Designation: E10 – 18

American Association State Highway 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 E10; 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 U.S. 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 test method includes requirements for the use of portable Brinell hardness testing machines that measure Brinell hardness by the Brinell hardness test principle and can meet the requirements of this test method, including the direct and indirect verifications of the testing machine. Portable Brinell hardness testing machines that cannot meet the direct verification requirements and can only be verified by indirect verification requirements are covered in Test Method E110.

1.3 This standard includes additional requirements in the following 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

1.4 This standard includes nonmandatory information in the following appendixes that relates to the Brinell hardness test:

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

1.5 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.

1.6 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A833 Test Method for Indentation Hardness of Metallic Materials by Comparison Hardness Testers

A956 Test Method for Leeb Hardness Testing of Steel Products

A1038 Test Method for Portable Hardness Testing by the Ultrasonic Contact Impedance Method

B647 Test Method for Indentation Hardness of Aluminum Alloys by Means of a Webster Hardness Gage

E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E74 Practices for Calibration and Verification for Force-Measuring Instruments

E110 Test Method for Rockwell and Brinell Hardness of Metallic Materials by Portable Hardness Testers

E140 Hardness Conversion Tables for Metals Relationship Among Brinell Hardness, Vickers Hardness, Rockwell Hardness, Superficial Hardness, Knoop Hardness, Scleroscope Hardness, and Leeb Hardness

E384 Test Method for Microindentation Hardness of Materials

2.2 *American Bearings Manufacturer Association Standard:*

ABMA 10-1989 Metal Balls[3]

[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, http://www.americanbearings.org.

*A Summary of Changes section appears at the end of this standard

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.

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).

3.1.10 *portable Brinell hardness testing machine*—a Brinell hardness testing machine that is designed to be transported, carried, set up, and operated by the users, and that measures Brinell hardness by the Brinell hardness test principle.

3.1.11 *movable Brinell hardness testing machine*—a Brinell hardness testing machine that is designed to be moved to different locations on a moveable frame, table or similar support that is integral to the testing machine (for example, securely fixed to a rolling table), or a Brinell hardness testing machine that is designed to move into the testing position prior to a test, (for example, securely fixed to a moving support arm), and has been previously verified to ensure that such moves will not affect the hardness result.

3.2 *Equations:*

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

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 N/kgf
d	Diameter value 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 (typically 2).
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 $= \frac{Test\ Force}{Surface\ area\ of\ indentation}$ $= \frac{2F_{kgf}}{\pi D\left(D-\sqrt{D^2-d^2}\right)}$

3.2.1 The *Brinell hardness number* is calculated as:

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

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

$$\bar{d} = \frac{d_1 + d_2 + \ldots + d_n}{n} \tag{2}$$

where:

d_1, d_2, ... d_n = diameter values of the indentations in mm, and
n = number of indentations (see Annex A4).

3.2.3 The *repeatability* R in the performance of a Brinell hardness machine at each hardness level, under the particular verification conditions, is estimated by the percent range of diameter values of n indentations made on a standardized test block as part of a performance verification, relative to the average of the n measured diameter values $\bar{d}$ (Eq 2), defined as:

$$R = 100 \times \frac{d_{max} - d_{min}}{\bar{d}} \quad (3)$$

where:

d_{max} = diameter value of the largest measured indentation
d_{min} = diameter value of the smallest measured indentation, and
$\bar{d}$(Eq 2) = average of the diameter values of the n indentations.

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

$$\bar{H} = \frac{H_1 + H_2 + \ldots + H_n}{n} \quad (4)$$

3.2.5 The *error* E in the performance of a Brinell hardness machine at each hardness level, under the particular verification conditions, is estimated by the percent error of the average of n indentation measurements made on a standardized test block as part of a performance verification relative to the certified average hardness value of the standardized test block, defined as:

$$E = 100 \times \left(\frac{\left| \bar{H} - H_{STD} \right|}{H_{STD}} \right) \quad (5)$$

where:

$\bar{H}$ (Eq 4) = average of n hardness tests $H_1, H_2, ..., H_n$ made on a standardized test block as part of a performance verification,
H_{STD} = certified average hardness value of the standardized test block, and
$|\bar{H} - H_{STD}|$ = absolute value (non-negative value without regard to its sign) of the difference between $\bar{H}$ and H_{STD}.

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.

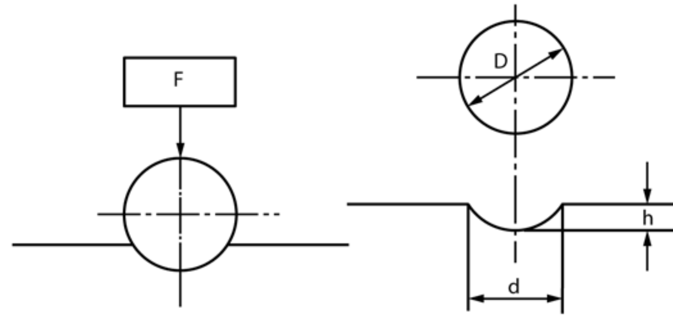

FIG. 1 Principle of Test

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.

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	–

5.2.5.2 *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.

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).

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.

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

5.7 *Use of Portable Brinell Hardness Testing Machines:*

5.7.1 A fixed-location Brinell hardness testing machine may not be capable of testing certain samples because of the sample size or weight, sample location, accessibility of the test point or other requirements. In these circumstances, the use of a portable Brinell hardness testing machine is an acceptable method to test these samples. This method allows the use of a portable Brinell hardness testing machine as follows.

5.7.1.1 The portable Brinell hardness testing machine shall meet the requirements of this method, including the test principle, apparatus, indenters, applied forces, test procedures and the direct and indirect verifications of the testing machine (except as indicated in Table A1.1). Test Method E110 covers portable Brinell hardness testing machines that cannot be directly verified or cannot pass direct verification, but meet the other requirements of this method.

5.7.1.2 A portable Brinell hardness testing machine shall be used only when testing circumstances make it impractical to use a fixed-location Brinell hardness testing machine. In such cases, it is recommended that an agreement or understanding be made between all parties involved (for example, testing service and customer) that a portable Brinell hardness testing machine will be used instead of a fixed-location Brinell hardness testing machine (see 5.7.1).

5.7.1.3 The portable Brinell hardness testing machine shall measure hardness by the Brinell hardness test principle (see 5.1). Portable hardness testing machines or instruments that measure hardness by other means or procedures different than the Brinell hardness test principle, such as those defined in Test Methods A833, A956, A1038 or B647, produce converted Brinell hardness values and do not comply with this method.

5.7.2 *Daily Verification of portable hardness testing machines*—Portable hardness testing machines are susceptible to damage when they are transported or carried from one test site to another. Therefore, in addition to complying with the daily verification requirements specified in 7.1 and Annex A1, a daily verification shall be performed at each test worksite where the hardness tests are to be made just prior to making the hardness tests. The verification shall be performed with the portable hardness testing machine oriented as closely as practical to the position that it will be used. It is recommended that the daily verification be repeated occasionally during testing and after testing is completed.

5.7.3 Additional reporting requirements, when using a portable Brinell hardness testing machine, are given in 9.2.

5.7.4 Portable hardness testing machines by the nature of their application may induce errors that could influence the test results. To understand the differences in results expected between portable and fixed-location Brinell hardness testing machines, the user should compare the results of the precision and bias studies given in Section 10 and in Test Method E110.

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.

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 should 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 recommended because of the risk in damaging the ball and the difficulty in measuring the indentation. The upper limit is recommended 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.

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						

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