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and Transportation Officials Standard
AASHTO No.: T70–86

Standard Test Method for Brinell Hardness of Metallic Materials[1]

This standard is issued under the fixed designation E 10; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This test method covers the determination of the Brinell hardness of metallic materials by the Brinell indentation hardness principle. This standard provides the requirements for a Brinell testing machine and the procedures for performing Brinell hardness tests.

1.2 This standard includes additional requirements in four annexes:

Verification of Brinell Hardness Testing Machines	Annex A1
Brinell Hardness Standardizing Machines	Annex A2
Standardization of Brinell Hardness Indenters	Annex A3
Standardization of Brinell Hardness Test Blocks	Annex A4

1.3 This standard includes nonmandatory information in an appendix which relates to the Brinell hardness test:

Table of Brinell Hardness Numbers	Appendix X1
Examples of Procedures for Determining Brinell Hardness Uncertainty	Appendix X2

1.4 At the time the Brinell hardness test was developed, the force levels were specified in units of kilograms-force (kgf). Although this standard specifies the unit of force in the International System of Units (SI) as the Newton (N), because of the historical precedent and continued common usage of kgf units, force values in kgf units are provided for information and much of the discussion in this standard refers to forces in kgf units.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E 74 Practice of Calibration of Force-Measuring Instruments for Verifying the Force Indication of Testing Machines

E 140 Hardness Conversion Tables for Metals Relationship Among Brinell Hardness, Vickers Hardness, Rockwell Hardness, Superficial Hardness, Knoop Hardness, and Scleroscope Hardness

E 384 Test Method for Microindentation Hardness of Materials

2.2 *American Bearings Manufacturer Association Standard:*

ABMA 10-1989 Metal Balls[3]

2.3 *ISO Standards:*

ISO/IEC 17011 Conformity Assessment—General Requirements for Accreditation Bodies Accrediting Conformity Assessment Bodies[4]

ISO/IEC 17025 General Requirements for the Competence of Calibration and Testing[4]

3. Terminology and Equations

3.1 *Definitions:*

3.1.1 *calibration*—determination of the values of the significant parameters by comparison with values indicated by a reference instrument or by a set of reference standards.

3.1.2 *verification*—checking or testing to assure conformance with the specification.

3.1.3 *standardization*—to bring in conformance with a known standard through verification or calibration.

3.1.4 *Brinell hardness test*—an indentation hardness test using a verified machine to force an indenter (tungsten carbide ball with diameter *D*), under specified conditions, into the surface of the material under test. The diameter of the resulting indentation *d* is measured after removal of the force.

3.1.5 *Brinell hardness number*—a number, which is proportional to the quotient obtained by dividing the test force by the curved surface area of the indentation which is assumed to be spherical and of the diameter of the ball.

[1] This test method is under the jurisdiction of ASTM Committee E28 on Mechanical Testing and is the direct responsibility of Subcommittee E28.06 on Indentation Hardness Testing.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Bearing Manufacturers Association (ABMA), 2025 M Street, NW, Suite 800, Washington, DC 20036.

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

3.1.6 *Brinell hardness scale*—a designation that identifies the specific combination of ball diameter and applied force used to perform the Brinell hardness test.

3.1.7 *Brinell hardness testing machine*—a Brinell hardness machine used for general testing purposes.

3.1.8 *Brinell hardness standardizing machine*—a Brinell hardness machine used for the standardization of Brinell hardness test blocks. The standardizing machine differs from a regular Brinell hardness testing machine by having tighter tolerances on certain parameters.

3.1.9 *force-diameter ratio*—a number calculated as the ratio of the test force in kgf to the square of the indenter ball diameter in mm (see Table 1).

3.2 *Equations*:

3.2.1 The *Brinell hardness number* is calculated as:

$$HBW = \frac{2F_{kgf}}{\pi D(D - \sqrt{D^2 - d^2})} \quad (1)$$

where:

F_{kgf} = test force in kgf,
D = diameter of the indenter ball in mm, and
d = measured mean diameter of the indentation in mm (see Table 1).

3.2.2 The *repeatability* R in the performance of a Brinell hardness machine at each hardness level, under the particular verification conditions, is estimated by the range of diameter measurements of n indentations made on a standardized test block as part of a performance verification, defined as:

$$R = d_{max} - d_{min} \quad (2)$$

where:

d_{max} = mean diameter of the largest measured indentation, and
d_{min} = mean diameter of the smallest measured indentation.

3.2.3 The *average* $\bar{H}$ of a set of n Brinell hardness measurement values H_1, H_2, ..., H_n is calculated as:

$$\bar{H} = \frac{H_1 + H_2 + ... + H_n}{n} \quad (3)$$

3.2.4 The *error* E in the performance of a Brinell hardness machine at each hardness level is determined as:

$$E = \bar{H} - H_{STD} \quad (4)$$

where:

$\bar{H}$ (Eq 3) = average of n hardness tests H_1, H_2, ..., H_n made on a standardized test block as part of a performance verification, and
H_{STD} = certified average hardness value of the standardized test block.

3.2.5 The *mean diameter of an indentation d* is calculated as:

$$d = \frac{d_1 + d_2 + ... + d_n}{n} \quad (5)$$

Where:

$d_1, d_2, ..., d_n$ = measured indentation diameters in mm, and
n = the number of diameter measurements.

3.2.6 The average mean diameter $\bar{d}$ of a set of indentations is calculated as:

$$\bar{d} = \frac{d1 + d2 + ... + dN}{N} \quad (6)$$

where:

$d1, d2, ... dN$ = mean indentation diameters in mm, and
N = number of indentations (see Annex A4).

