INTERNATIONAL

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Standard Test Method for Tensile Properties of Single Textile Fibers[1]

This standard is issued under the fixed designation ~~D3822;~~D3822/D3822M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the measurement of tensile properties of natural and man-made single textile fibers of sufficient length to permit mounting test specimens in a tensile testing machine.

1.2 This test method is also applicable to continuous (filament) and discontinuous (staple) fibers or filaments taken from yarns or tow. When the fibers to be tested contain crimp, or if the tow or yarns have been subjected to bulking, crimping, or texturing process, the tensile properties are determined after removal of the crimp.

NOTE 1—Testing of filaments taken from yarns or tow, included in this test method was originally covered in Test Method D2101, that is discontinued.

1.3 The words "fiber" and "filament" are used interchangeably throughout this test method.

1.4 This test method is also applicable to fibers removed from yarns, or from yarns processed further into fabrics. It should be recognized that yarn and manufacturing processes can influence or modify the tensile properties of fibers. Consequently, tensile properties determined on fibers taken from yarns, or from yarns that have been processed into fabrics, may be different than for the same fibers prior to being subjected to yarn or fabric manufacturing processes.

1.5 This test method provides directions for measuring the breaking force and elongation at break of single textile fibers and for calculating breaking tenacity, initial modulus, chord modulus, tangent modulus, tensile stress at specified elongation, and breaking toughness.

1.6 Procedures for measuring the tensile properties of both conditioned and wet single fibers are included. The test method is applicable to testing under a wide range of conditions.

1.7 As the length of the test specimen decreases, the tensile strength is likely to increase, but the accuracy of the tensile properties determined may decrease, which may require the need to increase the number of test specimens. This is particularly true for those properties dependent on the measurement of elongation, since the shorter lengths increase the relative effect of slippage and stretching of the test specimens within the jaws of either clamp.

1.8 The values stated in either ~~acceptable metric~~ SI units or ~~in other units shall~~ inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system ~~must~~shall be used independently of the ~~other, without combining values in any way.~~other. Combining values from the two systems may result in non-conformance with the standard.

1.9 *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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D76 Specification for Tensile Testing Machines for Textiles
D123 Terminology Relating to Textiles
D629 Test Methods for Quantitative Analysis of Textiles
D1577 Test Methods for Linear Density of Textile Fibers
D1776 Practice for Conditioning and Testing Textiles

[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.

D2101 Test Method for Tensile Properties of Single Man-Made Textile Fibers Taken From Yarns and Tows (Withdrawn 1995)[3]
D2258 Practice for Sampling Yarn for Testing
D3333 Practice for Sampling Manufactured Staple Fibers, Sliver, or Tow for Testing
D4849 Terminology Related to Yarns and Fibers
E178 Practice for Dealing With Outlying Observations

3. Terminology

3.1 For all terminology relating to D13.58, Yarns and Fibers, refer to Terminology D4849.

3.1.1 The following terms are relevant to this standard: breaking force, breaking tenacity, breaking toughness, chord modulus, corresponding elongation, corresponding force, elongation, elongation at break, elongation at specified force, fiber, filament, filament yarn, force at specified elongation, initial modulus, linear density, secant modulus, tangent modulus, tenacity, tow, yield point.

3.2 For all other terminology related to textiles, refer to Terminology D123.

4. Summary of Test Method

4.1 Single-fiber specimens are broken on a constant-rate-of-extension (CRE) type tensile testing machine at a predetermined ~~gage~~gauge length and rate of extension. Using the force-extension curve, the breaking force and elongation at break are determined. The force-elongation curve and linear density are used to calculate breaking tenacity, initial modulus, chord modulus, tangent modulus, tensile stress at specified elongation, and breaking toughness.

5. Significance and Use

5.1 Test Method D3822 using test specimens having ~~gage~~gauge lengths of 10 mm ~~(0.4 in.)~~[0.4 in.] or greater is considered satisfactory for acceptance testing of commercial shipments since the test method has been used extensively in the trade for acceptance testing. Critical differences noted in Tables 1 and 2 were obtained on man-made fibers having a ~~gage~~gauge length of ~~25.4~~25 mm ~~(1.0 in.)~~[1.0 in.] and ~~254~~250 mm ~~(10 in.).~~[10 in.]. Natural fibers or fibers having lesser or greater ~~gage~~gauge lengths may provide different values and may require comparative testing. (See 5.1.1.)

