Designation: E 140 – 97$^{\epsilon 3}$

An American National Standard

Standard Hardness Conversion Tables for Metals[1] Relationship Among Brinell Hardness Vickers Hardness, Rockwell Hardness, Superficial Hardness, Knoop Hardness, and Scleroscope Hardness

This standard is issued under the fixed designation E 140; 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—Equation X3.16 was corrected editorially in September 1999.
ε[2] NOTE—Table 3 was editorially revised in April 2000. Equations X2.8 and X5.1 were editorially revised in May 2000.
ε[3] NOTE—Equations X1.6, X1.8, X2.5, X3.6, X3.7, X3.11, X3.14, X3.16, X4.1, X4.6, X5.1, X6.3 X7.5 and X9.7 as well as Section X7.1.2 were editorially revised in May 2001.

1. Scope

1.1 Conversion Table 1 presents data in the Rockwell C hardness range on the relationship among Brinell hardness, Vickers hardness, Rockwell hardness, Rockwell superficial hardness, Knoop hardness, and Scleroscope hardness of non-austenitic steels including carbon, alloy, and tool steels in the as-forged, annealed, normalized, and quenched and tempered conditions provided that they are homogeneous.

1.2 Conversion Table 2 presents data in the Rockwell B hardness range on the relationship among Brinell hardness, Vickers hardness, Rockwell hardness, Rockwell superficial hardness, Knoop hardness, and Scleroscope hardness of non-austenitic steels including carbon, alloy, and tool steels in the as-forged, annealed, normalized, and quenched and tempered conditions provided that they are homogeneous.

1.3 Conversion Table 3 presents data on the relationship among Brinell hardness, Vickers hardness, Rockwell hardness, Rockwell superficial hardness, and Knoop hardness of nickel and high-nickel alloys (nickel content over 50 %). These hardness conversion relationships are intended to apply particularly to the following: nickel-aluminum-silicon specimens finished to commercial mill standards for hardness testing, covering the entire range of these alloys from their annealed to their heavily cold-worked or age-hardened conditions, including their intermediate conditions.

1.4 Conversion Table 4 presents data on the relationship among Brinell hardness, Vickers hardness, Rockwell hardness, and Rockwell superficial hardness of cartridge brass.

1.5 Conversion Table 5 presents data on the relationship between Brinell hardness and Rockwell B hardness of austenitic stainless steel plate in the annealed condition.

1.6 Conversion Table 6 presents data on the relationship between Rockwell hardness and Rockwell superficial hardness of austenitic stainless steel sheet.

1.7 Conversion Table 7 presents data on the relationship among Brinell hardness, Vickers hardness, Rockwell hardness, Rockwell superficial hardness, and Knoop hardness of copper.

1.8 Conversion Table 8 presents data on the relationship among Brinell hardness, Rockwell hardness, and Vickers hardness of alloyed white iron.

1.9 Conversion Table 9 presents data on the relationship among Brinell hardness, Vickers hardness, Rockwell hardness, and Rockwell superficial hardness of wrought aluminum products.

1.10 Many of the conversion values presented herein were obtained from computer-generated curves of actual test data. Most Rockwell hardness numbers are presented to the nearest 0.1 or 0.5 hardness number to permit accurate reproduction of these curves. Since all converted hardness values must be considered approximate, however, all converted Rockwell hardness numbers shall be rounded to the nearest whole number in accordance with Practice E 29.

1.11 Appendix X1-Appendix X9 contain equations developed from the data in Tables 1-9, respectively, to convert from one hardness scale to another. Since all converted hardness values must be considered approximate, however, all converted hardness numbers shall be rounded in accordance with Practice E 29.

1.12 Conversion of hardness values should be used only when it is impossible to test the material under the conditions specified, and when conversion is made it should be done with discretion and under controlled conditions. Each type of hardness test is subject to certain errors, but if precautions are

[1] These conversion tables are under the jurisdiction of ASTM Committee E28 on Mechanical Testing and are the direct responsibility of Subcommittee E28.06 on Indentation Hardness Testing.

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carefully observed, the reliability of hardness readings made on instruments of the indentation type will be found comparable. Differences in sensitivity within the range of a given hardness scale (for example, Rockwell B) may be greater than between two different scales or types of instruments. The conversion values, whether from the tables or calculated from the equations, are only approximate and may be inaccurate for specific application.

2. Referenced Documents

2.1 *ASTM Standards:*

E 10 Test Method for Brinell Hardness of Metallic Materials[2]

E 18 Test Method for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials[2]

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

E 92 Test Method for Vickers Hardness of Metallic Materials[2]

E 384 Test Method for Microhardness of Materials[2]

E 448 Practice for Scleroscope Hardness Testing of Metallic Materials[2]

3. Methods for Hardness Determinations

3.1 The hardness readings used with these conversion tables shall be determined in accordance with one of the following ASTM test methods:

3.1.1 *Vickers Hardness*—Test Method E 92.

3.1.2 *Brinell Hardness*—Test Method E 10.

3.1.3 *Rockwell Hardness*—Test Method E 18 Scales A, B, C, D, E, F, G, H, K, 15-N, 30-N, 45-N, 15-T, 30-T, 45-T, 15-W.

3.1.4 *Knoop Hardness*—Test Method E 384.

3.1.5 *Scleroscope* [4] *Hardness*—Practice E 448.

4. Apparatus and Reference Standards

4.1 The apparatus and reference standards shall conform to the description in Test Methods E 92, E 10, E 18, E 384, and Practice E 448.

5. Principle of Method of Conversion

5.1 Tests have proved that even the most reliable data cannot be fitted to a single conversion relationship for all metals. Indentation hardness is not a single fundamental property but a combination of properties, and the contribution of each to the hardness number varies with the type of test. The modulus of elasticity has been shown to influence conversions at high hardness levels; and at low hardness levels conversions between hardness scales measuring depth and those measuring diameter are likewise influenced by differences in the modulus of elasticity. Therefore separate conversion tables are necessary for different materials.

NOTE 1—Hardness conversion values for other metals based on comparative test on similar materials having similar mechanical properties will be added to this standard as the need arises.

6. Significance and Use

6.1 Since the various types of hardness tests do not all measure the same combination of material properties, conversion from one hardness scale to another is only an approximate process. Because of the wide range of variation among different materials, it is not possible to state confidence limits for the errors in using a conversion chart. Even in the case of a table established for a single material, such as the table for cartridge brass, some error is involved depending on composition and methods of processing (see Appendix X1).

6.2 Because of their approximate nature, conversion tables must be regarded as only an estimate of comparative values. It is recommended that hardness conversions be applied primarily to values such as specification limits, which are established by agreement or mandate, and that the conversion of test data be avoided whenever possible.

7. Reporting of Hardness Numbers

7.1 When reporting converted hardness numbers the measured hardness and test scale shall be indicated in parentheses as in the following example:

353 *HBW* (38 *HRC*) (1)

8. Keywords

8.1 conversion; hardness scale; metallic

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

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

[4] Registered trademark of the Shore Instrument and Manufacturing Co., Inc.

TABLE 1 Approximate Hardness Conversion Numbers for Non-Austenitic Steels (Rockwell C Hardness Range)[A, B]

Rockwell C Hardness Number 150 kgf (HRC)	Vickers Hardness Number (HV)	Brinell Hardness Number[C]		Knoop Hardness, Number 500-gf and Over (HK)	Rockwell Hardness Number		Rockwell Superficial Hardness Number			Sclero-scope Hard-ness Number[D]	Rockwell C Hardness Number 150 kgf (HRC)
		10-mm Standard Ball, 3000-kgf (HBS)	10-mm Carbide Ball, 3000-kgf (HBW)		A Scale, 60-kgf (HRA)	D Scale, 100-kgf (HRD)	15-N Scale, 15-kgf (HR 15-N)	30-N Scale, 30-kgf (HR 30-N)	45-N Scale, 45-kgf (HR 45-N)		
68	940	...	...	920	85.6	76.9	93.2	84.4	75.4	97.3	68
67	900	...	...	895	85.0	76.1	92.9	83.6	74.2	95.0	67
66	865	...	...	870	84.5	75.4	92.5	82.8	73.3	92.7	66
65	832	...	(739)	846	83.9	74.5	92.2	81.9	72.0	90.6	65
64	800	...	(722)	822	83.4	73.8	91.8	81.1	71.0	88.5	64
63	772	...	(705)	799	82.8	73.0	91.4	80.1	69.9	86.5	63
62	746	...	(688)	776	82.3	72.2	91.1	79.3	68.8	84.5	62
61	720	...	(670)	754	81.8	71.5	90.7	78.4	67.7	82.6	61
60	697	...	(654)	732	81.2	70.7	90.2	77.5	66.6	80.8	60
59	674	...	634	710	80.7	69.9	89.8	76.6	65.5	79.0	59
58	653	...	615	690	80.1	69.2	89.3	75.7	64.3	77.3	58
57	633	...	595	670	79.6	68.5	88.9	74.8	63.2	75.6	57
56	613	...	577	650	79.0	67.7	88.3	73.9	62.0	74.0	56
55	595	...	560	630	78.5	66.9	87.9	73.0	60.9	72.4	55
54	577	...	543	612	78.0	66.1	87.4	72.0	59.8	70.9	54
53	560	...	525	594	77.4	65.4	86.9	71.2	58.6	69.4	53
52	544	(500)	512	576	76.8	64.6	86.4	70.2	57.4	67.9	52
51	528	(487)	496	558	76.3	63.8	85.9	69.4	56.1	66.5	51
50	513	(475)	481	542	75.9	63.1	85.5	68.5	55.0	65.1	50
49	498	(464)	469	526	75.2	62.1	85.0	67.6	53.8	63.7	49
48	484	451	455	510	74.7	61.4	84.5	66.7	52.5	62.4	48
47	471	442	443	495	74.1	60.8	83.9	65.8	51.4	61.1	47
46	458	432	432	480	73.6	60.0	83.5	64.8	50.3	59.8	46
45	446	421	421	466	73.1	59.2	83.0	64.0	49.0	58.5	45
44	434	409	409	452	72.5	58.5	82.5	63.1	47.8	57.3	44
43	423	400	400	438	72.0	57.7	82.0	62.2	46.7	56.1	43
42	412	390	390	426	71.5	56.9	81.5	61.3	45.5	54.9	42
41	402	381	381	414	70.9	56.2	80.9	60.4	44.3	53.7	41
40	392	371	371	402	70.4	55.4	80.4	59.5	43.1	52.6	40
39	382	362	362	391	69.9	54.6	79.9	58.6	41.9	51.5	39
38	372	353	353	380	69.4	53.8	79.4	57.7	40.8	50.4	38
37	363	344	344	370	68.9	53.1	78.8	56.8	39.6	49.3	37
36	354	336	336	360	68.4	52.3	78.3	55.9	38.4	48.2	36
35	345	327	327	351	67.9	51.5	77.7	55.0	37.2	47.1	35
34	336	319	319	342	67.4	50.8	77.2	54.2	36.1	46.1	34
33	327	311	311	334	66.8	50.0	76.6	53.3	34.9	45.1	33
32	318	301	301	326	66.3	49.2	76.1	52.1	33.7	44.1	32
31	310	294	294	318	65.8	48.4	75.6	51.3	32.5	43.1	31
30	302	286	286	311	65.3	47.7	75.0	50.4	31.3	42.2	30
29	294	279	279	304	64.8	47.0	74.5	49.5	30.1	41.3	29
28	286	271	271	297	64.3	46.1	73.9	48.6	28.9	40.4	28
27	279	264	264	290	63.8	45.2	73.3	47.7	27.8	39.5	27
26	272	258	258	284	63.3	44.6	72.8	46.8	26.7	38.7	26
25	266	253	253	278	62.8	43.8	72.2	45.9	25.5	37.8	25
24	260	247	247	272	62.4	43.1	71.6	45.0	24.3	37.0	24
23	254	243	243	266	62.0	42.1	71.0	44.0	23.1	36.3	23
22	248	237	237	261	61.5	41.6	70.5	43.2	22.0	35.5	22
21	243	231	231	256	61.0	40.9	69.9	42.3	20.7	34.8	21
20	238	226	226	251	60.5	40.1	69.4	41.5	19.6	34.2	20

[A] In the table headings, *force* refers to total test forces.

