
Tissue paper and tissue products —
Part 4:
Determination of tensile strength,
stretch at maximum force and tensile
energy absorption

Papier tissue et produits tissue —

*Partie 4: Détermination de la résistance à la rupture par traction,
de l'allongement à la force maximale et de l'énergie absorbée à la
rupture par traction*



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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 6, *Paper, board and pulps*, Subcommittee SC 2, *Test methods and quality specifications for paper and board*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 172, *Pulp, paper and board*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This third edition cancels and replaces the second edition (ISO 12625-4:2016), which has been technically revised.

The main changes are as follows:

- inclusion of [Annex B](#), which describes a method of determining the tensile modulus.

A list of all parts in the ISO 12625 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Tissue paper and tissue products —

Part 4:

Determination of tensile strength, stretch at maximum force and tensile energy absorption

1 Scope

This document specifies a test method for the determination of the tensile strength, stretch at maximum force and tensile energy absorption of tissue paper and tissue products. It uses a tensile-testing apparatus operating with a constant rate of elongation.

It also specifies the method of calculating the tensile index and the tensile energy absorption index.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

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

ISO 1924-2, *Paper and board — Determination of tensile properties — Part 2: Constant rate of elongation method (20 mm/min)*

ISO 7500-1, *Metallic materials — Calibration and verification of static uniaxial testing machines — Part 1: Tension/compression testing machines — Calibration and verification of the force-measuring system*

ISO 12625-1, *Tissue paper and tissue products — Part 1: Vocabulary*

ISO 12625-6, *Tissue paper and tissue products — Part 6: Determination of grammage*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 12625-1 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1

tensile strength

maximum tensile force per unit width that a test piece will withstand before breaking

3.2

tensile index

I

tensile strength (3.1) divided by grammage

3.3

stretch at maximum force

ratio of the elongation of a test piece, over its initial length, at the moment when the maximum tensile force is reached during a tensile test

Note 1 to entry: Stretch at maximum force is expressed as a percentage of the initial test span length.

Note 2 to entry: This procedure uses slack correction and does not start to measure elongation until a force of $(0,25 \pm 0,05)$ N.

3.4

tensile energy absorption

TEA

amount of energy absorbed per unit surface area of a test piece while being stretched under application of tensile force, until the onset of break (the moment of maximum tensile force)

[SOURCE: ISO 12625-1:2019, 3.53.1.3]

3.5

tensile energy absorption index

I_z

tensile energy absorption (3.4) divided by grammage

[SOURCE: ISO 1924-2:2008, 3.7]

3.6

tensile modulus

M

slope between the two force points from a tensile force-elongation curve obtained from a constant rate of elongation apparatus

Note 1 to entry: In the paper industry, “modulus” refers to the tensile stiffness of paper with units of force per unit width (as opposed to true “stress” in engineering terms, which is force per unit area).

Note 2 to entry: This procedure is optional, but if tensile modulus is desired as a measurement from this method, it shall be measured and calculated according to the procedure in [Annex B](#).

4 Principle

A test piece of tissue paper or tissue product, of given dimensions, is stretched to break at a constant rate of elongation using a tensile-testing apparatus that measures and records the tensile force as a function of the elongation of the test piece.

From the recorded data, the tensile strength, the corresponding stretch at maximum force and the tensile energy absorption can be calculated.

The test can be carried out by a vertical or a horizontal tensile strength tester.

Precision data are available in [Annex A](#).

5 Apparatus

5.1 Tensile-testing apparatus

5.1.1 General

The tensile-testing apparatus shall be in accordance with ISO 1924-2. It shall be capable of stretching a test piece of tissue paper or tissue product of given dimensions, at a constant rate of elongation of 50 % of the initial test span length per minute (%/min), i.e. 50 mm/min for a 100 mm test span length and

25 mm/min for a 50 mm test span length, and recording the tensile force as a function of elongation on a strip chart recorder or any equivalent device.

The elongation shall be recorded to an accuracy of $\pm 0,1$ mm. The measurement of the elongation shall start at a force of $(0,25 \pm 0,05)$ N.

The force-measuring system (normally a load cell) shall measure loads with an accuracy of ± 1 % of the reading or $\pm 0,025$ N, whichever is greater, and shall be calibrated and verified to conform to the requirements of ISO 7500-1.

5.1.2 Means for measuring the area of the force-elongation curve

The tensile-testing apparatus shall provide a means for measuring the area between the force-elongation curve and the elongation axis to an accuracy of ± 2 % of the true value as determined by numerical integration of the raw data.

