Designation: D882 – 18

Standard Test Method for Tensile Properties of Thin Plastic Sheeting[1]

This standard is issued under the fixed designation D882; 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 U.S. Department of Defense.
These test methods have been approved for use by agencies of the Department of Defense to replace Method 1013 of Federal Test Method Standard 406.

1. Scope*

1.1 This test method covers the determination of tensile properties of plastics in the form of thin sheeting and films (less than 1.0 mm (0.04 in.) in thickness).

NOTE 1—Film is defined in Terminology D883 as an optional term for sheeting having a nominal thickness no greater than 0.25 mm (0.010 in.).

NOTE 2—Tensile properties of plastics 1.0 mm (0.04 in.) or greater in thickness shall be determined according to Test Method D638.

1.2 This test method can be used to test all plastics within the thickness range described and the capacity of the machine employed.

1.3 Specimen extension can be measured by grip separation, extension indicators, or displacement of gage marks.

1.4 The procedure for determining the tensile modulus of elasticity is included at one strain rate.

NOTE 3—The modulus determination is generally based on the use of grip separation as a measure of extension; however, the desirability of using extensometers, as described in 6.2, is recognized and provision for the use of such instrumentation is incorporated in the procedure.

1.5 Test data obtained by this test method is relevant and appropriate for use in engineering design.

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

1.7 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

NOTE 4—This test method is similar to ISO 527-3, but is not considered technically equivalent. ISO 527-3 allows for additional specimen configurations, specifies different test speeds, and requires an extensometer or gage marks on the specimen.

1.8 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D618 Practice for Conditioning Plastics for Testing
D638 Test Method for Tensile Properties of Plastics
D883 Terminology Relating to Plastics
D4000 Classification System for Specifying Plastic Materials
D5947 Test Methods for Physical Dimensions of Solid Plastics Specimens
D6287 Practice for Cutting Film and Sheeting Test Specimens
D6988 Guide for Determination of Thickness of Plastic Film Test Specimens
E4 Practices for Force Verification of Testing Machines
E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method
E2935 Practice for Conducting Equivalence Testing in Laboratory Applications

2.2 *ISO Standard:*

ISO 527-3 Plastics—Determination of Tensile Properties—Part 3: Test Conditions for Films and Sheets[3]

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms that appear in this test method relating to plastics, refer to Terminology D883.

3.2 *Definitions of Terms Specific to This Standard:*

[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, Sheeting, and Molded Products.

Current edition approved Aug. 1, 2018. Published August 2018. Originally approved in 1946. Last previous edition approved in 2012 as D882 - 12. DOI: 10.1520/D0882-18.

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

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

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

3.2.1 Definitions of terms and symbols relating to tension testing of plastics appear in the Annex to Test Method D638.

3.2.2 *line grips*—grips having faces designed to concentrate the entire gripping force along a single line perpendicular to the direction of testing stress. This is usually done by combining one standard flat face and an opposing face from which protrudes a half-round.

3.2.3 *flat grips*—grips having flat faces and lined with thin rubber, crocus-cloth, emery cloth, or pressure-sensitive tape.

3.2.4 *tear failure*—a tensile failure characterized by fracture initiating at one edge of the specimen and progressing across the specimen at a rate slow enough to produce an anomalous force-deformation curve.

4. Summary of Test Method

4.1 A specimen of uniform cross-section is loaded in tension via means of a mechanical testing machine. Force and or extension are recorded during the test. Various techniques for specimen gripping and extension measurement are addressed. Depending on the elongation of the material and the desired properties to be gained from the testing, various combinations of grip separation and test speed are utilized. Properties such as tensile stress, elongation and modulus can be calculated.

5. Significance and Use

5.1 Tensile properties determined by this test method are of value for the identification and characterization of materials for control and specification purposes. Tensile properties can vary with specimen thickness, method of preparation, speed of testing, type of grips used, and manner of measuring extension. Consequently, where precise comparative results are desired, these factors must be carefully controlled. This test method shall be used for referee purposes, unless otherwise indicated in particular material specifications. For many materials, there can 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 in Classification D4000 lists the ASTM materials standards that currently exist.

5.2 Tensile properties can be utilized to provide data for research and development and engineering design as well as quality control and specification. However, data from such tests cannot be considered significant for applications differing widely from the force-time scale of the test employed.

5.3 The tensile modulus of elasticity is an index of the stiffness of thin plastic sheeting. The reproducibility of test results is good when precise control is maintained over all test conditions. When different materials are being compared for stiffness, specimens of identical dimensions must be employed.

5.4 The tensile energy to break (TEB) is the total energy absorbed per unit volume of the specimen up to the point of rupture. In some texts this property has been referred to as *toughness*. It is used to evaluate materials that are subjected to heavy abuse or that can stall web transport equipment in the event of a machine malfunction in end-use applications. However, the rate of strain, specimen parameters, and especially flaws can cause large variations in the results. In that sense, caution is advised in utilizing TEB test results for end-use design applications.

5.5 Materials that fail by tearing give anomalous data which cannot be compared with those from normal failure.

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*—A set of grips for holding the test specimen between the fixed member and the movable member of the testing machine; grips can be either the fixed or self-aligning type. In either case, the gripping system must 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. When this type of grip is used, care must be 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 members of the testing machine in such a manner that they will move freely into alignment as soon as a force 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. The specimens must be aligned as perfectly as possible with the direction of pull so that no rotary motion will cause slippage to occur in the grips; there is a limit to the amount of misalignment self-aligning grips will accommodate.

