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**Paper and board — Determination  
of roughness/smoothness (air leak  
methods) —**

**Part 5:  
Oken method**

*Papier et carton — Détermination de la rugosité/du lissé (méthodes  
du débit d'air) —*

*Partie 5: Méthode Oken*

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# Contents

	Page
Foreword .....	iv
<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>1</b>
<b>5 Apparatus</b> .....	<b>2</b>
5.1 Oken Smoothness apparatus (two types) .....	2
5.2 Water column type .....	2
5.3 Electronic sensor type .....	6
<b>6 Sampling</b> .....	<b>7</b>
<b>7 Conditioning</b> .....	<b>7</b>
<b>8 Preparation of test pieces</b> .....	<b>7</b>
<b>9 Calibration</b> .....	<b>7</b>
<b>10 Procedure</b> .....	<b>8</b>
<b>11 Expression of results</b> .....	<b>8</b>
11.1 Reporting the results .....	8
11.2 Standard deviation and coefficient of variation .....	8
<b>12 Test report</b> .....	<b>8</b>
<b>Annex A (informative) Measurement principle of Oken smoothness</b> .....	<b>9</b>
<b>Annex B (informative) Precision data</b> .....	<b>11</b>
<b>Bibliography</b> .....	<b>13</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 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](http://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](http://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](http://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*.

A list of all the parts in the ISO 8791 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).

# Paper and board — Determination of roughness/ smoothness (air leak methods) —

## Part 5: Oken method

### 1 Scope

This document specifies the Oken method for determining the smoothness of paper and board using an apparatus which complies with the Oken method, as defined in this part of ISO 8791. It is applicable to all printing papers and boards.

### 2 Normative references

The following referenced documents are indispensable for the application 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 48, *Rubber, vulcanized or thermoplastic — Determination of hardness (hardness between 10 IRDH and 100 IRDH)*

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 4662, *Rubber, vulcanized or thermoplastic — Determination of rebound resilience*

### 3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

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

#### 3.1

##### **oken smoothness**

time required for a specific volume of air to leak from the gap between the flat measuring lands of the Oken tester and the surface of a test piece under specified conditions

Note 1 to entry: Oken smoothness is expressed in seconds per 100 ml (s/100 ml).

### 4 Principle

A test piece is placed between a rubber plate and measuring lands.

The air pressure on the inlet side of a narrow capillary of controlled dimensions is maintained at a constant value above atmospheric pressure. The air passes through the capillary and then leaks between the surface of the test piece and the measuring lands. The air pressure between the outlet side of the capillary and a test piece depends on the rate of flow of air between the measuring lands

and the surface of the test piece. It is measured and converted to Oken smoothness. For further details regarding the measurement principle, see [Annex A](#).

For details regarding the test method precision, see [Annex B](#).

## 5 Apparatus

### 5.1 Oken Smoothness apparatus (two types)

Use either the water column type described in [5.2](#) or the electronic sensor type described in [5.3](#).

### 5.2 Water column type

**5.2.1 The water column type**, see [Figure 1](#), consists of an air compressor, filter, pressure regulator, water column regulator, capillary, water column manometer, measuring head, and scale plate.

**5.2.1.1 The measuring head**, see [Figure 2](#), consists of a loading weight, rubber plate, and sensing head.

**5.2.1.1.1 The loading weight and rubber plate**, the loading weight has a circular even surface of not less than 48 mm in diameter and a mass that clamps the test piece at a pressure of  $(98,1 \pm 1,0)$  kPa. The rubber plate has a diameter of not less than 48 mm, a thickness of  $(4 \pm 0,2)$  mm, a hardness of  $(50 \pm 5)$  IRHD in accordance with ISO 48, and a rebound resilience of not less than 62 % in accordance with ISO 4662.

