Designation: D 2524 – 95 (Reapproved 2003)

Standard Test Method for Breaking Tenacity of Wool Fibers, Flat Bundle Method—⅛ -in. (3.2-mm) Gage Length[1]

This standard is issued under the fixed designation D 2524; 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 tenacity of wool fibers as a flat bundle with a ⅛ -in. (3.2-mm) clamp separation.

1.2 This test method is especially adapted to the fiber bundle clamps and strength testing instruments specified, but may be used on other tensile testing machines when equipped with appropriate adapters to accommodate the prescribed clamps.

1.3 This test method is applicable to wool in any form which can be hand-combed into small bundles of parallelized fibers.

NOTE 1—Other test methods for measuring breaking tenacity of fiber bundles include Test Methods D 1294, D 1445, and D 540.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.5 The values stated in inch-pound units are to be regarded as the standard. The SI units in parentheses are provided for information only.

2. Referenced Documents

2.1 *ASTM Standards:*

D 123 Terminology Relating to Textiles[2]

D 540 Testing Man-Made Staple Fibers[3]

D 1294 Test Method for Tensile Strengh and Breaking Tenacity of Wool Fiber Bundles—1-in. (25.4-mm). Gage Length[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 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.

3.1.2 *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 the grams-force times 9.81.

3.1.3 *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.).

3.1.4 *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.

3.1.5 *constant-rate-of-traverse (CRT) type tensile testing machine*, *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-measuring mechanism, producing a rate of increase of force or extension that is usually not constant and is dependent on the extension characteristics of the specimen.

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

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

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

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

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[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] Discontinued—See *1973 Annual Book of ASTM Standards*, Part 25.

3.1.10 *Discussion*—For the purposes of this method, the word *wool* is used in the generic sense, and includes reprocessed and reused wool as well as *wool* 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 A bundle of fibers is combed until parallel, placed under a uniform tension sufficient to remove as much crimp as possible without stretching the fibers, and secured in special clamps. The fibers are then cut to a known length, broken in the tensile testing machine, removed from the clamps, and weighed. Breaking tenacity is calculated from the ratio of breaking force to bundle linear density. The length measured under the applied tension is the basis for computing linear density from bundle mass.

5. Significance and Uses

5.1 Test Method D 2524 for testing wool fibers for tenacity is considered satisfactory for acceptance testing when the participating laboratories, using a reference wool, have shown acceptable between-laboratory precision. It is recommended that any program of acceptance testing be preceded by an interlaboratory check in the laboratory of the purchaser and the laboratory of the seller on replicate specimens of samples of the material to be evaluated. In cases of dispute, the statistical bias, if any, between the laboratory of the purchaser and the seller should be determined with each comparison being based on testing randomized specimens from one sample of material of the type being evaluated.

5.2 Values obtained from flat bundle tenacity show a good correlation with values obtained from single fiber tests and require much less time.

5.3 The basic differences between the procedures described in Test Method D 2524 and those described in Test Method D 1294 lie in the manner of clamping the bundles and the shorter gage length employed. The special clamps used in this method allow quicker and easier bundle preparation; however, for Test Method D 1294 no special clamps are required. Closer agreement with single fiber tenacity is also obtained with Test Method D 2524 than when using the procedure in Test Method D 1294.

5.4 As the observed tenacity of fibers depends in part on the type of tensile testing machine used and the time required to break the specimen, results obtained with the different types of machines which may be used in this method will not necessarily agree. The machines specifically designed for bundle testing are CRL testers which operate at a loading rate of 1 kgf/s and therefore reach the breaking force at variable times in the order of 5 s. CRE and CRT type machines would be expected to produce somewhat different results not only because of the inherent difference in operation but because CRE and CRT type machines are to be operated at a rate to achieve the breaking load in 20 s.

6. Apparatus and Materials

6.1 *Tensile Testing Machine*, having a capacity of at least 7 kgf (70 N), equipped to accommodate the specified flat bundle clamps. For CRL testing machines,[4] the rate of loading is specified as 1 kgf/s (10 N/s). For CRE and CRT machines, select a rate of operation which will reach the breaking force in an average time of 20 ± 3 s.

6.1.1 In case the CRE or CRT testing machine is not capable of operating as specified in 6.1, select a rate so as to reach the breaking force in an average time as close to 20 s as possible and report the average time to break.

NOTE 2—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.

6.2 *Balance*, suitable for weighing 2 to 6 mg with a sensitivity of 0.02 mg.

6.3 *Flat Bundle Clamps and Accessories*, including the following components:

NOTE 3—Pressley clamps and accessories have been found satisfactory for this purpose.[5] Adapters to fit the clamps to various tensile testing instruments are also available or can be fabricated.

6.3.1 *Clamps*, having a total thickness of 0.465 ± 0.001 in. (11.8 ± 0.03 mm) and a 0.125 ± 0.001-in. (3.2 ± 0.03-mm) spacer.