6.1.3.3 The test specimen shall be held in such a way that slippage relative to the grips is prevented insofar as possible. Grips lined with thin rubber, crocus-cloth, emery cloth, or pressure-sensitive tape as well as file-faced or serrated grips have been successfully used for many materials. The choice of grip surface will depend on the material tested, thickness, etc. Line grips padded on the round face with 0.75-1.00 mm (0.030-0.040 in.) blotting paper or filter paper have been found superior. Air-actuated grips have been found advantageous, particularly in the case of materials that tend to "neck" into the grips, since pressure is maintained at all times (see Notes 5-7). In cases where samples frequently fail at the edge of the grips, it could be advantageous to slightly increase the radius of curvature of the edges where the grips come in contact with the test area of the specimen.

NOTE 5—Caution needs to be taken when choosing the type of grips and the type of grip surfaces to use for testing specimens films composed of high strength LLDPE and VLDPE resins. Test results tend to differ more when comparing these types of specimens films tested with the grips lined with different materials.

NOTE 6—The gage of pressure sensitive tape, thin rubber, crocus-cloth, and emery cloth needs to be adequate enough to prevent slipping and premature failures of the test specimens (for example, pressure sensitive tape is used on the surface of the grips: the test specimen can may begin to tear at the edge of the grips during the test if the tape is too thin.).

NOTE 7—The grit size of crocus-cloth and emery cloth is suggested to be at least 800. The use of these materials helps to prevent test specimens from slipping in the grips. One must be cautious when using these materials so that premature failures of the test specimens do not occur.

6.1.4 *Drive Mechanism*—A drive mechanism for imparting to the movable member a uniform, controlled velocity with respect to the stationary member. The velocity shall be regulated as specified in Section 10.

6.1.5 *Force Indicator*—A suitable force-indicating mechanism capable of showing the total tensile force carried by the test specimen held by the grips. This mechanism shall be essentially free of inertial lag at the specified rate of testing (see Note 8). Unless a suitable extensometer is used (see 6.2), the motion of the weighing system shall not exceed 2 % of the specimen extension within the range being measured. The force indicator shall determine the tensile force applied to the specimen with an accuracy of ±1 % of the indicated value, or better. The accuracy of the testing machine shall be verified in accordance with Practices E4.

6.1.6 *Crosshead Extension Indicator*—A suitable extension-indicating mechanism capable of showing the amount of change in the separation of the grips, that is, crosshead movement. This mechanism shall be essentially free of inertial lag at the specified rate of testing (see Note 8) and shall indicate the crosshead movement with an accuracy of ±1 % of the indicated value, or better.

6.2 *Extensometer (Optional)*—A suitable instrument used for determining the distance between two designated points on the test specimen as the specimen is stretched. The use of this type of instrument is optional and is not required in this test method. This apparatus, if employed, shall be so designed as to minimize stress on the specimen at the contact points of the specimen and the instrument (see 9.3). It is desirable that this instrument automatically record the distance, or any change in it, as a function of the force on the test specimen or of the elapsed time from the start of the test, or both. If only the latter is obtained, force-time data must also be taken. This instrument must be essentially free of inertial lag at the specified speed of testing (see Note 8).

6.2.1 *Modulus of Elasticity and Low-Extension Measurements*—Extensometers used for modulus of elasticity and low-extension (less than 20 % elongation) measurements shall, at a minimum, be accurate to ±1 % and comply with the requirements set forth in Practice E83 for a Class C instrument.

6.2.2 *High-Extension Measurements*—Instrumentation and measuring techniques used for high-extension (20 % elongation or greater) measurements shall be accurate to ±10 % of the indicated value, or better.

NOTE 8—A sufficiently high response speed in the indicating and recording system for the force and extension data is essential. The response speed required of the system will depend in part on the material tested (high or low elongation) and the rate of straining.

6.3 *Thickness Gauge*—A dead-weight dial or digital micrometer as described in Test Methods D5947 or D6988 as appropriate for the material or specimen geometry being tested.

6.4 *Width-Measuring Devices*—Suitable test scales or other width measuring devices capable of measuring 0.25 mm (0.010 in.) or less.

6.5 *Specimen Cutter*—Refer to Practice D6287 for the apparatus and techniques for cutting film and sheeting used in this test method.

6.5.1 Devices that use razor blades have proven especially suitable for materials having an elongation-at-fracture above 10 to 20 %.

6.5.2 The use of a punch press or a striking die is not recommended because of their tendency to produce poor and inconsistent specimen edges.

6.5.3 The use of a cutting template and a single razor blade is not recommended as it will affect the parallelism of the test specimen.

7. Test Specimens

7.1 The test specimens shall consist of strips of uniform width and thickness at least 50 mm (2 in.) longer than the grip separation used.

7.2 The nominal width of the specimens shall be not less than 5.0 mm (0.20 in.) or greater than 25.4 mm (1.0 in.).

7.3 A width-thickness ratio of at least eight shall be used. Narrow specimens magnify effects of edge strains or flaws, or both.

7.4 The utmost care shall be exercised in cutting specimens to prevent nicks and tears that cause premature failures (see Note 9). The edges shall be parallel to within 5 % of the width over the length of the specimen between the grips.

NOTE 9—Microscopical examination of specimens can be used to detect flaws due to sample or specimen preparation.

7.5 Test specimens shall be selected so that thickness is uniform to within 10 % of the average thickness over the length of the specimen between the grips in the case of specimens 0.25 mm (0.010 in.) or less in thickness and to within 5 % in the case of specimens greater than 0.25 mm (0.010 in.) in thickness but less than 1.00 mm (0.040 in.) in thickness.

NOTE 10—In cases where thickness variations are in excess of those recommended in 7.5, results tend not to be characteristic of the material under test.

7.6 If the material is suspected of being anisotropic, two sets of test specimens shall be prepared having their long axes respectively parallel with and normal to the suspected direction of anisotropy.

7.7 For tensile modulus of elasticity determinations, a specimen gage length of 250 mm (10 in.) shall be considered as standard. This length is used in order to minimize the effects of grip slippage on test results. When this length is not feasible, test sections as short as 100 mm (4 in.) can be used if it has been shown that results are not appreciably affected. However, the 250-mm (10-in.) gage length shall be used for referee purposes. The speed of testing of shorter specimens must be adjusted in order for the strain rate to be equivalent to that of the standard specimen.

