
British Standard Method for

Brinell hardness test and for verification of Brinell hardness testing machines

Méthode d'essai de dureté Brinell et de vérification des machines d'essai de dureté Brinell

Brinellhärteprüfung und Prüfung von Brinellhärteprüfmaschinen

Foreword

This British Standard has been prepared under the direction of the Iron and Steel and the Non-ferrous Metals Standards Committees. In order to draw attention to the need for regular verification of testing machines and to the availability of traceability to the national standard hardness scales, publication has been arranged as a single standard. It supersedes BS 240 : Part 1 : 1962 and BS 240 : Part 2 : 1964 which are withdrawn.

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, particularly in respect of the different techniques for the direct measurement of the area of an indentation upon which the calculation of the hardness number is based and these are now recognized. Also, tungsten carbide balls are specified in view of experience in their use which has established that they will give the same hardness value as that obtained with steel balls for hardness up to 350 HB and additionally will show greater consistency with a longer life.

On the other hand, certain tests similar to the Brinell in concept, e.g. those applying a load at high rate in order to expedite rates of testing and those made with machines that deduce the surface area of indentations from measurements of their depths, cannot be deemed to satisfy the requirements of this British Standard. Nevertheless, such tests are known to be frequently used on a comparative basis and with certain types of uniform material they may give equally consistent results as those obtainable by a conventional procedure. Their use and the interpretation of the significance of the results obtained are a matter for negotiation between all parties concerned.

Continuity from the previous standard has been retained and cognizance has been taken of discussions in the International Organization for Standardization (ISO) and the International Organization for Legal Metrology (OIML). Thus, a Brinell hardness value is an explicit relationship between test force, ball diameter and area of indentation and although, in this standard, the test forces are now expressed in newtons, each value of force is given exactly to four figures in order to maintain the same hardness numbers as before in the established Brinell scales. In the interests of standardization and to minimize proliferation of the number of hardness scales, i.e. combinations of test force and ball diameter, particular attention has been given

to ensure that those chosen are generally in common use in major industries both in the UK and abroad. For convenience of reference, tabulations of calculated hardness values for the chosen scales are included in appendix D.

The standard also incorporates extensive detail changes that reflect the considerably improved knowledge of the effect of various parameters upon the possible accuracy of a Brinell hardness test. The committee has recognized the need to specify reasonable tolerances upon the various parameters and these collectively impose a limit of $\pm 4\%$ of hardness number upon the maximum overall inaccuracy of a testing machine. In addition, it is now more clearly established that the finite limit of accuracy that is likely to be obtainable from a Brinell hardness test is $\pm 2\%$ HB. The introduction of a separate indirect verification for the measuring microscope should enable specialist users to correlate the performance of observer and microscope and so to obtain this order of accuracy when it is required.

Detailed requirements for the thickness of a test piece and for the spacing of indentations ensure that hardness values so obtained will be traceable to the accepted national hardness scales. The interpretation of comparative results given by tests not meeting these requirements is a matter for negotiation between the parties concerned.

As previously, the full direct verification procedure is normally carried out on a new machine or after major overhaul of an existing machine; it incorporates further checking that the accuracy of the machine is valid 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. 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 during the period between verifications. Although these procedures are not part of the standard as such, recommended forms of procedure that do not impose onerous obligations upon users are included in appendices A and B.

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

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Section one. General

1 Scope

This British Standard describes a method of test for determining the Brinell hardness of metals up to 600 HB at room temperature.

In sections three and four procedures are given for direct and indirect methods of verification respectively of the accuracy of the Brinell testing machine.

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 indirect verifications (of the indenting machine and measuring apparatus). Performance tests using a specified number of calibrated test blocks and indentations which provide traceability.

2.2 direct verification. Traceable tests of the accuracy of the test force and indenter and measuring apparatus, and also includes the performance tests defined under indirect verification.

2.3 repeatability. The range of hardness values obtained on a test block in the indirect verification.

2.4 error. 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.

2.5 load/ball diameter ratio. The ratio of the load to the square of the ball diameter (f/D^2).

2.6 hardness scale. Range of hardness values given by the ball diameter and load.

