Designation: D689 – 17 (Reapproved 2024)

Standard Test Method for Internal Tearing Resistance of Paper[1]

This standard is issued under the fixed designation D689; 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 measures the force perpendicular to the plane of the paper required to tear multiple sheets of paper 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. In the case of tearing a single sheet of paper, the tearing resistance is measured directly.

NOTE 1—Similar procedures for making Elmendorf-type tear measurements are found in ISO 1974 and TAPPI T414.

1.2 This test method is not suitable for determining the cross-directional tearing resistance of highly directional boards and papers.

1.3 *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.*

1.4 *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]

D646 Test Method for Mass Per Unit Area of Paper and Paperboard of Aramid Papers (Basis Weight) (Withdrawn 2022)[3]

D685 Practice for Conditioning Paper and Paper Products for Testing

D1749 Practice for Interlaboratory Evaluation of Test Methods Used with Paper and Paper Products (Withdrawn 2010)[3]

E178 Practice for Dealing With Outlying Observations

2.2 *ISO Standard:*[4]

ISO 1974 Paper—Determination of Tearing Resistance (Elmendorf method)

2.3 *TAPPI Standard:*[5]

TAPPI T414 Internal Tearing Resistance of Paper

3. Summary of Test Method

3.1 One or more 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).

4. Significance and Use

4.1 This test method is widely used within the paper industry, in conjunction with other tests of strength, as a predictor of end-use performance of a wide range of grades of papers.

5. Apparatus

5.1 *Elmendorf-type Tearing Tester*—Several types 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.

5.2 *Instrumental and Procedural Variables*—Instruments and practices in use vary in at least two major respects:

5.2.1 *The Design of the Specimen Clamps*—Together with the structural characteristics of the paper governing the nature of the tear with respect to its splitting tendencies during the

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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.

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

[4] Available from American National Standards Institute, 25 W. 43rd St., 4th Floor, New York, NY 10036.

[5] Available from the Technical Association of the Pulp and Paper Industrial, P.O. Box 105113, Atlanta, GA 30348.

test, this has an appreciable influence on the mode of tearing and can result in significant differences (**1**)[6]. The procedure described in 5.3.7 reduces this effect. The clamp designs used by some manufacturers can vary even for their own models. Instruments are available with pneumatically activated grips as well, which minimizes variations due to differences in clamping pressures exerted by manually tightened grips.

5.2.2 *A Combined Variation in Testers and Testing Practices*—As measured tearing resistance increases or decreases for different types of paper, the measurement can become so large or so small as to be outside the practical range of the instrument. This problem can be overcome in one of two ways; change the number of sample sheets tested at one time to be changed, or the mass of the instrument pendulum can be changed either by adding augmenting weights or by replacing the entire pendulum with one of a different known mass. The tearing length must never be varied in an effort to alter the pendulum capacity.

5.2.3 These differences, 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 can alter the test values calculated on a single sheet basis substantially. 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 5.3.

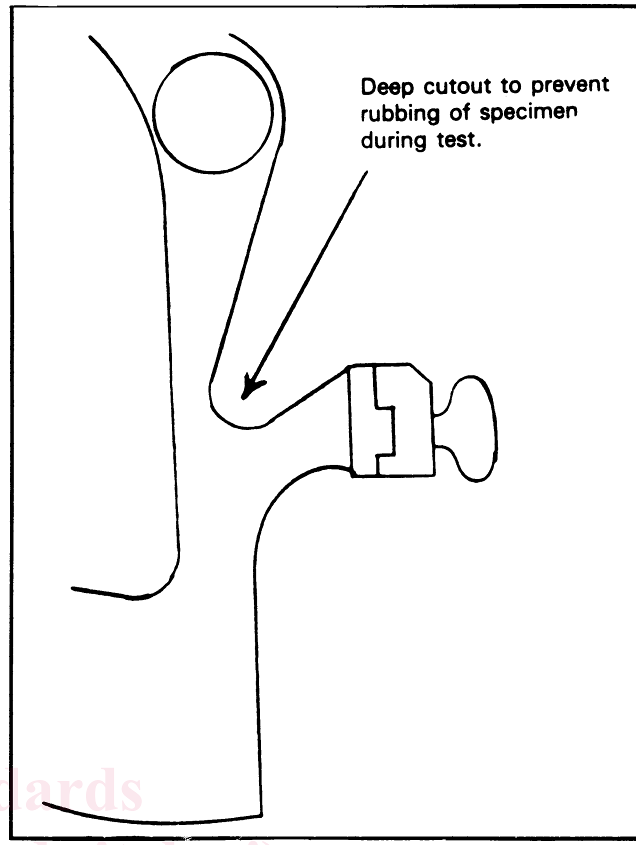

FIG. 1 Newer Testing Model with Deep Cutout

5.3 *Required Instrument for this Test Method:*

5.3.1 *Elmendorf Tearing Tester* (**2**, **3**, **4**), with a cutout 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:

5.3.2 *Stationary and Movable Clamp*—The movable clamp is carried on a pendulum formed by a sector of a circle free to swing on a ball bearing.