5.1.1 In cases of a dispute arising from differences in reported test results when using Test Method D3822 for acceptance testing of commercial shipments, the purchaser and the supplier should conduct comparative tests to determine if there is a statistical bias between their laboratories. Competent statistical assistance is recommended for the investigation of bias. As a minimum, the two parties should take a group of test specimens which are as homogeneous as possible and which are from a lot of material of the type in question. The test specimens should then be randomly assigned in equal numbers to each laboratory for testing. The average results from the two laboratories should be compared using Student's t-test for unpaired data and an acceptable probability level chosen by the two parties before the testing begins. If a bias is found, either its cause must be found and corrected or the purchaser and the supplier must agree to interpret future test results for that material in view of test results with consideration to the known bias.

5.2 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 fiber processing or conversion and on their end-use applications. Initial modulus is a measure of the resistance of the fiber to extension at forces below the yield point. The tangent modulus and tensile stress at specified elongation may be used to differentiate between the probable performance of fibers in processing and end-use performance. The breaking toughness is an indication of the durability of materials produced from the fiber.

5.3 It is recognized that computerized results are used extensively in the industry. When comparing results from two laboratories using computerized tensile testers, the algorithms used to derive results must be examined for parity, that is, how the maximum slope and specimen failure or rupture are determined.

5.4 The breaking strength of wet fibers tested in air may be different from wet fibers tested while immersed.

5.4.1 Tests on wet specimens are usually made only on fibers which show a loss in 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 fiber to detect adulteration by failure to show a gain in breaking force.

6. Apparatus and Reagents

6.1 *Constant-Rate-of-Extension (CRE) Type Tensile Testing Machine,* conforming to Specification D76, having adequate response characteristics to properly record the characteristics of the force-elongation curve, or the stress-strain curve of the fibers under test at the rate of extension specified in Table 3. The capacity of the machine must be selected for the break on the recorded curve to fall within 20 to 90 % of full scale, preferably within 50 to 90 % of full scale. It is permissible to use tensile testing

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

TABLE 3 Rate of Extension[A]

Estimated Elongation at Break of Specimen, %	Rate of Extension, % of Initial Specimen Length/min
Under 8	10
8 to 100, incl.	60
Over 100	240

[A] For the optimum degree of comparability, tensile properties of filaments should be measured at the same rate of extension.

TABLE 4 Fiber Tensile Properties Using a 25.4 mm (1 in.) Gage Length
Components of Variance Expressed as Standard Deviations[A]

Properties, Limits of Measure and Materials	Grand Average	Single-Operator Component	Within-Laboratory Component	Between Laboratory Component
Breaking Tenacity, gf/tex:				
Acetate	1.38	0.06	0.02	0.06
Aramid	28.24	5.07	0.00	0.00
Nylon	4.63	0.28	0.04	0.09
Polyester	4.20	0.19	0.00	0.08
Initial Modulus gf/tex:				
Acetate	35.82	2.64	2.97	4.50
Aramid	670.58	96.03	35.53	84.02
Nylon	23.97	2.26	2.06	4.70
Polyester	77.31	7.88	6.62	9.59
Elongation at Break, %				
Acetate	30.45	2.63	0.84	1.45
Aramid	4.20	0.45	0.00	0.32
Nylon	66.80	6.47	1.43	4.65
Polyester	53.14	5.40	0.69	3.42

TABLE 1 Fiber Tensile Properties Using a 25.4 mm [1 in.] Gauge Length
Critical Differences for the Conditions Noted[A]

