

---

---

**Paints and varnishes - Overview of  
test methods on hardness and wear  
resistance of coatings**

iTeh Standards  
(<https://standards.iteh.ai>)  
Document Preview

[ISO/TR 21555:2019](https://standards.iteh.ai/catalog/standards/iso/5207ec18-cc02-4a6f-84ed-dac73f1e874d/iso-tr-21555-2019)

<https://standards.iteh.ai/catalog/standards/iso/5207ec18-cc02-4a6f-84ed-dac73f1e874d/iso-tr-21555-2019>



**iTeh Standards**  
**(<https://standards.iteh.ai>)**  
**Document Preview**

[ISO/TR 21555:2019](https://standards.iteh.ai/catalog/standards/iso/5207ec18-cc02-4a6f-84ed-dac73f1e874d/iso-tr-21555-2019)

<https://standards.iteh.ai/catalog/standards/iso/5207ec18-cc02-4a6f-84ed-dac73f1e874d/iso-tr-21555-2019>



**COPYRIGHT PROTECTED DOCUMENT**

© ISO 2019

All rights reserved. Unless otherwise specified, or required in the context of its implementation, no part of this publication may be reproduced or utilized otherwise in any form or by any means, electronic or mechanical, including photocopying, or posting on the internet or an intranet, without prior written permission. Permission can be requested from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office  
CP 401 • Ch. de Blandonnet 8  
CH-1214 Vernier, Geneva  
Phone: +41 22 749 01 11  
Fax: +41 22 749 09 47  
Email: [copyright@iso.org](mailto:copyright@iso.org)  
Website: [www.iso.org](http://www.iso.org)

Published in Switzerland

# Contents

Page

<b>Foreword</b>	<b>iv</b>
<b>Introduction</b>	<b>v</b>
<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 Hardness tests</b>	<b>2</b>
4.1 Indentation tests with resting indenter	2
4.1.1 Indentation test with Buchholz indenter	2
4.1.2 Indentation test with Knoop indenter	5
4.1.3 Indentation test with Pfund indenter	6
4.1.4 Indentation test with Vickers indenter	8
4.2 Indentation tests with oscillating indenter	10
4.2.1 Oscillation damping test with König pendulum	10
4.2.2 Oscillation damping test with Persoz pendulum	11
4.2.3 Oscillation damping test with rocker	13
<b>5 Wear resistance tests</b>	<b>14</b>
5.1 Single-scratch tests	14
5.1.1 Scratch test with pencils	14
5.1.2 Scratch test with ball stylus 1	17
5.1.3 Scratch test with ball stylus 2	20
5.1.4 Scratch test with conical stylus 3	22
5.1.5 Scratch test with conical stylus 4	25
5.1.6 Scratch test with conical stylus 5	28
5.1.7 Scratch test with conical stylus 6	31
5.1.8 Scratch test with disc-shaped stylus	33
5.1.9 Scratch test with U-shaped stylus	37
5.2 Multiple scratch tests	39
5.2.1 Multiple scratch test with locked abrasive wheel	39
5.2.2 Multiple scratch test with abrasive cylinder	40
5.2.3 Multiple scratch test with rotating abrasive wheels	42
5.2.4 Multiple scratch test with rotating brush	43
5.3 Dry abrasion tests	45
5.3.1 Abrasion test with locked abrasive wheel	45
5.3.2 Abrasion test with rotating abrasive wheels 1	47
5.3.3 Abrasion test with abrasive wheels 2	48
5.3.4 Abrasion test with rotating abrasive wheels 3	50
5.3.5 Abrasion test with rotating abrasive wheels 4	51
5.4 Wet abrasion tests	53
5.4.1 Scrub test with brush	53
5.4.2 Scrub test with non-woven web 1	55
5.4.3 Scrub test with non-woven web 2	57
5.5 Falling-sand tests	60
5.5.1 Falling-sand test with corundum granulate	60
5.5.2 Falling-sand test with quartz sand	62
<b>Annex A (informative) Overview on test methods on hardness and wear resistance of coatings</b>	<b>64</b>
<b>Bibliography</b>	<b>69</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 35, *Paints and varnishes*, Subcommittee SC 9, *General test methods for paints and varnishes*.

