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Metallic materials — Rockwell hardness test —

Part 2:
Verification and calibration of testing machines (scales A, B, C, D, E, F, G, H, K, N, T)

Matériaux métalliques — Essai de dureté Rockwell —

Partie 2: Vérification et étalonnage des machines d'essai (échelles A, B, C, D, E, F, G, H, K, N, T)

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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 6508-2 was prepared by Technical Committee ISO/TC 164, *Mechanical testing of metals*, Subcommittee SC 3, *Hardness testing*.

This second edition cancels and replaces the first edition (ISO 6508-2:1999), which has been technically revised.

ISO 6508 consists of the following parts, under the general title *Metallic materials — Rockwell hardness test*:

— *Part 1: Test method (scales A, B, C, D, E, F, G, H, K, N, T)*

— *Part 2: Verification and calibration of testing machines (scales A, B, C, D, E, F, G, H, K, N, T)*

— *Part 3: Calibration of reference blocks (scales A, B, C, D, E, F, G, H, K, N, T)*

Introduction

Attention is drawn to the fact that, in this part of ISO 6508, the use of hardmetal for ball indenters is considered to be the standard type of Rockwell indenter ball. Steel indenter balls may be continued to be used if specified in a product specification, or by special agreement.

Metallic materials — Rockwell hardness test —

Part 2:
Verification and calibration of testing machines (scales A, B, C, D, E, F, G, H, K, N, T)

1 Scope

This part of ISO 6508 specifies a method of verification of testing machines for determining Rockwell hardness (scales A, B, C, D, E, F, G, H, K, N, T) in accordance with ISO 6508-1.

It specifies a direct 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 6508 is applicable to portable hardness testing machines.

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 376:2004, *Metallic materials — Calibration of force-proving instruments used for verification of uniaxial testing machines*

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

ISO 6508-1, *Metallic materials — Rockwell hardness test — Part 1: Test method (scales A, B, C, D, E, F, G, H, K, N, T)*

ISO 6508-3:2005, *Metallic materials — Rockwell hardness test — Part 3: Calibration of reference blocks (scales A, B, C, D, E, F, G, H, K, N, T)*

3 General conditions

Before a Rockwell 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 and in such a manner that the readings are not influenced.

It shall be checked that the readings are not affected either by movements of the test piece or by deformation of the frame. When a device is supplied, which locks the test piece against the upper part of the frame, the locking force shall exceed the total test force. The influence of deformations may be checked by using a plunger with a spherical tip (diameter of at least 10 mm), instead of the indenter, bearing against the anvil through a spacer and using the locking device when it is supplied. The material of the plunger and of the spacer have a hardness of at least 60 HRC. The readings of the measuring system (with preliminary force applied) before application and after removal of the additional force shall not differ by more than 1,5 Rockwell units (without locking equipment) and 0,5 Rockwell units (with locking equipment).

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 of 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 depth-measuring system;

d) verification of the testing cycle.

4.2 Calibration of the test force

4.2.1 The preliminary test force F_0 (see 4.2.4) and each total test force F used (see 4.2.5) shall be measured, and, whenever applicable, this shall be done at not less than three positions of the plunger spaced throughout its range of movement during testing. The preliminary test force shall be held for at least 2 s.

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

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

— by means of a force proving device in accordance with ISO 376:2004, class 1, or

— by balancing against a force, accurate to ± 0,2 %, applied by means of calibrated masses or by another method having the same accuracy.

4.2.4 The tolerance on the preliminary test force F_0 (before application and after removal of the additional test force F_1) shall be ± 2,0 %.

4.2.5 The tolerance on the total test force F shall be ± 1,0 %. Each individual value of F shall be within this tolerance.

4.3 Verification of the indenter

4.3.1 Diamond cone indenter (scales A, C, D, N)

To verify the reliable performance of the conical indenter in conformance with this part of ISO 6508, a direct and an indirect verification shall be carried out.

4.3.1.1 Direct verification

4.3.1.1.1 The surfaces of the diamond cone and spherical tip shall be polished for a penetration depth of 0,3 mm and shall blend in a truly tangential manner. Both surfaces shall be free from surface defects.