NOTE 11—Two round robin tests[4] have shown that, for materials of less than 0.25-mm (0.010 in.) in thickness, line grips padded on the round side with 1.0-mm (0.040-in.) blotting paper give the same results with a 100-mm (4-in.) test section as a 250-mm (10-in.) test section produces with flat-face grips.

NOTE 12—Excessive jaw slippage becomes increasingly difficult to overcome in cases where high modulus materials are tested in thicknesses greater than 0.25 mm (0.010 in.).

8. Conditioning

8.1 *Conditioning*—Condition the test specimens at 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 10 % relative humidity for not less than 40 h prior to test in accordance with Procedure A of Practice D618 unless otherwise specified by agreement or the relevant ASTM material specification. In cases of disagreement, the tolerances shall be ±1°C (±1.8°F) and ±5 % relative humidity.

8.2 *Test Conditions*—Conduct the tests at 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 10 % relative humidity unless otherwise specified by agreement or the relevant ASTM material specification. In cases of disagreement, the tolerances shall be ±1°C (±1.8°F) and ±5 % relative humidity.

9. Number of Test Specimens

9.1 In the case of isotropic materials, at least five specimens shall be tested from each sample.

9.2 In the case of anisotropic materials, at least ten specimens, five normal and five parallel with the principal axis of anisotropy, shall be tested from each sample.

9.3 *(Optional) It is acceptable to test a reduced number of test specimens:*

(1) No less than three test specimens shall be tested.

(2) No less than six test specimens in the case of anisotropic materials, three normal and three parallel with the principle axis of anisotropy, shall be tested.

(3) Allowed for in-line quality control sampling.

(4) Allowed for samples not sufficient in size to provide a minimum of five test specimens (10 test specimens for anisotropic materials).

(5) Standard deviation is not to be calculated or reported due to the reduced number of data points.

9.4 Specimens that fail at some obvious flaw or that fail outside the gage length shall be discarded and retests made, unless such flaws or conditions constitute a variable whose effect is being studied. However, jaw breaks (failures at the grip contact point) are acceptable if it has been shown that results from such tests are in essential agreement with values obtained from breaks occurring within the gage length.

NOTE 13—In the cases of some materials, examination of specimens, prior to and following testing, under crossed optical polarizers (polarizing films) provides a useful means of detecting flaws, which can be, or are, responsible for premature failure.

10. Speed of Testing

10.1 The speed of testing is the rate of separation of the two members (or grips) of the testing machine when running idle (under no force). This rate of separation shall be maintained within 5 % of the no-force value when running under full-capacity force.

10.2 The speed of testing shall be calculated from the required initial strain rate as specified in Table 1. The rate of grip separation shall be determined for the purpose of these test methods from the initial strain rate as follows:

$$A = BC \tag{1}$$

where:

A = rate of grip separation, mm (or in.)/min,
B = initial distance between grips, mm (or in.), and
C = initial strain rate, mm/mm·min (or in./in.·min).

10.3 The initial strain rate shall be as in Table 1 unless otherwise indicated by the specification for the material being tested.

NOTE 14—Results obtained at different initial strain rates are not comparable; consequently, where direct comparisons between materials in various elongation classes are required, a single initial strain rate must be used. For some materials it is advisable to select the strain rates on the basis of percent elongation at yield.

10.4 In cases where conflicting material classification, as determined by percent elongation at break values, results in a choice of strain rates, the lower rate shall be used.

10.5 If modulus values are being determined, separate specimens shall be used whenever strain rates and specimen dimensions are not the same as those employed in the test for other tensile properties.

11. Procedure

11.1 Select a force range such that specimen failure occurs within its upper two thirds. A few trial runs could be necessary to select a proper combination of force range and specimen width.

[4] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D20-1058.

TABLE 1 Crosshead Speeds and Initial Grip Separation[A]

Percent Elongation at Break	Initial Strain Rate, mm/mm·min (in./in.·min)	Initial Grip Separation		Rate of Grip Separation	
		mm	in.	mm/min	in./min
Modulus of Elasticity Determination					
	0.1	250	10	25	1.0
Determinations other than Elastic Modulus					
Less than 20	0.1	125	5	12.5	0.5
20 to 100	0.5	100	4	50	2.0
Greater than 100	10.0	50	2	500	20.0

[A] See Fig. A3.1 and Fig. A3.2 in Annex A3 to set the initial grip separation correctly.

11.2 Measure the cross-sectional area of the specimen at three points along its length (center and within approximately 13 mm of each end of the gage length). Measure the width to an accuracy of 0.25 mm (0.010 in.) or better. Measure the thickness to an accuracy of 0.0025 mm (0.0001 in.) or better for specimens less than 0.25 mm (0.010 in.) in thickness and to an accuracy of 1 % or better for specimens greater than 0.25 mm (0.010 in.) but less than 1.0 mm (0.040 in.) in thickness.

11.3 Set the initial grip separation in accordance with Table 1.

11.4 Set the rate of grip separation to give the desired strain rate, based on the initial distance between the grips, in accordance with Table 1. Zero the calibrated force weighing system, extension indicator(s) and recording system.

NOTE 15—Extensometers can be used for modulus of elasticity determinations with the expectation of obtaining more accurate values than can be obtained using grip separation as the effective gage length. Precautions must be taken to ensure that extensometer slippage and undue stressing of the specimen do not occur. Refer also to 7.7.

11.5 In cases where it is desired to measure a test section other than the total length between the grips, mark the ends of the desired test section with a soft, fine wax crayon or with ink. Do not scratch these marks onto the surface since such scratches can act as stress raisers and cause premature specimen failure. Extensometers can be used if available; in this case, the test section will be defined by the contact points of the extensometer.

