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Metallic materials — Rockwell hardness test —

Part 2:
Verification and calibration of testing machines and indenters

Matériaux métalliques — Essai de dureté Rockwell —

Partie 2: Vérification et étalonnage des machines d'essai et des pénétrateurs

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Foreword

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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 document 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).

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This document was prepared by Technical Committee ISO/TC 164, *Mechanical testing of metals*, Subcommittee SC 3, *Hardness testing,* in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 459, *ECISS - European Committee for Iron and Steel Standardization,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This fourth edition cancels and replaces the third edition (ISO 6508-2:2015), which has been technically revised.

The main changes are as follows:

— removed all statements of requirements, permissions, and recommendations from the Scope of the document (Clause 1);

— addition of Clause 3, Terms and definitions;

— modification of the requirements for the calibration and verification of the force and depth measuring systems (Clause 4);

— added a requirement for the hardness of the indenter ball holder (Clause 6);

— changed the layout of Table 8 (Clause 6);

— modified the requirements for direct and indirect calibration and verification (Clause 7);

— modified the information related to the determination of uncertainty of measurement (Annex B).

A list of all parts in the ISO 6508 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Metallic materials — Rockwell hardness test —

Part 2:
Verification and calibration of testing machines and indenters

1 Scope

This document specifies two separate methods of verification of testing machines (direct and indirect) for determining Rockwell hardness in accordance with ISO 6508-1, together with a method for verifying Rockwell hardness indenters.

The direct verification method is used to determine whether the main parameters associated with the machine function, such as applied force, depth measurement, and testing cycle timing, fall within specified tolerances. The indirect verification method uses a number of calibrated reference hardness blocks to determine how well the machine can measure a material of known hardness.

This document is applicable to stationary and portable hardness testing machines.

Attention is drawn to the fact that the use of tungsten carbide composite for ball indenters is considered to be the standard type of Rockwell indenter ball.

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 376, *Metallic materials — Calibration of force-proving instruments used for the 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*

ISO 6508-3, *Metallic materials — Rockwell 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 terminology databases for use in standardization at the following addresses:

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

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

4 General conditions

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

Especially, it should be checked that the test force can be applied and removed without shock, vibration, or overload and in such a manner that the readings are not influenced.

5 Direct verification of the testing machine

5.1 General

5.1.1 Direct verification involves calibration and verification of the following:

a) test forces;

b) depth-measuring system;

c) testing cycle;

d) machine hysteresis test.

5.1.2 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.

5.1.3 The instruments used for calibration shall be traceable to national standards.

5.1.4 An indirect verification according to Clause 6 shall be performed following a successful direct verification.

5.2 Calibration and verification of the test force

5.2.1 Each preliminary test force, F_0, (see 5.2.4) and each total test force, F, used (see 5.2.5) 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. For testing machine designs where the force is not influenced by the position of the plunger, e.g. controlled loading systems with closed-loop control, the test force can be calibrated in one position. The preliminary test force shall be held for at least 2 s.

5.2.2 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.

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

— by means of a force-proving device according to ISO 376 class 1 or better and calibrated for reversibility;

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

Evidence should be available to demonstrate that the output of the force-proving device does not vary by more than 0,2 % in the period 1 s to 30 s following a stepped change in force.

5.2.4 A relative error value, expressed as a percentage, shall be calculated for each measured force by the general Formula (1):

$$\Delta F_{\mathrm{rel},i,j} = 100 \times \frac{F_{i,j} - F_{\mathrm{RS}}}{F_{\mathrm{RS}}} \quad (1)$$

where $\Delta F_{\mathrm{rel},i,j}$ is the relative error of each force measurement value, $F_{i,j}$, (whether it is a preliminary force value, F_0, or the total force value, F) with respect to the reference force value, F_{RS}, to be measured.

The indices i and j of the force measurement value, $F_{i,j}$ indicate the j-th force measurement at the i-th plunger height position.

5.2.5 The maximum permissible relative error on each measurement of the preliminary test force, F_0, (before application and after removal of the additional test force, F_1) as calculated by Formula (1) shall be ±2,0 %. The range of all force measurements (highest value minus lowest value) at each measurement position shall be ≤ 1,5 % of F_0.

5.2.6 The maximum permissible relative error on each measurement of the total test force, F, as calculated by Formula (1), shall be ±1,0 %. The range of the force measurements (highest value minus lowest value) shall be ≤ 0,75 % of F.

5.3 Calibration and verification of the depth-measuring system

5.3.1 The depth-measuring system shall be calibrated by making known incremental movements of the indenter or the indenter holder.

5.3.2 The instrument or gauge blocks used to verify the depth-measuring system shall have a maximum expanded uncertainty of 0,000 3 mm when calculated with a 95 % confidence level.