3 Symbols and designation of hardness

3.1 General

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

Symbol	Term
D	Diameter of the indenter ball (in mm)
F	Test force (in N)
f	Load symbol representing the test force (see table 2) NOTE. $f = 0.102 \times F$.
d	Mean diameter of the indentation (in mm)
h	Depth of the indentation (in mm)
R_a	Arithmetic mean of surface roughness deviations from a straight line (in μm)
HB	Brinell hardness when either a steel or tungsten carbide indenter ball is used
HBS	Brinell hardness when a steel indenter ball is used
HBW	Brinell hardness when a tungsten carbide indenter ball is used

3.2 Hardness value

When defining a hardness value, the scale that has been used for the test shall be stated. The symbol HBS or HBW shall be preceded by the hardness value and supplemented by an index indicating the test conditions in the following order:

- (a) diameter of the indenter ball in millimetres;
- (b) a load symbol representing the test force (see table 2);
- (c) dwell time of full force in seconds, if different from the standard dwell time of 10 s to 15 s.

Example. 226 HBS 10/3000 indicates a Brinell hardness value of 226 obtained using a 10 mm diameter steel ball with a test force of 29.42 kN corresponding to a load symbol of 3000 (see table 2) and the standard dwell time of 10 s to 15 s.

Section two. Determination of Brinell hardness

4 Principle

An indenter comprising a hardened steel or tungsten carbide ball of diameter D mounted in a suitable holder is forced into the material with a test force F (see figure 1).

The diameter of the indentation left in the surface of the material after removal of the load, is measured at least in two directions at right angles. Alternatively, an improved estimate of the mean diameter, d , may be obtained from the average of a number of symmetrically placed measurements or from an assessment of the projected indentation area in the material surface.

The area of the curved surface of the indentation is calculated from the mean diameter, d , the indentation being considered as a segment of a sphere of diameter D .

The Brinell hardness is a number proportional to the quotient obtained by dividing the test force by the calculated curved surface area of the indentation.

5 Apparatus

5.1 Testing machine, capable of applying a predetermined force or forces within the range of 9.807 N to 29.42 kN, to the accuracy defined in 11.2.

5.2 Indenter, comprising a hardened steel or tungsten carbide ball complying with clause 12 and mounted in a suitable holder.

NOTE. The choice of ball to be used will depend on the hardness of the test material (see 6.1).

5.3 Measuring microscope or other measuring device, capable of measuring the indentation diameter to the accuracy defined in clause 13.

6 Conditions of test

NOTE. Tests which do not comply with clause 6 are of comparative value only.

6.1 Choice of indenter

For Brinell hardness of less than or equal to 450 HB, either a steel or a tungsten carbide ball shall be used, but in the range 350 HB to 450 HB the hardness values obtained may differ significantly and a tungsten carbide ball should preferably be used for values above 350 HB. When designating the hardness value in this hardness range, the appropriate symbol HBS or HBW shall be used.

A steel ball shall not be used for materials with a hardness exceeding 450 HB.

A tungsten carbide ball shall not be used for materials with a hardness exceeding 600 HB.

6.2 Test piece surface finish

The test piece shall have such a surface finish as to permit accurate measurement of the diameter of the indentation.

NOTE. The following surface finishes are recommended.

Ball size	Surface finish
10 mm and 5 mm	not greater than $2.0 \mu\text{m } R_a$
2.5 mm	not greater than $1.5 \mu\text{m } R_a$
2 mm and 1 mm	not greater than $1.0 \mu\text{m } R_a$

6.3 Test piece thickness

To ensure that the test is valid, the test piece shall be inspected after the test and there shall be no visible deformation at the back of the test piece. The thickness of the test piece shall be not less than eight times the depth, h , of the indentation (see appendix C).

