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Standard Test Method for Tensile Properties of Paper and Paperboard Using Constant-Rate-of-Elongation Apparatus¹

This standard is issued under the fixed designation D828; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

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

1. Scope

1.1 This test method covers procedures for determining tensile properties of paper and paperboard.

1.2 The procedures given in this test method are for use with constant-rate-of-elongation tensile testing equipment and as such, are able to be used with instruments designed for either vertical or horizontal operation, and whether manually operated or computer controlled.

1.3 These procedures are applicable for all types of paper, paperboard, paper products, and related materials within the measurement limitations of the equipment used. They are not for use with combined corrugated board.

1.4 Properties able to be determined using this test method include tensile strength, stretch, tensile energy absorption, tensile stiffness, breaking length, and tensile index.

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

1.6 *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.*

1.7 *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.*

¹ This test method is under the jurisdiction of ASTM Committee D09 on Electrical and Electronic Insulating Materials and is the direct responsibility of Subcommittee D09.01 on Electrical Insulating Products.

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2. Referenced Documents

2.1 ASTM Standards:²

D585 Practice for Sampling and Accepting a Single Lot of Paper, Paperboard, Fiberboard, and Related Product (Withdrawn 2010)³

D685 Practice for Conditioning Paper and Paper Products for Testing

D987 Test Method for Test for Stretch of Paper and Paper Products Under Tension (Withdrawn 1968)³

D1968 Terminology Relating to Paper and Paper Products
E122 Practice for Calculating Sample Size to Estimate, With Specified Precision, the Average for a Characteristic of a Lot or Process

3. Terminology

3.1 *Definitions:* For definitions of terms used in this test method, refer to Terminology D1968 or the *Dictionary of Paper*.⁴

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *line contact grips, n*—grips or jaws on a tensile testing machine having a clamping zone for gripping the specimen comprised of a cylindrical and a flat surface or two cylindrical surfaces whose axes are parallel.

3.2.2 *paper, n*—planar structures deposited from an aqueous suspension that has a thickness less than 1 mm containing organic material, nonorganic material, or a combination of the two.

4. Significance and Use

4.1 The tensile properties measured in this test method are fundamental properties associated with the manufacture, or end

² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

³ The last approved version of this historical standard is referenced on www.astm.org.

⁴ Available from the Technical Association of the Pulp and Paper Industry, PO Box 105113, Atlanta, GA 30348.

use, or both, of paper and paper products. It is possible for products to be influenced by, or indicative of: the type fibers used or the treatment of the fibers, or both, in a particular paper: or of specific manufacturing procedures used in producing a specific paper or paper product. Likewise, it is possible for paper converting operations to significantly impact properties measured using this test method, and this test method is a possible tool to measure and understand such effects.

4.2 Tensile strength is indicative of the serviceability of many papers, such as wrapping, bag, gummed tape, and cable wrapping, that are subjected to direct tensile stress. The tensile strength of printing papers is indicative of the potential resistance to web breaking during printing and other converting operations and during travel of the web from the roll through the equipment.

4.3 Stretch, and sometimes tensile stiffness are indicative of the ability of the paper to conform to a desired contour. These are important properties of creped papers, towels, napkins, decorative papers, industrially used paper tapes (both creped and pleated), bags, and liners for cans, barrels, and cartons.

5. Apparatus

5.1 *Tensile Testing Machine*, of the constant-rate-of elongation type conforming to the following criteria:

5.1.1 Two line contact grips or jaws for gripping the test specimens, with the line of contact perpendicular to the direction of the applied load, and with means for controlling and adjusting the clamping pressure.

NOTE 1—There is the possibility that are certain grades of paper that will be damaged by line contact grips. In these cases, as agreed upon between the users of this test method, it is allowable for other grips to be substituted, and that fact stated in the report.

5.1.1.1 The clamping surfaces of the two grips must be in the same plane and so aligned that they hold the test specimen in that plane throughout the test.

5.1.2 The distance between the line contact gripping zones of the grips at the beginning of a test must be adjustable and resettable to ± 0.5 mm (± 0.02 in.) for the specified initial test span (see 8.1 and 10.3.2).

5.1.3 The rate of separation of the two grips must be 25.4 mm/min \pm 5.0 mm/min (1.0 in./min \pm 0.2 in./min) or as otherwise noted (see 10.3.4), and once set, must be resettable and constant at the required rate to ± 4 % of the specified value.

