Designation: ~~D8054/D8054M – 16~~ D8054/D8054M – 22

Standard Test Methods for
Tensile Testing of Para-Aramid Flat Yarns[1]

This standard is issued under the fixed designation D8054/D8054M; 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 para-aramid flat yarns. The methods include testing procedure only and include no specifications or tolerances.

1.1.1 ~~This standard includes procedures used to measure force at specified elongation (FASE) of para-aramid flat yarns.~~

1.1.2 ~~This standard includes procedures used to measure linear density of para-aramid flat yarns.~~

1.1.3 ~~This standard includes procedures to determine modulus of para-aramid flat yarns.~~

1.2 This standard includes the following test methods:

	Section
Linear Density	10
Force at Specified Elongation (FASE)	11
Modulus	11

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined.

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D76 Specification for Tensile Testing Machines for Textiles

D123 Terminology Relating to Textiles

D1776/D1776M Practice for Conditioning and Testing Textiles

D1907/D1907M Test Method for Linear Density of Yarn (Yarn Number) by the Skein Method

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[1] These test methods are under the jurisdiction of ASTM Committee D13 on Textiles and are the direct responsibility of Subcommittee D13.19 on Industrial Fibers and Metallic Reinforcements.

Current edition approved ~~July 1, 2016~~Nov. 1, 2022. Published ~~November 2016~~November 2022. DOI: ~~10.1520/D8054_D8054M-16.~~10.1520/D8054_D8054M-22.

[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.

D2258 Practice for Sampling Yarn for Testing
D3800 Test Method for Density of High-Modulus Fibers
D4848 Terminology Related to Force, Deformation and Related Properties of Textiles
D6477 Terminology Relating to Tire Cord, Bead Wire, Hose Reinforcing Wire, and Fabrics
D6587 Test Method for Yarn Number Using Automatic Tester
D7269 Test Methods for Tensile Testing of Aramid Yarns
E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method
E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

3. Terminology

3.1 ~~Definitions:~~

3.1.1 ~~*flat yarn, n*—continuous filament yarns which, when removed from processing package are fully drawn, without twist and untextured.~~
3.1.1.1 ~~*Discussion*—~~
~~Flat yarn is either extruded in this form or it could be made as a slit cut structure with no additional processing modifying the extension direction of the individual elements (for example, filaments) in the yarn.~~

3.1 The following terms are relevant to this standard: ~~modulus,~~ elongation, <u>flat yarn,</u> force at specified elongation (FASE), force-elongation ~~curve.~~<u>curve, modulus.</u>

3.2 For definitions of terms related to industrial fibers and metallic reinforcements, see Terminology D6477.

3.3 For definitions of terms related to force and deformation in textiles, refer to Terminology D4848.

3.4 For definitions of other terms related to textiles, refer to Terminology D123.

4. Summary of Test Methods

4.1 Using various test methods and protocols identified in the procedures, this standard determines the tensile strength, force at specified elonation (FASE), linear density and modulus of para-aramid flat yarns.

5. Significance and Use

5.1 For application areas such as optical fiber and cable reinforcements, aramid is usually used in a linear – not twisted – form. For designing constructions like this, it is essential to use data based on a specimen without twist applied.

5.1.1 The modulus and FASE of twisted yarns demonstrate reduced values when compared to p-aramid flat yarns.

5.1.2 Use Test Method D7269 for testing of twisted p-aramid yarns.

5.2 The levels of tensile properties obtained when testing aramid yarns 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, gauge 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.

5.3 ~~The FASE is used to describe~~ <u>FASE (Force At Specified Elongation) describes</u> the absolute resistance of the p-aramid flat yarn to an imposed ~~deformation.~~<u>elongation.</u>

5.4 ~~The initial modulus of the yarn is the value most commonly used when a specified force is applied to the yarn.~~<u>Modulus is a measure of 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.</u>

5.5 Shape, size, and internal construction of the end-product can have appreciable effect on product performance. It is not possible, therefore, to evaluate the performance of end product in terms of the reinforcing material alone.

5.6 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 tensile testing equipment can be either manually operated or can be an automated device. The specifications and methods of calibration and verification of these machines shall conform to Specification ~~D76~~. The ~~testing machine~~ tester 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.~~ electronic data acquisition and data evaluation system.

