SAE The Engineering Society For Advancing Mobility Land Sea Air and Space®
INTERNATIONAL
400 Commonwealth Drive, Warrendale, PA 15096-0001

SURFACE VEHICLE STANDARDSTANDARD

SAE J417

REV. DEC83

Issued 1946-01
Revised 1983-12

Submitted for recognition as an American National Standard

HARDNESS TESTS AND HARDNESS NUMBER CONVERSIONS

Foreword—This Document has not changed other than to put it into the new SAE Technical Standards Board Format.

1. Scope—This report lists approximate hardness conversion values; test methods for Vickers Hardness, Brinell Hardness, Rockwell Hardness Rockwell Superficial Hardness, Shore Hardness; and information regarding surface preparation, specimen thickness, effect of curved surfaces, and recommendations for Rockwell surface hardness testing for case hardened parts.

The tables in this report give the approximate relationship of Vickers Brinell, Rockwell, and Scleroscope hardness values and corresponding approximate tensile strengths of steels. It is impossible to give exact relationships because of the inevitable influence of size, mass, composition, and method of heat treatment. Where more precise conversions are required, they should be developed specially for each steel composition, heat treatment, and part.

The accompanying conversion tables for steel hardness numbers are based on extensive tests on carbon and alloy steels, mostly in the heat treated condition, but have been found to be reliable on practically all constructional alloy steels and tool steels in the as-forged, annealed, normalized, and quenched and tempered conditions, provided they are homogeneous. Such special cases as high manganese steel, 18% chromium—8% nickel steel and other austenitic steels, and nickel base alloys, as well as constructional alloy steels and tool steels in the cold worked condition, may not conform to the relationships given with the same degree of accuracy as the steels for which the tables are intended.

All numbers in these tables given in bold face type were prepared jointly by the American Society for Testing and Materials, the American Society for Metals, and SAE from carefully checked data. The values given in regular face type were taken from the Army-Navy Approximate Hardness Tensile Strength Relationship of Carbon and Low Alloy Steels (ANQQ-H-201) published in the 1943 SAE Handbook, with only minor adjustments.

QUESTIONS REGARDING THIS DOCUMENT: (412) 772-8512 FAX: (412) 776-0243
TO PLACE A DOCUMENT ORDER; (412) 776-4970 FAX: (412) 776-0790
SAE WEB ADDRESS http://www.sae.org

2. References

2.1 Applicable Publications—The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest version of SAE publications shall apply.

2.1.1 SAE PUBLICATION—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J423—Methods of Measuring Case Depth
ANQQ-H-201—Army-Navy Approximate hardness Tensile Strength Relationship of Carbon and Low Alloy Steels (published in the 1943 SAE Handbook)

2.1.2 ASTM PUBLICATION—Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM E 10—Test Method for Brinell Hardness of Metallic Materials
ASTM E 18—Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials

3. *Use of Conversion Tables*—The conversions given in the accompanying Tables 1, 2, and 3 are recommended for use in converting the results of one form of hardness test to another only on flat surfaces and only when the specific test procedures and precautions outlined in the several hardness test methods are followed. Attention is called to the limitation in ASTM E 10 (Brinell Hardness Tests) on the use of the standard steel ball to hardness values less than 450 HB, and the use of a tungsten carbide ball to hardness values less than 630 HB. The Rockwell Superficial and Vickers Hardness tests require especially smooth surfaces for accurate results. In all tests, a specimen should be of sufficient thickness to avoid anvil effect—which thickness is roughly 10 times the depth of the indentation. It is important that conversions from Brinell Hardness to shallow impression type tests, such as Rockwell Superficial and Vickers Hardness tests, be made only on materials that are of uniform hardness to a depth at least 10 times that of the indentation. Such hardness conversions should not be made on surface hardened, coated, or decarburized surfaces. Although the Rockwell Hardness and the Rockwell Superficial Hardness values in the tables are given to tenths of a point in order to maintain exact relationships between the various scales, it is customary to report these values to the nearest point. Experience has shown that even under carefully controlled conditions, some deviations from the conversion relationships will occur.

The numbers given in parentheses in the tables are values beyond the practical range of usefulness of the type of' test under which they appear and have no strict application. They are included in the tables as a matter of information only, and should not be used for specifications.

4. *Vickers Hardness (HV), Table I*—Vickers Hardness is determined by forcing a square base diamond pyramid having an apex angle of 136 deg into the test specimen under loads usually of 3-50 kg and measuring the diagonals of the recovered indentations. The Vickers Hardness is defined as the load per unit area of surface contact in kilograms per square millimeter as calculated from the average diagonal as follows:

$$HV = \frac{2L \sin\frac{a}{2}}{d^2} \qquad \text{(Eq. 1)}$$

where:

HV = Vickers Hardness
d = length of average diagonal in millimeters
a = apex angle = 136 deg
L = load in kilograms

For further information on standard methods of Vickers Hardness Testing, refer to ASTM E 92-72.

