Designation: D 885 – 04

Standard Test Methods for Tire Cords, Tire Cord Fabrics, and Industrial Filament Yarns Made from Manufactured Organic-Base Fibers[1]

This standard is issued under the fixed designation D 885; 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 These test methods cover the testing of industrial filament yarns made wholly of manufactured organic-base fibers, cords twisted from such yarns, fabrics woven from such cords, and products that are made specifically for use in the manufacture of pneumatic tires. They may be applied to similar yarns and cords used for reinforcing other rubber goods and for other industrial applications. The test methods apply to nylon, polyester, rayon, and aramid yarns and tire cords twisted from such yarns and to fabrics made from such cords. The yarn or cord may be wound on cones, tubes, bobbins, spools, or beams; may be woven into fabric; or may be in some other form. The methods include testing procedure only and include no specifications or tolerances.

1.2 No procedure is included for the determination of fatigue resistance of cord, but several commonly used procedures for the measurement of fatigue resistance of cords in rubber were published in the appendix of these test methods in the *1967 Annual Book of ASTM Standards*, Part 24, and in earlier issues of Test Methods D 885.

1.3 The sections on "Growth of Conditioned Yarns and Cords," "Properties of Yarns and Cords at Elevated Temperature," and "Properties of Wet Yarns and Cords" have been moved to Appendix X1-Appendix X3 as non-mandatory informational items because of their very limited use by the industry and because precision and bias statements are not included.

1.4 This standard includes the following sections:

1.5 These test methods show the values in both SI and inch-pound units. SI units is the technically correct name for the system of metric units known as the International System of Units. Inch-pound units is the technically correct name for the customary units used in the United States. The values stated in either acceptable metric units or other units shall be regarded separately as standard. The values expressed in each system

[1] These test methods are under the jurisdiction of ASTM Committee D13 on Textiles and are the direct responsibility of Subcommittee D13.19 on Tire Cord and Fabrics.

Current edition approved Oct. 1, 2004. Published October 2004. Originally approved in 1946. Last previous edition approved in 2002 as D 885 – 03.

may not be exact equivalents; therefore, each system must be used independently of each other, without combining values in any way.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

D 76 Specification for Tensile Testing Machines for Textiles
D 123 Terminology Relating to Textiles
D 276 Test Methods for Identification of Fibers in Textiles
D 1423 Test Method for Twist in Yarns by the Direct-Counting
D 1777 Test Method for Thickness of Textile Materials
D 1907 Test Method for Yarn Number by the Skein Method
D 1909 Table of Commercial Moisture Regains for Textile Fibers
D 2138 Test Methods for Rubber Property—Adhesion to Textile Cord
D 2256 Test Methods for Tensile Properties of Yarns by the Single-Strand Method
D 2257 Test Method for Extractable Matter in Textiles
D 2258 Practice for Sampling Yarn for Testing
D 2462 Test Method for Moisture in Wool by Distillation with Toluene
D 2494 Test Method for Commercial Mass of a Shipment of Yarn or Man-Made Staple Fiber or Tow
D 2654 Test Methods for Moisture in Textiles
D 2969 Test Method for Steel Tire Cords
D 2970 Test Methods for Tire Cords, Tire Cord Fabrics, and Industrial Yarns Made from Glass Filaments
D 3774 Test Method for Width of Textile Fabric
D 3775 Test Method for Fabric Count of Woven Fabric
D 3776 Test Method for Mass per Unit Area (Weight) of Fabric
D 4393 Test Method for Strap Peel Adhesion of Reinforcing Cords or Fabrics to Rubber Compounds
D 4776 Test Method for Adhesion of Tire Cords and Other Reinforcing Cords to Rubber Compounds by H-Test Procedure
D 4848 Terminology of Force, Deformation and Related Properties of Textiles
D 5591 Test Method for Thermal Shrinkage Force of Yarn and Cord Using The Testrite Thermal Shrinkage Force Tester
D 6477 Terminology Relating to Tie Cord, Bead Wire, Hose Reinforcing Wire, and Fabrics

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms relating to tire cord, bead wire, hose wire, and tire cord fabrics, refer to Terminology D 6477.

3.1.1.1 The following terms are relevant to this standard: cord, cord twist, dip, dip pickup, in a textile cord or fabric, industrial yarn, moisture equilibrium for testing, for industrial yarns and tire cords, pneumatic tire, single twist, standard atmosphere for testing textiles, tabby sample, tire, and tire cord fabric.

3.1.2 For definitions of terms related to force and deformation in textiles, refer to Terminology D 4848.

3.1.2.1 The following terms are relevant to this standard: breaking force, breaking strength, breaking tenacity. breaking toughness, chord modulus, in a stress-strain curve, elongation, force at specified elongation (FASE), initial modulus, tensile strength, and work-to-break.

3.1.3 For definitions of other terms related to textiles, refer to Terminology D 123.

3.1.3.1 The following terms are relevant to this standard: fabric and growth.

4. Summary of Test Methods, General

4.1 A summary of the directions prescribed for the determination of specific properties is stated in the appropriate sections of specific test methods.

5. Significance and Use, General

5.1 The procedures in these test methods should be used with caution for acceptance of commercial shipments owing to the absence of factual information on the between-laboratory precision of many of the test procedures included in these test methods. It is recommended that any program of acceptance testing be preceded by an interlaboratory check in the laboratory of the purchaser and the laboratory of the supplier on replicate specimens of the materials to be tested for each property (or properties) to be evaluated.

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, test samples should be used that are as homogeneous as possible, that are drawn from the material from which the disparate test results were obtained, and that are randomly assigned in equal numbers to each laboratory for testing. Other materials with established test values may be used for this purpose. The test results from the two laboratories should be compared using a statistical test for unpaired data, at 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 must be adjusted in consideration of the known bias.

5.2 The significance and use of particular properties are discussed in the appropriate sections of specific test methods.

6. Sampling

6.1 *Yarn*:

6.1.1 *Packages*—For acceptance testing, sample each lot as directed in Practice D 2258. Place each laboratory sampling unit in a moisture-proof polyethylene bag or other moisture-proof container to protect the samples from atmospheric

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

changes until ready to condition the samples in the atmosphere for testing industrial yarns and tire cords. Take the number of specimens for testing specified for the specific property measurement to be made.

6.1.2 *Beams*—For acceptance testing, sample by winding yarns on a tube or spool by means of a winder using a tension of 5 ± 1 mN/tex (0.05 ± 0.01 gf/den). Take the yarn from the outside beam layers unless there is a question or disagreement regarding the shipment; in this case, take the sample only after removing yarn from the beam to a radial depth of 6 mm (¼ in.) or more to minimize the effects of handling and atmospheric changes that may have occurred during shipment or storage. Place each laboratory sampling unit in a moisture-proof polyethylene bag or other moisture-proof container to protect the samples from atmospheric changes until ready to condition the samples in the atmosphere for testing industrial yarns and tire cords. Take the number of specimens for testing specified for the specific property measurement to be made.

