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Fourth edition
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Metallic materials — Vickers hardness test —

Part 1:
Test method

Matériaux métalliques — Essai de dureté Vickers —

Partie 1: Méthode d'essai

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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).

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).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on 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 the following URL: www.iso.org/iso/foreword.html.

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

This fourth edition cancels and replaces the third edition (ISO 6507-1:2005), which has been technically revised.

The main changes compared to the previous edition are as follows:

— requirements for testing hardmetals and other cemented carbides have been added;

— all references of indentation diagonals, <0,020 mm, have been removed;

— resolution requirements for the measuring system have been defined;

— the lower test force limit of the Vickers microhardness test has been expanded to 0,009 807 N;

— requirements for the periodic (weekly or daily) verifications of the testing machine are normative, and the maximum permissible bias value has been revised. Requirements for the maximum permissible error in measuring a reference indentation have been revised;

— recommendations for inspection and monitoring of the indenter have been added;

— requirements have been added for the approach velocity of the indenter prior to contact with the sample surface;

— the timing requirements for the test force application and the duration at maximum test force have been revised to indicate target time values;

— Figure 2, which illustrates the requirements for the minimum distance between indentations, has been added, but the requirements have not changed;

— requirements have been added to the test report for reporting the test date and any hardness conversion method used;

— Annex D has been revised;

— Annexes E, F and G have been added concerning Vickers hardness measurement traceability, the CCM — Working group on hardness and adjustment of Köhler illumination systems.

A list of all parts in the ISO 6507 series can be found on the ISO website.

Metallic materials — Vickers hardness test —

Part 1:
Test method

1 Scope

This document specifies the Vickers hardness test method for the three different ranges of test force for metallic materials including hardmetals and other cemented carbides (see Table 1).

Table 1 — Ranges of test force

Ranges of test force, *F* N	Hardness symbol	Designation
$F \geq 49{,}03$	≥HV 5	Vickers hardness test
$1{,}961 \leq F < 49{,}03$	HV 0,2 to <HV 5	Low-force Vickers hardness test
$0{,}009\,807 \leq F < 1{,}961$	HV 0,001 to <HV 0,2	Vickers microhardness test

The Vickers hardness test is specified in this document for lengths of indentation diagonals between 0,020 mm and 1,400 mm. Using this method to determine Vickers hardness from smaller indentations is outside the scope of this document as results would suffer from large uncertainties due to the limitations of optical measurement and imperfections in tip geometry.

A periodic verification method is specified for routine checking of the testing machine in service by the user.

For specific materials and/or products, particular International Standards exist.

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 6507-2:2017, *Metallic materials — Vickers hardness test — Part 2: Verification and calibration of testing machines*

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

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:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at https://www.iso.org/obp

4 Principle

A diamond indenter, in the form of a right pyramid with a square base and with a specified angle between opposite faces at the vertex, is forced into the surface of a test piece followed by measurement of the diagonal length of the indentation left in the surface after removal of the test force, F (see Figure 1).

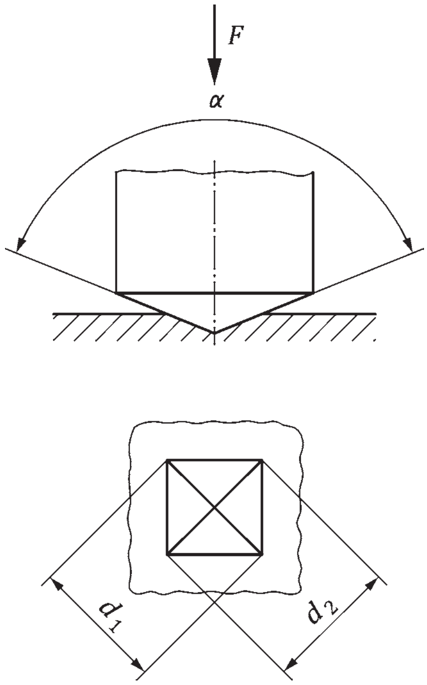


Figure 1 — Principle of the test, geometry of indenter and Vickers indentation

The Vickers hardness is proportional to the quotient obtained by dividing the test force by the area of the sloped surface of indentation, which is assumed to be a right pyramid with a square base and having at the vertex the same angle as the indenter.

NOTE 1 A right pyramid has its apex aligned with the centre of the base.

NOTE 2 As applicable, this document has adopted hardness test parameters as defined by the Working Group on Hardness (CCM-WGH) under the framework of the International Committee of Weights and Measures (CIPM) Consultative Committee for Mass and Related Quantities (CCM) (see Annex F).

5 Symbols and designations

5.1 Symbols and designations used in this document

See Table 2 and Figure 1.

Table 2 — Symbols and designations

Symbol	Designation
α	Mean angle between the opposite faces at the vertex of the pyramidal indenter (nominally 136°) (see Figure 1)
F	Test force, in newtons (N)
d	Arithmetic mean, in millimetres, of the two diagonal lengths d_1 and d_2 (see Figure 1)
HV	$\text{Vickers hardness} = \frac{\text{Test force (kgf)}}{\text{Surface area of indentation (mm}^2\text{)}}$ $= \frac{1}{g_n} \times \frac{\text{Test Force (N)}}{\text{Surface area of indentation (mm}^2\text{)}}$ $= \frac{1}{g_n} \times \frac{F}{d^2 / \left(2\sin\frac{\alpha}{2}\right)} = \frac{1}{g_n} \times \frac{2F\sin\frac{\alpha}{2}}{d^2}$ For the nominal angle α = 136°, $\text{Vickers hardness} \approx 0,1891 \times \frac{F}{d^2}$
NOTE 1 Standard acceleration due to gravity, g_n = 9,806 65 m/s^2 which is the conversion factor from kgf to N	
To reduce uncertainty, the Vickers hardness may be calculated using the actual mean indenter angle, α.	

5.2 Designation of hardness number

Vickers hardness, HV, is designated as shown in the following example.

640 HV 30 / 20

- 640 — Vickers hardness value
- HV — Hardness symbol
- 30 — Approximate kgf equivalent value of applied test force where (30 kgf = 294,2 N)
- / 20 — Duration time of test force (20 s) if not within the specified range (10 s to 15 s)

6 Testing machine

6.1 Testing machine

The testing machine shall be capable of applying a predetermined force or forces within the desired range of test forces, in accordance with ISO 6507-2.

6.2 Indenter

The indenter shall be a diamond in the shape of a right pyramid with a square base, as specified in ISO 6507-2.

6.3 Diagonal measuring system

The diagonal measuring system shall satisfy the requirements in ISO 6507-2.

Magnifications should be provided so that the diagonal can be enlarged to greater than 25 % but less than 75 % of the maximum possible optical field of view. Many objective lenses are nonlinear towards the edge of the field of view.

A diagonal measuring system using a camera for measurement can use 100 % of the camera's field of view provided it is designed to consider field of view limitations of the optical system.

The resolution required of the diagonal measuring system depends on the size of the smallest indentation to be measured and shall be in accordance with Table 3. In determining the resolution of the measuring system, the resolution of the microscope optics, the digital resolution of the measuring scale and the step-size of any stage movement, where applicable, should be taken into account.

Table 3 — Resolution of the measuring system

Diagonal length, *d* mm	**Resolution of the measuring system**
0,020 ≤ d < 0,080	0,000 4 mm
0,080 ≤ d ≤ 1,400	0,5 % of d

7 Test piece

7.1 Test surface

The test shall be carried out on a surface which is smooth and even, free from oxide scale, foreign matter and, in particular, completely free from lubricants, unless otherwise specified in product standards. The finish of the surface shall permit accurate determination of the diagonal length of the indentation.

For hardmetal samples, the thickness of the layer removed from the surface shall be not less than 0,2 mm.

