Designation: E 10 – 00

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 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 (Part A) covers the determination of the Brinell hardness of metallic materials, including methods for the verification of Brinell hardness testing machines (Part B) and the calibration of standardized hardness test blocks (Part C).

1.2 The values stated in SI units are to be regarded as the standard.

NOTE 1—In common terminology, the equivalent force in kgf is substituted for Newtons.

1.3 *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:*

E 4 Practices for Force Verification of Testing Machines[2]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[3]

E 74 Practice for Calibration of Force Measuring Instruments for Verifying the Force Indication of Testing Machines[2]

E 140 Hardness Conversion Tables for Metals[2]

3. Terminology

3.1 *Brinell hardness test*—An indenter (hardened steel ball or tungsten carbide ball with diameter D) is forced into the surface of a test piece and the diameter of the indentation d left in the surface after removal of the test force, F, is measured. (See Table 1 and Fig. 1 and Fig. 2.)

DISCUSSION 1—The steel or tungsten carbide ball may be used for materials with a Brinell hardness not exceeding 450.

DISCUSSION 2—The tungsten carbide ball shall be used for materials with a Brinell hardness greater than 450 and less than or equal to 650.

TABLE 1 Symbols and Designations

NOTE 1— Constant $= \frac{1}{g_n} = \frac{1}{9.806\,65} = 0.102$

Symbol	Designation
D	Diameter of the ball, mm
F	Test force, N
d	Mean diameter of the indentation, mm
h	Depth of the indentation, mm $= \frac{D - \sqrt{D^2 - d^2}}{2}$
HBS or HBW	Brinell hardness $= \text{Constant} \times \frac{\text{Test force}}{\text{Surface area of indentation}}$ $= 0.102 \times \frac{2F}{\pi D(D - \sqrt{D^2 - d^2})}$

DISCUSSION 3—For Brinell hardnesses above 450, a significant difference is observed between results obtained using steel balls and those obtained using tungsten carbide balls.

3.2 *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.

$$\text{HBS or HBW} = 0.102 \times \frac{2F}{\pi D(D - \sqrt{D^2 - d^2})} \quad \text{(See Table 1)} \tag{1}$$

where:

D = diameter of the ball, mm,
F = test force, N, and
d = mean diameter of the indentation, mm.

The Brinell hardness is denoted by the following symbols:

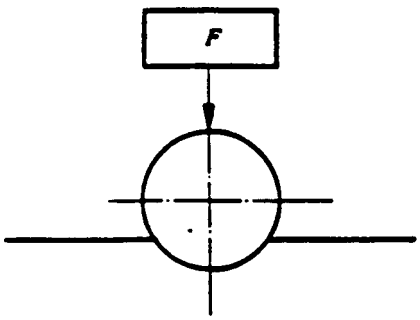

FIG. 1 Principle of Test

[1] This test method is under the jurisdiction of ASTM Committee E-28 on Mechanical Testing and is the direct responsibility of Subcommittee E28.06 on Indentation Hardness Testing.

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[2] *Annual Book of ASTM Standards*, Vol 03.01.

[3] *Annual Book of ASTM Standards*, Vol 14.02.

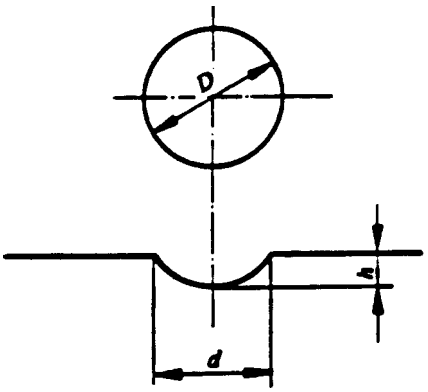

FIG. 2 Principle of Test

HBS in cases where a steel ball is used.
HBW in cases where a tungsten carbide ball is used.

NOTE 2—In former standards, in cases when a steel ball was used, the Brinell hardness was denoted by HB.

NOTE 3—The symbol HBS or HBW is preceded by the hardness value. When conditions other than those specified in 11.1.2 are used, the hardness value is supplemented by an index indicating the test conditions in the order:

(1) Diameter of the ball, in millimetres,

(2) A value representing the test force in kilogram-force (see Table 3), and

(3) Duration of loading, in seconds.

Examples:

350 HBS 5/750 = Brinell hardness of 350 determined with a steel ball of 5-mm diameter and with a test force of 7.355 kN (750 kgf) applied for 10 to 15 s.
600 HBW 1/30/20 = Brinell hardness of 600 determined with a tungsten carbide ball of 1-mm diameter and with a test force of 294.2 N (30 kgf) applied for 20 s.
Brinell hardness numbers vary with the test force used; however, test results will generally be in agreement when the ratio of the test force to the square of the ball diameter is held constant (see Table 3).

Table 2 lists the Brinell hardness numbers corresponding to various diameters of indentations for 29.4 kN (3000 kgf), 14.7 kN (1500 kgf), and 4.90 kN (500 kgf) test forces making it unnecessary to calculate for each test the value of the Brinell hardness number by the above equation in Table 1 when these forces are used with a 10-mm diameter ball.

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

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

4. Significance and Use

4.1 The Brinell hardness test is an empirical indentation hardness test. Brinell hardness tests 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. Brinell hardness testing at the specific location on a part may not represent the physical characteristics of the whole part or end product. Brinell hardness tests are considered satisfactory for acceptance testing of commercial shipments, and they have been used extensively in industry for this purpose.

A. GENERAL DESCRIPTION AND TEST PROCEDURE FOR BRINELL HARDNESS TESTS

5. Apparatus

5.1 *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. The design of the testing machines 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 shall be 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. See equipment manufacturer's instruction manual for a description of the machine's characteristics, limitations, and respective operating procedure.

5.2 *Brinell Balls*:

5.2.1 The standard ball for Brinell hardness testing shall be 10.000 mm in diameter with a deviation from this value of not more than 0.005 mm in any diameter. The ball shall be polished and free of surface defects. Smaller balls having the diameters and tolerances indicated in Table 4 may be also used provided the precautions set forth in 8.1 are observed.

