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# Standard Test Method for Breaking Strength and Elongation of Cotton Fibers (Flat Bundle Method)[1]

This standard is issued under the fixed designation D1445/D1445M; 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.

## INTRODUCTION

The flat bundle test for cotton fiber strength gained immediate acceptance after its introduction in 1953. The first successful instrument was an inclined plane device with the beam calibrated in pounds. The specimen was clamped with no space between the jaws and was called zero-gauge strength. Results were expressed in Pressley Index (P.I.) calculated as the force-to-break in pounds divided by the bundle weight in mg. Obviously, P.I. is not a standard engineering unit.

Before the introduction of the flat bundle test, cotton fiber strength had been measured by the Chandler round bundle test (see former Method D414) and the results expressed in pounds per square inch [psi]. The U.S. Department of Agriculture obtained results from both instruments on specimens from the same samples of a large number of cottons. From this study, an empirical equation to express flat bundle test results in psi was:

$$\text{Breaking strength, 1000 psi} = (10.81106 \times \text{P.I.}) - 0.12$$

When it was shown that a finite gauge length test was more highly correlated with yarn strength than tests made at zero gauge length, the clamp design was modified to accommodate a ⅛ in. [3.2 mm] spacer. Selection of an engineering unit for reporting of results from ⅛ in. [3.2 mm] gauge tests presented a problem. However, the use of the tex for linear density and the introduction of a pendulum type instrument calibrated in kilograms led to the expression of results in grams-force per tex [gf/tex]. The clamp width without spacer is 11.81 mm and with spacer is 15.00 mm. The bundle of fibers is mounted across the clamp width and trimmed to the width. The bundle mass is mg/11.81 mm or mg/15.00 mm.

The use of the flat bundle test in domestic and international commerce has had a long and successful history. Correcting this error in the empirical relationship would have serious adverse affects in the textile industry. Therefore, the empirical relationship is retained to calculate zero gauge cotton fiber tensile strength designated as the Pressley strength in Eq 3 and 4 of D1445/D1445M.



## 1. Scope

1.1 This test method covers the determination of (*1*) the tensile strength or breaking tenacity of cotton fibers as a flat bundle using a nominal zero gauge length, or (*2*) the tensile strength or breaking tenacity and the elongation at the breaking load of cotton fibers as a flat bundle with ⅛-in. [3.2-mm] clamp spacing. This test method is applicable to loose ginned cotton fibers of untreated cottons whether taken before processing or obtained from a textile product.

1.2 This test method is designed primarily for use with special fiber bundle clamps and special strength testing instruments but may be used with other tensile strength and elongation testing machines when equipped with appropriate adapters to accommodate the fiber clamps.

NOTE 1—Other methods for measuring the breaking tenacity of fiber bundles include Test Method D1294, Test for Breaking Strength of Wool Fiber Bundles—1 in gauge Length;[2] and D5867, Test Method for Measurement of Physical Properties of Cotton Fibers by High Volume Instruments.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each

[1] This method is under the jurisdiction of ASTM Committee D13 on Textiles and is the direct responsibility of Subcommittee D13.11 on Cotton Fibers.

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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.

system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

## 2. Referenced Documents

2.1 *ASTM Standards:*[2]

D123 Terminology Relating to Textiles
D1294 Test Method for Tensile Strength and Breaking Tenacity of Wool Fiber Bundles 1-in. (25.4-mm) Gage Length
D1441 Practice for Sampling Cotton Fibers for Testing
D1447 Test Method for Length and Length Uniformity of Cotton Fibers by Photoelectric Measurement
D1776 Practice for Conditioning and Testing Textiles
D3025 Practice for Standardizing Cotton Fiber Test Results by Use of Calibration Cotton Standards
D5867 Test Methods for Measurement of Physical Properties of Raw Cotton by Cotton Classification Instruments
D7139 Terminology for Cotton Fibers

## 3. Terminology

3.1 For all terminology related to D13.11, see Terminology D7139

3.1.1 The following terms are relevant to this standard: breaking force, breaking tenacity, cotton, elongation at breaking load, tenacity, tensile strength.

3.2 For all other terminology related to textiles, refer to Terminology D123.

## 4. Summary of Test Method

4.1 A bundle of cotton fibers is combed parallel with the aid of specialized clamps to minimize loose fibers that are in the bundle, secured in clamps, cut to a known length, broken in a tensile testing machine, and weighed. Tensile strength or breaking tenacity is calculated from the ratio of breaking load to bundle mass (weight).

