Standard Test Method for Bursting Strength of Paper[1]

This standard is issued under the fixed designation D 774/D 774M; 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 Department of Defense.

1. Scope

1.1 This test method covers measurements of the bursting strength of paper and paper products occurring as single or laminated flat sheets not over 0.6 mm [0.025 in.] in thickness having a bursting strength of 30 kPa up to 1400 kPa [4 psi up to 200 psi].

1.2 This test method is not intended for use in testing corrugated boxboard, liner board, or hardboards that tend to cut the thin rubber diaphragm.

NOTE 1—Similar procedures for making bursting strength measurements are found in ISO 2758 and TAPPI 403.

1.3 The values stated in either SI units or in other units shall be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system must be used independently of the other, without combining values in any way.

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

2. Referenced Documents

2.1 *ASTM Standards:*

D 585 Practice for Sampling and Accepting a Single Lot of Paper, Paperboard, Fiberboard, or Related Products[2]

D 646 Test Method for Grammage of Paper and Paperboard (Weight per Unit Area)[2]

D 685 Practice for Conditioning Paper and Paper Products for Testing[2]

D 1968 Terminology Relating to Paper and Paper Products[2]

2.2 *ISO Standard:*

ISO 2758 Paper—Determination of bursting strength[3]

2.3 *TAPPI Standard:*

TAPPI T 403 Bursting strength of paper[4]

3. Terminology

3.1 *Definitions:* Definitions shall be in accordance with Terminology D 1968 and the *Dictionary of Paper.*[4]

4. Significance and Use

4.1 Bursting strength is widely used as a measure of the resistance to rupture in many kinds of paper. The test is relatively easy and inexpensive to make and appears to simulate some use requirements.

5. Apparatus

5.1 *Bursting Tester*, having the following features and auxiliary equipment:

5.1.1 *Clamp*, for firmly and uniformly securing the test specimen without slippage during the test (recommended clamping load 2700 N [600 lb]) between two annular, plane, parallel, and preferably stainless steel surfaces.

5.1.1.1 The upper clamping surface (the clamping ring) has a circular opening 30.50 ± 0.05 mm [1.200 ± 0.002 in.] in diameter. The surface which is in contact with the paper during testing has a continuous, spiral, 60° V-groove, at least 0.25 mm [0.010 in.] deep and of 0.8 mm [1⁄32 in.] pitch, the groove starting at 3.2 mm [1⁄8in.] from the edge of the opening. The circular edge of the opening that is in contact with the paper during testing is relieved of sharpness with a very fine abrasive cloth (such as crocus cloth) but not rounded off enough to alter the diameter of the opening.

5.1.1.2 The lower clamping surface (the diaphragm plate) has an opening 33.1 ± 0.1 mm [1.302 ± 0.003 in.] in diameter. Its surface has a series of concentric 60° V-grooves 0.30 mm [0.012 in.] deep, 0.8 mm [1⁄32in.] apart, the center of the first groove being 3.2 mm [1⁄8in.] from the edge of the opening. The thickness of the plate at the opening is 0.66 mm [0.026 in.]. The lower edge which is in contact with the rubber diaphragm is rounded to an arc of 6.4 mm [0.25 in.] radius to prevent cutting of the diaphragm when pressure is applied.

5.1.1.3 The clamping ring is connected to a clamping mechanism through a swivel-type joint or other means to

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[2] *Annual Book of ASTM Standards*, Vol 15.09.

[3] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

[4] Available from the Technical Association of the Pulp and Paper Industry, Technology Park/Atlanta P.O. Box 105113, Atlanta, GA 30348.

TABLE 1 Gage Characteristics

Range of bursting pressure		Range of gage		Scale graduation intervals		Expansibility of gage	
kPa	psi	kPa	psi	kPa	psi	mL/kPa	mL/psi
28–77	4–11	0–105	0–15	0.7	0.1		
56–161	8–23	0–210	0–30	1.5	0.2	0.080	0.011
105–135	15–45	0–420	0–60	3.5	0.5	0.050	0.007
210–630	30–90	0–840	0–120	3.5	0.5	0.030	0.004
525–1575	75–225	0–2100	0–300	14.0	2.0	0.007	0.001

ensure an even clamping pressure. During tests, the circular edges of the openings in the two clamping plates are required to be concentric to within 0.25 mm [0.01 in.].

NOTE 2—Because the clamping mechanism and clamping surfaces are subject to considerable wear or distortion, they should be examined periodically and repaired or replaced when necessary.

5.1.2 *Circular Diaphragm*, of pure gum rubber, 0.85 ± 0.05 mm [0.034 ± 0.002 in.] thick. This is clamped between the lower clamping plate and the rest of the apparatus, so that before the diaphragm is stretched by pressure underneath, the center of its upper surface is below the plane of the clamping surface. The pressure required to raise the free surface of the diaphragm 9 mm [3⁄8in.] above the top surface of the diaphragm plate is required to be 30± 5 kPa [4.3 ± 0.8 psi]. In testing, a bridge gage may be used, the test being carried out with the clamping ring removed. The diaphragm should be inspected frequently for permanent distortion and, if distorted, replaced.

