



Designation: D 4272 – 99

Standard Test Method for Total Energy Impact of Plastic Films By Dart Drop¹

This standard is issued under the fixed designation D 4272; 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 approval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope *

1.1 This test method describes the determination of the total energy impact of plastic films by measuring the kinetic energy lost by a free-falling dart that passes through the film.

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

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.*

NOTE 1—The ISO reference for this test method is ISO 7765-2; however, this test method is not equivalent to Test Method D 4272. The ISO test method calls for a direct readout of energy by using a load cell as part of the impactor head, while Test Method D 4272 calls for a constant weight impactor, then measuring the time of travel through a given distance to get energy values. Therefore, the two are not equivalent in this respect.

2. Referenced Documents

2.1 ASTM Standards:

D 374 Test Methods for Thickness of Solid Electrical Insulation²

D 618 Practice for Conditioning Plastics and Electrical Insulating Materials for Testing³

D 1709 Test Methods for Impact Resistance of Plastic Film by the Free-Falling Dart Method³

D 3420 Test Method for Dynamic Ball Burst (Pendulum) Impact Resistance of Plastic Film⁴

E 171 Specification for Standard Atmospheres for Conditioning and Testing Flexible Barrier Materials⁵

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method⁶

¹ This test method is under the jurisdiction of ASTM Committee D-20 on Plastics and is the direct responsibility of Subcommittee D 20.19 on Film and Sheeting. Current edition approved Aug. 10, 1999. Published September 1999. Originally published as D 4272 – 83. Last previous edition D 4272 – 96.

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 15.09.

⁶ Annual Book of ASTM Standards, Vol 14.02.

2.2 ISO Standard:
ISO 7765-2⁷

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 *free-fall time*—the measured time required for the dart to travel through the sensing area with no film specimen in the clamp.

3.1.2 *missile weight*—the weight of the dart plus the total value of incremental weights attached, including the locking collar.

3.1.3 *test-fall time*—the measured time for the dart to travel through the sensing area with a film specimen in the clamp.

4. Summary of Test Method

4.1 The velocity of a freely falling dart of specified shape that has passed through a sheet of plastic film is determined by means of a photoelectric speed trap. The kinetic energy corresponding to this velocity is calculated and compared with the kinetic energy of the same dart measured without a plastic film in place. The loss in kinetic energy, suffered by the dart that ruptured the film, is used as an index of impact resistance.

5. Significance and Use

5.1 Evaluation of the impact toughness of film is important in predicting the performance of a material in applications such as packaging, construction, and other uses. The test simulates the action encountered in applications where moderate-velocity blunt impacts occur in relatively small areas of film.

5.2 The values obtained by this test method are highly dependent on the method and conditions of film fabrication as well as the type and grade of resin.

5.3 Test methods employing different missile velocities, impinging surface diameters, or effective specimen diameters will most likely produce different results. Data obtained by this test method cannot necessarily be compared directly with those obtained by the other test methods.

5.4 The impact resistance of a film, while partly dependent on thickness, does not have a simple correlation with sample thickness. Hence, impact values expressed in joules (ft-lbf)