4.2 Elongation at the breaking force may be determined on the specimens tested for breaking strength with ⅛-in. [3.2-mm] clamp spacing. The elongation is normally calculated as a percentage of the nominal gauge length.

## 5. Significance and Use

5.1 This test method is considered satisfactory for acceptance testing when the levels of the laboratories are controlled by the use of the same reference standard cotton samples because the current estimates of between-laboratory precision are acceptable under these conditions. If there are differences of practical significance between reported test results for two laboratories (or more), comparative tests should be performed to determine if there is a statistical bias between them, using competent statistical assistance. As a minimum, ensure the test samples to be used are as homogeneous as possible, are drawn from the material from which the disparate test results were obtained, and are randomly assigned in equal numbers to each laboratory for testing. The test from the two laboratories should be compared using a statistical test for unpaired data, at a probability level chosen prior to the testing series. If a bias is found, either its cause must be found and corrected, or future test results for that material must be adjusted in consideration of the known bias.

5.2 This test method is useful in research studies to determine the influence of variety, environment, and processing on fiber strength and elongation; and in studies of the relationships between these fiber properties, processing performance, and quality of end-product.

5.3 Values obtained for flat bundle tenacity and elongation show a high correlation with values measured on single fibers and require much less time and skill.

5.4 Studies have shown that strength measurements obtained with different types of instruments are highly correlated, but the results are on different levels.[3]

5.5 By use of correction factors calculated from tests made on standard calibration samples of known or established test values, the results obtained with different types of instruments at a specified gauge length can be adjusted to comparable levels. Due to the normal variation in cottons, strength test results for one gauge length cannot be reliably estimated from tests made at a different gauge length.

5.6 The terms tensile strength and breaking tenacity are sometimes used interchangeably. They are relational but are not equivalent (see 12.1.1 and 12.1.2). Tenacity is commonly expressed as centinewtons per tex (cN/tex), grams-force per denier (gf/den) or pounds-force per denier (lbf/den). Tenacity in centinewtons/tex is numerically equal to tenacity in grams-force/tex times 0.981.

## 6. Apparatus and Materials

6.1 *Tensile Testing Machine*—Either of two commercially available fiber bundle tensile testing machines, one of the pendulum type and one of the inclined-plane type, described in Appendix X1, or other machine from which comparable results can be obtained.

6.2 *Laboratory Balance:*

6.2.1 *Balance,* having a capacity of 3 or 5 mg and a sensitivity of ±0.01 mg for the zero gauge length test.

6.2.2 *Balance,* having a capacity of 5 or 10 mg and a sensitivity of 0.01 mg for ⅛-in. [3.2-mm] gauge length test.

[3] Burley, Jr., S. T., and Carpenter, F., "Evaluation of Results Obtained on Available Types of Fiber Strength Testers Using Various Gauge Spacings and Their Relation to Yarn Strength," *Textile Research Journal (TRJ)*, Vol 24, 1954, pp. 251-260.

6.3 Ancillary equipment from the instrument manufacturers.

6.3.1 *Clamp Vise* (Pressley type or Stelometer type), with a device to indicate approximately 8 lbf·in. [9 kgf·cm] torque.

6.3.2 *Fiber Clamps,* having a total thickness of 0.465 ± 0.001 in. [11.81 ± 0.02 mm].

6.3.3 *Spacer,* having a thickness of 0.125 ± 0.001 in. [3.2 ± 0.02 mm].

6.3.4 *Clamp Wrench* or Torque Wrench.

6.3.5 *Coarse Comb,* approximately 8 teeth/in. [3 teeth/cm], or Fibrograph comb.

6.3.6 *Fine Comb,* approximately 52 teeth/in. [20 teeth/cm].

6.3.7 *Black Paper,* to hold bundles.

6.3.8 *Shearing Knife.*

6.3.9 *Tweezers.*

6.3.10 *Standard Calibration Cotton,* having specified fiber strength.

6.3.11 *Fiber Clips or Sample Clips.*

## 7. Sampling

7.1 Take lot sample and laboratory samples as directed in Practice D1441.

## 8. Preparation, Calibration, and Verification of Apparatus

8.1 *Tensile testing instrument*—Before making fiber strength tests, check the instrument and clamp vise for mechanical adjustment as directed for the specific instrument in Appendix X1, or in accordance with the manufacturer's instructions.

8.2 *Laboratory balance*—Check the zero setting of the laboratory balance and make sure its sensitivity is within the range to be used.

8.3 *Clamp leathers*—Inspect the leathers in the clamps frequently to ensure that they are in good condition. Keep the inner edges of the leathers trimmed flush with the metal surface and replace the leathers as soon as grooves are observed.