5.1.3 Means of applying controlled, increasing, hydrostatic pressure by a fluid, at the rate of 95 ± 5 mL/min to the underside of the diaphragm until the specimen bursts. The recommended fluid is *USP* (96 %) glycerin. Purified ethylene glycol (the permanent types of radiator antifreeze with additives are not satisfactory) may be substituted if desired.

NOTE 3—The hydraulic system, including the gages or transducers, must be mounted so as to be free from externally induced vibration.

NOTE 4—Because the bursting resistance of paper increases with increased rate of loading, the rate of strain must be maintained effectively constant to obtain reproducible results. Any air present in the hydraulic system of the tester will lower the rate of distortion of the specimen and must be substantially removed. Air is most commonly trapped under the rubber diaphragm and in the tubes of the gages. A simple method of testing for the presence of excessive quantities of air is given in 8.3.

5.1.4 *Pressure Gage*— A maximum-reading pressure gage of the bourdon type, of appropriate capacity and with a graduated circular scale 95 mm [3¾ in.] or more in diameter.

5.1.4.1 The choice and characteristics of the gage are given in Table 1. The 0 to 840 kPa [0 to 120 psi] range gage may be used for any test within its capacity, if so noted in the report.

5.1.4.2 The expansibility of a gage is in the volume of liquid entering the gage tube per unit increase in pressure when air is absent. It can be determined most conveniently by means of a dilatometer device described by Tuck and Mason **(1)**[5]. The gage expansibility must be within 15 % of the specified value.

NOTE 5—An appreciable flow of liquid into the gage occurs from the start of the test to the instant of burst. A gage, therefore, reduces the rate of distension of the specimen by an amount depending upon its expansibility. When a number of gages are mounted on a single apparatus, care must be taken that only the gage on which the measurement is being made is open to the hydraulic system; otherwise an erroneously low burst pressure will be recorded.

5.1.4.3 To avoid overloading and possible damage to the gage, a preliminary bursting test should be made with a high-capacity gage.

5.1.5 As an alternative, a pressure transducer which connects to the tester in the same manner as the gage along with its necessary signal processing circuitry may be used. This transducer displays the results in a digital form, and in addition, may provide an output for communication with various data processing devices (and can be substituted for the pressure gage in 5.1.4).

5.1.5.1 Typical transducer ranges are shown in Table 2.

5.1.5.2 To avoid overloading and possibly damaging the transducer, a preliminary bursting test should be made with a high-capacity transducer.

6. Sampling

6.1 Obtain the sample for testing in accordance with Practice D 585.

7. Test Specimens

7.1 Not less than 20 specimens, each at least 64 by 64 mm (2.5 by 2.5 in.), shall be obtained from each test unit of the sample, so as to be representative of the test unit.

8. Calibration and Maintenance

8.1 Calibrate the pressure-indicating device by means of a dead-weight tester of the piston type. If the device is a Bourdon-type gage, it must be calibrated while inclined at the same angle at which it is to be used. Preferably, calibrate with the gage in its normal position. For an instrument error of less than 3 %, calibrate the pressure-indicating device in such a manner that known pressures are applied dynamically at approximately the same rate as in testing of paper. Maximum reading pressure devices are subject to dynamic errors as well as ordinary static calibration errors. A suitable method of dynamic calibration for greater precision is described in Tuck et al. **(2)**.

8.1.1 Calibrate gages in frequent use at least once a month. If a gage is accidentally used beyond its capacity, recalibrate before it is used again.

8.2 *Calibration of Transducer/Readout System*—Calibrate the transducer can be calibrated on the same device as is used to calibrate gages.

8.2.1 Calibrate transducers in frequent use should be calibrated at least once a month.

[5] The boldface numbers in parentheses refer to the list of references at the end of this test method.

TABLE 2 Transducer/Digital Readout Characteristics

Range of bursting pressure		Range of transducer		Accuracy	
kPa	psi	kPa	psi	kPa	psi
5–300	2–50	0–300	0–50	1.0	0.25
5–500	2–100	0–500	0–100	2.5	0.5
10–1000	2–200	0–1000	0–200	5.0	1.0
30–3000	5–500	0–3000	0–500	15.0	2.5

8.3 Check for air in system. Any time that maintenance is carried out on the apparatus that could allow air to enter the hydraulic system, take steps to ensure that all of the air has been removed.

8.3.1 To determine if there is air in the system, first apply pressure as described in 5.1.2 to raise the diaphragm 9 mm (⅜ in.) above the top of the diaphragm plate and hold for 1 min. Any air trapped between the diaphragm and the fluid will show up as a white spot under the surface of the diaphragm. If this occurs, reinstall the diaphragm.