6.2 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 face before passing to the other similar clamp (see Appendix X1; Fig. X1.1). Clamps with a minimum wrap angle of 180° are required for yarns with a linear density up to 3500 decitex [3000 denier]. For linear densities above 3500 decitex [3000 denier], clamps with a minimum wrap angle of 270° are recommended to prevent slippage. See Note 1.

6.3 Clamps shall grip the test specimen without spurious slippage or damage to the test specimen which can result in jaw 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 or specimen failure, or both, in the clamping zone. ~~(see Appendix X1; Figure X1.1). It is recommended to use pneumatic clamps which can be operated using a foot pedal.~~

~~6.3 The compliance of the total testing system (tensile tester, load cell, and clamping system) shall be less than 0.2 μm [10⁻⁶ in.] per newton.~~

6.4 *Gauge Length*—The gauge length ~~is~~ shall be the total length ~~between the jaw faces~~ 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 Appendix X1~~Fig.~~; Fig. X1.1~~X1.1)~~.).

Note 1—The selected testing equipment (tester, clamp, gauge length) is known to have an influence on the properties measured. A method for eliminating the influences introduced by the selected testing equipment is given in Test Methods D7269, Appendix X1.

7. Sampling

7.1 *Yarn*—For acceptance testing, sample each lot as directed in Practice D2258. Take the number of specimens for testing specified for the specific property measurement to be made.

7.1.1 *Number of Samples and Specimens*—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. 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 yarn.

7.1.2 *Preparation of Samples*—Remove and discard a minimum of 25 m [~~75~~[27 yd] from the outside of the package before taking the sample or any specimens. Use care in handling the sample. Special care should be used to prevent over handling and disruption of the filament alignment in the yarn bundle. Discard any sample subjected to any change of twist, kinking, or making any bend with a diameter less than 10 times the yarn thickness (or diameter).

8. Conditioning

8.1 Without pre-drying, bring the bobbin with yarn to equilibrium in the atmosphere for testing as directed in Practice D1776/D1776M for aramid.

~~9. Linear Density~~

~~9.1 This test method is used to determine the linear density of flat yarn for use in the calculation of tensile properties such as modulus.~~

~~9.1.1 Determine linear density as directed in Option 1 of Test Method D1907/D1907M or use an Automated Tester as directed in Test Method D6587. For both test methods, condition the yarn as specified in Section 8.~~

~~9.1.2 If scoured oven-dried linear density is needed, use Test Method D1907/D1907M, Option 5.~~

~~9.2 Report the average linear density of the sample and the method used.~~

9. Sample Preparation

9.1 *Sample Preparation*—Take test specimens directly from the original package. Rewound and skein specimen will likely result in lower values. Remove the surface layer and discard.

9.2 *Specimen Preparation*—Mount the sample onto a frame using the "Rolling take off" method. Examples of suitable frames are shown in Fig. 1. Take off test specimen tangentially from the bobbin directly without touching any of the measured part of the yarn and without applying any twist.

9.3 Holding the yarn firmly at the free end and using the "rolling take off" method, remove about 1 m for the specimen. Do not use yarn within 50 mm of either end of the sample ball. Do not let test specimen sag or loop.

