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Paper — Determination of tearing resistance (Elmendorf method)

Papier — Détermination de la résistance au déchirement (Méthode Elmendorf)

Reference number
ISO 1974:1990(E)

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 1974 was prepared by Technical Committee ISO/TC 6, *Paper, board and pulps*.

This third edition cancels and replaces the second edition (ISO 1974:1985), of which this constitutes a complete revision. In particular, this edition deals only with single tear testers, all references to double tear instruments having been deleted, and allows for the use of digital read-out variants. An alternative calibration procedure has been included.

Annexes A and B provide details of the apparatus and calibration procedures respectively. Annex C refers to units used with older apparatus.

Annexes A and B form an integral part of this International Standard. Annex C is for information only.

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Paper — Determination of tearing resistance (Elmendorf method)

1 Scope

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

This International Standard does not apply to corrugated fibreboard, but it may be applied to the components of such boards. It is not suitable for determining the cross-direction tearing resistance of highly directional paper (or board).

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 186:1985, *Paper and board — Sampling to determine average quality*.

ISO 187:1977, *Paper and board — Conditioning of samples*.

ISO 536:1976, *Paper and board — Determination of grammage*.

3 Definitions

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

3.1 tearing resistance: The mean force required to continue the tearing started by an initial cut in a single sheet of paper (or board). If the initial cut is in the machine direction, the result is given as machine-direction tearing resistance; similarly, if the initial cut is in the cross direction, the result is given as cross-direction tearing resistance. The result is expressed in millinewtons (mN).

3.2 tear index: The tearing resistance of the paper (or board) divided by its grammage. The result is expressed in millinewton square metres per gram ($mN \cdot m^2/g$).

4 Principle

A test piece of superimposed sheets (normally four), with a specified pre-cut slit, is torn through a fixed distance using a pendulum which applies the tearing force by moving in a plane perpendicular to the initial plane of the test piece. The work done in tearing the test piece is measured by the loss in potential energy of the pendulum.

The average tearing force (work done divided by the total distance torn) is indicated by a scale on the pendulum or a digital display.

The tearing resistance of the paper is determined from the average tearing force and the number of sheets comprising the test piece.

5 Apparatus

5.1 Elmendorf-type tear tester, of suitable capacity complying with the requirements specified in annex A.

NOTES

1 Some apparatus may be equipped with digital indication of tearing resistance. Such apparatus normally replaces the friction pointer system with a transducer for sensing the angular movement of the pendulum. Transducer outputs are electrically processed to give a direct digital read-out of average tearing resistance. In other respects this type of apparatus conforms to the requirements of annex A.

2 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 and overcoming friction 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. This is a major source of error on such apparatus, and apparatus on which this occurs are not considered suitable for testing in accordance with this International Standard. Instruments, modified by a suitable cut out to avoid this problem are available.

5.2 Augmenting masses or **interchangeable pendulums** to increase the tearing force capacity of the apparatus.

5.3 Means for preparing the test piece: may comprise a suitable die, guillotine or template and knife.

6 Sampling

Sample in accordance with ISO 186.

7 Conditioning

Condition the sample in accordance with ISO 187.

8 Preparation of test pieces

Prepare the test pieces in the same conditioning atmosphere used to condition the samples. There shall be no folds, creases or other visible defects in the area from which the test piece is cut and the test piece shall not include any part of the sample that is less than 15 mm from the edge of the sheet or reel. If watermarks are present, this should be stated in the test report.

Identify the two sides of the paper in a convenient way, for example, side one and side two and, with the same side up, from each specimen cut four rectangular sheets of the same size between 50 mm ± 2 mm and 76 mm ± 2 mm wide with edges parallel to the desired test direction and of such a length that after the initial cut has been made either as part of the test piece preparation or by means of the integral knife (see clause A.1), the untorn length is 43,0 mm ± 0,5 mm long. Assemble the cut sheets into sets of four to make up the test pieces. Alternatively, arrange four specimens with their machine directions parallel and the same sides facing the same way and cut the test piece simultaneously as described above. The untorn length shall be as specified above.

The edges of the sheets comprising the test piece shall be free and not stuck together.

NOTE 3 The exact test piece dimensions depend on the design of the apparatus clamps used. For certain apparatus the appropriate dimensions are 50 mm wide × 63 mm long; for others 50 mm wide × 65 mm long or 63 mm wide × 76 mm long. A guillotine giving the appropriate test piece dimensions is normally supplied with the apparatus.

Cut sufficient test pieces to give a minimum of 10 valid tests in each required principal direction of the paper (i.e. a total of at least 40 sheets in each direction).

9 Procedure

Carry out the tests in the same conditioning atmosphere used to condition the samples.

Set up and check the instrument as described in annex A. If necessary, calibrate the apparatus as described in annex B.

