INTERNATIONAL STANDARD

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Metallic materials — Brinell hardness test —

Part 1: Test method

Matériaux métalliques — Essai de dureté Brinell —

Partie 1: Méthode d'essai

Reference number
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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 6506-1 was prepared by Technical Committee ISO/TC 164, *Mechanical testing of metals*, Subcommittee SC 3, *Hardness testing.*

This second edition, together with ISO 6506-4, cancels and replaces the first edition (ISO 6506-1:1999), 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: Table of hardness values*

Introduction

Attention is drawn to the fact that in this part of ISO 6506, only the use of the hardmetal ball indenter is specified.

The designation of the Brinell hardness is HBW and should not be confused with the former designation HB, or HBS when a steel ball indenter was used.

Periodic checking of the testing machine described in the informative Annex A is good metrological practice. It is intended to make this annex normative in the next revision of this part of ISO 6506.

Metallic materials — Brinell hardness test —

Part 1: **Test method**

1 Scope

This part of ISO 6506 specifies the method for the Brinell hardness test for metallic materials and is applicable up to the limit of 650 HBW.

For specific materials and/or products, particular International Standards exist (i.e. ISO 4498-1).

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 4498-1, *Sintered metal materials, excluding hardmetals — Determination of apparent hardness — Part 1: Materials of essentially uniform section hardness*

ISO 6506-2:2005, *Metallic materials — Brinell hardness test — Part 2: Verification and calibration of testing machines*

ISO 6506-4, *Metallic materials — Brinell hardness test — Part 4: Table of hardness values*

3 Principle

An indenter (hardmetal ball with diameter D) is forced into the surface of a test piece and, after removal of the force F, the diameter of the indentation d left in the surface is measured.

The Brinell hardness is proportional to the quotient obtained by dividing the test force by the curved surface area of the indentation. The indentation is assumed to retain the shape of the ball, and its surface area is calculated from the mean indentation diameter and the ball diameter.

4 Symbols and abbreviated terms

4.1 See Figure 1 and Table 1.

Table 1 — Symbols and abbreviated terms

Symbol / Abbreviated term	Designation	Unit
D	Diameter of the ball	mm
F	Test force	N
d	Mean diameter of the indentation $d = \frac{d_1 + d_2}{2}$	mm
d_1, d_2	Indentation diameters measured at 90°	mm
h	Depth of indentation $h = \frac{D}{2}(1-\sqrt{1-d^2/D^2})$	mm
HBW	Brinell hardness $= \text{Constant} \times \frac{\text{Test force}}{\text{Surface area of indentation}}$ $\text{HBW} = 0{,}102 \times \frac{2F}{\pi D^2 (1-\sqrt{1-d^2/D^2})}$	
$0{,}102 \times F/D^2$	force-diameter ratio	N/mm^2
NOTE Constant $= 0{,}102 \approx \frac{1}{9{,}806\ 65}$, where 9,806 65 is the conversion factor from kgf to N.		

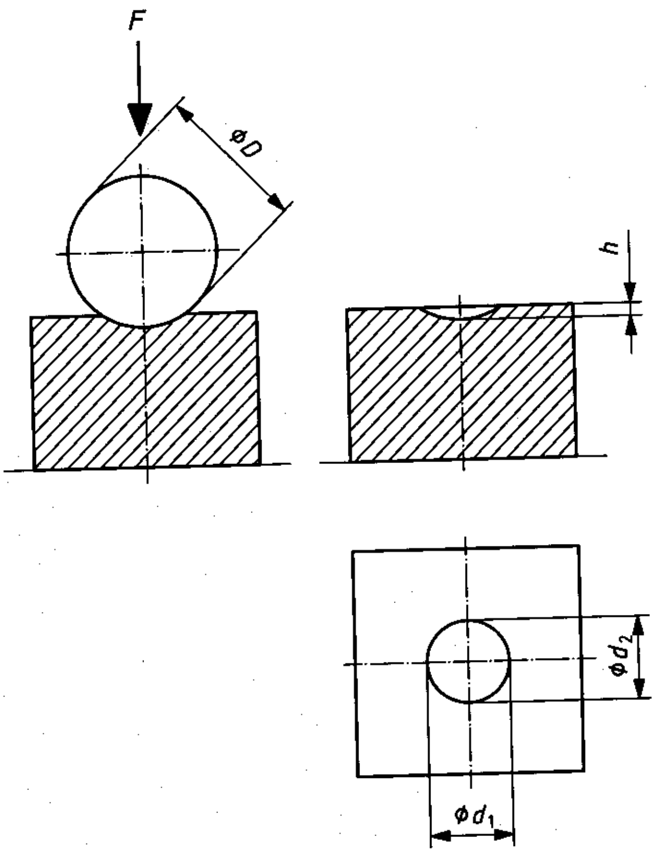
4.2 The following is an example of the designation of Brinell hardness, HBW.