TABLE 1—APPROXIMATE EQUIVALENT HARDNESS NUMBERS[a] FOR VICKERS HARDNESS NUMBERS (HV), FOR STEEL

	Brinell Hardness No. 10-mm Ball, 3000-kg Load[b]		Rockwell Hardness No.[b]				Rockwell Superficial Hardness No., Superficial Brale Penetrator					
Vickers Hardness No.	Standard Ball	Tungsten-Carbide Ball	A-Scale, 60-kg Load, Brale Penetrator	B-Scale, 100-kg Load, 1.6-mm (1/16-in) Dia Ball	C-Scale, 150-kg Load, Brale Penetrator	D-Scale, 100-kg Load, Brale Penetrator	15-N Scale, 15-kg Load	30-N Scale, 30-kg Load	45-N Scale, 45-kg Load	Shore Scleroscope Hardness No.	Tensile Strength (Approximate) in MPa (1000 psi)	Vickers Hardness No.
Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col. 10	Col. 11	Col. 12	Col. 13
940	—	—	85.6	—	68.0	76.9	93.2	84.4	75.4	97	—	940
920	—	—	85.3	—	67.5	76.5	93.0	84.0	74.8	96	—	920
900	—	—	85.0	—	67.0	76.1	92.9	83.6	74.2	95	—	900
880	—	(767)	84.7	—	66.4	75.7	92.7	83.1	73.6	93	—	880
860	—	(757)	84.4	—	65.9	75.3	92.5	82.7	73.1	92	—	860
840	—	(745)	84.1	—	65.3	74.8	92.3	82.2	72.2	91	—	840
820	—	(733)	83.8	—	64.7	74.3	92.1	81.7	71.8	90	—	820
800	—	(722)	83.4	—	64.0	73.8	91.8	81.1	71.0	88	—	800
780	—	(710)	83.0	—	63.3	73.3	91.5	80.4	70.2	87	—	780
760	—	(698)	82.6	—	62.5	72.6	91.2	79.7	69.4	86	—	760
740	—	(684)	82.2	—	61.8	72.1	91.0	79.1	68.6	84	—	740
720	—	(670)	81.8	—	61.0	71.5	90.7	78.4	67.7	83	—	720
700	—	(656)	81.3	—	60.1	70.8	90.3	77.6	66.7	81	—	700
690	—	(647)	81.1	—	59.7	70.5	90.1	77.2	66.2	—	—	690
680	—	(638)	80.8	—	59.2	70.1	89.8	76.8	65.7	80	—	680
670	—	630	80.6	—	58.8	69.8	89.7	76.4	65.3	—	—	670
660	—	620	80.3	—	58.3	69.4	89.5	75.9	64.7	79	—	660
650	—	611	80.0	—	57.8	69.0	89.2	75.5	64.1	—	—	650
640	—	601	79.8	—	57.3	68.7	89.0	75.1	63.5	77	—	640
630	—	591	79.5	—	56.8	68.3	88.8	74.6	63.0	—	—	630
620	—	582	79.2	—	56.3	67.9	88.5	74.2	62.4	75	—	620
610	—	573	78.9	—	55.7	67.5	88.2	73.6	61.7	—	—	610
600	—	564	78.6	—	55.2	67.0	88.0	73.2	61.2	74	—	600
590	—	554	78.4	—	54.7	66.7	87.8	72.7	60.5	—	2055 (298)	590
580	—	545	78.0	—	54.1	66.2	87.5	72.1	59.9	72	2020 (293)	580
570	—	535	77.8	—	53.6	65.8	87.2	71.7	59.3	—	1985 (288)	570
560	—	525	77.4	—	53.0	65.4	86.9	71.2	58.6	71	1950 (283)	560
550	(505)	517	77.0	—	52.3	64.8	86.6	70.5	57.8	—	1905 (276)	550
540	(496)	507	76.7	—	51.7	64.4	86.3	70.0	57.0	69	1860 (270)	540
530	(488)	497	76.4	—	51.1	63.9	86.0	69.5	56.2	—	1825 (265)	530
520	(480)	488	76.1	—	50.5	63.5	85.7	69.0	55.6	67	1795 (260)	520
510	(473)	479	75.7	—	49.8	62.9	85.4	68.3	54.7	—	1750 (254)	510
500	(465)	471	75.3	—	49.1	62.2	85.0	67.7	53.9	66	1705 (247)	500
490	(456)	460	74.9	—	48.4	61.6	84.7	67.1	53.1	—	1660 (241)	490
480	448	452	74.5	—	47.7	61.3	84.3	66.4	52.2	64	1620 (235)	480
470	441	442	74.1	—	46.9	60.7	83.9	65.7	51.3	—	1570 (228)	470
460	433	433	73.6	—	46.1	60.1	83.6	64.9	50.4	62	1530 (222)	460
450	425	425	73.3	—	45.3	59.4	83.2	64.3	49.4	—	1495 (217)	450
440	415	415	72.8	—	44.5	58.8	82.8	63.5	48.4	59	1460 (212)	440
430	405	405	72.3	—	43.6	58.2	82.3	62.7	47.4	—	1410 (205)	430
420	397	397	71.8	—	42.7	57.5	81.8	61.9	46.4	57	1370 (199)	420
410	388	388	71.4	—	41.8	56.8	81.4	61.1	45.3	—	1330 (193)	410
400	379	379	70.8	—	40.8	56.0	81.0	60.2	44.1	55	1290 (187)	400
390	369	369	70.3	—	39.8	55.2	80.3	59.3	42.9	—	1240 (180)	390
380	360	360	69.8	(110.0)	38.8	54.4	79.8	58.4	41.7	52	1205 (175)	380
370	350	350	69.2	—	37.7	53.6	79.2	57.4	40.4	—	1170 (170)	370
360	341	341	68.7	(109.0)	36.6	52.8	78.6	56.4	39.1	50	1130 (164)	360
350	331	331	68.1	—	35.5	51.9	78.0	55.4	37.8	—	1095 (159)	350
340	322	322	67.6	(108.0)	34.4	51.1	77.4	54.4	36.5	47	1070 (155)	340
330	313	313	67.0	—	33.3	50.2	76.8	53.6	35.2	—	1035 (150)	330
320	303	303	66.4	(107.0)	32.2	49.4	76.2	52.3	33.9	45	1005 (146)	320
310	294	294	65.8	—	31.0	48.4	75.6	51.3	32.5	—	980 (142)	310
300	284	284	65.2	(105.5)	29.8	47.5	74.9	50.2	31.1	42	950 (138)	300
295	280	280	64.8	—	29.2	47.1	74.6	49.7	30.4	—	935 (136)	295
290	275	275	64.5	(104.5)	28.5	46.5	74.2	49.0	29.5	41	915 (133)	290
285	270	270	64.2	—	27.8	46.0	73.8	48.4	28.7	—	905 (131)	285
280	265	265	63.8	(103.5)	27.1	45.3	73.4	47.8	27.9	40	890 (129)	280
275	261	261	63.5	—	26.4	44.9	73.0	47.2	27.1	—	875 (127)	275
270	256	256	63.1	(102.0)	25.6	44.3	72.6	46.4	26.2	38	855 (124)	270
265	252	252	62.7	—	24.8	43.7	72.1	45.7	25.2	—	840 (122)	265
260	247	247	62.4	(101.0)	24.0	43.1	71.6	45.0	24.3	37	825 (120)	260
255	243	243	62.0	—	23.1	42.2	71.1	44.2	23.2	—	805 (117)	255
250	238	238	61.6	99.5	22.2	41.7	70.6	43.4	22.2	36	795 (115)	250
245	233	233	61.2	—	21.3	41.1	70.1	42.5	21.1	—	780 (113)	245
240	228	228	60.7	98.1	20.3	40.3	69.6	41.7	19.9	34	765 (111)	240
230	219	219	—	96.7	(18.0)	—	—	—	—	33	730 (106)	230
220	209	209	—	95.0	(15.7)	—	—	—	—	32	695 (101)	220
210	200	200	—	93.4	(13.4)	—	—	—	—	30	670 (97)	210
200	190	190	—	91.5	(11.0)	—	—	—	—	29	635 (92)	200
190	181	181	—	89.5	(8.5)	—	—	—	—	28	605 (88)	190

