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# Standard Test Methods for Tensile Testing of Aramid Yarns[1]

This standard is issued under the fixed designation D 7269; 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 tensile testing of aramid yarns, cords twisted from such yarns, and fabrics woven 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 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 may not be exact equivalents; therefore, each system must be used independently of each other, without combining values in any way.

1.3 This standard includes the following test methods:

| | Section |
|---|---|
| Breaking Strength (Force) | 11 |
| Breaking Tenacity | 12 |
| Breaking Toughness | 17 |
| Elongation at Break | 13 |
| Force at Specified Elongation (FASE) | 14 |
| Linear Density | 10 |
| Modulus | 15 |
| Work-to-Break | 16 |



1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety 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 885 Test Methods for Tire Cords, Tire Cord Fabrics, and Industrial Filament Yarns Made from Manufactured Organic-Base Fibers

D 1776 Practice for Conditioning and Testing Textiles

D 1907 Test Method for Linear Density of Yarn (Yarn Number) by the Skein Method

D 1909 Standard Table of Commercial Moisture Regains for Textile Fibers

D 2258 Practice for Sampling Yarn for Testing

D 4848 Terminology Related to Force, Deformation and Related Properties of Textiles

D 6477 Terminology Relating to Tire Cord, Bead Wire, Hose Reinforcing Wire, and Fabrics

## 3. Terminology

3.1 *Definitions*:

3.1.1 For definitions of terms relating to tire cord 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

[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 .

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

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 Method

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

4.2 A conditioned or oven-dried specimen of aramid 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.

## 5. Significance and Use

5.1 The levels of tensile properties obtained when testing aramid yarns and tire cords are dependent 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. Testing conditions accordingly are specified precisely to obtain reproducible test results on a specific sample.

5.2 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.

5.3 *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.

5.4 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.

5.5 *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.

5.6 *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.

5.7 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.

5.8 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.

## 6. Apparatus

6.1 *Tensile Testing Machine*—A single-strand tensile testing machine of the constant rate of extension (CRE) 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). It is permissible to use tensile testing machines that have a means for calculating and displaying the required results without the use of an autographic recorder. It is also permissible to use automated tensile testing equipment.

6.1.1 *Clamps*—Bollard type clamps, in which the specimen is gripped between plane-faced jaws and then makes a partial turn (wrap angle) around a curved extension (or other type of snubbing device) of one jaw before passing to the other similar clamp (see Fig. 1). Clamps with a wrap angle of 3.14 rad (180°) is recommended for yarns with a linear density up to 10 000 decitex (9000 denier). For linear densities above 10 000 decitex (9000 denier), clamps with a wrap angle of 4.71 rad (270°) is required to prevent slippage.

6.1.1.1 Clamps shall grip the test specimen without spurious slippage or damage to the test specimen which can result in jaw

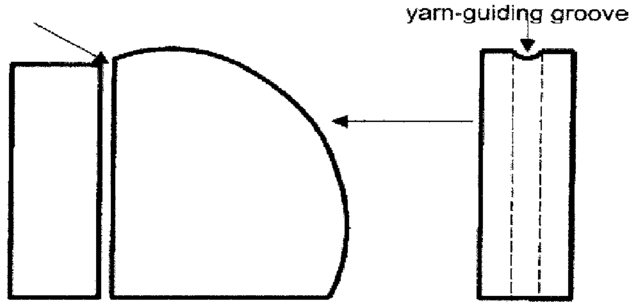


FIG. 1 Principle of Bollard Type Clamps

breaks. The clamps shall maintain constant gripping conditions during the test by means of pneumatic or hydraulic clamps. The surface of the jaws in contact with the specimen shall be of a material and configuration that minimizes slippage and/or specimen failure in the clamping zone.

6.1.2 *Gauge Length*—The gauge length shall be the total length of yarn measured between the clamping point A of the first clamp and the point B of the second clamp in the starting position (see Fig. 2).

