Designation: D 5733 – 99

Standard Test Method for Tearing Strength of Nonwoven Fabrics by the Trapezoid Procedure[1]

This standard is issued under the fixed designation D 5733; 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 measurement of the tearing strength of nonwoven fabrics by the trapezoid procedure using a recording constant-rate-of-extension (CRE) tensile testing machine.

1.1.1 The CRE-type tensile testing machine has become the preferred test apparatus for determining trapezoid tearing strength. It is recognized that some constant-rate-of-traverse (CRT) tensile testing machines continue to be used. As a consequence, these test instruments may be used when agreed upon between the purchaser and the supplier. The conditions for the CRT-type tensile tester as used with this test are included in Appendix X1.

1.2 This test method applies to most nonwoven fabrics including those that are treated or untreated, heavily sized, coated, or resin-treated. This test method may not be useful for highloft nonwoven fabrics.

1.3 Trapezoid tear strength as measured in this test method is the maximum tearing force required to continue or propagate a tear started previously in the specimen. The reported value is not directly related to the force required to initiate or start a tear.

1.4 The values stated in SI units are to be regarded as the standard. The inch-pound units given in parentheses 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:*

D 76 Specification for Tensile Testing Machines for Textiles[2]

D 123 Terminology Relating to Textiles[2]

D 1776 Practice for Conditioning Textiles for Testing[2]

D 2904 Practice for Interlaboratory Testing of a Textile Test Method That Produces Normally Distributed Data[2]

D 4848 Terminology of Force, Deformation, and Related Properties of Textiles[3]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *lengthwise direction, n—in textiles*, the direction in a machine-made fabric parallel to the direction of movement the fabric followed in the manufacturing machine.

3.1.1.1 *Discussion*—For nonwovens, an easily distinguishable pattern for orientation may not be apparent, especially if removed from the roll. Care should be taken to maintain the directionality by clearly marking the direction.

3.1.2 *nonwoven fabric, n*—a textile structure produced by bonding or interlocking of fibers, or both, accomplished by mechanical, chemical, thermal, or solvent means, or combination thereof.

3.1.3 *tearing force, n*—the average force required to continue a tear previously started in a fabric.

3.1.3.1 *Discussion*—For nonwovens, the tearing force is recorded as the maximum force required to continue a tear previously started in a fabric. The tearing force may appear as a single peak or a series of peaks on a force-extension curve, depending on the nature of the material. Typically for nonwoven fabrics, if a small decrease in force occurs at a time when the applied force is increasing, it is not considered as a peak unless the indicated force exceeds the force required to break, individually or collectively, the fibers, fiber bonds, or fiber interlocks. Lower shifts corresponding to fiber movement do not qualify as peaks since the fibers, fiber bonds, or fiber interlocks are not broken. The trapezoid tearing force may be calculated from a single-peak or multiple-peak force-extension curve.

3.1.4 *tearing strength, n*—the force required either to start or to continue or propagate a tear in a fabric followed in the manufacturing process.

3.1.5 *widthwise direction, n—in textiles*, the direction in a machine-made fabric perpendicular to the direction of movement the fabric followed in the manufacturing machine.

3.2 *Definitions*—For definitions of other terms related to force and deformation of textiles used in this test method, refer to Terminology D 4848. For definitions of other textile terms, refer to Terminology D 123.

[1] This test method is under the jurisdiction of ASTM Committee D-13 on Textiles and is the direct responsibility of Subcommittee D13.64 on Nonwoven Fabric.

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[2] *Annual Book of ASTM Standards*, Vol 07.01.

[3] *Annual Book of ASTM Standards*, Vol 07.02.

4. Summary of Test Method

4.1 An outline of an isosceles trapezoid is marked on a rectangular specimen cut for the determination of tearing strength (see Fig. 1). The specimen is slit at the center of the smallest base of the trapezoid to start the tear. The nonparallel sides of the trapezoid marked on the specimen are clamped in parallel jaws of a tensile testing machine. The separation of the jaws is continuously increased to apply a force to propagate the tear across the specimen. At the same time, the force developed is recorded. The maximum force to continue the tear is calculated from autographic chart recorders, or microprocessor data collection systems.

5. Significance and Use

5.1 This test method is used in the trade for acceptance testing of commercial shipments of nonwoven fabrics, however, caution is advised since information about between-laboratory precision is incomplete. Comparative tests as directed in 5.1.1 may be advisable.

