Designation: D 2256 – 02

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

This standard is issued under the fixed designation D 2256; 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 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 Method D 885, and Specification D 578.

NOTE 2—For directions covering the determination of breaking force of yarn by the skein method refer to Test Method D 1578.

1.3 *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 Specifications for Tensile Testing Machines for Textiles[2]
D 123 Terminology Relating to Textiles[2]
D 578 Specification for Glass Fiber Yarns[2]
D 885 Test Methods for Tire Cords, Tire Cord Fabrics, and Industrial Filament Yarns Made from Manufactured Organic-Base Fibers[2]
D 1578 Test Method for Breaking Strength of Yarn in Skein Form[2]
D 1776 Practice for Conditioning and Testing Textiles[2]
D 2258 Practice for Sampling Yarn for Testing[2]
D 2904 Practice for Interlaboratory Testing of a Textile Test Method that Produces Normally Distributed Data[2]
D 2906 Practice for Statements on Precision and Bias for Textiles[2]
D 3822 Test Method for Tensile Properties of Single Textile Fibers[3]
D 4848 Terminology of Force, Deformation and Related Properties of Textiles[3]
D 4849 Terminology Relating to Yarns and Fibers[3]
E 178 Practice for Dealing with Outlying Observations[4]

3. Terminology

3.1 *Definitions:*

3.1.1 Refer to Terminology D 4848 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 D 123 and Terminology D 4849 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.

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[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 Test Methods, General.

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[2] *Annual Book of ASTM Standards*, Vol 07.01.

[3] *Annual Book of ASTM Standards*, Vol 07.02.

[4] *Annual Book of ASTM Standards*, Vol 14.02.

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.

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 D 2256 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 aramid 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.[5] Consistent results are also obtained between different manufacturers of CRL tension testing machines when they are operated at the same time-to-break. The

[5] 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.

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 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 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 D 76, 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 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.

NOTE 4—Test machines capable of both tension and compression are acceptable for use with Test Method D 2256 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 D 76.

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 Methods D 885 (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 D 2258. 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 D 2258. 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 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 length per minute, that is, 300 ± 10 mm/min (12 ± 0.5 in./min) for 250-mm (10-in.) gage lengths on CRT and CRE tension testing machines.

9.3 *Gage 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 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 5 ± 0.1 cN/tex (0.5 gf/tex) 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/ $\sqrt{T}$) or 43 ± 4 tpcm/ $\sqrt{D}$ (110 ± 10 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 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 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 D 1776 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 D 1776 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, which is 21± 1°C (70 ± 2°F) and 65 ± 2 % relative humidity.

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.

11.3 *Condition 3, Wet Specimens Immersed on Tension Testing Machine*—Mount the dry specimen in the tension testing machine in the normal setup. Bring the water-bath tank in position to immerse the entire specimen (see 9.3.1). Soak the specimen in the water as described in 11.2.1 (Note 11).

NOTE 11—To minimize testing time, specimens may be wet-out in a separate container, then transferred immediately upon removal from the water bath to the tension testing machine equipped with a water-bath tank.

11.4 *Condition 4, Oven-Dried Specimens*—Oven-dry the specimens as directed in the oven-dried breaking force (strength) procedure in Methods D 885. Remove a specimen from the container and immediately mount the oven-dried specimen in the tension testing machine in the normal setup. Testing must begin within 20 ± 2 s after removal of the specimen from the container or discard the specimen and take a new one.

11.5 *Condition 5, at High Temperatures*—Position the oven in the tension testing machine to expose the entire specimen. Preheat the oven until equilibrium is reached at the specified temperature. Mount the specimen in the tension testing machine in the normal setup. Set the oven for the specified time at the specified temperature as determined by an applicable order or contract. The specimens are exposed for the specified time and tested while at the specified temperature (see 9.3.1).

11.6 *Condition 6, at Low Temperatures*—Position the cold chamber in the tension testing machine to expose the entire specimen. Mount the specimen in the tension testing machine in the normal setup. Set the cold chamber for the specified time at the specified temperature as determined by an applicable order contract. The specimens are exposed for the specified time and tested while at the specified temperature (see 9.3.1).

12. Measurement of Tensile Properties

12.1 Start the tension testing machine and the area integrator, if used, and continue running the test to rupture. Stop the machine and reset to the initial gage position. Record the test results to three significant figures.

