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

This standard is issued under the fixed designation D 3822; 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 D 2101, 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 units or in other units shall be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system must be used independently of the other, without combining values in any way.

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:*

D 76 Specification for Tensile Testing Machine for Textiles[2]
D 123 Terminology Relating to Textiles[2]
D 578 Specification for Glass Fiber Yarns[2]
D 629 Test Methods for Quantitative Analysis of Textiles[2]
D 1577 Test Methods for Linear Density of Textile Fibers[2]
D 1776 Practice for Conditioning Textiles for Testing[2]
D 2101 Test Method for Tensile Properties of Single Man-Made Fibers Taken from Yarns and Tow[3]
D 2258 Practice for Sampling Yarn for Testing[2]
D 3333 Practice for Sampling Man-Made Staple Fibers, Sliver, or Tow for Testing[4]
D 4848 Terminology Relating to Force and Deformation Properties of Textiles[4]
E 178 Practice for Dealing with Outlying Observations[5]

3. Terminology

3.1 *Definitions:*

3.1.1 *breaking force, n*—the maximum force applied to a material carried to rupture.

3.1.1.1 *Discussion*—The observed breaking force for fibers and filaments is generally expressed as millinewton (mN) or gram-force (gf).

3.1.2 *breaking tenacity, n*—the tenacity at the breaking force.

3.1.2.1 *Discussion*—Breaking tenacity is commonly expressed as centinewton per tex (cN/tex) or gram-force per denier (gf/den). The breaking tenacity is calculated from the breaking force and the linear density of the unstrained specimen or obtained directly from tensile testing machines that can be suitably adjusted to indicate tenacity instead of force for specimens of known linear density.

3.1.3 *breaking toughness, n*—toughness up to the breaking force.

3.1.3.1 *Discussion*—Breaking toughness is proportional to the area under the force-elongation curve from the origin to the breaking force. In textile strands, it is expressed as work (joules) per unit linear density.

3.1.4 *chord modulus, n—in a stress-strain curve*, the ratio of the change in stress to the change in strain between two specified points on the curve.

3.1.4.1 *Discussion*—The chord modulus is expressed in centinewton per tex (cN/tex), or in gram-force per denier (gf/den).

3.1.5 *corresponding elongation, n*—see elongation at specified force.

3.1.6 *corresponding force, n*—see *force at specified elongation.*

3.1.7 *elongation, n*—the ratio of the extension of a material to the length of the material prior to stretching, expressed as a percent.

3.1.7.1 *Discussion*—Elongation may be measured at any specified force or at rupture.

3.1.8 *elongation at break, n*—the elongation corresponding to the breaking force. (Syn. *breaking elongation.*)

3.1.9 *elongation at specified force, (EASF) n*—the elongation associated with a specified force on the force-extension curve. (Syn. *corresponding elongation.*)

3.1.10 *fiber, n—in textiles*, a generic term for any one of the various types of matter that form the basic elements of a textile and that is characterized by having a length at least 100 times its diameter.

3.1.10.1 *Discussion*—Refer to D 123 definitions for man-made fiber and natural fiber, and Annex A1 and Annex A2 for additional information.

3.1.11 *filament, n—in textiles*, continuous fiber of indefinite length.

3.1.12 *filament yarn, n*—a yarn composed of (continuous) filaments assembled with or without twist.

3.1.13 *force at specified elongation (FASE), n*—the force associated with a specific elongation on the force-extension or force-elongation curve. (Syn. *corresponding force.*)

3.1.14 *initial modulus, n—in a stress-strain curve*, the slope of the initial straight portion of the curve.

3.1.14.1 *Discussion*—The modulus is the ratio of the change in stress, expressed in centinewton per tex (cN/tex) or gram-force per denier (gf/den), to the change in strain, expressed as a fraction of the original length.

3.1.15 *linear density, n*—mass per unit length; the quotient obtained by dividing the mass of a fiber or yarn by its length.

3.1.15.1 *Discussion*—The tex unit (gram per kilometre) is preferred over the denier unit (gram per 9 kilometres).

3.1.16 *secant modulus, n*—deprecated term in textile terminology. Use the preferred term *chord modulus.*

3.1.17 *tangent modulus, n—in a stress-strain curve*, the ratio of change in stress to change in strain derived from the tangent to any point on the curve.

3.1.18 *tenacity, n—in a tensile test*, the force exerted on the specimen based on the linear density of the unstrained material.

3.1.18.1 *Discussion*—Tenacity is commonly expressed as centinewton per tex (cN/tex) or gram-force per denier (gf/d).

3.1.19 *tow, n—in man-made fibers*, a twistless multifilament strand suitable for conversion into staple fibers or sliver, or for direct spinning into yarn.

3.1.20 *yield point, n—in a stress-strain curve*, the point beyond which work is not completely recoverable and permanent deformation takes place.

3.1.20.1 *Discussion*—In textile fibers, an exact proportionality does not exist between force and extension and there is not a true yield point. The point on the force-extension curve beyond which the force-extension ratio changes from that existing during the first essentially straight line portion of the curve is frequently called the yield point of a textile strand or fiber. With animal fibers, permanent deformation does not occur until the extension reaches about 30 %, or when the rate of extension is extremely slow or the fiber is held under tension for a long time. In fact, if animal fiber is stretched in water, or at high humidity conditions, to as much as 30 % of the original length and allowed to relax for 24 h, the original force-extension curves may be reproduced.

3.1.21 Refer to Terminology D 123 for definitions of other textile terms and Terminology D 4848 for definitions of terms related to force and deformation used in this test method.

