
**Metallic materials — Vickers hardness
test —**

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

Matériaux métalliques — Essai de dureté Vickers —

Partie 2: Vérification et étalonnage des machines d'essai



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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

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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 6507-2 was prepared by Technical Committee ISO/TC 164, *Mechanical testing of metals*, Subcommittee SC 3, *Hardness testing*.

This ~~fourth~~^{third} edition cancels and replaces the ~~third~~^{second} edition (ISO 6507-2:2005~~1997~~), which has been technically revised.

ISO 6507 consists of the following parts, under the general title *Metallic materials — Vickers 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 — Vickers hardness test —

Part 2: Verification and calibration of testing machines

1 Scope

This part of ISO 6507 specifies a method of verification of testing machines for determining Vickers hardness in accordance with ISO 6507-1.

It specifies a direct verification method for checking the main functions of the machine operation, and an indirect method suitable for the overall checking of the machine. The indirect method may be used on its own for periodic routine checking of the machine in service.

If a testing machine is also to be used for other methods of hardness testing, it shall be verified independently for each method.

This part of ISO 6507 is ~~not~~ applicable to ~~portable~~ hardness testing machines based on different measurement principles, e. g., ultrasonic impedance method.

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

ISO 3878, *Hardmetals — Vickers hardness test*

ISO 6507-1:2005, *Metallic materials — Vickers hardness test — Part 1: Test method*

ISO 6507-3, *Metallic materials — Vickers hardness test — Part 3: Calibration of reference blocks*

3 General conditions

Before a Vickers hardness testing machine is verified, the machine shall be checked to ensure that it is properly set up in accordance with the manufacturer's instructions:

Especially, it should be checked that:

- a) the plunger holding the indenter is capable of sliding in its guide;
- b) the indenter-holder is firmly mounted in the plunger;
- c) the test force can be applied and removed without shock, ~~or~~ vibration or overshoot and in such a manner that the readings are not influenced;

- d) if the measuring system is integral with the machine
 - the change from removing the test force to measuring mode does not influence the readings,
 - illumination does not affect the readings,
 - the centre of the indentation is in the centre of the field of view, if necessary.

The illumination device of the measuring microscope shall produce uniform lighting of the whole observed field and maximum contrast between the indentation and the surrounding surface.

It is recommended that calibrations and verifications of Vickers hardness testing machines be conducted by laboratories accredited to the requirements of ISO/IEC 17025 (or an equivalent) by an accrediting body recognized by the International Laboratory Accreditation Cooperation (ILAC) as operating to the requirements of ISO/IEC 17011

4 Direct verification

4.1 General

4.1.1 Direct verification should be carried out at a temperature of (23 ± 5) °C. If the verification is made outside this temperature range, this shall be reported in the verification report.

4.1.2 The instruments used for verification and calibration shall be traceable to national standards.

4.1.3 Direct verification involves:

- a) calibration of the test force;
- b) verification of the indenter;
- c) calibration of the measuring system;
- d) verification of the testing cycle.

4.2 Calibration of the test force

4.2.1 Each test force used within the working range of the testing machine shall be measured. Whenever applicable, this shall be done at not less than three positions of the plunger uniformly spaced throughout its range of movement during testing.

For testing machines whose test force is apparently not influenced by the position of the plunger, e. g., closed-loop controlled loading system, the test force can be calibrated in one position.

4.2.2 Three readings shall be taken for each test force at each position of the plunger. Immediately before each reading is taken, the plunger shall have been moved in the same direction as during testing.

4.2.3 The test force shall be measured by one of the following two methods:

- by means of an elastic proving device in accordance with [the minimum of ISO 376:2004](#), class 1, or
- by balancing against a force, accurate to $\pm 0,2$ %, applied by means of calibrated masses or another method with the same accuracy.

4.2.4 Each measurement of the force shall be within the tolerances of the nominal value of the test force, as given in Table 1.

Table 1

Ranges of the test force, F N	Tolerances %
$F \geq 1,961$	$\pm 1,0$
$0,098\ 07 \leq F < 1,961$	$\pm 1,5$

4.3 Verification of the indenter

4.3.1 The four faces of the square-based diamond pyramid shall be polished and free from surface defects.

4.3.2 The verification of the shape of the indenter can be made by direct measurement or by measurement of its projection on a screen.

