



Standard Test Method for Folding Endurance of Paper by the Schopper Tester¹

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1. Scope

1.1 This test method describes the use of the Schopper type of folding apparatus. It is suitable for papers having a thickness of 0.25 mm (0.010 in.) or less.

1.2 The procedure for the M.I.T.-type apparatus is given in Test Method D2176.

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

2. Referenced Documents

2.1 ASTM Standards:²

D585 Practice for Sampling and Accepting a Single Lot of Paper, Paperboard, Fiberboard, and Related Product

D685 Practice for Conditioning Paper and Paper Products for Testing

D776 Test Method for Determination of Effect of Dry Heat on Properties of Paper and Board

D1968 Terminology Relating to Paper and Paper Products

D2176 Test Method for Folding Endurance of Paper by the M.I.T. Tester

D4714 Test Method for Determination of Effect of Moist Heat (50 % Relative Humidity and 90°C) on Properties of Paper and Board

E122 Practice for Calculating Sample Size to Estimate, With Specified Precision, the Average for a Characteristic of a Lot or Process

2.2 ISO Standard:

ISO 5626 Paper Determination of Folding Endurance³

3. Terminology

3.1 *Definitions*—Definitions shall be in accordance with Terminology D1968 and the *Dictionary of Paper*.⁴

4. Significance and Use

4.1 Folding endurance is not a measure of the foldability of paper, but a measure of the strength of paper. In many cases, it is a better measure of strength than the conventional tests for tensile strength, bursting strength, and tearing resistance. The uniqueness of the folding endurance tests leads to many special uses for this test method.

4.2 Folding endurance is determined by the number of times that the paper can be folded before it loses enough tensile strength to break under the conditions of the test. It is the only one of the four strength tests that uses a repetitive mechanical treatment to weaken the sheet. Therefore, it is the only one of the strength tests that measures the durability of paper subjected to repeated or rough handling. It is an important test for paper that will be subjected to continued folding and unfolding during use. Examples are maps and printed materials such as music, pamphlets, folded prints, and blueprints. It is also an important test for any paper that will be handled repeatedly or which might be subjected to rough treatment when it is being used.

4.3 The ratio between the machine direction and cross direction folding endurance is a good measure of the fiber orientation in the sheet. For most papers, the machine direction test will be higher than the cross direction test, and the more the fibers are oriented in the machine direction, the greater the difference will be. If the cross direction is higher than the machine direction, the paper has an unusually large number of fibers oriented in the cross direction. This information may also be obtained from tests for tensile strength and tearing resistance but the folding endurance test is much more sensitive to these differences than the other two tests.

4.4 Folding endurance is more sensitive to the flexibility in the paper than the other strength tests. Because flexibility is lost with aging, folding endurance is commonly used as an indicator of strength loss in accelerated aging tests.

¹ This test method is under the jurisdiction of ASTM Committee D06 on Paper and Paper Products and is the direct responsibility of Subcommittee D06.92 on Standard Documents Relating to Paper and Paper Products.

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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 Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, <http://www.ansi.org>.

⁴ Available from Technical Association of the Pulp and Paper Industry (TAPPI), 15 Technology Parkway South, Norcross, GA 30092, <http://www.tappi.org>.

4.5 The folding endurance test is made on a very small section of the paper (15 mm by approximately 1 mm). The test is sensitive to very small changes in the paper, and as a result there will be a significant variation in the tests made on the same sheet using these very small test areas. The better the formation, the smaller this variation will be. Therefore, the variation in individual fold numbers is an indirect indication of the uniformity of the formation.

4.6 Variability of data from tests made on the same sheet of paper has sometimes raised concerns regarding the value of the folding test. This variability comes in part from the sensitivity of the test to changes in the papermaking process, and in part from the very wide range of values that will be encountered for apparently similar papers. For example, low fold endurance papers may have values as low as two or three folds, while strong papers will withstand 5000 or more folds. Other strength tests might typically vary by an order of magnitude for strong and weak papers, but would not approach the 1000-fold differences sometimes seen for fold. A process or furnish change causing a 10 % change in fold might not be detected by another strength test such as tensile or tear. Folding endurance is a reliable measure of paper strength, particularly for the grades mentioned in 4.2; however, differences in the range of 10 % in fold numbers may not have practical significance.