**5.2.1.1.2 The sensing head**, has 10 concentric measuring lands and nine grooves. The outermost measuring land has a width of  $(0,5 \pm 0,03)$  mm, and an outside diameter of  $(46 \pm 0,03)$  mm. The width of the other nine measuring lands is  $(1 \pm 0,03)$  mm. The inside diameter of innermost measuring land is  $(9 \pm 0,03)$  mm. All grooves have a width of  $(1 \pm 0,03)$  mm, and a depth of 0,5 mm to 1,2 mm. Five grooves have air outlet holes and four grooves have air inlet holes arranged alternately. A tube connects the sensing head to the pressure measuring chamber.

**5.2.1.2 The air compressor and regulator**, supply compressed and filtered air. The air is controlled to approximately 10 kPa by the air regulator.

**5.2.1.3 The water column regulator and capillary**, provide a constant pressure. The water column regulator consists of a water tank with an internal diameter of approximately 100 mm and a height of approximately 700 mm, and a constant pressure chamber with a side tube. The open end of the side tube is  $(500 \pm 0,5)$  mm below the water surface.

The air at approximately 10 kPa introduced into the constant pressure chamber is controlled to  $(4,90 \pm 0,01)$  kPa ( $500 \pm 1$  mmH<sub>2</sub>O) and transferred to the pressure measuring chamber through the capillary.

The capillary consists of a narrow tube made of stainless material with an inner diameter of approximately 0,3 mm and a length of approximately 50 mm. The capillary length shall be strictly adjusted so that constant K in [Formula \(1\)](#), see [5.2.1.4](#), is 100.

**5.2.1.4 The water column manometer and scale plate**, comprise the pressure measurement system. The water column manometer is connected to the water tank at a depth greater than 500 mm below the surface of the water in the water tank by a pipe with a diameter large enough (with a minimum of 3 mm) to allow water to transfer smoothly between the manometer and water tank. The manometer is connected to the sensing head and capillary. The scale plate for reading smoothness is marked in the units of seconds per 100 ml. The scale of smoothness is determined by [Formula \(1\)](#):

$$T = \frac{K * P}{P_c - P} \quad (1)$$

$T$  is the Oken smoothness;

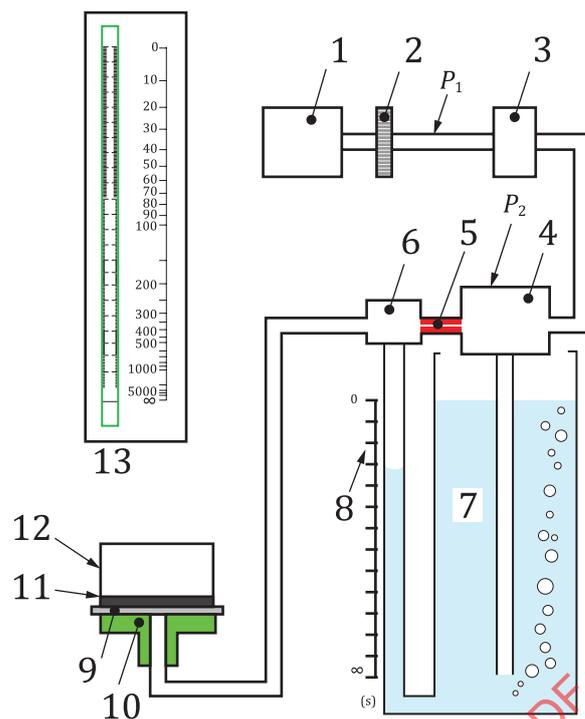
$K$  is the constant;

$P$  is the pressure at the pressure measuring chamber;

$P_c$  is the pressure at the constant pressure chamber.

The scale shall cover the range 0 s to infinity ( $\infty$  s) with scale readings of 0 s/100 ml at a pressure drop of zero (0 mmH<sub>2</sub>O), 100 s/100 ml at the midpoint 250 mm below the surface level in the tank and ( $\infty$ ) s/100 ml at a pressure of 4,90 kPa (500 mmH<sub>2</sub>O).

NOTE High or low air resistance type of Oken tester with different capillary dimensions or measurement areas are available for shorter measurement time or higher precision. However, these types of Oken tester are out of the scope of this part of ISO 8791.