(Table continued on next page)

TABLE 1—APPROXIMATE EQUIVALENT HARDNESS NUMBERS[a] FOR VICKERS HARDNESS NUMBERS (HV), FOR STEEL
(continued)

Vickers Hardness No.	Brinell Hardness No. 10-mm Ball, 3000-kg Load[b]		Rockwell Hardness No.[b]				Rockwell Superficial Hardness No., Superficial Brale Penetrator			Shore Scleroscope Hardness No.	Tensile Strength (Approximate) in MPa (1000 psi)	Vickers Hardness No.
	Standard Ball	Tungsten-Carbide Ball	A-Scale, 60-kg Load, Brale Penetrator	B-Scale, 100-kg Load, 1.6-mm (1/16-in) Dia Ball	C-Scale, 150-kg Load, Brale Penetrator	D-Scale, 100-kg Load, Brale Penetrator	15-N Scale, 15-kg Load	30-N Scale, 30-kg Load	45-N Scale, 45-kg Load			
Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col. 10	Col. 11	Col. 12	Col. 13
180	171	171	—	87.1	(6.0)	—	—	—	—	26	580 (84)	180
170	162	162	—	85.0	(3.0)	—	—	—	—	25	545 (79)	170
160	152	152	—	81.7	(0.0)	—	—	—	—	24	515 (75)	160
150	143	143	—	78.7	—	—	—	—	—	22	490 (71)	150
140	133	133	—	75.0	—	—	—	—	—	21	455 (66)	140
130	124	124	—	71.2	—	—	—	—	—	20	425 (62)	130
120	114	114	—	66.7	—	—	—	—	—	—	390 (57)	120
110	105	105	—	62.3	—	—	—	—	—	—	—	110
100	95	95	—	56.2	—	—	—	—	—	—	—	100
95	90	90	—	52.0	—	—	—	—	—	—	—	95
90	86	86	—	48.0	—	—	—	—	—	—	—	90
85	81	81	—	41.0	—	—	—	—	—	—	—	85

[a] The values in this table shown in **bold face type** correspond to the values shown in the corresponding joint SAE-ASM-ASTM Committee on Hardness Conversions as printed in ASTM E 140, Table 1.
[b] Values in ( ) are beyond normal range and are given for information only.