NOTE The use of gauge blocks to verify the depth measuring system may not be appropriate for all types of Rockwell hardness machines.

5.3.3 Calibrate the testing machine's depth measurement system at not less than four evenly spaced intervals covering the full range of the normal working depth for the required scales to be calibrated in the testing machine. Three cycles of depth readings shall be taken over the evenly spaced intervals of the depth measuring system.

NOTE The maximum depth required for each scale is different, ranging from 0,25 mm for Rockwell regular scale B to 0,04 mm for Rockwell superficial scale 15N.

5.3.4 Some testing machines have a long-stroke depth measuring system where the location of the working range of the depth measuring system varies to suit the sample. This type of testing machine shall be able to electronically verify that the depth measuring device is continuous over the full range. These types of testers shall be verified using the following steps:

a) at the approximate top, midpoint and bottom of the total stroke of the measuring device, verify the depth measurement system at no less than four evenly spaced intervals of approximately 0,05 mm at each of the three locations;

b) operate the actuator over its full range of travel to monitor whether the displacement measurement is continuous. The displacement indication shall be continuously indicated over the full range.

5.3.5 Calculate the difference, $\Delta L_{i,j}$, between each depth measurement value, $L_{i,j}$ and the reference value of the calibration device, L_{RS}, in accordance with the general Formula (2):

$$\Delta L_{i,j} = L_{i,j} - L_{RS} \quad (2)$$

The indices i and j of the depth measurement value, $L_{i,j}$ indicate the j-th depth measurement at the i-th interval of the depth measuring system.

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.

5.4 Calibration and verification of the testing cycle

5.4.1 The testing cycle is to be calibrated by the testing machine manufacturer at the time of manufacture and when the testing machine undergoes repair which may have affected the testing cycle. Calibration of the complete testing cycle is not required as part of the direct verification at other times, see Table 10.

5.4.2 The testing cycle shall conform to the testing cycle specified in ISO 6508-1.

5.4.3 For testing machines that automatically control the testing cycle, the measurement uncertainty ($k = 2$) of the timing instrument used to verify the testing cycle shall not exceed 0,2 s. It is recommended that the measured times for the testing cycle, plus or minus the measurement uncertainty ($k = 2$) of the calibration measurements, not exceed the timing limits specified in ISO 6508-1.

5.4.4 For testing machines that require the user to manually control the testing cycle, the testing machine shall be verified to be capable of achieving the specified testing cycle.

5.5 Calibration and verification of the machine hysteresis

5.5.1 The machine shall be checked to ensure that the readings are not affected by a hysteresial flexure of testing machine components (e.g. frame, specimen holder, etc.) during a test. The influence of any hysteresis behaviour shall be checked by making repeated hardness tests using a spherical indenter of at least 10 mm diameter, bearing directly against the specimen holder or through a spacer such that no permanent deformation occurs. A parallel block placed between the indenter holder and the specimen holder may be used instead of a blunt indenter. The material of the blunt indenter and of the spacer or parallel block shall have a hardness of at least 60 HRC.

5.5.2 Perform repeated Rockwell tests using the setup specified in 5.5.1. The tests shall be conducted using the Rockwell scale with the highest test force that is used during normal testing. Repeat the hysteresis verification procedure for a maximum of 10 measurements and average the last three tests.

5.5.3 The average of the last three tests shall indicate a hardness number of (130 ± 1,0) Rockwell units when the regular Rockwell ball scales B, E, F, G, H, and K are used, or within (100 ± 1,0) Rockwell units when any other Rockwell scale is used.

6 Indirect verification of the testing machine

6.1 General

6.1.1 Indirect verification involves the calibration and verification of the testing machine by performing tests on reference blocks.

6.1.2 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.

6.2 Procedure

6.2.1 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 will be used. For each scale to be verified, reference blocks from each of the hardness ranges given in Table 1 shall be used. The hardness values of the blocks shall be chosen to approximate the limits of the intended use. It is recommended to perform the same test cycle used when the reference blocks were calibrated.

Only the calibrated surfaces of the test blocks are to be used for testing.

6.2.2 On each reference block, a minimum of five indentations, made in accordance with ISO 6508-1, shall be uniformly distributed over the test surface and each hardness number observed to a resolution of no greater than 0,2 HR 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 specimen holder are seating correctly. The results of these preliminary indentations shall be ignored.

