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Standard Test Method for Tearing Strength of Fabrics by Falling-Pendulum Type (Elmendorf) Apparatus[1]

This standard is issued under the fixed designation D 1424; 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.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This test method covers the determination of the force required to propagate a single-rip tear starting from a cut in a fabric and using a falling-pendulum type (Elmendorf) apparatus.

1.2 This test method applies to most fabrics including woven, layered blankets, napped pile, blanket, and air bag fabrics, provided the fabric does not tear in the direction crosswise to the direction of the force application during the test. The fabrics may be untreated, heavily sized, coated, resin-treated, or otherwise treated. Instructions are provided for testing specimens with, or without, wetting.

1.3 This method is suitable only for the warp direction tests of warp-knit fabrics. It is not suited for the course direction of warp knit fabrics or either direction of most other knitted fabrics.

1.4 The values stated in either SI units or U.S. customary units are to be regarded as standard, but must be used independently of each other. The U.S. customary units may be approximate.

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]

D 123 Terminology Relating to Textiles

D 629 Test Methods for Quantitative Analysis of Textiles

D 1776 Practice for Conditioning and Testing Textiles

D 2261 Test Method for Tearing Strength of Fabrics by the Tongue (Single Rip) Procedure (Constant-Rate-of-Extension Tensile Testing Machine)

D 2904 Practice for Interlaboratory Testing of a Textile Test Method that Produces Normally Distributed Data

D 2906 Practice for Statements on Precision and Bias for Textiles

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

D 4850 Terminology Relating to Fabric

D 5587 Test Method for Tearing Strength of Fabrics by Trapezoid Procedure

3. Terminology

~~3.1 *Definitions:*~~

~~3.1.1 *cross-machine direction, CD*, *n*—the direction in the plane of the fabric perpendicular to the direction of manufacture.~~

~~3.1.1.1 *Discussion*—The term cross-machine direction is used to refer to the direction analogous to coursewise or filling direction in woven fabrics, respectively.~~

~~3.1.2 *length of tear*, *n*— *in tear testing of fabrics*, the measured distance propagated in a specimen by a tearing force from the initiation of the test to the termination of the test.~~

~~3.1.3 *machine direction, MD*, *n*—the direction in the plane of the fabric parallel to the direction of manufacture.~~

[1] This test method is under the jurisdiction of ASTM Committee D13 on Textiles and is the direct responsibility of Subcommittee D13.60 on Fabric Test Methods, Specific.

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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.

~~3.1.3.1*Discussion*—The term machine direction is used to refer to the direction analogous to walewise or warp direction in woven fabrics, respectively.~~

~~3.1.4*tearing energy*, *n*—the work done in tearing a material.~~

~~3.1.5*tearing force*, *n— in fabric*, the force applied to propagate a tear initiated under specified conditions.~~

~~3.1.6*tear resistance*, *n— in textiles*, the resistance to a tearing force.~~

~~3.1.7*tearing strength*, *n— in fabrics*, the force required to propagate a tear after its initiation.~~

~~3.1.8*fabric*, *n—in textiles* , a planar structure consisting of yarns or fibers.~~

~~3.1.9For definitions of other textile terms used in this test method, refer to Terminology D123. For definitions of other terms related to force and deformation in textiles, refer to Terminology D4848.~~

3.1 For all terminology relating to D13.59, Fabric Test Methods, General, refer to Terminology D 4850.

3.2 For all terminology relating to Force, Deformation and Related Properties in Textiles, refer to Terminology D 4848.

3.2.1 The following terms are relevant to this standard: cross-machine direction, CD, length of tear, machine direction, MD, tearing energy, tearing force, tear resistance, tearing strength, fabric.

3.3 For all other terminology related to textiles, refer to Terminology D 123.

4. Summary of Test Method

4.1 A slit is centrally precut in a test specimen held between two clamps and the specimen is torn through a fixed distance. The resistance to tearing is in part factored into the scale reading of the instrument and is computed from this reading and the pendulum capacity.