TABLE 2—APPROXIMATE EQUIVALENT HARDNESS NUMBERS[a] FOR BRINELL HARDNESS NUMBERS[b], FOR STEEL

Brinell Indentation Dia, mm	Brinell Hardness No.,[b] 10-mm Ball, 3000-kg Load		Vickers Hardness No.	Rockwell Hardness No.[b]				Rockwell Superficial Hardness No. Superficial Brale Penetrator			Shore Sclero-scope Hardness No.	Tensile Strength (Approxi-mate) in MPa (1000 psi)	Brinell Indentation Dia, mm
	Standard Ball	Tungsten-Carbide Ball		A-Scale, 60-kg Load, Brale Penetrator	B-Scale, 100-kg Load 1.6-mm (1/16-in) Dia Ball	C-Scale, 150-kg Load Brale Penetrator	D-Scale, 100-kg Load Brale Penetrator	15-N Scale, 15-kg Load	30-N Scale, 30-kg Load	45-N Scale, 45-kg Load			
Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col. 10	Col. 11	Col. 12	Col. 13	Col. 14
—	—	—	940	85.6	—	68.0	76.9	93.2	84.4	75.4	97	—	—
—	—	—	920	85.3	—	67.5	76.5	93.0	84.0	74.8	96	—	—
—	—	—	900	85.0	—	67.0	76.1	92.9	83.6	74.2	95	—	—
—	—	(767)	880	84.7	—	66.4	75.7	92.7	83.1	73.6	93	—	—
—	—	(757)	860	84.4	—	65.9	75.3	92.5	82.7	73.1	92	—	—
2.25	—	(745)	840	84.1	—	65.3	74.8	92.3	82.2	72.2	91	—	2.25
—	—	(733)	820	83.8	—	64.7	74.3	92.1	81.7	71.8	90	—	—
—	—	(722)	800	83.4	—	64.0	73.8	91.8	81.1	71.0	88	—	—
2.30	—	(712)	—	—	—	—	—	—	—	—	—	—	2.30
—	—	(710)	780	83.0	—	63.3	73.3	91.5	80.4	70.2	87	—	—
—	—	(698)	760	82.6	—	62.5	72.6	91.2	79.7	69.4	86	—	—
—	—	(684)	740	82.2	—	61.8	72.1	91.0	79.1	68.6	—	—	—
2.35	—	(682)	**737**	**82.2**	—	**61.7**	**72.0**	**91.0**	**79.0**	**68.5**	84	—	**2.35**
—	—	(670)	720	81.8	—	61.0	71.5	90.7	78.4	67.7	83	—	—
—	—	(656)	700	81.3	—	60.1	70.8	90.3	77.6	66.7	—	—	—
2.40	—	(653)	**697**	**81.2**	—	**60.0**	**70.7**	**90.2**	**77.5**	**66.5**	81	—	**2.40**
—	—	(647)	690	81.1	—	59.7	70.5	90.1	77.2	66.2	—	—	—
—	—	(638)	680	80.8	—	59.2	70.1	89.8	76.8	65.7	80	—	—
—	—	630	670	80.6	—	58.8	69.8	89.7	76.4	65.3	—	—	—
2.45	—	**627**	**667**	**80.5**	—	**58.7**	**69.7**	**89.6**	**76.3**	**65.1**	79	—	**2.45**
2.50	—	—	**677**	**80.7**	—	**59.1**	**70.0**	**89.8**	**76.8**	**65.7**	—	—	**2.50**
	—	**601**	**640**	**79.8**	—	**57.3**	**68.7**	**89.0**	**75.1**	**63.5**	77	—	
2.55	—	—	**640**	**79.8**	—	**57.3**	**68.7**	**89.0**	**75.1**	**63.5**	—	—	**2.55**
	—	**578**	**615**	**79.1**	—	**56.0**	**67.7**	**88.4**	**73.9**	**62.1**	75	—	
2.60	—	—	**607**	**78.8**	—	**55.6**	**67.4**	**88.1**	**73.5**	**61.6**	—	—	**2.60**
	—	**555**	**591**	**78.4**	—	**54.7**	**66.7**	**87.8**	**72.7**	**60.6**	73	2055 (298)	
2.65	—	—	**579**	**78.0**	—	**54.0**	**66.1**	**87.5**	**72.0**	**59.8**	—	2015 (292)	**2.65**
	—	**534**	**569**	**77.8**	—	**53.5**	**65.8**	**87.2**	**71.6**	**59.2**	71	1985 (288)	
2.70	—	—	**553**	**77.1**	—	**52.5**	**65.0**	**86.7**	**70.7**	**58.0**	—	1915 (278)	**2.70**
	—	**514**	**547**	**76.9**	—	**52.1**	**64.7**	**86.5**	**70.3**	**57.6**	70	1890 (274)	
2.75	(495)	—	**539**	**76.7**	—	**51.6**	**64.3**	**86.3**	**69.9**	**56.9**	—	1855 (269)	**2.75**
	—	—	**530**	**76.4**	—	**51.1**	**63.9**	**86.0**	**69.5**	**56.2**	—	1825 (265)	
	—	**495**	**528**	**76.3**	—	**51.0**	**63.8**	**85.9**	**69.4**	**56.1**	68	1820 (264)	
2.80	(477)	—	**516**	**75.9**	—	**50.3**	**63.2**	**85.6**	**68.7**	**55.2**	—	1780 (258)	**2.80**
	—	—	**508**	**75.6**	—	**49.6**	**62.7**	**85.3**	**68.2**	**54.5**	—	1740 (252)	
	—	**477**	**508**	**75.6**	—	**49.6**	**62.7**	**85.3**	**68.2**	**54.5**	66	1740 (252)	

(Table continued on next page)

TABLE 2—APPROXIMATE EQUIVALENT HARDNESS NUMBERS[a] FOR BRINELL HARDNESS NUMBERS[b], FOR STEEL (continued)