4.3.1.1.2 The verification of the shape of the indenter can be made by direct measurement or by measurement of its projection on a screen. The verification shall be made at not less than four equally spaced sections.

4.3.1.1.3 The diamond cone shall have an included angle of (120 ± 0,35)°.

Deviations from straightness of the generatrix of the diamond cone, adjacent to the blend, shall not exceed 0,002 mm over a minimum length of 0,4 mm.

4.3.1.1.4 The angle between the axis of the diamond cone and the axis of the indenter-holder (normal to the seating surface) shall not exceed 0,5°.

4.3.1.1.5 The tip of the indenter shall be spherical. Its radius shall be determined from single values, measured in the axial section planes defined in 4.3.1.1.2. The distance between the concentric circles shall be no more than 0,004 mm. Each single value shall be within (0,2 ± 0,015) mm. The mean value out of at least four single values shall be within (0,2 ± 0,01) mm.

NOTE 1 The radius can be obtained by determining the intersection of two segments of the concentric circles.

NOTE 2 The single value is the mean value of the two radii of the concentric circles.

Measurement with a collimator device is also available. In this case, the measurements should be carried out at least in four central angles and the central angle of 120° must be included.

4.3.1.2 Indirect verification

The hardness values given by the testing machine depend not only on the dimensions given in 4.3.1.1.3 and 4.3.1.1.5, but also on the surface roughness and the position of the crystallographic axes of the diamond, and the seating of the diamond in its holder.

To examine this influence, the indirect verification of the indenter shall be performed on four reference blocks which shall be calibrated for the hardness levels given in Table 1 or on blocks giving equivalent total depths of indentation.

Table 1 — Hardness levels for different scales

Scale	Hardness	Ranges
HRC	23	20 to 26
HRC	55	52 to 58
HR45N	43	40 to 46
HR15N	91	88 to 94

For each block, the mean hardness value of three indentations made using the indenter to be verified shall not differ from the mean hardness value of the three indentations obtained with the indenter, calibrated in accordance with 4.5 of ISO 6508-3:2005 by more than ± 0,8 Rockwell units. The indentations made with the indenter to be verified and with the above-mentioned indenter should be adjacent.

NOTE This can be performed with a calibration machine in accordance with the procedure described in Clause 5 of ISO 6508-3:2005.

The hardness testing machines used for this indirect verification shall comply with the following tolerances for the test forces:

F_0: ± 1,0 %

F: ± 0,5 %

The test shall be carried out in accordance with ISO 6508-1.

4.3.2 Ball indenter (scales B, E, F, G, H, K, T)

4.3.2.1 For the purpose of verifying the size and the hardness of the balls, one sample selected at random from a batch shall be tested. The balls verified for hardness shall be discarded.

4.3.2.2 The balls shall be polished and free from surface defects.

4.3.2.3 The user shall either measure the balls to ensure that they meet the following requirements, or shall obtain balls from a supplier certifying that the following conditions are met.

4.3.2.3.1 The diameter, measured at no less than three positions, shall not differ from the nominal diameter by more than the tolerance given in Table 2.

Table 2 — Tolerances for the different ball diameters

Rockwell hardness scale	Ball diameter mm	Tolerance mm
B	1,587 5	± 0,003 5
F	1,587 5	± 0,003 5
G	1,587 5	± 0,003 5
T	1,587 5	± 0,003 5
E	3,175	± 0,004
H	3,175	± 0,004
K	3,175	± 0,004

4.3.2.3.2 The characteristics of the hardmetal balls shall be as follows:

— hardness: the hardness shall be no less than 1 500 HV, when determined using a test force of at least 4,903 N in accordance with ISO 6507-1. The hardmetal ball may be tested directly on this spherical surface or by sectioning the ball and testing on the ball interior. An example for HV 10 is given in Table 3.

— density: $\rho = (14{,}8 \pm 0{,}2)\ \text{g/cm}^3$.