[B] Appendix X1 contains equations converting determined hardness scale numbers to Rockwell C hardness numbers for non-austenitic steels. Refer to 1.11 before using conversion equations.

[C] The Brinell hardness numbers in parentheses are outside the range recommended for Brinell hardness testing in 8.1 of Test Method E 10.

[D] These Scleroscope hardness conversions are based on Vickers—Scleroscope hardness relationships developed from Vickers hardness data provided by the National Bureau of Standards for 13 steel reference blocks, Scleroscope hardness values obtained on these blocks by the Shore Instrument and Mfg. Co., Inc., the Roll Manufacturers Institute, and members of this institute, and also on hardness conversions previously published by the American Society for Metals and the Roll Manufacturers Institute.

TABLE 2 Approximate Hardness Conversion Numbers for Non-Austenitic Steels (Rockwell B Hardness Range)[A, B]

Rockwell B Hardness Number, 100-kgf (HRB)	Vickers Hardness Number (HV)	Brinell Hardness Number, 3000-kgf, (HBS)	Knoop Hardness Number, 500-gf, and Over (HK)	Rockwell A Hardness Number, 60-kgf, (HRA)	Rockwell F Hardness Number, 60-kgf, (HRF)	Rockwell Superficial Hardness Number			Rockwell B Hardness Number, 100-kgf, (HRB)
						15-T Scale, 15-kgf, (HR 15-T)	30-T Scale, 30-kgf, (HR 30-T)	45-T Scale, 45-kgf, (HR 45-T)	
100	240	240	251	61.5	...	93.1	83.1	72.9	100
99	234	234	246	60.9	...	92.8	82.5	71.9	99
98	228	228	241	60.2	...	92.5	81.8	70.9	98
97	222	222	236	59.5	...	92.1	81.1	69.9	97
96	216	216	231	58.9	...	91.8	80.4	68.9	96
95	210	210	226	58.3	...	91.5	79.8	67.9	95
94	205	205	221	57.6	...	91.2	79.1	66.9	94
93	200	200	216	57.0	...	90.8	78.4	65.9	93
92	195	195	211	56.4	...	90.5	77.8	64.8	92
91	190	190	206	55.8	...	90.2	77.1	63.8	91
90	185	185	201	55.2	...	89.9	76.4	62.8	90
89	180	180	196	54.6	...	89.5	75.8	61.8	89
88	176	176	192	54.0	...	89.2	75.1	60.8	88
87	172	172	188	53.4	...	88.9	74.4	59.8	87
86	169	169	184	52.8	...	88.6	73.8	58.8	86
85	165	165	180	52.3	...	88.2	73.1	57.8	85
84	162	162	176	51.7	...	87.9	72.4	56.8	84
83	159	159	173	51.1	...	87.6	71.8	55.8	83
82	156	156	170	50.6	...	87.3	71.1	54.8	82
81	153	153	167	50.0	...	86.9	70.4	53.8	81
80	150	150	164	49.5	...	86.6	69.7	52.8	80
79	147	147	161	48.9	...	86.3	69.1	51.8	79
78	144	144	158	48.4	...	86.0	68.4	50.8	78
77	141	141	155	47.9	...	85.6	67.7	49.8	77
76	139	139	152	47.3	...	85.3	67.1	48.8	76
75	137	137	150	46.8	99.6	85.0	66.4	47.8	75
74	135	135	147	46.3	99.1	84.7	65.7	46.8	74
73	132	132	145	45.8	98.5	84.3	65.1	45.8	73
72	130	130	143	45.3	98.0	84.0	64.4	44.8	72
71	127	127	141	44.8	97.4	83.7	63.7	43.8	71
70	125	125	139	44.3	96.8	83.4	63.1	42.8	70
69	123	123	137	43.8	96.2	83.0	62.4	41.8	69
68	121	121	135	43.3	95.6	82.7	61.7	40.8	68
67	119	119	133	42.8	95.1	82.4	61.0	39.8	67
66	117	117	131	42.3	94.5	82.1	60.4	38.7	66
65	116	116	129	41.8	93.9	81.8	59.7	37.7	65
64	114	114	127	41.4	93.4	81.4	59.0	36.7	64
63	112	112	125	40.9	92.8	81.1	58.4	35.7	63
62	110	110	124	40.4	92.2	80.8	57.7	34.7	62
61	108	108	122	40.0	91.7	80.5	57.0	33.7	61
60	107	107	120	39.5	91.1	80.1	56.4	32.7	60

Rockwell B Hardness Number, 100-kgf, (HRB)	Vickers Hardness Number (HV)	Brinell Hardness Number, 3000-kgf, 10-mm Ball	Knoop Hardness Number, 500-gf and Over	Rockwell A Hardness Number, 60-kgf, Diamond Penetrator	Rockwell F Hardness Number, 60-kgf, 1/16-in. (1.588-mm) Ball	Rockwell Superficial Hardness Number			Rockwell B Hardness Number, 100-kgf, 1/16-in. (1.588-mm) Ball
						15-T Scale, 15-kgf, 1/16-in. (1.588-mm) Ball	30-T Scale, 30-kgf, 1/16-in. (1.588-mm) Ball	45-T Scale, 45-kgf, 1/16-in. (1.588-mm) Ball	
59	106	106	118	39.0	90.5	79.8	55.7	31.7	59
58	104	104	117	38.6	90.0	79.5	55.0	30.7	58
57	103	103	115	38.1	89.4	79.2	54.4	29.7	57
56	101	101	114	37.7	88.8	78.8	53.7	28.7	56
55	100	100	112	37.2	88.2	78.5	53.0	27.7	55
54	...	...	111	36.8	87.7	78.2	52.4	26.7	54
53	...	...	110	36.3	87.1	77.9	51.7	25.7	53
52	...	...	109	35.9	86.5	77.5	51.0	24.7	52
51	...	...	108	35.5	86.0	77.2	50.3	23.7	51
50	...	...	107	35.0	85.4	76.9	49.7	22.7	50
49	...	...	106	34.6	84.8	76.6	49.0	21.7	49
48	...	...	105	34.1	84.3	76.2	48.3	20.7	48
47	...	...	104	33.7	83.7	75.9	47.7	19.7	47
46	...	...	103	33.3	83.1	75.6	47.0	18.7	46
45	...	...	102	32.9	82.6	75.3	46.3	17.7	45
44	...	...	101	32.4	82.0	74.9	45.7	16.7	44
43	...	...	100	32.0	81.4	74.6	45.0	15.7	43
42	...	...	99	31.6	80.8	74.3	44.3	14.7	42
41	...	...	98	31.2	80.3	74.0	43.7	13.6	41
40	...	...	97	30.7	79.7	73.6	43.0	12.6	40

TABLE 2 *Continued*

Rockwell B Hardness Number, 100-kgf, (HRB)	Vickers Hardness Number (HV)	Brinell Hardness Number, 3000-kgf, 10-mm Ball	Knoop Hardness Number, 500-gf and Over	Rockwell A Hardness Number, 60-kgf, Diamond Penetrator	Rockwell F Hardness Number, 60-kgf, 1/16-in. (1.588-mm) Ball	Rockwell Superficial Hardness Number			Rockwell B Hardness Number, 100-kgf, 1/16-in. (1.588-mm) Ball
						15-T Scale, 15-kgf, 1/16-in. (1.588-mm) Ball	30-T Scale, 30-kgf, 1/16-in. (1.588-mm) Ball	45-T Scale, 45-kgf, 1/16-in. (1.588-mm) Ball	
39	...	...	96	30.3	79.1	73.3	42.3	11.6	39
38	...	...	95	29.9	78.6	73.0	41.6	10.6	38
37	...	...	94	29.5	78.0	72.7	41.0	9.6	37
36	...	...	93	29.1	77.4	72.3	40.3	8.6	36
35	...	...	92	28.7	76.9	72.0	39.6	7.6	35
34	...	...	91	28.2	76.3	71.7	39.0	6.6	34
33	...	...	90	27.8	75.7	71.4	38.3	5.6	33
32	...	...	89	27.4	75.2	71.0	37.6	4.6	32
31	...	...	88	27.0	74.6	70.7	37.0	3.6	31
30	...	...	87	26.6	74.0	70.4	36.3	2.6	30

[A] In table headings, kgf refers to total test force.

[B] Appendix X2 contains equations converting determined hardness numbers to Rockwell B hardness numbers for non-austenitic steels. Refer to 1.11 before using conversion equations.

TABLE 3 Approximate Hardness Conversion Numbers for Nickel and High-Nickel Alloys[A, B, C]

NOTE 1—See Supplement to Table 3.

NOTE 2—The use of hardness scales for hardness values shown in parentheses is not recommended since they are beyond the ranges recommended for accuracy. Such values are shown for comparative purposes only, where comparisons may be desired and the recommended machine and scale are not available.