5. Significance and Use

5.1 This test method for the determination of tearing strength by the falling pendulum type apparatus is used in the trade for the acceptance testing of commercial shipments of fabrics, but caution is advised since technicians may fail to get good agreement between results on certain fabrics. Comparative tests as directed in 5.1.1 may be needed.

5.1.1 In case of a dispute arising from differences in reported test results when using this test method for acceptance testing of commercial shipments, the purchaser and the supplier should conduct comparative tests to determine if there is a statistical bias between their laboratories. Statistical assistance is recommended for the investigation of bias. As a minimum, the two parties should take a group of test specimens that are as homogeneous as possible and that are from a lot of fabric of the type in question. The test specimens should then be randomly assigned in equal numbers to each laboratory for testing. The average results from the two laboratories should be compared using appropriate statistical analysis and an acceptable probability level chosen by the two parties before the testing began. If a bias is found, either its cause must be found and corrected or the purchaser and the supplier must agree to interpret future test results with consideration to the known bias.

5.2 Microprocessor systems for automatic collection of data can provide economical and reliable results when properly calibrated. See Test Methods D 2261 and D 5587.

6. Apparatus

6.1 *Falling-Pendulum (Elmendorf) Type Tester*[3]—The tester includes: a stationary clamp, a clamp carried on a pendulum that is free to swing on a bearing, means for leveling as applicable, means for holding the pendulum in a raised position, means for instantly releasing the pendulum, and means for measuring the force to tear the test specimen.

6.1.1 A knife can be mounted on a stationary post for initial slitting of the specimens centered between the clamps and adjusted in height to give a tearing distance of 43.0 ± 0.15 mm (1.69 ± 0.005 in.); that is, the distance between the end of the slit made by the knife and the upper edge of the specimen is 43.0 ± 0.15 mm (1.69 ± 0.005 in.) when the lower edge of the 63.0-mm (2.5 ± 0.005 in.) wide specimen rests against the bottom of the clamp.

6.1.2 With the pendulum in its initial position ready for a test, the two clamps are separated by a distance of 2.5 ± 0.25 mm (0.1 ± 0.01 in.) and are aligned such that the clamped specimen lies in a plane parallel to the axis of the pendulum, the plane making an angle of 0.480 rad (27.5 ± 0.5°) with the perpendicular line joining the axis and the horizontal line formed by the top edges of the clamping jaws. The distance between the axis and the top edges of the clamping jaws is 103± 0.1 mm (4.055 ± 0.004 in.). The clamping surface in each jaw is at least 25 mm (1.0 in.) wide and 15.9 ± 0.1 mm (0.625 ± 0.004 in.) deep.

6.1.3 The tester may have a pointer mounted on the same axis as the pendulum to register the tearing force, or it may be substituted by means of calculating and displaying the required results without the use of a pointer, such as digital display and computer driven systems. Preferably the clamps may be air actuated, but manual clamping is permitted.

6.1.4 The test instrument should be equipped to provide interchangeable full scale force ranges. Typical full scale ranges are shown in Table A3.1.

6.2 *Calibration Weight(s)* for graduation of 50 % of the full scale force range, or other means as described by the manufacturer of the test apparatus.

6.3 *Cutting Die* having essentially the shape and dimensions shown in Fig. 1(a) or (b). Either die provides the basic rectangular test specimen 100 ± 2 mm (4 ± 0.05 in.) long by 63 ± 0.15 mm (2.5 ± 0.005 in.) wide, along with additional fabric at the top

[3] Apparatus is commercially available.

