Designation: D 1294 – 95a (Reapproved 2001)

Standard Test Method for Tensile Strength and Breaking Tenacity of Wool Fiber Bundles 1-in. (25.4-mm) Gage Length[1]

This standard is issued under the fixed designation D 1294; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the determination of the breaking force (or load) and estimation of the tensile strength and tenacity of wool fiber bundles with a 1-in. (25.4-mm) gage length. A procedure for preparation of the fiber bundle is included.

1.2 The values stated in inch-pound units are to be regarded as standard; the values in SI units are provided for information only. Because the instrument is calibrated in inch-pound units, inch-pound units are shown first, contrary to Committee D13 policy.

NOTE 1—For other methods of measuring breaking tenacity of fiber bundles, refer to Test Methods D 1445 and D 2524.

NOTE 2—This test method can be used for other fibers that lend themselves to the same kind of preparation but the difference in density must be taken into account when calculating the tensile strength. It is not necessary to know or correct for the density of a fiber when calculating breaking tenacity.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibiltiy 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 1445 Test Method for Breaking Strength and Elongation of Cotton Fibers (Flat Bundle Method)[2]

D 1776 Practice for Conditioning Textiles for Testing[2]

D 2524 Test Method for Breaking Tenacity of Wool Fibers, Flat Bundle Method—⅛-in. (3.2-mm) Gage Length[2]

D 2525 Practice for Sampling Wool for Moisture[2]

3. Terminology

3.1 *Definitions:*

3.1.1 *breaking tenacity*, *n*—the tenacity corresponding to the breaking load.

3.1.1.1 *Discussion*—Breaking tenacity is commonly expressed as grams-force per tex (gf/tex), grams-force per denier (gf/den), millinewtons per tex mN/tex), or millinewtons per denier (mN/den). Millinewtons are numerically equal to grams-force times 9.81.

3.1.2 *constant-rate-of-extension (CRE) type tensile testing machine*, *n—in tensile testing*, an apparatus in which the pulling clamp moves at a uniform rate, and the force-measuring mechanism moves a negligible distance with increasing force, less than 0.13 mm (0.005 in.).

3.1.3 *constant-rate-of-loading (CRL) type tensile testing machine*, *n—in tensile testing*, an apparatus in which the rate of increase of the force is uniform with time after the first 3 s and the specimen is free to elongate, this elongation being dependent on the extension characteristics of the specimen at any applied force.

3.1.4 *constant-rate-of-traverse tensile testing machine (CRT)*, *n—in tensile testing*, an apparatus in which the pulling clamp moves at a uniform rate and the force is applied through the other clamp, which moves appreciably to actuate a force-mechanism, producing a rate of increase of force or extension that is usually not constant and is dependent upon the extension characteristics of the specimen.

3.1.5 *gage length*, *n— in tensile testing*, the length of a specimen measured between the points of attachment to clamps while under uniform tension.

3.1.6 *recycled wool*, *n— as defined in the Wool Products Labeling Act as amended in 1980*, "the resulting fiber when wool has been woven or felted into a wool product which, without ever having been utilized in any way by the ultimate consumer, subsequently has been made into a fibrous state, or the resulting fiber when wool or reprocessed wool has been spun, woven knitted or felted into a wool product which, after having been used in any way by the ultimate consumer, subsequently has been made into a fibrous state."

3.1.6.1 *Discussion*—In the amended Act of 1980, the term "recycled wool" replaced the terms "reprocessed wool" and "reused wool."

3.1.7 *tenacity*, *n—in a tensile test*, the force exerted on the specimen based on the linear density of the unstrained specimen.

[1] This test method is under the jurisdiction of ASTM Committee D13 on Textiles and is the direct responsibility of Subcommittee D13.13 on Wool and Wool Felt.

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

3.1.7.1 *Discussion*—In textiles, tenacity is considered a property of fibers and yarns, and tensile strain is the complementary property of fabrics. In direct yarn numbering systems, tenacity is forced divided by linear density. In indirect yarn numbering systems, tenacity is force times the reciprocal linear density.

3.1.8 *tensile strength*, *n*—the strength of a material under tension as distinct from compression, torsion or shear.

3.1.8.1 *Discussion*—Technically, strength is a characteristic that is expressed in terms of force. Historically, however, tensile strength has been commonly expressed in terms of force per unit base, for example, the cross-sectional area of the unstrained material. Some common units are newtons per square metre (N/m^2) and pounds-force per square inch (psi).