Table 1 — 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 95 HRA	K	40 to 60 HRKW 65 to 80 HRKW 85 to 100 HRKW
B	10 to 50 HRBW 60 to 80 HRBW 85 to 100 HRBW	15N	70 to 77 HR15N 78 to 88 HR15N 89 to 94 HR15N
C	10 to 30 HRC 35 to 55 HRC 60 to 70 HRC	30N	42 to 54 HR30N 55 to 73 HR30N 74 to 86 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 77 HR45N
E	70 to 77 HREW 84 to 90 HREW 93 to 100 HREW	15T	67 to 80 HR15TW 81 to 87 HR15TW 88 to 93 HR15TW
F	60 to 75 HRFW 80 to 90 HRFW 94 to 100 HRFW	30T	29 to 56 HR30TW 57 to 69 HR30TW 70 to 82 HR30TW
G	30 to 50 HRGW 55 to 75 HRGW 80 to 94 HRGW	45T	10 to 33 HR45TW 34 to 54 HR45TW 55 to 72 HR45TW
H	80 to 94 HRHW 96 to 100 HRHW		

6.3 Repeatability

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

The repeatability range, *r*, of the testing machine in Rockwell units, under the particular verification conditions, is determined by Formula (3):

$$r = H_n - H_1 \quad (3)$$

The mean hardness value of all indentations $\overline{H}$ is defined according to Formula (4):

$$\overline{H} = \frac{H_1 + H_2 + H_3 + H_4 + \ldots + H_n}{n} \tag{4}$$

where

$H_1, H_2, H_3, H_4, \ldots H_n$	are the hardness values corresponding to all the indentations;
n	is the total number of indentations.

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

Table 2 — Permissible repeatability range and bias of the testing machine

Rockwell hardness scale	Hardness range of the reference block	Permissible bias Rockwell units b	Permissible repeatability range of the testing machine[a] r
A	20 to 75 HRA > 75 to 95 HRA	±2 HRA ±1,5 HRA	≤ 0,02 (100 − $\overline{H}$) or 0,8 HRA Rockwell units[b]
B	10 to 45 HRBW > 45 to 80 HRBW > 80 to 100 HRBW	±4 HRBW ±3 HRBW ±2 HRBW	≤ 0,04 (130 − $\overline{H}$) HRBW Rockwell units
C	10 to 70 HRC	±1,5 HRC	≤ 0,02 (100 − $\overline{H}$) or 0,8 HRC Rockwell units[b]
D	40 to 70 HRD > 70 to 77 HRD	±2 HRD ±1,5 HRD	≤ 0,02 (100 − $\overline{H}$) or 0,8 HRD Rockwell units[b]
E	70 to 90 HREW > 90 to 100 HREW	±2,5 HREW ±2 HREW	≤ 0,04 (130 − $\overline{H}$) HREW Rockwell units
F	60 to 90 HRFW > 90 to 100 HRFW	±3 HRFW ±2 HRFW	≤ 0,04 (130 − $\overline{H}$) HRFW Rockwell units
G	30 to 50 HRGW > 50 to 75 HRGW > 75 to 94 HRGW	±6 HRGW ±4,5 HRGW ±3 HRGW	≤ 0,04 (130 − $\overline{H}$) HRGW Rockwell units
H	80 to 100 HRHW	±2 HRHW	≤ 0,04 (130 − $\overline{H}$) HRHW Rockwell units
K	40 to 60 HRKW > 60 to 80 HRKW > 80 to 100 HRKW	±4 HRKW ±3 HRKW ±2 HRKW	≤ 0,04 (130 − $\overline{H}$) HRKW Rockwell units
15N, 30N, 45N	All ranges	±2 HRN	≤ 0,04 (100 − $\overline{H}$) or 1,2 HRN Rockwell units [b]
15T, 30T, 45T	All ranges	±3 HRTW	≤ 0,06 (100 − $\overline{H}$) or 2,4 HRTW Rockwell units[b]

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

[b] The one with a greater value becomes the permissible repeatability range of the testing machine.

NOTE The requirements for permissible repeatability range, r, and/or permissible bias, b, might be different in ASTM E 18.

6.4 Bias

6.4.1 The bias, b, of the testing machine in Rockwell units, under the particular calibration conditions, is expressed by the following Formula (5):

$$b = \overline{H} - H_{CRM} \qquad (5)$$

where

$\overline{H}$ is the mean hardness value, from Formula (4);

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

6.4.2 The bias of the testing machine shall not exceed the values given in Table 2.

6.5 Uncertainty of measurement

A method to determine the uncertainty of measurement of the calibration results of the hardness testing machines is given in Annex B.

7 Calibration and verification of Rockwell hardness indenters

7.1 General

7.1.1 Indenter calibrations and verifications 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.

7.1.2 The instruments used for calibration and verifications shall be traceable to national standards.

7.2 Diamond indenter

7.2.1 General

To verify the reliable performance of the spheroconical diamond indenter in conformance with this document, a direct and an indirect calibration and verification shall be carried out on each indenter.