EXAMPLE

600 HBW 1 / 30 / 20

- /20 — duration time of test force (20 s), if not within the specified range (10 s to 15 s)
- 30 — approximate kgf equivalent value of applied test force, where 30 kgf = 294,2 N
- 1 — ball diameter in mm
- HBW — hardness symbol
- 600 — Brinell hardness value

NOTE In former standards, in cases when a steel ball had been used, the Brinell hardness was denoted by HB or HBS.



For symbols, see Table 1.

Figure 1 — Principle of test

5 Apparatus

5.1 Testing machine, capable of applying a predetermined test force or forces within the range of 9,807 N to 29,42 kN, in accordance with ISO 6506-2.

5.2 Indenter, a polished hardmetal ball, as specified in ISO 6506-2.

5.3 Measuring device, as specified in ISO 6506-2.

NOTE A suggested procedure for periodic checks by the user is given in Annex A.

6 Test piece

6.1 The test shall be carried out on a surface which is smooth and even, free from oxide scale, foreign matter and, in particular, free from lubricants. The test piece shall have a surface finish that will allow an accurate measurement of the diameter of the indentation.

6.2 Preparation shall be carried out in such a way that any alteration of the surface, for example, due to excessive heating or cold-working, is minimized.

6.3 The thickness of the test piece shall be at least eight times the depth of indentation. Values for the minimum thickness of the test piece in relation to the mean diameter of indentation are given in Annex B.

Visible deformation at the back of the test piece can indicate that the test piece is too thin.

7 Procedure

7.1 In general, the test is to be carried out at ambient temperature within the limits of 10 °C to 35 °C. Tests carried out under controlled conditions shall be made at a temperature of (23 ± 5) °C.

7.2 The test forces given in Table 2 shall be used.

NOTE Other test forces and force-diameter ratios may be used by special agreement.

7.3 The test force shall be chosen so that the diameter of the indentation d lies between the values 0,24 D and 0,6 D.

Table 3 indicates recommended force-diameter ratios ($0,102 \times F/D^2$) that are appropriate for use when testing certain materials and hardness levels.

In order to test the largest representative area of the test piece, the diameter of the testing ball shall be chosen to be as large as possible.

When the thickness of the test piece permits, a 10 mm diameter ball is preferred.

7.4 The test piece shall be placed on a rigid support. The contact surfaces shall be clean and free from foreign matter (scale, oil, dirt, etc). It is important that the test piece lies firmly on the support so that displacement cannot occur during the test.

7.5 Bring the indenter into contact with the test surface and apply the test force in a direction perpendicular to the surface, without shock, vibration or overrun, until the applied force attains the specified value. The time from the initial application of force to the time the full test force is reached shall not be less than 2 s nor greater than 8 s. Maintain the test force for 10 s to 15 s. For certain materials, where a longer duration of the test force is required; this time shall be applied with a tolerance of ± 2 s.

7.6 Throughout the test, the testing machine shall be protected from significant shock or vibration, which can influence the test result.

7.7 The distance of the edge of the test piece to the centre of each indentation shall be a minimum of two and a half times the mean indentation diameter.

The distance between the centres of two adjacent indentations shall be at least three times the mean indentation diameter.

