



Designation: D 1709 – 03

Standard Test Methods for Impact Resistance of Plastic Film by the Free-Falling Dart Method¹

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1. Scope*

1.1 These test methods cover the determination of the energy that causes plastic film to fail under specified conditions of impact of a free-falling dart. This energy is expressed in terms of the weight (mass) of the missile falling from a specified height which would result in 50 % failure of specimens tested.

1.2 Two test methods are described:

1.2.1 *Test Method A* employs a dart with a 38.10 ± 0.13 -mm [1.500 ± 0.005 -in.] diameter hemispherical head dropped from a height of 0.66 ± 0.01 m [26.0 ± 0.4 in.]. This test method may be used for films whose impact resistances require masses of about 50 g or less to about 2 kg to fracture them.

1.2.2 *Test Method B* employs a dart with a 50.80 ± 0.13 -mm [2.000 ± 0.005 -in.] diameter hemispherical head dropped from a height of 1.50 ± 0.03 m [60.0 ± 0.25 , -1.70 in.]. Its range of applicability is from about 0.3 kg to about 2 kg.

1.3 Two testing techniques are described:

1.3.1 The standard technique is the staircase method. By this technique, a uniform missile weight increment is employed during test and the missile weight is decreased or increased by the uniform increment after test of each specimen, depending upon the result (fail or not fail) observed for the specimen.

1.3.2 The alternative technique provides for testing specimens in successive groups of ten. One missile weight is employed for each group and missile weight is varied in uniform increments from group to group.

1.3.3 The staircase technique and the alternative technique give equivalent results both as to the values of impact failure weight which are obtained and as to the precisions with which they are determined.

1.4 The values stated in SI units are to be regarded as standard. The values stated in parentheses are for information only.

NOTE 1—Tests on materials that do not break, for any reason, are not considered to be valid. It has been noted that certain materials may stretch so far as to bottom out at the base of certain test instruments without

actually rupturing. Subcommittee D20.19 is currently considering methods for testing these materials. Anyone interested in participating in a Task Group should contact the Chairman of Subcommittee D20.19 through ASTM International Headquarters.

NOTE 2—This test method is technically equivalent to ISO 7765-1:1988, with the exception of a larger tolerance on the drop height in Test Method B. Also, the ISO method does not allow the alternative testing technique described in Section 11 of this test method.

1.5 *This standard does not purport to address 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 374 Test Methods for Thickness of Solid Electrical Insulation²
- D 618 Practice for Conditioning Plastics for Testing³
- D 883 Terminology Relating to Plastics³
- D 1248 Specification for Polyethylene Plastics Extrusion Materials for Wire and Cable³
- D 3420 Test Method for Dynamic Ball Burst (Pendulum) Impact Resistance of Plastic Film⁴
- D 4272 Test Method for Total Energy Impact of Plastic Films by Dart Drop⁴
- E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods⁵
- E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method⁵

2.2 ISO Standard:

- ISO 7765:1988 Plastic Film and Sheeting—Determination of Impact Resistance by the Free Falling Dart Method—Part 1: Staircase Method⁶

3. Terminology

3.1 *Definitions*—For definitions related to plastics, see Terminology D 883.

¹ These test methods are under the jurisdiction of ASTM Committee D20 on Plastics and are the direct responsibility of Subcommittee D20.19 on Film and Sheeting.

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² *Annual Book of ASTM Standards*, Vol 10.01.

³ *Annual Book of ASTM Standards*, Vol 08.01.

⁴ *Annual Book of ASTM Standards*, Vol 08.02.

⁵ *Annual Book of ASTM Standards*, Vol 14.02.

⁶ Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

*A Summary of Changes section appears at the end of this standard.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *failure*—any break through the film that can be observed readily by feeling or by viewing the specimen under backlighted condition.

3.2.2 *impact failure weight*—that missile weight, estimated statistically, at which 50 % of the specimens would fail in the specified test.

3.2.3 *missile weight*—the weight (mass) of the dart plus the total value of incremental weights attached *plus* the locking collar.

4. Significance and Use

4.1 Test Methods A and B are used to establish the weight of the dart when 50 % of the specimens fail under the conditions specified. Data obtained by one test method cannot be compared directly with the other test method nor with those obtained from tests employing different conditions of missile velocity, impinging surface diameter, effective specimen diameter, and thickness. The values obtained by these test variables are highly dependent on the method of film fabrication.