8.4 *Check Test – Use of Standard Calibration Cotton Samples*—Each day before making other tests, make a check test of at least three specimens per technician on one or more standard calibration samples to check the reproducibility and uniformity of results. If available, use standard calibration samples with test values within the range of the unknown samples being tested. Make additional check tests in a similar manner at least three more times during a working day to obtain results for the calculation of correction factors. The calculated breaking tenacity or tensile strength values of the samples tested during the same time period can be adjusted to the standard level by applying the correction factor (see Eq 9 and Eq 10) calculated from the check test. This factor is used to adjust the level of observed results for operator, instrument and other uncontrolled sources of differences in testing.

8.4.1 The correction factors described in Practice D3025 are required to obtain standard strength results because the results are highly affected by both operator technique and testing machine differences. When adjusting the results to the standard level for the type testing machine being used, the correction factors for individual operators and different testing machines do not normally exceed the range of 0.90 to 1.10. When adjusting the results to the more commonly used standard level for the inclined-plane type testing machine, however, the correction factor for the pendulum-type testing machine is usually within the range of 1.16 to 1.36. The difference in the size of the correction factors for the different type testing machines is primarily because of a difference in the rate of force. The ⅛-in. [3.2-mm] gauge test values of the Calibration Cotton Standards for the inclined-plane type testing machine are greater by a factor of 1.26 than those for the pendulum-type testing machine.

## 9. Conditioning

9.1 Bring the laboratory sample from the dry side to moisture equilibrium for testing in the standard atmospheres for textile testing according to Practice D1776.

NOTE 2—Cotton is normally received in the laboratory in a relatively "dry" condition, making special preconditioning procedures unnecessary. Samples that are obviously damp should be preconditioned before being brought into the laboratory for conditioning.

## 10. Sampling, Test Specimens and Test Units

10.1 From a conditioned laboratory sample, pull small tufts (pinches) of cotton fibers to make the test specimens (flat bundles). Tufts taken from Fibrograph beards as prepared by Test Method D1447 may be used.

10.1.1 Prepare a tuft of fibers either (*1*) by taking two small pinches at random from the unblended laboratory sample and placing them one on top of the other near their mid-points, or (*2*) by taking a section from a blended laboratory sample. Hold the tuft between the thumb and forefinger and comb with a coarse comb to remove foreign matter and short fiber. When one end of the tuft has been combed, reverse the tuft and comb the other end, taking care that the fibers in the middle portion of the tuft are well combed. Approximately 10 strokes are necessary for combing each end of the tuft. Prepare two to six tufts, each weighing 60 to 80 mg, from each sample to be tested. Before testing, condition the tufts as directed in Section 9.

10.1.2 Prepare two to six tufts, each weighing 60 to 80 mg, from each laboratory sample or Fibrograph beard to be tested.

10.2 Prepare the specimen as directed in either 10.2.1 or 10.2.2.

10.2.1 Grasp a prepared tuft near the midpoint between the center and the end of the tuft, and pull out a portion of the fibers to form a specimen. Hold the specimen firmly by one end and pull the fibers through the fine comb on the vise two or three times to remove loose fibers, neps, and trash. Comb the other end of the specimen in the same manner, keeping the fiber ends aligned while the middle portion is combed. Maintain the width of the specimen at approximately ¼ in. [6 mm]. If the specimen weighs greater than 80 mg (see 10.1.2), remove fibers from either side to obtain the correct weight.

10.2.2 Grasp a group of fibers on a Fibrograph comb, using the fiber clip or similar device to grip the fibers at a point at least ⅝ in. [15 mm] from the teeth of the comb. Pull these fibers, which constitute the specimen, through the Fibrograph comb teeth three or four times to straighten them and remove loose fibers. Use tweezers to remove any remaining neps or foreign matter. The specimen is now ready to be placed in the clamps.

10.3 Depending on the precision desired, and if possible, have two operators participate in the testing with each one testing one half the number of specimens.

## 11. Procedure

11.1 Place a test specimen in the fiber clamps as directed in either 11.1.1 or 11.1.2.

11.1.1 Using a Pressley-type clamp vise, lock the fiber clamps in the vise, and then open the clamps. Hold both ends of the specimen, keeping it approximately ¼ in. [6 mm] wide, and place it in the center of the open clamps. Apply sufficient tension to hold the fibers straight while the jaws of the clamps are lowered and tightened in place by applying an 8-lbf·in. [9-kgt·cm] torque. The torque is controlled by the clamp vise or by a torque wrench. Remove the fiber clamps from the vise. Shear off the protruding ends of the specimen with the shearing knife, shearing downward and away from the leather face of the clamps.