6.2 *Cord*:

6.2.1 *Number of Samples and Specimens*—The size of an acceptance sampling lot of tire cord shall be not more than one truck or rail car load or as determined by agreement between the purchaser and the supplier. Take samples at random from each of a number of cones, tubes, bobbins, or spools within a lot to be as representative as possible within practical limitations. Make only one observation on an individual package for each physical property determination. Take the number of samples, therefore, that will be sufficient to cover the total number of specimens required for the determination of all physical properties of the tire cord. The recommended number of specimens is included in the appropriate sections of specific test methods covered in this standard. Where such is not specified, the number of specimens is as agreed upon between buyer and supplier.

6.2.2 *Preparation of Samples*—Remove and discard a minimum of 25 m (25 yd) from the outside of the package before taking the sample or any specimens. If specimens are not taken directly from the original package, preferably wind the sample on a tube or spool by means of a winder using a tension of 5 ± 1 mN/tex (0.05 ± 0.01 gf/den). If the sample is collected as a loosely wound package, or in the form of a skein, some shrinkage invariably will occur, in which case, report that the observed results were determined on a relaxed sample. Use care in handling the sample. Discard any sample subjected to any change of twist, kinking, or making any bend with a diameter less than 10 times the yarn/cord thickness (or diameter). Place the sample in a moisture-proof polyethylene bag or other moisture-proof container to protect it from atmospheric changes until ready to condition the sample in the test atmosphere for industrial yarns and tire cords.

6.3 *Tire Cord Fabric*:

6.3.1 *Number of Samples and Specimens*—The sizes of an acceptance sampling lot of tire cord fabric shall be one loom creel of cord. Take a sample from at least one roll of fabric per lot. From each roll of tire cord fabric, take the number of specimens as specified in the test method for each property to be measured.

6.3.2 *Size of Sample*—Take a sample equal to the length of cord between the regular tabby woven at the end of the roll and a special tabby woven a short distance from the end when the roll of fabric is manufactured. For rolls that do not have a special woven tabby, improvise a tabby by the use of gummed tape or strips of cemented fabric applied across a section of the cord fabric to give a tabby sample length at least 0.5-m (18-in.) long and at least one tenth of the roll width wide.

6.3.3 *Preparation of Samples*—Cut the warp cords of the fabric along the center line of the special tabby for a distance equal to the width of the sample. If this distance is less than the full width of the fabric, cut the filling yarns of the sample and of the special and regular tabbies in the direction parallel with the warp cords. The resulting section of cord fabric is the tabby sample. Attach the tabby sample to a piece of cardboard or fiberboard, the length of which shall be equal to at least the length of the cord warp between tabbies. Fold the tabby portions of the sample over each end of the board, and secure the sample to the board with pressure-sensitive tape or staples. Use care to avoid contact of tape or staples with the area to be tested. Handle the sample carefully, and hold it under sufficient tension in the warp direction to prevent the cords from kinking. Discard any specimen subjected to change of twist, kinking, or making any bend with a diameter less than 10 times the yarn/cord thickness (or diameter). The board with the sample may be folded lengthwise and parallel with the warp for convenience. Place the board with the fabric sample in a polyethylene bag, or wrap it with several layers of polyethylene film, to protect the sample from changes in atmospheric moisture content until ready to condition the sample in the atmosphere for testing industrial yarns and tire cords. Use care during subsequent handling of the sample to prevent any change in the cord twist and to avoid kinking the cords.

6.4 *Cord from Cured Tires*:

6.4.1 *Number of Samples and Specimens*—For each test, test ten cords from each location or ply of each tire.

6.4.2 *Preparation of Samples*—Obtain a tire section comprising approximately one sixth of the whole tire. Smaller sections may be used, particularly for carcass cord samples of radial tires. If it is suspected that cords may be damaged in pulling them from the tire, immerse the section in a solvent[3] for 1 to 3 days to swell and soften the rubber. For convenience, turn the section inside out, if possible; clamp one of the beads in a vise. Mark a line along the inside of the section approximating the cord path of the first ply. Make a shallow cut down to the first ply along this line. Make an incision adjoining and perpendicular to this first cut at sufficient depth to sever several first-ply cords. Carefully cut and pull these cords from the tire from bead to bead following the cord path. Discard these initial cords. After initial cords are removed, remove bands of cords for testing by cutting near the bead through Ply 1 cords adjacent to the trough formed in initial cord removal. Carefully pull several cord bands approximately 2 cm (¾ in.) in width from the tire. Identify bands, fully including tire number and ply number. Remove the remainder of Ply 1 to

[3] Heptane, 1,1,1-trichloroethane, and a mixture of 50/50 Freon 113 and Stoddard Solvent have been used for this purpose.

uncover Ply 2. Proceed with Ply 2 or additional plies as directed for Ply 1. If the cords to be removed are from a tire having only one ply of reinforcement in the area to be sampled, for example, carcass ply of many radial tires reinforced with glass, aramid, or steel, it is preferable to remove cords for testing one at a time from the tire section itself. It is preferred that cord be removed in such a manner that it is not subjected to narrow-radius bending, such as a 3.14 rad (180°) bend back upon itself. This is accomplished by first removing and discarding a band of cords in the ply being sampled, then pulling the exposed cord at the edge of the ply (still in the tire section) by applying tension to this single cord as much within the plane of the ply as possible and in such a direction that the cord is subject to a bend of less than 1.05 rad (60°) at the tear point from its adjacent cord. The same principles just described also apply to areas of the tire (such as the tread) composed of multiple plies of high modulus cords.

6.4.3 *Preparation of Specimens for Testing from a Ply Band*—Make a cut approximately 20 mm (¾ in.) long between each cord at one end of the ply band. Strip every other cord from the band to a length sufficient for testing; leave a small unstripped cord portion attached to the band to facilitate handling. Cut individual ends from the band for testing.

6.4.3.1 Large variations in properties can occur within the same cord depending on its location within the tire. Select the location in the tire to be sampled and take a length of cord from this location for subsequent testing. Use a testing length appropriate for the length of the specimen to obtain data that reflect the relationship between the cord properties and the location in the tire.

7. Conditioning

7.1 Bring all specimens of yarn, cord, and fabric to moisture equilibrium for testing in the atmosphere for testing industrial yarns. Approach moisture equilibrium of rayon samples from the dry side, but not from a moisture-free condition.

7.1.1 The moisture equilibrium of conditioned aramid yarns and tire cords made from such yarns can be affected by heat and humidity conditions to which the samples have been previously exposed.