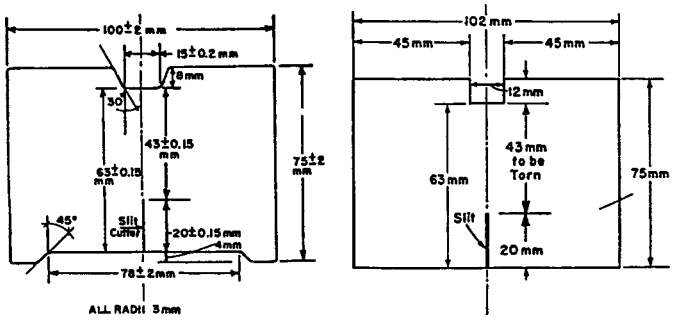

FIG. 1 Die Diagram for Cutting Notched Specimens

edge of the specimen to help ensure the bottom portion of specimen will be torn during the test. The critical dimension of the test specimen is the distance 43.0 ± 0.15 mm (1.69± 0.005 in.) which is to be torn during the test.

NOTE 1—The improved die model shown in Fig. 1(a) has two new features not found in the original model, Fig. 1(b), namely a cutout for the bottom of the specimen to aid in centering it in the clamps, and (optional) provision for cutting the 20.0 mm (0.75 in.) slit prior to inserting the specimen in the tester. These dies can be made to order by most die manufacturers.

6.4 *Air Pressure Regulator*, capable of controlling gage air pressure between 410 kPa and 620 kPa (60 psi and 90 psi), when applicable, for air clamps.

6.5 *Setting Gage for Cutting Blade* that will provide a cut slit that leaves a 43 ± 0.15 mm (1.69 ± 0.005 in.) specimen tearing distance for a 63 ± 0.15 mm (2.5 ± 0.005 in.) wide specimen, or equivalent.

6.6 *Jaw Spacing Gage* 2.5 ± 0.25 mm (0.1 ± 0.01 in.) width, or equivalent.

6.7 *Oil*, light weight, non-gumming clock type.

6.8 *Silicone Grease*, when applicable, for air clamp lubrication.

6.9 *Vacuum Cleaner*, when applicable, for cleaning dust and fiber from sensor, or equivalent.

7. Sampling and Test Specimens

7.1 *Lot Sample*—As a lot sample for acceptance testing, randomly select the number of rolls or pieces of fabric directed in an applicable material specification or other agreement between the purchaser and the supplier. Consider the rolls or pieces of fabric to be the primary sampling units. In the absence of such an agreement, take the number of fabric rolls or pieces specified in Table 1.

NOTE 2—An adequate specification or other agreement between the purchaser and supplier requires taking into account the variability between rolls or pieces of fabric and between specimens from a swatch from a roll or piece of fabric to provide a sampling plan with a meaningful producer's risk, consumer's risk, acceptable quality level, and limiting quality level.

7.2 *Laboratory Sample*—For acceptance testing, take a swatch extending the width of the fabric and approximately 1 m (1 yd) along the machine direction from each roll or piece in the lot sample. For rolls of fabric, take a sample that will exclude fabric from the outer wrap of the roll or the inner wrap around the core of the roll of fabric.

7.3 *Test Specimens*—From each laboratory sampling unit, take five specimens from the machine direction and five specimens from the cross-machine direction, for each test condition described in 9.1 and 9.2, as applicable to a material specification or contract order.

7.3.1 *Direction of Test*—Consider the long direction of the specimen as the direction of test.

7.3.2 *Cutting Test Specimens*—Take the specimens to be used for the measurement of machine direction with the longer dimension parallel to the machine direction. Take the specimens to be used for the measurement of the cross-machine with the longer dimension parallel to the cross-machine direction. Use the cutting die described in 6.3 and shown in Fig. 1(a) or (b), as applicable. When specimens are to be tested wet, cut from areas adjacent to the dry test specimens. Label to maintain specimen identity.

7.3.2.1 In cutting the woven fabric specimens, take care to align the yarns running in the short direction parallel with the die such that when the slit is cut, the subsequent tear will take place between these yarns and not across them. This precaution is most important when testing bowed fabrics.