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 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 D 3822 using test specimens having gage lengths of 10 mm (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 length of 25.4 mm (1.0 in.) and 254 mm (10 in.). Natural fibers or fibers having lesser or greater gage 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 D 3822 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

[1] This test method is under the jurisdiction of ASTM Committee D13 on Textiles and is the direct responsibility of Subcommittee D13.58 on Yarn and Fiber Test Methods.

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[2] *Annual Book of ASTM Standards*, Vol 07.01.
[3] Discontinued: see *1995 Annual Book of ASTM Standards*, Vol 07.01.
[4] *Annual Book of ASTM Standards*, Vol 07.02.
[5] *Annual Book of ASTM Standards*, Vol 14.02.

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

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

TABLE 2 Fiber Tensile Properties Using a 254 mm (10 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	0.19	0.21	0.23
	10	0.06	0.10	0.13
	20	0.04	0.09	0.13
	40	0.03	0.09	0.12
Aramid	1	8.73	9.27	9.68
	10	2.76	4.15	5.01
	20	1.95	3.67	4.61
	40	1.38	3.40	4.40
Nylon	1	0.69	0.74	0.83
	10	0.22	0.33	0.51
	20	0.15	0.29	0.49
	40	0.11	0.27	0.47
Polyester	1	0.69	0.78	0.79
	10	0.22	0.42	0.43
	20	0.15	0.39	0.40
	40	0.11	0.38	0.39
Initial Modulus, gf/tex				
Acetate	1	4.02	4.82	5.29
	10	1.27	2.95	3.67
	20	0.90	2.81	3.56
	40	0.64	2.74	3.50
Aramid	1	191.8	191.8	243.7
	10	60.6	60.6	162.2
	20	42.9	42.9	156.4
	40	30.3	30.3	153.5
Nylon	1	4.85	7.08	10.71
	10	1.53	5.38	9.67
	20	1.08	5.27	9.60
	40	0.77	5.21	9.58
Polyester	1	12.25	15.66	17.11
	10	3.87	10.50	12.56
	20	2.74	10.13	12.26
	40	1.94	9.95	12.11
Elongation at Break, %				
Acetate	1	8.23	8.65	8.82
	10	2.60	3.72	4.10
	20	1.84	3.24	3.66
	40	1.30	2.96	3.42
Aramid	1	0.64	0.73	0.77
	10	0.20	0.41	0.48
	20	0.14	0.39	0.46
	40	0.10	0.37	0.45
Nylon	1	14.80	16.20	16.20
	10	4.68	8.09	8.09
	20	3.31	7.38	7.38
	40	2.34	7.00	7.00
Polyester	1	13.77	13.87	15.35
	10	4.36	4.65	8.05
	20	3.08	3.49	7.44
	40	2.18	2.72	7.11

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

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 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

rce and 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 D 76, 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 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.

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 length.

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.

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[6] 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 D 3333 or Practice D 2258. 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 D 3333 or Practice D 2258. 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) 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) 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 D 1577.

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

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 D 629.

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.

9.3 Adjust the distance between the clamps to obtain the selected nominal gage length of at least 10 mm (0.4 in.) and, when applicable, 250 mm (10 in.) or more. The most common gage lengths are 10, 20, 25, and 250 mm (0.4, 0.4, 1.0 and 10 in.).

NOTE 5—The results obtained are normally subject to less error if the gage length is selected to be as large as possible, consistent with the length of fibers to be tested. When comparisons are to be made between different fibers or where it is necessary to obtain comparable results in different laboratories, it is advisable to use the same gage length for all tests, selecting it to accommodate the shortest fibers of interest.

9.3.1 If the fiber specimen is mounted on tabs before being placed in the testing machine, the distance between tabs defines the nominal gage length (See Annex A1).

9.4 Set the extension speed to provide the rate of elongation specified in Table 3 for the gage length selected.

9.5 When using microprocessor automatic data gathering systems, set the appropriate parameters as defined in the manufacturer's instruction.

10. Conditioning

10.1 Precondition the specimens by bringing them to approximate moisture equilibrium in the standard atmosphere for preconditioning textiles as directed in Practice D 1776.

10.2 After preconditioning, bring the test specimens to moisture equilibrium for testing in the standard atmosphere for testing textiles as directed in Practice D 1776 or, if applicable, in the specified atmosphere in which the testing is to be performed.

11. Procedure

11.1 Test the conditioned specimens in the standard atmosphere for testing textiles, which is 21 ± 1°C (70 ± 2°F) and 65 ± 2 % relative humidity.

11.2 Mount a test specimen in the jaws of the clamps, removing slack without stretching the specimen. The specimen must be straight within the jaws and extreme care must be taken to ensure that the fiber specimen lies on the line of action between the force-measuring device and the point where the fiber leaves the moving jaw face. Any misalignment that tends to produce transverse motion of the clamps and jaws will introduce errors in measurements of elongation and may contribute to premature fiber failure.

11.2.1 For testing wet specimens without immersion, remove a specimen from the water and immediately mount it in the clamps as directed in 11.1 and 11.2. Perform the test within two minutes after removal of the specimen from the water.

11.2.2 For testing wet specimens while immersed, secure the specimens into the clamps of the tensile tester and submerge in the tank containing 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.). Test while the specimens are immersed in the water bath.

NOTE 6—In general, it will be found that no one type of fiber mounting will be suitable for all types and sizes of fibers and experience may show that some mounting techniques are much more efficient than others. Experience and operator preferences have been found to be of importance in selecting the most satisfactory mounting methods for a given laboratory.

11.3 For specimens having crimp, use a pretension of 0.3 to 1.0 cN/tex (0.03 to 0.11 gf/d) to remove the crimp while the fiber is placed in the clamps. If certain fibers with a high degree of crimp require greater pretensioning than the amount specified, determine the minimum pretension as directed in Appendix XI of Test Method D 1577. If, by visual examination, the crimp is not completely removed even at these greater force applications, record this fact.

