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**Tissue paper and tissue products —**  
**Part 12:**  
**Determination of tensile strength of**  
**perforated lines and calculation of**  
**perforation efficiency**

*Papier tissue et produits tissue —*

*Partie 12: Détermination de la résistance à la rupture par traction  
des lignes de prédécoupe et calcul de l'efficacité des perforations*

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CH-1214 Vernier, Geneva  
Phone: +41 22 749 01 11  
Email: [copyright@iso.org](mailto:copyright@iso.org)  
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# Contents

|                                                                                  | Page      |
|----------------------------------------------------------------------------------|-----------|
| Foreword.....                                                                    | iv        |
| Introduction.....                                                                | v         |
| <b>1 Scope.....</b>                                                              | <b>1</b>  |
| <b>2 Normative references.....</b>                                               | <b>1</b>  |
| <b>3 Terms and definitions.....</b>                                              | <b>1</b>  |
| <b>4 Principle.....</b>                                                          | <b>2</b>  |
| <b>5 Apparatus.....</b>                                                          | <b>2</b>  |
| <b>6 Sampling.....</b>                                                           | <b>3</b>  |
| <b>7 Conditioning.....</b>                                                       | <b>3</b>  |
| <b>8 Preparation of test pieces.....</b>                                         | <b>3</b>  |
| 8.1 Dimensions.....                                                              | 3         |
| 8.1.1 Non-perforated test pieces.....                                            | 3         |
| 8.1.2 Perforated test pieces.....                                                | 3         |
| 8.2 Number of test pieces.....                                                   | 3         |
| <b>9 Procedure.....</b>                                                          | <b>4</b>  |
| 9.1 General.....                                                                 | 4         |
| 9.2 Non-perforated test pieces.....                                              | 4         |
| 9.3 Perforated test pieces.....                                                  | 4         |
| <b>10 Calculation.....</b>                                                       | <b>6</b>  |
| 10.1 Tensile strength.....                                                       | 6         |
| 10.2 Calculation of perforation efficiency.....                                  | 6         |
| <b>11 Test report.....</b>                                                       | <b>6</b>  |
| <b>Annex A (informative) Influence of a pre-cut in the perforation line.....</b> | <b>8</b>  |
| <b>Annex B (informative) Influence of paper ageing.....</b>                      | <b>11</b> |
| <b>Annex C (informative) Precision.....</b>                                      | <b>13</b> |
| <b>Bibliography.....</b>                                                         | <b>15</b> |

## 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 document 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](http://www.iso.org/directives)).

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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 second edition cancels and replaces the first edition (ISO 12625-12:2010), which has been technically revised.

The main changes are as follows:

- the expression of the rate of elongation has been changed from a value expressed in mm/min into a value expressed in the rate of elongation of the initial test span length in %/min, independently from the test piece length (see [5.1](#));
- precisions have been added in case of decrease of the distance between the clamping lines (see [5.2](#)).

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](http://www.iso.org/members.html).

## Introduction

Tissue papers such as toilet paper and kitchen towel are often pre-cut. They are used after separation of two consecutive sheets.

It is important to know the efficiency of the pre-cut perforations.

The perforation strength should be enough to ensure the product cohesion, but not too high, so that sheets can be easily separated.

The method described in this document uses forces applied perpendicular to the perforation lines.

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# Tissue paper and tissue products —

## Part 12:

# Determination of tensile strength of perforated lines and calculation of perforation efficiency

## 1 Scope

This document specifies a test method for the determination of the tensile strength of perforated lines of tissue paper. It uses a tensile-testing apparatus operating with a constant rate of elongation.

This method is only used for measuring machine-direction tensile strength, that is for cross-direction perforations on tissue paper.

The calculation of perforation efficiency is also specified in this document.

## 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 12625-4, *Tissue paper and tissue products — Part 4: Determination of tensile strength, stretch at maximum force and tensile energy absorption*

## 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

*S*

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

### 3.2 perforation efficiency

$E_p$   
difference between the *tensile strengths* (3.1) of non-perforated and perforated material from the same sample divided by the tensile strength of non-perforated material

Note 1 to entry: The perforation efficiency is expressed as a percentage.

