INTERNATIONAL
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OIML R 39

Edition 2006 (E)

Rockwell hardness machines

Machines de dureté Rockwell

OIML R 39 Edition 2006 (E)

ORGANISATION INTERNATIONALE
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Contents

Foreword

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This publication - reference OIML R 39, edition 2006 (E) - was developed by the OIML Technical Subcommittee TC 10/SC 5 *Hardness standardized blocks and hardness testing machines*. It was approved for final publication by the International Committee of Legal Metrology in 2006 and will be submitted to the International Conference of Legal Metrology in 2008 for formal sanction. This Edition supersedes the previous edition of OIML R 39 (Edition 1981).

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Rockwell hardness machines

1 Scope

1.1 The Rockwell hardness test is an indentation hardness test using a verified machine to force an indenter, under specified conditions, into the surface of the material under test. The Rockwell hardness value is based on the permanent increase in the indentation depth as the force on the indenter is varied in a specified manner.

1.2 This Recommendation gives the metrological and technical requirements and the verification and testing procedures necessary for metrological control of Rockwell hardness machines subject to national laws and regulations. For metrological control, only requirements for initial verification and subsequent verification are covered since, in general, type evaluation is not considered to be practical for these measuring systems.

1.3 Throughout this Recommendation and the accompanying Annexes, the designation “Rockwell hardness machine” will be used as a general term that covers two instrument classes: the Rockwell standardizing machine and the Rockwell testing machine.

1.4 This Recommendation covers Rockwell hardness machines capable of conducting Rockwell indentation hardness tests. The Rockwell hardness scales covered by this recommendation are: A, B, C, D, E, F, G, H, K and superficial scales 15N, 30N, 45N, 15T, 30T and 45T. Throughout this Recommendation, Rockwell scales are often represented by a single letter designation without the preceding “HR”. For brevity, the "S" and "W" designations often have been left off the scale designations for ball scales. In these cases, the requirements apply equally for Rockwell tests using either steel or tungsten carbide ball indenters. In addition, occasionally the Rockwell superficial scales 15N, 30N and 45N are specified as a group using only the single designation N, and similarly the 15T, 30T and 45T scales are specified as a group using the single designation T. In these cases, the requirements apply equally to each of the three N or T scales.

1.5 This Recommendation does not cover instruments that provide a correlated Rockwell hardness value by performing tests other than by the Rockwell indentation hardness test.

1.6 This Recommendation does not cover primary national Rockwell hardness standardizing machines.

1.7 The requirements for the verification and standardization of Rockwell hardness reference test blocks are addressed in OIML R 11 *Rockwell hardness reference test blocks* (OIML, 1974).

1.8 The requirements for Rockwell hardness indenters are addressed in OIML R 36 *Indenters for Rockwell hardness machines* (OIML, 1980).

1.9 Requirements and recommendations for the determination of hardness measurement uncertainty are not addressed by this Recommendation.

Note: The most current editions of some international Rockwell hardness standards [1,2,3,4,5] include guidelines for estimating Rockwell hardness uncertainty.

2 Terminology

2.1 Rockwell (indentation) hardness test

Mechanical test in which an indenter of a specified size and shape (diamond spheroconical or a steel or tungsten-carbide ball) is forced into the surface of a test material.

Initially, a preliminary force F_0 is applied to the indenter. The force on the indenter is increased in a specified manner by an additional force F_1 to achieve the total force F, then the additional force F_1 is removed and the force on the indenter is returned to the preliminary force F_0. The depth of indentation is measured before and after application of the additional force F_1, while maintaining the preliminary force F_0 (see Annex A). A Rockwell hardness value for the test material is derived from the difference in the indentation depths (see Fig. 1).

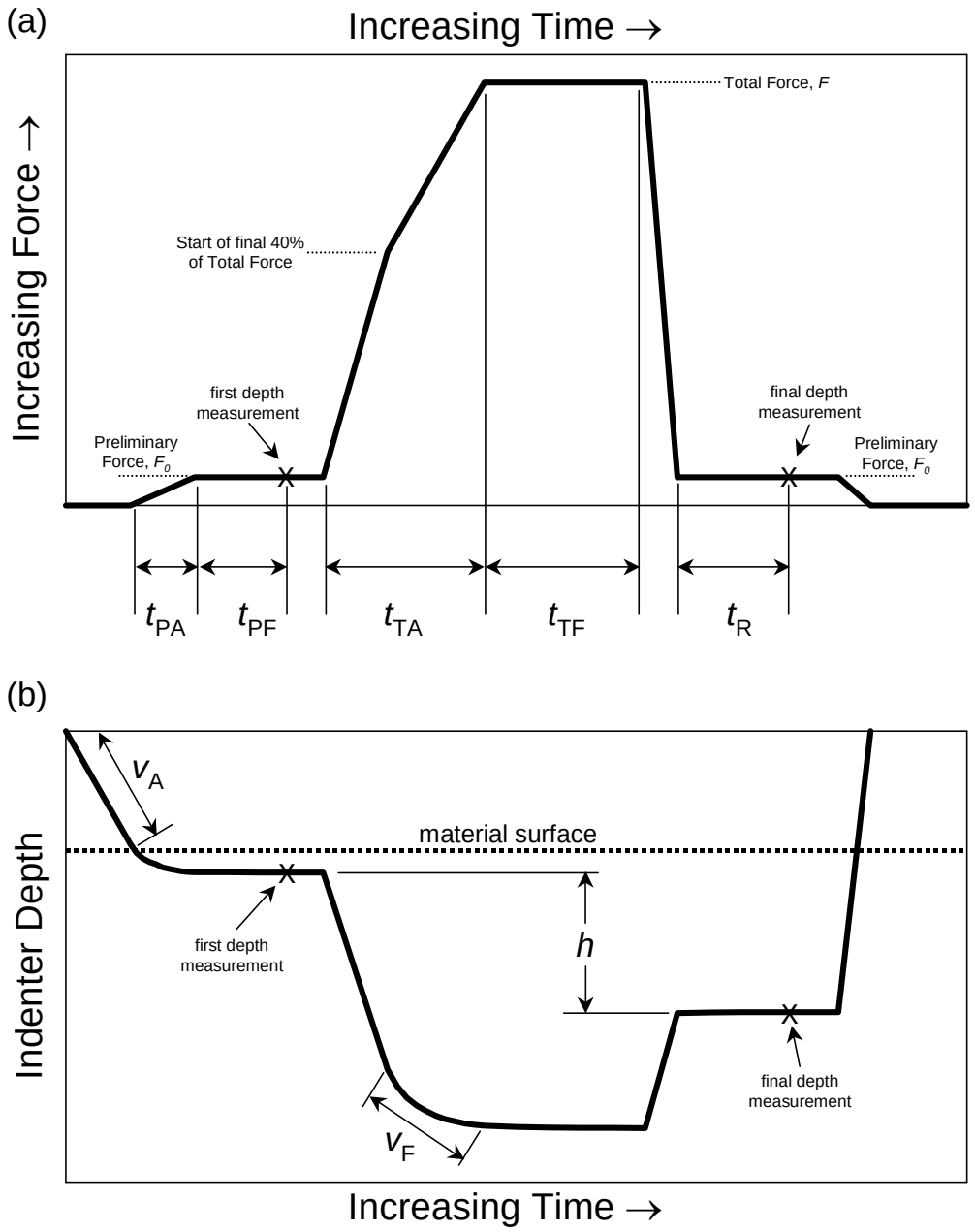

Figure 1 **Plots of force vs. time (a) and indenter-depth vs. time (b) for a Rockwell hardness test illustrating the test cycle parts and the difference in indenter depth measurements *h* (see 4.4.1 for the definitions of the symbols)**

2.2 Rockwell hardness (value)

Number determined from a Rockwell hardness test, derived from the difference in the indentation depths before and after application of the additional force F_1, while maintaining the preliminary test force F_0. The difference in indentation depths is measured as *h* (see Fig. 1) in mm. The calculation is dependent on the specific combination of indenter type and the forces used.