12.2 If a specimen slips in the jaws, breaks at the edge of or in the jaws, or if for any reason attributed to faulty 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.

12.2.1 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 yarn. In the absence of other criteria for rejecting a so-called jaw break, any break occurring within 3 mm (⅛ in.) of the jaws which results in a value below 20 % of the average of the breaking force of all the other breaks shall be discarded. No other break shall be discarded unless the test is known to be faulty. 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.

12.2.2 If a yarn manifests any slippage in the jaws or if more than 24 % 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 yarn may be coated under the jaw face area, or (*3*) the surface of the jaw face may be modified. If any of these modifications are used, state the method of modification in the report.

12.3 For instructions regarding the preparation of specimens made from glass fiber to minimize damage in the jaws, see Specification D 578.

12.4 Measure the elongation of the yarn to three significant figures at any stated force by means of a suitable recording device at the same time as the breaking force is determined unless otherwise agreed upon, as provided for in an applicable material specification.

CALCULATIONS

13. Breaking Force

13.1 Record the breaking force of individual specimens; that is, the maximum force to cause a specimen to rupture as read directly from the tension testing machine expressed in Newtons (pounds force) N (lbf).

14. Breaking Tenacity

14.1 Calculate the breaking tenacity of individual specimens using Eq 1, as follows:

$$B = F/T \tag{1}$$

where:

B = breaking tenacity, cN (gf, lbf) per tex or cN (gf, lbf) per denier,
F = breaking force, CN (gf, lbf), and
T = linear density, tex (denier).

15. Elongation

15.1 Calculate the elongation of individual specimens from *XY*-type recorders using Eq 2, as follows:

$$\epsilon_p = (E \times R \times 100)/(C \times L_g) \tag{2}$$

where:

ϵ_p = elongation percent,
E = distance along the zero force axis from the point corresponding to the point where the force-elongation curve passes the pre-tension force to a point of corresponding force, mm (in.),
R = testing speed rate, mm/min (in./min),
C = recording chart speed, mm/min (in./min), and
L_g = nominal gage length, mm (in.)

16. Initial Modulus

16.1 Locate the maximum slope and draw a line tangent to the force-elongation curve between the tangent point for this tangent line and the proportional elastic limit and through the zero force axis. Measure the force and the corresponding elongation with respect to the force axis. Calculate initial modulus using Eq 3. (See Appendix X1 and Fig. X1.1 and Fig. X1.2.)

$$J_o = (F \times 100)/(\epsilon_p \times T) \tag{3}$$

where:

J_o = initial modulus, cN/tex (gf/den),
F = determined force on the drawn tangent line, cN (gf, lbf),
ϵ_p = corresponding elongation with respect to the drawn tangent line and determined force, %, and
T = linear density, tex (denier).

17. Chord Modulus

17.1 Determine the force for a specified elongation, such as 10 %, and label that point on the force-elongation curve as P_2. Likewise, label a second point, P_1 at a specified elongation, such as 0 % elongation. Draw a straight line (secant) through Points P_1 and P_2 intersecting the zero force axis. Other elongation values may be used, for example, when provided for in an applicable material specification. Calculate chord modulus using Eq 4. (See Appendix X2 and Fig. X2.1.)

$$J_{ch} = (F \times 100)/(\epsilon_p \times T) \tag{4}$$

where:

J_{ch} = chord modulus between specified elongations, cN/tex (gf/den, lbf/den),
F = determined force on the constructed line, cN (gf, lbf),
ϵ_p = corresponding elongation with respect to the constructed line and determined force, %, and
T = linear density, tex (denier).

18. Breaking Toughness

18.1 When using the force-elongation curves, draw a line from the point of maximum force of each specimen perpendicular to the elongation axis. Measure the area bounded by the curve, the perpendicular and the elongation axis by means of an integrator or a planimeter, or cut out the area of the chart under the force-elongation curve, weigh it, and calculate the area under the curve using the weight of the unit area.

18.2 When determining the breaking toughness of yarns that exhibit take-up of slack caused by crimp or design, the area under the force-elongation 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 observed for the breaking toughness.