NOTE The following chemical composition is recommended:

— tungsten carbide (WC) balance
— total other carbides 2,0 %
— cobalt (Co) 5,0 % to 7,0 %

4.3.2.3.3 The hardness of steel balls shall be no less than 750 HV, when determined using a test force of 98,07 N in accordance with ISO 6507-1 (see Table 3).

Table 3 — Values of the mean diagonal (HV10) for the determination of the hardness of the ball indenters

Ball diameter mm	**Maximum value of the mean diagonal made on the spherical surface of the ball with a Vickers indenter at 98,07 N** (HV10) mm	
	Steel ball	**Hardmetal ball**
3,175	0,153	0,109
1,587 5	0,150	0,107

4.4 Calibration of the depth-measuring system

4.4.1 The depth-measuring system shall be calibrated over no less than three intervals, including the intervals corresponding to the lowest and highest hardness for which the scales are normally used, by making known incremental movements of the indenter in the direction of increasing hardness values.

4.4.2 The instrument used to verify the depth-measuring system shall have an accuracy of 0,000 2 mm. The depth-measuring system shall correctly indicate within ± 0,001 mm for the scales A to K and within ± 0,000 5 mm for scales N and T, i. e. within ± 0,5 of a scale unit, over each range.

NOTE If it is not possible to verify the depth-measuring system directly, its performance can be derived from the results of an indirect verification, using reference blocks and a certified indenter, and making corrections for known errors (see 5.2).

4.5 Verification of the testing cycle

The testing cycle shall conform to the testing cycle given in ISO 6508-1 and shall be timed with an uncertainty less than ± 0,5 s.

5 Indirect verification

5.1 General

Indirect verification should be carried out at a temperature of (23 ± 5) °C by means of reference blocks calibrated in accordance with ISO 6508-3. If the verification is made outside of this temperature range, this shall be reported in the verification report.

5.2 Procedure

5.2.1 For the indirect verification of a testing machine, the following procedures shall be applied.

The testing machine shall be verified for each scale for which it shall be used. For each scale to be verified, reference blocks from each of the hardness ranges given in Table 4 shall be used. The hardness values of the blocks shall be chosen to approximate the limits of the intended use.

5.2.2 On each reference block, five indentations shall be uniformly distributed over the test surface and each hardness number observed to within 0,2 of a scale unit. Before making these indentations, at least two preliminary indentations shall be made to ensure that the machine is working freely and that the reference block, the indenter and the anvil are seating correctly. The results of these preliminary indentations shall be ignored. The test shall be made in accordance with ISO 6508-1.

Table 4 — Hardness ranges for different scales

Rockwell hardness scale	Hardness range of reference block	Rockwell hardness scale	Hardness range of reference block
A	20 to 40 HRA 45 to 75 HRA 80 to 88 HRA	K	40 to 60 HRK 65 to 80 HRK 85 to 100 HRK
B	20 to 50 HRB 60 to 80 HRB 85 to 100 HRB	15N	70 to 77 HR15N 78 to 88 HR15N 89 to 91 HR15N
C	20 to 30 HRC 35 to 55 HRC 60 to 70 HRC	30N	42 to 54 HR30N 55 to 73 HR30N 74 to 80 HR30N
D	40 to 47 HRD 55 to 63 HRD 70 to 77 HRD	45N	20 to 31 HR45N 32 to 61 HR45N 63 to 70 HR45N
E	70 to 77 HRE 84 to 90 HRE 93 to 100 HRE	15T	73 to 80 HR15T 81 to 87 HR15T 88 to 93 HR15T
F	60 to 75 HRF 80 to 90 HRF 94 to 100 HRF	30T	43 to 56 HR30T 57 to 69 HR30T 70 to 82 HR30T
G	30 to 50 HRG 55 to 75 HRG 80 to 94 HRG	45T	12 to 33 HR45T 34 to 54 HR45T 55 to 72 HR45T
H	80 to 94 HRH 96 to 100 HRH		

5.3 Repeatability

5.3.1 For each reference block, let H_1, H_2, H_3, H_4, H_5 be the values of the measured hardness arranged in increasing order of magnitude.

