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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



Reference number
ISO 1924-2:1994(E)

Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 1924-2 was prepared by Technical Committee ISO/TC 6, *Paper, board and pulps*, Subcommittee SC 2, *Test methods and quality specifications for paper and board*.

This second edition cancels and replaces the first edition (ISO 1924-2:1985), which has been technically revised.

ISO 1924 consists of the following parts, under the general title *Paper and board — Determination of tensile properties*:

- *Part 1: Constant rate of loading method*
- *Part 2: Constant rate of elongation method*

Annex A forms an integral part of this part of ISO 1924.

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Introduction

The method specified in this part of ISO 1924 for the determination of tensile properties is related to the method specified in ISO 1924-1.

This method uses a test instrument operating at a constant rate of elongation, whereas the method described in ISO 1924-1 uses a constant rate of application of tensile force which causes failure in a mean time of $20 \text{ s} \pm 5 \text{ s}$.

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 when the time to fail is of the same order for the respective tests.

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Paper and board — Determination of tensile properties —

Part 2:

Constant rate of elongation method

1 Scope

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

Testing in conformance with this part of ISO 1924 always includes the measurement of tensile strength. Measurement or calculation of other properties is subject to agreement between the parties concerned.

This part of ISO 1924 applies to all papers and boards, including papers with a high stretch at break if the results are within the capacity of the test instrument. It also applies to the components of corrugated board but not, however, to corrugated board itself.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 1924. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 1924 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 186:1994, *Paper and board — Sampling to determine average quality*.

ISO 187:1990, *Paper, board and pulps — Standard atmosphere for conditioning and testing and procedure for monitoring the atmosphere and conditioning of samples*.

ISO 534:1988, *Paper and board — Determination of thickness and apparent bulk density or apparent sheet density*.

ISO 536:—¹⁾, *Paper and board — Determination of grammage*.

ISO 5270:1979, *Pulps — Laboratory sheets — Determination of physical properties*.

3 Definitions

For the purposes 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 test method.

3.2 tensile index: Tensile strength (expressed in kilonewtons per metre) divided by grammage.

3.3 stretch at break: The measured elongation at the moment of rupture of a test piece of paper or

1) To be published. (Revision of ISO 536:1976)

board when extended under conditions defined in the standard method of test. It is expressed as a percentage of the initial test length.

3.4 tensile energy absorption: The amount of energy per unit surface area (test length $\times$ width) of a paper or board absorbed during straining it to rupture.

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

3.6 modulus of elasticity: The ratio of the stretching force per unit cross-sectional area to the elongation per unit length.

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 the tensile force and elongation are continuously recorded, the tensile energy absorption and the modulus of elasticity may be determined.

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

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 an electronic integrator or an equivalent device. The tensile-testing apparatus includes the items listed in 5.1.1 and 5.1.2.

5.1.1 Means of measuring and indicating the tensile force to an accuracy of $\pm 1\%$ of the true force and, if required, the elongation to an accuracy of $\pm 0,1\%$ stretch.

NOTE 1 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 joints of the apparatus. The latter is dependent upon the load applied and the error may increase due to wear of the joints of an 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 so as to be capable of gripping the test piece without damage or slippage along a straight line across the full width of the test piece and have means for controlling and 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 2 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° while under load. 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 to within 1° while under load (see figure 1).

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

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

5.3 Means of measuring the work done (for example an integrator) in stretching and rupturing the test piece, with an accuracy of $\pm 1\%$. Such devices should be capable of being programmed to take account of different initial test lengths.

This apparatus is required if tensile energy absorption is to be determined.

5.4 Means of plotting the force/elongation curve and measuring the maximum slope of the curve.

This is required only if the modulus of elasticity is to be determined.

6 Sampling

If the test is to be done on a batch of paper or board, sample the batch in accordance with ISO 186.

7 Conditioning

Condition the sample in accordance with the requirements of ISO 187.

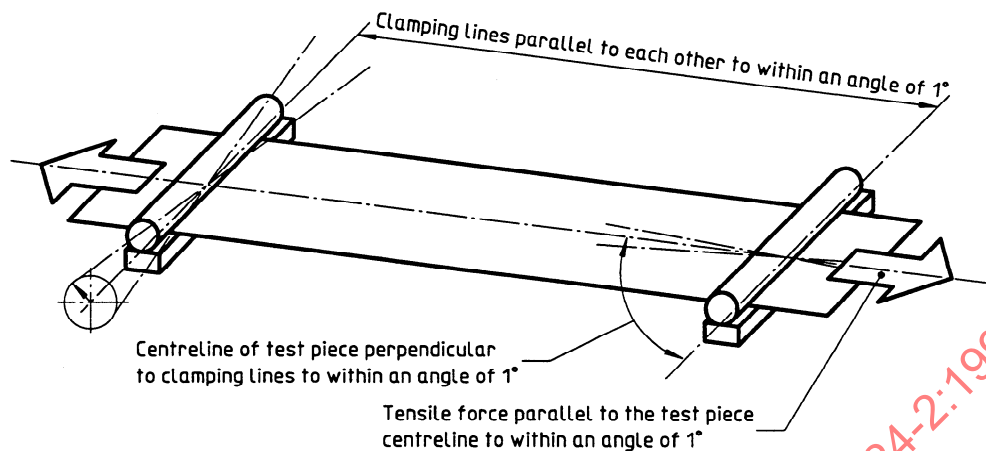


Figure 1 — Relationship between the clamping lines and test piece

8 Preparation of test pieces

Carry out the preparation of the test pieces in the same atmospheric conditions used for conditioning the sample (see clause 7).

