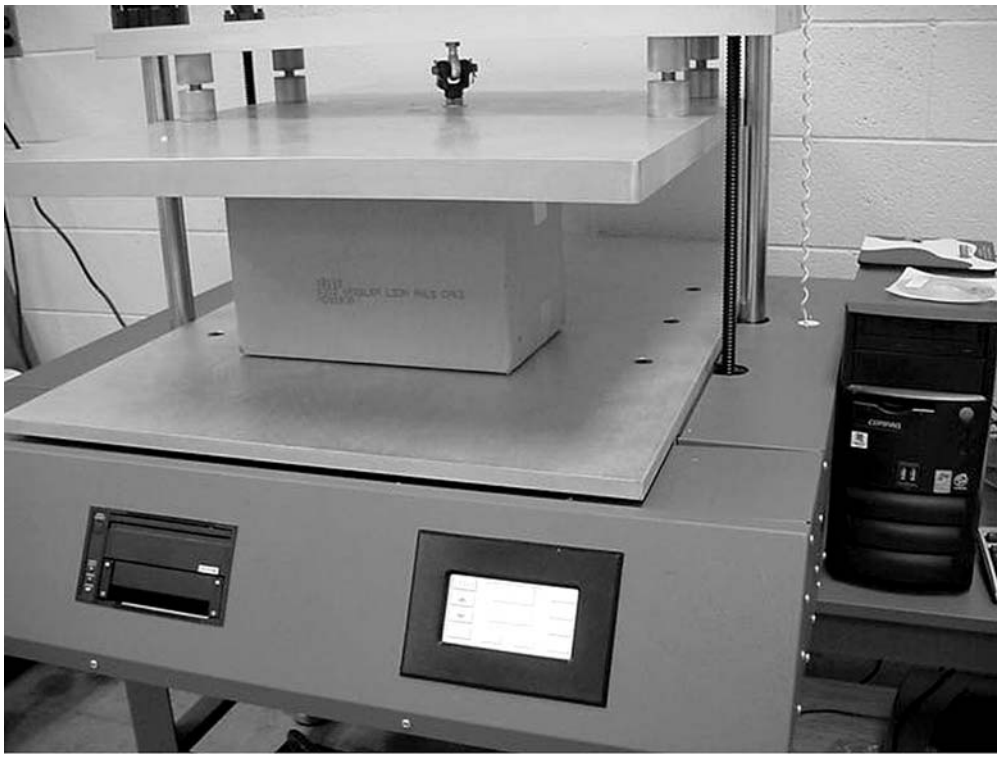


FIG. 3 Container Under Constant Load in Compression Test Machine With Fixed Platen

acceptance criteria suitable for their purpose. It is advisable to compare test results from proposed containers with the test results on similar containers whose shipping history is known.

10.2 In many cases, the acceptance criteria of a package that has been subjected to the test plan can be one of the following:

Criterion 1—Product is damage-free.

Criterion 2—Package is intact.

Other acceptance criteria, including provision for accepting minimal damage to the product or package, may be indicated. Acceptance criteria may include a provision for the condition of package. The form and content of acceptance criteria may vary widely, according to the particular situation. Criteria may range from the most rudimentary to highly quantitative scoring or analysis systems.

11. Procedure

11.1 Prior to test, select the constant load to which the container will be subjected. The selection may be based on:

11.1.1 The load to which a bottom container will be subjected to in storage, for example, warehouse.

11.1.2 A percentage of the value obtained by Test Method D642 on a similar container.

NOTE 1—For corrugated containers, the work of Kellicutt and Landt[4] may be used as a guide to the selection of the percentage but at no time should the load exceed 85 % of the test value derived by Method D642 testing.

11.2 When using a compression machine (Fig. 3 and Fig. 4), center the specimen on the bottom platen of the testing apparatus so as not to incur eccentric loading. Induce the test load on the specimen. The load shall be slowly applied at a near uniform rate until the container supports the entire load. When using dead weights (Fig. 1 and Fig. 2), this is accomplished by lowering the support jacks and completely freeing the upper platen.

11.3 For a controlled fixture on a compression machine, set it to a constant load control mode. The timing device is then started. An initial observation and record of zero deformation shall begin at the end of 60 s after full load to establish base-time reference. Additional observations will be made after 5 min, 10 min, 30 min, 60 min, and 2 h. Thereafter, observations and reading of deformation shall be made at predetermined intervals, until the specified test period is over, or the container fails.

11.4 *Moisture Content (When Specified):*

11.4.1 *Fiberboard Containers*—Determine the moisture content of fiberboard at the end of the test in accordance with Test Method D644.

11.4.2 *Wood Container*—Determine the moisture content of wood at the end of the test in accordance with Test Methods D4442.

[4] Kellicut, K. Q., and Landt, E. F., "Safe Stacking Life of Corrugated Boxes," *Fibre Containers*, Vol 36, No. 9, Sept. 1951.

FIG. 4 Unitized Load Under Constant Load in Compression Machine With Swivel (Floating) Platen

12. Calculation

12.1 This test produces time-to-failure data that does not conform to the normal or Gaussian distribution: The logarithms of the data, natural or common, do tend to be normally distributed. Before analysis, transform the data using the following equation:

$$C = \log D \quad (1)$$

where:

C = transformed datum, and
D = observed datum.

12.2 The arithmetic mean of the transformed data is the recommended measure of central tendency. The antilog of this average is a median estimate for the observed data.