4.7 The fact that a small difference between two fold numbers is not significant creates a problem as to what should be considered a significant difference. A difference of 30 between averages of 20 and 50 would be very significant, but a difference of 30 when the averages are 600 and 630 would be meaningless. To solve this problem, folding endurance is reported as the average of the logarithms of the individual fold numbers. For example, the fold numbers of 20 and 50 become folding endurances of 1.301 and 1.699 or a difference of 0.398, which would be a significant difference. The fold numbers of 600 and 630 would become folding endurances of 2.778 and 2.799, or a difference of only 0.021, which would not be a significant difference.

NOTE 1—To determine the difference that must be exceeded in order to consider the difference to be significant, follow the same procedure that would be used to calculate the precision of any other strength test. However, for other strength tests, the absolute value will usually increase as the average test value increases and as a result, the repeatability is expressed as a percentage. Because the folding endurance is expressed as the logarithm of the fold number, the absolute repeatability value may represent all levels of folding endurance. The value will vary depending upon the variability of the paper being tested, but it should not vary because of the magnitude of the folding endurance. The repeatability should be about the same for a fold number of 600 as it is for a fold number of 60.

5. Apparatus

5.1 *Folding Tester*, consisting of the following:

5.1.1 *Clamping Jaws*, two horizontally opposed and movable, which hold a specimen 100 mm (4 in.) long under variable tension during the folding cycle, while a slotted folding blade, sliding back and forth between four creasing rollers, folds the paper at 105 to 125 double folds/min. The clamps are supported from below on rollers, and while in motion, are freely suspended between tension springs. The folding blade is 0.50 ± 0.0125 mm (0.020 ± 0.0005 in.) thick,

with a vertical folding slot 0.50 ± 0.0125 mm (0.020 ± 0.0005 in.) wide, the slot extending somewhat above and below the normal position of the test specimen. The vertical edges of the slot are cylindrical, with radius equal to half the thickness of the blade. The four creasing rollers, each 6 mm (approximately 0.25 in.) in diameter and 18 mm (approximately 0.75 in.) long, are arranged symmetrically about the midposition of the folding slot, and provided with antifriction or jeweled bearings.

5.1.2 *Counter*, to register the number of double folds and to stop the instrument when the specimen breaks.

5.1.3 *Motor*—A means of imparting approximate harmonic motion to the reciprocating blade at 115 ± 10 double folds/min.

5.2 *Cutter*, to provide test strips, 15.0 ± 0.1 mm (0.590 ± 0.004 in.) wide, with clean edges.

5.3 *Calibration Equipment*:

5.3.1 A device for applying a tension of 7.60 N (780 gf) on the spring loaded jaw as specified in the calibration instructions.

5.3.2 A device for measuring a variable tension on the spring loaded jaw ranging from 9.3 to 10.3 N (950 to 1050 gf) as specified in the calibration instructions.

6. Sampling

6.1 If the paper is being tested to determine the acceptance of a lot, obtain a sample in accordance with Practice D585.

6.2 Where testing is for purposes other than acceptance, Practice E122 may be used as an alternative for sampling purposes.

7. Test Specimens

7.1 From each conditioned sample, cut ten specimens in each principal direction of the paper, with each specimen having a width of 15.0 ± 0.1 mm (0.590 ± 0.004 in.) and a length of 100 mm (4 in.). Select specimens that are free from wrinkles or blemishes not inherent in the paper and be sure that the area where the folding is to take place does not contain any portion of a watermark and appears to be of average opacity.

7.2 Handle each specimen by an end and do not touch it with hands in the region in which it is to be folded.

8. Adjustment and Calibration

8.1 Test the clamps as follows:

8.1.1 Insert a specimen in place and alternately apply and release the tension a number of times. Then, with tension released, note whether the specimen remains smooth and straight as originally inserted. Buckling or waviness indicates a faulty clamp which has allowed the specimen to slip.

8.1.2 Inspect and correct the supporting rollers for worn surfaces and for bearing friction. Adjust the rollers so that they do not bind against the clamps in any position. With a feeler gage, check the four creasing rollers for parallelism and clearance. Also, make sure that the two edges of the folding slot are parallel with each other and with the creasing rollers. The distance between the folding blade and the two creasing rollers on each side is required to be 0.38 ± 0.05 mm (0.015 ± 0.002 in.), and the width between the rollers of the space occupied by the unbent specimen should be approximately 5