Designation: D7744/D7744M – 11

Standard Test Methods for Tensile Testing of High Performance Polyethylene Tapes[1]

This standard is issued under the fixed designation D7744/D7744M; 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 The test method covers the tensile testing of high performance polyethylene tapes. The method includes testing procedure only and includes no specifications or tolerances.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

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]

D76 Specification for Tensile Testing Machines for Textiles
D123 Terminology Relating to Textiles
D1776 Practice for Conditioning and Testing Textiles
D1907 Test Method for Linear Density of Yarn (Yarn Number) by the Skein Method
D2258 Practice for Sampling Yarn for Testing
D4848 Terminology Related to Force, Deformation and Related Properties of Textiles
D5947 Test Methods for Physical Dimensions of Solid Plastics Specimens
E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods
E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

3. Terminology

3.1 *Definitions:*

3.1.1 *high-performance polyethylene, n*—a polyethylene yarn or tape with a tenacity at break of minimally 1000 mN/tex [11 gpd].

3.1.2 *tape, n—in high performance end-uses*, a flat, highly-oriented strip of polymer material.

3.2 *Definitions:*For definitions of terms related to force and deformation in textiles, refer to Terminology D4848.

3.3 The following terms are relevant to this standard: breaking force, breaking strength, breaking tenacity, breaking toughness, modulus, force-extension curve, force-elongation curve, elongation, force at specified elongation (FASE), tensile strength, and work-to-break.

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

4. Summary of Test Method

4.1 A conditioned polyethylene tape is clamped in a constant rate of extension tensile testing machine (CRE) and then stretched or loaded until broken.

4.2 Breaking force, elongation, and force at specified elongation (FASE) are determined directly. Modulus and work-to-break are calculated from the force-elongation curve.

5. Significance and Use

5.1 The levels of tensile properties obtained when testing high performance polyethylene tapes 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.

[1] This test method is under the jurisdiction of ASTM Committee D13 on Textiles and is the direct responsibility of Subcommittee D13.19 on Industrial Fibers and Metallic Reinforcements.

Current edition approved July 15, 2011. Published September 2011. DOI: 10.1520/D7744_D7744M–11.

[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.

5.2 *Breaking strength* is used in engineering calculations when designing various types of products. When needed to compare intrinsic strength characteristics tapes of different sizes or different types of tape, breaking tenacity is very useful because, for a given type of tape, breaking force is approximately proportional to linear density.

5.3 *Elongation* of tape is taken into consideration in the design and engineering of reinforced 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 material during the various stages involved in the processing.

5.5 *Modulus* is a measure of the resistance of tape to extension as a force is applied. 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 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.

5.8 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 D76. 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.

6.1.1 *Clamps*—Side action grips with flat jaw faces. The test specimen shall be held in such a way that slippage relative to the grips is prevented insofar as possible. Flat faced grips were found to fulfill this requirement. The width of the jaw faces should be equal or larger than the sample width. The use of paper has been found to reduce slippage. Air-actuated or hydraulic grips have been found advantageous. In cases where samples frequently fail at the edge of the grips, it may be advantageous to increase slightly the radius of curvature of these edges where the grips come in contact with the test area of the specimen.

6.1.2 The compliance of the total testing system (tensile tester, loadcell and clamping system) shall be less than 0.2 µm [10^{-6} in.] per Newton.

6.1.3 *Gauge Length*—The gauge length shall be the total length between the jaw faces.

6.1.4 Use a crosshead travel rate in mm/min [in./min] of preferably 50 or 100 % of the nominal gauge length in millimeters [inches] of the specimen. The rate used must be reported.

7. Sampling

7.1 *Tape:*

7.1.1 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.

8. Conditioning

8.1 Bring all specimens to equilibrium in the atmosphere prior to testing for at least 3 h as directed in Practice D1776 (UHMW Polyethylene).

9. Sample Preparation

9.1 The width and the thickness of the samples are determined in accordance with Practice D5947, Option C. The thickness must be equal or less than 250 µm [10^{-3} in.]. The width of the samples must be in the range of 2 to 150 mm [0.1 to 6 in.]. Due to constraints of the tensile equipment, the test cannot be used for tapes wider than that limit. If the width exceeds 150 mm [6 in.], the sample must be cut to width so that it fulfills this requirement.

10. Linear Density

10.1 *Scope*—This test method issued to determine the linear density of tape for use in the calculation of tensile properties such as modulus and tenacity.

10.2 *Number of Specimens*—Five specimens of 1 m [40 in.] length of tape.

10.3 *Procedure*—Determine linear density form weighing the five individual tapes as directed in Option 1 of Test Method D1907 except condition the tape as specified in Section 8.

11. Breaking Strength (Force) of Conditioned Tapes

11.1 *Scope*—This test method is used to determine the breaking strength (force) of tapes after conditioning in the atmosphere for testing (UHMW Polyethylene).

11.2 *Number of Specimens*—Test five specimens.

11.3 *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 gauge length of the specimen, measured between the jaws faces of the clamps, is preferably 300 ± 2 mm [12 ± 0.10 in.]. Make all tests on the conditioned tapes in the atmosphere for UHMW Polyethylene. 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 tape. 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 11.3.1) or
Slack start procedure (see 11.3.2).