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).

<https://standards.iteh.ai/catalog/standards/iso/5207ec18-cc02-4a6f-84ed-dac73f1e874d/iso-tr-21555-2019>

## Introduction

The determination of the hardness and of the wear resistance is one of the most important preconditions for evaluating the resistance of coatings to mechanical stress.

The procedures and numerical data given in this document provide a rough overview; detailed information is found in the applicable standards.

For all of the methods for the evaluation of the hardness and of the wear resistance the visco-elastic properties have a wide influence on the test result. Consequently, the time between testing and evaluation are agreed and observed.

Mechanical properties of coatings depend on, among others, temperature and moisture content. Consequently, the tests should be carried out immediately after the conditioning phase.

The tests are preferably carried out in the climatic chamber.

Each method has its specific application. An unsuitable method may lead to false conclusions. All of the test methods require a certain expertise of the test person. For most of the test methods the test results depend on, among others, the film thickness of the coating to be tested.

**iTeh Standards**  
**(<https://standards.iteh.ai>)**  
**Document Preview**

[ISO/TR 21555:2019](https://standards.iteh.ai/catalog/standards/iso/5207ec18-cc02-4a6f-84ed-dac73f1e874d/iso-tr-21555-2019)

<https://standards.iteh.ai/catalog/standards/iso/5207ec18-cc02-4a6f-84ed-dac73f1e874d/iso-tr-21555-2019>



# Paints and varnishes - Overview of test methods on hardness and wear resistance of coatings

## 1 Scope

This document provides an overview for selecting the most suitable test method regarding the evaluation of the hardness and the wear resistance of coatings.

[Annex A](#) gives a summarized list of test methods for the evaluation of the hardness and of the wear resistance of coatings for different stresses.

Methods for testing cross-linking (wear test in connection with solvents) and abrasion tests with multiple impacts are not covered by 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 4618, *Paints and varnishes — Terms and definitions*

## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 4618 and the following 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

#### **hardness**

ability of a dry film or coat to resist indentation or penetration by a solid object

[SOURCE: ISO 4618:2014, 2.136]

### 3.2

#### **wear**

irreversible change of a coating which is caused by the mechanical impact of moved objects

### 3.3

#### **stylus**

scratching tool with specified geometry

[SOURCE: ISO 22557:2019, 3.1]

### 3.4

#### **scratch**

line-shaped damage of a coating which is caused by the impact of a loaded object being moved over the coating

### 3.5

#### **mar**

blemish on the surface of a coating, extending over a particular area of the coating and visible due to the difference in the light-reflection properties of the area affected compared with the light-reflection properties of adjacent areas

[SOURCE: ISO 4618:2014, 1.152]

### 3.6

#### **abrasion**

*wear* (3.2) which is caused by removal of coating material on a surface

### 3.7

#### **repeatability conditions**

conditions where independent test results are obtained with the same method on identical test items in the same laboratory by the same operator using the same equipment within short intervals of time

[SOURCE: ISO 5725-1:1994, 3.14]

### 3.8

#### **repeatability limit**

##### ***r***

the value less than or equal to which the absolute difference between two test results obtained under *repeatability conditions* (3.7) may be expected to be with a probability of 95 %

[SOURCE: ISO 5725-1:1994, 3.16]

### 3.9

#### **reproducibility conditions**

conditions where test results are obtained with the same method on identical test items in different laboratories with different operators using different equipment

[SOURCE: ISO 5725-1:1994, 3.18]

### 3.10

#### **reproducibility limit**

##### ***R***

the value less than or equal to which the absolute difference between two test results obtained under *reproducibility conditions* (3.8) may be expected to be with a probability of 95 %

[SOURCE: ISO 5725-1:1994, 3.20]

