



Standard Test Method for Tear Resistance (Graves Tear) of Plastic Film and Sheet¹

This standard is issued under the fixed designation D 1004; 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.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This test method² covers the determination of the tear resistance of flexible plastic film and sheeting at very low rates of loading, 51 mm [2 in.]/min. and is designed to measure the force to initiate tearing. The specimen geometry of this test method produces a stress concentration in a small area of the specimen. The maximum stress, usually found near the onset of tearing, is recorded as the tear resistance in newtons [or pounds-force]. The method is not applicable for film or sheeting material where brittle failures occur during testing or where maximum extension is greater than 101.6 mm [4 in.].

NOTE 1—Film has been arbitrarily defined as sheeting having nominal thickness not greater than 0.25 mm [0.010 in.].

1.2 *Constant-Rate-of-Grip Separation Test*—This test method employs a constant rate of separation of the grips holding the test specimen.

1.2.1 Specimen extension may be measured in this test method by grip separation.

1.3 The values stated in SI units are to be regarded as the standard. The values given in brackets are provided for information only.

1.4 *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 2—There is no similar or equivalent ISO standard.

2. Referenced Documents

2.1 ASTM Standards:³

D 618 Practice for Conditioning Plastics for Testing

D 882 Test Method for Tensile Properties of Thin Plastic Sheet

D 883 Terminology Relating to Plastics

D 4000 Classification System for Specifying Plastic Materials

D 5947 Test Methods for Physical Dimensions of Solid Plastics Specimens

E 4 Practices for Force Verification of Testing Machines

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

2.2 ASTM Adjuncts:

Die Drawings⁴

3. Terminology

3.1 Definitions:

Definitions of terms applying to this test method appear in Terminology D 883.

4. Summary of Test Method

4.1 The force to initiate tearing across a specific geometry of a film or sheeting specimen is measured using a constant-rate-of-grip separation machine. The force necessary to initiate the tear is calculated from the load-time or load-displacement data.

5. Significance and Use

5.1 Tear resistance of plastic film or sheeting is a complex function of its ultimate resistance to rupture. The specimen geometry and speed of testing in this test method are controlled to produce tearing in a small area of stress concentration at rates far below those usually encountered in service. Experience has shown the test to have its best reliability for materials which do not have brittle failure or do not elongate greater than two hundred percent during testing.

5.2 The data from this test method furnish comparative information for ranking the tearing resistance of plastic specimens of similar composition. Actual use performance in tearing of some plastics may not necessarily correlate with data from this test method.

¹ This test method is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.19 on Film and Sheet.

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² The following reference may be of interest in connection with this test method: Graves, F. L., "The Evaluation of Tear Resistance in Elastomers," *India Rubber World*, Vol 111, No. 3, December 1944, pp. 305–308.

³ 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.

⁴ Available from ASTM International Headquarters. Order Adjunct No. ADJD1004.

5.3 The resistance to tear of plastic film and sheeting, while partly dependent upon thickness, has no simple correlation with specimen thickness. Hence, tearing forces measured in newtons [or pounds-force] cannot be normalized over a wide range of specimen thickness without producing misleading data as to the actual tearing resistance of the material. Data from this test method are comparable only from specimens, which vary by no more than $\pm 10\%$ from the nominal or average thickness of all specimens tested. Therefore, the tearing resistance is expressed in maximum newtons [or pounds-force] of force to tear the specimen.

5.4 The tear resistance of plastic film may be a specification that requires the use of this test method, but with some procedural modifications that take precedence when adhering to the specification. Therefore, it is advisable to refer to that material specification before using this test method. Table 1 of Classification System D 4000 lists the ASTM materials standards that currently exist.

6. Apparatus

6.1 *Testing Machine*—A testing machine of the constant rate-of crosshead-movement type and comprising essentially the following:

6.1.1 *Fixed Member*—A fixed or essentially stationary member carrying one grip.

6.1.2 *Movable Member*—A movable member carrying a second grip.

6.1.3 *Grips*—Preferably, a set of self-aligning grips for holding the test specimen between the fixed member and the movable member of the testing machine. The grips should minimize both slippage and uneven stress distribution.