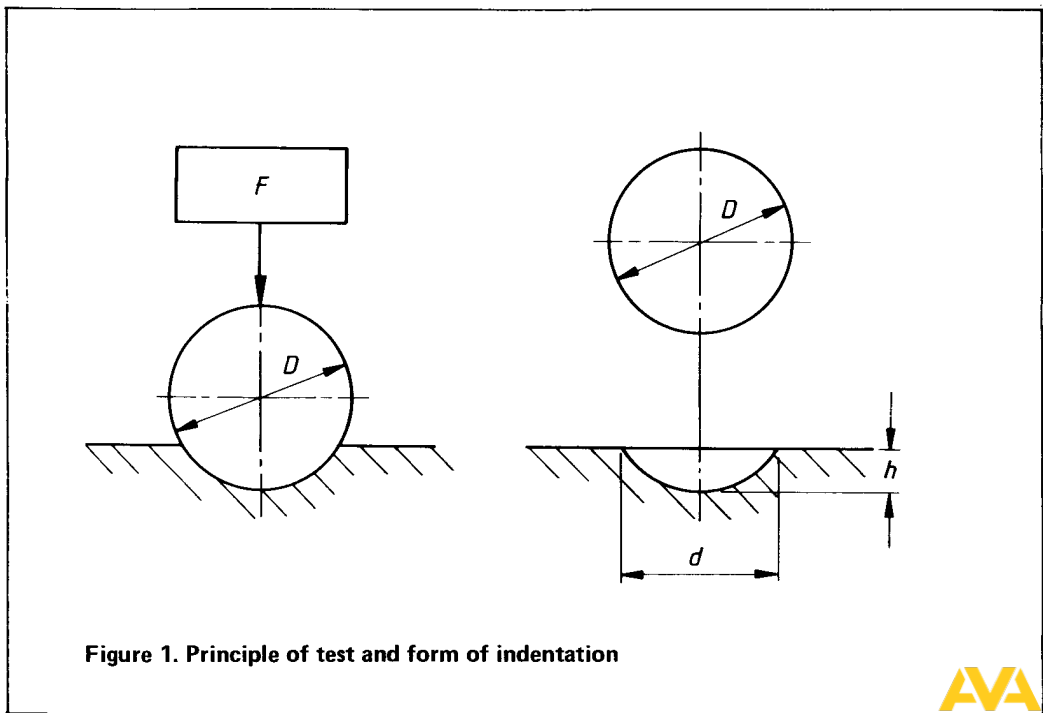


Figure 1. Principle of test and form of indentation



The appropriate depth of the indentation h (in mm) is calculated as follows:

$$h = \frac{0.102F}{\pi D \times HB} = \frac{f}{\pi D \times HB}$$

6.4 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 mean diameter of the indentation.

The distance between the centres of two adjacent indentations shall be at least 3 times the mean diameter of the indentation.

NOTE. Effect of metallurgical structure. For materials of coarse metallurgical structure, the indentation should be large enough to ensure that the average hardness of the material is obtained. Where possible, when the structure is known to be non-uniform, several indentations should be made and an average value taken.

7 Determination of f/D^2 ratio and hardness scale

7.1 f/D^2 ratios

The same value of f/D^2 will, in principle, give the same hardness value for different loads and the values to be used will depend on the nature and hardness of the material being tested.

Four standard values of f/D^2 have been adopted, i.e. 30, 10, 5 and 1 and one of these shall be used.

NOTE. For guidance, where no value is specified in the relevant British Standard for the material being tested, recommended values for some representative materials are given in table 1.

Table 1. Values of f/D^2 for representative materials		
Material	Typical HB value of material	f/D^2
Steels, nickel alloys, cast iron and titanium alloys	Above 100	30
Copper, copper alloys and aluminium alloys	30 to 200	10
Aluminium	15 to 100	5
Lead, tin	3 to 20	1

7.2 Brinell scales

A Brinell hardness scale is defined by the combination of a specified ball diameter and a specified force. The scales normally used are listed in table 2 with a load symbol representing the test force.

The permitted range of a Brinell scale is limited by the ratio of d/D which shall be between 0.25 and 0.6 (see appendix D).

7.3 Choice of Brinell hardness scale

The choice of a scale to be used for a particular test is determined by two factors:

- (a) the value of the ratio f/D^2 ; and
- (b) the size of the indentation that will provide optimum information and accuracy.

The force and ball diameter most suitable for any hardness measurement being made shall be selected from the correlated values given in table 2.

8 Test procedure

Locate the test piece rigidly in relation to the indenter. Apply the force 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. Misalignments of the test piece of 10° or more may cause unacceptable errors.

Maintain the full force for a period (i.e. a dwell time) of 10 s to 15 s unless otherwise stated in the material specification.