3.1.9 *wool*, *n*—the fibrous covering of sheep, *Ovis* species.

3.1.9.1 *Discussion*—For the purposes of this test method, the word *wool* is used in the generic sense, and includes both *wool* as defined in the Wool Products Labeling Act of 1939 as well as recycled wool as defined in the amended Act of 1980.

3.1.10 *wool*, *n—as defined in the Wool Products Labeling Act of 1939*, "the fiber from the fleece of the sheep or lamb, or hair of the Angora goat or Cashmere goat (and may include the so called specialty fibers from the hair of the camel, alpaca, llama, and vicuna) which has never been reclaimed from any woven or felted wool product."

3.1.11 For definitions of other textile terms used in this test method, refer to Terminology D 123.

4. Summary of Test Method

4.1 The strength determination is based on the load required to break a bundle of fibers which had been parallelized and held under uniform tension with masking tape. A 1-in. (25.4-mm) spacing between the tapes (and clamps at the zero setting) makes possible the cutting and weighing of this amount of fiber for use in calculating the strength expressed as breaking tenacity in grams-force per tex or tensile strength in pounds-force per square inch.

5. Significance and Use

5.1 Test Method D 1294 for the determination of tensile strength may be used for the acceptance testing of commercial shipments of wool, but caution is advised since technicians may fail to get good agreement between results. 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 Test Method D 1294 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. 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 Student's *t*-test for unpaired data and an acceptable probability level chosen by the two parties before the 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 the light of the known bias.

5.2 This test method is useful in studying the relationship between fiber strength and product quality; results should be considered comparative rather than fundamental since the strength found will be lower than the sum of the strengths of the individual fibers present due to slight differences in tensioning.

5.3 Elongation may be obtained also but the accuracy of elongation measurements is limited and their determination is, therefore, not included as a formal part of this test method.

5.4 The basic differences between the procedures employed in this test method and those of Test Method D 2524 are in the gage lengths employed and the methods of clamping. In Test Method D 2524, specific clamps are required whereas in Test Method D 1294, any conventional clamps may be used. Results for breaking load determined by Test Method D 2524 average 30 % higher than those obtained by Test Method D 1294.

6. Apparatus and Materials

6.1 *Comb*, fine, sharp.[3]

6.2 *Analytical Balance*, with a sensitivity of 0.0001 g.

6.3 *Tensile Testing Machine*, a CRE or CRT Type about 50-lb (22-kg) capacity machine as prescribed in Specification D 76, capable of operating the moving clamp at a uniform speed of 10.0 ± 0.5 in./min (250 ± 12 mm/min). If a CRL type machine is used, it should be capable of operating at a rate of loading of 1 kgf/s (10 N/s). In no case shall the working range be outside the limits recommended by the manufacturer.

NOTE 3—There may be no overall correlation between the results obtained with the CRE, CRT, or CRL type testing machines. Consequently, these three machines cannot be used interchangeably.

6.4 *Metal Plates*, 2 by 1-in. (50.8 by 25.4-mm) with one rubber-covered surface. The plates should be rigid, flat, and approximately 0.1 in. (2.5 mm) thick with one rubber face approximately 0.06 in. (1.5 mm) thick (Note 4). Two plates are required to prepare a bundle for testing.

NOTE 4—These plates can be made by gluing rubber sheeting approximately 0.06 in. (1.5 mm) thick to the face of the plate.

6.5 *Hand Vise*,[3] preferably of the spring-type.

6.6 *Masking Tape*, 2-in. (50-mm) wide, heavy.

7. Sampling

7.1 *Division into Lots*—Treat a single shipment of a single fiber type as a lot.

7.2 *Lot Sample*—As a lot sample for acceptance testing, take at random the number of shipping containers directed in an applicable material specification or other agreement between the purchaser and the supplier, such as an agreement to use Practice D 2525. Consider shipping containers to be the primary sampling units.

7.3 *Laboratory Sample*—For acceptance testing, take a laboratory sample from each shipping container in the lot sample as follows:

[3] The comb and hand vise supplied with the Suter Sorter wool fiber stapling apparatus are suitable for this test method and are available from the Alfred Suter Co., Inc., Prel Plaza, Orangeburg, NY 10962.