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. Competent 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 material of the type in question. 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 the appropriate Student's *t*-test and an acceptable probability level chosen by the two parties before testing is begun. 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 in view of the known bias.

5.2 The trapezoid tear method is a test that produces tension along a reasonably defined course such that the tear propagates across the width of the specimen. It is useful for estimating the relative tear resistance of different fabrics or different directions in the same fabric.

5.3 For nonwoven fabrics, because the individual fibers are more or less randomly oriented and capable of some reorientation in the direction of the applied force, the maximum trapezoid tearing strength is reached when the resistance to further reorientation is greater than the force required to rupture one or more fibers or the fiber interlocking, simultaneously. The tearing strength is determined primarily by the bonding or interlocking of fibers in the structure.

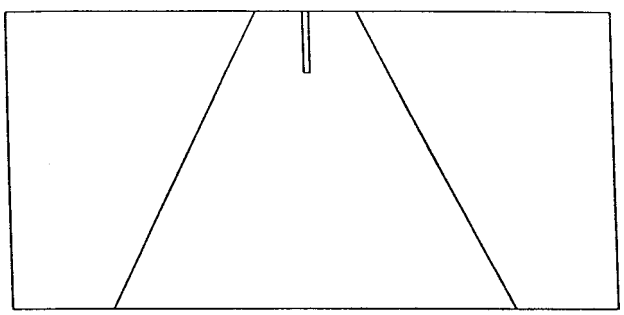


FIG. 1 Diagram of Marked Trapezoid Specimen

5.4 Depending on the nature of the specimen, the data recording devices usually will show the tearing force in the form of single peak. The highest peak appears to reflect the strength combination needed to stop a tear in a fabric of the same construction.

5.5 Most nonwoven fabrics can be tested by this test method. Some modification of clamping techniques may be necessary for a given fabric, depending upon its structure. Special adaptation may be necessary with strong fabrics, or fabrics made from glass fibers, to prevent them from slipping in the clamps or being damaged as a result of being gripped in the clamps.

5.6 The CRE-type is the preferred tensile testing machine. This test method allows the use of the CRT-type tensile machine when agreed upon between the purchaser and the supplier. However, there may be no overall correlation between the results obtained with the CRT machine and the CRE machine. Consequently, these two tensile testers cannot be used interchangeably unless the degree of quantitative correlation has been established between the purchaser and the supplier. In any event, the CRE machine shall prevail.

6. Apparatus

6.1 *Tensile Testing Machine*, of the constant-rate-of-extension (CRE) type conforming to the requirements of Specification D 76 with autographic recorder, or automatic microprocessor data gathering systems.

6.2 *Clamps*, having all gripping surfaces parallel, flat, and capable of preventing slipping of the specimen during a test, and measuring 50 by no less than 75 mm (2 by no less than 3 in.), with the longer dimension perpendicular to the direction of application of the force.

6.2.1 The use of hydraulic pneumatic clamping systems with a minimum of 50 by 75-mm (2 by 3-in.) serrated or rubber jaw faces having a clamping force at the grip faces of 13 to 14 kN (2900 to 3111 lbf) is recommended. Manual clamping is permitted providing no slippage of the specimen is observed.

6.2.2 For some materials, to prevent slippage when using jaw faces other than serrated, such as rubber-faced jaws, they may be covered with a No. 80 to 120 medium-grit emery cloth. Secure the emery cloth to the jaw faces with pressuresensitive tape.

