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International Standard ISO 1974

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Paper — Determination of tearing resistance

Papier — Détermination de la résistance au déchirement

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Paper — Determination of tearing resistance

1 Scope and field of application

This International Standard specifies a method for determining the internal tearing resistance of paper. It may also be used for light boards if the tearing resistance is within the range of the instrument used.

It does not apply to combined corrugated boards.

2 References

ISO 186, *Paper and board — Sampling to determine average quality.*

ISO 187, *Paper and board — Conditioning of samples.*

ISO 536, *Paper and board — Determination of grammage.*

3 Definitions

For the purpose of this International Standard, the following definitions apply.

3.1 internal tearing resistance : The mean force required to continue the tearing of an initial cut in a single sheet of paper. If the initial slit is in the machine direction, the result is given as machine direction tearing resistance; similarly for the cross direction.

3.2 tear index : The tearing resistance of the paper or board divided by its grammage.

4 Principle

An initial cut or cuts is/are made

a) in several sheets simultaneously, or

b) in a single sheet of paper.

Several (normally four) sheets together, or the single sheet, are/is torn through a fixed distance using a pendulum to apply the tearing force. The work done in tearing the test piece is measured by the loss in potential energy of the pendulum. The scale is calibrated to indicate the average tearing force (work done divided by the total distance torn). The internal tearing resistance of the paper is determined from the average tearing force and the number of sheets in the test piece.

5 Apparatus

There are two basic designs of testing apparatus in common use :

a) single tear testers [1], in which the test pieces are cut to shape, usually on a guillotine, and a single initial cut is made in the test pieces after clamping on the instrument using a pre-set pivoted knife mounted on the instrument;

b) double tear testers [2], in which the test pieces are cut and two initial cuts made, usually on a guillotine, before the test pieces are clamped in the instrument.

In this International Standard the use of both types of instrument is specified.

Under the conditions of this test, the total work done by the pendulum includes the work done in tearing the paper and also the work done in lifting and bending the test piece, overcoming frictional losses between the torn edges of the test piece. With some instruments, the total work done also includes overcoming frictional forces due to the test piece rubbing on the pendulum during the test, but this is a major source of error with some papers and such instruments, and instruments on which this occurs are not to be considered suitable for testing in accordance with this International Standard.

Instruments are available which are fitted with transducers and digital read-out equipment. In use, the transducer converts the work done by the pendulum into a directly proportional electric signal which is displayed in digital form on a meter. Digital read-out instruments may be used provided their mechanical components comply with the requirements of this International Standard and the results obtained can be shown to be comparable with results from non-digital pendulum testers.

1) Examples are the TAPPI-Elmendorf, Lhomargy and Thwing-Elmendorf tear testers.

2) An example is the Marx-Elmendorf tear tester.

5.1 Single tear testers

The apparatus consists of a suitably mounted pendulum which is free to swing about a horizontal axis from bearings of very low frictional resistance. The paper is held by two clamps, one of which is attached to the frame and the other to the pendulum. The clamping surfaces are at least 25 mm wide and 15 mm deep.

In the initial position, before the paper is torn, the pendulum is displaced from its equilibrium position and held by a hand operated catch. The distance between the clamps is then 2,8 ± 0,3 mm and the clamping surfaces lie in a vertical plane which is perpendicular to the plane of oscillation of the pendulum. The upper edges of the clamping surfaces are in a horizontal line lying at a distance of 104 ± 1 mm from the axis of the pendulum and the plane containing this line and the pendulum axis makes an angle of 27,5° ± 30′ with the vertical.

The method depends on measuring the energy given up by the pendulum in tearing the test piece. A common method of measurement is, for example, by means of a sleeve to which a pointer is attached, mounted on the pendulum coaxially; the position of the pointer relative to the pendulum can be read from a circumferential scale carried on the pendulum. The frictional resistance of this sleeve should be kept within certain specified limits. (For adjustment of this resistance, see annex A.)

The pointer engages an adjustable stop on the base plate, and the scale pointer and stop are so arranged that the scale reading is a measure of the work done in tearing the paper test piece. The adjustable pointer stop provides a means for setting the scale reading at zero when no work is done in tearing. This adjustment provides an approximate compensation for pendulum and pointer friction at other positions.