11.4 Start the tensile testing machine and any associated auxiliary equipment, extending the fiber specimen to break at the selected extension speed and record the data of interest. For fibers of low stiffness, it may be advisable to first back off the moving jaw of the testing machine to allow the fiber to be slack at the time the testing machine is started.

11.5 After breaking the specimen, return the testing machine to its starting condition and remove all remains of the broken specimen from the clamp faces. Pieces of broken fiber remaining in the jaws may adversely affect the ability of the jaws to properly hold the succeeding specimens.

11.6 Test successive specimens as directed in 11.1-11.5 until the remaining specimens have been broken. If the number of fiber specimens failing at the jaw-fiber interface exceeds 5 % of the number tested, repeat the test after adjusting the jaw faces and clamping mechanism as described in 11.6.1-11.6.3.

11.6.1 If a specimen slips in the jaws, breaks at the edge or in the jaws, or, if for any reason attributable to faulty machine operation the result falls 20 % below the average of the breaking force for the set of specimens, discard the result and test another specimen. Continue until the required number of acceptable breaks have been obtained.

11.6.2 The decision to discard the results of a break shall be based on observation of the specimen during the test and upon the inherent variability of the fiber. It is difficult to determine the precise reason for certain specimens breaking near the edge of the jaws. If a jaw break is caused by damage to the specimen by the jaws, then the results should be discarded. If, however, it is merely due to randomly distributed weak places, it is a perfectly legitimate result. Refer to Practice E 178 for treatment of outlying data points.

11.6.3 If a fiber manifests any slippage in the jaws or if more than 25 % of the specimens break at a point within 3 mm (⅛ in.) of the edge of the jaw, then (*1*) the jaws may be padded, (*2*) the fiber may be coated under the jaw face area, or (*3*) the surface of the jaw face may be modified. If any of the modifications listed above are used, state the method of modification in the report.

11.7 Obtain the elongation data by means of a suitable recording device, or computer, at the same time as the breaking force is determined unless otherwise agreed upon, as provided for in an applicable material specification.

12. Calculation

12.1 *Breaking Force*—Record the breaking force of individual specimens to three significant digits as read directly from the tension testing machine expressed in cN (gf).

12.2 *Breaking Tenacity*—Calculate the breaking tenacity of individual specimens to three significant digits, using Eq 1:

$$Y = F / D_L \tag{1}$$

where:

Y = breaking tenacity in mN/tex (gf/den),
F = breaking force in cN (gf), and
D_L = linear density in tex (denier).

12.3 *Effective Specimen Length*—Calculate the effective specimen length of individual specimens to three significant digits, using Eq 2: (See Annex A2 and Figs. X1.1 and X1.2.)

$$L_e = L_i + \Delta L_c \tag{2}$$

where:

L_e = effective specimen length, mm (in.),
L_i = initial distance between clamps (gage length), mm (in.), and
ΔL_c = additional specimen length corresponding to the clamp error as determined in A2.2, when required.

12.4 *Elongation*—From XY type recorders, calculate the elongation at break, or other specified elongation, of individual specimens to three significant digits using Eq 3:

$$\epsilon_s = (\Delta L \times R_s \times 100)/(C_s \times L_e) \tag{3}$$

where:

ϵ_s = elongation percent, at the specified force,
ΔL = distance along the zero-stress axis from the point corresponding to the point where the tangent line to the initial straight-line section of the stress-strain curve intersects the zero-stress axis, to a point corresponding to the breaking stress, or other specified stress, mm (in.),
R_s = testing speed rate, mm/min (in./min),
C_s = recording chart speed, mm/min (in./min), and
L_e = effective specimen length, mm (in.).

12.5 *Initial Modulus*—Locate the maximum slope and draw a line tangent to the stress-strain curve between the tangent point for this tangent line and the proportional elastic limit and through the zero-stress axis. Measure the stress and the corresponding elongation with respect to the stress axis. Calculate initial modulus in cN/tex (gf/d) to three significant digits, using Eq 4 (see Appendix X2 and Figs. X1.1 and X1.2):

$$J_i = S/\epsilon_p \tag{4}$$

where:

J_i = initial modulus, cN/tex (gf/den),
S = determined stress on the drawn tangent line cN/tex (gf/den), and
ϵ_p = corresponding strain with respect to the drawn tangent line and determined stress.

12.6 *Chord Modulus*—Determine the stress for a specified elongation, such as 10 %, and label that point on the stress-strain curve as P_2. Likewise, label a second point, P_1 at a specified elongation, such as 0 % elongation. Draw a straight line through points P_1 and P_2 intersecting the zero-stress axis. Other elongation values may be used, for example, when provided for in an applicable material specification. Calculate chord modulus in cN/tex (gf/d) to three significant digits, using Eq 5 (see Appendix X2 and Fig. X2.1):

$$J_{ch} = S/\epsilon_p \tag{5}$$

where:

J_{ch} = chord modulus between specified elongations, cN/tex (gf/den),
S = determined stress on the constructed line, cN/tex (gf/den), and
ϵ_p = corresponding strain with respect to the constructed line and determined stress.

12.7 *Breaking Toughness*—When using the stress-strain curves, draw a line from the point of breaking force of each specimen perpendicular to the extension axis. Measure the area bounded by the curve, the perpendicular and the extension axis by means of an integrator or a planimeter, or cut out the area of the chart under the stress-strain curve, weigh it, and calculate the area under the curve using the mass of the unit area.