8. Identification of Fibers

8.1 Identify the common types of manufactured organic-base fibers as directed in Test Methods D 276.

9. Commercial Mass

9.1 *Yarn*—Determine the commercial mass of a yarn shipment as directed in Option II of Test Method D 2494. Take samples of yarn from the outside of beams unless there is a question or disagreement regarding a shipment; in this case, take a sample of yarn only after yarn has been removed from a beam to a radial depth of 6 mm (¼ in.) or more. Take a sample 15 to 20-m (15 to 20-yd) long, which is composed of all ends of yarn on the beam, and cut this sample crosswise to obtain two specimens of approximately equal mass. Place the specimens in moisture-proof polyethylene bags or other moisture-proof containers until ready to begin the analysis.

9.2 *Cord and Tire Cord Fabric*—Determine the commercial mass of tire cord and tire cord fabric as agreed upon between the purchaser and the supplier.

10. Moisture Regain, Actual

10.1 *Scope*—This test is used to determine the amount of moisture in yarn or cord at moisture equilibrium at the time of testing for moisture dependent properties, such as tenacity and elongation.

10.2 *Summary of Test Method*—Specimens of yarn or cord, which are taken at the tensile testing machine at the time that tensile tests are being made, are weighed and dried in an oven until they reach a constant mass. The observed moisture loss is calculated and reported as percent regain.

10.3 *Significance and Use*—This test method is used not only to determine moisture regain of the original sample but is also used to develop data, which may be used to correct observed tensile properties of rayon yarns and cords to a standard regain basis. Because the moisture regain levels of different specimens vary even after conditioning in a test atmosphere and because tensile properties are affected by moisture regain, it is advisable to correct observed tensile values when there is substantial variation from a standard moisture regain level. Directions for making such corrections are included in Section 11 for Linear Density, Section 17 for Breaking Strength, and Section 20 for Elongation. It is assumed that no significant amount of nonaqueous volatile matter is present and that all loss in mass is moisture. If such materials are present, apply a suitable correction, or determine the true amount of moisture by the toluene distillation method as directed in Procedure 3 of Test Method D 2462.

10.4 *Apparatus*:

10.4.1 *Oven*—An oven with circulating air maintained at a temperature of 105 ± 3°C (221 ± 6°F) and with fresh air replacement rate of 20 to 50 times the oven-volume per hour, the fresh air being taken from the standard atmosphere of 24 ± 1°C (75 ± 2°F) and 55 ± 2 % RH. The air shall pass freely through and around the specimens. The specimens must not be subjected to direct radiation from the heating unit. The oven has to be large enough to handle the required number of spools or racks and has to be equipped with suitable removable creels for placing the spools or reels in the oven or with supports for the special mounting racks for the same purpose, or both. The oven may be combined with a balance, in which case the design must prevent disturbance of the balance due to circulating air during the weighing operation.

10.5 *Preparation of Specimen*—Take a single specimen of yarn or cord weighing at least 10 g from the original sample at the testing machine at the time that tensile properties are being determined (see Note 1). Place this specimen in a covered weighing bottle. Do not touch the specimen with the bare hands.

NOTE 1—The determination of moisture regain can be combined with the determination of linear density (Section 11) if the specimen is long enough to meet the length and mass tolerances and if the skein is exposed to the same atmosphere as the sample to be used for determination of tensile properties.

10.6 *Procedure*—Weigh the specimen to 0.01 g and dry it in the ventilated oven at a temperature of 105 ± 3°C (221 ± 6°F).

Dry the specimen to constant mass, that is, until it loses no more than 0.1 % of its mass at 15-min intervals if weighed in the oven or at 30-min intervals if weighed outside the oven. For specimens that are weighed outside the oven, use a weighing bottle with tight-fitting cover, and cool the specimen and container to room temperature in a desiccator before weighing.

10.7 *Calculation*:

10.7.1 Calculate the moisture regain of the specimen using Eq 1:

$$MR = [(W - D)/D] \times 100 \quad (1)$$

where:

MR = moisture regain, %,
W = original mass of specimen, g, and
D = oven-dried mass of specimen, g.

10.7.2 Calculate the average for the sample and use this value for determining the amount of adjustment to make in Sections 17 and 20 to the observed breaking force and elongation of yarn or cord.

10.8 *Report*:

10.8.1 State that the specimens were tested as described in Section 10 of Test Methods D 885. Describe the material or product sampled and the method of sampling used.

10.8.2 Report the average moisture regain for each sample.

10.9 *Precision and Bias*:

10.9.1 *Precision*—See Test Methods D 2654, Procedure 1.

10.9.2 *Bias*—See 39.3.

11. Linear Density

11.1 *Scope*—This test method is used to determine the linear density of yarn or cord for use in the calculation of tensile properties, such as modulus and tenacity.

11.2 *Number of Specimens*—Test five specimens of yarn or cord. This number is based on the assumption that the applicable coefficient of variation is 1.0 % and the allowable variation is 0.9 % of average with a probability level of 95 %.

11.3 *Procedure for Yarn*—Determine the linear density of yarn as directed in Option 1 of Test Method D 1907, except condition the yarn as specified in Section 7. Use Option 3 for rayon. If oven-dried and finish-free linear density is needed, use Option 5 or Option 6 with an allowance for moisture regain.

11.4 *Procedure for Cord*—Determine the linear density of cord on packages or removed from a tabby sample of fabric by the procedures prescribed as follows for either conditioned cords or oven-dried cords (see 11.4.2).

11.4.1 *Preparation of Specimens*—Take specimens having a minimum length of 10 m (10 yd) from samples of cord on cones, tubes, bobbins, or spools. For tabby samples of fabric, use a sufficient number of ends to give a minimum length of 10 m (10 yd) of cord for each specimen. Measure the length of the specimen to within 0.1 % while under a tension corresponding with 5 ± 1 mN/tex (0.05 ± 0.01 gf/den) (see Note 2). Weigh the conditioned specimen to the nearest 1 mg. If a balance of the required sensitivity (1 mg) for weighing the 10 m (10 yd) specimen is not available, take a longer specimen or multiple ends.

NOTE 2—When arbitration is not involved, an approximation of the specified tension may be obtained by applying one of the forces listed as follows for the specified groups of yarn and cord sizes:

Linear Density of Specimen	Amount of Force N	gf
Below 400 tex (3600 denier)	1	100
400 to 600 tex (3600 to 5400 denier)	2	200
600 to 800 tex (5400 to 7200 denier)	3	300
Above 800 tex (7200 denier)	4	400

11.4.2 *Procedure for Oven-Dried Specimens*—Using an oven with circulating air maintained at a temperature of 105 ± 3°C (221 ± 6°F) (see Section 10.4), dry the specimen to constant mass; that is, until it loses no more than 0.1 % of its mass at 15-min intervals if weighed to the nearest 1 mg in the oven or at 30-min intervals if weighed outside the oven. For specimens that are weighed outside the oven, use a weighing bottle with a tight-fitting cover and cool the specimen and container to room temperature in a desiccator before weighing. Weigh the specimen of the oven-dried cord to the nearest 1 mg.