7.2 Preparation

Surface preparation shall be carried out in such a way as to prevent surface damage or alteration of the surface hardness due to excessive heating or cold-working.

Due to the small depth of Vickers microhardness indentations, it is essential that special precautions be taken during preparation. It is recommended to use a polishing/electropolishing process which is suitable for the material to be measured.

7.3 Thickness

The thickness of the test piece or of the layer under test shall be at least 1,5 times the diagonal length of the indentation as defined in Annex A. No deformation shall be visible at the back of the test piece after the test.

The thickness of a hardmetal test piece shall be at least 1 mm.

NOTE The depth of the indentation is approximately 1/7 of the diagonal length (0,143 d).

7.4 Tests on curved surfaces

For tests on curved surfaces, the corrections given in Tables B.1 to B.6 shall be applied.

7.5 Support of unstable test pieces

For a test piece of small cross-section or of irregular shape, either a dedicated support should be used or it should be mounted in a similar manner to a metallographic micro-section in appropriate material so that it is adequately supported and does not move during the force application.

8 Procedure

8.1 Test temperature

The test is normally carried out at ambient temperature within the limits of 10 °C to 35 °C. If the test is carried out at a temperature outside this range, it shall be noted in the test report. Tests carried out under controlled conditions shall be made at a temperature of (23 ± 5) °C.

8.2 Test force

The test forces given in Table 4 are typical. Other test forces may be used including greater than 980,7 N, but not less than 0,009 807 N. Test forces shall be chosen that result in indentations with diagonals greater than 0,020 mm.

NOTE For hardmetals, the preferred test force is 294,2 N (HV 30).

Table 4 — Typical test forces

Hardness test[a]		Low-force hardness test		Microhardness test	
Hardness symbol	Nominal value of the test force, F N	Hardness symbol	Nominal value of the test force, F N	Hardness symbol	Nominal value of the test force, F N
—	—	—	—	HV 0,001	0,009 807
—	—	—	—	HV 0,002	0,019 61
—	—	—	—	HV 0,003	0,029 42
—	—	—	—	HV 0,005	0.049 03
HV 5	49,03	HV 0,2	1,961	HV 0,01	0,098 07
HV 10	98,07	HV 0,3	2,942	HV 0,015	0,147 1
HV 20	196,1	HV 0,5	4,903	HV 0,02	0,196 1
HV 30	294,2	HV 1	9,807	HV 0,025	0,245 2
HV 50	490,3	HV 2	19,61	HV 0,05	0,490 3
HV 100[a]	980,7	HV 3	29,42	HV 0,1	0,980 7

[a] Nominal test forces greater than 980,7 N may be applied.

8.3 Periodic verification

The periodic verification defined in Annex C shall be performed within a week prior to use for each test force used but is recommended on the day of use. The periodic verification is recommended whenever the test force is changed. The periodic verification shall be done whenever the indenter is changed.

8.4 Test piece support and orientation

The test piece shall be placed on a rigid support. The support 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 any displacement that affects the test result cannot occur during the test.

For anisotropic materials, for example, those which have been heavily cold-worked, there could be a difference between the lengths of the two diagonals of the indentation. Therefore, where possible, the indentation should be made so that the diagonals are oriented in plane at approximately 45° to the direction of cold-working. The specification for the product could indicate limits for the differences between the lengths of the two diagonals.

8.5 Focus on test surface

The diagonal measuring system microscope shall be focused so that the specimen surface and the desired test location can be observed.

NOTE Some testing machines do not require that the microscope be focused on the specimen surface.

8.6 Test force application

The indenter shall be brought into contact with the test surface and the test force shall be applied in a direction perpendicular to the surface, without shock, vibration or overload, until the applied force attains the specified value. The time from the initial application of the force until the full test force is reached shall be 7^{+1}_{-5} s.

NOTE 1 The requirements for the time durations are given with asymmetric limits. For example, 7^{+1}_{-5} s indicates that 7 s is the nominal time duration, with an acceptable range of not less than 2 s (calculated as 7 s – 5 s) to not more than 8 s (calculated as 7 s + 1 s).

For the Vickers hardness range and low-force Vickers hardness range tests, the indenter shall contact the test piece at a velocity of ≤0,2 mm/s. For micro-hardness tests, the indenter shall contact the test piece at a velocity of ≤0,070 mm/s.

The duration of the test force shall be 14^{+1}_{-4} s, except for tests on materials whose time-dependent properties would make this an unsuitable range. For these tests, this duration shall be specified as part of the hardness designation (see 5.2).

NOTE 2 There is evidence that some materials are sensitive to the rate of straining which causes changes in the value of the yield strength. The corresponding effect on the termination of the formation of an indentation can make alterations in the hardness value.

8.7 Prevention of the effect of shock or vibration

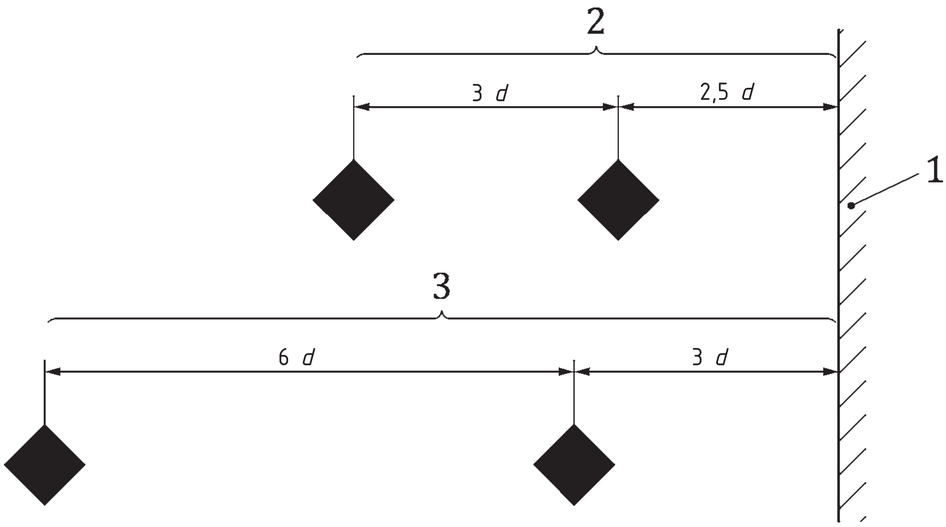
Throughout the test, the testing machine shall be protected from shock or vibration[5].

8.8 Minimum distance between adjacent indentations

The minimum distance between adjacent indentations and the minimum distance between an indentation and the edge of the test piece are shown in Figure 2.

The distance between the centre of any indentation and the edge of the test piece shall be at least 2,5 times the mean diagonal length of the indentation in the case of steel, copper and copper alloys and at least three times the mean diagonal length of the indentation in the case of light metals, lead and tin and their alloys.

The distance between the centres of two adjacent indentations shall be at least three times the mean diagonal length of the indentation in the case of steel, copper and copper alloys and at least six times the mean diagonal length in the case of light metals, lead and tin and their alloys. If two adjacent indentations differ in size, the spacing shall be based on the mean diagonal length of the larger indentation.



Key

1 edge of test piece

2 steel, copper and copper alloys

3 light metals, lead and tin and their alloys

Figure 2 — Minimum distance for Vickers indentations

8.9 Measurement of the diagonal length

The lengths of the two diagonals shall be measured. The arithmetical mean of the two readings shall be taken for the calculation of the Vickers hardness. For all tests, the perimeter of the indentation shall be clearly defined in the field of view of the microscope.

Magnifications should be selected so that the diagonal can be enlarged to greater than 25 %, but less than 75 % of the maximum possible optical field of view; see 6.3.