5.1.4 The tensile testing machine must be equipped with a load measuring device and a recorder or other suitable indicator of the measured load at points of interest during the test, an example of which might be a micro processor and digital readout device or cathode ray tube screen, capable of reading the measured loading force accurately to 0.25 % of the full range of the load measuring device. The load measuring circuitry must be capable of accurate calibration, and must maintain that calibration accuracy to ± 0.5 % of the full-scale value.

5.1.5 The tensile testing machine must be equipped with an elongation measuring device and a recorder or other suitable indicator of the measured elongation at points of interest, an example of which might be a microprocessor and digital readout device or cathode ray tube screen, capable of accurate

calibration and of indicating the elongation values to a readability and accuracy of ± 0.05 % stretch (that is ± 0.09 mm elongation for an original specimen test span of 180 mm).

5.1.6 The tensile testing machine must be capable of providing the measurement data required for making the calculations specified in Section 11, whether by presentation of data in the form of a recorder trace of the tensile force-elongation behavior of the material being tested such that data required by the user is able to be readily determined from the recorder trace, or whether by storage of required data points in a form usable and retrievable by the user for calculations as specified in Section 11, or whether by including calculation algorithms suitable for direct display of the calculations specified in Section 11. Where calculation algorithms are included, it is the responsibility of the manufacturer of the instrument to clearly document the calculation basis for the values that are reported, and that they do or do not comply with the calculations specified in Section 11. The user of the instrument must, in turn, determine that reported values are suitable for any particular information need. Numerous other calculations are possible, based on the tensile strength-elongation of a material, and are permissible to be included in an instrument used for making the measurements described in this test method, as agreed upon between the manufacturer and the purchaser of the instrument.

5.2 *Alignment Jig*, to facilitate centering and aligning the specimen in the instrument grips, so that the clamping lines of contact are perpendicular to the direction of the applied force and the center line (long dimension) of the specimen coincides with the direction of the applied force. Use optional, as agreed upon between the users of this test method. Such a device is described in TAPPI Journal (1).⁵

5.3 *Planimeter or Integrator*, to measure the area beneath the load-elongation curve or to compute directly the work to rupture. The specific characteristics of the testing machine used will dictate the need for this device. Most modern electronic tensile testing machines include the necessary calculation capabilities in the software resident in the instrument. See 5.1.6.

5.4 *Specimen Cutter*, a device capable of cutting specimens for testing that are uniform in width to within at least ± 0.5 mm (± 0.02 in.) or less of the specified specimen width, and with edges parallel to within 0.1 mm (0.004 in.). The double-blade strip cutter of the JDC-type is quite satisfactory for this requirement. Cutting dies, that comply with or exceed the tolerances stated herein, are an acceptable alternative the guillotine style cutter mentioned above. Single-blade “paper cutters” do not comply with the requirements for a specimen cutter for purposes of this test method.

5.5 *Magnifier and Scale or Similar Optical Comparator*, for use in measuring specimen widths and determining that specimens comply with 5.4. It is important to understand that the requirements of 5.4 apply to the test specimen, not to the specimen cutter. The tolerances to which the cutter or cutting

⁵ The boldface numbers in parentheses refer to the list of references at the end of this standard.

die itself must be designed are those that produce test specimens of the stated tolerance.

NOTE 2—Automated tensile testing instruments providing automated sample handling, laboratory management, or data acquisition, or any of these in combination, are available. These instruments provide features not limited to calibration, calibration check, automation of testing sequence, storing of testing programs including rate of grip separation or distance of grip separation, or both, cutting of test strips, acquiring of test data, and accurately determining tensile breaking properties including those listed in Section 11. This test method is acceptable to be used with any such equipment, provided the equipment complies with the requirements of Section 5.

6. Sampling

6.1 *Acceptance Sampling*—Acceptance sampling shall be done in accordance with Practice D585.

6.2 —*Sampling for Other Purposes*—The sampling and the number of test specimens depend on the purpose of the testing. Practice E122 is recommended.

7. Test Specimens

7.1 The standard dimension for test specimens required for performing this test method is 25.4 mm \pm 0.5 mm (1.00 in. \pm 0.02 in.) wide and of such length, usually about 254 mm (10.0 in.) to allow sufficient specimen for clamping in the instrument grips when the standard distance between the grip clamping zones is 180 mm \pm 5 mm (7.1 in. \pm 0.2 in.). A common width dimension, found in many ISO Standards and used for some specific grades of paper based on specification or agreement between the buyer and the seller, is 15.0 mm (0.591 in.). (Note that the information in A1.2.2, *Effect of Test Specimen Width*, contradicts this variability statement.)

