International Standard ISO 1924/2

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Paper and board — Determination of tensile properties — Part 2 : Constant rate of elongation method

Papier et carton — Détermination des propriétés de traction — Partie 2 : Méthode à gradient d'allongement constant

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Foreword

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Paper and board — Determination of tensile properties — Part 2 : Constant rate of elongation method

0 Introduction

The method specified in this part of ISO 1924 for the determination of tensile strength is similar to the method specified in ISO 1924/1. This method uses a test instrument operating at a constant rate of elongation. The method described in ISO 1924/1 uses a constant rate of application of tensile force which causes failure in a mean time of 20 ± 5 s.

Because of the different principles involved, the comparison of results obtained by using apparatus complying with ISO 1924/1 and this part of ISO 1924 is not recommended. Where such a comparison is necessary, it should only be undertaken where the time to fail is of the same order for the respective tests.

1 Scope and field of application

This part of ISO 1924 specifies a method of measuring the tensile strength, stretch at break, and the tensile energy absorption of paper and board using a test instrument operating with a constant rate of elongation. It also specifies methods for calculating the tensile index, the tensile energy absorption index and the breaking length.

It applies to all papers and board with the exception of papers with high elongation and corrugated board, but may be applied to the components of such board.

2 References

ISO 186, *Paper and board — Sampling to determine average quality.* [1)]

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

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

ISO 1924/1, *Paper and board — Determination of tensile properties — Part 1 : Constant rate of loading method.*

ISO 5270, *Pulps — Laboratory sheets — Determination of physical properties.*

3 Definitions

For the purpose of this part of ISO 1924, the following definitions apply.

3.1 tensile strength: The maximum tensile force per unit width that paper and board will withstand before breaking under the conditions defined in the standard method of test.

3.2 breaking length: The calculated limiting length of a strip of paper or board of any uniform width, beyond which, if such a strip were suspended by one end, it would break under its own weight.

3.3 tensile index: Tensile strength (expressed in newtons per metre) divided by grammage.

3.4 stretch at break: The measured elongation at the moment of rupture of a test piece of paper or board when extended under conditions defined in the standard method of test. It is usually expressed as a percentage of the initial test length.

3.5 tensile energy absorption: The total work done per unit area of a paper or board when stretching it to rupture.

3.6 tensile energy absorption index: Tensile energy absorption divided by grammage.

4 Principle

A test piece of given dimensions is stretched to rupture at a constant rate of elongation using a tensile testing apparatus that measures the tensile force and, if required, the elongation of the test piece. The maximum tensile force and, if required, the corresponding elongation are recorded.

If tensile force and test piece elongation are continuously recorded, the tensile energy absorption may be determined.

From the results obtained and a knowledge of the grammage of the sample, the breaking length, the tensile index and the tensile energy absorption index may be calculated.

1) At present at the stage of draft. (Revision of ISO 186-1977.)

5 Apparatus

5.1 Tensile testing apparatus, designed to extend a test piece of given dimensions at an appropriate constant rate of elongation and to measure the tensile force and, if required, the elongation produced. The tensile force may be recorded as a function of the elongation on a strip chart recorder or an equivalent device. The tensile testing apparatus includes:

5.1.1 Means of measuring and, if appropriate, **recording** the tensile force to an accuracy of ± 1 % of the true force and, if required, the elongation to an accuracy of ± 0,1 mm.

NOTE — The accuracy of measurement of elongation is very important. An appropriate extensometer, placed directly on the test piece, is recommended for accurate measurement of true elongation. This is to avoid the possibility of including, in the measurement, any apparent elongation which may result from undetected slippage of the test piece in the clamps or from the take-up in the universal joints of the apparatus. The latter is dependent upon the load applied and the error may increase due to wear of the joints of apparatus which has been in use for some time.

5.1.2 Clamps, two in number, for holding a test piece of the required width (see clause 8). Each clamp shall be designed to grip the test piece firmly but without damage along a straight line across the full width of the test piece and have means for adjusting the clamping force. The clamping surfaces of the clamps shall be in the same plane and so aligned that they hold the test piece in that plane throughout the test.

NOTE — The clamps should preferably grip the test piece between a cylindrical and a flat surface, or between two cylindrical surfaces, with the plane of the test piece tangential to the cylindrical surface.

Other types of clamps may be used provided no slippage of or damage to the test piece occurs during test.

The clamping lines shall remain parallel to within ± 1° for the duration of the test. In addition, the clamping lines shall remain perpendicular to the direction of the applied tensile force and to the long dimension of the test piece within ± 1° during the test.

The distances between the clamping lines shall be adjustable to the test length required, to within ± 1,0 mm.

