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Standard Test Method for Tensile Properties of Yarns by the Single-Strand Method[1]

This standard is issued under the fixed designation D2256/D2256M; 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.

1. Scope

1.1 This test method covers the determination of tensile properties of monofilament, multifilament, and spun yarns, either single, plied, or cabled with the exception of yarns that stretch more than 5.0 % when tension is increased from 0.05 to 1.0 cN/tex [0.5 to 1.0 gf/tex].

1.2 This test method covers the measurement of breaking force and elongation of yarns and includes directions for the calculation of breaking tenacity, initial modulus, chord modulus, and breaking toughness.

1.2.1 Options are included for the testing of specimens in: *(A)* straight, *(B)* knotted, and *(C)* looped form.

1.2.2 Conditions of test are included for the testing of specimens that are: *(1)* conditioned air, *(2)* wet, not immersed, *(3)* wet, immersed, *(4)* oven-dried, *(5)* exposed to elevated temperature, or *(6)* exposed to low temperature.

NOTE 1—Special methods for testing yarns made from specific fibers; namely, glass, flax, hemp, ramie, and kraft paper and for specific products; namely, tire cords and rope, have been published: Test Methods D885, and Specification D578.

NOTE 2—For directions covering the determination of breaking force of yarn by the skein method refer to Test Method D1578.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

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

1.5 *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]

[1] This test method is under the jurisdiction of ASTM Committee D13 on Textiles and is the direct responsibility of Subcommittee D13.58 on Yarns and Fibers.

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[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.

~~D76~~D76/D76M Specification for Tensile Testing Machines for Textiles
D123 Terminology Relating to Textiles
D578 Specification for Glass Fiber Strands
D885 Test Methods for Tire Cords, Tire Cord Fabrics, and Industrial Filament Yarns Made from Manufactured Organic-Base Fibers
D1578 Test Method for Breaking Strength of Yarn in Skein Form
D1776 Practice for Conditioning and Testing Textiles
D2258 Practice for Sampling Yarn for Testing
D2904 Practice for Interlaboratory Testing of a Textile Test Method that Produces Normally Distributed Data (Withdrawn 2008)[3]
D2906 Practice for Statements on Precision and Bias for Textiles (Withdrawn 2008)[3]
D4848 Terminology Related to Force, Deformation and Related Properties of Textiles
D4849 Terminology Related to Yarns and Fibers
E178 Practice for Dealing With Outlying Observations

3. Terminology

3.1 *Definitions:*

3.1.1 Refer to Terminology D4848 for definitions of the following terms used in this standard: breaking force, breaking strength, breaking tenacity, breaking toughness, chord modulus, elongation, elongation at break, elongation at rupture, initial modulus, knot-breaking force, knot breaking strength, linear density, loop breaking force, loop-breaking strength, single-strand breaking force, single-strand breaking strength, strength and tenacity.

3.1.2 Refer to Terminology D123 and Terminology D4849 and for definitions of other terms used in this standard.

4. Summary of Test Method

4.1 Single-strand yarn specimens are broken on a tension testing machine at a predetermined elongation rate and the breaking force and the elongation at break are determined. Elongation at a specified force or the force or tenacity at a specified elongation may also be obtained. Breaking force, breaking tenacity, elongation, initial and chord modulus, and breaking toughness of the test specimen, in terms of linear density, may be calculated from machine scales, dials, recording charts, or by an interfaced computer.

4.2 This test method offers the following three physical configurations of the specimen:

4.2.1 *Configuration A,* straight.

4.2.2 *Configuration B,* knotted.

4.2.3 *Configuration C,* looped.

4.3 This test method also offers the following six conditions of test with respect to moisture content of the specimens at the time of testing:

4.3.1 *Condition 1,* conditioned to moisture equilibrium for testing with standard atmosphere for testing textiles.

4.3.2 *Condition 2,* wet not immersed.

4.3.3 *Condition 3,* wet immersed.

4.3.4 *Condition 4,* oven-dried.

4.3.5 *Condition 5,* high temperature.

4.3.6 *Condition 6,* low temperature.

4.4 A test option is specified by combining a specimen configuration and a moisture content condition, for example, Option A1 means a straight specimen conditioned and tested in a standard atmosphere for testing textiles.

[3] The last approved version of this historical standard is referenced on www.astm.org.

4.5 Unless otherwise indicated, the phrase "single-strand breaking force" is associated with Option A1.

5. Significance and Use

5.1 *Acceptance Testing*—Option A1 of Test Method D2256 is considered satisfactory for acceptance testing of commercial shipments because the test method has been used extensively in the trade for acceptance testing. However, this statement is not applicable to knot and loop breaking force tests, tests on wet specimens, tests on oven-dried specimens, or tests on specimens exposed to low or high temperatures and should be used with caution for acceptance testing because factual information on between-laboratory precision and bias is not available.

