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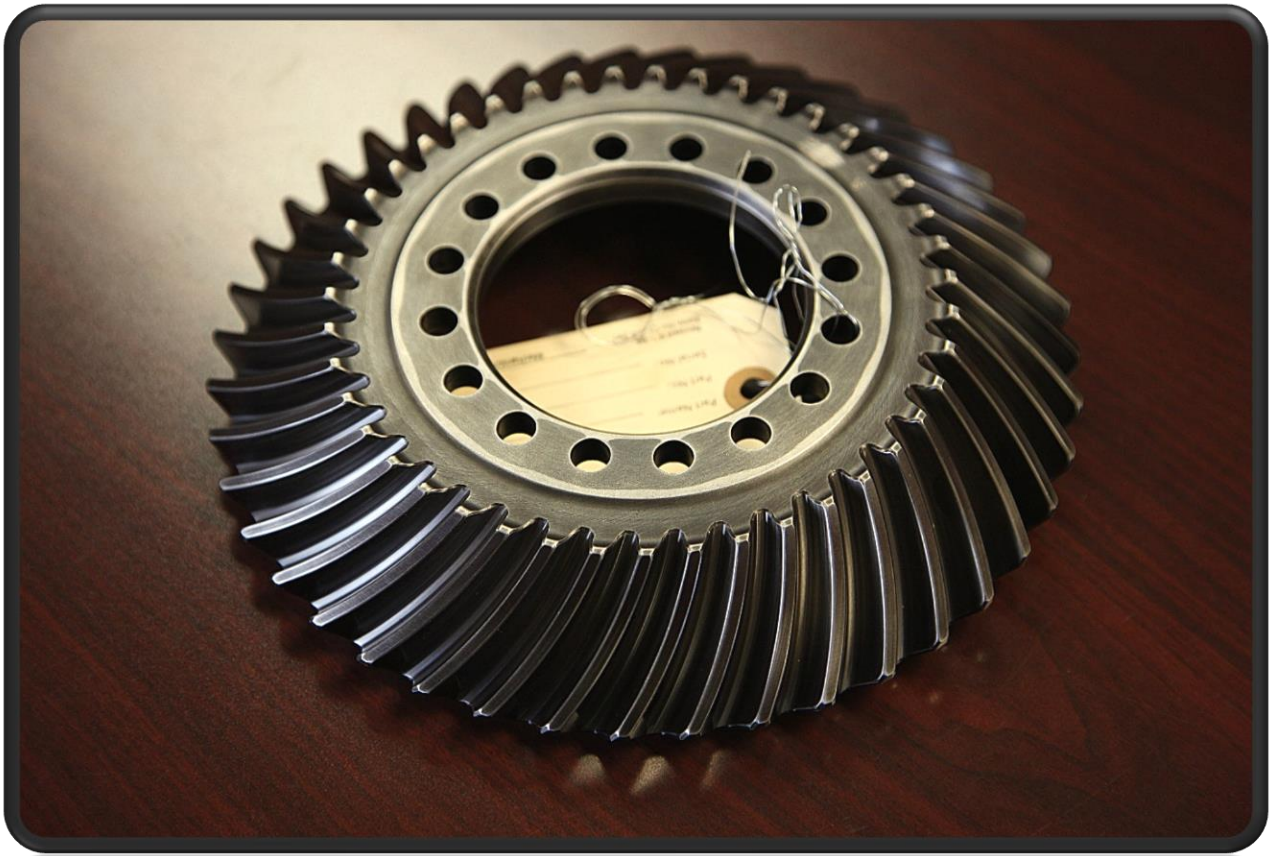
What Every Engineer Should Know About… Hardness Testing



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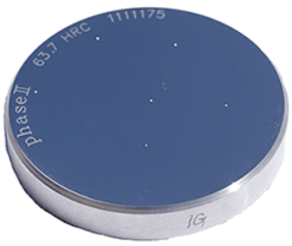
Introduction

Material hardness testing is a common industry practice that generates useful information about metals and other materials. One definition of hardness testing is *a collection of methods for measuring a definite characteristic of materials; namely, the resistance to penetration of a specific indenter under the application of a certain static force for a definite time using precise measuring procedures*. More succinctly, hardness is *the ability of a material to resist permanent indentation*. Hardness is technically *not* an intrinsic material property; rather, it empirically relates tensile strength, wear resistance, ductility, and other characteristics. The hardness characteristic is derived from composition, thermal and mechanical history of the material, and microstructure.

The hardness testing scales covered in this course are Mohs, Rockwell, Brinell, Vickers, Knoop, and Shore. Each is different and specializes in particular uses. Although there are other hardness testing methods (see next section), this course focuses on the more common methods used in industry. No single hardness testing method is suitable for all materials and situations. This document introduces the various methods and provides context and applications for each. Note: this is not a comprehensive instruction manual and should not be utilitzed as a specification or reference regarding how to conduct a hardness test. It is merely an introduction to the various methods an engineer may encounter. Related topics that are not addressed in this document include uncertainty, error, repeatability, calibration, standardization, and verification.

Hardness testing is useful for commercial purposes when selecting materials, identifying unknown materials, and maintain quality control. It is generally inexpensive, non-destructive, and is easily done by a trained operator. Nonetheless, it is a very local characteristic and one should never assume that the test specimen material is homogenous and demonstrates uniform results matching the tested location. Hardness may be skewed when a material is plated by a different element, decarburized, case hardened, welded, flame cut, shot peened, overheated, and so on. Very thin materials will also produce different hardness values than a thicker material of identical composition.