Properties, Limits of Measure and Materials	Number of Observations in Each Average	Single-Operator Precision	Within-Laboratory Precision	Between Laboratory Precision
Breaking Tenacity, mN/tex:				
Acetate	1	1.7	1.8	2.4
	10	0.5	0.8	1.8
	20	0.4	0.7	1.8
	40	0.3	0.6	1.8
Aramid	1	137.8	137.8	137.8
	10	43.5	43.5	43.5
	20	30.8	30.8	30.8
	40	21.8	21.8	21.8
Nylon	1	7.6	7.6	8.0
	10	2.4	2.6	3.6
	20	1.7	2.1	3.1
	40	1.2	1.7	2.9
Polyester	1	5.2	5.2	5.6
	10	1.7	1.7	2.7
	20	1.2	1.2	2.5
	40	0.8	0.8	2.4
Initial Modulus Mn/tex:				
Acetate	1	71.8	108.0	163.2
	10	22.7	83.8	148.3
	20	16.1	82.3	147.4
	40	11.4	81.5	147.0
Aramid	1	2610	2783	3600
	10	826	1270	2613
	20	583	1129	2547
	40	413	1050	2513
Nylon	1	61.4	83.1	152.4
	10	19.4	59.2	140.8
	20	13.7	57.7	140.1
	40	9.7	56.8	139.8
Polyester	1	214.2	279.7	382.4
	10	67.8	209.4	323.9
	20	47.9	186.2	320.3
	40	33.8	183.1	318.5
Elongation at Break, %				
Acetate	1	7.29	7.65	8.64
	10	2.3	3.28	5.18
	20	1.63	2.84	4.92

Properties, Limits of Measure and Materials	Number of Observations in Each Average	Single-Operator Precision	Within-Laboratory Precision	Between Laboratory Precision
	40	1.15	2.6	4.78
Aramid	1	1.25	1.25	1.53
	10	0.39	0.39	0.97
	20	0.28	0.28	0.93
	40	0.2	0.2	0.91
Nylon	1	17.93	18.36	22.43
	10	5.67	6.92	14.63
	20	4.01	5.64	14.01
	40	2.84	4.87	13.78
Polyester	1	14.97	15.09	17.82
	10	4.73	5.1	10.76
	20	3.35	3.85	10.23
	40	2.37	3.04	9.95

[A] The ~~square roots of the components~~critical differences were calculated using ~~of variance are being reported to express the variability in the appropriate units of measure rather than as the squares of those units of measure.~~= 1.960, which is based on infinite degrees of freedom.

TABLE ~~1~~ Fiber Tensile Properties Using ~~25.4 mm (1 in.) Gage~~ Length Critical Differences for the Conditions Noted[A]

Properties, Limits of Measure and Materials	Number of Observations in Each Average	Single-Operator Precision	Within-Laboratory Precision	~~Between~~ Laboratory Precision
Breaking Tenacity, gf/tex:				
Acetate	1	0.17	0.18	0.24
	10	0.05	0.08	0.18
	20	0.04	0.07	0.18
	40	0.03	0.06	0.18
Aramid	1	14.05	14.05	14.05
	10	4.44	4.44	4.44
	20	3.14	3.14	3.14
	40	2.22	2.22	2.22
Nylon	1	0.78	0.78	0.82
	10	0.24	0.27	0.37
	20	0.17	0.21	0.32
	40	0.12	0.17	0.30
Polyester	1	0.53	0.53	0.57
	10	0.17	0.17	0.28
	20	0.12	0.12	0.25
	40	0.08	0.08	0.24
Initial Modulus, gf/tex				
Acetate	1	7.32	11.01	16.64
	10	2.31	8.55	15.12
	20	1.64	8.39	15.03
	40	1.16	8.31	14.99
Aramid	1	266.1	283.8	367.1
	10	84.2	129.5	266.5
	20	59.5	115.1	259.7
	40	42.1	107.1	256.3
Nylon	1	6.26	8.47	15.54
	10	1.98	6.04	14.36
	20	1.40	5.88	14.29
	40	0.99	5.79	14.26
Polyester	1	21.84	28.52	38.99
	10	6.91	21.35	33.03
	20	4.88	18.99	32.66
	40	3.45	18.67	32.48
Elongation at Break, %				
Acetate	1	7.29	7.65	8.64
	10	2.30	3.28	5.18
	20	1.63	2.84	4.92
	40	1.15	2.60	4.78
Aramid	1	1.25	1.25	1.53
	10	0.39	0.39	0.97
	20	0.28	0.28	0.93
	40	0.20	0.20	0.91
Nylon	1	17.93	18.36	22.43
	10	5.67	6.92	14.63
	20	4.01	5.64	14.01
	40	2.84	4.87	13.78
Polyester	1	14.97	15.09	17.82
	10	4.73	5.10	10.76
	20	3.35	3.85	10.23
	40	2.37	3.04	9.95

