Correlation of Hardness Values to Tensile Strength

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Various procedures and approaches are utilized to determine if a given material is suitable for a certain application. The material may be tested for its ability to deform satisfactorily during a forming operation, or perhaps for its ability to operate under a certain stress level at high temperatures. For technological purposes, economy and ease of testing are important factors.

Hardness tests: In many cases it is possible to substitute for the relatively time consuming and costly tensile test with a more convenient test of the plastic deformation behavior of metals, a hardness test. Hardness is defined as resistance of a material to penetration of its surface, and the majority of commercial hardness testers force a small penetrator (indenter) into the metal by means of an applied load. A definite value is obtained as the hardness of the metal, and this number can be related to the tensile strength of the metal.

In the Rockwell test, hardness is measured by the depth to which the penetrator moves under a fixed load. The elastic component of the deformation is subtracted from the total movement. In the Brinell and Vickers/Knoop scales, on the other hand, the hardness is measured by dividing the load by the area of an indentation formed by pressing the corresponding indenters into the metal. Therefore while the Rockwell number is read directly from a gage, which is part of the tester, the Brinell and Vickers/Knoop require optical measurements of the diameters or diagonals, respectively.

While all indentation hardness tests may be thought to serve the same purpose, each one has definite advantages with some being more applicable to certain types of materials and size and shape parts than the others. Brinell is used primarily for forgings and cast irons. Its large test area allows an average representative value to be obtained in a material that contains features/phases with vastly different properties (i.e. graphite, matrix, carbides, etc.). Vickers and Knoop are used on very small and thin parts as well as for case depth determinations, and Rockwell on almost all other applications. The table below provides basic information regarding the most commonly used hardness tests.

Type	Penetrator	Usual load range, kg	Typical range of hardness	Surface preparation needed for testing
Rockwell-C Scale	Diamond cone	150	Medium to very hard	Fine sanding
Rockwell-B Scale	1/16" carbide ball	100	Soft to medium	Fine sanding
Brinell	10 mm carbide ball	500-3,000	Soft to hard	Coarse sanding
Vickers	Diamond pyramid	0.5-100	Very soft to very hard	Polishing
Knoop (microhardness)	Diamond pyramid	0.01-1	Very soft to very hard	Fine polishing

Although the Rockwell test procedure is relatively straight forward, a number of items can contribute to inconsistent and incorrect readings and should not be overlooked. These items include the following:

- Cleanliness of the tested surface and the support anvil
- Curvature of the surface (correction factors must be used)
- Test surface not being perpendicular to the indenter
- Readings taken too close to the sample edge
- Readings taken too close together
- Test sample too thin for the hardness scale being used
- Part not supported properly
- Damaged indenter

Standard method for testing metallic materials using the Rockwell scales can be found in ASTM E18.

CONVERSION TO OTHER HARDNESS SCALES OR PROPERTIES

There is no general method of accurately converting the hardness numbers determined on one scale to hardness numbers on another scale, or to tensile strength values. Nevertheless, hardness conversion tables are published by ASTM, and often by hardness equipment manufacturers in the literature. Such conversions are, at best, approximations and therefore should be treated with caution. The Standard Hardness Conversion Tables for Metals, ASTM E140, give approximate conversion values for specific materials such as steel, austenitic stainless steel, nickel and high nickel alloys, cartridge brass, copper alloys, and alloyed white cast irons. The first two tables below, which are reproduced from ASTM A370, give the approximate interrelationships of hardness values and approximate tensile strength of steels. It is possible that steels of various compositions and processing histories will deviate in hardness-tensile strength relationship from the data presented below. Also, the data in these tables should not be used for austenitic stainless steels, but have been shown to be applicable for ferritic and martensitic stainless steels. Furthermore, the data in these tables should not be used to establish a relationship between hardness values and tensile strength of hard drawn wire. Where more precise conversions are required, they should be developed specifically for each steel composition, heat treatment, and part. The third table is reproduced from SAE J417, whereas the fourth one is published by Wilson-Instron Corporation. Cautions should be exercised if conversions from these tables are used for the acceptance or rejection of a product.