11.4.3 *Calculation*—Calculate the linear density of each specimen in tex (denier) units using Eq 2, Eq 3, Eq 4, or Eq 5:

$$LD_{tc} = (1000 \times M_o \times K)/L_o \quad (2)$$

$$LD_{dc} = (9000 \times M_o \times K)/L_o \quad (3)$$

$$LD_{ta} = (1000 \times M_c)/L_o \quad (4)$$

$$LD_{da} = (9000 \times M_c)/L_o \quad (5)$$

where:

LD_{tc} = linear density at commercial moisture regain, tex,
LD_{dc} = linear density at commercial moisture regain, denier,
LD_{ta} = linear density at actual moisture regain, tex,
LD_{da} = linear density at actual moisture regain, denier,
M_o = mass of oven-dried specimen, g,
M_c = mass of conditioned specimen, g,
L_o = length of specimen, m (yd ÷ 1.09 or yd × 0.918), and
K = factor for commercial moisture regain.

11.4.3.1 Determine the factor K using Eq 6:

$$K = (100 + CMR)/100 \quad (6)$$

where:

CMR = commercial moisture regain, %.

For the commercial moisture regain, see Table 1. See also Table D 1909.

Example for rayon:

$$K = (100 + 11)/100 = 1.11 \quad (7)$$

TABLE 1 Commercial Moisture Regains of Manufactured Fibers Used in Tire Cords[A]

	%
Rayon	11.0
Nylon	4.5
Polyester	0.4
Aramid	
high modulus yarns	3.5
standard yarns	7.0

[A]Commercial moisture regain of fibers not listed in this table shall be as agreed upon between the purchaser and the supplier or as in Table D 1909. Values in Table 1 are consistent with those in Table D 1909.

11.4.3.2 For dipped cord, correct the observed linear density for dip solids pickup using Eq 8, Eq 9, or Eq 10. The oven-dried linear density should be corrected for dip solids pickup, not the conditioned linear density. For fibers with low percentage moisture regain, Eq 9 can be used with no correction for moisture regain.

$$LD_{dp} = [100/(100 + DPU)) + (MR_{dc}/100)] \times [100/(100 + MR_{dc})] \times LD_{dc} \quad (8)$$

$$LD_{dp} = [(LD_{dc} \times 100)/(100 + DPU)] \quad (9)$$

$$LD_{dpmr} = [(100 + MR_{gc})/100] \times [100/(100 + MR_{dc})] \times [(100 \times LD_{dc})/(DPU/(100 + DPU)] \quad (10)$$

where:

LD_{dp} = linear density corrected for dip pickup, tex (denier),
LD_{dpmr} = linear density corrected for dip pickup and moisture regain, tex (denier),
LD_{dc} = observed linear density of dipped cord, tex (denier),
DPU = percentage dip pickup, % (see Section 35),
MR_{gc} = percentage commercial moisture regain of greige cord, %, and
MR_{dc} = percentage moisture regain of dipped cord, %.

11.4.4 *Report*:

11.4.4.1 State that the specimens were tested as directed in Section 11 of Test Methods D 885. Describe the material or product sampled and the method of sampling used.

11.4.4.2 Report the option or procedure used, the number of specimens tested, and the average linear density.

11.4.4.3 Report the basis on which linear density is being reported (for greige, dipped, and so forth.).

11.4.5 *Precision and Bias*:

11.4.5.1 *Precision*—See Section 39.

11.4.5.2 *Bias*—See 39.3.

TENSILE PROPERTIES OF YARNS AND CORDS

12. Scope

12.1 These test methods are used to determine the tensile properties of yarns or cords.

13. Summary of Test Method

13.1 A conditioned or oven-dried specimen of yarn or cord is clamped in a tensile testing machine and then stretched or loaded until broken. Breaking force, elongation, and force at specified elongation (FASE) are determined directly. Modulus and work-to-break are calculated from the force-elongation curve. The output of a constant-rate-of-extension (CRE) tensile testing machine can be connected with electronic recording and computing equipment, which may be programmed to calculate and print the test results of tensile properties of interest.

14. Significance and Use, Tensile Properties

14.1 The levels of tensile properties obtained when testing industrial yarns and tire cords are dependent to a certain extent on the age and history of the specimen and on the specific conditions used during the test. Among these conditions are rate of stretching, type of clamps, gage length of specimen, temperature and humidity of the atmosphere, rate of airflow across the specimen, and temperature and moisture content of the specimen. The relative importance of these factors varies with each type of fiber. Testing conditions accordingly are specified precisely to obtain reproducible test results on a specific sample.

14.2 Because the force-bearing ability of a reinforced rubber product is related to the strength of the yarn or cord used as a reinforcing material, *breaking strength* is used in engineering calculations when designing various types of textile reinforced rubber products. When needed to compare intrinsic strength characteristics of yarns or cords of different sizes or different types of fiber, *breaking tenacity* is very useful because, for a given type of fiber, breaking force is approximately proportional to linear density.

14.3 *Elongation* of yarn or cord is taken into consideration in the design and engineering of reinforced rubber products because of its effect on uniformity of the finished product and its dimensional stability during service.

14.4 The *FASE* is used to monitor changes in characteristics of the textile material during the various stages involved in the processing and incorporation of yarn or cord into a rubber product.

14.5 *Modulus* is a measure of the resistance of yarn or cord to extension as a force is applied. It is useful for estimating the response of a textile reinforced structure to the application of varying forces and rates of stretching. Although modulus may be determined at any specified force, initial modulus is the value most commonly used.

14.6 *Work-to-break* is dependent on the relationship of force to elongation. It is a measure of the ability of a textile structure to absorb mechanical energy. *Breaking toughness* is work-to-break per unit mass.

14.7 It should be emphasized that, although the preceding parameters are related to the performance of a textile-reinforced product, the actual configuration of the product is significant. Shape, size, and internal construction also can have appreciable effect on product performance. It is not possible, therefore, to evaluate the performance of a textile reinforced product in terms of the reinforcing material alone.