5.2.2 A hardened steel ball having a hardness of at least 746 HV10 using a 98.07-N (10-kgf) test force (see Table 8) may be used on material having a Brinell hardness value not over 450, or a tungsten carbide ball having a hardness of 1500 HV10 on material over 450.

NOTE 4—**Caution:** The Brinell test is not recommended for material having hardness over 650 HBW (see 8.1).

5.2.2.1 The chemical composition of tungsten carbide balls shall be:

Tungsten Carbide (WC)	Balance
Cobalt (Co)	5.0 to 7.0 %
Total other Carbides	2.0 % max

NOTE 5—In order to conform with future ISO standards there will be a proposal to eliminate the use of steel balls and only use tungsten carbide balls for this test method.

5.2.3 If a ball is used in a test of a specimen which shows a Brinell hardness number greater than the limit for the ball as detailed in 5.2.2, the results of the test shall be considered invalid and the ball shall be discarded.

5.3 *Measuring Device*—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 direct measuring of the diameter to 0.1 mm and the estimation of the diameter to 0.05 mm.

NOTE 6—This requirement applies to the construction of the device only and is not a requirement for measurement of the indentation.

6. Test Specimen

6.1 There is no standard shape or size for a Brinell test specimen. The specimen upon which the indentation is made shall 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

TABLE 2 Brinell Hardness Numbers[A]

(Ball 10 mm in Diameter, Applied Forces of 500, 1500, and 3000 kgf)

NOTE 1—The values given in this table for Brinell hardness numbers are merely solutions of the equation given in the definition in 3.2, and include values for impression diameters outside the ranges recommended in 8.1. These values are indicated by italics.

Diameter of Indentation, mm	Brinell Hardness Number			Diameter of Indentation, mm	Brinell Hardness Number			Diameter of Indentation, mm	Brinell Hardness Number			Diameter of Indentation, mm	Brinell Hardness Number		
	500-kgf Load	1500-kgf Load	3000-kgf Load		500-kgf Load	1500-kgf Load	3000-kgf Load		500-kgf Load	1500-kgf Load	3000-kgf Load		500-kgf Load	1500-kgf Load	3000-kgf Load
2.00	*158*	*473*	*945*	2.60	92.6	278	555	3.20	60.5	182	363	3.80	42.4	127	255
2.01	*156*	*468*	*936*	2.61	91.8	276	551	3.21	60.1	180	361	3.81	42.2	127	253
2.02	*154*	*463*	*926*	2.62	91.1	273	547	3.22	59.8	179	359	3.82	42.0	126	252
2.03	*153*	*459*	*917*	2.63	90.4	271	543	3.23	59.4	178	356	3.83	41.7	125	250
2.04	*151*	*454*	*908*	2.64	89.7	269	538	3.24	59.0	177	354	3.84	41.5	125	249
2.05	*150*	*450*	*899*	2.65	89.0	267	534	3.25	58.6	176	352	3.85	41.3	124	248
2.06	*148*	*445*	*890*	2.66	88.4	265	530	3.26	58.3	175	350	3.86	41.1	123	246
2.07	*147*	*441*	*882*	2.67	87.7	263	526	3.27	57.9	174	347	3.87	40.9	123	245
2.08	*146*	*437*	*873*	2.68	87.0	261	522	3.28	57.5	173	345	3.88	40.6	122	244
2.09	*144*	*432*	*865*	2.69	86.4	259	518	3.29	57.2	172	343	3.89	40.4	121	242
2.10	*143*	*428*	*856*	2.70	85.7	257	514	3.30	56.8	170	341	3.90	40.2	121	241
2.11	*141*	*424*	*848*	2.71	85.1	255	510	3.31	56.5	169	339	3.91	40.0	120	240
2.12	*140*	*420*	*840*	2.72	84.4	253	507	3.32	56.1	168	337	3.92	39.8	119	239
2.13	*139*	*416*	*832*	2.73	83.8	251	503	3.33	55.8	167	335	3.93	39.6	119	237
2.14	*137*	*412*	*824*	2.74	83.2	250	499	3.34	55.4	166	333	3.94	39.4	118	236
2.15	*136*	*408*	*817*	2.75	82.6	248	495	3.35	55.1	165	331	3.95	39.1	117	235
2.16	*135*	*404*	*809*	2.76	81.9	246	492	3.36	54.8	164	329	3.96	38.9	117	234
2.17	*134*	*401*	*802*	2.77	81.3	244	488	3.37	54.4	163	326	3.97	38.7	116	232
2.18	*132*	*397*	*794*	2.78	80.8	242	485	3.38	54.1	162	325	3.98	38.5	116	231
2.19	*131*	*393*	*787*	2.79	80.2	240	481	3.39	53.8	161	323	3.99	38.3	115	230
2.20	*130*	*390*	*780*	2.80	79.6	239	477	3.40	53.4	160	321	4.00	38.1	114	229
2.21	*129*	*386*	*772*	2.81	79.0	237	474	3.41	53.1	159	319	4.01	37.9	114	228
2.22	*128*	*383*	*765*	2.82	78.4	235	471	3.42	52.8	158	317	4.02	37.7	113	226
2.23	*126*	*379*	*758*	2.83	77.9	234	467	3.43	52.5	157	315	4.03	37.5	113	225
2.24	*125*	*376*	*752*	2.84	77.3	232	464	3.44	52.2	156	313	4.04	37.3	112	224
2.25	*124*	*372*	*745*	2.85	76.8	230	461	3.45	51.8	156	311	4.05	37.1	111	223
2.26	*123*	*369*	*738*	2.86	76.2	229	457	3.46	51.5	155	309	4.06	37.0	111	222
2.27	*122*	*366*	*732*	2.87	75.7	227	454	3.47	51.2	154	307	4.07	36.8	110	221
2.28	*121*	*363*	*725*	2.88	75.1	225	451	3.48	50.9	153	306	4.08	36.6	110	219
2.29	*120*	*359*	*719*	2.89	74.6	224	448	3.49	50.6	152	304	4.09	36.4	109	218
2.30	*119*	*356*	*712*	2.90	74.1	222	444	3.50	50.3	151	302	4.10	36.2	109	217
2.31	*118*	*353*	*706*	2.91	73.6	221	441	3.51	50.0	150	300	4.11	36.0	108	216
2.32	*117*	*350*	*700*	2.92	73.0	219	438	3.52	49.7	149	298	4.12	35.8	108	215
2.33	*116*	*347*	*694*	2.93	72.5	218	435	3.53	49.4	148	297	4.13	35.7	107	214
2.34	*115*	*344*	*688*	2.94	72.0	216	432	3.54	49.2	147	295	4.14	35.5	106	213
2.35	*114*	*341*	*682*	2.95	71.5	215	429	3.55	48.9	147	293	4.15	35.3	106	212
2.36	*113*	*338*	*676*	2.96	71.0	213	426	3.56	48.6	146	292	4.16	35.1	105	211
2.37	*112*	*335*	*670*	2.97	70.5	212	423	3.57	48.3	145	290	4.17	34.9	105	210
2.38	*111*	*332*	*665*	2.98	70.1	210	420	3.58	48.0	144	288	4.18	34.8	104	209
2.39	*110*	*330*	*659*	2.99	69.6	209	417	3.59	47.7	143	286	4.19	34.6	104	208
2.40	*109*	*327*	*653*	3.00	69.1	207	415	3.60	47.5	142	285	4.20	34.4	103	207
2.41	108	324	648	3.01	68.6	206	412	3.61	47.2	142	283	4.21	34.2	103	205
2.42	107	322	643	3.02	68.2	205	409	3.62	46.9	141	282	4.22	34.1	102	204
2.43	106	319	637	3.03	67.7	203	406	3.63	46.7	140	280	4.23	33.9	102	203
2.44	105	316	632	3.04	67.3	202	404	3.64	46.4	139	278	4.24	33.7	101	202
2.45	104	313	627	3.05	66.8	200	401	3.65	46.1	138	277	4.25	33.6	101	201
2.46	104	311	621	3.06	66.4	199	398	3.66	45.9	138	275	4.26	33.4	100	200
2.47	103	308	616	3.07	65.9	198	395	3.67	45.6	137	274	4.27	33.2	99.7	199
2.48	102	306	611	3.08	65.5	196	393	3.68	45.4	136	272	4.28	33.1	99.2	198
2.49	101	303	606	3.09	65.0	195	390	3.69	45.1	135	271	4.29	32.9	98.8	198
2.50	100	301	601	3.10	64.6	194	388	3.70	44.9	135	269	4.30	32.8	98.3	197
2.51	99.4	298	597	3.11	64.2	193	385	3.71	44.6	134	268	4.31	32.6	97.8	196
2.52	98.6	296	592	3.12	63.8	191	383	3.72	44.4	133	266	4.32	32.4	97.3	195
2.53	97.8	294	587	3.13	63.3	190	380	3.73	44.1	132	265	4.33	32.3	96.8	194
2.54	97.1	291	582	3.14	62.9	189	378	3.74	43.9	132	263	4.34	32.1	96.4	193
2.55	96.3	289	578	3.15	62.5	188	375	3.75	43.6	131	262	4.35	32.0	95.9	192
2.56	95.5	287	573	3.16	62.1	186	373	3.76	43.4	130	260	4.36	31.8	95.5	191
2.57	94.8	284	569	3.17	61.7	185	370	3.77	43.1	129	259	4.37	31.7	95.0	190
2.58	94.0	282	564	3.18	61.3	184	368	3.78	42.9	129	257	4.38	31.5	94.5	189
2.59	93.3	280	560	3.19	60.9	183	366	3.79	42.7	128	256	4.39	31.4	94.1	188