The use of reference blocks is necessary, which are known materials manufactured to have homogenous hardness on all of their surface. Reference blocks must be treated with the utmost care as they are the basis for confirming that a hardness machine is within calibration and tolerance requirements. Reference blocks should be obtained with signed certificates of authenticity and precision. Normal practice demands an operator to perform a daily hadness check on a reference block (i.e indirect verification).



Types of Hardness Tests

Indentation

Hardness is evaluated by the amount of permanent (plastic) deformation of the material when a given static load is applied to the indenter. Material flow may be measured by area or depth of indentation. Rockwell, Brinell, Vickers, Knoop, and Shore methods all fall under this category.

Scratch Hardness

Scratch hardness is a relative method that uses a known material to scratch an unknown material. If it scratches, the known material is harder than the test material. If not, the inverse is true. The Mohs and file scratch methods are within this classification.

Microhardness

Microhardness is similar to indentation except it is only evaluated by the area of indentation, not depth. Minimal loads are applied to test thin (down to 0.0005 in) material microhardness.

Rebound

The rebound method is a dynamic indentation test which relates to the elastic limit of the material instead of tensile strength or work hardened properties. A mass is dropped from a fixed height onto the test material and the height of rebound is measured, which correlates with the material hardness. Scleroscope and Leeb are rebound tests.

Abrasion & Erosion

Material hardness is associated with wear resistance, and one is frequently used to evaluate the other property. Wear tests are conducted with some form of abrasive applied at a specific force and relative motion. Wear tests are slow compared to indentation tests, and also can be misleading unless the variables are accurately simulated.

Electromagnetic

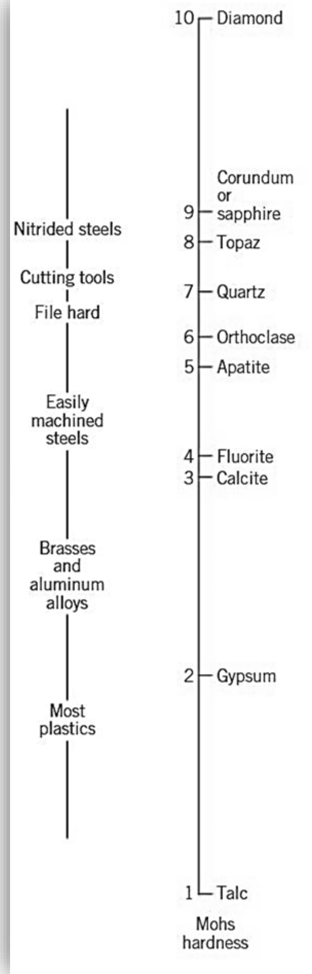
Electromagnetic testing, although not technically a hardnesss test, can be used to evaluate and sort steel on the basis of hardness. Known flux density can be compared with test material to determine hardness. The degree of unbalance correlates with hardness variation.

Mohs Hardness

The Mohs hardness scale employs known materials to define hardness benchmarks via scratch test. Devised by German mineralogist Friedrich Moh (1773-1839) in the early 19th century, the Mohs scale is non-linear, generally qualitative, and represents hardness of common minerals by assigning a value to each, beginning at 1 (softest) to 10 (hardest). Each material on the scale establishes a relative standard to compare with the test material. Any material with a greater integer value can scratch a lesser value material, although the scratching procedure is not well defined. None of the following are typical engineering materials (except, perhaps, gypsum in sheetrock), and it is unlikely the Mohs scale will be used by a metallurgist or design engineer; however, it is a straightforward benchmark to begin this course. The Mohs test is similar in method to a file hardness test. ASTM C1895 *Standard Test Method for Determination of Mohs Scratch Hardness* provides procedures and standards.

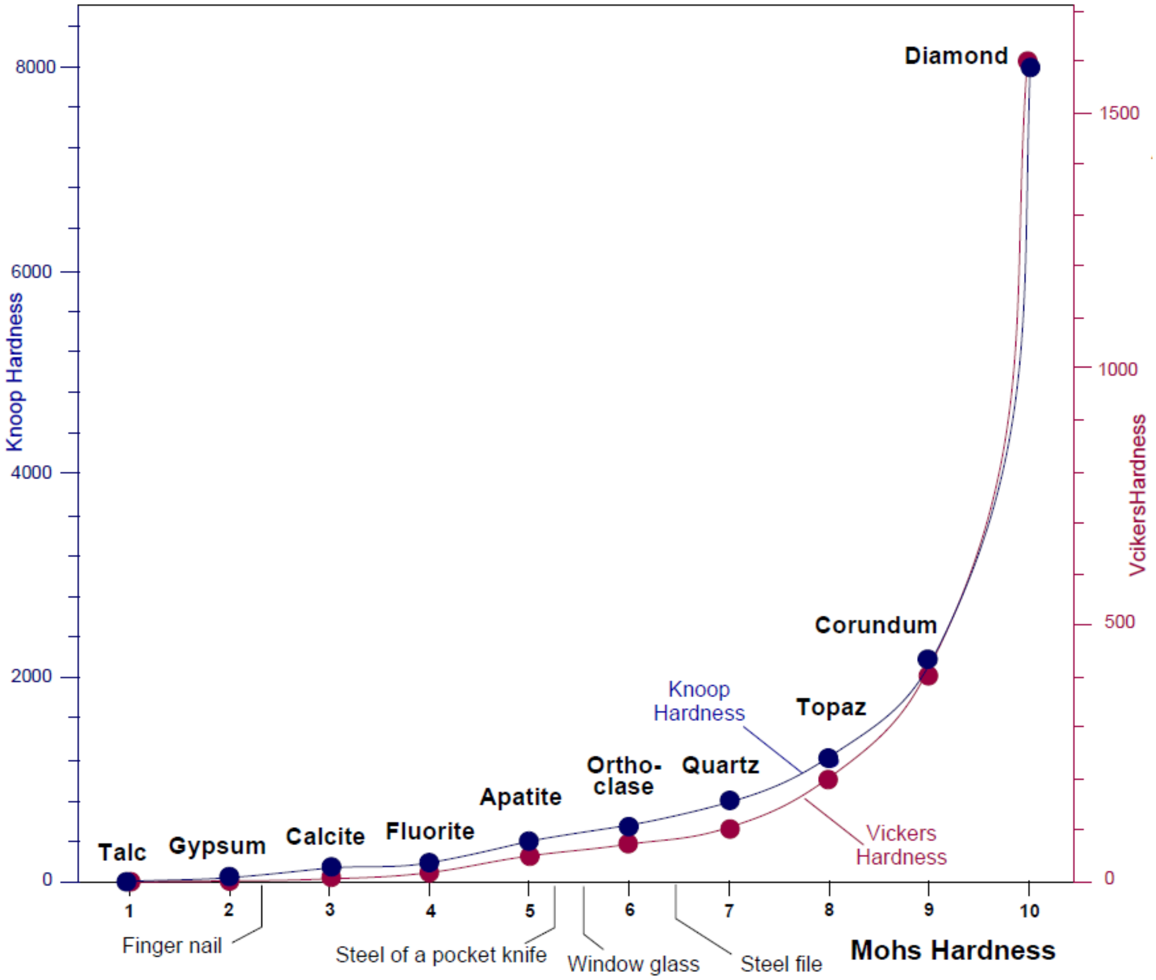
The minerals on the Mohs scale are as follows:

1	Talc
2	Gypsum
3	Calcite
4	Fluorite
5	Apatite
6	Orthoclase
7	Quartz
8	Topaz
9	Corundum
10	Diamond



Mohs Scale Test Kit

The non-linearity of the Mohs scale is represented in the following graph, with correlating Knoop and Vickers hardness:



Rockwell Hardness

The Rockwell hardness test is, by far, the most widely used hardness testing method for several reasons: it's simple, fast, and versatile. However, there are 30 different scales under the Rockwell umbrella, so it is important to understand the entire system. Invented in 1919 by Stanley P. Rockwell, the Rockwell test was originally used for process control in heat treating bearing components. Rockwell hardness is determined by a mechanical test that has many variations, depending on material characteristics. By adjusting the indenter and applied force, each scale represents a sub-type of material hardness. The Rockwell test is useful for material selection, process and quality control, and acceptance testing of commercial products.

Rockwell indenters vary. For the common A/C/D scales, the indenter is a 120-degree spheroconical diamond point, which is used for steels and hard alloys. Softer metals that employ the other scales use ball indenters ranging from 1/16" – ½" diameter. Superficial hardness tests (for very thin specimens) use ball indenters. The following tables from ASTM E18 *Standard Test Method for Rockwell Hardness of Metallic Materials* specifies indenters, test force, and material application for Rockwell tests:

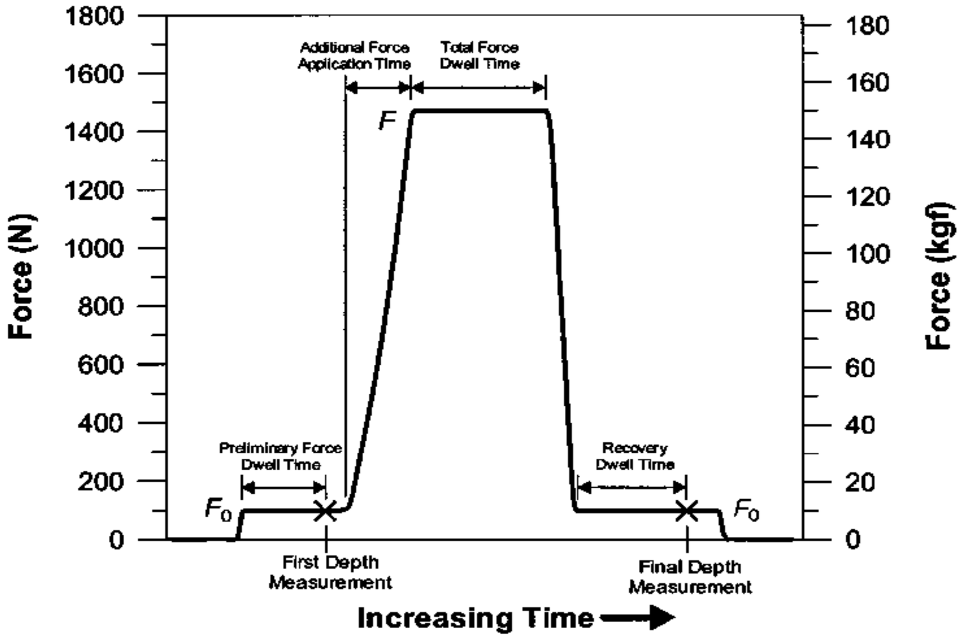
TABLE 1 Rockwell Hardness Scales

Scale Symbol	Indenter	Total Test Force, kgf	Dial Figures	Typical Applications of Scales
B	1/16-in. (1.588-mm) ball	100	red	Copper alloys, soft steels, aluminum alloys, malleable iron, etc.
C	diamond	150	black	Steel, hard cast irons, pearlitic malleable iron, titanium, deep case hardened steel, and other materials harder than B100.
A	diamond	60	black	Cemented carbides, thin steel, and shallow case-hardened steel.
D	diamond	100	black	Thin steel and medium case hardened steel, and pearlitic malleable iron.
E	1/8-in. (3.175-mm) ball	100	red	Cast iron, aluminum and magnesium alloys, bearing metals.
F	1/16-in. (1.588-mm) ball	60	red	Annealed copper alloys, thin soft sheet metals.
G	1/16-in. (1.588-mm) ball	150	red	Malleable irons, copper-nickel-zinc and cupro-nickel alloys. Upper limit G92 to avoid possible flattening of ball.
H	1/8-in. (3.175-mm) ball	60	red	Aluminum, zinc, lead. Bearing metals and other very soft or thin materials. Use smallest ball and heaviest load that does not give anvil effect.
K	1/8-in. (3.175-mm) ball	150	red	
L	1/4-in. (6.350-mm) ball	60	red	
M	1/4-in. (6.350-mm) ball	100	red	
P	1/4-in. (6.350-mm) ball	150	red	
R	1/2-in. (12.70-mm) ball	60	red	
S	1/2-in. (12.70-mm) ball	100	red	
V	1/2-in. (12.70-mm) ball	150	red	