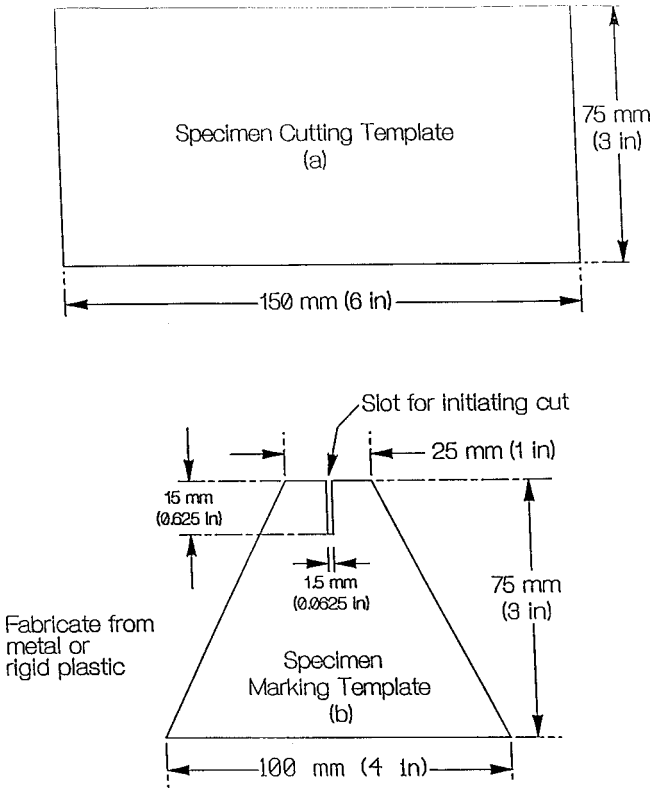
6.3 *Cutting Die or Template*, having essentially the shape and dimensions with tolerances of ± 0.5 % shown in Fig. 2(*a*).

6.4 *Trapezoidal-Shaped Template*, having dimensions with tolerances of ± 0.5 % as shown in Fig. 2(*b*).

7. Sampling and Test Specimens

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

NOTE 1—An adequate specification or other agreement between the



NOTE 1—All tolerances ± 0.5 %.

FIG. 2 Templates for Cutting (a) and Marking (b) Trapezoid Test Specimens

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

Number of Rolls, 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 maximum of ten rolls or pieces

purchaser and the supplier requires taking into account the variability between rolls or pieces of fabric and between specimens from a swatch from a roll or pieces 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 the laboratory sample, take a sample 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.

7.3 *Test Specimens*—From each laboratory sampling unit, take five specimens from the lengthwise direction and five specimens from the widthwise direction, for each test condition described in 8.1-8.3 as, applicable to a material specification or contract order. Use the cutting die or template described in 6.3 and shown in Fig. 2. Mark each specimen with an isosceles trapezoid template (see Figs. 1 and 2). Make a preliminary cut 15 mm (0.625 in.) long at the center of the 25-mm (1-in.) edge, as shown in Figs. 1 and 2.

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

7.3.2 *Cutting Test Specimens*—Take the specimens for the measurement of the lengthwise direction from different positions across the fabric width. Take the specimens for the measurement of the widthwise direction from different positions along the length of the fabric. Cut the specimens to be used for the measurement of the lengthwise direction with the shorter dimension parallel to the lengthwise direction. Cut the specimens to be used for the measurement of the widthwise direction with the shorter dimension parallel to the widthwise direction. When specimens are to be tested wet, take the specimens from areas adjacent to the dry test specimens. Label to maintain specimen identity.

7.3.2.1 Cut specimens representing a broad distribution across the width 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, and so forth, on the specimens when handling.

7.3.2.2 Refer to Fig. 3 for illustration of the relationship of specimen orientation with respect to test direction.

8. Preparation of Apparatus

8.1 Set the distance between the clamps at the start of the test at 25 ± 1 mm (1 ± 0.05 in.). Select the full-scale force range of the testing machine such that the maximum force occurs between 15 and 85 % of full-scale force.

8.2 Set the testing speed to 300 ± 10 mm (12± 0.5 in./min).

8.3 Verify calibration of the tensile testing machine as directed in the manufacturer's instructions or Specification D 76.

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

9. Conditioning

9.1 *Condition 1, Unspecified Testing Conditioning*—No conditioning is required unless otherwise specified in a material specification or contract order.

9.2 *Condition 2, Standard Testing Conditioning*:

9.2.1 When specified, precondition the specimens by bringing them to approximate moisture equilibrium in the standard atmosphere for preconditioning textiles as directed in Practice D 1776.

9.2.2 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.

9.3 *Condition 3, Wet Specimen Conditioning Testing*:

9.3.1 Place the specimens in a container and submerge in distilled or deionized water at ambient temperature until thoroughly soaked (see 9.3.1.1).