The repeatability r of the testing machine, under the particular verification conditions, is determined by the following quantity:

$$r = H_5 - H_1 \quad (1)$$

The mean hardness value of the five indentations $\overline{H}$ is defined as follows:

$$\overline{H} = \frac{H_1 + H_2 + H_3 + H_4 + H_5}{5} \quad (2)$$

where H_1, H_2, H_3, H_4, H_5 are the hardness values corresponding to the five indentations.

5.3.2 The repeatability of the testing machine being verified shall be considered satisfactory if it satisfies the conditions given in Table 5. Permissible repeatability is presented graphically in Figures A.1 and A.2.

Table 5 — Permissible repeatability and error of the testing machine

Rockwell hardness scale	**Hardness range of the reference block**	**Permissible error** Rockwell units	**Permissible repeatability of the testing machine**[a]
A	20 to $\leqslant$ 75 HRA > 75 to $\leqslant$ 88 HRA	± 2 HRA ± 1,5 HRA	$\leqslant$ 0,02 (100 – $\overline{H}$) or 0,8 Rockwell units[b]
B	20 to $\leqslant$ 45 HRB > 45 to $\leqslant$ 80 HRB > 80 to $\leqslant$ 100 HRB	± 4 HRB ± 3 HRB ± 2 HRB	$\leqslant$ 0,04 (130 – $\overline{H}$) or 1,2 Rockwell units[b]
C	20 to $\leqslant$ 70 HRC	± 1,5 HRC	$\leqslant$ 0,02 (100 – $\overline{H}$) or 0,8 Rockwell units[b]
D	40 to $\leqslant$ 70 HRD > 70 to $\leqslant$ 77 HRD	± 2 HRD ± 1,5 HRD	$\leqslant$ 0,02 (100 – $\overline{H}$) or 0,8 Rockwell units[b]
E	70 to $\leqslant$ 90 HRE > 90 to $\leqslant$ 100 HRE	± 2,5 HRE ± 2 HRE	$\leqslant$ 0,04 (130 – $\overline{H}$) or 1,2 Rockwell units[b]
F	60 to $\leqslant$ 90 HRF > 90 to $\leqslant$ 100 HRF	± 3 HRF ± 2 HRF	$\leqslant$ 0,04 (130 – $\overline{H}$) or 1,2 Rockwell units[b]
G	30 to $\leqslant$ 50 HRG > 50 to $\leqslant$ 75 HRG > 75 to $\leqslant$ 94 HRG	± 6 HRG ± 4,5 HRG ± 3 HRG	$\leqslant$ 0,04 (130 – $\overline{H}$) or 1,2 Rockwell units[b]
H	80 to $\leqslant$ 100 HRH	± 2 HRH	$\leqslant$ 0,04 (130 – $\overline{H}$) or 1,2 Rockwell units[b]
K	40 to $\leqslant$ 60 HRK > 60 to $\leqslant$ 80 HRK > 80 to $\leqslant$ 100 HRK	± 4 HRK ± 3 HRK ± 2 HRK	$\leqslant$ 0,04 (130 – $\overline{H}$) or 1,2 Rockwell units[b]
N		± 2 HRN	$\leqslant$ 0,04 (100 – $\overline{H}$) or 1,2 Rockwell units [b]
T		± 3 HRT	$\leqslant$ 0,06 (100 – $\overline{H}$) or 2,4 Rockwell units[b]

[a] where $\overline{H}$ is the mean hardness value

[b] whichever is greater

5.4 Error

5.4.1 The error, E, of the testing machine under the particular verification conditions is expressed by the following equation:

$$E = \overline{H} - H_c \tag{3}$$

where

$\overline{H}$ is the mean hardness value;

H_c is the specified hardness of the reference block used.