4.3.3 The angle between the opposite faces at the vertex of the diamond pyramid shall be $136^\circ \pm 0,5^\circ$ (see Figure 1).

NOTE The angle between the opposite faces may also be determined by the angle between the opposite edges; this value is $148,11^\circ \pm 0,76^\circ$.

4.3.4 The angle between the axis of the diamond pyramid and the axis of the indenter-holder (normal to the seating surface) shall be less than $0,50^\circ$. The four faces shall meet at a point; the maximum permissible length of the line of conjunction between opposite faces is given in Table 2 (see also Figure 2).

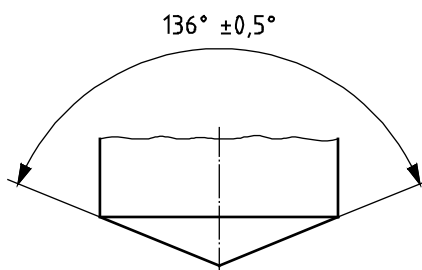
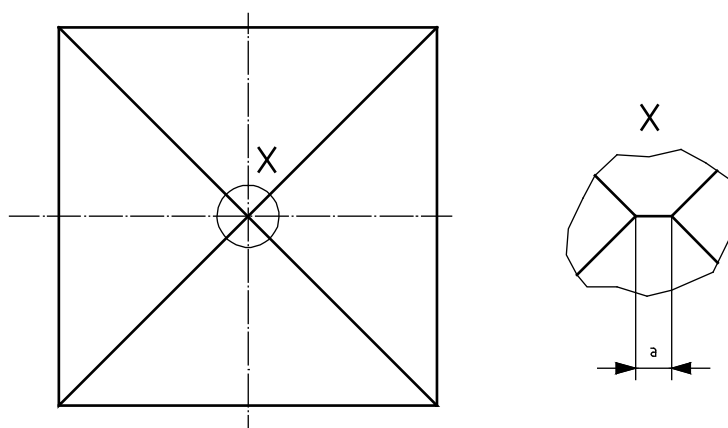


Figure 1 — Angle of the diamond pyramid



Key

a = length of line of conjunction

Figure 2 — Line of conjunction on the top of the indenter (schematic)

Table 2

Ranges of test force, F N	Maximum permissible length of the line of conjunction, a mm
$F \geq 49,03$	0,002
$1,961 \leq F < 49,03$	0,001
$0,098\ 07 \leq F < 1,961$	0,000 5

4.4 Calibration of the measuring system

4.4.1 The resolution required of the measuring system depends on the size of the smallest indentation to be measured.

The scale of the measuring system shall be graduated to permit estimation of the diagonals of the indentation in accordance with Table 3.

Table 3

Diagonal length, d mm	Resolution of the measuring system	Maximum permissible error
$d \leq 0,040$	0,000 2 mm	0,000 4 mm
$0,040 < d \leq 0,200$	0,5 % of d	1,0 % of d
$d > 0,200$	0,001 mm	0,002 mm

NOTE The diagonal length of the indentation determines the necessary magnification V of the measuring system according to the following condition:
 $V \times d \geq 14$ mm
 For indentation diagonals $d < 0,035$ mm this condition may not be fulfilled, but the magnification should be at least $\times 400$.

The resolution of the measuring system for Vickers hardness testing of hardmetals is specified in ISO 3878.

4.4.2 The measuring system shall be verified by measurements made on an object micrometer at a minimum of five intervals over each working range.

The maximum permissible error shall not exceed the values given in Table 3.

4.5 Verification of the testing cycle

The testing cycle shall be timed with an uncertainty of $\pm 1,0$ s and shall conform to the testing cycle of ISO 6507-1.

5 Indirect verification

5.1 Verification temperature

Indirect verification should be carried out at a temperature of (23 ± 5) °C by means of reference blocks calibrated in accordance with ISO 6507-3. If the verification is made outside this temperature range, this shall be reported in the verification report.

~~5.2—On each reference block, the reference indentation shall be measured. For each block, the difference between the mean measured value and the certified mean diagonal shall not exceed the maximum permissible errors given in Table 3.~~

5.23 Test force and hardness levels

The machine shall be verified at each test force which is used. For each test force, two reference blocks shall be selected from the hardness ranges specified below. The blocks shall be chosen so that at least one reference block in each hardness range is used for the verification.

