Designation: D2653 − 07 (Reapproved 2012)

Standard Test Method for Tensile Properties of Elastomeric Yarns (CRE Type Tensile Testing Machines)[1]

This standard is issued under the fixed designation D2653; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the determination of the tensile properties of "as produced" elastomeric yarns made from natural rubber, spandex or other elastomers, using a constant-rate-of-extension (CRE) type tensile testing machine. The properties included in this test method are: (*1*) force at first filament break, (*2*) tenacity at first filament break, (*3*) elongation at first filament break, (*4*) work to break at first filament break, and (*5*) toughness at first filament break.

1.2 This test method does not apply to covered, wrapped, or core-spun yarns or yarns spun from elastomeric staple.

1.3 This test method is applicable to elastomeric yarns in the range from 40 to 3200 dtex (36 to 2900 denier).

1.4 The values stated in either SI units or U.S. Customary units are to be regarded separately as standard. Within the text, the U.S. Customary units are given in parentheses. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other.

1.5 *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]

D76 Specification for Tensile Testing Machines for Textiles
D123 Terminology Relating to Textiles
D1776 Practice for Conditioning and Testing Textiles
D2258 Practice for Sampling Yarn for Testing
D2591 Test Method for Linear Density of Elastomeric Yarns (Short Length Specimens)
D4848 Terminology Related to Force, Deformation and Related Properties of Textiles
D4849 Terminology Related to Yarns and Fibers
D6717 Test Method for Linear Density of Elastomeric Yarns (Skein Specimens)

3. Terminology

3.1 For all terminology relating to D13.58, Yarns and Fibers, refer to Terminology D4849.

3.1.1 The following terms are relevant to this standard: elastomeric yarn, elongation, force, linear density, tenacity, toughness, work, work to break.

3.2 For definitions of other terms related to force and deformation, refer to Terminology D4848. For all other terminology related to textiles, refer to Terminology D123.

4. Summary of Test Method

4.1 A specimen is clamped in a CRE-type tensile testing machine and extended to rupture. Force at first filament break and elongation at first filament break, work and toughness are calculated from a force-elongation curve or with an interfaced computer. Tenacity at first filament break can be calculated based on the determined linear density of the yarn. Other properties, such as force at specified elongation (FASE), elongation at specified force (EASF), may also be calculated.

5. Significance and Use

5.1 This test method is considered satisfactory for acceptance testing of commercial shipments since current estimates of between-laboratory precision are acceptable and the method is used extensively in the trade for acceptance testing.

5.1.1 If there are differences of practical significance between reported test results for two laboratories (or more), comparative tests should be performed to determine if there is a statistical bias between them, using competent statistical assistance. As a minimum, use samples for such comparative tests that are as homogeneous as possible, drawn from the same lot of material as the samples that resulted in disparate results during initial testing, and randomly assigned in equal numbers to each laboratory. The test results from the laboratories involved should be compared using a statistical test for unpaired data, at a probability level chosen prior to the testing

[1] This test method is under the jurisdiction of ASTM Committee D13 on Textiles and is the direct responsibility of Subcommittee D13.58 on Yarns and Fibers.

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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.

series. If bias is found, either its cause must be found and corrected, or future test results for that material must be adjusted in consideration of the known bias.

5.2 The force at first filament break of elastomeric yarns may depend on its construction and manufacturing process and provides an indication of the breaking strength of fabrics made from the yarn.

5.3 Elongation is an indication of the ability of a fiber to absorb energy. The elongation of yarn or fabric must be great enough to withstand strains experienced in processing and end use, and to absorb the energies of applied forces repeatedly.

5.4 Fabric manufacturers use force and elongation information of elastomeric yarns in determining machine set-up conditions.

5.5 Other parameters such as elongation at specified force (EASF), force (or tenacity) at specified elongation (FASE, TASE), work and toughness may be calculated from force-elongation curves. EASF and FASE information is needed for tests involving cycling of yarn in determination of elastic properties.