## 4 Hardness tests

### 4.1 Indentation tests with resting indenter

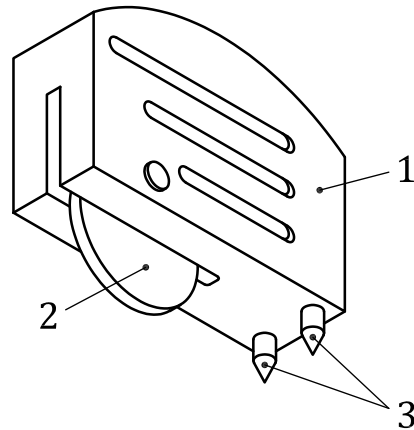
#### 4.1.1 Indentation test with Buchholz indenter

##### — Description

An indenter made of hardened steel, the shape and dimensions of which are specified in accordance with Buchholz, impacts the coating under a load (500 g, corresponding to 4,96 N) for 30 s and produces an indentation. After a resting time of 35 s the indentation length (mm) is determined under specified lighting conditions using a measuring microscope (×20 magnification).

[Figure 1](#) shows the test device and [Figure 2](#) shows the Buchholz indenter. [Figure 3](#) illustrates the microscopic measurement of the indentation.

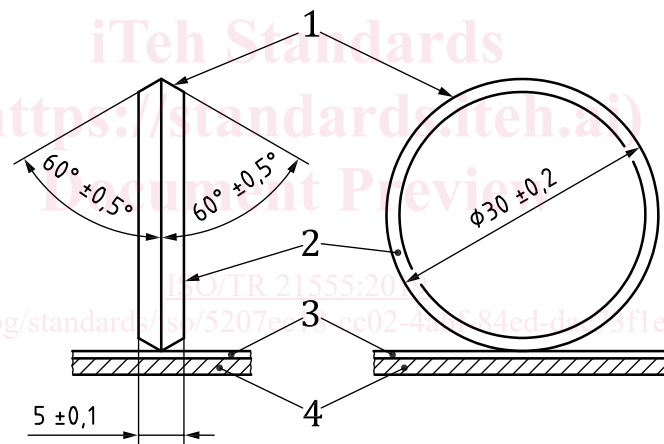


**Key**

- 1 steel block
- 2 indenter
- 3 tip

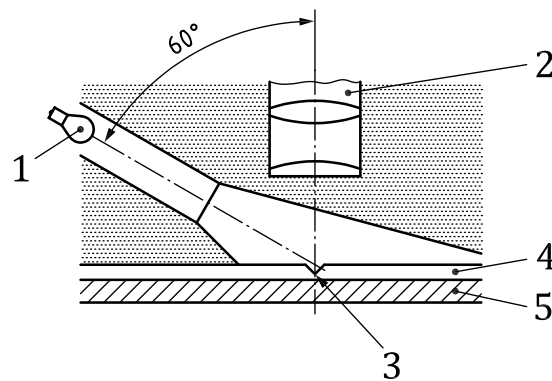
**Figure 1 — Indentation tester in accordance with Buchholz**

Dimensions in millimetres

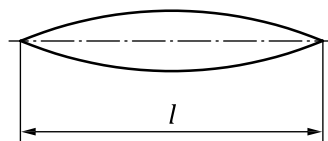
**Key**

- 1 indentation edge
- 2 indenter
- 3 coating
- 4 substrate

**Figure 2 — Buchholz indenter**



a) Arrangement of the light source and of the microscope



b) Image of the Buchholz indentation

**Key**

- 1 light source
- 2 microscope
- 3 indentation
- 4 coating
- 5 substrate
- $l$  indentation length

**Figure 3 — Measuring the Buchholz indentation**

— **Application**

The indentation test with Buchholz indenter is generally applicable.

— **Calibration**

A calibration method is not specified.

— **Procedure**

- Condition test panel (23 °C / 50 % relative humidity /  $\geq 16$  h)
- First, lower the tips of the test device onto the coating, and then carefully lower the indenter.
- Leave the loaded indenter on the coating for 30 s and remove in reverse order.
- 35 s after removal of the load determine the indentation length (mm) using a measuring microscope (see [Figure 3](#)).

— **Evaluation**

Test result is the indentation length (mm), as mean value of five determinations.

— **Precision**

The repeatability limit  $r$  is 0,23 mm.

The reproducibility limit  $R$  is 0,45 mm.