the test force appears on the side of the piece opposite the indentation. As a general rule, the thickness of the specimen shall be at least ten times the depth of the indentation (Table 5).

6.1.2 The minimum width shall conform with the requirements of 8.3.

6.1.3 *Finish*—When necessary, the surface on which the

TABLE 2 *Continued*

Diameter of Indentation, mm	Brinell Hardness Number			Diameter of Indentation, mm	Brinell Hardness Number			Diameter of Indentation, mm	Brinell Hardness Number			Diameter of Indentation, mm	Brinell Hardness Number		
	500-kgf Load	1500-kgf Load	3000-kgf Load		500-kgf Load	1500-kgf Load	3000-kgf Load		500-kgf Load	1500-kgf Load	3000-kgf Load		500-kgf Load	1500-kgf Load	3000-kgf Load
4.40	31.2	93.6	187	5.05	23.3	69.8	140	5.70	17.8	53.5	107	6.35	*14.0*	42.0	84.0
4.41	31.1	93.2	186	5.06	23.2	69.5	139	5.71	17.8	53.3	107	6.36	*13.9*	41.8	83.7
4.42	30.9	92.7	185	5.07	23.1	69.2	138	5.72	17.7	53.1	106	6.37	*13.9*	41.7	83.4
4.43	30.8	92.3	185	5.08	23.0	68.9	138	5.73	17.6	52.9	106	6.38	*13.8*	41.5	83.1
4.44	30.6	91.8	184	5.09	22.9	68.6	137	5.74	17.6	52.7	105	6.39	*13.8*	41.4	82.8
4.45	30.5	91.4	183	5.10	22.8	68.3	137	5.75	17.5	52.5	105	6.40	*13.7*	41.2	82.5
4.46	30.3	91.0	182	5.11	22.7	68.0	136	5.76	17.4	52.3	105	6.41	*13.7*	41.1	82.2
4.47	30.2	90.5	181	5.12	22.6	67.7	135	5.77	17.4	52.1	104	6.42	*13.6*	40.9	81.9
4.48	30.0	90.1	180	5.13	22.5	67.4	135	5.78	17.3	51.9	104	6.43	*13.6*	40.8	81.6
4.49	29.9	89.7	179	5.14	22.4	67.1	134	5.79	17.2	51.7	103	6.44	*13.5*	40.6	81.3
4.50	29.8	89.3	179	5.15	22.3	66.9	134	5.80	17.2	51.5	103	6.45	*13.5*	40.5	81.0
4.51	29.6	88.8	178	5.16	22.2	66.6	133	5.81	17.1	51.3	103	6.46	*13.4*	40.4	80.7
4.52	29.5	88.4	177	5.17	22.1	66.3	133	5.82	17.0	51.1	102	6.47	*13.4*	40.2	80.4
4.53	29.3	88.0	176	5.18	22.0	66.0	132	5.83	17.0	50.9	102	6.48	*13.4*	40.1	80.1
4.54	29.2	87.6	175	5.19	21.9	65.8	132	5.84	16.9	50.7	101	6.49	*13.3*	39.9	79.8
4.55	29.1	87.2	174	5.20	21.8	65.5	131	5.85	16.8	50.5	101	6.50	*13.3*	39.8	79.6
4.56	28.9	86.8	174	5.21	21.7	65.2	130	5.86	16.8	50.3	101	6.51	*13.2*	39.6	79.3
4.57	28.8	86.4	173	5.22	21.6	64.9	130	5.87	16.7	50.2	100	6.52	*13.2*	39.5	79.0
4.58	28.7	86.0	172	5.23	21.6	64.7	129	5.88	16.7	50.0	99.9	6.53	*13.1*	39.4	78.7
4.59	28.5	85.6	171	5.24	21.5	64.4	129	5.89	16.6	49.8	99.5	6.54	*13.1*	39.2	78.4
4.60	28.4	85.4	170	5.25	21.4	64.1	128	5.90	16.5	49.6	99.2	6.55	*13.0*	39.1	78.2
4.61	28.3	84.8	170	5.26	21.3	63.9	128	5.91	16.5	49.4	98.8	6.56	*13.0*	38.9	78.0
4.62	28.1	84.4	169	5.27	21.2	63.6	127	5.92	16.4	49.2	98.4	6.57	*12.9*	38.8	77.6
4.63	28.0	84.0	168	5.28	21.1	63.3	127	5.93	16.3	49.0	98.0	6.58	*12.9*	38.7	77.3
4.64	27.9	83.6	167	5.29	21.0	63.1	126	5.94	16.3	48.8	97.7	6.59	*12.8*	38.5	77.1
4.65	27.8	83.3	167	5.30	20.9	62.8	126	5.95	16.2	48.7	97.3	6.60	*12.8*	38.4	76.8
4.66	27.6	82.9	166	5.31	20.9	62.6	125	5.96	16.2	48.5	96.9	6.61	*12.8*	38.3	76.5
4.67	27.5	82.5	165	5.32	20.8	62.3	125	5.97	16.1	48.3	96.6	6.62	*12.7*	38.1	76.2
4.68	27.4	82.1	164	5.33	20.7	62.1	124	5.98	16.0	48.1	96.2	6.63	*12.7*	38.0	76.0
