INTERNATIONAL

Designation: ~~D7744/D7744M – 11~~ D7744/D7744M – 20

Standard Test Methods for Tensile Testing of High Performance Polyethylene ~~Tapes~~Films[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~~These test ~~method covers~~methods cover the tensile testing of high performance polyethylene ~~tapes.~~films. The ~~method includes~~methods include testing procedure only and ~~includes~~include 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~~are not ~~be~~necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the ~~other. Combining~~other, and values from the two systems ~~may result in non-conformance with the standard.~~shall not be combined.

1.3 This standard includes the following test methods:

	Section
~~Breaking Strength (Force)~~	~~11~~
Breaking Force	11
Breaking Tenacity	12
~~Breaking Toughness~~	~~17~~
Toughness at Break	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~~ safety, health, and ~~health~~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
D883 Terminology Relating to Plastics
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
D3800 Test Method for Density of High-Modulus Fibers
D4848 Terminology Related to Force, Deformation and Related Properties of Textiles
D5947 Test Methods for Physical Dimensions of Solid Plastics Specimens
D7269/D7269M Test Methods for Tensile Testing of Aramid Yarns

[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.

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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.

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 manufactured fiber or film made of a polymer prepared by the polymerization of ethylene as the sole monomer which has a minimum of tenacity at break of minimally 1000 mN/tex [11 gpd].20 gpd.

3.1.1.1 *Discussion—*

General–The following acronyms are used to describe this category of fibers:

UHMWPE – Ultra high molecular weight polyethylene
HMPE – High modulus polyethylene
HPPE – High performance polyethylene

Specific–For other definitions related to polyethylene refer to Terminology D883.

3.1.2 *tape,film, n—in highplastics,* performance end-uses,an optional a flat, highly-oriented strip of polymer material.term for sheeting having a nominal thickness not greater than 0.25 mm [0.01 in.].

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

3.2 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, tenacity, elongation, force at specified elongation (FASE), tensile strength, force-elongation curve, force-extension curve, modulus, toughness at break, 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 high performance polyethylene tapefilm 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 tapesfilms 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.

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

5.3 *Elongation* of tapefilm 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 tapefilm 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 toughnessToughness at break* 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 tensile testing machines shall be equipped with a data acquisition and a data evaluation system.

6.2 ~~*Tensile Testing Machine*—~~*Clamps—*~~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~~Side action grips with flat jaw faces shall be used. 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 ~~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.~~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.

~~6.1.1 *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.~~

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6.4 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.

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

NOTE 1—The selected testing equipment (tester, clamp) and gauge length are known to have an influence on the properties measured. When required, the influences introduced by the selected testing equipment can be eliminated using the method as given in Test Methods D7269/D7269M, Appendix X1.

7. Sampling

7.1 ~~*Tape:*~~*Film:*

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~~ should not exceed 150 mm [6 in.]. Due to constraints of the tensile equipment, the test cannot be used for ~~tapes~~films 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 was issued to determine the linear density of ~~tape~~film 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.~~film.

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

10.4 Calculate the average linear density of the sample.

11. Breaking Strength (Force) Force of Conditioned TapesFilms

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).force of films.

11.2 *Number of Specimens*—Test five specimens.

11.3 *Procedure*—Make all tests on the conditioned films in the atmosphere for high performance polyethylene. 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 theas stated in 6.2 atmosphere is:

$$300 \pm 1\text{mm}\,[12.0 \pm 0.05\text{ in.}]$$

for

NOTE 2—As stated in the procedures in 11.3.1 and 11.3.2, a test result is valid when the specimen breaks within the free length between the clamps. 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).

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 film. Depending on the equipment being used and the availability of online computer control and data processing, either can be used: *Slack start procedure* (preferred procedure; see 11.3.1) or *Pretension-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 tapefilm is positioned in the centerline of the jaws of the clamp. Operate the testing machine at the rate as specified in 6.1.36.1 and stretch the specimen until it ruptures. When the specimen breaks, read the breaking force (*BF*) (maximum force) in Newtons [pounds-force] from the force-elongation curve, from the dial, from the display, or by electronic means. [pounds-force]. Discard specimens that do not break in the jaws or within 10 mm [with the free length between ⅛ in.] of the edge of the jaws. the clamp. 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.] will be slightly greater as specified in 10.311.3, but always will be somewhat more due to slack in the specimen after closing the clamps..