After removal of the force determine the mean diameter of the indentation from one of the following:

- (a) the average of measurements taken in two directions at right angles;
- (b) the average of a greater number of symmetrically placed measurements;
- (c) an assessment of the projected indentation area in the material surface.

9 Calculation of Brinell hardness value

When the indentations are made on flat surfaces, calculate the Brinell hardness using the following equation.

NOTE 1. For convenience computed values are given in tables 9 to 28 for each of the hardness scales given in table 2.

$$HB = \text{Constant} \times \frac{\text{Test force}}{\text{Calculated surface area of indentation}}$$

or

$$HB = 0.102 \times \frac{2F}{\pi D \{D - \sqrt{D^2 - d^2}\}}$$

$$= \frac{2f}{\pi D \{D - \sqrt{D^2 - d^2}\}}$$

The hardness value shall be expressed as designated in accordance with 3.2.

NOTE 2. Hardness measurements made on test pieces with curved surfaces should be regarded as being of comparative value only.

*Constant = $\frac{1}{g_n} = \frac{1}{9.80665}$ = approximately 0.102.

Table 2. Correlated values of ball diameter and force corresponding to values of f/D^2 of 30, 10, 5 and 1				
Hardness scale	f/D^2	Ball diameter D	Load symbol f	Test force F
		mm		N
HB 10/3000	30	10	3000	29 420
HB 10/1000	10	10	1000	9 807
HB 10/500	5	10	500	4 903
HB 10/100	1	10	100	980.7
HB 5/750	30	5	750	7 355
HB 5/250	10	5	250	2 452
HB 5/125	5	5	125	1 226
HB 5/25	1	5	25	245.2
HB 2.5/187.5	30	2.5	187.5	1 839
HB 2.5/62.5	10	2.5	62.5	612.9
HB 2.5/31.25	5	2.5	31.25	306.5
HB 2.5/6.25	1	2.5	6.25	61.29
HB 2/120	30	2	120	1 177
HB 2/40	10	2	40	392.3
HB 2/20	5	2	20	196.1
HB 2/4	1	2	4	39.23
HB 1/30	30	1	30	294.2
HB 1/10	10	1	10	98.07
HB 1/5	5	1	5	49.03
HB 1/1	1	1	1	9.807

Section three. Direct verification of accuracy of the testing machine

10 Principle

Direct verification of the accuracy of a Brinell hardness testing machine involves verification of the accuracy of the applied forces, the physical characteristics of the indenter balls and the accuracy of the indentation measurement apparatus.

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 The steady forces applied by the machine (see table 2) shall be verified in accordance with BS 1610 : Part 1 by means of either:

- (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 Regardless of the position of the indenter carrier within its working range each steady force shall be correct within $\pm 0.5\%$ of its nominal value. For each force, readings shall be taken at three or more positions of the carrier and each reading of the measured force shall be within 0.5% of the nominal force.

11.3 The force shall be applied 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.

11.4 If the machine is designed to provide an automatic time cycle, it shall be verified that the time for which full force is maintained is 10 s to 15 s. If, as may be required for tests on some materials, a machine provides a time cycle that maintains the full force for a duration other than 10 s to 15 s, this duration shall be verified and shall be within a tolerance of ± 2 s.

12 Indenter

12.1 General

For the purpose of verifying the size and hardness of balls that are to be used in the indenter at least three balls shall be selected at random from a batch. It shall be verified that the size, hardness, finish and chemical composition (for tungsten carbide only) of the balls shall comply with 12.2 to 12.5.

12.2 Dimensions

The balls shall comply with the following requirements:

- (a) the average diameter of a ball shall not differ from the nominal value by more than the relevant tolerance given in table 3;
- (b) the error in sphericity of a ball, which is defined as the greatest radial distance between any point on the ball surface and the circumscribing sphere, shall not exceed the tolerance for the appropriate size of ball given in table 3.

Table 3. Dimensions of indenter balls for testing machines

Ball diameter	Maximum error from nominal diameter	Maximum error in sphericity
mm	mm	mm
10	± 0.020	0.004
5	± 0.010	0.002
2.5	± 0.005	0.001
2	± 0.004	0.0008
1	± 0.002	0.0004

12.3 Surface finish

The ball shall be free from surface defects and the surface roughness, R_a , shall not exceed $0.05\text{ }\mu\text{m}$.