NOTE 16—Measurement of a specific test section is necessary with some materials having high elongation. As the specimen elongates, the accompanying reduction in area results in a loosening of material at the inside edge of the grips. This reduction and loosening moves back into the grips as further elongation and reduction in area takes place. In effect, this causes problems similar to grip slippage, that is, exaggerates measured extension.

11.6 Place the test specimen in the grips of the testing machine, taking care to align the long axis of the specimen with an imaginary line joining the points of attachment of the grips to the machine. Tighten the grips evenly and firmly to the degree necessary to minimize slipping of the specimen during test.

11.7 Start the machine and record force versus extension.

11.7.1 When the total length between the grips is used as the test area, record force versus grip separation.

11.7.2 When a specific test area has been marked on the specimen, follow the displacement of the edge boundary lines with respect to each other with dividers or some other suitable device. If a force-extension curve is desired, plot various extensions versus corresponding forces sustained, as measured by the force indicator.

11.7.3 When an extensometer is used, record force versus extension of the test area measured by the extensometer.

11.8 If modulus values are being determined, select a force range and chart rate to produce a force-extension curve of between 30 and 60° to the *X* axis. For maximum accuracy, use the most sensitive force scale for which this condition can be met. It is acceptable to discontinue the test when the force-extension curve deviates from linearity.

11.9 In the case of materials being evaluated for secant modulus, the test can be discontinued when the specified extension is reached.

11.10 If tensile energy to break is being determined, some provision must be made for integration of the stress-strain curve. This can be either an electronic integration during the test or a subsequent determination from the area of the finished stress-strain curve (see Annex A2).

12. Calculation

12.1 Toe compensation shall be made in accordance with Annex A1 unless it can be shown that the toe region of the curve is not due to the takeup of slack, seating of the specimen, or other artifact, but rather is an authentic material response.

12.2 *Breaking Factor* (nominal) shall be calculated by dividing the maximum force by the original average width of the specimen. The result shall be expressed in force per unit of width, usually newtons per metre (or pounds per inch) of width, and reported to three significant figures. The thickness of the film shall always be stated to the nearest 0.0025 mm (0.0001 in.).

Example—Breaking Factor = 1.75 kN/m (10.0 lbf/in.) of width for 0.1300-mm (0.0051-in.) thickness.

NOTE 17—This method of reporting is useful for very thin films (0.13 mm (0.005 in.) and less) for which breaking force is not proportional to cross-sectional area and whose thickness is difficult to determine with precision. Furthermore, films which are in effect laminar due to orientation, skin effects, nonuniform crystallinity, etc., have tensile properties disproportionate to cross-sectional area.

12.3 *Tensile Strength* (nominal) shall be calculated by dividing the maximum force by the original average cross-sectional area of the specimen. The result shall be expressed in force per unit area, usually megapascals (or pounds-force per square inch). This value shall be reported to three significant figures. The maximum force can occur at the yield point, the breaking point, or in the area between the yield point and the breaking point.

NOTE 18—When tear failure occurs, so indicate and calculate results based on force and elongation at which tear initiates, as reflected in the force-deformation curve.

12.4 *Tensile Strength at Break* (nominal) shall be calculated in the same way as the tensile strength except that the force at break shall be used in place of the maximum force (Note 18 and Note 19).

NOTE 19—In many cases tensile strength and tensile strength at break are identical, but not always.

12.5 *Percent Elongation at Break* shall be calculated by dividing the extension at the moment of rupture of the specimen by the initial gage length of the specimen and multiplying by 100. When gage marks or extensometers are used to define a specific test section, only this length shall be used in the calculation; otherwise the distance between the grips shall be used. The result shall be expressed in percent and reported to two significant figures (see Note 18).

12.6 *Tensile Yield Strength,* where applicable, shall be calculated by dividing the force at the yield point by the original average cross-sectional area of the specimen. The

result shall be expressed in force per unit area, usually megapascals (or pounds-force per square inch). This value shall be reported to three significant figures. Alternatively, for materials that exhibit Hookean behavior in the initial part of the curve, an offset yield strength shall be obtained as described in the Appendix of Test Method D638. In this case the value shall be given as "yield strength at —% offset."

12.7 *Percent Elongation at Yield,* where applicable, shall be calculated by dividing the extension at the yield point by the initial gage length of specimen and multiplying by 100. When gauge marks or extensometers are used to define a specific test section, only this length shall be used in the calculation. Before calculating, correct the extension for "toe compensation" as described in Annex A1. The results shall be expressed in percent and reported to two significant figures. When offset yield strength is used, the elongation at the offset yield strength shall be calculated.

12.8 *Elastic Modulus,* shall be calculated by drawing a tangent to the initial linear portion of the force-extension curve, selecting any point on this tangent, and dividing the tensile stress by the corresponding strain. Before calculating, correct the extension for "toe compensation" as described in Annex A1. For purposes of this determination, the tensile stress shall be calculated by dividing the force by the average original cross section of the test section. The result shall be expressed in force per unit area, usually megapascals (or pounds-force per square inch), and reported to three significant figures.

12.9 *Secant Modulus,* at a designated strain, shall be calculated by dividing the corresponding stress (nominal) by the designated strain. Elastic modulus values are preferable and shall be calculated whenever possible. However, for materials where no proportionality is evident, the secant modulus values shall be calculated. Draw the tangent as directed in A1.3 and Fig. A1.2 of Annex A1, and mark off the designated strain from the yield point where the tangent line goes through zero stress. The stress to be used in the calculation is then determined by dividing the force at the designated strain on the force-extension curve by the original average cross-sectional area of the specimen.