12.7.1 When determining the breaking toughness of fibers that exhibit slack caused by crimp or design, the area under the stress-strain curve which precedes the initial modulus line represents the work to remove this slack. Automatic area measuring equipment may or may not include this area in measuring breaking toughness, and therefore, such information should be reported along with the value obtained for the breaking toughness.

12.7.2 Calculate the breaking toughness to three significant digits for each specimen when using XY-type recorders using Eq 6 or when using automatic area measuring equipment using Eq 7:

$$T_u = (A_c \times F_{fs} \times R_s)/(W_c \times C_s \times D_L \times L_e) \tag{6}$$

$$T_u = (I_r \times F_{fs} \times R_s)/(I_c \times D_l \times L_e) \tag{7}$$

where:

T_u = breaking toughness, J/g (gf/den),
A_c = area under the stress-strain curve, mm^2,
F_{fs} = full scale force range, cN (gf),
R_s = testing speed rate, mm/min (in./min),
W_c = recording chart width, mm (in.),
C_s = recording chart speed, mm/min (in./min),

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D_l = linear density, dtex (denier),
L_e = effective specimen length, mm (in.),
I_r = integrator reading, and
I_c = integrator constant, per minute, determined as directed by the manufacturer.

12.8 *Average Values*—Calculate the average values for breaking force, breaking tenacity, elongation at break, initial modulus, chord modulus, tangent modulus, tensile stress at specified elongation, and breaking toughness for each laboratory sampling unit and the lot.

12.9 *Computer Generated Data*—When data is automatically computer generated, calculations are generally contained in the associated software. In any event, it is recommended that computer generated data be verified against known property values, or by manual calibration.

12.10 If requested, also calculate the standard deviation or the coefficient of variation, or both, for the properties of interest.

13. Report

13.1 State that the specimens were tested as directed in ASTM Test Method D 3822. Describe the material or product sampled and the method of sampling used.

13.2 Report the following information for both, the laboratory sampling units and the lot average as applicable to a material specification or contract order.

13.2.1 Average breaking force.

13.2.2 Average breaking tenacity or tenacity at a specific elongation.

13.2.3 Average elongation at break or other specified force.

13.2.4 Average initial modulus.

13.2.5 Average chord modulus and the two elongations used in the calculation.

13.2.6 Average tangent modulus and the point on the stress-strain curve at which it was calculated.

13.2.7 Tensile stress and the specified elongation.

13.2.8 Breaking toughness, and whether or not the work-to-remove crimp is included in the value.

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

[A] The square roots of the components 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.

TABLE 5 Fiber Tensile Properties Using a 254 mm (10 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	1.25	0.07	0.03	0.03
Aramid	21.61	3.15	1.12	1.01
Nylon	4.22	0.25	0.09	0.14
Polyester	3.80	0.25	0.13	0.03
Initial Modulus gf/tex				
Acetate	39.66	1.45	0.96	0.79
Aramid	839.86	69.20	0.00	54.28
Nylon	25.04	1.75	1.86	2.90
Polyester	95.09	4.42	3.52	2.49
Elongation at Break, %				
Acetate	25.15	2.97	0.96	0.62
Aramid	2.55	0.23	0.13	0.09
Nylon	52.54	5.34	2.38	0.00
Polyester	38.30	4.97	0.59	2.37

[A] The square roots of the components of variance are being reported to express the variability in the appropriate units of measure rather than as the square of those units of measure.

13.2.9 Standard deviation, coefficient of variation, or both, for each property, if calculated.

13.2.10 Effective specimen length, when applicable.

13.2.11 Testing temperature and percent relative humidity if the test was performed on specimens conditioned at other than the standard conditions for testing textiles.

13.2.12 For wet specimens, whether specimens were tested wet in air, or while immersed, and the temperature of the water.

13.2.13 If requested, include a force-elongation curve, with chart axis-units and speed indicated, as part of the report.

13.2.14 Number of specimens tested.

13.2.15 Pretension applied, if any.

13.2.16 Make and model of tensile testing machine.

13.2.17 Type of clamps used.

13.2.18 Type of padding used in jaws, technique for tabbing of specimens gripped in the jaws, or modification of jaw faces if used.

13.2.19 Nominal gage length, clamp error, rate of specimen extension and full scale force range used for testing.

13.2.20 For computer derived data, identify how slope and breaking points were determined and identify the program (software) used.

14. Precision and Bias [7]

14.1 *Interlaboratory Test Data*—An interlaboratory test was run in 1981 in which randomly-drawn samples of four materials were tested in each of six laboratories. Two operators in each laboratory each tested ten specimens of each material using both a 10-in. gage length and a 1-in. gage length. The components of variance for tenacity, initial modulus and elongation at break expressed as standard deviations were calculated to be the values listed in Table 4 for gage lengths of 1 in. and Table 5 for gage lengths of 10 in. The four classes of fibers were: 4.2 denier low tenacity acetate; 3.0 denier medium

[7] ASTM Research Report No. RR: D13-1088. A copy is available from ASTM Headquarters.

tenacity, low modulus nylon; 5.0 denier medium tenacity, high modulus polyester; and 1.5 denier high tenacity, high modulus aramid.

14.2 *Precision*—For the components of variance reported in Tables 4 and 5, two averages of observed values should be considered significantly different at the 95 % probability level if the difference equals or exceeds the critical differences listed in Tables 1 and 2, respectively.

NOTE 7—The tabulated values of the critical differences should be considered to be a general statement, particularly with respect to between-laboratory precision. Before a meaningful statement can be made about two specific laboratories, the amount of statistical bias, if any, between them must be established, with each comparison being based on recent data obtained on specimens taken from a lot of material to the type being evaluated so as to be as nearly homogeneous as possible and then randomly assigned in equal numbers to each of the laboratories.