7.1.1 It is possible specifications requiring specimen widths other than those in 7.1 will be encountered. Specimen width used must always be included in the report when it deviates from 7.1. The impact of specimen width is addressed in Annex A1.

7.2 From each conditioned test unit of the sample, cut ten test specimens in each of the two principle directions of the paper having the dimension stated in 7.1 using a specimen cutter complying with 5.4.

7.3 Ensure that the specimen strips chosen for testing are free from abnormalities such as creases, holes, wrinkles, or other features not typical of the paper itself that will possibly impact tensile strength values.

7.4 In cases where it is not possible to obtain specimens complying with 7.1 with regard to specimen length, or 7.3 with regard to freedom from abnormalities, a smaller initial distance between the two instrument grips is permissible, with accompanying requirements for shorter test specimens and as agreed upon between the buyer and the seller, or required in relevant specifications. In addition, a change in rate of grip separation is possible. In such cases the deviation from this test method must be reported. Further information on these points is found in Annex A1.

7.5 In some cases, as agreed upon between the buyer and the seller, or required in relevant specifications, it is permissible to perform testing on test specimens of lesser or greater width

than that specified in 7.1. In such cases, the deviation from this test method must be reported. Further information on this point is available in Annex A1.

8. Calibration

8.1 Because of the large number of tensile testing machines available that conform to the requirements of 5.1, specific calibration procedures for individual instruments is beyond the scope of this test method, and must be obtained from the manufacturer of the equipment. The following are general considerations that must be included, along with other considerations unique to specific instruments, as part of calibration procedures for use with this test method.

8.1.1 Regularly inspect the machine for cleanliness and for faults such as wear, misalignment, loose parts, or damage. Clean, grease, or otherwise service the machine at regular intervals, as recommended by the manufacturer or determined by the user of a particular machine. Make all necessary repairs when faults are found.

8.1.2 Level the machine accurately in the two principle directions using a carpenter's level or similar device.

8.1.3 Align the clamping grips that hold the specimen in the plane of the applied load, as required in 5.1.1.

8.1.4 Position the specimen grips as required in 5.1.2, or as agreed upon between the buyer and the seller in 7.4.

8.1.5 Determine and adjust the clamping pressure on the specimen grips so that neither slippage or specimen damage occurs. Papers prepared from more highly hydrated or beaten fibers, such as tracing paper or glassine, present the most difficult gripping problems. For use with the widest possible range of papers, adjustment of grip pressure by making tests on strong tracing paper is generally satisfactory. Excessive pressure at the grip is evidenced by straight-line breaks in, and immediately adjacent to the clamping zone. Insufficient pressure is evidenced by an abrupt discontinuity in the measured tensile strength prior to specimen rupture, or a wider than normal impression of the clamping line on the specimen after rupture, or both. Some level of experimentation will be required to achieve a satisfactory clamping pressure for specific types of paper or paper products.

8.1.6 After it is established that the testing machine is in good working order and has been properly leveled, periodic calibration of the load measuring system with standard weights is required. For referee testing and to comply with many different quality management programs, or both, the weights used shall have traceability to a national standardizing organization such as NIST. Weights covering the entire range of the load-measuring component in the testing machine shall be available, and include about ten weights spaced fairly evenly throughout the measuring range. Attach the weights to the clamp connected to the load measuring device in a suitable manner or as directed in the instrument instructions, being sure to eliminate the weight of any weight support from the indicated value of the weight itself. Note the value measured when the system is in equilibrium. As stated in 5.1.4, allowable deviation from true weight is ± 0.5 % of the fullscale range of the measuring component.

8.1.7 Periodic verification of the extension measuring system is required. Set the clamping grips to a specific separation

as required in 5.1.2 or agreed upon based on 7.4. Verify the exact separation of the grips to the nearest 0.05 mm using a caliper of verified accuracy. Operate the grip separating system (commonly called the cross head on vertical tensile testing machines) as specified in 5.1.3 for a desired time period, measured to the nearest 0.1 s. Based on the speed at which the cross head is set to travel (25.4 mm/min as specified in 5.1.3, or some other speed) calculate the expected distance between grips (original separation plus the distance represented by multiplying the cross-head speed times the seconds of travel). Measure the actual distance with the caliper. The measured and calculated distances must agree within ± 0.09 mm (see 5.1.5). Repeat for several different time intervals within the expected 15- to 30-s duration of a tensile test to rupture (see 10.3.4).

