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Metallic materials — Brinell hardness test —

Part 3:
Calibration of reference blocks

Matériaux métalliques — Essai de dureté Brinell —

Partie 3: Étalonnage des blocs de référence

Reference number
ISO 6506-3:2014(E)

Contents

Page

Foreword

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The committee responsible for this document is ISO/TC 164, *Mechanical testing of metals*, Subcommittee SC 3, *Hardness testing*.

This third edition cancels and replaces the second edition (ISO 6506-3:2005), which has been technically revised.

ISO 6506 consists of the following parts, under the general title *Metallic materials — Brinell hardness test*:

— *Part 1: Test method*

— *Part 2: Verification and calibration of testing machines*

— *Part 3: Calibration of reference blocks*

— *Part 4: Tables of hardness values*

Metallic materials — Brinell hardness test —

Part 3:
Calibration of reference blocks

1 Scope

This part of ISO 6506 specifies a method for the calibration of reference blocks to be used in the indirect verification of Brinell hardness testing machines as described in ISO 6506-2.

The procedures necessary to ensure metrological traceability of the calibration machine are also specified.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 376, *Metallic materials — Calibration of force-proving instruments used for the verification of uniaxial testing machines*

ISO 6506-1:2014, *Metallic materials — Brinell hardness test — Part 1: Test method*

ISO 6506-2:2014, *Metallic materials — Brinell hardness test — Part 2: Verification and calibration of testing machines*

3 Manufacture of reference blocks

3.1 The block shall be specially manufactured for use as a reference block.

NOTE Attention is drawn to the need to use a manufacturing process which will give the necessary homogeneity, stability of structure, and uniformity of surface hardness.

3.2 Each metal block to be calibrated shall be of a thickness not less than

— 16 mm for 10 mm balls,

— 12 mm for 5 mm balls, or

— 6 mm for smaller balls.

NOTE 12 mm for 10 mm balls can be used only if the hardness of the reference block is greater than 150 HBW.

3.3 The reference blocks shall be free of magnetism. It is recommended that the manufacturer shall ensure that the blocks, if of steel, have been demagnetized at the end of the manufacturing process.

3.4 The flatness of the two surfaces and the parallelism of the reference block shall be in accordance with Table 1.

Table 1 — Requirements for the reference blocks

Diameter of ball mm	Tolerance in flatness of the surfaces mm	Tolerance in parallelism mm over 50 mm	Permissible surface roughness *Ra*[a] µm	
			Test surface	Bottom surface
10	0,040	0,050	0,3	0,8
5	0,030	0,040	0,2	0,8
2,5	0,020	0,030	0,1	0,8
1,0	0,020	0,030	0,05	0,8

[a] Sampling length: l = 0,80 mm (see ISO 4287).

3.5 The test surface shall be free from scratches which interfere with the measurement of the indentations (see Table 1).

3.6 To verify that no material is subsequently removed from the reference block, the thickness at the time of calibration shall be marked on it to the nearest 0,1 mm, or an identifying mark shall be made on the test surface [see 8.1, item e)].

4 Calibration machine

4.1 In addition to fulfilling the general requirements specified in ISO 6506-2:2014, Clause 3, the calibration machine shall also meet the requirements given in 4.2 to 4.7.

4.2 The machine shall be verified directly in intervals not exceeding 12 months.

Direct verification involves

a) measurement of the test forces,

b) measurement of the diameter, hardness, and density of the indenter ball,

c) calibration of the indentation diameter measuring device, and

d) measurement of the testing cycle, if this is not possible, at least the force versus time behaviour.

4.3 The instruments used for verification and calibration shall be traceable to the SI.

4.4 Each test force shall be measured a minimum of three times using an elastic proving device of ISO 376 class 0,5 or better. For machines that apply the force by hydraulic or weight systems, these force measurements shall be made at each of three different indenter positions uniformly spaced throughout its range of movement during machine operation. The mean measurement (at each indenter position, where applicable) shall agree with the nominal value to within ±0,1 %.

4.5 The indenters shall be measured as specified in ISO 6506-2:2014, 4.3, and shall meet the size, hardness, and density requirements given there.

4.6 The scale of the indentation diameter measuring system shall be graduated to read to 0,002 mm for indentations made with 10 mm and 5 mm balls, and 0,001 mm for indentations made with balls of less than 5 mm diameter.

The indentation diameter measuring system shall be calibrated against a standard scale at a minimum of five intervals over each working range. The performance of the indentation diameter measuring system (defined as the sum of the measured deviation from the standard scale and the expanded uncertainty of the standard scale) in relation to the diameters of indentation shall be as given in Table 2.

Table 2 — Performance of the indentation diameter measuring device

Diameter of indentation mm	Performance mm
$d < 1$	±0,000 5
$1 \leq d < 2,5$	±0,001 0
$d \geq 2,5$	±0,002 0

4.7 The testing cycle shall conform to the testing cycle described in ISO 6506-1 and shall be timed with an uncertainty less than ±0,5 s.