5.4.2 The error of the testing machine shall not exceed the values given in Table 5.

5.5 Uncertainty of measurement

The determination of the uncertainty of measurement of the calibration results of the hardness testing machines 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 — Direct verifications of hardness testing machines

Requirements of verification	Force	Measuring system	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 month 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 6508;

b) method of verification (direct and/or indirect);

c) identification data for the hardness testing machine;

d) means of verification (reference blocks, elastic proving devices, etc.);

e) Rockwell hardness scale(s) verified;

f) verification temperature;

g) result obtained;

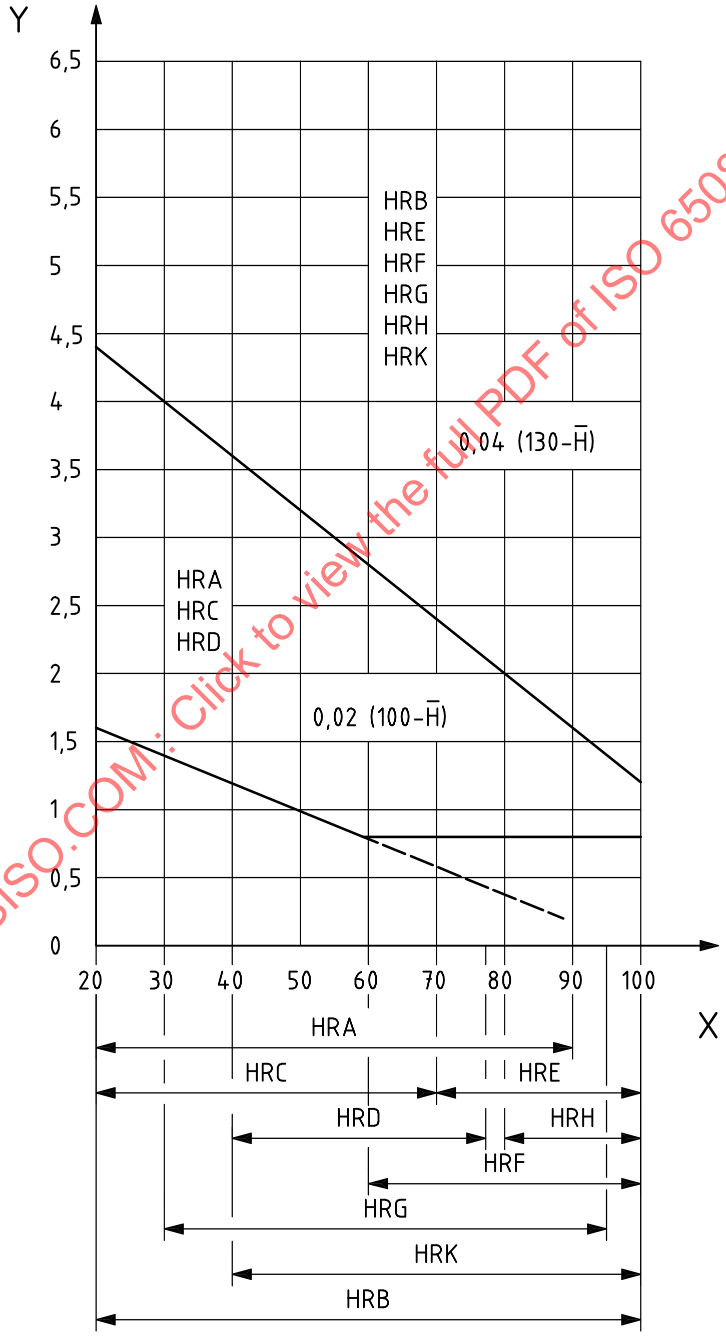
h) date of verification and reference to the verification institution;

i) uncertainty of the verification result.

Annex A
(normative)

Repeatability of testing machines

The permissible repeatability of testing machines is presented graphically in Figures A.1 and A.2.