Vickers Hardness Number	Brinell Hardness Number	Rockwell Hardness Number								Rockwell Superficial Hardness Number					
Vickers Indenter 1, 5, 10, 30-kgf (HV)	10-mm Standard Ball, 3000-kgf (HBS)	A Scale 60-kgf Diamond Penetrator (HRA)	B Scale 100-kgf 1/16-in. (1.588-mm) Ball (HRB)	C Scale 150-kgf Diamond Penetrator (HRC)	D Scale 100-kgf Diamond Penetrator (HRD)	E Scale 100-kgf 1/8-in. (3.175-mm) Ball (HRE)	F Scale 60-kgf 1/16-in. (1.588-mm) Ball (HRF)	G Scale 150-kgf 1/16-in. (1.588-mm) Ball (HRG)	K Scale 150-kgf 1/8-in. (3.175-mm) Ball (HRK)	15-N Scale 15-kgf Superficial Diamond Penetrator (HR 15-N)	30-N Scale 30-kgf Superficial Diamond Penetrator (HR 30-N)	45-N Scale 45-kgf Superficial Diamond Penetrator (HR 45-N)	15-T Scale 15-kgf 1/16-in. (1.588-mm) Ball (HR 15-T)	30-T Scale 30-kgf 1/16-in. (1.588-mm) Ball (HR 30-T)	45-T Scale 45-kgf 1/16-in. (1.588-mm) Ball (HR 45-T)
513	(479)	75.5	...	50.0	63.0	...	...	...	...	85.5	68.0	54.5	...	...	...
481	450	74.5	...	48.0	61.5	...	...	...	...	84.5	66.5	52.5	...	...	...
452	425	73.5	...	46.0	60.0	...	...	...	...	83.5	64.5	50.0	...	...	...
427	403	72.5	...	44.0	58.5	...	...	...	...	82.5	63.0	47.5	...	...	...
404	382	71.5	...	42.0	57.0	...	...	...	...	81.5	61.0	45.5	...	...	...
382	363	70.5	...	40.0	55.5	...	...	...	...	80.5	59.5	43.0	...	...	...
362	346	69.5	...	38.0	54.0	...	...	...	...	79.5	58.0	41.0	...	...	...
344	329	68.5	...	36.0	52.5	...	...	...	...	78.5	56.0	38.5	...	...	...
326	313	67.5	...	34.0	50.5	...	...	...	...	77.5	54.5	36.0	...	...	...
309	298	66.5	(106)	32.0	49.5	...	(116.5)	94.0	...	76.5	52.5	34.0	94.5	85.5	77.0
285	275	64.5	(104)	28.5	46.5	...	(115.5)	91.0	...	75.0	49.5	30.0	94.0	84.5	75.0
266	258	63.0	(102)	25.5	44.5	...	(114.5)	87.5	...	73.5	47.0	26.5	93.0	83.0	73.0
248	241	61.5	100	22.5	42.0	...	(113.0)	84.5	...	72.0	44.5	23.0	92.5	81.5	71.0
234	228	60.5	98	20.0	40.0	...	(112.0)	81.5	...	70.5	42.0	20.0	92.0	80.5	69.0
220	215	59.0	96	(17.0)	38.0	...	(111.0)	78.5	100.0	69.0	39.5	17.0	91.0	79.0	67.0
209	204	57.5	94	(14.5)	36.0	...	(110.0)	75.5	98.0	68.0	37.5	14.0	90.5	77.5	65.0
198	194	56.5	92	(12.0)	34.0	...	(108.5)	72.0	96.5	66.5	35.5	11.0	89.5	76.0	63.0
188	184	55.0	90	(9.0)	32.0	(108.5)	(107.5)	69.0	94.5	65.0	32.5	7.5	89.0	75.0	61.0
179	176	53.5	88	(6.5)	30.0	(107.0)	(106.5)	65.5	93.0	64.0	30.5	5.0	88.0	73.5	59.5
171	168	52.5	86	(4.0)	28.0	(106.0)	(105.0)	62.5	91.0	62.5	28.5	2.0	87.5	72.0	57.5
164	161	51.5	84	(2.0)	26.5	(104.5)	(104.0)	59.5	89.0	61.5	26.5	(−0.5)	87.0	70.5	55.5
157	155	50.0	82	...	24.5	(103.0)	(103.0)	56.5	87.5	...	...	...	86.0	69.5	53.5
151	149	49.0	80	...	22.5	(102.0)	(101.5)	53.0	85.5	...	...	...	85.5	68.0	51.5
145	144	47.5	78	...	21.0	(100.5)	(100.5)	50.0	83.5	...	...	...	84.5	66.5	49.5
140	139	46.5	76	...	(19.0)	99.5	99.5	47.0	82.0	...	...	...	84.0	65.5	47.5
135	134	45.5	74	...	(17.5)	98.0	98.5	43.5	80.0	...	...	...	83.0	64.0	45.5
130	129	44.0	72	...	(16.0)	97.0	97.0	40.5	78.0	...	...	...	82.5	62.5	43.5
126	125	43.0	70	...	(14.5)	95.5	96.0	37.5	76.5	...	...	...	82.0	61.0	41.5
122	121	42.0	68	...	(13.0)	94.5	95.0	34.5	74.5	...	...	...	81.0	60.0	39.5
119	118	41.0	66	...	(11.5)	93.0	93.5	31.0	72.5		...	...	80.5	58.5	37.5
115	114	40.0	64	...	(10.0)	91.5	92.5	...	71.0	...	...	...	79.5	57.0	35.5
112	111	39.0	62	...	(8.0)	90.5	91.5	...	69.0	...	...	...	79.0	56.0	33.5
108	108	...	60	...	...	89.0	90.0	...	67.5	...	...	...	78.5	54.5	31.5
106	106	...	58	...	...	88.0	89.0	...	65.5	...	...	...	77.5	53.0	29.5
103	103	...	56	...	...	86.5	88.0	...	63.5	...	...	...	77.0	51.5	27.5
100	100	...	54	...	...	85.5	87.0	...	62.0	...	...	...	76.0	50.5	25.5
98	98	...	52	...	...	84.0	85.5	...	60.0	...	...	...	75.5	49.0	23.5
95	95	...	50	...	...	83.0	84.5	...	58.0	...	...	...	74.5	47.5	21.5

TABLE 3 *Continued*

Vickers Hardness Number	Brinell Hardness Number	Rockwell Hardness Number								Rockwell Superficial Hardness Number					
Vickers Indenter 1, 5, 10, 30-kgf (HV)	10-mm Standard Ball, 3000-kgf (HBS)	A Scale	B Scale	C Scale	D Scale	E Scale	F Scale	G Scale	K Scale	15-N Scale	30-N Scale	45-N Scale	15-T Scale	30-T Scale	45-T Scale
		60-kgf Diamond Penetrator (HRA)	100-kgf 1/16-in. (1.588-mm) Ball (HRB)	150-kgf Diamond Penetrator (HRC)	100-kgf Diamond Penetrator (HRD)	100-kgf 1/8-in. (3.175-mm) Ball (HRE)	60-kgf 1/16-in. (1.588-mm) Ball (HRF)	150-kgf 1/16-in. (1.588-mm) Ball (HRG)	150-kgf 1/8-in. (3.175-mm) Ball (HRK)	15-kgf Superficial Diamond Penetrator (HR 15-N)	30-kgf Superficial Diamond Penetrator (HR 30-N)	45-kgf Superficial Diamond Penetrator (HR 45-N)	15-kgf 1/16-in. (1.588-mm) Ball (HR 15-T)	30-kgf 1/16-in. (1.588-mm) Ball (HR 30-T)	45-kgf 1/16-in. (1.588-mm) Ball (HR 45-T)
93	93	...	48	...	...	81.5	83.5	...	56.5	...	...	...	74.0	46.5	19.5
91	91	...	46	...	...	80.5	82.0	...	54.5	...	...	...	73.5	45.0	17.0
89	89	...	44	...	...	79.0	81.0	...	52.5	...	...	...	72.5	43.5	14.5
87	87	...	42	...	...	78.0	80.0	...	51.0	...	...	...	72.0	42.0	12.5
85	85	...	40	...	...	76.5	79.0	...	49.0	...	...	...	71.0	41.0	10.0
83	83	...	38	...	...	75.0	77.5	...	47.0	...	...	...	70.5	39.5	7.5
81	81	...	36	...	...	74.0	76.5	...	45.5	...	...	...	70.0	38.0	5.5
79	79	...	34	...	...	72.5	75.5	...	43.5	...	...	...	69.0	36.5	3.0
78	78	...	32	...	...	71.5	74.0	...	42.0	...	...	...	68.5	35.5	1.0
77	77	...	30	...	...	70.0	73.0	...	40.0	...	...	...	67.5	34.0	(−1.5)

TABLE 3 *Continued*

Vickers Hardness Number	Knoop Hardness Number
Vickers Indenter 1,5,10,30-kgf (HV)	Knoop Indenter 500 and 1000-gf (HK)
382	436
362	413
344	392
326	372
309	352
285	325
266	304
248	283
234	267
220	251
209	239
198	226
188	215
179	204
171	195
164	187
157	179
151	173
145	166
140	160
135	154
130	149
126	144
122	140
119	136

[A] In table headings, kgf or gf refers to total test force.

[B] Appendix X3 contains equations converting determined hardness scale numbers to Vickers hardness numbers for nickel and high-nickel alloys. Refer to 1.11 before using conversion equations.

[C] Note that in Table 5 of Test Method E 10 (appears in the *Annual Book of ASTM Standards*, Vol 03.01), the use of a 3000-kgf force is recommended (but not mandatory) for material in the hardness range from 96 to 600 HV, and a 1500-kgf force is recommended (but not mandatory) for material in the hardness range from 48 to 300 HV. These recommendations are designed to limit impression diameters to the range from 2.50 to 6.0 mm. The Brinell hardness numbers in this conversion table are based on tests using a 3000-kgf force. When the 1500-kgf force is used for the softer nickel and high-nickel alloys, these conversion relationships do not apply.