14.3 *Bias*—The values of the tenacity, initial modulus, and elongation at break can only be defined in terms of a specific test method. Within this limitation, the procedures in Test Method D 3822 for measuring these properties has no known bias.

15. Keywords

15.1 tension (tensile) properties/tests; textile fiber

ANNEXES

(Mandatory Information)

A1. TABBING TECHNIQUE FOR FIBER

A1.1 Scope

A1.1.1 Due to the inherent nature of some fibers, a means is required to protect or cushion the ends of the fiber that lay in the clamp to minimize clamp breaks. The procedure described below has been used successfully to minimize the occurrence of jaw breaks.

A1.2 Summary of Tabbing Technique

A1.2.1 A single fiber is secured to a cardboard substrate by means of an epoxy resin. This assembly is placed centrally in the clamps of a tensile tester. Cardboard material is removed from the assembly in the gage area without making contact with the fiber.

A1.3 Materials

A1.3.1 *Poster Board*, or equivalent.

A1.3.1.1 The colors of the board and cardboard (A1.3.2) should contrast and be different from the color of the fiber for ease of viewing.

A1.3.2 *Sub 65 Grade Cardboard*, or equivalent. (See A1.3.1.1.)

A1.3.3 *Paper Cutter*.

A1.3.4 *Steel Rule*, 0.25 mm (0.01 in.) graduations.

A1.3.5 *Cutting Die*, 14 ± 0.25 mm (0.55 ± 0.01 in.) diameter.

A1.3.6 *Bonding Resin* (See A1.1).

NOTE A1.1—A mixture by weight of 60 parts Ciba Geigy 6004 Epoxy Resin® and 40 parts General Mills Versimid 125 polyamide resin® has been found suitable for this purpose. Other mixtures can be used providing specimen damage does not occur or that specimens do not break or slip at the jaw faces.

A1.3.7 *Tweezers*.

A1.3.8 *Surgical Shears*, or alternately, a needle nose solder gun.

A1.3.9 *Lighted Magnifying Glass Stand*, at least 8× power to aid in positioning specimens while tabbing.

A1.4 Specimen Preparation

A1.4.1 Using the paper cutter, prepare a sufficient number of cardboard squares having dimensions of 25 mm by 25 mm (1 in. by 1 in.).

A1.4.1.1 Die cut 14 mm (0.55 in.) diameter holes approximately in the center of the 25 mm by 25 mm (1 in. by 1 in.) cardboard squares.

A1.4.2 Place a piece of poster board on a flat table or bench top. (This is used as background material for convenience in viewing the specimens during preparation.)

A1.4.3 Prepare a sufficient amount of bonding resin to accommodate the number of specimens that are to be prepared.

A1.4.4 Separate and place the required number of die cut cardboard squares on the poster board, in turn, under the lighted magnifying glass. This magnification provides for ease of viewing the fiber during resin mounting to the cardboard square.

A1.4.5 Apply a small amount of bonding resin centrally to each of the required die-cut squares at two opposite locations beginning at the inside edge and extending outward to the outer edge. Apply the resin such that it is on an imaginary line parallel with one of the other two edges but not on the absolute edges.

A1.4.6 Using tweezers without grasping the fiber in the gage area, position the fiber across the areas of resin on the cardboard square. Do this for all specimens. Do not touch the segment of the fiber within the gage length at any time during the specimen preparation.

A1.4.7 Allow the resin to cure 12 to 16 h in a protected area.

A1.4.8 Using the paper cutter, carefully trim the outer edges of the cardboard parallel to the fiber until approximately 1 mm (0.05 in.) of cardboard remains on each side of the fiber.

A1.4.9 The specimen preparation is completed after the specimen is centrally placed in the clamps of the tensile tester. At this time, the 1 mm (0.05 in.) width of cardboard is severed at both sides of the fiber by means of either surgical shears or solder gun without touching the fiber.

A2. EFFECTIVE SPECIMEN LENGTH

A2.1 The effective specimen length can be determined by adding the initial length between the clamp faces (nominal gage length) and adding the length contributed by the clamp error (see Fig. A2.1).

A2.1.1 The fiber clamps used in tensile testing can affect the apparent fiber properties observed. The customary method of determining specimen elongation, by measuring clamp separation, assumes that the stresses applied to the specimen during the test are confined by the clamps to the original specimen length. Most fiber clamps do not completely confine the stresses, and therefore, an erroneously high elongation may be indicated as the result of being based on a nominal gage length which is shorter than the effective gage length.

A2.1.2 Clamp errors may occur in nondestructive testing, such as tests for elastic performance, modulus, etc., as well as in destructive testing. In all cases, the procedure for estimation of effective gage length should employ stresses comparable to those experienced in the corresponding tensile testing.

A2.1.3 The magnitude of the error determined for any one clamping system may varying according to the surface characteristics, linear density, test environment, breaking force, and extensibility of the material. Accordingly, changes in any of these factors will require a re-evaluation of the error.

A2.2 Determine the clamp error as follows:

A2.2.1 Mount the fibers in the clamps in the normal manner using a pretension of 10 to 50 cN/tex (0.01 to 0.05 gf/d). (See Note A2.1.)

NOTE A2.1—The use of a pretension eliminates slack in the mounted specimen. Any slack would be erroneously computed as clamp error by the testing procedure.