NOTE 1 In general, decreasing the test force increases the scatter of results of the measurements. This is particularly true for low-force Vickers hardness tests and Vickers microhardness tests, where the principal limitation will arise in the measurement of the diagonals of the indentation. For Vickers microhardness, the accuracy of determination of the mean diagonal length is unlikely to be better than ±0,001 mm when using an optical microscope (see References [6] to [9]).

NOTE 2 A helpful technique for adjusting optical systems that have Köhler illumination is given in Annex G.

For flat surfaces, the difference between the lengths of the diagonals should not be greater than 5 %. If the difference is greater, this shall be stated in the test report.

8.10 Calculation of hardness value

Calculate the Vickers hardness value using the formula given in Table 2. The Vickers hardness value can also be determined using the calculation tables given in ISO 6507-4. For curved surfaces, the correction factors given in Annex B shall be applied.

9 Uncertainty of the results

A complete evaluation of the uncertainty should be done according to JCGM 100:2008[4].

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, a Euramet guideline[10] is available.

— The other possibility is based on indirect calibration using a hardness reference block [below abbreviated as certified reference material (CRM)] (see References [10] to [13]). A guideline for the determination is given in Annex D.

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 (JCGM 100:2008, Clause 4[4]).

10 Test report

The test report shall include the following information unless otherwise agreed by the parties concerned:

a) a reference to this document, i.e., ISO 6507-1;

b) all information necessary for identification of the test piece;

c) the date of the test;

d) the hardness result obtained in HV, reported in the format defined in 5.2;

e) all operations not specified in this document or regarded as optional;

f) details of any circumstances that affected the results;

g) the temperature of the test, if it is outside the ambient range specified in 8.1;

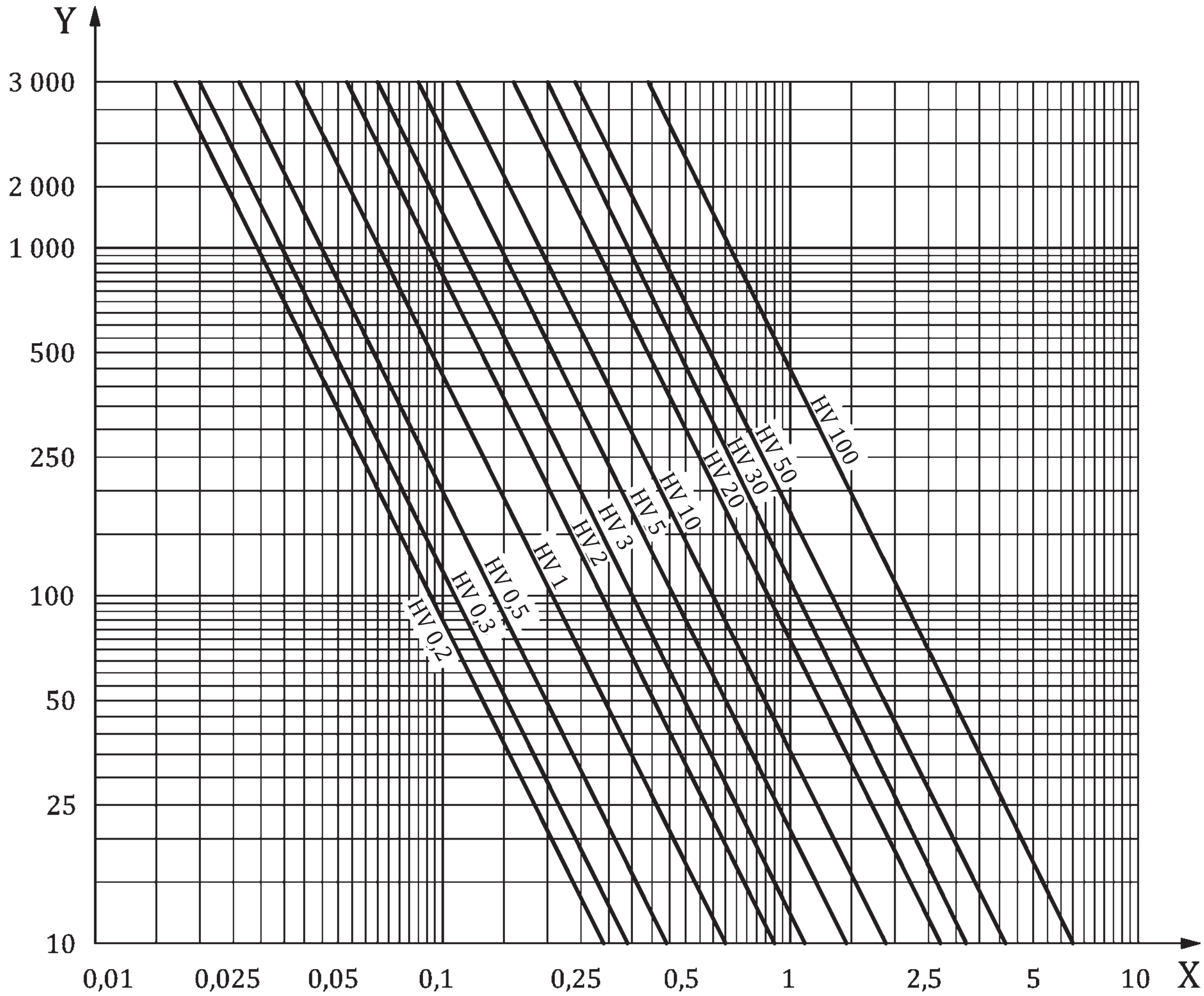
h) where conversion to another hardness scale is also performed, the basis and method of this conversion .

There is no general process of accurately converting Vickers hardness into other scales of hardness or into tensile strength. Such conversions, therefore, should be avoided, unless a reliable basis for conversion can be obtained by comparison tests (see also ISO 18265).

NOTE A strict comparison of hardness values is only possible at identical test forces.

Annex A
(normative)

Minimum thickness of the test piece in relation to the test force and to the hardness

