BSI

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British Standard Methods for

Hardness test (Rockwell method) and for verification of hardness testing machines (Rockwell method)

Méthodes d'essai de dureté (dureté Rockwell) et de vérification des machines d'essai de dureté (Rockwell)

Verfahren zur Härteprüfung (Rockwell-Verfahren) und zur Prüfung von Härteprüfmaschinen (Rockwell-Verfahren)

Foreword

This British Standard has been prepared under the direction of the Iron and Steel and Non-ferrous Metals Standards Committees. It is published as a single document in order to draw attention to the need for regular verification of hardness testing machines (Rockwell method) and to the availability of traceability to the national standard hardness scales. This British Standard supersedes BS 891 : Part 1 : 1962 and BS 891 : Part 2 : 1964, which are withdrawn.

The Technical Committee has taken full account of ISO 6508 and ISO 716 prepared by the International Organization for Standardization (ISO).

The Technical Committee has reconsidered the scope of this standard with the intention of including new developments wherever justifiable. For instance, major changes have occurred in the design of testing machines and in order to differentiate between the inherently greater accuracy of the new digital machines, grade 1 requirements are specified for these machines and less demanding grade 2 requirements are specified for older analogue machines.

In addition, requirements for anvils, including surface finish, have been specified and more demanding tolerances have been specified for indenters in order to give greater accuracy and long term reproducibility resulting from, for example, changes in the indenters.

As previously, the full direct verification procedure is carried out on a new machine or after major overhaul of a machine. Further checking that the accuracy of the machine is valid is provided by application of the indirect verification, following machine assembly and installation. Regular checks of accuracy of an installed machine, e.g. as part of quality assurance procedures or immediately after servicing, would normally be carried out by means of the indirect procedure (see appendix A). As the extent of usage of machines varies considerably it is not possible to give rules for frequency of such verifications. Guidance may be obtained on the basis of informed technical judgement from recognized calibrating authorities.

Considerable importance is attached by the committee to routine monitoring and maintenance of a testing machine's performance between verifications. Although these procedures are not part of the standard as such, a recommended form of procedure that does not impose onerous obligations upon users is given in appendix A.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Contents

Section one. General

1 Scope

This British Standard describes a method of test for determining the Rockwell hardness of metals at room temperature. In sections three and four, methods are described for direct and indirect verification respectively of the accuracy of a machine for testing Rockwell hardness.

NOTE. The titles of the publications referred to in this standard are listed on the inside back cover.

2 Definitions

For the purposes of this British Standard the following definitions apply.

2.1 hardness scale. A scale represented by a capital letter, which is associated with the type of indenter and force being used.

2.2 error in roundness (of a cone measured in a section normal to the indenter). The greatest radial distance between any point on the conical surface and the circumscribing circle.

2.3 error in sphericity (of a ball). The greatest radial distance between any point on the ball surface and the circumscribing sphere.

2.4 indirect verification (of a hardness testing machine). A performance test, using a specified number of calibrated test blocks and indentations, which provides traceability.

2.5 direct verification (of a hardness testing machine). Traceable tests of the accuracy of the test force, indenter geometry and measuring system and the performance tests given under indirect verification (see section four).

2.6 repeatability (of a testing machine). The range of hardness values obtained on a test block in the indirect verification.

2.7 error (of a testing machine). The difference between the mean hardness value obtained on a test block in the indirect verification and the value assigned to the test block by the calibrating authority.

3 Symbols and designations of hardness

3.1 Symbols

For the purposes of this British Standard the following symbols apply.

Symbol	Term
α	Angle of the diamond cone in degrees
R	Radius of curvature at the tip of the diamond cone (in mm)
D	Diameter of steel ball (in mm)
F_0	Preliminary test force (in N)
F_1	Additional test force (in N)
F	Total test force (in N)
h_0	Depth of indentation (in mm) under preliminary test force before application of additional test force
h_1	Increase in depth of indentation (in mm) under additional test force
e	Permanent increase of depth of indentation under preliminary test force after removal of additional test force (in Rockwell units of 0.002 mm)
E	A constant depending on form of the indenter as follows: 100 units when a diamond cone indenter is used 130 units when a steel ball indenter is used
HR	Rockwell hardness number
R_a	Average surface roughness (in μm) (equivalent to CLA value)

NOTE. See BS 1134.

3.2 Hardness value

When defining a hardness value, the scale that has been used for the test shall be stated. The symbol HR shall be preceded by the hardness value and followed by a capital letter representing the scale that has been used.

Example. 50 HRC indicates a Rockwell hardness of 50 in the C scale, obtained using a diamond indenter with a preliminary test force of 98.07 N and a total test force of 1471 N (see table 1).

Section two. Determination of Rockwell hardness

4 Principle

An indenter comprising a diamond cone or a hardened steel ball mounted rigidly in a suitable holder is forced into the material with a preliminary test force F_0 (see figures 1(a) and 2(a)). When equilibrium has been reached, an indicating device, which follows the movements of the indenter and so responds to changes in depth of penetration, is set to a datum position.

While the preliminary test force is still applied it is augmented by an additional test force F_1 with a resulting increase in penetration (see figures 1(b) and 2(b)). When equilibrium has again been reached, the additional force is removed but the preliminary force is maintained.

Removal of F_1 allows a partial recovery, so reducing the depth of penetration (see figures 1(c) and 2(c)). The permanent increase in depth of penetration e resulting from the application and removal of the additional force is used to deduce the Rockwell hardness number by means of the following equation:

$$HR = E - e$$

The unit of measurement for e is 0.002 mm.

The type of indenter used, the magnitudes of the preliminary, additional and total test forces and the constant E for the Rockwell scales of hardness covered by this standard are given in table 1. Also given is the field of application for each hardness scale in terms of the Rockwell hardness range.

5 Test apparatus

5.1 *Hardness testing machine* (Rockwell), capable of applying a preliminary test force of 98.07 N and total test forces of 588.4 N, 980.7 N and 1471 N to the accuracy specified in 11.3.

5.2 *Indenter*, comprising a diamond cone or hardened steel ball, complying with clause 12 and mounted in a holder.

5.3 *Measuring device*, capable of measuring changes in penetration depth to the accuracy specified in clause 13.

5.4 *Flat anvils*, complying with clause 14.