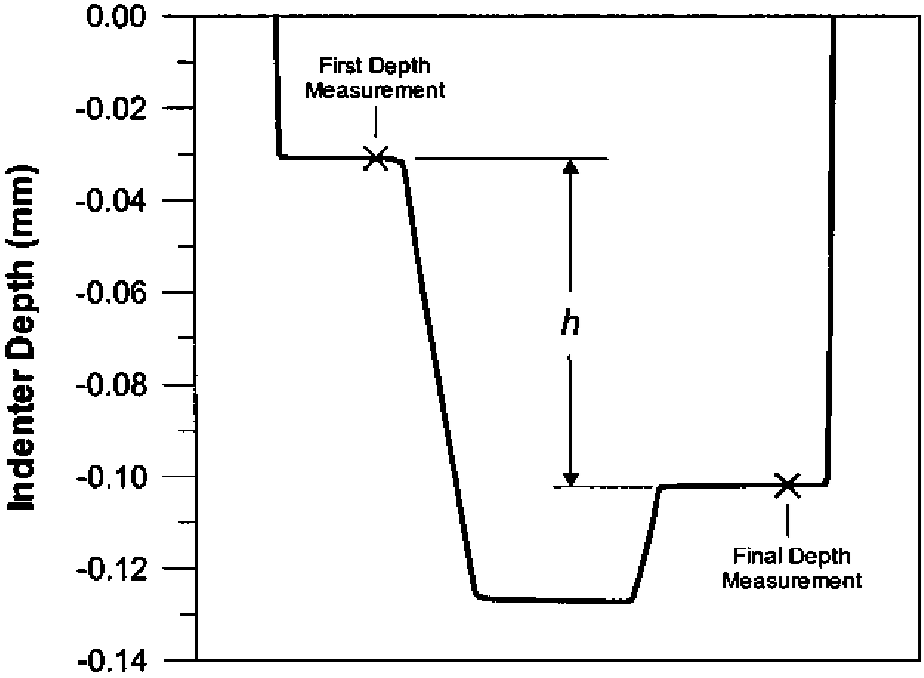
TABLE 2 Rockwell Superficial Hardness Scales

Total Test Force, kgf (N)	Scale Symbols				
	N Scale, Diamond Indenter	T Scale, 1/16-in. (1.588-mm) Ball	W Scale, 1/8-in. (3.175-mm) Ball	X Scale, 1/4-in. (6.350-mm) Ball	Y Scale, 1/2-in. (12.70-mm) Ball
15 (147)	15N	15T	15W	15X	15Y
30 (294)	30N	30T	30W	30X	30Y
45 (441)	45N	45T	45W	45X	45Y

Two levels of force are applied to the indenter at specific rates and with specific dwell times during a Rockwell test. Unlike Brinell and Vickers tests, where the indentation size is measured, Rockwell establishes hardness by measuring the difference in depth of the indenter. This graph represents dwell times for each stage of a Rockwell test:



Here, the depth of indentation is illustrated:



The preliminary force (minor load) is applied to the indenter and held steady for a period of time. Then, the secondary force (major load) is added to the minor load and held constant. Finally, the force is removed from the indenter. The difference between the indentation depth measurements (*h*) is used to calculate the Rockwell hardness number, where the unit of *h* is mm:

$$\text{Rockwell Hardness} = 100 - \frac{h}{0.002}$$

$$\text{Rockwell Superficial Hardness} = 100 - \frac{h}{0.001}$$

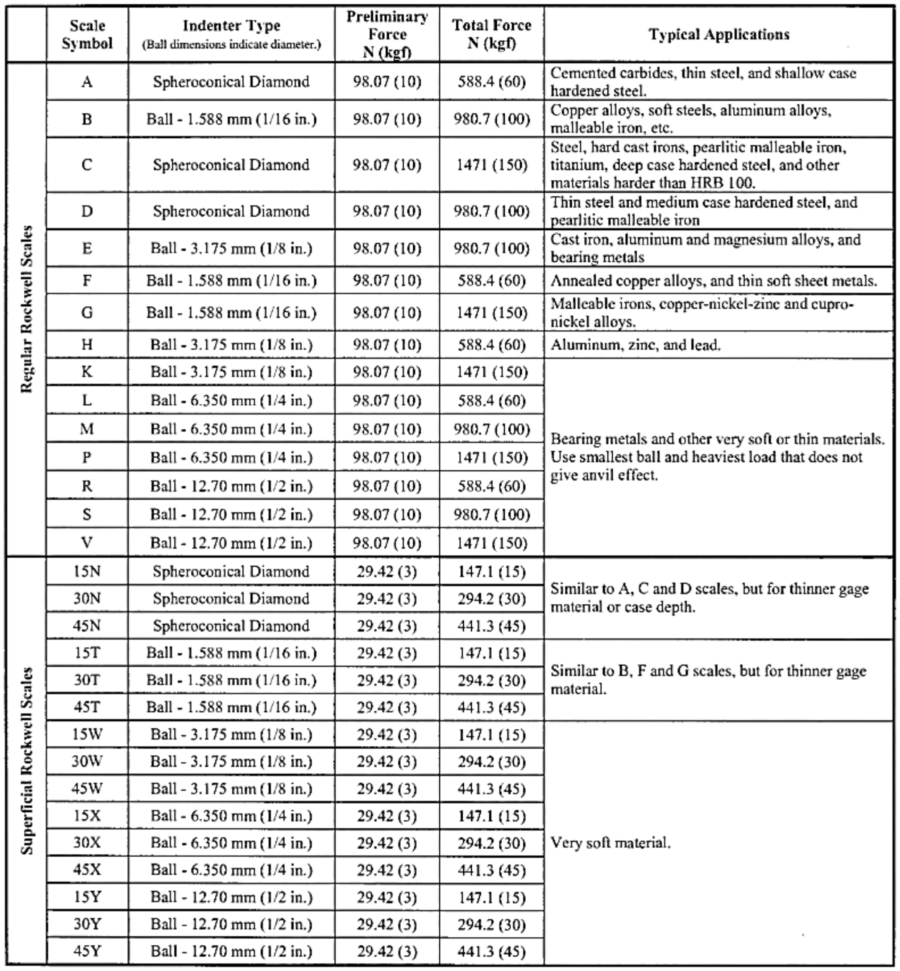
Spheroconical Indenter

$$\text{Rockwell Hardness} = 130 - \frac{h}{0.002}$$

$$\text{Rockwell Superficial Hardness} = 100 - \frac{h}{0.001}$$

Ball Indenter

This chart, similar to the chart of Page 7, specifies the preliminary (minor) force as well as the total force (major). For example, a Rockwell C test would require the machine to be adjusted to a 10 kgf minor load and 150 kgf major load setting. Application of the forces may be applied manually or automatically, depending on the machine. Digital machines typically automatically adjust the applied load based on which scale is selected.



	Scale Symbol	Indenter Type (Ball dimensions indicate diameter.)	Preliminary Force N (kgf)	Total Force N (kgf)	Typical Applications
Regular Rockwell Scales	A	Spheroconical Diamond	98.07 (10)	588.4 (60)	Cemented carbides, thin steel, and shallow case hardened steel.
	B	Ball - 1.588 mm (1/16 in.)	98.07 (10)	980.7 (100)	Copper alloys, soft steels, aluminum alloys, malleable iron, etc.
	C	Spheroconical Diamond	98.07 (10)	1471 (150)	Steel, hard cast irons, pearlitic malleable iron, titanium, deep case hardened steel, and other materials harder than HRB 100.
	D	Spheroconical Diamond	98.07 (10)	980.7 (100)	Thin steel and medium case hardened steel, and pearlitic malleable iron
	E	Ball - 3.175 mm (1/8 in.)	98.07 (10)	980.7 (100)	Cast iron, aluminum and magnesium alloys, and bearing metals
	F	Ball - 1.588 mm (1/16 in.)	98.07 (10)	588.4 (60)	Annealed copper alloys, and thin soft sheet metals.
	G	Ball - 1.588 mm (1/16 in.)	98.07 (10)	1471 (150)	Malleable irons, copper-nickel-zinc and cupro-nickel alloys.
	H	Ball - 3.175 mm (1/8 in.)	98.07 (10)	588.4 (60)	Aluminum, zinc, and lead.
	K	Ball - 3.175 mm (1/8 in.)	98.07 (10)	1471 (150)	Bearing metals and other very soft or thin materials. Use smallest ball and heaviest load that does not give anvil effect.
	L	Ball - 6.350 mm (1/4 in.)	98.07 (10)	588.4 (60)	
	M	Ball - 6.350 mm (1/4 in.)	98.07 (10)	980.7 (100)	
	P	Ball - 6.350 mm (1/4 in.)	98.07 (10)	1471 (150)	
	R	Ball - 12.70 mm (1/2 in.)	98.07 (10)	588.4 (60)	
	S	Ball - 12.70 mm (1/2 in.)	98.07 (10)	980.7 (100)	
	V	Ball - 12.70 mm (1/2 in.)	98.07 (10)	1471 (150)	
Superficial Rockwell Scales	15N	Spheroconical Diamond	29.42 (3)	147.1 (15)	Similar to A, C and D scales, but for thinner gage material or case depth.
	30N	Spheroconical Diamond	29.42 (3)	294.2 (30)	
	45N	Spheroconical Diamond	29.42 (3)	441.3 (45)	
	15T	Ball - 1.588 mm (1/16 in.)	29.42 (3)	147.1 (15)	Similar to B, F and G scales, but for thinner gage material.
	30T	Ball - 1.588 mm (1/16 in.)	29.42 (3)	294.2 (30)	
	45T	Ball - 1.588 mm (1/16 in.)	29.42 (3)	441.3 (45)	
	15W	Ball - 3.175 mm (1/8 in.)	29.42 (3)	147.1 (15)	Very soft material.
	30W	Ball - 3.175 mm (1/8 in.)	29.42 (3)	294.2 (30)	
	45W	Ball - 3.175 mm (1/8 in.)	29.42 (3)	441.3 (45)	
	15X	Ball - 6.350 mm (1/4 in.)	29.42 (3)	147.1 (15)	
	30X	Ball - 6.350 mm (1/4 in.)	29.42 (3)	294.2 (30)	
	45X	Ball - 6.350 mm (1/4 in.)	29.42 (3)	441.3 (45)	
	15Y	Ball - 12.70 mm (1/2 in.)	29.42 (3)	147.1 (15)	
	30Y	Ball - 12.70 mm (1/2 in.)	29.42 (3)	294.2 (30)	
	45Y	Ball - 12.70 mm (1/2 in.)	29.42 (3)	441.3 (45)	

It is important to specify which scale is being referred to when identifying a Rockwell number. For example, a material resulting in a 68 on the C scale would be designated as HRC 68. An 83 on the 30N superficial scale (diamond indenter) would be called out as 83 HR30N.