NOTE Most modern tensile testers are equipped with an electronic or electro-mechanical integrator that can be used for this purpose. The area can also be determined from a graphical output of the data on chart paper using a planimeter.

5.1.3 Clamps

The tensile-testing apparatus shall have two clamps of at least 50 mm in width. Each clamp shall be designed to grip the test piece firmly along a straight line across the full width of the test piece, without causing any damage, and shall have means for adjusting the clamping force.

The clamps should preferably grip the test piece between a cylindrical and a flat surface, with the plane of the test piece tangential to the cylindrical surface. Other types of clamps may be used if it can be ensured that the test piece does not slip or suffer any damage during the test.

During the test, the clamping lines shall be parallel to each other within an angle of 1° . The clamping lines shall be perpendicular to the direction of the applied tensile force and to the longest dimension of the test piece to the same level of accuracy.

The distance between the clamping lines (i.e. the test span length) shall be adjusted to (100 ± 1) mm, except that a test span length of (50 ± 1) mm shall be used for finished paper products of which one or both of the dimensions is insufficient to provide a test piece of the length required in [7.2](#).

NOTE Toilet tissue sheets having one or both dimensions of about 98 mm are an example of such a material.

5.2 Cutting device

The cutting device shall be capable of repeatedly cutting test pieces $(50,0 \pm 0,5)$ mm wide, with undamaged, straight, smooth and parallel edges.

6 Conditioning

Condition the samples in accordance with ISO 187 and keep them in the standard atmosphere throughout the test.

Conditioning shall be done prior to the preparation of test pieces.

7 Preparation of test pieces

7.1 General

7.1.1 If the tests are being made to evaluate a lot, the sample shall be selected in accordance with ISO 186. If the tests are being made on another type of sample, make sure that the specimens taken are

representative of the sample. Each test piece shall be free from perforations and faults not normally inherent in the tissue.

7.1.2 For converted tissue products, testing shall be done on the product as received, regardless of the number of plies that are supplied as a product unit. Generally, a single finished product sheet is suitable for use as a test piece.

7.1.3 Tissue that has not been converted into a finished product shall be tested as a single ply unless otherwise agreed between the parties concerned.

7.2 Dimensions

Each test piece shall be $(50,0 \pm 0,5)$ mm in width and at least 150 mm in length. With the exception of tissue paper or tissue products with an embossed pattern over all or part of the surface, the test pieces shall be free of creases, kinks, wrinkles, folds or other thickness variations.

For finished products with dimensions or perforations that make cutting of a test piece of at least 150 mm impossible, cut the longest piece possible. In such cases, a test span length of (50 ± 1) mm for the tensile tester clamps ([5.1.3](#)) shall be used. This deviation from the normal procedure shall be recorded in the test report.

7.3 Number of test pieces

Cut at least 10 test pieces in the machine direction and 10 test pieces in the cross direction for the selected specimens, making a total of at least 20 test pieces from each sample of tissue paper or tissue product.

8 Procedure

8.1 Ensure that the tensile-testing apparatus is calibrated and check the zero position of the recording device. Check that the clamps are aligned to meet the requirements in [5.1.3](#).

8.2 The elongation rate between the clamps shall be kept constant at 50 % of the initial test span length per minute, i.e. 50 mm/min for a 100 mm test span length and 25 mm/min for a 50 mm test span length.

8.3 Place the test piece in the clamps so that any observable slack is eliminated but the test piece is not placed under any significant strain ([5.1](#)). The test piece shall not be clamped with a force greater than 0,25 N (i.e. 5 N/m).

8.4 Do not touch the test area of the test piece between the clamps with the fingers. Align the test piece as parallel as possible to the pulling direction, tightly clamp the test piece and initiate the test. The test continues until the test piece breaks.

8.5 Test the test pieces from each sample. Record all readings, except for test pieces that break within 5 mm from the clamping line, until 10 valid results are available for each direction. If more than 20 % of the test pieces cut from a particular specimen break within 5 mm of the clamping line, reject all the readings obtained for that specimen. Inspect the apparatus for conformity with the specifications and take the appropriate remedial measures.

9 Calculation

9.1 General

Calculate and report the results separately for the machine direction and for the cross direction from [Formula \(1\)](#) to [Formula \(6\)](#).