8.2 Perform such other maintenance and/or calibration required for the proper performance of the tensile testing machine used such that it complies with all requirements of this test method and all recommended calibration and maintenance programs of the manufacturer.

9. Conditioning

9.1 Condition the samples in accordance with Practice D685.

9.1.1 Erratic results are possible with exposure of the samples to high relative humidity prior to preconditioning and conditioning, with either a decrease or increase in tensile strength or stretch, or both. Careful protection of the sample from extremes in humidity from the time of sampling until testing is very important.

10. Procedure

10.1 Perform all testing in an environment as specified in Practice D685.

10.2 Adjust and calibrate the testing machine as required in Section 8.

10.3 The standard testing parameters required by this test method are as follows:

10.3.1 *Specimen Width*—25.4 mm (1.00 in.), see 7.1,

10.3.2 *Effective Specimen Length (Grip Separation at Start of Test)*—180 mm (7.1 in.), see 7.1,

10.3.3 *Nominal Specimen Length*—254 mm, see 7.1, and

10.3.4 *Rate of Grip Separation During Test*—25.4 mm/min, see 5.1.3.

10.3.4.1 This rate of grip separation generally results in sample rupture in less than 30 s and more than 10 s. In cases where rupture consistently requires greater than 30 s, a more rapid rate of grip separation must be used, so that sample rupture occurs in between 10 and 30 s. Where a grip separation other than that stated in 10.3.4 is used, the actual grip separation speed must be reported, as required in 12.1.5.

10.3.5 For purposes of testing shipping sack and shipping sack paper for compliance with tensile energy absorption carrier and federal requirements,⁶ an effective specimen length

(grip separation at start of test) of 122 mm (4.2 in.) and a rate of grip separation of 25.4 mm/min must be used.

10.3.6 Adjust data recording components for data recording as required for the material being tested, particularly with regard to the full-scale range of the load measuring system.

10.3.7 Where specimen tensile strength is unknown, preliminary tests are required to achieve proper instrument settings.

10.3.8 Place one end of a test specimen into one of the instrument grips, align it, and clamp it in place. Place the other end of the test specimen in the other grip. Carefully remove slack, but to not stretch the specimen. Close the second clamp. While handling the test specimen, avoid touching the area that will be between the two clamping zones with the fingers.

10.3.9 Verify correct clamping pressure (see 8.1.5).

10.3.10 Test ten specimens in each principle direction for each test unit.

10.3.11 Reject any test value in which the test specimen slips in the jaws, breaks within the clamping zone, or shows evidence of uneven stretching across its width. Also, reject any test values for test specimens that break within 5 mm (0.2 in.) of the clamping zone if further inspection indicates the break location is due to improper clamping conditions or misalignment of the specimen. If more than 20 % of the specimens for a given sample are rejected, reject all readings for the sample, inspect the testing machine for conformance with specifications, and take any steps necessary to correct problems identified.

10.3.12 Record values for tensile strength, elongation, and other calculated quantities as required or provided for by the instrument being used for each specimen strip tested. Automatic accumulation of the values in a data file in instrument software is permissible if the instrument is so equipped, or transferred directly into a central data system.

10.3.13 For any case in which deviations from this procedure are made, particularly because of small sample length, all deviations and the reason for them must be documented in the report.

11. Calculation or Interpretation of Results

11.1 For each test unit and in each principle direction, calculate the average value for the tensile strength at rupture using the data from 10.3.12. Add the value for each individual specimen and divide by the total number of specimens tested.

11.1.1 The customary units of tensile strength are force per width. In cases where a 1.00-in. specimen is tested, the customary unit is force per inch. In cases where a 15 mm specimen is tested, customary units are force per 15 mm. Where other specimen widths are required, the specification will generally state units to be used in reporting data.

11.2 In like manner to that described for tensile strength in 11.1, calculate the average value for elongation at rupture. If desired, report this value as the percentage of the original effective specimen length (see 10.3.2).

11.3 Calculate the average tensile energy absorption prior to rupture for each principle direction of each test unit, again by adding together the individual test values of tensile energy absorption and dividing by the total specimens tested.

⁶ Freight Classification Rule 40, National Motor Freight Classification, Item 200, UUS 48, and Department of Transportation 178.236.