12.10 *Tensile Energy to Break,* where applicable, shall be calculated by integrating the energy per unit volume under the stress-strain curve or by integrating the total energy absorbed and dividing it by the volume of the original gage region of the specimen. As indicated in Annex A2, this shall be done directly during the test by an electronic integrator, or subsequently by computation from the area of the plotted curve. The result shall be expressed in energy per unit volume, usually in megajoules per cubic metre (or inch-pounds-force per cubic inch). This value shall be reported to two significant figures.

12.11 For each series of tests, the arithmetic mean of all values obtained shall be calculated to the proper number of significant figures.

12.12 The standard deviation (estimated) shall be calculated as follows and reported to two significant figures:

$$s = \sqrt{\left(\sum X^2 - n\,\bar{X}^2\right)/(n-1)} \qquad (2)$$

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.

13. Report

13.1 Report the following information:

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

13.1.2 Method of preparing test specimens,

13.1.3 Thickness, width, and length of test specimens,

13.1.4 Number of specimens tested,

13.1.5 Strain rate employed,

13.1.6 Grip separation (initial),

13.1.7 Crosshead speed (rate of grip separation),

13.1.8 Gage length (if different from grip separation),

13.1.9 Type of grips used, including facing (if any),

13.1.10 Conditioning procedure (test conditions, temperature, and relative humidity if nonstandard),

13.1.11 Anomalous behavior such as tear failure and failure at a grip,

13.1.12 Average breaking factor and standard deviation,

13.1.13 Average tensile strength (nominal) and standard deviation,

13.1.14 Average tensile strength at break (nominal) and standard deviation,

13.1.15 Average percent elongation at break and standard deviation,

13.1.16 Where applicable, average tensile energy to break and standard deviation,

13.1.17 In the case of materials exhibiting "yield" phenomenon: average yield strength and standard deviation; and average percent elongation at yield and standard deviation,

13.1.18 For materials which do not exhibit a yield point: average —% offset yield strength and standard deviation; and average percent elongation at —% offset yield strength and standard deviation,

13.1.19 Average modulus of elasticity and standard deviation (if secant modulus is used, so indicate and report strain at which calculated), and

13.1.20 When an extensometer is employed, so indicate.

14. Precision and Bias

14.1 Two interlaboratory tests have been run for these tensile properties. The first was run for modulus only, in 1977, in which randomly drawn samples of four thin (~0.025 mm (0.001-in.)) materials were tested with five specimens in each laboratory. Elastic (tangent) modulus measurements were made by six laboratories, and secant (1 %) modulus measurements were taken by five laboratories. The relative precision obtained in this interlaboratory study is in Table 2.

TABLE 2 Precision Data for Modulus

Material	Thickness, mils	Average, 10^3 psi	S_r, 10^3 psi	S_R, 10^3 psi	I_r, 10^3 psi	I_R, 10^3 psi
Tangent Modulus						
LDPE	1.4	53.9	1.81	8.81	5.12	24.9
HDPE	1.6	191	5.47	16.2	15.5	45.9
PP	1.1	425	10.3	31.5	29.0	89.1
PET	0.9	672	13.8	55.5	39.1	157.1
Secant Modulus						
LDPE	1.4	45.0	2.11	3.43	5.98	9.70
HDPE	1.6	150	3.29	9.58	9.30	27.1
PP	1.1	372	4.66	26.5	13.2	74.9
PET	0.9	640	10.0	27.5	28.4	77.8

14.1.1 In deriving the estimates in Table 2, statistical outliers were not removed, in keeping with Practice E691.[5]

14.1.2 The within-lab standard deviation of a mean value, $S_{\bar{x}}$, in each case was determined from the standard deviation, $S_{\bar{x}}$, of the five individual specimens as follows: $S_{\bar{x}} = S_x/(5)^{1/2}$. The $S_{\bar{x}}$ values were pooled among laboratories for a given material to obtain the within-lab standard deviation, S_r, of a test result (mean of five specimens). See 14.3 – 14.3.2 for definitions of terms in the tables.

14.2 An interlaboratory test was run for all the other tensile properties except modulus in 1981, in which randomly drawn samples of six materials (one of these in three thicknesses) ranging in thickness from 0.019 to 0.178 mm (0.00075 to 0.007 in.) were tested in seven laboratories. A test result was defined as the mean of five specimen determinations. However, each laboratory tested eight specimens, and the $S_{\bar{x}}$ was determined from $S_{\bar{x}} = S_x/(5)^{1/2}$ as above. This was done to improve the quality of the statistics while maintaining their applicability to a five-specimen test result. The materials and their thicknesses are identified in Tables 3-7, each of which contain data for one of the following properties: tensile yield strength, yield elongation, tensile strength, tensile elongation at break, and tensile energy at break (see Note 20).[6]

NOTE 20—Subsequent to filing the research report, examination of the LDPE used in this study between crossed polarizers revealed lengthwise lines representing substantial widthwise variation in molecular orientation that probably was not successfully randomized out of the between-labs component of variance.

14.3 For the purpose of compiling summary statistics, a test result has been defined to be the average of five replicate measurements of a property for a material in a laboratory, as specified in this test method. Summary statistics are given in Table 3. In each table, for the material indicated, *S(r)* is the pooled within-laboratory standard deviation of a test result, *S(R)* is the between-laboratory standard deviation of a test result, where r equals $2.83 \times S(r)$ (see 14.3.1) and R equals $2.83 \times S(R)$ (see 14.3.2). (**Warning—**The following explanations of I_r and I_R (14.3 – 14.3.3) are only intended to present a meaningful way of considering the *Approximate* precision of this test method. Do not rigorously apply the data in Table 2 to the acceptance or rejection of material, as those data are specific to the round robin and are not necessarily representative of other lots, conditions, materials, or laboratories. Users of this test method need to apply the principles outlined in Practice E691 to generate data specific to their laboratory and materials, or between specific laboratories. The principles of 14.3 – 14.3.3 would then be valid for such data.)