5.6 This test method was developed using elastomeric yarns in the "as-produced" condition, but may be used for treated elastomeric yarns provided the treatment is specified. The method does not cover the removal of finish for determination of tensile properties of "finish-free" elastomeric yarns.

6. Apparatus[3]

6.1 *Specimen Boards,* with short pile or plush surfaces or black or contrasting color, for storing specimens during conditioning.

6.2 *Tensile Testing Machine,* CRE-type, conforming to Specification D76 with respect to force indication, working range, capacity and verification of recorded elongation, and designed for operation at a pulling speed of 500 mm/min (20 in./min) or 1000 % extension per min.

6.3 *Clamping Assembly,* pneumatically operated, with jaw faces as described in 6.3.1 or 6.3.2.

6.3.1 *Option A, Preferred*—One jaw with a flat acrylic face nominally 25 mm × 12.5 mm (1 in. × 0.5 in.) and the opposing jaw approximately 12.5 mm (0.5 in.) wide with a convex [approximately 7.1 mm (0.28 in.) radius], steel or chrome face.

6.3.2 *Option B*—One jaw with a flat, steel or chrome face nominally 25 mm × 12.5 mm (1 in. × 0.5 in.) and the opposing jaw approximately 12.5 mm (0.5 in.) wide with a convex [approximately 8.5 mm (0.375 in.) radius] acrylic face.

6.4 *Computer or Microprocessor,* interfaced, with automatic data gathering system, optional.

6.5 *Tensioning Weights,* with various masses from 10 mg to 3 g as required to pretension the specimen to 30 to 50 mN/tex (0.3 to 0.5 mgf/d) before testing.

6.6 *Air Supply,* capable of providing 415 kPa (60 psi) to the pneumatic clamps.

[3] Apparatus and accessories are commercially available. Clamps may need to be modified to accept jaw faces and attachment to some tensile testing machine.

7. Sampling, Test Specimens, and Test Units

7.1 *Lot Sample*—As a lot sample for acceptance testing, take a random number of shipping units directed in an applicable material specification or other agreement between the purchaser and the supplier, such as an agreement to use Practice D2258. Consider shipping cases or other shipping units to be the primary sampling units.

NOTE 1—An adequate specification or other agreement between the purchaser and the supplier requires taking into account the variability between shipping units, between packages or ends within a shipping unit, and between specimens from a single package to provide a sampling with a meaningful producer's risk, consumer's risk, acceptable quality level and limiting quality level.

7.2 *Laboratory Sample*—As a laboratory sample for acceptance testing, take at random from each shipping unit in the lot sample the number of packages directed in an applicable material specification or other agreement between the purchaser and the supplier, such as an agreement to use Practice D2258. Preferably, take the same number of packages from each of the shipping units, determine at random which shipping units are to have each number of packages for testing.

7.3 *Test Specimens*—From each package or end in the laboratory sample, take specimens as directed in 7.3.1.

7.3.1 Remove the outer layer of yarn from the package. Avoid any damaged areas in selecting segments for testing. Carefully unwind yarn from the package with as low as tension as possible to avoid stretching. As test specimens, cut approximately 125 mm (5 in.) long segments of yarn from each package, taking them at intervals of at least 1 m (1 yd). Three of the six specimens are used as spare to allow for unacceptable breaks, such as caused by slippage or breaking in the clamps.

7.4 Determine the tex (denier) of the yarn for each laboratory sample using Test Method D2591 or Test Method D6717.

8. Preparation of Apparatus

8.1 Prepare and verify the calibration of the tensile testing machine as directed in the manufacturer's instructions.

8.2 Set up and adjust the CRE-type tensile testing machine as follows:

8.2.1 Examine the acrylic jaw face of the clamps for wear and replace as needed. Position the clamp faces with their contact line horizontal.

8.2.2 Set the distance between clamps, (gage length) to 50 ± 1 mm (2 ± 0.05 in.), nip to nip.

NOTE 2—A convenient technique for checking the gage length is to place a piece of carbon paper and white paper in the clamps and close the clamps. The distance between the marks made on the white paper by the carbon paper represents the set gage length.

