WI 180808.07

T 414

DRAFT NO. 3-SARG

DATE May 18, 2021

WORKING GROUP CHAIRMAN Steve Berg

SUBJECT CATEGORY Physical Properties

RELATED METHODS See "Additional Information"

CAUTION:
This Test Method may include safety precautions which are believed to be appropriate at the time of publication of the method. The intent of these is to alert the user of the method to safety issues related to such use. The user is responsible for determining that the safety precautions are complete and are appropriate to their use of the method, and for ensuring that suitable safety practices have not changed since publication of the method. This method may require the use, disposal, or both, of chemicals which may present serious health hazards to humans. Procedures for the handling of such substances are set forth on Material Safety Data Sheets which must be developed by all manufacturers and importers of potentially hazardous chemicals and maintained by all distributors of potentially hazardous chemicals. Prior to the use of this method, the user must determine whether any of the chemicals to be used or disposed of are potentially hazardous and, if so, must follow strictly the procedures specified by both the manufacturer, as well as local, state, and federal authorities for safe use and disposal of these chemicals.

Internal tearing resistance of paper (Elmendorf-type method)

(Five-year review of Official Method T 414 om-12)

(Changes from Draft 1 incorporated)

1. Scope

1.1 This method measures the force perpendicular to the plane of the paper required to tear multiple plies through a specified distance after the tear has been started using an Elmendorf-type tearing tester. It does not measure edge-tear resistance. The measured results may be used to calculate the approximate tearing resistance of a single sheet. It is not suitable for single-ply tear testing.

1.2 For highly directional boards and papers, prepare specimens according to T 496 "Specimen Preparation for Cross Directional Internal Tearing Resistance for Paper, Paperboard and Related Materials." See section 8.5.

1.3 Caution is recommended in interpreting results from weakly bonded sheets, especially those containing lightly refined long-fibered chemical pulps. The low rate of tear when multiple plies are torn simultaneously may produce erroneously high results (*1*).

2. Summary

Multiple sheets of the sample material are torn together through a fixed distance by means of the pendulum of an Elmendorf-type tearing tester. The work done in tearing is measured by the loss in potential energy of the pendulum. The instrument scale is calibrated to indicate the average force exerted when a certain number of plies are torn together (work done divided by the total distance torn).

3. Significant test variables

3.1 Several Elmendorf-type tearing testers are available and in use throughout the world, principally those of Australian, British, German, Swedish, and United States manufacture. In addition, testing practices also vary, as is reflected in the related methods for these countries or others listed in 11.3. Instruments and practices in use vary in at least three major respects:

3.1.1 The first difference is in the design of the pendulum sector. Instruments conforming to the requirements specified under Section 4 have a deep cutout in the pendulum sector to prevent friction between the specimen and the pendulum. The oldest model, without the deep cutout, permitted the specimen to come in contact with the sector during the test and gave values significantly higher than those obtained using conforming instruments. The magnitude of difference in values, which have been observed (*2*) to be as much as 10%, varies as a function of instrument and different types and grammages of paper.

3.1.2 The second difference is in the design of the specimen clamps which, together with the structural characteristics of the paper which govern the nature of the tear with respect to its splitting tendencies during the test, can have an appreciable influence on the mode of tearing and may result in significant differences (*3*). The procedure described in Section 7.3 reduces this effect. The clamp designs used by some manufacturers may vary even for their own models. Instruments are available with pneumatically activated grips; their use minimizes variations due to differences in clamping pressures exerted by manually tightened grips.

3.1.3 The third difference results from a combined variation in testers and testing practices. As measured tearing resistance increases or decreases for different types of paper, it may become so large or so small as to be outside the practical range of the instrument. This problem may be overcome by changing the number of plies tested at one time. The tearing length must never be varied in an effort to alter the pendulum capacity.