14.3.1 *Repeatability*—The value below which the absolute difference between two test results obtained under repeatability conditions is likely to occur with a probability of approximately 0.95 (95 %).

14.3.2 *Reproducibility*—The value below which the absolute difference between two test results obtained under reproducibility conditions is likely to occur with a probability of approximately 0.95 (95 %).

14.3.3 For further information, see Practice E691 and for information on equivalence testing, see Practice E2935.

[5] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D20-1084.

[6] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D20-1101.

TABLE 3 Precision Data for Yield Stress

Material	Thickness, mils	Average, 10^3 psi	$(S_r)^A$ 10^3 psi	$(S_R)^B$ 10^3 psi	$I(r)^C$ 10^3 psi	$I(R)^D$ 10^3 psi
LDPE	1.0	1.49	0.051	0.13	0.14	0.37
HDPE	1.0	4.33	0.084	0.16	0.24	0.44
PP	0.75	6.40	0.13	0.52	0.37	1.46
PC	4.0	8.59	0.072	0.29	0.20	0.82
CTA	5.3	11.4	0.12	0.50	0.34	1.43
PET	4.0	14.3	0.12	0.23	0.34	0.66
PET	2.5	14.4	0.14	0.54	0.40	1.52
PET	7.0	14.4	0.13	0.36	0.37	1.03

[A] S_r is the within-laboratory standard deviation of the average.
[B] S_R is the between-laboratories standard deviation of the average.
[C] $I_r = 2.83\ S_r$.
[D] $I_R = 2.83\ S_R$.

TABLE 4 Precision Data for Yield Elongation

Material	Thickness, mils	Average, %	$(S_r)^A$, %	$(S_R)^B$, %	$I(r)^C$, %	$I(R)^D$, %
PP	0.75	3.5	0.15	0.41	0.42	1.2
PET	2.5	5.2	0.26	0.92	0.74	2.6
PET	4.0	5.3	0.25	0.60	0.71	1.7
PET	7.0	5.4	0.14	1.05	0.40	3.0
CTA	5.3	5.4	0.19	0.99	0.54	2.8
PC	4.0	6.9	0.24	0.98	0.68	2.8
HDPE	1.0	8.8	0.32	1.82	0.91	5.2
LDPE	1.0	10.0	0.55	3.41	1.56	9.6

NOTE 1—See Table 3 for footnote explanation.

TABLE 5 Precision Data for Tensile Strength

Material	Thickness, mils	Average, 10^3 psi	$(S_r)^A$ 10^3 psi	$(S_R)^B$ 10^3 psi	$I(r)^C$ 10^3 psi	$I(R)^D$ 10^3 psi
LDPE	1.0	3.42	0.14	0.53	0.40	1.5
HDPE	1.0	6.87	0.27	0.81	0.76	2.3
PC	4.0	12.0	0.34	0.93	0.96	2.6
CTA	5.3	14.6	0.20	1.37	0.57	3.9
PP	0.75	28.4	1.57	4.56	4.4	12.9
PET	4.0	28.9	0.65	1.27	1.8	3.6
PET	7.0	30.3	0.83	1.32	2.3	3.7
PET	2.5	30.6	1.22	2.64	3.4	7.5

NOTE 1—See Table 3 for footnote explanation.

TABLE 6 Precision Data for Elongation at Break

Material	Thickness, mils	Average, %	$(S_r)^A$, %	$(S_R)^B$, %	$I(r)^C$, %	$I(R)^D$, %
CTA	5.3	26.4	1.0	4.3	3	12
PP	0.75	57.8	4.4	12.7	12	36
PET	2.5	120	8.0	14.6	23	41
PET	7.0	132	5.8	10.6	16	30
PET	4.0	134	4.4	12.2	12	35
PC	4.0	155	5.4	17.1	15	48
LDPE	1.0	205	24.4	73.3	69	210
HDPE	1.0	570	26.0	91.7	74	260

NOTE 1—See Table 3 for footnote explanation.

TABLE 7 Precision Data for Tensile Energy to Break

Material	Thickness, mils	Average, 10^3 $\frac{\text{in./lb}}{\text{in.}^3}$	$(S_r)^A$ 10^3 $\frac{\text{in./lb}}{\text{in.}^3}$	$(S_R)^B$ 10^3 $\frac{\text{in./lb}}{\text{in.}^3}$	$I(r)^C$ 10^3 $\frac{\text{in./lb}}{\text{in.}^3}$	$I(R)^D$ 10^3 $\frac{\text{in./lb}}{\text{in.}^3}$
CTA	5.0	3.14	0.14	0.70	0.4	2.0
LDPE	1.0	5.55	0.84	2.47	2.4	7.0
PP	0.75	11.3	1.19	3.11	3.4	8.8
PC	4.0	12.9	0.59	1.55	1.7	4.4
HDPE	1.0	26.0	1.87	5.02	5.3	14.2
PET	2.5	26.1	2.13	4.20	6.0	11.9
PET	4.0	27.1	1.42	2.75	4.0	7.8
PET	7.0	28.4	1.71	2.72	4.8	7.7

NOTE 1—See Table 3 for footnote explanation.

14.4 *Bias*—The systematic error which contributes to the difference between a test result and a true (or reference) value. There are no recognized standards on which to base an estimate of bias for these test methods.