2.2.1 For scales that use a diamond spheroconical indenter, the Rockwell hardness value is calculated as follows where *h* is in mm:

$$Rockwell\ Hardness = 100 - \frac{h}{0.002} \quad \text{(HRA, HRC, HRD)}$$

$$Rockwell\ Superficial\ Hardness = 100 - \frac{h}{0.001} \quad \text{(HR15N, HR30N, HR45N)}$$

2.2.2 For scales that use a ball indenter, the Rockwell hardness value is calculated as follows where *h* is in mm:

$$Rockwell\ Hardness = 130 - \frac{h}{0.002} \quad \text{(HRB, HRE, HRF, HRG, HRH, HRK)}$$

$$Rockwell\ Superficial\ Hardness = 100 - \frac{h}{0.001} \quad \text{(HR15T, HR30T, HR45T)}$$

2.3 Rockwell (hardness) scale

Designation (see 3.2) given to a Rockwell hardness test which defines the specific combination of indenter type, preliminary force, and total force (see Table 1) used. A specific range of Rockwell hardness values is associated with each scale such that higher Rockwell hardness values indicate a harder material.

2.4 Rockwell hardness machine

Device or assembly of devices used for determining the Rockwell hardness of primarily metallic materials by performing a Rockwell indentation hardness test. Rockwell hardness machines are grouped into two classes:

- *Rockwell standardizing machine:* Rockwell hardness machine used primarily for the standardization of Rockwell hardness indenters and for the standardization of Rockwell hardness reference test blocks. The Rockwell standardizing machine may also be used for general testing purposes. The Rockwell standardizing machine differs from a Rockwell testing machine by having smaller maximum permissible errors on certain parameters, which are defined in section 4 of this Recommendation. Standardizing machines may also be referred to as calibration machines.
- *Rockwell testing machine:* Rockwell hardness machine used for general testing purposes.

2.5 primary national Rockwell standardizing machine

Primary Rockwell hardness standardizing machine used by a country's primary national laboratory for hardness standardization to standardize primary reference test blocks. The primary national laboratory for hardness standardization is usually a National Metrology Institute (NMI).

2.6 reference test block

Hardness test block that has been certified to have a Rockwell hardness value that is traceable to a specific Rockwell hardness standard. Reference test blocks are used for the indirect verification and the daily verification of Rockwell hardness machines.

2.7 primary reference test block

Reference test block that has been certified by a primary national laboratory for hardness standardization and assigned with a Rockwell hardness value that is directly traceable to a country's national hardness standards.

2.8 test cycle

Sequence of applying the test forces during the Rockwell hardness test. The test cycle may be described by force variations with time as the indenter penetrates the test sample.

2.9 direct method (verification)

Process for verifying that individual components of the Rockwell hardness machine are operating within maximum permissible errors by directly measuring specified parameters.

2.10 indirect method (verification)

Process for verifying that the hardness measuring performance of the Rockwell hardness machine is within maximum permissible errors by conducting hardness measurements using reference test blocks.

2.11 repeatability

Closeness of the agreement between the results of successive measurements on a uniform test sample when there is a relatively short time interval between measurements carried out by the same observer using the same test procedures at the same location under similar ambient conditions.

2.12 maximum permissible error (of a Rockwell hardness machine)

Extreme value of error in a measured Rockwell hardness value permitted by specifications, regulations, etc., such as this Recommendation, for a given Rockwell hardness machine.

3 Measurement units

3.1 A Rockwell hardness value is derived from the difference in the indentation depths *h* (see Fig. 1), before and after application of the additional force, while maintaining the preliminary test force. For all Rockwell hardness scales, the unit of measurement for *h* is mm; however, Rockwell hardness is reported as a dimensionless number derived from the value of *h*. It is common practice to refer to each whole number of a Rockwell hardness scale as a Rockwell hardness unit (HR) of that scale. A Rockwell hardness unit has no physical meaning.

3.2 Rockwell hardness values shall be reported with a scale designation representing the type of indenter and force levels that were used (see Table 1). The calculated hardness value shall be followed by the symbol “HR” and the scale designation. When a ball indenter is used, the scale designation shall be followed by the letter "S" when steel balls are used and by the letter "W" when tungsten-carbide (hardmetal) balls are used.

Examples:

64 HRC = Rockwell hardness value of 64 on the Rockwell C scale.

81 HR30N = Rockwell superficial hardness value of 81 on the Rockwell 30N scale.

72 HRBW = Rockwell hardness value of 72 on the Rockwell B scale, using a tungsten carbide ball indenter.

Table 1 Rockwell hardness scales with the corresponding test forces and indenters used*

Rockwell scales Preliminary test force: 98.07 N (10 kgf)				Superficial Rockwell scales Preliminary test force: 29.42 N (3 kgf)			
Scale	Additional test force	Total test force	Indenter**	Scale	Additional test force	Total test force	Indenter**
A	490.3 N (50 kgf)	588.4 N (60 kgf)	Spheroconical Diamond	15N	117.7 N (12 kgf)	147.1 N (15 kgf)	Spheroconical Diamond
B	882.6 N (90 kgf)	980.7 N (100 kgf)	Ball 1.5875 mm (1/16 in.)	30N	264.8 N (27 kgf)	294.2 N (30 kgf)	Spheroconical Diamond
C	1373 N (140 kgf)	1471 N (150 kgf)	Spheroconical Diamond	45N	411.9 N (42 kgf)	441.3 N (45 kgf)	Spheroconical Diamond
D	882.6 N (90 kgf)	980.7 N (100 kgf)	Spheroconical Diamond				
E	882.6 N (90 kgf)	980.7 N (100 kgf)	Ball 3.175 mm (1/8 in.)	15T	117.7 N (12 kgf)	147.1 N (15 kgf)	Ball 1.5875 mm (1/16 in.)
F	490.3 N (50 kgf)	588.4 N (60 kgf)	Ball 1.5875 mm (1/16 in.)	30T	264.8 N (27 kgf)	294.2 N (30 kgf)	Ball 1.5875 mm (1/16 in.)
G	1373 N (140 kgf)	1471 N (150 kgf)	Ball 1.5875 mm (1/16 in.)	45T	411.9 N (42 kgf)	441.3 N (45 kgf)	Ball 1.5875 mm (1/16 in.)
H	490.3 N (50 kgf)	588.4 N (60 kgf)	Ball 3.175 mm (1/8 in.)				
K	1373 N (140 kgf)	1471 N (150 kgf)	Ball 3.175 mm (1/8 in.)				

* The units of kilogram-force (kgf), associated with test forces, and inches (in.), associated with indenter ball diameters, are included for reference in addition to SI units because of their common historical usage in some countries.

** The dimension given for the ball indenters is the diameter of the ball.

4 Metrological requirements: Maximum permissible errors

Rockwell hardness machines shall comply with the following requirements during verification tests and in service.

4.1 Application of forces

4.1.1 Each preliminary test force F_0 as applied by the Rockwell hardness machine, before application and after removal of the additional force F_1, shall meet the corresponding maximum permissible errors as specified in Table 2.

4.1.2 Each total test force F as applied by the Rockwell hardness machine shall meet the corresponding maximum permissible errors as specified in Table 3.