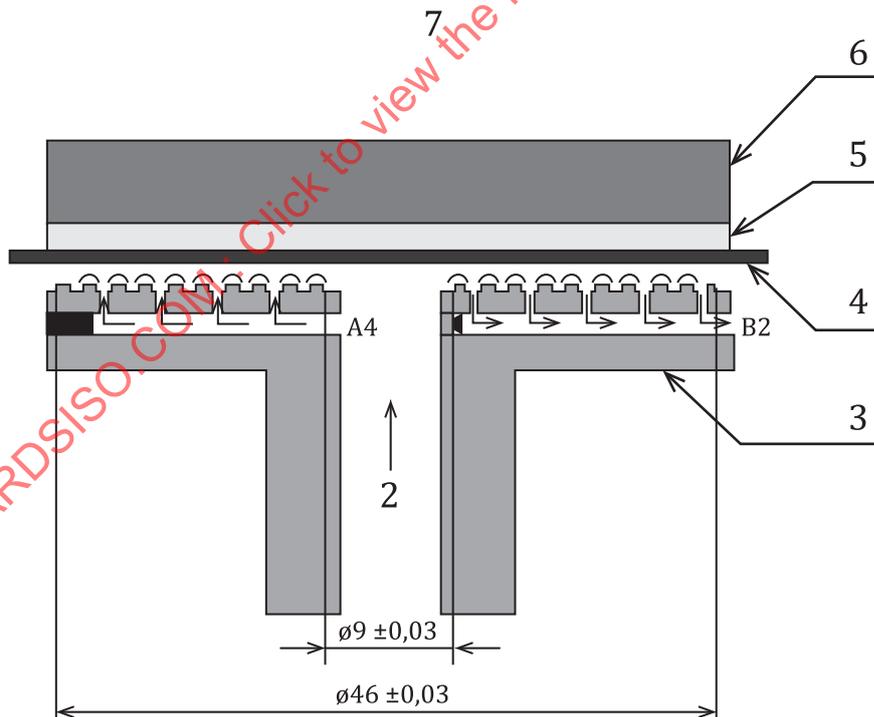
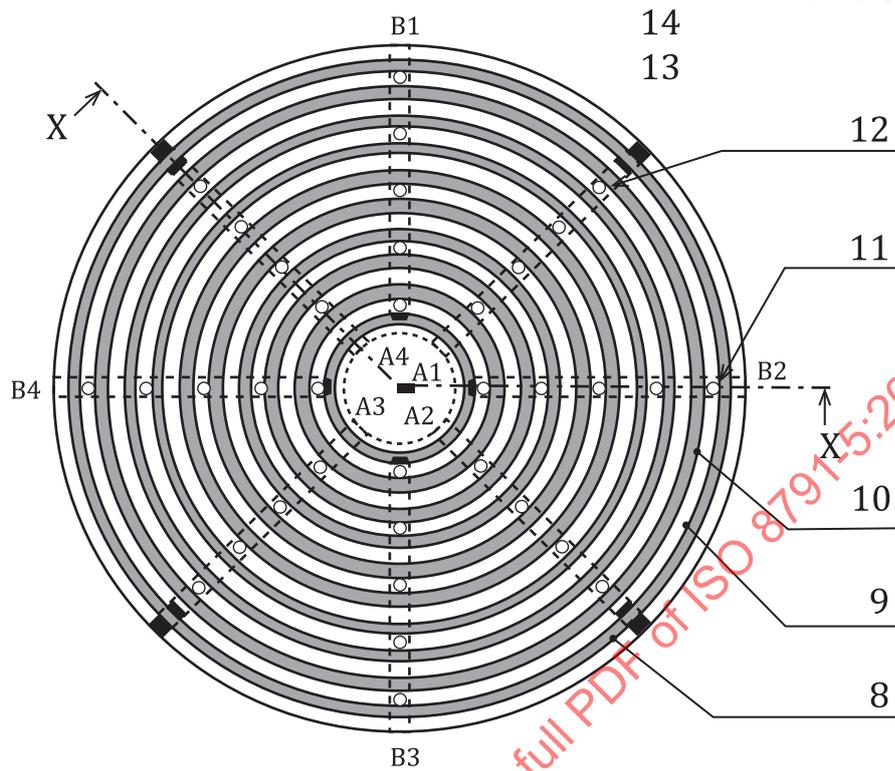