15. Keywords

15.1 modulus of elasticity; plastic film; plastic sheeting; tensile properties; tensile strength; toughness; yield stress

ANNEXES

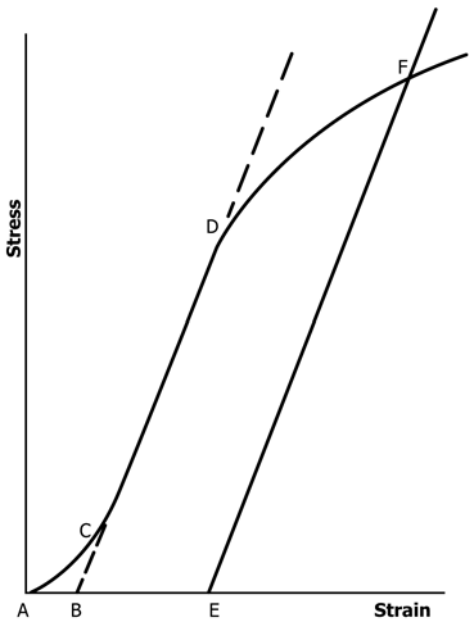
(Mandatory Information)

A1. TOE COMPENSATION

A1.1 In a typical stress-strain curve (Fig. A1.1) there is a toe region, *AC*, which does not represent a property of the material. It is an artifact caused by a takeup of slack, and alignment or seating of the specimen. In order to obtain correct values of such parameters as modulus, strain, and offset yield point, this artifact must be compensated for to give the corrected zero point on the strain or extension axis.

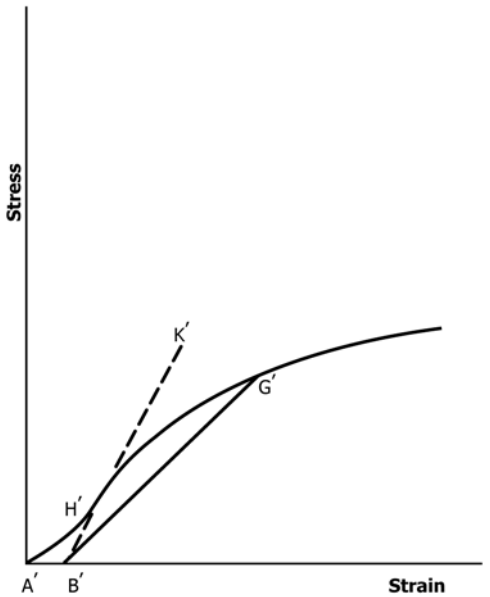
A1.2 In the case of a material exhibiting a region of Hookean (linear) behavior (Fig. A1.1), a continuation of the linear (*CD*) region of the curve is constructed through the zero-stress axis. This intersection (*B*) is the corrected zero-strain point from which all extensions or strains must be measured, including the yield offset (*BE*), if applicable. The elastic modulus can be determined by dividing the stress at any point along the line *CD* (or its extension) by the strain at the same point (measured from point *B*, defined as zero-strain).

A1.3 In the case of a material that does not exhibit any linear region (Fig. A1.2), the same kind of toe correction of the zero-strain point can be made by constructing a tangent to the maximum slope at the inflection point (*H′*). This is extended to intersect the strain axis at point *B*', the corrected zero-strain point. Using point *B*' as zero strain, the stress at any point (*G*') on the curve can be divided by the strain at that point to obtain a secant modulus (slope of line *B*' *G*'). For those materials with no linear region, any attempt to use the tangent through the inflection point as a basis for determination of an offset yield point can result in unacceptable error.



NOTE 1—Some equipment plot the mirror image of this graph.

FIG. A1.1 Material with Hookean Region



NOTE 1—Some equipment plot the mirror image of this graph.

FIG. A1.2 Material with No Hookean Region

A2. DETERMINATION OF TENSILE ENERGY TO BREAK

A2.1 Tensile energy to break (TEB) is defined by the area under the stress-strain curve, or

$$\text{TEB} = \int_0^{\varepsilon_T} S\, d\varepsilon \qquad \text{(A2.1)}$$

where S is the stress at any strain, ε, and ε_T is the strain at rupture. The value is in units of energy per unit volume of the specimen's initial gage region. TEB is most conveniently and accurately measured with a tension tester equipped with an integrator. The calculation is then:

$$TEB = (I/K) \qquad \text{(A2.2)}$$

$$\frac{(\text{full scale load})\,(\text{chart speed})\,(\text{crosshead speed/chart speed})}{(\text{mean caliper})\,(\text{specimen width})\,(\text{gage length})}$$

where I is the integrator count reading and K is the maximum possible count per unit time for a constant full scale force. This whole calculation is typically done electronically. The results are best expressed in megajoules per cubic metre (or inch-pounds-force per cubic inch).

A2.2 Without an integrator, the area under the recorded stress-strain curve can be measured by planimeter, counting squares, or weighing the cut-out curve. These techniques are time-consuming and likely to be less accurate, since the force scale on some chart paper is not in round-number dimensions. Moreover, if the curve coordinates are in terms of force and extension instead of stress and strain, the calculated energy, corresponding to the measured area, must be divided by the product of gage length, specimen width, and mean caliper:

$$(\text{curve area})\,(\text{force per unit chart scale}) \qquad \text{(A2.3)}$$

$$\text{TEB} = \frac{(\text{extension per unit chart travel})}{(\text{mean caliper})\,(\text{specimen width})\,(\text{gage length})}$$

A2.3 For example, if the area under a force-extension curve is 60,000 mm^2, the force coordinate is 2.0 N/mm of chart scale, the extension coordinate is 0.25 mm of extension per mm of chart travel, and the specimen dimensions are 0.1 mm caliper, 15 mm width and 100 mm gage length, then the calculation for tensile energy to break is:

$$\text{TEB} = \frac{(60\ 000\ \text{mm}^2)\,(2.0\ \text{N/mm})\,(0.25 \times 10^{-3}\ \text{m/mm})}{(0.1 \times 10^{-3}\text{m})\,(15 \times 10^{-3}\text{m})\,(100 \times 10^{-3}\text{m})} \qquad \text{(A2.4)}$$

$$\text{TEB} = 200\ \text{MJ/m}^3$$

A3. SETTING THE CORRECT INITIAL GRIP SEPARATION

A3.1 Initial Grip Separation Settings Using Flat Grip Inserts and Line Grip Inserts (Fig. A3.1 and Fig. A3.2)