Table 2 Maximum permissible errors of the preliminary test forces for the Rockwell testing and standardizing machines *

Preliminary test force N (kgf)	Rockwell testing machine Maximum permissible errors are ± 2.0 % N (kgf)	Rockwell standardizing machine Maximum permissible errors are ± 0.2 % N (Kgf)
29.42 (3)	± 0.59 (± 0.06)	± 0.059 (± 0.006)
98.07 (10)	± 1.96 (± 0.20)	± 0.196 (± 0.020)

* The units of kilogram-force (kgf), associated with test forces, and inches (in.), associated with indenter ball diameters, are included for reference in addition to SI units because of their common historical usage in some countries.

Table 3 Maximum permissible errors of the total test forces for the Rockwell testing and standardizing machines *

Total force N (kgf)	Rockwell testing machine Maximum permissible errors are ± 1.0 % N (kgf)	Rockwell standardizing machine Maximum permissible errors are ± 0.1 % N (kgf)
147.1 (15)	± 1.47 (± 0.15)	± 0.147 (± 0.015)
294.2 (30)	± 2.94 (± 0.30)	± 0.294 (± 0.030)
441.3 (45)	± 4.41 (± 0.45)	± 0.441 (± 0.045)
588.4 (60)	± 5.88 (± 0.60)	± 0.588 (± 0.060)
980.7 (100)	± 9.81 (± 1.00)	± 0.981 (± 0.100)
1471 (150)	± 14.7 (± 1.50)	± 1.471 (± 0.150)

* The units of kilogram-force (kgf), associated with test forces, and inches (in.), associated with indenter ball diameters, are included for reference in addition to SI units because of their common historical usage in some countries.

4.2 Depth-measuring device and hardness indicating device

The indenter depth-measuring device, when coupled with the hardness-indicating device, shall indicate a change in depth within the corresponding maximum permissible errors as specified in Table 4.

Table 4 Maximum permissible errors of the depth-measuring device for Rockwell testing and standardizing machines

	Rockwell testing machine Maximum permissible errors		Rockwell standardizing machine Maximum permissible errors	
Rockwell scales	mm	Equivalent Rockwell Hardness Units HR	mm	Equivalent Rockwell Hardness Units HR
A, B, C, D, E, F, G, H, K	± 0.001	± 0.5	± 0.0002	± 0.1
15N, 30N, 45N 15T, 30T, 45T	± 0.0005	± 0.5	± 0.0002	± 0.2

4.3 Indenter

4.3.1 Each indenter to be used with the Rockwell testing or standardizing machines shall meet the maximum permissible error requirements of OIML R 36 for geometrical features and for performance.

4.3.2 As a minimum, a Test Class indenter shall be used with testing machines.

4.3.3 A Standardizing Class indenter shall be used with standardizing machines.

4.4 Test cycle

4.4.1 This Recommendation specifies the Rockwell testing cycle by stating requirements for separate parts of the cycle. These parts are defined as follows, and illustrated for a Rockwell test in Fig. 1:

1. Approach velocity v_A: the velocity of the indenter at the point of contact with the test material.
2. Preliminary force duration t_{PF}: the time period beginning when the preliminary force F_0 is fully applied and ending when the first baseline depth of indentation is measured.
3. Additional force application time t_{TA}: the time for applying the additional force F_1 to obtain the full total force F. In the case of Rockwell standardizing machines, the indenter average velocity v_F during the final 40 % of the force application is also specified for some Rockwell scales.
4. Total force duration t_{TF}: the time period when the total force F is fully applied.
5. Elastic recovery duration t_R: the time period beginning when the additional force F_1 is fully removed, and ending when the second and final depth of indentation is measured.

4.4.2 Rockwell hardness machines shall be capable of meeting the testing parameters as specified in Table 5.

Table 5 Testing parameters (see Fig. 1) *

Testing parameter	Testing machine	Standardizing machine
Indenter approach velocity, v_A	Not applicable	≤ 1 mm/s
Preliminary force duration, t_{PF}	≤ 3.0 s	≤ 3.0 s
Additional force application time t_{TA}	1.0 s to 8.0 s	1.0 s to 8.0 s
Average indenter velocity v_F during the final 40 % of total force application. (Scales A, B, C, D, E, F, G, H, K, 45N, and 45T only)	Not applicable	0.020 to 0.040 mm/s
Total force duration t_{TF}	4.0 s ± 2.0 s	4.0 s ± 2.0 s
Elastic recovery duration t_R	Not applicable	3.0 s to 5.0 s

* The Working Group on Hardness, WGH, of the Comité International des Poids et Mesures, CIPM, is currently working on improving the definition of the Rockwell hardness test, which will likely include better defining the parameters of the testing cycle. When agreement within the WGH is obtained, the requirements within this Recommendation will be revised to reflect the WGH definition. Currently, there is no maximum permissible error requirement for the preliminary force application time t_{PA}.

4.5 Machine hysteresis

4.5.1 A test for examining the magnitude of the measurement hysteresis in a Rockwell hardness machine is given in Annex B. The objective of the test is to perform a purely elastic test that results in no permanent indentation. In this way, the level of hysteresis in the flexure of the testing machine, indenter and depth measurement system can be determined. The level of the measurement hysteresis is the difference in the readings of the measuring device before and after application of the additional force F_1, while under the preliminary force F_0, and can be determined from the hardness value.

4.5.2 The Rockwell hardness machine shall meet the measurement and maximum permissible error requirements specified in Table 6.

Table 6 Maximum permissible errors for the machine hysteresis test

Rockwell hardness scales	Testing machine		Standardizing machine	
	Target Rockwell hardness value (HR)	Maximum permissible error (HR)	Target Rockwell hardness value (HR)	Maximum permissible error (HR)
A, C, D	100	± 1.5	100	± 0.2
B, E, F, G, H, K	130	± 1.5	130	± 0.2
15N, 30N, 45N, 15T, 30T, 45T	100	± 1.5	100	± 0.2

4.6 Hardness measurement result

4.6.1 The repeatability *R* of the Rockwell hardness machine, as determined by the indirect method verification, shall be within the maximum permissible errors as specified in Table 7 for each Rockwell scale.

4.6.2 The bias *B* of the Rockwell hardness machine, as determined by the indirect verification, shall be within the maximum permissible errors as specified in Table 8 for each Rockwell scale.

Table 7 Maximum permissible errors of the repeatability *R* of the Rockwell hardness machine

Rockwell hardness scale	Repeatability *R* Maximum permissible error * (HR)
A, C, D	Greater of 0.02 (100 - $\overline{H}$) or 0.8 Rockwell units
B, E, F, G, H, K	Greater of 0.04 (130 - $\overline{H}$) or 1.2 Rockwell units
15N, 30N, 45N	Greater of 0.04 (100 - $\overline{H}$) or 1.2 Rockwell units
15T, 30T, 45T	Greater of 0.06 (100 - $\overline{H}$) or 2.4 Rockwell units

* where $\overline{H}$ is the mean hardness value.