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

If the modulus of elasticity is required, determine the thickness of the sample in accordance with ISO 534.

NOTE 3 It is necessary to measure the thickness of each test piece for accurate determinations of elastic modulus and not the mean thickness as in ISO 534. However, the anvil diameter in ISO 534 is 16 mm so that for a 15 mm wide test piece the pressure is slightly greater than the specified 100 kPa. The modulus of elasticity determined by this method is therefore only an approximation.

Prepare the 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 a specimen within 15 mm of the edge of any sheet or roll. If it is necessary to include watermarks, this fact shall be noted in the test report.

NOTE 4 Laboratory hand sheets are excluded from the restriction that the test piece shall not include any part within 15 mm of the edge (see also ISO 5270).

Cut test pieces one at a time. Cut sufficient test pieces to ensure 10 valid results in each required 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 $\pm 0,1$ mm, cleanly cut and undamaged.

NOTE 5 Some paper, for example soft tissue, is difficult to cut cleanly. In such cases, a pad of two or three sheets of the paper, interleaved with a harder paper, for example bond, may be prepared and test pieces cut from this pad.

The dimensions of the test piece shall be as follows:

- a) the width shall be $15 \text{ mm} \pm 0,1 \text{ mm}$;

NOTE 6 In certain circumstances or for paper such as tissue, $25 \text{ mm} \pm 0,1 \text{ mm}$ or $50 \text{ mm} \pm 0,1 \text{ mm}$ widths may be used and this fact should be noted in the test report. The results of such tests should not be considered to be identical to those obtained using the standard width.

- b) the length shall be such that the test piece can be clamped without handling the section of the test piece between the lines of clamping. When testing laboratory hand sheets, special instructions apply; see ISO 5270.

NOTE 7 For some products, for example toilet tissue, dimensions are less than the required test length of 180 mm. In these cases, use the longest test piece that can be achieved consistent with note 8 and record the length in the test report.

9 Procedure

9.1 Calibration and adjustment of apparatus

Set up the apparatus as recommended by the manufacturer. If required, calibrate the force-measuring

component of the apparatus and the elongation-measuring mechanism as indicated in annex A.

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 mean distance between the clamping lines) is $180 \text{ mm} \pm 1 \text{ mm}$ (see note 8). 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 $20 \text{ mm/min} \pm 5 \text{ mm/min}$.

NOTES

8 In some circumstances, for example a high-stretch paper or a product of limited size, a smaller test length may be used. When such a situation arises, it is recommended that the rate of elongation is adjusted so that its numerical value is $(10 \pm 2,5) \%$ of the unstressed test length. In such cases, the test length used and the rate of elongation should be noted in the test report.

9 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 rate of elongation may be used, but this rate should be noted in the test report.

9.2 Determination

Carry out the tests in the same atmospheric conditions used for conditioning the sample (see clause 7).

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

Adjust the clamps to the required initial test length and place the test piece in the clamps, ensuring that the test area between the clamping lines is not touched by the fingers. The use of disposable or light weight cotton gloves is recommended when handling the test pieces. Align and tightly clamp the test piece so that any observable slack is eliminated but the test piece is not placed under any significant stress. Ensure that the test piece is clamped in such a manner that it is parallel to the direction of the application of the tensile force (see figure 1).

NOTES

10 For instruments which hold the test piece in the vertical position, it may be convenient to attach a small weight, for example a mass of 10 g for lightweight paper, to the lower end of the test piece whilst placing it in the clamp in

order to eliminate the slack. This procedure may not be suitable for high-elongation papers.

11 With soft tissue paper it may be difficult to take out the "observable slack" without applying stress to the test piece. In such cases, a minimum amount of slack may be left in the test piece.

Commence the test and continue it until the test piece ruptures. Record the maximum tensile force exerted and, if required, record either the elongation in millimetres or, for direct-reading instruments, the stretch at break as a percentage.

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

Record all readings. However, if more than 20 % of the test pieces cut from a particular sample break within 10 mm of the clamps, inspect the testing apparatus for conformity with the requirements of 5.1 and 9.1. If the apparatus is faulty, reject all the results and take appropriate remedial action. The number of test pieces which break within 10 mm of the clamps should be included in the test report.