7.3.1 For loose fiber, grease, and scoured wool, reduce the mass of clean fiber submitted for testing to approximately 15 g by randomly selecting pieces throughout the mass. Form into a loose sliver by hand.

7.3.2 For card sliver and top, cut a length of sliver about 20 in. (500 mm) long from each ball submitted for testing.

7.3.3 For roving, cut a length about 20 in. (500 mm) long from each spool submitted for testing and include all ends.

7.4 *Test Specimens*—Scour or solvent-extract the laboratory sample until residual contamination is 1 % or less of the laboratory mass, as established by further cleaning of a part of the laboratory sample. From each unit in the laboratory sample, prepare five test specimens as directed in 9.1.

8. Preconditioning and Conditioning

8.1 Bring the laboratory sample to moisture equilibrium for testing in the standard atmosphere for testing textiles, as directed in Practice D 1776.

9. Preparation of Specimens

9.1 Prepare each specimen by drawing small groups of fibers from at least five locations in a unit of the laboratory sample. Parallelize and combine them in a bundle which may be held conveniently between the thumb and forefinger. Choose the size of the bundle so that in the final bundle the 1-in. (25.4-mm) length of fiber between the clamps of the testing machine has a mass of between 15 and 25 mg.

9.2 Transfer one end of the bundle to the hand vise and comb the rest of the bundle to remove the short fibers and to parallelize the remainder (see Fig. 1).

9.3 Transfer the hand vise to the other end of the bundle and repeat the combing operation.

NOTE 5—The procedure described in 9.2 and 9.3 may have to be repeated several times until the fibers are parallel.

9.4 Tension the fibers between the vise and the fingers as uniformly as possible (Fig. 2) and lay them across the rubber-faced plate (Fig. 3). On top of this plate and the fibers, place a second plate (Fig. 4) and hold it in place. Maintain pressure between these two plates, first by hand and then by vise (Fig. 5), until the masking tape is applied. Apply 1-in. (25.4-mm) squares of heavy masking tape to the protruding ends on each side of the plates on both top and bottom surfaces of the bundle (Fig. 6). During this application, tension the protruding fibers as evenly as possible while laying them across the masking tape. The final bundles should look like those shown in Fig. 7 with a 1-in. (25.4-mm) spacing between the tapes. The specimens are now ready to test.

10. Procedure

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

10.2 Insert the conditioned test specimen in the testing machine using a gage length of 1 in. (25.4 mm) and break the test specimen in accordance with the manufacturer's instructions.

10.3 After the specimen has been broken, record the breaking force (or load).

10.4 Cut the fibers with a razor blade at the edge of each clamp and place the fibers in a weighing bottle.

10.5 Weigh and record the mass to the nearest 0.0001 g.

11. Calculation

11.1 Calculate the average breaking force (or load) for a 1-in. (25.4-mm) bundle length. The strength may be expressed either in breaking tenacity (grams force per tex) calculated using Eq 1 or in tensile strength (pounds force per square inch) using Eq 2, whichever is desired (see Appendix).

$$\text{Breaking tenacity, gf/tex} = (B/M) \times 0.01152 \quad (1)$$

$$\text{Tensile strength, lbf/in.} = (B/M) \times 21.47 \quad (2)$$

where:

B = bundle breaking load, lbf, and
M = bundle mass, g.

If the testing machine is graduated in grams:

$$\text{Breaking tenacity, gf/tex} = (b/M) \times 2.540 \times 10^{-5} \quad (3)$$

$$\text{Tensile strength, lbf/in.}^2 = (b/M) \times 4.733 \times 10^{-2} \quad (4)$$

where:

b = bundle breaking load, gf, and
M = bundle mass, g.