18.3 Calculate the breaking toughness for each specimen when using *XY*-type recorders using Eq 5, or when using automatic area measuring equipment using Eq 6, as follows:

$$T_u = (A_c \times S \times R)/(W_c \times C \times T \times L) \tag{5}$$

$$T_u = (V \times S \times R)/(I_c \times T \times L) \tag{6}$$

where:

T_u = breaking toughness, J/g (gf·cm/den cm, in. lbf/den cm),
A_c = area under the force-elongation curve, cm^2($in.^2$),
S = full-scale force range, cN (gf, lbf),
R = testing speed rate, cm/min (in./min),
W_c = recording chart width, cm (in.),
C = recording chart speed, cm/min (in./min),
T = linear density, tex or denier,
L = nominal gage length of specimen, cm (in.),
V = integrator reading, and
I_c = integrator constant, per minute, determined as directed by the manufacturer.

19. Average Values

19.1 Calculate the average values for breaking force, elongation, initial modulus, chord modulus, and breaking toughness of the observations for the individual specimens tested to three significant figures.

REPORT, PRECISION AND BIAS, AND INDEXING

20. Report

20.1 Report that the specimens were tested as directed in Test Method D 2256. Describe the material or product sampled and the method of sampling used.

20.2 Report all of the following applicable items:

20.2.1 Average breaking force in N, gf, or lbf.

20.2.2 Average breaking tenacity or tenacity at a specified elongation in cN/tex, cN/den, gf/tex, gf/den, or lbf/den.

20.2.3 Average elongation at specified force in percent.

20.2.4 Test option and condition used.

20.2.5 If requested, the average initial or chord modulus in cN/tex, gf/den, or lbf/den. For chord modulus, state that portion of the force-elongation curve used to determine the modulus, such as, 0 to 10 % elongation, reported as 10 % chord modulus. Other portions of the force-elongation curve can be reported as requested.

20.2.6 If requested, the average breaking toughness in joules/g (gf·cm/den cm, in. lbf/den cm).

20.2.7 If calculated, the standard deviation, coefficient of variation, or both, of any of the properties.

20.2.8 If requested, include a force-elongation curve as part of the report.

20.2.9 Number of specimens tested.

20.2.10 Make and model of tension testing machine.

20.2.11 Type of clamps used.

20.2.12 Type of padding used in jaws, modification of specimens gripped in the jaws, or modification of jaw faces, if used.

20.2.13 Full-scale force range used for testing.

21. Precision and Bias

21.1 *Interlaboratory Test Data*—An interlaboratory test was run in 1992 through 1994 in which randomly-drawn samples of four materials were tested in each of the number of laboratories as shown below. Two operators in respective laboratories each tested ten specimens of each material using 3 different criteria: (1) manual test machine with 10-in. gage and testing speed of 10 in./min, (2) manual test machine with 10-in. gage and break criterion of 20 ± 3 s, and (3) automatic test machine with a break criterion of 5 ± 1 s. Analysis of the data was conducted using Practices D 2904 and D 2906. The components of variance for breaking strength and elongation at break expressed as standard deviations were calculated to be the values listed in Table 1 for respective test criteria. The four classes of fibers, test criteria, and number of participating laboratories were:

TABLE 1 Components of Variance Expressed as Standard Deviations[A]

