Bursting strength of paper

1. Scope

This method is designed to measure the maximum bursting strength of paper and paper products having a bursting strength of 50 kPa up to 1200 kPa (7 psi up to 157 psi) and in the form of flat sheets of up to 0.6 mm (0.025 in.) thick. It is not intended for use in testing corrugated, fiberboard, linerboard, or hardboards that tend to cut the thin rubber diaphragm of the bursting tester. For testing paperboard and linerboard, see TAPPI T 807 “Bursting Strength of Paperboard and Linerboard”; for testing corrugated and solid fiberboard, see TAPPI T 810 “Bursting Strength of Corrugated and Solid Fiberboard.”

2. Summary

The test specimen, held between annular clamps, is subjected to an increasing pressure by a rubber diaphragm, which is expanded by hydraulic pressure at a controlled rate, until the test specimen ruptures. The maximum pressure reading up to the rupture point is recorded as the bursting strength.

3. Significance

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

4. Definition

Bursting strength of a material is defined as the maximum hydrostatic pressure required to produce rupture of the material when a controlled and constantly increasing pressure is applied through a rubber diaphragm to a circular area, 30.5 mm (1.20 in.) diameter. The area of the material under test is initially flat and held rigidly at the circumference but is free to bulge during the test.
5.  Apparatus

5.1  *Bursting tester*, having the following:

5.1.1  A clamp for firmly and uniformly securing the test specimen without slippage during the test. The clamp shall have two annular, grooved, parallel and preferably stainless steel surfaces. The recommended maximum clamping pressure is 1200 kPa. The clamping pressure should be adjustable to accommodate different strength papers without specimen slippage.

5.1.1.1  The upper clamping surface (the clamping ring) has a circular opening 30.50 mm (1.2 in.) ± 0.05 mm in diameter. To minimize slippage, the surface which is in contact with the paper during testing has either a continuous spiral or concentric V-grooves in the surface. The continuous spiral is a 60° V-groove no less than 0.25 mm (0.010 in.) deep with a pitch of 0.8 mm (1/32 in.). The groove starts 3.2 mm (1/8 in.) ± 0.1 mm from the edge of the circular opening. The concentric grooves are 60° V-grooves not less than 0.25 mm (0.010 in.) deep and 0.9 mm (1/32 in.) ± 0.1 mm apart. The innermost groove is 3.2 mm (1/8 in.) ± 1 mm from the edge of the circular opening. The diameter of the upper clamp should be at least 48 mm.

5.1.1.2  The lower clamping surface (the diaphragm plate) has an opening 33.1 mm (1.302 in) ± 0.1 mm in diameter. Its surface has a series of concentric 60° V-grooves 0.30 mm (0.012 in.) deep, 0.8 mm (1/32 in.) apart, the center of the first groove being 3.2 mm (1/8 in.) 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 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 1:  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  A circular diaphragm of pure gum rubber free of fillers, 0.85 ± 0.05 mm (0.034 ± 0.002 in.) thick. A deadweight micrometer can be used to measure thickness of diaphragm. The diaphragm is clamped between the lower clamping plate and the rest of the apparatus, so that before the diaphragm is stretched by pressure underneath it, 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 (3/8 in.) above the top surface of the diaphragm plate is required to be 30 ± 5 kPa (4.3 ± 0.8 psi). In testing this, 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 1.6 mL/s ± 0.1 mL/s to the underside of the diaphragm until the specimen bursts. The recommended fluid is USP (96%) glycerin. Purified ethylene glycol (not the permanent types of radiator antifreeze with additives) may be substituted if desired.

NOTE 2:  The hydraulic system, including the gages or transducers, must be mounted so as to be free from externally induced vibration.

NOTE 3:  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 more 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 6.3.

5.1.4  A maximum-reading pressure gage of the Bourdon type, of appropriate capacity and with a graduated circular scale 95 mm (3 3/4 in.) or more in diameter. Pressure sensitive electronic gages as described in 5.1.5 are widely replacing the Bourdon type gages.