3.2 The foregoing, together with other lesser differences in design details between instruments or testing practices, preclude specifying a tearing instrument and method that would give essentially the same test results when using Elmendorf instruments of different design and manufacture. Even for one specific model, some procedural

variables such as the number of plies torn may alter the test values calculated on a single sheet basis substantially. Hence, by necessity, this reference method must be arbitrary and is limited to the described procedure used with instruments conforming to all of the requirements specified under Section 4.

4. Apparatus

4.1 Elmendorf tearing tester (*4-6*), with a cut-out as shown in Fig. 1, which prevents the specimen from coming in contact with the pendulum sector during the test, and having the following elements:

4.1.1 A stationary clamp; a movable clamp carried on a pendulum formed by a sector of a circle free to swing on a ball bearing; a knife mounted on a stationary post for starting the tear; means for leveling the instrument; means for holding the pendulum in a raised position and for releasing it instantaneously; and means for registering the maximum arc through which the pendulum swings when released.

4.1.1.1 The registering means may consist of a graduated scale mounted on the pendulum, a pointer mounted on the same axis as the pendulum with constant friction just sufficient to stop the pointer at the highest point reached by the swing of the sector, and an adjustable pointer stop for setting the zero of the instrument.

4.1.1.2 The pointer and scale may be replaced by a digital readout unit which gives readings of equivalent accuracy and precision (*7*).

4.1.2 With the pendulum in its initial position ready for a test, the clamps are separated by an interval of 2.8 ± 0.3 mm and are so aligned that the specimen clamped in them lies in a plane parallel to the axis of the pendulum, the plane making an angle of 27.5 ± 0.5° with the perpendicular line joining the axis and the horizontal line formed by the top edges of the clamping jaws. The distance between the axis and the top edges of the clamping jaws is 102.7 ± 0.1 mm. The clamping surface in each jaw is at least 25 mm wide and 15.9 ± 0.1 mm deep.

NOTE 1: Instruments commonly available in the United States are usually equipped with 36 ± 1 mm wide jaws. Instruments may be equipped with jaws as narrow as 25 mm. Testing has shown that the effect of jaw width on test results is statistically insignificant. It is recommended, however, that the test specimen length be adjusted to match jaw width. See Note 3 4.

4.1.3 The instrument measures the energy (work done) used by the pendulum in tearing the test specimen. To convert to average tearing force, the energy is divided by the total distance through which the force is applied. This division may be accomplished by the electronics in digital read-out instruments so that the read-out is directly in grams-force or in millinewtons (SI unit of force). For pointer and scale instruments, the scale may be in millinewtons or in grams-force for a specified number of plies; i.e., when the specified number of plies are torn together, the scale reading gives the average tearing resistance (force) of a single ply.

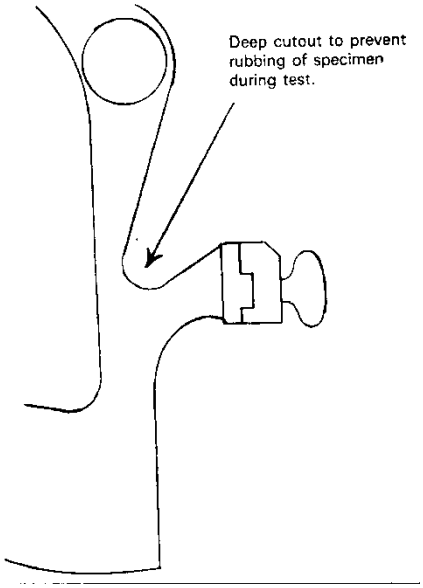

Fig. 1. Newer testing model with deep cutout.