Single Material Comparison	Standard Deviation, Units of Measure				
Name of Property Name of Product Test Type	Grand Average	No. of Tests per Package	Single-Operator Component	Within Laboratory Component	Between Laboratory Component
Breaking Strength, lb[B]					
Nylon, 7.8 tex (70 denier)					
Manual, 10 ipm, 10 in. gage	0.52	10	0.040	0.013	0.031
Manual, 20 ± 3 s	0.55	10	0.364	0.006	0.054
Automatic, 5 ± 1 s	0.56	10	0.038	0.012	0.019
Polyester, 150/34					
Manual, 10 ipm, 10 in. gage	1.25	10	0.060	0.000	0.073
Manual, 20 ± 3 s	1.28	10	0.089	0.034	0.070
Automatic, 5 ± 1 s	1.26	10	0.041	0.000	0.049
Cotton, 32/1					
Manual, 10 ipm, 10 in. gage	0.57	10	0.060	0.000	0.068
Manual, 20 ± 3 s	0.56	10	0.065	0.000	0.066
Automatic, 5 ± 1 s	0.59	10	0.062	0.013	0.031
Glass, 66 tex (600 denier)					
Manual, 10 ipm, 10 in. gage	7.23	10	0.748	0.297	1.450
Manual, 20 ± 3 s	8.53	10	0.481	0.219	0.926
Automatic, 5 ± 1 s	8.02	10	0.650	0.000	0.631
Elongation at break, %					
Nylon, 7.8 tex (70 Denier)					
Manual, 10 ipm, 10 in. gage	55.70	10	5.187	0.677	10.928
Manual, 20 ± 3 s	55.30	10	3.210	1.333	12.966
Automatic, 5 ± 1 s	59.70	10	3.044	0.000	5.222
Polyester, 150/34					
Manual, 10 ipm, 10 in. gage	29.30	10	3.626	0.000	8.359
Manual, 20 ± 3 s	32.30	10	3.343	0.000	8.440
Automatic, 5 ± 1 s	33.20	10	2.162	0.000	4.615
Cotton, 32/1					
Manual, 10 ipm, 10 in. gage	6.31	10	0.551	0.203	1.068
Manual, 20 ± 3 s	6.16	10	0.515	0.063	1.209
Automatic, 5 ± 1 s	6.39	10	0.477	0.454	0.234
Glass, 66 tex (600 denier)					
Manual, 10 ipm, 10 in. gage	2.23	10	0.456	0.157	0.588
Manual, 20 ± 3 s	2.50	10	0.146	0.091	0.402
Automatic, 5 ± 1 s	2.37	10	0.196	0.000	0.202

[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.

[B] The tests were conducted in U.S. Customary units and are expressed in pounds. Multiply pounds by 454 for gram units and pounds by 444.8 for a N units.

Material	Test Criteria Number (Number of Participating Laboratories)
7.8 tex (70 denier) nylon	1 (4) 2 (5) 3 (6)
150/34 polyester	1 (5) 2 (5) 3 (6)
32/1 cotton	1 (5) 2 (5) 3 (6)
66 tex (600 denier) glass	1 (3) 2 (4) 3 (5)

21.2 *Summary*—In comparing two averages, the differences should not exceed the single-operator precision values shown in Table 2 and Table 3 for the respective number of tests and for materials having averages similar to those shown in Table 2 and Table 3 in 95 out of 100 cases when all the observations are taken by the same well-trained operator using the same piece of equipment and specimens drawn randomly from the sample of material. Larger differences likely are to occur under all other circumstances.

21.3 *Precision*—For the components of variance reported in Table 1, 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 Table 2 and Table 3, for breaking strength and elongation to break, respectively.

TABLE 2 Critical Differences, for Conditions as Noted[A]

Single Material Comparison, Units as Indicated				
Name of Property Name of Product Test Type	No. of Tests in Each Average	Single-Operator Precision	Within-Laboratory Precision	Between-Laboratory Precision
Breaking Strength, lb[B]				
Nylon, 7.8 tex (70 Denier)				
Manual, 10 ipm, 10 in. gage	1	0.11	0.12	0.14
	2	0.08	0.09	0.12
	5	0.05	0.06	0.10
	10	0.03	0.05	0.10
Manual, 20 ± 3 s	1	0.10	0.10	0.18
	2	0.07	0.07	0.17
	5	0.05	0.05	0.16
	10	0.03	0.04	0.16
Automatic, 5 ± 1 s	1	0.10	0.11	0.12
	2	0.07	0.08	0.10
	5	0.05	0.06	0.08
	10	0.03	0.05	0.07
Polyester, 150/34				
Manual, 10 ipm, 10 in. gage	1	0.16	0.16	0.26
	2	0.12	0.12	0.23
	5	0.07	0.07	0.22
	10	0.05	0.05	0.21
Manual, 20 ± 3 s	1	0.25	0.26	0.33
	2	0.17	0.20	0.28
	5	0.11	0.15	0.24
	10	0.08	0.12	0.23
Automatic, 5 ± 1 s	1	0.11	0.11	0.18
	2	0.08	0.08	0.16
	5	0.05	0.05	0.14
	10	0.04	0.04	0.14
Cotton, 32/1				
Manual, 10 ipm, 10 in. gage	1	0.17	0.17	0.25
	2	0.12	0.12	0.22
	5	0.07	0.07	0.20
	10	0.05	0.05	0.19
Manual, 20 ± 3 s	1	0.18	0.18	0.26
	2	0.13	0.13	0.22
	5	0.08	0.08	0.20
	10	0.06	0.06	0.19
Automatic, 5 ± 1 s	1	0.17	0.18	0.20
	2	0.12	0.13	0.15
	5	0.08	0.09	0.12
	10	0.05	0.07	0.11
Glass, 66 tex (600 denier)				
Manual, 10 ipm, 10 in. gage	1	2.07	2.23	4.59
	2	1.47	1.68	4.35
	5	0.95	1.24	4.20
	10	0.67	1.05	4.15
Manual, 20 ± 3 s	1	1.34	1.47	2.96
	2	0.95	1.13	2.80
	5	0.60	0.85	2.71
	10	0.42	0.74	2.67
Automatic, 5 ± 1 s	1	1.80	1.80	2.51
	2	1.30	1.27	2.16
	5	0.76	0.76	3.54
	10	0.57	0.57	1.84