TABLE 1 Symbols and Designations

Symbol	Designation
D	Diameter of the ball, mm
F	Test force, N
F_{kgf}	Test force, kgf $F_{kgf} = \frac{1}{g_n} \times F$ where g_n is the acceleration due to gravity. g_n = 9.80665 kgf/N
d	Mean diameter of the indentation, mm $d = \frac{d_1 + d_2 + ... + d_n}{n}$ where $d_1 + d_2 + ... + d_n$ are the measured indentation diameters in mm, and n is the number of diameter measurements.
h	Depth of the indentation, mm $h = \frac{D - \sqrt{D^2 - d^2}}{2}$
Force-Diameter ratio	$= \frac{F_{kgf}}{D^2}$
HBW	Brinell hardness $= \frac{Test\ Force}{Surface\ area\ of\ indentation}$ $= \frac{2F_{kgf}}{\pi D(D - \sqrt{D^2 - d^2})}$

4. Significance and Use

4.1 The Brinell hardness test is an indentation hardness test that can provide useful information about metallic materials. This information may correlate to tensile strength, wear resistance, ductility, or other physical characteristics of metallic materials, and may be useful in quality control and selection of materials.

4.2 Brinell hardness tests are considered satisfactory for acceptance testing of commercial shipments, and have been used extensively in industry for this purpose.

4.3 Brinell hardness testing at a specific location on a part may not represent the physical characteristics of the whole part or end product.

5. Principles of Test and Apparatus

5.1 *Brinell Hardness Test Principle*—The general principle of the Brinell indentation hardness test consists of two steps (see Fig. 1).

5.1.1 *Step 1*—The indenter is brought into contact with the test specimen in a direction perpendicular to the surface, and the test force F is applied. The test force is held for a specified dwell time and then removed.

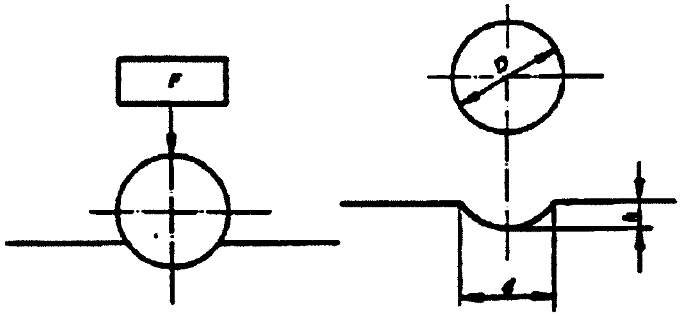

FIG. 1 Principle of Test

5.1.2 *Step 2*—The diameter of the indentation is measured in at least two directions perpendicular to each other. The Brinell hardness value is derived from the mean of the diameter measurements.

5.2 *Brinell Testing Machine*—Equipment for Brinell hardness testing usually consists of a testing machine, which supports the test specimen and applies an indenting force to a ball in contact with the specimen, and a system for measuring the mean diameter of the indentation in accordance with the Brinell hardness test principle. The design of the testing machine shall be such that no rocking or lateral movement of the indenter or specimen occurs while the force is being applied. The design of the testing machine shall ensure that the force to the indenter is applied smoothly and without impact forces. Precautions shall be taken to prevent a momentary high test force caused by the inertia of the system, hydraulic system overshoot, etc.

5.2.1 See the Equipment Manufacturer's Instruction Manual for a description of the machine's characteristics, limitations, and respective operating procedures.

5.2.2 *Anvils*—An anvil, or specimen support, should be used that is suitable for the specimen to be tested. The seating and supporting surfaces of all anvils should be clean and free of foreign material. Typically, anvils need only be replaced if they fail to support the test surface perpendicular to the indenter, or they are deemed unsafe.

5.2.3 *Indenters*—Indenters for the Brinell hardness test shall be tungsten carbide balls of four allowed diameters (1, 2.5, 5 and 10 mm). Indenters shall meet the requirements defined in Annex A3.

5.2.4 Oil, dirt, or other foreign materials shall not be allowed to accumulate on the indenter, as this will affect the test results.

5.2.5 *Measurement Device*—The measurement device used for the measurement of the diameter of Brinell indentations may be an integral part of the hardness machine or a separate stand-alone instrument. The allowable measurement devices are classified into two types. The Type A device includes microscopes having movable measuring lines with some type of indicator or computerized measuring system, or an image analysis system. The Type B device is a hand-held microscope (usually 20× or 40×) with fixed measuring lines.

5.2.5.1 *Type A Device*—The acceptable minimum resolution for a Type A device shall be as given in Table 2.

5.2.5.2 *Type B Device*—The acceptable maximum spacing between the graduated lines of Type B devices shall be as given in Table 2. Type B devices shall not be used for measuring indentations made with 2.5 mm and 1 mm ball indenters.

TABLE 2 Resolution and Graduation Spacing of Indentation Measuring Devices

Ball Diameter mm	Type A: Minimum Indicator Resolution mm	Type B: Maximum Graduation Spacing mm
10	0.0100	0.100
5	0.0050	0.050
2.5	0.0025	–
1	0.0010	–

5.3 *Verification*—Brinell testing machines and indentation measurement devices shall be verified periodically in accordance with Annex A1.

5.4 *Test Blocks*—Test blocks meeting the requirements of Annex A4 shall be used to verify the testing machine in accordance with Annex A1.

5.5 *Brinell Hardness Scales*—The combinations of indenters and test forces define the Brinell hardness scales. The standard Brinell hardness scales and test forces are given in Table 3, corresponding to force-diameter ratios (see Table 1) of 1, 1.25, 2.5, 5, 10 and 30. Brinell hardness values should be determined and reported in accordance with one of these standard scales. Other scales using non-standard test forces may be used by special agreement. Examples of other scales and the corresponding force-diameter ratio (in parentheses) are HBW 10/750 (7.5), HBW 10/2000 (20), HBW 10/2500 (25), HBW 5/187.5 (7.5), and HBW 5/500 (20).