4.2 The results obtained by Test Methods A and B are greatly influenced by the quality of film under test. The confidence limits of data obtained by this procedure can, therefore, vary significantly, depending on the sample quality, uniformity of film gage, die marks, contaminants, etc. (see Section 15).

4.3 Test Methods A and B have been found useful for specification purposes. Correlation between test results and field performance can usually be established.

4.4 The impact resistance of plastic film, while partly dependent on thickness, has no simple correlation with sample thickness. Hence, impact values cannot be normalized over a range of thickness without producing misleading data as to the actual impact resistance of the material. Data from these test methods are comparable only for specimens that vary by no more than ± 25 % from the nominal or average thickness of the specimens tested.

4.5 Several impact test methods are used for film. It is sometimes desirable to know the relationships among test results derived by different test methods. A study was conducted in which four films made from two resins (polypropylene and linear low-density polyethylene), with two film thicknesses for each resin, were impacted using Test Methods D 1709 (Method A), D 3420 (Procedures A and B), and D 4272. The test results are shown in the Appendix. Differences in results between Test Methods D 1709 and D 4272 may be expected since Test Methods D 1709 represents failure initiated energy, while Test Method D 4272 is initiation plus completion energy. Some films may show consistency when the initiation energy is the same as the total energy. This statement and the test data also appear in the significance sections and appendixes of Test Methods D 3420 and D 4272.

5. Apparatus

5.1 The apparatus shall be constructed essentially as shown in Fig. 1, using the following components common to both test methods:

5.1.1 *Dart Well*—If the dart impact machine utilizes an enclosed dart well, it must contain a single unobstructed vent with a minimum area of 625 mm^2 ($\sim 1 \text{ in.}^2$) to provide adequate venting.

NOTE 3—Some dart impact machine designs utilize enclosed dart wells that do not permit adequate venting to the atmosphere during impact. Data have shown that this has a significant effect on the observed impact value, especially with films that exhibit high elongation during testing, resulting in atypically high impact values.

NOTE 4—The use of smaller, multiple vents is permitted if it can be demonstrated that the venting efficiency is comparable and has no statistically significant effect on the values obtained.

5.1.2 *Specimen Clamp*—A two-piece annular specimen clamp having an inside diameter of $125 \pm 2.0 \text{ mm}$ [$5.0 + 0.0, -0.15 \text{ in.}$] and conforming to the following requirements:

5.1.2.1 The lower or stationary half of the clamp shall be mounted rigidly so that the plane of the specimen is horizontal.

5.1.2.2 The upper or movable part of the clamp shall be designed to maintain positive and plane contact with the lower part of the clamp when in position. The clamps shall be provided with suitable means of maintaining sufficient contact to hold the film sample firmly in place during the test. Pneumatically operated clamps have been successfully employed.