Note 2 to entry: The higher the perforation efficiency, the easier the sheet separation.

## 4 Principle

A perforated test piece of tissue paper or tissue product, of given dimensions, is stretched to break in the machine direction 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 is calculated.

In order to determine the perforation efficiency, measurements are performed both on perforated and non-perforated sections of the tissue product.

Precision data are available in [Annex C](#). Information on the influence of a pre-cut and ageing is available in [Annexes A](#) and [B](#).

## 5 Apparatus

### 5.1 Tensile-testing apparatus.

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 rate of elongation of  $(50 \pm 2) \%$  of the initial test span length per minute, i.e.  $(50 \pm 2)$  mm/min for a 100 mm test span length and  $(25 \pm 1)$  mm/min for a 50 mm test span length, and of recording the tensile force as a function of elongation on a strip chart recorder or any equivalent device. The force-measuring system (normally a load cell) shall measure loads with an accuracy of  $\pm 1 \%$  of the reading or  $\pm 0,025$  N, whichever is greater, and shall conform with ISO 7500-1.

### 5.2 Tensile-tester 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  $1^\circ$ . 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  $(100 \pm 1)$  mm. In cases where the distance between perforations on the finished products is less than 150 mm (as mentioned in [8.1.2](#)), a test span length of  $(50 \pm 1)$  mm shall be used. If distance between perforation is less than 75 mm, then each perforated test piece shall be  $(50 \pm 0,5)$  mm in width and the maximum available length in the machine direction may be used.

This and other deviations from the specified procedure shall be recorded in the test report.

### 5.3 Cutting device.

The cutting device shall meet the requirements of ISO 12625-4 and shall produce test pieces  $(50,0 \pm 0,5)$  mm wide, with undamaged, straight, smooth and parallel edges.

## 6 Sampling

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 the specimens taken are representative of the sample received.

## 7 Conditioning

Condition the samples in accordance with ISO 187, unless otherwise agreed between the parties concerned, and keep them in the standard atmosphere throughout the test.

## 8 Preparation of test pieces

### 8.1 Dimensions

#### 8.1.1 Non-perforated test pieces

If the distance between perforations is 150 mm or longer, then non-perforated test pieces shall be  $(50 \pm 0,5)$  mm in width and at least 150 mm in length in the machine direction, excluding perforations and defects.

If the distance between perforations is less than 150 mm, then non-perforated test pieces shall be  $(50 \pm 0,5)$  mm in width and at least 75 mm in length in the machine direction, excluding perforations and defects.

#### 8.1.2 Perforated test pieces

Perforated test pieces shall be cut from different sheets than those used for tests outside the perforated lines (non-perforated test pieces). If the distance between perforations is 150 mm or longer, then each perforated test piece shall be  $(50 \pm 0,5)$  mm in width and at least 150 mm in length in the machine direction, excluding defects, with its perforation located approximately equal distance from each end.

If the distance between perforations is less than 150 mm, then each perforated test piece shall be  $(50 \pm 0,5)$  mm in width and at least 75 mm in length in the machine direction, excluding defects, with its perforation located approximately equal distance from each end.

If the distance between perforations is less than 75 mm, then each perforated test piece shall be  $(50 \pm 0,5)$  mm in width and the maximum available length in the machine direction may be used.

Each of the 10 perforated test pieces shall be cut from different sheets (in the machine direction).

### 8.2 Number of test pieces

Cut sufficient test pieces to ensure 10 valid results on non-perforated papers and 10 valid results on perforated papers for each sample of tissue product.

Care should be taken not to handle the test pieces in any way that can decrease the perforation tensile strength (by stretching or breaking any of the perforations).

## 9 Procedure

### 9.1 General

Ensure that the tensile-testing apparatus is calibrated. Check that the force reading is zero when there is no load on the sample.

For test pieces that are 150 mm or longer, set the distance between the clamping lines to  $(100 \pm 1)$  mm. For test pieces that are less than 150 mm in length, set the distance between the clamping lines to  $(50 \pm 1)$  mm.