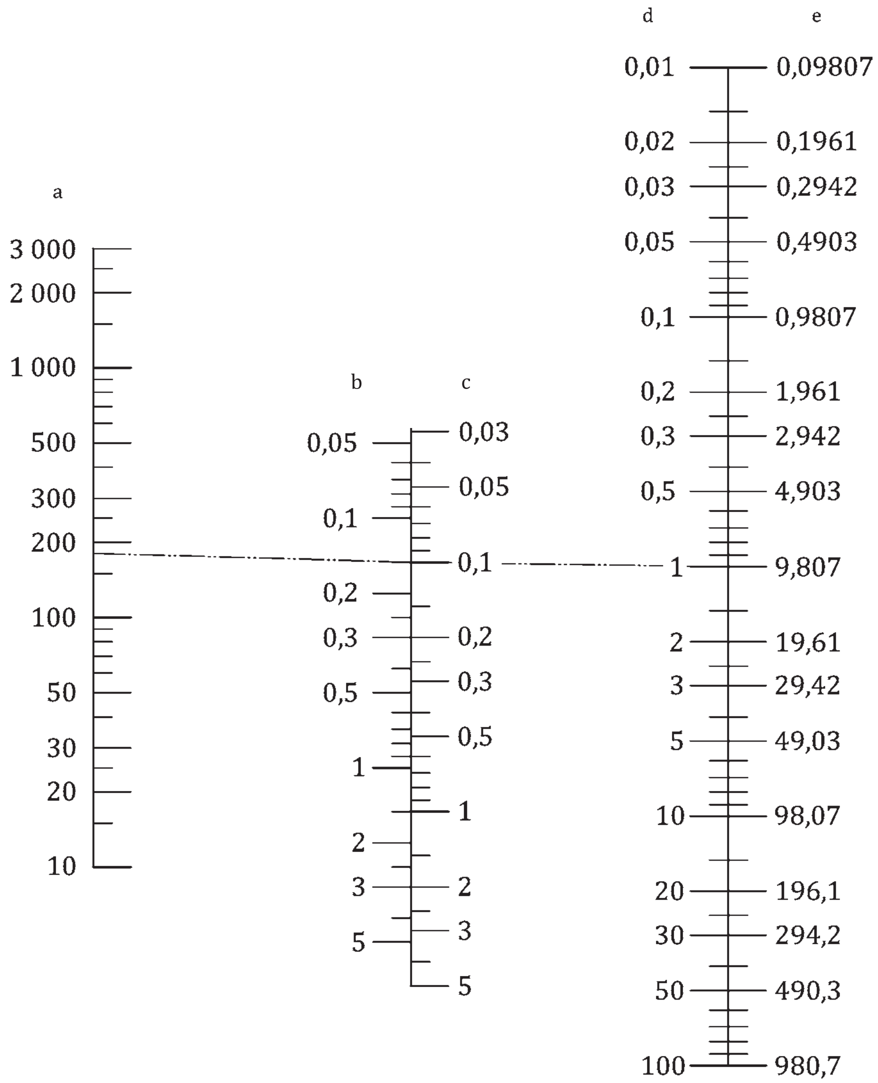


Key

X thickness of the test piece, mm

Y hardness, HV

Figure A.1 — Minimum thickness of the test piece in relation to the test force and to the hardness (HV 0,2 to HV 100)



Key

a Hardness value, HV.

b Minimum thickness, *t*, mm.

c Diagonal length, *d*, mm.

d Hardness symbol, HV.

e Test force *F*, N.

Figure A.2 — Nomogram designed for the minimum thickness of the test piece (HV 0,01 to HV 100)

The nomogram shown in Figure A.2 has been designed for the minimum thickness of a test piece, assuming that the minimum thickness has to be 1,5 times the diagonal length of the indentation. The required thickness is given by the point of intersection of the minimum thickness scale and a line (shown dotted in the example in Figure A.2) joining the test force (right-hand scale) with the hardness (left-hand scale).

Annex B
(normative)

Tables of correction factors for use in tests made on curved surfaces

B.1 Spherical surfaces

Tables B.1 and B.2 give the correction factors when tests are made on spherical surfaces.

The correction factors are tabulated in terms of the ratio of the mean diagonal, *d*, of the indentation to the diameter, *D*, of the sphere.

EXAMPLE

Convex sphere, D = 10 mm

Test force, F = 98,07 N

Mean diagonal of indentation, d = 0,150 mm

$$\frac{d}{D}=\frac{0,150}{10}=0,015$$

$$\text{Vickers hardness}=0,1891\times\frac{98,07}{(0,15)^2}=824\ \text{HV}\,10$$

Correction factor from Table B.1, by interpolation = 0,983

Hardness of sphere = 824 × 0,983 = 810 HV 10

Table B.1 — Convex spherical surfaces

d/D	Correction factor	*d/D*	Correction factor
0,004	0,995	0,086	0,920
0,009	0,990	0,093	0,915
0,013	0,985	0,100	0,910
0,018	0,980	0,107	0,905
0,023	0,975	0,114	0,900
0,028	0,970	0,122	0,895
0,033	0,965	0,130	0,890
0,038	0,960	0,139	0,885
0,043	0,955	0,147	0,880
0,049	0,950	0,156	0,875
0,055	0,945	0,165	0,870
0,061	0,940	0,175	0,865
0,067	0,935	0,185	0,860
0,073	0,930	0,195	0,855
0,079	0,925	0,206	0,850

Table B.2 — Concave spherical surfaces

d/D	Correction factor	*d/D*	Correction factor
0,004	1,005	0,057	1,080
0,008	1,010	0,060	1,085
0,012	1,015	0,063	1,090
0,016	1,020	0,066	1,095
0,020	1,025	0,069	1,100
0,024	1,030	0,071	1,105
0,028	1,035	0,074	1,110
0,031	1,040	0,077	1,115
0,035	1,045	0,079	1,120
0,038	1,050	0,082	1,125
0,041	1,055	0,084	1,130
0,045	1,060	0,087	1,135
0,048	1,065	0,089	1,140
0,051	1,070	0,091	1,145
0,054	1,075	0,094	1,150

B.2 Cylindrical surfaces

Tables B.3 to B.6 give the correction factors when tests are made on cylindrical surfaces.

The correction factors are tabulated in terms of the ratio of the mean diagonal, *d*, of the indentation to the diameter, *D*, of the cylinder.

EXAMPLE

Concave cylinder, one diagonal of the indentation parallel to axis, $D = 5$ mm

Test force, $F = 294{,}2$ N

Mean diagonal of indentation, $d = 0{,}415$ mm

$$\frac{d}{D} = \frac{0{,}415}{5} = 0{,}083$$

$$\text{Vickers hardness} = 0{,}1891 \times \frac{294{,}2}{(0{,}415)^2} = 323\ \text{HV}\ 30$$

Correction factor from Table B.6 = 1,075

Hardness of cylinder = 323 × 1,075 = 347 HV 30

Table B.3 — Convex cylindrical surfaces — Diagonals at 45° to the axis

d/D	Correction factor	*d/D*	Correction factor
0,009	0,995	0,119	0,935
0,017	0,990	0,129	0,930
0,026	0,985	0,139	0,925
0,035	0,980	0,149	0,920
0,044	0,975	0,159	0,915
0,053	0,970	0,169	0,910
0,062	0,965	0,179	0,095
0,071	0,960	0,189	0,900
0,081	0,955	0,200	0,895
0,090	0,950		
0,100	0,945		
0,109	0,940		

Table B.4 — Concave cylindrical surfaces — Diagonals at 45° to the axis

d/D	Correction factor	*d/D*	Correction factor
0,009	1,005	0,127	1,080
0,017	1,010	0,134	1,085
0,025	1,015	0,141	1,090
0,034	1,020	0,148	1,095
0,042	1,025	0,155	1,100
0,050	1,030	0,162	1,105
0,058	1,035	0,169	1,110
0,066	1,040	0,176	1,115
0,074	1,045	0,183	1,120
0,082	1,050	0,189	1,125
0,089	1,055	0,196	1,130
0,097	1,060	0,203	1,135
0,104	1,065	0,209	1,140
0,112	1,070	0,216	1,145
0,119	1,075	0,222	1,150

Table B.5 — Convex cylindrical surfaces — One diagonal parallel to the axis

d/D	Correction factor	*d/D*	Correction factor
0,009	0,995	0,085	0,965
0,019	0,990	0,104	0,960
0,029	0,985	0,126	0,955
0,041	0,980	0,153	0,950
0,054	0,975	0,189	0,945
0,068	0,970	0,243	0,940

Table B.6 — Concave cylindrical surfaces — One diagonal parallel to the axis

d/*D*	Correction factor	*d*/*D*	Correction factor
0,008	1,005	0,087	1,080
0,016	1,010	0,090	1,085
0,023	1,015	0,093	1,090
0,030	1,020	0,097	1,095
0,036	1,025	1,100	1,100
0,042	1,030	0,103	1,105
0,048	1,035	0,105	1,110
0,053	1,040	0,108	1,115
0,058	1,045	0,111	1,120
0,063	1,050	0,113	1,125
0,067	1,055	0,116	1,130
0,071	1,060	0,118	1,135
0,076	1,065	0,120	1,140
0,079	1,070	0,123	1,145
0,083	1,075	0,125	1,150

Annex C
(normative)

Procedure for periodic checking of the testing machine, diagonal measuring system and the indenter by the user

C.1 Periodic verification

The indenter to be used for the periodic verification shall be the same as used for testing. A hardness reference block shall be chosen for testing that is calibrated in accordance to ISO 6507-3 on the scale and at the approximate hardness level at which the machine will be used.