8.2.3 Use a force measuring system such that the breaking force will fall between 30 and 80 percent of its full scale capacity.

8.2.4 Set the crosshead speed to 500 mm/min (20 in./min) or 1000 % extension per min.

8.2.5 Set the extension measuring system as follows:

8.2.5.1 When using a chart recorder, set the chart speed to 500 mm/min (20 in./min). Not needed with computer interfaced testing machines.

8.2.5.2 When using an interfaced computer or microprocessor, set parameters to obtain selected properties using supplier's directions and Specification D76.

8.2.6 Set air pressure for pneumatic clamps to 415 kPa (60 psi). At this pressure, the clamping force is approximately 450 N (100 lb).

9. Conditioning

9.1 No preconditioning is required. for currently produced rubber yarns and other elastomeric yarns.

9.2 Condition the specimens relaxed on specimen boards in the standard atmosphere for testing textiles as directed in Practice D1776 which is 21 ± 1°C (70 ± 2°F) and 65 ± 2 % relative humidity for a minimum of 4 h.

10. Procedure

10.1 Test the relaxed specimens in the standard atmosphere for testing textiles.

NOTE 3—The force measuring system should be zeroed prior to running any specimens and periodically during the course of the test, particularly if drift is observed in the zero value of the force measuring system.

10.2 Select the appropriate pretensioning weight based on the linear density of the yarn that will provide a 30 to 50 mN/tex (0.3 to 0.5 mgf/d) tension to the yarn.

10.3 Attach the selected tensioning weight (10.2) to the specimen such that when the specimen is place in the lower clamp, the tensioning weight will hang freely.

10.4 Position a specimen centrally between the top clamp faces and close the clamp. Ensure that the tensioning weight is hanging freely below the botton clamp.

10.5 Close the lower clamp and remove the tensioning weight.

10.6 Start the tester and observe the specimen behavior. Record the breaking force when the first filament break is observed.

10.6.1 If the specimen breaks within 3 mm (0.13 in.) of either jaw, or the slippage is indicated by a leveling in the force direction with abnormally high elongation, discard the result and test another specimen from the same package.

10.6.2 If many specimens exhibit what appears to be slippage, replace the acrylic jaw face and retest.

10.7 Remove the specimen and continue testing until a total of 3 specimens have been tested for each laboratory sampling unit.

11. Calculation or Interpretation of Results

11.1 *Force at First Filament Break*—Calculate the Force at First Filament Break (FFB) as follows:

11.1.1 Read the force at FFB value to the nearest 0.1 cN (0.1 gf) from the force elongation curve and record the value.

NOTE 4—In elastomeric yarns, FFB is the first on the force-elongation curve that is followed by a drop in force of at least 5 % of the force at that point for this specimen or the equivalent in a computer algorithm.

11.1.2 Calculate the average force at FFB for each laboratory sampling unit and for the lot.

11.2 *Tenacity at First Filament Break*—Calculate the Tenacity at First Filament break as follows:

11.2.1 Calculate the tenacity at FFB for each specimen to the nearest 0.1 cN/tex (0.01 gf/d), using Eq 1.

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

where:

T = tenacity at FFB, cN/tex (gf/d),
F = force at FFB, cN (gf), and
D = average linear density, tex (denier).

11.2.2 Calculate the average breaking tenacity for each laboratory sampling unit and for the lot.

11.3 *Percent Elongation at First Filament Break*—Calculate the Percent Elongation at First Filament Break as follows:

11.3.1 Read the elongation at the force at FFB value for each specimen to the nearest 0.1 % from the force-elongation curves.

11.3.1.1 If force-extension curves are used, determine the extension corresponding to the force at FFB and calculate the percent elongation at FFB, using Eq 2.

$$E = 100 \times L/G \tag{2}$$

where:

E = elongation at FFB, %,
L = the extension (distance on the extension axis from the origin to the extension line corresponding to the force at FFB), mm (in.), and
G = the nominal gage length, mm (in.).