5.1.1 If there are differences of practical significance between reported test results for two laboratories (or more), comparative tests should be performed to determine if there is a statistical bias between them, using competent statistical assistance. As a minimum, use the samples for such a comparative tests that are as homogeneous as possible, drawn from the same lot of material as the samples that resulted in disparate results during initial testing and randomly assigned in equal numbers to each laboratory. The test results from the laboratories involved should be compared using a statistical test for unpaired data, a probability level chosen prior to the testing series. If a bias is found, either its cause must be found and corrected, or future test results for that material must be adjusted in consideration of the known bias.

5.2 *Fundamental Properties*—The breaking tenacity, calculated from the breaking force and the linear density, and the elongation are fundamental properties that are widely used to establish limitations on yarn processing or conversion and on their end-use applications. Initial modulus is a measure of the resistance of the yarn to extension at forces below the yield point. The chord modulus is used to estimate the resistance to imposed strain. The breaking toughness is a measure of the work necessary to break the yarn.

5.3 *Comparison to Skein Testing*—The single-strand method gives a more accurate measure of breaking force present in the material than does the skein method and uses less material. The skein-breaking force is always lower than the sum of the breaking forces of the same number of ends broken individually.

5.4 *Applicability*—Most yarns can be tested by this test method. Some modification of clamping techniques may be necessary for a given yarn depending upon its structure and composition. To prevent slippage in the clamps or damage as a result of being gripped in the clamps, special clamping adaptations may be necessary with high modulus yarns made from fibers such as glass or extended chain polyolefin. Specimen clamping may be modified as required at the discretion of the individual laboratory providing a representative force-elongation curve is obtained. In any event, the procedure described in this test method for obtaining tensile properties must be maintained.

5.5 *Breaking Strength*—The breaking strength of a yarn influences the breaking strength of fabrics made from the yarn, although the breaking strength of a fabric also depends on its construction and may be affected by manufacturing operations.

5.5.1 Because breaking strength for any fiber-type is approximately proportional to linear density, strands of different sizes can be compared by converting the observed breaking strength to breaking tenacity (centinewtons per tex, grams-force per tex, or grams-force per denier).

5.6 *Elongation*—The elongation of a yarn has an influence on the manufacturing process and the products made. It provides an indication of the likely stretch behavior of garment areas such as knees, elbows, or other points of stress. It also provides design criteria for stretch behavior of yarns or cords used as reinforcement for items such as plastic products, hose, and tires.

5.7 *Force-Elongation Curve*—Force-elongation curves permit the calculation of various values, not all of which are discussed in this test method, such as elongation at break, elongation at specified force, force at specified elongation, initial elastic modulus which is resistance to stretching, compliance which is ability to yield under stress, and is the reciprocal of the elastic modulus, and area under the curve, a measure of toughness, which is proportional to the work done.

NOTE 3—Force-elongation curves can be converted to stress-strain curves if the force is converted to unit stress, such as to centinewtons per tex, or pounds per square inch, or pascals, or grams-force per tex, or grams-force per denier, and the elongation is based on change per unit length.

5.8 *Knot and Loop Breaking Force*—The reduction in breaking force due to the presence of a knot or loop is considered a measure of the brittleness of the yarn. Elongation in knot or loop tests is not known to have any significance and is not usually reported.

5.9 *Rate of Operation*—In general, the breaking force decreases slightly as time-to-break increases.

5.9.1 Operation of CRT, CRE, and CRL tension testing machines at a constant time-to-break has been found to minimize differences in test results between the three types of tension testing machines. When tensile tests are performed at a fixed time-to-break, then reasonable agreement in breaking force has generally been found to exist between CRT and CRE tension testing machines.[4] Consistent results are also obtained between different manufacturers of CRL tension testing machines when they are operated at the same time-to-break. The agreement is not necessarily good, however, between CRE or CRT tension testing machines on the one hand and CRL tension testing machines on the other even when they are all operated at the same time-to-break. The CRE-type tester is the preferred tension testing machine.

5.9.2 This test method specifies an average time-to-break of 20 ± 3 s as recommended by ~~ISO~~Specification D76/D76M~~TC 38 on Textiles, The International Standards Association test committee for standardizing tests for fibers, yarns, and fabrics. ~~. It also provides for alternate speeds, such as 300 ± 10 mm [12 ± 0.5 in.]/min when using a 250-mm [10-in.] ~~gage~~gauge length. See 9.2.