TABLE 1 Number of Rolls or Pieces of Fabric in the Lot Sample

Number of Rolls or Pieces in Lot, Inclusive	Number of Rolls or Pieces in Lot Sample
1 to 3	all
4 to 24	4
25 to 50	5
over 50	10 % to a max of 10 rolls or pieces

7.3.2.2 Cut specimens representing a broad distribution across the width and length, and preferably along the diagonal of the laboratory sample, and no nearer the edge than one-tenth its width. Ensure specimens are free of folds, creases, or wrinkles. Avoid getting oil, water, grease, etc. on the specimens when handling.

NOTE 3—The reading obtained is directly proportional to the length of the material torn, therefore, it is essential that the specimen be prepared to the exact size specified.

8. Preparation of Apparatus and Calibration

8.1 Select test instrument force range, such that the tear occurs between 20 and 80 % or 20 and 60 % of the full-scale range as applicable. Ensure the clamps are spaced as directed in A1.4.

NOTE 4—For standard test apparatus, the useable portion of the full scale force range is 20 to 80 %. For the high capacity test instrument, the useable portion of the full scale force range is 20 to 60 %.

8.2 When equipped with a registering sensor, examine the scale and the complementary sensor, as applicable. Using care and without touching the sensor, vacuum away any loose fibers and dust.

8.3 Examine the knife edge for sharpness, wear, and central alignment as directed in A1.5-A1.7.

8.4 For air clamps, set the air gage pressure to the clamps to about 550 kPa (80 psi).

8.4.1 Maximum gage pressure should be no more than 620 kPa (90 psi) and minimum gage pressure no less than 410 kPa (60 psi).

8.5 When using microprocessor automatic data gathering systems, set the appropriate parameters as defined in the manufacturer's instructions.

8.6 Verify the calibration of the selected pendulum full scale force range using the procedure described in Annex A2, unless otherwise specified.

9. Conditioning

9.1 *Condition 1, Standard Testing Conditioning*:

9.1.1 Precondition the specimens by bringing them to approximate moisture equilibrium in the standard atmosphere for preconditioning textiles as directed in Practice D 1776, unless otherwise directed in a material specification or contract order.

9.1.2 After preconditioning, bring the test specimens to moisture equilibrium for testing in the standard atmosphere for testing textiles as directed in Practice D 1776 or, if applicable, in the specified atmosphere in which the testing is to be performed, unless otherwise directed in a material specification or contract order.

9.2 *Condition 2, Wet Specimen Testing Conditioning*:

9.2.1 When desizing treatments are specified prior to wet testing, use desizing treatments that will not affect the normal physical property of the fabric as directed in Test Method D 629.

9.2.2 Submerge the specimens in a container of distilled or deionized water at ambient temperature until thoroughly soaked (see 8.2.1.1).

9.2.2.1 The time of immersion must be sufficient to wet out the specimens, as indicated by no significant change in tearing force followed by longer periods of immersion. For most fabrics this time period will be about 1 h. For fabrics not readily wet out with water, such as those treated with water-repellent, or water resistant materials, add a 0.1 % solution of a nonionic wetting agent to the water bath.

10. Procedure

10.1 Test the conditioned specimens in the standard atmosphere for testing textiles, which is 21 ± 1°C (70 ± 2°F) and 65 ± 2 % relative humidity, unless otherwise directed in a material specification or contract order.

10.2 Position the pendulum to the starting position and the force recording mechanism to its zero-force position.

10.3 *For Tester-Slit Specimens*:

10.3.1 Place the long sides of the specimen centrally in the clamps with the bottom edge carefully set against the stops and the upper edge parallel to the top of the clamps. Close the clamps, securing the specimen with approximately the same tension on both clamps. The specimen should lie free with its upper area directed toward the pendulum to ensure a shearing action.

10.3.2 Using the built-in knife blade cut a 20 mm (0.787 in.) slit in the specimen extending from the bottom edge and leaving a balance of fabric 43.0 ± 0.15 mm (1.69 ± 0.005 in.) remaining to be torn.