Mount the pivoted knife used to produce the initial tear so that the distance to be torn after cutting will be 43,0 ± 0,5 mm, and the distance above the clamp and the end of the tear is 4,0 ± 0,5 mm.

Adjust and check the instrument as described in annex A, and calibrate it as described in annex B.

In order to provide for the measurement of a wider range of tearing resistance, interchangeable pendulums or additional weights may be used. Each pendulum or pendulum/weight combination will have a different scale factor or different scale and may have different base zero marks.

Most instruments have graduated scales, the scale reading then being the appropriate tearing resistance for a given number of sheets, most frequently 8, 16 or 32. When testing four sheets simultaneously as specified in this method, multiply the scale reading by 2, 4 or 8 respectively to give the tearing resistance in millinewtons as indicated in clause 8.

In some instruments of this type, it is possible for a test piece of the dimensions specified in this method to foul the pendulum during the test. Such instruments, without modification, are not to be considered suitable for testing in accordance with this International Standard.

5.2 Double tear testers

The apparatus consists of a suitably mounted pendulum which is free to swing about a horizontal axis from bearings of very low frictional resistance. The paper is held by two clamps one of which is attached to the frame and the other to the pendulum. The clamp attached to the frame should be at least 100 mm long and 10 mm deep, and the clamp attached to the pendulum should be at least 50 mm long and 10 mm deep. Both clamps should be symmetrical about the plane of the pendulum.

In the initial position before the paper is torn, the pendulum is displaced from its equilibrium position and held by a hand operated catch. Arrange the clamping surfaces so that when the clamps are closed with no test piece in position, the clamp attached to the instrument frame has vertical clamping surfaces and the clamping surfaces of the clamp attached to the pendulum are in the same horizontal plane as the top edge of the frame clamp, with the edges of the clamps separated by a distance of 10,0 ± 0,5 mm. The upper edges of the clamping surfaces of the clamp attached to the frame should be in a horizontal line lying at a distance of 100 ± 1 mm from the axis of the pendulum.

The method depends on measuring the energy given up by the pendulum in tearing the test piece. A common method of measurement is, for example, by means of a sleeve to which a pointer is attached, mounted on the pendulum coaxially; the position of the pointer relative to the pendulum can be read from a circumferential scale carried on the pendulum. Keep the frictional resistance of this sleeve within certain specified limits. (For adjustment of this resistance, see annex A.)

The adjustable pointer stop provides a means for setting the scale reading at zero when no work is done in tearing. This adjustment provides an approximate compensation for pendulum and pointer friction at other positions.

Adjust and check the instrument as described in annex A, and calibrate it as described in annex B.

In order to provide for the measurement of a wider range of tearing resistance, interchangeable pendulums or additional weights may be used. Each pendulum or pendulum/weight combination will have a different scale factor or different scale and may have different base zero marks.

Most instruments have graduated scales, the scale reading then being the appropriate tearing resistance for a given number of sheets, normally three. When testing four sheets simultaneously as specified in this method, multiply the scale reading by 0,75 to give the tearing resistance in millinewtons as indicated in clause 8.

6 Preparation of test pieces

6.1 Sampling

Carry out the sampling in accordance with ISO 186. No creases, obvious flaws or watermarks should be included in the test area and test pieces should not include any part of the sample within 15 mm of the edge of any sheet or roll. If it is necessary to include watermarks, report this fact.

6.2 Conditioning

Condition the paper before the test pieces are cut, in accordance with ISO 187, and carry out cutting and testing under these conditions.

6.3 Cutting of test pieces

6.3.1 Single tear testers

Arrange four specimens with their machine directions parallel and their wire sides facing the same way. Through all four specimens cut rectangular test pieces between 50 and 80 mm wide with edges parallel to the desired test direction, and of such a length that after the initial tear has been made in the manner specified, the untorn length of the test piece is 43,0 ± 0,5 mm. The edges of the test pieces shall be free and not stuck together. If desired for better precision, the rectangular test pieces may be cut singly and then assembled in sets of four. (See the note.)

Cut sufficient test pieces so that a minimum of 10 tests may be made with the tear running in the machine and cross directions respectively.

NOTE — The exact test piece dimensions depend on the design of the instrument clamps used. For some instruments the appropriate dimensions are 50 mm wide × 62 mm long; for others 50 mm wide × 65 mm long or 76 mm wide × 63 mm long. A guillotine giving the appropriate test piece dimensions is normally supplied with the instrument.