TABLE 4 Approximate Hardness Conversion Numbers for Cartridge Brass (70 % Copper 30 % Zinc Alloy)[A,B]

Vickers Hardness Number (HV)	Rockwell Hardness Number		Rockwell Superficial Hardness Number			Brinell Hardness Number
	B Scale, 100-kgf, 1/16-in. (1.588-mm) Ball (HRB)	F Scale, 60-kgf 1/16-in. (1.588-mm) Ball (HRF)	15-T Scale, 15-kgf,1/16-in. (1.588-mm) Ball (HR 15-T)	30-T Scale, 30-kgf, 1/16-in. (1.588-mm) Ball (HR 30-T)	45-T Scale, 45-kgf, 1/16-in. (1.588-mm) Ball (HR 45-T)	500-kgf, 10-mm Ball (HBS)
196	93.5	110.0	90.0	77.5	66.0	169
194	...	109.5	...	...	65.5	167
192	93.0	...	...	77.0	65.0	166
190	92.5	109.0	...	76.5	64.5	164
188	92.0	...	89.5	...	64.0	162
186	91.5	108.5	...	76.0	63.5	161
184	91.0	...	...	75.5	63.0	159
182	90.5	108.0	89.0	...	62.5	157
180	90.0	107.5	...	75.0	62.0	156
178	89.0	...	...	74.5	61.5	154
176	88.5	107.0	...	...	61.0	152
174	88.0	...	88.5	74.0	60.5	150
172	87.5	106.5	...	73.5	60.0	149
170	87.0	...	...	...	59.5	147
168	86.0	106.0	88.0	73.0	59.0	146
166	85.5	...	...	72.5	58.5	144
164	85.0	105.5	...	72.0	58.0	142
162	84.0	105.0	87.5	...	57.5	141
160	83.5	...	...	71.5	56.5	139
158	83.0	104.5	...	71.0	56.0	138
156	82.0	104.0	87.0	70.5	55.5	136
154	81.5	103.5	...	70.0	54.5	135
152	80.5	103.0	...	...	54.0	133
150	80.0	...	86.5	69.5	53.5	131
148	79.0	102.5	...	69.0	53.0	129
146	78.0	102.0	...	68.5	52.5	128
144	77.5	101.5	86.0	68.0	51.5	126
142	77.0	101.0	...	67.5	51.0	124
140	76.0	100.5	85.5	67.0	50.0	122
138	75.0	100.0	...	66.5	49.0	121
136	74.5	99.5	85.0	66.0	48.0	120
134	73.5	99.0	...	65.5	47.5	118
132	73.0	98.5	84.5	65.0	46.5	116
130	72.0	98.0	84.0	64.5	45.5	114
128	71.0	97.5	...	63.5	45.0	113
126	70.0	97.0	83.5	63.0	44.0	112
124	69.0	96.5	...	62.5	43.0	110
122	68.0	96.0	83.0	62.0	42.0	108
120	67.0	95.5	...	61.0	41.0	106
118	66.0	95.0	82.5	60.5	40.0	105
116	65.0	94.5	82.0	60.0	39.0	103
114	64.0	94.0	81.5	59.5	38.0	101
112	63.0	93.0	81.0	58.5	37.0	99
110	62.0	92.6	80.5	58.0	35.5	97
108	61.0	92.0	...	57.0	34.5	95
106	59.5	91.2	80.0	56.0	33.0	94
104	58.0	90.5	79.5	55.0	32.0	92
102	57.0	89.8	79.0	54.5	30.5	90
100	56.0	89.0	78.5	53.5	29.5	88
98	54.0	88.0	78.0	52.5	28.0	86
96	53.0	87.2	77.5	51.5	26.5	85
94	51.0	86.3	77.0	50.5	24.5	83
92	49.5	85.4	76.5	49.0	23.0	82
90	47.5	84.4	75.5	48.0	21.0	80
88	46.0	83.5	75.0	47.0	19.0	79
86	44.0	82.3	74.5	45.5	17.0	77
84	42.0	81.2	73.5	44.0	14.5	76
82	40.0	80.0	73.0	43.0	12.5	74
80	37.5	78.6	72.0	41.0	10.0	72
78	35.0	77.4	71.5	39.5	7.5	70
76	32.5	76.0	70.5	38.0	4.5	68
74	30.0	74.8	70.0	36.0	1.0	66
72	27.5	73.2	69.0	34.0	...	64
70	24.5	71.8	68.0	32.0	...	63
68	21.5	70.0	67.0	30.0	...	62
66	18.5	68.5	66.0	28.0	...	61
64	15.5	66.8	65.0	25.5	...	59
62	12.5	65.0	63.5	23.0	...	57

TABLE 4 *Continued*

Vickers Hardness Number (HV)	Rockwell Hardness Number		Rockwell Superficial Hardness Number			Brinell Hardness Number
	B Scale, 100-kgf, 1/16-in. (1.588-mm) Ball (HRB)	F Scale, 60-kgf 1/16-in. (1.588-mm) Ball (HRF)	15-T Scale, 15-kgf,1/16-in. (1.588-mm) Ball (HR 15-T)	30-T Scale, 30-kgf, 1/16-in. (1.588-mm) Ball (HR 30-T)	45-T Scale, 45-kgf, 1/16-in. (1.588-mm) Ball (HR 45-T)	500-kgf, 10-mm Ball (HBS)
60	10.0	62.5	62.5	...	...	55
58	...	61.0	61.0	18.0	...	53
56	...	58.8	60.0	15.0	...	52
54	...	56.5	58.5	12.0	...	50
52	...	53.5	57.0	...	...	48
50	...	50.5	55.5	...	...	47
49	...	49.0	54.5	...	...	46
48	...	47.0	53.5	...	...	45
47	...	45.0	...	...	...	44
46	...	43.0	...	...	...	43
45	...	40.0	...	...	...	42

[A] In table headings, kgf or gf refers to total test force.

[B] Appendix X4 contains equations converting determined hardness scale numbers to Vickers hardness numbers for cartridge brass. Refer to 1.11 before using conversion equations.

TABLE 5 Approximate Brinell-Rockwell B Hardness Conversion Numbers for Austenitic Stainless Steel Plate in Annealed Condition[A,B]

Rockwell Hardness Number, B Scale (100-kgf, 1/16-in. (1.588-mm) ball) (HRB)	Brinell Hardness Number (3000-kgf, 10-mm ball) (HBS)
100	256
99	248
98	240
97	233
96	226
95	219
94	213
93	207
92	202
91	197
90	192
89	187
88	183
87	178
86	174
85	170
84	167
83	163
82	160
81	156
80	153
79	150
78	147
77	144
76	142
75	139
74	137
73	135
72	132
71	130
70	128
69	126
68	124
67	122
66	120
65	118
64	116
63	114
62	113
61	111
60	110

[A] In table headings, kgf or gf refers to total test force.

[B] Appendix X5 contains an equation converting determined Brinell hardness numbers to Rockwell B hardness numbers for austenitic steel plate in the annealed condition. Refer to 1.11 before using this conversion equation.

TABLE 6 Approximate Rockwell Hardness Conversion Numbers for Austenitic Stainless Steel Sheet[A,B]

NOTE 1—These conversions are based on interlaboratory tests conducted on the following grades: Types 201, 202, 301, 302, 304, 304L, 305, 316, 316L, 321, and 347. Tempers ranged from annealed to extra hard for Type 301, with a smaller range of tempers for the other types. Test coupon thicknesses ranged from approximately 0.1 in. (2.5 mm) to 0.050 in. (1.27 mm).

Rockwell Hardness Number		Rockwell Superficial Hardness Number		
C Scale, 150-kgf Diamond Penetrator (HRC)	A Scale, 60-kgf, Diamond Penetrator (HRA)	15-N Scale, 15-kgf, Superficial Diamond Penetrator (HR 15-N)	30-N Scale, 30-kgf, Superficial Diamond Penetrator (HR 30-N)	45-N Scale, 45-kgf, Superficial Diamond Penetrator (HR 45-N)
48	74.4	84.1	66.2	52.1
47	73.9	83.6	65.3	50.9
46	73.4	83.1	64.5	49.8
45	72.9	82.6	63.6	48.7
44	72.4	82.1	62.7	47.5
43	71.9	81.6	61.8	46.4
42	71.4	81.0	61.0	45.2
41	70.9	80.5	60.1	44.1
40	70.4	80.0	59.2	43.0
39	69.9	79.5	58.4	41.8
38	69.3	79.0	57.5	40.7
37	68.8	78.5	56.6	39.6
36	68.3	78.0	55.7	38.4
35	67.8	77.5	54.9	37.3
34	67.3	77.0	54.0	36.1
33	66.8	76.5	53.1	35.0
32	66.3	75.9	52.3	33.9
31	65.8	75.4	51.4	32.7
30	65.3	74.9	50.5	31.6
29	64.8	74.4	49.6	30.4
28	64.3	73.9	48.8	29.3
27	63.8	73.4	47.9	28.2
26	63.3	72.9	47.0	27.0
25	62.8	72.4	46.2	25.9
24	62.3	71.9	45.3	24.8
23	61.8	71.3	44.4	23.6
22	61.3	70.8	43.5	22.5
21	60.8	70.3	42.7	21.3
20	60.3	69.8	41.8	20.2

B Scale, 100-kgf, 1/16-in. (1.588-mm) Ball (HRB)	A Scale, 60-kgf, Diamond Penetrator (HRA)	F Scale, 60-kgf, 1/16-in. (1.588-mm) Ball[C] (HRF)	15-T Scale, 15-kgf, 1/16-in. (1.588-mm) Ball (HR 15-T)	30-T Scale, 30-kgf, 1/16-in. (1.588-mm) Ball (HR 30-T)	45-T Scale, 45-kgf, 1/16-in. (1.588-mm) Ball (HR 45-T)
100	61.5	(113.9)	91.5	80.4	70.2
99	60.9	(113.2)	91.2	79.7	69.2
98	60.3	(112.5)	90.8	79.0	68.2
97	59.7	(111.8)	90.4	78.3	67.2
96	59.1	(111.1)	90.1	77.7	66.1
95	58.5	(110.5)	89.7	77.0	65.1
94	58.0	(109.8)	89.3	76.3	64.1
93	57.4	(109.1)	88.9	75.6	63.1
92	56.8	(108.4)	88.6	74.9	62.1
91	56.2	(107.8)	88.2	74.2	61.1
90	55.6	(107.1)	87.8	73.5	60.1
89	55.0	(106.4)	87.5	72.8	59.0
88	54.5	(105.7)	87.1	72.1	58.0
87	53.9	(105.0)	86.7	71.4	57.0
86	53.3	(104.4)	86.4	70.7	56.0
85	52.7	(103.7)	86.0	70.0	55.0
84	52.1	(103.0)	85.6	69.3	54.0
83	51.5	(102.3)	85.2	68.6	52.9
82	50.9	(101.7)	84.9	67.9	51.9
81	50.4	(101.0)	84.5	67.2	50.9
80	49.8	(100.3)	84.1	66.5	49.9
79	49.2	99.6	83.8	65.8	48.9
78	48.6	99.0	83.4	65.1	47.9
77	48.0	98.3	83.0	64.4	46.8
76	47.4	97.6	82.6	63.7	45.8
75	46.9	96.9	82.3	63.0	44.8
74	46.3	96.2	81.9	62.4	43.8
73	45.7	95.6	81.5	61.7	42.8
72	45.1	94.9	81.2	61.0	41.8
71	44.5	94.2	80.8	60.3	40.7
70	43.9	93.5	80.4	59.6	39.7

TABLE 6 *Continued*

B Scale, 100-kgf, 1/16-in. (1.588-mm) Ball (HRB)	A Scale, 60-kgf, Diamond Penetrator (HRA)	F Scale, 60-kgf, 1/16-in. (1.588-mm) Ball[C] (HRF)	15-T Scale, 15-kgf, 1/16-in. (1.588-mm) Ball (HR 15-T)	30-T Scale, 30-kgf, 1/16-in. (1.588-mm) Ball (HR 30-T)	45-T Scale, 45-kgf, 1/16-in. (1.588-mm) Ball (HR 45-T)
69	43.3	92.8	80.1	58.9	38.7
68	42.8	92.2	79.7	58.2	37.7
67	42.2	91.5	79.3	57.5	36.7
66	41.6	90.8	78.9	56.8	35.7
65	41.0	90.1	78.6	56.1	34.7
64	40.4	89.5	78.2	55.4	33.6
63	39.8	88.8	77.8	54.7	32.6
62	39.3	88.1	77.5	54.0	31.6
61	38.7	87.4	77.1	53.3	30.6
60	38.1	86.8	76.7	52.6	29.6
Standard deviation[C]	1.44	2.75	2.29	1.67	1.57

[A] In table headings, kgf or gf refers to total test force.