7.8 Measure the diameter of each indentation in two directions perpendicular to each other. The arithmetic mean of the two readings shall be taken for the calculation of the Brinell hardness.

NOTE For automatic measuring systems, the following may be used:

— the average of a greater number of equally spaced measurements;

— an assessment of the projected indentation area into the material surface.

7.9 ISO 6506-4 contains a calculation table, which shall be used to determine the Brinell hardness for tests on flat surfaces.

Table 2 — Test forces for the different testing conditions

Hardness symbol	Ball diameter D mm	Force-diameter ratio $0{,}102 \times F/D^2$ N/mm²	Nominal value of test force F	
HBW 10/3 000	10	30	29,42	kN
HBW 10/1 500	10	15	14,71	kN
HBW 10/1 000	10	10	9,807	kN
HBW 10/500	10	5	4,903	kN
HBW 10/250	10	2,5	2,452	kN
HBW 10/100	10	1	980,7	N
HBW 5/750	5	30	7,355	kN
HBW 5/250	5	10	2,452	kN
HBW 5/125	5	5	1,226	kN
HBW 5/62,5	5	2,5	612,9	N
HBW 5/25	5	1	245,2	N
HBW 2,5/187,5	2,5	30	1,839	kN
HBW 2,5/62,5	2,5	10	612,9	N
HBW 2,5/31,25	2,5	5	306,5	N
HBW 2,5/15,625	2,5	2,5	153,2	N
HBW 2,5/6,25	2,5	1	61,29	N
HBW 1/30	1	30	294,2	N
HBW 1/10	1	10	98,07	N
HBW 1/5	1	5	49,03	N
HBW 1/2,5	1	2,5	24,52	N
HBW 1/1	1	1	9,807	N

Table 3 — Ratio $0{,}102 \times F/D^2$ for different metallic materials

Material	Brinell hardness HBW	Force-diameter ratio $0{,}102 \times F/D^2$ N/mm²
Steel, nickel alloys, titanium alloys		30
Cast iron [a]	< 140 ⩾ 140	10 30
Copper and copper alloys	< 35	5
	35 to 200	10
	> 200	30
Light metals and their alloys	< 35	2,5
	35 to 80	5 10 15
	> 80	10 15
Lead, tin		1
Sintered metal	According to ISO 4498-1	

[a] For the testing of cast iron, the nominal diameter of the ball shall be 2,5 mm, 5 mm or 10 mm.

8 Uncertainty of the results

A complete evaluation of the uncertainty should be done according to the *Guide to the expression of uncertainty in measurement* (GUM) [1].

Independent of the type of sources, for hardness, there are two possibilities for the determination of the uncertainty.

— One possibility is based on the evaluation of all relevant sources appearing during a direct calibration. As a reference, an EA guideline [2] is available.

— The other possibility is based on indirect calibration using a hardness-reference block, abbreviated below as CRM (certified reference material) (see References [2] to [5]). A guideline for the determination is given in Annex C.

It may not always be possible to quantify all the identified contributions to the uncertainty. In this case, an estimate of type A standard uncertainty may be obtained from the statistical analysis of repeated indentations into the test piece. Care should be taken, if standard uncertainties of type A and B are summarized, that the contributions are not counted twice (see Clause 4 of GUM:1993 [1]).

9 Test report

The test report shall include the following information:

a) a reference to this part of ISO 6506;

b) all details necessary for the complete identification of the test piece;

c) the test temperature, if it is not within the limits 10 °C to 35 °C;

d) the result obtained;

e) additional requirements outside the scope of this part of ISO 6506;

f) details of any occurrence which may have affected the result.

There is no general process of accurately converting Brinell hardness into other scales of hardness or into tensile strength. These conversions should therefore be avoided, unless a reliable basis for the conversion can be obtained by comparative tests.

NOTE It should be noted that for anisotropic materials, for example, those which have been heavily cold-worked, there may be a difference between the lengths of the two diameters of the indentation. The specification for the product may indicate limits for such differences.

Annex A
(informative)

Procedure for periodic checking of the testing machine by the user

A check of the machine should be carried out on each day that the machine is used, at approximately each hardness level, and for each range or scale that is to be used.