11.1.2 Using a Stelometer-type clamp vise, lock the fiber clamps in the vise, and then open the clamps. Lift the fixed clamp on the vise and insert the loose ends of the flat-bundle specimen held in the fiber clip. Draw the fiber clip forward until it falls into place over the hook of the tension level. Apply sufficient pressure on the fixed clamp to prevent fiber slippage and release the spring lever to apply tension on the specimen. Close and tighten the clamps, applying a torque of 8 lbf·in. [9 kgt·cm]. Tighten the clamp farthest from the clip first to ensure correct tension between the clamps. Remove the clamps from the vise and shear off the protruding fibers as in 11.1.1. This method for placement of the flat bundle in the clamps provides a uniform pretension on the specimen, which is necessary to secure reliable measurements of elongation.

11.2 Insert prepared clamps in the tensile testing machine and release the locking or trigger mechanism to break the test specimen in accordance with instructions furnished by the manufacturers of the specific instruments (see Appendix X1). After the specimen has been broken, record the breaking force to the nearest scale reading. Remove the clamps from the instrument, check to see that all fibers are broken, and place the clamps in the vise.

11.2.1 If all of the fibers are not broken, or if the fibers are broken irregularly, 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, being careful to collect all of the broken fibers with tweezers, and weigh them to the nearest 0.01 mg. If desired, the broken specimens may be placed temporarily in folded black papers, stored in the standard atmosphere for testing textiles, and weighed later. To avoid a gain in weight from moisture pickup, do not touch the fibers with the fingers while collecting and weighing the specimen.

## 12. Calculation

12.1 Calculate the unadjusted fiber bundle strength for each specimen from the breaking force and the bundle weight using Eq 1-8.

12.1.1 Zero gauge strength tests based on a bundle length of 0.465 in. [11.81 mm]:

$$B = 5.36\,F/m \tag{1}$$

$$B = 11.81\,f/m \tag{2}$$

$$T = 10.81\,F/m \tag{3}$$

$$T = 23.83\,f/m \tag{4}$$

$$B = 0.496\,T \tag{5}$$

$$T = 2.016\,B \tag{6}$$

where:

$B$ = breaking tenacity, gf/tex
$T$ = tensile strength, 1000 psi
$F$ = breaking force, lbf
$f$ = breaking force, Kgf, and
$m$ = bundle mass, mg.

NOTE 3—Because the area of the cotton in the bundle cannot be determined precisely, the test does not provide a measure of tensile strength directly. The breaking tenacity results obtained are converted to the equivalent level of the tensile strength results obtained by the Chandler round bundle test. The conversion formula was established empirically from tests using both the flat bundle and the round bundle methods performed on a large number of cotton samples, which included a wide range of fiber properties. The Chandler round bundle method is described in former Methods D414. The constant of 10.81 in Eq 3 assumes a density of 1.42 for cotton. The density of cotton has been reported in the range of 1.52 to 1.56. Using a density of 1.52 will result in a constant of about 11.58 in Eq 3 and will yield a result about 7 percent higher.

12.1.2 Tests on ⅛-in. [3.2-mm] gauge specimens based on a bundle length of 0.490 in. [15-mm]:

$$B = 6.80\,F/m \tag{7}$$

$$B = 15.00\,f/m \tag{8}$$

where the terms in the equations are defined in 12.1.1.

12.2 Calculate the average breaking tenacity or tensile strength for each sample from the specimen values calculated in Eq 1-8.

12.3 Calculate the correction factor by Eq 9 as follows:

$$Fc = Cs/Co \tag{9}$$

where:

$Fc$ = correction factor,
$Cs$ = standard value for calibration cottons, and
$Co$ = observed value for calibration cottons

Adjust the average breaking tenacity or tensile strength by Eq 10 as follows:

$$A = VFc \tag{10}$$

where:

$A$ = adjusted breaking tenacity or tensile strength
$V$ = observed breaking tenacity or tensile strength, and

$Fc$ = correction factor

A suggested worksheet is shown in Appendix X2.

12.4 Calculate the breaking elongation from the measurements of the specimen lengths at zero force and at the breaking force by Eq 11 as follows:

$$E = 80\,(L - N)/N \quad (11)$$

where:

$E$ = elongation, percent.
$L$ = Length of specimen at break, inch
$N$ = Nominal gauge length, and
80 = 0.8 (100).