[B] Appendix X6 contains equations converting determined hardness numbers to Rockwell C and Rockwell B hardness numbers for austenitic stainless steel sheet. Refer to 1.11 before using conversion equations.

[C] Observed standard deviation of the interlaboratory test data about the indicated conversion line.

TABLE 7 Approximate Hardness Conversion Numbers for Copper, No. 102 to 142 Inclusive[A, B]

Vickers Hardness Number		Knoop Hardness Number		Rockwell Superficial Hardness Number			Rockwell Hardness Number		Rockwell Superficial Hardness Number			Brinell Hardness Number	
1-kgf (HV)	100-gf (HV)	1-kgf (HK)	500-gf (HK)	15-T Scale, 15-kgf 1/16-in. (1.588-mm) Ball (HR 15-T)	15-T Scale, 15-kgf 1/16-in. (1.588-mm) Ball (HR 15-T)	30-T Scale, 30-kgf 1/16-in. (1.588-mm) Ball (HR 30-T)	B Scale, 100-kgf 1/16-in. (1.588-mm) Ball (HRB)	F Scale, 60-kgf 1/16-in. (1.588-mm) Ball (HRF)	15-T Scale, 15-kgf 1/16-in. (1.588-mm) Ball (HR 15-T)	30-T Scale, 30-kgf 1/16-in. (1.588-mm) Ball (HR 30-T)	45-T Scale, 45-kgf 1/16-in. (1.588-mm) Ball (HR 45-T)	500-kgf, 10-mm Diameter Ball (HBS)	20-kgf 2-mm Diameter Ball (HBS)
				0.010-in. (0.25-mm) Strip	0.020-in. (0.51-mm) Strip		0.040-in. (1.02-mm) Strip and Greater					0.080-in. (2.03-mm) Strip	0.040-in. (1.02-mm) Strip
130	127.0	138.7	133.8	...	85.0	...	67.0	99.0	...	69.5	49.0	...	119.0
128	125.2	136.8	132.1	83.0	84.5	...	66.0	98.0	87.0	68.5	48.0	...	117.5
126	123.6	134.9	130.4	...	84.0	...	65.0	97.0	...	67.5	46.5	120.0	115.0
124	121.9	133.0	128.7	82.5	83.5	...	64.0	96.0	86.0	66.5	45.0	117.5	113.0
122	121.1	131.0	127.0	...	83.0	...	62.5	95.5	85.5	66.0	44.0	115.0	111.0
120	118.5	129.0	125.2	82.0	82.5	...	61.0	95.0	...	65.0	42.5	112.0	109.0
118	116.8	127.1	123.5	81.5	...	...	59.5	94.0	85.0	64.0	41.0	110.0	107.5
116	115.0	125.1	121.7	...	82.0	...	58.5	93.0	...	63.0	40.0	107.0	105.5
114	113.5	123.2	119.9	81.0	81.5	...	57.0	92.5	84.5	62.0	38.5	105.0	103.5
112	111.8	121.4	118.1	80.5	81.0	...	55.0	91.5	...	61.0	37.0	102.0	102.0
110	109.9	119.5	116.3	80.0	...	...	53.5	91.0	84.0	60.0	36.0	99.5	100.0
108	108.3	117.5	114.5	...	80.5	...	52.0	90.5	83.5	59.0	34.5	97.0	98.0
106	106.6	115.6	112.6	79.5	80.0	...	50.0	89.5	...	58.0	33.0	94.5	96.0
104	104.9	113.5	110.1	79.0	79.5	...	48.0	88.5	83.0	57.0	32.0	92.0	94.0
102	103.2	111.5	108.0	78.5	79.0	...	46.5	87.5	82.5	56.0	30.0	89.5	92.0
100	101.5	109.4	106.0	78.0	78.0	...	44.5	87.0	82.0	55.0	28.5	87.0	90.0
98	99.8	107.3	104.0	77.5	77.5	...	42.0	85.5	81.0	53.5	26.5	84.5	88.0
96	98.0	105.3	102.1	77.0	77.0	...	40.0	84.5	80.5	52.0	25.5	82.0	86.5
94	96.4	103.2	100.0	76.5	76.5	...	38.0	83.0	80.0	51.0	23.0	79.5	85.0
92	94.7	101.0	98.0	76.0	75.5	...	35.5	82.0	79.0	49.0	21.0	77.0	83.0
90	93.0	98.9	96.0	75.5	75.0	...	33.0	81.0	78.0	47.5	19.0	74.5	81.0
88	91.2	96.9	94.0	75.0	74.5	...	30.5	79.5	77.0	46.0	16.5	...	79.0
86	89.7	95.5	92.0	74.5	73.5	...	28.0	78.0	76.0	44.0	14.0	...	77.0
84	87.9	92.3	90.0	74.0	73.0	...	25.5	76.5	75.0	43.0	12.0	...	75.0
82	86.1	90.1	87.9	73.5	72.0	...	23.0	74.5	74.5	41.0	9.5	...	73.0
80	84.5	87.9	86.0	72.5	71.0	...	20.0	73.0	73.5	39.5	7.0	...	71.5
78	82.8	85.7	84.0	72.0	70.0	...	17.0	71.0	72.5	37.5	5.0	...	69.5
76	81.0	83.5	81.9	71.5	69.5	...	14.5	69.0	71.5	36.0	2.0	...	67.5
74	79.2	81.1	79.9	71.0	68.5	...	11.5	67.5	70.0	34.0	...	...	66.0
72	77.6	78.9	78.7	70.0	67.5	...	8.5	66.0	69.0	32.0	...	...	64.0
70	75.8	76.8	76.6	69.5	66.5	...	5.0	64.0	67.5	30.0	...	...	62.0
68	74.3	74.1	74.4	69.0	65.5	...	2.0	62.0	66.0	28.0	...	...	60.5
66	72.6	71.9	71.9	68.0	64.5	...	...	60.0	64.5	25.5	...	...	58.5
64	70.9	69.5	70.0	67.5	63.5	...	...	58.0	63.5	23.5	...	...	57.0
62	69.1	67.0	67.9	66.5	62.0	...	...	56.0	61.0	21.0	...	...	55.0
60	67.5	64.6	65.9	66.0	61.0	...	...	54.0	59.0	18.0	...	...	53.0
58	65.8	62.0	63.8	65.0	60.0	...	...	51.5	57.0	15.5	...	...	51.5
56	64.0	59.8	61.8	64.5	58.5	...	...	49.0	55.0	13.0	...	...	49.5
54	62.3	57.4	59.5	63.5	57.5	...	...	47.0	53.0	10.0	...	...	48.0
52	60.7	55.0	57.2	63.0	56.0	...	...	44.0	51.5	7.5	...	...	46.5
50	58.9	52.8	55.0	62.0	55.0	...	...	41.5	49.5	4.5	...	...	44.5
48	57.3	50.3	52.7	61.0	53.5	...	...	39.0	47.5	1.5	...	...	42.0
46	55.8	48.0	50.2	60.5	52.0	...	...	36.0	45.0	...	...	...	41.0
44	53.9	45.9	47.8	59.5	51.0	...	...	33.5	43.0	...	...	...	...
42	52.2	43.7	45.2	58.5	49.5	...	...	30.5	41.0	...	...	...	...
40	51.3	40.2	42.8	57.5	48.0	...	...	28.0	38.5	...	...	...	...

[A] In table headings, kgf or gf refers to total test force.

[B] Appendix X7 contains equations converting determined hardness scale numbers to Vickers hardness numbers for copper, numbers 102 to 142 inclusive. Refer to 1.11 before using conversion equations.

TABLE 8 Approximate Hardness Conversion Numbers for Alloyed White Irons [A, B, C]

Vickers Hardness, HV 50	Brinell Hardness, HBW	Rockwell C Hardness, HRC	Vickers Hardness, HV 50	Brinell[D] Hardness, HBW	Rockwell C Hardness, HRC
1000	(903)[E]	70	680	621	57
980	(886)	69	660	604	56
960	(868)	68	640	586	55
940	(850)	68	620	569	54
920	(833)	67	600	551	53
900	(815)	66	580	533	52
880	(798)	66	560	516	51
860	(780)	65	540	498	50
840	(762)	64	520	481	48
820	(745)	63	500	463	47
800	(727)	62	480	445	45
780	(710)	62	460	428	44
760	(692)	61	440	410	42
740	(674)	60	420	393	40
720	(657)	59	400	375	38
700	(639)	58	380	357	35

[A] Data were generated in an interlaboratory comparison program conducted by American Foundrymen's Society Special Irons Subcommittee, 5-D. Supporting data available on loan from ASTM Headquarters. Request RR: E28-1003.

[B] In table headings, kgf or gf refers to total test force.

[C] Appendix X8 contains equations converting determined hardness scale numbers to Vickers hardness numbers for alloyed white irons. Refer to 1.11 before using conversion equations.

[D] Ten-millimetre tungsten carbide ball.

[E] Brinell hardness numbers in parentheses are above the maximum hardness recommended by Test Method E 10 and are presented for information only.