4.1.4 Instruments of several capacities e.g., about 2000, 4000, 8000, 16,000, 32,000 mN (200, 400, 800, 1600, 3200 gf) and perhaps others are available, with the several capacities being achieved by individual instruments, interchangeable pendulum sectors, or augmenting weights. The instrument recognized as "standard" for this method has a capacity of 1600 gf (SI equivalent 15.7 N); i.e., it has a pendulum sector of such mass and mass distribution that its 0 to 100 scale is a direct reading in grams-force per ply when 16 plies are torn together. For a 16-ply test specimen, the tearing distance K = 16 x 4.3 cm (tearing distance per ply) × 2 = 137.6 cm, the factor 2 being included since in tearing a given length the force is applied twice the distance. Likewise, for a 16-ply test specimen, the tearing energy per ply for a scale reading of 100 would then be 100 gf x 137.6 cm or 13760 gf cm (SI equivalent 1349.4 mJ). For some of the instruments of different capacities where different numbers of plies are required, or when the number of plies tested using the "standard" instrument differs from 16, different values of K and/or the tearing energy per ply may be calculated, using the above calculation as a model.

4.1.5 In the "standard" instrument, the zero reading on the scale is at about 70° from the center line (i.e., the vertical balance line when the pendulum hangs freely), the 100 reading is at about 21° from the center line, and a vertical force of 1057.3 ± 2.0 gf (SI equivalent 10.369 ± 0.020 N) applied at 22.000 ± 0.005 cm from the pendulum axis is required to hold the pendulum sector at 90° from its freely hanging position to give a total capacity at 1600 gf ± 6.4 gf.

4.1.6 The cutting knife for the test specimen is centered between the clamps and adjusted in height so that the tearing distance is 43.0 ± 0.2 mm; i.e., the distance between the end of the slit made by the knife and the upper edge of the specimen is 43.0 ± 0.2 mm when the lower edge of the 63.0-mm wide specimen rests against the bottom of the clamp.

4.2 *Specimen cutter*. To insure parallel specimens 63.0 ± 0.15-mm wide with sharp and clean edges, it is desirable to use the type having two hardened and ground base shears, twin knives tensioned against the base shears, and a hold-down mechanism.

5. Calibration and adjustment

Calibrate and adjust the instrument according to the instrument manufacturer's directions.

6. Safety precautions

6.1 Keep fingers away from blade when making the initial cut.

6.2 Take care that the pendulum path is completely clear before releasing the pendulum.

6.3 Ensure that the instrument does not "walk" when the pendulum swings. If it moves, with successive tears, it may move to the edge of the bench and fall off.

7. Sampling and test specimens

7.1 Sample the paper in accordance with TAPPI T 400 "Sampling and Accepting a Single Lot of Paper, Paperboard, Containerboard, or Related Product." From each test unit of the sample, prepare 10 representative specimens in each principal direction of the paper, unless a test in only one direction is required. For each specimen keep the wire sides of all the plies facing the same way.

NOTE 2: It has been found (*9*) that there is usually no advantage in testing more than 10 specimens of a homogeneous test unit of the sample.

7.2 Cut each ply for a test specimen at least 53 mm long by 63.0 ± 0.15 mm wide, taking all the plies to be torn together from a single sheet, or if this does not provide sufficient material, from adjacent sheets of a unit.

NOTE 3: The correct length of the test specimen to be used in making a test, measured in millimeters, is equal to the distance between the outermost edges of each of the instrument's jaws (± 2 mm). For the instrument described in 4.1.2, that distance is at least 2 x 25 mm (the minimum width for each jaw face) plus 2.8 mm (the distance between the clamps) or at least 53 mm. In the United States, the majority of instruments have jaws 36 ± 1 mm wide. In such cases, a test specimen length of 76 ± 2.0 mm, specified in T 496 "Specimen Preparation for Cross Directional Internal Tearing Resistance for Paper, Paperboard and Related Materials," continues to be the correct length.

7.3 Determine from a preliminary test or the product specification how many plies are needed to make up a specimen so that, when torn together on the instrument having a 15.7-N (1600 gf) capacity, they give an instrument scale reading nearest 40% of full scale.