4.69	27.3	81.8	164	5.34	20.6	61.8	124	5.99	16.0	47.9	95.9	6.64	*12.6*	37.9	75.7
4.70	27.1	81.4	163	5.35	20.5	61.5	123	6.00	*15.9*	47.7	95.5	6.65	*12.6*	37.7	75.4
4.71	27.0	81.0	162	5.36	20.4	61.3	123	6.01	*15.9*	47.6	95.1	6.66	*12.5*	37.6	75.2
4.72	26.9	80.7	161	5.37	20.3	61.0	122	6.02	*15.8*	47.4	94.8	6.67	*12.5*	37.5	74.9
4.73	26.8	80.3	161	5.38	20.3	60.8	122	6.03	*15.7*	47.2	94.4	6.68	*12.4*	37.3	74.7
4.74	26.6	79.9	160	5.39	20.2	60.6	121	6.04	*15.7*	47.0	94.1	6.69	*12.4*	37.2	74.4
4.75	26.5	79.6	159	5.40	20.1	60.3	121	6.05	*15.6*	46.8	93.7	6.70	*12.4*	37.1	74.1
4.76	26.4	79.2	158	5.41	20.0	60.1	120	6.06	*15.6*	46.7	93.4	6.71	*12.3*	36.9	73.9
4.77	26.3	78.9	158	5.42	19.9	59.8	120	6.07	*15.5*	46.5	93.0	6.72	*12.3*	36.8	73.6
4.78	26.2	78.5	157	5.43	19.9	59.6	119	6.08	*15.4*	46.3	92.7	6.73	*12.2*	36.7	73.4
4.79	26.1	78.2	156	5.44	19.8	59.3	119	6.09	*15.4*	46.2	92.3	6.74	*12.2*	36.6	73.1
4.80	25.9	77.8	156	5.45	19.7	59.1	118	6.10	*15.3*	46.0	92.0	6.75	*12.1*	36.4	72.8
4.81	25.8	77.5	155	5.46	19.6	58.9	118	6.11	*15.3*	45.8	91.7	6.76	*12.1*	36.3	72.6
4.82	25.7	77.1	154	5.47	19.5	58.6	117	6.12	*15.2*	45.7	91.3	6.77	*12.1*	36.2	72.3
4.83	25.6	76.8	154	5.48	19.5	58.4	117	6.13	*15.2*	45.5	91.0	6.78	*12.0*	36.0	72.1
4.84	25.5	76.4	153	5.49	19.4	58.2	116	6.14	*15.1*	45.3	90.6	6.79	*12.0*	35.9	71.8
4.85	25.4	76.1	152	5.50	19.3	57.9	116	6.15	*15.1*	45.2	90.3	6.80	*11.9*	35.8	71.6
4.86	25.3	75.8	152	5.51	19.2	57.7	115	6.16	*15.0*	45.0	90.0	6.81	*11.9*	35.7	71.3
4.87	25.1	75.4	151	5.52	19.2	57.5	115	6.17	*14.9*	44.8	89.6	6.82	*11.8*	35.5	71.1
4.88	25.0	75.1	150	5.53	19.1	57.2	114	6.18	*14.9*	44.7	89.3	6.83	*11.8*	35.4	70.8
4.89	24.9	74.8	150	5.54	19.0	57.0	114	6.19	*14.8*	44.5	89.0	6.84	*11.8*	35.3	70.6
4.90	24.8	74.4	149	5.55	18.9	56.8	114	6.20	*14.7*	44.3	88.7	6.86	*11.7*	35.2	70.4
4.91	24.7	74.1	148	5.56	18.9	56.6	113	6.21	*14.7*	44.2	88.3	6.86	*11.7*	35.1	70.1
4.92	24.6	73.8	148	5.57	18.8	56.3	113	6.22	*14.7*	44.0	88.0	6.87	*11.6*	34.9	69.9
4.93	24.5	73.5	147	5.58	18.7	56.1	112	6.23	*14.6*	43.8	87.7	6.88	*11.6*	34.8	69.6
4.94	24.4	73.2	146	5.59	18.6	55.9	112	6.24	*14.6*	43.7	87.4	6.89	*11.6*	34.7	69.4
4.95	24.3	72.8	146	5.60	18.6	55.7	111	6.25	*14.5*	43.5	87.1	6.90	*11.5*	34.6	69.2
4.96	24.2	72.5	145	5.61	18.5	55.5	111	6.26	*14.5*	43.4	86.7	6.91	*11.5*	34.5	68.9
4.97	24.1	72.2	144	5.62	18.4	55.2	110	6.27	*14.4*	43.2	86.4	6.92	*11.4*	34.3	68.7
4.98	24.0	71.9	144	5.63	18.3	55.0	110	6.28	*14.4*	43.1	86.1	6.93	*11.4*	34.2	68.4
4.99	23.9	71.6	143	5.64	18.3	54.8	110	6.29	*14.3*	42.9	85.8	6.94	*11.4*	34.1	68.2
5.00	23.8	71.3	143	5.65	18.2	54.6	109	6.30	*14.2*	42.7	85.5	6.95	*11.3*	34.0	68.0
5.01	23.7	71.0	142	5.66	18.1	54.4	109	6.31	*14.2*	42.6	85.2	6.96	*11.3*	33.9	67.7
5.02	23.6	70.7	141	5.67	18.1	54.2	108	6.32	*14.1*	42.4	84.9	6.97	*11.3*	33.8	67.5
5.03	23.5	70.4	141	5.68	18.0	54.0	108	6.33	*14.1*	42.3	84.6	6.98	*11.2*	33.6	67.3
5.04	23.4	70.1	140	5.69	17.9	53.7	107	6.34	*14.0*	42.1	84.3	6.99	*11.2*	33.5	67.0