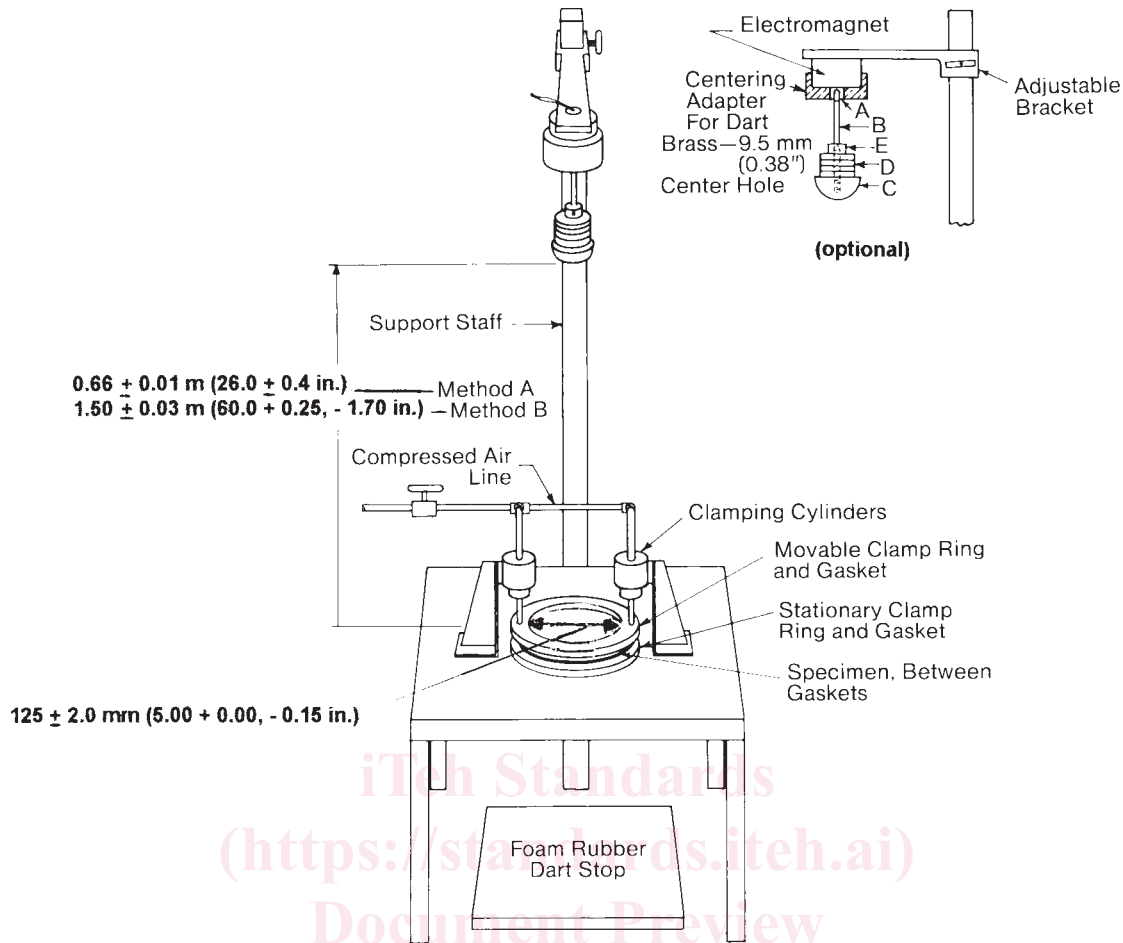
5.1.2.3 Rubber-like gaskets may be affixed to the specimen contact surfaces of both clamps to provide a cushion which minimizes thickness variation effects. Rubber gasketing $3.0 \pm 1 \text{ mm}$ [$0.125 + 0.025, -0.04 \text{ in.}$] thick, of 50 to 60 Shore A durometer hardness, $125 \pm 2.0 \text{ mm}$ [$5.00 + 0.00, -0.15 \text{ in.}$] in inside diameter and $150 \pm 3.0 \text{ mm}$ [$6.0 + 0.02, -0.2 \text{ in.}$] in outside diameter has been found satisfactory for this purpose.

5.1.2.4 Slippage of films greater than 0.10 mm [0.004 in.] in thickness may be minimized or eliminated by securing crocus cloth or 50D garnet abrasive paper to the gaskets with double sensitive tape so that the abrasive surface is in direct contact with the film. There should be sufficient clamping force to eliminate detectable slippage. Other means of reducing slippage such as additional clamping devices or positive clamping surfaces may be used provided that the film is not weakened at the inside wall of the specimen clamps and that the effective diameter of $125 \pm 2.0 \text{ mm}$ [$5.00 + 0.00, -0.15 \text{ in.}$] of the film is not changed.

5.1.3 *Dart Release Mechanism*, capable of supporting a 2-kg weight shall be used for supporting and releasing the dart assembly. It shall be equipped with a centering device, such as a removable plumb bob, to ensure a reproducible drop. Either an electromagnetic- or pneumatic-operated release mechanism may be used.

5.1.4 *Positioning Device*—The apparatus shall be able to drop the dart from heights of $0.66 \pm 0.01 \text{ m}$ [$26.0 \pm 0.4 \text{ in.}$] for Test Method A and $1.50 \pm 0.03 \text{ m}$ [$60.0 + 0.25, -1.70 \text{ in.}$] for Test Method B. The distance between the impinging surface of the dart head and the surface of the test specimen is considered to be the drop height. The dart shall be positioned vertically above the center of the test specimen.