⁷ Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

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

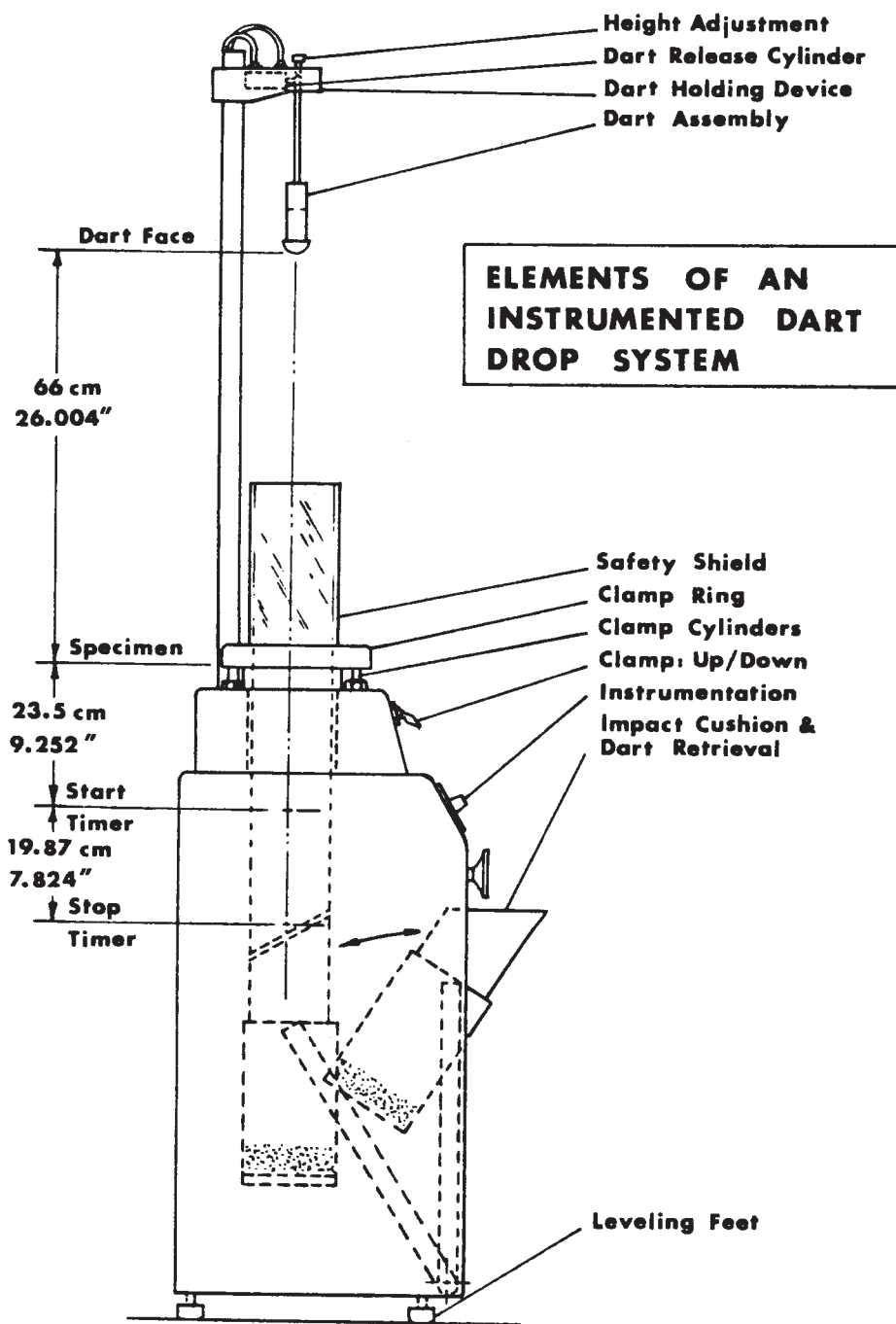


FIG. 1 Elements of an Instrumented Dart Drop System

normalized over a range of thickness will not necessarily be linear with thickness. Data from this test method are comparable only for specimens that vary by no more than $\pm 15\%$ from the nominal or average thickness of the specimens tested.

5.5 The test results obtained by this test method are greatly influenced by the quality of film under test. The influence of variability of data obtained by this procedure will, therefore, depend strongly on the sample quality, uniformity of film gage, the presence of die marks, contaminants, etc.

5.6 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 (Test Method A), Test Method D 3420 (Procedures A and B), and Test Method D 4272. The test results are shown in Appendix X2. Differences in results between Test Methods D 1709 and D 4272 are 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 and appendixes sections of Test Methods D 1709 and D 3420.

6. Apparatus

6.1 *Free-Falling Dart*, as described in Test Methods D 1709, Test Method A.

NOTE 2—Pneumatically operated annular clamps have been successfully employed with a supply of compressed air capable of maintaining a pressure of at least 0.552 MPa (80 psi) sufficient to prevent film slippage. Pressure may be reduced if fracture of the film due to clamping occurs. Clamping diameter is 127 mm (5 in.).

6.2 *Time Counter*, with a sensitivity to measure in 10^{-5} s.

6.3 *Light-Sensitive Speed Trap*, to activate the time counter device.

6.4 *Micrometer*, accurate to ± 0.0025 mm (± 0.0001 in.) for measuring specimen thickness (see Test Methods D 374).

6.5 *Darts*, with 38.10 ± 0.13 -mm (1.500 ± 0.005 -in.) diameter hemispherical stainless steel head. Dart weight equals 227 g (0.5 lb).

NOTE 3—Stem diameter of 9.52 mm (0.37 in.) has been found satisfactory to resist bending.

6.6 *Dart Weights* (five), starting at 227 g (0.5 lb) and increasing in 227-g (0.5-lb) increments to 1135 g (2.5 lb). Weights are made by cutting metal rod stock, such as lead or steel, to various lengths. Weight diameter shall be 31.8 mm (1.25 in.) or less.

7. Test Specimens

7.1 The minimum size for a single determination is at least 165.0 by 152.5 mm ($6\frac{1}{2}$ by 6 in.). However, for convenience in handling, 165.0 by 200 mm ($6\frac{1}{2}$ by 8 in.) is preferred, or a roll 165.0 mm wide can be fed.

7.2 The specimens shall be representative of the film under study and shall be taken from the sample sheet in a manner representative of sound sampling practice.