**Key**

- |   |  |       |                        |
|---|--|-------|------------------------|
| 1 | air compressor   | 9     | test piece             |
| 2 | filter   | 10    | sensing head           |
| 3 | pressure regulator   | 11    | rubber plate           |
| 4 | water column regulator / constant pressure chamber         | 12    | loading weight         |
| 5 | capillary  | 13    | example of scale plate |
| 6 | water column regulator / pressure measuring chamber sensor | $P_1$ | approximately 10 kPa   |
| 7 | water tank   | $P_2$ | 4,90 kPa               |
| 8 | scale plate  |       |                        |

**Figure 1 — Diagram of water column type Oken tester**

Dimensions in millimetres



1

**Key**

- |   |                      |    |                        |
|---|----------------------|----|------------------------|
| 1 | sectional view X-X   | 8  | outermost contact ring |
| 2 | air                  | 9  | groove                 |
| 3 | specified ring shape | 10 | contact ring           |
| 4 | test piece           | 11 | air outlet hole        |

5	rubber plate	12	air inlet hole
6	loading weight	13	A1-A4 Passage connected air supply
7	sensing head	14	B1-B4 Passage leading to atmosphere

Figure 2 — Diagram of measuring head

### 5.3 Electronic sensor type

**5.3.1 The electronic sensor type**, see [Figure 3](#), consists of air compressor, filter, pressure regulator, constant pressure chamber, capillary, pressure sensor, sensor amplifier, measuring head, and digital display.

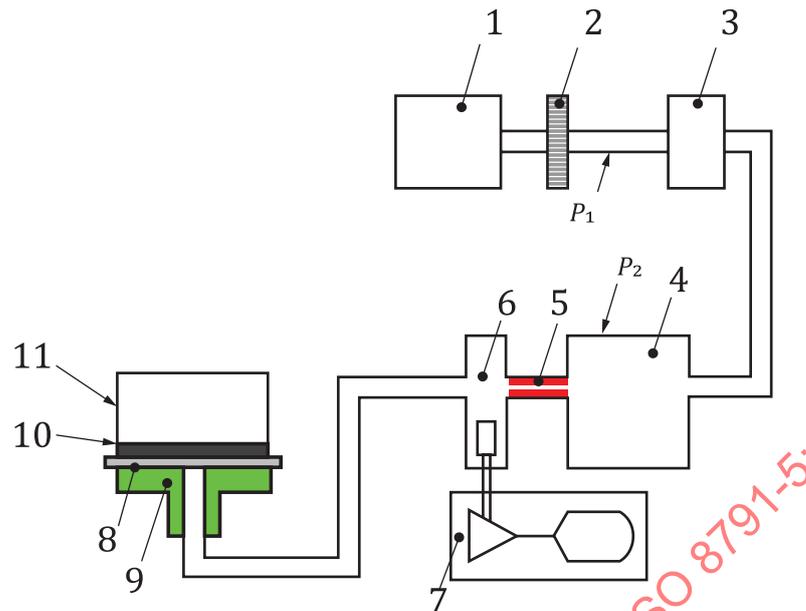
**5.3.1.1 The measuring head**, consists of a loading weight, rubber plate, and sensing head. The structure is the same as the measuring head ([5.2.1.1](#)) for the water column type.

**5.3.1.2 The air compressor and regulator**, supply compressed and filtered air. The air is controlled to approximately 10 kPa by the air regulator.