9.2 Tensile strength

Calculate the mean maximum tensile force ($\bar{F}$) in newtons from all the single values (F) available representing acceptable test results. Calculate the mean tensile strength ($\bar{S}$) from [Formula \(1\)](#):

$$\bar{S} = \frac{\bar{F}}{w} \times 10^3 \quad (1)$$

where

$\bar{S}$ is the tensile strength, expressed in newtons per metre (N/m);

$\bar{F}$ is the maximum tensile force in newtons (N);

w is the initial width, in millimetres, of the test piece (50 mm).

Report the tensile strength in newtons per metre to three significant figures.

9.3 Tensile index

Calculate the tensile index, I , from [Formula \(2\)](#):

$$I = \frac{\bar{S}}{g} \quad (2)$$

where

I is the tensile index, expressed in newton metres per gram (Nm/g);

$\bar{S}$ is the tensile strength in newtons per metre (N/m);

g is the grammage, in grams per square metre (g/m^2), determined in accordance with ISO 12625-6.

If required, report the tensile index in newton metres per gram to three significant figures.

9.4 Stretch at maximum force

Calculate the mean elongation at break corresponding to the stretch of the test piece at the moment when the maximum force is reached. Calculate the stretch at maximum force, A , from [Formula \(3\)](#):

$$A = \frac{\varepsilon}{l} \times 100 \quad (3)$$

where

A is the mean stretch at maximum force in per cent (%);

ε is the mean elongation at maximum force in millimetres (mm);

l is the length of the test piece between the clamps, before elongation (see [5.1.3](#)), in millimetres (mm).

Report the result to the first decimal place.

9.5 Tensile energy absorption

Determine the area under the force-elongation curve up to the point of maximum tensile force and calculate the tensile energy absorption, Z , from [Formula \(4\)](#):

$$Z = \frac{E}{w \times l} \times 1\,000 \quad (4)$$

and the mean tensile energy absorption, $\bar{Z}$, from [Formula \(5\)](#):

$$\bar{Z} = \frac{\sum Z}{n} \quad (5)$$

where

- Z is the tensile energy absorption by a single test piece during the test until maximum force, in joules per square metre (J/m²);
- $\bar{Z}$ is the mean tensile energy absorption in joules per square metre (J/m²);
- E is the work, in millijoules, equivalent to the area under the force-elongation curve (mJ);
- w is the initial width, in millimetres, of the test piece (50 mm);
- l is the initial test length, in millimetres (standard 100 mm);
- n is the number of single values of the tensile energy absorption.

Report the mean tensile energy absorption in joules per square metre (J/m²) to the first decimal place.

9.6 Tensile energy absorption index

Calculate the tensile energy absorption index, I_Z , using [Formula \(6\)](#):

$$I_Z = \frac{\bar{Z}}{g} \quad (6)$$

where

- I_Z is the tensile energy absorption index, in joules per gram (J/g);
- $\bar{Z}$ is the mean tensile energy absorption, in joules per square metre (J/m²);
- g is the grammage, in grams per square metre (g/m²), determined in accordance with ISO 12625-6.

If required, report the tensile energy absorption index, in joules per gram, to the first decimal place.

10 Test report

The test report shall include the following information:

- a) a reference to this document, i.e. ISO 12625-4:2022;
- b) the date and place of testing;
- c) the description and identification of the sample (for example, product category and dimensions under test);

- d) the conditioning atmosphere used;
- e) the direction of the test;
- f) the number of test pieces;
- g) report tensile strength, stretch at maximum force and tensile energy absorption as specified in [Clause 9](#), and if required, tensile index and tensile energy absorption index (report basis weight in case of indexes are required);
- h) the standard deviation reported to two significant figures;
- i) any deviation from this document and any other circumstances that may have affected the test results.

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Annex A (informative)

Precision

A.1 General

The data have been obtained from CEPI-CTS, the Comparative Testing Service of the Confederation of European Paper Industries. The results are from a test round performed in 2012 by qualified laboratories. Two samples were tested according to this document. The data for tensile strength are presented in [Clause A.2](#). The data for stretch at maximum force are presented in [Clause A.3](#).

The repeatability and reproducibility results from the test are reported in [Table A.1](#) to [Table A.4](#).

Precision data for tensile energy absorption is not available.

The calculations were made according to ISO/TS 24498 and TAPPI T 1200 sp-07^[5].

The repeatability standard deviation reported in [Table A.1](#) and [Table A.3](#) is the “pooled” repeatability standard deviation, which means that the standard deviation is calculated as the root-mean-square of the standard deviations of the participating laboratories. This differs from the conventional definition of repeatability in ISO 5725-1.