TABLE 9 Approximate Hardness Conversion Numbers for Wrought Aluminum Products[A, B, C]

Brinell Hardness Number 500-kgf, (10-mm Ball) (HBS)	Vickers Hardness Number 15-kgf, (HV)	Rockwell Hardness Number			Rockwell Superficial Hardness Number		
		B Scale 100-kgf, 1/16-in. Ball (HRB)	E Scale 100-kgf, 1/8-in. Ball (HRE)	H Scale 60-kgf, 1/8-in. Ball (HRH)	15-T Scale 15-kgf, 1/16-in. Ball (HR 15-T)	30-T Scale 30-kgf, 1/16-in. Ball (HR 30-T)	15-W Scale 15-kgf, 1/8-in. Ball (HR 15-W)
160	189	91	...	...	89	77	95
155	183	90	...	...	89	76	95
150	177	89	...	...	89	75	94
145	171	87	...	...	88	74	94
140	165	86	...	...	88	73	94
135	159	84	...	...	87	71	93
130	153	81	...	...	87		
70	93						
125	147	79	...	...	86	68	92
120	141	76	...	...	86	67	92
115	135	72	101	...	86	65	91
110	129	69	100	...	85	63	91
105	123	65	99	...	84	61	91
100	117	60	98	...	83	59	90
95	111	56	96	...	82	57	90
90	105	51	94	108	81	54	89
85	98	46	91	107	80	52	89
80	92	40	88	106	78	50	88
75	86	34	84	104	76	47	87
70	80	28	80	102	74	44	86
65	74	...	75	100	72	...	85
60	68	...	70	97	70	...	83
55	62	...	65	94	67	...	82
50	56	...	59	91	64	...	80
45	50	...	53	87	62	...	79
40	44	...	46	83	59	...	77

[A] Data were generated in an interlaboratory test program conducted by ASTM Subcommittee E28.06. Supporting data available from ASTM Headquarters. Request RR: E28-1005.

[B] In table headings, kgf or gf refers to total test force.

[C] Appendix X9 contains equations converting determined hardness scale numbers to Brinell numbers for wrought aluminum products. Refer to 1.11 before using conversion equations.

APPENDIXES

(Nonmandatory Information)

X1. HARDNESS CONVERSION EQUATIONS FOR NON-AUSTENITIC STEELS (DETERMINED HARDNESS SCALE NUMBERS TO ROCKWELL C HARDNESS NUMBERS)

X1.1 The following equations were generated from the specific hardness numbers contained in Table 1 and should not be used for converting numbers outside of the defined hardness range. Due to inherent inaccuracies in the conversion process, the converted number should be rounded to the nearest whole number in accordance with Practice E 29.

X1.1.1 From Vickers hardness to Rockwell C hardness:

$$HRC = +3.14900E{+}01 + 7.96683E{-}02(HV) - 3.55432E{-}05(HV)^2 - 6.72816E{+}03(HV)^{-1}$$
$$R^2 = 0.9999 \quad \text{(X1.1)}$$

X1.1.2 From Brinell hardness (10-mm diameter steel ball, 3000-kgf force) to Rockwell C hardness:

$$HRC = +8.35260E{+}01 - 8.68203E{-}02(HBS) + 1.44229E{-}04(HBS)^2 - 1.15905E{+}04(HBS)^{-1}$$
$$R^2 = 0.9998 \quad \text{(X1.2)}$$

X1.1.3 From Brinell hardness (10-mm diameter tungsten carbide ball, 3000-kgf force) to Rockwell C hardness:

$$HRC = +1.81673E{+}01 + 1.20388E{-}01(HBW) - 6.94388E{-}05(HBW)^2 - 4.88327E{+}03(HBW)^{-1}$$
$$R^2 = 0.9998 \quad \text{(X1.3)}$$

X1.1.4 From Knoop hardness (500-gf force and greater) to Rockwell C hardness:

$$HRC = +6.43102E{+}01 + 7.59497E{-}03(HK_{500-1000}) + 1.13729E{-}05(HK_{500-1000})^2 - 1.17515E + 04(HK500\text{–}1000)^{-1}$$
$$R^2 = 1.0000 \quad \text{(X1.4)}$$

X1.1.5 From Rockwell A hardness to Rockwell C hardness:

$$HRC = -1.25501E{+}02 + 2.76747E + 00(HRA) - 5.94178E{-}03(HRA)^2$$
$$R^2 = 0.9999 \quad \text{(X1.5)}$$

X1.1.6 From Rockwell D hardness to Rockwell C hardness:

$$HRC = -3.20806E{+}01 + 1.30193E{+}00(HRD)$$
$$R^2 = 1.0000 \quad \text{(X1.6)}$$

X1.1.7 From Rockwell 15N hardness to Rockwell C hardness:

$$HRC = -3.74666E + 02 + 1.27582E + 01(HR15N) - 1.48317E{-}01(HR15N)^2 + 6.68816E{-}04(HR15N)^3$$
$$R^2 = 0.9999 \quad \text{(X1.7)}$$

X1.1.8 From Rockwell 30N hardness to Rockwell C hardness:

$$HRC = -2.60390E{+}01 + 1.11079E{+}00(HR30N)$$
$$R^2 = 1.0000 \quad \text{(X1.8)}$$

X1.1.9 From Rockwell 45N hardness to Rockwell C hardness:

$$HRC = +3.18978E{+}00 + 8.54135E{-}01(HR45N)$$
$$R^2 = 0.9999 \quad \text{(X1.9)}$$

X1.1.10 From Scleroscope hardness to Rockwell C hardness:

$$HRC = +1.14708E{+}01 + 9.61667E{-}01(HSc) - 3.15195E{-}03(HSc)^2 - 6.97208E{+}02(HSc)^{-1}$$
$$R^2 = 1.0000 \quad \text{(X1.10)}$$

X2. HARDNESS CONVERSION EQUATIONS FOR NON-AUSTENITIC STEELS (DETERMINED HARDNESS SCALE NUMBERS TO ROCKWELL B HARDNESS NUMBERS)

X2.1 The following equations were generated from the specific hardness numbers contained in Table 2 and should not be used for converting numbers outside of the defined hardness range. Due to inherent inaccuracies in the conversion process, the converted number should be rounded to the nearest whole number in accordance with Practice E 29.

X2.1.1 From Vickers hardness to Rockwell B hardness:

$$HRB = +1.14665E{+}02 + 8.82795E{-}02(HV) - 1.41855E{-}04(HV)^2 - 6.69528E{+}03(HV)^{-1}$$
$$R^2 = 0.9998 \quad \text{(X2.1)}$$

X2.1.2 From Brinell hardness (10-mm diameter steel ball, 3000-kgf force) to Rockwell B hardness:

$$HRB = +1.14665E{+}02 + 8.82795E{-}02(HBS) - 1.41855E{-}04(HBS)^2 - 6.69528E{+}03(HBS)^{-1}$$
$$R^2 = 0.9998 \quad \text{(X2.2)}$$

X2.1.3 From Knoop hardness (500-gf force and greater) to Rockwell B hardness:

$$HRB = +1.75357E{+}02 - 2.37706E{-}01(HK_{500-1000}) + 4.56743E{-}04(HK_{500-1000})^2 - 1.12480E{+}04(HK_{500-1000})^{-1}$$
$$R^2 = 0.9996 \quad \text{(X2.3)}$$

X2.1.4 From Rockwell A hardness to Rockwell B hardness:

$$HRB = -4.82350E{+}01 + 3.33354E{+}00(HRA) - 1.50107E{-}02(HRA)^2$$
$$R^2 = 1.0000 \quad \text{(X2.4)}$$

X2.1.5 From Rockwell F hardness to Rockwell B hardness:

$$HRB = -9.99816E{+}01 + 1.75617E{+}00(HRF)$$
$$R^2 = 1.0000 \quad \text{(X2.5)}$$

X2.1.6 From Rockwell 15T hardness to Rockwell B hardness:

$$\text{HRB} = -1.86934\text{E}+02 + 3.08173\text{E}+00(\text{HR15T})$$
$$R^2 = 1.0000 \quad \text{(X2.6)}$$

X2.1.7 From Rockwell 30T hardness to Rockwell B hardness:

$$\text{HRB} = -2.42568\text{E}+01 + 1.49484\text{E}+00(\text{HR30T})$$
$$R^2 = 1.0000 \quad \text{(X2.7)}$$

X2.1.8 From Rockwell 45T hardness to Rockwell B hardness:

$$\text{HRB} = +2.74135\text{E}+01 + 9.95874\text{E}-01(\text{HR45T})$$
$$R^2 = 1.0000 \quad \text{(X2.8)}$$

X3. HARDNESS CONVERSION EQUATIONS FOR NICKEL AND HIGH-NICKEL ALLOYS (DETERMINED HARDNESS SCALE NUMBERS TO VICKERS HARDNESS NUMBERS)

X3.1 The following equations were generated from the specific hardness numbers contained in Table 3 and should not be used for converting numbers outside of the defined hardness range. Due to inherent inaccuracies in the conversion process, the converted number should be rounded to the nearest whole number in accordance with Practice E 29.

X3.1.1 From Brinell hardness (10-mm diameter steel ball, 3000-kgf force) to Vickers hardness (1.5, 10, and 30-kgf forces):

$$\text{HV 1.5,10,30} = +8.52592\text{E}-02 + 9.82889\text{E}-01(\text{HBS}) + 1.89707\text{E}-04(\text{HBS})^2$$
$$R^2 = 1.0000 \quad \text{(X3.1)}$$

X3.1.2 From Rockwell A hardness to Vickers hardness (1.5, 10, and 30-kgf forces):

$$(\text{HV 1.5,10,30})^{-1} = +2.13852\text{E}-02 - 3.84341\text{E}-04(\text{HRA}) + 1.67455\text{E}-06(\text{HRA})^2$$
$$R^2 = 0.9998 \quad \text{(X3.2)}$$

X3.1.3 From Rockwell B hardness to Vickers hardness (1.5, 10, and 30-kgf forces):

$$(\text{HV 1.5, 10, 30})^{-1} = +1.69552\text{E}-02 - 1.29200\text{E}-04(\text{HRB})$$
$$R^2 = 0.9999 \quad \text{(X3.3)}$$

X3.1.4 From Rockwell C hardness to Vickers hardness (1.5, 10, and 30-kgf forces):

$$(\text{HV 1.5, 10, 30})^{-1} = +6.24553\text{E}-03 - 1.08014\text{E}-04(\text{HRC}) + 4.32021\text{E}-07(\text{HRC})^2$$
$$R^2 = 0.9995 \quad \text{(X3.4)}$$

X3.1.5 From Rockwell D hardness to Vickers hardness (1.5, 10, and 30-kgf forces):

$$(\text{HV 1.5, 10, 30})^{-1} = +1.04408\text{E}-02 - 1.86498\text{E}-04(\text{HRD}) + 8.16952\text{E}-07(\text{HRD})^2$$
$$R^2 = 0.9998 \quad \text{(X3.5)}$$

X3.1.6 From Rockwell E hardness to Vickers hardness (1.5, 10, and 30-kgf forces):

$$(\text{HV 1.5, 10, 30})^{-1} = +2.72286\text{E}-02 - 2.01993\text{E}-04(\text{HRE})$$
$$R^2 = 0.9994 \quad \text{(X3.6)}$$