Carry out a few tests by the procedure described below in order to select the appropriate pendulum or pendulum/augmenting mass 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 noted in the report.

Raise the pendulum to its initial position and secure it by the pendulum release mechanism.

Carefully position the test piece in the clamps so that the slit, if pre-made, is centrally situated between the clamp on the frame and the clamp on the pendulum, and tighten the clamps. Where applicable, operate the knife to produce the required slit. Set the pointer if fitted, against its stop.

Sharply depress the pendulum release mechanism and holding it down, gently catch the pendulum by hand on its return swing without disturbing the position of the pointer, if fitted. Record the scale reading to the nearest scale division for the capacity used.

NOTE 4 Digital read-out instruments may have slightly different arrangements for releasing and arresting the pendulum. In such cases follow the manufacturer's instructions.

Return the pendulum and, if fitted, the pointer to the initial position and remove the torn paper. Repeat this procedure for the other test pieces, orientating them so that side one faces towards and away from the pendulum alternately.

The path of the tear may deviate from the direction of the slit. If the mean deviation exceeds 10 mm in one or two out of 10 tests, reject these results and carry out further tests to bring the number of satisfactory tests up to 10. If in more than two of the test pieces the deviation exceeds 10 mm, include the results and state 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 mean centre line of the torn band through the test pieces.

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

NOTES

5 The apparent tearing resistance is dependent on the number of sheets torn simultaneously. With some papers, the difference in apparent tearing resistance when one and four plies are torn simultaneously may exceed 20 %. Comparison between four plies and two or more plies (up to 16) shows smaller differences than between one and four plies, but these differences may still be significant.

6 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.

10 Calculation and expression of results

For each direction tested, calculate the mean scale reading and, from the following equations, the tearing resistance and the tear index:

$$F = \frac{\bar{F}p}{n}$$

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

where

F is the tearing resistance, expressed in millinewtons;

$\bar{F}$ is the mean scale reading, expressed in millinewtons;

p is the number of sheets torn simultaneously for which the pendulum scale has been calibrated to give a direct tearing resistance reading, in millinewtons (commonly the value of this factor is 4, 8, 16 or 32);

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, expressed in grams per square metre, and determined in accordance with ISO 536.

Calculate the coefficient of variation of the results from the individual scale readings.

11 Precision

Regular comparative testing in the USA, involving 120 laboratories testing 12 papers, indicated the repeatability of the method to be about 3,5 %.

The same comparison indicated the reproducibility to be about 18 %.

12 Test report

The test report shall include the following particulars:

a) reference to this International Standard;

b) date and place of testing;

c) description and identification of material tested;

d) the direction of the test (machine direction, cross direction);

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

f) the tearing resistance, in millinewtons, and the tear index, in millinewton square metres per gram, to three significant figures, in the direction tested;

g) the coefficient of variation of results;

h) the manufacturer, model number and pendulum factor (p) of the apparatus;

i) the number of sheets torn simultaneously;

j) any deviation in tear from the correct path, or whether extensive "skinning" occured;

NOTE 7 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 this International Standard or other circumstances which may have had an influence on the results;

l) the grammage of the paper or any other factor which may assist in interpretation of the results.

Annex A
(normative)

Description, adjustment and maintenance of single tear testers

A.1 Description

The apparatus consists of a frame, mounted on a rigid base, carrying a pendulum and pointer assembly (see figure A.1). Two clamps, one on the frame and one on the pendulum are provided to hold the test piece. The clamping surfaces shall be at least 25 mm wide and 15 mm deep. The pendulum is free to swing on an essentially frictionless bearing about a horizontal axis.

NOTE 8 On some apparatus the pointer assembly has been replaced by a transducer/digital read-out system but in other respects conforms to the requirements of this annex.

When the pendulum is in its initial position, ready for test, the clamps shall be separated by a distance of 2,8 mm ± 0,3 mm and so aligned that the test piece clamped in them lies in a plane 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 mm ± 2 mm from the axis of the pendulum. The plane containing this line and the pendulum axis makes an angle of 27,5° ± 0,5° with the plane of the test piece.

The pendulum carries a circumferential scale suitably calibrated for the capacity of the instrument. Instruments are available with the following capacities:

grams-force (gf)	millinewtons (mN)
200	2 000
400	4 000
800	8 000
1 600	16 000
3 200	32 000
6 400	64 000

All apparatus of these capacities comply which the basic requirements given above, but it is essential that apparatus of the correct capacity is selected for the material to be tested.

The scale reading is normally appropriate to the tearing resistance for a given number of sheets (normally 4, 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 10.

The pointer, if fitted, is mounted on the same axis as the pendulum, there being sufficient constant friction to stop the pointer at the highest point reached by the swing of the pendulum.