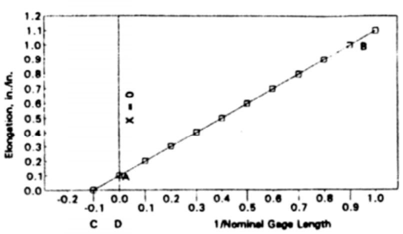

FIG. A2.1 Example of Plot to Determine Clamp Error

A2.2.2 Mark the recorder chart to locate the crosshead in reference to chart position (Note A2.2).

NOTE A2.2—The marking of the crosshead position in reference to the chart position allows observance of any slack caused by the extrusion of the fiber specimen from the clamp during tightening of the clamp.

A2.2.3 Break the representative groups of fibers at three or more different nominal gage lengths (Note A2.3). Maintain the same rate of extension at each gage length.

NOTE A2.3—Limits within which the gage lengths are chosen will be dictated by the accuracy with which the shortest gage length can be determined, and in the case of a destructive test, the maximum length of specimen which will not be affected by flaw distribution. The latter point is of importance when, by increasing the gage length, the probability of including a major flaw (causing premature fiber failure) in the test length is increased. Flaw inclusion may be suspected when the average elongation does not increase proportionately with increase in gage length. This will be indicated when the straight line plot (Fig. A2.1) curves toward the abscissa at longer gage lengths.

A2.2.4 Break ten specimens in each representative group of fibers. If the variation in average breaking tenacity among data obtained at different gage lengths is greater than ± 3 percent, break additional specimens until the variation in average breaking tenacity among groups does not exceed ± 3 percent.

A2.2.5 Calculate the average apparent elongation at break in denominate units, for each nominal gage length. Plot the apparent elongation versus the nominal gage length (for example see Fig. A2.1). Draw a straight line (Note Note A2.4) through the plotted points to the nominal gage length axis, point C, and extrapolate to zero elongation (BC, Fig. A2.1). The distance between the intersection of this line and zero nominal gage length, along the gage length axis (CD), represents the average clamp errof.

NOTE A2.4—The preferred procedure for drawing the line is by means of the least squares method, although in many cases visual inspection is adequate.

A2.3 Calculate the Effective Gage Length as follows:

$$\text{Effective Gage Length} = \text{(clamp error length + nominal gage length)} \quad \text{(A2.1)}$$

APPENDIXES

(Nonmandatory Information)

X1. INITIAL MODULUS

X1.1 In the case of a fiber exhibiting a region that obeys Hooke's law (Fig. X1.1), a continuation of the linear region of the stress-strain curve is constructed through the zero-stress axis. This intersection point B is the zero extension point from which strain is measured.

X1.1.1 The initial modulus can be determined by dividing the stress at any point along the line BD (or its extension) by the strain at the same point (measured from point B, defined as zero-strain). Point C, the point where line BD first touches the stress-strain curve is the tangent point.

X1.2 In the case of a fiber that does not exhibit any linear region (Fig. X1.2), a tangent K′B′ is constructed to the maximum slope and its extension intersecting the zero-stress axis at point B′. This intersection point B′ is the zero point from which strain is measured. Point C′, the point where line K′B′ first touches the stress-strain curve, is the tangent point.

X1.2.1 The initial modulus may be determined by dividing the stress at any point along line B′K′ (or its extension) by the strain at the same point (measured from point B′, defined as zero-strain).

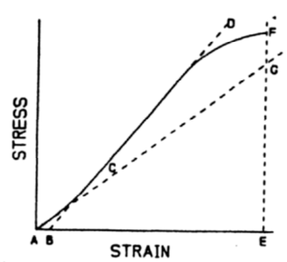

FIG. X1.1 Example of Material with Hookean Region

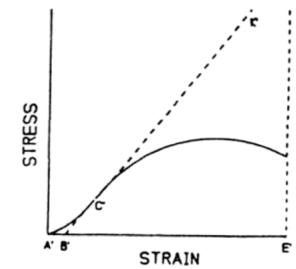

FIG. X1.2 Example of Material with No Hookean Region

X2. CHORD MODULUS

X2.1 In a typical stress-strain curve (Fig. X2.1), a straight line is constructed through the zero-stress axis, such as zero strain point A″ and a second point, such as 10 % strain, point M″. The intersection point A″ is the zero strain point from which the specimen strain is measured.

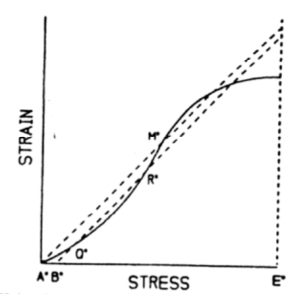

FIG. X2.1 Example of Construction for Chord Modulus

X2.1.1 The chord modulus may be calculated by dividing the stress at any point along line A″M″ (or its extension) by the specimen stress at the same point (measured from point A″, defined as zero strain).

X2.1.2 Fig. X2.1 also represents a straight line constructed through any two specified points, point Q″ and point R″, other than zero and 10 % strain. In this case, the line extends through the zero stress axis at point B″. This intersection is the zero strain point from which specimen strain is measured. The chord modulus can be determined by dividing the stress at any point along the Q″R″ (or its extension) by the specimen strain at the same point (measured from point B″, defined as zero strain).

A2. EFFECTIVE SPECIMEN LENGTH

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A2.1.2 Clamp errors may occur in nondestructive testing, such as tests for elastic performance, modulus, etc., as well as in destructive testing. In all cases, the procedure for estimation of effective gage length should employ stresses comparable to those experienced in the corresponding tensile testing.

A2.1.3 The magnitude of the error determined for any one clamping system may varying according to the surface characteristics, linear density, test environment, breaking force, and extensibility of the material. Accordingly, changes in any of these factors will require a re-evaluation of the error.

A2.2 Determine the clamp error as follows:

A2.2.1 Mount the fibers in the clamps in the normal manner using a pretension of 10 to 50 cN/tex (0.01 to 0.05 gf/d). (See Note A2.1.)