9.4 Clamp the specimen in the clamps ensuring that when clamped the tension does not exceed 20 mN/tex.

9.5 During testing, monitor the sample for slippage and splayed yarn due to excessive catenary.

9.6 If slippage is monitored, reject by deletion, clean clamps and repeat.

NOTE 2—Test specimen should be taken off freely with no great drag on the specimen which would increase tension, but still with enough tension applied by hand to remove and keep removed any catenary present. This is particularly important when the specimen is made up of more than one threadline as it requires more tension by hand to ensure that the catenary is all removed. As long as the mounted specimen does not give a reading greater than 20 mN/tex, the test will be valid.
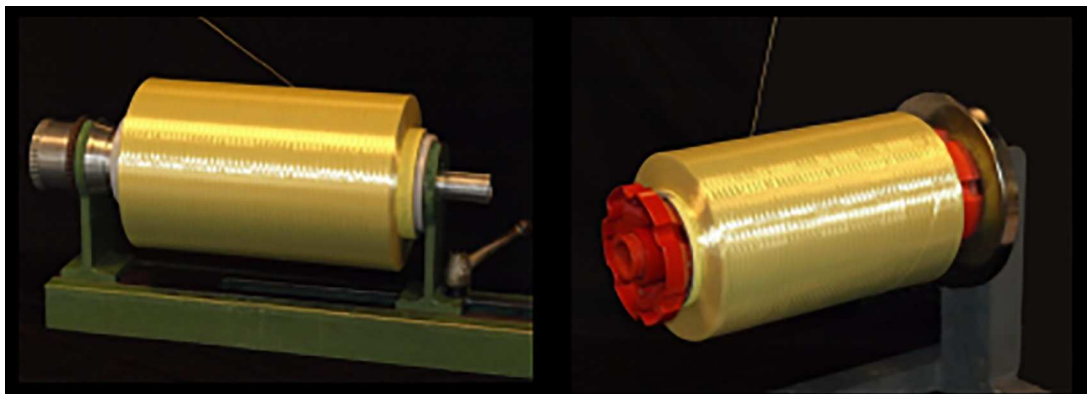

FIG. 1 Examples of Frames/Holders for "Rolling Take Off" Sampling

10. Linear Density

10.1 This test method is used to determine the linear density of flat yarn for use in the calculation of tensile properties such as modulus.

10.1.1 Determine linear density as directed in Option 1 of Test Method D1907/D1907M or use an Automated Tester as directed in Test Method D6587. For both test methods, condition the yarn as specified in Section 8.

10.1.2 If scoured oven-dried linear density is needed, use Test Method D1907/D1907M, Option 5.

10.2 Report the average linear density of the sample and the method used.

11. Determination of the Modulus of FASE Values of Aramid Flat Yarn

This test method describes two options for the determination of the modulus and FASE values of aramid flat yarn:

Option 1: Measurement of the FASE and modulus of flat yarns (see 11.1).

Option 2: Compute the flat yarn FASE and modulus from twisted yarn test-results (see 11.2).

11.1 *Option 1: Tensile Testing of Flat Yarns:*

11.1.1 *General:*

11.1.1.1 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 of this 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.[3]

11.1.1.2 *Tensile Tester*—Select a load cell and the settings of the tensile tester such that the estimated breaking force of the specimen will fall in the range from ~~10~~10 % to ~~90 %~~ 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 load cell amplifier.

11.1.1.3 *Gauge Length*—Adjust the distance between the clamps on the testing machine so that the nominal gauge length of the specimen, measured between the jaw faces of the clamps, is ~~500~~500 mm ± 2 mm ~~[20.00~~[20.00 in. ± 0.01 in.]. For bollard type clamps with a wrap angle of 270° or higher a gauge length of 635 mm ± 2 mm [25.0 in. ± 0.1 in.] is recommended. Make all tests on the conditioned yarns in the atmosphere for aramid yarn. Remove the specimen from the sample and handle it to prevent any change in configuration prior to closing the jaws of the clamps on the specimen. Avoid any damage to the yarn.

11.1.1.4 *Test Speed*—Use a crosshead travel rate of ~~250~~250 mm⁄min ± 1 mm/min ~~[10.00~~[10.00 in.⁄min ± 0.05 in./min]. This is 50 % of the nominal gauge length of the specimen.

11.1.1.5 *Slack Start*—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 11.1.1.4 and stretch the specimen until it ruptures. 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. The gauge length is defined as the length at a pretension level of 20 mN/tex. The slack start procedure has the effect that the nominal gauge length of the specimen is not exactly 500 mm [20 in.] as specified in 11.1.1.3, but always will be slightly increased due to slack in the specimen after closing the clamps.

11.1.2 *Tenacity:*

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

11.1.2.1 This test method is used to determine the tenacity of yarns after conditioning in the atmosphere for testing aramid at any force level. The calculation of tenacity is required to determine the modulus (11.1.4).

11.1.2.2 *Tenacity*—Tenacity is defined by dividing the load (force) by the linear density using Eq 1.

$$T_F = \frac{F}{LD}$$

(1)

where:

F = force, N [gf],
LD = linear density, tex [den], and
T_F = tenacity, N/tex [gf/den].

11.1.2.3 *Reporting*—This parameter is used for determining the modulus and is not reported.

11.1.3 *Elongation of Flat Yarns:*

11.1.3.1 This test method is used to determine the elongation of yarns after conditioning in the atmosphere for testing aramid at any forced level. The calculation of elongation from clamp displacement is required in order to determine Modulus and FASE.