7.2.2 Direct calibration and verification of the diamond indenter

7.2.2.1 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 smooth tangential manner. Both surfaces shall be free from surface defects.

7.2.2.2 The verification of the shape of the indenter can be made by direct measurement or optically. The verification shall be made at not less than four unique equally spaced axial planes (for example, at 0°, 45°, 90°, 135°). Measurement with a collimator device is also acceptable. In this case, the measurements should be carried out at least in four central angles and the central angle of 120° shall be included.

The location where the spherical tip and the cone of the diamond blend together will vary depending on the values of the tip radius and cone angle. Ideally for a perfect indenter geometry, the blend point is located at 100 µm from the indenter axis measured along a line normal to the indenter axis. To avoid including the blend area in the measurement of the tip radius and cone angle, the portion of the diamond surface between 80 µm and 120 µm may be ignored.

7.2.2.3 The instruments used to verify the shape of the diamond indenter shall have the following maximum expanded uncertainty when calculated with a 95 % confidence level:

— angle: 0,1°;

— radius: 0,005 mm.

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

7.2.2.5 The tip of the indenter shall be spherical. Its mean radius shall be determined from at least four single values, measured in the axial section planes specified in 7.2.2.2. Each single value shall be within (0,2 ± 0,015) mm. The mean value shall be within (0,2 ± 0,01) mm. Local deviations from a true radius shall not exceed 0,002 mm.

7.2.3 Indirect verification of diamond indenters

7.2.3.1 The hardness values given by the testing machine depend not only on the dimensions of the tip radius and cone angle, 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 these influences, an indirect verification of the performance of the diamond indenter shall be accomplished by making a series of tests on reference blocks that meet the requirements of ISO 6508-3 and comparing the results against a calibration diamond indenter that meets the requirements of ISO 6508-3.

This indirect verification shall be performed using a calibration machine that meets the relevant paragraphs of ISO 6508-3.

Diamond indenters may be certified for use for either:

— only the regular Rockwell diamond scales, or

— only the superficial Rockwell diamond scales, or

— both the regular and superficial Rockwell diamond scales, or

— any singular or limited combination of diamond scales.

NOTE It might be necessary to use a diamond indenter on a reduced number of test scales due to force limitations, such as a side cut diamond indenter for testing gear tooth profiles, or other considerations.

7.2.3.2 The reference blocks used for this indirect verification shall be chosen at the hardness levels given in Tables 3, 4, 5, 6, or 7 depending on the scales for which the indenter is to be certified. When verifying diamond indenters to be used on a limited number of scales, use the reference blocks specified in Table 5 for the HRC scale and/or the appropriate scale row(s) in Table 7 for any other diamond scale.

NOTE The alternate hardness levels given in Table 4 are provided to accommodate indenters calibrated to other International Standards. It is believed that calibrations conducted to Table 3 or Table 4 will yield equivalent results.

Table 3 — Hardness levels for diamond indenters used for Rockwell regular and superficial scales (A, C, D, and N)

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

Table 4 — Alternate hardness levels for diamond indenters used for Rockwell regular and superficial scales (A, C, D, and N)

Scale	Nominal hardness	Ranges
HRC	25	22 to 28
HRC	63	60 to 65
HR30N	64	60 to 69
HR15N	91	88 to 94

Table 5 — Hardness levels for diamond indenters to be used for Rockwell regular scale testing only (A, C, and D)

Scale	Nominal hardness	Ranges
HRC	25	22 to 28
HRC	63	60 to 65

Table 6 — Hardness levels for diamond indenters to be used for Rockwell superficial scale testing only (N)

Scale	Nominal hardness	Ranges
HR15N	91	88 to 94
HR30N	64	60 to 69
HR45N	25	22 to 29

Table 7 — Hardness levels for diamond indenters to be used for limited scale testing

Scale	High nominal hardness	High hardness range	Low nominal hardness	Low hardness range
HRA	83	81 to 84	63	61 to 65
HRD	73	70 to 75	44	41 to 46
HR15N	91	88 to 94	72	70 to 74
HR30N	80	77 to 82	46	43 to 49
HR45N	70	66 to 72	25	22 to 29

7.2.3.3 The testing shall be carried out in accordance with ISO 6508-1 using the following procedure.

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 three indentations obtained with the calibration indenter by more than ±0,8 Rockwell units. The indentations made with the indenter to be verified and with the calibration indenter should be adjacent to each other on each block.

7.3 Ball indenter

Ball indenters normally consist of a spherical ball and a separate appropriately designed holder. Single-piece spherically tipped indenters are allowed, provided the surface of the indenter that makes contact with the test piece meets the size, shape, finish, and hardness requirements specified in 7.3.1, and it meets the performance requirements specified in 7.3.2.