7.3 The sample shall be free of pinholes, wrinkles, folds, or other obvious imperfections, unless such imperfections are the variables under study.

7.4 A minimum of five test specimens is required to obtain a reliable test result for a film sample.

7.5 The film shall be identified with material, roll or lot number, extruder (if known), type (blown or cast), date of manufacture, treatment, sample source, and date of receipt.

7.6 Measure and record the thickness of the film specimens in the area of impact to the nearest 0.0025 mm (0.0001 in.). Reject samples that vary by more than 15 % from the nominal or average thickness.

8. Preparation of Apparatus

8.1 Turn on the counter and the power supply for the light-sensing unit and allow to warm up in sufficient time to reach equilibrium. (See manufacturer's instructions.)

8.2 Without prior knowledge of the impact resistance of the film tested or specific instructions, use a 908-g (2-lb) dart weight at 0.66-m (26-in.) height.

8.3 Position the dart vertically in the holder and clamp the dart with the dart-holding device. Allow a few seconds for any vibration to subside and release the dart. Record the free-fall time.

8.4 Repeat 8.3 four more times. Average the five measured times and record as t_1 .

8.4.1 The time reading of each of the five free-falls shall be within ± 30 μ s of the average. If it is not, check the timing system, the position of the sensing element, etc. until this repeatability is obtained with five free-falls.

8.4.2 The dart shall not vibrate or rotate in the holder and shall fall straight.

8.4.3 To ensure consistency in drop of the dart and position of impact of the dart on the film, the dart tip next to the holder can be scribed so that it can be lined up in the same position each time.

9. Conditioning

9.1 *Conditioning*—Unless otherwise specified, condition the test specimens at $23 \pm 2^\circ\text{C}$ ($73.4 \pm 3.6^\circ\text{F}$) and $50 \pm 5\%$ relative humidity for not less than 40 h prior to test in accordance with Procedure A of Practice D 618. In cases of disagreement, the tolerances shall be $\pm 1^\circ\text{C}$ ($\pm 1.8^\circ\text{F}$) and $\pm 2\%$ relative humidity.

9.2 *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 (Specification E 171). In cases of disagreement, the tolerances shall be $\pm 1^\circ\text{C}$ ($\pm 1.8^\circ\text{F}$) and $\pm 2\%$ relative humidity.

10. Test Procedure

10.1 Place the specimen over the bottom part of the clamp, making sure that it is uniformly flat, that it is free of wrinkles and folds, and that it covers the gasket at all points.

10.2 Clamp in place with the top part of the clamp by applying air pressure to the cylinders.

10.3 Position the dart vertically in the holder and clamp the dart with the dart-holding device.

10.4 Wait a few seconds for any vibrations to subside.

10.5 Release the dart. The dart shall fall straight.

10.6 Record the test-fall time, t_2 .

10.7 Examine the film to determine the type of failure: for example, hole, tear, shatter, etc.

10.8 Repeat 10.1-10.7 for the remaining specimens.

NOTE 4—**Caution:** The dart may be deflected on some ductile materials, thus causing erroneous results. It is recommended that such materials be rerun using a heavier weight.

11. Calculation

11.1 Calculate the energy to rupture for each test specimen as follows (the derivation of the equation is given in Appendix X1):

In SI units:

$$E = \frac{m}{2g} \left[d^2 \left(\frac{1}{t_1^2} - \frac{1}{t_2^2} \right) + \frac{g^2}{4} (t_1^2 - t_2^2) \right] \quad (1)$$

where:

E = energy to rupture, J,

- m = missile mass, kg,
- g = gravitational constant, 9.81 m/s²,
- d = distance between sensing elements, m,
- t_1 = average free-fall time, s, and
- t_2 = test-fall time, s.

In inch-pound units:

$$E = \frac{m}{2g} \left[d^2 \left(\frac{1}{t_1^2} - \frac{1}{t_2^2} \right) + \frac{g^2}{4} (t_1^2 - t_2^2) \right] \quad (2)$$

where:

- E = energy to rupture, ft·lbf,
- m = missile mass, lb,
- g = gravitational constant, 32.2 ft/s²,
- d = distance between sensing elements, ft,
- t_1 = average free-fall time, s, and
- t_2 = test-fall time, s.

11.2 Calculate the energy to rupture for the film sample as the average of the five energy values for the test specimens.

12. Report

12.1 Report the following information:

12.1.1 Complete identification and description of the material tested, including type, source, manufacturer's code, principle dimensions, and previous history.