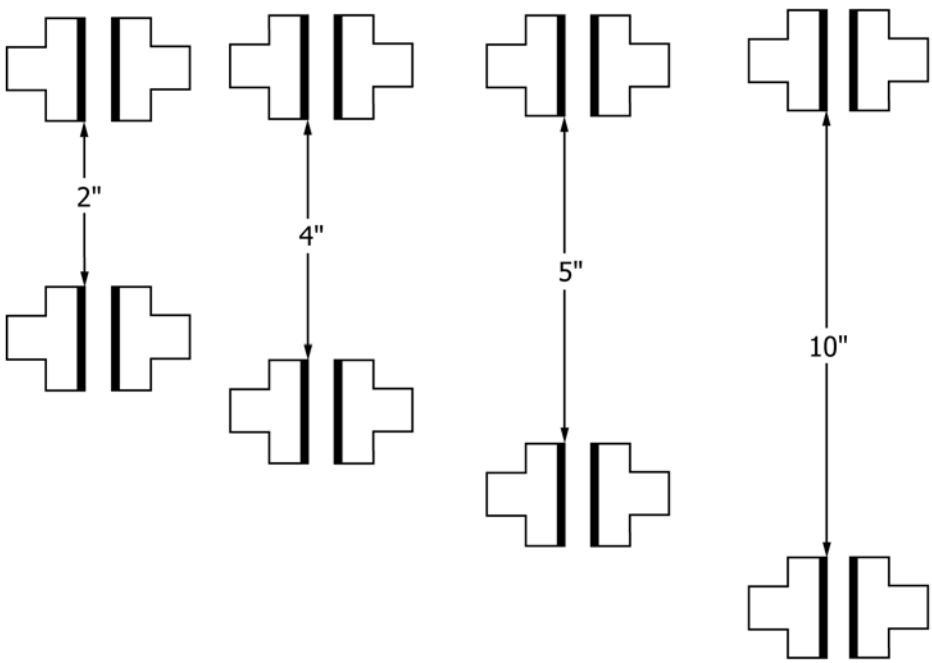


FIG. A3.1 Initial Grip Separation Using Flat Grip Inserts

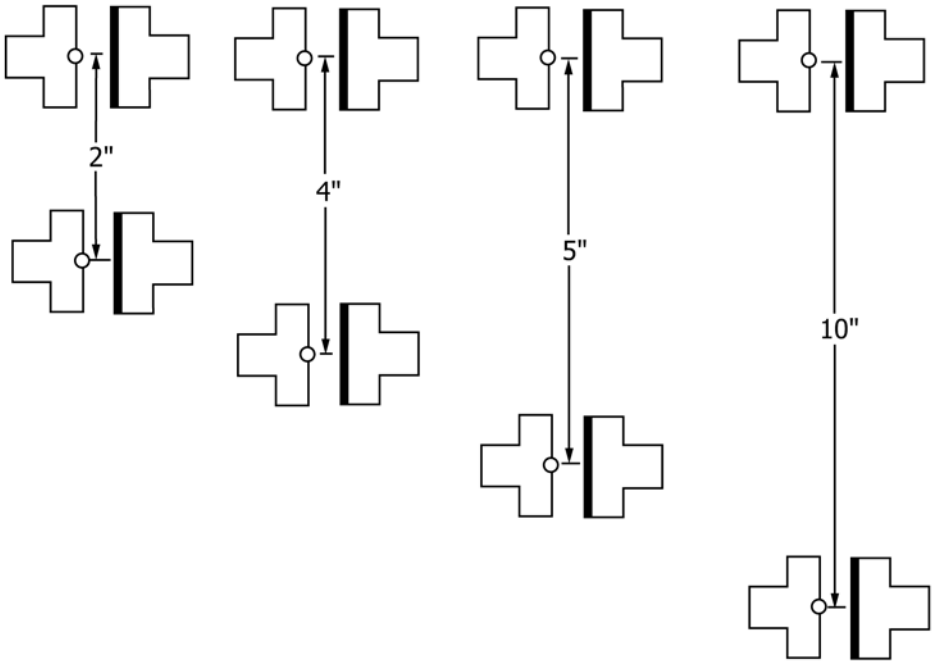


FIG. A3.2 Initial Grip Separation Using Line Grip Inserts

A3.2 It is acceptable for the shape of the grip inserts to differ depending on the testing instrument being used, but the distance between the points of contact will be the same.

A3.3 Calculation of ultimate elongation will be incorrect if the initial grip separation is not set correctly.

A3.4 The initial strain rate required will be incorrect if the initial grip separation is not set correctly.

SUMMARY OF CHANGES

Committee D20 has identified the location of selected changes to this standard since the last issue (D882 - 12) that may impact the use of this standard. (August 1, 2018)

(1) Added Section 4 Summary of Test Method.
(2) Renumbered subsequent sections after the addition of Section 4.
(3) Subsection 7.5: Clarified that the 10% uniformity of thickness is based on average thickness.
(4) Subsection 9.3: Removed redundancy of stating that the number of specimens needs to be reported as it is already stated in the report section.
(5) Subsection 11.2: Clarified the number of measurements to take for cross-sectional area. Now states to take three as opposed to several.
(6) Subsection 12.2: Revised to use average width of specimen as opposed to minimum to stay consistent with how stress and modulus are calculated.
(7) Subsections 12.3 and 12.6: Revised to use original average cross-sectional area as opposed to original minimum cross-sectional area to stay consistent with how modulus is calculated.
(8) Subsection 14.3.1 and 14.3.2: Revised using the new ASTM D20 boiler plate statements for reproducibility and repeatability.
(9) The term “chart recorder” was changed to “instrument” in Annex A1, Note 1 of Figure A1.1 and Annex A1, Note 1 of Figure A1.2.
(10) Permissive language removed throughout where applicable.