— ≤ 225 HV

— 400 HV to 600 HV

— > 700 HV

5.34 Testing machines with one test force

When verifying testing machines using only one test force, three reference blocks shall be used, one in each of the ranges specified in 5.2.

5.45 Number of indentations

On each reference block, five indentations shall be made and measured. The test shall be carried out in accordance with ISO 6507-1.

5.56 Testing machines to used for one hardness level

For special purposes, a hardness testing machine may be verified at one hardness value only, corresponding approximately to that of the tests to be made.

5.67 Verification result

For each reference block, let d_1, d_2, d_3, d_4, d_5 be the arithmetic mean values of the measured lengths of the two diagonals of the indentations, arranged in increasing order of magnitude, and

$$\bar{d} = \frac{d_1 + d_2 + d_3 + d_4 + d_5}{5} \quad (1)$$

5.78 Repeatability

The repeatability of the testing machine, under the particular verification conditions, is determined by the difference

$$r = d_5 - d_1 \quad (2)$$

The repeatability, expressed as a percentage of \bar{d} , is calculated as:

$$r_{\text{rel}} = 100 \times \frac{d_5 - d_1}{\bar{d}} \quad (3)$$

The repeatability of the testing machine verified is not considered satisfactory unless it satisfies the conditions given in Table 4.

Table 4

Hardness of the reference block	Maximum permissible repeatability of the testing machine $r_{rel.}\%$		
	HV 5 to HV 100	HV 0,2 to HV 5	< HV 0,2
≤ 225 HV	3,0 ^a	6,0 ^a	9,0 ^a
> 225 HV	2,0 ^a	4,0 ^a	5,0 ^a

^a or 0,001 mm, whichever is greater.

Hardness of the reference block	Repeatability of the testing machine max						
	$r_{rel.}\%$			r_{HV}^b			
	HV 5 to HV 100	HV 0,2 to HV 5	< HV 0,2	HV 5 to HV 100		HV 0,2 to < HV 5	
			Hardness of the reference block	HV	Hardness of the reference block	HV	
≤ 225 HV	3,0 ^a	6,0 ^a	9,0 ^a	100	6	100	12
				200	12	200	24
> 225 HV	2,0 ^a	4,0 ^a	5,0 ^a	250	10	250	20
				350	14	350	28
				600	24	600	48
				750	30	750	60

^a or 0,001 mm, whichever is greater.
^b HV: Vickers hardness.

5.89 Bias

The bias error, b_E , of the testing machine under the particular verification conditions is characterized by the difference:

$$b = \bar{H} - H_C \quad E = \bar{H} - H_C \tag{4}$$

where

$$\bar{H} = \frac{H_1 + H_2 + H_3 + H_4 + H_5}{5} \tag{5}$$

where

H_1, H_2, H_3, H_4, H_5 are the hardness values corresponding to d_1, d_2, d_3, d_4, d_5 ;

H_C is the certified specified hardness of the reference block used.

The percent bias error, $b_{E,rel}$, is calculated by the following equation:

$$b_{rel} = 100 \cdot \frac{\bar{H} - H_c}{H_c} \quad E_{rel} = 100 \times \frac{\bar{H} - H_c}{H_c} \quad (6)$$

The maximum **biaserror** of the testing machine, expressed as a percentage of the specified hardness of the reference block, shall not exceed the values given in Table 5.

Table 5

Hardness symbol	Maximum permissible percentage biaserror bE_{rel} , of the hardness testing machine															
	Hardness, HV															
	50	100	150	200	250	300	350	400	450	500	600	700	800	900	1 000	1 500
HV 0,01																
HV 0,015	10															
HV 0,02	8															
HV 0,025	8	10														
HV 0,05	6	8	9	10												
HV 0,1	5	6	7	8	8	9	10	10	11							
HV 0,2		4		6		8		9		10	11	11	12	12		
HV 0,3		4		5		6		7		8	9	10	10	11	11	
HV 0,5		3		5		5		6		6	7	7	8	8	9	11
HV 1		3		4		4		4		5	5	5	6	6	6	8
HV 2		3		3		3		4		4	4	4	4	5	5	6
HV 3		3		3		3		3		3	4	4	4	4	4	5
HV 5		3		3		3		3		3	3	3	3	3	4	4
HV 10		3		3		3		3		3	3	3	3	3	3	3
HV 20		3		3		3		3		3	3	3	3	3	3	3
HV 30		3		3		2		2		2	2	2	2	2	2	2
HV 50		3		3		2		2		2	2	2	2	2	2	2
HV 100				3		2		2		2	2	2	2	2	2	2

NOTE 1 Values are not given when the length of the indentation diagonal is less than 0,020 mm.

