Standard Test Method for Column Crush Properties of Blown Thermoplastic Containers[1]

This standard is issued under the fixed designation D 2659; 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 covers the determination of mechanical properties of blown thermoplastic containers when loaded under columnar crush conditions at a constant rate of compressive deflection. Any container, whether blown commercially or in the laboratory, may be used as the test specimen.

1.2 The values stated in SI units are to be regarded as the standard.

NOTE 1—There is no similar or equivalent ISO 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.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 618 Practice for Conditioning Plastics for Testing[2]

D 1248 Specification for Polyethylene Plastics Extrusion Materials for Wire and Cable[2]

E 4 Practices for Force Verification of Testing Machines[3]

E 83 Practice for Verification and Classification of Extensometers[3]

3. Terminology

3.1 *Definitions:*

3.1.1 *crushing yield load*—the first load at which an increase of deflection occurs with no increase in load in a compressive crushing test. It is expressed in units of kilograms (or pounds) of load.

NOTE 2—In some cases, usually as a result of design or styling features, or both, of a specific container, multiple values of the crushing yield load may be observed, a small deflection may occur with no increase or with a decrease in the crush load, followed by resumption of the normal crush load change with deflection. This phenomenon cannot be ignored in the evaluation of the column crush properties of a blown thermoplastic container, since it may be a very useful designated failure point for the application under consideration. The load at which this abrupt change occurs may be chosen as a crushing yield load for study. In such a case, the report of results should be accompanied by a proper description of the crushing yield load selected.

3.1.2 *crushing load at failure*—the crushing load applied to a blown thermoplastic container that produces a failure by fracture or parting of the material in any portion of said container. It is expressed in kilograms (or pounds).

3.1.3 *deflection at crushing yield load*—the decrease in length of the container specimen produced at the crushing yield load along the center line of testing (axis of crushing, see Fig. 1). It is expressed in millimetres (or inches).

3.1.4 *apparent crushing stiffness*—the ratio of the crushing load to the corresponding deflection at a point on the linear portion of the crushing load deflection curve. It is expressed in newtons per metre (or pounds per inch).

4. Significance and Use

4.1 Column crush tests provide information about the crushing properties of blown thermoplastic containers when employed under conditions approximating those under which the tests are made.

4.2 The column crush properties include the crushing yield load, deflection at crushing yield load, crushing load at failure, and apparent crushing stiffness. Blown thermoplastic containers made from materials that possess a low order of ductility may fail in crushing by brittle fracture. In such cases, the crushing yield load is equivalent to the crushing load at failure. Blown thermoplastic containers made of ductile materials may not exhibit a crushing load at failure although they will normally provide a crushing yield load value.

4.3 Column crush tests provide a standard method of obtaining data for research and development, applications, design, quality control, acceptance or rejection under specifications, and special purposes. The tests cannot be considered significant for engineering design in applications differing widely from the load - time scale of the standard test. Such applications require additional tests such as impact, creep, and fatigue.

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[2] *Annual Book of ASTM Standards*, Vol 08.01.

[3] *Annual Book of ASTM Standards*, Vol 03.01.

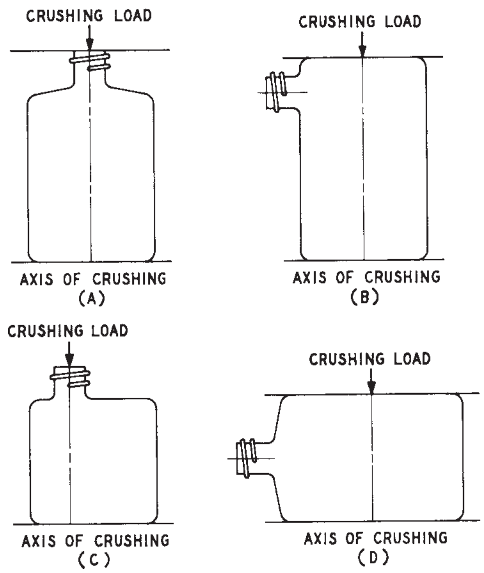

FIG. 1 Typical Crushing Axes

4.4 Before proceeding with this test method, reference should be made to the specification of the material being tested. Any test specimen preparation, conditioning, dimensions, or testing parameters, or combination thereof, covered in the materials specification shall take precedence over those mentioned in this test method. If there are no material specifications, then the default conditions apply.

5. Apparatus

5.1 *Testing Machine*—Any suitable testing machine capable of control of constant-rate-of-crosshead movement and comprising essentially the following:

5.1.1 *Drive Mechanism*—A drive mechanism imparting the crosshead movable member of a uniform, controlled velocity with respect to the fixed member, this velocity to be regulated as specified in Section 9.