Apart from the frame, the base also carries the pendulum release mechanism and, if fitted, an adjustable pointer stop. The pendulum release mechanism provides a means of holding the pendulum in a raised position and releasing it without imparting shock. The adjustable pointer stop provides a means of setting the zero of the apparatus.

Where an integral knife is fitted to produce the initial tear, this is mounted so that the distance to be torn after cutting is 43,0 mm ± 0,5 mm and the distance above the clamp and the end of the tear is 4,0 mm ± 0,5 mm.

NOTE 9 In some apparatus the clamp depth is 15 mm and the test pieces are 63 mm in length. In such cases the distance between the clamp and the start of the tear must be 5,0 mm ± 0,5 mm in order to maintain the correct length of tear.

A.2 Adjustment and maintenance

Follow the procedure described below for each pendulum/augmenting mass combination used.

A.2.1 Inspection

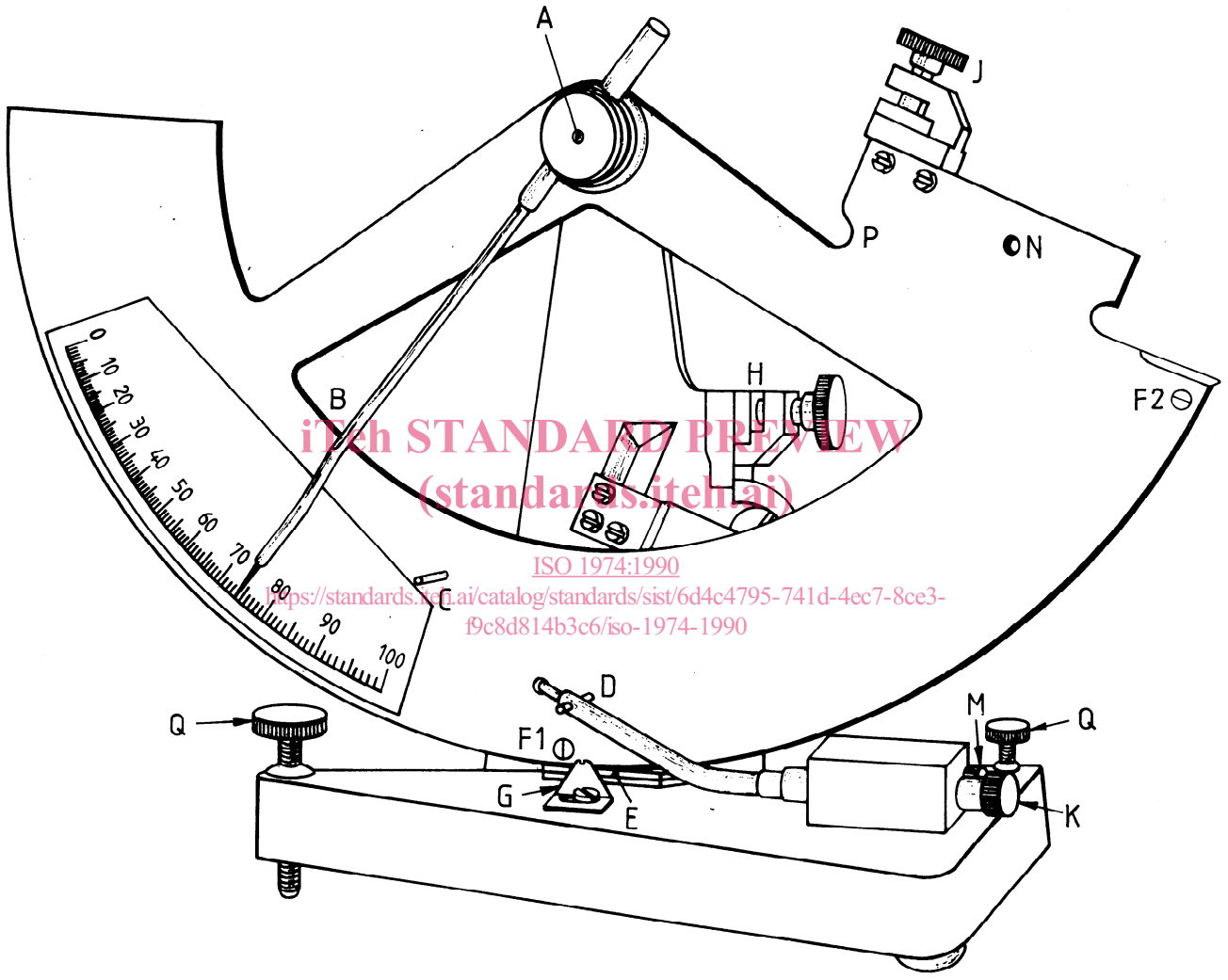
Check the following items and make adjustments as necessary:

a) check that the pendulum shaft is not bent;