5.1.5 *Micrometer*, accurate to $\pm 0.0025 \text{ mm}$ [$\pm 0.0001 \text{ in.}$] in the range from 0.0025 mm [0.0001 in.] to 1 mm [0.4 in.] for measuring specimen thickness (see Test Methods D 374).



NOTE—Legend Dart Assembly:

- A. Steel shaft tip 6.5 ± 1 mm [$0.25 + 0.04, -0.03$ in.] OD by 12.5 ± 0.2 mm [$0.50 + 0.00, -0.02$ in.] long.
- B. Dart shaft: 6.5 ± 1 mm [$0.25 + 0.04, -0.03$ in.] OD and at least 115 mm [4.5 in.] long: $\frac{1}{4}$ -20 thd. (N.C.) 12.5 ± 0.2 mm [$0.50 + 0.00, -0.02$ in.] long on bottom: No. 5-40 thd. (N.F.) for steel tip.
- C. Hemispherical head: Method A— 38.10 ± 0.13 -mm [1.500 ± 0.005 -in.] in diameter. Method B— 50.80 ± 0.13 -mm [2.000 ± 0.005 in.] in diameter.
- D. Removable weights.
- E. Collar and screw.

FIG. 1 Apparatus for Free-Falling Dart Impact Test for Plastic Film

5.1.6 *Cushioning and Shielding Devices*, to protect personnel and to avoid damaging the impinging surface of the dart. These devices shall not interfere with the dart or the specimen prior to penetrating the specimen.

5.1.7 *Collar* with inside diameter of approximately 7 mm [0.28 in.] and with set screw for securing collar to dart shaft.

5.2 *Darts* for Test Methods A and B shall have hemispherical heads, each fitted with a 6.5 ± 1 -mm [$0.25 + 0.04, -0.03$ -in.] diameter shaft at least 115 mm [4.5 in.] long to accommodate removable incremental weights. Each dart weight shall be known to ± 0.5 % relative. Dart head surfaces shall be free of nicks, scratches, or other irregularities. The shaft shall be attached to the center of the flat surface of the head with its longitudinal axis perpendicular to the surface. If an electromagnet is used, the shaft shall be made of material that is not magnetic and shall have a steel tip 125 ± 0.2 mm [$0.50 + 0.00, -0.02$ in.] long at the end held by the electromagnet.

5.2.1 For Test Method A, the dart head shall be 38.10 ± 0.13 -mm [1.500 ± 0.005 -in.] in diameter. It may be

constructed of smooth, polished aluminum, phenolic, or other low-density material of similar hardness.

5.2.2 For Test Method B, the dart head shall be 50.80 ± 0.13 -mm [2.000 ± 0.005 in.] in diameter. It may be constructed of smooth, polished stainless steel or other material of similar durability.

5.3 The material of construction of the dart head shall be referenced in the report using the following designations:

Material Construction	Designation
Stainless Steel	A
Aluminum	B
Phenolic	C
Composite	D
Other	E

NOTE 5—Data have shown a sensitivity of impact results related to the material of construction and finish of the dart head used. The differences have been especially significant when testing films exhibiting high impact, or high elongation characteristics, or both. This issue, together with related concerns, is currently under study in Subcommittee D20.19.

5.4 *Incremental Weights* for Test Methods A and B shall be of stainless steel or brass and cylindrical in shape. Each shall have a center hole $6.6 + 1.0, -0.00$ mm [$0.26 + 0.03, -0.00$ in.] in diameter. The thickness of each shall be adjusted to obtain the specified weight within $\pm 0.5\%$. The diameter of the weights shall not exceed the diameter of the dart head. Suggested combination of weights for the specified diameters are as follows:

5.4.1 For Test Method A, 31.5 ± 1 -mm [$1.25 + 0.03, -0.05$ -in.] diameter weights.

Number 2 or more	Weight, g
8	5
8	15
8	30
8	60

5.4.2 For Test Method B, 45.0 ± 1 -mm [$1.75 + 0.06, -0.02$ -in.] diameter weights.

Number 2 or more	Weight, g
8	15
8	45
8	90

5.4.3 Optionally, additional weights, each $120 \text{ g} \pm 0.5\%$ for Test Method A or $180 \text{ g} \pm 0.5\%$ for Test Method B, may be constructed for use if it is necessary to extend the missile weight beyond that attainable when using all weights in the standard set.