6.1.3.1 Fixed grips are rigidly attached to the fixed and movable members of the testing machine. Fixed grips may be used if extreme care is taken to ensure that the test specimen is inserted and clamped so that the long axis of the test specimen coincides with the direction of pull through the center line of the grip assembly.

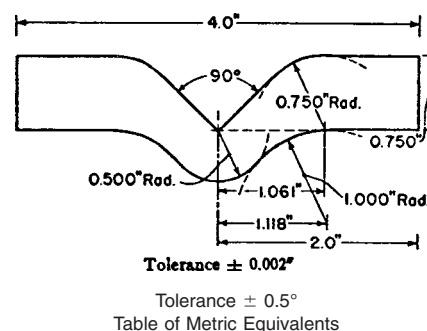
6.1.3.2 Self-aligning grips are attached to the fixed and movable member of the testing machine in such a manner that they will move freely into alignment as soon as any load is applied so that the long axis of the test specimen will coincide with the direction of the applied pull through the center line of the grip assembly.

NOTE 3—The specimens should be aligned as perfectly as possible with the direction of pull so that no rotary motion that may induce slippage will occur in the grips; there is a limit to the amount of misalignment self-aligning grips will accommodate.

NOTE 4—Grips lined with thin rubber have been used successfully. Grips may be of the self-tightening type. In cases where specimens frequently fail at the edge of the grips, the radius of curvature of the edges of the grips may be increased slightly at the point where they come in contact with the specimen.

6.1.4 *Drive Mechanism*—A drive mechanism capable of separating the movable member (grip) from the stationary member (grip) at a controlled velocity of 51 mm [2 in.] \pm 5 %/min.

6.1.5 *Load Indicator*—A suitable load-indicating mechanism capable of showing the total tensile load carried by the test specimen held by the grips. The testing machine shall be



| in. | mm |
|-------|--------|
| 4.0 | 101.60 |
| 0.750 | 19.05 |
| 1.061 | 26.95 |
| 1.000 | 25.40 |
| 1.118 | 28.40 |
| 2.0 | 50.80 |
| 0.002 | 0.051 |
| 0.500 | 12.70 |

FIG. 1 Die for Tear Test Specimen

essentially free from inertial lag at the specified rate of testing and shall indicate the load with an accuracy of $\pm 1\%$. The accuracy of the testing machine shall be verified in accordance with Practices E 4.

6.1.6 *Crosshead Extension Indicator*—A suitable extension-indicating mechanism capable of showing the amount of change in the separation of the grips (crosshead movement).

6.2 *Thickness*—A micrometer as prescribed in Test Methods D 5947, or an equivalent measuring device, reading to 0.025 mm [0.001 in.] or less. The pressure exerted by the gage on the specimen being measured shall not distort or deform the specimen. For thin films, ≤ 0.025 mm [0.001 in.], or films which exhibit visual deformation during measurement, a maximum pressure of 70 kPa [10 psi] is recommended. For thicker or stiffer films, the pressure shall be between 160 and 185 kPa [23 and 27 psi].

6.3 *Die*⁴—A die having the dimensions shown in Fig. 1 shall be used to cut all specimens. The 90° angle shall be honed sharp with no radius or have a minimum practical radius. The cutting edge of the die shall have a 5° negative rake, and shall be kept sharp and free from nicks to avoid leaving ragged edges on the specimen. Wetting the surface of the sample and the cutting edges of the die with water may facilitate cutting. The sample shall rest on the smooth, slightly yielding surface that will not damage the die blade. Lightweight cardboard or a piece of leather belting is suitable. Care should be taken that the cut edges of the specimen are perpendicular to its other surfaces and that the edges have a minimum of concavity.

7. Test Specimens

7.1 The test specimens shall be cut out with a die conforming to the dimensions shown in Fig. 1 and shall not vary by more than 0.5 % from these dimensions. The cutting edges of the die shall be kept sharp and free of all nicks to avoid leaving ragged edges on the specimens.

NOTE 5—Caution should be used to ensure all samples are the same dimension if multiple specimens are cut at one time by stacking (layering) film.