5.6 *Calculation of the Brinell Hardness Number*—The Brinell hardness number shall be calculated from the mean

TABLE 3 Test Conditions and Recommended Hardness Range

Brinell Hardness Scale	Ball Diameter *D* mm	Force-Diameter Ratio[A]	Nominal Value of Test Force, F: N	Nominal Value of Test Force, F: kgf	Recommended Hardness Range HBW
HBW 10/3000	10	30	29420	3000	95.5 to 650
HBW 10/1500	10	15	14710	1500	47.7 to 327
HBW 10/1000	10	10	9807	1000	31.8 to 218
HBW 10/500	10	5	4903	500	15.9 to 109
HBW 10/250	10	2.5	2452	250	7.96 to 54.5
HBW 10/125	10	1.25	1226	125	3.98 to 27.2
HBW 10/100	10	1	980.7	100	3.18 to 21.8
HBW 5/750	5	30	7355	750	95.5 to 650
HBW 5/250	5	10	2452	250	31.8 to 218
HBW 5/125	5	5	1226	125	15.9 to 109
HBW 5/62.5	5	2.5	612.9	62.5	7.96 to 54.5
HBW 5/31.25	5	1.25	306.5	31.25	3.98 to 27.2
HBW 5/25	5	1	245.2	25	3.18 to 21.8
HBW 2.5/187.5	2.5	30	1839	187.5	95.5 to 650
HBW 2.5/62.5	2.5	10	612.9	62.5	31.8 to 218
HBW 2.5/31.25	2.5	5	306.5	31.25	15.9 to 109
HBW 2.5/15.625	2.5	2.5	153.2	15.625	7.96 to 54.5
HBW 2.5/7.8125	2.5	1.25	76.61	7.8125	3.98 to 27.2
HBW 2.5/6.25	2.5	1	61.29	6.25	3.18 to 21.8
HBW 1/30	1	30	294.2	30	95.5 to 650
HBW 1/10	1	10	98.07	10	31.8 to 218
HBW 1/5	1	5	49.03	5	15.9 to 109
HBW 1/2.5	1	2.5	24.52	2.5	7.96 to 54.5
HBW 1/1.25	1	1.25	12.26	1.25	3.98 to 27.2
HBW 1/1	1	1	9.807	1	3.18 to 21.8

[A] See Table 1.

diameter *d* of the indentation using Eq 1 or from the values given in Appendix X1.

5.6.1 Brinell hardness values shall not be designated by a number alone because it is necessary to indicate which indenter and which force has been employed in making the test (see Table 3). Brinell hardness numbers shall be followed by the symbol HBW, and be supplemented by an index indicating the test conditions in the following order:

5.6.1.1 Diameter of the ball, mm,

5.6.1.2 A value representing the test force, kgf, (see Table 3) and,

5.6.1.3 The applied force dwell time, s, if other than 10 s to 15 s.

5.6.2 The only exception to the above requirement is for the HBW 10/3000 scale when a 10 s to 15 s dwell time is used. Only in the case of this one Brinell hardness scale may the designation be reported simply as HBW.

5.6.3 *Examples*:

220 HBW = Brinell hardness of 220 determined with a ball of 10 mm diameter and with a test force of 29.42 kN (3000 kgf) applied for 10 s to 15 s

350 HBW 5/750 = Brinell hardness of 350 determined with a ball of 5 mm diameter and with a test force of 7.355 kN (750 kgf) applied for 10 s to 15 s

600 HBW 1/30/20 = Brinell hardness of 600 determined with a ball of 1 mm diameter and with a test force of 294.2 N (30 kgf) applied for 20 s

6. Test Piece

6.1 There is no standard shape or size for a Brinell test specimen. The test piece on which the indentation is made should conform to the following:

6.1.1 *Thickness*—The thickness of the specimen tested shall be such that no bulge or other marking showing the effect of the test force appears on the side of the piece opposite the indentation. The thickness of the material under test should be at least ten times the depth of the indentation *h* (see Table 4). Table 4 can also be used as a guideline for the minimum depth of a layer of a material, such as a coating.

TABLE 4 Minimum Specimen Thickness Based on Ten-Times the Indentation Depth

Diameter of Indentation, *d*	Minimum Specimen Thickness							
	10 mm Ball		5 mm Ball		2.5 mm Ball		1 mm Ball	
mm	mm	in.	mm	in.	mm	in.	mm	in.
0.2							0.1	0.004
0.3							0.2	0.009
0.4							0.4	0.016
0.5							0.7	0.026
0.6					0.4	0.014	1.0	0.039
0.7					0.5	0.020		
0.8					0.7	0.026		
0.9					0.8	0.033		
1.0					1.0	0.041		
1.1					1.3	0.050		
1.2			0.7	0.029	1.5	0.060		
1.3			0.9	0.034	1.8	0.072		
1.4			1.0	0.039	2.1	0.084		
1.5			1.2	0.045	2.5	0.098		
1.6			1.3	0.052				
1.7			1.5	0.059				
1.8			1.7	0.066				
1.9			1.9	0.074				
2.0			2.1	0.082				
2.2			2.6	0.100				
2.4	1.5	0.058	3.1	0.121				
2.6	1.7	0.068	3.6	0.144				
2.8	2.0	0.079	4.3	0.169				
3.0	2.3	0.091	5.0	0.197				
3.2	2.6	0.104						
3.4	3.0	0.117						
3.6	3.4	0.132						
3.8	3.8	0.148						
4.0	4.2	0.164						
4.2	4.6	0.182						
4.4	5.1	0.201						
4.6	5.6	0.221						
4.8	6.1	0.242						
5.0	6.7	0.264						
5.2	7.3	0.287						
5.4	7.9	0.312						
5.6	8.6	0.338						
5.8	9.3	0.365						

NOTE 1—Brinell hardness testing can use high test forces. Under certain conditions of testing a relatively thin material or coating on a material with high hardness, there is a potential for the test material to break or shatter under load resulting in serious personal injury or damage to equipment. Users are strongly cautioned to exercise extreme care when testing a material that could potentially fail under load. If there is a concern or doubt, do not test the material.

6.1.2 *Width*—The minimum width shall conform to the requirements for indentation spacing.

6.1.3 *Finish*—When necessary, the surface on which the indentation is to be made should be filed, ground, machined or polished flat with abrasive material so that the edge of the indentation can be clearly defined to permit the measurement of the diameter to the specified accuracy. Preparation shall be carried out in such a way that any alteration of the surface hardness of the test surface (for example, due to overheating or cold-working) is minimized.

7. Test Procedure

7.1 The diameter of the indentation shall be between 24 and 60 % of the ball diameter. Approximate Brinell hardness numbers are given in Table 3 for the above range of indentation diameters.