6. Test Specimen

6.1 Test specimens shall be large enough to extend outside the specimen clamp gaskets at all points. The specimens shall be representative of the film under study and shall be taken from the sheet or tube in a manner representative of sound sampling practice. This is to ensure that the whole of the sheet be represented in the test unless such sampling constitutes a variable under study.

6.2 The specimens shall be free of pinholes, wrinkles, folds, or other obvious imperfections, unless such imperfections constitute variables under study.

7. Conditioning

7.1 *Conditioning*—Follow the conditioning requirements specified in the materials specification for the material that is being tested. Otherwise, condition the test specimens at $23 \pm 2^\circ\text{C}$ [70 to 77°F] and $50 \pm 5\%$ 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 $\pm 1^\circ\text{C}$ [$\pm 1.8^\circ\text{F}$] and $\pm 2\%$ relative humidity.

7.2 *Test Conditions*—Conduct tests in the standard laboratory atmosphere of $23 \pm 2^\circ\text{C}$ [$73.4 \pm 3.6^\circ\text{F}$] and $50 \pm 5\%$ relative humidity unless otherwise specified in the materials specification. In cases of disagreement, the tolerances shall be $\pm 1^\circ\text{C}$ [$\pm 1.8^\circ\text{F}$] and $\pm 2\%$ relative humidity.

8. Preparation of Apparatus

8.1 Set up the apparatus for testing by Test Method A or by Test Method B.

8.1.1 For Test Method A select a dart with a 38.10 ± 0.13 -mm [1.500 ± 0.005 -in.] diameter hemispherical head. For Test Method B, select a dart with a 50.80 ± 0.13 -mm [2.000 ± 0.005 -in.] diameter hemispherical head.

8.1.2 Activate the dart release mechanism and insert the steel shaft tip into the mechanism. The dart should be held in place by the dart release mechanism. Adjust the drop height (the vertical distance from the plane of a clamped specimen to the bottom surface of the dart head) to 0.66 ± 0.01 m [26.0 ± 0.4 in.] for Test Method A or to 1.50 ± 0.03 m [$60.0 + 0.25, -1.70$ in.] for Test Method B. (**Caution**—For safety reasons, remove the dart while making position adjustments.)

8.1.3 With a trial film specimen clamped between the specimen clamps and with no added weights on the dart, release the dart and observe the point at which the dart impacts the specimen, catching the dart after it bounces off the film surface. If necessary, adjust the dart release mechanism so that, in repeated trials, the dart reproducibly impacts the center of the clamped portion of the film.

8.2 Check the apparatus periodically to make sure specimen slippage during testing is not occurring. If slippage occurs, this is reason to reject the results. The likelihood of occurrence of slippage increases with increasing dart weight and with increasing drop height and is greater with some materials than with others. Slippage may be checked conveniently during the course of testing of a routine sample at a missile weight wherein both failures and non-failures are being observed. Either of the following procedures is effective.

8.2.1 Before dropping the missile on a clamped specimen, draw a circle on the film using a ball-point pen in contact with the inside wall of the upper clamp. Apply only the pressure of the pen itself to the film. (**Caution**—For safety reasons, the dart should not be in the dart release mechanism while drawing the circle.) After the dart is dropped and prior to removing the plastic film, draw another circle using a ball-point pen of another color. If the lines are drawn, distinct double lines at any point on the circumference show that slippage has occurred.

8.2.2 If crocus cloth or sandpaper is affixed to the gaskets to effect greater gripping, determine slippage simply by inspecting the clamped film area after impact for evidence of scratch marks produced as slippage occurred.

STAIRCASE TESTING TECHNIQUE

9. Procedure

9.1 By this technique, a uniform missile weight increment is employed during test and the missile weight is changed after test of each specimen.

9.2 Select Test Method A or Test Method B for use, as desired, or as required by the relevant material specification. Set up the apparatus for testing as described in 8.1. If desired, carry out a slippage check as described in 8.2 at some point during the course of testing.

9.3 Measure and record the average thickness of the test specimens in the area of impact to the nearest 0.0025 mm [0.0001 in.].

9.4 For a starting point, select a missile weight near the expected impact failure weight. Add the necessary number of