FIG. 1 Combing of Bundle

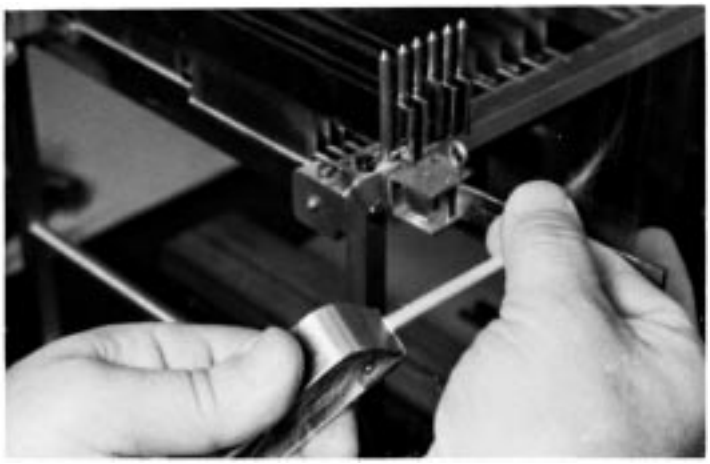

FIG. 2 Tensioning of Fibers

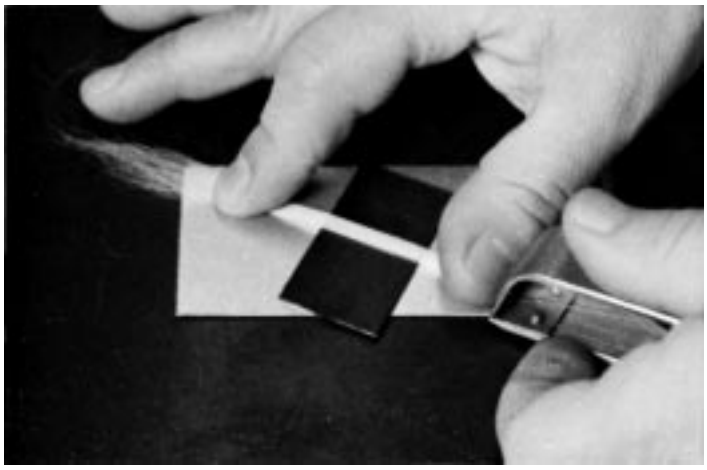

FIG. 3 Laying the Fibers Across Plate

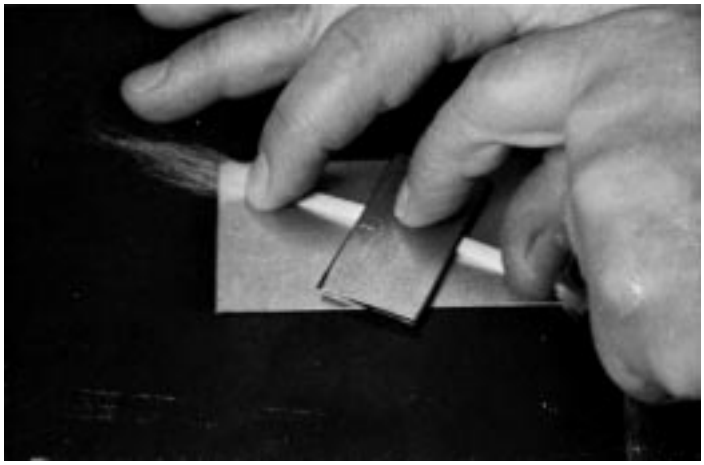

FIG. 4 Placing of Second Plate

12. Report

12.1 State that the specimens were tested as directed in ASTM Test Method D 1294. Describe the material(s) or product(s) sampled and the method of sampling used. Describe the tensile testing machine and operating specifications.