Table 8 Maximum permissible errors of the bias *B* of the Rockwell hardness machine

Rockwell hardness scale	Hardness range of the reference test block	Bias *B* Maximum permissible error	Rockwell hardness scale	Hardness range of the reference test block	Bias *B* Maximum permissible error
A	20 to ≤ 75 HRA > 75 to ≤ 88 HRA	± 2 HRA ± 1.5 HRA	G	30 to ≤ 50 HRG > 50 to ≤ 75 HRG > 75 to ≤ 94 HRG	± 6 HRG ± 4.5 HRG ± 3 HRG
B	20 to ≤ 45 HRB > 45 to ≤ 80 HRB > 80 to ≤ 100 HRB	± 4 HRB ± 3 HRB ± 2 HRB	H	80 to ≤ 100 HRH	± 2 HRH
C	20 to ≤ 70 HRC	± 1.5 HRC	K	40 to ≤ 60 HRK > 60 to ≤ 80 HRK > 80 to ≤ 100 HRK	± 4 HRK ± 3 HRK ± 2 HRK
D	40 to ≤ 70 HRD > 70 to ≤ 77 HRD	± 2 HRD ± 1.5 HRD			
E	70 to ≤ 90 HRE > 90 to ≤ 100 HRE	± 2.5 HRE ± 2 HRE	15N, 30N, 45N	All	± 2 HRN
F	60 to ≤ 90 HRF > 90 to ≤ 100 HRF	± 3 HRF ± 2 HRF	15T, 30T, 45T	All	± 3 HRT

5 Technical requirements

5.1 The Rockwell hardness machine shall be capable of performing a Rockwell indentation hardness test. The machine design may include the capability of conducting tests for one or more of the Rockwell scales given in Table 1. The machine may also be designed to perform other functions such as tests of other hardness scales.

5.2 The Rockwell hardness machine shall be designed such that the parts of the test cycle may be timed manually by the operator or automatically by the Rockwell hardness machine.

5.3 A Rockwell hardness machine shall have the following components:

- frame
- force application system
- indenter depth measuring system
- hardness indicating system
- indenter(s)
- indenter holder
- test piece support device.

5.3.1 Frame

The machine frame shall be designed with sufficient rigidity and stiffness such that, during the application of forces, deformation of the frame is minimized and measurement results are not appreciably affected.

5.3.2 Force application system

5.3.2.1 The force application system shall be capable of applying the forces, as given in Table 1, corresponding to the Rockwell scale(s) for which the Rockwell hardness machine is designed.

5.3.2.2 The force application system shall be designed to apply the forces without shock, vibration or oscillation in a manner that will not significantly affect the hardness measurement result.

5.3.2.3 The force application system shall be capable of applying and maintaining the forces in accordance with the test cycle requirements.

5.3.3 Indenter depth measuring system

5.3.3.1 The indenter depth measuring system shall be designed to measure the depth of the indenter with respect to the test surface of the test piece. Reference to the test surface may be made through the test piece, test piece support device and test frame as long as the flexure of these components does not exhibit excessive hysteresis that would adversely affect the hardness measurement result (see the machine hysteresis requirements in clause 4.5).

5.3.3.2 The indenter depth measuring system shall be designed to determine the relative difference in the penetration depth of the indenter at two specific times in the test cycle (see Fig. 1). The first test cycle time occurs immediately following the specified preliminary force duration. The second test cycle time occurs immediately following the specified elastic recovery duration.

5.3.3.3 The indenter depth measuring system may use any appropriate measuring principle to measure the indenter depth (e.g. mechanical, electrical, optical) as long as its capabilities and operation meet the requirements in clause 4.2. The system shall be capable of converting the measurement of h into Rockwell hardness units.

5.3.4 Hardness indicating system

5.3.4.1 The hardness indicating system shall indicate the resultant Rockwell hardness value of the test material and indicate the Rockwell scale designation corresponding to the indenter and test forces used.

5.3.4.2 For Rockwell testing machines, the hardness indicating device may be analog or digital. The scales and indications shall be clear and well defined. Examples of indicating devices include a dial gage or a digital indicator.

5.3.4.3 For Rockwell standardizing machines, the hardness indicating device shall be a digital indicator.

5.3.5 Indenter(s)

5.3.5.1 Each indenter to be used with the Rockwell testing or standardizing machines shall meet the requirements of OIML R 36 for physical characteristics.

5.3.6 Indenter holder

5.3.6.1 The indenter holder shall be of a design that assures that the indenter is always installed in a position such that the axis of the indenter is parallel to the line of the indenting force.

5.3.6.2 The indenter holder shall be of a design that prevents movement of the indenter within the holder throughout the hardness test.

5.3.7 Test piece support device

5.3.7.1 The test piece support device may include a positioning device that is intended to bring the test piece into the test position. The positioning device may also be used to apply the preliminary force.

5.3.7.2 The test piece support device may be designed to accommodate interchangeable support fixtures. The interchangeable support fixtures may be designed with slip connections that are not permanently fixed to the support device.

5.3.7.3 The test piece support device may be a flat surface or a special device suitable to the test piece.

5.3.7.4 The test piece support device shall be designed such that the surface to be tested is supported perpendicular to the direction of the test forces and remains perpendicular during the positioning process and throughout the test.

5.4 Machine manual

Manufacturers of hardness testing machines shall provide a manual or relevant software that clearly and concisely describes the operation, routine maintenance and checking of the machine. It shall also specify the operating range of the machine with regard to temperature.

5.5 Markings and security

5.5.1 The Rockwell hardness machine shall bear the following information on a descriptive plate which shall be permanently affixed and in a visible location:

- manufacturer's name or trademark
- machine class (testing or standardizing)
- model number
- serial number (when the machine design includes weights, the serial number shall be repeated on each weight)
- year of manufacture
- a statement that the machine is capable of meeting the requirements of OIML R 39.

5.5.2 The plate must be attached to the machine by a device on which the verification mark (see 6.5) is applied in such a way that the plate cannot be removed without affecting this mark.

5.5.3 The mechanisms and devices used to adjust the performance characteristics of the machine shall be designed such that a security seal or other means for providing security may be applied so as to prevent any tampering likely to change the metrological characteristics of the machine. The Rockwell hardness machine manufacturer shall specify the locations for the security seals.

6 Metrological controls

6.1 No adjustments shall be made to any component of the Rockwell hardness machine that will affect the hardness measurement, or the calculation or display of the hardness value, except as the result of a failed direct method verification. No adjustments of the Rockwell hardness machine shall be made as the result of a failed indirect method verification.

6.2 Initial verification

6.2.1 An initial verification shall be carried out at the location of use when the Rockwell hardness machine is first installed.

6.2.2 An initial verification shall be carried out in the following sequence in accordance with the verification procedures of Annex B:

1. The operating manual or relevant instructions and software shall be reviewed for completeness and clarity. The Rockwell hardness machine shall be inspected in conjunction with a review of the manufacturer's specifications to determine that these specifications are met.
2. General examination (see B.1).
3. Verification by the direct method (see B.3).
4. Verification by the indirect method (see B.4).

6.2.3 Only those Rockwell scales that have been verified by the direct method and the indirect method may be used for applications under legal control

6.3 Subsequent verification

6.3.1 A subsequent verification may include a direct method verification of the Rockwell hardness machine's components and an indirect method verification of the performance of the Rockwell hardness machine, depending on the class of machine and the verification schedule.

6.3.2 In cases where the Rockwell hardness machine will be subjected to cleaning and/or maintenance procedures, the procedures for assessing the initial condition of the Rockwell hardness machine shall be conducted prior to any cleaning and/or maintenance.

6.3.3 The following procedures shall be carried out for a subsequent verification in the order listed in accordance with Annex B and per the verification schedule given in 6.3.4 and 6.3.5:

1. General examination (see B.1).
2. Determine the initial condition, if required (see B.2).
3. Verification by the direct method, when required (see B.3).
4. Verification by the indirect method (see B.4).

6.3.4 Subsequent direct method verification schedule

6.3.4.1 The procedures for a subsequent verification by the direct method shall be carried out in the following circumstances and at the location of use:

- Within a period not exceeding 24 months for a Rockwell testing machine and not exceeding 12 months for a Rockwell standardizing machine from the initial (or a previous subsequent) direct method verification.
- When the Rockwell hardness machine is dismantled and reassembled, such as during repairs or reconditioning.
- When the Rockwell hardness machine is moved to a different location.
- When a subsequent indirect verification has not been carried out for a period greater than 12 months.
- When the maximum permissible errors are exceeded during the subsequent indirect method verification.