6 Conditions of test

6.1 Test piece surfaces

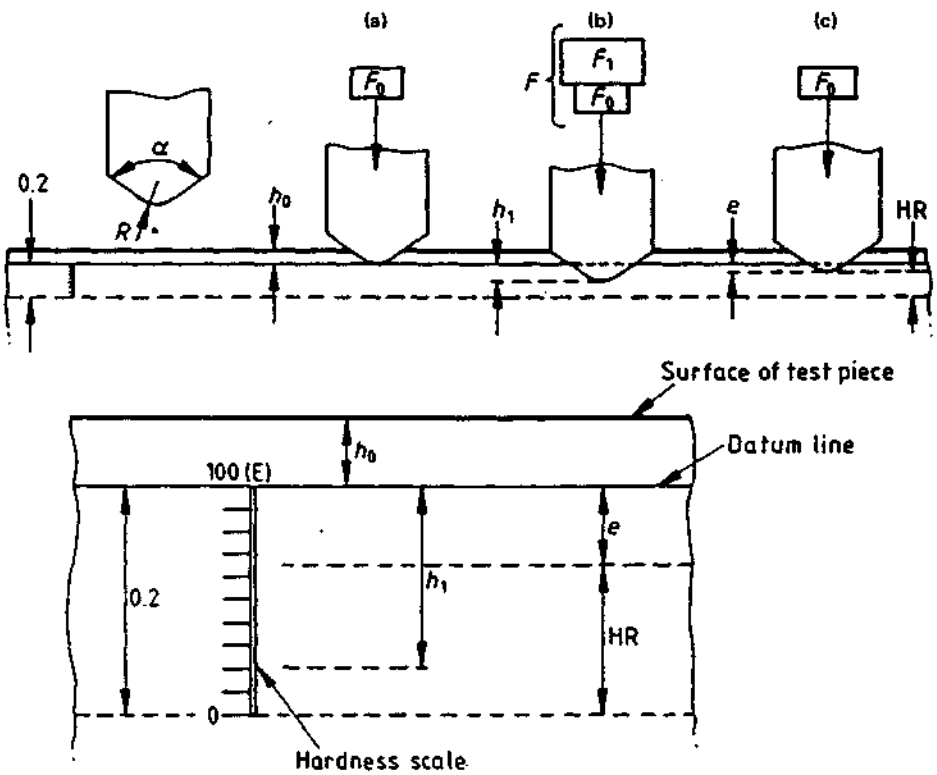
Test piece surfaces shall be smooth and free from scale and foreign matter. In particular, the surface in contact with the anvil and the surface to be indented shall be clean and dry unless otherwise specified in the product standard.

6.2 Test piece thickness

No deformation shall be visible on the underside of the test piece after the test. The thickness of the test piece shall be at least 10 times the depth of the indentation (see figure 3).

Table 1. Rockwell hardness scales

Scale	Indenter	Preliminary force, F_0	Additional force, F_1	Total force, F	Constant, E	Range
		N	N	N		
HRA	Diamond cone	98.07	490.3	588.4	100	20 to 88 HRA
HRB	1.5875 mm steel ball	98.07	882.6	980.7	130	30 to 100 HRB
HRC	Diamond cone	98.07	1373	1471	100	20 to 70 HRC
HRD	Diamond cone	98.07	882.6	980.7	100	40 to 77 HRD
HRE	3.175 mm steel ball	98.07	882.6	980.7	130	70 to 100 HRE
HRF	1.5875 mm steel ball	98.07	490.3	588.4	130	60 to 100 HRF
HRG	1.5875 mm steel ball	98.07	1373	1471	130	30 to 94 HRG
HRH	3.175 mm steel ball	98.07	490.3	588.4	130	80 to 100 HRH
HRK	3.175 mm steel ball	98.07	1373	1471	130	40 to 100 HRK



Dimensions are in millimetres.

Figure 1. Surface of test piece with diamond cone (Rockwell scales HRA, HRC or HRD)

6.3 Location of indentations

The distance between the centre of any indentation and the edge of the test piece shall be at least 2.5 times the diameter of the indentation and not less than 1 mm. The distance between the centres of two adjacent indentations shall be at least three times the diameter of the indentation (see figure 4).

7 Test procedure

Locate the test piece rigidly in relation to the indenter. Apply the test forces along the axis of the indenter and normal to the surface of the test piece, in such a manner that the indenter is forced into the test piece without shock or vibration.

NOTE 1. It is important that the test piece lies firmly on the support so that displacement can not occur during the test.

NOTE 2. Test piece misalignments of 10° or more may cause unacceptable errors.

NOTE 3. An anvil having a protuberance of about 6 mm diameter may be used, with advantage, for test pieces that are not flat.

Bring the indenter into contact with the test surface and apply the preliminary test force F_0. Set the measuring device reading to the value corresponding to the constant E and increase the force, in not less than 2 s and not more than 8 s, by the additional force F_1 to obtain a total test force F. Maintain F for a period (i.e. a dwell time) of 2 s to 6 s unless otherwise stated in the product standard. After removal of F_1, maintain F_0 until the reading of the depth measuring device has been taken.

NOTE 4. After any removal and replacement of the indenter or test piece support, it should be ascertained that the item is correctly mounted in its housing. After such a change has been made, the first two readings should be disregarded.

