INTERNATIONAL

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Standard Test Method for Total Energy Impact of Plastic Films By Dart Drop[1]

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 reapproval. 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~~ brackets 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.

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[1] This test method is under the jurisdiction of ASTM Committee D-20 on Plastics and is the direct responsibility of Subcommittee D20.19 on Film and Sheeting .

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

2. Referenced Documents

2.1 *ASTM Standards:* [2]

D 374 Test Methods for Thickness of Solid Electrical Insulation

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

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

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

[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*, Vol 10.01. volume information, refer to the standard's Document Summary page on the ASTM website.

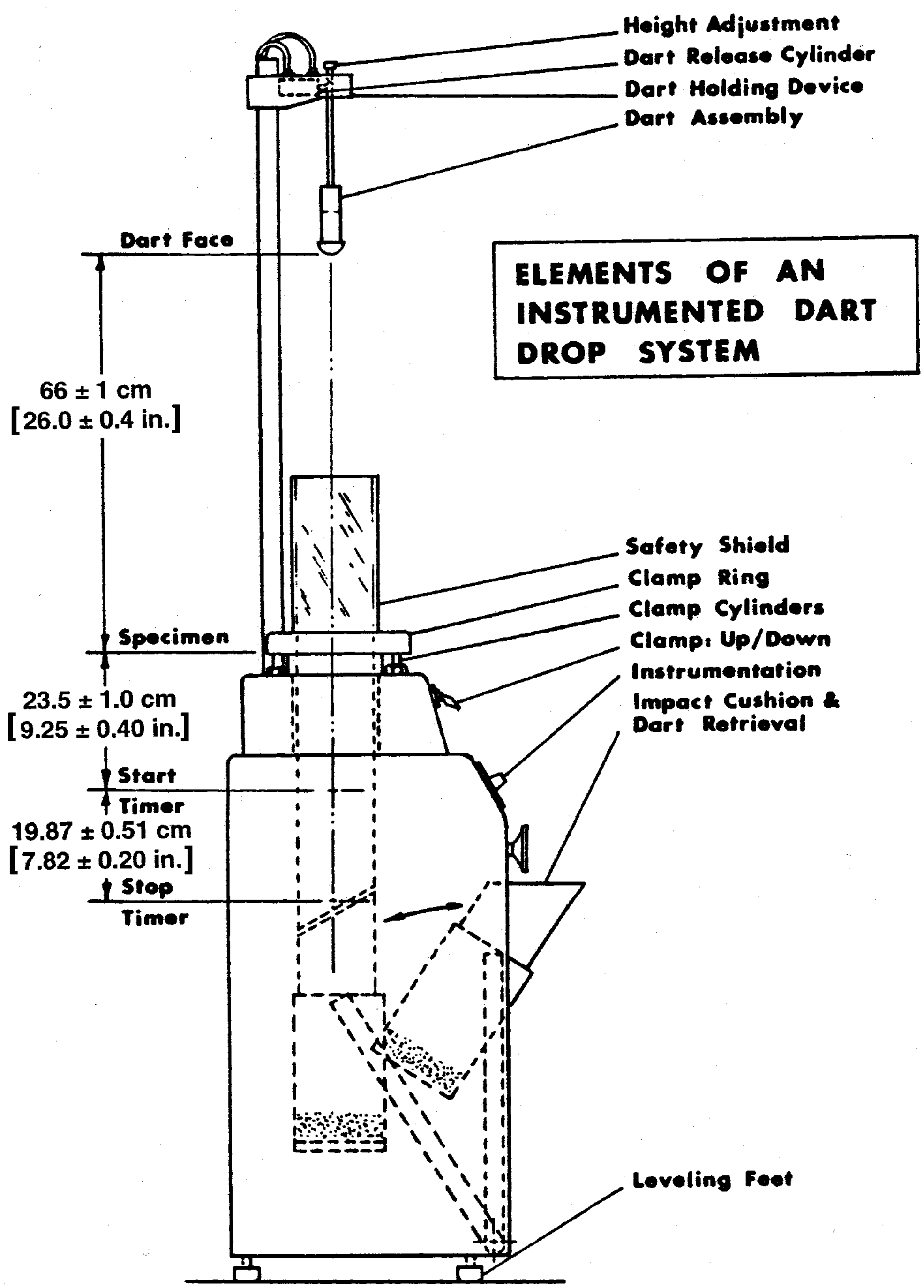

FIG. 1 Elements of an Instrumented Dart Drop System

E 171 Specification for Standard Atmospheres for Conditioning and Testing Flexible Barrier Materials
E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method
2.2 *ISO Standard:*[3]
ISO 7765–2 Plastics Film and Sheeting—Determination of Impact Resistance by the Free Falling Dart Method—Part 2: Instrumented Puncture Test

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 energy of the dart that ruptured due to rupturing of 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) 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 ±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, thickness, 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*,
6.1 The test apparatus shall be constructed essentially as described shown in Test Methods D 1709, Test Method A.