Brinell Indentation Dia, mm	Brinell Hardness No.,[b] 10-mm Ball, 3000-kg Load		Vickers Hardness No.	Rockwell Hardness No.[b]				Rockwell Superficial Hardness No. Superficial Brale Penetrator			Shore Scleroscope Hardness No.	Tensile Strength (Approximate) in MPa (1000 psi)	Brinell Indentation Dia, mm
	Standard Ball	Tungsten-Carbide Ball		A-Scale, 60-kg Load, Brale Penetrator	B-Scale, 100-kg Load 1.6-mm (1/16-in) Dia Ball	C-Scale, 150-kg Load Brale Penetrator	D-Scale, 100-kg Load Brale Penetrator	15-N Scale, 15-kg Load	30-N Scale, 30-kg Load	45-N Scale, 45-kg Load			
Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col. 10	Col. 11	Col. 12	Col. 13	Col. 14
2.85	(461)	—	495	75.1	—	48.8	61.9	84.9	67.4	53.5	—	1680 (244)	2.85
	—	—	491	74.9	—	48.5	61.7	84.7	67.2	53.2	—	1670 (242)	
	—	461	491	74.9	—	48.5	61.7	84.7	67.2	53.2	65	1670 (242)	
2.90	444	—	474	74.3	—	47.2	61.0	84.1	66.0	51.7	—	1595 (231)	2.90
	—	—	472	74.2	—	47.1	60.8	84.0	65.8	51.5	—	1585 (230)	
	—	444	472	74.2	—	47.1	60.8	84.0	65.8	51.5	63	1585 (230)	
2.95	429	429	455	73.4	—	45.7	59.7	83.4	64.6	49.9	61	1510 (219)	2.95
3.00	415	415	440	72.8	—	44.5	58.8	82.8	63.5	48.4	59	1460 (212)	3.00
3.05	401	401	425	72.0	—	43.1	57.8	82.0	62.3	46.9	58	1390 (202)	3.05
3.10	388	388	410	71.4	—	41.8	56.8	81.4	61.1	45.3	56	1330 (193)	3.10
3.15	375	375	396	70.6	—	40.4	55.7	80.6	59.9	43.6	54	1270 (184)	3.15
3.20	363	363	383	70.0	—	39.1	54.6	80.0	58.7	42.0	52	1220 (177)	3.20
3.25	352	352	372	69.3	(110.0)	37.9	53.8	79.3	57.6	40.5	51	1180 (171)	3.25
3.30	341	341	360	68.7	(109.0)	36.6	52.8	78.6	56.4	39.1	50	1130 (164)	3.30
3.35	331	331	350	68.1	(108.5)	35.5	51.9	78.0	55.4	37.8	48	1095 (159)	3.35
3.40	321	321	339	67.5	(108.0)	34.3	51.0	77.3	54.3	36.4	47	1060 (154)	3.40
3.45	311	311	328	66.9	(107.5)	33.1	50.0	76.7	53.3	34.4	46	1025 (149)	3.45
3.50	302	302	319	66.3	(107.0)	32.1	49.3	76.1	52.2	33.8	45	1005 (146)	3.50
3.55	293	293	309	65.7	(106.0)	30.9	48.3	75.5	51.2	32.4	43	970 (141)	3.55
3.60	285	285	301	65.3	(105.5)	29.9	47.6	75.0	50.3	31.2	—	950 (138)	3.60
3.65	277	277	292	64.6	(104.5)	28.8	46.7	74.4	49.3	29.9	41	925 (134)	3.65
3.70	269	269	284	64.1	(104.0)	27.6	45.9	73.7	48.3	28.5	40	895 (130)	3.70
3.75	262	262	276	63.6	(103.0)	26.6	45.0	73.1	47.3	27.3	39	875 (127)	3.75
3.80	255	255	269	63.0	(102.0)	25.4	44.2	72.5	46.2	26.0	38	850 (123)	3.80
3.85	248	248	261	62.5	(101.0)	24.2	43.2	71.7	45.1	24.5	37	825 (120)	3.85
3.90	241	241	253	61.8	100.0	22.8	42.0	70.9	43.9	22.8	36	800 (116)	3.90
3.95	235	235	247	61.4	99.0	21.7	41.4	70.3	42.9	21.5	35	785 (114)	3.95
4.00	229	229	241	60.8	98.2	20.5	40.5	69.7	41.9	20.1	34	765 (111)	4.00
4.05	223	223	234	—	97.3	(18.8)	—	—	—	—	—	—	4.05
4.10	217	217	228	—	96.4	(17.5)	—	—	—	—	33	725 (105)	4.10
4.15	212	212	222	—	95.5	(16.0)	—	—	—	—	—	705 (102)	4.15
4.20	207	207	218	—	94.6	(15.2)	—	—	—	—	32	690 (100)	4.20
4.25	201	201	212	—	93.8	(13.8)	—	—	—	—	31	675 (98)	4.25
4.30	197	197	207	—	92.8	(12.7)	—	—	—	—	30	655 (95)	4.30
4.35	192	192	202	—	91.9	(11.5)	—	—	—	—	29	640 (93)	4.35
4.40	187	187	196	—	90.7	(10.0)	—	—	—	—	—	620 (90)	4.40
4.45	183	183	192	—	90.0	(9.0)	—	—	—	—	28	615 (89)	4.45
4.50	179	179	188	—	89.0	(8.0)	—	—	—	—	27	600 (87)	4.50
4.55	174	174	182	—	87.8	(6.4)	—	—	—	—	—	585 (85)	4.55
4.60	170	170	178	—	86.8	(5.4)	—	—	—	—	26	570 (83)	4.60
4.65	167	167	175	—	86.0	(4.4)	—	—	—	—	—	560 (81)	4.65
4.70	163	163	171	—	85.0	(3.3)	—	—	—	—	25	545 (79)	4.70
4.80	156	156	163	—	82.9	(0.9)	—	—	—	—	—	525 (76)	4.80
4.90	149	149	156	—	80.8	—	—	—	—	—	23	505 (73)	4.90
5.00	143	143	150	—	78.7	—	—	—	—	—	22	490 (71)	5.00
5.10	137	137	143	—	76.4	—	—	—	—	—	21	460 (67)	5.10
5.20	131	131	137	—	74.0	—	—	—	—	—	—	450 (65)	5.20
5.30	126	126	132	—	72.0	—	—	—	—	—	20	435 (63)	5.30
5.40	121	121	127	—	69.8	—	—	—	—	—	19	415 (60)	5.40
5.50	116	116	122	—	67.6	—	—	—	—	—	18	400 (58)	5.50
5.60	111	111	117	—	65.7	—	—	—	—	—	15	385 (56)	5.60

[a] This table corresponds to the table in ASM Metals Handbook, 8th Edition, Vol. 1, page 1235, and is included in this report for convenience. It has been modified to add metric equivalents for approximate tensile strength values, and to indicate Brinell hardness values that are beyond the recommended range for this test.