6.1.3 Use a crosshead travel rate in mm/min (in./min) of 50 % of the nominal gauge length in millimeters (inches) of the specimen for para-aramids; 100 % of the nominal gauge length in millimeters (inches) of the specimen for meta-aramids.

## 7. Sampling

7.1 *Yarn*:

7.1.1 *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 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.

7.1.2 *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



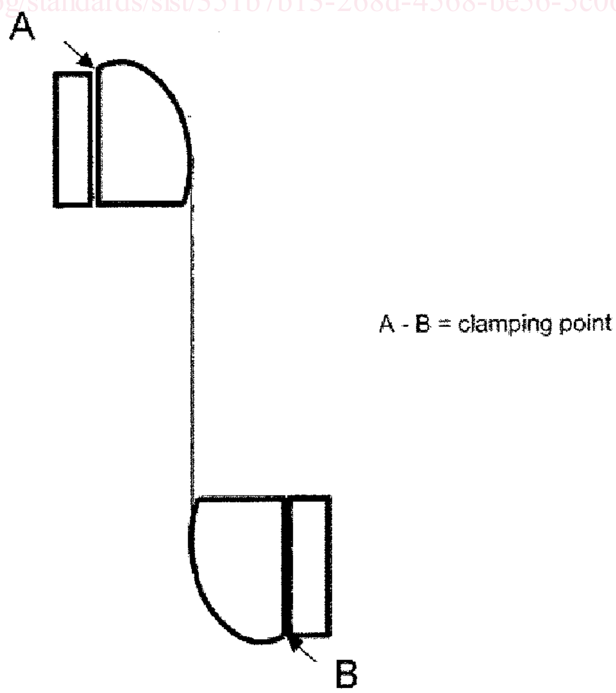


FIG. 2 Principle of Specimen Fixing in Bollard Type Jaws

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.

7.2 *Cord*:

7.2.1 *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.

7.2.2 *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.

7.3 *Tire Cord Fabric*:

7.3.1 *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.

7.3.2 *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.

7.3.3 *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.

7.4 *Cord from Cured Tires*:

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

7.4.2 *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 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

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

principles just described also apply to areas of the tire (such as the tread) composed of multiple plies of high modulus cords.

7.4.3 *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.

7.4.3.1 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.

## 8. Conditioning

8.1 Bring all specimens of yarn, cord, and fabric to moisture equilibrium for testing in the atmosphere for testing industrial yarns for at least 14 h as directed in Practice D 1776.

8.1.1 Standard aramid yarn shall be pre-conditioned at 45 ± 5°C (113 ± 40°F) for 3 to 6 h.

8.1.2 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.

## 9. Sample Preparation

9.1 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. Machine twisting by means of a ring twister using steel insert travelers is recommended. The twist tension should be approximately 10 mN/tex (0.10 gf/den). If used, anti-balloon rings must be chromium plated. ~~.~~ For aramid yarns the amount of twist to be inserted depends upon the linear density and shall be ~~calculated using Eq 1 and 2:~~

~~$$T_{tpm} = (1055 \pm 50)/\sqrt{(LD_t)} \quad (1)$$~~

~~$$T_{tpi} = (80.3 \pm 4)/\sqrt{(LD_d)} \quad (2)$$~~

~~where:~~ approximately:

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

| Linear density dtex | Twist tpm |
|---|---|
| 180-240 | 230 |
| 240-380 | 190 |
| 380-500 | 160 |
| 500-650 | 140 |
| 650-775 | 125 |
| 775-1050 | 110 |
| 1050-1400 | 95 |
| 1400-2100 | 80 |
| 2100-4500 | 60 |
| 4500-7000 | 45 |
| 7000-9500 | 35 |
| 9500-> | 30 |



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

9.2.1 Modestly increases breaking force; too much twist reduces breaking force,

9.2.2 Increases elongation at break, and

9.2.3 Reduces modulus (the slope of the force-elongation curve).

9.3 Manner of inserting the twist into the yarn, manually or with a twisting machine, can influence the test results.