12.4 Hardness

A Vickers hardness test in accordance with BS 427 : Part 1 shall be made on the curved surface of the ball using the load for the HV10 scale. The balls shall comply with the following requirements:

- (a) for steel balls the hardness shall be not less than 800 HV10;
- (b) for tungsten carbide balls the hardness shall be not less than 1500 HV10.

Either the appropriate correction for curvature in accordance with BS 427 : Part 1 shall be made to the measured hardness value or, alternatively, the mean measured diagonal of the indentation shall be compared with the appropriate maximum value given in table 4.

Table 4. Hardness of indenter balls

Ball diameter	Maximum value of indentation diagonal in curved surface of ball	
	Steel ball	Tungsten carbide ball
mm	mm	mm
10	0.151	0.111
5	0.150	0.110
2.5	0.148	0.109
2	0.147	0.108
1	0.143	0.106

12.5 Chemical composition

The composition of the tungsten carbide ball shall be as follows.

Tungsten carbide (WC):	balance
Total other carbides:	2 % max.
Cobalt (Co):	5 % to 7 %

13 Measuring apparatus

13.1 General

The requirements of 13.2 or 13.3 shall apply depending upon the measuring system used.

13.2 Indentation diameter measurement

The measuring microscope or other measuring device shall be verified by measurements with a calibrated length standard (e.g. a stage micrometer) at a minimum of five intervals over each of the applicable working ranges given in table 5.

The maximum error shall not exceed 0.5 % of any interval in the working range.

13.3 Indentation area measurement

An area measuring device shall be verified by measurements made on calibrated circular areas complying with the diametral range of requirements given in 13.2.

The maximum error shall not exceed 1 % of the calibrated area in any interval of the working range.

NOTE. This maximum error of 1 % of area is equivalent to 0.5 % of the diameter (see 13.2).

14 Performance test

When tested in accordance with the indirect verification procedure in clause 19, the testing machine shall be accurate to the limits specified in clause 20.

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 20.2(b).

Table 5. Maximum permissible error of measuring system			
Ball diameter	Working range of indentation sizes	Maximum permissible error at	
		Minimum interval	Maximum interval
mm	mm	mm	mm
10	2.5 to 6	0.0125	0.03
5	1.25 to 3	0.0062	0.015
2.5	0.625 to 1.5	0.0031	0.0075
2	0.5 to 1.2	0.0025	0.006
1	0.25 to 0.6	0.0012	0.003

Section four. Indirect verification of accuracy of the testing machine

15 Principle

Indirect verification of the accuracy of a Brinell hardness testing machine requires the use of hardness test blocks which have been calibrated on a standardizing machine. The verification procedure then involves checking that the testing machine measures with sufficient accuracy the known hardness of the calibrated blocks.

Calibrated test blocks may be obtained from appropriate manufacturers. They shall be manufactured and calibrated in accordance with clauses 16 and 17 and their hardness shall be documented in accordance with 17.8.

16 Manufacture of hardness test blocks

16.1 Each metal block to be standardized shall be manufactured to give homogeneity and stability of structure. The block, if of steel, shall be demagnetized.

16.2 The minimum thickness of the block, the flatness and surface roughness of the test surface and the underside, and the maximum variation in thickness shall be as given in table 6.

16.3 The finish of the test surface shall provide a suitable reflectivity and be free from scratches which would interfere with measurements of the indentations.

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

17 Calibration of hardness test blocks

17.1 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 Brinell scale, i.e. with one load and with one diameter of ball.

The calibration of the block shall be carried out using a standardizing machine complying with clause 18.

The hardness value assigned to a block shall, where appropriate, be traceable to the national standard hardness scale (or where this is not available to the scale defined by a standardizing machine) either directly or indirectly through a hierarchical chain such as that provided by the British Calibration Service.

NOTE. National Standard Brinell scales (HB 10/3000 and HB 5/750) are defined by a standardizing machine maintained at the National Physical Laboratory, Teddington.

17.2 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 ($3d$).

The distance between the centres of two adjacent indentations shall be at least four times the mean diameter of the indentation ($4d$).