Prior to making the check, the measuring device should be indirectly verified (for each range/scale and hardness level) using a reference indentation on a hardness-reference block, calibrated in accordance with ISO 6506-3. The measured dimension should agree with the certified value to within 0,5 %. If the measuring device fails this test, appropriate action should be taken.

The check involves at least one indentation being made on a hardness-reference block, calibrated in accordance with ISO 6506-3. If the difference between the mean measured hardness and the block's certified value is within the permissible error limits given in Table 2 of ISO 6506-2:2005, the machine may be regarded as satisfactory. If not, an indirect verification should be performed.

A record of these results should be maintained over a period of time, and used to measure reproducibility and monitor drift of the machine.

Annex B
(normative)

Minimum thickness of the test piece in relation to the mean diameter of indentation

Table B.1

Dimensions in millimetres

Mean diameter of the indentation d	Minimum thickness of the test piece			
	D = 1	D = 2,5	D = 5	D = 10
0,2	0,08			
0,3	0,18			
0,4	0,33			
0,5	0,54			
0,6	0,80	0,29		
0,7		0,40		
0,8		0,53		
0,9		0,67		
1,0		0,83		
1,1		1,02		
1,2		1,23	0,58	
1,3		1,46	0,69	
1,4		1,72	0,80	
1,5		2,00	0,92	
1,6			1,05	
1,7			1,19	
1,8			1,34	
1,9			1,50	
2,0			1,67	
2,2			2,04	
2,4			2,46	1,17
2,6			2,92	1,38
2,8			3,43	1,60
3,0			4,00	1,84
3,2				2,10
3,4				2,38
3,6				2,68
3,8				3,00
4,0				3,34
4,2				3,70
4,4				4,08
4,6				4,48
4,8				4,91
5,0				5,36
5,2				5,83
5,4				6,33
5,6				6,86
5,8				7,42
6,0				8,00

Annex C
(informative)

Uncertainty of the measured hardness values

C.1 General requirements

The approach for determining uncertainty, presented in this annex, considers only those uncertainties associated with the overall measurement performance of the hardness testing machine with respect to the hardness-reference blocks (abbreviated as CRM below). These performance uncertainties reflect the combined effect of all the separate uncertainties (indirect verification). Because of this approach, it is important that the individual machine components are operating within the tolerances. It is strongly recommended that this procedure be applied for a maximum of one year after the successful passing of a direct verification.

Figure C.1 shows the four-level structure of the metrological chain necessary to define and disseminate hardness scales. The chain starts at the **international level**, using international definitions of the various hardness scales to carry out international intercomparisons. A number of *primary hardness standard machines* at the **national level** "produce" *primary hardness-reference blocks* for the calibration laboratory level. Naturally, direct calibration and the verification of these machines should be at the highest possible accuracy.