Before performing the periodic verification, the diagonal measuring system shall be indirectly verified using one of the reference indentations on the hardness reference block. The measured indentation length shall agree with the certified value to within the greater of 0,001 mm or 1,25 % of the indentation length. If the diagonal measuring system fails this test, a second reference indentation may be measured. If the diagonal measuring system fails this second test, the diagonal measuring system shall be adjusted or repaired and undergo direct and indirect verification according to ISO 6507-2.

At least two hardness measurements shall be made on the calibrated surface of the hardness reference block. The indentations shall be uniformly distributed over the surface of the reference block. The machine is regarded as satisfactory if the maximum positive or negative percent bias, b_{rel}, for each reading does not exceed the limits shown in Table C.1.

The percent bias, b_{rel}, is calculated according to Formula (C.1):

$$b_{rel} = 100 \times \frac{H - H_{CRM}}{H_{CRM}} \tag{C.1}$$

where

H is the hardness value corresponding to the hardness measurement taken;

H_{CRM} is the certified hardness of the reference block used.

If the testing machine fails this test, verify that the indenter and testing machine are in good working condition and repeat the periodic verification. If the machine continues to fail the periodic verification, an indirect verification according to ISO 6507-2 shall be performed. A record of the periodic verification results should be maintained over a period of time and used to measure reproducibility and monitor drift of the machine.

Table C.1 — Maximum permissible percent HV bias

Mean diagonal length, $\bar{d}$ **mm**	**Maximum permissible percent HV bias,** b_{rel}, **of the testing machine ± %HV**
$0{,}02 \le \bar{d} < 0{,}14$	$0{,}21/\bar{d} + 1{,}5$
$0{,}14 \le \bar{d} \le 1{,}400$	3

NOTE The criteria specified in this document for the performance of the testing machine have been developed and refined over a significant period of time. When determining a specific tolerance that the machine needs to meet, the uncertainty associated with the use of measuring equipment and/or reference standards 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 made when performing a periodic verification of the machine.

C.2 Indenter inspection

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. lf 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 meet all of the requirements of ISO 6507-2.

Annex D
(informative)

Uncertainty of the measured hardness values

D.1 General requirements

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

Most product specifications have tolerances that have been developed over the past years based mainly on the requirements of the product but also, in part, on the performance of the machine used to make the hardness measurement. These tolerances, therefore, incorporate a contribution due to the uncertainty of the hardness measurement and it would be inappropriate to make any further allowance for this uncertainty by, for example, reducing the specified tolerance by the estimated uncertainty of the hardness measurement. In other words, where a product specification states that the hardness of an item shall be higher or lower than a certain value, this should be interpreted as simply specifying that the calculated hardness value(s) shall meet this requirement, unless specifically stated otherwise in the product standard. However, there may be special circumstances where reducing tolerance by the measurement uncertainty is appropriate. This should only be done by agreement of the parties involved.

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 to 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.

Annex E 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.

D.2 General procedure

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

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

— the certified calibration value of the hardness reference block used, and

— the mean hardness value of the five indentations made in this block during calibration of the hardness testing machine (see ISO 6507-2) can be implemented in different ways into the determination of uncertainty.

Two methods are given for determining the uncertainty of hardness measurements.

— Method M1 accounts for the systematic bias of the hardness machine in two different ways. In one approach, the uncertainty contribution from the systematic bias is added arithmetically to this value. In the other approach, a correction is made to the measurement result to compensate for the systematic bias.

— Method M2 allows the determination of uncertainty without having to consider the magnitude of the systematic bias.

Additional information on calculating hardness uncertainties can be found in References [4] and [10].

NOTE 1 This uncertainty approach makes no allowance for any possible drift in the machine performance subsequent to its last calibration, as it assumes that any such changes will be insignificant in magnitude. As such, most of this analysis could be performed immediately after the machine's calibration and the results included in the machine's calibration certificate.

NOTE 2 In this annex, "CRM" stands for "certified reference material". In hardness testing standards, certified reference material is equivalent to the hardness reference block, i.e. a piece of material with a certified value and associated uncertainty.

D.3 Procedures for calculating uncertainty: Hardness measurement values

D.3.1 Procedure with bias (method M1)

The method M1 procedure for the determination of measurement uncertainty is explained in Table D.1. The measurement bias, b, of the hardness testing machine can be expected to be a systematic effect. In JCGM 100:2008[4], it is recommended that a correction be used to compensate for systematic effects, and this is the basis of M1. The result of using this method is that either all determined hardness values, x, have to be reduced by b or the uncertainty, U, has to be increased by b. The procedure for the determination of U_{M1} is explained in Table D.1.

The combined expanded measurement uncertainty for a single hardness measurement, x, is calculated according to Formula (D.1):

$$U_{M1} = k \times \sqrt{u_{H}^{2} + 2 \times u_{ms}^{2} + u_{HTM}^{2}} \quad (D.1)$$

where

u_H is a contribution to the measurement uncertainty due to the lack of measurement repeatability of the hardness testing machine;

u_{ms} is a contribution to the measurement uncertainty due to the resolution of the hardness testing machine. Both the resolution of the length measurement indicating instrument and the optical resolution of the measuring microscope shall be considered. In most cases, the overall resolution of the measurement system should be included twice in the calculation of u_H due to resolving the positions of both ends of the diagonal independently;

u_{HTM} is a contribution to the measurement uncertainty due to the standard uncertainty of the bias measurement, b, generated by the hardness testing machine (this value is reported as a result of the indirect verification defined in ISO 6507-2) and is defined according to Formula (D.2):

$$u_{HTM} = \sqrt{u_{CRM}^{2} + u_{HCRM}^{2} + 2 \times u_{ms}^{2}} \quad (D.2)$$

where

u_{CRM} is the contribution to the measurement uncertainty due to the calibration uncertainty of the certified value of the CRM according to the calibration certificate for $k = 1$;

u_{HCRM} is the contribution to the measurement uncertainty due to the combination of the lack of measurement repeatability of the hardness testing machine and the hardness nonuniformity of the CRM, calculated as the standard deviation of the mean of the hardness measurements when measuring the CRM;

u_{ms} is the contribution to the measurement uncertainty due to the resolution of the hardness testing machine when measuring the CRM.

The result of the measurement can be reported in two ways:

— as X_{corr}, where the measurement value, x, is corrected for the measurement bias, b, calculated according to Formula (D.3):

$$X_{corr} = (x - b) \pm U_{M1} \quad \text{(D.3)}$$

— or as X_{ucorr}, where the measurement value, x, is not corrected for the measurement bias, b, and the expanded uncertainty, U, is increased by the absolute value of the bias according to Formula (D.4):

$$X_{ucorr} = x \pm \left[U_{M1} + |b| \right] \quad \text{(D.4)}$$

When method M1 is used, it can also be appropriate to include additional uncertainty contributions within the RSS term relating to the value of b employed. This will particularly be the case when

— the measured hardness is significantly different from the hardness levels of the blocks used during the machine's calibration,

— the machine's bias value varies significantly throughout its calibrated range,

— the material being measured is different from the material of the hardness reference blocks used during the machine's calibration, or

— the day-to-day performance (reproducibility) of the hardness testing machine varies significantly.

The calculations of these additional contributions to the measurement uncertainty are not discussed here. In all circumstances, a robust method for estimating the uncertainty associated with b is required.

D.3.2 Procedure without bias (method M2)

As an alternative to method M1, method M2 can be used in some circumstances. Method M2 is only valid for hardness testing machines that have passed an indirect verification in accordance with ISO 6507-2 using the value $|b| + U_{HTM}$, rather than only the bias value, b, when determining compliance with the maximum permissible deviation of the bias (see ISO 6507-2). In method M2, the maximum permissible bias, b_E, (the positive amount by which the machine's reading is allowed to differ from the reference block's value), as specified in ISO 6507-2:2017, Table 5 is used to define one component, u_E, of the uncertainty. There is no correction of the hardness values with respect to the bias limit. The procedure for the determination of U is explained in Table D.1.