5.9.3 The tolerance of ±3 s for the time-to-break is wide enough to permit convenient adjustment of the tension testing machine's rate of operation, and it is narrow enough to ensure good agreement between tests. The difference in breaking force between tests at 17 and 23 s will usually not exceed 1.5 % of the higher value.

5.9.4 In case a tension testing machine is not capable of being operated at 20-s time-to-break, alternative rates of operation are included in this test method. These alternative rates may be used only by agreement between the parties concerned or when required in an applicable material specification.

5.10 *Tests on Wet Specimens*—Tests on wet specimens are usually made only on yarns which show a loss of breaking force when wet or when exposed to high humidity, for example, yarns made from animal fibers and man-made fibers based on regenerated and modified cellulose. Wet tests are made on flax yarns to detect adulteration by failure to show a gain in breaking force.

5.11 *Tests on Oven-Dried Specimens and Specimens at High Temperatures*—Tests on oven-dried specimens at standard or high temperatures are usually made only on yarns that will be used at high temperatures or will be used under very dry conditions which will affect the observed breaking force, for example, on rayon yarns intended for use in tire cords and yarns for other industrial purposes. Note that results obtained when testing oven-dried specimens at standard temperature will not necessarily agree with the results obtained when testing oven-dried yarns at high temperatures.

5.12 *Tests on Specimens at Low Temperatures*—Tests on specimens exposed to low temperatures are usually made only on yarns that will be used at low temperatures, for example, yarns used in outerwear designed for cold climates or outer-space situations. Low-temperature tests are made on coated yarns used in the manufacture of materials used in outdoor applications, such as screening fabrics.

6. Apparatus and Reagents

6.1 *Tension Testing Machine,* of the CRE, CRL, or CRT type, conforming to Specification ~~D76~~D76/D76M, with respect to force indication, working range, capacity, and verification of recorded elongation, and designed for operation at the rates specified in 9.1. A variable-speed drive, a change of gears, or interchangeable weights are required to obtain the 20-s time-to-break. If the rate of operation is adjusted in steps, the steps should be no greater than 1.25:1.00. The tension testing machine may be equipped with: (*1*) clamps having flat-faced jaws or (*2*) capstan-, drum-, or snubbing-type clamps (Note 5). Automatic (self-loading and recording) single-end tension testing machines may be used, provided they meet the requirements as to ~~gage~~gauge length, rate of operation, and accuracy of calibration. The tension testing machine may be interfaced with a computer system for operation and data gathering. The CRE-type tension testing machine is recommended unless otherwise agreed upon between the purchaser and the supplier.

[4] Tweedie, A. S., Metton, M. T., and Fry, J. M., *Textile Research Journal*, Vol 29, March 1959, pp. 235–251, and Tweedie, A. S., and Metton, M. T., *Textile Research Journal*, Vol 29, March 1959, pp. 589–591.

NOTE 4—Test machines capable of both tension and compression are acceptable for use with Test Method D2256 when operated in the tension mode.

NOTE 5—Flat-faced clamps are usually used with fine yarns. The snubbing-type clamps are used with coarse yarns or yarns that show a high breaking force. They are also used when specimens slip in the clamps or the number of breaks at or close to the jaws exceeds statistical expectations. To check slippage, make a mark on the specimen as close as possible to the back of each clamp, operate the machine to break the specimen, and observe whether the marks have moved from the jaw faces of either clamp.

6.1.1 Recorders on tension testing machines must have adequate pen response to properly record the force-elongation curve as specified in Specification ~~D76~~D76/D76M.

6.2 *Tank,* that can be fitted to the tension testing machine and used to test specimens while immersed in water.

6.3 *Container,* separate from the testing machine for wetting out specimens to be tested without immersion.

6.4 *Area-Measuring Device*—An integrating accessory to the tension testing machine or a planimeter.

6.5 *Distilled or Deionized Water and Nonionic Wetting Agent,* for wet specimens only.

6.6 *Conditioning Rack and Umbrella Reel (or Holder),* on which specimens, cut to convenient length, may be clamped and from which they may be taken one at a time without loss of twist.

6.7 *Peg or Spindle,* on which the package may be mounted to rotate freely as specimens are taken (for samples on bobbins, spools, tubes, etc.).

6.8 *Holder,* on which the yarn may be supported without tension and without loss of twist while in the water (for wet specimens only).

6.9 *Oven and Specimen Holders,* described in Test Methods D885 (for oven-dried specimens only).

6.10 *Oven,* that can be fitted to the tension testing machine and used to test specimens while exposed to elevated temperatures, as specified by an applicable order or contract. See Note 6.