The material used to manufacture the portion of the ball holder that supports the test force should have a minimum hardness of 25 HRC. The ball should protrude sufficiently from its holder to prevent the holder from contacting the test material.

7.3.1 Direct calibration and verification of the ball indenter

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

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

7.3.1.3 The diameter, measured at no less than three positions, shall not differ from the nominal diameter by more than the tolerance given in Table 8.

Table 8 — Tolerances for the different ball diameters

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

7.3.1.4 The characteristics of the tungsten carbide composite 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 (HV 0,5) in accordance with ISO 6507-1. The 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 9;

— Density: ρ = (14,8 ± 0,2) g/cm^3.

The following chemical composition is recommended:

— tungsten carbide (WC): balance;

— total other carbides: 2,0 %;

— cobalt (Co): 5,0 % to 7,0 %.

7.3.1.5 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 9).

NOTE Hardened steel balls are only used when performing the Special HR30TSm and HR15TSm test for thin products according to ISO 6508-1.

Table 9 — 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	
	Hardened steel ball	Tungsten carbide composite ball
3,175		0,109
1,587 5	0,150	0,107

7.3.2 Indirect verification of the ball holder assembly

7.3.2.1 The B, E, F, G, H, K, T scale hardness values given by the testing machine depends not only on the dimensions of the ball indenter, but also on the seating and alignment of the ball in its holder. To examine these influences, an indirect verification of the performance of the ball indenter assembly shall be done by making a series of tests on a reference block that meets the requirements of ISO 6508-3, using a tester that meets the requirements of this document, following the procedures specified in ISO 6508-1.

7.3.2.2 Perform at least three tests on at least one HRBW scale (or the scale with the highest test force that the indenter is going to be used to perform) test block.

7.3.2.3 The mean hardness value of three indentations made using the ball holder assembly to be verified shall not differ from the certified hardness value of the test block by more than the permissible bias specified in Table 2.

7.4 Marking

7.4.1 All diamond indenters and ball holder assemblies shall be serialized. When it is not practical to mark the serial number on the indenter due to size limitations, the serial number shall be marked on the container.

7.4.2 Diamond indenters with limited range of use shall be appropriately marked. For example, diamond indenters certified for use on the superficial N scale only may be marked with an N and diamonds certified for use on the regular A, C, and D scales only may be marked with a C.

8 Intervals between direct and indirect calibrations and verifications

8.1 The schedules for the direct verification of Rockwell hardness testing machines are given in Table 10. As the procedure for direct verification of the testing machine has not changed from the previous revision, it is not necessary to reconduct the direct verification to state compliance to this standard.

8.2 Indirect verification shall be performed at least once annually, not to exceed 13 months, and after a direct verification has been performed. For high-use machines, a smaller interval might be appropriate.

8.3 When a testing machine is moved, a modified indirect verification shall be performed. In this case, the procedures of Clause 5 shall be followed except that a minimum of two reference blocks from the hardness ranges given in Table 1 shall be tested for each scale the testing machine will be used, and a minimum of two indentations shall be made on each block. This verification does not apply to portable testing machines or to testing machines that are designed to be moved and have been previously verified to ensure that moving will not affect the hardness result.

8.4 If an indirect verification has not been performed within 13 months, a direct verification shall be performed before the tester can be used (see Table 10).

Table 10 — Direct verifications of hardness testing machines

Requirements of verification	Force	Measuring system	Test cycle	Machine hysteresis	Indenter[a]
before setting to work first time	x	x	x	x	x
after dismantling and reassembling, if force, measuring system or test cycle are affected	x	x	x	x	
failure of indirect verification[b]	x	x	(x)[c]	x	
indirect verification > 13 months ago	x	x	(x)[c]	x	

[a] In addition, it is recommended that the diamond indenter be directly verified after two 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 an indenter known to measure correctly) that the indenter was the cause of the failure.

[c] At minimum, verify the duration of the total test forces.

9 Verification report

A verification report is required for the direct and indirect verifications of testing machines and indenters. The verification report certificate shall at minimum include the following information:

a) a reference to this document, i.e. ISO 6508-2:2023;

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

c) identification data for the hardness testing machine, or indenter/ball holder;

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

e) Rockwell hardness scale(s) and if appropriate, the verified ranges of scale(s) verified;

f) diamond scale indenter reports shall indicate the scale(s) the indenter is certified to perform;

g) verification temperature, if the verification was carried out outside of (23 ± 5) °C;

h) result obtained;

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

j) uncertainty of the verification result. Examples are indicated in Annex B;