5.2 Device for cutting test pieces to the dimensions required (see clauses 8 and 9).

5.3 Planimeter, or other means of measuring the area between the tensile force-elongation curve and the elongation axis, or an integrator for directly computing the work required to rupture the test piece, recording to an accuracy of ± 2 %. This apparatus is required if it is desired to determine the tensile energy absorption.

6 Sampling

Sampling shall be carried out in accordance with ISO 186.

7 Conditioning

Samples shall be conditioned in accordance with ISO 187.

8 Preparation of test pieces

Carry out the preparation of the test pieces in the standard atmospheric conditions used for conditioning the sample.

If the breaking length or tensile index is required, determine the grammage of the sample in accordance with ISO 536.

Prepare test pieces from specimens taken at random from those selected in accordance with clause 6. No creases, obvious flaws or watermarks shall be included in the test area and test pieces shall 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, this fact shall be reported.

NOTE — Laboratory hand sheets are excluded from the restriction that test pieces shall not include any part within 15 mm of the edge.

Cut test pieces one at a time. Cut sufficient test pieces to ensure 10 valid results are obtained in each principal direction of the paper or board, i.e. the machine and cross directions (see 9.2).

The long edges of the test pieces shall be straight, parallel to within ± 0,1 mm, cleanly cut and undamaged.

NOTE — Some paper, for example soft tissue, is difficult to cut cleanly. In such cases, a pad of two or three sheets of tissue interleaved with a harder paper, for example bond, may be prepared and the test pieces cut from this pad.

The dimensions of the test pieces shall be as follows:

a) the width shall be 15; 25; or 50 mm, with a tolerance of −0,1 mm and +0,2 mm;

NOTE — All widths have equal status and the selection of width is governed by the width of the clamps of the available apparatus and/or the type of paper or board under test.

b) the length shall be such that the test piece can be clamped without handling the section of the test piece between the clamps; a minimum length of 250 mm is usually sufficient. When testing laboratory hand sheets special instructions apply; see ISO 5270.

NOTE — Some product dimensions, for example toilet tissue, are less than the required test span of 180 mm. In these cases, use the longest test length that can be achieved and record the length used in the test report.

9 Procedure

9.1 Calibration and adjustment of apparatus

Set up the apparatus as recommended by the manufacturer. Calibrate the force-measuring component of the apparatus, and if required, the extension-measuring mechanism as indicated in the annex.

Verify that the clamps are aligned to meet the requirements of 5.1.2.

Adjust the clamping load so that neither slipping of the test piece nor damage to it occurs during the test.

Position the clamps so that the test length (the distance between the closest points at which the test piece is firmly gripped) is 180 ± 1,0 mm (see note 1). Verify that the test length is correct by measuring the distance between the two impressions produced by the clamps when clamping strips of thin aluminium foil.

Adjust the rate of separation of the clamps, i.e. the rate of elongation of the test piece, to that appropriate for the test length used, as given in table 1. (See note 2.)

Table 1 — Rate of elongation

Nominal test length	Rate of elongation
mm	mm/min
180	20 ± 5
100	10 ± 2,5

NOTES

1 In some circumstances, a different test length may be used. For example, when testing board, a test span of 200 ± 1,00 mm may be required. When testing laboratory hand sheets (see ISO 5270), it may be difficult to place a test piece into a 100 mm test span without touching the surface of the test area between the clamps. In this case a 90 mm test span may be used.

2 For some qualities of paper and board, the test piece may fail quickly, for example in less than 5 s, or take some time, for example more than 30 s. In such cases, a different constant rate of elongation may be used, but this rate must be reported.

9.2 Determination

Carry out the tests in the standard atmospheric conditions used for conditioning the sample.

Verify the zero position of the measuring, and if used recording, devices.

Adjust the clamps to the required test length and place the test piece in the clamps ensuring that the test area between the clamps is not touched by the fingers. Align and tightly clamp the test piece so that any observable slack is eliminated but the test piece is not placed under any significant strain. Ensure that the test piece is clamped in such a manner that its edges are parallel to the direction of the application of the tensile force.

NOTE — It may be convenient to attach a small weight, for example a mass of 10 g for light-weight paper, to the lower end of the test piece whilst placing it in the clamp in order to eliminate the slack.

Commence the test and continue it until the test piece ruptures. Record the maximum tensile force exerted and, if required, the stretch at break, in millimetres, to within ± 0,1 mm, and the work equivalent, in joules, to within 2 % of the area under the force-elongation curve. Instruments fitted with an integrator provide a direct reading of the work equivalent.