NOTE 4: The work done in tearing a number of sheets of paper includes a certain amount of work to bend the paper continuously as it is torn to provide for the rubbing of the torn edges of the specimen together and to lift the paper. The number of plies torn at one time and their size can affect the test result with some papers. Empirical requirements for both the apparatus and the method are therefore necessary to keep the additional work not used for tearing to a definite quantity. For this reason, in making comparisons between two or more sets of paper of the same type and grammage, use the same number of plies for each set.

8 Procedure

8.1 Precondition, condition, and test the specimens in accordance with TAPPI T 402 "Standard Conditioning and Testing Atmospheres for Paper, Board, Pulp Handsheets, and Related Products."

8.2 Raise the pendulum sector to its initial position and set the pointer against its stop. Center the specimen in the clamps with the bottom edge carefully set against the stops. Securely clamp the specimen using approximately the same pressure on both clamps. Make the initial knife cut. Depress the pendulum stop quickly as far as it will go to release the pendulum. Hold down the stop until after the tear is completed and catch the pendulum on the return swing without disturbing the position of the pointer.

8.3 Make only one test per specimen, each specimen consisting of the same number of plies. Make tests alternately with the wire sides of all the plies of a specimen facing the pendulum and with the wire sides of all the plies away from the pendulum. Make certain that the specimen leans toward and not away from the pendulum by gently bending the specimen at the clamp if necessary, but in doing so avoid affecting the moisture content of the test area (*10*).

8.4 Record the scale readings to the nearest half division; also record the number of plies used in the specimens.

8.5 If the sheets split extensively when being torn, report this. If the line of tear fails to pass through the top edge of the specimen but deviates to one side, note and report this, but do not use the reading so obtained. If more than one-third of the tests exhibit this behavior, this method should not be used for the material concerned. Preparing the test specimens according to T 496 "Specimen Preparation for Cross Directional Internal Tearing Resistance for Paper, Paperboard and Related Materials" may alleviate this problem.

8.6 Calculate the average tearing force in millinewtons and, if desired, in grams-force required to tear a single ply as follows:

8.6.1 For the standard 1600-gf instrument with 0-100 scale:

$$\text{Average tearing force, mN} = (16 \times 9.81 \times \text{average scale reading}) / \text{number of plies}$$

$$\text{Average tearing force, gf} = (16 \times \text{average scale reading}) / \text{number of plies}$$

8.6.2 If an instrument has an SI metric scale (e.g., 0-1000 graduations):

Average tearing force, mN = (16 × avg. scale reading × capacity, N) / (number of plies × 15.7 N)

Average tearing force, gf = (16 × avg. scale reading × capacity, N) / (9.81 × number of plies × 15.7 N)

8.6.3 If an instrument has a direct-reading scale (e.g., digital read-out) that directly gives the force per ply when preset for the number of plies:

Average tearing force, mN = scale reading if directly in millinewtons, *or*
= 9.81 × scale reading if in grams-force

Average tearing force, gf = scale reading / 9.81, if scale is in millinewtons, *or*
= scale reading if directly in grams-force

9. Report

9.1 Report results with the tear parallel with the machine direction as resistance to internal tearing in the machine direction and those with the tear perpendicular to the machine direction as resistance to internal tearing in the cross direction.

9.2 For each principal direction, report the average, maximum, and minimum of accepted test values of the force required to tear a single ply to three significant figures.

9.3 For a complete report, state the number of plies torn at one time; the number and value of any rejected readings and reasons for their rejection; and the make and model number of the instrument used.

9.4 Report extensive sheet splitting.

9.5 If the samples were prepared according to T 496 “Specimen Preparation for Cross Directional Internal Tearing Resistance for Paper, Paperboard and Related Materials,” report so.

10. Precision

10.1 Tearing strength:

10.1.1 Repeatability (within a laboratory) = 4%

10.1.2 Reproducibility (between laboratories) = 17%

10.2 Repeatability and reproducibility are estimates of the maximum difference (at 95% confidence) that

should be expected when comparing test results for materials similar to those described below under similar test conditions. These estimates may not be valid for different materials and testing conditions.