[A] The critical differences were calculated using $t = 1.960$, which is based on infinite df.
[B] See Table 1, Note B.

TABLE 3 Critical Differences, for Conditions as Noted[A]

Name of Property Name of Product Test Type	No. of Tests in Each Average	Single-Operator Precision	Within-Laboratory Precision	Between-Laboratory Precision
Single Material Comparison, Units as Indicated				
Elongation at Break, %				
Nylon, 7.8 tex (70 Denier)				
Manual, 10 ipm. 10 in. gage	1	14.38	14.50	33.58
	2	10.17	10.34	32.00
	5	6.43	6.70	31.02
	10	4.55	4.92	30.68
Manual, 20 ± 3 s	1	8.90	9.63	37.20
	2	6.29	7.30	36.67
	5	3.98	5.43	36.34
	10	2.81	4.64	36.23
Automatic, 5 ± 1 s	1	8.44	8.44	16.75
	2	5.97	5.97	15.65
	5	3.77	3.77	14.96
	10	2.67	2.67	14.72
Polyester, 150/34				
Manual, 10 ipm, 10 in. gage	1	10.05	10.05	25.25
	2	7.10	7.10	24.23
	5	4.49	4.49	23.60
	10	3.18	3.18	23.38
Manual, 20 ± 3 s	1	9.26	9.26	25.16
	2	6.55	6.56	24.29
	5	4.14	4.14	23.75
	10	2.93	2.93	23.57
Automatic, 5 ± 1 s	1	5.99	5.99	14.12
	2	4.24	4.24	13.47
	5	2.68	2.68	13.07
	10	1.89	1.89	12.93
Cotton, 32/1				
Manual, 10 ipm, 10 in. gage	1	1.53	1.63	3.38
	2	1.08	1.22	3.20
	5	0.68	0.88	3.09
	10	0.48	0.74	3.05
Manual, 20 ± 3 s	1	1.43	1.44	3.65
	2	1.01	1.02	3.50
	5	0.68	0.88	3.09
	10	0.48	0.74	3.05
Automatic, 5 ± 1 s	1	1.32	1.82	1.94
	2	0.93	1.57	1.70
	5	0.59	1.39	1.53
	10	0.42	1.33	1.48
Glass, 66 tex (600 denier)				
Manual, 10 ipm, 10 in. gage	1	1.26	1.34	2.11
	2	0.89	0.99	1.90
	5	0.57	0.71	1.78
	10	0.40	0.59	1.73
Manual, 20 ± 3 s	1	0.40	0.48	1.21
	2	0.29	0.88	1.18
	5	0.18	0.31	1.16
	10	0.13	0.28	1.15
Automatic, 5 ± 1 s	1	0.54	0.54	0.78
	2	0.38	0.38	0.68
	5	0.27	0.27	0.62
	10	0.17	0.17	0.59

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

NOTE 12—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.

NOTE 13—Since the interlaboratory test for the 70 denier nylon and the 600 denier glass used only four and three laboratories, respectively for the manual test at a crosshead of 10 in./min, estimates should be used with special caution.

21.4 *Bias*—The values of the breaking strength and elongation at break only can be defined in terms of a specific test method. Within this limitation, the procedures in this test method for measuring these properties have no known bias.