6.3.5 Subsequent indirect method verification schedule

6.3.5.1 The procedures for a subsequent verification by the indirect method shall be carried out in the following circumstances and at the location of use:

- Following a direct method verification, except when the direct method verification fails. All Rockwell scales that will be used for future testing shall be verified by the indirect method.
- At a frequency that depends on the maintenance protocol and the number of times the machine is used, but at a minimum within a period not exceeding 12 months from the previous subsequent indirect method verification. All Rockwell scales that will be used for future testing shall be verified by the indirect method.

6.3.6 Only those Rockwell scales that have been verified by the direct method and the indirect method may be used for applications under legal control.

6.4 Metrological supervision

6.4.1 In the case of Rockwell testing machines, the daily check procedures shall be performed in accordance with Annex B each day that hardness tests are to be made and whenever the indenter, test force, or test piece support device is changed. The configuration of some special application support devices will not permit the testing of reference blocks (e.g. v-block supports for cylindrical samples). In these cases, the machine shall be verified with a suitable support for testing reference blocks prior to using the special application support device.

6.4.2 In the case of Rockwell standardizing machines, the calibration laboratory shall track the performance of the Rockwell standardizing machine using acceptable statistical control techniques such as control charts. The control charts are intended to indicate a loss of measurement control in the performance of the Rockwell standardizing machine.

6.4.3 If the maximum permissible errors are exceeded, the Rockwell hardness machine no longer satisfies the requirements of this Recommendation and shall no longer be used for applications under legal control.

6.5 Verification mark

6.5.1 Upon completion of a successful verification, a verification mark (for example, in the form of non-removable adhesive backed paper) shall be applied in a manner such that the descriptive plate cannot be removed without adversely affecting this mark. A separate verification mark is required for direct verification and indirect verification. The verification marks shall include the following information:

- reference to this OIML Recommendation R 39
- Rockwell hardness scales verified (indirect only)
- identification number(s) of diamond indenter (indirect only)
- date of verification
- name of verification agency.

6.5.2 If, during a subsequent verification, the Rockwell hardness machine does not meet the requirements of clauses 4 and 5, its verification mark shall be obliterated.

7 Test method and test report format

7.1 The methods to be used for the verification of Rockwell hardness machines are given in Annex B.

7.2 The test report format is given in Annex C.

8 Practical instructions

Rockwell hardness testing machines and their accessories shall be installed at locations where the ambient environmental conditions, building structures, vibration, and other such factors do not adversely affect their operational or metrological characteristics.

Annex A
(Mandatory)

Rockwell hardness test procedure

A.1 Daily check

A.1.1 As part of the test procedure, the Rockwell hardness machine shall be checked each day of use in accordance with the daily check procedure of Annex B (see B.5).

A.2 Measurement procedure

A.2.1 Bring the indenter into contact with the test surface in a direction perpendicular to the surface and at a velocity within the specified maximum contact velocity.

A.2.2 Apply the appropriate preliminary test force F_0 (see Table 1).

A.2.3 Maintain the preliminary force for the specified preliminary force dwell time (see Table 5).

A.2.4 At the end of the preliminary force dwell time, immediately establish the reference position of the baseline depth of indentation (see Manufacturer's instruction manual).

A.2.5 Increase the force by the value of the additional test force F_1 needed to obtain the required total test force F for a given hardness scale (see Table 1). The additional force F_1 shall be applied within the specified application time range (see Table 5).

A.2.6 Maintain the total force F for the specified total force dwell time (see Table 5).

A.2.7 Remove the additional test force F_1 while maintaining the preliminary test force F_0.

A.2.8 Maintain the preliminary test force F_0 for the specified dwell time for elastic recovery (see Table 5).

A.2.9 At the end of the dwell time for elastic recovery, immediately establish the final depth of indentation (see Manufacturer's instruction manual) and determine the difference h between the final and baseline depths (see Fig. 1). The Rockwell hardness machine shall determine these measurements automatically and indicate the resulting Rockwell hardness value, which is derived from the differential increase in depth of indentation.

A.2.10 Throughout the test, the apparatus shall be protected from shock or vibration that could affect the hardness measurement result.

A.2.11 After each change, or removal and replacement, of the indenter or the test piece support device, it shall be ascertained that the indenter or support device is correctly installed. The first two readings after an indenter or support device has been installed shall be disregarded. The operation of the machine shall be checked in accordance with the daily check method specified in Annex B (see B.5).

A.3 Indentation spacing

A.3.1 The distance between the centers of two adjacent indentations shall be at least four times the diameter of the indentation, but not less than 2 mm.

A.3.2 The distance from the center of any indentation to an edge of the test piece shall be at least two and a half times the diameter of the indentation, but not less than 1 mm.

Annex B
(Mandatory)

Verification methods

B.1 General examination

B.1.1 Examine the testing location to ensure that the Rockwell hardness machine is protected from shock or vibration that could affect the hardness measurement result.

B.1.2 Examine the test location to ensure that, in the case of a Rockwell testing machine, the test area is maintained at a temperature within the limits of 10 °C to 35 °C. In the case of a Rockwell standardizing machine, the test area shall be maintained at a temperature within the limits of 23 ± 5 °C. Tests performed outside this temperature range are not considered to be in conformance with this Recommendation.

B.2 Assessing the condition prior to routine cleaning and maintenance (initial condition)

B.2.1 It is common practice in many countries to conduct routine cleaning and maintenance of Rockwell hardness machines at the time of verification. It is important to document the performance of a Rockwell hardness machine and indenter in the condition that it was last used prior to cleaning and maintenance. If the Rockwell hardness machine is to undergo any cleaning or maintenance prior to the direct method verification or the indirect method verification, perform the following test procedures to assess the performance of the testing machine in the initial condition. If no cleaning or maintenance will be performed, assessing the performance of the testing machine in the initial condition is not required.

B.2.2 The assessment of the initial condition should determine the performance of the Rockwell hardness machine at each force level that the Rockwell hardness machine is capable of applying. Therefore, for each of these force levels, at least one corresponding Rockwell scale shall be verified. The Rockwell scales chosen should reflect the scales used most often, and should include both ball and diamond indenters when appropriate. Suggested Rockwell scales to verify are given in Table B.1.

Table B.1 Suggested Rockwell scales for the determination of the initial condition

Preliminary force N (kgf)	Total force N (kgf)	Suggested Rockwell scale
98.07 (10)	588.4 (60)	HRA
98.07 (10)	980.7 (100)	HRB
98.07 (10)	1471 (150)	HRC
29.42 (3)	147.1 (15)	HR15N
29.42 (3)	294. 2 (30)	HR30T
29.42 (3)	441.3 (45)	HR45N

B.2.3 Reference test blocks shall be used in the low, middle and high hardness ranges for each scale to be verified. These ranges are given in Table B.2. In the case of Rockwell standardizing machines, the test blocks shall be primary reference test blocks.

B.2.4 The indenter(s) to be used for the verification shall be the same indenter(s) that were used by the laboratory since the last verification.

B.2.5 The test cycle to be used for the verification should be as close as practical to the test cycle used when the reference test blocks were standardized.

B.2.6 All Rockwell hardness tests shall be carried out in accordance with Annex A.

B.2.7 The Rockwell hardness machine shall not be adjusted between tests made on the three test blocks.