12.1.2 Energy to rupture for film sample, J (ft·lbf).

12.1.3 Type of break.

12.1.4 Average thickness and range of thickness for specimens tested to nearest 0.0025 mm (0.0001 in.).

12.1.5 Date of test.

12.1.6 Manufacturer and test instrument model number.

12.1.7 Dart weight.

13. Precision and Bias

13.1 *Precision*—An interlaboratory round-robin study⁸ was conducted by ten laboratories using three materials. Defining a test result to be the average impact resistance from test of five specimens per sample, analysis of the round-robin data in accordance with Practice E 691 led to the following summary statistics for a test result:

	Energy to Rupture, J	Coefficient of Variation, %	
		Within-Laboratories (V _r)	Between Laboratories (V _R)
Polystyrene	0.125	13.0	20.2
Polyethylene	1.61	4.2	8.1
Polypropylene	3.38	12.5	20.9

13.2 *Bias*—Impact resistance is known only as a result of empirical measurement. Therefore, a statement regarding bias is not applicable, as the true value of the property is not known.

NOTE 5—An updated precision and bias statement for this test method is currently in preparation.

14. Keywords

14.1 energy to break; falling apart; film; free-falling dart; impact; instrumented impact; polyolefins; polystyrene; total energy

⁸ Supporting data are available on loan from ASTM Headquarters. Request RR:D 20-1104.

APPENDIXES

(Nonmandatory Information)

X1. DERIVATION OF FORMULA

X1.1 The kinetic energy of a dart of mass (m) traveling at a velocity of v is as follows:

$$\text{kinetic energy} = 1/2 mv^2 \quad (X1.1)$$

X1.2 If the time of the free-fall to travel between two light-sensing elements is t_1 , the distance traveled is d , and the velocity entering the speed trap is v_1 then:

$$d = 1/2 gt_1^2 + v_1 t_1 \quad (X1.2)$$

or, solving for v_1 :

$$v_1 = (d/t_1) - (gt_1/2) \quad (X1.3)$$

X1.3 If the time of the dart to travel between the sensing elements after breaking the film is t_2 then:

$$d = 1/2 gt_2^2 + v_2 t_2 \quad (X1.4)$$

and

$$v_2 = (d/t_2) - (gt_2/2) \quad (X1.5)$$

X1.4 We define the impact energy as the kinetic energy lost

in breaking the film as follows:

In SI units:

$$E = \frac{m}{2g} \left[d^2 \left(\frac{1}{t_1^2} - \frac{1}{t_2^2} \right) + \frac{g^2}{4} (t_1^2 - t_2^2) \right] \quad (X1.6)$$

where:

- E = energy to rupture, J,
- m = missile mass, kg,
- g = gravitational constant, 9.81 m/s²,
- d = distance between sensing elements, m,
- t_1 = average free-fall time, s, and
- t_2 = test-fall time, s.

In inch-pound units:

$$E = \frac{m}{2g} \left[d^2 \left(\frac{1}{t_1^2} - \frac{1}{t_2^2} \right) + \frac{g^2}{4} (t_1^2 - t_2^2) \right] \quad (X1.7)$$

where:

- E = energy to rupture, ft·lbf,
- m = missile mass, lb,



g = gravitational constant, 32.2 ft/s²,
 d = distance between sensing elements, ft,

t_1 = average free-fall time, s, and
 t_2 = test-fall time, s.

X2. IMPACT VALUES BY FOUR TEST METHODS

Material ^A	D 3420 Procedure A ^B	D 3420 Procedure B ^C	D 1709 (Test Method A)		D 4272	
	J	J	g	J	ft-lbf	J
PP, 1 mil	0.30	0.27	^D	^D	0.07 ^E	0.09 ^E
PP, 2 mil	0.95	0.65	75 ^F	0.49 ^F	5.17 ^E	7.01 ^E
LLDPE, 1 mil	0.52	0.41	47 ^G	0.30 ^G	0.36 ^H	0.49 ^H
LLDPE, 3.5 mil	1.43	0.97	309 ^I	2.00 ^I	2.46 ^H	3.34 ^H

^ALLDPE (linear low-density polyethylene).
^BFour laboratories, two sets of data each.
^CEight laboratories, two sets of data each.
^DMinimum weight of the tester was too heavy.
^EOne laboratory, one set of data.
^FThree laboratories, one set of data each.
^GTwo laboratories, one set of data each.
^HTwo laboratories, one set of data each.
^IFive laboratories, one set of data each.

SUMMARY OF CHANGES

This section identifies the location of selected changes to this test method. For the convenience of the user, Committee D20 has highlighted those changes that may impact the use of this test method. This section may also include descriptions of the changes or reasons for the changes, or both.

D 4272-99:

Revised 11.1 and X1.4.

ASTM International takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.

This standard is copyrighted by ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States. Individual reprints (single or multiple copies) of this standard may be obtained by contacting ASTM at the above address or at 610-832-9585 (phone), 610-832-9555 (fax), or service@astm.org (e-mail); or through the ASTM website (www.astm.org).