NOTE 2—A lower limit in indentation diameter is necessary because of the risk in damaging the ball and the difficulty in measuring the indentation. The upper limit is necessary because of a reduction in sensitivity as the diameter of the indentation approaches the ball diameter. The thickness and spacing requirements may determine the maximum permissible diameter of indentation for a specific test.

NOTE 3—It is not mandatory that Brinell tests conform to the hardness scales of Table 3. It should be realized that different Brinell hardness numbers may be obtained for a given material by using different forces on the same size of ball. For the purpose of obtaining a continuous scale of values, it may be desirable to use a single force to cover the complete range of hardness for a given class of materials.

7.2 The Brinell hardness test is not recommended for materials above 650 HBW 10/3000.

7.3 Direct comparisons of Brinell hardness numbers for tests using different scales can be made only if the force-diameter ratio is maintained (see Table 3). Brinell hardness tests made on the same test material, but using different force-diameter ratios, will produce different Brinell hardness numbers.

7.3.1 *Example*—An HBW 10/500 test will usually approximate an HBW 5/125 test since the force-diameter ratio is 5 for both scales. However, a value of 160 HBW 10/500 will be approximately equal to 180 HBW 10/3000 on the same test material because of different force-diameter ratios (5 and 30, respectively).

7.4 *Daily Verification*—A daily verification of the testing machine shall be performed in accordance with Annex A1 prior to making hardness tests. It is also recommended that the operation of the machine be checked in accordance with the daily verification method specified in Annex A1 after each change of the test force, anvil or the indenter.

7.5 *Indentation Procedure*—The Brinell hardness test shall be carried out as follows:

7.5.1 Bring the indenter into contact with the test surface in a direction perpendicular to the surface without shock, vibration or overshoot. The angle between the indenter force-line and the surface of the specimen should be perpendicular.

7.5.2 Apply the test force *F* within 1 to 8 s. Faster force application times are permitted if it is demonstrated that test results are not affected.

7.5.3 Maintain the fully applied test force for 10 s to 15 s, with the following exception.

7.5.3.1 In the case of materials exhibiting excessive plastic flow after application of the test force, special considerations may be necessary since the indenter will continue to penetrate into the material. Testing of these materials may require the use of a longer applied force dwell time than stated above, which should be specified in the product specification. When an extended applied force dwell time is used, the dwell time shall be recorded and reported with the test results (see 5.6.1).

7.5.4 At the end of the dwell time, immediately remove the test force without shock or vibration.

7.6 *Measurement of Indentation*:

7.6.1 Measure the diameter of each indentation in two directions, perpendicular (90°) to each other. Additional measurements of the indentation diameter may also be made. The arithmetic mean of the measurements shall be used for the calculation of the Brinell hardness number.

7.6.2 For routine testing, the diameter of the indentation shall be measured to the resolution of the measuring device when using a Type A device, or one-half the graduation spacing when using a Type B device.

7.6.3 For tests on flat surfaces, the difference between the largest and smallest measured diameters for the same indentation shall not exceed 0.1 mm unless it is specified in the product specification, such as for an anisotropic grain structure where the difference can be 0.2 mm.

7.6.4 When indentations are made on a curved surface, the minimum radius of curvature of the surface shall be two and a half times the diameter of the ball. Indentations made on curved surfaces may be slightly elliptical rather than circular in shape. The measurements of the indentation shall be taken as the mean of the major and minor axes.

7.7 *Indentation Spacing*—The distance between the centers of two adjacent indentations shall be at least three times the diameter of the mean indentation.

7.7.1 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 mean indentation.

7.8 Brinell hardness tests should be carried out at an ambient temperature within the limits of 10 to 35°C (50 to 95°F). Users of the Brinell test are cautioned that the temperature of the test material and the temperature of the hardness tester may affect the test results. Consequently, users should ensure that the test temperature does not adversely affect the hardness measurement.

8. Conversion to Other Hardness Scales or Tensile Strength Values

8.1 There is no general method of accurately converting the Brinell hardness numbers on one scale to Brinell hardness numbers on another scale, or to other types of hardness numbers, or to tensile strength values. Such conversions are, at best, approximations and, therefore should be avoided except for special cases where a reliable basis for the approximate conversion has been obtained by comparison tests.

NOTE 4—The Standard Hardness Conversion Tables for Metals, E 140, give approximate conversion values for specific materials such as steel, austenitic stainless steel, nickel and high-nickel alloys, cartridge brass, copper alloys, and alloyed white cast irons.

9. Report

9.1 At a minimum, the test report shall include the following information:

9.1.1 The Brinell hardness value $\overline{H}$ of the test results rounded to three significant digits in accordance with Practice E 29, for example, 125 HBW or 99.2 HBW.

9.1.2 The test conditions, when other than a 3000 kgf (29.42 kN) applied force, a 10 mm ball diameter, and a 10 s to 15 s application of test force are used (see 5.6.1).

9.1.3 A statement that the indentation measuring device was Type A, when such a device is used. When a Type B indentation measuring device is used, no statement is required.

9.1.4 The ambient temperature of the test, if outside the limits of 10 to 35°C (50 to 95°F), unless it has been shown to not affect the measurement result.

10. Precision and Bias

10.1 The precision of this test method is based on an interlaboratory study of Test Method E 10 conducted in 2006. This replaces a previous study which used steel ball indenters. Each of eight laboratories tested the Brinell hardness of metallic materials. Three analyses were performed on a total of seven different materials of varying levels of hardness. Three replicates of each analysis were performed. The results from this study are filed in an ASTM Research Report.[5]

10.2 *Repeatability*—Two test results obtained within one laboratory shall be judged not equivalent if they differ by more than the *r* is the interval value for that material; *r* is the interval representing the critical difference between two test results for the same material, obtained by the same operator using the same equipment on the same day in the same laboratory.

10.3 *Reproducibility*—Two test results should be judged not equivalent if they differ by more than the *R* value for that

[5] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: E28-1023.

material; *R* is the interval representing the difference between two test results for the same material, obtained by different operators using different equipment in different laboratories.

10.4 Any judgment in accordance with statements 10.2 or 10.3 would have an approximate 95 % probability of being correct.