5.3.3 *Knife,* mounted on a stationary post for starting the tear.

5.3.4 *Means for Leveling the Instrument.*

5.3.5 *Pendulum Holder*—Means for holding the pendulum in a raised position and for releasing it instantaneously.

5.3.6 *Means for Registering the Maximum Arc* through which the pendulum swings when released. The registering means can 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.

5.3.6.1 The pointer and scale can be replaced by a digital readout unit which gives readings of equivalent accuracy and precision (**5**).

5.3.7 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 2—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. It is possible for instruments currently available to 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.

5.3.8 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 can be accomplished by the electronics in digital readout instruments so that the readout is directly in grams-force or in millinewtons (SI unit of force). For pointer and scale instruments, the scale could be in millinewtons or in grams-force for a specified number of plies; for example, when the specified number of plies are torn together, the scale reading gives the average tearing resistance (force) of a single ply.

5.3.9 Instruments of several capacities (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,

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

or augmenting weights. The instrument recognized as "standard" for this test method has a capacity of 1600 gf (15.7 N), having 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 $K = 16 \times 4.3$ cm (tearing distance per ply) × 2 = 137.6 cm. The factor 2 is 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 × 137.6 cm or 13 760 gf·cm (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* or the tearing energy per ply, or both, can be calculated.

5.3.10 n the "standard" instrument, the zero reading on the scale is at about 70° from the center line (that is, 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 (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. Other tearing instruments will require vertical forces that are factors of 2 greater or smaller than 1057.3 gf and, if calibrated in millinewtons, the zero reading would remain at 70° and the 1000 reading would be at about 19° (or the 981 reading at about 21°).

5.3.11 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; for example, 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.

5.4 Instruments are available for automated testing that incorporates automatic sample insertion, automatic sample cutting, and so forth, in addition to electronic data readout as specified in 5.3.4. These automated instruments can be used, provided the conditions specified in 5.3 are met.

5.5 *Specimen Cutter,* to ensure parallel specimens 63 ± 0.15 mm wide with sharp and clean edges. For this purpose, 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.

6. Sampling and Test Specimens

6.1 Obtain the sample to be tested in accordance with Methods D585.

6.2 From each test unit of the sample, prepare ten representative specimens in each principal direction of the paper, unless a test in only one direction is required. For each specimen, arbitrarily designate one side of the material in some way, such as "primary side", "print side", "wire side", "side one", and so forth. For each specimen, keep the designated sides of all the plies facing the same way.

NOTE 3—It has been found (**6**) that there is usually no advantage in testing more than ten specimens of a homogeneous test unit of the sample.

6.3 Cut each ply for a test specimen so that its dimension on the side placed in the clamps is at least 53 mm and the dimension through which the tear will be propagated is 63.0 ± 0.15 mm. Take all the plies to be torn together from a single sheet. If sufficient material is not provided, take from adjacent sheets of a unit.

NOTE 4—The correct dimension for the side of the test specimen that will be placed in the clamps is equal to the distance between the outermost edges of each of the instrument's jaws (±2 mm). For the instrument described in 5.3, that distance is at least 2 × 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 the instruments have jaws 36 + 1 mm wide. A dimension of 76 ± 2.0 mm for the side of the sample to be held in the clamps is correct.

7. Calibration and Adjustment

7.1 As noted in Section 5, several Elmendorf-type testers are available and in use at the present time. Minor differences in calibration or adjustment procedures, or both, can apply to instruments obtained from different vendors that comply with 5.3, thus it is questionable that specific calibration procedures can be used for all instruments complying with 5.3. The information contained in this section is to be used as a guide in placing an individual instrument into proper calibration for use in performing the test.

7.2 *Verification of Scale*—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 can 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.

7.2.1 *Potential Energy Method*—The procedure (**7**) for verification is as follows: Anchor and level the tester. 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 centimetres, 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 determines the height, h, of the center of gravity of the weight above the fixed surface.

7.2.2 Use the following formula for the standard 1600-gf tester:

$$W(h - H) \text{ in gf} - \text{cm} \quad (1)$$

where:

$W(h\text{-}H)/K$	=	the pointer reading, and
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.