NOTE 2 For intermediate values, the maximum permissible error may be obtained by interpolation.

NOTE 3 The values for microhardness testing machines are based on a maximum permissible error of 0,001 mm or 2 % of the mean diagonal length of indentation, whichever is the greater.

5.940 **Uncertainty of calibration**

The determination of the uncertainty of measurement of the calibration results of the hardness testing machine is given in Annex B.

6 Intervals between verifications

The specifications for the direct verifications of hardness testing machines are given in Table 6.

Indirect verification shall be performed at least once every 12 months and after a direct verification has been performed.

Table 6

Requirements of verification	Force	Measuring device	Test cycle	Indenter ^a
Before setting to work first time	x	x	x	x
After dismantling and reassembling, if force, measuring system or test cycle are affected	x	x	x	
Failure of indirect verification ^b	x	x	x	
Indirect verification > 14 months ago	x	x	x	

^a In addition, it is recommended that the indenter be directly verified after 2 years of use.

^b Direct verification of these parameters may be carried out sequentially (until the machine passes indirect verification) and is not required if it can be demonstrated (e.g. by tests with a reference indenter) that the indenter was the cause of the failure.

7 Verification report/calibration certificate

The verification report/calibration certificate shall include the following information:

- a) a reference to this part of ISO 6507;
- b) method of verification (direct and/or indirect);
- c) identification data of the hardness testing machine;
- d) means of verification (reference blocks, elastic proving devices, etc);
- e) test forces verified;
- f) verification temperature;
- g) the result obtained;
- h) date of verification and reference to the verification institution;
- i) uncertainty of the verification result.

Annex A (informative)

Notes on diamond indenters

Experience has shown that a number of initially satisfactory indenters can become defective after use for a comparatively short time. This is due to small cracks, pits or other flaws in the surface. If such faults are detected in time, many indenters may be reclaimed by regrinding. If not, any small defects on the surface rapidly worsen and make the indenter useless.

Therefore,

- the condition of indenters should be monitored by visually checking the aspect of the indentation on a reference block, each day the testing machine is used;
- the verification of the indenter is no longer valid when the indenter shows defects;
- reground or otherwise repaired indenters shall be reverified.

Annex B (informative)

Uncertainty of measurement of the calibration results of the hardness testing machine

The metrological chain necessary to define and disseminate hardness scales is shown in Figure D.1 in ISO 6507-1:2005.

B.1 Direct calibration of the hardness testing machine

B.1.1 Calibration of the test force

The combined relative standard uncertainty of the test force calibration is calculated according to the following equation:

$$u_F = \sqrt{u_{FRS}^2 + u_{FHTM}^2} \quad (\text{B.1})$$

where

u_{FRS} is the relative uncertainty of measurement of the force transducer (from calibration certificate);

u_{FHTM} is the relative standard uncertainty of the test force generated by the hardness testing machine.

The uncertainty of measurement of the reference instrument, force transducer, is indicated in the corresponding calibration certificate. The influence quantities, like

- temperature dependence,
- long-term stability, and
- interpolation deviation,

should be considered for critical applications. Depending on the design of the force transducer, the rotational position of the transducer related to the indenter axis of the hardness testing machine should be considered.