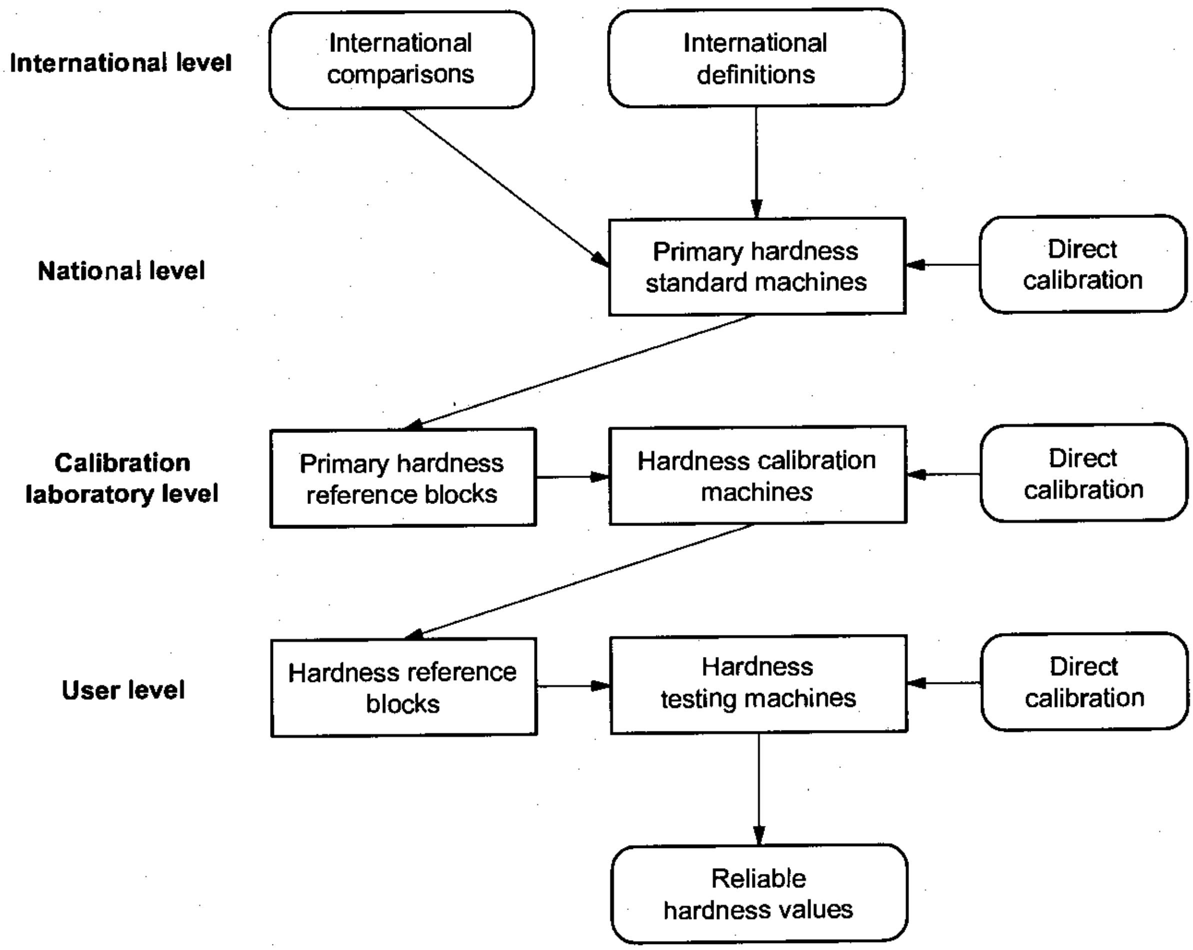


Figure C.1 — Structure of the metrological chain for the definition and dissemination of hardness scales

C.2 General procedure

The procedure calculates a combined uncertainty u_I by the Root-Squared-Sum-Method (RSS) out of the different sources given in Table C.1. Table C.1 contains all symbols used and their designations. The expanded uncertainty, U, is derived from u_I by multiplying with the coverage factor $k = 2$.

C.3 Bias of the machine

The bias b of a hardness testing machine (also named error), which is derived from the difference between

— the mean value of the five indentations during calibration of the hardness testing machine, and

— the calibration value of the hardness-reference block,

can be implemented in different ways into the determination of uncertainty.

C.4 Procedures for calculating uncertainty: hardness measurement values

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

C.4.1 Procedure without bias (method 1)

Method 1 (abbreviated as M1) is a simplified method, which can be used without considering the systematic error of the hardness testing machine.

In M1, the error limit (that means the range in which the machine is allowed to differ from the reference standard), is used to define the source u_E of the uncertainty. There is no correction of the hardness values with respect to the error.

The procedure for the determination of U is explained in Table C.1 (see References [1] and [2] in the Bibliography).

$$U = k \cdot \sqrt{u_E^2 + u_{CRM}^2 + u_H^2 + u_{\bar{x}}^2 + u_{ms}^2} \quad (C.1)$$

where the result of the measurement is given by

$$\bar{X} = \bar{x} \pm U \quad (C.2)$$

C.4.2 Procedure with bias (method 2)

As an alternative to M1, the method 2 (abbreviated as M2) may be used. This is correlated with the conduct of a control chart. M2 may lead to smaller values of uncertainty.