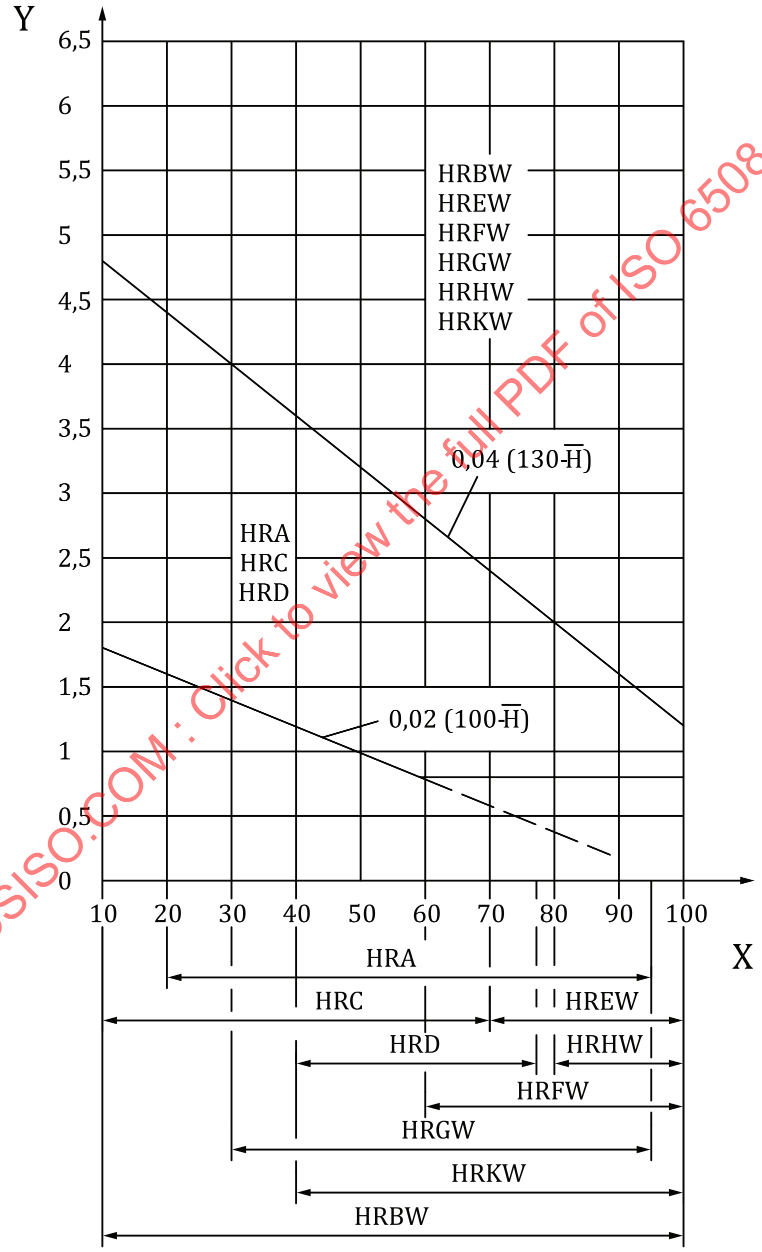
k) any deviation from the procedure;

l) any unusual features observed.

Annex A
(normative)