12.3 The standard deviation of the transformed data is the recommended measure of variability or dispersion. Statistical calculations should use this standard deviation directly, without transforming it to observed units of time. The antilogs of upper and lower confidence limits will be in observed units of time and will not be symmetrical about the median estimate. (See Annex A1.)

NOTE 2—Calculations based on the Weibull distribution are an acceptable alternative to these procedures. (See Annex A2.)

13. Report

13.1 The report shall include the following:

13.1.1 Dimensions of the container under test; its complete structural specifications; kind of material; description and specification of blocking and cushioning if used; spacing, size, and kind of fasteners; method of closing; and net and gross mass.

13.1.2 Description of the contents of the container, if any.

13.1.3 Acceptance criteria that have been established.

13.1.4 A detailed report of the test on each container, including damage to the container and contents, together with any observations that may assist in correctly interpreting results, or aid in improving the design of the container.

13.1.5 A graph or table showing the deflection versus time for each test.

13.1.6 The method of conditioning the container including the temperature and relative humidity of the conditioning atmosphere, the moisture content of the material (where applicable), and the results of any supplementary test of the materials from which the container was made.

13.1.7 Report the number of containers tested, and the mean, and standard deviation in transformed units, and the median estimate in observed units of time.

13.1.8 The compression test results from Method D642.

13.1.9 A statement to the effect that all tests were performed in full compliance with this test method noting any variations. Report which option of test apparatus was used, dead weight or compression machine. Report which option of movable loading platen was used for compression machines, swiveled (floating) or fixed.

14. Precision and Bias

14.1 *Precision*—The subcommittee has conducted an analysis of the data based on limited testing by one laboratory. These were top loaded empty regular slotted corrugated containers tested until failure with the time to failure reported in days. The within-laboratory repeatability standard deviation of the common (base 10) logarithms of the days to failure was 0.336. Repeatability may depend on the specific container and conditions of testing. Some packages may be expected to be higher or lower than this. The between-laboratory reproducibility precision has not been determined. Information on use of creep data for predicting container failure is also available.[5,6]

14.2 *Bias*—No justifiable statement can be made on the bias of this test method since a true or absolute value cannot be established by an accepted reference method.

15. Keywords

15.1 compression test; creep test; duration of load; packaging; shipping container; shipping unit; stacking life; storage environment

[5] Burgess, G., Singh, S.P., and Srinangyam, M., "Predicting Collapse Times for Corrugated Boxes Under Constant Top Load Using Short Term Creep Tests," *Journal of Testing and Evaluation*, Volume 33, No. 4.

[6] Singh, S.P., and Burgess, G., "Creep Performance Data for Corrugated Boxes: Accelerated vs. Long Term Compression Strength," *Inside Preshipment Testing*, 3rd Quarter, 2003.

ANNEXES

(Mandatory Information)

A1. EXAMPLE OF CALCULATIONS BASED ON LOGARITHMIC CONVERSION

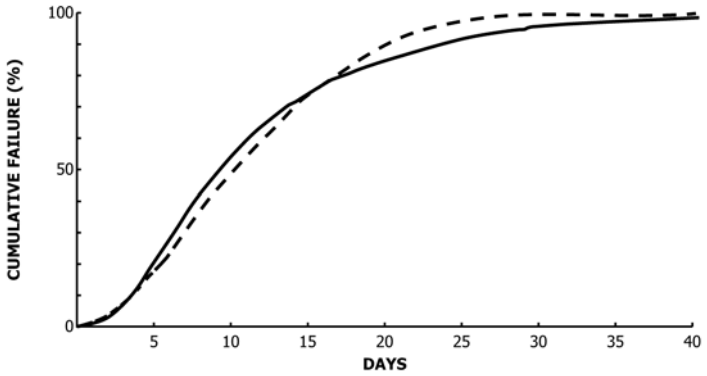
A1.1 The following example demonstrates the method of calculation for time-to-failure data described in the test method. If ten identical containers were tested with the same load, some variation in the times-to-failure for the containers would be expected. For example, a set of ten data points might be: 5.26, 13.56, 6.74, 16.03, 25.23, 11.43, 1.84, 10.97, 13.18, and 8.08 days to failure. It is convenient to list the time to failure (Y) in one column and its logarithm (X) in another column as shown below:

Y	$X = \log(Y)$
5.26 days	0.72
13.56	1.13
6.74	0.83
16.03	1.20
25.23	1.40
11.43	1.06
1.84	0.26
10.97	1.04
13.18	1.12
8.08	0.91

Standard statistical calculations are conducted on the log data (X), which are assumed to be from a normally distributed population. For this example, the average (arithmetic mean) and the sample standard deviation of the log data (X) are calculated to be $\bar{X} = 0.966$ and $s = 0.314$, as estimates of the population parameters. The antilog of the average is 9.25 days and is reported as the central tendency. Other standard statistical calculations also would be based on the log data (X).

A2. EXAMPLE OF WEIBULL CALCULATIONS

A2.1 The Weibull distribution can be fit to the same data from the example in Annex A1. Graphical as well as several computer aided techniques are available to estimate the population parameters. A computer analysis of this set of data yielded an Alpha Scale Parameter of 12.66 and a Beta Shape Parameter of 1.89. From these it would be estimated that 10 % of the population of containers would fail by 3.85 days and 50 % of the containers would fail by 10.43 days.



NOTE 1—The solid line represents the log-normal distribution

FIG. A2.1 Comparative Plots of the Cumulative Failure versus Time for the Example