The error b (step 10) can be expected to be a systematic effect. In GUM [1], it is recommended to use a correction to compensate for such systematic effects. This is the base of M2. The error limit u_E is no longer in the calculation of the uncertainty but all determined hardness values have to be corrected by b or U_{corr} has to be increased by b. The procedure for the determination of U_{corr} is explained in Table C.1 (see References [4] and [5]).

$$U_{corr} = k \sqrt{u_{CRM}^2 + u_H^2 + u_{\bar{x}}^2 + u_{ms}^2 + u_b^2} \quad (C.3)$$

where the result of the measurement is given by

$$\overline{X}_{\text{corr}} = (\overline{x} + \overline{b}) \pm U_{\text{corr}} \tag{C.4}$$

or by

$$\overline{X}_{u\,\text{corr}} = \overline{x} \pm \left(U_{\text{corr}} + \left|\overline{b}\right|\right) \tag{C.5}$$

depending on whether the bias (error) $\overline{b}$ is thought to be part of the mean value or of the uncertainty.

C.5 Expression of the result of measurement

For the expression of the result of measurement, the method used should be indicated. In general, as a result of the measurement, method 1 [Equation (C.2)] should be used (see also Table C.1, step 12).

Table C.1 — Determination of the expanded uncertainty according to methods M1 and M2

Step Method	Sources of uncertainty	Symbols	Formula	Literature/Certificate	Example [..] = HBW 2,5/187,5
1 M1	Standard uncertainty according to the (1σ) maximum permissible error	u_E	$u_E = \frac{u_{E,2r} \cdot \bar{x}_{CRM}}{2,8}$	Permissible error $u_{E,2r}$ according to ISO 6506-2:2005 Table 2 $\bar{x}_{CRM}$ according to calibration certificate of CRM. See Note 1.	$u_E = \frac{0,02 \times 246,8}{2,8} = 1,76$
2 M1 M2	Standard uncertainty of hardness of CRM (for detailed calculation see ISO 6506-3:2005, Table A.4)	u_{CRM}	$u_{CRM} = \frac{U_{CRM}}{2}$	U_{CRM} according to calibration certificate of CRM See Note 2.	$u_{CRM} = \frac{2,2}{2} = 1,10$
3 M1 M2	Mean value ($\bar{H}$) and standard deviation (s_H) of the measurement on CRM	$\bar{H}$ s_H	$\bar{H} = \frac{\sum_{i=1}^{n} H_i}{n}$ $s_H = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(H_i - \bar{H})^2}$	H_i according to ISO 6506-2:2005, Subclause 5.7 For the calculation of s_H, the larger value of s_{H1} and s_{H2} will be taken.	Single values H_i: (1) 246,0 – 245,0 – 246,0 – 246,0 – 246,0 $\bar{H}_1 = 245,8$; $s_{H1} = 0,45$ (2) 245,0 – 246,0 – 247,0 – 246,0 – 247,0 $\bar{H}_2 = 246,2$; $s_{H2} = 0,84$
4 M1 M2	Standard uncertainty of hardness testing machine when measuring CRM	$u_{\bar{H}}$	$u_{\bar{H}} = \frac{t \cdot s_H}{\sqrt{n}}$	$t = 1,14$ for $n = 5$	$u_{\bar{H}} = \frac{1,14 \times 0,84}{\sqrt{5}} = 0,43$
5 M1 M2	Mean value $(\bar{x})$ and standard deviation (s_x) of the testing of a test piece	$\bar{x}$ s_x	$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$ $s_x = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2}$	$n = 5$ 5 measurements on the test piece. See Note 3. If $n = 1$, $s_x = 0$. The certificate should state that the uncertainty applies only to the specific reading, not to the test piece as a whole	Single values 288,0 – 290,0 – 285,0 – 285,0 – 282,0 $\bar{x} = 286,0$ $s_x = 3,08$

Table C.1 (*continued*)