[b] Values in ( ) are beyond normal range and are given for information only.

TABLE 3—BRINELL HARDNESS NUMBERS (10 MM BALL DIAMETER)

Dia of Indentation, mm	Loads, kg						Dia of Indentation, mm	Loads, kg					
	500[a]	1000	1500	2000	2500	3000[b]		500[a]	1000	1500	2000	2500	3000[b]
2.00	158	316	473	632	788	945	4.25	33.6	67.2	101	134	167	201
2.05	150	300	450	600	750	899	4.30	32.8	65.6	98.5	131	164	197
2.10	143	286	428	572	714	856	4.35	32.0	64.0	96.0	128	160	192
2.15	136	272	409	544	681	817	4.40	31.2	62.4	93.5	125	156	187
2.20	130	260	390	520	650	780	4.45	30.5	61.0	91.5	122	153	183
2.25	124	248	373	496	621	745	4.50	29.8	59.6	89.5	119	149	179
2.30	119	238	356	476	593	712	4.55	29.1	58.2	87.0	116	145	174
2.35	114	228	341	456	568	682	4.60	28.4	56.8	85.0	114	142	170
2.40	109	218	327	436	545	653	4.65	27.8	55.6	83.5	111	139	167
2.45	104	208	314	416	522	627	4.70	27.1	54.2	81.5	108	136	163
2.50	100	200	301	400	500	601	4.75	26.5	53.0	79.5	106	133	159
2.55	96.3	193	289	385	482	578	4.80	25.9	51.8	78.0	104	130	156
2.60	92.6	185	278	370	462	555	4.85	25.4	50.8	76.0	102	127	152
2.65	89.0	178	267	356	445	534	4.90	24.8	49.6	74.5	99.2	124	149
2.70	85.7	171	257	343	429	514	4.95	24.3	48.6	73.0	97.2	122	146
2.75	82.6	165	248	330	413	495	5.00	23.8	47.6	71.5	95.2	119	143
2.80	79.6	159	239	318	398	477	5.05	23.3	46.6	70.0	93.2	117	140
2.85	76.8	154	231	307	384	461	5.10	22.8	45.6	68.5	91.2	114	137
2.90	74.1	148	222	296	371	444	5.15	22.3	44.6	67.0	89.2	112	134
2.95	71.5	143	215	286	358	429	5.20	21.8	43.6	65.5	87.2	109	131
3.00	69.1	138	208	276	346	415	5.25	21.4	42.8	64.0	85.6	107	128
3.05	66.8	134	201	267	334	401	5.30	20.9	41.8	63.0	83.6	105	126
3.10	64.6	129	194	258	324	388	5.35	20.5	41.0	61.5	82.0	103	123
3.15	62.5	125	188	250	313	375	5.40	20.1	40.2	60.5	80.4	101	121
3.20	60.5	121	182	242	303	363	5.45	19.7	39.4	59.0	78.8	98.5	118
3.25	58.6	117	176	234	293	352	5.50	19.3	38.6	58.0	77.2	96.5	116
3.30	56.8	114	171	227	284	341	5.55	18.9	37.8	57.0	75.6	95.0	114
3.35	55.1	110	166	220	276	331	5.60	18.6	37.2	55.5	74.4	92.5	111
3.40	53.4	107	161	214	267	321	5.65	18.2	36.4	54.5	72.8	90.8	109
3.45	51.8	104	156	207	259	311	5.70	17.8	35.6	53.5	71.2	89.2	107
3.50	50.3	101	151	201	252	302	5.75	17.5	35.0	52.5	70.0	87.5	105
3.55	48.9	97.8	147	196	244	293	5.80	17.2	34.4	51.5	68.8	85.8	103
3.60	47.5	95.0	143	190	238	285	5.85	16.8	33.6	50.5	67.2	84.2	101
3.65	46.1	92.2	139	184	231	277	5.90	16.5	33.0	49.6	66.0	82.5	99.2
3.70	44.9	89.8	135	180	225	269	5.95	16.2	32.4	48.7	64.8	81.2	97.3
3.75	43.6	87.2	131	174	218	262	6.00	15.9	31.8	47.8	63.6	79.5	95.5
3.80	42.4	84.8	128	170	212	255	6.05	15.6	31.2	46.9	62.4	78.0	93.7
3.85	41.3	82.6	124	165	207	248	6.10	15.3	30.6	46.0	61.2	76.7	92.0
3.90	40.2	80.4	121	161	201	241	6.15	15.1	30.2	45.2	60.4	75.3	90.3
3.95	39.1	78.2	118	156	196	235	6.20	14.8	29.6	44.4	59.2	73.8	88.7
4.00	38.1	76.2	115	152	191	229	6.25	14.5	29.0	43.6	58.0	72.6	87.1
4.05	37.1	74.2	112	148	186	223	6.30	14.2	28.4	42.8	56.8	71.3	85.5
4.10	36.2	72.4	109	145	181	217	6.35	14.0	28.0	42.0	56.0	70.0	84.0
4.15	35.3	70.6	106	141	177	212	6.40	13.7	27.4	41.3	54.8	68.8	82.5
4.20	34.4	68.8	104	138	172	207	6.45	13.5	27.0	40.5	54.0	67.5	81.0