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.

Use the same distance between clamping lines and elongation speed for both perforated and non-perforated test pieces for a given sample.

Carry out all testing in the same standard atmosphere as used for conditioning.

### 9.2 Non-perforated test pieces

Place the non-perforated test piece in the clamps so that any observable slack is eliminated but the test piece is not placed under any significant strain (see [Figure 1](#)). The test piece shall not be clamped with a tension greater than 5 N/m.

Minimize touching the test area of the test piece between the clamps with the fingers. Align and tightly clamp the test piece and carry out the test.

**NOTE** Any deviation from the vertical line would induce a decrease in the measured tensile strength of the non-perforated test pieces, and thus result in a lower calculated perforation efficiency than the true one.

Continue the test until the test piece ruptures and record the maximum tensile force.

Repeat the described procedure until 10 valid results are obtained.

Record all the readings, except those for test pieces that break within 5 mm of the clamping line.

### 9.3 Perforated test pieces

Place the perforated test piece in the clamps so that any observable slack is eliminated but the test piece is not placed under any significant strain. The test piece shall not be clamped with a tension greater than 5 N/m. The perforation line shall be approximately equal distance between the lower and upper clamps (see [Figure 2](#)).

Minimize touching the test area of the test piece between the clamps with the fingers. Align and tightly clamp the test piece and carry out the test.

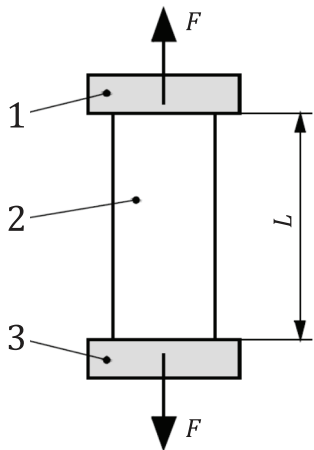
**NOTE** Any deviation from the vertical line would induce a decrease in the measured tensile strength of the perforated test pieces, and thus result in a greater calculated perforation efficiency than the true one.

Continue the test until the test piece ruptures. A valid test occurs when the test piece breaks at the perforation line. Record the maximum tensile force in newtons (N) for each valid test.

Repeat the described procedure until 10 valid results are obtained.

Record all the valid test readings, except those for test pieces that did not break at the perforation line. If more than one test piece breaks outside the perforation line, record the total number of tests that did not break at the perforation line and divide by the total number of perforation tests to yield a calculated result of “% of test pieces that broke outside of the perforation line” for that sample, and include in the test report, see [Clause 11](#) list item e).

Dimensions in millimetres



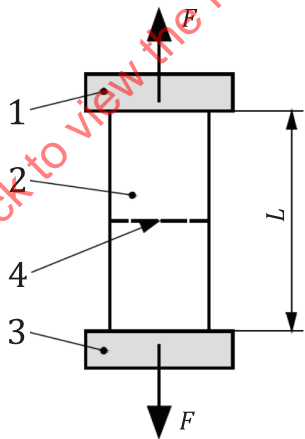
**Key**

- 1 upper clamp
- 2 test piece
- 3 lower clamp

$F$  maximum tensile force  
 $L$   $(100 \pm 1)$  mm

**Figure 1 — Non-perforated test piece**

Dimensions in millimetres



**Key**

- 1 upper clamp
- 2 test piece
- 3 lower clamp
- 4 perforation line

$F$  maximum tensile force  
 $L$   $(100 \pm 1)$  mm

**Figure 2 — Perforated test piece**

## 10 Calculation

### 10.1 Tensile strength

Calculate the mean maximum tensile force,  $\bar{F}$ , in newtons, from all single valid maximum tensile force,  $F$ , test results, considering perforated and non-perforated test pieces separately.

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 mean tensile strength, in newtons per metre;

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

$w$  is the sample width: 50 mm.

Report the tensile strength, in newtons per metre, to three significant figures for both non-perforated and perforated test pieces.