**5.3.1.3 The constant pressure chamber and capillary**, are the same as those for the water column type ([5.2.1.3](#)). Air at the pressure controlled by the electronic pressure regulator is transferred to the measuring head through the capillary

**5.3.1.4 The pressure measuring chamber, electronic pressure sensor, amplifier, and digital display**, comprise the electronic sensing system. The digital display shows the pressure of the pressure measuring chamber and Oken smoothness calculated from the pressure, as units of kilopascal or mmH<sub>2</sub>O and seconds per 100 ml, respectively.

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**Key**

1	air compressor	8	test piece
2	filter	9	sensing head
3	electronic pressure regulator	10	rubber plate
4	constant pressure chamber	11	loading weight
5	capillary	$P_1$	approximately 10 kPa
6	pressure measuring chamber / electronic pressure sensor	$P_2$	4,90 kPa
7	amplifier / digital display		

**Figure 3 — Diagram of electronic sensor type Oken tester**

## 6 Sampling

If the mean quality of a lot is to be determined, sampling shall be in accordance with ISO 186. If the tests are made on another type of sample, make sure that the test pieces taken are representative of the sample received.

## 7 Conditioning

Condition the sample in accordance with ISO 187.

## 8 Preparation of test pieces

Prepare the test pieces in the same atmospheric conditions as those used to condition the sample. Cut no less than 10 test pieces for each side to be tested. An adequate test piece size is 100 mm x 100 mm, and their surfaces shall be identified in some convenient way (e.g. side one and side two).

The test area shall be free from folds, wrinkles, holes, watermarks or defects not inherent in the sample. Do not handle the part of the test piece which will become part of the test area.

## 9 Calibration

Calibrate the apparatus according to instructions of the manufacturer.

Check the pressure displayed by the water column manometer or the digitally displayed pressure without placing anything on the measuring head. The reading shall be  $0 \pm 0,01$  kPa or  $0 \pm 1$  mmH<sub>2</sub>O, respectively. For the water column type, if the water column manometer does not read zero, adjust the water column manometer by adjusting the volume of water in the water tank, whereas the electronic regulator automatically calibrates the pressure.

The apparatus shall be tested for air leakage. Clean the rubber plate and sensing head. Place the rubber plate directly on the sensing head and the loading weight on the rubber plate. The reading should exceed 4,88 kPa or 498 mmH<sub>2</sub>O. If the pressure is lower than that specified pressure, leakage is the likely cause. Check the sensing head, rubber plate and tubes for defects and repair or replace as necessary.

## 10 Procedure

Carry out the test in the same atmospheric conditions as those used to condition the samples.

Tests shall be performed according to the instructions of the manufacturer. Test a minimum of 10 test pieces.

Clamp a test piece between the sensing head and rubber plate with the surface to be measured against the sensing head. Read the Oken smoothness value on the scale plate, for the water column type, or digital display, for the electronic type instrument, once the reading becomes stable.

If required, determine the smoothness of the other side of the sample with 10 more test pieces. Repeat the procedure until 10 valid measurements are obtained for each side.

## 11 Expression of results

### 11.1 Reporting the results

Calculate the mean of the smoothness readings, to two significant figures for each side tested.

### 11.2 Standard deviation and coefficient of variation

If the standard deviation or coefficient of variation is required, calculate the standard deviation or coefficient of variation of smoothness, to two significant figures for each side tested.

## 12 Test report

The test report shall include the following information:

- a) reference to this document, e.g. ISO 8791-5:2020;
- b) date and place of testing;
- c) all the information necessary for complete identification of the sample;
- d) the conditioning atmosphere used;
- e) the number of test pieces tested;
- f) the type of Oken tester used;
- g) the mean smoothness for each side, as specified in [11.1](#);
- h) if required, the standard deviation or coefficient of variation for each side, as specified in [11.2](#);
- i) any deviation from the specified procedure which may have affected the result.

## Annex A (informative)

### Measurement principle of Oken smoothness

The principle for the calculation of Oken smoothness from measured pressure to graduate the scale plate or display smoothness digitally is described below<sup>[6]</sup>.