EXAMPLE

Uncertainty of measurement of the force transducer (from calibration certificate): $U_{FRS} = 0,12 \% (k = 2)$

Calibration value of the force transducer $F_{RS} = 294,2 \text{ N}$

Table B.1 — Results of the test force calibration

Number of height position for test force calibration i	Series 1 $\frac{F_{i1} F_{i2}}{N}$	Series 2 $\frac{F_{i2} F_{i3}}{N}$	Series 3 $\frac{F_{i3} F_{i4}}{N}$	Mean value $\frac{F_i}{N}$, N	Relative deviation $\frac{\Delta F_{rel,i}}{\bar{F}}$, %	Relative standard measurement uncertainty $\frac{u_{FHTM,i}}{\bar{F}}$, %
1	294,7	294,9	294,5	294,7	0,2017	0,04
2	293,9	294,5	294,6	294,3	0,003	0,1107
3	293,1	294,0	293,7	293,6	-0,2220	0,1709

where

$$\Delta F_{rel,i} = \frac{\bar{F}_i - F_{RS}}{F_{RS}} \quad \Delta F_{rel} = \frac{F_{RS} - \bar{F}}{\bar{F}} \tag{B.2}$$

$$u_{FHTM,i} = \frac{s_{F_i}}{\bar{F}_i} \cdot \frac{t}{\sqrt{n}} \quad u_{FHTM} = \frac{s_{F_i}}{\bar{F}} \cdot \frac{1}{\sqrt{n}}, \quad (n = 3, t = 1.32) \tag{B.3}$$

s_{F_i} is the standard deviation of the test-force indication values in the i -th height position.

In Table B.2, the maximum value of u_{FHTM} from Table B.1 is used.

Table B.2 — Calculation of the uncertainty of measurement of the test force

Quantity X_i	Estimated value x_i	Relative limit values a_i	Distribution type	Symbol	Relative standard measurement uncertainty $u(x_i)$	Sensitivity coefficient c_i	Relative uncertainty contribution $u_i(H)$
Force transducer u_{FRS}	294,2 N	$\pm 0.20\%$ ^a	Normal	u_{FRS}	$06,60 \times 10^{-34}$	1	$06,60 \times 10^{-34}$
Accuracy of generated force u_{FHTM}	0,06 N	$\pm 1\%$	Normal	u_{FHTM}	$19,70 \times 10^{-34}$	1	$19,70 \times 10^{-34}$
Relative combined standard uncertainty $u_{\underline{F}}$							$14,808 \times 10^{-3}$
Relative expanded uncertainty of measurement $U_{\underline{F}}(k = 2)$							$23,25 \times 10^{-3}$
^a The maximum permissible repeatability of Class 1 force proving device.							

Table B.3 — Calculation of the maximum relative deviation of the test force including the uncertainty of measurement of the reference instrument

Relative deviation of test force ΔF_{rel} %	Expanded relative measurement uncertainty of test force U_F %	Max. relative deviation of test force including measurement uncertainty of reference instrument ΔF_{max} %
-0,220	0,3522	0,5742

where

$$\Delta F_{\max} = |\Delta F_{\text{rel}}| + U_F \tag{B.4}$$

The result of the example means that the deviation of the test force, including the uncertainty of measurement of the reference instrument specified in 4.2 amounting to ± 1,0 % is complied with.

B.1.2 Calibration of the optical measuring system

The combined relative standard uncertainty of the reference instrument for the measuring system is calculated as follows:

$$u_L = \sqrt{u_{\text{LRS}}^2 + u_{\text{ms}}^2 + u_{\text{LHTM}}^2} \tag{B.5}$$

where

u_{LRS} is the relative uncertainty of measurement of the object micrometer (reference standard) from the calibration certificate for $k = 1$;

u_{ms} is the relative uncertainty of measurement due to the resolution of the measuring system;

u_{LHTM} is the relative standard uncertainty of measurement of the hardness testing machine.

The uncertainty of measurement of the reference instrument for the optical measuring system, the object micrometer, is indicated in the corresponding calibration certificate. The influence quantities, for example,

- temperature dependence,
- long-term stability, and
- interpolation deviation,

do not exert an essential influence on the uncertainty of measurement of the object micrometer.