10.5 Results from the interlaboratory study are summarized in Tables 5-7.

10.6 *Bias*—At the time of the study, there was no accepted reference material suitable for determining the bias for this test method, therefore no statement on bias can be made.

TABLE 5 Summary of Statistical Information (500 kg Test Force)

Test Material	$\bar{X}$	$S\bar{X}$	Sr	SR	r_{PB}	R_{PB}
100 HBW Test Block	101.71	2.31	0.91	2.42	2.56	6.78

TABLE 6 Summary of Statistical Information (500 kg Test Force)

Test Material	$\bar{X}$	$S\bar{X}$	Sr	SR	r_{PB}	R_{PB}
170 HBW Test Block	175.42	2.08	0.89	2.21	2.49	6.18
225 HBW Test Block	221.83	4.00	2.20	4.38	6.16	12.28
300 HBW Test Block	284.63	5.48	2.64	5.89	7.39	16.48

TABLE 7 Summary of Statistical Information (500 kg Test Force)

Test Material	$\bar{X}$	$S\bar{X}$	Sr	SR	r_{PB}	R_{PB}
500 HBW Test Block	502.21	11.78	4.74	12.40	13.28	34.71
300 HBW Test Block	291.25	6.72	2.08	6.93	5.83	19.42
200 HBW Test Block	197.71	5.64	4.47	6.72	12.51	18.80

11. Keywords

11.1 Brinell; hardness; mechanical test; metals

ANNEXES

(Mandatory Information)

A1. VERIFICATION OF BRINELL HARDNESS TESTING MACHINES

A1.1 Scope

A1.1.1 Annex A1 specifies three types of procedures for verifying Brinell hardness testing machines: direct verification, indirect verification, and daily verification.

A1.1.2 Direct verification is a process for verifying that critical components of the hardness testing machine are within allowable tolerances by directly measuring the test forces, indentation measuring system, and testing cycle.

A1.1.3 Indirect verification is a process for periodically verifying the performance of the testing machine by means of standardized test blocks and indenters.

A1.1.4 The daily verification is a process for monitoring the performance of the testing machine between indirect verifications by means of standardized test blocks.

A1.2 General Requirements

A1.2.1 The testing machine shall be verified at specific instances and at periodic intervals as specified in Table A1.1, and when circumstances occur that may affect the performance of the testing machine.

A1.2.2 The temperature at the verification site shall be measured with an instrument having an accuracy of at least ±2.0°C or ±3.6°F. It is recommended that the temperature be monitored throughout the verification period, and significant temperature variations be recorded and reported. The temperature at the verification site does not need to be measured for a daily verification.

TABLE A1.1 Verification Schedule for a Brinell Testing Machine

Verification Procedure	Schedule
Direct verification	When a testing machine is new, or when adjustments, modifications or repairs are made that could affect the application of the test forces or the measuring system. When a testing machine fails an indirect verification.
Indirect verification	Recommended every 12 months, or more often if needed. Shall be no longer than every 18 months. When a test machine is installed, [only the procedure for verifying the as-found condition is required, (see A1.4.4). When a test machine is moved, [only the procedure for verifying the as-found condition is required, (see A1.4.4). This does not apply to machines that are designed to be moved or that move prior to each test, when it has been previously demonstrated that such a move will not affect the hardness result. Following a direct verification.
Daily verification	Required each day that hardness tests are made. Recommended whenever the indenter or test force is changed.

A1.2.3 All instruments used to make measurements required by this Annex shall be calibrated traceable to national standards when a system of traceability exists, except as noted otherwise.

A1.2.4 Indirect verification of the testing machine shall be performed at the location where it will be used.

A1.2.5 Direct verification of newly manufactured or rebuilt testing machines may be performed at the place of manufacture, rebuild, repair or the location of use.

NOTE A1.1—It is recommended that the calibration agency that is used to conduct the verifications of Brinell hardness testing machines be accredited to the requirements of ISO 17025 (or an equivalent) by an accrediting body recognized by the International Laboratory Accreditation Cooperation (ILAC) as operating to the requirements of ISO/IEC 17011.

A1.3 Direct Verification

A1.3.1 A direct verification of the testing machine shall be performed at specific instances in accordance with Table A1.1. The test forces, indentation measuring system and testing cycle shall be verified as follows.

NOTE A1.2—Direct verification is a useful tool for determining the sources of error in a Brinell hardness testing machine. It is recommended that testing machines undergo direct verification periodically to make certain that errors in one component of the machine are not being offset by errors in another component.

A1.3.2 *Verification of the Test Forces*—For each Brinell scale that will be used, the corresponding test force shall be measured. The test forces shall be measured by means of a Class A elastic force measuring instrument having an accuracy of at least 0.25 %, as described in Practice E 74.

A1.3.2.1 Make three measurements of each force. The forces shall be measured as they are applied during testing; however, longer dwell times are allowed when necessary to enable the measuring device to obtain accurate measurements.

A1.3.2.2 Each test force F shall be accurate to within ±1 % of the nominal test force as defined in Table 3.

A1.3.3 *Verification of the Indentation Measuring System*—The measuring device used to determine the diameter of the indentation shall be verified at five intervals over the working range by comparison with an accurate scale such as a stage micrometer. The accuracy of the stage micrometer used to verify both Type A and Type B devices shall be at least 0.005 mm for 5 mm and 10 mm ball tests and at least 0.001 mm for 2.5 mm and 1 mm ball tests.

A1.3.3.1 For Type A devices, the error between the stage micrometer and the measuring device over each interval shall not exceed the Type A minimum indicator resolution shown in Table 2 for the size of ball to be used.

A1.3.3.2 For Type B devices, it is not possible to determine a quantitative error value. Position the measuring device such that the lines of the measuring device line-up with the lines of the stage micrometer as closely as possible. If any lines of the measuring device do not, at least partially, overlap the corresponding lines of the stage micrometer, then the measuring device shall be adjusted.