Conversion Data for Non-austenitic Steels[1]

Rockwell C Scale, 150-kgf Load, Diamond Penetrator	Vickers Hardness Number	Brinell Hardness, 3000-kgf Load, 10-mm Ball	Knoop Hardness, 500-gf Load and Over	Rockwell A Scale, 60-kgf Load, Diamond Penetrator	Rockwell Superficial Hardness			
					15N Scale, 15-kgf Load, Diamond Penetrator	30N Scale 30-kgf Load, Diamond Penetrator	45N Scale, 45-kgf Load, Diamond Penetrator	Approximate Tensile Strength, ksi (MPa)
68	940	...	920	85.6	93.2	84.4	75.4	...
67	900	...	895	85.0	92.9	83.6	74.2	...
66	865	...	870	84.5	92.5	82.8	73.3	...
65	832	739	846	83.9	92.2	81.9	72.0	...
64	800	722	822	83.4	91.8	81.1	71.0	...
63	772	706	799	82.8	91.4	80.1	69.9	...
62	746	688	776	82.3	91.1	79.3	68.8	...
61	720	670	754	81.8	90.7	78.4	67.7	...
60	697	654	732	81.2	90.2	77.5	66.6	...
59	674	634	710	80.7	89.8	76.6	65.5	351 (2420)
58	653	615	690	80.1	89.3	75.7	64.3	338 (2330)
57	633	595	670	79.6	88.9	74.8	63.2	325 (2240)
56	613	577	650	79.0	88.3	73.9	62.0	313 (2160)
55	595	560	630	78.5	87.9	73.0	60.9	301 (2070)
54	577	543	612	78.0	87.4	72.0	59.8	292 (2010)
53	560	525	594	77.4	86.9	71.2	58.6	283 (1950)
52	544	512	576	76.8	86.4	70.2	57.4	273 (1880)
51	528	496	558	76.3	85.9	69.4	56.1	264 (1820)
50	513	482	542	75.9	85.5	68.5	55.0	255 (1760)
49	498	468	526	75.2	85.0	67.6	53.8	246 (1700)
48	484	455	510	74.7	84.5	66.7	52.5	238 (1640)
47	471	442	495	74.1	83.9	65.8	51.4	229 (1580)
46	458	432	480	73.6	83.5	64.8	50.3	221 (1520)
45	446	421	466	73.1	83.0	64.0	49.0	215 (1480)
44	434	409	452	72.5	82.5	63.1	47.8	208 (1430)
43	423	400	438	72.0	82.0	62.2	46.7	201 (1390)
42	412	390	426	71.5	81.5	61.3	45.5	194 (1340)
41	402	381	414	70.9	80.9	60.4	44.3	188 (1300)
40	392	371	402	70.4	80.4	59.5	43.1	182 (1250)
39	382	362	391	69.9	79.9	58.6	41.9	177 (1220)
38	372	353	380	69.4	79.4	57.7	40.8	171 (1180)
37	363	344	370	68.9	78.8	56.8	39.6	166 (1140)
36	354	336	360	68.4	78.3	55.9	38.4	161 (1110)
35	345	327	351	67.9	77.7	55.0	37.2	156 (1080)
34	336	319	342	67.4	77.2	54.2	36.1	152 (1050)
33	327	311	334	66.8	76.6	53.3	34.9	149 (1030)
32	318	301	326	66.3	76.1	52.1	33.7	146 (1010)
31	310	294	318	65.8	75.6	51.3	32.5	141 (970)
30	302	286	311	65.3	75.0	50.4	31.3	138 (950)
29	294	279	304	64.6	74.5	49.5	30.1	135 (930)
28	286	271	297	64.3	73.9	48.6	28.9	131 (900)
27	279	264	290	63.8	73.3	47.7	27.8	128 (880)
26	272	258	284	63.3	72.8	46.8	26.7	125 (860)
25	266	253	278	62.8	72.2	45.9	25.5	123 (850)
24	260	247	272	62.4	71.6	45.0	24.3	119 (820)
23	254	243	266	62.0	71.0	44.0	23.1	117 (810)
22	248	237	261	61.5	70.5	43.2	22.0	115 (790)
21	243	231	256	61.0	69.9	42.3	20.7	112 (770)
20	238	226	251	60.5	69.4	41.5	19.6	110 (760)

[1]Table is reproduced from ASTM A370

Conversion Data for Non-austenitic Steels[1]