EXAMPLE

Uncertainty of measurement of the object micrometer: $U_{\text{LRS}} = 0,000\ 5\ \text{mm}$ ($k = 2$)

Resolution of the measuring system $\delta_{\text{ms}} = 0,1\ \mu\text{m}$

Table B.4 — Results of the calibration of the measuring system

Indication value of the object micrometer $\frac{L_{RS,i}}{L_{RS}}$ mm	Series 1 $\frac{L_{i1}}{L_1}$ mm	Series 2 $\frac{L_{i2}}{L_2}$ mm	Series 3 $\frac{L_{i3}}{L_3}$ mm	Mean value $\frac{\bar{L}_i}{\bar{L}}$ mm	Relative deviation $\frac{\Delta L_{\text{rel},i}}{\bar{L}}$ %	Relative standard measurement uncertainty $\frac{u_{\text{LHTM},i}}{\bar{L}_{\text{HTM}}}$ %
0,05	0,050 0	0,050 0	0,050 1	0,050 04	0,07	0,097
0,10	0,100 2	0,100 0	0,100 1	0,100 1	0,10	0,086
0,20	0,200 1	0,199 9	0,200 1	0,200 0	0,02	0,043
0,30	0,299 7	0,300 1	0,300 1	0,300 0	− 0,01	0,064
0,40	0,400 2	0,400 1	0,400 3	0,400 2	0,05	0,024

where

$$u_{LHTM,i} = \frac{s_{L_i}}{L_i} \cdot \frac{t}{\sqrt{n}} u_{LHTM} = \frac{s_{L_i}}{L} \cdot \frac{1}{\sqrt{n}}, (n = 3, t = 1.32) \tag{B.6}$$

$$\Delta L_{rel,i} = \frac{\bar{L}_i - L_{RS,i}}{L_{RS,i}} \Delta L_{rel} = \frac{\bar{L} - L_{RS}}{L_{RS}} \tag{B.7}$$

s_{L_i} is the standard deviation of the length indication values for the i -th indication value of the object micrometer.

Table B.5 — Calculation of the uncertainty of measurement of the measuring system

Quantity X_i	Estimated value x_i	Limit value a_i	Distribution type	Symbol	Relative standard measurement uncertainty $u(x_i)$	Sensitivity coefficient c_i	Relative uncertainty contribution $u_i (H)$
<u>Object micrometer</u> L_{RS}	0,40 mm	0,5 μ m	Normal	u_{RS}	<u>64,39</u> $\times 10^{-4}$	1	<u>64,03</u> $\times 10^{-4}$
<u>Resolution of the measuring system</u> $\#ms$	0 mm	0,1 μ m	Rectangular	u_{ms}	$0,7 \times 10^{-4}$	1	$0,7 \times 10^{-4}$
<u>Accuracy of the measuring system</u> $\#LHTM$	0		Normal	u_{LHTM}	<u>86,87</u> $\times 10^{-4}$	1	<u>86,87</u> $\times 10^{-4}$
Relative combined uncertainty of measurement u_L , % (related to $L_{RS} = 0,4$ mm)							<u>0,1107</u>
Relative expanded uncertainty of measurement U_L ($k = 2$), %							<u>0,2214</u>

Table B.6 — Calculation of the maximum relative deviation of the measuring system including the uncertainty of measurement of the length reference instrument

Test length L_{RS}	Relative deviation of the measuring system ΔL_{rel}	Expanded relative uncertainty of measurement U_L	Max. relative deviation of measuring system incl. measurement uncertainty of length reference instrument ΔL_{max}
	%	%	%
0,40 mm	<u>0,405</u>	<u>0,2214</u>	<u>0,274</u>

where

$$\Delta L_{max} = |\Delta L_{rel}| + U_L \tag{B.8}$$

The result of the example means that the deviation of the measuring system, including the uncertainty of measurement of the length reference instrument specified in 4.4 amounting to $\pm 0,5$ % is complied with.

B.1.3 Verification of the indenter

The indenter, consisting of indenter tip and holder, cannot be verified, respectively calibrated, in-site. A valid calibration certificate of an accredited calibration laboratory shall exist which confirms the geometrical deviations of the indenter (see 4.3).

B.1.4 Verification of the test cycle

In 4.5, the permissible deviation for every section of the test cycle is stipulated as ± 0,5 s. While measuring with a usual time measuring system (stopwatch), the uncertainty of measurement can be indicated as 0,1 s. Therefore, an estimation of the uncertainty of measurement is not necessary.