11.3.2 Calculate the average percent elongation at FFB for each laboratory sampling unit and for the lot.

11.4 *Work to Break at First Filament Break (FFB)*—Calculate the Work to Break at FFB as follows:

11.4.1 Using the force-extension curve, draw a line from the point of first filament break of each specimen perpendicular to the extension axis. Measure the area bounded by the curve, the perpendicular, and the extension axis. This area may be estimated by counting squares, measured with a planimeter, or determined by electronic means.

11.4.2 Calculate the work to break at FFB for each specimen to the nearest. 0.01 mJ (0.01 in-lbf.), or the specific work to break at FFB to the nearest 0.01 J/m (0.01 in-lbf./in.) using Eq 3 or Eq 4.

$$W_b = A \times F \times E \tag{3}$$

$$W_{sb} = A \times F \times E/G \tag{4}$$

where:

W_b = work to break, J (gf-in.),
W_{sb} = specific work to break, J/m (gf-in/in.),
A = area under the force-extension curve, $mm^2 \times 10^{-5}$ ($in.^2$).
F = force scale factor of chart, (N/mm (gf/in.),
E = extension scale factor of chart, mm/mm (in./in.), and
G = gage length of specimen, mm (in.).

11.4.3 Calculate the average work to break at FFB or average specific work to break at FFB for each laboratory sampling unit and for the lot.

11.5 *Toughness at First Filament Break (FFB)*—Calculate the Toughness at FFB as follows:

11.5.1 Calculate the breaking toughness for each specimen to the nearest 0.01 J/g (0.01 gf-in./den-in.), using Eq 5.

$$T_b = W_{sb}/LD \quad (5)$$

where:

T_b = breaking toughness, J/g (gf-in./den-in.), and
LD = linear density, tex (denier).

11.5.2 Calculate the average breaking toughness for each laboratory sampling unit and for the lot.

11.6 *Coefficient of Variation and Standard Deviation*—When required, calculate the Coefficient of Variation and Standard Deviation for the properties requested for each laboratory sampling unit and for the lot.

11.7 *Computer-Processed Data*—When data is automatically computer processed, calculations are generally contained in the associated software and the results displayed or printed, or both. In any event, it is recommended that the computer-processed data be verified against known property values and that the software be described in the report.

12. Report

12.1 State that the tests were made as directed in Test Method D2653. Describe the material or product tested and the method of sampling used.

12.2 Report the following information for each laboratory sampling unit and for the lot:

12.2.1 Linear density and the test method used,
12.2.2 Force at FFB,
12.2.3 Tenacity at FFB,
12.2.4 Elongation at FFB,
12.2.5 Work to break or specific work to break,
12.2.6 Breaking toughness,
12.2.7 Individual values for force at FFB, tenacity at FFB, and elongation at FFB, if requested,
12.2.8 Coefficient of variation or standard deviation values, if calculated,
12.2.9 Make and model of the tensile testing machine and the capacity used,
12.2.10 Option for the clamping system used,
12.2.11 For computer-processed data, identify the program (software) used, and
12.2.12 Any modification of the test method.

13. Precision and Bias

13.1 An interlaboratory study was performed in November 2000 to estimate variability of the test method. The study included four laboratories. Two or three operators from each laboratory each measured three specimens for three different denier elastomeric yarns on two different dates. ANOVA was used to determine the average values and variance components. These values are shown in Tables 1-6.

TABLE 1 Response = Force @ First Filament Break, g

Denier	Average	V(lab)	V(operator)	V(date)	V(specimen)
40	57.11348	36.34674	0	27.60811	63.66935
210	145.1820	4.46393	36.74334	21.24004	237.50700
840	647.9056	0	507.08340	135.20430	2208.8040

TABLE 2 Response = Tenacity @ First Filament Break, g/d

Denier	Average	V(lab)	V(operator)	V(date)	V(specimen)
40	1.427837	0.02272	0	0.01851	0.03979
210	0.691343	0.00010	0.00083	0.00048	0.00539
840	0.771316	0	0.00072	0.00019	0.00404