12.2 Report the following information:

12.2.1 Average tensile strength in gf/tex to one decimal place or mN/tex to the nearest whole number,

12.2.2 Average tensile strength in lbf/in.^{2} to three significant figures,

12.2.3 Estimated standard deviation or coefficient of variation, if calculated, and

FIG. 5 Maintaining the Pressure

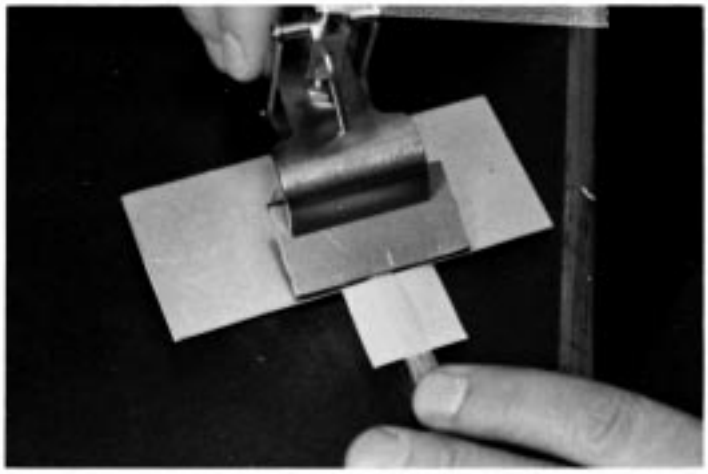

FIG. 6 Applying Masking Tape

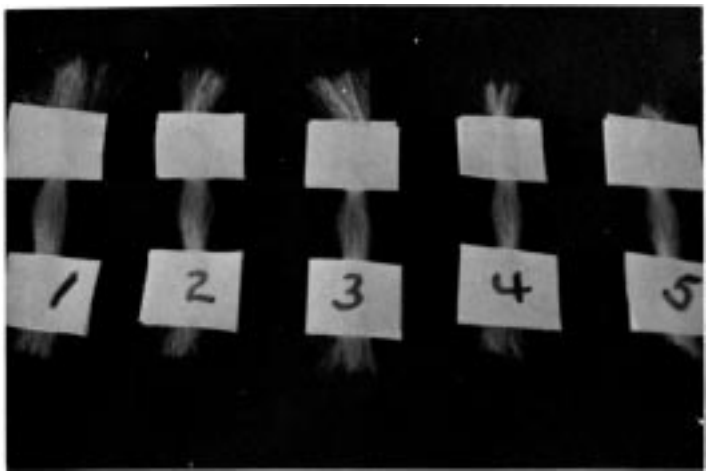

FIG. 7 Final Bundles

12.2.4 The number of specimens tested.

13. Precision and Bias

13.1 *Interlaboratory Test Data*—An interlaboratory test was run in 1962 in which randomly drawn samples of three types of wool were tested in six laboratories. Each laboratory used one operator who tested five specimens of each type of wool. The components of variance expressed as coefficients of variation were calculated to be the values listed in Table 1.

TABLE 1 Components of Variance as Coefficients of Variation, Percent of the Average

Type of Wool	Single-Operator Component	Between-Laboratory Component
64's wool	6.2	5.8
46's wool	5.2	9.0
Uruguay wool	6.4	9.7

13.2 *Precision*—For the components of variance listed in Table 1, two averages of observed values should be considered significantly different at the 95 % probability level if the difference equals or exceeds the critical values listed in Table 2.

NOTE 6—The tabulated values of the critical 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 randomly drawn from one sample of the material to be tested.

13.3 *Bias*—The true value of breaking strength of wool fiber bundles can be defined only in terms of a specific test method. Within this limitation, Test Method D 1294 has no known bias.

TABLE 2 Critical Differences for the Conditions Noted, [A,B] Percent of the Grand Average

Type of Wool	Number of Observations in Each Average	Single-Operator Precision	Between-Laboratory Precision
64's wool	1	17.2	23.5
	4	8.6	18.2
	8	6.1	17.2
46's wool	1	14.4	28.8
	4	7.2	26.0
	8	5.1	25.5
Uruguay wool	1	17.7	32.2
	4	8.9	28.3
	8	6.3	27.6

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

[B] To convert the values of the critical differences to units of measure, multiply the average of the two specific sets of data being compared by the critical differences expressed as a decimal fraction.

14. Keywords

14.1 breaking strength; wool

APPENDIX

(Nonmandatory Information)

X1. BASIS OF EQUATIONS FOR BREAKING TENACITY AND TENSILE STRENGTH

X1.1 Eq X1.1 and Eq X1.2 below include all of the factors needed to calculate breaking tenacity and tensile strength. Assuming a length of 1 in. (25.4 mm) and a density of 1.31, the equations can be reduced to those presented as Eq X1.1 and Eq X1.2.

Breaking tenacity, gf/tex

$$= (2.54 \times 453.6 \times BL)/(100 \times 1000 \times M) \quad \text{(X1.1)}$$

$$\text{Tensile strength, lbf/in.}^2 = (2.54)^3 \times (GLB/M) \quad \text{(X1.2)}$$

where:

G = density, taken as 1.31 g/cm^3 for wool (when this test is used for fibers other than wool, the appropriate value of density should be used),
L = bundle length, in.,
B = bundle breaking load, lbf,
M = bundle mass, g, and
2.54 = conversion factor from in. to cm.

NOTE X1.1—To convert lbf/in.^{2} to gf/tex, multiply lbf/in.^{2} by 53.25×10^{-5}.