Repeatability of testing machines

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

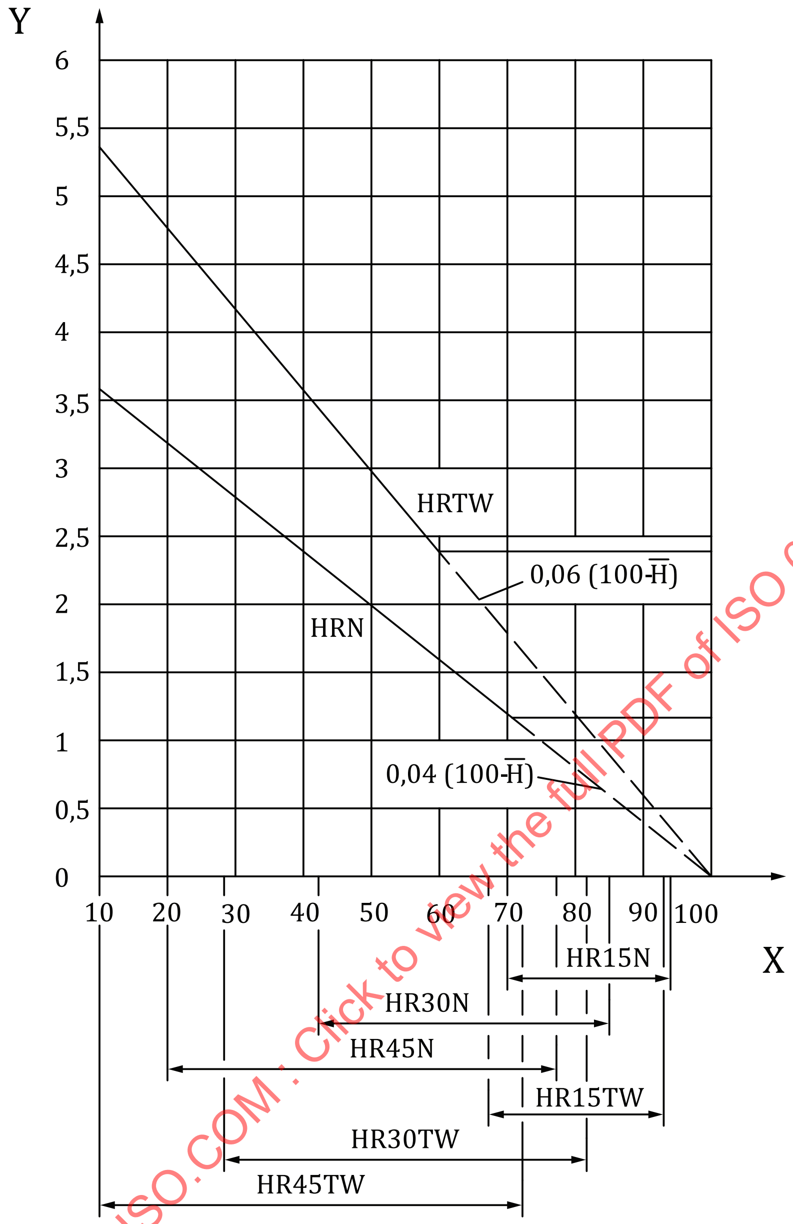


Key

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 General

Measurement uncertainty analysis is a useful tool to help determine sources of error and to understand differences between measured values. This annex gives guidance on uncertainty estimation, but the methods contained are for information only, unless specifically instructed otherwise by the customer. 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 direct or indirect verification of the machine. In each case, it is simply the measured value resulting from the use of the specified measuring equipment and/or reference standards that is used to assess whether or not the machine complies with this document. However, there can be special circumstances where reducing the tolerance by the measurement uncertainty is appropriate. This should only be done by agreement of the parties involved.

B.2 Direct verification — Uncertainty of calibration of machine components

B.2.1 Uncertainty of calibration of the test force

For the direct calibration of force, the difference ΔF between each individual measurement of force applied by the hardness machine and the corresponding force value indicated by the reference instrument is calculated and reported. The direct verification verifies whether each ΔF is within the specified maximum permissible limits. Consequently, the following is a procedure to calculate the uncertainties of the ΔF values with respect to the true value of force specified by the test. The combined relative standard uncertainty of the test force calibration at the i-th height position is calculated according to Formula (B.1):

$$u_{\mathrm{F},i} = \sqrt{u_{\mathrm{FRS}}^2 + u_{\mathrm{FHTM},i}^2} \tag{B.1}$$

where

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

$u_{\mathrm{FHTM},i}$ is the relative standard uncertainty of the test force generated by the hardness testing machine at the i-th height position.

The uncertainty of measurement of the reference instrument, force transducer, is indicated in the corresponding calibration certificate. Influence quantities like the following should be considered for critical applications:

— temperature dependence;

— long-term stability;

— interpolation deviation.

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 ISO 6508-1.

EXAMPLE Direct verification of the applied force of the testing machine.

Calibration value of the force transducer (force to be measured): F_{RS} = 1 471,0 N

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

$$\Delta F_{\text{rel},i,j} = 100 \times \frac{F_{i,j} - F_{RS}}{F_{RS}} \tag{B.2}$$

where $F_{i,j}$ is the j-th test-force indication value in the i-th height position.

$$u_{FRS} = \frac{U_{FRS}}{2} \tag{B.3}$$

$$u_{\text{FHTM},i} = 100 \times \frac{s_{F,i}}{\bar{F}_i} \times t \tag{B.4}$$

where $s_{F,i}$ is the standard deviation and $\bar{F}_i$ is the mean of the test-force indication values in the i-th height position.

Table B.1 — Results of the test force calibration

Number of height position for test force calibration i	Force indication 1 $F_{i,1}$ N	Force indication 2 $F_{i,2}$ N	Force indication 3 $F_{i,3}$ N	Mean value $\bar{F}_i$ N	Standard deviation $s_{F,i}$ N
1	1 471,5	1 471,9	1 471,7	1 471,7	0,200
2	1 472,1	1 472,3	1 472,7	1 472,4	0,306
3	1 472,2	1 473,5	1 471,3	1 472,3	1,106

The following example calculations will use values of the force indication 1 at the height position 3 from Table B.1. See Table B.2.