TABLE 3 Response = Work to First Filament Break, J

Denier	Average	V(lab)	V(operator)	V(date)	V(specimen)
40	37.54321	17.89520	0	10.45010	30.44907
210	101.4323	0	0	12.07802	94.03040
840	498.795	43.61584	466.80750	209.62120	1490.4360

TABLE 4 Response = Specific Work to First Filament Break, J/m

Denier	Average	V(lab)	V(operator)	V(date)	V(specimen)
40	0.73904	0.00693	0	0.00405	0.01180
210	1.99669	0	0	0.00468	0.03644
840	9.8188	0.01690	0.18089	0.08123	0.85656

TABLE 5 Response = Toughness @ First Filament Break, J/g

Denier	Average	V(lab)	V(operator)	V(date)	V(specimen)
40	166.2839	351.05420	0	205.15720	597.32640
210	85.57281	0	0	8.59637	66.92483
840	105.2014	1.94019	20.76523	9.32469	66.29980

TABLE 6 Elongation @ First Filament Break, %

Denier	Average	V(lab)	V(operator)	V(date)	V(specimen)
40	471.4709	342.6012	0	35.4937	447.8952
210	479.4841	0	0	12.0755	235.2360
840	519.4032	54.4163	95.8410	8.9328	221.6005

TABLE 7 Force @ First Filament Break, g

Denier	s_r	Repeatability	S_R	Reproducibility
40	7.97931	22.11751	11.97383	31.55834
210	15.41126	42.71784	17.31919	48.00634
840	48.00634	130.27157	53.39561	148.00509

TABLE 8 Response = Tenacity @ First Filament Break, g/d

Denier	s_r	Repeatability	S_R	Reproducibility
40	0.19948	0.55294	0.28463	0.78896
210	0.07339	0.20342	0.08247	0.22861
840	0.05595	0.15508	0.06357	0.17620

13.2 Method repeatability is defined as the "maximum difference" that can "reasonably" be expected between two test results obtained on the same material when the test results are obtained in the same laboratory. Repeatability standard deviation, s_r, is taken to be the square root of the "specimen" variance component, and represents within-operator precision. Method reproducibility is defined as the "maximum difference" that can "reasonably" be expected between two test results obtained on the same material when the test results are

TABLE 9 Work @ First Filament Break, J

Denier	s_r	Repeatability	S_R	Reproducibility
40	5.51807	15.29530	7.66775	21.25392
210	9.69693	26.87851	10.30089	28.55262
840	38.60617	107.01083	47.01575	130.32100

TABLE 10 Specific Work @ First Filament Break, J/m

Denier	s_r	Repeatability	S_R	Reproducibility
40	0.10862	0.30109	0.15095	0.41840
210	0.19088	0.52911	0.20277	0.56206
840	0.75996	2.10651	0.92551	2.56537

TABLE 11 Response = Toughness @ First Filament Break, J/g

Denier	s_r	Repeatability	S_R	Reproducibility
40	24.44026	67.74495	33.96377	94.14277
210	8.18076	22.67591	8.69029	24.08826
840	8.14247	22.56977	9.91614	27.48615

obtained from different laboratories.[4] s_R, the total standard deviation, is formed by taking the square root of the sum of intra- and inter-laboratory variance components. Tables 7-12 illustrate these values.

[4] John Mandel and Theodore W. Lashof, 1987. The Nature of Repeatability and Reproducibility. Jour. Quality Technology, 19 (1).

TABLE 12 Elongation @ First Filament Break, %

Denier	s_r	Repeatability	S_R	Reproducibility
40	21.16353	58.66233	28.74004	79.66334
210	15.33741	42.51312	15.72614	43.59063
840	14.88625	41.26259	19.51386	54.08965

NOTE 5—Because the interlaboratory test included less than the recommended five laboratories, estimates of precision data in Tables 1-12 may be either underestimated or overestimated to a considerable extent and should be used with special caution.

13.3 The procedure of this test method produces a test value that can be defined only in terms of a test method. There is no independent, referee method by which bias may be determined. This test method has no known bias.

14. Keywords

14.1 breaking strength; elastomeric yarn; elongation; first filament break; tenacity; toughness; work to break