9.3.1.1 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 one hour. For fabrics not readily wet out with water, such as those treated with water-repellent or water-resistance materials, add a 0.1 % solution of

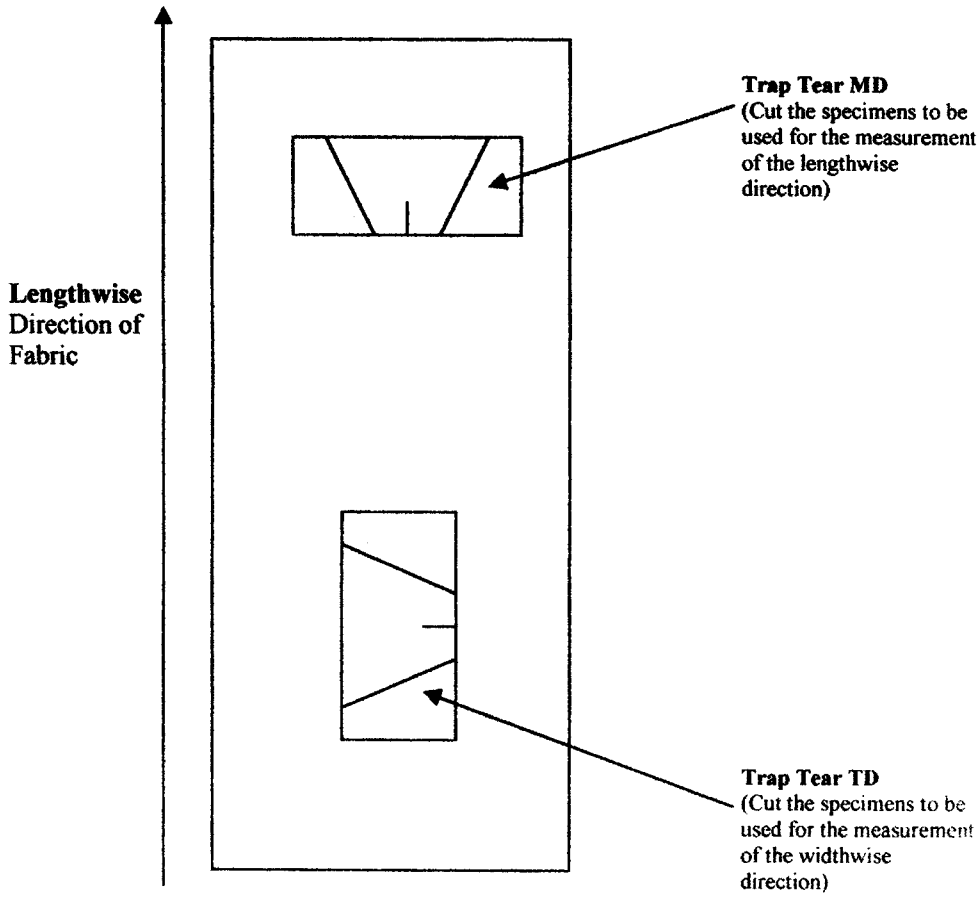


FIG. 3 Illustration of Test Direction and Orientation of Specimens Within Laboratory Sample

a nonionic wetting agent to the water bath.

10. Procedure

10.1 Test the specimens in the atmosphere as directed in an applicable material specification or contract order.

10.2 Secure the test specimen in the machine, clamping along the nonparallel sides of the trapezoid such that the end edges of the clamps are in line with the 25-mm (1-in.) long side of the trapezoid, and the cut is halfway between the clamps. Hold the short edge taut and let the remaining fabric lie in folds.

10.2.1 For wet specimens, remove the specimens from the water and immediately mount it on the testing machine in the normal setup. Perform the test within 2 min after removal of the specimen from the water. If more than 2 min elapse between taking the wet specimen from the water bath and starting a tensile testing machine, discard the specimen and take another.

10.2.2 Start the machine and record the tearing force on the recording device. The tearing force may increase to a simple maximum value, or may show several maxima and minima, as shown in Fig. 4.

10.2.3 After the crosshead has moved to produce approximately 6 mm (0.25 in.) of fabric tear, record the maximum tearing force (see Fig. 4). Stop the crosshead motion after a total clamp separation of approximately 75 mm (3 in.) or the fabric has torn completely across and return the crosshead to its starting position.