From the given direct verification parameters and Table B.1:

$$\Delta F_{\text{rel},3,1} = 100 \times \frac{1\ 472,2 - 1\ 471,0}{1\ 471,0} = 0,08\ \%$$ (for force indication j=1 at the height position i=3)

$$u_{FRS} = \frac{U_{FRS}}{2} = 0,06\ \%$$

$$u_{\text{FHTM},1} = 100 \times \frac{s_{F,3}}{\bar{F}_3} \times t = 100 \times \frac{1,106}{1\ 472,3} \times 1,32 = 9,9 \times 10^{-2}\ \%$$ (for three readings, t =1,32)

Table B.2 — Calculation of the uncertainty of measurement of the test force (for height position *i* = 3 from Table B.1)

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 standard measurement uncertainty symbol	Relative uncertainty contribution u_i
Force transducer indication	1 471,0 N		Normal	$6,0 \times 10^{-2}$ %	1	u_{FRS}	$6,0 \times 10^{-2}$ %
Generated test force	1 471,0 N	1,0 %	Normal	$9,9 \times 10^{-2}$ %	1	$u_{FHTM,3}$	$9,9 \times 10^{-2}$ %
Relative combined standard uncertainty of measurement for height position 3, $u_{F,3}$							$1,2 \times 10^{-1}$ %
Relative expanded uncertainty of measurement for height position 3, $U_{F,3}$ ($k = 2$)							$2,3 \times 10^{-1}$ %

The above calculations shall be done for all height positions.

Table B.3 shows the relative deviation of one test force measurement (1 471 N force indication 1; height 3) and the corresponding expanded relative uncertainty of the test force deviation, $\Delta F_{rel,3,1}$. There can be circumstances where the user needs to account for the relative expanded uncertainty of the test force deviation, U_F, generated by the hardness testing machine when determining compliance with the maximum permissible relative deviation of the test force. In Table B.3, a value of $\Delta F_{max,3,1}$ is also calculated as follows:

$$\Delta F_{max,i,j} = \left|\Delta F_{rel,i,j}\right| + U_{F,i} \tag{B.5}$$

which combines the relative deviation of one test force measurement with the expanded relative uncertainty of the test force. In this case, the value of $\Delta F_{max,3,1}$, rather than the force deviation value, $\Delta F_{rel,3,1}$, is compared to 5.2.5 to determine compliance.

Table B.3 — Calculation of the relative deviation of one test force measurement combined with the expanded relative uncertainty of the test force measurement

Relative deviation of test force [force indication 1; height 3] $\Delta F_{rel,3,1}$	**Expanded combined relative uncertainty of the test force** $U_{F,3}$	**Relative deviation of test force combined with the expanded relative uncertainty of the test force** $\Delta F_{max,3,1}$
0,08 %	0,23 %	0,31 %

B.2.2 Uncertainty of depth-measuring system

For the direct verification of depth-measuring system, the difference ΔL between each individual measurement of depth measured by the hardness machine and the corresponding depth value indicated by the reference instrument is calculated and reported. The direct verification verifies whether each ΔL is within specified maximum permissible limits. Consequently, the following is a procedure to calculate the uncertainties of the ΔL values with respect to the true value of the depth. The combined standard uncertainty of the depth-measuring system for the *i*-th depth intervals calculated as follows:

$$u_{L,i} = \sqrt{u_{LRS}^2 + u_{ms}^2 + u_{LHTM,i}^2} \tag{B.6}$$

where

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

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

$u_{LHTM,i}$ is the standard uncertainty of measurement of the hardness testing machine at the i-th depth interval.

The uncertainty of measurement of the reference instrument for the depth-measuring system, the depth calibration device, is indicated in the corresponding calibration certificate. It is assumed that quantities, such as the following, do not exert an essential influence on the uncertainty of measurement of the depth calibration device:

— temperature dependence;

— long-term stability;

— interpolation deviation.

EXAMPLE Direct verification of the depth measuring system of the testing machine for the A to K scales.

Expanded uncertainty of measurement of depth calibration system: U_{LRS} = 0,000 2 mm (k = 2) (from calibration certificate)

Resolution of the depth-measuring system: δ_{ms} = 0,5 µm

Three measurements of depth are made at each of five intervals of depth as shown in Table B.4.

$$\Delta L_{i,j} = L_{i,j} - L_{RS} \quad \text{(B.7)}$$

where $L_{i,j}$ is the j-th measured depth value at the i-th depth interval.

$$u_{LRS} = \frac{U_{LRS}}{2} \quad \text{(B.8)}$$

$$u_{LHTM,i} = s_{L,i} \times t \quad \text{(B.9)}$$

where $s_{L,i}$ is the standard deviation of the depth indication values for the i-th depth interval.

$$u_{ms} = \frac{\delta_{ms}}{2\sqrt{3}} \quad \text{(B.10)}$$