6.3.2 *Clamp Vise*, with a device to indicate approximately 8 lbf·in. (0.9 N·m) torque.

6.3.3 *Clamp Wrench*.

6.4 *Coarse Comb*, approximately 8 teeth per in. (3 per 10 mm).

6.5 *Fine Comb*, approximately 50 teeth per in. (20 per 10 mm).

6.6 *Black Paper*, to hold bundles.

6.7 *Shearing Knife or Razor Blade*.

6.8 *Tweezers*.

6.9 *Torque Wrench or Friction Disk Wrench*, to indicate approximately 8 lbf·in. (0.9 N·m) torque (optional).

6.10 *Standard Wool Top Sample*[6], having an assigned breaking tenacity of 11.4 gf/tex (112 mN/tex).

NOTE 4—The standard wool top sample, USDA Lot 58-27, has a breaking tenacity (based on single fiber tests) of 11.4 ± 0.6 gf/tex, at the 95 % probability level.

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 shipment 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.

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[4] The Stelometer, manufactured by the Special Instruments Laboratory, Inc., 312 W. Vine St., Knoxville, TN 37901; and the Clemson Tester (no longer available) have been found satisfactory for this purpose.

[5] Available from J. M. Doebrich and Co., P. O. Box 2789, Tucson, AZ 85702.

[6] Available from the Wool and Mohair Laboratory, Livestock and Seed Division, AMS, U.S. Department of Agriculture, 711 "O" Street, Greeley, CO 80631.

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

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 10.1.

8. Preparation, Calibration, and Verification of Apparatus

8.1 *Tensile Testing Machine*—Check the calibration of the instrument according to the manufacturer's instruction.

8.2 *Balance*—Check the zero reading and the sensitivity in the range to be used.

9. Preconditioning and Conditioning

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

10. Preparation of Specimens

10.1 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. Depending on fiber entanglement, take a sufficient number of fibers so that, after combining, an aligned specimen of 2 to 6 mg is available for testing.

10.2 Grasp the tuft about one-fourth the distance from the end of the tuft with the thumb and forefinger or a fiber hand vise[7] and comb the protruding end with the coarse comb to remove loose fibers and foreign material and to secure partial parallelization of the fibers. Reverse the tuft and repeat the combing on the other end.

10.3 Grasp the partially parallelized tuft at both ends using the fingers of one hand, thumb and ring finger holding one end and middle and index fingers holding the other end. Complete the parallelization of the fibers in the tuft by combing with the fine comb; with each pass of the comb release the end of the tuft toward which the comb is moving and grasp again immediately after the comb passes the holding position. To avoid moisture transfer from fingers to fibers, do not handle the middle section of the tuft. If the specimen is estimated to be too heavy, remove fibers during the combing operation from either side with the tip of the comb to obtain the correct specimen size. The specimen is now ready to be placed in the clamps.

11. Procedure

11.1 Test the conditioned specimens in the standard atmosphere for testing.

11.2 Inspect the leather faces of the clamps frequently to ensure that they are in good condition. Keep the inner edges of the leathers trimmed flush with the metal surfaces and replace the leathers as soon as grooves become evident to the touch.

11.3 Place the parallelized specimen (10.3) in the clamps in the following manner: Using a Pressley type vise, lock the clamps with a ⅛ -in. (3.2-mm) spacer separating the clamps of the vise and open the jaws of the clamps. Hold both ends of the specimen as directed in 10.3, keeping the specimen approximately ¼ in. (6 mm) wide, and place it in the central part of the open clamps. Maintain sufficient tension on the specimen to hold the fibers straight while the jaws of the clamps are lowered and tightened in place by applying an 8 lbf·in. (0.9 N·m) torque. The torque may be controlled by either a vise-mounted, torque-indicating instrument or by a friction disk wrench.

11.4 Remove the clamps from the vise. Shear off the protruding ends of the specimen with the shearing knife or razor blade, cutting downward and away from the leather face of the clamps and flush with the surface.

11.5 Insert the loaded clamps in the tensile testing machine and break the test specimen in accordance with the manufacturer's instructions. For other than the special instruments designed specifically for flat bundle testing, operate the test instrument as directed in 6.1.

11.6 After the specimen has been broken, record the breaking force to the nearest scale or chart reading. Remove the clamps from the instrument and place the clamps in the vise. Check to see that all fibers are broken. If all the fibers are not broken, are broken irregularly indicating some slippage of fibers in the clamps, or if the breaking force is less than the required minimum for the instrument used, discard the specimen and make a new test. If the break is acceptable, open the clamps, collect all the broken fibers with tweezers, and weigh to the nearest 0.02 mg (Note 5). To avoid gain in weight from moisture pickup, do not touch the fibers with the fingers while collecting and weighing the specimen.