5 Calibration procedure

The reference blocks shall be calibrated in a calibration machine as described in Clause 4, at a temperature of (23 ± 5) °C, using the general procedure described in ISO 6506-1. During calibration, the thermal drift should not exceed 1 °C.

The maximum velocity of the indenter immediately before it touches the surface of the test block shall be as specified in Table 3.

Table 3 — Maximum indenter approach velocity

Ball diameter mm	Maximum velocity $mm \cdot s^{-1}$
1	0,3
2,5	0,6
5 or 10	1,0

The time from the initial application of force to the time the full test force is reached shall be (7 ± 1) s. The duration of the test force shall be (14 ± 1) s.

6 Number of indentations

On each reference block, at least five indentations shall be made, uniformly distributed over the entire test surface. At least one of the indentations shall be identified as a reference indentation [see 8.3, item e)].

NOTE Performing more than five indentations might reduce the measurement uncertainty.

7 Non-uniformity of reference block

7.1 Let d_1, d_2, d_3, d_4, and d_5 be the values of the mean measured diameters of the indentations arranged in increasing order of magnitude.

The non-uniformity of the block under the particular conditions of calibration is characterized by

$$R = d_5 - d_1 \tag{1}$$

and is expressed as a percentage of $\bar{d}$

$$R_{rel} = 100 \times \frac{(d_5 - d_1)}{\bar{d}} \tag{2}$$

where

$$\bar{d} = \frac{d_1 + d_2 + d_3 + d_4 + d_5}{5} \tag{3}$$

7.2 The maximum permissible value of non-uniformity of a reference block shall be as specified in Table 4.

Table 4 — Maximum permissible value of non-uniformity

$\bar{d}$ mm	**Maximum permissible value of non-uniformity,** R_{rel} %
$\bar{d}$ < 0,5	2,0
0,5 ≤ $\bar{d}$ ≤ 1	1,5
$\bar{d}$ > 1	1,0
NOTE For hardness values less than 225 HBW, the maximum permissible value of non-uniformity can be 2,0 %.	

7.3 Methods for determining the uncertainty of measurement of hardness reference blocks are given in Annex A and Reference [6].

8 Marking

8.1 Each reference block shall be marked with the following:

a) arithmetic mean of the hardness values found in the block calibration, for example: 348 HBW 5/750;

b) name or mark of the supplier or manufacturer;

c) serial number;

d) name or mark of the calibration agency;

e) thickness of the block or an identifying mark on the test surface (see 3.6);

f) year of calibration, if not indicated in the serial number.

8.2 Any mark put on the side of the block shall be upright when the test surface is the upper face.

8.3 Each delivered reference block shall be accompanied by a document giving at least the following information:

a) a reference to this part of ISO 6506 (i.e. ISO 6506-3);

b) the identity of the block;

c) the date of calibration;

d) the arithmetic mean of the hardness values and its associated uncertainty and the value characterizing the non-uniformity of the block (see 7.1);

e) information about the location of the reference indentation(s) and the orientations and values of the measured diameters, together with the mean measured diameter(s).

9 Validity

The hardness-reference block is only valid for the scale for which it was calibrated.

The calibration validity should be limited to a duration of five years. Attention is drawn to the fact that, for Al- and Cu-alloys, the calibration validity should be reduced to two to three years.

Annex A
(informative)

Uncertainty of the mean hardness value of reference blocks

A.1 General

Measurement uncertainty analysis is a useful tool to help determine sources of error and to understand differences between measured values. This annex gives guidance on uncertainty estimation but the values derived are for information only, unless specifically instructed otherwise by the customer.

The criteria specified in this part of ISO 6506 for the calibration requirements of the reference block have been developed and refined over a significant period of time. When determining a specific tolerance that the reference block needs to meet, the uncertainty associated with the use of measuring equipment has been incorporated within this tolerance and it would therefore be inappropriate to make any further allowance for this uncertainty by, for example, reducing the tolerance by the measurement uncertainty. This applies to all measurements associated with the manufacture and calibration of the reference blocks and also to all measurements made when performing a verification of the calibration machine. In each case, it is simply the measured value resulting from the use of the specified measuring equipment that is used to assess compliance with this part of ISO 6506.

The metrological chain necessary to define and disseminate hardness scales is shown in ISO 6506-1:2014, Figure C.1.

A.2 Direct verification of the calibration machine

A.2.1 Measurement of the test force

See ISO 6506-2:2014, Annex A.

A.2.2 Calibration of the indentation diameter measuring system

See ISO 6506-2:2014, Annex A.

A.2.3 Measurement of the indenter

See ISO 6506-2:2014, Annex A.

A.2.4 Measurement of the test cycle

See ISO 6506-2:2014, Annex A.

A.3 Indirect verification of the calibration machine

NOTE In this annex, the index “CRM (Certified Reference Material)” means, according to the definitions of the hardness testing standards, “Hardness Reference Block”.