[A] Prepared by the Engineering Mechanics Section, National Bureau of Standards.

indentation is to be made shall be filed, ground, machined or polished with abrasive material so that the edge of the indentation shall be clearly defined to permit the measurement of the diameter to the specified accuracy (see 9.1). Care should be taken to avoid overheating or cold working the surface.

TABLE 3 Test Conditions

Hardness Symbol	Ball Diameter D, mm	0.102 F / D^2	Test Force F Nominal Value	
HBS (HBW) 10/3000	10	30	29.42	kN − (3000 kgf)
HBS (HBW) 10/1500	10	15	14.71	kN − (1500 kgf)
HBS (HBW) 10/1000	10	10	9.807	kN − (1000 kgf)
HBS (HBW) 10/500	10	5	4.903	kN − (500 kgf)
HBS (HBW) 10/250	10	2.5	2.452	kN − (250 kgf)
HBS (HBW) 10/125	10	1.25	1.226	kN − (125 kgf)
HBS (HBW) 10/100	10	1	980.7	N − (100 kgf)
HBS (HBW) 5/750	5	30	7.355	kN − (750 kgf)
HBS (HBW) 5/250	5	10	2.452	kN − (250 kgf)
HBS (HBW) 5/125	5	5	1.226	kN − (125 kgf)
HBS (HBW) 5/62.5	5	2.5	612.9	N − (62.5 kgf)
HBS (HBW) 5/31.25	5	1.25	306.5	N − (31.25 kgf)
HBS (HBW) 5/25	5	1	245.2	N − (25 kgf)
HBS (HBW) 2.5/187.5	2.5	30	1.839	kN − (187.5 kgf)
HBS (HBW) 2.5/62.5	2.5	10	612.9	N − (62.5 kgf)
HBS (HBW) 2.5/31.25	2.5	5	306.5	N − (31.25 kgf)
HBS (HBW) 2.5/15.625	2.5	2.5	153.2	N − (15.625 kgf)
HBS (HBW) 2.5/7.812.5	2.5	1.25	76.61	N − (7.8125 kgf)
HBS (HBW) 2.5/6.25	2.5	1	61.29	N − (6.25 kgf)
HBS (HBW) 2/120	2	30	1.177	kN − (120 kgf)
HBS (HBW) 2/40	2	10	392.3	N − (40 kgf)
HBS (HBW) 2/20	2	5	196.1	N − (20 kgf)
HBS (HBW) 2/10	2	2.5	98.07	N − (10 kgf)
HBS (HBW) 2/5	2	1.25	49.03	N − (5 kgf)
HBS (HBW) 2/4	2	1	39.23	N − (4 kgf)
HBS (HBW) 1/30	1	30	294.2	N − (30 kgf)
HBS (HBW) 1/10	1	10	98.07	N − (10 kgf)
HBS (HBW) 1/5	1	5	49.03	N − (5 kgf)
HBS (HBW) 1/2.5	1	2.5	24.52	N − (2.5 kgf)
HBS (HBW) 1/1.25	1	1.25	12.26	N − (1.25 kgf)
HBS (HBW) 1/1	1	1	9.807	N − (1 kgf)