15. Apparatus

15.1 *Tensile Testing Machine*—A single-strand tensile testing machine of one of the following types:

Type	Principle of Operation
CRE	constant-rate-of-specimen extension
CRL	constant-rate-of-loading (inclined plane type)
CRT	constant-rate-of-transverse (pendulum type)

The specifications and methods of calibration and verification of these machines shall conform to Specification D 76. The testing machine shall be equipped with an autographic recorder (rectilinear coordinates preferred) and clamps of the cam or pneumatic type having fixed snubbing surfaces, that are integral with one of the clamping surfaces. The snubbing surfaces may be circular with a diameter of not less than 12.5 mm (½ in.) or semi-involute. It is also permissible to use tensile testing machines that have a means for calculating and displaying the required results without the use of an autographic recorder. CRE-type tensile testing machines are the preferred type of test equipment to be used. Correlation of results from CRL- and CRT-type tensile testing machines with results from CRE-type tensile testing machines is poor, and a bias determination must be made. For tensile testing of aramid fibers, the CRL- and CRT-types of tensile testing machines are considered to be not suitable and are not recommended.

15.1.1 *CRE-Type Tensile Testing Machines*—For all fiber types, except aramid fibers, use a crosshead travel rate in mm/min (in./min) of 120 % (100 % alternate) of the nominal gage length in millimetres (inches) of the specimen. For aramid fibers use a crosshead travel rate in mm/min (in./min) of 50 % of the nominal gage length in millimetres (inches) of the specimen.

15.1.2 *CRL-Type Tensile Testing Machines*—Use the following rates of loading:

For rayon	25 ± 3 (mN/tex)/s (18 ± 2 (gf/den)/min)
For nylon and polyester	50 ± 7 (mN/tex)/s (35 ± 5 (gf/den)/min)

15.1.3 *CRT-Type Tensile Testing Machines*—For all fiber types, except aramids, use a rate of traverse in mm/min (in./min) of 120 % (100 % alternate) of the nominal gage length in millimetres (inches) of the specimen.

16. Breaking Strength (Force) of Conditioned Yarns and Cords

16.1 *Scope*—This test method is used to determine the breaking strength (force) of yarns and cords after conditioning in the atmosphere for testing industrial yarns and tire cords.

16.2 *Number of Specimens*—Test ten specimens. This number is based on the data for cords in Table 2, which shows precision to be expected at the probability level of 95 % based on ten breaks from a single test spool of cord of each polymer type on various cords.

16.3 *Procedure*—Select a loading cell and the settings of the tensile tester such that the estimated breaking force of the specimen will fall in the range from 10 to 90 % of the full-scale force effective at the time of the specimen break. This selection of the full scale force may be done manually by the operator before the start of the test or by electronic means or computer control during the test by automatically adjusting the amplification of the loading cell amplifier. Adjust the distance between the clamps on the testing machine so that the nominal gage length of the specimen, measured from nip to nip of the jaws of the clamps, is 250 ± 1 mm (10 ± 0.05 in.) (alternate 500 ± 2 mm (20 ± 0.10 in.)). Make all tests on the conditioned yarns and cords in the atmosphere for testing industrial yarns and tire cords (Note 3, Note 4, and Note 5 provide useful information in obtaining more consistent results in tensile testing). Remove the specimen from the sample and handle it to prevent any change in twist prior to closing the jaws of the clamps on the specimen. For essentially zero twist yarns, refer to Note 5. Do not touch that portion of the specimen that will be between the clamps with bare hands. Depending on the equipment being used and the availability of on-line computer control and data processing, either can be used:

pretension-start procedure (see 16.3.1) or
slack start procedure (see 16.3.2).

16.3.1 *Pretension-Start Procedure*—Use a tensioning device that applies a pretension corresponding to 20 ± 1 mN/tex (0.20 ± 0.01 gf/den) for aramid fibers; use 5 ± 1 mN/tex (0.05 ± 0.01 gf/den) for all other fibers (see Note 3 and Note 4). This device may be a weight, a spring, or an air-actuated mechanism. Thread one end of the specimen between the jaws of the clamp connected to the loading cell and close it. Place the other end through the jaw of the second clamp and fix a pretension weight to the unclamped end or pull the thread such that the specified pretension in the test specimen is applied. Close the second clamp and operate the testing machine at the rate specified in 15.1. When the specimen breaks (ruptures), read the breaking force (maximum force) in newtons (pounds-force) from the force-elongation (or force-extension) curve on the chart, from the dial, from the display, or by electronic means. Discard specimens that break in the jaws or within 10 mm (⅛ in.) of the nip of the jaws. If the clamps are of the air-actuated type, adjust the air pressure so that specimens will not slip in the jaws, but keep air pressure below the level that will cause specimens to break at the edge of the jaws.

NOTE 3—When arbitration of test data is involved, use care in the application of the pretension force that may be specified because the actual pretension in the specimen commonly is different from the amount applied externally because of losses due to friction in the clamp. Check the pretension before starting the testing machine. The actual pretension can be measured by strain gages. Other tension-measuring instruments with sufficient accuracy may be used, provided that the specimen is threaded through the instrument prior to being placed in the second clamp. This procedure is necessary because many instruments require appreciable displacement of the specimen.

NOTE 4—When arbitration is not involved, one of the following approximations of the specified pretension may be used. Either exert a force of 120 % of the nominal pretension to the unclamped end of the specimen prior to closing the second grip, or apply one of the forces listed as follows for the specified groups of yarn and cord sizes to secure the necessary pretension.

Linear Density of Specimen	Amount of Force	
	N	gf
Below 400 tex (3600 denier)	1	100
400 to 600 tex (3600 to 5400 denier)	2	200
600 to 800 tex (5400 to 7200 denier)	3	300
Above 800 tex (7200 denier)	4	400

When using a CRE-type tensile machine, a third technique is to close the upper clamp, then apply pretension by pulling on the specimen until the recorder pen moves approximately ½ chart division from the zero line on the chart when using a force scale that is the same as that used for determining the breaking force.

16.3.2 *Slack Start Procedure*—Thread one end of the specimen between the jaws of one of the clamps and close it. Place the other end of the specimen through the jaws of the second clamp and keep the specimen just slack (zero tension) and close the clamp, taking care that the thread is positioned in the centerline of the jaws of the clamp. Operate the testing machine at the rate as specified in 15.1 and stretch the specimen until it ruptures. When the specimen breaks, read the breaking force (maximum force) in newtons (pounds-force) from the force-elongation curve, from the dial, from the display, or by electronic means. Discard specimens that break in the jaws or within 10 mm (⅛ in.) of the nip of the jaws. If the clamps are of the air-actuated type, adjust the air pressure to prevent specimens slipping in the jaws, but keep the air pressure below the level that will cause specimens to break at the edge of the jaws. This slack start procedure has the effect

TABLE 2 Critical Differences, Expressed as Percent of Observed Average (Except as Noted)[A,B]