NOTE A2.1—The use of a pretension eliminates slack in the mounted specimen. Any slack would be erroneously computed as clamp error by the testing procedure.

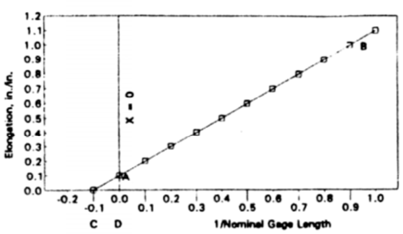

FIG. A2.1 Example of Plot to Determine Clamp Error

A2.2.2 Mark the recorder chart to locate the crosshead in reference to chart position (Note A2.2).

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A2.2.4 Break ten specimens in each representative group of fibers. If the variation in average breaking tenacity among data obtained at different gage lengths is greater than ± 3 percent, break additional specimens until the variation in average breaking tenacity among groups does not exceed ± 3 percent.

A2.2.5 Calculate the average apparent elongation at break in denominate units, for each nominal gage length. Plot the apparent elongation versus the nominal gage length (for example see Fig. A2.1). Draw a straight line (Note Note A2.4) through the plotted points to the nominal gage length axis, point C, and extrapolate to zero elongation (BC, Fig. A2.1). The distance between the intersection of this line and zero nominal gage length, along the gage length axis (CD), represents the average clamp errot.

NOTE A2.4—The preferred procedure for drawing the line is by means of the least squares method, although in many cases visual inspection is adequate.

A2.3 Calculate the Effective Gage Length as follows:

$$\text{Effective Gage Length} = \text{(clamp error length + nominal gage length)} \qquad (A2.1)$$

APPENDIXES

(Nonmandatory Information)

X1. INITIAL MODULUS

X1.1 In the case of a fiber exhibiting a region that obeys Hooke's law (Fig. X1.1), a continuation of the linear region of the stress-strain curve is constructed through the zero-stress axis. This intersection point B is the zero extension point from which strain is measured.

X1.1.1 The initial modulus can be determined by dividing the stress at any point along the line BD (or its extension) by the strain at the same point (measured from point B, defined as zero-strain). Point C, the point where line BD first touches the stress-strain curve is the tangent point.

X1.2 In the case of a fiber that does not exhibit any linear region (Fig. X1.2), a tangent K′B′ is constructed to the maximum slope and its extension intersecting the zero-stress axis at point B′. This intersection point B′ is the zero point from which strain is measured. Point C′, the point where line K′B′ first touches the stress-strain curve, is the tangent point.

X1.2.1 The initial modulus may be determined by dividing the stress at any point along line B′K′ (or its extension) by the strain at the same point (measured from point B′, defined as zero-strain).

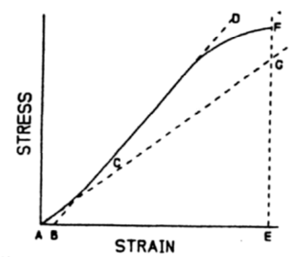

FIG. X1.1 Example of Material with Hookean Region

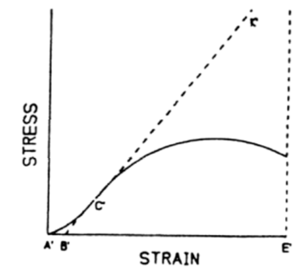

FIG. X1.2 Example of Material with No Hookean Region

X2. CHORD MODULUS

X2.1 In a typical stress-strain curve (Fig. X2.1), a straight line is constructed through the zero-stress axis, such as zero strain point A″ and a second point, such as 10 % strain, point M″. The intersection point A″ is the zero strain point from which the specimen strain is measured.

X2.1.1 The chord modulus may be calculated by dividing the stress at any point along line A″M″ (or its extension) by the specimen stress at the same point (measured from point A″, defined as zero strain).

X2.1.2 Fig. X2.1 also represents a straight line constructed through any two specified points, point Q″ and point R″, other than zero and 10 % strain. In this case, the line extends through the zero stress axis at point B″. This intersection is the zero strain point from which specimen strain is measured. The chord modulus can be determined by dividing the stress at any point along the Q″R″ (or its extension) by the specimen strain at the same point (measured from point B″, defined as zero strain).

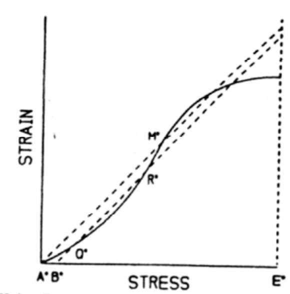

FIG. X2.1 Example of Construction for Chord Modulus

A2. EFFECTIVE SPECIMEN LENGTH

A2.1 The effective specimen length can be determined by adding the initial length between the clamp faces (nominal gage length) and adding the length contributed by the clamp error (see Fig. A2.1).

A2.1.1 The fiber clamps used in tensile testing can affect the apparent fiber properties observed. The customary method of determining specimen elongation, by measuring clamp separation, assumes that the stresses applied to the specimen during the test are confined by the clamps to the original specimen length. Most fiber clamps do not completely confine the stresses, and therefore, an erroneously high elongation may be indicated as the result of being based on a nominal gage length which is shorter than the effective gage length.

A2.1.2 Clamp errors may occur in nondestructive testing, such as tests for elastic performance, modulus, etc., as well as in destructive testing. In all cases, the procedure for estimation of effective gage length should employ stresses comparable to those experienced in the corresponding tensile testing.

A2.1.3 The magnitude of the error determined for any one clamping system may varying according to the surface characteristics, linear density, test environment, breaking force, and extensibility of the material. Accordingly, changes in any of these factors will require a re-evaluation of the error.