6.3.2 Double tear testers

Arrange four specimens with their machine directions parallel and their wire sides facing the same way. Through all four specimens cut rectangular test pieces 100 ± 1 mm × 62 ± 1 mm with the short edges running parallel to the desired test direction. The edges of the test pieces shall be free and not stuck together. If desired for better precision, the rectangular test pieces may be cut singly and then assembled in sets of four. Cut two slits starting in one of the longer edges and parallel to the shorter edges, each positioned 25 ± 1 mm from the short edges, each extending to a point 44,0 ± 0,5 mm from the unslit longer edge of the test piece. (See the note.)

Cut sufficient test pieces so that a minimum of 10 tests may be made with the tear running in the machine and cross directions respectively.

NOTE — A guillotine giving the appropriate test piece dimensions and slit lengths is normally supplied with the instrument.

7 Procedure

7.1 Single tear testers

Select the appropriate pendulum or pendulum/weight combination. It is desirable to arrange for the mean readings to fall within the range 20 % to 80 % of the full scale reading although values based on readings taken outside these limits may be reported.

Immediately before testing, level the instrument as described in annex A and check both the equilibrium position of the pendulum and the zero reading. Swing the pendulum until it is held in its starting position by the pendulum stop. With the test piece correctly orientated and with the wire sides facing the knife, clamp the test piece centrally in the jaws so that the lower edge of each test piece rests on the bottom of the jaws and the lateral edges of the test piece coincide. Slit the test piece with the pivoted knife and allow the knife to return to the rest position. Ensure that the pointer is in contact with the pointer stop.

By hand depress the pendulum stop smartly and, keeping the stop depressed, catch the pendulum gently as it approaches the initial position on the return swing. Note the reading indicated by the pointer to the nearest 5 units for instruments scaled 0 to 1 000 (0,5 for instruments scaled 0 to 100). Return the pendulum and pointer to the initial position, and remove the torn paper. Repeat this procedure for the other test pieces, orientating them wire side left and right alternately.

The path of the tear may deviate from the direction of the knife slit. If the deviation exceeds 10 mm on one or two out of 10 tests, reject these results and carry out further tests to bring the number of satisfactory tests up to a minimum of 10. If in more than two of the test pieces the deviation exceeds 10 mm, include the results and note the fact in the test report.

If, instead of tearing in the normal way, the paper of any test piece peels apart so as to expose a wide band of torn surface (the effect known as "skinning"), apply the criteria in the preceding paragraph to the centre line of the torn band through the test pieces.

If the tearing resistance of the paper or board is such that satisfactory results cannot be obtained using a test piece made up from four sheets, tests may be carried out using more or fewer sheets. State this fact clearly in the test report.

NOTE — The apparent tearing resistance is very dependent on the number of sheets torn simultaneously. With some papers the difference in apparent tearing resistances when one and four plies are torn simultaneously may exceed 20 %.

7.2 Double tear testers

Select the appropriate pendulum/additional weight combination. It is desirable to arrange for the mean readings to fall within the range 20 % to 80 % of the full scale reading although values based on readings taken outside these limits may be reported.

Immediately before testing, level the instrument as described in annex A and check both the equilibrium position of the pendulum and the zero reading. Swing the pendulum until it is held in its starting position by the pendulum stop. Place the two outside tongues of the test piece in the fixed clamp and the central tongue in the pendulum clamp. Tighten first the fixed clamp and then the pendulum clamp, so that the test piece projects vertically above the fixed clamp. The test piece should not be strained and a slight bend in the unclamped portion of the tongue can be tolerated. Ensure that the pointer is in contact with the pendulum stop.

By hand depress the pendulum stop smartly and, keeping the stop depressed, catch the pendulum gently as it approaches the initial position on the return swing. Note the reading indicated by the pointer to the nearest 5 units for instruments scaled 0 to 1 000 or 1 100 (0,5 unit for instruments scaled 0 to 100 or 110). Return the pendulum and pointer to the initial position, and remove the torn paper. Repeat this procedure for the other test pieces, orientating them wire side left and right alternately.