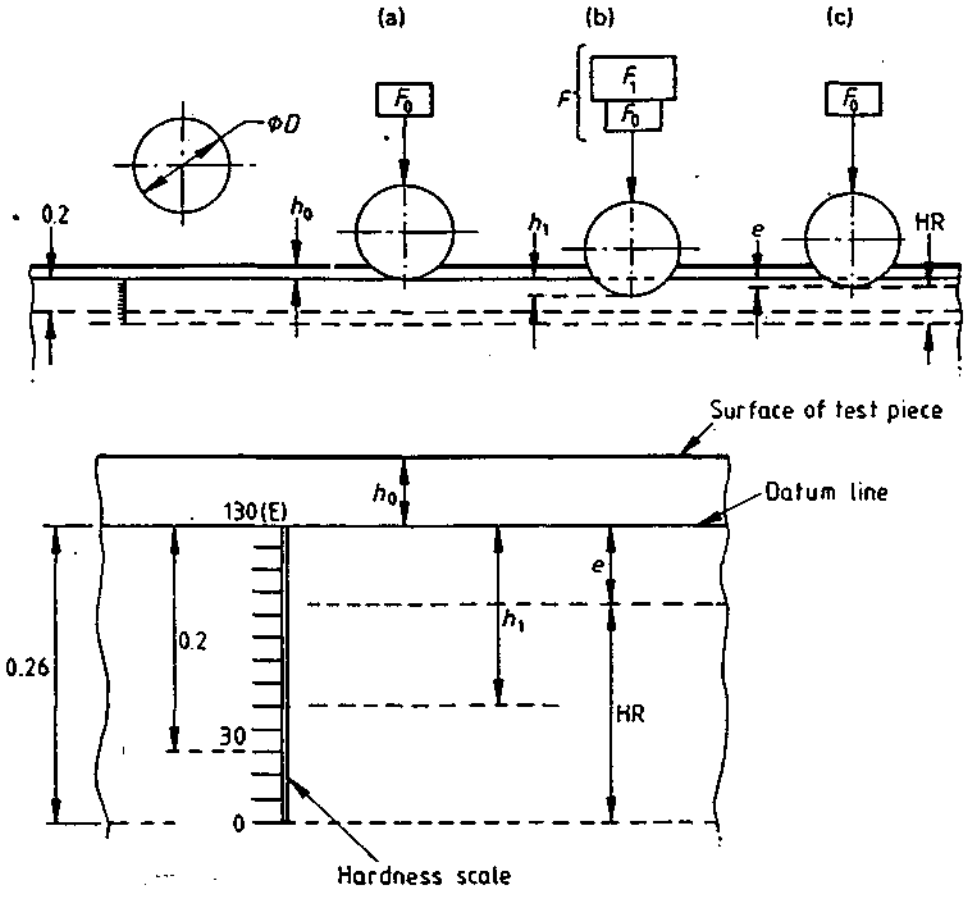
8 Calculations

For tests on flat surfaces, derive the Rockwell hardness number from the permanent increase in depth of indentation e (see clause 4).

NOTE 1. The Rockwell hardness number is usually read directly from the measuring device.

For tests on convex cylindrical surfaces apply the corrections given in appendix C.

NOTE 2. In the absence of established conversions for tests on concave cylindrical and spherical surfaces, hardness values should be regarded as comparative.



All dimensions are in millimetres.

Figure 2. Surface of test piece with steel ball (Rockwell scales HRB, HRE, HRF, HRG, HRH or HRK)

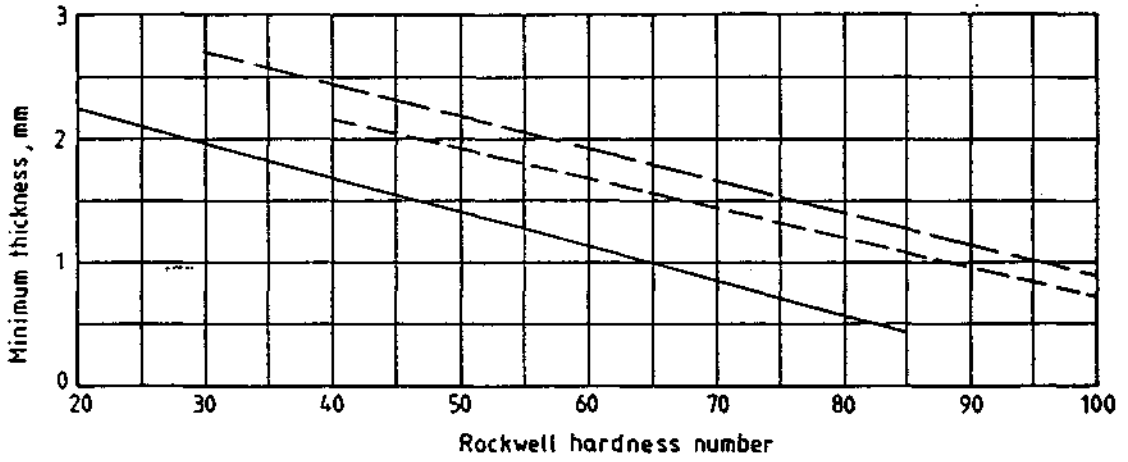


Figure 3. Graph of minimum thickness of test piece against Rockwell hardness number