TABLE 4 Tolerances for Brinell Hardness Balls

Ball Diameter, mm	Tolerance, mm
10	±0.005
5	±0.004
2.5	±0.003
2	±0.003
1	±0.003

TABLE 5 Minimum Thickness Requirements for Brinell Hardness Tests

Minimum Thickness of Specimen		Minimum Hardness for Which the Brinell Test May Safely Be Made		
in.	mm	3000-kgf Load	1500-kgf Load	500-kgf Load
1/16	1.6	602	301	100
1/8	3.2	301	150	50
3/16	4.8	201	100	33
1/4	6.4	150	75	25
5/16	8.0	120	60	20
3/8	9.6	100	50	17

7. Verification of Testing Machine

7.1 *Verification Methods*—The hardness testing machine shall be verified in accordance with one of the two acceptable methods of verifying Brinell hardness testing machines as given in Part B.

7.2 *Test Force Range*—When direct verification is used, the Brinell hardness testing machine is acceptable for use over a test force range within which the error in test force does not exceed ±1 %. When indirect verification is used, the Brinell hardness machine is acceptable for use over a test force range within which the mean hardness value obtained is within ±3 % of the Brinell hardness of the standardized test blocks used.

TABLE 6 Hardness Ranges Used By Standard Test Block Method

Steel Ball	Hardmetal Ball
100 to 200 HBS	100 to 200 HBW
250 to 350 HBS	300 to 400 HBW
	500 to 600 HBW

TABLE 7 Standard Test Forces

Ball Diameter, mm	Force	Recommended Range, HB
10	29.42 kN (3000 kgf)	96 to 600
10	14.7 kN (1500 kgf)	48 to 300
10	4.90 kN (500 kgf)	16 to 100

TABLE 8 Mean Diagonal with Vickers Indenter

Ball Diameter, mm	Maximum Value of Mean Diagonal Made on the Steel Ball with a Vickers Indenter at 96.07 N (HV 10), mm
10	0.146
5	0.145
2.5	0.143
2	0.142
1	0.139

8. Procedure

8.1 *Magnitude of Test Force*—Typically, the force in the standard Brinell test shall be 29.42 kN (3000 kgf), 14.7 kN (1500 kgf), or 4.90 kN (500 kgf). It is recommended that the diameter of the indentation be between 24 and 60 % of the ball diameter. A lower limit in indentation diameter is necessary because of the risk in damaging the ball and difficulty 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 of 6.1.1, 6.1.2, and 8.3 may determine the maximum permissible diameter of indentation for a specific test. Table 7 gives standard test forces and approximate Brinell hardness numbers for the above range of indentation diameters. It is not mandatory that the Brinell test conform to these hardness ranges, but it should be realized that different Brinell hardness numbers may be obtained for a given material by using different forces on a 10-mm diameter ball. For the purpose of obtaining a continuous scale of values it may be desirable, however, to use a single force to cover the complete range of hardness for a given class of materials. For softer metals, forces of 2.45 kN (250 kgf), 1.23 kN (125 kgf), or 0.981 kN (100 kgf) are sometimes used. The force used shall be specifically stated in the test report (see 11.1.2).

8.1.1 For testing thin or small specimens, a ball less than 10 mm in diameter is sometimes used. Such tests (which are not

to be regarded as standard tests) will approximate the standard tests more closely if the relation between the applied force, *F*, measured in Newtons, and the diameter of the ball, *D*, measured in millimetres is the same as in the standard tests,

where:

$0.102F/D^2$ = 30 for 29.42 kN (3000 kgf) force and 10-mm ball

$0.102F/D^2$ = 15 for 14.72 kN (1500 kgf) force and 10-mm ball

$0.102F/D^2$ = 5 for 4.90 kN (500 kgf) force and 10-mm ball

Example—A 1.23-kN (125-kgf) test force on a 5-mm diameter ball would approximate a standard 4.90-kN (500-kgf) test force on a 10-mm diameter ball.

8.1.2 Tests for soft metals are often made with the following force-diameter ratios:

$$0.102F/D^2 = 2.5 \quad (2)$$

$$0.102F/D^2 = 1.25$$

$$0.102F/D^2 = 1.0$$

When balls smaller than 10 mm in diameter are used, both the test force and ball size shall be specifically stated in the test report (see 3.2, Note 3, and 11.1.2).

8.2 *Radius of Curvature*—When indentations are made on a curved surface, the minimum radius of curvature of the surface shall be not less than 2½ 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.

8.3 *Spacing of Indentations*—The distance of the center of the indentation from the edge of the specimen or edge of another indentation shall be at least two and one half times the diameter of the indentation.

8.4 *Application of Test Force*—Apply the force to the specimen uniformly taking precautions to prevent a momentary overload of the system. Apply the full test force for 10 to 15 s.

8.4.1 If a duration of test force application other than 10 to 15 s is used, results of the test shall be reported using the nomenclature outlined in 4.2 and 11.1.2.

8.5 *Alignment*—The angle between the indentor force line and the surface of the specimen shall be 90 ± 2°.

9. Measurement of Indentation

9.1 *Diameter*—In the Brinell hardness test, two diameters of the indentation at right angles to each other shall be measured and their mean value used as a basis for calculation of the Brinell hardness number for flat specimens. If the largest and smallest diameters for two readings of the same indentation differ by 0.1 mm or more, refer to the material specifications for further guidance. For routine tests and for tests to determine compliance with a material or product specification, the diameter of the indentation shall be estimated to 0.05 mm (0.0020 in.).

NOTE 7—These measurements are usually made with a low-magnification portable measuring device (approximately 20×) having a fixed scale in the eyepiece. If a more accurate determination is needed, as in referee or standardization tests, a laboratory comparator such as a micrometer measuring device is required.

10. Conversion to Other Hardness Scales or Tensile Strength Values

10.1 There is no general method for accurately converting Brinell hardness numbers to other hardness scales or tensile strength values. Such conversion 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 8—Hardness Conversion Tables E 140 for Metals give approximate hardness conversion values for specific materials such as steel, austenitic stainless steel, nickel and high-nickel alloys, and cartridge brass.

