BS ISO 6370-2:2020

BSI Standards Publication

Vitreous and porcelain enamels — Determination of the resistance to abrasion

Part 2: Loss in mass after sub-surface abrasion

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National foreword

This British Standard is the UK implementation of ISO 6370-2:2020. It supersedes BS ISO 6370-2:2011, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee STI/36, Vitreous enamel coatings.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Published by BSI Standards Limited 2020

ISBN 978 0 580 99975 8

ICS 25.220.50

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 29 February 2020.

Amendments/corrigenda issued since publication

Date	Text affected

BS ISO 6370-2:2020

INTERNATIONAL STANDARD

ISO 6370-2

Third edition
2020-02-10

Vitreous and porcelain enamels — Determination of the resistance to abrasion —

Part 2: Loss in mass after sub-surface abrasion

Émaux vitrifiés — Détermination de la résistance à l'abrasion —

Partie 2: Perte de masse après abrasion de la couche superficielle

Reference number
ISO 6370-2:2020(E)

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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).

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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 107, *Metallic and other inorganic coatings*.

This third edition cancels and replaces the second edition (ISO 6370-2:2011), which has been technically revised. The main changes compared with the previous edition are as follows:

— terms and definitions have been added;

— sanidine (potassium feldspar) has been included as an additional abrasive option for testing;

— the requirements for steel balls have been amended.

A list of all parts in the ISO 6370 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.

Introduction

Extensive tests have shown that, with the comparative method described in this document, the uncertainty of measurement of test results is ± 5 %. Furthermore, absolute quantities for the amount of wear give little information, because abrasives used in practice differ considerably in their effect on enamelled surfaces. Each abrasion test with a standardized method can only be carried out with the aim of providing a general classification of various vitreous and porcelain enamels in relation to each other. Absolute quantities for the amount of wear are therefore not required.

Numerous tests have shown that the three required test periods of 30 min were sufficient to obtain comparable results. If the vitreous and porcelain enamel coat to be tested is thicker than 0,2 mm, it is not necessary to determine the loss in mass after each 30 min test period, because the abrasion under the conditions described in this document is directly proportional to the test duration.

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INTERNATIONAL STANDARD ISO 6370-2:2020

Vitreous and porcelain enamels — Determination of the resistance to abrasion —

Part 2:
Loss in mass after sub-surface abrasion

WARNING — This document may not be compliant with some countries' health and safety legislations and calls for the use of substances and/or procedures that may be injurious to health if adequate safety measures are not taken. This document does not address any health hazards, safety or environmental matters and legislations associated with its use. It is the responsibility of the user of this document to establish appropriate health, safety and environmentally acceptable practices.

1 Scope

This document specifies a test method for determining the resistance of vitreous and porcelain enamel coatings to abrasion by rubbing, grinding or other mechanical effects.

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 648, *Laboratory glassware — Single-volume pipettes*

ISO 3696, *Water for analytical laboratory use — Specification and test methods*

ISO 6344-2, *Coated abrasives — Grain size analysis — Part 2: Determination of grain size distribution of macrogrits P12 to P220*

ISO 6370-1:1991, *Vitreous and porcelain enamels — Determination of the resistance to abrasion — Part 1: Abrasion testing apparatus*

ISO 28764, *Vitreous and porcelain enamels — Production of specimens for testing enamels on sheet steel, sheet aluminium and cast iron*

3 Terms and definitions

No terms and definitions are listed in this document.

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/

4 Principle

Mounting of three similarly enamelled test specimens and three reference glass plates in the testing apparatus. Simultaneous exposure of the separated test specimens and reference glass plates to the abrasion attack of a mixture of fused aluminium oxide grains, steel balls and water for three periods of

7 Test specimens

7.1 Prepare the test specimens in accordance with the International Standards for the appropriate basis metal.

Specimens for testing vitreous and porcelain enamels for sheet steel and cast iron shall be prepared in accordance with ISO 28764.

7.2 Rinse each test specimen and reference glass plate with water (5.2) and wipe it thoroughly with ethanol (5.1). Dry the test specimens and the reference glass plates in the drying oven (6.4) for 2 h at 120 °C ± 5 °C. Remove them from the oven and allow them to stand for at least 2 h in the desiccators (6.5) and weigh each specimen to the nearest 0,2 mg (initial mass).

8 Procedure

8.1 Carry out one test with each set of at least three test specimens and three reference glass plates.

8.2 Fix the test specimens and the reference glass plates on the oscillating table of the abrasion testing apparatus (6.1) with the aid of the retaining rings, sealing rings and clamping devices, so that the cover coat sides of the test specimens and the float-bath surface (see Annex A) of the reference glass plates are facing the interior of the retaining rings (see ISO 6370-1:1991, Figure 1).