Property Measured	Number of Observations in Each Average	Critical Differences	
		Single-Operator Precision	Between-Laboratory Precision
Table 4a 840/2 Nylon Cord (12 × 12 twist): [C]			
Breaking strength, lbf	10	1.41	4.57
Elongation at break, %	10	4.50	13.60
Load at specified elongation (LASE) (reported at 14 % E), lbf	10	4.97	20.70
Modulus, gf/den	10	5.05	8.31
Work-to-break, in.·lbf/in.	10	6.69	10.41
Thickness of cords, mils	10	0.56[D]	1.46[D]
Twist, tpi: Cord	10	0.27[D]	0.43[D]
Singles	10	0.12[D]	0.25
Linear density, den:[C]			
From bobbin	5	1.07	4.49
From tabby	5	0.40	4.54
Table 4b 1000/3 Polyester Cord (10 × 10 twist):			
Breaking Strength, lbf	10	1.72	4.65
Elongation at break, %	10	2.66	9.95
Load at specified elongation (LASE) (reported at 10 % *E*), lbf	10	5.15	5.59
Modulus, gf/den	10	4.75	4.75
Work-to-break, in.·lbf/in.	10	4.83	16.07
Thickness of cords, mils	10	0.52[D]	0.52[D]
Twist, tpi: Cord	10	0.21[D]	0.47[D]
Singles	10	0.11[D]	0.29[D]
Linear density, den:			
From bobbin	5	0.47	1.86
From tabby	5	0.65	2.83
Table 4c 1650/3 Rayon Cord (11 × 10 twist): [E]			
Breaking strength, lbf	10	2.73	5.62
Elongation at break, %	10	3.04	6.49
Load at Specified Elongation (LASE) (reported at 6 % E), lbf	10	4.67	19.20
Thickness of cords, mils	10	0.66[D]	2.07[D]
Twist, tpi: Cord	10	0.24[D]	0.51[D]
Singles	10	0.14[D]	0.30[D]
Linear density, den:			
From bobbin	5	0.37	2.98
From tabby	5	0.41	1.58
Table 4d 1500/2 High-Modulus Aramid Cord (4 × 4 twist):			
Breaking strength, lbf	10	1.06	6.68
Elongation at Break, %	10	2.26	20.80
Modulus, gf/den	10	3.22	19.69
Work-to-break, in.·lbf/in.	10	3.89	48.99
Thickness of cords, mils	10	0.77[D]	10.73[D]
Twist, tpi: Cord	10	0.09[D]	0.34[D]
Singles	10	0.09[D]	0.24[D]
Table 4e 1500/2 High-Modulus Aramid Cord (7.5 × 7.5 twist):			
Breaking strength, lbf	10	2.11	9.79
Elongation at break, %	10	2.18	26.70
Modulus, gf/den	10	2.13	35.43
Work-to-break, in.·lbf/in.	10	8.41	43.77
Thickness of cords, mils	10	0.77[D]	8.49[D]
Twist, tpi: Cord	10	0.09[D]	0.40[D]
Singles	10	0.09[D]	0.56[D]
Load at specified elongation (LASE) without Rosin (reported at 2 % E), lbf.	10	1.12	13.00
Table 4f 1500/1 High-Modulus Aramid Yarn:			
Breaking strength, lbf	10	1.33	9.46
Elongation at break, %	10	2.55	23.39
Modulus, gf/den	10	4.43	14.68

[A] The critical differences were calculated using $t = 1.960$ which is based on infinite degrees of freedom.
[B] To convert the values of the critical difference expressed as a percent of the grand average to units of measure, multiply the average of the two specific sets of data being compared by the critical differences expressed as a decimal fraction.
[C] 1260/2 nylon cord for linear density.
[D] Properties noted in this table have critical differences in the units shown rather than as a percent of the grand average.
[E] Rayon data, except thickness, twist, and linear density, are for oven-dry cord.

that the nominal gage length of the specimen is not exactly 250 (or 500) mm (10 (or 20) in.) as specified in 16.3, but always will be somewhat more due to slack in the specimen after closing the clamps.

NOTE 5—Because of the difficulty of securing the same tension in all the filaments and because of slippage in the clamps, variable results may be obtained when testing zero-twist multifilament yarns unless a small amount of twist is inserted prior to testing. A twist of 60 t/m (1.5 tpi) inserted into zero-twist yarns of different sizes has been found satisfactory for the purpose of tensile testing. Historically, twist up to 120 t/m (3.0 tpi) have been used in some cases. For aramid yarns the amount of twist to be inserted shall be calculated using Eq 11 and Eq 12:

$$T_{tpm} = (1055 \pm 50)/\sqrt{(LD_t)} \quad (11)$$

$$T_{tpi} = (80.3 \pm 4)/\sqrt{(LD_d)} \quad (12)$$

where:

T_{tpm} = twist, tpm,
T_{tpi} = twist, tpi,
LD_t = linear density, tex, and
LD_d = linear density, denier.

Inserting some twist in zero-twist yarns for tensile testing has the following effects on the test results:

a. modestly increases breaking force; too much twist reduces breaking force,
b. increases elongation at break, and
c. reduces modulus (the slope of the force-elongation curve).

Manner of inserting the twist into the yarn, manually or with a twisting machine, can influence the test results, especially for the aramid yarns.

16.3.3 The velocity of conditioned air flowing across a specimen while determining tensile properties can have a measurable effect on the breaking force and elongation at break because of the Gough-Joule effect. The magnitude ofthis effect depends on the type of fiber, air velocity, and sample history. Interlaboratory testing of nylon, polyester, and rayon cords indicates that air velocities of less than 250 mm/s (50 ft/min) across the specimen will not significantly bias the comparison of cord properties between laboratories.[4]

16.3.4 As diameters and strengths of cords increase, clamps with larger snubbing surfaces and greater holding power or capacity may be required to prevent slippage of cords in testing machine clamps or an excessive number of jaw breaks. The levels of cord size and strength at which such higher capacity clamps are required must be determined by experiment because they will vary with the type of fiber and construction. Some clamps with larger snubbing surfaces and greater holding power or capacity may be too large to allow a 250 or 500-mm (10 or 20-in.) gage length. In those cases, use the appropriate gage length for the clamp in use. If slippage of cords cannot be prevented with the highest capacity clamps available to the user, it has been found useful to apply powdered rosin to the two portions of the cord that will be held between the snubbing surfaces. Use of rosin has been found particularly useful in testing organic cords that have been adhesive treated.

16.4 *Calculation*—Calculate the average breaking force from the observed breaking forces of specimens read from the testing machine chart or dial to the nearest 0.5 N (0.1 lbf).

16.5 *Report*:

16.5.1 State that the specimens were tested as directed in Section 16 of Test Methods D 885. Describe the material or product sampled and the method of sampling used.

16.5.2 Report the option or procedure used; the number of specimens tested; the amount of twist, if any, inserted into the yarn for the tensile testing; and the breaking force for the sample as the breaking strength.