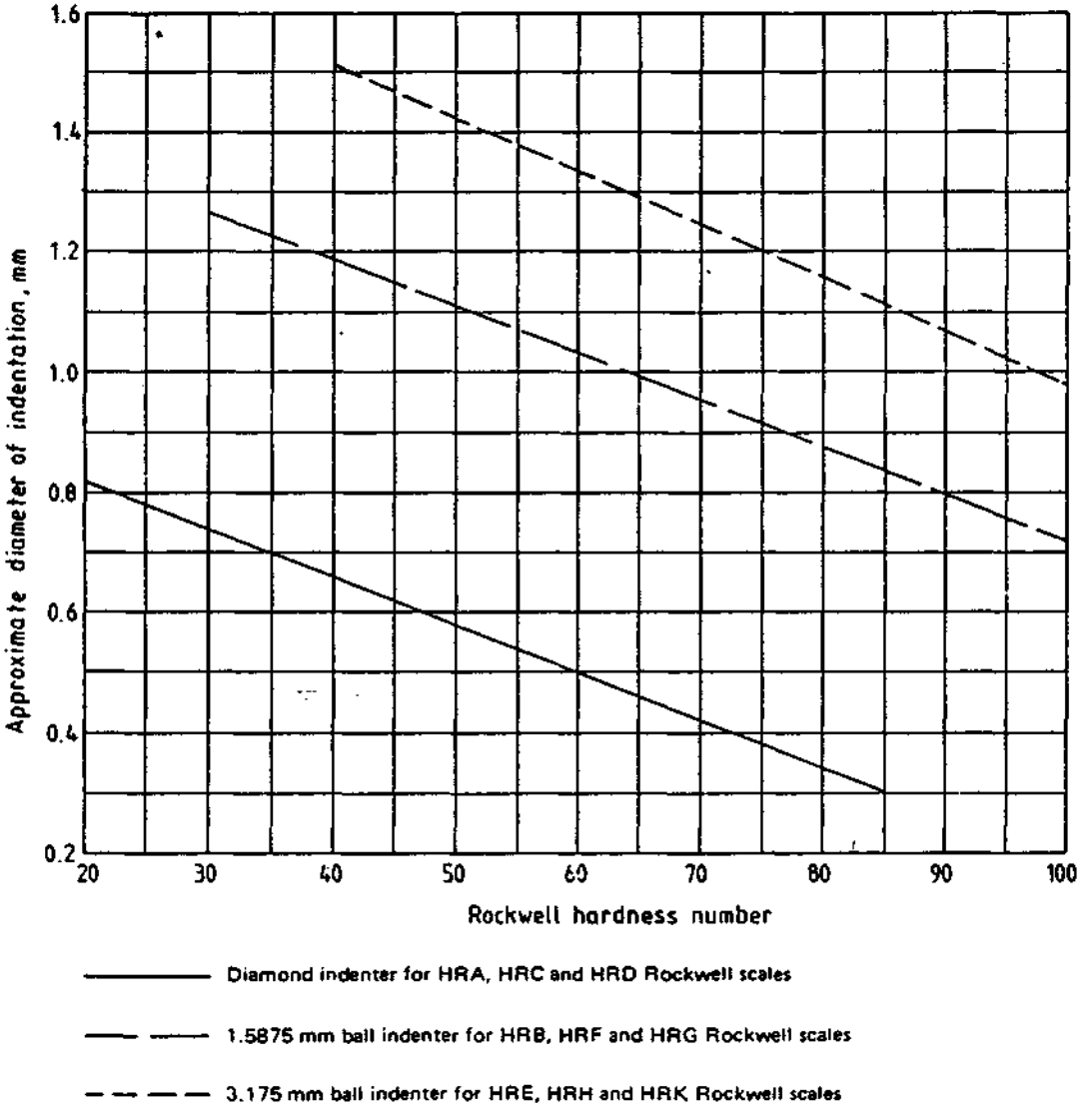


Figure 4. Graph of approximate diameter of indentation for calculation of indentation location against Rockwell hardness number

Section three. Direct verification of accuracy of the testing machine

9 Principle

The accuracy of the applied forces, the physical characteristics of the indenter and anvil and the accuracy of the depth measuring device are determined.

10 Traceability

The calibration of all measurement equipment used in the verification shall be traceable to the national reference standards. The direct verification shall also include a performance test (indirect verification) in accordance with section four.

11 Force

11.1 Verify the steady forces applied by the machine (see table 1) in accordance with BS 1610 : Part 1 by means of either of the following:

(a) elastic proving devices previously calibrated to grade 0.5 of BS 1610 : Part 2; or

(b) proving levers and masses that have been calibrated in accordance with BS 1610 : Part 2.

11.2 For each force, take three repeat readings at three or more positions of the carrier.

NOTE. Immediately before each reading is taken, the plunger will have moved in the same direction as during a normal test.

11.3 Each reading of the measured preliminary test force F_0, both before application and after removal of the additional test force F_1, shall be within 2 % of the nominal force.

11.4 Each reading of the measured total test force F shall be within 0.7 % of the nominal force.

11.5 Apply the forces without shock or vibration. The magnitude of any additional impact force shall be less than 0.5 % of the nominal force.

NOTE. When necessary, the impact force should be reduced by means of a dash-pot or other device.

12 Indenter

12.1 Diamond cone indenter (scales HRA, HRC and HRD)

12.1.1 The surface of the diamond cone and of the spherical tip shall be polished or ground for a penetration depth of 0.3 mm (equivalent to 0.55 mm conical generator) and shall be free from surface defects.

NOTE. No surface defects should be visible at a magnification in the range X150 to X400.

Measure the geometry of the indenter in at least four sections except when roundness is measured (see 12.1.2).

12.1.2 The diamond cone shall have an included angle of 120 ± 0.35° in each section measured.

NOTE 1. Deviations from straightness of the generator of the diamond cone, adjacent to the blend, should not exceed 0.0006 mm over a minimum length of 0.40 mm. Such a deviation could introduce a variation of 40' (approximately 0.65°).

NOTE 2. The error in roundness of the cone, measured in a section normal to the indenter axis adjacent to the blend, should not exceed 0.008 mm (see 12.1.4). Measurement of roundness should enable sections with minimum and maximum errors to be selected thus permitting measurements of the geometry of the indenter in only two sections.

12.1.3 The angle between the axis of the diamond cone and the axis of the indenter holder, normal to the seating surface, shall not exceed 0.5°.

12.1.4 The spherical tip of the diamond cone shall have a mean radius of 0.200 ± 0.010 mm. In each measured section, the radius shall be 0.200 ± 0.015 mm and local deviations from a truly spherical surface shall not exceed 0.002 mm.

NOTE. If the error in roundness of the cone measured in a section normal to the indenter axis adjacent to the blend exceeds 0.008 mm it will not be possible to manufacture the indenter to these radial tolerances.

12.1.5 The surface of the cone and spherical tip shall blend in a tangential manner.

12.1.6 Indirectly verify the indenter by comparing its performance in a standardizing machine with the performance of the machine's reference indenter.

Carry out tests on a minimum of three hardness test blocks selected to cover the range of the field of application of the HRC scale given in table 1. When the indenter is also to be used for the HRA or HRD scales, carry out tests on one additional block in the range 80 HRA to 88 HRA.

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 standardizing indenter by more than 0.5 scale unit.

Place the indentations with the indenter to be verified and with the standardizing indenter on the test block in adjacent pairs. Carry out the tests in accordance with 19.1.

12.2 Steel ball indenter (scales HRB, HRE, HRF, HRG, HRH and HRK)

12.2.1 *Dimensions.* The average diameter of a ball shall not differ from the nominal diameter by more than the appropriate tolerance given in table 2. The error in sphericity of a ball shall not exceed the appropriate value given in table 2.

Table 2. Dimensions of indenter balls for testing machines

Rockwell hardness scale	Ball diameter	Maximum error from nominal diameter	Maximum error in sphericity
	mm	mm	mm
HRB, HRF, HRG	1.5875	± 0.0025	0.0025
HRE, HRH, HRK	3.175	± 0.005	0.005

12.2.2 *Surface finish.* The ball shall be free from surface defects and the surface finish R_a shall not exceed 0.05 µm.

12.2.3 *Hardness.* Carry out a Vickers hardness test in accordance with BS 427 : Part 1 on the curved surface of the ball using the load for the HV10 scale. The hardness shall be not less than 800 HV10.

Either the appropriate correction for curvature in accordance with appendix B of BS 427 : Part 1 : 1961 shall be made to the measured hardness value or the mean measured diagonal of the indentation shall be not more than the appropriate maximum value given in table 3.