The repeatability and reproducibility limits reported are estimates of the maximum difference which should be expected in 19 of 20 instances, when comparing two test results for material similar to those described under similar test conditions. These estimates may not be valid for different materials or different test conditions. Repeatability and reproducibility limits are calculated by multiplying the repeatability and reproducibility standard deviations by 2,77.

NOTE 1 The repeatability standard deviation and the within-laboratory standard deviation are identical. However, the reproducibility standard deviation is not the same as between-laboratories standard deviation. The reproducibility standard deviation includes both the between-laboratories standard deviation and the standard deviation within a laboratory, i.e.:

$$s_{\text{repeatability}}^2 = s_{\text{within lab}}^2$$

but

$$s_{\text{reproducibility}}^2 = s_{\text{within lab}}^2 + s_{\text{between lab}}^2$$

NOTE 2 $2,77 = 1,96 \sqrt{2}$, provided that the test results have a normal distribution and that the standard deviation, s , is based on a large number of tests.

A.2 Tensile strength

Table A.1 — Repeatability results of an interlaboratory test by qualified laboratories (tensile strength)

Sample	Number of laboratories	Mean tensile strength	Repeatability standard deviation	Coefficient of variation	Repeatability limit
		N/m	s_r N/m	$C_{V,r}$ %	r N/m
A	11	121	9,0	7,4	25
B	10	643	27	4,2	74

Table A.2 — Reproducibility results of an interlaboratory test by qualified laboratories (tensile strength)

Sample	Number of laboratories	Mean tensile strength	Reproducibility standard deviation	Coefficient of variation	Reproducibility limit
		N/m	s_R N/m	$C_{V,R}$ %	R N/m
A	11	121	11	9,1	30
B	10	643	30	4,7	84

A.3 Stretch at maximum force

Table A.3 — Repeatability results of an interlaboratory test by qualified laboratories (stretch at maximum force)

Sample	Number of laboratories	Mean stretch at maximum force	Repeatability standard deviation	Coefficient of variation	Repeatability limit
		%	s_r %	$C_{V,r}$ %	r %
A	10	16,8	1,7	9,9	4,6
B	10	15,5	0,76	4,9	2,1

Table A.4 — Reproducibility results of an interlaboratory test by qualified laboratories (stretch at maximum force)

Sample	Number of laboratories	Mean stretch at maximum force	Reproducibility standard deviation	Coefficient of variation	Reproducibility limit
		%	s_R %	$C_{V,R}$ %	R %
A	10	16,8	1,9	11	5,1
B	10	15,5	1,3	8,1	3,5

Annex B (informative)

Tensile modulus determination

B.1 General

This annex specifies a test method for the determination of tensile modulus of tissue paper and tissue products, which is defined as the slope between the two force points of 5 N/m and 25 N/m from a tensile force-elongation curve obtained from a constant rate of elongation of 50 % of the initial test span length per minute (%/min); i.e. 50 mm/min for a 100 mm test span length and 25 mm/min for a 50 mm test span length.

This procedure is optional, but if tensile modulus is desired as a measurement from this method, it shall be measured and calculated according to the procedure given in this annex.

B.2 Procedure

B.2.1 Ensure that the tensile testing apparatus is calibrated and check the zero position of the recording device.

B.2.2 Follow the testing procedure in [8.1](#) to [8.4](#), with a rate of elongation between the clamps constant at $(50 \pm 1) \text{ %/min}$.

B.3 Calculation

B.3.1 General

Calculate and report the results separately for the machine direction and for the cross direction.

B.3.2 Tensile modulus

Determine the elongation distance (mm) at 2 N/m and 22 N/m. Calculate the tensile modulus in N/m from [Formula \(B.1\)](#):

$$M = \frac{1\,000 \times l \times (f_2 - f_1)}{w \times (e_2 - e_1)} \quad (\text{B.1})$$

where

M is the tensile modulus, in newtons per metre (N/m);

l is the gauge length in millimetres (50 mm or 100 mm);

f_1 is the force corresponding to 2,0 N/m or the closest to 2,0 N/m;

f_2 is the force corresponding to 22,0 N/m or the closest to 22,0 N/m;

w is the initial width, in millimetres, of the test piece (50 mm);

e_1 is the elongation distance from l , corresponding to 2,0 N/m or the closest to 2,0 N/m, in millimetres;