Rockwell B Scale, 100-kgf Load 1/16-in. (1.588-mm) Ball	Vickers Hardness Number	Brinell Hardness, 3000-kgf Load, 10-mm Ball	Knoop Hardness, 500-gf Load and Over	Rockwell A Scale, 60-kgf Load, Diamond Penetrator	Rockwell F Scale, 60-kgf Load, 1/16-in. (1.588-mm) Ball	Rockwell Superficial Hardness			Approximate Tensile Strength ksi (MPa)
						15T Scale, 15-kgf Load, 1/16-in. (1.588-mm) Ball	30T Scale, 30-kgf Load, 1/16-in. (1.588-mm) Ball	45T Scale, 45-kgf Load, 1/16-in. (1.588-mm) Ball	
100	240	240	251	61.5	...	93.1	83.1	72.9	116 (800)
99	234	234	246	60.9	...	92.8	82.5	71.9	114 (785)
98	228	228	241	60.2	...	92.5	81.8	70.9	109 (750)
97	222	222	236	59.5	...	92.1	81.1	69.9	104 (715)
96	216	216	231	58.9	...	91.8	80.4	68.9	102 (705)
95	210	210	226	58.3	...	91.5	79.8	67.9	100 (690)
94	205	205	221	57.6	...	91.2	79.1	66.9	98 (675)
93	200	200	216	57.0	...	90.8	78.4	65.9	94 (650)
92	195	195	211	56.4	...	90.5	77.8	64.8	92 (635)
91	190	190	206	55.8	...	90.2	77.1	63.8	90 (620)
90	185	185	201	55.2	...	89.9	76.4	62.8	89 (615)
89	180	180	196	54.6	...	89.5	75.8	61.8	88 (605)
88	176	176	192	54.0	...	89.2	75.1	60.8	86 (590)
87	172	172	188	53.4	...	88.9	74.4	59.8	84 (580)
86	169	169	184	52.8	...	88.6	73.8	58.8	83 (570)
85	165	165	180	52.3	...	88.2	73.1	57.8	82 (565)
84	162	162	176	51.7	...	87.9	72.4	56.8	81 (560)
83	159	159	173	51.1	...	87.6	71.8	55.8	80 (550)
82	156	156	170	50.6	...	87.3	71.1	54.8	77 (530)
81	153	153	167	50.0	...	86.9	70.4	53.8	73 (505)
80	150	150	164	49.5	...	86.6	69.7	52.8	72 (495)
79	147	147	161	48.9	...	86.3	69.1	51.8	70 (485)
78	144	144	158	48.4	...	86.0	68.4	50.8	69 (475)
77	141	141	155	47.9	...	85.6	67.7	49.8	68 (470)
76	139	139	152	47.3	...	85.3	67.1	48.8	67 (460)
75	137	137	150	46.8	99.6	85.0	66.4	47.8	66 (455)
74	135	135	147	46.3	99.1	84.7	65.7	46.8	65 (450)
73	132	132	145	45.8	98.5	84.3	65.1	45.8	64 (440)
72	130	130	143	45.3	98.0	84.0	64.4	44.8	63 (435)
71	127	127	141	44.8	97.4	83.7	63.7	43.8	62 (425)
70	125	125	139	44.3	96.8	83.4	63.1	42.8	61 (420)
69	123	123	137	43.8	96.2	83.0	62.4	41.8	60 (415)
68	121	121	135	43.3	95.6	82.7	61.7	40.8	59 (405)
67	119	119	133	42.8	95.1	82.4	61.0	39.8	58 (400)
66	117	117	131	42.3	94.5	82.1	60.4	38.7	57 (395)
65	116	116	129	41.8	93.9	81.8	59.7	37.7	56 (385)
64	114	114	127	41.4	93.4	81.4	59.0	36.7	...
63	112	112	125	40.9	92.8	81.1	58.4	35.7	...
62	110	110	124	40.4	92.2	80.8	57.7	34.7	...
61	108	108	122	40.0	91.7	80.5	57.0	33.7	...
60	107	107	120	39.5	91.1	80.1	56.4	32.7	...
59	106	106	118	39.0	90.5	79.8	55.7	31.7	...
58	104	104	117	38.6	90.0	79.5	55.0	30.7	...
57	103	103	115	38.1	89.4	79.2	54.4	29.7	...
56	101	101	114	37.7	88.8	78.8	53.7	28.7	...
55	100	100	112	37.2	88.2	78.5	53.0	27.7	...
54	...	...	111	36.8	87.7	78.2	52.4	26.7	...
53	...	...	110	36.3	87.1	77.9	51.7	25.7	...
52	...	...	109	35.9	86.5	77.5	51.0	24.7	...
51	...	...	108	35.5	86.0	77.2	50.3	23.7	...
50	...	...	107	35.0	85.4	76.9	49.7	22.7	...
49	...	...	106	34.6	84.8	76.6	49.0	21.7	...
48	...	...	105	34.1	84.3	76.2	48.3	20.7	...
47	...	...	104	33.7	83.7	75.9	47.7	19.7	...
46	...	...	103	33.3	83.1	75.6	47.0	18.7	...
45	...	...	102	32.9	82.6	75.3	46.3	17.7	...
44	...	...	101	32.4	82.0	74.9	45.7	16.7	...
43	...	...	100	32.0	81.4	74.6	45.0	15.7	...
42	...	...	99	31.6	80.8	74.3	44.3	14.7	...
41	...	...	98	31.2	80.3	74.0	43.7	13.6	...
40	...	...	97	30.7	79.7	73.6	43.0	12.6	...
39	...	...	96	30.3	79.1	73.3	42.3	11.6	...
38	...	...	95	29.9	78.6	73.0	41.6	10.6	...
37	...	...	94	29.5	78.0	72.7	41.0	9.6	...
36	...	...	93	29.1	77.4	72.3	40.3	8.6	...
35	...	...	92	28.7	76.9	72.0	39.6	7.6	...
34	...	...	91	28.2	76.3	71.7	39.0	6.6	...
33	...	...	90	27.8	75.7	71.4	38.3	5.6	...