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

c) ensure that the pointer is undamaged and rigidly attached to the sleeve;

d) where fitted, check that the knife fitting is secure and that the cutting edge is sharp and undamaged. The blade shall be midway between, and at right angles to the top of the clamps. If sharpening is required, make sure that after replacement the depth of the uncut portion is as specified in clause 8 and in A.2.6;



A	Bearings	H	Stationary clamp
B	Pointer	J	Pendulum clamp
C	Pendulum pointer stop	K	Pendulum catch adjusting screw
D	Adjustable pointer stop	M	Pointer stop adjusting screw
E	Pendulum catch	N	Tapped hole for attaching calibrated masses
F	Pendulum index marks	P	Cut out to prevent test piece fouling the pendulum
G	Base index mark	Q	Adjusting screws

Figure A.1 — Elmendorf-type tearing apparatus

e) for apparatus fitted with transducers, check mounting and operation in accordance with the manufacturer's instructions.

A.2.2 Levelling

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

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

The pointer should be turned vertically upwards during these operations.

For digital read-out apparatus, level the apparatus according to the manufacturer's instructions.

A.2.3 Zero adjustment

After levelling, operate the apparatus several times with the pendulum clamp empty and closed. If the pointer does not register zero, adjust the pointer stop until zero is obtained.

For digital read-out instruments, check and adjust zero according to the manufacturer's instructions.

NOTE 10 Do not change the level to adjust zero.

A.2.4 Pendulum friction

Make a reference mark on the pendulum release mechanism 25 mm to the right of the pendulum catch. Release the pendulum, turn the pointer if fitted, so that it points vertically upwards and return the pendulum to its initial position. On releasing the pendulum and keeping the release mechanism depressed, the pendulum should make at least 35 complete oscillations before the edge of the pendulum which engages the pendulum catch no longer passes to the left of the reference mark. Otherwise clean, oil or adjust the bearing as appropriate for the type of apparatus.

For digital read-out apparatus, it may be necessary to make a reference mark on something other than the pendulum release mechanism and also on the pendulum.

A.2.5 Pointer friction

Check the zero setting as in A.2.3. Set the pendulum in its initial position with its clamp empty and closed and with the pointer on zero. Release the mechanism and stop the swing before the pendulum has completed its swing back to the left. Estimate the distance the pointer has been deflected from the zero mark. This should be within the range of 4 to 8 scale divisions.

NOTE 11 Do not oil the pointer bearing, but a drop of clock oil may be applied to the pointer friction pin plunger so that it will move freely up and down in its housing.

Too low a pointer friction is usually due to wear or compression of the linings and is remedied by roughening or replacing the lining.

After adjusting the pointer friction, check the instrument zero.

A.2.6 Tearing length

Check that the tearing length, i.e. the length after making the initial cut is 43,0 mm ± 0,5 mm. If this is not the case, adjust the integral knife, if fitted, the die, template or guillotine used.

Annex B
(normative)

Calibration of apparatus

B.1 Calibration by means of check masses

The calibration of wholly mechanical apparatus may be checked by measuring the work done by the pendulum in raising various attached check masses.

The indicated scale reading is then compared with the amount of work done. Many tear testers are provided with a threaded hole to assist in the attachment of check masses.

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

Set up the apparatus and check it as specified in annex A. With a check mass attached, operate the apparatus with the clamps closed and empty 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 reading, Y, from one of the following equations as appropriate.

a) For apparatus graduated in grams-force:

$$Y = \frac{m(h - H) \times 1000}{0{,}086 \times p}$$

b) For apparatus graduated in millinewtons:

$$Y = \frac{9{,}81 \times m(h - H) \times 1000}{0{,}086 \times p}$$

where

Y is the correct scale reading (scale units);

m is the mass, in kilograms, of the check mass;

h is the height, in metres, of the centre of gravity of the attached mass, above the horizontal datum line with the pendulum in the position that gives the scale reading Y;

H is the height, in metres, of the centre of gravity of the attached mass, above the horizontal datum line with the pendulum in the initial position;

p is the pendulum factor (see clause 10).

Repeat with other check masses and prepare a graph of $(h - H)$ for different scale readings.

For routine calibration checks it is then only necessary to determine the scale reading for a given added check mass to read off the corresponding value of $(h - H)$ 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.

Digital read-out apparatus are not always conveniently calibrated by the above method because of the electronic sensing systems. In such cases, alternative calibration methods specified by the manufacturer are acceptable, provided the validity of such methods can be demonstrated.

B.2 Alternative procedure

Sets of check masses, calibrated to specific values and constructed with tongues to fit into the pendulum clamp are available. When these are used check the calibration of the apparatus as follows.

Set up the apparatus and check it as described in annex A. Raise the pendulum to its initial position and fix a check mass in the clamp. Operate the apparatus and determine the scale reading. Repeat for other check masses in the set. The scale readings should agree with the specified values of the check masses 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.