A2.2 Determine the clamp error as follows:

A2.2.1 Mount the fibers in the clamps in the normal manner using a pretension of 10 to 50 cN/tex (0.01 to 0.05 gf/d). (See Note A2.1.)

NOTE A2.1—The use of a pretension eliminates slack in the mounted specimen. Any slack would be erroneously computed as clamp error by the testing procedure.

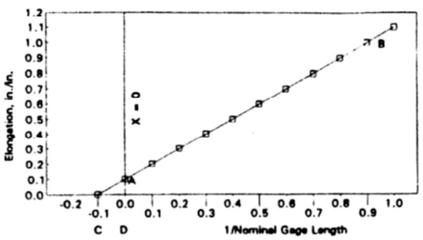

FIG. A2.1 Example of Plot to Determine Clamp Error

A2.2.2 Mark the recorder chart to locate the crosshead in reference to chart position (Note A2.2).

NOTE A2.2—The marking of the crosshead position in reference to the chart position allows observance of any slack caused by the extrusion of the fiber specimen from the clamp during tightening of the clamp.

A2.2.3 Break the representative groups of fibers at three or more different nominal gage lengths (Note A2.3). Maintain the same rate of extension at each gage length.

NOTE A2.3—Limits within which the gage lengths are chosen will be dictated by the accuracy with which the shortest gage length can be determined, and in the case of a destructive test, the maximum length of specimen which will not be affected by flaw distribution. The latter point is of importance when, by increasing the gage length, the probability of including a major flaw (causing premature fiber failure) in the test length is increased. Flaw inclusion may be suspected when the average elongation does not increase proportionately with increase in gage length. This will be indicated when the straight line plot (Fig. A2.1) curves toward the abscissa at longer gage lengths.

A2.2.4 Break ten specimens in each representative group of fibers. If the variation in average breaking tenacity among data obtained at different gage lengths is greater than ± 3 percent, break additional specimens until the variation in average breaking tenacity among groups does not exceed ± 3 percent.

A2.2.5 Calculate the average apparent elongation at break in denominate units, for each nominal gage length. Plot the apparent elongation versus the nominal gage length (for example see Fig. A2.1). Draw a straight line (Note Note A2.4) through the plotted points to the nominal gage length axis, point C, and extrapolate to zero elongation (BC, Fig. A2.1). The distance between the intersection of this line and zero nominal gage length, along the gage length axis (CD), represents the average clamp error.

NOTE A2.4—The preferred procedure for drawing the line is by means of the least squares method, although in many cases visual inspection is adequate.

A2.3 Calculate the Effective Gage Length as follows:

Effective Gage Length = (A2.1)

(clamp error length + nominal gage length)

APPENDIXES

(Nonmandatory Information)

X1. INITIAL MODULUS

X1.1 In the case of a fiber exhibiting a region that obeys Hooke's law (Fig. X1.1), a continuation of the linear region of the stress-strain curve is constructed through the zero-stress axis. This intersection point B is the zero extension point from which strain is measured.

X1.1.1 The initial modulus can be determined by dividing the stress at any point along the line BD (or its extension) by the strain at the same point (measured from point B, defined as zero-strain). Point C, the point where line BD first touches the stress-strain curve is the tangent point.

X1.2 In the case of a fiber that does not exhibit any linear region (Fig. X1.2), a tangent K'B' is constructed to the maximum slope and its extension intersecting the zero-stress axis at point B'. This intersection point B' is the zero point from which strain is measured. Point C', the point where line K'B' first touches the stress-strain curve, is the tangent point.

X1.2.1 The initial modulus may be determined by dividing the stress at any point along line B'K' (or its extension) by the strain at the same point (measured from point B', defined as zero-strain).

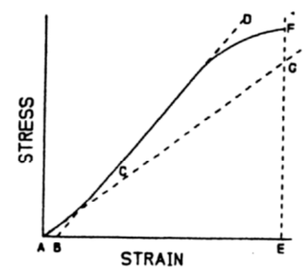

FIG. X1.1 Example of Material with Hookean Region

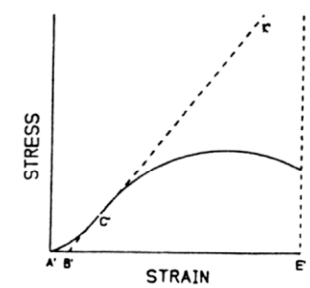

FIG. X1.2 Example of Material with No Hookean Region

X2. CHORD MODULUS

X2.1 In a typical stress-strain curve (Fig. X2.1), a straight line is constructed through the zero-stress axis, such as zero strain point A" and a second point, such as 10 % strain, point M". The intersection point A" is the zero strain point from which the specimen strain is measured.

X2.1.1 The chord modulus may be calculated by dividing the stress at any point along line A"M" (or its extension) by the specimen stress at the same point (measured from point A", defined as zero strain).

X2.1.2 Fig. X2.1 also represents a straight line constructed through any two specified points, point Q" and point R", other than zero and 10 % strain. In this case, the line extends through the zero stress axis at point B". This intersection is the zero strain point from which specimen strain is measured. The chord modulus can be determined by dividing the stress at any point along the Q"R" (or its extension) by the specimen strain at the same point (measured from point B", defined as zero strain).

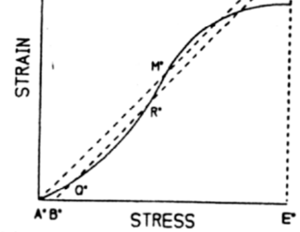

FIG. X2.1 Example of Construction for Chord Modulus