TABLE 2 Fiber Tensile Properties Using a 254 mm [10 in.] Gauge Length Critical Differences for the Conditions Noted[A]

Properties, Limits of Measure and Materials	Number of Observations in Each Average	Single-Operator Precision	Within-Laboratory Precision	Between Laboratory Precision
Breaking Tenacity, mN/tex				
Acetate	1	1.86	2.06	2.26
	10	0.59	0.98	1.27
	20	0.39	0.88	1.27
	40	0.29	0.88	1.18
Aramid	1	85.61	90.91	94.93
	10	27.07	40.70	49.13
	20	19.12	35.99	45.21
	40	13.53	33.34	43.15
Nylon	1	6.77	7.26	8.14

Properties, Limits of Measure and Materials	Number of Observations in Each Average	Single-Operator Precision	Within-Laboratory Precision	Between Laboratory Precision
	10	2.16	3.24	5.00
	20	1.47	2.84	4.81
—	40	1.08	2.65	4.61
Polyester	1	6.77	7.65	7.75
	10	2.16	4.12	4.22
	20	1.47	3.82	3.92
	40	1.08	3.73	3.82
Initial Modulus, mN/tex				
Acetate	1	39.42	47.27	51.88
—	10	12.45	28.93	35.99
	20	8.83	27.56	34.91
	40	6.28	26.87	34.32
Aramid	1	1881	1881	2390
	10	594	594	1591
	20	421	421	1534
	40	297	297	1505
Nylon	1	47.56	69.43	105.03
	10	15.00	52.76	94.83
	20	10.59	51.68	94.14
	40	7.55	51.09	93.95
Polyester	1	120.13	153.57	167.79
	10	37.95	102.97	123.17
	20	26.87	99.34	120.23
	40	19.02	97.58	118.76
Elongation at Break, %				
Acetate	1	8.23	8.65	8.82
	10	2.6	3.72	4.1
	20	1.84	3.24	3.66
	40	1.3	2.96	3.42
Aramid	1	0.64	0.73	0.77
	10	0.2	0.41	0.48
	20	0.14	0.39	0.46
	40	0.1	0.37	0.45
Nylon	1	14.8	16.2	16.2
	10	4.68	8.09	8.09
	20	3.31	7.38	7.38
	40	2.34	7	7
Polyester	1	13.77	13.87	16.35
	10	4.36	4.65	8.05
	20	3.08	3.49	7.44
	40	2.18	2.72	7.11

A ~~The~~ The critical differences were calculated using ~~$t = 1.960$,~~ = 1.960, which is based on infinite degrees of ~~freedom.~~ freedom

TABLE 3 Rate of Extension[A]

Estimated Elongation at Break of Specimen, %	Rate of Extension, % of Initial Specimen Length/min
Under 8	10
8 to 100, incl.	60
Over 100	240

A For the optimum degree of comparability, tensile properties of filaments should be measured at the same rate of extension.

machines that have a means of calculating and displaying the required results without the use of an autographic recorder. The tensile testing machine must be equipped with a tank to provide for breaking fibers immersed in a liquid, if tests on wet immersed specimens are required.

NOTE 2—Special force-measuring systems may be used to directly record the tenacity in ~~cN/tex.~~ mN/tex.

6.2 *Clamps,* with flat jaws for gripping the fiber specimens and designed to minimize slippage in the clamps during the test,

6.2.1 *Tabs,* when required, of thin plastic or other material for use with cementing techniques (See Annex A1); and

6.2.2 *Cement or Adhesive*—The adhesive must be capable of binding the tabs to the fibers without affecting the moisture content of the specimen.

NOTE 3—For wet testing, the tabs and adhesive must be waterproof.