NOTE. In order to facilitate the implementation of these restrictions, when the blocks are used for the indirect verification of testing machines, it is recommended that guidance should be given as to the maximum number of indentations that can be made on a given size of test block. This guidance may conveniently take the form of an etched grid of lines on the test surface of the block. Such a grid can also be used for identification of particular indentations.

17.3 Calibration procedure

Carry out the test in accordance with clause 8 under the following conditions.

(a) *Application of load.* The load shall be applied gradually and the full force shall be maintained for 10 s to 15 s.

(b) *Measurement of indentation.* Each indentation shall be measured independently by at least two observers and the hardness value assigned to the block shall be the mean of the hardness values so obtained.

17.4 Uniformity of hardness

Not less than five indentations distributed over the test surface shall be made on the block.

Table 6. Dimensions of hardness test blocks					
Diameter of ball	Minimum thickness	Maximum variation in flatness	Maximum variation in thickness	Maximum surface roughness R_a	
				Test surface	Bottom surface
mm	mm	mm	mm/50 mm	μm	μm
10	16	0.05	0.05	0.3	0.8
5	12	0.025	0.025	0.2	0.8
<2.5	6	0.01	0.015	0.1	0.4

The block shall be regarded as sufficiently uniform for standardization purposes if the range of hardness values obtained from the indentations does not exceed 2 % of the mean hardness value for hardness values > 125 or 3 % for hardness values < 125 .

17.5 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 unit for values of 200 HB and over and to the nearest half unit for lower hardness values.

17.6 Reference indentation

One of the five indentations shall be selected as a reference indentation for the indirect verification of the measuring apparatus. It shall be identified with a permanent mark in line with one of the measured diameters.

17.7 Marking

Each block shall be marked by the manufacturer with his name or mark, a serial number, and the mean hardness value. If the marking is on the side of the block, it shall be upright when the test surface is uppermost.

NOTE. It is preferable for the marking to be on the side of the block or, alternatively, it may be on the test surface.

17.8 Documentation

The standardizing authority shall issue a document stating:

- (a) a reference to this British Standard for traceability purposes;
- (b) the serial number of the block;
- (c) the hardness value assigned to the block and the hardness scale used, e.g. 255 HBS (HBW) 10/3000;
- (d) the maximum and minimum hardness values obtained in the calibration;
- (e) the mean diameter of the reference indentation and its identification;
- (f) the manufacturer's name and date of calibration.

18 Standardizing machine

18.1 Direct verification

The standardizing machines used for calibrating the blocks (comprising the indenting machine, the indenter and the measuring microscope) shall satisfy the following requirements.

- (a) *Force*. Regardless of the position of the indenter carrier within its working range, each steady force shall be correct within ± 0.1 % of its nominal value.
- (b) *Indenter*. The indenter balls shall comply with clause 12, except that the dimensional tolerances given in table 7 shall apply.

Table 7. Dimensions of indenter balls for standardizing machines

Ball diameter	Maximum error from nominal diameter	Maximum error in sphericity
mm	mm	mm
10	± 0.010	0.002
5	± 0.005	0.001
2.5	± 0.0025	0.0005
2	± 0.002	0.0004
1	± 0.001	0.0004

(c) *Measuring microscope*. The measuring microscope shall be calibrated so as to ensure that any interval within the working range can be measured correctly in accordance with the following requirements:

- maximum error ± 0.002 mm within the range 1 mm to 6 mm;
- maximum error ± 0.001 mm within the range 0.25 mm to 1 mm.

18.2 Indirect verification of measuring microscope

The performance of the measuring microscope shall be verified by measurements of appropriately sized sets of five standardized indentations, previously calibrated by the National Physical Laboratory (NPL).

For each observer (see 17.3(b)), the average diameter obtained from measurements of a set of five indentations shall be within 0.5 % of the assigned mean diameter value.

18.3 Monitoring of standardizing machine

The accuracy and stability of the Brinell hardness scales defined by standardizing machines shall be monitored in accordance with the following.