16.6 *Precision and Bias*:

16.6.1 *Precision*—See Section 39.

16.6.2 *Bias*—See 39.3.

17. Adjustment of Observed Breaking Strength (Force) of Rayon Yarns and Cords to a Specified Moisture Regain Level

17.1 *Scope*—This test method is used to adjust the observed breaking strength (force) of rayon yarns and cords to a specified moisture regain level.

17.2 *Calculation*—If the moisture regain of a rayon sample at the time of testing is within ±0.3 % of the regain level specification, report the average observed breaking force as the breaking strength. If the moisture regain is outside the ±0.3 % limit, adjust the observed breaking strength to the specification regain basis using a suitable adjustment factor. Establish this factor for a specific material by making breaking tests at a sufficient number of different moisture regain levels to determine the slope of the "breaking strength (force) versus moisture regain" curve. Apply the factor using Eq 13:

$$BS = BF \times F \quad (13)$$

where:

BS = breaking strength, adjusted to specification moisture regain level, N (lbf),
BF = observed average breaking force, N (lbf), and
F = factor for adjusting observed breaking forces to a specified moisture regain level.

18. Breaking Tenacity of Conditioned Yarns and Cords

18.1 *Scope*—This test method is used to determine the breaking tenacity of yarns and cords after conditioning in the atmosphere for testing industrial yarns and tire cords.

18.2 *Calculation*—Calculate the breaking tenacity of the sample in terms of millinewtons per tex (mN/tex) (grams-force per denier (gf/den)) from the breaking strength and the linear density using Eq 14 and Eq 15:

$$BT_n = (BF_n \times 1000/LD_t) \quad (14)$$

$$BT_g = (BF_l \times 454/LD_d) \quad (15)$$

where:

BT_n = breaking tenacity, mN/tex,
BT_g = breaking tenacity, gf/den,
BF_n = average breaking force, N,
BF_l = average breaking force, lbf,
LD_t = measured linear density, tex, and
LD_d = measured linear density, denier.

18.3 *Report*:

18.3.1 State that the specimens were tested as directed in Section 18 of Test Methods D 885. Describe the material or product sampled and the method of sampling used.

18.3.2 Report the option or procedure used, the number of specimens tested, and the breaking tenacity for the sample.

18.4 *Precision and Bias*:

18.4.1 *Precision*—See Section 39.

18.4.2 *Bias*—See 39.3.

19. Elongation at Break of Conditioned Yarns and Cords

19.1 *Scope*—This test method is used to determine the elongation at break of yarns and cords after conditioning in the atmosphere for testing industrial yarns and tire cords.

[4] See Jones, R. E., and Desson, M. J., "Adiabatic Effects on Tensile Testing," *Journal of the I.R.I.*, June 1967.

19.2 *Procedure*—Determine the elongation at break of each conditioned specimen when determining its breaking force (see Section 16). Read the extension at the breaking force from the autographic recorder or by electronic means. The general equation for elongation at break is given in Eq 16:

$$EB = (E_{bf}/L_o) \times 100 \quad (16)$$

where:
EB = elongation at break, %,
E_{bf} = extension of specimen at the breaking force, mm (in.), and
L_o = length of the specimen, under specified pretension measured from nip-to-nip of the holding clamps, mm (in.).

19.2.1 *Pretension Start*—Use Eq 16.

19.2.2 *Slack Start*—Calculate the gage length (L_o) to include the slack using Eq 17:

$$L_o = L_s + DP \quad (17)$$

where:
L_o = length of the specimen, under specified pretension, measured from nip-to-nip of the holding clamps, mm (in.),
L_s = gage length after clamping specimen (absolute distance nip-to-nip before movement of crosshead), mm (in.), and
DP = displacement of crosshead to reach the specified pretension of the specimen (see Fig. 1), mm (in.).

The pretension for aramid corresponds with 20 ± 1 mN/tex (0.20 ± 0.01 gf/den) and for other yarns and cord to 5 ± 1 mN/tex (0.05 ± 0.01 gf/den).

The general equation for elongation at break for the slack start procedure is given in Eq 18:

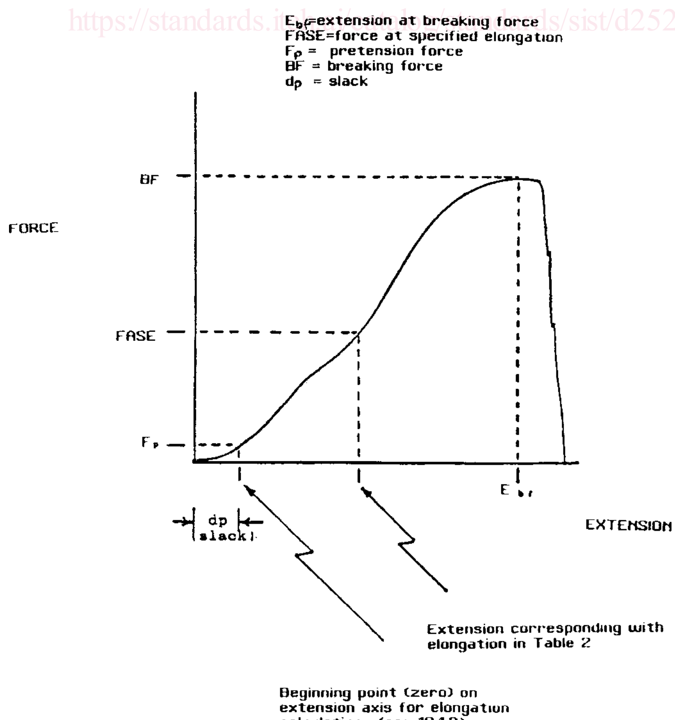

FIG. 1 Force-Extention Curve

$$EB = [E_{bf}/(L_s + DP)] * 100 \quad (18)$$

where:
EB = elongation at break, %,
E_{bf} = extension of specimen at the breaking force, mm (in.),
L_s = gage length after clamping specimen (absolute distance nip-to-nip before movement of crosshead), mm (in.), and
DP = displacement of crosshead to reach the specified pretension of the specinen (see Fig. 1), mm (in.).

19.2.3 Elongation also may be determined from the force-elongation curve at any force.

19.3 *Calculation*—Calculate the average elongation of the sample to the nearest 0.1 %.

19.4 *Report*:

19.4.1 State that the specimens were tested as directed in Section 19 of Test Methods D 885. Describe the material or product sampled and the method of sampling used.

19.4.2 Report the option or procedure used, the number of specimens tested, and the elongation for the sample.

19.5 *Precision and Bias*:

19.5.1 *Precision*—See Section 39.

19.5.2 *Bias*—See 39.3.

20. Adjustment of Observed Elongation of Rayon Yarns and Cords to a Specified Moisture Regain Level

20.1 *Scope*—This test method is used to adjust the observed elongation of rayon yarns and cords to a specified moisture regain level.