B.2.8 Prior to testing the reference test blocks, ensure that the Rockwell hardness machine is working freely, and that the indenter and test piece support device are seated adequately. Make at least two hardness measurements on a uniform test piece having hardness in the scale to be verified. The results of these measurements need not be recorded.

B.2.9 Make five Rockwell hardness measurements distributed uniformly over the surface of each of the reference test blocks.

B.2.9.1 Bias B - Let $\overline{H}$ be the average of the five hardness measurements. For each hardness level of each hardness scale, the bias B of the performance of the Rockwell hardness machine relative to the calibrated value of the reference block is determined as:

$$B = \overline{H} - H_{ref},$$

where H_{ref} is the certified average hardness value of the reference test block.

B.2.9.2 Repeatability R - Let $H_1, H_2, \ldots, H_5$ be the five hardness values, arranged in increasing order of magnitude. The repeatability R of the Rockwell hardness machine, under the particular verification conditions, can be estimated by the range of the five measurement values, defined as:

$$R = H_5 - H_1.$$

Table B.2 Rockwell hardness ranges for different scales

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

B.2.9.3 If any calculations of the repeatability R or the bias B of the Rockwell hardness machine fall outside the maximum permissible errors given in Tables 7 and 8, then the laboratory's metrological

supervision procedures should be reviewed and improved. Hardness measurements that were made since the last verification for that particular hardness scale and hardness level may be suspect.

B.2.10 Routine cleaning and maintenance may be conducted following the determination of the initial condition.

B.3 Direct method verification

B.3.1 Direct method verification involves verifying that the components of the Rockwell hardness machine are within allowable tolerances by directly measuring specified parameters. The following parameters of the Rockwell hardness machine shall be verified: test forces, depth measuring system, machine hysteresis, and indenter(s). If any of the direct method verifications fail the specified requirements, the Rockwell hardness machine shall be adjusted or repaired and calibrated to meet the maximum permissible errors. Any other component that may have been affected by an adjustment or repair shall also be verified again by direct verification.

Note B1 The designs of many Rockwell hardness machines prevent verification of each of the parts of the test cycle at the location of use. Thus, the manufacturer shall ensure that the parts of the test cycle applied automatically by the Rockwell hardness machine are within the maximum permissible errors specified in Table 5, and, for the parts of the test cycle applied manually by the operator, that the Rockwell hardness machine is capable of being operated within the maximum permissible errors specified in Table 5. Verification of the test cycle is not required as part of an initial or subsequent verification.

B.3.2 All instruments used to make verification measurements shall be capable of making measurements traceable to national standards where a system of traceability exists.

B.3.3 The procedures to apply when performing a direct verification are as follows.

B.3.3.1 Verification of the test forces

B.3.3.1.1 For each Rockwell scale used, the corresponding test forces shall be measured. Measure each preliminary test force F_0 before application of the additional force F_1, each total test force F, and each preliminary test force F_0 after removal of the additional force F_1.

B.3.3.1.2 The test forces of a Rockwell testing machine shall be measured by one of the following two methods:

- with an elastic force-measuring instrument meeting the requirements of a Class 1 device in accordance with ISO 376:2004 [6],
- balancing against a force, accurate to ± 0.2 %, applied by means of standardized masses through a mechanical system.

B.3.3.1.3 The test forces of a Rockwell standardizing machine shall be measured with an elastic force-measuring instrument meeting the requirements of a Class 0.5 device in accordance with ISO 376:2004 [6].

B.3.3.1.4 For hardness machines that apply the forces by weight/lever systems or by spring systems, each force shall be measured at not less than three positions of the plunger, uniformly spaced throughout its range of movement during testing. This requirement does not apply to machines that apply the forces by closed-loop load-cell systems.

B.3.3.1.5 Make three measurements of each force. The three measurements shall be made at each position of the plunger when applicable. The forces shall be measured as they are applied during testing; however, longer dwell times are allowed to obtain accurate measurements. No adjustments are allowed between measurements.

B.3.3.1.6 Each measured preliminary test force F_0 and each measured total test force F shall be within the maximum permissible errors specified in Tables 2 and 3, respectively.

B.3.3.2 Verification of the depth-measuring device and hardness indicating device

B.3.3.2.1 The depth-measuring device coupled with the hardness-indicating device shall be verified by means of an instrument or reference standard having an expanded uncertainty (2σ) no greater than 0.0002 mm.

B.3.3.2.2 Verify the Rockwell hardness machine's measurement of depth at not less than three evenly spaced increments of the range of the normal working depth of the testing machine, in the direction of increasing hardness values. The normal working depth range shall correspond to the lowest and highest hardness values for the Rockwell scales that will be tested.

Note B2 Verification of the Rockwell hardness machine's measurement of depth at only three intervals may not be sufficient to evaluate the nonlinearity of the depth-measuring device. In some cases, more than ten intervals may be required.

B.3.3.2.3 Some Rockwell hardness machines have a long-stroke depth measuring system where the location of the working range of the depth measuring system varies depending on the thickness of the test material. This type of hardness machine shall have a system to electronically verify that the depth-measuring device is continuous over its full range and free from dirt or other discontinuities that could affect its measurement capability. These types of hardness machines shall be verified using the following steps.

- At the approximate top, mid point, and bottom of the total stroke of the measuring device, verify the device at no less than three evenly spaced increments of approximately 0.05 mm at each of the three locations.
- Operate the actuator over its full range of travel and monitor the electronic continuity detection system. The system shall indicate continuity over the full range.

B.3.3.2.4 Each depth measurement shall be within the maximum permissible errors specified in Table 4.

B.3.3.3 Verification of machine hysteresis

B.3.3.3.1 The purpose of this verification is to determine the level of hysteresis in the flexure of the Rockwell hardness machine by performing a purely elastic test that results in no permanent indentation. Perform a number of Rockwell hardness tests using a blunt indenter (examples: spherical indenter with a large radius, or flat indenter with rounded edges) acting directly onto a very hard test piece or the test piece support device and using the highest test force to be used. Repeat the tests at the same location on the test piece until there is no upward or downward trend in successive measurement values. These measurements shall be discarded.

B.3.3.3.2 Perform at least five additional Rockwell tests at the same location on the test piece using the blunt indenter. Let H_1, H_2, …, H_n be the n hardness values, and let $\overline{H}$ be the average of the n values.

B.3.3.3.3 The average $\overline{H}$ of the measurement results shall indicate a hardness number within the maximum permissible error specified in Table 6.

B.3.3.4 Verification of indenters

B.3.3.4.1 Verification of Rockwell indenters shall be conducted in accordance with the verification schedule and requirements of OIML R 36.

B.4 Indirect method verification

B.4.1 The indirect method verification is used to verify the performance of the Rockwell hardness machine by means of reference test blocks. The indirect method verification shall be performed using each indenter that the laboratory will be using during the period before the next indirect verification.

B.4.2 Reference test blocks shall be used in the low, middle and high hardness ranges for each scale to be verified. These ranges are given in Table B.2. In the case of Rockwell standardizing machines, the test blocks shall be primary reference test blocks.

B.4.3 The test cycle to be used for the indirect verification should be as close as possible to the test cycle used by standardizing laboratory to standardize the reference test blocks.

B.4.4 All Rockwell hardness tests shall be carried out in accordance with Annex A.

B.4.5 Prior to testing the reference test blocks, ensure that the Rockwell hardness machine is working freely, and that the indenter and test piece support device are seated adequately. Make at least two hardness measurements on a uniform test piece having a hardness in the scale to be verified. The results of these measurements need not be recorded.

B.4.6 Make five Rockwell hardness measurements distributed uniformly over the surface of each of the reference test blocks.