6.11 *Cold Chamber,* that can be fitted to the tension testing machine and used to test specimens while exposed to low temperatures, such as – 40°C [–40°F] as specified by an applicable order or contract. See Note 6.

NOTE 6—Units described in 6.10 and 6.11 can be obtained as a single-unit environmental chamber capable of exposing yarns to both low and elevated temperatures.

7. Sampling

7.1 *Lot Sample*—As a lot sample for acceptance testing, take at random the number of shipping units directed in an applicable material specification or other agreement between the purchaser and the supplier, such as an agreement to use Practice D2258. Consider shipping cases or other shipping units to be the primary sampling units.

NOTE 7—An adequate specification or other agreement between the purchaser and the supplier requires taking into account the variability between shipping units, between packages or ends within a shipping unit, and between specimens from a single package so as to provide a sampling plan with a meaningful producer's risk, consumer's risk, acceptable quality level, and limiting quality level.

7.2 *Laboratory Sample*—As a laboratory sample for acceptance testing, take at random from each shipping unit in the lot sample the number of packages or ends directed in an applicable material specification or other agreement between the purchaser and the supplier such as an agreement to use Practice D2258. Preferably, the same number of packages should be taken from each shipping unit in the lot sample. If differing numbers of packages are to be taken from shipping units in the lot sample, determine at random which shipping units are to have each number of packages drawn.

7.3 *Test Specimens*—From each package in the laboratory sample, take three specimens. When packages other than beams contain more than one parallel wound end, select one end from which to prepare the three specimens. For beams, take three specimens from each end in the laboratory sample.

8. Conditioning of Specimens

8.1 Precondition and condition test specimens as directed in Section 11 for each applicable test option and condition of test as determined by an applicable purchase order or contract.

8.1.1 Avoid any change in twist or stretching of the yarn, or both, during handling.

PROCEDURE

9. Rate of Operation and ~~Gage~~Gauge Length

9.1 *Preferred Rate of Operation*—Operate all tension testing machines at a rate to reach the breaking force in an average time of 20 ± 3 s from the start of the test. Break one or more trial specimens, observe the time-to-break, and adjust the rate of crosshead displacement if necessary.

9.2 *Alternative Rates of Operation*—In case the tension testing machine is not capable of operating as specified in 9.1, select a rate that will reach the breaking force in an average time as close to 20 s as possible and report the average time to break. For CRL tension testing machines, the rate of force application per minute should be approximately three times the breaking force, and for CRE tension testing machines the rate of extension per minute should be approximately three times the elongation at break. On CRT tension testing machines with interchangeable or adjustable pendulum weights, the lower capacity ranges result in longer times to break, and higher capacities result in shorter times. These approximate rates are not acceptable for referee testing where a time to break of 20 ± 3 s is specified.

9.2.1 By agreement, or if required by material specifications, other operating rates may be used, for example, adjusting the rate to 120± 5 % of the ~~gage~~gauge length per minute, that is, 300 ± 10 mm/min [12 ± 0.5 in./min] for ~~250-mm~~ 250 mm [10-in.] ~~gage~~gauge lengths on CRT and CRE tension testing machines.

9.3 *~~Gage~~Gauge Length*—Adjust the tension testing machine in the starting position to a distance of 250 ± 3 mm [10 ± 0.1 in.], or by agreement 500 ± 5 mm [20 ± 0.2 in.], from nip to nip of the clamps along the specimen axis (including any portion in contact with snubbing surfaces).

9.3.1 For Conditions 2, 4, 5, and 6, using tension testing machines with an equipped water tank, oven, or cold chamber, the pulling mechanism may require repositioning to allow for shrinkage or stretch. When elongation is measured, the change in the ~~gage~~gauge length must be considered in the calculation. When shrinkage interferes with determination of elongation measurements; cooling of the test chamber may be required between subsequent loading of individual specimens.

10. Configurations of Test Specimens

10.1 *Configuration A, Straight Specimen*—Handle specimens in a manner to avoid any change in twist or any stretching of the specimen, or both (Note 8). Secure one end of the specimen in one of the clamps of the tension testing machine. Place the other end in the other clamp, applying 0.5 ± 0.1 cN/tex or 0.05 gf/den pre-tension which is considered satisfactory to remove any slack or kinks from most yarns without appreciable stretching. Close the second clamp. Avoid touching the portion of the specimen between the clamps with bare hands.