The combined expanded measurement uncertainty for a single future hardness measurement is calculated according to Formula (D.5):

$$U_{M2} = k \times \sqrt{u_H^2 + 2 \times u_{ms}^2 + u_E^2} \quad \text{(D.5)}$$

where

u_H is a contribution to the measurement uncertainty due to the lack of measurement repeatability of the hardness testing machine;

u_{ms} is a contribution to the measurement uncertainty due to the resolution of the hardness testing machine. Both the resolution of the length measurement indicating instrument and the optical resolution of the measuring microscope shall be considered. In most cases, the overall resolution of the measurement system should be included twice in the calculation of u_H due to resolving the positions of both ends of the long diagonal independently;

u_E is a contribution to the measurement uncertainty due to the maximum permissible deviation of the bias, $u_E = b_E / \sqrt{3}$ (rectangular distribution), where b_E is the maximum permissible deviation of the bias as specified in ISO 6507-2, and the result of the measurement is calculated according to Formula (D.6):

$$X = x \pm U_{M2} \quad \text{(D.6)}$$

D.4 Expression of the result of measurement

EXAMPLE

A hardness testing machine makes a single Vickers hardness measurement, x, on a test sample.

Single hardness measurement value, x: x = 410 HV 30

Diagonal length, d: d = 0,368 4 mm

Resolution of the length diagonal measuring system is calculated according to Formula (D.7):

$$\delta_{ms} = \sqrt{\delta_{OR}^2 + \delta_{IR}^2} \quad \text{(D.7)}$$

δ_{ms} = 0,000 51 mm

where

δ_{OR} is the optical resolution of the microscope objective (0,000 5 mm);

δ_{IR} is the resolution of the display indicator of the measuring system (0,000 1 mm).

The last indirect verification of the testing machine determined a measurement bias, b, with an uncertainty of the bias, U_{HTM}, using a CRM of $\overline{H}_{CRM} = 401{,}6$ HV 30 with a reported uncertainty, U_{CRM}, of 5,0 HV 30. The hardness of this CRM was the closest to the test sample hardness of those CRMs used for the indirect verification.

Testing machine measurement bias, b: b = 1,62 HV 30

Uncertainty of the testing machine measurement bias, U_{HTM}: U_{HTM} = 5,14 HV 30

To determine the lack of repeatability of the testing machine, the laboratory made five HV 30 measurements, H_i, on a CRM having a similar hardness to the test sample. The five measurements were made adjacent to each other adhering to spacing requirements in order to reduce the influence of block non-uniformity.

Five measurement values, H_i: 405,5 HV 30; 399,0 HV 30; 400,9 HV 30; 403,4 HV 30; 397,5 HV 30

Mean measurement value, $\overline{H} : \overline{H} = 401{,}3$ HV 30

Standard deviation of the measurement values, $s_H : s_H = 3{,}2$ HV 30

The value of s_H based on measurements from the last indirect verification according to ISO 6507-2 may be used instead of conducting the above repeatability tests; however, this standard deviation value will usually overestimate the lack of repeatability uncertainty component since it also includes the CRM non-uniformity.

For this example,

$|b| + U_{HTM} = 1,62 + 5,14 = 6,76$ HV 30 and

b_E = 3 % of 410 HV 30 = 12,3 HV 30.

Since the testing machine bias plus the expanded uncertainty in determining the bias $\left[|b| + U_{HTM}\right]$ is within the maximum permissible bias, b_E, either Method M1 or Method M2 may be used.

Table D.1 — Determination of the expanded uncertainly according to methods M1 and M2

Step	Sources of uncertainty	Symbols	Formula	Literature/certificate	Example
1 **M1,M2**	Measurement result	x			x = 410 HV 30
2 **M1**	Bias value, b, and uncertainty, U_{HTM}, of the bias of the hardness testing machine from the indirect verification	b U_{HTM} u_{HTM}	$u_{HTM} = \frac{U_{HTM}}{2}$	b and U_{HTM} according to an indirect verification report using a CRM of $\overline{H}_{CRM}$ = 401,6 HV 30 (see NOTE 1)	b = 1,62 HV 30 U_{HTM} = 5,14 HV 30 $u_{HTM} = \frac{5,14}{2} = 2,57$ HV 30
3 **M2**	Maximum permissible deviation of the bias	b_E	b_E = Maximum positive value of permissible bias	Permissible bias, b, according to ISO 6507-2:2017, Table 5	b_E = 3 % $b_E = \frac{3 \times 410}{100} = 12,3$ HV 30
4 **M2**	Standard uncertainty due to the maximum permissible deviation of the bias	u_E	$u_E = b_E / \sqrt{3}$	Rectangular distribution	$u_E = \frac{12,3}{\sqrt{3}} = 7,10$ HV 30
5 **M1,M2**	The standard deviation of repeatability measurements	s_H	$s_H = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} \left(H_i - \overline{H}\right)^2}$	Five measurements are made by the laboratory on a CRM having a hardness similar to the test sample (see NOTE 2)	s_H = 3,2 HV 30
6 **M1,M2**	Standard uncertainty due to lack of repeatability	U_H	$u_H = t \times s_H$	t = 1,14 for n = 5 (see JCGM 100:2008[4])	$u_H = 1,14 \times 3,2 = 3,69$ HV 30
7 **M1,M2**	Standard uncertainty due to resolution of the hardness value indicating display	u_{ms}	$u_{ms} = -\frac{2x}{d} \times \frac{\delta_{ms}}{2\sqrt{3}}$	δ_{ms} = 0,000 51 mm x = 410 HV 30 d = 0,368 4 mm (see NOTE 3)	$u_{ms} = -\frac{2 \times 410,0}{0,368\,4} \times \frac{0,000\,51}{2 \times \sqrt{3}} = -0,33$ HV 30

Table D.1 *(continued)*

Step	Sources of uncertainty	Symbols	Formula	Literature/certificate	Example
8 **M1**	Determination of the expanded uncertainty	U_{M1}	$U_{M1} = k \times \sqrt{u_H^2 + 2 \times u_{ms}^2 + u_{HTM}^2}$	Steps 2, 6, and 7 $k = 2$	U_{M1} = 9,04 HV 30
9 **M1**	Measurement result with modified hardness	X_{corr}	$X_{corr} = (x - b) \pm U_{M1}$	Steps 1, 2 and 8	x = 410 HV 30 $X_{corr} = (408 \pm 9)$ HV 30
10 **M1**	Measurement result with modified uncertainty	X_{ucorr}	$X_{ucorr} = x \pm (U_{M1} + \|b\|)$	Steps 1, 2 and 8	x = 410 HV 30 $X_{ucorr} = (410 \pm 11)$ HV 30
11 **M2**	Determination of the expanded uncertainty	U_{M2}	$U_{M2} = k \times \sqrt{u_H^2 + 2 \times u_{ms}^2 + u_E^2}$	Steps 4, 6, and 7 $k = 2$	U_{M2} = 16,0 HV 30
12 **M2**	Measurement result	X	$X = x \pm U_{M2}$	Steps 1 and 11	x = 410 HV 30 $X = (410 \pm 16)$ HV 30

NOTE 1 If 0,8 $b_E < b <$ 1,0 b_E, the relationship of hardness values between CRM and sample should be considered.