20.2 *Procedure*—If the moisture regain of a rayon specimen at the time of testing is within ±0.3 % of the regain level specification, report the average observed elongation at break. If the moisture regain is outside the ±0.3 % limit, adjust the observed elongation to the specification regain basis using a suitable adjustment factor. Establish this factor for a specific material by making elongation tests at a sufficient number of different moisture regain levels to determine the slope of the "elongation at break versus regain" curve. Apply the factor using Eq 19:

$$E_a = E \times F \quad (19)$$

where:
E_a = elongation, adjusted to specification moisture regain level, %,
E = observed elongation, %, and
F = factor for adjusting observed elongation to an elongation at specification moisture regain level.

21. Force at Specified Elongation (FASE) of Conditioned Yarns and Cords

21.1 *Scope*—This test method is used to determine the force at specified elongation (FASE) of yarns and cords after conditioning in the atmosphere for testing industrial yarns and tire cords.

21.2 *Procedure*:

21.2.1 *Nylon, Polyester, Rayon, and Aramid Yarns and Cords*—Determine the force at specified elongation (FASE) of each conditioned specimen when determining its breaking force (see Section 16 and Fig. 1). Read the force directly from the force-extension curve (see Fig. 1) or by electronic means or with an on-line computer at the specified value of elongation for the fiber types listed in Table 3.

21.2.1.1 Assure that the displacement (DP) of the crosshead to remove slack is taken into account when using slack start procedure. Follow same general procedure as for elongation at break (see 19.2 and Fig. 1).

21.2.1.2 Use Eq 20 in the case of slack start procedure to locate extension corresponding to specified elongation. Extension is measured from the pretension point (see Fig. 1), where the slack is removed from the specimen.

$$E_x = E_s \times (L_s + DP)/100 \quad (20)$$

where:

E_x = extension, mm (in.),
E_s = specified elongation, %,
L_s = gage length after clamping specimen (absolute distance nip-to-nip before movement of crosshead), mm (in.), and
DP = displacement of crosshead to reach the specified pretension of the specimen (see Fig. 1), mm (in.).

21.2.1.2.1 Read force, N (lbf), corresponding to above extension from the ordinate of the force-extension curve.

21.3 *Calculation*—Calculate the average FASE of the sample to the nearest 0.5 N (0.1 lbf).

21.4 *Report*:

21.4.1 State that the specimens were tested as directed in Section 21 of Test Methods D 885. Describe the material or product sampled and the method of sampling used.

21.4.2 Report the option or procedure used, the number of specimens tested, and the FASE for the sample.

21.5 *Precision and Bias*:

21.5.1 *Precision*—See Section 39.

21.5.2 *Bias*—See 39.3.

22. Modulus of Conditioned Yarns and Cords

22.1 *Initial Modulus*:

22.1.1 *Scope*—This test method is used to determine the initial modulus of yarns and cords after conditioning in the atmosphere for testing industrial yarns and tire cords.

22.1.2 *Procedure*:

22.1.2.1 *Nylon, Polyester, or Rayon Yarns and Cords*—Determine the initial modulus of each conditioned specimen when determining its breaking force (see Section 16). Using the force-elongation curve (see Fig. 2), draw a tangent to the initial straight-line portion of the curve. Extend this tangent to the abscissa (elongation axis), and upwards to a point that corresponds to slightly more than 10 % elongation. On the abscissa, measure and mark a distance equal to 10 % elongation of the specimen gage length beginning at the point of intersection of the tangent with the abscissa. At the 10 % mark, draw a line perpendicular to the abscissa and extend it upwards until it intersects the tangent to the curve. This point represents the force required for 10 % elongation of the specimen at the rate represented by the straight line portion of the force-elongation curve. When electronic means are used, determine the modulus of the initial straight-line portion of the above curve. Calculate the modulus of a specimen, to the nearest 10 mN/tex (0.1 gf/den) using Eq 21 and Eq 22:

TABLE 3 Elongation Values for Determination of FASE

Type of Fiber	Greige	Adhesive Processed Cord
Rayon	6	3
Nylon	14	5
Polyester	10	5
Aramid	2	1

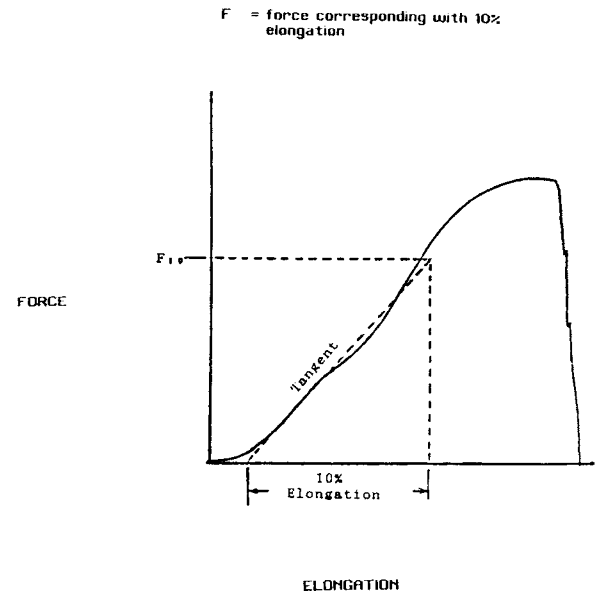

FIG. 2 Force-Elongation Curve for the Determination of Initial Modulus

$$M_{in} = (10^4 \times F_{10n})/LD_t \quad (21)$$

$$M_{ig} = (4560 \times F_{10g})/LD_d \quad (22)$$

where:

M_{in} = initial modulus, mN/tex,
M_{ig} = initial modulus, gf/den,
F_{10n} = force at 10 % elongation, N,
F_{10g} = force at 10 % elongation, lbf,
LD_t = nominal linear density, tex (using Option 1 of Test Method D 1907), and
LD_d = nominal linear density, denier (using Option 1 of Test Method D 1907).

22.1.2.1.1 The CRL- and CRT-type tensile testing machines are not suited for modulus measurements; both types of testers tend to distort the slope of the force-elongation curve and do not guarantee the required accuracy for these tests.

22.1.2.2 *Chord-Modulus Yarns and Cords*—Determine the chord modulus of each conditioned specimen from the force-elongation curve (see Fig. 3). Determine the chord modulus between the points A and B as specified in Table 4. Locate the points A and B on the ordinate at the forces equivalent to A mN/tex (gf/den) and B mN/tex (gf/den) respectively. Draw from each of these two points respectively a line perpendicular to the ordinate to the intersection with the force-elongation curve. From these intersection points determine the related elongation values by drawing perpendicular lines to the abscissa.