10.2.4 If a fabric slips in the jaws or if 25 % or more of the specimens break at a point within 5 mm (0.25 in.) of the edge

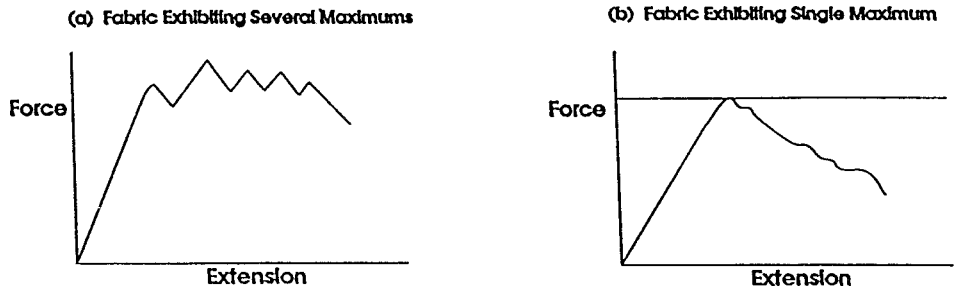


FIG. 4 Typical Trapezoid Tearing Force-Extension Curves for Individual Test Specimens

of the jaw, then the jaws may be padded; the fabric may be coated under the jaw face area; or the jaw face may be modified. If any of these modifications are used, state the method of modification in the report.

10.2.5 If 25 % or more of the specimens break at a point within 5 mm (0.25 in.) of the edge of the jaw after making the modifications described in 10.2.4 consider the fabric untearable by this test method.

10.2.6 Report if the tear occurs crosswise to the direction of applied force.

10.2.7 Remove the tested specimen and continue as directed in 10.2-10.2.6 until five specimens have been tested for each principal direction from each laboratory sampling unit.

11. Calculation

11.1 *Tearing Force, Individual Specimens*—Calculate the trapezoid tearing force for individual specimens using readings directly from the data collection system. Record the maximum tearing force to the nearest 0.5 N (0.1 lbf), unless otherwise agreed upon between the purchaser and the supplier.

11.2 *Tearing Strength*—Calculate the average trapezoid tearing for each principal direction of each laboratory sample and the lot.

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

11.4 *Computer-Processed Data*—When data is automatically computer processed, calculations are generally contained in the associated software. Record values as read from the direct reading scale to the nearest 0.5 N (0.1 lbf). 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 trapezoid tearing strength was determined as directed in this test method. Describe the material or product sampled and the method of sampling used.

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

12.2.1 Trapezoid tearing strength for each principal direction, as requested,

12.2.2 Number of specimens tested for each direction,

12.2.3 Condition of the specimens (dry or wet),

12.2.4 When calculated, the standard deviation or the coefficient of variation,

12.2.5 For computer processed data, identify the program (software) used,

12.2.6 Make, model, and capacity of testing machine,

12.2.7 Type of clamps used,

12.2.8 Test room conditioning, and

12.2.9 Any modification of the test method.

13. Precision and Bias

13.1 *Summary*—Preliminary interlaboratory test data have shown that the variance in testing tearing strength of nonwoven fabrics by this test method is dependent upon the nominal tearing strength and to some extent the manufacturing method of the material under evaluation; therefore, no general statement can be made concerning least critical differences. The following data were generated during the interlaboratory test and are presented for reference. In comparing two averages of five observations, the difference between averages should not exceed the following values 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 same sample having a nominal tearing strength indicated:

Nominal Tearing Strength (lbf) (Critical Differences)	Tearing Strength (lbf) (Critical Differences)
Machine Direction	
0.50	0.09
2.30	0.42
3.15	0.82
18.60	3.52
Transverse Direction	
0.45 (Meltblown)	0.11
0.50 (Wet Laid)	0.06
0.55 (Dry Laid)	0.12
0.70 (Resin Bonded)	0.16
0.84 (Thermal)	0.29
7.75 (Hydroentangled)	0.83

Larger differences are likely to occur under all other circumstances. This procedure for determining thickness has no other known bias and is considered a referee method.

13.2 *Interlaboratory Test Data*—A preliminary interlaboratory test was run in 1992 in which randomly drawn samples of six materials were tested in each of six laboratories utilizing the "dry" conditions. Data from two laboratories was deleted as obvious outliers when procedural errors were found to be present. Two operators in each laboratory tested five specimens of each material. The six materials used in this evaluation were all manufactured by different processes. Analysis of the data using the adjunct to Practice D 2904 suggested reporting the components of variance and least critical differences based upon nominal tearing strength, with some interaction based on the manufacturing method. The components of variance, expressed as standard deviations, for each nominal tearing strength, and where appropriate the method of manufacturing are listed in Table 2 (see Note 2). Further testing is in progress to elucidate the ruggedness of this test method and possible revision.