Table 3. Hardness of indenter balls

Rockwell hardness scale	Ball diameter	Maximum value of indentation diagonal in curved surface of ball
	mm	mm
HRB, HRF, HRG	1.5875	0.146
HRE, HRH, HRK	3.175	0.149

13 Measuring device

Verify the depth measuring device at not less than three points, including the points corresponding to the lowest and highest hardness for which the scales are normally used, by making known incremental movements of the indenter in the direction of increasing hardness value. The depth measuring device shall indicate correctly within ± 0.001 mm, i.e. within ± 0.5 scale unit, at each point.

14 Anvils

14.1 Anvils shall have a minimum surface hardness of 58 HRC.

14.2 The surface of a flat anvil shall have a finish and flatness as follows:

finish: not greater than 0.2 μm R_a;

flatness: error not greater than 2.5 μm/100 mm.

15 Performance test

When tested in accordance with the indirect verification procedure in clause 20, the testing machine shall be accurate within the limits specified in clause 21.

NOTE. The indirect verification confirms that the sum of the individual errors assessed in the direct verification does not exceed the allowable error given in table 5.

Section four. Indirect verification of accuracy of the testing machine

16 Principle

Measurements are made to determine the accuracy with which the testing machine measures the known hardness of test blocks that have been calibrated on a standardizing machine.

NOTE. Calibrated test blocks can be obtained from appropriate manufacturers with standardizing authority.

17 Manufacture of hardness test blocks

17.1 Each metal block to be calibrated on a standardizing machine shall be manufactured to give homogeneity and stability of structure. Steel blocks shall be demagnetized.

17.2 Each metal block shall be of a thickness not less than 6 mm.

17.3 The maximum variation in flatness of the surfaces shall not exceed 0.010 mm. The bottom of the blocks shall not be convex. The maximum variation in thickness shall not exceed 0.015 mm/50 mm.

17.4 The test surface and bottom surface shall be free from foreign matter that interferes with the measurement of the indentations. The surface roughness of both surfaces R_a shall not exceed 0.2 µm.

17.5 No material shall be removed from the block after it has been calibrated.

18 Calibration of hardness test blocks

18.1 General

The calibration of the block shall establish its uniformity of hardness and its hardness value. The test block shall be calibrated in one selected Rockwell scale, e.g. HRC scale.

The hardness value assigned to a block shall be directly or indirectly traceable to the national standard hardness scale through a hierarchical chain such as that provided by the British Calibration Service.

NOTE. National standard Rockwell scales HRA, HRB and HRC are defined by standardizing machines that are maintained at the National Physical Laboratory, Teddington.

18.2 Location of indentations

The distance between the centre of any indentation and the edge of the test block shall be at least three times the mean diameter of the indentation and not less than 2 mm. The distance between the centre of two adjacent indentations shall be at least five times the mean diameter of the indentations.

18.3 Calibration procedure

Carry out the test using a standardizing machine complying with clause 19.

18.4 Uniformity of hardness

Ten indentations distributed over the test surface shall be made on the block. The range of hardness values obtained from the 10 indentations shall not exceed the following values:

(a) 1.5 % e or 0.4 scale unit, whichever is the greater, for the HRA scale;

(b) 1.5 % e for the HRC and HRD scales;

(c) 3 % e for the HRB, HRE, HRF, HRG, HRH and HRK scales.

NOTE. e is the mean permanent increase of depth of indentation and is equal to E minus the mean of 10 hardness values.

18.5 Hardness value

The hardness value assigned to the block shall be the mean hardness value obtained when examining the block for uniformity. This value shall be rounded to the nearest 0.1 scale unit.

18.6 Marking

Each block shall be marked by the manufacturer with his name or trademark, a serial number and the mean hardness value. The marking shall be either on the test surface or on a side face of the block such that the marking is upright when the test surface is uppermost.

18.7 Documentation

The standardizing authority shall issue a document stating the following:

(a) the number and date of this British Standard, i.e. BS 891 : 1989;

(b) the serial number of the block;

(c) the hardness value assigned to the block and the hardness scale used, e.g. 55 HRC;

(d) the maximum and minimum hardness values obtained in the calibration of the block;

(e) the manufacturer's name and the date of calibration

(f) the thickness of the block where the marking is only on a side face of the block.

19 Standardizing machine

19.1 Direct verification

19.1.1 *General.* The standardizing machine used for calibrating the hardness test blocks shall comply with 19.1.2 to 19.1.6.

19.1.2 *Force.* Regardless of the position of the indenter carrier within its working range, the preliminary force F_0 shall be correct within ± 0.2 % of its nominal value, both before application and after removal of the additional force F_1. Each reading of the measured total force F shall be within ± 0.1 % of the nominal test force.

19.1.3 *Diamond cone indenter*

19.1.3.1 The surface of the diamond cone and of the spherical tip shall be polished for a penetration depth of 0.3 mm (equivalent to 0.55 mm conical generator) and no surface defects shall be visible at a magnification in the range x 150 to x 400.

19.1.3.2 The diamond cone shall have a mean included angle of 120 ± 0.10°. In each measured section, the included angle shall be 120 ± 0.17°. Deviations from straightness of the generator of the diamond cone, adjacent to the blend, shall not exceed 0.0003 mm over a minimum length of 0.40 mm. The error in roundness of the cone, measured in a section normal to the indenter axis adjacent to the blend, shall not exceed 0.004 mm.

19.1.3.3 The angle between the axis of the diamond cone and the axis of the indenter holder, normal to the seating surface, shall not exceed 0.3°.

19.1.3.4 The spherical tip of the diamond cone shall have a mean radius of 0.200 ± 0.005 mm. In each measured section, the radius shall be 0.200 ± 0.007 mm and local deviations from a truly spherical surface shall not exceed 0.002 mm.

19.1.3.5 The indenter shall be indirectly verified by comparing its performance in a standardizing machine with the performance of the machine's reference indenter.

Tests shall be made on a minimum of four hardness test blocks selected to cover the range of the field of application of the scale given in table 1, i.e. HRA, HRC or HRD.

For each block, the mean hardness value of five indentations made using the indenter to be verified shall not differ from the mean hardness of five adjacent indentations obtained with the standardizing indenter by more than 0.3 scale unit.