Values in the table correspond to the formula:

$$HB = \frac{2P}{\pi D\,(D - \sqrt{D^2 - d^2})}$$

[a] For 500 kg load and 10 mm ball:

$$HB = \frac{31.83}{10 - \sqrt{10 - d^2}}$$

[b] For 3000 kg load and 10 mm ball:

$$HB = \frac{191.0}{10 - \sqrt{10 - d^2}}$$

5. *Brinell Hardness—Tables 2 and 3*

5.1 Test Ball—The diameter of the ball shall be 10.00 ± 0.005 mm (0.3937 ± 0.0004 in). The load applied shall be 3000 kg (6614 lb) for at least 15 s on iron and steel. The standard ball is hardened steel; a tungsten carbide ball is used to test hard materials.

5.2 Test Impression—The average diameter of the impression shall be obtained from two measurements at right angles to each other, made with an instrument having a reading error not over 0.01 mm (0.0004 in).

5.3 Test Specimen—The surface of the specimen should be flat and reasonably free from scratches. The specimen shall be taken deep enough to represent the true composition of the material to be tested, and the test surface shall be maintained in a plane normal to the direction of the testing load.

5.4 Exceptions—This test should not be used on soft steels less than 10 mm (3/8 in) thick or on areas small enough to permit deflection of the edges of the specimen owing to the flow from the ball depression.

For further information on standard methods of Brinell Hardness testing, refer to ASTM E 10. For Brinell Hardness Numbers for Various Loads, see Table 3.

6. *Rockwell Hardness—Table 4*

6.1 Principle of Test—The Rockwell Hardness tester is essentially a machine that measures hardness by determining the depth of penetration of a penetrator into the specimen under certain arbitrarily fixed conditions of test. The penetrator may be either a steel ball or a diamond sphero-conical penetrator. The hardness value as read from the dial (more recent testers incorporate digital readings) is an arbitrary number which is related to the depth of indentation, and since the scales are reversed, the number is higher the harder the material. A minor load of 10 kg is first applied which causes an initial penetration which sets the penetrator on the material and holds it in position. The dial is set at zero on the black figure scale and the major load is applied. After the major load is applied and removed, according to standard procedure, the reading is taken while the minor load is still in position.

6.2 Preparation of Surfaces—Concordant results are dependent on surface roughness being much less than the size of the impression. Surfaces that are ridged perceptibly to the eye by rough grinding or machining offer unequal support to the penetrator. The degree of surface preparation then depends, to some extent, on the requirements of testing, whether they be production or research.

6.3 Thickness of Specimens—The minimum allowable thickness of any specimen varies according to the hardness, the load applied, and the kind of test point or penetrator used. See Tables 2 and 3 of ASTM E 18 for selection of Rockwell scales for a given hardness and thickness of specimen.

6.4 Curved Surfaces—Data for hardness tests on a highly curved surface should be accompanied by a statement of the radius of curvature. In testing small rounds, the effect of curvature can be eliminated by making a small flat spot on the specimen. See Tables 5 and 6 of ASTM E 18 for corrections for tests on cylindrical specimens.

6.5 Case Hardened Parts—The following information defines the minimum effective case depths which will allow the accurate determination of indentation surface hardness measurements for standard and superficial hardness tests. These practices are for fully hardened cases either as quenched or with low [approximately 175 °C (350 °F)] temperature temper. Tempering to lower hardness levels may require less indention load than described.

Effective case is defined as the depth to 50 HRC or its equivalent (see SAE J423). These practices will not avoid errors caused by surface metal of reduced hardness resulting from decarburization, retained austenite, grinding damage, etc. These recommendations may be used for all levels of core hardness.