11.3.1 *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 tape is positioned in the centerline of the jaws of the clamp. Operate the testing machine at the rate as specified in 6.1.3 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 edge 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 that the nominal gauge length of the specimen is not exactly 300 mm [12 in.] as specified in 10.3, but always will be somewhat more due to slack in the specimen after closing the clamps.

11.3.2 *Pretension-Start Procedure*—Use a tensioning device that applies a pretension corresponding to 20 ± 1 mN/tex [0.20 ± 0.01 gf/den] for high performance PE tapes. This device may be a weight, a spring, or an air-actuated mechanism. Place 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 6.1.4. When the specimen breaks (ruptures), read the breaking force (maximum force) in Newtons [pounds-force] from the 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 [⅜ 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.

11.4 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 tape, 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]

11.5 *Calculation*—Calculate the average breaking force from the observed breaking forces of specimens.

11.6 *Report:*

11.6.1 State that the specimens were tested as directed in Section 10 of Test Methods D7744. Describe the material or product sampled and the method of sampling used.

11.6.2 Report the option or procedure used; then number of specimens tested; and the breaking force for the sample as the breaking strength.

11.7 *Precision and Bias:*

11.7.1 See Section 19.

12. Breaking Tenacity of Conditioned Tapes

12.1 *Scope*—This test method is used to determine the breaking tenacity of polyethylene tapes after conditioning in the atmosphere for testing UHMW Polyethylene.

12.2 *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 1 or Eq 2.

$$BT_n = \frac{BF_n \cdot 1000}{LD_t} \quad (1)$$

$$BT_g = \frac{BF_l \cdot 454}{LD_d} \quad (2)$$

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.

12.3 *Report:*

12.3.1 State that the specimens were tested as directed in Section 12 of Test Methods D7744. Describe the material or product sampled and the method of sampling used.

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

12.4 *Precision and Bias:*

12.4.1 See Section 19.

13. Elongation at Break of Conditioned Tapes

13.1 *Scope*—This test method is used to determine the elongation at break of tapes after conditioning in the atmosphere for testing UHMW Polyethylene.

13.2 *Procedure*—Determine the elongation at break of each conditioned specimen when determining its breaking force (see Section 12). Read the extension at the breaking force from the

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

autographic recorder or by electronic means. The general equation for elongation at break is given in Eq 3:

$$EB = \frac{E_{bf}}{L_o} \cdot 100\,\% \quad (3)$$

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.].

13.2.1 *Slack Start*—Calculate the gauge length (L_o) to include the slack using Eq 4:

$$L_o = L_s + DP \quad (4)$$

where:

L_o = length of the specimen, under specified pretension, measured from nip-to-nip of the holding clamps, mm [in.],
L_s = gauge 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.].

13.2.1.1 The pretension for PE tape corresponds with 20 ± 1 mN/tex [0.20 ± 0.01 gf/den].

13.2.1.2 The general equation for elongation at break for the slack start procedure is given in Eq 5.

$$EB = \frac{E_{bf}}{L_s + DP} \cdot 100\,\% \quad (5)$$

where:

EB = elongation at break, %,
EB_{bf} = extension of specimen at the breaking force, mm [in.],
L_s = gauge 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.].

13.2.2 Elongation also may be determined from the force-elongation curve at any force (see Fig. 1).

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

13.4 *Report:*

13.4.1 State that the specimens were tested as directed in Section 13 of Test Methods D7744. Describe the material or product sampled and the method of sampling used.

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

13.5 *Precision and Bias:*

13.5.1 See Section 19.

14. Force at Specified Elongation (FASE) of Conditioned Tapes

14.1 *Scope*—This test method is used to determine the force at specified elongation (FASE) of tapes after conditioning in the atmosphere for UHMW Polyethylene.

14.2 *Procedure*—Determine the force at specified elongation (FASE) of each conditioned specimen when determining its breaking force (see Section 11 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 listed in Table 1.

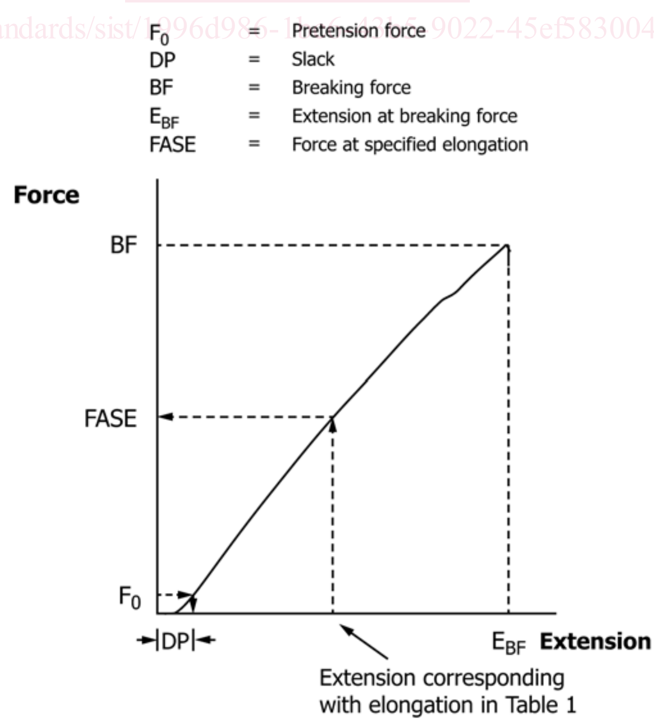

FIG. 1 Force-elongation Curve