If multiple tests are required on a single specimen (or reference block), the indentations must be spaced apart. Each indentation deforms the material within a small radius of the original location. To avoid distorting the subsequent test, ASTM E18 advises moving three indention diameters away from the initial test site. Also, 2-1/2 diameters are recommended spacing from the edge of the material specimen:

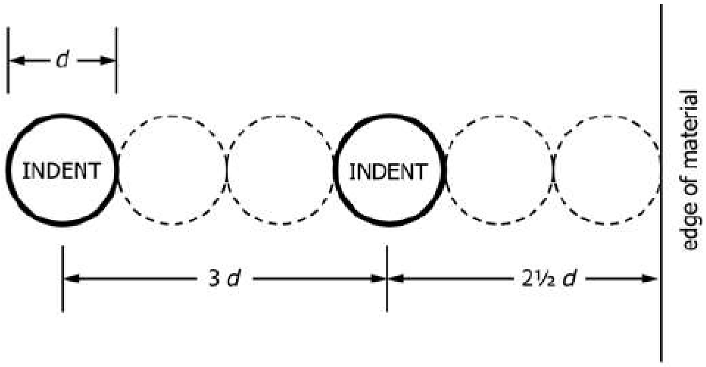


FIG. 3 Schematic of Minimum Indentation Spacing

For round specimens (round stock, pipe, etc.), a compensation factor must be used. Since the curved surface of the part is only perpendicular to the indenter in one axis, an adjustment must be made. This value is added to the Rockwell number and is based on the curvature diameter and dial reading:

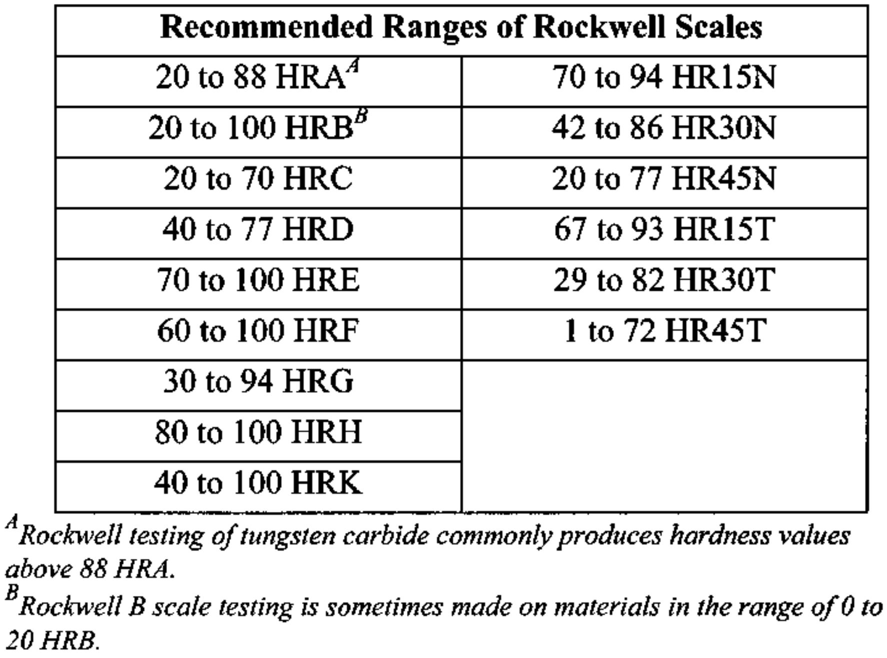
TABLE A6.1 Corrections to be Added to Rockwell C, A, and D Values Obtained on Convex Cylindrical Surfaces of Various Diameters[A]

Dial Reading	Diameters of Convex Cylindrical Surfaces								
	¼ in. (6.4 mm)	⅜ in. (10 mm)	½ in. (13 mm)	⅝ in. (16 mm)	¾ in. (19 mm)	⅞ in. (22 mm)	1 in. (25 mm)	1¼ in. (32 mm)	1½ in. (38 mm)
	Corrections to be Added to Rockwell C, A, and D Values[B]								
20	6.0	4.5	3.5	2.5	2.0	1.5	1.5	1.0	1.0
25	5.5	4.0	3.0	2.5	2.0	1.5	1.0	1.0	1.0
30	5.0	3.5	2.5	2.0	1.5	1.5	1.0	1.0	0.5
35	4.0	3.0	2.0	1.5	1.5	1.0	1.0	0.5	0.5
40	3.5	2.5	2.0	1.5	1.0	1.0	1.0	0.5	0.5
45	3.0	2.0	1.5	1.0	1.0	1.0	0.5	0.5	0.5
50	2.5	2.0	1.5	1.0	1.0	0.5	0.5	0.5	0.5
55	2.0	1.5	1.0	1.0	0.5	0.5	0.5	0.5	0
60	1.5	1.0	1.0	0.5	0.5	0.5	0.5	0	0
65	1.5	1.0	1.0	0.5	0.5	0.5	0.5	0	0
70	1.0	1.0	0.5	0.5	0.5	0.5	0.5	0	0
75	1.0	0.5	0.5	0.5	0.5	0.5	0	0	0
80	0.5	0.5	0.5	0.5	0.5	0	0	0	0
85	0.5	0.5	0.5	0	0	0	0	0	0
90	0.5	0	0	0	0	0	0	0	0

[A] When testing cylindrical specimens, the accuracy of the test will be seriously affected by alignment of elevating screw, V-anvil, indenters, surface finish, and the straightness of the cylinder.

