This TAPPI Test Method has been adopted and endorsed by the Tag and Label Manufacturers Institute, Inc. (TLMI)

T 414 om-98
OFFICIAL STANDARD – 1926
TENTATIVE STANDARD – 1964
OFFICIAL TEST METHOD – 1982
REVISED – 1988
WITHDRAWN – 1997
REINSTATED (OFFICIAL METHOD) – 1998

Internal tearing resistance of paper (Elmendorf-type method)

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. The measured results can be used to calculate the approximate tearing resistance of a single sheet. It is not suitable for single-ply tear testing; a separate method for single-ply tear will be available.

1.2 It is not suitable for determining the cross-directional tearing resistance of highly directional boards and papers. These materials are covered by TAPPI T 496 "Cross Directional Internal Tearing Resistance of Paperboard."

1.3 For edge-tear resistance see TAPPI T 470 "Edge Tearing Resistance of Paper (Finch Method)."

2. Summary

More than one sheet 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 One difference is in the design of the pendulum sector. The oldest model without deep cutout permitted the specimen to come in contact with the sector during the test and gave values significantly higher than those obtained using the newer models *with* a deep cutout (see Fig. 1) which eliminate this undesirable friction. The magnitude of the difference in value obtained using different styles of the instrument described in this test method varies as a function of instrument and with different types and grammages of paper. The instrument having the oldest-style sector does not meet the requirements of this test method. With a few materials, test values have been observed (*1*) to be as much as 10% greater with the oldest-style sector.

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 (*2*). 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 as well; 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 (*3–5*), 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.

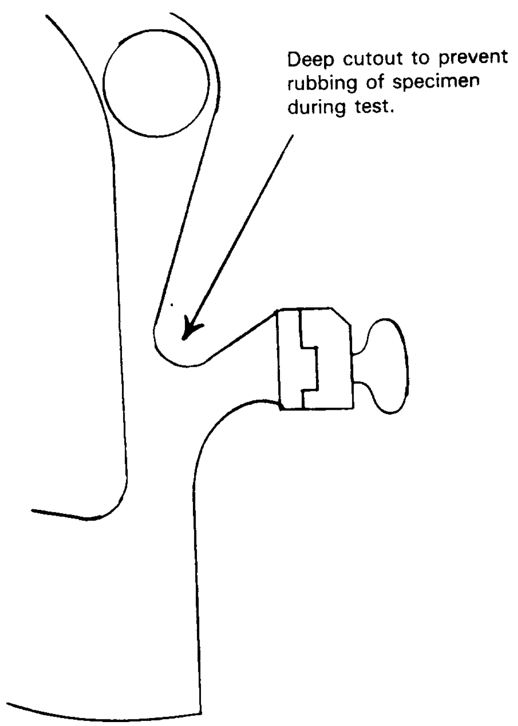

Fig. 1. Newer testing model with deep cutout.

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 (*6*).

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 103.0 ± 0.1 mm. The clamping surface in each jaw is at least 25 mm wide and 15.9 ± 0.1 mm deep.

NOTE 1: In the past, it has been the practice for instruments commonly available in the United States to be equipped with 36 ± 1 mm wide jaws. Instruments currently available, however, 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 4.

4.1.3 The instrument measures the energy (work done) used by the pendulum in tearing the test specimen. In order to convert to average tearing force, the energy must be 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 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.

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 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) x 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

5.1 *Verification of scale*

5.1.1 Once the scale has been verified, it is unnecessary to repeat this step, provided the tester is kept in adjustment and no parts become changed or perceptibly worn. The scale may be verified either by the potential energy method or by the method which uses the check weights obtainable from the manufacturer. The potential energy method is relatively time-consuming and complicated. The check weight method is relatively simple.