X3.1.7 From Rockwell F hardness to Vickers hardness (1.5, 10, and 30-kgf forces):

$$(\text{HV 1.5, 10, 30})^{-1} = +2.94130\text{E}-02 - 2.23861\text{E}-04(\text{HRF}) \quad \text{(X3.7)}$$
$$R^2 = 0.9991$$

X3.1.8 From Rockwell G hardness to Vickers hardness (1.5, 10, and 30-kgf forces):

$$(\text{HV 1.5, 10, 30})^{-1} = +1.10239\text{E}-02 - 8.27628\text{E}-05(\text{HRG}) \quad \text{(X3.8)}$$
$$R^2 = 0.9999$$

X3.1.9 From Rockwell K hardness to Vickers hardness (1.5, 10, and 30-kgf forces):

$$(\text{HV 1.5, 10, 30})^{-1} = +1.87458\text{E}-02 - 1.41851\text{E}-04(\text{HRK})$$
$$R^2 = 0.9998 \quad \text{(X3.9)}$$

X3.1.10 From Rockwell 15N hardness to Vickers hardness (1.5, 10, and 30-kgf forces):

$$(\text{HV 1.5, 10, 30})^{-1} = +2.59838\text{E}-02 - 4.31479\text{E}-04(\text{HR15N}) + 1.75469\text{E}-06(\text{HR15N})^2$$
$$R^2 = 0.9998 \quad \text{(X3.10)}$$

X3.1.11 From Rockwell 30N hardness to Vickers hardness (1.5, 10, and 30-kgf forces):

$$(\text{HV 1.5, 10, 30})^{-1} = +9.85078\text{E}-03 - 1.58346\text{E}-04(\text{HR30N}) + 6.16727\text{E}-07(\text{HR30N})^2$$
$$R^2 = 0.9997 \quad \text{(X3.11)}$$

X3.1.12 From Rockwell 45N hardness to Vickers hardness (1.5, 10, and 30-kgf forces):

$$(\text{HV 1.5, 10, 30})^{-1} = +6.03882\text{E}-03 - 9.51201\text{E}-05(\text{HR45N}) + 3.63345\text{E}-07(\text{HR45N})^2$$
$$R^2 = 0.9998 \quad \text{(X3.12)}$$

X3.1.13 From Rockwell 15T hardness to Vickers hardness (1.5, 10, and 30-kgf forces):

$$(\text{HV 1.5, 10, 30})^{-1} = +3.71482\text{E}-02 - 3.49957\text{E}-04(\text{HR15T}) - 8.92693\text{E}-08(\text{HR15T})^2$$
$$R^2 = 0.9996 \quad \text{(X3.13)}$$

X3.1.14 From Rockwell 30T hardness to Vickers hardness (1.5, 10, and 30-kgf forces):

$$(\text{HV 1.5, 10, 30})^{-1} = +1.94133\text{E}-02 - 1.85296\text{E}-04(\text{HR30T}) - 4.01798\text{E}-08(\text{HR30T})^2$$
$$R^2 = 0.9998 \quad \text{(X3.14)}$$

X3.1.15 From Rockwell 45T hardness to Vickers hardness (1.5, 10, and 30-kgf forces):

$$(\text{HV 1.5, 10, 30})^{-1} = +1.29736\text{E}-02 - 1.14693\text{E}-04(\text{HR45T}) - 1.61879\text{E}-07(\text{HR45T})^2$$

$$R^2 = 0.9998 \quad \text{(X3.15)}$$

X3.1.16 From Knoop hardness (500 and 1000-gf forces) to Vickers hardness (1.5, 10, and 30-kgf forces):

$$\text{HV 1.5, 10, 30} = -5.08687\text{E}{-}01 + 8.78046\text{E}{-}01(\text{HK}_{500,1000})$$
$$R^2 = 1.0000 \quad \text{(X3.16)}$$

X4. HARDNESS CONVERSION EQUATIONS FOR CARTRIDGE BRASS (DETERMINED HARDNESS SCALE NUMBERS TO VICKERS HARDNESS NUMBERS)

X4.1 The following equations were generated from the specific hardness numbers contained in Table 4 and should not be used for converting numbers outside of the defined hardness range. Due to inherent inaccuracies in the conversion process, the converted number should be rounded to the nearest whole number in accordance with Practice E 29.

X4.1.1 From Rockwell B hardness to Vickers hardness:

$$(\text{HV})^{-1} = +1.77793\text{E}{-}02 - 1.31112\text{E}{-}04(\text{HRB}) - 3.77903\text{E}{-}07(\text{HRB})^2 + 3.55271\text{E}{-}09(\text{HRB})^3$$
$$R^2 = 0.9996 \quad \text{(X4.1)}$$

X4.1.2 From Rockwell F hardness to Vickers hardness:

$$(\text{HV})^{-1} = +2.95966\text{E}{-}02 - 1.03725\text{E}{-}04(\text{HRF}) - 2.31669\text{E}{-}06(\text{HRF})^2 + 1.12203\text{E}{-}08(\text{HRF})^3$$
$$R^2 = 0.9998 \quad \text{(X4.2)}$$

X4.1.3 From Rockwell 15T hardness to Vickers hardness:

$$(\text{HV})^{-1} = +7.65595\text{E}{-}02 - 1.79133\text{E}{-}03(\text{HR15T}) + 1.84105\text{E}{-}05(\text{HR15T})^2 - 8.14318\text{E}{-}08(\text{HR15T})^3$$
$$R^2 = 0.9998 \quad \text{(X4.3)}$$

X4.1.4 From Rockwell 30T hardness to Vickers hardness:

$$(\text{HV})^{-1} = +2.08924\text{E}{-}02 - 2.03448\text{E}{-}04(\text{HR30T}) - 2.80441\text{E}{-}08(\text{HR30T})^2 + 1.33185\text{E}{-}10(\text{HR30T})^3$$
$$R^2 = 0.9998 \quad \text{(X4.4)}$$

X4.1.5 From Rockwell 45T hardness to Vickers hardness:

$$(\text{HV})^{-1} = +1.36295\text{E}{-}02 - 1.03553\text{E}{-}04(\text{HR45T}) - 9.70546\text{E}{-}07(\text{HR45T})^2 + 8.77834\text{E}{-}09(\text{HR45T})^3$$
$$R^2 = 0.9999 \quad \text{(X4.5)}$$

X4.1.6 From Brinell hardness (10-mm diameter steel ball, 500-kgf force) to Vickers hardness:

$$\text{HV} = -5.60725\text{E}{+}00 + 1.19007\text{E}{+}00(\text{HBS 10/500/15})$$
$$R^2 = 0.9998 \quad \text{(X4.6)}$$

X5. HARDNESS CONVERSION EQUATION FOR ANNEALED AUSTENITIC STAINLESS STEEL PLATE (DETERMINED BRINELL HARDNESS NUMBERS TO ROCKWELL B HARDNESS NUMBERS)

X5.1 The following equation was generated from the specific hardness numbers contained in Table 5 and should not be used for converting numbers outside of the defined hardness range. Due to inherent inaccuracies in the conversion process, the converted number should be rounded to the nearest whole number in accordance with Practice E 29.

X5.1.1 From Brinell hardness (10-mm steel diameter ball, 3000-kgf force) to Rockwell B hardness:

$$\text{HRB} = +1.29998\text{E}{+}02 - 7.66860\text{E}{+}03(\text{HBS})^{-1}$$
$$R^2 = 0.9999 \quad \text{(X5.1)}$$

X6. HARDNESS CONVERSION EQUATIONS FOR AUSTENITIC STAINLESS STEEL SHEET (DETERMINED HARDNESS SCALE NUMBERS TO ROCKWELL C OR ROCKWELL B HARDNESS NUMBERS

X6.1 The following equations were generated from the specific hardness numbers contained in Table 6 and should not be used for converting numbers outside of the defined hardness range. Due to inherent inaccuracies in the conversion process, the converted number should be rounded to the nearest whole number in accordance with Practice E 29.

X6.1.1 From Rockwell A hardness to Rockwell C hardness:

$$\text{HRC} = -9.94148\text{E}{+}01 + 1.98137\text{E}{+}00(\text{HRA})$$
$$R^2 = 1.0000 \quad \text{(X6.1)}$$

X6.1.2 From Rockwell 15N hardness to Rockwell C hardness:

$$\text{HRC} = -1.16608\text{E}{+}02 + 1.95692\text{E}{+}00(\text{HR15N})$$
$$R^2 = 1.0000 \quad \text{(X6.2)}$$

X6.1.3 From Rockwell 30N hardness to Rockwell C hardness:

$$\text{HRC} = -2.79663\text{E}{+}01 + 1.14752\text{E}{+}00(\text{HR30N})$$
$$R^2 = 1.0000 \quad \text{(X6.3)}$$

X6.1.4 From Rockwell 45N hardness to Rockwell C hardness:

$$\text{HRC} = +2.25782\text{E}{+}00 + 8.78362\text{E}{-}01(\text{HR45N})$$
$$R^2 = 1.0000 \quad \text{(X6.4)}$$

X6.1.5 From Rockwell A hardness to Rockwell B hardness:

$$\text{HRB} = -5.16024\text{E}{+}00 + 1.71080\text{E}{+}00(\text{HRA})$$
$$R^2 = 1.0000 \quad \text{(X6.5)}$$

X6.1.6 From Rockwell F hardness to Rockwell B hardness:

$$HRB = -6.79918E+01 + 1.47539E+00(HRF)$$
$$R^2 = 0.9999 \quad \text{(X6.6)}$$

X6.1.7 From Rockwell 15T hardness to Rockwell B hardness:

$$HRB = -1.47089E+02 + 2.69928E+00(HR15T)$$
$$R^2 = 1.0000 \quad \text{(X6.7)}$$

X6.1.8 From Rockwell 30T hardness to Rockwell B hardness:

$$HRB = -1.56777E+01 + 1.43818E+00(HR30T)$$
$$R^2 = 1.0000 \quad \text{(X6.8)}$$

X6.1.9 From Rockwell 45T hardness to Rockwell B hardness:

$$HRB = +3.08896E+01 + 9.84321E-01(HR45T)$$
$$R^2 = 1.0000 \quad \text{(X6.9)}$$

X7. HARDNESS CONVERSION EQUATIONS FOR COPPER, NOS. 102 TO 142 INCLUSIVE (DETERMINED HARDNESS SCALE NUMBERS TO VICKERS HARDNESS NUMBERS)

X7.1 The following equations were generated from the specific hardness numbers contained in Table 7 and should not be used for converting numbers outside of the defined hardness range. Due to inherent inaccuracies in the conversion process, the converted number should be rounded to the nearest whole number in accordance with Practice E 29.