5.1.2 *Load Indicator*—A load-indicating mechanism capable of showing the total crushing load carried by the test specimen. The mechanism shall be essentially free from inertia-lag at the specified rate of testing and shall indicate the crushing load with an accuracy of ±1 %. The accuracy of the testing machine shall be verified at least once a year, in accordance with Practices E 4.

5.2 *Extensometer*—A suitable instrument for determining the distance between the two surfaces of load application on the test specimen at any time during the test. It is desirable that this instrument automatically record this distance, or any change in it as a function of the crushing load on the test specimen. The instrument shall be essentially free of inertia-lag at the specified rate of loading and shall conform to the requirements for a Class B-2 extensometer, as defined in Practice E 83.

6. Test Specimens

6.1 The specimens for testing shall be the blown thermoplastic container under investigation. The specimens must be free of obvious defects such as rocker bottoms or bent necks, unless such defects constitute a variable to be studied. The surfaces of the container that bear on the fixed and movable members of the testing machine shall be parallel to each other.

NOTE 3—In the event that the bearing surface of the blown thermoplastic container deviates noticeably from the parallel relationship, the construction and use of a suitable testing jig will be necessary. This jig shall be attached to that crosshead member of the testing machine that contacts the nonparallel surface of the container. Similarly, some blown thermoplastic container designs may cause slippage on the machine crushing surfaces. In this event, a nonslip material such as masking tape should be applied to the slipping member of the testing machine.

7. Conditioning

7.1 *Conditioning*—Condition the test specimens at 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 5 % relative humidity for not less than 40 h prior to test in accordance with Procedure A of Practice D 618, for those tests where conditioning is required. In cases of disagreement, the tolerances shall be ± 1°C (±1.8°F) and ±2 % relative humidity.

7.2 *Test Conditions*—Conduct tests in the standard laboratory atmosphere of 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 5 % relative humidity, unless otherwise specified in the test methods. In cases of disagreement, the tolerances shall be ±1°C (±1.8°F) and± 2 % relative humidity.

NOTE 4—Blown thermoplastic container test specimens that are made of materials known to be insensitive to changes of relative humidity, may be conditioned at the Standard Laboratory Temperature of 23 ± 2°C (73.4± 3.6°F) for a period of 24 h, unless otherwise specified.

8. Number of Test Specimens

8.1 At least 20 specimens shall be tested for each sample on any given axis of crushing. If more than one axis of crushing is to be studied, at least 20 specimens shall be tested for each axis.

8.2 Specimens that fail at some obvious fortuitous flaw shall be discarded and retests made, unless such flaws constitute a variable to be studied. The data should be discarded and the number of rejected specimens noted.

9. Speed of Testing

9.1 Speed of testing shall be the relative rate of motion of the fixed and movable members of the testing machine during the test. Rate of motion of the movable member, when the machine is running idle, may be used if it can be shown that the resulting speed of testing is within the limits of variation allowed.

9.2 The speed of testing shall be constant within ±10 %.

9.3 The speed of testing shall be chosen in the range from 12.5 mm (0.50 in.)/min to 50.0 mm (2.0 in.)/min.

NOTE 5—Round-robin tests have shown that precision of measurements is less than satisfactory when testing speeds less than 12.5 mm (0.50 in.)/min or more than 50.0 mm (2.0 in.)/min were employed for a limited number of blown thermoplastic container styles and designs. Lower or higher testing speeds may be used if it can be shown that the precision of the resulting measurements is satisfactory.

NOTE 6—A testing speed of 25.0 ± 2.5 mm (1.0 ± 0.1 in.)/min has been found useful. It is desirable, however, that several speeds of testing be evaluated when a new blown thermoplastic container is to be studied, since different performance behavior may be observed at different testing speeds.

10. Procedure

10.1 Conduct the tests in the standard laboratory atmosphere of 50 ± 5 % relative humidity and 23 ± 2°C (73.4 ± 3.6°F) unless the material used to make the specimen is known to be unaffected by change of relative humidity. In this latter case, the tests may be conducted at the standard laboratory temperature of 23 ± 2°C (73.4 ± 3.6°F).

10.2 Determine the weight of the test specimen to the nearest 0.1 g.

10.3 Place the test specimen between the members of the testing machine, taking care to align the axis of crushing with the center line of the movable member of the testing machine and to ensure that the bearing surfaces of the test specimen are parallel to the bearing surfaces of the testing machine fixed and movable members. Provide a vent to allow equalization of air pressure during the crushing test. Adjust the movable member of the testing machine until it just contacts the top of the test specimen.

NOTE 7—The axis of crushing must be carefully selected so as to provide measurements along the desired blown thermoplastic container center line. Fig. 1 shows typical axes of crushing selections.