For a nominal gauge length of ⅛ [0.125] in., Eq 11 becomes:

$$E = 640\,(L - 0.125) \quad (12)$$

where the terms in the equation are defined above.

NOTE 4—The factor, 0.8, included in the breaking elongation formula compensates for the slippage of fibers in clamps.

12.5 Calculate the average breaking elongation for each sample from the specimen values calculated in Eq 11 or Eq 12.

## 13. Report

13.1 State that the specimens were tested as directed in Test Method D1445/D1445M. Describe the material or product sampled and the method of sampling used.

13.2 Report the following information:

13.2.1 Adjusted average breaking tenacity to 1 decimal [grams-force per tex], or

13.2.2 Adjusted average tensile strength, 1000 psi, to the nearest whole number,

13.2.3 Average breaking elongation in percent, if determined, to the nearest whole number,

13.2.4 Type of testing machine, and

13.2.5 Nominal gauge length.

## 14. Precision and Bias

14.1 *Interlaboratory Test Data*[4]—An interlaboratory test was carried out in 1969 in which two operators in each of two laboratories performed breaking strength and elongation tests on cotton fibers. Each of the two operators tested three specimens from each of five subsamples from each cotton to establish standard values for each of five different cottons. The operators performed strength tests at both zero and ⅛-in. [3-mm] gauge length with the Pressley instrument and strength and elongation tests in combination at ⅛-in. [3-mm] gauge length with the Stelometer instrument. The operators performing these tests had better than average skill and extensive experience. Each of the subsamples were coded with different numbers and the results were decoded after the tests were completed. The levels of participating laboratories were controlled by the use of the same group of calibration cottons. The components of variance calculated from the results of these tests and expressed as standard deviations are listed in Table 1.

[4] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D13-1011. A copy is available on loan from ASTM Headquarters, 100 Barr Harbor Drive, Conshohocken, PA 19428.

**TABLE 1 Standard Deviations for Single-Operator, Between Operator-within Laboratory and Between-Laboratory Components of Variance for Results of Cotton Fiber Strength Tests**

| Test item | Single-Operator | Within-Laboratory |
|---|---|---|
| Pressley instrument: | | |
| Zero-gauge strength, 1000 psi | 2.488 | 0.320 |
| ⅛-in. gauge tenacity, gf/tex | 0.9680 | 0.0211 |
| Stelometer instrument: | | |
| ⅛-in. gauge tenacity, gf/tex | 0.6990 | 0.0464 |
| ⅛-in. gauge elongation, percentage points | 1.6362 | 0.0371 |

**TABLE 2 Critical Differences Between Two Means in Cotton Fiber Strength Tests for the Conditions Noted**[A]

| Number of Specimens in Test and Item[A] | Single-Operator | Within-Laboratory | Between-Laboratory |
|---|---|---|---|
| Six-specimen test: | | | |
| Pressley instrument: | | | |
| Zero-gauge strength, 1000 psi | 2.8 | 3.0 | 3.0 |
| ⅛-in. gauge tenacity, gf/tex | 1.10 | 1.10 | 1.66 |
| Stelometer instrument: | | | |
| ⅛-in. gauge tenacity, gf/tex | .79 | .80 | .85 |
| ⅛-in. gauge elongation, percentage points | 1.85 | 1.85 | 2.24 |
| Two-specimen test: | | | |
| Pressley instrument: | | | |
| Zero-gauge strength, 1000 psi | 4.9 | 5.0 | 5.0 |
| ⅛-in. gauge tenacity, gf/tex | 1.90 | 1.90 | 2.27 |
| Stelometer instrument: | | | |
| ⅛-in. gauge tenacity, gf/tex | 1.37 | 1.38 | 1.40 |
| ⅛-in. gauge elongation, percentage points | 3.21 | 3.21 | 3.45 |

[A] The values for the critical differences listed in Table 2, were calculated using $t = 1.960$ which is based on an infinite number of degrees of freedom. These values are applicable only when the tests are performed by skilled operators in laboratories which control the level of results by use of standard calibration cottons.

14.2 *Precision*—For the components of variance in Table 1, the averages of observed values for both the six specimen and the two specimen tests should be considered significantly different at the 95 percent probability level if the difference equals or exceeds the critical differences in Table 2.

NOTE 5—The tabulated values for the critical differences listed in Table 2 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 randomized specimens from one sample of the material to be tested.

14.3 *Bias*—When controlled by the use of calibration cotton standards, the procedures in Test Method D1445 for breaking strength and elongation have no bias and are accepted as a referee method.

## 15. Keywords

15.1 breaking strength; cotton; elongation