NOTE 2 The value of s_H based on measurements from the last indirect verification according to ISO 6507-2 can be used, but will usually overestimate the lack of repeatability uncertainty component since it includes the CRM non-uniformity. In circumstances where the average of multiple hardness measurements on a test sample is to be reported, rather than a single hardness measurement, the value of s_H in Step 5 should be replaced with the standard deviation of the multiple hardness measurements of the sample under test divided by the square-root of the number of hardness measurements, n, and the value of t in Step 6 should be appropriate for the n measurements ($u_H = t \times s_H / \sqrt{n}$). The calculated uncertainty contribution, u_H, will then also account for the nonuniformity of the test sample.

NOTE 3 The sensitivity coefficient $-2x/d$ follows from $\partial x / \partial d$ for converting uncertainty in diagonal length (mm) to uncertainty in HV.

Annex E
(informative)

Vickers hardness measurement traceability

E.1 Traceability definition

The path to traceability for a Vickers hardness measurement is different compared to many other measurement quantities, such as length or temperature. This is primarily because hardness measurement including Vickers is made following a defined test procedure using a testing machine that makes multiple measurements of different parameters, e.g. force, length, time, during the test. Each of these measurements, as well as other test parameters, influences the hardness result.

The International Vocabulary of Metrology (VIM3)[14] defines metrological traceability as:

> ***metrological traceability*** *— property of a measurement result whereby the result can be related to a reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty, VIM3, 2012*.

From this definition, two things are necessary for a measurement result to have traceability: 1) an unbroken chain of calibrations, each contributing to the measurement uncertainty and 2) a reference to which traceability is claimed. These will define the metrological traceability chain.

E.2 Chains of calibrations

ISO 6507-2 specifies a set of calibration and verification procedures required to demonstrate that the testing machine is suitable for use in accordance with this document. The calibration procedures include direct measurements of various components affecting the machine's performance, such as the test forces, indenter shape, and indentation measuring equipment, as well as hardness measurements of a range of reference blocks. Each of these calibration measurements has specified limits within which the result must lie in order for the machine to pass its verification. Historically, the calibration and verification of the machine components has been termed the machine's Direct Verification and the calibration and verification of the testing machine by reference block measurements its Indirect Verification.

ISO 6507-3 specifies both the procedure required to calibrate the reference blocks used in the Indirect Verification of the testing machine and also the required calibration and verification procedures of the machine used to calibrate these blocks.

When considering an "unbroken chain of calibrations" to provide measurement traceability to the testing machine, it is apparent that this could come via either the Direct Verification or Indirect Verification path.

Direct Verification requirements specify measurements of individual components of the testing machine, with traceability of each of these measurements being achieved through calibration chains to the International System of units (SI), usually as realized by the National Metrology Institute (NMI). These calibration chains are illustrated on the right-hand side of Figure E.1. Together, these calibration chains form a potential traceability path for a testing machine.

The left-hand side of Figure E.1 illustrates a traceability path made through a single calibration chain for each level in the calibration hierarchy, i.e. national, calibration and user, that includes the calibration of reference blocks and the subsequent Indirect Verification of Vickers hardness machines. A (national level) primary standard machine calibrates primary reference blocks that are then used to calibrate a (calibration level) calibration machine. This machine calibrates reference blocks that are finally used to calibrate a (user level) testing machine.

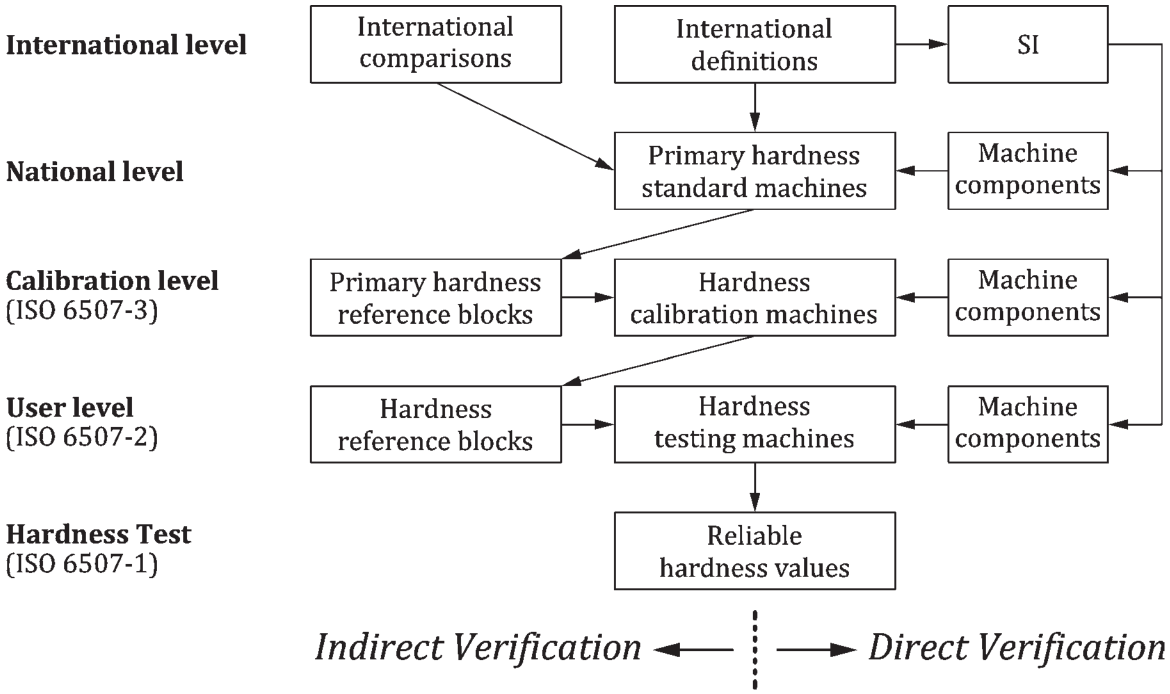


Figure E.1 — Chains of calibrations

E.3 Vickers hardness reference

The other requirement for achieving traceability is a reference to which traceability is claimed. Vickers hardness is not a fundamental property of a material, but rather an ordinal quantity dependent on a defined test method. Ideally, the ultimate reference for a Vickers hardness measurement should be an internationally agreed definition of this method, including values of all test parameters. Hardness traceability would then be to this definition through a laboratory's realization or fulfillment of the definition, the accuracy of this realization being reflected in the laboratory's measurement uncertainty and confirmed by international comparisons. The internationally agreed definition would be developed by the CCM Working Group on Hardness (CCM-WGH) (see Annex F) and realized by NMIs that standardize Vickers hardness. At this time, the CCM-WGH has not developed definitions for Vickers hardness scales so the highest reference is usually an NMI's realization of the Vickers scales based on its own chosen definition of the test. In cases where an NMI does not calibrate reference blocks for certain Vickers scales, the highest reference within a country may be a calibration laboratory's realization of the Vickers scale definition.

E.4 Practical issues

Either one of the two traceability paths of calibration chains illustrated in Figure E.1 (left-hand side and right-hand side) could theoretically provide traceability to an appropriate Vickers hardness reference. However, there are practical issues with both that must be considered. For the Direct Verification path given on the right-hand side of Figure E.1, it is extremely difficult to identify, measure and, if necessary, correct for all parameters that may affect the measured hardness value. Even if the machine passes its Direct Verification, traceability will not be ensured if one or more uncontrolled or unidentified parameters have a significant effect. This is often the case and becomes more of an issue at lower levels in the calibration hierarchy.

The Indirect Verification calibration chain shown on the left-hand side of Figure E.1 also has practical issues to be considered. One consequence of using a testing machine having multiple components, each making measurements during the hardness test, is that an error in one component's measurement can be compensated or offset by an error in a different component's measurement. This can result in accurate hardness measurements for the specific hardness levels and block materials tested during the indirect verification; however, measurement error can increase when testing other hardness levels or materials. If the errors in the individual machine components are significant, then traceability again may not be ensured.