NOTE 8—Round-robin tests have shown that pressure changes within a sealed blown thermoplastic container during column crush tests will change the values obtained. If the seal is not consistent, the accuracy and precision of the measurement will be adversely affected. Furthermore, testing of sealed specimens can result in explosive failure, so that testing is not recommended without proper safeguard. Thus, venting of the specimens is necessary, not only to ensure accuracy and precision of measurements, but, also, as a safety precaution, and to ensure a correct basis for obtaining comparable measurement data. In the case of (a) and (c) in Fig. 1, this may be accomplished by allowing the container opening to remain unsealed and drilling a hole in the testing machine member that bears on this opening.

10.4 If the crushing yield load data only are desired, proceed as follows:

10.4.1 Set the speed control at the desired speed of testing and start the machine.

10.4.2 Record the load carried by the specimen as defined in 3.1 and the location of the yield or failure of the specimen.

10.5 If crush load - deflection data are desired, proceed as follows:

10.5.1 Attach or adjust the extensometer, or both.

10.5.2 Set the speed control at the desired speed of testing and start the machine.

10.5.3 Record crush loads and corresponding deflection at appropriate intervals of deflection, or, if the test machine is equipped with an automatic recording device, record the crush load - deflection curve to the desired end point. In either case, also record the location of the yield or failure of the specimen.

11. Calculation

11.1 *Crushing Yield Load*—Determine the crushing yield load by observation of that point on the crush load - deflection curve at which an increase in deflection occurs without an increase in crush load. Express the result in kilograms (or pounds) and report to three significant figures.

11.2 *Crushing Load at Failure*—Determine the crushing load at failure by observation of that point on the crush load - deflection curve that corresponds to the failure by fracture or parting of the material. Express the results in kilograms (or pounds) and report to three significant figures.

11.3 *Deflection at Crushing Yield Load*—Determine the deflection at crushing yield load by observation of the decrease in length produced in gage length of the specimen at the crushing yield load. Express the results in millimetres (or inches) and report the result to three significant figures.

11.4 *Apparent Crushing Stiffness*—Calculate the apparent crushing stiffness by selecting any point on the initial straight line portion of the crush load - deflection curve and dividing the crush load at this point by the corresponding deflection. Express the results in newtons per metre (or pounds per inch) and report to three significant figures.

NOTE 9—Some blown thermoplastic containers may not show linear behavior in the crushing load-deflection curve (see 12.1.11).

11.5 For each sample of at least 20 test specimens, calculate to three significant figures the arithmetic mean of all values obtained and report as the "average value" for the particular property in question.

11.6 For each lot of samples tested, calculate the standard deviation (estimated) as follows and report to two significant figures.

$$s = \sqrt{(\Sigma X^2 - n\bar{X}^2)/(n-1)} \quad (1)$$

where:

s = estimated standard deviation,
X = value of a single observation,
n = number of observations, and
$\bar{X}$ = arithmetic mean of the set of observations.

12. Report

12.1 Report the following information:

12.1.1 Complete identification of the blown thermoplastic container tested, such as type, source, manufacturer, form, and previous history,

12.1.2 Purpose of test,

12.1.3 Conditioning procedure used,

12.1.4 Atmospheric conditions in test room,

12.1.5 Description of axis of crushing used,

12.1.6 Number and weight of specimens, average value, and standard deviation,

12.1.7 Speed of testing,

12.1.8 Crushing yield load, average value, and standard deviation,

12.1.9 Crushing strength at failure, average value, standard deviation, and description of failure,

12.1.10 Deflection at crushing yield point, average value, and standard deviation,

12.1.11 Apparent crushing stiffness, average value, and standard deviation, as well as specification at the point chosen in the case of a crush load - deflection curve that is nonlinear,

12.1.12 Description of the yield or any other failure phenomenon of the specimen, and

12.1.13 Date of test.

13. Precision and Bias

13.1 The between-laboratories *reproducibility* of this test method was determined on a 2015-cm^3 (68-oz) cylindrical container (capacity measured to overflow), weighing approximately 70 g made from a Type III polyethylene plastic (Specification D 1248). The speed of testing was 25.4 mm/min. The sample size was 20 containers. The containers were made in a single laboratory from a single mold and tested in five different laboratories. The average values and between-laboratories standard deviations obtained were:

	X	*s*
Crushing yield load, kg (lb)	35.1 (77.4)	1.68 (3.7)
Deflection at crushing yield load, mm (in.)	8.941 (0.352)	0.787 (0.031)
Apparent crushing stiffness, N/m (lb/in.)	55.7 (493)	3.6 (32)

13.2 The within-laboratory *repeatability* of this test method gave similar results on bottles made from the same mold and the same raw material.

13.3 These containers did not exhibit crushing strength at failure.

13.4 Since there is no accepted reference method for this test method, the bias of this test method cannot be determined.

14. Keywords

14.1 crush properties; plastic containers