A1.3.4 *Verification of the Testing Cycle*—The testing machine shall be verified to be capable of meeting the testing cycle tolerances specified in 7.5. Direct verification of the testing cycle is to be verified by the testing machine manufacturer at the time of manufacture, or when the testing machine is returned to the manufacturer for repair, or when a problem with the testing cycle is suspected. Verification of the testing cycle is recommended but not required as part of the direct verification at other times.

A1.3.5 *Direct Verification Failure*—If any of the direct verifications fail the specified requirements, the testing machine shall not be used until it is adjusted or repaired. If the test forces, indentation measuring system or testing cycle may have been affected by an adjustment or repair, the affected components shall be verified again by a direct verification.

A1.4 Indirect Verification

A1.4.1 An indirect verification of the testing machine shall be performed in accordance with the schedule given in Table A1.1 Indirect verifications may be required more frequently than stated in Table A1.1 and should be based on the usage of the testing machine.

A1.4.2 The testing machine shall be verified for each test force and for each ball diameter that will be used prior to the next indirect verification. Hardness tests made using Brinell scales that have not been verified within the schedule given in Table A1.1 do not meet this standard.

A1.4.3 Standardized test blocks used for the indirect verification shall meet the requirements of Annex A4. When two test blocks are to be tested for the same Brinell scale, a low hardness block and a high hardness block shall be chosen having a minimum difference in hardness as given in Table A1.2.

NOTE A1.3—It is recognized that appropriate standardized test blocks are not available for all geometric shapes, materials, or hardness ranges.

TABLE A1.2 Minimum Difference Between Hardness Blocks Used for Indirect Verification

Hardness Scale	Force-Diameter Ratio	Minimum Difference Between Hardness Blocks
HBW 10/3000	30	100 HBW
HBW 5/750		
HBW 2.5/187.5		
HBW 1/30		
HBW 10/1500	15	60 HBW
HBW 10/1000	10	40 HBW
HBW 5/250		
HBW 2.5/62.5		
HBW 1/10		
HBW 10/500	5	20 HBW
HBW 5/125		
HBW 2.5/31.25		
HBW 1/5		
HBW 10/250	2.5	10 HBW
HBW 5/62.5		
HBW 2.5/15.625		
HBW 1/2		
HBW 10/125	1.25	5 HBW
HBW 5/31.25		
HBW 2.5/7.8125		
HBW 1/1.25		
HBW 10/100	1	4 HBW
HBW 5/25		
HBW 2.5/6.25		
HBW 1/1		

A1.4.4 *As-found Condition*—It is recommended that the as-found condition of the testing machine be assessed as part of an indirect verification. This is important for documenting the historical performance of the machine. This procedure should be conducted by the verification agency prior to any cleaning, maintenance, adjustments, or repairs.

A1.4.4.1 When the as-found condition of the testing machine is assessed, the assessment shall be made using the user's indenter ball that is normally used with the testing machine.

A1.4.4.2 One or more standardized test blocks in the range of normal testing should be tested for each Brinell scale that will undergo indirect verification.

A1.4.4.3 On each standardized test block, make at least two Brinell hardness tests distributed uniformly over the test surface. Determine the repeatability R and the error E (Eq 2 and Eq 4) in the performance of the testing machine for each standardized test block that is measured.

A1.4.4.4 The repeatability R and the error E should be within the tolerances of Table A1.3. If the calculated values of the repeatability R or the error E fall outside the specified tolerances, this is an indication that the hardness tests made since the last indirect verification may be suspect.

A1.4.5 *Cleaning and Maintenance*—Perform cleaning and routine maintenance of the testing machine (when required) in accordance with the manufacturer's specifications and instructions.

A1.4.6 *Indirect Verification Procedure*—The indirect verification procedure is designed to verify that for all of the Brinell hardness scales to be used, each test force is being accurately applied, each indenter-ball size is correct, and the measuring device is calibrated correctly for the range of indentation sizes that these scales produce. This is accomplished by making Brinell hardness tests on test blocks that have been calibrated for appropriate Brinell hardness scales that employ each of the corresponding test forces and indenter ball sizes.

TABLE A1.3 Repeatability and Error of the Testing Machine

Reference Block Hardness HBW	Maximum Permissible Repeatability, R % of $\bar{d}$ (see Eq 6)	Maximum Permissible Error, E % of H
HBW ≤ 125	3	3
125 < HBW ≤ 225	2.5	3
HBW > 225	2	3

A1.4.6.1 The calibrated values and Brinell hardness scales of the test blocks shall be chosen such that the following criteria are met:

(1) For each test force that will be used, at least one block shall be tested.

(2) For each indenter-ball size that will be used, at least two blocks shall be tested, one from a low hardness level and one from a high hardness level having a difference in Brinell hardness as specified in Table A1.2. If more than one of the Brinell hardness scales to be verified employs the same ball size, then the highest test force shall be verified on the block from the low hardness level to produce the largest indentation size, and the lowest test force shall be tested on the block from the high hardness level to produce the smallest indentation size. The two extremes of indentation size will verify the capability of the measuring device. The blocks need not be from scales of the same force/diameter ratio.

(3) Each test block's calibrated Brinell scale is one of the scales to be verified.

Example 1—A testing machine is to be verified for the HBW 10/3000 and HBW 5/750 scales. At a minimum, two blocks for each of the two ball sizes are required for the verification, for a total of four test blocks: one block from the low hardness level of the HBW 10/3000 scale, one block from the high hardness level of the HBW 10/3000 scale, one block from the low hardness level of the HBW 5/750 scale, and one block from the high hardness level of the HBW 5/750 scale. Note that both test forces are also tested.

Example 2—A testing machine is to be verified for the HBW 10/3000, HBW 10/1500 and HBW 10/1000 scales. At a minimum, one block for each of the force levels are required for the verification, for a total of three test blocks: one block from the low hardness level of the HBW 10/3000 scale, one block from the high hardness level of the HBW 10/1000 scale, and one block from any hardness level of the HBW 10/1500 scale. In this case, although there is only one ball size, there are three test forces that must be verified. The highest test force (29420 N, 3000 kgf) scale is tested on a low hardness level hardness block, and the lowest test force (9807 N, 1000 kgf) scale is tested on a high hardness level test block. The middle test force (14710 N, 1500 kgf) scale may be tested on either a low or high hardness level test block.