10 Expression of results

10.1 General

Calculate and express separately the results obtained in each required 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:

t	is the mean thickness of the test piece, in millimetres (see note 3);
E	is the work equivalent, in joules or millijoules, of the area under the force/elongation curve;
E^*	is the mean modulus of elasticity, in meganewtons per square metre (MPa);
g	is the mean 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;
Δl_i	is the selected change in test length, in millimetres (see figure 2);
w_i	is the initial width, in millimetres, of the test piece;
$\bar{F}$	is the mean maximum tensile force, in newtons;
ΔF	is the change in force, in newtons, corresponding to Δl_i (see figure 2);
I	is the tensile index, expressed in newton metres per gram;
Z	is the tensile energy absorption, expressed in joules per square metre;
$\bar{Z}$	is the mean 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

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

Express the tensile strength to three significant figures.

NOTE 12 For lightweight 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 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

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

NOTE 13 Tensile index is calculated from the means of measured values for tensile strength and grammage. The

grammage determination has a variability of its own which is independent of the variability of the force measurement. The calculation of the standard deviation of the tensile index from the variability of the force measurement and the mean grammage would result in an understatement of the standard deviation. For this reason, calculation of the standard deviation of the tensile index is not recommended.

10.5 Stretch at break

10.5.1 If required and if the instrument measures elongation in millimetres, for each reading calculate the stretch at break as a percentage of the initial test length and then calculate the mean stretch at break and express the results to the first decimal place.

If the instrument measures stretch at break as a percentage, calculate the mean stretch at break to the first decimal place.

10.5.2 Calculate the standard deviation of the results.

10.6 Tensile energy absorption

10.6.1 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. Calculate the tensile energy absorption from the equation

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

where E is expressed in joules, or

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

where E is expressed in millijoules.

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

10.6.2 Calculate the standard deviation of the results.

10.7 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.

10.8 Modulus of elasticity

If required, calculate the modulus of elasticity of each required direction from the equation

$$E^* = \frac{\Delta F \times l_i}{w_i \times t \times \Delta l_i}$$

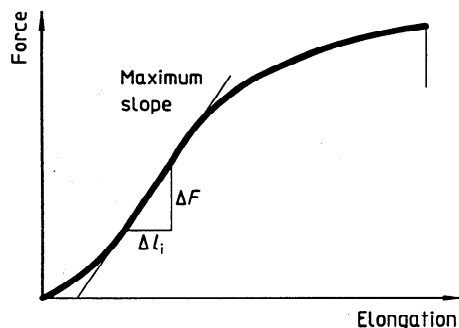


Figure 2 — Concept used in the determination of the modulus of elasticity

Express the modulus of elasticity 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 values given in table 1 for repeatability and reproducibility of the method.

11.1 Repeatability

The difference between 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.

Table 1 — Repeatability and reproducibility

Test range	Method	Mean repeatability %	Mean reproducibility %
0,5 kN/m to 1,3 kN/m	tensile	5,8	not known
2,9 kN/m 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 J/m ² to 200 J/m ²	tensile energy absorption	10	28

NOTE — These data are largely based on the older technology of strip chart recorders and planimeters.

12 Test report

The test report shall include the following information:

- a) reference to this part of ISO 1924;
- b) precise identification of the sample;
- c) date and place of testing;
- d) the conditioning atmosphere used;
- e) the width of test piece used if not $15 \text{ mm} \pm 0,1 \text{ mm}$;
- f) the test length used for the test if not $180 \text{ mm} \pm 1 \text{ mm}$;
- g) the rate of elongation used for the test if not $20 \text{ mm/min} \pm 5 \text{ mm/min}$;
- h) the number of test pieces used for the test, the number of valid readings taken and the number

of test pieces which broke within 10 mm of the clamps;

- i) the mean tensile strength for each principal direction tested;
- j) if required, the mean stretch at break, expressed as a percentage of the initial test length;
- k) if required, the mean tensile energy absorption;
- l) if required, the standard deviation of each of the above properties reported;
- m) if required, the mean modulus of elasticity;
- n) if required, tensile index and/or tensile energy absorption index;
- o) the grammage and/or thickness of the sample, if determined;
- p) any departure from this part of ISO 1924 and any circumstances that may have affected the results.

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Annex A

(normative)

Calibration of the apparatus

The frequency of calibration cannot be prescribed since it is dependent on how often the apparatus is used. It is, however, recommended that the calibration be checked at monthly intervals as a minimum.

Calibrate the force-measuring component of the apparatus, including the recording mechanism, if used, using weights with masses known to an accuracy of $\pm 0,1$ %. Calculate the force exerted as the product of the mass of the weight and the local acceleration of free fall due to gravity. Alternatively, calibration rigs such as pre-calibrated elastic-proving devices may be used.

Calibrate, under load, the elongation-measuring mechanism of the apparatus, including the recording device, if used, throughout the required elongation

range with either inside vernier calipers or gauge blocks.

In some tensile-testing apparatus, the force-measuring component may lengthen when loaded. To ensure that this does not influence the results, calibrate both the force and the elongation-measuring components of the instrument at several points within the relevant working range.

If an integrator is used with the apparatus in order to measure tensile energy absorption, calibrate it over the relevant ranges of force and extension in accordance with the manufacturer's instructions.

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

Verify any plotting instrument used for the measurement of the modulus of elasticity.

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