10.3 The estimates of repeatability and reproducibility are based on results from the Paper and Paperboard Interlaboratory Program conducted by CTS. The results were derived from testing conducted in 2009 and 2010 using the om-08 version of this method. Tearing strength testing was conducted on three categories of paper: newsprint with grammage of 48.8 g/m^2 (30 lb)., offset printing papers in the range of 74 g/m^2 to 104 g/m^2 (50 lb to 70 lb), and packaging and heavy weight printing papers in the range of 135 g/m^2 to 199 g/m^2. Laboratories made 10 determinations for each test result. All tearing strength results were made using multiple plies; typically 16 plies were used for newsprint, 8 plies for printing papers, and 4 plies for packaging and heavy weight printing papers. The estimates in the chart below are based on 10 results per sample for each grade. Repeatability was estimated from a single test result in accordance with procedures in TAPPI T 1200 for estimating repeatability by test determinations.

Data table for tearing strength

Paper grade	*Average*	*Repeatability r and %r*		*Reproducibility R and %R*		*Labs included*
Newsprint	21	0.9	4.3%	4.1	19.5%	14
Offset	56	1.8	3.1%	9.8	17.3%	72
Packaging and printing	207	9.1	4.5%	31.3	14.9%	39

11. Keywords

Paper, Tear strength, Tensile properties

12 Additional information

12.1 Effective date of issue: To be assigned.

12.2 The principal changes made in the 2012 revision are to reflect the changes of T 496 from an Official Method to a Standard Practice, the removal of references to a single-ply tear method, returning the pendulum length specification to the original length specified by Armin Elmendorf, inserting a new precision section, and adding a safety section.

12.3 Related methods: Australian AS/NZS 1301.400s; Canadian PAPTAC, D.9; ISO 1974.

12.4 Other references related to this method are by Jones and Galley (*11*), Van den Akker, Wink, and Van Eperen (*12*), Sun, Wilson, and Bach (*13*), Lashof (*14*), and Swartout and Setterholm (*15*).

Literature cited

1. Seth, R. S. and Blinco, K. M., "Comparison of Brecht-Imset and Elmendorf Tear Strengths," *TAPPI Journal*, January 1990.
2. Cohen, W. E., and Watson, A. J., *Proc. Australian Pulp Paper Ind. Tech. Assn.* **3**: 212 (1949).
3. Wink, W. A., and Van Eperen, R. H., *Tappi* **46**: 323 (1963).
4. Elmendorf, A., "Strength Test for Paper," *Paper* **26**: 302 (1920).
5. Elmendorf, A., "The Principle of the Elmendorf Paper Tester," *Paper* **28**: (1921).
6. Institute of Paper Chemistry, "Tearing Strength of Paper, Part I," Instrumentation Studies XLVI, *Paper Trade J.* **118** (5):13 (1944).
7. Yarber, W. H. II, and Zdzieborski, J. H. George, *Tappi* **55**: 1064 (1972).
8. Clark, J. d'A., *Tech. Assn. Papers. Series XV* **1**:262 (1932); *Paper Trade J.* **94** (1): 33 (1932).
9. Lashof, T. W., *Tappi* **45**: 656 (1962).
10. Balder, E. E., *Tappi* **63** (8): 103 (1980).
11. Jones, H.W.H., and Galley, W., *Pulp Paper Mag. Can.* **53**(5): 116 (1952).
12. Van DenAkker, J. A., Wink, W. A., and Van Eperen, R. H., *Tappi* **50** (9): 46 (1967).
13. Sun, B. C., Wilson, J. W., and Bach, L., *Tappi* **59** (10): 106 (176).
14. Lashof, T. W., *Tappi* **47**: 445 (1964).
15. Swartout, J. T., and Setterholm, V. C., U.S. Forest Service Research Note FPL, 05 (May 1968).

Your comments and suggestions on this procedure are earnestly requested and should be sent to the TAPPI Standards Department. ■