### 10.2 Calculation of perforation efficiency

Calculate the perforation efficiency,  $E_p$  from [Formula \(2\)](#):

$$E_p = 100 \times \left[ 1 - \left( \frac{\bar{S}_p}{\bar{S}_{np}} \right) \right] \quad (2)$$

where

$E_p$  is the perforation efficiency, expressed as a percentage;

$\bar{S}_p$  is the mean tensile strength of perforated test pieces, in newtons per metre;

$\bar{S}_{np}$  is the mean tensile strength of non-perforated test pieces, in newtons per metre.

Report the perforation efficiency, as a percentage, to three significant figures.

## 11 Test report

The test report shall include the following information:

- a reference to this document, i.e. ISO 12625-12:2023;
- date and place of testing;
- description and identification of the sample (such as the product category, number of plies);
- test span length: i.e. 100 mm or 50 mm;
- number of single values used to calculate the tensile strength and the perforation efficiency, and, if applicable, the BOP (%) i.e. “% of test pieces that broke outside of the perforation line” (as described in [9.3](#)); if the BOP is omitted, it shall be assumed that the BOP % was zero for that sample;

- f) tensile strength in the machine direction for both non-perforated and perforated test pieces, in newtons per metre, rounded to:
  - 1) 0,1 N/m for loads up to 100 N/m;
  - 2) 1 N/m for loads over 100 N/m;
- g) standard deviation or coefficient of variation of the tensile strengths;
- h) perforation efficiency, in %, to three significant figures;
- i) any departure from this document and any other circumstances that can have affected the test results.

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## Annex A (informative)

### Influence of a pre-cut in the perforation line

As the number of tie bars can vary from one test piece to another and in order to always have the same starting point, it was planned during the interlaboratory test to include “non-pre-cut test pieces” where tests are performed on the complete perforation line and “pre-cut test pieces” with a 10 mm pre-cut. The influence of the pre-cutting has thus been studied.

The 10 mm pre-cut was made on one edge by each participating laboratory before testing in accordance with TAPPI T402 sp-08:2013<sup>[2]</sup>. This parameter was also considered as a variable.

As can be concluded from [Table A.1](#) and [Figures A.1](#) and [A.2](#), measurements of the perforation strength with pre-cut test pieces are not recommended.

As the efficiency is calculated from the mean of the results, reproducibility values could not be derived from the results obtained.

**Table A.1 — Results of the interlaboratory test on pre-cut test pieces**

| Type of paper,<br>sample code |     | Perforation efficiency on<br>pre-cut test pieces |                                               |
|-------------------------------|-----|--------------------------------------------------|-----------------------------------------------|
|                               |     | Average<br>perforation<br>efficiency             | Standard deviation<br>between<br>laboratories |
|                               |     | %                                                | %                                             |
| Toilet paper 4-ply            | TP1 | 79,4                                             | 1,61                                          |
| Toilet paper 5-ply            | TP2 | 86,4                                             | 1,50                                          |
| Toilet paper 2-ply            | TP3 | 80,5                                             | 1,42                                          |
| Toilet paper 3-ply            | TP4 | 77,7                                             | 2,08                                          |
| Toilet paper 2-ply            | TP5 | 76,9                                             | 1,09                                          |
| Industrial wipes 1-ply        | W1  | 79,5                                             | 1,32                                          |
| Industrial wipes              | W2  | 72,1                                             | 3,80                                          |
| Toilet paper 4-ply            | TP6 | 76,9                                             | 2,00                                          |
| Toilet paper 3-ply            | TP7 | 77,3                                             | 1,62                                          |
| Paper towel 3-ply             | PT1 | 88,2                                             | 1,28                                          |
| Paper towel 4-ply             | PT2 | 88,2                                             | 0,70                                          |
| Paper towels                  | PT3 | 77,7                                             | 3,37                                          |

On perforated test pieces, the tensile strength can vary depending on the number of tie bars in the 50 mm perforation line, but it is compensated by the quantity of test pieces used as shown from the standard deviation in [Table A.1](#).