The path of the tear may deviate from the direction of the knife slits. If the deviation exceeds 10 mm on one or two out of 10 tests, reject these results and carry out further tests to bring the number of satisfactory tests up to a minimum of 10. If in more than two of the test pieces the deviation exceeds 10 mm, include the results and note the fact in the test report.

If, instead of tearing in the normal way, the paper of any test piece peels apart so as to expose a wide band of torn surface (the effect known as "skinning"), apply the criteria in the preceding paragraph to the centre line of the torn band through the test pieces.

If the tearing resistance of the paper or board is such that satisfactory results cannot be obtained using a test piece made up from four sheets, tests may be carried out using more or fewer sheets. State this fact clearly in the test report.

NOTES

1 If the sheets curl, ensure that they lean towards and not away from the pendulum by bending them gently at the clamp. In doing so avoid affecting the moisture content of the test areas.

2 The apparent tearing resistance is very dependent on the number of sheets torn simultaneously. With some papers the difference in apparent tearing resistances when one and four plies are torn simultaneously may exceed 20 %.

8 Expression of results

Calculate the mean scale reading and, from the following equations, the tearing resistance or the tear index

$$a = \frac{SP}{n}$$

$$X = \frac{a}{g}$$

where

a is the tearing resistance, in millinewtons;

S is the mean scale reading in the direction tested;

P is the pendulum factor, i.e. theoretically the number of sheets torn simultaneously for which the pendulum scale has been calibrated to give a direct tearing resistance reading in millinewtons, commonly 3 (double tear testers), 8, 16 or 32 (single tear testers);

n is the number of sheets torn simultaneously (normally four);

X is the tear index expressed in millinewton square metres per gram ($mN \cdot m^2/g$);

g is the grammage (basis weight), expressed in grams per square metre, and determined in accordance with ISO 536.

9 Test report

The test report shall include the following information :

a) date and place of testing;

b) description and identification of the material tested;

c) machine direction of the test;

d) number of replicate tests carried out, if other than 10;

e) mean tearing resistance, in millinewtons, or the tear index, to three significant figures, in the direction tested;

f) coefficient of variation of the results;

g) method used (single tear or double tear), and manufacturer and model number of the instrument;

h) number of sheets torn simultaneously, if other than four;

j) whether the tear deviated from the correct path, or extensive "skinning" occurred;

NOTE — Tests in which these effects have occurred may give spuriously high or low results, which should be interpreted with great caution.

k) any other departures from the specified procedure;

m) grammage (basis weight) of the paper or any other factor which may assist the interpretation of the results.

Annex A

Adjustment and maintenance of instruments

Use the following procedure for each of the pendulum/additional weight combinations used.

A.1 Single tear testers

A.1.1 Inspection

Check the following items and make any necessary adjustments.

a) Check that the pendulum shaft is not bent.

b) Check that the distance between clamps is 2,8 ± 0,3 mm and that when the pendulum is in its initial position, the clamps are in alignment.

c) Check that the knife fitting is secure, and that the cutting edge is sharp and undamaged. The blade shall be situated midway between, and at right angles to, the top of the clamps.

d) Ensure that the pointer is undamaged and rigidly attached to the sleeve.

A.1.2 Levelling

Mount the instrument on a rigid bench and, if possible, firmly attach it to the bench.

With the pendulum clamp closed, adjust the level of the instrument so that the pendulum hangs vertically and the index marks on the pendulum and base coincide. With the stop depressed, displace the pendulum slightly and after it comes to rest check that the index marks still coincide.

A.1.3 Zero adjustment

After levelling, operate the instrument several times with clamps empty and closed to ascertain whether the pointer registers zero. If zero is not registered, move the adjustable pointer stop.

A.1.4 Pendulum friction

Make a reference mark on the stop mechanism 25 mm to the right of the edge of the pendulum catch. Raise the sector to its initial position and set the pointer so that it does not meet the pointer stop when the instrument is operated.

When the sector is released and the pendulum stop held down, the sector should make at least 35 complete oscillations before the edge of the sector which engages with the catch no longer passes to the left of the reference mark. Otherwise clean, oil or adjust the bearing.