Example 3—A testing machine is to be verified for only the HBW 10/3000 scale. At a minimum, two test blocks are required for the verification: one block from the low hardness level of the HBW 10/3000 scale, and one block from the high hardness level of the HBW 10/3000 scale. In this case, although there is only one Brinell scale to be verified, two test blocks of different hardness levels are required for the verification.

A1.4.6.2 Prior to making the indirect verification hardness tests, the measuring device shall be indirectly verified by measuring the diameters of two reference indentations (see A4.5.6) chosen from the reference blocks to be used for the indirect verification. Locate the reference indentation on each reference block. The two reference indentations to be measured shall be the indentation having the smallest diameter and the indentation having the largest diameter. For Type A devices, the measured dimensions shall agree with the certified diameter values within 0.5 %. For Type B devices, the measured dimensions shall be estimated to agree with the certified diameter values within ±0.02 mm for 10 mm ball indentations and ±0.01 mm for 5 mm ball indentations. If any of the differences is larger, the measuring device shall be directly verified in accordance with A1.3.3. As an alternative to measuring reference indentations, the measuring device may be directly verified in accordance with A1.3.3.

A1.4.6.3 The testing machine shall be verified with the user's indenter ball(s) that will normally be used for testing.

A1.4.6.4 On each standardized test block, make three tests when using a 5 mm or 10 mm ball, or make five tests when using a 2.5 mm or 1 mm ball distributed uniformly over the test surface. Determine the repeatability *R* and the error *E* (Eq 2 and Eq 4) in the performance of the testing machine for each hardness level of each Brinell scale to be verified. The repeatability *R* and the error *E* shall be within the tolerances of Table A1.3.

A1.4.6.5 If the measurements of error *E* or repeatability *R* using the user's indenter fall outside of the specified tolerances, the indirect verification tests may be repeated using a different ball.

A1.4.6.6 The indirect verification shall be approved only when the testing machine measurements of repeatability and error meet the specified tolerances with the user's indenter ball.

A1.4.7 In cases where it is necessary to replace the indenter ball during the period between indirect verifications, the new indenter ball shall be verified for use with the specific testing machine. The user may perform the verification by following the verification procedures for the as-found condition given above in A1.4.4.

A1.5 Daily Verification

A1.5.1 The daily verification is intended as a tool for the user to monitor the performance of the testing machine between indirect verifications. At a minimum, the daily verification shall be performed in accordance with the schedule given in Table A1.1 for each Brinell scale that will be used.

A1.5.2 *Daily Verification Procedure*—The procedure to use when performing a daily verification are as follows.

A1.5.2.1 At least one standardized test block that meets the requirements of Annex A4 shall be tested for each Brinell scale to be used prior to its use. When test blocks are commercially available, the hardness level of the test blocks should be chosen at approximately the same hardness value as the material to be measured.

A1.5.2.2 The indenter ball to be used for the daily verification shall be the indenter ball that is normally used for testing.

A1.5.2.3 Make at least two hardness tests on each of the daily verification test blocks. The tests shall be distributed uniformly over the surface of the test blocks.

A1.5.2.4 Determine the error *E* in the performance of the testing machine (Eq 4) for each standardized test block that is measured. If the difference between any of the hardness test values and the certified value of the test block is outside the maximum permissible error tolerances given in Table A1.3, then also determine the repeatability *R* (Eq 2).

A1.5.2.5 If the error *E* and the repeatability *R* (if calculated) for each test block are within the tolerances given in Table A1.3, then the testing machine with the indenter may be regarded as performing satisfactorily.

A1.5.2.6 If the error *E* or the repeatability *R* (if calculated) for any of the test blocks is outside the tolerances, the daily verification may be repeated with a different ball or indenter. If the error *E* or the repeatability *R* again falls outside of tolerances for any of the test blocks, an indirect verification shall be performed. Whenever a testing machine fails a daily verification, the hardness tests made since the last valid daily verification may be suspect.

A1.5.2.7 If the Brinell testing machine fails daily verification using test blocks, the measuring device should be verified by measuring a reference indentation (see A4.5.6) on the standardized test block. The measured dimension should agree with the certified diameter value within the tolerances given in A1.4.6.2. If the difference is larger, the measuring device should be directly verified in accordance with A1.3.3.

NOTE A1.4—It is highly recommended that the results obtained from the daily verification testing be recorded using accepted Statistical Process Control techniques, such as, but not limited to, X-bar (measurement averages) and R-charts (measurement ranges), and histograms.

A1.6 Verification Report

A1.6.1 A verification report is required for direct and indirect verifications. A verification report is not required for a daily verification.

A1.6.2 The verification report shall be produced by the person performing the verification and include the following information when available as a result of the verification performed.

A1.6.3 *Direct Verification*:

A1.6.3.1 Reference to this ASTM test method.

A1.6.3.2 Identification of the hardness testing machine, including the serial number, and model number.

A1.6.3.3 Identification of the indentation measuring device(s), including the serial number, model number, and whether it is a Type A or B device.

A1.6.3.4 Identification of all devices (elastic proving devices, etc.) used for the verification, including serial numbers, and identification of standards to which traceability is made.

A1.6.3.5 Test temperature at the time of verification reported to a resolution of at least 1°C. The temperature at the verification site does not need to be recorded for a daily verification unless the temperature is outside recommended limits or can be shown to affect the test results.

A1.6.3.6 The individual measurement values and calculated results used to determine whether the testing machine meets the requirements of the verification performed. It is recommended that the uncertainty in the calculated results used to determine whether the testing machine meets the requirements of the verification performed also be reported.

A1.6.3.7 Description of adjustments or maintenance done to the testing machine, when applicable.

A1.6.3.8 Date of verification and reference to the verifying agency or department.

A1.6.3.9 Signature of the person performing the verification.

A1.6.4 *Indirect Verification*:

A1.6.4.1 Reference to this ASTM test method.

A1.6.4.2 Identification of the hardness testing machine, including the serial number and model number.

A1.6.4.3 Identification of all devices (test blocks, indenters, etc.) used for the verification, including serial numbers, and identification of standards to which traceability is made.