— **Reference**

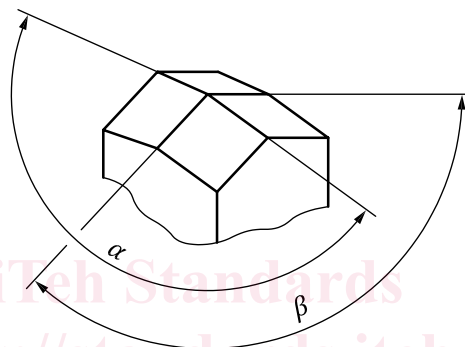
The indentation test with Buchholz indenter is specified in ISO 2815.

#### 4.1.2 Indentation test with Knoop indenter

— **Description**

A diamond indenter, the shape and dimensions of which are specified in accordance with Knoop, impacts the coating under a load (25 g, corresponding to 0,245 N) for 18 s and produces an indentation. Immediately after removal of the load the length (mm) of the long diagonal of the indentation is determined using a measuring microscope. From this, the “Knoop Hardness Number” KHN ( $\text{kg/mm}^2$ ) is calculated.

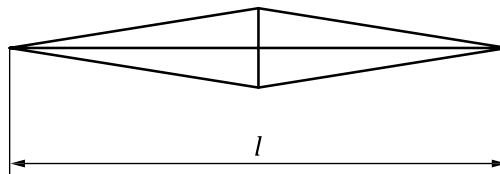
[Figure 4](#) shows the dimensions of the Knoop indenter. [Figure 5](#) shows the top view of the Knoop indentation.



**Key**

- $\alpha$  angle of the longitudinal edge ( $172,5^\circ$ )  
 $\beta$  angle of the transverse edge ( $130^\circ$ )

**Figure 4 — Dimensions of the Knoop indenter**



**Key**

- $l$  indentation length

**Figure 5 — Top view of the Knoop indentation**

— **Application**

The indentation test with Knoop indenter is generally applicable.

— **Calibration**

On a reference block the KHN value is determined and compared to the nominal value.

— **Procedure**

- Condition test panel ( $23^\circ\text{C}$  / 50 % relative humidity /  $\geq 24$  h).
- Lower the test device onto the coating in a plane area.

- Lower the indenter and apply the specified test load.
- Leave the loaded indenter on the coating for 18 s.
- Immediately after the removal of the load, determine the indentation length  $l$  (mm) using a measuring microscope (see [Figure 5](#)).

— **Evaluation**

Calculate the KHN value using the measured length  $l$ :  $KHN = 0,356 / l^2$ . (Factor 0,356 results from the test load and the shape factor of the indenter.)

Test result is the KHN value (kg/mm), as mean value of  $n$  determinations. (The number  $n$  is agreed.)

NOTE In accordance with ISO 4545-1, the Knoop hardness is expressed in HK, which is different from the KHN used here.

— **Precision**

The repeatability (in accordance with ASTM D1474/D1474M) is 9 %.

The reproducibility (in accordance with ASTM D1474/D1474M) is 24 %.

— **Reference**

The indentation test with Knoop indenter is specified in ASTM D1474/D1474M-13, Method A: Knoop Indentation Hardness.

A general method for the determination of the Knoop hardness HK is specified in ISO 4545-1.

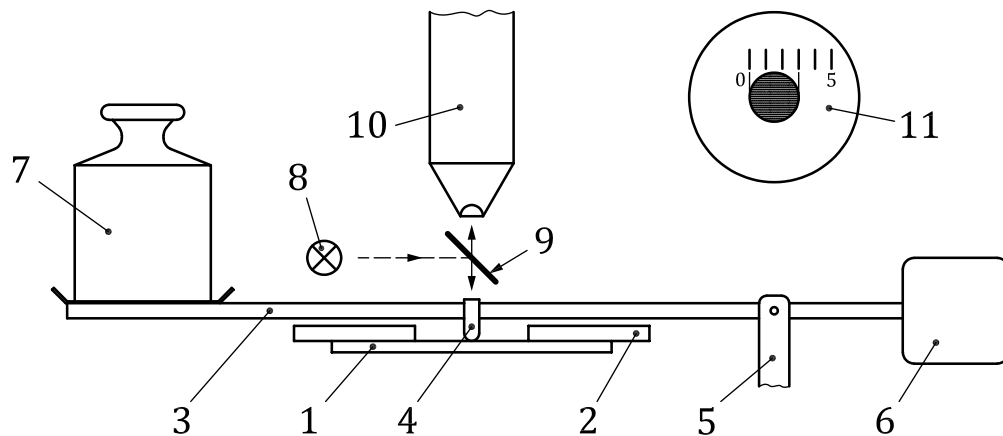
For testing automobile coatings, the method is also described in References [\[47\]](#) and [\[56\]](#).