7.2 Machine direction specimens are cut perpendicular to the machine direction and transverse direction specimens are cut perpendicular to the transverse direction.

7.3 At least ten specimens shall be tested for each sample, in the case of isotropic materials.

7.4 Test a minimum of ten specimens each in the machine direction and in the transverse direction for each anisotropic test sample.

7.5 Data from specimens which break at some obvious flaw or which break in or at the edges of the grips shall be discarded and additional specimens tested, unless such failures constitute a variable whose effect is being studied.

7.6 Data from specimens which deviate markedly from the mean value of all tests shall be rejected if the deviation of the doubtful value is more than five times the standard deviation from the mean value obtained by excluding the doubtful results.

NOTE 6—For certain materials whose properties vary considerably throughout the film or sheeting, as many as 50 specimens cut from random portions of the sheet must be tested if reliable tear resistance data are desired.

8. Conditioning

8.1 *Conditioning*—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, 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.

8.2 *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 applicable ASTM material specification. In cases of disagreements, the tolerances shall be $\pm 1^\circ\text{C}$ [$\pm 1.8^\circ\text{F}$] and $\pm 2\%$ relative humidity.

9. Procedure

9.1 An initial jaw separation of 25.4 mm [1 in.] shall be used. The rate of travel of the power activated grip shall be 51-mm [2-in.]/min.

NOTE 7—In this test method, resistance to tear is calculated from the maximum load recorded. In testing most plastics, this maximum load is generated at the onset of tearing across the 13-mm [0.5-in.] testing width of the specimen.

9.2 Measure the thickness of the specimen at several points in the notched area to the accuracy limits of the measuring devices specified in 6.2. Record the average thickness in microns [mil].

9.3 Place the specimen in the grips of the testing machine so that the long axis of the enlarged ends of the specimen is in line with the center line of the grip assembly.

9.4 After complete rupture of the specimen, the maximum tearing load in newtons [pounds-force], and the maximum extension in mm [in.] shall be recorded.

10. Calculation

10.1 Calculate the mean maximum resistance to tearing, and the maximum extension for all specimens tested in each

TABLE 1 Initial Tear Resistance (Graves Tear) Machine Direction

| Material | Values Expressed in Units of Grams-Force | | | | |
|---------------|--|---------|---------|--------|--------|
| | Average | S_r^A | S_R^B | r^C | R^D |
| LDPE—LD 104 | 314.6 | 31.98 | 55.79 | 89.53 | 156.2 |
| LLDPE | 384.9 | 7.80 | 41.73 | 21.84 | 116.8 |
| Polystyrene | 459.8 | 98.06 | 261.6 | 274.6 | 732.3 |
| HDPE No. 2 | 474.0 | 19.82 | 55.42 | 55.51 | 155.2 |
| Polypropylene | 503.9 | 29.87 | 77.45 | 83.64 | 216.9 |
| HDPE No. 1 | 570.9 | 36.35 | 78.20 | 101.8 | 219.0 |
| Polyester | 2494.0 | 6407.9 | 599.2 | 1142.0 | 1678.0 |

^A S_r = within-laboratory standard deviation for the material stated. It is obtained by pooling the standard deviations of the test results from each laboratory:

$$S_r = [\sum (S_i)^2 + (S_2)^2 \dots + (S_n)^2 / n]^{1/2}$$

^B S_R = between-laboratories standard deviation for the material stated. It is a pooling of the amounts by which the average of the test results for each laboratory deviate from the overall average for that material.

^C r = within-laboratory repeatability limit = $2.8 \times S_r$.

^D R = between-laboratories reproducibility limit = $2.8 \times S_R$.

principal direction of orientation. Record maximum tear resistance expressed in newtons [pounds-force] to three significant figures and maximum extension expressed in mm [in.] to two significant figures.

NOTE 8—Resistance to tear may be expressed in newtons per microns, [pounds-force per mil] of specimen thickness where correlation for the particular material being tested has been established. However, it should be realized that comparison between films of dissimilar thickness may not be valid.