11.3.1 Use the following formulas to calculate tensile energy absorption in joules per square meter. See **Annex A1** for derivation of constants:

$$\begin{aligned} TEA &= 1 \times 10^6 A' / LW \\ &= 9.807 \times 10^4 A' / LW \\ &= 175.1 a / lw \end{aligned}$$

where:

TEA = tensile energy absorption, J/m²,
 L = initial test span, mm,
 W = specimen width, mm,
 A = area under the load-elongation curve, J, and
 A' = area under the load-elongation curve, kgf-cm.

11.3.2 While the units in **11.3.1** are preferred, if foot pound-force per foot² are desired, use the following formula:

$$tea = 12a/lw$$

where:

tea = tensile energy absorption, ft-lbf/ft²,
 a = area under the load-elongation curve, lbf-in.,
 l = initial test span, in., and
 w = specimen width, in.

11.3.3 To convert from tea to TEA , use the following formula:

$$TEA = 14.60 \times tea$$

11.4 Using instrument software or a recorder trace of the test data, calculate tensile stiffness, if desired, as the average slope of the elastic region of the test data in agreed units of force per elongation (strain). For purposes of this analysis, the elastic region over which this average value is determined must begin at a load value no lower than 5 % of the elastic limit, and must not go beyond 75 % of the elastic limit, and the data used must comprise at least 20 % of the elastic region of the test data. <https://standards.iteh.ai/catalog/standards/sist/dd2d49ed-4828-2024-9101-b5301c1901b6/astm-d828-22>

11.5 For purposes of determining specimen rupture in **11.1**, **11.2**, and **11.3**, the specimen will be deemed to have ruptured when maximum tensile load has been reached and the tensile load has dropped no more than 0.25 % of the instrument full-scale load below the maximum load. This procedure is applicable so long as maximum strain occurs at rupture, which is usually the case for paper samples. For instruments including software packages to determine rupture, it is the responsibility of the user to determine that the conditions stated here are fulfilled. Frequently, instrument “peak” (rupture) detecting algorithms are variable by user input, to allow the instruments to be used for a wide variety of testing activities.

11.6 Calculate breaking length, when required, using the following formula:

$$\begin{aligned} BL &= 102000(T / R) \\ &= 3658(T' / R') \end{aligned}$$

where:

BL = breaking length, m,
 T = tensile strength, kN/m,
 R = grammage, g/m²,
 T' = tensile strength, lbf/in., and

R' = mass per unit area, lb/1000 ft².

11.6.1 It is customary to measure R or R' under “air dry” conditions, rather than under the conditions specified in Practice **D685**. The buyer and seller must agree on the exact calculation convention being used when breaking length is included in a specification.

11.7 Calculate tensile index, when required, using the following formula:

$$\begin{aligned} TI &= 1000 (T / R) \\ &= 36.87 (T' / R') \end{aligned}$$

where:

TI = tensile index, and

$N \cdot m/g$, T , T' , R , and R' are in accordance with **11.6**.

11.8 All of the above calculations are available in software packages for use within test instruments themselves, or within personal computer or larger laboratory computerized data management systems. It is the responsibility of the user to determine exactly what calculations and units are required, and that desired data is being generated.

11.9 The following are the required units for tensile properties determined using this test method in the absence of agreements between the buyer and the seller to use other units:

- 11.9.1 Tensile strength, kN/m,
- 11.9.2 Elongation, %,
- 11.9.3 Tensile energy absorption, J/m²,
- 11.9.4 Tensile stiffness, kN/m,
- 11.9.5 Breaking length, m, and
- 11.9.6 Tensile index, N-m/g.

12. Report

12.1 Report at least the following information for each test unit in each principle direction to three significant figures. Units of reporting are to be as specified in **11.9** unless the seller and the buyer agree to use other units:

- 12.1.1 Average tensile strength and range or standard deviation,
- 12.1.2 Average percentage elongation and range or standard deviation,
- 12.1.3 Average tensile energy absorption and range or standard deviation,
- 12.1.4 The number of tests rejected and the reason for rejection, and
- 12.1.5 Any deviations from the procedures specified as standard in this test method, including, but not limited to, deviations in sample length or width, rate of jaw separation, clamping and configurations, or features of equipment design.

13. Precision and Bias

13.1 *Repeatability*—The critical limits of repeatability between which two test results, each representing the average of values determined on ten test specimens of the same test unit within the same laboratory by the same operator will fall 95 % of the time, calculated as the percentage of the average of the two results are as follows:

- 13.1.1 *Tensile Strength*—5 %,
- 13.1.2 *Stretch*—9 %, and