5.1.2 *Potential energy method.* The procedure (*7*) for verification is as follows: Anchor and level the tester as later described. Clamp a known weight (in grams) W to the radial edge of the sector beneath the jaws, the center of gravity of the weight (including means of attaching) having been previously marked by a punched dot on the face of the weight that is to be toward the front of the instrument. Close the jaw of the clamp in the sector. Raise and set the sector as for tearing a sheet and, by means of a surface gauge or cathetometer, measure in centimeters, to the nearest 0.01 cm, the height H of the center of gravity of the weight above a fixed horizontal surface. Then release the sector, allow it to swing and note the pointer reading. Without touching the pointer, raise the sector until the edge of the pointer just meets with its stop, in which position again determine the height h of the center of gravity of the weight above the fixed surface.

5.1.2.1 The work done is $W(h-H)$ gf cm. For the standard 1600 gf tester, the pointer reading should be $W(h-H)/K$, where K = 137.6 cm. For other instruments graduated for grams-force of greater or lesser capacity, the reading will be factors of 2 greater or smaller. If graduated for millinewtons, the additional factor 9.81 must be applied.

5.1.2.2 One or more weights may be clamped on the edge of the sector for each calibration point, the work done in raising each weight being calculated and added together.

5.1.2.3 If the deviations of the indicated readings are greater than one-half division, the instrument should be returned to the manufacturer for repair and adjustment.

5.1.2.4 Calibration weights may or may not be available from the manufacturer of the instrument for use in calibration.

5.1.3 *Verification of Scale – Check Weight Method*. Use Check Weights calibrated for suitable scale values (i.e., 20%, 50% and 80% of pendulum capacity.) Different Check Weights are needed for each pendulum capacity.

5.1.3.1 With the pendulum in the raised position, attach the weight into position and fasten it securely, according to the manufacturer's instructions. Depress the pendulum stop, thus releasing the pendulum, and catch the pendulum on the return swing. Read the indicating device to the nearest division.

5.1.3.2 Repeat this procedure with each of the check weights.

5.2 *Adjustment of tearing distance*

5.2.1 To check the 43.0-mm tearing distance, apply a small amount of graphite (from an ordinary pencil), to the cutting knife so that when the cut is made, some of the graphite transfers to the paper. This serves to contrast the cut from the uncut portion of the paper and facilitates the measurement. Make this measurement with a vernier caliper with a depth gauge or a good quality steel rule, readable to 0.2 mm or better under magnification. You may also check that the cut is 20 mm at the same time. An alternative procedure is to use a go, no-go gauge, which may be available from the manufacturer of the instrument.

5.3 *Adjustment of instrument for operation*

5.3.1 *Pendulum notching.* Sometimes, as a result of frequent use, a notch is worn in the pendulum sector at the point of contact with the sector stop, giving a jerky release of the pendulum. If this happens, either repair the sector by cutting out and replacing the worn edge, or adjust the height of the stop to the very lowest point of the sector edge. In this case, recheck the calibration of the scale.

5.3.2 *Clamp alignment and knife condition.* Rest the pendulum sector against its stop, and check the alignment of the clamps. Adjust the pendulum stop if necessary. Verify by visual check that the knife is centered between the clamps, and adjust if necessary. Check the sharpness of the knife. A dull knife will result in a square notch near the top of the cut with the paper pushed out. If necessary, sharpen the knife with a rough stone; a rough edge is better than a sharp, smooth edge. Check the tearing distance and adjust the height of the knife if necessary. *Do not* change the dimensions of the specimen to adjust the tearing distance.

5.3.3 *Instrument mounting.* Support the instrument on a table so rigid that there will be no perceptible movement of the table or instrument during the swing of the pendulum. Any movement of the instrument base during the swinging of the pendulum may be a significant source of error.

NOTE 2: Threaded bolt holes are usually provided in the base of the instrument and may be used to secure the instrument to the table. An alternative procedure is to place the instrument on a guide which ensures that the instrument always has the same position on the table. Such a guide may be available from the manufacturer of the instrument.

5.3.4 *Instrument leveling*. Level the instrument so that, with the sector free, the line on the sector indicating the vertical from the point of suspension is bisected by the edge of the pendulum stop mechanism.