[1]Table is reproduced from ASTM A370

Conversion Data for Non-austenitic Steels[1]

Rockwell hardness C scale (HRC)	Vickers hardness (HV)	Brinell hardnes (HB) Ball : 10mm in diameter/Load : 3000kgf		Rockwell hardness			Rockwell superficial hardness Diamond conical penetrator			Shore hardness (Hs)	Tensile strength (Approximate value) MPa (kgf/mm²)	Rockwell hardness C scale
		Standard ball	Tungsten carbide ball	A scale (HRA) Load : 60kgf Diamond conical penetrator	B scale (HRB) Load : 100kgf Ball of 1.6mm (1/16") dia.	D scale (HRD) Load : 100kgf Diamond conical penetrator	15-N Scale Load :15kgf	30-N Scale Load : 30kgf	45-N Scale Load : 45kgf			
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 (212)	55
54	577	—	543	78.0	—	66.1	87.4	72.0	59.8	72	2015 (205)	54
53	560	—	525	77.4	—	65.4	86.9	71.2	58.5	71	1950 (199)	53
52	544	(500)	512	76.8	—	64.6	86.4	70.2	57.4	69	1880 (192)	52
51	528	(487)	496	76.3	—	63.8	85.9	69.4	56.1	68	1820 (186)	51
50	513	(475)	481	75.9	—	63.1	85.5	68.5	55.0	67	1760 (179)	50
49	498	(464)	469	75.2	—	62.1	85.0	67.6	53.8	66	1695 (173)	49
48	484	451	455	74.7	—	61.4	84.5	66.7	52.5	64	1635 (167)	48
47	471	442	443	74.1	—	60.8	83.9	65.8	51.4	63	1580 (161)	47
46	458	432	432	73.6	—	60.0	83.5	64.8	50.3	62	1530 (156)	46
45	446	421	421	73.1	—	59.2	83.0	64.0	49.0	60	1480 (151)	45
44	434	409	409	72.5	—	58.5	82.5	63.1	47.8	58	1435 (146)	44
43	423	400	400	72.0	—	57.7	82.0	62.2	46.7	57	1385 (141)	43
42	412	390	390	71.5	—	56.9	81.5	61.3	45.5	56	1340 (136)	42
41	402	381	381	70.9	—	56.2	80.9	60.4	44.3	55	1295 (132)	41
40	392	371	371	70.4	—	55.4	80.4	59.5	43.1	54	1250 (127)	40
39	382	362	362	69.9	—	54.6	79.9	58.6	41.9	52	1215 (124)	39
38	372	353	353	69.4	—	53.8	79.4	57.7	40.8	51	1180 (120)	38
37	363	344	344	68.9	—	53.1	78.8	56.8	39.6	50	1160 (118)	37
36	354	336	336	68.4	(109.0)	52.3	78.3	55.9	38.4	49	1115 (114)	36
35	345	327	327	67.9	(108.5)	51.5	77.7	55.0	37.2	48	1080 (110)	35
34	336	319	319	67.4	(108.0)	50.8	77.2	54.2	36.1	47	1055 (108)	34
33	327	311	311	66.8	(107.5)	50.0	76.6	53.3	34.9	46	1025 (105)	33
32	318	301	301	66.3	(107.0)	49.2	76.1	52.1	33.7	44	1000 (102)	32
31	310	294	294	65.8	(106.0)	48.4	75.6	51.3	32.7	43	980 (100)	31
30	302	286	286	65.3	(105.5)	47.7	75.0	50.4	31.3	42	950 (97)	30
29	294	279	279	64.7	(104.5)	47.0	74.5	49.5	30.1	41	930 (95)	29
28	286	271	271	64.3	(104.0)	46.1	73.9	48.6	28.9	41	910 (93)	28
27	279	264	264	63.8	(103.0)	45.2	73.3	47.7	27.8	40	880 (90)	27
26	272	258	258	63.3	(102.5)	44.6	72.8	46.8	26.7	38	860 (88)	26
25	266	253	253	62.8	(101.5)	43.8	72.2	45.9	25.5	38	840 (86)	25
24	260	247	247	62.4	(101.0)	43.1	71.6	45.0	24.3	37	825 (84)	24
23	254	243	243	62.0	100.0	42.1	71.0	44.0	23.1	36	805 (82)	23
22	248	237	237	61.5	99.0	41.6	70.5	43.2	22.0	35	785 (80)	22
21	243	231	231	61.0	98.5	40.9	69.9	42.3	20.7	35	770 (79)	21
20	238	226	226	60.5	97.8	40.1	69.4	41.5	19.6	34	760 (77)	20
(18)	230	219	219	—	96.7	—	—	—	—	33	730 (75)	(18)
(16)	222	212	212	—	95.5	—	—	—	—	32	705 (72)	(16)
(14)	213	203	203	—	93.9	—	—	—	—	31	675 (69)	(14)
(12)	204	194	194	—	92.3	—	—	—	—	29	650 (66)	(12)
(10)	196	187	187	—	90.7	—	—	—	—	28	620 (63)	(10)
(8)	188	179	179	—	89.5	—	—	—	—	27	600 (61)	(8)
(6)	180	171	171	—	87.1	—	—	—	—	26	580 (59)	(6)
(4)	173	165	165	—	85.5	—	—	—	—	25	550 (56)	(4)
(2)	166	158	158	—	83.5	—	—	—	—	24	530 (54)	(2)
(0)	160	152	152	—	81.7	—	—	—	—	24	515 (53)	(0)