11.1.3.2 *Pretension*—The pretension for aramid yarns corresponds with ~~20~~20 mN/tex $\pm$ 1 mN/tex ~~[0.20~~[0.20 gf/den $\pm$ 0.01 gf/den].

11.1.3.3 *Slack Start*—Calculate the specimen length (L_0) including the slack using Eq 2:

$$L_0 = L_S + DP$$

(2)

where:

L_0 = gauge length of the specimen, under specified pretension, measured from nip-to-nip of the holding clamlps, mm [in.],
L_s = length after clamping specimens (absolute distance nip-to-nip before movement of crosshead), mm [in.], and
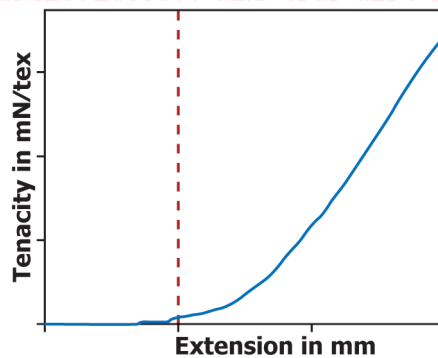DP = displacement of crosshead to reach the specified pretension of the specimen (see Fig. 2).

FIG. 2 Force-Extension Curve

11.1.3.4 *Elongation*—The general equation for elongation is given in Eq 3:

$$E_F = \frac{l_f}{L_0} \cdot 100\%$$

(3)

where:

E_F = elongation at force F, %,

l_F = extension of specimen at force F, mm [in.],
L_0 = length of the specimen, under specified pretension, measured from nip-to-nip of the holding clamps, mm [in.].

11.1.3.5 *Reporting*—This parameter is used for determining the modulus and FASE and is not reported.

11.1.4 *Modulus of Yarns:*

11.1.4.1 This test method is used to determine the modulus of yarns after conditioning in the atmosphere for testing aramid.
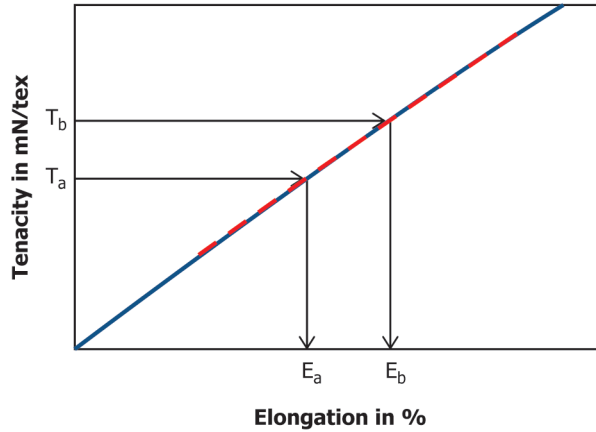
FIG. 3 Tenacity-Elongation Curve for the Determination of Modulus

where:

T_a = tenacity Lower Limit as specified in Table 1
T_b = tenacity Upper Limit as specified in Table 1
E_a = elongation point corresponding to Upper Limit Force in Table 1
E_b = elongation point corresponding to Upper Limit Force in Table 1

11.1.4.2 *Procedure: Modulus Yarns*—Determine the modulus of each conditioned specimen from the tenacity-elongation curve (see Fig. 3). Determine the modulus between the points as specified in Fig. 3 and Table 1. Locate the points E_{a1} and E_{b1} on the

TABLE 1 Lower and Upper Limit of the Modulus Intervals

Type of Fiber	Lower Limit, Ta		Upper Limit, Tb	
	N/tex	[gf/den]	N/tex	[gf/den]
aramid	0.30	[3.4]	0.40	[4.5]

ordinate at the forces F_{a1} and F_{b1} equivalent to the lower and the upper tenacity limit in N/tex [gf/den] as given in Table 1. 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.

11.1.4.3 Calculate the modulus *CM* of a specimen using Eq 4:

$$CM = 100 \cdot \frac{T_b - T_a}{E_b - E_a}$$

(4)

where:

CM = modulus, N/tex [gf/den],
T_b = upper limit in N/tex [gf/den],
T_a = lower limit in N/tex [gf/den],