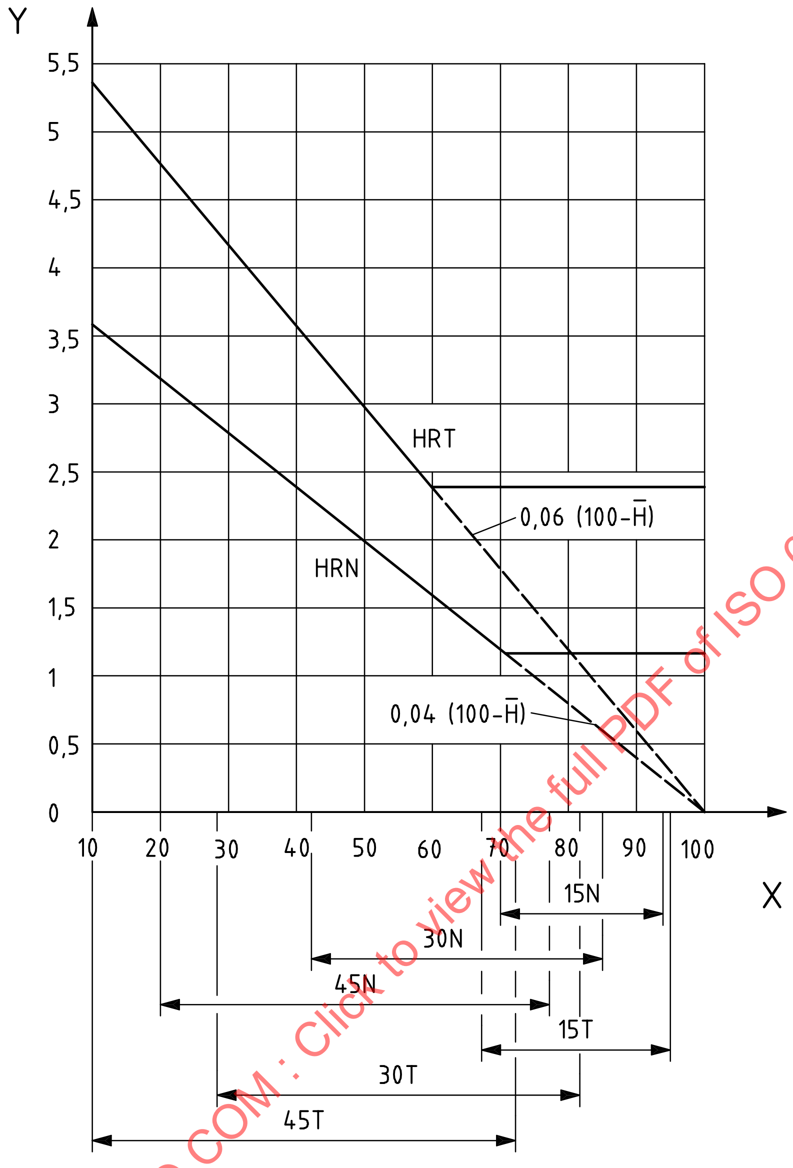


Key

X Rockwell hardness

Y repeatability of testing machines

Figure A.1 — Rockwell hardness (scales A, B, C, D, E, F, G, H and K)



Key

X Rockwell hardness

Y repeatability of testing machines

Figure A.2 — Rockwell superficial hardness (scales N and T)

Annex B
(informative)

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

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:

$$u_F = \sqrt{u_{FRS}^2 + u_{FHTM}^2} \tag{B.1}$$

with

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.

NOTE The metrological chain necessary to define and disseminate hardness scales is shown in Figure G.1 in ISO 6508-1:2005.

For example

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

Calibration value of the force transducer $F_{RS} = 1471{,}0$ N

Table B.1 — Results of the test force calibration

Number of height position for test force calibration	Series 1 F_1 N	Series 2 F_2 N	Series 3 F_3 N	Mean value $\overline{F}$ N	Relative deviation ΔF_{rel} %	Relative standard measurement uncertainty u_{FHTM} %
1	1 471,5	1 471,9	1 471,7	1 471,7	0,05	0,008
2	1 472,1	1 472,3	1 472,7	1 472,3	0,09	0,012
3	1 472,2	1 473,5	1 471,3	1 472,3	0,09	0,043

where

$$\Delta F_{rel} = \frac{F_{RS} - \overline{F}}{\overline{F}} \tag{B.2}$$

$$u_{FHTM} = \frac{s_{Fi}}{\overline{F}} \cdot \frac{1}{\sqrt{n}}, (n = 3) \tag{B.3}$$