5.1.4.1  The choice and characteristics of the Bourdon gage are given in Table 1. The 0-840 kPa (0-120 psi) range gage may be used for any test within its capacity, if so noted in the report. The Bourdon gage should have an accuracy of ± 1% of reading.

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1 Names of suppliers of testing equipment and materials for this method may be found on the Test Equipment Suppliers list in the bound set of TAPPI Test Methods, or may be available from the TAPPI Technical Operations Department.
### Table 1. Bourdon Gage characteristics.

<table>
<thead>
<tr>
<th>Range of bursting pressure (kPa)</th>
<th>Range of gage (psi)</th>
<th>Scale graduation intervals (kPa psi)</th>
<th>Expansibility of gage (mL/kPa mL/psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>28-77</td>
<td>4-11</td>
<td>0-105 0-15</td>
<td>0.7 0.1</td>
</tr>
<tr>
<td>56-161</td>
<td>8-23</td>
<td>0-210 0-30</td>
<td>1.5 0.2</td>
</tr>
<tr>
<td>105-315</td>
<td>15-45</td>
<td>0-420 0-60</td>
<td>3.5 0.5</td>
</tr>
<tr>
<td>210-630</td>
<td>30-90</td>
<td>0-840 0-120</td>
<td>3.5 0.5</td>
</tr>
<tr>
<td>525-1575</td>
<td>75-225</td>
<td>0-2100 0-300</td>
<td>14.0 2.0</td>
</tr>
</tbody>
</table>

5.1.4.2 The expansibility of a gage is 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). The gage expansibility must be within 15% of the specified value.

NOTE 4: 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 Pressure sensitive electronic gages are today widely replacing the Bourdon type gages. The advantage is that one sensor normally can handle the entire measuring range.

5.1.5.1 These pressure transducers must have at least an accuracy of 1% of measurement or ± 10 kPa (1.5 psi) which ever provides the greater accuracy.

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

NOTE 5: When using a pressure transducer, the results may be lower than an instrument using a Bourdon gage due to the expansibility of the Bourdon gage which does not occur with the pressure transducer.

### 6. Calibration and maintenance

6.1 The pressure indicating device shall be calibrated 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, the calibration is to be carried out with the gage in its normal position. For an instrument error of less than 3%, the pressure indicating device shall be calibrated 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 by Tuck et al. (2).

6.1.1 Gages in frequent use should be calibrated at least once a month. If a gage is accidentally used beyond its capacity, it must be recalibrated before it is used again.

6.2 Calibration of transducer / readout system. The transducer can be calibrated on the same device as used to calibrate gages, or as per manufacturer's recommendations.

6.2.1 Transducers in frequent use should be calibrated at least once a month.

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

6.3.1 To determine if there is air in the system, first apply pressure as described in 5.1.2 to raise the diaphragm 9 mm (3/8 in.) above the top of the diaphragm plate and hold for one minute. 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, the diaphragm must be reinstalled.

6.3.2 After changing the diaphragm, if it is necessary to purge air from the rest of the hydraulic system. See the manufacturer’s operation manual for instructions.
6.4 **Check condition of clamping surfaces.** The samples should be checked frequently for any indentions, wrinkles or marks that may indicate the clamping surfaces are in poor condition. The clamps themselves can be visually examined for excessive wear that could affect clamping pressure. Carbon paper between two sheets of paper can be used to check for uniform clamping pressure.

7. **Sampling and test specimens**

If the paper is being tested to evaluate a lot of paper, obtain a sample in accordance with TAPPI T 400 “Sampling and Accepting a Single Lot of Paper, Paperboard, Containerboard, or Related Product.” From each test unit take 20 specimens, each at least 62 x 62 mm (2.5 x 2.5 in.). Avoid areas including watermarks, creases, or visible damage. Identify the wire side of the specimens (see TAPPI T 455 “Identification of Wire Side of Paper”).