[1]Table is reproduced from SAE J417
The figures in blue are based on ASTM E140 (adjusted by SAE, ASM and ASTM in collaboration)
The figures in parentheses are less frequently used values and indicated for reference only

Conversion chart for soft steels and most non-ferrous metals[1]

Rockwell							Superficial			Knoop	Brinell		Tensile Strength
B	F	G	A	E	H	K	15-T	30-T	45-T	HK	HB	HB/HV	KSI
100 kg 1/16" ball	60 kg 1/16" ball	150 kg 1/16" ball	60 kg Brale	100 kg 1/8" ball	60 kg 1/8" ball	150 kg 1/8" ball	15 kg 1/16" ball	30 kg 1/16" ball	45 kg 1/16" ball	500 gm and over	500 kg 10 mm ball	3000 kg 10 kg	1000 lbs/ sq in
100		82.5	61.5				93.1	83.1	72.9	251	201	240	116
99		81.0	60.9				92.8	82.5	71.9	246	195	234	114
98		79.0	60.2				92.5	81.8	70.9	241	189	228	109
97		77.5	59.5				92.1	81.1	69.9	236	184	222	104
96		76.0	58.9				91.8	80.4	68.9	231	179	216	102
95		74.0	58.3				91.5	79.8	67.9	226	175	210	100
94		72.5	57.6				91.2	79.1	66.9	221	171	205	98
93		71.0	57.0				90.8	78.4	65.9	216	167	200	94
92		69.0	56.4			NA	90.5	77.8	64.8	211	163	195	92
91		67.5	55.8			100	90.2	77.1	63.8	206	160	190	90
90		66.0	55.2			99.5	89.9	76.4	62.8	201	157	185	89
89		64.0	54.6			98.0	89.5	75.8	61.8	196	154	180	88
88		62.5	54.0			97.0	89.2	75.1	60.8	192	151	176	86
87		61.0	53.4			96.5	88.9	74.4	59.8	188	148	172	84
86		59.0	52.8			95.5	88.6	73.8	58.8	184	145	169	83
85		57.5	52.3			94.5	88.2	73.1	57.8	180	142	165	82
84		56.0	51.7			94.0	87.9	72.4	56.8	176	140	162	81
83		54.0	51.1			93.0	87.6	71.8	55.8	173	137	159	80
82		52.5	50.6			92.0	87.3	71.1	54.8	170	135	156	77
81		51.0	50.0			91.0	86.9	70.4	53.8	167	133	153	73
80		49.0	49.5			90.5	86.6	69.7	52.8	164	130	150	72
79		47.5	48.9			89.5	86.3	69.1	51.8	161	128	147	70
78		46.0	48.4			88.5	86.0	68.4	50.8	158	126	144	69
77		44.0	47.9			88.0	85.6	67.7	49.8	155	124	141	68
76	NA	42.5	47.3			87.0	85.3	67.1	48.8	152	122	139	67
75	99.6	41.0	46.8			86.0	85.0	66.4	47.8	150	120	137	66
74	99.1	39.0	46.3			85.0	84.7	65.7	46.8	147	118	135	65
73	98.5	37.5	45.8			84.5	84.3	65.1	45.8	145	116	132	64
72	98.0	36.0	45.3	NA		83.5	84.0	64.4	44.8	143	114	130	63
71	97.4	34.5	44.8	100		82.5	83.7	63.7	43.8	141	112	127	62
70	96.8	32.5	44.3	99.5		81.5	83.4	63.1	42.8	139	110	125	61
69	96.2	31.0	43.8	99.0		81.0	83.0	62.4	41.8	137	109	123	60
68	95.6	29.5	43.3	98.0		80.0	82.7	61.7	40.8	135	107	121	59
67	95.1	28.0	42.8	97.5		79.0	82.4	61.0	39.8	133	106	119	58
66	94.5	26.5	42.3	97.0		78.0	82.1	60.4	38.7	131	104	117	57
65	93.9	25.0	41.8	96.0		77.5	81.8	59.7	37.7	129	102	116	56
64	93.4	23.5	41.4	95.5		76.5	81.4	59.0	36.7	127	101	114	NA
63	92.8	22.0	40.9	95.0		75.5	81.1	58.4	35.7	125	99	112	
62	92.2	20.5	40.4	94.5		74.5	80.8	57.7	34.7	124	98	110	
61	91.7	19.0	40.0	93.5		74.0	80.5	57.0	33.7	122	96	108	
60	91.1	17.5	39.5	93.0		73.0	80.1	56.4	32.7	120	95	107	
59	90.5	16.0	39.0	92.5		72.0	79.8	55.7	31.7	118	94	106	

