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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.

ε[1] NOTE—Section 8.4.1 was editorially updated in June 2004.

1. Scope*

1.1 This test method (Test Method A) covers the determination of the Brinell hardness of metallic materials, including methods for the verification of Brinell hardness testing machines (Test Method B) and the calibration of standardized hardness test blocks (Test Method 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 N.

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 of Calibration of Force-Measuring Instruments for Verifying the Force Indication of Testing Machines[2]

E 140 Hardness Conversion Tables for Metals Relationship Among Brinell Hardness, Vickers Hardness, Rockwell Hardness, Rockwell Superficial Hardness, Knoop Hardness, and Scleroscope Hardness[2]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *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.

$$\text{HBW} = 0.102 \times \frac{2F}{\pi D(D - \sqrt{D^2 - d^2})} \quad \text{(See Table1)} \qquad (1)$$

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 symbol: HBW.

3.1.1.1 *Discussion*—In former standards, a steel ball was allowed for hardness values below 450. In cases when a steel ball was used, the Brinell hardness was denoted by HB or HBS.

3.1.1.2 *Discussion*—The symbol 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 mm,
(*2*) A value representing the test force in kg/f (see Table 3), and,
(*3*) Duration of loading, in s.

Examples:
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 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.

3.1.1.3 *Discussion*—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).

3.1.1.4 *Discussion*—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.

3.1.2 *Brinell hardness test*—an indenter (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 Figs. 1 and 2.)

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

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

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

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 $= \frac{D - \sqrt{D^2 - d^2}}{2}$
HBW	Brinell hardness $= \text{Constant} \times \frac{\text{Test force}}{\text{Surface area of indentation}}$ $= 0.102 \times \frac{2F}{\pi D(D - \sqrt{D^2 - d^2})}$

3.1.2.1 *Discussion*—The tungsten carbide ball may be used for materials with a Brinell hardness not exceeding 650.

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

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

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.

TEST METHOD 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 used also provided the precautions set forth in 8.1 are observed.

5.2.2 The tungsten carbide ball indenter shall have a minimum hardness of 1500 HV10.

NOTE 2—**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

5.2.2.2 The use of hardened steel ball indenters has been eliminated from this test method. Only tungsten carbide balls may now be used for this test method.

5.2.3 If a ball is used to test a specimen which shows a Brinell hardness greater than 650, the result should be considered suspect and the ball inspected for damage. If there is any evidence of damage, the ball shall be replaced.

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 3—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 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 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.

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 Test Method 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 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 3.1.1, 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 Force	1500-kgf Force	3000-kgf Force		500-kgf Force	1500-kgf Force	3000-kgf Force		500-kgf Force	1500-kgf Force	3000-kgf Force		500-kgf Force	1500-kgf Force	3000-kgf Force
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

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 Force	1500-kgf Force	3000-kgf Force		500-kgf Force	1500-kgf Force	3000-kgf Force		500-kgf Force	1500-kgf Force	3000-kgf Force		500-kgf Force	1500-kgf Force	3000-kgf Force
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.