s_{Fi} 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	Relative standard measurement uncertainty $u(x_i)$	Sensitivity coefficient c_i	Relative uncertainty contribution $u_i(H)$
u_{FRS}	1 471,0 N		Normal	$6,0 \times 10^{-4}$	1	$6,0 \times 10^{-4}$
u_{FHTM}	1 471,0 N		Normal	$4,3 \times 10^{-4}$	1	$4,3 \times 10^{-4}$
Relative combined standard uncertainty u_F						$7,4 \times 10^{-4}$
Relative expanded uncertainty of measurement U_F $(k = 2)$						$1,5 \times 10^{-3}$

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 uncertainty of test force U_F %	Max. relative deviation of test force including measurement uncertainty of reference instrument ΔF_{max} %
0,09	0,15	0,24

In Table B.3, ΔF_{max} is calculated as follows:

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

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 Depth-measuring system

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

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

where

u_{LRS} is the relative uncertainty of measurement of the depth calibration device (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 depth-measuring system, the depth calibration device, 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 depth calibration device.

For example:

Uncertainty of measurement of depth calibration system: $u_{LRS} = 0{,}000\,2$ mm ($k = 2$)

Resolution of the depth-measuring system $\delta_{ms} = 0{,}5$ µm

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

Rated value of the depth-measuring system L_{RS} mm	Series 1 L_1 mm	Series 2 L_2 mm	Series 3 L_3 mm	Mean value $\bar{L}$ mm	Relative deviation ΔL_{rel} %	Relative standard measurement uncertainty u_{LHTM} %
0,060	0,060 3	0,060 2	0,060 0	0,060 2	0,33	0,15
0,080	0,080 5	0,080 3	0,080 2	0,080 3	0,38	0,11
0,100	0,100 7	0,100 2	0,100 3	0,100 4	0,40	0,15
0,120	0,120 3	0,120 5	0,120 1	0,120 3	0,25	0,10
0,140	0,140 5	0,140 6	0,140 3	0,140 5	0,33	0,06
0,160	0,160 6	0,160 3	0,160 2	0,160 4	0,23	0,07

In Table B.4:

$$u_{\text{LHTM}} = \frac{s_{\text{L}i}}{\bar{L}} \cdot \frac{1}{\sqrt{n}}, \ (n = 3) \quad \text{(B.6)}$$

$$\Delta L_{\text{rel}} = \frac{\bar{L} - L_{\text{RS}}}{L_{\text{RS}}} \quad \text{(B.7)}$$

$s_{\text{L}i}$ 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	Relative standard measurement uncertainty $u(x_i)$	Sensitivity coefficient c_i	Uncertainty contribution $u_i(H)$
u_{LRS}	0 mm	$1{,}0 \times 10^{-4}$ mm	Normal	$1{,}0 \times 10^{-4}$	1	$1{,}0 \times 10^{-4}$
u_{ms}	0 mm	$0{,}5 \times 10^{-4}$ mm	Rectangular	$1{,}8 \times 10^{-4}$	1	$1{,}8 \times 10^{-4}$
u_{LHTM}	0,06 mm	0,15 %	Normal	$9{,}6 \times 10^{-4}$	1	$9{,}6 \times 10^{-4}$
Relative combined uncertainty of measurement u_{L}, (related to 0,16 mm), %						0,098
Relative expanded uncertainty of measurement U_{L} ($k = 2$), %						0,20

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} mm	Relative deviation of the measuring system ΔL_{rel} %	Expanded relative uncertainty of measurement U_{L} %	Max. relative deviation of measuring system including measurement uncertainty of length reference instrument ΔL_{max} %
0,16 mm	0,33	0,20	0,53

In Table B.6:

$$\Delta L_{\text{max}} = \left| \Delta L_{\text{rel}} \right| + U_{\text{L}} \quad \text{(B.8)}$$

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 ± 1,0 µm ($L_{\text{RS}} \times \Delta L_{\text{max}} = 0{,}16$ mm $\times$ 0,57 % = 0,000 91 mm), 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).