NOTE 2—Pneumatically operated annular clamps have been successfully employed with Fig. 1 and include the following:

6.1.1 A rigid base containing a supply of compressed air capable of maintaining specimen clamping device, a pressure of light sensitive speed trap, and a dart well or chamber for catching and retrieving the dart after impact.
6.1.2 A rigid fixture for holding the dart at least 0.552 MPa (80 psi) sufficient to prevent the proper height above the film slippage. Pressure surface. The dart holding fixture may be reduced if fracture attached to or form an integral part of the film due base unit.

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[3] Available from American National Standards, Vol 08.01 Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

6.1.3 The dimensions of the impact apparatus shall conform to clamping occurs. Clamping diameter is 127 mm (5 in.). those shown in Fig. 1 and those listed below.

6.2 *TSpecific Requirements for Individual Components*:

6.2.1 *Base*—The base shall be rigid enough to prevent movement between the specimen clamp and components of the timing system during impact. It shall be located on a flat surface that provides adequate support to prevent downward movement of the unit during impact. It shall be leveled to insure that the impact surface of the specimen is exactly perpendicular to the trajectory of the dart.

6.2.2 *Specimen Clamp*,—The apparatus shall be equipped with a sensitivity circular clamp to hold the specimen. The clamp may be mechanically, pneumatically, or hydraulically actuated. The diameter of the clamped area shall be 127 ± 2 mm [5.0 ± 0.1 in.]. The clamping surface may be equipped with rubber O-rings, round gaskets or other circular devices to prevent slippage of the specimen during impact. The clamp shall hold the specimen so that the impact surface is exactly perpendicular to the trajectory of the dart and at the correct distance from the tip of the dart. During impact, the specimen shall be held with enough force to prevent slippage but not great enough to distort, fracture, or otherwise damage the specimen in 10^{-5} s.

6.3 such a way as to affect the impact strength of the film.

6.2.3 *Light-Sensitive Speed Trap*—A system comprised of photocells, lasers, or other non-mechanical devices connected to activate the time counter device.

6.4 *Micrometer*, accurate timing device to ±0.0025 mm (±0.0001 in.) for measuring measure the time-of-flight of the dart. The distance from the bottom surface of the specimen thickness (see Test Methods D 374).

6.5 *Darts*, with 38.10± 0.13-mm (1.500 to the upper (starting) sensor shall be 23.5 ± 1.0 cm [9.25 ± 0.405- in.)]. The length of the speed trap, that is, the distamnce betweren them starting and stopping sensors shall be 19.87 ± 0.51 cm [7.82 ± 0.20 in.].

6.2.4 *Timing Device*—An electronic timer capabl ste of measurinlg to the nearest 10^{-5} s.

6.2.5 *Dart Well*—The bottom of the dart well shall contain adequate cushioning material to prevent damage to the dart head. Dart weight equals 227 g (0.5 lb). If the impact machine utilizes an enclosed dart well, it must contain a single unobstructed vent with a minimum area of 645 mm^2 [~1in. ^{2}] to provide adequate venting.

NOTE 32—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 3—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.

6.2.6 *Dart Holding Fixture*—An electromagnetic, pneumatic, or mechanical system to suspend the dart in position above the test specimen. It shall be adjustable vertically and horizontally relative to the impact surface to insure that the dart falls from the correct height and directly onto the center of the clamped specimen. This fixture may be an integral part of the base. When the dart is in position to drop, the distance between the lower tip of the dart and the upper surface of the specimen shall be 66 ± 1 cm [26.0 ± 0.4 in.]. A plumb bob shall be used to precisely center the fixture over the specimen clamp to insure that the dart strikes the center of the specimen. The fixture shall release the dart without imparting any vertical or horizontal force that might affect the trajectory of the dart.

6.2.7 *Dart*—The impact dart shall have a single 38.10 ± 0.13 mm [1.500 ± 0.005 in.] diameter hemispherical stainless steel head. It shall have a mass of 227 ± 5 g [0.50 ± 0.01 lb] and a shaft of sufficient length and diameter to accommodate any additional weights used to increase the mass of the dart. The shaft shall be attached to the center of the flat surface of the dart head with its longitudinal axis perpendicular to the surface. The impact surface of the dart head shall be free of nicks, scratches, or other irregularities.

NOTE 4—A stem diameter of 9.52 mm ([0.37 in.)] has been found to be satisfactory to resist bending.