- (a) A minimum of two scales shall be monitored except when the use of the machine is restricted to the calibration of hardness test blocks in a single Brinell scale.
- (b) A set of at least three test blocks covering the range of the first scale and two test blocks covering the range of the second scale, which comply with the uniformity of hardness requirement given in 17.4, shall be provided.
- (c) Periodic monitoring values shall be obtained from the mean of three indentations on each block and the periodic monitoring tests shall be made at regular intervals of not more than 3 months.
- (d) An assessment of the performance of the machine shall be made from the recorded monitoring values over a period of time and shall show that a monitoring value is reproducible within ± 1 % HB of the average of the monitoring values obtained for the block.
- (e) When the HB 10/3000 and HB 5/750 scales are monitored, 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 $\pm 1.5\%$ HB of the mean standard hardness value for the block.

NOTE. Where no national standard Brinell scale is maintained, the performance of standardizing machines should be co-ordinated by means of inter-comparisons of standardizing machines using hardness test blocks.

19 Indirect verification procedure

19.1 Before carrying out the procedure, ascertain in a preliminary inspection that the machine is correctly set up on a rigid support free from vibration, and that the indenter is securely fixed to the carrier.

19.2 Adjust the illuminating system of the measuring microscope or other measuring device to give uniform intensity over the field of view and maximum contrast between the indentation and the undisturbed surface of the block.

NOTE. Portable measuring microscopes with adjustments that alter the magnification ratio should be adjusted when necessary in conjunction with a stage micrometer. The microscope should also be adjusted to minimize parallax error.

19.3 Carry out the indirect verification of the testing machine including the measuring apparatus in accordance with section two using hardness blocks calibrated in accordance with clause 17.

Make the preliminary verification of the measuring device by measurements of the reference indentation in each of the test blocks in accordance with 19.4. For direct diametrical measurements, ensure that one of the two measured diameters of the indentations is in line with the permanent mark, which indicates the location of the reference indentation.

19.4 Verify the testing machine using any of the hardness scales given in table 8 in accordance with the following.

For each hardness scale, when $f/D^2 = 30$, hardness test blocks are to be selected for at least two of the hardness ranges given in table 8 and when $f/D^2 = 10$, one hardness test block is to be used.

On each hardness block, make no less than five indentations in accordance with clause 8 spaced over the surface of the test block in accordance with 17.2, then measure each indentation.

19.5 For multi-scale machines, a minimum of two hardness scales shall be verified and at least four hardness test blocks of different scales or ranges shall be used.

Table 8. Test block hardness for verifiable hardness scales

Hardness range	f/D^2	Verifiable hardness scales
100 to 200 HB	10	HB 10/1000, HB 5/250, HB 2/40, HB 1/10
100 to 200 HB 250 to 350 HB 500 to 600 HBW	30 30 30	HB 10/3000, HB 5/750, HB 2.5/187.5, HB 2/120, HB 1/30

NOTE. The maximum hardness values corresponding to an f/D^2 of 5 and 1 are 100 HB and 20 HB respectively. Traceable hardness test blocks are not available and so the corresponding hardness scales are not verifiable.

19.6 Verification is carried out using the same type of indenter ball (steel or tungsten carbide) as will be used for testing, which will be valid for:

- (a) hardness < 450 HBS when a steel ball is used;
- (b) hardness < 600 HBW when a tungsten carbide ball is used.

20 Assessment of accuracy of measuring apparatus and testing machine

20.1 Accuracy of measuring apparatus

The accuracy of the measuring apparatus shall be deemed satisfactory if the mean measured diameter of each reference indentation is within $\pm 1\%$ of the assigned diameter.

20.2 Accuracy of the testing machine

The accuracy of the machine shall be deemed satisfactory if the hardness values obtained in each test of five indentations meet the following requirements for repeatability and error.

- (a) *Repeatability.* The range of the five hardness values, i.e. the difference between the largest and the smallest value, shall not exceed 4 % for hardness > 125 HB or 5 % for hardness < 125 HB, of the assigned hardness value of the test block.
- (b) *Error.* The mean hardness value determined for the five indentations shall be within $\pm 2\%$ of the assigned hardness value of the test block.

Appendices

Appendix A. Monitoring the accuracy of the test machine

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

A.2 Monitoring the accuracy of the testing machine should be carried out in accordance with clause 8 and 17.2 using hardness test blocks calibrated under the conditions specified in clause 17.

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 the requirements in clause 17 using a testing machine monitored in accordance with 17.1 and 18.3.