#### A.1 Definitions of Oken smoothness

The Oken tester is designed to measure Oken smoothness  $T$ , assuming that air behaves as a laminar flow. Oken smoothness  $T$  is time in seconds required for the volume  $V_k = 100$  ml of air, measured at room pressure, under the pressure difference  $P_k = 2,36$  kPa to pass through the gap between the flat measuring lands and surface of a test piece.

#### A.2 Adjustment of the capillary length

The air flow rate  $Q$  (ml/s) through the capillary from the constant pressure chamber at the pressure ( $P_c$ ) to the pressure measurement chamber at a pressure ( $P$ ) is equal to the air flow rate through the gap between the flat measuring lands and surface of a test piece, expressed as  $Q$  (ml/s) as well, when the relevant air volume is measured at room pressure (see [Figures 1](#) and [2](#)). A rate of laminar air flow would be proportional to the pressure difference, and [Formulae \(A.1\)](#) and [\(A.2\)](#) apply.

$$Q = K_c (P_c - P) \quad (\text{A.1})$$

$$Q = K_s * P \quad (\text{A.2})$$

where

$K_c$  is the coefficient of air flow ability [ml/(s kPa)] of the capillary and the gap between the flat measuring lands and surface of a test piece;

$K_s$  is the coefficient of air flow ability [ml/(s kPa)] of the gap between the flat measuring lands and surface of a test piece and assumed to be specific to the test piece, and not dependent on the pressure  $P$ ;

For Oken smoothness  $T$  and air flow rate ( $Q_k$ ) (ml/s) in the specified condition — 2,36 kPa and 100 ml,

$$Q_k = K_s * P_k \quad (\text{A.3})$$

$$T = \frac{V_k}{Q_k} = \frac{100}{K_s P_k} \quad (\text{A.4})$$

When [Formula \(A.1\)](#) and subsequently [Formula \(A.2\)](#) are substituted into [Formula \(A.4\)](#), [Formula \(A.5\)](#) is obtained.

$$T = \frac{100P}{Q * P_k} = \frac{100P}{K_c P_k (P_c - P)} = \frac{100}{K_c P_k} * \frac{P}{(P_c - P)} = K * \frac{P}{(P_c - P)} \quad (\text{A.5})$$

where

$$K = \frac{100}{K_c P_k} \quad (\text{A.6})$$

For the Oken tester, the scale is graduated so that  $T = 100$  at  $P = 0,5P_c$ . In this condition, [Formula \(A.5\)](#) leads to  $K = 100$  and [Formula \(A.6\)](#) leads to

$$K_c = \frac{1}{P_k} \quad (\text{A.7})$$

This means that the capillary length shall be adjusted so that  $K_c$  satisfies [Formula \(A.7\)](#). In this case,  $P = 0$  and [Formula \(A.1\)](#) becomes  $Q = K_c P_c$ . By definition, time  $T_c$ (s), required for the passage of 100 ml of air is such that  $T_c = 100/Q = 100/K_c P_c$ , and when this relationship is substituted into [Formula \(A.7\)](#), [Formula \(A.8\)](#) is obtained.

$$T_c = 100 \frac{P_k}{P_c} \quad (\text{A.8})$$

Therefore, the capillary length should be adjusted so that  $T_c = 48,2$  s, which is calculated by substituting  $P_k = 2,36$  kPa and  $P_c = 4,90$  kPa into [Formula \(A.8\)](#).

### A.3 Graduation of Oken smoothness from the measured pressure

If the relationship between pressure difference  $P$  and Oken smoothness  $T$  is known, graduation on the scale plate or digital display of  $T$  will become possible. This relationship is  $T = T_k = K * P / (P_c - P)$ , as shown by [Formula \(A.5\)](#). If a pressure difference  $P$  is expressed in water surface depth in the water column manometer,  $P_c = 500$  mmH<sub>2</sub>O (equivalent to 4,90 kPa) and  $K = 100$ . Therefore, the conversion formula  $T = 100P / (500 - P)$  applies. For example, a water surface depth of 300 mmH<sub>2</sub>O corresponds to  $T = 100 \times 300 / (500 - 300) = 150$  (s).