19.1.4 *Steel ball indenter.* The average diameter of a ball shall not differ from the nominal diameter by more than the appropriate tolerance given in table 4. The error in sphericity of a ball shall not exceed the appropriate value given in table 4.

Table 4. Dimensions of indenter balls for standardizing machines

Rockwell hardness scale	Ball diameter	Maximum error from nominal diameter	Maximum error in sphericity
	mm	mm	mm
HRB, HRF, HRG	1.5875	± 0.00125	0.00125
HRE, HRH, HRK	3.175	± 0.0025	0.0025

19.1.5 *Measuring device.* The depth measuring device shall be calibrated so as to ensure that any interval in the working range can be measured correctly within ± 0.0002 mm, i.e. within ± 0.1 scale unit.

19.1.6 *Method of force application.* The mechanism that controls the application of the test force shall be one of the following.

(a) *Type A.* Type A mechanism shall employ a device, e.g. a spring or dash-pot, to reduce the velocity of penetration of the indenter during the period of penetration. The initial velocity prior to penetration of the test block shall be not greater than 1 mm/s.

(b) *Type B.* Type B mechanism shall maintain a constant velocity in the range 0.005 mm/s to 0.020 mm/s.

Bring the indenter into contact with the test surface and apply the preliminary test force F_0 without shock or vibration. Maintain F_0 for a dwell period of not less than 2 s and not more than 20 s. Set the measuring device to its datum position and increase the force from F_0 to the total test force F. In type A mechanism machines, this shall be done in not less than 2 s and not more than 8 s.

Maintain the additional test force F_1 for a dwell period of not less than 3 s and not more than 5 s. Obtain the final reading immediately after F_1 has been removed.

NOTE. Corrections to the hardness values should be evaluated for the effects of deviations from the above criteria for a particular standardizing machine.

19.2 Monitoring of standardizing machine

The accuracy and stability of the Rockwell hardness scales defined by standardizing machines shall be monitored as follows.

(a) A minimum of two scales shall be monitored, selected from the three traceable scales available, i.e. HRA, HRB and HRC.

(b) A set of at least three test blocks covering the range of the first scale and three test blocks covering the range of the second scale shall be provided. The uniformity of hardness of each block shall comply with 18.4.

(c) Periodic monitoring values shall be obtained from the mean of five indentations in each block and the periodic monitoring tests shall be made at regular intervals of not more than 3 months. The location of the indentations on the test block shall comply with 18.2.

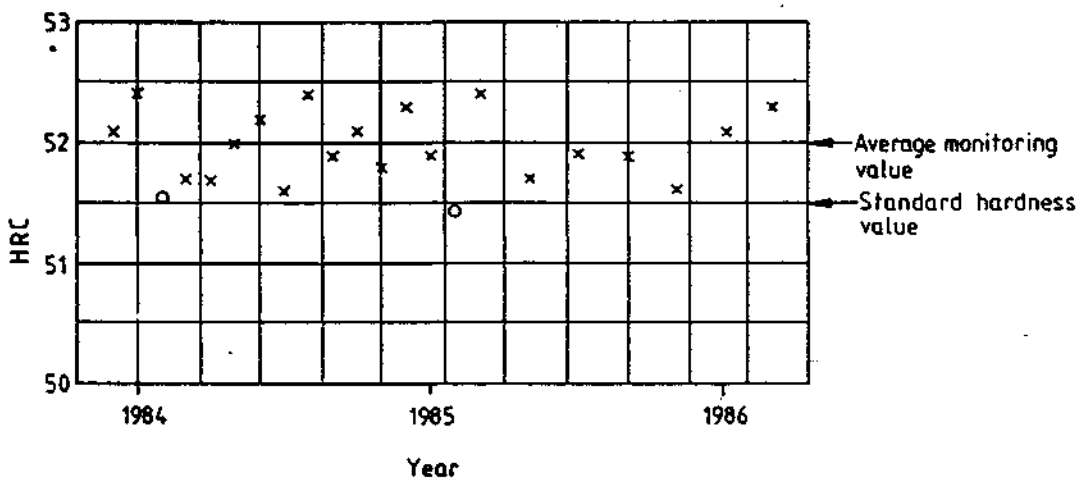
(d) An assessment of the performance of the machine shall be made from the recorded monitoring values over a period and shall show that a monitoring value is reproducible within ± 0.5 scale unit of the average of the monitoring values obtained for the block.

(e) The test blocks shall be calibrated at least twice (initially and at mid-life) by the standardizing machine that defines the national standard scale. The monitoring values shall be reproducible within the following number of scale units of the mean national standard hardness value for the block:

HRA $<$ 65 ± 1.0
HRA $\geqslant$ 65 ± 0.5
HRB $<$ 60 ± 1.5
HRB $\geqslant$ 60 ± 1.0
HRC $<$ 60 ± 1.0
HRC $\geqslant$ 60 ± 0.5.

NOTE 1. Typical permitted monitoring results for a standardizing machine are shown in figure 5.

NOTE 2. A standardizing machine that complies with the requirements in clause 19 may be used to calibrate blocks in any of the scales given in table 1.



Key
x = monitoring value (mean of five indentations)
o = NPL calibration value

Figure 5. Typical permitted monitoring results for a standardizing machine

20 Procedure for indirect verification of the testing machine

20.1 First, ascertain that the testing machine is correctly set up on a rigid support free from significant vibration and that the indenter is securely fixed to the carrier.

If the testing machine has a specimen clamping device, check that the clamping force is greater than the maximum test force.

Ascertain that readings of the measuring device are not influenced by deformation of the frame and displacement of the supporting mechanism by more than 0.5 scale unit.

NOTE. The effect of deformations on the readings may be checked by using a plain-ended carrier in place of the indenter, bearing directly on the anvil.

20.2 Carry out the indirect verification of the testing machine in accordance with clause 7 and using hardness test blocks calibrated in accordance with clause 18.

20.3 Before making test indentations, make at least two preliminary indentations to ensure that the machine is working freely and that the test block, indenter and anvil are seating correctly. Do not record the results of these preliminary indentations.

20.4 On each hardness test block, make five indentations distributed over the surface of the test piece. The location of the indentations shall comply with 18.2. Observe and record the hardness number to at least 0.2 of a scale unit.

20.5 Verify the testing machine in at least two scales selected from the three scales HRA, HRB, and HRC. Use three test blocks per scale, one selected from each of the hardness ranges given in table 5.