10.4 *For Die-Cut or Manually Slit Specimens*:

10.4.1 If a die without a slit is used, manually cut a 20 mm (0.787 in.) long slit in the center of one edge of the long direction of the specimen. Ensure that the balance of the fabric remaining to be torn is 43 ± 0.15 mm (1.69 ± 0.005 in.).

NOTE 5—The length of the cut is important, see Note 3.

10.4.2 Place the parallel, unslit sides of the specimen in the clamps with the bottom edge carefully set against the stops, the upper edge parallel to the top of the clamp and the slit centrally located between the clamps. Close the clamps, securing the specimen with approximately the same tension on both clamps. The specimen should lie free with its upper area directed toward the pendulum to ensure a shearing action.

10.5 *For Wet Specimen Testing*:

10.5.1 Remove a specimen from the water and immediately mount it on the testing machine in the normal set-up. Perform the test within 2 min after removal of the specimen from the water. Otherwise, discard the specimen and replace with another one.

10.6 Depress the pendulum stop downward to its limit and hold it until the tear is completed and the pendulum has completed its forward swing. Catch the pendulum just after the threshold of its backward swing and return to its locked starting position. When equipped, be careful not to disturb the position of the pointer. Record the scale reading required to completely tear the test specimen.

10.6.1 The decision to discard the results of a tear shall be based on observation of the specimen during a test and upon the inherent variability of the material. In the absence of other criteria, such as in a material specification, if an unusual cause is detected, the value may be discarded and another specimen tested.

10.6.2 Reject readings obtained where the specimen slips in the jaw or where the tear deviates more than 6 mm (0.25 in.) away from the projection of the original slit. Note when puckering occurs during the test.

10.6.3 For microprocessor systems, follow the manufacturer's directions for removing values from memory when the decision to discard a tear value has been made. Otherwise, for some test instruments manual calculation of the average is required.

10.6.4 If, during the test, the scale reading does not reach 20 % or reaches over 80 % (60 % when applicable, see Table A3.1) of full scale range, change to the next lower or higher full scale range, as applicable. See 8.6.

10.6.5 Record if the tear was cross-wise to the normal (parallel) direction of tear and report that specimen, or that sample, as applicable, as untearable.

10.7 Remove the torn specimen and continue until five tears have been recorded for each test direction and test condition, as required, from each laboratory sampling unit.

11. Calculations

11.1 *Tearing Force, Individual Specimens* :

11.1.1 *Standard Test Instrument*—Determine the tearing force for individual specimens to the nearest 1 % of full-scale range using Eq 1.

$$F_t = R_s \times C_s/100 \quad (1)$$

where:

F_t = tearing force, cN (gf) or lbf,
R_s = scale reading,
C_s = full scale capacity, cN (gf) or lbf.

11.1.2 *Heavy Duty Test Instrument*—Determine the tearing force for individual specimens to the nearest 1 % of full-scale range using Eq 2.

$$F_t = R_s \times 100 \quad (2)$$

where:

F_t = tearing force, cN (gf) or lbf, and
R_s = scale reading, cN (gf) or lbf.

11.2 *Tearing Strength*—Calculate the tearing strength as the average tearing force for each test direction and testing condition of the laboratory sampling unit and for the lot, to the nearest 1 % of full-scale range in cN, (gf) or lbf.

11.3 *Standard Deviation and Coefficient of Variation* —Calculate when requested.

11.4 *Computer-Processed Data*—When data are automatically computer-processed, calculations are generally contained in the associated software. Record values as read from the direct reading scale to the nearest mN (gf). In any event, it is recommended that computer-processed data be verified against known property values and its software described in the report.

12. Report

12.1 Report that the Elmendorf tearing strength was determined as directed in Test Method D 1424. Describe the fabric or product sampled and the method of sampling used.

NOTE 6—Some instruments may require different calculations than percentage of scale. In those cases, refer to manufacturer's recommended calculations.