10.2 Calculate standard deviation.

11. Report

11.1 Report the following information:

11.1.1 Complete identification of the material tested, including type, source, manufacturer's code number, form, principal dimensions, previous history, and orientation of sample with respect to anisotropy, if any.

11.1.2 Average thickness of each test specimen and average thickness of all test specimens.

11.1.3 Type of testing machine used.

11.1.4 Number of specimens tested in each principal direction.

11.1.5 Average value of tear resistance calculated in newtons [pounds-force] and the maximum extension in mm [in.].

11.1.6 Standard deviation from the averaged values obtained for specimens tested in each principal direction.

12. Precision and Bias ⁵

12.1 Table 1 and Table 2 are based on a round robin conducted between 1986 and 1990 in accordance with Practice E 691, involving seven materials tested by seven laboratories. For each material, all the samples were prepared at one source, and randomized sections of film were sent to each of the laboratories which prepared the test specimens and tested them. Each "test result" was the average of ten determinations. Each laboratory obtained two test results for each material.

⁵ Supporting data are available from ASTM Headquarters. Request RR:20-1177.

TABLE 2 Initial Tear Resistance (Graves Tear) Transverse Direction

| Material | Values Expressed in Units of Grams–Force | | | | |
|---------------|--|---------|---------|-------|--------|
| | Average | S_r^A | S_R^B | r^C | R^D |
| LDPE—LD 104 | 325.1 | 15.24 | 34.63 | 42.67 | 96.96 |
| LLDPE | 366.6 | 20.52 | 28.53 | 57.45 | 79.89 |
| HDPE No. 2 | 411.1 | 31.70 | 82.06 | 88.76 | 229.8 |
| Polypropylene | 468.0 | 33.94 | 86.73 | 95.02 | 242.8 |
| Polystyrene | 481.4 | 101.7 | 263.7 | 284.7 | 738.2 |
| HDPE No. 1 | 523.9 | 46.02 | 97.75 | 128.9 | 273.7 |
| Polyester | 2341.0 | 317.2 | 443.2 | 888.1 | 1241.0 |

^A S_r = within-laboratory standard deviation for the material stated. It is obtained by pooling the standard deviations of the test results from each laboratory:

$$S_r = \left[\frac{\sum (S_i)^2 + (S_2)^2 \dots + (S_n)^2}{n} \right]^{\frac{1}{2}}$$

^B S_R = between-laboratories standard deviation for the material stated. It is a pooling of the amounts by which the average of the test results for each laboratory deviate from the overall average for that material.

^C r = within-laboratory repeatability limit = $2.8 \times S_r$.

^D R = between-laboratories reproducibility limit = $2.8 \times S_R$.

12.2 Concept of r and R —Warning—The following explanations of r and R (12.2-12.2.3) are only intended to present a meaningful way of considering the approximate precision of this test method. The data in Table 1 and Table 2 should not be rigorously applied to acceptance or rejection of material, as those data are specific to the round robin and may not be representative of other lots, conditions, materials, or laborato-

ries. Users of this test method should apply the principles outlined in Practice E 691 to generate data specific to their laboratory and materials, or between specific laboratories. The principles of 12.2-12.2.3 would then be valid for such data. If S_r and S_R have been calculated from a large enough body of data and for test results that were the result of testing ten specimens:

12.2.1 Repeatability Limit, r —(Comparing two test results for the same material, obtained by the same operator using the same equipment on the same day.) The two test results should be judged not equivalent if they differ by more than the “ r ” value for that material.

12.2.2 Reproducibility Limit, R —(Comparing two test results for the same material, obtained by different operators using different equipment in different laboratories.) The two test results should be judged not equivalent if they differ by more than the “ R ” value for that material.

12.2.3 Any judgment in accordance with 12.2.1 or 12.2.2 would have an approximate 95 % (0.95) probability of being correct.

12.3 There are no recognized standards to estimate bias of this test method.

13. Keywords

13.1 Graves; plastic film; tear; tear initiation; thin sheeting

SUMMARY OF CHANGES

Committee D20 has identified the location of selected changes to this standard since the last issue (D 1004 - 03) that may impact the use of this standard. (April 1, 2007)

(I) Revised 7.4.

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