8.3 Fill each retaining ring with an abrading charge and close it with the stopper. The abrading charge consists of the following:

— 80 g of steel balls (5.3) that are 4 mm in diameter;

— 60 g of steel balls (5.3) that are 3 mm in diameter;

— 35 g of steel balls (5.3) that are 2 mm in diameter;

— 20 ml ± 0,2 ml of water (5.2);

— 3 g + 0,01 g of abrasives (5.4).

The limiting deviations in mass for the balls: mass of each single ball.

8.4 Start the oscillating table of the abrasion testing apparatus for a period of 30 min ± 1 min, corresponding to 9 000 rotations ± 300 rotations. Then, remove the specimens and reference glass plates, and thoroughly rinse the test specimens, the reference glass plates, the retaining rings and the sealing rings under running water. Dry the test specimens and reference glass plates in air and replace them on the abrasion testing apparatus with a fresh abrading charge (see 8.3). The steel balls may be used again after thorough cleaning.

If the thickness of the enamel coat to be tested is less than 0,2 mm, it is recommended to weigh the test specimen before the next test period.

Start the oscillating table for a further period of 30 min and then repeat the whole procedure a third time. If the vitreous and porcelain enamel coat being tested has already disappeared, interrupt the test.

8.5 After three test periods of 30 min, remove the test specimens and the reference glass plates from the abrasion testing apparatus. Rinse them thoroughly under running water and then with distilled water (5.2). Dry the test specimens and the reference glass plates in the drying oven (6.4) for 2 h at

120 °C ± 5 °C. Then allow them to stand for at least 2 h in the desiccator (6.5) and weigh each to the nearest 0,2 mg (final mass).

A porous surface of the test specimen after abrasion can cause an increase in mass due to the absorption of water. This phenomenon shall be stated in the test report under any unusual features noted during the testing (see Clause 10).

9 Expression of results

9.1 Calculate, for each test specimen and reference glass plate, the loss in mass, Δm, in milligrams (mg).

Calculate the relative amount of wear w_r using Formula (1):

$$w_r = \frac{\Delta m_{S1} + \Delta m_{S2} + \Delta m_{S3}}{\Delta m_{R1} + \Delta m_{R2} + \Delta m_{R3}} \quad (1)$$

where

$\Delta m_{S1}, \Delta m_{S2}, \Delta m_{S3}$ are the respective losses in mass of the three test specimens S1, S2 and S3 tested;

$\Delta m_{R1}, \Delta m_{R2}, \Delta m_{R3}$ are the respective losses in mass of the three reference glass plates tested.

9.2 Calculate the value α for the test specimen tested and the reference glass plates tested using Formula (2):

$$\alpha = \frac{\Delta m_1 + \Delta m_2 + \Delta m_3}{\left(\Delta m_1^2 + \Delta m_2^2 + \Delta m_3^2 - \Delta m_1 \Delta m_2 - \Delta m_2 \Delta m_3 - \Delta m_1 \Delta m_3\right)^{1/2}} \quad (2)$$

The abrasion test is considered as reliable if, for each test specimen tested, $\alpha_S > 60$ and, for each reference glass plate tested, $\alpha_R > 60$.

If the values α_S and/or α_R are less than 60, carry out a further test with new test specimens.

For the calculation of uncertainty of measurement of wear, see Annex B.

10 Test report

The test report shall include the following information:

a) a reference to this document, i.e. ISO 6370;

b) a description of the test specimens;

c) the date of the test;

d) a reference to which abrasive (5.4) was used;

e) the relative amount of wear, w_r;

f) in case of interruption, the duration of the abrasion test;

g) any unusual features noted during the testing.

Annex A
(informative)

Identification of the float-bath surface of the reference glass plates

A.1 General

The float-bath surface of the glass can be identified by one of methods given in A.2 to A.4.

A.2 Chemical method

A.2.1 Reagents

A.2.1.1 Etching solution, containing the following reagents, which are thoroughly mixed:

— 10 ml of concentrated hydrochloric acid;

— 10 ml of distilled water;

— 8 ml of 40 % (volume fraction) hydrofluoric acid.

A.2.1.2 Cacotheline, 0,1 % (volume fraction) solution in distilled water.

A.2.2 Procedure

Place 2 or 3 drops of the etching solution (A.2.1.1) on the surface, followed by 1 or 2 drops of the cacotheline solution (A.2.1.2).

A.2.3 Expression of results

A.2.3.1 Float-bath surface

In 5 s to 10 s, a purple colouration is observed.