[1]Wilson Conversion Chart, Instron Corporation

The ultimate tensile strength of a carbon steel can also be estimated by using the simple formula:

UTS= 500 x BHN

This formula applies only to steels.

There is limited information regarding hardness versus tensile strength for cast irons in the literature. The table and the figure below list values for the most common grades of gray and ductile irons in various conditions.

Typical hardness versus tensile strength of cast iron test bars[1]

Material	Standard Grade/Class	Brinell Hardness	Tensile Strength, MPa (psi)
Gray Iron (as-cast)	20	156	152 (22,000)
	25	174	179 (26,000)
	30	210	214 (31,000)
	35	212	252 (36,500)
	40	235	293 (42,500)
	50	262	362 (52,500)
	60	302	431 (62,500)
Ductile Iron (heat-treated)	60-40-18	167	461 (66,900)
	65-45-12	167	464 (67,300)
	80-55-06	192	559 (81,100)
	120-90-02	331	974 (141,300)

[1]ASM Metals Reference Book

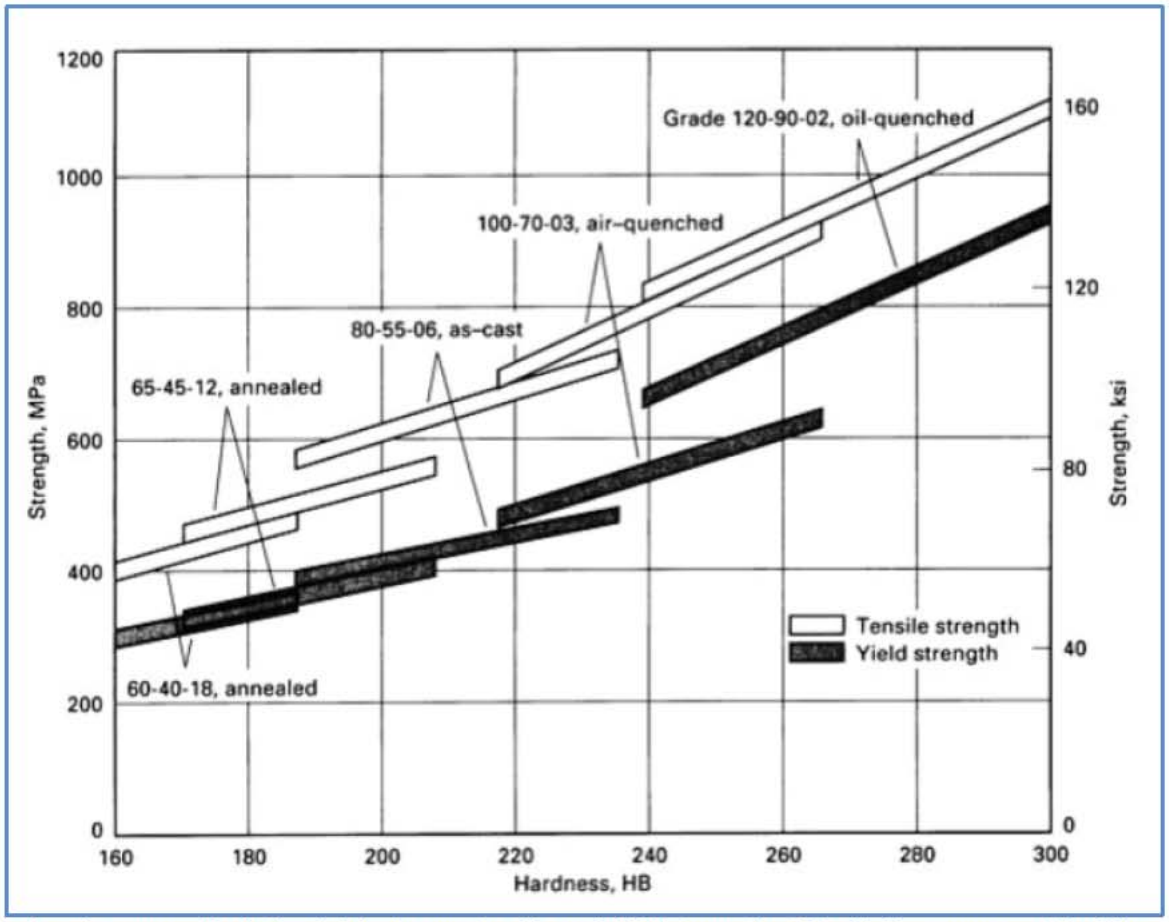
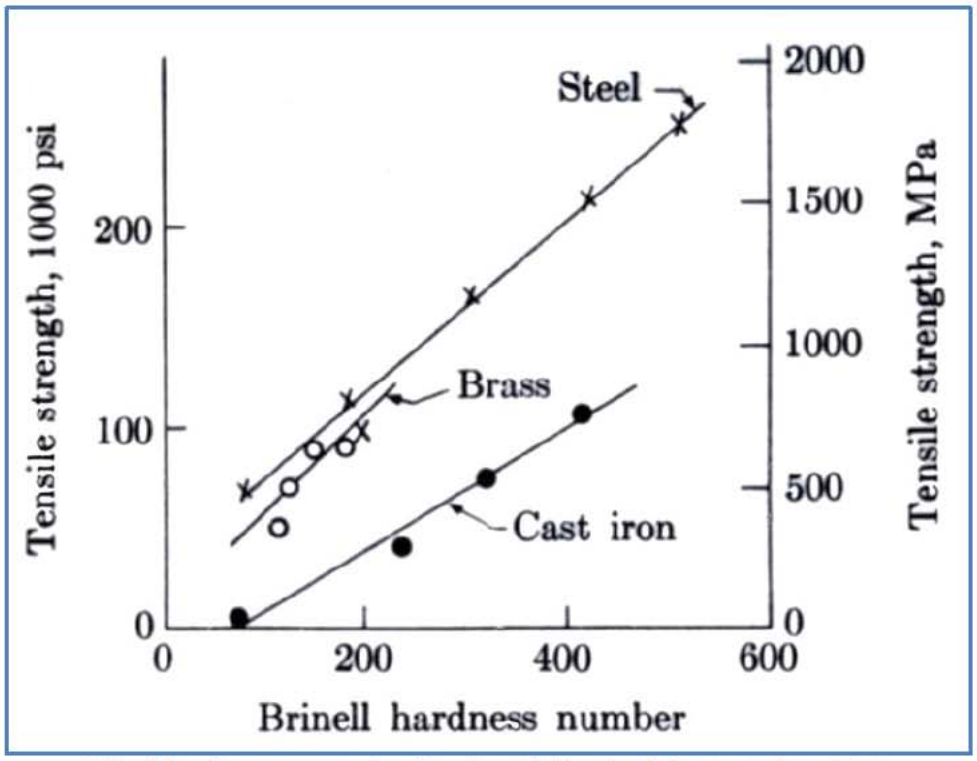


Figure showing general relationship between tensile and yield strength of ductile irons versus Brinell hardness (ASM Handbook, Volume 4, Heat Treating)

As expected, the hardness and the strength of a material are closely related. Graphs illustrating these relationships for various materials are shown below:



Brinell hardness versus tensile strength for steel, brass and cast iron
(Elements of Materials Science and Engineering-Van Vlack)