#### 4.1.3 Indentation test with Pfund indenter

— **Description**

A transparent quartz or sapphire indenter (hemisphere Ø 0,318 mm), the shape and dimensions of which are specified in accordance with Pfund, impacts the coating under load (1 kg, corresponding to 9,8 N) for 60 s and produces an indentation. Immediately after that the diameter (mm) of the indentation under load by the transparent indenter is determined using a measuring microscope. From this, the "Pfund Hardness Number" PHN (kg/mm<sup>2</sup>) is calculated.

[Figure 6](#) shows the principle of the indentation test with Pfund indenter.

**Key**

- 1 test panel
- 2 stop
- 3 load arm
- 4 transparent indenter
- 5 pivot
- 6 tare weight
- 7 load weight
- 8 light source
- 9 semi-transparent mirror
- 10 measuring microscope
- 11 microscopic image (Pfund indentation and scale)

**Figure 6 — Principle of the indentation test****— Application**

The indentation test with Pfund indenter is generally applicable.

**— Calibration**

On a reference block the PHN value is determined and compared to the nominal value.

**— Procedure**

- Condition test panel (23 °C / 50 % relative humidity / ≥ 24 h).
- Lower the test device onto the coating in a plane area.
- Lower the indenter and apply the specified test load.
- Leave the loaded indenter on the coating for 60 s.
- After that, still loaded, determine diameter  $d$  (mm) of the indentation through the transparent indenter using a measuring microscope.

**— Evaluation**

Calculate the PHN value using the measured diameter  $d$ :  $PHN = 1,27 / d^2$ . (Factor 1,27 results from the test load and the shape factor of the indenter.)

Test result is the PHN value (kg/mm<sup>2</sup>), as mean value of at least 5 determinations.

— **Precision**

The repeatability (in accordance with ASTM D1474/D1474M) is 18 %.

The reproducibility (in accordance with ASTM D1474/D1474M) is 36 %.

— **Reference**

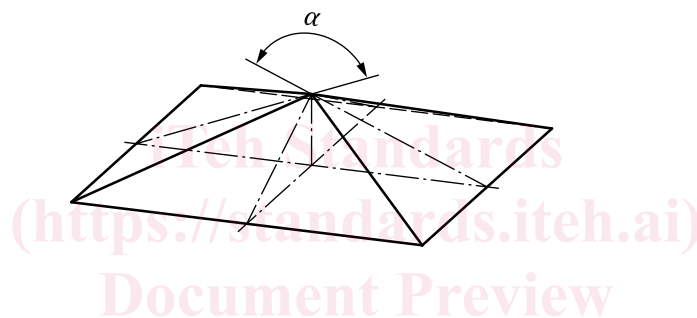
An indentation test with Pfund indenter is specified in ASTM D1474/D1474M-13, Method B: Pfund Indentation Hardness.

#### 4.1.4 Indentation test with Vickers indenter

— **Description**

A diamond indenter, the shape and dimensions of which are specified in accordance with Vickers, is pressed into the coating under increasing, controlled load. The Martens hardness  $HM$  ( $N/mm^2$ ) in dependence of the indentation depth is calculated from the measured indentation depth ( $\mu m$ ) and the respective test load ( $N$ ).

[Figure 7](#) shows the dimensions of the indenter and [Figure 8](#) shows the test principle.



**Key**

$\alpha$  pyramid angle ( $136^\circ$ )

**Figure 7 — Schematic diagram of the Vickers indenter**