[B] These corrections are approximate only and represent the averages to the nearest 0.5 Rockwell number, of numerous actual observations.

Although Rockwell scales are defined from 0 to 100, the sensitivity and accuracy of the test diminishes at the upper and lower ends of the scale. ISO standards recommend the following ranges to be used. If a test falls outside of the given range, the next higher or lower scale should be used.



Recommended Ranges of Rockwell Scales	
20 to 88 HRA[A]	70 to 94 HR15N
20 to 100 HRB[B]	42 to 86 HR30N
20 to 70 HRC	20 to 77 HR45N
40 to 77 HRD	67 to 93 HR15T
70 to 100 HRE	29 to 82 HR30T
60 to 100 HRF	1 to 72 HR45T
30 to 94 HRG	
80 to 100 HRH	
40 to 100 HRK	

[A] *Rockwell testing of tungsten carbide commonly produces hardness values above 88 HRA.*

[B] *Rockwell B scale testing is sometimes made on materials in the range of 0 to 20 HRB.*

Brinell Hardness

Developed by Swedish engineer Johann Brinell in the late 19th century, the Brinell test is universally used in the metal working industry. ASTM E10 *Standard Test Method for Brinell Hardness of Metallic Materials* provides requirements and procedures for this test. The Brinell method employs a tungsten carbide ball indenter and a 1-30 kgf static force for a nominal 10-15 second dwell time. The indentation diameter is measured with a microscope and used to calculate the hardness number. The process of Brinell testing is very similar to Rockwell testing, and many procedures are identical.

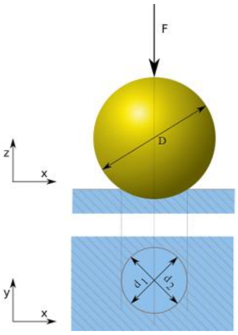
The Brinell test is especially useful when applied to castings, where surface finish is generally rough and material properties vary on a microscopic scale. The relatively large indenter provides an average surface hardness.

If a hardness indentation diameter is less than 2.4 mm or larger than 6 mm, it should not be used. The material is either too hard or too soft to provide an accurate reading.

Calculation of the Brinell hardness number is as follows:

$$BHN = \frac{PD}{2\pi(D - \sqrt{D^2 - d^2})}$$

where P = test load (kg)
D = Ball diameter (mm)
d = Indentation diameter (mm)



Brinell Indenters and Anvils

The combination of indenter and test force define the Brinell hardness scales, much like Rockwell. This table from ASTM E10 specifies each scale with recommended hardness ranges:

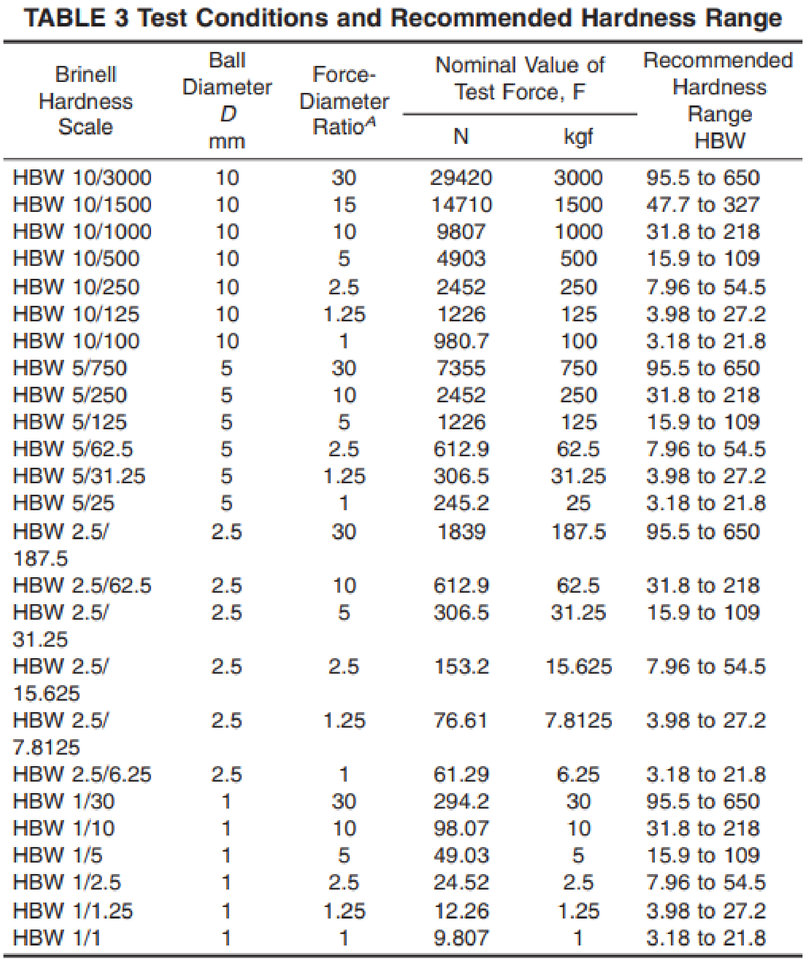
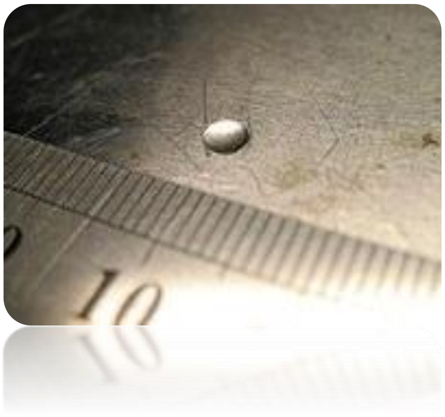