21.4.1 Interlaboratory testing indicated a bias between laboratories for modulus values related to the common selection of the force-extension curve slope and differences between various software used to calculate the modulus values. Of those laboratories reporting values representing the three test criteria used in the interlaboratory test, the following range of values were observed:

Material	Initial Modulus, Range of Values, gf/tex
7.8 tex (70 denier) nylon	148–183
150/34 polyester	214–856

32/1 cotton	195–245
66 tex (600 denier) glass	1017–2299

21.4.1.1 Before a meaningful statement can be made about two specific laboratories performing modulus tests on yarns using this test method, 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 of the type being evaluated, so as to be as nearly homogeneous as possible, and then randomly assigned in equal numbers in each laboratory. See 5.1.1.

22. Keywords

22.1 breaking strength; elongation; yarns

ANNEX

(Mandatory Information)

A1. DIRECTION OF KNOTS

A1.1 *Descriptive Terms Specific to Fig. A1.1 and Fig. A1.2:*

A1.1.1 *overhand knot*—a simple single knot, tied in either direction.

A1.1.2 *bight*—a bend or loop; the middle portion as distinguished from the ends. In Fig. A1.1 and Fig. A1.2, the bight lies toward the bottom of the page.

A1.1.3 *type "O" knot*—one in which, when the bight is below, the bight crosses over the right-hand end, as shown in Fig. A1.1(b).

A1.1.4 *type "U" knot*—one in which, when the bight is below, the bight crosses under the right-hand end as shown in Fig. A1.2(b).

A1.2 *Choice of Knots:*

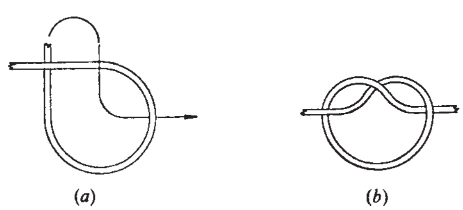

FIG. A1.1 Type "O" Knot

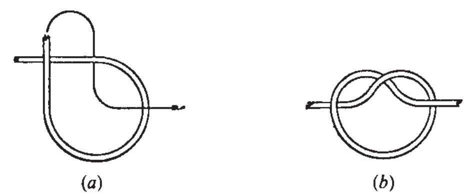

FIG. A1.2 Type "U" Knot

A1.2.1 Unless otherwise agreed, use the Type "O" knot for Z twist yarns and Type "U" for S twist yarns. In plied yarns, the last twist determines the type of knot to be used.

A1.3 *Tying Knots:*

A1.3.1 To tie the Type "O" knot, bend the right-hand end downward and bring it up behind the left-hand end, as shown in Fig. A1.1(a), then bring the right-hand end forward and pass it through the bight from front to back.

A1.3.2 To tie the Type "U" knot, bend the right-hand end downward and bring it up in front of the left-hand end, as shown in Fig. A1.2(a); then bring the right-hand end forward through the bight from behind.

APPENDIXES

(Nonmandatory Information)

X1. INITIAL MODULUS

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

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

X1.2 In the case of a yarn 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-force 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 force-elongation curve, is the tangent point.

X1.2.1 The initial modulus may be determined by dividing the force 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).