NOTE 5—If desired, the broken specimens may be stored temporarily in the standard atmosphere for testing in folded black papers and weighed later.

11.7 Make a check test on a standard sample each day before making other tests and repeat the check after every ten samples to check the level of testing results. Calculate and record for each operator a correction factor based on results secured in tests made on the standard sample. Maintain a separate record of each operator's correction factors and use, as the operator's norm, the average of the last five factors to correct the next ten tests (Note 6). If a correction factor is observed that differs by more than 5 % from the established norm, reject the factor and examine the instrument and technique carefully. Make any indicated adjustments to either the instrument or the technique and make a new test on the

[7] The hand vise supplied with the Suter Sorter wool fiber stapling apparatus is suitable for this purpose. Available from the Alfred Suter Co., Inc., Prel Plaza, Orangeburg, NY 10962.

standard sample. If an abnormal factor is observed for the second time, establish a new factor to correct the results observed on specimens of unknown samples by averaging the two factors obtained from tests on the standard sample before and after the tests on the unknowns. Continue to use the two factor averaging until a new norm has been established from five successive factors all within ± 5 % of the average of the five.

NOTE 6—Interlaboratory tests have shown that experienced technicians established correction factors ranging from 1.00 to 1.10, while those of less experienced technicians may range as high as 1.30. Experience has also shown that an individual technician's correction factor changes slowly and is primarily dependent on the technique of bundle preparation.

12. Calculations

12.1 Calculate the fiber bundle breaking tenacity of the ⅛ -in. (3.2-mm) gage specimens, having a total bundle length of 0.590 in. (15 mm), from the breaking force and the mass of the bundle using Eq 1 or Eq 2:

$$\text{Breaking tenacity, gf/tex} = \frac{\text{breaking force in lbf} \times 6.80}{\text{bundle mass in mg}} \quad (1)$$

$$= \frac{\text{breaking force in kgf} \times 15.00}{\text{bundle mass in mg}} \quad (2)$$

NOTE 7—Millinewtons per tex (mN/tex) equals grams-force per tex (gf/tex) times 9.81.

12.1.1 Calculate any needed correction factor using Eq 3:

$$\text{Correction factor} = \frac{\text{specified value for the standard wool}}{\text{observed value for the standard wool}} \quad (3)$$

12.2 Calculate the average breaking tenacity of all specimens and adjust the average using Eq 4:

$$\text{Adjusted breaking tenacity for the sample} = \text{observed value for the sample} \times \text{applicable correction factor} \quad (4)$$

12.3 Calculate the standard deviation or the coefficient of variation of the individual specimens, if required.

13. Report

13.1 State that the tests were made as directed in ASTM Test Method D 2524. Describe the material(s) or product(s) sampled and the method of sampling used. Report the following information:

13.2 *Conditions of Test*:

13.2.1 Type of tensile testing machine, and

13.2.2 Rate of instrument operation, if not fixed.

13.3 *Results*:

13.3.1 Adjusted average breaking tenacity in gf/tex to one decimal place or mN/tex to the nearest whole number.

13.3.2 The estimated standard deviation, *s*, or coefficient of variation, *v*, if calculated.

13.3.3 The number of specimens tested, *n*.

14. Precision and Bias

14.1 Based on an interlaboratory test in 1965, the average coefficient of variation within groups of five replicates per test in 55 tests of scoured wool was 4.9 % with 95 % less than 9.1 %. In 65 tests of wool top with five replicates per test, the average coefficient of variation within groups of five replicates was 3.2 % with 95 % less than 6.8 %. In this test, a standard wool was not used and no correction factor applied.

14.1.1 A standard wool sample, USDA Lot 58-27, was used to adjust the results secured in a test in 1966 which included two operators in each of seven laboratories; six replicates were tested for each of two wool tops (a coarse low-crimp wool and a fine crimpy wool). Three different types of instruments were used; four laboratories used one type, and the other two types were each used in two laboratories with one of these laboratories using both types. In this test, a significant difference was found only among laboratories using a specific type of instrument. The average single-operator coefficient of variation was 4 % for both wool tops.

14.2 *Single-Operator Precision*—Based on the data in 14.1.1 and 14.1.1, the precision of an average of five replicate specimens of either fine or coarse wool top after adjustment based on the use of a standard sample is expected to be within the limits of ± 8 % at the 95 % probability level.

14.3 *Between-Laboratory Precision*—Based on the data in 14.1.1, the precision of an average of two operators each testing six replicates of either fine or coarse wool top after adjustment based on the use of a standard sample is expected to be within the limits of ± 3 % at the 95 % probability level.

14.4 *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 2524 for testing for breaking tenacity of wool fibers, flat bundle method, ⅛ -in. (3.2-mm) gage length has no known bias.

15. Keywords

15.1 breaking tenacity; fibers; wool