NOTE. Where appropriate, the hardness values of the blocks shoul approximate to the hardness of intended use.

21 Assessment of accuracy of the testing machine

Machines for testing Rockwell hardness shall be graded in accordance with the maximum permissible values given in table 5 for the error of the mean hardness value. In additic the accuracy of the machine shall be such that the hardnes values obtained in each test of five indentations comply with the following requirements for repeatability and erro:

(a) *Repeatability.* The range of the five hardness values (i.e. the difference between the largest and smallest value) shall not exceed the following values:

(1) 3 % *e* or 0.8 scale unit, whichever is the greater, for the HRA scale;

(2) 3 % *e* for the HRC scale;

(3) 6 % *e* for the HRB scale.

NOTE. The repeatability requirements are given graphically in figure 6.

(b) *Error.* The mean of the five hardness values shall no: differ from the value assigned to the block by more than the permissible error given in table 5.

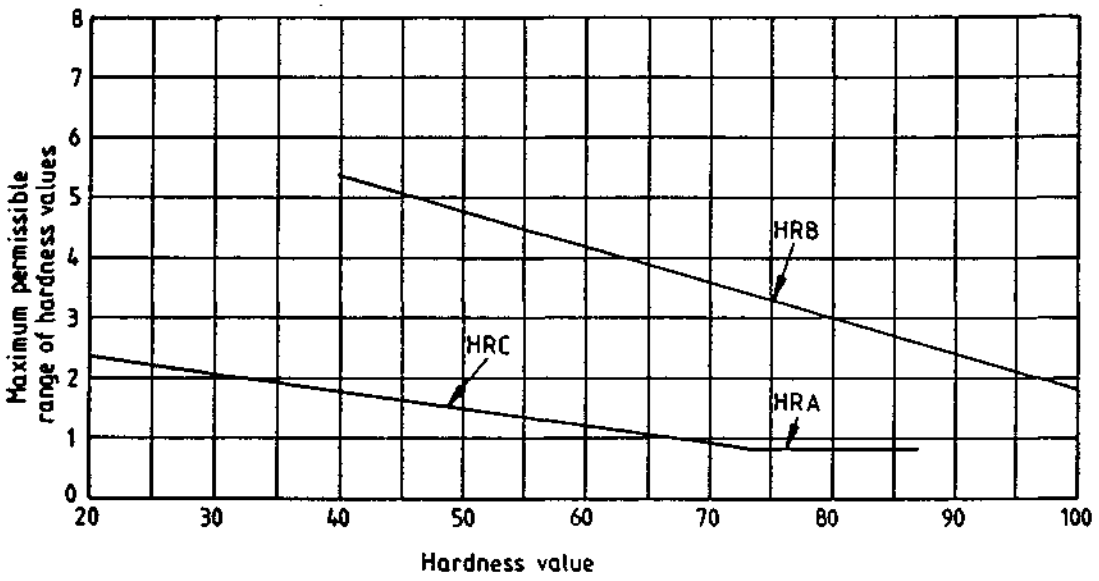


Figure 6. Repeatability requirements at different hardness values

Table 5. Allowable error in value of test block hardness determined in indirect verification

Rockwell hardness scale	Hardness range of standardized block	Maximum permissible error	
		Grade 1	Grade 2
		Rockwell units	Rockwell units
HRA	40 to 65	± 1	± 1.5
	68 to 78	± 0.5	± 1
	81 to 87	± 0.5	± 1
HRB	40 to 55	± 1.5	± 2
	60 to 75	± 1	± 1.5
	80 to 100	± 1	± 1.5
HRC	20 to 30	± 1	± 1.5
	35 to 55	± 1	± 1.5
	60 to 70	± 0.5	± 1

Appendices

Appendix A. Monitoring the accuracy of the testing machine

A.1 The procedure for monitoring the accuracy of a testing machine involves making regular tests on the same hardness test block and recording the results for assessment.

A.2 Monitoring should be carried out in accordance with clause 7 and using hardness test blocks calibrated in accordance with clause 18. The location of the indentations on the test block should comply with 18.2.

NOTE. In special cases, when it is desirable in place of test blocks to use test specimens of the same material or form as the components to be tested, the test specimens should be calibrated in accordance with clause 17 using a testing machine monitored in accordance with 19.2.

A.3 The testing machine should be in its usual condition and the indenter being used should be in the machine.

A.4 Whenever possible a test block should be provided of a similar hardness and calibrated in the same Rockwell scale as that being used by the testing machine. Tests should be repeated at regular intervals. A single hardness test should be made on the block on each day that the machine is to be in use and the result should be recorded. When necessary, a second test should be made and the results of both tests should be recorded.

NOTE 1. The results of at least two preliminary indentations should be ignored.

NOTE 2. For multiscale operations, the procedure should be repeated with a second test block having a different Rockwell hardness, while the intervals between tests should be extended.

A.5 An assessment of the accuracy of the machine should be made from the recorded monitoring values over a period and the machine should be deemed satisfactory for its nominated grade if an individual hardness value is reproducible within the values given in table 6 from the assigned value of the block.

Appendix B. Additional information on the hardness test (Rockwell) procedure

B.1 The testing machine should not be sited in gritty or dusty conditions, nor in a position subject to excessive vibration or temperature changes.

The performance of the machine should be frequently checked by means of calibrated hardness test blocks (see appendix A).

B.2 The indenter should be examined regularly for signs of damage and replaced whenever these are found. The results of any test made with a damaged indenter could be incorrect and should be discarded.

B.3 The surfaces of the indenter and of the test piece should be free from lubricant unless the product standard specifies otherwise.

B.4 The seating surfaces of the anvil and of the indenter holder should be examined periodically for freedom from burrs, rust and corrosion.

B.5 The speed of loading given in clause 7 should be maintained as alteration may lead to erroneous hardness values.

NOTE 1. *There is evidence that some materials may be sensitive* to the rate of straining resulting in small changes in the value of the yield stress. The corresponding effect on the termination of the formation of an indentation may cause alterations in the hardness value.

NOTE 2. The rate of straining in a testing machine is controlled by the time taken for the formation of an indentation (see clause 7). The minimum time of 2 s is intended to apply to the formation of an indentation in hard material using, for example, the HRC scale, whereas the maximum time of 8 s is intended to apply to the formation of an indentation in soft material using, for example, the HRB scale.