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

6.4 *Auxiliary Equipment*—The testing machine may be equipped with auxiliary equipment to permit the automatic recording of data or the calculation of any required tensile property. The auxiliary equipment must be capable of recording data and performing calculations in a manner consistent with the definitions and instructions for calculations as described in this test method.

6.5 *Area-Measuring Device*—An integrating accessory to the tensile testing machine or a planimeter. The device shall measure area with an accuracy of ±1 %.

6.6 *Jig,* to aid in accurately mounting test specimens on tabs at the specified ~~gage~~gauge length.

6.7 *Distilled or Deionized Water,* for use in wet specimen testing.

6.8 *Wetting Agent, Nonionic*—For wet specimen testing, for example, Triton X-100[4] to make 0.1 % aqueous solution using water described in 6.7.

7. Sampling

7.1 *Lot Sampling*—As a lot sample for acceptance testing, take at random the number of shipping containers directed in the applicable material specification or other agreement between the purchaser and supplier, such as an agreement to use Practice D3333 or Practice D2258. Consider shipping containers to be the primary sampling units.

NOTE 4—An adequate specification or other agreement between the purchaser or supplier requires taking into account the variability between shipping units, between packages, ends or other laboratory sampling unit within a shipping unit if applicable, and with specimens from a single package, end or other laboratory sampling unit to provide a sampling plan with a meaningful producer's risk, consumer's risk, acceptable quality level, and limiting quantity level.

7.2 *Laboratory Sample*—As a laboratory sample for acceptance testing, take at random from each shipping container in the lot sample the number of laboratory sampling units as directed in an applicable material specification or other agreement between purchaser and supplier such as an agreement to use Practice D3333 or Practice D2258. Preferably, the same number of laboratory sampling units are taken from each shipping container in the lot sample. If differing numbers of laboratory sampling units are to be taken from shipping containers in the lot sample, determine at random which shipping containers are to have each number of laboratory units drawn.

7.2.1 *For Staple Fiber*—Take 50 g samples from laboratory sampling units.

7.2.2 *For Sliver (or Top) or Tow*—Take 1 m ~~(1 yd)~~[3 yd] from the leading end which has a clean, uniform appearance from each laboratory sampling unit.

7.2.3 *For Yarns*—Take at least a 1 m ~~(1 yd)~~[3 yd] length from each laboratory sampling unit.

7.3 *Test Specimens*—From each laboratory sampling unit, take 20 fiber specimens at random. If the standard deviation determined for the 20 specimens is more than a value agreed upon between the purchaser and supplier prior to testing, continue testing in groups of 20 specimens from the same laboratory sampling unit until the standard deviation for all specimens tested is not more than the agreed-to value or, by agreement, stop testing after a specified number.

7.3.1 Carefully remove twist before taking specimens from yarn. Using tweezers and grasping each specimen at one end, gently remove the required number of specimens from the laboratory sampling units for testing. In some cases, if specimens are not to be tested immediately, place them on a short-pile or plush surface for storage until ready to test.

8. Preparation of Test Specimens

8.1 Measure the linear density of each specimen as directed in Test Methods D1577.

8.2 If fibers are to be tabbed, select a technique from Annex A1 or some other technique agreed upon by the purchaser and supplier.

8.3 For testing wet specimens without immersion, place the specimens in a container and submerge in a 0.1 % aqueous solution of a nonionic wetting agent in distilled or deionized water at ambient temperature until thoroughly soaked. (See 8.3.1 and 8.3.2.)

8.3.1 The time of immersion must be sufficient to completely wet out the specimens, as indicated by no significant changes in breaking force, or elongation at break when followed by longer periods of immersion.

8.3.2 When desizing treatments are specified prior to wet testing, use desizing treatments that will not effect the normal physical property of the material as directed in Test Methods D629.

8.4 For wet specimens tested while immersed, proceed as directed in 11.2.2.

9. Preparation of Test Apparatus

9.1 Select the appropriate force range for the fiber to be tested.

9.2 Verify that the tensile tester is within calibration as specified in the manufacturer's instructions.

[4] Triton-X 100 is a registered trademark of Rohm & Haas.