A1.6.4.4 Test temperature at the time of verification reported to a resolution of 1°C.

A1.6.4.5 The Brinell hardness scale(s) verified.

A1.6.4.6 The individual test values and calculated results used to determine whether the testing machine meets the requirements of the verification performed. Measurements made to determine the as-found condition of the testing machine shall be included whenever they are made. It is recommended that the uncertainty in the calculated results used to determine whether the testing machine meets the requirements of the verification performed also be reported.

A1.6.4.7 Description of maintenance done to the testing machine, when applicable.

A1.6.4.8 Date of verification and reference to the verifying agency or department.

A1.6.4.9 Signature of the person performing the verification.

A1.6.5 *Daily Verification*:

A1.6.5.1 No verification report is required; however, it is recommended that records be kept of the daily verification results, including the verification date, measurement results, certified value of the test block, test block identification, and the name of the person that performed the verification, etc. (see also Note A1.4). These records can be used to evaluate the performance of the hardness machine over time.

A2. BRINELL HARDNESS STANDARDIZING MACHINES

A2.1 Scope

A2.1.1 Annex A2 specifies the requirements for the capabilities, usage, periodic verification, and monitoring of a Brinell hardness standardizing machine. The Brinell hardness standardizing machine differs from a Brinell hardness testing machine by having tighter tolerances on certain performance attributes such as force application and the indentation measuring device. A Brinell standardizing machine is used for the standardization of Brinell test blocks as described in Annex A4.

A2.2 Accreditation

A2.2.1 The agency conducting direct and/or indirect verifications of Brinell hardness standardizing machines shall be accredited to the requirements of ISO 17025 (or an equivalent) by an accrediting body recognized by the International Laboratory Accreditation Cooperation (ILAC) as operating to the requirements of ISO/IEC 17011. An agency accredited to perform verifications of Brinell hardness standardizing machines may perform the verifications of its own standardizing machines. The standardizing laboratory shall have a certificate/scope of accreditation stating the types of verifications (direct and/or indirect) and the Brinell hardness scales that are covered by the accreditation.

NOTE A2.1—Accreditation is a new requirement starting with this edition of the standard.

A2.3 Apparatus

A2.3.1 The standardizing machine shall satisfy the requirements of Section 5 for a Brinell hardness testing machine with the following additional requirements.

A2.3.2 The standardizing machine shall be designed such that each test force can be selected by an operator without their ability to adjust away from the value set at the time of verification.

A2.3.3 *Measurement Device*—The measuring device shall be a Type A device as described in 5.2.5. The divisions of the micrometer scale of the microscope or other measuring devices used for the measurement of the diameter of the indentations shall be such as to permit the estimation of the diameter to within the tolerances given in Table A2.1.

A2.3.4 *Indenters*—Indenters as specified in Annex A3 shall be used.

A2.3.5 *Testing Cycle*—The standardizing machine shall be capable of meeting a desired test cycle parameter value within the tolerances specified in Table A2.2 for each part of the test cycle.

A2.4 Laboratory Environment

A2.4.1 The standardizing machine shall be located in a temperature and relative-humidity controlled room with tolerances for these conditions given in Table A2.3. The accuracy of the temperature and relative-humidity measuring instruments shall be as given in Table A2.3.

A2.4.2 The temperature and relative-humidity of the standardizing laboratory shall be monitored prior to standardization and throughout the standardizing procedure.

A2.4.3 The standardizing machine, indenter(s), and test blocks to be standardized must be in an environment meeting the tolerances of Table A2.3 for at least one hour prior to standardization.

A2.4.4 During the standardization process, the standardizing machine shall be isolated from any vibration that may affect the measurements.

TABLE A2.1 Resolution of Indentation Measuring Device

Ball Indenter Diameter mm	Minimum Resolution mm
10	±0.002
5	±0.002
2.5	±0.001
1	±0.001

TABLE A2.2 Testing Cycle Requirements

Testing Cycle Parameter	Tolerance
Indenter contact velocity	≤1 mm/s
Time for application of test force	2.0 to 8.0 s
Dwell time for test force	10 to 15 s

TABLE A2.3 Standardization Laboratory Environmental Requirements

Environmental Parameter	Tolerance	Accuracy of Measuring Instrument
Temperature	23 ± 2°C (73 ± 5°F)	±1°C (2°F)
Relative humidity	≤70 %	±10 %

A2.5 Standardizing Machine Verifications

A2.5.1 The standardizing machine shall undergo direct verification at periodic intervals and when circumstances occur that may affect the performance of the standardizing machine, according to the schedule given in Table A2.4.

NOTE A2.2—Periodic direct verification (every 12 months) is a new requirement starting with this edition of the standard. In previous editions of this standard, direct verification was used only as an alternative to indirect verification (which is no longer required) for machine verification.

A2.5.2 The standardizing machine shall undergo monitoring verifications each day that standardizations are made, according to the schedule given in Table A2.4.

A2.5.3 All instruments used to make measurements required by this Annex shall be calibrated traceable to national standards where a system of traceability exists, except as noted otherwise.

A2.5.4 The standardizing machine shall be verified at the location where it will be used.

A2.6 Direct Verification Procedures

A2.6.1 Perform a direct verification of the standardizing machine in accordance with the schedule given in Table A2.4. The test forces, indentation measuring system and the testing cycle shall be verified.

A2.6.2 *Perform Cleaning and Maintenance*—If required, cleaning and routine maintenance of the standardizing machine shall be made before conducting direct or indirect verifications in accordance with the manufacturer's specifications and instructions.

A2.6.3 *Verification of the Test Forces*—For each Brinell scale that will be used, the associated test force shall be measured. The test forces shall be measured by means of a

TABLE A2.4 Verification Schedule for a Brinell Hardness Standardizing Machine

Verification	Schedule
Direct Verification	At a maximum, shall be within 12 months prior to standardization testing. When a standardizing machine is new, moved, or when adjustments, modifications or repairs are made that could affect the application of the test forces, the indentation measuring system, or the testing cycle.
Monitoring	Each day that test blocks are to be calibrated. Either a direct verification or performance.