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

A.4 Before making a hardness test the measuring apparatus should be indirectly verified in accordance with 19.2 and 20.1. If the error in 20.1 is greater than 1 % a correction factor should be applied. This correction may vary with individual observers.

A.5 A test block should be provided of a similar hardness and calibrated in the same Brinell scale as that being used by the testing machine. On each monitoring occasion a single hardness test should be made on the block. When necessary a second test should be made and the results of both tests should be recorded. Tests should be repeated at regular intervals, e.g. on each day that the machine is to be in continuous use.

NOTE. For multi-scale machines the procedure should be repeated with a second test block having a different Brinell hardness while the intervals between tests should be extended.

A.6 An assessment of the accuracy of the machine should be made from the recorded monitoring values over a period of time and the machine should be deemed satisfactory if the hardness value is reproducible within ± 3 % HB of the assigned value for the block.

Appendix B. Advisory comment upon Brinell hardness testing procedure

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

The performance of the testing machine and measuring apparatus should be frequently checked by means of calibrated hardness test blocks. (See appendix A.)

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

B.3 The surface of the indenter ball and of the test piece need to be completely free from any trace of lubricants.

B.4 Although the same value of f/D^2 will in principle give the same hardness values for different loads (see clause 7), there will in general be discrepancies between hardness values obtained with different f/D^2 ratios. Hardness values should therefore be quoted in conjunction with the appropriate Brinell scale used for the test, e.g. 226 HBS 10/3000.

B.5 For some materials the requirement that the thickness of the test piece shall not be less than eight times the depth of the 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 from thicker test pieces. Test parameters should therefore be chosen where possible to avoid such difficulties.

B.6 As there is no general procedure for accurately converting Brinell 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 beforehand by direct test on the material concerned (see BS 860).

Appendix C. Minimum thickness of test piece

For convenience when carrying out tests in accordance with this standard, tables 9(a) to 9(d), which are based on the requirements of 6.3, give the minimum thickness of test pieces for selected hardness scales (i.e. ball diameter and force) and hardness values.

Table 9. Minimum thickness of test piece for f/D^2 of 30, 10, 5 and 1											
(a) $f/D^2 = 1$						(c) $f/D^2 = 10$					
Hardness scale	Brinell hardness value					Hardness scale	Brinell hardness value				
	3 HB	5 HB	10 HB	15 HB	20 HB		30 HB	75 HB	120 HB	160 HB	200 HB
	Minimum thickness						Minimum thickness				
	mm	mm	mm	mm	mm		mm	mm	mm	mm	mm
HB 10/100	8.49	5.09	2.55	1.70	1.27	HB 10/1000	8.49	3.40	2.12	1.59	1.27
HB 5/25	4.24	2.55	1.27	0.85	0.64	HB 5/250	4.24	1.70	1.06	0.80	0.64
HB 2.5/6.25	2.12	1.27	0.64	0.42	0.32	HB 2.5/62.5	2.12	0.85	0.53	0.40	0.32
HB 2/4	1.69	1.02	0.51	0.34	0.25	HB 2/40	1.70	0.68	0.42	0.32	0.25
HB 1/1	0.85	0.51	0.25	0.17	—	HB 1/10	0.85	0.34	0.21	0.16	—
(b) $f/D^2 = 5$						(d) $f/D^2 = 30$					
Hardness scale	Brinell hardness value					Hardness scale	Brinell hardness value				
	15 HB	30 HB	50 HB	75 HB	100 HB		100 HB	200 HB	300 HB	400 HB	500 HB
	Minimum thicknesses						Minimum thickness				
	mm	mm	mm	mm	mm		mm	mm	mm	mm	mm
HB 10/500	8.49	4.24	2.55	1.70	1.27	HB 10/3000	7.64	3.82	2.55	1.91	1.70
HB 5/125	4.24	2.12	1.27	0.85	0.64	HB 5/750	3.82	1.91	1.27	0.95	0.85
HB 2.5/31.25	2.12	1.06	0.64	0.42	0.32	HB 2.5/187.5	1.91	0.95	0.64	0.48	0.42
HB 2/20	1.70	0.85	0.51	0.34	0.25	HB 2/120	1.53	0.76	0.51	0.38	0.34
HB 1/5	0.85	0.42	0.25	0.17	—	HB 1/30	0.74	0.38	0.25	0.19	—