5.3.5 *Pendulum friction (older instruments).* Draw a pencil line on the stop-mechanism 25 mm to the right of the edge of the sector stop. Raise the sector to its initial position and set the pointer against its stop. On releasing the sector and holding the sector stop down, the sector should make at least 20 complete oscillations before the edge of the section which engages the stop no longer passes to the left of the pencil line. Otherwise, clean, oil, and adjust the bearing.

5.3.6 *Pendulum friction (newer instruments)*. In recent years, a new type of frictionless bearing made of synthetic material has been used. This bearing will not necessarily allow the pendulum sector to make 20 complete oscillations as the older one did. This does not mean that there is excess friction in the pendulum swing. These newer bearings should not be oiled. Consult the instructions supplied with the instrument for guidance. Some instruments have a "zero-calibration" to eliminate the influence of the different kinds of friction involved. That means that the test is started by letting the pendulum swing without any test piece. (There is a connection between the pendulum and a incremental encoder.) The instrument stores this as a reference value in internal memory. During normal paper testing with the instrument, the reference value is subtracted from the measured value. If the instrument is equipped with pneumatically activated grips, check that the tubing used does not hinder pendulum action.

5.3.7 *Pointer adjustments*

5.3.7.1 *Pointer zero reading.* Operate the leveled instrument several times with nothing in the jaws, the movable jaw being closed. If zero is not registered, the pointer stop should be adjusted until the zero reading is obtained. Do not change the level to adjust the zero.

5.3.7.2 *Pointer friction*. Set the pointer at the zero reading on the scale before releasing the sector, and after release see that the pointer is pushed not less than 2.5 mm nor more than 4.0 mm beyond the zero. If the pointer friction does not cause it to lie between these two distances, remove the pointer, wipe the bearing clean, and apply a trace of good clock oil to the groove of the bearing, adjust the spring tension or make other adjustments to achieve the specified friction. Reassemble, readjust the zero setting, and recheck the pointer friction.

5.3.8 For digital instruments with automatic calibrations, follow the manufacturer's instructions and consult the manual for maintenance.

6. Sampling and test specimens

6.1 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 3: It has been found (*8*) that there is usually no advantage in testing more than 10 specimens of a homogeneous test unit of the sample.

6.2 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 4: 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 previous versions of this method, continues to be the correct length.

6.3 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 5: 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.

7. Procedure

7.1 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."

7.2 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.

7.3 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 (*9*).

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

7.5 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. If the sheets split extensively when being torn, this also should be reported.

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

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

Average tearing force, mN = (16 × 9.81 × average scale reading) / number of plies

Average tearing force, gf = (16 × average scale reading) / number of plies

7.6.2 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)

7.6.3 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

8. Report

8.1 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.

8.2 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.

8.3 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. Precision

9.1 On the basis of studies made in accordance with TAPPI T 1200 "Interlaboratory Evaluation of Test Methods Used with Paper and Board Products," the precision of test results representing the average of ten readings, has been found to be as follows:

9.1.1 Repeatability (within a laboratory) = 4.2%

9.1.2 Reproducibility (between laboratories) = 12.5%

9.2 In each of the above situations, two test results, each representing an average of ten readings, may be considered alike with a probability of 95% when the two results agree within the appropriate value shown above.

10. Keywords

Paper, Tear strength, Tensile properties

11. Additional information

11.1 Effective date of issue: February 27, 1998.

11.2 The principal changes made in this revision are: (a) exclusion of pendulums of weights other than 1600 gf; (b) exclusion of references to single-ply testing; (c) inclusion of digital instruments; and (d) inclusion of instruments with check weights not mounted in clamps.

11.3 Related methods: ASTM, D 689; Australian APPITA, P 400; British BS 4468; Canadian CPPA, D.9; ISO 1974; SCAN-P 11:73.

11.4 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*).

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Your comments and suggestions on this procedure are earnestly requested and should be sent to the TAPPI Technical Operations Manager. ■