A.1.5 Pointer friction

With the pendulum in the initial position and the pointer set to zero on the scale, release the pendulum stop and estimate the distance the pointer has been deflected past the zero mark. This distance shall be less than the following limits :

a) for instruments graduated from 0 to 1 000 to give a direct tearing resistance reading for 32 sheets torn simultaneously : less than 10 scale units;

b) for instruments graduated from 0 to 1 000 to give a direct tearing resistance reading for 16 sheets torn simultaneously : less than 20 scale units;

c) for instruments graduated from 0 to 1 000 to give a direct tearing resistance reading for 8 sheets torn simultaneously : less than 40 scale units.

If the pointer friction is not within the specified limits, clean or adjust the bearing surfaces. The average of four zero readings taken just before any set of 10 replicate tests should not differ from the average of four readings taken immediately after the tests by more than 1 % of the test value.

Unless specifically permitted by the instrument manufacturer, do not apply oil to the bearing.

After checking or adjusting the pointer friction, check the zero adjustment (see A.1.3).

A.1.6 Tearing length

Adjust the position of the knife. Check that the tearing length is 43,0 ± 0,5 mm. If this is not so, adjust the dimensions of the guillotine or template used.

A.2 Double tear testers

A.2.1 Inspection

Check the following items and make any necessary adjustments.

a) Check that the pendulum shaft is not bent.

b) Check that the clamps are parallel, in alignment and separated by the specified distance (10 ± 1 mm).

c) Ensure that the pointer is undamaged and rigidly attached to the sleeve.

A.2.2 Levelling

Mount the instrument on a rigid bench and, if possible, firmly attach it to the bench.

With the pendulum clamp closed, adjust the level of the instrument so that the pendulum hangs vertically and the index marks on the pendulum and base coincide. With the stop depressed, displace the pendulum slightly and after it comes to rest check that the index marks still coincide.

A.2.3 Zero adjustment

After levelling, operate the instrument several times with the clamps empty and closed to ascertain whether the pointer registers zero. If zero is not registered, move the adjustable pointer stop.

A.2.4 Pendulum friction

Set the pendulum in its initial position and set the pointer as far to the left as it will go. Depress the pendulum stop and allow the pendulum to swing freely. It should make at least 180 complete swings before coming to rest. Otherwise clean, oil or adjust the pendulum bearings.

A.2.5 Pointer friction

With the pendulum in its initial position and the pointer held against the pointer stop throughout the procedure, depress the pendulum stop. The pendulum should make not less than 11 complete swings before coming to rest. If it does not, clean or adjust the pointer bearing. The average of four zero readings taken just before any set of 10 replicate tests should not differ from the average of four readings taken immediately after the tests by more than 1 % of the test value.

Unless specifically permitted by the instrument manufacturer, do not apply oil to this bearing.

After any adjustment of the bearing, check the zero adjustment.

A.2.6 Tearing length

Check that the tearing length is 44,0 $\pm$ 0,5 mm. If this is not so, adjust the dimensions of the guillotine or template used.

Annex B

Calibration of instruments

Calibration of the instrument may be checked by measuring the work done by the pendulum in raising various attached weights. The indicated scale reading is then compared with the amount of work done. Many tear testers are provided with a threaded hole to aid the attachment of weights.

The position of the centre of gravity of the attached weights should be known.

Set up the instrument and check it as specified in annex A. With various weights attached, operate the instrument without a test piece in position and determine the scale reading and height above a horizontal datum surface of the centre of gravity of the additional weight corresponding to this scale reading.

Calculate the correct scale readings Y from one of the formulae

Single tear testers :

$$Y = \frac{9{,}81 \times m\,(h_1 - h_0)}{0{,}086 \times P}$$

Double tear testers :

$$Y = \frac{9{,}81 \times m\,(h_1 - h_0)}{0{,}176 \times P}$$

where

Y is the correct scale reading (scale units);

m is the mass, in kilograms, of the added weight;

h_1 is the height, in metres, above the datum surface of the centre of gravity of the attached weight;

h_0 is the height, in metres, of the centre of gravity of the attached weight above the datum surface with the pendulum in the initial position;

P is the pendulum factor (see clause 8).

For routine calibration checks, an alternative procedure is to prepare a graph giving $(h_1 - h_0)$ for different scale readings. It is then only necessary to determine the scale reading for a given added weight, to read off the corresponding value of $(h_1 - h_0)$ and to calculate the error using this value.

Calculated and indicated scale readings should agree to within $\pm$ 1 %. If they do not, the fault should if possible be found and remedied. Otherwise prepare a correction chart and adjust the results accordingly.