8.3.2 Observe the pressure developed. Pressures less than the following indicate the presence of excessive quantities of air in the system (or erroneous gage expansibilities in an instrument equipped with a gage).

Gage Range	Pressure Developed, kPa [psi]
0 to 30	83 [12]
0 to 60	138 [20]
0 to 120	241 [35]
0 to 300	621 [90]

8.3.3 A gradual loss in the pressure obtained indicates a leak in the system; correct this.

8.3.4 After changing the diaphragm, if it is necessary to purge air from the rest of the hydraulic system, clamp a piece of sheet metal over the diaphragm so that it cannot distend. Remove the cap from the bleeder valve adjacent to the gage or transducer. By means of a special device for forcing hydraulic fluid into the system or by manually operating the hydraulic system, force the hydraulic fluid through the system until it emerges from the bleeder valve with an even flow and no evidence of free air bubbles are observed. Replace the cap on the bleeder valve before the fluid stops flowing. Remove sheet metal from clamping device and check diaphragm height, adjusting if necessary.

9. Conditioning

9.1 Condition the sample in accordance with Practice D 685, and make all tests in the same standard atmosphere.

10. Procedure

10.1 Unless the approximate strength of the paper under testing is known, make a preliminary test to determine the required capacity of the measuring device (gage or transducer) being used. See Table 1 and Table 2. To avoid overload and possible damage to a measuring device, begin the preliminary bursting tests with a high-capacity gage. See 5.1.

10.2 Clamp the specimen securely in position, apply the hydrostatic pressure as specified in 5.1.3 until the specimen ruptures, and record the maximum registered by the pressure gage. Watch carefully for any movement (buckling) of the unclamped margin of the specimen. If slippage is indicated, discard the test and increase the clamping pressure for subsequent tests.

10.3 Make at least ten acceptable tests, applying an equal number to each side of the paper. Make no tests on areas containing watermarks, creases, imperfections, or visible damage.

10.4 After each test, return the measuring device to zero. For the gage unit, this involves gently returning the indicator needle to the zero point.

11. Calculation

11.1 Calculate bursting strength as the arithmetic mean of the test results (corrected for any gage error) on each sample.

11.2 To convert burst in psi (or points) to burst in kPa, use the following conversion: burst (psi) × 6.8948 = burst (kPa).

11.3 The following additional calculations are sometimes requested on burst test data. Determine grammage (basis weight) as described in Test Method D 646.

$$\text{Burst index} = \frac{\text{burst, kPa}}{\text{grammage, g/m}^2}$$

$$\text{Burst factor} = \frac{\text{burst, g/cm}^2}{\text{grammage, g/m}^2\ \text{(usually oven dry)}}$$

$$\text{Burst ratio} = \frac{\text{burst, psi}}{\text{basis weight, lb/ream}}$$

Burst ratio is sometimes called "points per pound."

11.4 The mathematical relationship between burst factor and burst index (see 11.3) is as follows:

$$\text{Burst factor}\left(\frac{\text{g/cm}^2}{\text{g/m}^2}\right) \times 9.8067 \times 10^{-2} = \text{Burst index}\left(\frac{\text{kPa}}{\text{g/m}^2}\right)$$

12. Report

12.1 Report the following information:

12.1.1 Bursting strength in kilopascals (or pounds per square inch) as the arithmetical mean, corrected for any gage error, to three significant figures.

12.1.1.1 Upon agreement of parties involved in the testing, results may be reported with units of "points." See 3.1.2.

12.1.2 Number of tests made.

12.1.3 Maximum and minimum values of acceptable results.

12.1.4 Type of instrument used, including whether equipped with a gage or pressure transducer.

13. Precision and Bias

13.1 *Precision*:

13.1.1 Repeatability (within a laboratory) = 5.4 %.

13.1.2 Comparability (between materials) = 9.5 %.

13.1.3 Reproducibility (between laboratories) = 14.3 %.

13.1.4 These values are based on data obtained in an interlaboratory study **(3)** among 50 laboratories, on 34 materials using Perkins Model C instruments.

13.2 *Bias*—The procedure in this test method has no bias because the value of bursting strength is defined only in terms of the test method.

14. Keywords

14.1 bursting strength; Mullen test; paper; paper products

REFERENCES

(**1**) Tuck, N. G. M., and Mason, S. G., "Some Factors Influencing the Accuracy of Mullen Testers," *Pulp Paper Magazine* Canada 50 (11): 132 (1949).

(**2**) Tuck, N. G. M., Faichney, L. M., and Mason, S. G., "The Dynamic Calibration of Maximum-Reading Pressure Gages," *Pulp Paper Magazine* Canada 54 (5): 102 (1953).

(**3**) Randall, E. B., Jr., and Lashof, T. W., "An Interlaboratory Study of the Measurement of the Bursting Strength of Paper," Tappi 53 (5): 799 (1970).