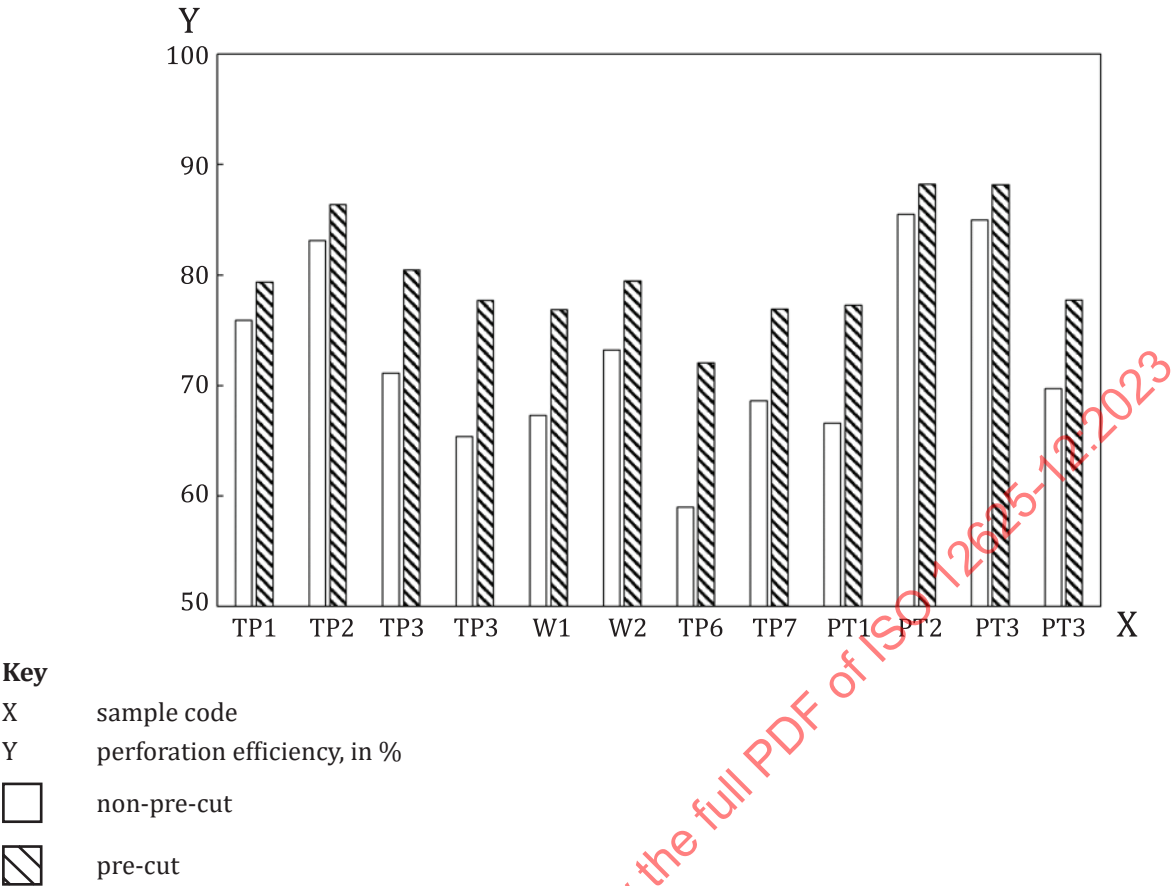


Figure A.1 — Average perforation efficiency, %

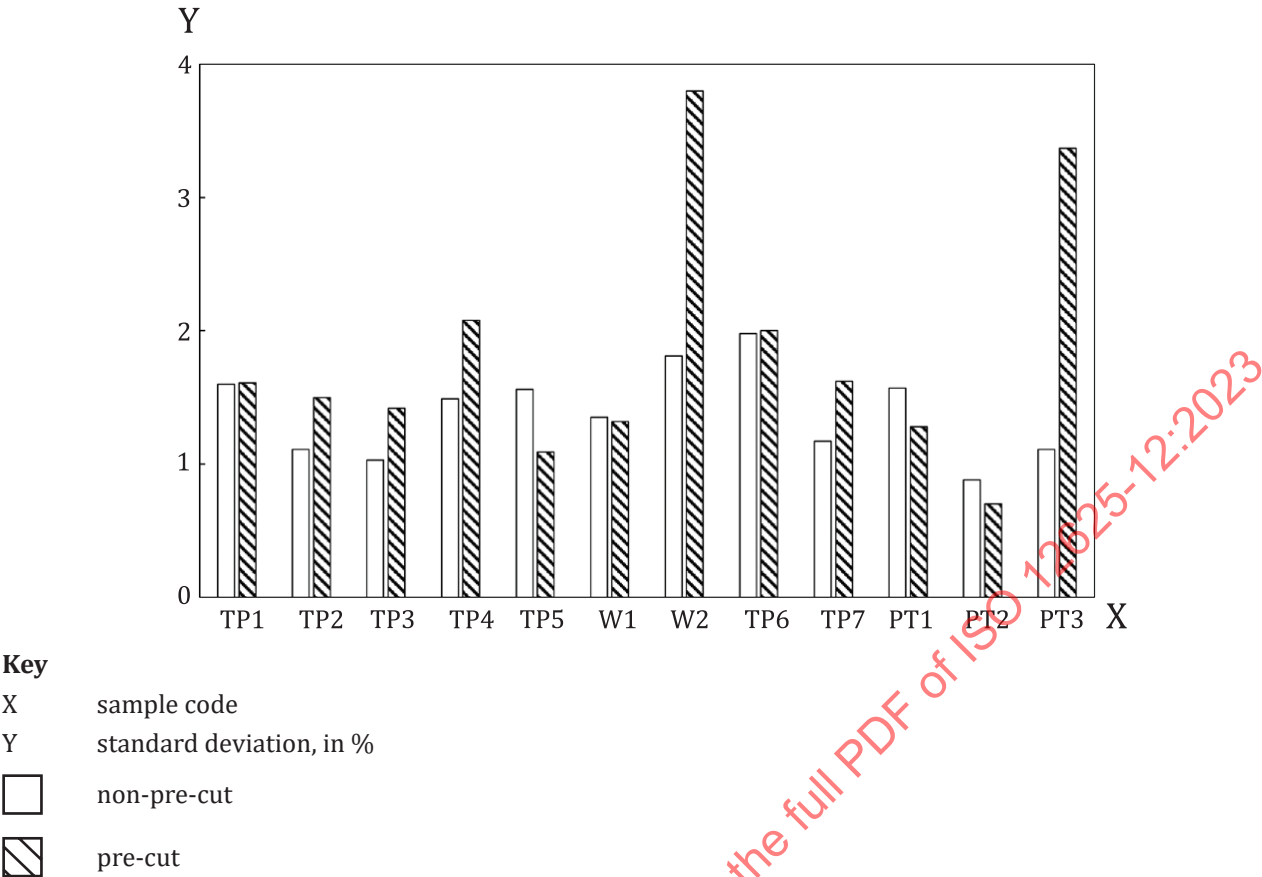


Figure A.2 — Average perforation efficiency and the standard deviation between laboratories, %

## Annex B (informative)

### Influence of paper ageing

The influence of paper ageing was studied by performing tests on four tissue products (two toilet papers and two paper towels) sampled on the converting line. Seven different laboratories were involved in this study.

The following settings were considered:

- a) with 23 °C and 50 % relative humidity conditioning after reception by the participating laboratories in accordance with ISO 287:2017<sup>[1]</sup>;
- b) with 80 °C ageing during 30 min;
- c) with 105 °C ageing during 15 min;
- d) after one to six weeks, storage at 23 °C and 50 % relative humidity.

The results are reported in [Figure B.1](#) and lead to the conclusion that ageing of papers may be performed before testing the perforation efficiency because

- the two methods of accelerated ageing produce the same results, and
- a slight decrease in perforation efficiency with ageing can be observed, but it is not significant due to the standard deviation of the measurements.