12.2 Report the following information for each laboratory sampling unit and for the lot as applicable to a material specification or contract order.

12.2.1 Elmendorf tearing strength for each test direction and testing condition, as requested.

12.2.2 Condition of test (with or without wetting).

12.2.3 Puckering, if it occurs during the test.

12.2.4 Number of tests rejected because of crosswise tearing.

12.2.5 When calculated, the standard deviation or the coefficient of variation.

12.2.6 For computer-processed data, identify the program (software) used.

12.2.7 Make, model and capacity of testing machine.

TABLE 2 Elmendorf Tear Strength, g

Machine Type and Materials[B]	Number of Observations in Each Average	Critical Differences for the Conditions Noted[A]: Single-Operator Precision	Within-Laboratory Precision	Between-Laboratory Precision
Standard Machine				
Plain, spun yarns, MAT 2	1	556	556	632
	2	393	393	495
	5	249	249	391
	10	176	176	349
Plain, spun yarns, MAT 4	1	135	146	184
	2	95	111	158
	5	60	83	140
	10	43	72	133
Plain, cont. fil. yarns, MAT 5	1	538	557	765
	2	380	407	664
	5	240	281	595
	10	170	224	570
Heavy Duty Machine				
Twill, spun yarns, MAT 1	1	405	482	497
	2	286	387	406
	5	181	317	340
	10	128	290	315
Plain, spun yarns, MAT 3	1	934	934	1280
	2	660	660	1097
	5	418	418	970
	10	295	295	924
Denin twill, spun yarns, MAT 9	1	561	653	1478
	2	397	519	1224
	5	251	418	1390
	10	177	378	1379

[A] The critical differences were calculated using $t = 1.960$, which is based on infinite degrees of freedom.

[B] See 13.2 and 13.3 for additional material description.

12.2.8 Type of clamps used, manual or pneumatic (including pressure).

12.2.9 Any modification of the test method.

13. Precision and Bias

13.1 *Summary*—In comparing two averages, the differences should not exceed the single-operator precision values shown in Table 2 for the respective number of tests, and for fabrics having averages similar to those shown in Table 2, in 95 out of 100 cases when all the observations are taken by the same well-trained operator using the same piece of equipment and specimens are randomly drawn from the sample of fabric. Larger differences are likely to occur under all other circumstances.

13.2 *Elmendorf Tearing Strength, Standard Equipment, Interlaboratory Test Data*—An interlaboratory test was run in 1994–1995 in which randomly-drawn samples of three fabrics were tested in each of eleven laboratories. Two operators in each laboratory each tested eight specimens of each fabric using Test Method D 1424. Four of the eight specimens were tested on one day and four specimens were tested on a second day. Analysis of the data was conducted using the Practice D 2904 and Practice D 2906. The components of variance for Elmendorf tear strength expressed as standard deviations were calculated to be the values listed in Table 3. The three woven fabric types were:

(1) Material 2—S/1016H, 2/1 basket plain weave sheeting, with spun yarns,

(2) Material 4—S/0008H, plain weave sheeting, with spun yarns,

(3) Material 5—S/2438, plain weave, oxford, spun yarns.

13.3 *Elmendorf Tearing Strength, Heavy Duty Equipment, Interlaboratory Test Data*—An interlaboratory test was run in 1994 in which randomly-drawn samples of three fabrics were tested in six laboratories. Two operators in each laboratory each tested eight specimens of each fabric using Test Method D 1424. Four of the eight specimens were tested on one day and four specimens were tested on a second day. Analysis of the data was conducted using Practice D 2904 and Practice D 2906. The components of variance for Elmendorf tear strength expressed as standard deviations were calculated to be the values listed in Table 3. The three woven fabric types were:

(1) Material 1—S/179B, twill weave, with spun yarns,

(2) Material 3—S/1008H, plain weave sheeting, with spun yarns,