Test at least 10 test pieces, cut in each principal direction of the paper or board, in order to obtain 10 valid results in each direction.

Record all readings, except for those test pieces which break within 10 mm of the clamps. However, if more than 20 % of the test pieces cut from a particular sample break within 10 mm of the clamps, reject all the readings obtained for that sample, inspect the testing apparatus for conformity with the requirements of 5.1 and 9.1 and take the appropriate remedial action.

10 Expression of results

10.1 General

Calculate and express separately the results obtained in each principal direction of the paper or board. For machine-made paper or board, these will correspond to the machine and cross directions. For laboratory hand sheets, no such distinction can be made.

10.2 Symbols

The symbols used in the equations are as follows:

m is the mean mass, in milligrams, of the strip between the clamps;

l_B is the breaking length, in kilometres;

E is the work equivalent, in joules or millijoules, of the area under the force-elongation curve;

g is the grammage, expressed in grams per square metre;

S is the tensile strength, expressed in kilonewtons per metre;

l_i is the initial test length, in millimetres, between the clamps;

w is the width, in millimetres, of the test piece;

$\bar{F}$ is the mean tensile force, in newtons;

I is the tensile index, expressed in newton metres per gram;

Z is the tensile energy absorption, expressed in joules per square metre;

I_Z is the tensile energy absorption index, expressed in millijoules per gram.

10.3 Tensile strength

10.3.1 Calculate the tensile strength of the test pieces from the equation

$$S = \frac{\bar{F}}{w}$$

Express the tensile strength to three significant figures.

NOTE — For light-weight paper (for example tissue), it may be preferable to express the tensile strength in newtons per metre.

10.3.2 Calculate the standard deviation of the results.

10.4 Breaking length

If required, calculate the breaking length from the equation

$$l_B = \frac{1}{9,8} \times \frac{S}{g} \times 10^3$$

or

$$l_B = \frac{1}{9,8} \times \frac{\bar{F}}{wg} \times 10^3$$

Alternatively, l_B may be calculated from the equation

$$l_B = \frac{\bar{F} l_i}{9,8\ m}$$

NOTE — For instruments calibrated in kilograms-force, the equation becomes

$$l_B = \frac{\bar{F} l_i}{m}$$

10.5 Tensile index

If required, calculate the tensile index from the equation

$$I = \frac{S}{g} \times 10^3$$

Express the tensile index to three significant figures.

Alternatively, I may be calculated from the equation

$$I = \frac{\bar{F}}{wg} \times 10^3$$

10.6 Stretch at break

10.6.1 If required, calculate the mean stretch at break of the test pieces in millimetres, then calculate the stretch at break as a percentage of the initial test length and express the results to the first decimal place.

10.6.2 Calculate the standard deviation of the results.

10.7 Tensile energy absorption

10.7.1 If required, determine the tensile energy absorption of each test piece, either by means of an integrator instrument attached to the tensile testing apparatus or from the area under the force-elongation curve up to the point of maximum tensile force. If the area under the force-elongation curve is used, calculate the tensile energy absorption from the equation

$$Z = \frac{E}{wl_i} \times 10^6$$

where E is expressed in joules, or

$$Z = \frac{E}{wl_i} \times 10^3$$

where E is expressed in millijoules.

Calculate the mean tensile energy absorption and express it to three significant figures.

10.7.2 Calculate the standard deviation of the results.

10.8 Tensile energy absorption index

If required, calculate the tensile energy absorption index using the equation

$$I_Z = \frac{\bar{Z}}{g} \times 10^3$$

Express the tensile energy absorption index to three significant figures.

11 Precision

The precision of the test depends on the variability of the paper or board being tested. Results of testing carried out independently in the Netherlands and USA have been combined to produce the figures for repeatability and reproducibility of the method as shown in table 2.

Table 2 — Repeatability and reproducibility

Test range	Method	Mean repeatability (%)	Mean reproducibility
0,5 to 1,3 kN/m	tensile	5,8	not known
2,9 to 11,5 kN/m	tensile	3,8	12 %
0,7 to 1,9 %	stretch	9,0	not known
1,4 to 2,6 %	stretch	6,6	30 %
2,3 to 7,0 %	stretch	4,5	not known
30 to 200 J/m²	tensile energy absorption	10	28 %

11.1 Repeatability

The difference between the two single test results found on identical test material by one operator using the same apparatus within a short time interval will exceed the repeatability on average not more than one in 20 instances of the normal and correct operation of the method.

11.2 Reproducibility

The difference between two single and independent results found by two operators working in different laboratories on identical test material will exceed the reproducibility on average not more than one in 20 instances of the normal and correct operation of the method.