B.2 Indirect verification of the hardness testing machine

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

The uncertainty of measurement of the indirect verification of the hardness testing machine follows from the equation:

$$u_{HTM} = \sqrt{u_{CRM}^2 + u_{CRM-D}^2 + u_H^2 + u_{ms}^2} \tag{B.9}$$

where

u_{CRM} is the calibration uncertainty of the hardness reference block according to the calibration certificate for $k = 1$;

u_{CRM-D} is the hardness change of the hardness reference block since its last calibration due to drift (negligible for use of the hardness reference block complying with the standard);

u_H is the standard uncertainty of hardness testing machine when measuring CRM;

u_{ms} is the uncertainty due to the resolution of the hardness testing machine.

EXAMPLE

Hardness of the hardness reference block $H_{CRM} = (400,0 \pm 5,0) \text{ HV30}$

Uncertainty of measurement of the hardness reference block $U_{CRM} = \pm 5,0 \text{ HV30}$

Resolution of the hardness testing machine $\delta_{ms} = 0,1 \mu\text{m}$

Table B.7 — Results of the indirect verification

No.	Measured indentation diagonal d , mm	Calculated hardness value H , HV ^a
1	0,371 6 _{min}	402,9 _{max}
2	0,372 4	401,1
3	0,372 8 _{max}	400,3 _{min}
4	0,371 9	402,2
5	0,372 2	401,5
Mean value \bar{H}	0,372 2	401,6
Standard deviation s_H		0,99

^a HV: Vickers hardness.

$$\begin{aligned} \bar{b} &= \bar{H} - H_{CRM} \\ \bar{b} &= 401,6 - 400,0 = 1,6 \text{ HV} \end{aligned} \tag{B.10}$$

$$u_H = \frac{t \cdot s_H}{\sqrt{n}} \tag{B.11}$$

For $t = 1,15$, $n = 5$ and $s_H = 0,99$ HV follows:

$$u_H = 0,51 \text{ HV}$$

B.3 Budget of uncertainty of measurement

Table B.8 — 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 $u_i(H)$
u_{CRM}	400 HV ^b	2,50 HV	Normal	1,0	2,50 HV
u_H	0 HV	0,51 HV	Normal	1,0	0,51 HV
u_{ms}	0 HV	0,000 03 mm	Rectangular	2 145,1 ^a	0,06 HV
u_{CMR-D}	0 HV	0 HV	Triangular	1,0	0 HV
Combined uncertainty of measurement u_{HTM}					2,55 HV
Expanded uncertainty of measurement $U_{HTM} (k = 2)$					5,1 HV
^a $c = \partial H / \partial d = 2(H/d)$ for $H = 400$ HV30 and $d = 0,372 9$ mm.					
^b HV: Vickers hardness.					

Table B.9 — Maximum deviation of the hardness testing machine including the uncertainty of measurement

Measured hardness on the hardness testing machine H	Expanded uncertainty of measurement U_{HTM}	Deviation of the testing machine when calibrating with the reference block $ \bar{b} $	Maximum deviation of the testing machine including uncertainty of measurement ΔH_{HTMmax}
HV	HV	HV	HV
401,6 HV30	5,1	1,6	6,7
HV: Vickers hardness.			

where

$$\bar{b} = \bar{H} - H_{CRM} \tag{B.12}$$

$$\Delta H_{HTMmax} = U_{HTM} + |\bar{b}| = 5,1 + 1,6 = 6,7 \text{ HV}$$

The result of the example above means that the permissible limit deviation of the testing machine, including the uncertainty of measurement of the testing machine specified in Clause 5 amounting to $\pm 2\%$ ($\Delta H_{HTMmax} / H = 1,7\%$), is complied with.

Bibliography

- [1] SAWLA A. *Uncertainty of measurement in the verification and calibration of the force measuring systems of testing machines*, Proceedings of the Asia-Pacific symposium on measurement of force, mass and torque (APMF), Tsukuba, Japan, Novembre 2000
- [2] WEHRSTEDT A., PATKOVSKY I. *News in the field of standardization about verification and calibration of materials testing machines*, May 2001, EMPA Academy 2001
- [3] GABAUER W. *Manual codes of practice for the determination of uncertainties in mechanical tests on metallic materials, The estimation of uncertainties in hardness measurements*, Project No. SMT4-CT97-2165, UNCERT COP 14:2000
- [4] POLZIN, T., SCHWENK D. Method for Uncertainty Determination of Hardness Testing; PC File for Determination, *Materialprüfung* **44** (2002) 3, pp. 64–71