E.5 Vickers hardness measurement traceability

E.5.1 General

The above issues indicate that both types of traceability path usually need to be in place for achieving Vickers hardness measurement traceability. However, traceability can be achieved based on only one of the two paths if careful examination and evaluation of the measurement process is made. For example, at the National Level, the traceability of an NMI's primary Vickers hardness standard machine is achieved through a Direct Verification calibration chain since there is no recognized higher-level hardness reference artefact. Traceability through this path is possible since NMIs typically have the capability to thoroughly evaluate their measurement systems and their uncertainty levels are confirmed through international comparisons with other NMIs. In contrast, decades of Vickers hardness measurement experience has shown that, for the lower levels in the calibration hierarchy, it is most practical to obtain traceability and determine measurement uncertainty based primarily on the Indirect Verification calibration chain; however, proper traceability of the individual machine component quantity values is also important. This traceability scheme has proven to be suitable for industrial Vickers hardness measurements.

E.5.2 Calibration level traceability

Measurement traceability is best obtained through the Indirect Verification calibration chain using primary reference blocks that have been calibrated at the National NMI level. This is also the path that should be used for the determination of measurement uncertainty. At the same time, however, the specified components of the calibration machine should be calibrated on a frequent basis to ensure that offsetting errors are not significant. Hardness traceability should be to the NMI's realization of the CCM-WGH definition of the Vickers scale or when there is an absence of a CCM-WGH definition; traceability should be to the NMI's realization of its own chosen definition. If the NMI does not provide calibrated reference blocks or conduct comparison measurements with a calibration laboratory and it is not practical to use reference blocks of another NMI, then the reference to which traceability is claimed may need to be to the calibration laboratory's realization of the Vickers scale definition based on an international test method, such as that defined by this standard. In this case, the calibration laboratory's measurement traceability may be achieved through the Indirect Verification path using consensus reference block standards or through the Direct Verification path confirmed by intercomparisons.

E.5.3 User level traceability

Measurement traceability is best obtained through the Indirect Verification calibration chain using reference blocks that have been calibrated at the calibration level or national level. As with calibration level traceability, this is the most practical path and should also be used for the determination of measurement uncertainty. It is also desirable that the components of the hardness machine periodically undergo Direct Verification to ensure that offsetting errors are not significant. However, typical industrial practice is for these measurements to be made only when the hardness machine is manufactured or repaired, which is the minimum requirement of this document.

NOTE The following terms used in this annex are in accordance with the VIM3[14]:

— calibration;

— calibration hierarchy;

— metrological traceability;

— metrological traceability chain;

— ordinal quantity;

— verification.

Annex F
(informative)

CCM — Working group on hardness

In 1999, at the 88th Session of the International Committee of Weights and Measures (CIPM), Dr Kozo Iizuka, President of the Consultative Committee for Mass and Related Quantities (CCM), stated "Although the definition of hardness scales is certainly conventional in the sense of the use of arbitrarily chosen formula, the testing method is defined by a combination of physical quantities expressed by SI units; the standard of hardness is established and maintained in most of NMIs and the traceability to the standard of NMIs is demanded in industry and elsewhere." The subsequent discussions led to the realization that hardness standards should be included in the key comparison database (KCDB) for the mutual recognition arrangement (MRA) and thus, a full Working Group on Hardness (CCM-WGH) was established in the framework of the CCM[15].

The establishment of the CCM-WGH provided a technical-diplomatic framework in which hardness influence parameters can be examined and improved international definitions of the hardness tests can be proposed and approved for NMI use to reduce the measurement differences at the highest national level. Due to the necessity of international agreement, the CCM-WGH has a close liaison with ISO/TC 164/SC 3 in order to ensure proper dissemination of the hardness scales. The most significant improvement of the CCM-WGH definitions is that the parameters of the hardness test are defined with specific values, rather than ranges of acceptable limits as specified by this test method. As applicable, this document has adopted the defined values of the CCM–WGH definitions as the values to use.

The CCM-WGH definitions are published at http://www.bipm.org/.

Annex G
(informative)

Adjustment of Köhler illumination systems

G.1 General

While some optical systems are permanently aligned, others have means of minor adjustments. To gain the utmost in resolution, the following adjustments may be helpful.

G.2 Köhler illumination

Focus, to critical sharpness, the surface of a flat polished specimen.

Centre the illuminating source.

Centrally align the field and aperture diaphragms.

Open the field diaphragm so that it just disappears from the field of view.

Remove the eyepiece and examine the rear focal plane of the objective. If all the components are in their proper places, the source of illumination and the aperture diaphragm will appear in sharp focus.

A full-aperture diaphragm is preferred for maximum resolving power. If the glare is excessive, reduce the aperture; but never use less than 3/4 of the opening, since resolution would be decreased and diffraction phenomena could lead to false measurements.

If the light is too strong for eye comfort, reduce the intensity by using of an appropriate neutral density filter or rheostat control.

Bibliography

[1] ISO 6507-4, *Metallic materials — Vickers hardness test — Part 4: Tables of hardness values*

[2] ISO 18265, *Metallic materials — Conversion of hardness values*

[3] ISO 23718, *Metallic materials — Mechanical testing — Vocabulary*

[4] JCGM 100:2008*(GUM 1995 with minor corrections), Evaluation of measurement data - Guide to the expression of uncertainty in measurement. BIPM/IEC/IFCC/ILAC/ISO/IUPAC/IUPAP/OIML, 2008*

[5] SANPONPUTE. T, MEESAPLAK, A, *Vibration Effect on Vickers Hardness Measurement*, Proceedings of IMEKO 2010 TC3, TC5 and TC22 Conferences, pp. 145-149

[6] Dengel D. *Wichtige Gesichtspunkte für die Härtemessung nach Vickers und nach Knoop im Bereich der Kleinlast- und Mikrohärte*, Z. f. Werkstofftechnik **4** (1973), pp. 292-298. (Note: short extract.)

[7] Bückle H. *Mikrohärteprüfung und ihre Anwendung*. Verlag Berliner Union Stuttgart, 1965, pp. 296. (Note: very extensive.)

[8] Bückle H. *Echte und scheinbare Fehlerquellen bei der Mikrohärteprüfung:* Ihre Klassifizierung und Auswirkung auf die Messwerte. VDI-Berichte **11** (1957), pp. 29-43. (Note: extensive.)

[9] Matthaei E. *Härteprüfung mit kleinen Prüfkräften und ihre Anwendung bei Randschichten (kritische Literaturbewertung)*, pp. 47, 192 Schrifttumshinweise. Verlag DGM-Informationsgesellschaft Oberursel, 1987. (Note: overall view of sources.)

[10] EURAMET cg-16 Ver. 2.0, *Guidelines on the Estimation of Uncertainty in Hardness Measurements*, 2011

[11] Gabauer W. *Manual of 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

[12] Gabauer W., & Binder O. *Abschätzung der Messunsicherheit in der Härteprüfung unter Verwendung der indirekten Kalibriermethode*, DVM Werkstoffprüfung, Tagungsband 2000, S. pp. 255-261

[13] Polzin T., & Schwenk D. *Estimation of Uncertainty of Hardness Testing; PC file for the determination*, Materialprüfung, **3**, 2002 (44), pp. 64-71

[14] VIM. International vocabulary of metrology — Basic and general concepts and associated terms, VIM, 3rd edition (2008 version with minor corrections), JCGM 200: 2012 available via http://www.bipm.org/en/publications/guides/vim.html

[15] Iizuka K. Worldwide Activities Around Hardness Measurement - Activities in CCM/CIPM, IMEKO/TC5, OIML/TC10 and ISO/TC164 in Proceedings HARDMEKO 2007, Tsukuba, Japan, 2007, 1-4

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