11.3.2 *Pretension-Start Procedure—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.

11.3.2.1 Use a tensioning device that applies a pretension corresponding to 20 ± 1 mN/tex [0.20 ± 0.01 gf/den] for high performance PE films. 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.

11.3.2.2 Place the sample between the clamps and close them. Move the crosshead until the pretension has been reached. Correct the gauge length for the displacement necessary to achieve the pretension. When the specimen breaks, read the breaking force (*BF*) (maximum force) in Newtons [pounds-force]. Discard specimens that do not break within the free length between the clamps. 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,~~film, 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 and the standard deviation from the observed breaking forces of specimens.

11.6 ~~*Report:*~~ Report results as stated in Section 18.

~~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~~Films

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

12.2 *Calculation*—Calculate the breaking tenacity of the sample in terms of ~~milliNewtons~~milliNewton per tex (mN/tex) (grams-force per denier (gf/den)) from the breaking ~~strength~~force and the linear density using Eq 1 or Eq 2.

$$BT_n = \frac{BF_n \cdot 1000}{LD_t} \tag{1}$$

$$BT_n = \frac{BF_n \cdot 1000}{LD_t} \tag{1}$$

$$BT_g = \frac{BF_l \cdot 454}{LD_d} \tag{2}$$

$$BT_g = \frac{BF_l \cdot 454}{LD_d} \tag{2}$$

where:~~*where:*~~

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

12.3 Calculate the average and standard deviation of the breaking tenacity.

12.4 ~~*Report:*~~ Report results as stated in Section 18.

~~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.~~

12.5 *Precision and Bias:*

12.5.1 See Section 19.

13. Elongation at Break of Conditioned ~~Tapes~~Films

13.1 *Scope*—This test method is used to determine the elongation at break of ~~tapes~~films after conditioning in the atmosphere for testing ~~UHMW Polyethylene.~~high performance 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 autographic recorder or by electronic means. The general equation for elongation at break is given in~~ force.~~Eq 3:~~

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

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

~~*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~~3:

$$L_o = L_s + DP \quad (3)$$

where:~~*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~~ high performance polyethylene film is 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 The equation for elongation at break for the slack start procedure and for the pretensioned procedure by moving the crosshead is given in Eq 4.

$$EB = \frac{E_{bf}}{L_s + DP} \cdot 100\,\% \quad (4)$$

where:

EB = elongation at break, %,

F_0 = Pretension force
DP = Slack
BF = Breaking force
E_{bf} = Extension at breaking force
$FASE$ = Force at specified elongation

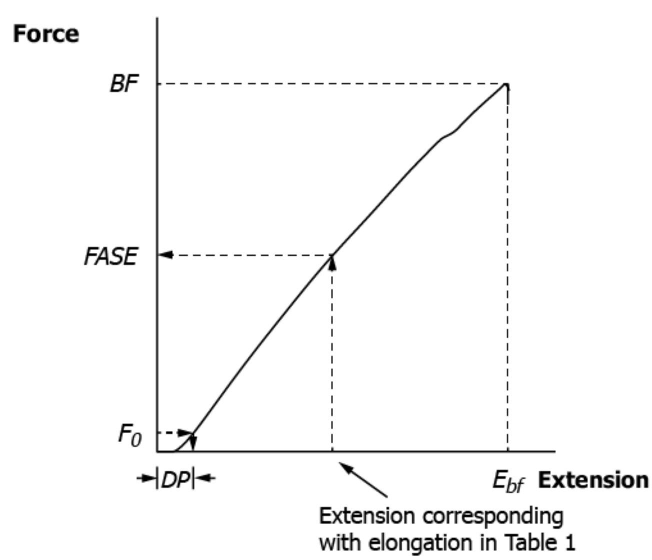

FIG. 1 Force-elongation Curve