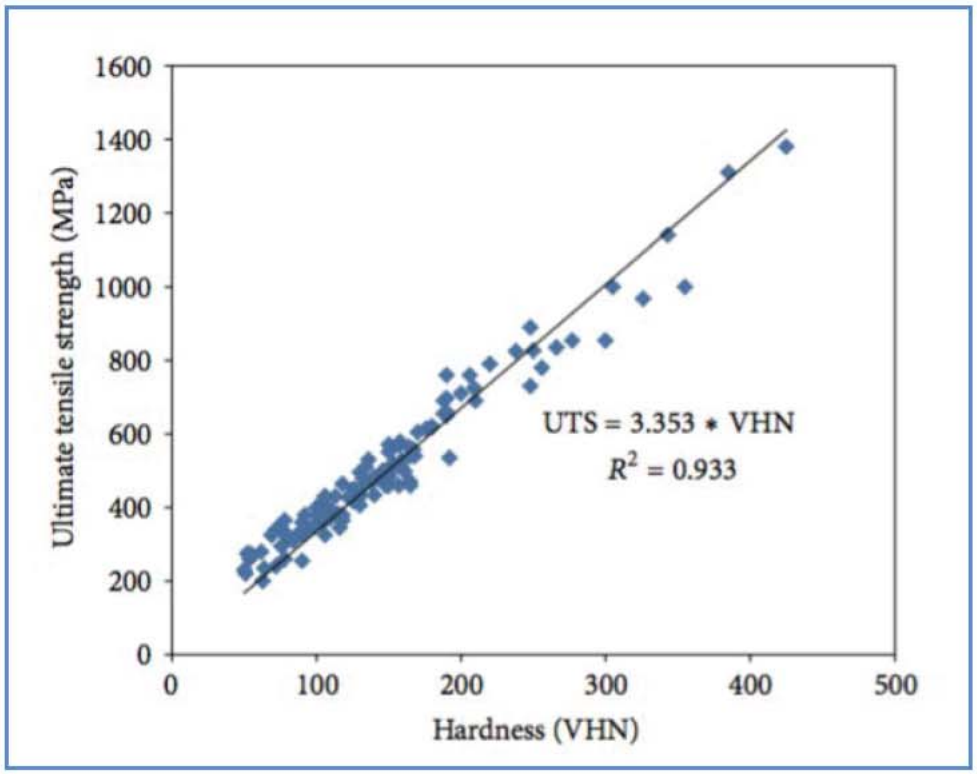


Figure showing correlation between Vickers hardness versus tensile strength of copper alloys
(On the Prediction of Strength from Hardness for Copper Alloys, Journal of Materials, Vol. 2013)

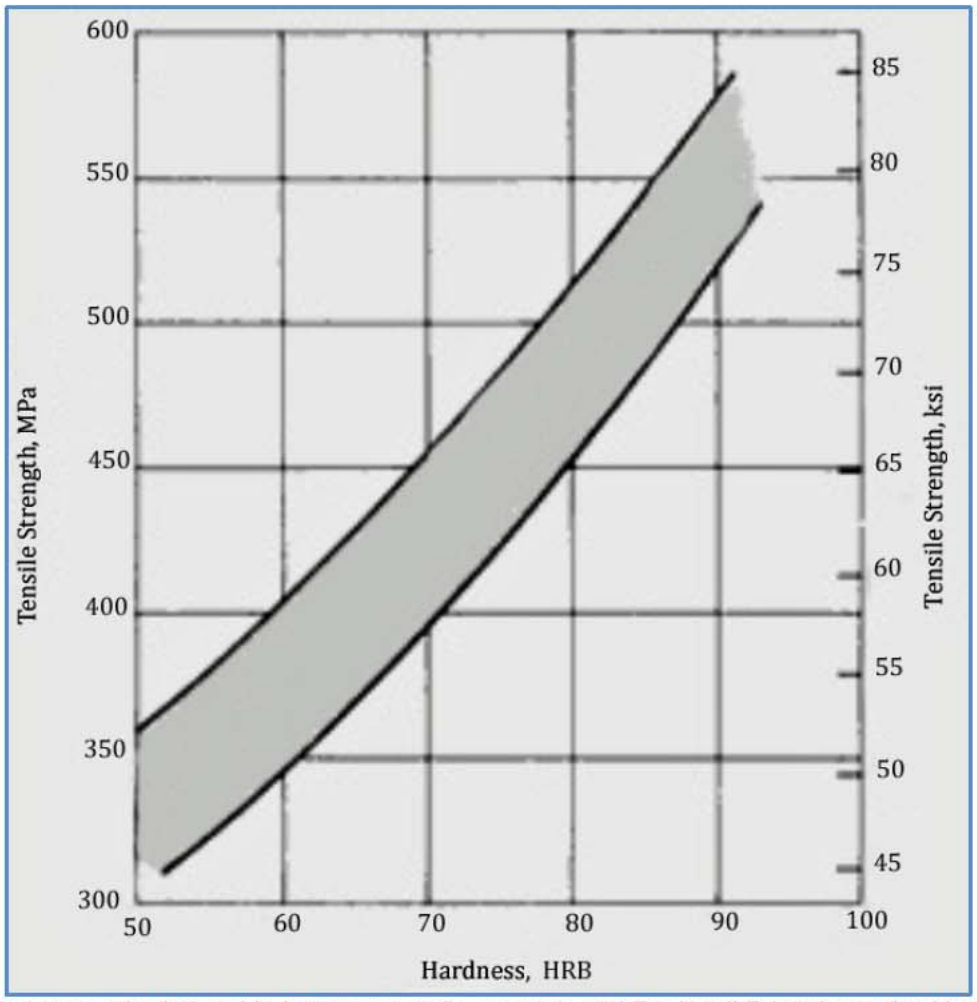


Figure showing general relationship between tensile strength and Rockwell B hardness for Aluminum alloys (ASM Handbook, Volume 4, Heat Treating)