13.3 *Precision*—For the components of variance listed in Table 2, the averages of two observed values should be

TABLE 2 Components of Variance as Standard Deviations[A]

NOTE 1—Tearing strength expressed in pounds-force.

Nominal Tearing Strength	Single-Operator Component	Within-Laboratory Component	Between-Laboratory Component
Machine Direction			
0.50	0.07	0.06	0.06
2.30	0.33	0.44	0.57
3.15	0.66	0.46	0.76
18.60	2.84	1.89	2.00
Transverse Direction			
0.45 (Meltblown)	0.09	0.08	0.06
0.50 (Wet laid)	0.05	0.10	0.03
0.55 (Dry laid)	0.10	0.10	0.06
0.70 (Resin bonded)	0.13	0.16	0.12
0.84 (Thermal)	0.23	0.13	0.08
7.75 (Hydroentangled)	0.67	1.25	0.00

[A] lbf × 4.45 = newtons

considered significantly different at the 95 % probability level if the difference equals or exceeds the critical differences listed in Table 3 (see Note 3). Due to the dependence of the components of variance on nominal tearing strength and to some extent the manufacturing process no meaningful statement can be made at this time relative to betweenmaterial comparisons.

13.4 *Bias*—The procedure in this test method for determining the tearing strength of nonwoven fabrics has not been checked against accepted reference materials but contains no known bias other than those noted. This test method is accepted as a referee method.

NOTE 2—The square roots of the components of variance are listed in Table 2 so that the variability is expressed in the appropriate units of measure rather than as the square of those units of measure.

NOTE 3—The values of the tabulated differences should be considered to be a general statement, particularly with respect to between-laboratory precision. Before a meaningful statement can be made about two specific laboratories, the amount of statistical bias, if any, between them must be established with each comparison being based on recent data obtained on specimens taken from a lot of material of the type being evaluated so as to be as homogeneous as possible, and then randomly assigned in equal numbers to each of the laboratories.

TABLE 3 Critical Differences for Conditions Noted 95 % Probability Level[A]

NOTE 1—Tearing strength expressed in pounds-force.

Nominal Tearing Strength	Observations in Each Average	Single-Operator Precision	Within-Laboratory Precision	Between-Laboratory Precision
Machine Direction				
0.50	5	0.09	0.19	0.26
	10	0.06	0.18	0.25
2.30	5	0.42	1.30	2.06
	10	0.29	1.26	2.03
3.15	5	0.82	1.52	2.59
	10	0.58	1.40	2.53
18.60	5	3.52	6.31	8.40
	10	2.49	5.79	8.02
Transverse Direction				
0.45 (Meltblown)	5	0.11	0.25	0.29
	10	0.08	0.23	0.28
0.050 (Wet Laid)	5	0.06	0.28	0.29
	10	0.05	0.27	0.29
0.55 (Dry Laid)	5	0.12	0.31	0.35
	10	0.09	0.30	0.34
0.70 (Resin Bonded)	5	0.16	0.48	0.58
	10	0.12	0.47	0.57
0.84 (Thermal)	5	0.29	0.46	0.51
	10	0.20	0.41	0.47
7.75 (Hydroentangled)	5	0.83	3.58	3.58
	10	0.59	3.53	3.53

[A] lbf × 4.45 = newtons

14. Keywords

14.1 nonwoven fabric; tearing strength; trapezoid

APPENDIX

(Nonmandatory Information)

X1. CONDITIONS WHEN USING CRT-TYPE TENSILE TESTER

X1.1 The following information is provided for determining trapezoid tearing strength using the CRT-type tensile tester when agreed upon between the purchaser and the supplier. The conditions cited are used with this test method as a substitute, as applicable.

X1.2 Tensile testing machine, of the constant-rate-of traverse (CRT) pendulum type conforming to the requirements of Specification D 76 with autographic recorder, or automatic microprocessor data gathering systems.

X1.3 Set the testing speed to 300 ± 10 mm/min (12 ± 0.5 in./min). Disengage the pawls from the rachet to render them inoperative.

X1.4 Report that the trapezoid tearing test was determined using a CRT-type tensile tester.