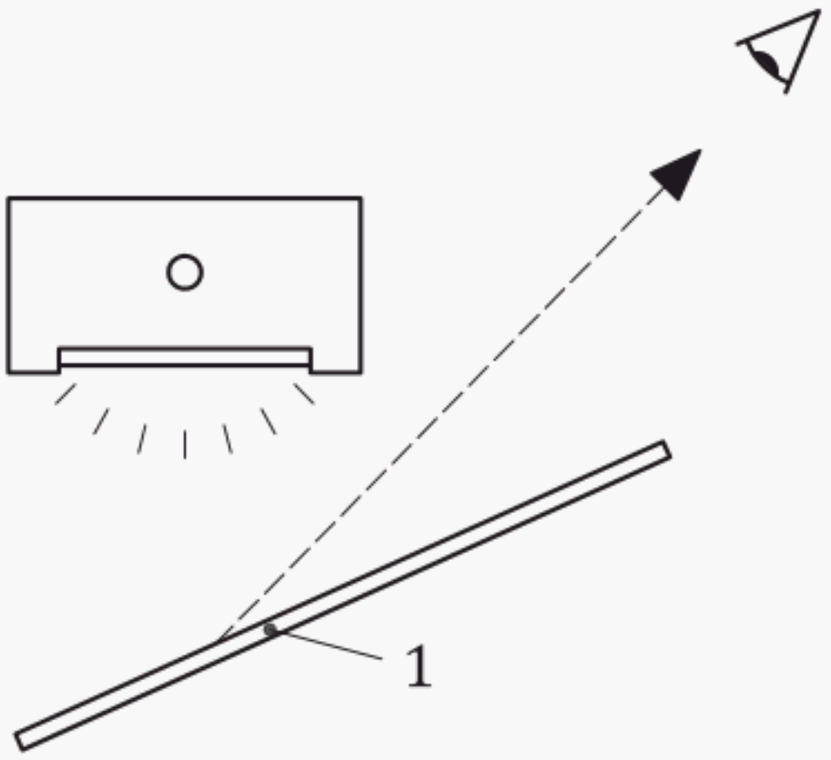
A.2.3.2 Top surface

The solution remains yellow.

A.3 Ultraviolet method

Use a lamp with an ultraviolet filter giving a peak output in the range of wavelengths between 254 nm and 365 nm, arranged as shown in Figure A.1.

When viewed from the angle shown in Figure A.1 in a dark room, the float-bath surface exhibits a slight fluorescence.



Key

1 glass

Figure A.1 — Arrangement for the ultraviolet method

WARNING — Ultraviolet radiation in this region of the spectrum will damage the eyes and suitable protective goggles with an ultraviolet-filter shall be used.

A.4 Energy-dispersion-analysis method

Comparison of the two surfaces of the glass by energy dispersion analysis will reveal the tin content of the float-bath surface, which is not present on the other surface.

Annex B
(informative)

Calculation of uncertainty of measurement of wear

The values α_S and α_R are closely connected with basic terms of the theory of error calculation.

To calculate the statistical error of the mean arithmetic values

$$\overline{\Delta m_S} = \frac{1}{3}\left(\Delta m_{S1} + \Delta m_{S2} + \Delta m_{S3}\right)$$

and

$$\overline{\Delta m_R} = \frac{1}{3}\left(\Delta m_{R1} + \Delta m_{R2} + \Delta m_{R3}\right)$$

according to the general formula

$$S_{\bar{x}}^2 = \frac{1}{n(n-1)}\left[\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2\right]$$

the following formulae are valid:

$$S_{\overline{\Delta m}} = \frac{1}{3}\left(\Delta m_1^2 + \Delta m_2^2 + \Delta m_3^2 - \Delta m_1 \Delta m_2 - \Delta m_2 \Delta m_3 - \Delta m_1 \Delta m_3\right)^{1/2}$$

$$S_{\overline{\Delta m_S}} = \overline{\Delta m_S}\left(\frac{1}{\alpha_S}\right)$$

$$S_{\overline{\Delta m_R}} = \overline{\Delta m_R}\left(\frac{1}{\alpha_R}\right)$$

For a confidence level of 95 % of three measurements, the fractile of the Student-Fisher distribution is $t_{95} = 4{,}3$. Consequently, the following formulae are obtained if relative errors of the mean values of less than 7 % are required.

$$\frac{4{,}3 S_{\overline{\Delta m_S}}}{\Delta m_S} \leq 0{,}07$$

$$\frac{4{,}3 S_{\overline{\Delta m_R}}}{\Delta m_R} \leq 0{,}07$$

This leads directly to

$$\frac{4{,}3}{\alpha_S} \leq 0{,}07$$

$$\frac{4{,}3}{\alpha_R} \leq 0{,}07$$

Or, respectively,

$\alpha_S > 60$

and

$\alpha_R > 60$

According to the law of Gauss for the error propagation and assuming a probability of 90 %, the error for the determination of the relative amount of wear w_r is less than

$$\sqrt{(0{,}07)^2 + (0{,}07)^2} \approx 0{,}1 \text{ or } 10\,\%$$

if the stated requirements for α_S and α_R are fulfilled.

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[1] ISO 683-17, *Heat-treated steels, alloy steels and free-cutting steels — Part 17: Ball and roller bearing steels*

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