11. Report

11.1 Whenever a Brinell hardness number is used, provide the following information:

11.1.1 The Brinell hardness number, which shall be reported rounded to three significant digits in accordance with rounding method in Practice E 29 (example, 125 HBS, 99.2 HBS),

11.1.2 The test conditions when the Brinell hardness number is determined from forces other than 29.42 kN (3000 kgf), ball diameters other than 10 mm, and test force applications other than 10 to 15 s (see 3.2 and 8.4).

12. Precision and Bias

12.1 *Precision*—An interlaboratory comparison program is now in progress which, when completed, will be the basis of a statement on precision.

12.2 *Bias*—There is no basis for defining the bias for this test method.

B. VERIFICATION OF BRINELL HARDNESS TESTING MACHINES

13. Scope

13.1 Part B covers two procedures for the verification of Brinell hardness testing machines. These are:

13.1.1 *Direct Verification*—Separate verification of force application, indenter, and the measuring device for measuring the diameter of the indentation.

13.1.2 *Indirect Verification*—Verification by the standardized test block method.

13.2 New or rebuilt machines shall be initially checked by the direct verification method (see 13.1.1) before being placed in service.

13.3 Machines used for routine testing may be checked by either verification method.

14. General Requirements

14.1 Before a Brinell hardness testing machine is verified, the machine shall be examined to ensure that:

14.1.1 The machine is properly set up.

14.1.2 The ball holder, with a new ball whose nominal diameter has been checked (see 15.1.2), is firmly mounted in the plunger.

14.1.3 The force will be applied and removed without shock or vibration.

14.2 If the measuring device is integral with the machine, the machine shall be examined to ensure that:

14.2.1 The change from test force application to measuring does not influence the readings.

14.2.2 The method of illumination does not affect the readings.

14.2.3 The center of the indentation is in the center of the field of view.

15. Verification

15.1 *Direct Verification*—Separate verification of force application, indenter, and measuring device:

15.1.1 *Force Application*—Brinell hardness testing machines shall be verified at the test force(s) at which it is used. The test forces will be checked periodically with a force measuring device traceable to national standards (in the United States, National Institute of Standards and Technology) in the manner described in Practices E 4. A Brinell hardness testing machine is acceptable for use when the test force error does not exceed ±1 %.

15.1.2 *Indenter*—The indenter to be verified shall be a new ball selected at random from a lot meeting the hardness requirements specified in 5.2. The diameter of each ball shall be verified at not less than three positions and the mean of these readings shall not differ from the nominal diameter by more than the tolerance specified in Table 4.

15.1.3 *Measuring Device*—The measuring device used to determine the diameter of the indentation shall be verified at five intervals over the working range by the use of an accurate scale such as a stage micrometer. The adjustment of the device shall be such that, throughout the range covered, the difference between the scale divisions of the device and of the calibrating scale does not exceed 0.01 mm (0.0004 in.).

15.1.4 The verification is incomplete if a verification report is not issued.

15.2 *Indirect Verification*—Verification by standardized test block method.

15.2.1 A Brinell hardness testing machine may also be checked by making a series of at least five indentations on standardized hardness test blocks (Part C).

15.2.2 If the machine is to be used at conditions other than 10/29.42 kN (3000 kgf)/15, the machine shall also be verified at those other conditions.

15.2.3 The testing machine shall be verified for each test force and for each size of ball used. For each test force, standardized blocks within the hardness ranges given in Table 6, depending on the type of ball, shall be used.

NOTE 9—When the hardness test in question makes it impossible to reach the higher hardness range defined in Table 6 (for $0.102/F/D^2 = 5$ or 10), the verification may be carried out with two blocks from the lower hardness range.

15.2.3.1 Verification shall be carried out using the same type of ball (steel or carbide) as will be used for testing and this verification will be valid:

(*1*) For hardnesses ≤ 450 HBS when steel balls are used, and

(*2*) For hardnesses ≤ 650 HBW when tungsten carbide balls are used.

15.2.4 *Repeatability*—For each standardized block, let d_1, d_2, . . ., d_n be the mean values of the measured diameter of the indentations, arranged in increasing order of magnitude. The repeatability of the testing machine under the particular verification conditions is determined by the following quantity:

$$d_n - d_1 \tag{3}$$

The repeatability of the testing machine verified is not considered satisfactory unless it satisfies the conditions given in Table 9.

15.2.5 *Error*—The error of the testing machine under the particular verification conditions is characterized by the following quantity:

$$\bar{H} - H \tag{4}$$

where:
error = $\bar{H} - H$

$$\overline{H} = \frac{H_1 + H_2 \ldots H_n}{n} \tag{5}$$

H_1, H_2, . . ., H_n = the hardness values corresponding to d_1, d_2, . . ., d_n, and
H = specified hardness of the standardized block.

15.2.6 The Brinell hardness testing machine shall be considered verified if the mean hardness differs by no more than 3 % from the hardness value of the standardized hardness test block.

15.2.7 The verification is incomplete if a verification report is not issued.

15.3 *Verification Report*—The test report shall include the following information:

15.3.1 Reference to this ASTM test method,

15.3.2 Method of verification (direct or indirect),

15.3.3 Identification of the hardness testing machine,

15.3.4 Means of verification (test blocks, elastic proving devices, etc.),

15.3.5 Type of indenter and test force,

15.3.6 The result obtained,

15.3.7 Date of verification and reference to the calibration institution, and

15.3.8 Identity of person performing the verification.

16. Procedure for Periodic Checks by the User

16.1 Verification by the standardized test block method (15.2) is too lengthy for daily use. Instead, the following is recommended:

16.1.1 Make at least one routine check in accordance with 16.1.2 each day that the testing machine is used.

16.1.2 Consult the machine manufacturer's start-up procedures. Select the force, indenter, and measuring device which

TABLE 9 Repeatability of Testing Machine

Hardness of Standardized Block HBS (HBW)	Repeatability of the Testing Machine, max	Examples of Equivalent Hardnesses			
		HBS		HBW	
		H	H_1–H_5, max	*H*	H_1–H_5, max
<225	0.04 $\bar{d}$	100	9	100	9
		200	17	200	17
>225	0.02 $\bar{d}$	250	10	300	12
		350	14	400	17
				500	20
				600	24

will be used for the routine testing. Make at least two indentations on a standardized hardness test block. If the mean of these two values falls within the tolerances required (see 15.2.6), the hardness machine may be regarded as producing satisfactory hardness results. If not, the hardness machine shall be verified as described in 15.2.