X7.1.1 From Vickers hardness (100-gf force) to Vickers hardness (1-kgf force):

$$HV\ 1 = -1.94066E+01 + 1.17624E+00(HV_{100})$$
$$R^2 = 0.9999 \quad \text{(X7.1)}$$

X7.1.2 From Knoop hardness (1-kgf force) to Vickers hardness (1-kgf force):

$$HV\ 1 = +1.1858E+01 + 6.42195E-01(HK_{1000}) + 1.50709E-03(HK_{1000})^2$$
$$R^2 = 0.9999 \quad \text{(X7.2)}$$

X7.1.3 From Knoop hardness (500 gf force) to Vickers hardness (1-kgf force):

$$HV\ 1 = +4.04249E+00 + 7.73167E-01(HK_{500}) + 1.22866E-03(HK_{500})^2$$
$$R^2 = 0.9998 \quad \text{(X7.3)}$$

X7.1.4 From Rockwell 15T hardness to Vickers hardness (1-kgf force) for 0.010-in. (0.25-mm) strip:

$$(HV\ 1)^{-1} = +3.37918E-01 - 1.15500E-02(HR15T) + 1.40059E-04(HR15T)^2 - 5.88157E-07(HR15T)^3$$
$$R^2 = 0.9997 \quad \text{(X7.4)}$$

X7.1.5 From Rockwell 15T hardness to Vickers hardness (1-kgf force) for 0.020-in. (0.51-mm) strip:

$$(HV\ 1)^{-1} = +1.25038E-01 - 3.80747E-03(HR15T) + 4.54150E-05(HR15T)^2 - 1.98661E-07(HR15T)^3$$
$$R^2 = 0.9997 \quad \text{(X7.5)}$$

X7.1.6 From Rockwell B hardness to Vickers hardness (1-kgf force) for 0.040-in. (1.02-mm) and greater strip:

$$(HV\ 1)^{-1} = +1.49881E-02 - 1.39326E-04(HRB) + 8.82686E-07(HRB)^2 - 6.30498E-09(HRB)^3$$
$$R^2 = 0.9999 \quad \text{(X7.6)}$$

X7.1.7 From Rockwell F hardness to Vickers hardness (1-kgf force) for 0.040-in. (1.02-mm) and greater strip:

$$(HV\ 1)^{-1} = +4.03378E-02 - 7.12218E-04(HRF) + 6.46922E-06(HRF)^2 - 2.64942E-08(HRF)^3$$
$$R^2 = 0.9998 \quad \text{(X7.7)}$$

X7.1.8 From Rockwell 15T hardness to Vickers hardness (1-kgf force) for 0.040-in. (1.02-mm) and greater strip:

$$(HV\ 1)^{-1} = +6.91162E-02 - 1.89938E-03(HR15T) + 2.43142E-05(HR15T)^2 - 1.21657E-07(HR15T)^3$$
$$R^2 = 0.9994 \quad \text{(X7.8)}$$

X7.1.9 From Rockwell 30T hardness to Vickers hardness (1-kgf force) for 0.040-in. (1.02-mm) and greater strip:

$$(HV\ 1)^{-1} = +2.12081E-02 - 2.79029E-04(HR30T) + 1.85833E-06(HR30T)^2 - 9.41015E-09(HR30T)^3$$
$$R^2 = 0.9999 \quad \text{(X7.9)}$$

X7.1.10 From Rockwell 45T hardness to Vickers hardness (1-kgf force) for 0.040-in. (1.02-mm) and greater strip:

$$(HV\ 1)^{-1} = +1.33602E-02 - 1.16936E-04(HR45T) - 2.02801E-07(HR45T)^2 + 4.40268E-09(HR45T)^3$$
$$R^2 = 0.9995 \quad \text{(X7.10)}$$

X7.1.11 From Brinell hardness (10-mm diameter steel ball, 500-kgf force) to Vickers hardness (1-kgf force) for 0.080- in. (2.03-mm) strip:

$$HV\ 1 = +2.77693E+01 + 8.62358E-01(HBS\ 10/500/15) - 3.66858E-04(HBS\ 10/500/15)^2$$
$$R^2 = 0.9999 \quad \text{(X7.11)}$$

X7.1.12 From Brinell hardness (2-mm diameter steel ball, 20-kgf force) to Vickers hardness (1-kgf force) for 0.040 in. (1.02-mm) strip:

$$HV\ 1 = -1.01087E+00 + 1.18352E+00(HBS\ 2/20/15) - 7.02625E-04(HBS\ 2/20/15)^2$$
$$R^2 = 0.9999 \quad \text{(X7.12)}$$

X8. HARDNESS CONVERSION EQUATIONS FOR ALLOYED WHITE IRON (DETERMINED HARDNESS SCALE NUMBERS TO VICKERS HARDNESS NUMBERS)

X8.1 The following equations were generated from the specific hardness numbers contained in Table 8 and should not be used for converting numbers outside of the defined hardness range. Due to inherent inaccuracies in the conversion process, the converted number should be rounded to the nearest whole number in accordance with Practice E 29.

X8.1.1 From Brinell hardness (10-mm diameter tungsten carbide ball, 3000-kgf force) to Vickers hardness (50-kgf force):

$$\text{HV 50} = -2.61008\text{E}+01 + 1.13635\text{E}+00(\text{HBW})$$
$$R^2 = 1.0000 \quad \text{(X8.1)}$$

X8.1.2 From Rockwell C hardness to Vickers hardness (50-kgf force):

$$\text{HV 50} = +5.72753\text{E}+02 - 1.71996\text{E}+01(\text{HRC}) + 3.33893\text{E}-01(\text{HRC})^2$$
$$R^2 = 0.9991 \quad \text{(X8.2)}$$

X9. HARDNESS CONVERSION EQUATIONS FOR WROUGHT ALUMINUM PRODUCTS (DETERMINED HARDNESS SCALE NUMBERS TO BRINELL HARDNESS NUMBERS)

X9.1 The following equations were generated from the specific hardness numbers contained in Table 9 and should not be used for converting numbers outside of the defined hardness range. Due to inherent inaccuracies in the conversion process, the converted number should be rounded to the nearest whole number in accordance with Practice E 29.

X9.1.1 From Vickers hardness (15-kgf force) to Brinell hardness (10-mm diameter steel ball, 500-kgf force):

$$\text{HBS 10/500/15} = +3.76211\text{E}+00 + 8.25368\text{E}-01(\text{HV 15})$$
$$R^2 = 1.0000 \quad \text{(X9.1)}$$

X9.1.2 From Rockwell B hardness to Brinell hardness (10-mm diameter steel ball, 500-kgf force):

$$(\text{HBS 10/500/15})^{-1} = +2.09261\text{E}-02 - 3.13747\text{E}-04(\text{HRB}) + 3.24720\text{E}-06(\text{HRB})^2 - 1.71476\text{E}-08(\text{HRB})^3$$
$$R^2 = 0.9995 \quad \text{(X9.2)}$$

X9.1.3 From Rockwell E hardness to Brinell hardness (10-mm diameter steel ball, 500-kgf force):

$$(\text{HBS 10/500/15})^{-1} = +7.44356\text{E}-02 - 1.82782\text{E}-03(\text{HRE}) + 2.04718\text{E}-05(\text{HRE})^2 - 8.75260\text{E}-08(\text{HRE})^3$$
$$R^2 = 0.9989 \quad \text{(X9.3)}$$

X9.1.4 From Rockwell H hardness to Brinell hardness (10-mm diameter steel ball, 500-kgf force):

$$(\text{HBS 10/500/15})^{-1} = +4.00460\text{E}-01 - 1.06615\text{E}-02(\text{HRH}) + 1.02525\text{E}-04(\text{HRH})^2 - 3.44242\text{E}-07(\text{HRH})^3$$
$$R^2 = 0.9995 \quad \text{(X9.4)}$$

X9.1.5 From Rockwell 15T hardness to Brinell hardness (10-mm diameter steel ball, 500-kgf force):

$$(\text{HBS 10/500/15})^{-1} = +3.35165\text{E}-01 - 1.16197\text{E}-02(\text{HR15T}) + 1.44778\text{E}-04(\text{HR15T})^2 - 6.26187\text{E}-07(\text{HR15T})^3$$
$$R^2 = 0.9988 \quad \text{(X9.5)}$$

X9.1.6 From Rockwell 30T hardness to Brinell hardness (10-mm diameter steel ball, 500-kgf force):

$$(\text{HBS 10/500/15})^{-1} = +4.68610\text{E}-02 - 1.24964\text{E}-03(\text{HR30T}) + 1.45528\text{E}-05(\text{HR30T})^2 - 6.71417\text{E}-08(\text{HR30T})^3$$
$$R^2 = 0.9994 \quad \text{(X9.6)}$$

X9.1.7 From Rockwell 15W hardness to Brinell hardness (10-mm diameter steel ball, 500-kgf force):

$$(\text{HBS 10/500/15}) = -7.10127\text{E}+03 + 2.71267\text{E}+02(\text{HR15W}) - 3.46213\text{E}+00(\text{HR15W})^2 + 1.48551\text{E}-02(\text{HR15W})^3$$
$$R^2 = 0.9924 \quad \text{(X9.7)}$$

X10. EFFECT OF STRAIN HARDENING ON HARDNESS CONVERSION RELATIONSHIPS

X10.1 For ferrous and nonferrous metals softer than 240 HB, a single set of hardness conversion relationships inevitably introduces large errors because of the wide difference that may exist in the amount of cold working before testing, as well as the amount that occurs during the test itself. This dependence on strain-hardening characteristics can be demonstrated by the Rockwell scales 15-T, 30-T, 45-T, F, and B, in which forces ranging from 15 to 100 kgf are applied on a 1⁄16-in. (1.588-mm) diameter ball indenter. As higher forces are used, the increased strain raises the hardness by an amount that depends on the pretest capacity of the metal for strain hardening. An annealed metal of high capacity for strain hardening will harden much more in the test than will a cold-worked metal. For example, an annealed iron and a cold-rolled aluminum alloy may have hardnesses of 71 and 72 HR 15T, respectively. The hardnesses are 31 HRB for the soft annealed iron and 7 HRB for the cold-rolled aluminum alloy.

X10.2 On the other hand, if materials have Brinell or Rockwell hardness values that are approximately equal in the annealed state as well as after heavy cold deformation, these materials will have similar hardness conversion relationships

for all degrees of strain hardening. This is true of yellow brasses and low-carbon steels and irons. The limiting conditions can usually be identified by the appearance of the hardness indentations themselves. Soft annealed metals have characteristic“ sinking” type indentation contours when indenters of the ball type are used. On the other hand, heavily cold-worked metals have sharp “ridging” type indentations. While annealed metals are being progressively cold worked, the indentation contours pass through a “flat” stage in which the lip of the indentation is neither round nor sharply ridged. It is necessary to base hardness conversions on comparative tests of similar materials that also have very similar mechanical properties.