B.4.6.1 Bias B - Let $\overline{H}$ be the average of the five hardness measurements. For each hardness level of each hardness scale, the bias *B* of the performance of the Rockwell hardness machine relative to the calibrated value of the reference block is determined as:

$$B = \overline{H} - H_{ref} ,$$

where H_{ref} is the certified average hardness value of the reference test block.

B.4.6.2 Repeatability R – Let $H_1, H_2, \ldots, H_5$ be the five hardness values, arranged in increasing order of magnitude. The repeatability *R* of the Rockwell hardness machine, under the particular verification conditions, can be estimated by the range of the five measurement values, defined as:

$$R = H_5 - H_1 .$$

B.4.7 If any calculations of the repeatability *R* or the bias *B* of the Rockwell hardness machine measurements fall outside the maximum permissible errors given in Tables 7 and 8, the Rockwell hardness machine shall not have passed the indirect method verification using that specific indenter. A number of corrective actions may be attempted to bring the Rockwell hardness machine within the maximum permissible errors. These actions include cleaning and maintenance or replacing the test piece support device. No adjustments to the force application system, depth measuring system, or the hardness determination and indicating system may be made. The indirect method verification procedures may be repeated after making the allowed corrective actions.

B.4.8 Repeat the preceding indirect method verification procedures for each of the indenters to be used for future testing. If more than one indenter will be used for the same hardness scale, separate verifications shall be made for each indenter.

B.4.9 The indirect method verification is valid only when at least one of the indenters passes the verification requirements for each of the Rockwell scales verified.

B.4.10 If the testing machine cannot pass the indirect method verification, a direct method verification shall be performed.

B.5 Daily check

B.5.1 Reference test blocks shall be used to monitor the performance of the Rockwell hardness machine during the period between direct and indirect verifications. At least two reference test blocks shall be hardness tested. The hardness levels of the test blocks shall be chosen to bracket above and below the range of hardness values that the test machine is expected to measure.

B.5.2 Prior to testing the reference blocks, ensure that the test machine is working freely, and that the indenter and test piece support device are adequately seated. Make at least two hardness measurements on a uniform test piece having a hardness in the scale to be verified. The results of these measurements need not be recorded.

B.5.3 Make at least three hardness measurements on each of the reference test blocks. The tests shall be distributed uniformly over the surface of the test blocks

B.5.4 If the average of the hardness measurements for each reference test block is within the maximum permissible errors given in Table 8, the Rockwell hardness machine may be regarded as performing satisfactorily. If not, an indirect verification shall be performed.

Annex C
(Mandatory)

Test report format

(To be used for initial and subsequent verifications)

Report No. _____
OIML Recommendation R 39, Edition 2006

C.1 Type of verification (check one)
☐ INITIAL VERIFICATION
☐ SUBSEQUENT VERIFICATION

C.2 Name and address of the Verification Agency

_____
_____
_____
_____

C.3 Name and address of the owner of the Rockwell hardness machine

_____
_____
_____
_____

C.4 Location at which the verification was carried out, if other than indicated in C.3

_____
_____
_____
_____

C.5 Hardness machine identification

C.5.1 Manufacturer: _____

C.5.2 Model number: _____

C.5.3 Serial number: _____

C.5.4 Machine class (check one)
☐ ROCKWELL STANDARDIZING MACHINE
☐ ROCKWELL TESTING MACHINE

C.5.5 Capability (check one)

☐ REGULAR ROCKWELL SCALES ONLY

☐ SUPERFICIAL ROCKWELL SCALES ONLY

☐ REGULAR AND SUPERFICIAL ROCKWELL SCALES

C.5.6 Is the Rockwell hardness machine capable of making measurements other than Rockwell hardness tests?

☐ Yes ☐ No

If yes, describe:

_____

_____

C.5.7 Hardness display resolution (HR): _____

C.6 Operating manual (INITIAL VERIFICATION only)

C.6.1 Do the operating manual or relevant instructions and software have complete and clear instructions?

☐ Yes ☐ No

Comments:

_____

_____

C.6.2 Do the manufacturer's specifications indicate that an operator will be capable of controlling the Rockwell hardness machine such that each element of the test cycle will be within the maximum permissible errors?

☐ Yes ☐ No

Comments:

_____

_____

C.7 General examination

C.7.1 Is the Rockwell hardness machine protected from shock or vibration that could affect the hardness measurement result?

☐ Yes ☐ No

Comments:

_____

_____

C.7.2 Is the test area maintained at a temperature within allowable limits?

☐ Yes ☐ No

Comments:

_____

_____

C.7.3 Temperature at the location of the Rockwell hardness machine, before verification testing: _____ °C

C.8 Assessing the initial condition (if necessary) (SUBSEQUENT VERIFICATION only)

C.8.1 Rockwell scales assessed:

_____

C.8.2 Initial condition test measurements: Complete Table C.1

C.8.3 Are the repeatability and bias values for the initial condition within the maximum permissible errors?

☐ Yes ☐ No

Comments:

_____

_____

C.8.4 Describe any adjustments or maintenance done to the Rockwell hardness machine:

_____

_____

_____

_____

C.9 Direct method verification (when required)

C.9.1 Verification of the test forces

C.9.1.1 Briefly describe the Rockwell hardness machine's mechanism(s) for applying the test forces:

_____

_____

_____

_____

C.9.1.2 Reference force-measuring instrument identification:

C.9.1.2.1 Manufacturer: _____

C.9.1.2.2 Owner: _____

C.9.1.2.3 Model number: _____

C.9.1.2.4 Serial number: _____

C.9.1.2.5 Force range: _____

C.9.1.2.6 Uncertainty: _____

C.9.1.2.7 Date of verification or calibration: _____

C.9.1.3 Is the verification or calibration traceable to primary national reference standards?

☐ Yes ☐ No

Comments:

_____

_____

C.9.1.4 Force measurements: Complete Table C.2.

If adjustments are made to or maintenance is carried out on the force application system, indicate the initial force measurements and the final force measurements. Repeat Table C.2, if necessary.

C.9.1.5 Is each measured preliminary test force F_0 and each measured total test force F within the maximum permissible errors?

☐ Yes ☐ No

Comments:

_____

_____

C.9.1.6 Describe any adjustments made to or maintenance carried out on the force application system:

_____

_____

_____

C.9.2 Verification of the depth-measuring device and hardness indicating device

C.9.2.1 Hardness indicating system (check one)

☐ DIGITAL

☐ ANALOG

C.9.2.2 Resolution of hardness indicating system: _____ (HR)

C.9.2.3 Briefly describe the Rockwell hardness machine's mechanism for measuring penetration depth:

_____

_____

_____

C.9.2.4 Reference depth-measuring instrument or reference standard identification:

C.9.2.4.1 Manufacturer: _____

C.9.2.4.2 Owner: _____

C.9.2.4.3 Model number: _____

C.9.2.4.4 Serial number: _____

C.9.2.4.5 Uncertainty: _____

C.9.2.4.6 Date of verification or calibration: _____

C.9.2.5 Is the verification or calibration traceable to primary national reference standards?

☐ Yes ☐ No

Comments:

_____

_____

C.9.2.6 Depth-measuring system verification measurements: Complete Table C.3.

If any adjustments are made to or maintenance carried out on the depth-measuring system, indicate the initial measurements and the final measurements.

C.9.2.7 Is each verification measurement of the depth-measuring system within the maximum permissible errors?