NOTE 8—Because of the difficulty of securing the same tension in all the filaments and because of slippage in the clamps, erratic results are frequently obtained with zero-twist multifilament yarns unless a small amount of twist is inserted before testing. A twist of ~~14 ± 1 tpcm/$\sqrt{T}$~~

~~(36±3 tpi/$\sqrt{T}$)~~

14 ±1 tpcm/$\sqrt{T}$ (36 ±3 tpi/$\sqrt{T}$)

or ~~43 ± 4 tpcm/$\sqrt{D}$~~

~~(110±10 tpi/$\sqrt{D}$)~~

$$43 \pm 4 \text{ tpcm}/\sqrt{D}\ (110 \pm 10 \text{ tpi}/\sqrt{D})$$

where *T* equals yarn number in tex and *D* equals yarn number in denier, is usually satisfactory. But, for unfamiliar materials it may be necessary to test with several different twist levels and determine the maximum breaking force. Twist a test specimen length that is about 225 mm [9 in.] longer than the ~~gage~~gauge length.

10.2 *Configuration B, Knot-Breaking Force*—Handle specimens in a manner to avoid any change in twist or any stretching of the specimen, or both (Note 8). Place one end of the specimen in one clamp of the machine, tie a single overhand knot near the middle of the specimen, place the other end in the second clamp, and tighten the clamp. Take care that the knot is always tied in the direction specified (see Annex A1), as the breaking force may be different depending on whether the knot is made with or against the direction of twist.

10.2.1 For Configuration B, Conditions 2, 3, 4, 5, and 6, tie loose knots in specimens before water or temperature exposure to avoid handling between exposure and testing.

10.3 *Configuration C, Loop-Breaking Force*—Handle specimens in a manner to avoid any change in twist or any stretching of the specimen, or both (Note 8). Each specimen consists of two pieces of yarn taken from one package or end. Secure both ends of one piece in one clamp of the tension testing machine without a change in twist having the length of the loop about one half the ~~gage~~gauge length. Pass one end of the second piece through the loop formed by the first, place both ends of the second piece in the other clamp of the machine, and close the clamp.

10.3.1 For Configuration C, Conditions 2, 3, 4, and 6, prepare the looped specimens before water or temperature exposure to avoid handling between exposure and testing.

11. Testing Conditions

11.1 *Condition 1, Ambient Air*—Reel a short skein from each of the packages forming the laboratory sample. Precondition the skeins as directed in Practice D1776 by bringing the material into approximate moisture equilibrium with an atmosphere having a relative humidity between 5 and 25 % at a temperature no higher than 50°C [120°F]. After preconditioning, bring the sample skeins to moisture equilibrium for testing in the standard atmosphere for testing textiles. Equilibrium is considered to have been reached when two successive weighings not less than 15 min apart do not differ by more than 0.1 % of the weight of the yarn.

NOTE 9—Conditioning in skein form is much more rapid than conditioning of tightly wound packages and is needed whenever other tests are to be made on the same sample, that is, tests requiring a large amount of conditioned material. However, the outer layers of a tight package reach approximate equilibrium in a reasonable length of time; and where only a few yards are to be used and extreme accuracy is not required (as, for example, in production control work) it may be more convenient to condition the yarn in package form.

NOTE 10—It is recognized that in practice yarns are frequently not weighed to determine when moisture equilibrium has been reached. While such a procedure cannot be accepted in cases of dispute, it may be sufficient in routine testing to expose the material to the standard atmosphere for testing for a reasonable period of time before the specimens are tested. A time of at least 24 h has been found acceptable in most cases. However, certain fibers may exhibit slow moisture equalization rates from the "as received" in shipment condition. When this is known, a preconditioning cycle, as described in Practice D1776 may be agreed upon between contractual parties.

11.1.1 Mount the specimen directly in the tension testing machine and test in the standard atmosphere for testing textiles as directed in Practice D1776.

11.2 *Condition 2, Wet Specimens Not Immersed on Tension Testing Machine*—Without disturbing twist, place the specimen on a holder and submerge in distilled or deionized water at room temperature until thoroughly soaked (see 11.2.1). Remove the specimen from the water and immediately mount it in the tension testing machine in the normal setup. If more than 60 s elapse between taking the wet specimen from the water bath and starting a tension testing machine without a tank, discard the specimen and take another.

11.2.1 The time of immersion must be sufficient to wet out the specimens thoroughly, as indicated by no significant further change in breaking force or elongation following longer periods of immersion. This time period will be at least 2 min for regenerated cellulose yarns and at least 10 min for acetate. For yarns not readily wet out with water, such as those treated with water-repellent or water-resistant materials, add a 0.1 % solution of a nonionic wetting agent to the water bath. Do not use any agent that will affect the physical properties of the yarn appreciably. When wet modulus is to be determined, some fiber types may require at least 24 h of immersion prior to testing.