By the indirect verification with primary reference blocks, the overall function of the calibration machine is checked and the repeatability as well as the deviation of the calibration machine from the actual hardness value are determined.

The uncertainty of measurement of the indirect calibration of the calibration machine follows from the formula:

$$u_{CM} = \sqrt{u_{CRM-P}^2 + u_{xCRM-1}^2 + u_{CRM-D}^2 + u_{ms}^2} \quad (A.1)$$

where

$u_{CRM\text{-}P}$ is the calibration uncertainty of the primary reference block according to the calibration certificate for $k = 1$;

$u_{xCRM\text{-}1}$ is the repeatability of the calibration machine;

$u_{CRM\text{-}D}$ is the hardness change of the primary reference block since its last calibration due to drift;

u_{ms} is the standard uncertainty due to the resolution of the indentation diameter measuring system.

EXAMPLE

Primary reference block: (591,7 ± 3,6) HBW 2,5/187,5

Uncertainty of measurement of the primary reference block: $u_{CRM\text{-}1}$ = ± 1,8 HBW 2,5/187,5

Time drift of the primary reference block: $u_{CRM\text{-}D} = 0$

Resolution of the indentation diameter measuring system: δ_{ms} = 0,1 µm

Table A.1 — Results of the indirect verification

Number	Measured indentation diameter d mm	Calculated hardness value H HBW
1	0,630 5_{max}	$591{,}4_{min}$
2	0,630 0	592,3
3	0,629 5_{min}	$593{,}3_{max}$
4	0,629 7	592,9
5	0,629 5	593,3
Mean value $\bar{H}$	0,629 8	592,6
Standard deviation s_{xCRM-1}	0,000 42	0,81
HBW: Brinell hardness		

$$u_{xCRM-1} = \frac{t \cdot s_{xCRM-1}}{\sqrt{n}} = 0,41 \quad (A.2)$$

(t = 1,14 for n = 5)

Table A.2 — Budget of uncertainty of measurement

Quantity X_i	Estimated value x_i	Standard uncertainty of measurement $u(x_i)$	Distribution type	Sensitivity coefficient c_i	Uncertainty contribution $u_i(H)$ HBW
$u_{CRM\text{-}P}$	591,7 HBW	1,8 HBW	Normal	1,0	1,80
$u_{xCRM\text{-}1}$	592,6 HBW	0,41 HBW	Normal	1,0	0,41
U_{ms}	630,0 µm	0,1 µm	Rectangular	–1 909,2 HBW/mm (see Note)	0,06
$u_{CRM\text{-}D}$	0,0 HBW	0,0 HBW	Triangular	1,0	0,0
Combined uncertainty of measurement, u_{CM}					1,85

NOTE The sensitivity coefficient follows from:

$$\frac{\partial H}{\partial d} = -\frac{H}{d} \cdot \frac{D + \sqrt{D^2 - d^2}}{\sqrt{D^2 - d^2}} \tag{A.3}$$

for H = 591,7 HBW, D = 2,5 mm, d = 0,630 0 mm.

A.4 Uncertainty of measurement of reference blocks

The uncertainty of measurement of reference blocks follows from Formula (A.4):

$$u_{CRM} = \sqrt{u_{CM}^2 + u_{xCRM-2}^2} \tag{A.4}$$

where

u_{CRM} is the calibration uncertainty of reference blocks;

$u_{xCRM\text{-}2}$ is the standard uncertainty due to the inhomogeneity of the hardness distribution of the reference block;

u_{CM} see Formula (A.1).

Table A.3 — Determination of the inhomogeneity of the reference block

Number	Measured indentation diameter d mm	Calculated hardness value H HBW
1	0,630 4_{max}	$591{,}01_{min}$
2	0,630 1	591,60
3	0,629 4_{min}	$592{,}92_{max}$
4	0,629 6	592,53
5	0,629 7	592,34
Mean value $\overline{H}$	0,629 8	592,08
Standard deviation $s_{xCRM\text{-}2}$	0,000 40	0,77

Standard uncertainty of CRM:

$$u_{x\,\mathrm{CRM-2}} = \frac{t \cdot s_{x\,\mathrm{CRM-2}}}{\sqrt{n}} \tag{A.5}$$

with t = 1,14 and n = 5:

$u_{x\mathrm{CRM\text{-}2}}$ = 0,39 HBW

Table A.4 — Uncertainty of measurement of the reference block

Hardness of reference block H_{CRM} HBW	**Inhomogeneity of the reference block** $u_{x\mathrm{CRM\text{-}2}}$ HBW	**Uncertainty of measurement of the calibration machine** u_{CM} HBW	**Expanded calibration uncertainty of reference block** U_{CRM} HBW
592,64	0, 39	1,85	3,8

with

$$U_{\mathrm{CRM}} = 2\sqrt{u_{\mathrm{CM}}^2 + u_{x\mathrm{CRM-2}}^2} \tag{A.6}$$

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