Table 6. Error in hardness value for monitoring

Rockwell hardness scale	Hardness range of standardized block	Maximum permissible error	
		Grade 1	Grade 2
		Rockwell units	Rockwell units
HRA	< 65	± 1.5	± 2
	> 65	± 1	± 1.5
HRB	< 60	± 2	± 3
	> 60	± 1.5	± 2
HRC	< 60	± 1.5	± 2
	> 60	± 1	± 1.5

Appendices

Appendix A. Monitoring the accuracy of the testing machine

A.1 The procedure for monitoring the accuracy of a testing machine involves making regular tests on the same hardness test block and recording the results for assessment.

A.2 Monitoring should be carried out in accordance with clause 7 and using hardness test blocks calibrated in accordance with clause 18. The location of the indentations on the test block should comply with 18.2.

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NOTE 1. The results of at least two preliminary indentations should be ignored.

NOTE 2. For multiscale operations, the procedure should be repeated with a second test block having a different Rockwell hardness, while the intervals between tests should be extended.

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Appendix B. Additional information on the hardness test (Rockwell) procedure

B.1 The testing machine should not be sited in gritty or dusty conditions, nor in a position subject to excessive vibration or temperature changes.

The performance of the machine should be frequently checked by means of calibrated hardness test blocks (see appendix A).

B.2 The indenter should be examined regularly for signs of damage and replaced whenever these are found. The results of any test made with a damaged indenter could be incorrect and should be discarded.

B.3 The surfaces of the indenter and of the test piece should be free from lubricant unless the product standard specifies otherwise.

B.4 The seating surfaces of the anvil and of the indenter holder should be examined periodically for freedom from burrs, rust and corrosion.

B.5 The speed of loading given in clause 7 should be maintained as alteration may lead to erroneous hardness values.

NOTE 1. There is evidence that some materials may be sensitive to the rate of straining resulting in small changes in the value of the yield stress. The corresponding effect on the termination of the formation of an indentation may cause alterations in the hardness value.

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Table 6. Error in hardness value for monitoring

Rockwell hardness scale	Hardness range of standardized block	Maximum permissible error	
		Grade 1	Grade 2
		Rockwell units	Rockwell units
HRA	< 65	± 1.5	± 2
	> 65	± 1	± 1.5
HRB	< 60	± 2	± 3
	> 60	± 1.5	± 2
HRC	< 60	± 1.5	± 2
	> 60	± 1	± 1.5

B.6 For some materials, the requirement that the thickness of the test piece shall be not less than 10 times the depth of indentation may be unduly restrictive. If, in particular circumstances, it becomes necessary to accept a lower ratio of thickness to depth, the hardness value may be influenced by the size and hardness of the anvil, and a special investigation may be needed to establish what influence these factors exert on the true hardness as obtained with thicker test pieces. Alternatively, test results on thin specimens should be confined to comparative testing.

B.7 As there is no general procedure for accurately converting Rockwell hardness into other scales of hardness, it is recommended that such conversions should be avoided, except for special cases where a reliable basis for the conversion has been established by direct tests on the material concerned (see BS 860).

Appendix C. Corrections to Rockwell hardness values obtained on convex cylindrical surfaces

The correction, in hardness units, corresponding to a particular hardness and diameter of cylindrical test piece, should be added to the Rockwell hardness value obtained from the test (see tables 7 and 8).

Table 7. Correction for test results obtained with diamond cone indenter using scales HRA, HRC and HRD

Rockwell hardness	Diameter of cylindrical test piece								
	6 mm	10 mm	13 mm	16 mm	19 mm	22 mm	25 mm	32 mm	38 mm
	Correction (in Rockwell units)								
20				2.5	2.0	1.5	1.5	1.0	1.0
25			3.0	2.5	2.0	1.5	1.0	1.0	1.0
30			2.5	2.0	1.5	1.5	1.0	1.0	0.5
35		3.0	2.0	1.5	1.5	1.0	1.0	0.5	0.5
40		2.5	2.0	1.5	1.0	1.0	1.0	0.5	0.5
45	3.0	2.0	1.5	1.0	1.0	1.0	0.5	0.5	0.5
50	2.5	2.0	1.5	1.0	1.0	0.5	0.5	0.5	0.5
55	2.0	1.5	1.0	1.0	1.0	0.5	0.5	0.5	0
60	1.5	1.0	1.0	0.5	0.5	0.5	0.5	0	0
65	1.5	1.0	1.0	0.5	0.5	0.5	0.5	0	0
70	1.0	1.0	0.5	0.5	0.5	0.5	0.5	0	0
75	1.0	0.5	0.5	0.5	0.5	0.5	0	0	0
80	0.5	0.5	0.5	0.5	0.5	0	0	0	0
85	0.5	0.5	0.5	0	0	0	0	0	0
90	0.5	0	0	0	0	0	0	0	0

NOTE. Corrections greater than 3 HRA, HRC and HRD are not considered acceptable and are therefore not included.

Table 8. Correction for test results obtained with ball indenter using scales HRB, HRE, HRF, HRG, HRH and HRK

Rockwell hardness	Diameter of cylindrical test piece						
	6 mm	10 mm	13 mm	16 mm	19 mm	22 mm	25 mm
	Correction (in Rockwell units)						
30			5.0	4.5	3.5	3.0	2.5
40			4.5	4.0	3.0	2.5	2.5
50			4.0	3.5	3.0	2.5	2.0
60		5.0	3.5	3.0	2.5	2.0	2.0
70		4.0	3.0	2.5	2.0	2.0	1.5
80	5.0	3.5	2.5	2.0	1.5	1.5	1.5
90	4.0	3.0	2.0	1.5	1.5	1.5	1.0
100	3.5	2.5	1.5	1.5	1.0	1.0	0.5

NOTE. Corrections greater than 5 HRB, HRE, HRF, HRG, HRH and HRK are not considered acceptable and are therefore not included.

Publications referred to

BS 427 Method for Vickers hardness test
Part 1 Testing of metals
BS 860 Tables for comparison of hardness scales
BS 1134 Method for the assessment of surface texture
Part 1 Method and instrumentation
Part 2 General information and guidance
BS 1610 Materials testing machines and force verification equipment
Part 1 Specification for the grading of the forces applied by materials testing machines
Part 2 Specification for the grading of equipment used for the verification of the forces applied by materials testing machines

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