6.62.8 *Dart Weights* (five), starting at—Weights to increase the mass of the dart in 227 ± 5 g (0.5 lb) and increasing in 227-g (0.5-lb) [0.50 ± 0.01 lb] increments to a total of 1135 ± 25 g ([2.50 ± 0.05 lb)]. The diameter of the weights shall be 31.8 mm [1.25 in.] or less and they shall attach securely to the dart stem. Weights are made by cutting metal rod stock, such as shall be of rigid, metallic construction, that is, not filled with lead shot or s other loose material. In adjusting the mass of the dart, incremental weights may be added individually or as a single weight equivalent to various lengths. Weight diameter the appropriate mass. If single weights are used, their masses shall vary in 227 g [0.5 lb] increments.

6.3 *Other Required Equipment*:

6.3.1 *Micrometer*—For measuring specimen thickness with an accuracy of ±0.80025 mm (1 [±0.250001 in.]. (See Test Method D 374).

6.3.2 *Plumb Bob*—For adjusting the dart holding fixture so that the dart strikes the specimen in the center of the specimen clamp.

7. Test Specimens

7.1 The minimum size for a single determination is at least 165.0 by 152.5 mm (6½ [6.5 by 6 in.)]. However, for convenience in handling, 165.0 by 200 mm (6½ [6.5 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)~~ 908 g [2 lb] dart weight at ~~0.66-m (26-in.)~~ 66 cm [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 µs 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 ± 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. In cases of disagreement, the tolerances shall be ±1°C ~~(~~ [±1.8°F~~)~~] and ±2% relative humidity.

9.2 *Test Conditions*—Conduct tests in the standard laboratory atmosphere of 23 ± 2°C ~~(~~ [73.4 ± 3.6°F~~)~~] and 50 ± 5 % relative humidity (Specification E 171). In cases of disagreement, the tolerances shall be ±1°C ~~(~~ [±1.8°F~~)~~] and ±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, O-ring, or other mounting surface at all points.

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

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. Some ductile materials may cause deflection of the dart, thus causing erroneous results. Such materials shall be retested using a heavier dart.

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:

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

where:

E = energy to rupture, J,
m = missile mass, kg,
g = gravitational constant, 9.81 m/s^2,
d = distance between sensing elements, m,
t_1 = average free-fall time, s, and
t_2 = test-fall time, s.

In inch-pound units:

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

where:

E = energy to rupture, ft·lbf,
m = missile mass, lb,
g = gravitational constant, 32.2 ft/s^2,
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.~~ mass, g.

13. Precision and Bias

13.1 *Precision*—An interlaboratory round-robin study[4] 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:

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[4] Supporting data are available on loan from ASTM Standards, Vol 08.02. Headquarters. Request RR:D20–1104.

		Coefficient of Variation, %		
		~~Within-~~	~~Between~~	
			Within-	Betw
		Energy to	Laboratories	Labor
Rupture, J		(V_r)	(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~~ needed. Anyone interested in ~~preparation.~~ conducting a new round robin study is asked to contact the Subcommittee chairperson.

14. Keywords

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

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:

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

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:

$$d = 1/2\, g t_1^2 + v_1 t_1 \quad \text{(X1.2)}$$

or, solving for v_1:

$$v_1 = (d/t_1) - (g t_1/2) \quad \text{(X1.3)}$$

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

$$d = 1/2\, g t_2^2 + v_2 t_2 \quad \text{(X1.4)}$$

and

$$v_2 = (d/t_2) - (g t_2/2) \quad \text{(X1.5)}$$

X1.4 ~~We define the~~ The impact energy is defined as the kinetic energy lost in breaking the film as follows:

In SI units:

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

where:
E = energy to rupture, J,
m = missile mass, kg,
g = gravitational constant, 9.81 m/s^2,
d = distance between sensing elements, m,
t_1 = average free-fall time, s, and
t_2 = test-fall time, s.

In inch-pound units:

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

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

g = gravitational constant, 32.2 ft/s ^{2},
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]

[A]PP (polypropylene), LLDPE (linear low-density polyethylene).
[B]Four laboratories, two sets of data each.
[C]Eight laboratories, two sets of data each.
[D]Minimum weight of the tester was too heavy.
[E]One laboratory, one set of data.
[F]Three laboratories, one set of data each.
[G]Two laboratories, one set of data each.
[H]Two laboratories, one set of data each.
[I]Five 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– - 03:
(*1*) Five year review conducted.
(*2*) Updated Section 2.
(*3*) Completely revised Section 6.
(*4*) Editorial revisions to 4.1, 5.3, 5.5, 7.1, 8.2, 10.1, 10.2, 12.1.7, 14.1, X1.4, and Appendix X2 (Footnote A).
(*5*) Deleted Note 4 under 10.8 and incorporated this into 10.7.
(*6*) Revised Note 5.
(*7*) Added tolerances to dimensions in Fig. 1.
D 4272 - 99:
Revised 11.1 and X1.4.