TABLE 4—APPROXIMATE EQUIVALENT HARDNESS NUMBERS[a] FOR ROCKWELL C HARDNESS NUMBERS, FOR STEEL

Rockwell C-Scale Hardness No.[b]	Vickers Hardness No.	Brinell Hardness No. 10-mm Ball, 3000-kg Load[b]		Rockwell Hardness No.[b]			Rockwell, Superficial Hardness No., Superficial Brale Penetrator			Shore Scleroscope Hardness No.	Tensile Strength (Approximate) in Mpa (1000 psi)	Rockwell C-Scale Hardness No.[b]
		Standard Ball	Tungsten-Carbide Ball	A-Scale, 60-kg Load, Brale Penetrator	B-Scale, 100-kg Load, 1.6-mm (1/16-in) Dia Ball	D-Scale, 100-kg Load, Brale Penetrator	15-N Scale, 15-kg Load	30-N Scale, 30-kg Load	45-N Scale, 45-kg Load			
Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col. 10	Col. 11	Col. 12	Col. 13
68	940	—	—	85.6	—	76.9	93.2	84.4	75.4	97	—	68
67	900	—	—	85.0	—	76.1	92.9	83.6	74.2	95	—	67
66	865	—	—	84.5	—	75.4	92.5	82.8	73.3	92	—	66
65	832	—	(739)	83.9	—	74.5	92.2	81.9	72.0	91	—	65
64	800	—	(722)	83.4	—	73.8	91.8	81.1	71.0	88	—	64
63	772	—	(705)	82.8	—	73.0	91.4	80.1	69.9	87	—	63
62	746	—	(688)	82.3	—	72.2	91.1	79.3	68.8	85	—	62
61	720	—	(670)	81.8	—	71.5	90.7	78.4	67.7	83	—	61
60	697	—	(654)	81.2	—	70.7	90.2	77.5	66.6	81	—	60
59	674	—	(634)	80.7	—	69.9	89.8	76.6	65.5	80	—	59
58	653	—	615	80.1	—	69.2	89.3	75.7	64.3	78	—	58
57	633	—	595	79.6	—	68.5	88.9	74.8	63.2	76	—	57
56	613	—	577	79.0	—	67.7	88.3	73.9	62.0	75	—	56
55	595	—	560	78.5	—	66.9	87.9	73.0	60.9	74	2075 (301)	55
54	577	—	543	78.0	—	66.1	87.4	72.0	59.8	72	2015 (292)	54
53	560	—	525	77.4	—	65.4	86.9	71.2	58.6	71	1950 (283)	53
52	544	(500)	512	76.8	—	64.6	86.4	70.2	57.4	69	1880 (273)	52
51	528	(487)	496	76.3	—	63.8	85.9	69.4	56.1	68	1820 (264)	51
50	513	(475)	481	75.9	—	63.1	85.5	68.5	55.0	67	1760 (255)	50
49	498	(464)	469	75.2	—	62.1	85.0	67.6	53.8	66	1695 (246)	49
48	484	451	455	74.7	—	61.4	84.5	66.7	52.5	64	1635 (237)	48
47	471	442	443	74.1	—	60.8	83.9	65.8	51.4	63	1580 (229)	47
46	458	432	432	73.6	—	60.0	83.5	64.8	50.3	62	1530 (222)	46
45	446	421	421	73.1	—	59.2	83.0	64.0	49.0	60	1480 (215)	45
44	434	409	409	72.5	—	58.5	82.5	63.1	47.8	58	1435 (208)	44
43	423	400	400	72.0	—	57.7	82.0	62.2	46.7	57	1385 (201)	43
42	412	390	390	71.5	—	56.9	81.5	61.3	45.5	56	1340 (194)	42
41	402	381	381	70.9	—	56.2	80.9	60.4	44.3	55	1295 (188)	41
40	392	371	371	70.4	—	55.4	80.4	59.5	43.1	54	1250 (181)	40
39	382	362	362	69.9	—	54.6	79.9	58.6	41.9	52	1215 (176)	39
38	372	353	353	69.4	—	53.8	79.4	57.7	40.8	51	1180 (171)	38
37	363	344	344	68.9	—	53.1	78.8	56.8	39.6	50	1160 (168)	37
36	354	336	336	68.4	(109.0)	52.3	78.3	55.9	38.4	49	1115 (162)	36
35	345	327	327	67.9	(108.5)	51.5	77.7	55.0	37.2	48	1080 (157)	35
34	336	319	319	67.4	(108.0)	50.8	77.2	54.2	36.1	47	1055 (153)	34
33	327	311	311	66.8	(107.5)	50.0	76.6	53.3	34.9	46	1025 (149)	33
32	318	301	301	66.3	(107.0)	49.2	76.1	52.1	33.7	44	1000 (145)	32
31	310	294	294	65.8	(106.0)	48.4	75.6	51.3	32.5	43	980 (142)	31
30	302	286	286	65.3	(105.5)	47.7	75.0	50.4	31.3	42	950 (138)	30
29	294	279	279	64.7	(104.5)	47.0	74.5	49.5	30.1	41	930 (135)	29
28	286	271	271	64.3	(104.0)	46.1	73.9	48.6	28.9	41	910 (132)	28
27	279	264	264	63.8	(103.0)	45.2	73.3	47.7	27.8	40	880 (128)	27
26	272	258	258	63.3	(102.5)	44.6	72.8	46.8	26.7	38	860 (125)	26
25	266	253	253	62.8	(101.5)	43.8	72.2	45.9	25.5	38	840 (122)	25
24	260	247	247	62.4	(101.0)	43.1	71.6	45.0	24.3	37	825 (120)	24
23	254	243	243	62.0	100.0	42.1	71.0	44.0	23.1	36	805 (117)	23
22	248	237	237	61.5	99.0	41.6	70.5	43.2	22.0	35	785 (114)	22
21	243	231	231	61.0	98.5	40.9	69.9	42.3	20.7	35	770 (112)	21
20	238	226	226	60.5	97.8	40.1	69.4	41.5	19.6	34	760 (110)	20
(18)	230	219	219	—	96.7	—	—	—	—	33	730 (106)	(18)
(16)	222	212	212	—	95.5	—	—	—	—	32	705 (102)	(16)
(14)	213	203	203	—	93.9	—	—	—	—	31	675 (98)	(14)
(12)	204	194	194	—	92.3	—	—	—	—	29	650 (94)	(12)
(10)	196	187	187	—	90.7	—	—	—	—	28	620 (90)	(10)
(8)	188	179	179	—	89.5	—	—	—	—	27	600 (87)	(8)
(6)	180	171	171	—	87.1	—	—	—	—	26	580 (84)	(6)
(4)	173	165	165	—	85.5	—	—	—	—	25	550 (80)	(4)
(2)	166	158	158	—	83.5	—	—	—	—	24	530 (77)	(2)
(0)	160	152	152	—	81.7	—	—	—	—	24	515 (75)	(0)

ϕ [a] The values in this table shown in **bold face type** correspond to the values shown in the corresponding joint SAE-ASM-ASTM Committee on Hardness Conversions as printed in ASTM E 140, Table 1.

[b] Values in ( ) are beyond normal range and are given for information only.