Step Method	Sources of uncertainty	Symbols	Formula	Literature/Certificate	Example [..] = HBW 2,5/187,5
6 M1 M2	Standard uncertainty when measuring a test piece	$u_{\bar{x}}$	$u_{\bar{x}} = \frac{t \cdot s_x}{\sqrt{n}}$	t = 1,14	$u_{\bar{x}} = \frac{1,14 \times 3,08}{\sqrt{5}} = 1,57$
7 M2	Standard uncertainty according to the resolution of the length measuring system	u_{ms}	$u_{ms} = \frac{\delta_{ms}}{2\sqrt{3}}$	δ_{ms} = 1 HBW	$u_{ms} = \frac{1}{2\sqrt{3}} = 0,29$
8 M2	Deviation of hardness testing machine from calibration value	b	$b = \bar{H} - \bar{x}_{CRM}$	Steps 2 and 3. See Note 4	$b_1 = 245,8 - 246,8 = -1,0$ $b_2 = 246,2 - 246,8 = -0,6$
9 M2	Standard deviation of the deviation b	s_b	$\bar{b} = \frac{1}{n_m}\sum_{i=1}^{n_m} b_i$ $s_b = \sqrt{\frac{1}{n_m - 1}\sum_{i=1}^{n_m}(b_i - \bar{b})^2}$	Step 8 for n_m = 2 number of measurement series	$\bar{b} = -0,8$ $s_b = 0,28$
10 M2	Standard uncertainty of the determination of b. Can be determined only after the second series of measurements	u_b	$u_b = \frac{t \cdot s_b}{\sqrt{n_m}}$	Step 9 t = 1,84 for n_m = 2 See Note 5	$u_b = \frac{1,84 \times 0,28}{\sqrt{2}} = 0,36$
11 M1	Determination of the expanded uncertainty	U	$U = k \cdot \sqrt{u_E^2 + u_{CRM}^2 + u_{\bar{H}}^2 + u_{\bar{x}}^2 + u_{ms}^2}$	Step 1 to 7 k = 2	$U = 2 \cdot \sqrt{1,76^2 + 1,10^2 + 0,43^2 + 1,59^2 + 0,29^2}$ U = 5,3 HBW
12 M1	Result of the measurement	$\bar{X}$	$\bar{X} = \bar{x} \pm U$	Steps 5 and 11	$\bar{X}$ = (286,0 ± 5,3) HBW (M1)
13 M2	Determination of the corrected expanded uncertainty	U_{corr}	$U_{corr} = k \cdot \sqrt{u_{CRM}^2 + u_{\bar{H}}^2 + u_{\bar{x}}^2 + u_{ms}^2 + u_b^2}$	Step 2 to 7 and 10 k = 2	$U_{corr} = 2 \cdot \sqrt{1,10^2 + 0,43^2 + 1,59^2 + 0,29^2 + 0,36^2}$. U_{corr} = 4,1 HBW

14 **M2**	Result of the measurement with corrected mean value	$\overline{X}_{corr}$	$\overline{X}_{corr} = (\overline{x} + \overline{b}) \pm U_{corr}$	Steps 5, 8 and 13	$\overline{X}_{corr} = (285{,}2 \pm 4{,}1)$ HBW (M2)
15 **M2**	Result of the measurement with corrected uncertainty	$\overline{X}_{u\,corr}$	$\overline{X}_{u\,corr} = \overline{x} \pm (U_{corr} + \lvert\overline{b}\rvert)$	Steps 5, 8 and 13	$\overline{X}_{u\,corr} = (286{,}0 \pm 4{,}9)$ HBW (M2)

NOTE 1 The factor 2,8 is derived from the determination of the standard uncertainty for a rectangular distribution, based on experiments.

NOTE 2 If necessary, the hardness change of the CRM has to be considered.

NOTE 3 If between the measurement of the CRM and the test piece, the optics of the device are changed, the corresponding influence should be considered.

NOTE 4 If $0{,}8\, u_{E,2r} < b < 1{,}0\, u_{E,2r}$, the relationship of hardness values between CRM and sample should be considered.

NOTE 5 Because, for $n_m = 2$, in the uncertainty u_b the influence of the long-term change of b is not contained, for critical applications it may be necessary to raise the number of measurements n_m.

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