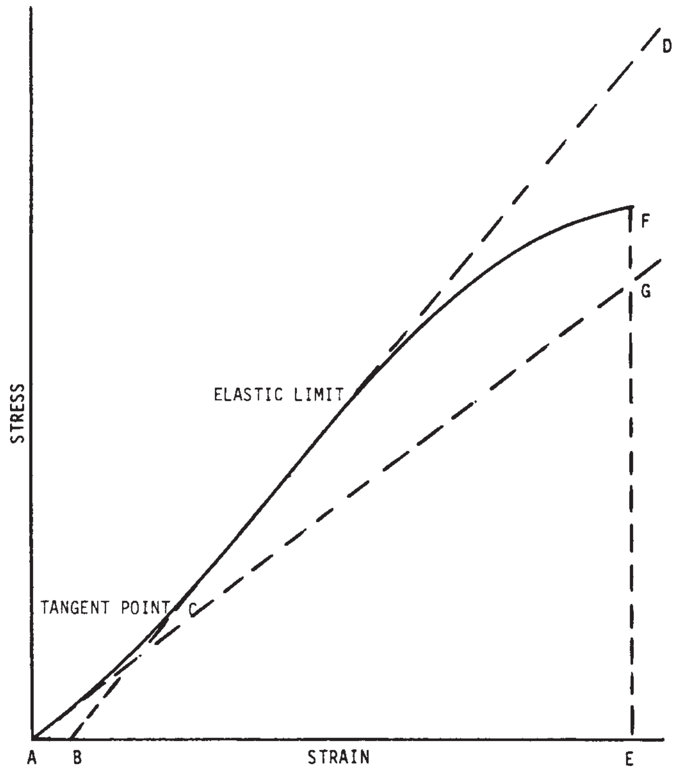

FIG. X1.1 Material with Hookean Region

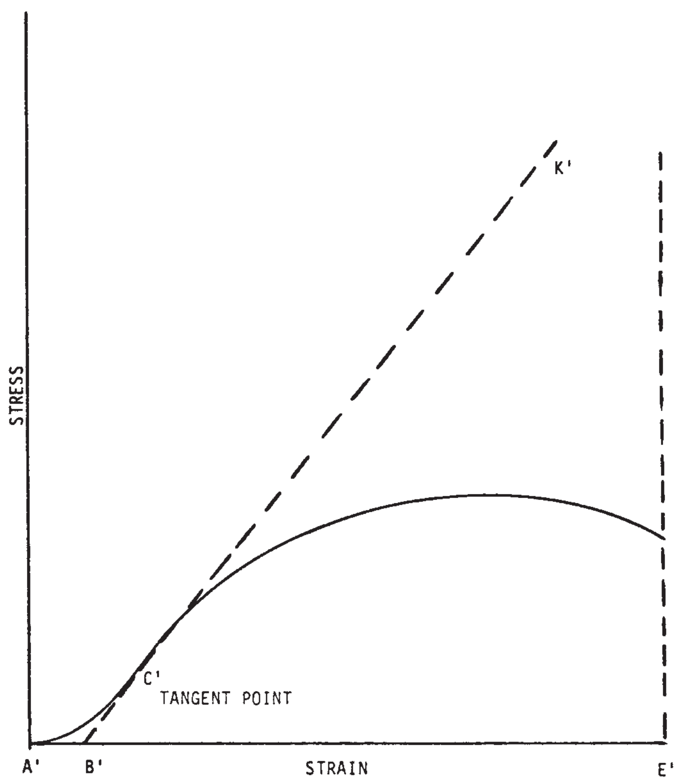

FIG. X1.2 Material with No Hookean Region

X2. CHORD MODULUS

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

X2.1.1 The chord modulus may be determined by dividing the force at any point along line A″M″ (or its extension) by the elongation 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 load axis at Point B″. This intersection is the zero elongation point from which elongation is measured. The chord modulus can be determined by dividing the force at any point along Line Q″R″ (or its extension) by the elongation at the same point (measured from Point B″, defined as zero strain).

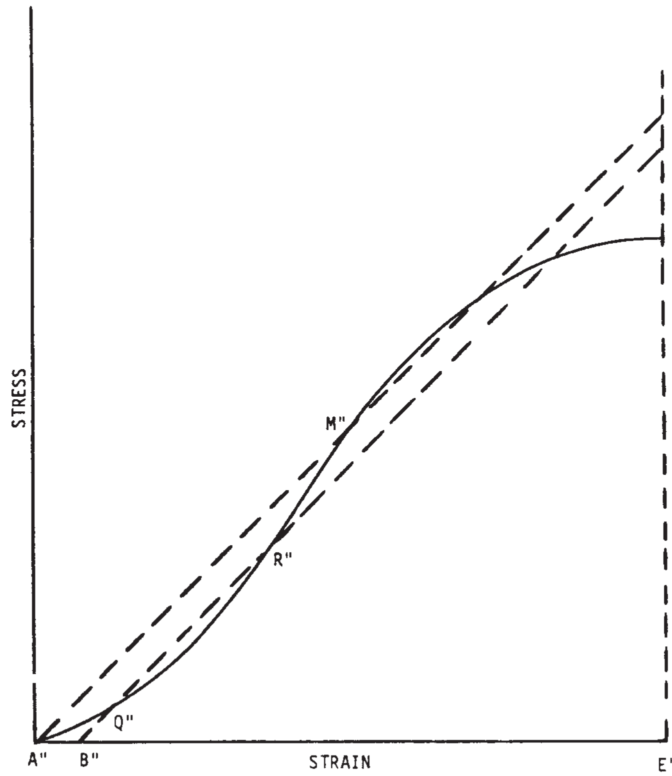

FIG. X2.1 Construction for Chord Modulus