C. CALIBRATION OF STANDARDIZED HARDNESS TEST BLOCKS FOR BRINELL HARDNESS TESTING MACHINES

17. Scope

17.1 Part C covers the calibration of standardized hardness test blocks for the verification of Brinell hardness testing machines as described in Part B.

18. Manufacture

18.1 Each metal block to be calibrated shall be not less than 16 mm (⅝ in.) in thickness for 10-mm balls, 12 mm (½ in.) thick for 5-mm balls, and 6 mm (¼in.) thick for smaller balls.

18.1.1 The maximum surface area of the test block shall be 40 cm^2 (6 $in.^2$) for balls less than 5 mm in diameter, and 150 cm^2 (24 $in.^2$) for balls equal to or greater than 5 mm in diameter.

18.2 Each block shall be specially prepared and heat treated to give the necessary homogeneity and stability of structure.

18.3 The maximum error in parallelism shall not exceed 0.0008 mm/mm (in./in.) for blocks when used with balls having a diameter greater than or equal to 5 mm and 0.0002 mm/mm (in./in.) for blocks when used with balls having a diameter less than 5 mm. The maximum deviation in flatness of the block surfaces shall not exceed 0.02 mm (0.0008 in.) and 0.005 mm (0.0002 in.) for balls having diameters equal to or greater than 5 mm and less than 5 mm, respectively.

18.4 The supporting surface of the test block shall have a ground finish and shall have a mean surface roughness height rating that shall not exceed 0.0008-mm (32-µin.) centerline average.

18.5 The test surface shall be free of scratches which would interfere with measurements of the diameters of the indentation.

18.5.1 The mean surface roughness height of the test surface rating shall not exceed 0.0003-mm (12-µin.) center line average for the standard 10-mm ball. For smaller balls a maximum mean test surface roughness height rating of 0.00015 mm (6 µin.) is recommended.

18.6 To permit checking that no material is subsequently removed from the standardized block, its thickness at the time of standardization shall be marked on it to the nearest 0.1 mm (0.004 in.), or an identifying mark shall be made on the test surface. (See Section 24.)

18.7 Each block, if of steel, shall be demagnetized by the manufacturer and maintained demagnetized by the user.

18.8 Each block must be uniquely serialized by the manufacturer for traceability.

19. Standardizing Procedure

19.1 The standardized blocks shall be calibrated on a Brinell hardness testing machine which was verified in accordance with the requirements of 15.1.

19.2 The mechanism that controls the application of the force shall ensure that the speed of approach immediately before the ball touches the specimen and the speed of penetration does not exceed 1 mm/s (0.040 in./s).

19.3 The test force shall be within 0.25 % of the nominal force. Use of a Practice E 74 Class AA device will be required to verify the force.

19.4 The test force shall be applied for 10 to 15 s.

19.5 The standardized blocks shall be calibrated at a temperature of 23 ± 5°C, using the general procedure described in Part A.

20. Indenter

20.1 A ball conforming to the requirements of 15.1.2 shall be used for calibrating standardized hardness test blocks.

21. Number of Indentations

21.1 At least five uniformly distributed indentations shall be made on the test surface of the block.

22. Measurement of the Diameters of the Indentation

22.1 The illuminating system of the measuring device shall be adjusted to give uniform intensity over the field of view and maximum contrast between the indentations and the undisturbed surface of the block.

22.2 The measuring device shall be graduated to read 0.002 mm (0.00008 in.) for indentations made with balls of 5-mm diameter or larger and 0.001 mm (0.00004 in.) for indentations made with balls of smaller diameter.

22.3 The measuring device shall be checked by a stage micrometer, or by other suitable means to ensure that the difference between readings corresponding to any two divisions of the instrument is within ±0.001 mm (0.00004 in.) for balls of less than 5-mm diameter and within ±0.002 mm (0.00008 in.) for balls of larger diameter.

23. Uniformity of Hardness

23.1 If d_1, d_2, . . ., d_n are the mean values of the measured diameters as determined by one observer and arranged in increasing order of magnitude, the range of the hardness readings, measured from the last block, is defined as $d_n - d_1$ where n = at least 5 indentations.

23.2 The range of hardness readings shall be equal to or less than 2 % of the mean diameter for Brinell hardness numbers equal to or less than 225 and 1 % for Brinell hardness number values greater than 225.

24. Marking

24.1 Each standardized block shall be marked with the following:

24.1.1 The arithmetic mean of the hardness values found in the standardizing test and the type of ball used.

24.1.2 The name or mark of the supplier.

24.1.3 The serial number or other unique identification of the block.

24.1.4 Name or mark of the calibrating agency if different from supplier.

24.1.5 The thickness of the block or an official mark on the test surface (see 18.6).

24.1.6 The year of calibration. It is sufficient that the year of calibration be incorporated into the serial number of the block.

24.2 All of the markings except the official mark should be placed outside of the test area or on the side of the block. When the markings are on the side of the block, the markings shall be upright when the test surface is the upper face.

24.3 Each block shall be supplied with a certificate showing the results of the individual standardizing tests and the arithmetic mean of those tests, including the following:

24.3.1 Date of standardization,

24.3.2 Serial number of block, and

24.3.3 Name of manufacturer or mark of supplier.

25. Keywords

25.1 Brinell hardness; metallic