☐ Yes ☐ No

Comments:

_____

_____

C.9.2.8 Describe any adjustments or maintenance done to the depth-measuring system:

_____

_____

_____

C.9.3 Verification of the test cycle

C.9.3.1 The test cycle is controlled (check one):

☐ FULLY MANUALLY

☐ BOTH MANUALLY AND AUTOMATICALLY

(for example, the preliminary force dwell time is controlled manually, and the remainder of the test cycle is controlled automatically)

☐ FULLY AUTOMATICALLY

Comments:

_____

_____

_____

C.9.3.2 When the test cycle is partially or fully controlled automatically, may the test cycle elements be varied by the operator?

☐ Yes

☐ No

☐ Partially

Comments:

_____

_____

_____

C.9.3.3 When the Rockwell hardness machine design allows the operator to set the timing or control of the test cycle, were the settings found to be within the maximum permissible errors?

☐ Yes

☐ No

Comments:

_____

_____

_____

C.9.3.4 If the answer to C.9.3.3 is "no", were the settings adjusted to be within the maximum permissible errors?

☐ Yes

☐ No

Comments:

_____

_____

_____

C.9.4 Verification of machine hysteresis

C.9.4.1 Briefly describe the method used for measuring the machine hysteresis:

_____

_____

_____

C.9.4.2 Machine hysteresis verification measurements: Complete Table C.4.

If any adjustments are made to or maintenance carried out on the Rockwell hardness machine to lower the machine hysteresis value or to bring the value within the maximum permissible errors, indicate the initial measurements and the final measurements.

C.9.4.3 Is the verification measurement of the machine hysteresis within the maximum permissible errors?

☐ Yes

☐ No

Comments:

_____

_____

_____

C.9.4.4 Describe any adjustments or maintenance done to the Rockwell hardness machine to improve the machine hysteresis value:

_____

_____

_____

C.9.5 Verification of indenters

C.9.5.1 Does the laboratory maintain documentation showing that all indenters have been verified as being acceptable in accordance with OIML R 36?

☐ Yes

☐ No

Comments:

_____

_____

_____

C.10 Indirect method verification

C.10.1 Rockwell scales verified and reference test block identification: Complete Table C.5.

Comments:

_____

_____

_____

C.10.2 Indirect method verification test measurements: Complete Table C.6.

C.10.3 Are the repeatability and bias values for the indirect method verification of each Rockwell scale within the maximum permissible errors?

☐ Yes

☐ No

Comments:

_____

_____

_____

C.10.4 Does the laboratory correct subsequent hardness measurements based on the bias errors?

☐ Yes

☐ No

If Yes, does the laboratory use a valid and appropriate method to make the corrections?

☐ Yes

☐ No

Comments:

_____

_____

_____

C.10.5 Identify all indenters verified for use with the Rockwell hardness machine.

Serial number or ID	Indenter type	Applicable Rockwell scales

C.11 Conclusion

C.11.1 Temperature at the location of the Rockwell hardness machine, following verification testing: _____ °C

C.11.2 Give a brief statement of the conclusions as to whether the Rockwell hardness machine meets the requirements of this Recommendation:

_____
_____
_____
_____
_____
_____
_____
_____

C.11.3 Person(s) responsible for the verification:

Name: _____ _____
Title: _____ _____
Signature: _____ _____
Date: _____ _____

Table C.1 Initial condition test measurements

	Reference block Serial No.	Block certified value	Test measurements 1	2	3	4	5	Mean	Bias	Repeatability
Scale _______ Indenter Serial No. or ID ____________	Low hardness									
	Med. hardness									
	High hardness									
Scale _______ Indenter Serial No. or ID ____________	Low hardness									
	Med. hardness									
	High hardness									
Scale _______ Indenter Serial No. or ID ____________	Low hardness									
	Med. hardness									
	High hardness									
Scale _______ Indenter Serial No. or ID ____________	Low hardness									
	Med. hardness									
	High hardness									
Scale _______ Indenter Serial No. or ID ____________	Low hardness									
	Med. hardness									
	High hardness									
Scale _______ Indenter Serial No. or ID ____________	Low hardness									
	Med. hardness									
	High hardness									

Table C.2 Direct method verification of the test forces (Replicate this table for each of the three plunger positions)

INITIAL FORCE MEASUREMENTS

	Standard force N (kgf)	Force measurements		
		1	2	3
Preliminary force levels (F_0) before application of the additional force	29.42 (3)			
	98.07 (10)			
Total force levels (F)	147.1 (15)			
	294.2 (30)			
	441.3 (45)			
	588.4 (60)			
	980.7 (100)			
	1471 (150)			
Preliminary force levels (F_0) after removal of the additional force	29.42 (3)			
	98.07 (10)			

FINAL FORCE MEASUREMENTS

	Standard force N (kgf)	Force measurements		
		1	2	3
Preliminary force levels (F_0) before application of the additional force	29.42 (3)			
	98.07 (10)			
Total force levels (F)	147.1 (15)			
	294.2 (30)			
	441.3 (45)			
	588.4 (60)			
	980.7 (100)			
	1471 (150)			
Preliminary force levels (F_0) after removal of the additional force	29.42 (3)			
	98.07 (10)			

Table C.3 Direct method verification of the depth-measuring system

INITIAL MEASUREMENTS

Indicated value (if in HR units)	Indicated value (mm)	Reference value (mm)	Error

FINAL MEASUREMENTS

Indicated value (if in HR units)	Indicated value (mm)	Reference value (mm)	Error

Table C4 Direct method verification of the machine hysteresis

INITIAL MEASUREMENTS

	Measurement value (HR units)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
Mean	

FINAL MEASUREMENTS

	Measurement value (HR units)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
Mean	

Table C.5 Indirect method verification - Rockwell scales verified and reference test block identification

Rockwell scale	Low hardness		Medium hardness		High hardness		Reference standard traceable to
	Serial No.	Certified value	Serial No.	Certified value	Serial No.	Certified value	

Table C.6 Indirect method verification test measurements

Rockwell Scale	Reference Block Serial No.	Test measurements					Mean	Bias	Repeatability
		1	2	3	4	5			
______	Low hardness								
	Med. hardness								
	High hardness								
______	Low hardness								
	Med. hardness								
	High hardness								
______	Low hardness								
	Med. hardness								
	High hardness								
______	Low hardness								
	Med. hardness								
	High hardness								
______	Low hardness								
	Med. hardness								
	High hardness								
______	Low hardness								
	Med. hardness								
	High hardness								
______	Low hardness								
	Med. hardness								
	High hardness								
______	Low hardness								
	Med. hardness								
	High hardness								

Table C.6 (continued) Indirect method verification test measurements

Rockwell Scale	Reference block Serial No.	Test measurements 1	2	3	4	5	Mean	Bias	Repeatability
______	Low hardness								
	Med. hardness								
	High hardness								
______	Low hardness								
	Med. hardness								
	High hardness								
______	Low hardness								
	Med. hardness								
	High hardness								
______	Low hardness								
	Med. hardness								
	High hardness								
______	Low hardness								
	Med. hardness								
	High hardness								
______	Low hardness								
	Med. hardness								
	High hardness								
______	Low hardness								
	Med. hardness								
	High hardness								
______	Low hardness								
	Med. hardness								
	High hardness								

Annex D
(Informative)

References

[1] ASTM E 18-05 Standard Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials, West Conshohocken, PA, ASTM-International

[2] EA-10/16, EA Guidelines on the Estimation of Uncertainty in Hardness Measurements, European Co-operation fro Accreditation

[3] ISO 6508-1:2005, Metallic materials – Rockwell hardness test – Part 1: Test method (scales, A, B, C, D, E, F, G, H, K, N, T), Geneva

[4] ISO 6508-2:2005, 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), Geneva

[5] 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), Geneva

[6] ISO 376:2004, Metallic materials – Calibration of force-proving instruments used for the verification of uniaxial testing machines.