8. **Conditioning**

Condition and test the specimens in an atmosphere in accordance with TAPPI T 402 “Standard Conditioning and Testing Atmospheres for Paper, Board, Pulp Handsheets, and Related Products.”

9. **Procedure**

9.1 Clamp a specimen securely in position, overlapping the specimen at all points. Apply the hydrostatic pressure as specified until the specimen ruptures, and record the maximum pressure registered. Watch carefully for any movement of the unclamped margin of the specimen. If slippage is indicated, discard the test and increase the clamping pressure. If it appears that excessive clamping pressure damaged the specimen, discard the test and reduce the clamping pressure.

9.2 After each test return the pressure indicator gently to zero.

9.3 Make ten tests on each side of the paper.

10. **Report**

10.1 For each side of the paper, report the bursting strength in kilopascals (or pounds per square in.) as the arithmetical mean, corrected for any gage error, to three significant figures. Include the number of tests and either the standard deviation or, alternatively, the maximum and minimum values of accepted tests.

10.2 If desired, the burst index (bursting strength per grammage) may be reported. It may be calculated as follows:

\[ X = \frac{P}{W} \]

where

- \(X\) = burst index, kPa·m²/g
- \(P\) = bursting strength, kPa
- \(W\) = weight per unit area, g/m², as determined in accordance with TAPPI T 410 “Grammage of Paper and Paperboard.”

10.3 The term “points” is frequently used in place of pounds per square inch as an expression for bursting strength of paper. The results may be so reported if desired.

11. **Precision**

11.1 Repeatability (within a laboratory) = 22%.

11.2 Reproducibility (between laboratories) = 28%; in accordance with definitions of these terms in TAPPI T 1206 “Precision Statement for Test Methods.”

11.3 Collaborative Testing Service data for the 1994 - 1995 program year indicates bursting strength data as follows (partial listing by range):
Table 2. Bursting Strength Data

<table>
<thead>
<tr>
<th>Paper Type</th>
<th># of Labs (average)</th>
<th>Materials (range)</th>
<th>Grand Mean (r), PSI</th>
<th>Repeatability (r), PSI (%)</th>
<th>Reproducibility (R), PSI (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newsprint</td>
<td>13</td>
<td>16</td>
<td>10.62 (9.2 - 12.4)</td>
<td>2.67 25.1%</td>
<td>3.20 30.1%</td>
</tr>
<tr>
<td>Printing</td>
<td>93</td>
<td>16</td>
<td>29.8 (19.9 - 40.3)</td>
<td>6.47 22.2%</td>
<td>8.40 28.9%</td>
</tr>
<tr>
<td>Packaging</td>
<td>64</td>
<td>16</td>
<td>54.3 (41.4 - 74.2)</td>
<td>10.42 19.4%</td>
<td>14.22 26.4%</td>
</tr>
</tbody>
</table>

Taken from Collaborative Testing Services Paper and Paperboard Program Report Nos. 152 through 159 from 1994 and 1995 reflecting Analyses 304 (Newsprint), 305 (Printing Papers) and 306 (Packaging Papers).

The user of these precision data is advised that it is based on actual mill testing, laboratory testing, or both. There is no knowledge of the exact degree to which personnel skills or equipment were optimized during its generation. The precision quoted provides an estimate of typical variation in test results which may be encountered when this method is routinely used by two or more parties.

12. Keywords

Burst strength, paper, burst index.

13. Additional information

13.2 For checking purposes, bursting tests on aluminum foil may be used. Standardized foils for pressure up to about 800 kPa (about 115 psi) may be obtained from several sources.
13.3 Terms used to express burst include:

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

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

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

Burst ratio is sometimes called "points per pound."

13.5 Methods for evaluation of pumping rate and presence of air in the system/gage expansion specifications can be found in SCAN P24 “Paper Burst Strength.”
References


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