TABLE 3 Test Conditions and Recommended Hardness Range

Brinell Hardness Scale	Ball Diameter *D* mm	Force-Diameter Ratio[A]	Nominal Value of Test Force, F		Recommended Hardness Range HBW
			N	kgf	
HBW 10/3000	10	30	29420	3000	95.5 to 650
HBW 10/1500	10	15	14710	1500	47.7 to 327
HBW 10/1000	10	10	9807	1000	31.8 to 218
HBW 10/500	10	5	4903	500	15.9 to 109
HBW 10/250	10	2.5	2452	250	7.96 to 54.5
HBW 10/125	10	1.25	1226	125	3.98 to 27.2
HBW 10/100	10	1	980.7	100	3.18 to 21.8
HBW 5/750	5	30	7355	750	95.5 to 650
HBW 5/250	5	10	2452	250	31.8 to 218
HBW 5/125	5	5	1226	125	15.9 to 109
HBW 5/62.5	5	2.5	612.9	62.5	7.96 to 54.5
HBW 5/31.25	5	1.25	306.5	31.25	3.98 to 27.2
HBW 5/25	5	1	245.2	25	3.18 to 21.8
HBW 2.5/187.5	2.5	30	1839	187.5	95.5 to 650
HBW 2.5/62.5	2.5	10	612.9	62.5	31.8 to 218
HBW 2.5/31.25	2.5	5	306.5	31.25	15.9 to 109
HBW 2.5/15.625	2.5	2.5	153.2	15.625	7.96 to 54.5
HBW 2.5/7.8125	2.5	1.25	76.61	7.8125	3.98 to 27.2
HBW 2.5/6.25	2.5	1	61.29	6.25	3.18 to 21.8
HBW 1/30	1	30	294.2	30	95.5 to 650
HBW 1/10	1	10	98.07	10	31.8 to 218
HBW 1/5	1	5	49.03	5	15.9 to 109
HBW 1/2.5	1	2.5	24.52	2.5	7.96 to 54.5
HBW 1/1.25	1	1.25	12.26	1.25	3.98 to 27.2
HBW 1/1	1	1	9.807	1	3.18 to 21.8



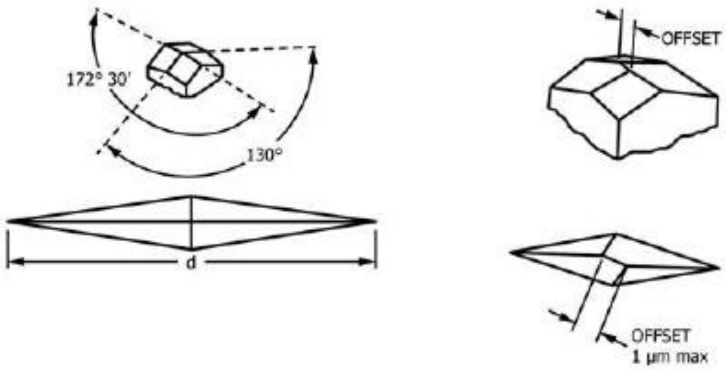
Also similar to Rockwell, if multiple tests are required on a single specimen (or reference block), the indentations must be spaced apart. ASTM E10 advises moving three indention diameters away from the initial test site. Also, 2-1/2 diameters are recommended spacing from the edge of the material specimen.

When specifying which scale is being referred to when identifying a Brinell hardness material resulting in, for example, a 350 on the 5/750 scale would be designation 350 HBW 5/750. The exception to specifying the dwell time / load is for the HBW 10/3000 scale where a Brinell hardness may simply be reported as HBW. Note: outdated steel indenters were labeled as HBS but have been superseded with tungsten carbide.

Knoop & Vickers

The **Knoop scale** was developed in 1939 by Frederick Knoop, of the U.S. National Bureau of Standards. Knoop hardness is ascertained by measuring the area of indentation of a diamond indenter with a specific set of facets pressed into the test material at a set pressure for a particular amount of time. Force values are commonly specified as gf and kgf. ASTM E92 *Standard Test Method for Vickers Hardness and Knoop Hardness of Metallic Materials* provides requirements and procedures for this test.

The Knoop indenter is a highly polished, pointed, and rhombic-based pyramidal diamond with edge angles of 172° 30’ and 130° 0’, as shown here:



To calculate Knoop hardness (HK), the diagonals of the indentation left in the surface are measure with a microscope. Then, the Knoop hardness value is calculated by the following equations, based on a load with units of kgf:

$$HK = \frac{Test\ Force}{Projected\ Area} \text{ where } A_p = d^2\, x\, c_p$$

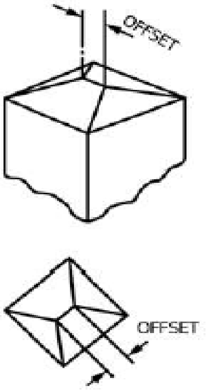
Note: c_p is a constant relating the projected area to the square of the length of the long diagonal.

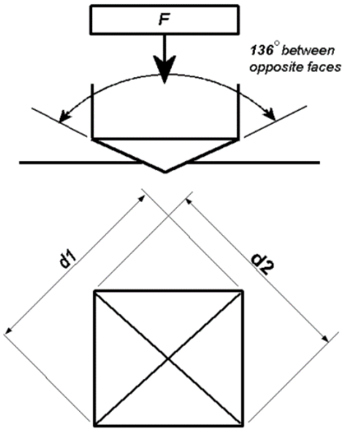
The resolved Knoop equation is $K = \frac{14.229\,F}{d^2}$, where *d* is the long indentation diagonal length (mm), and F is the test force (kgf).

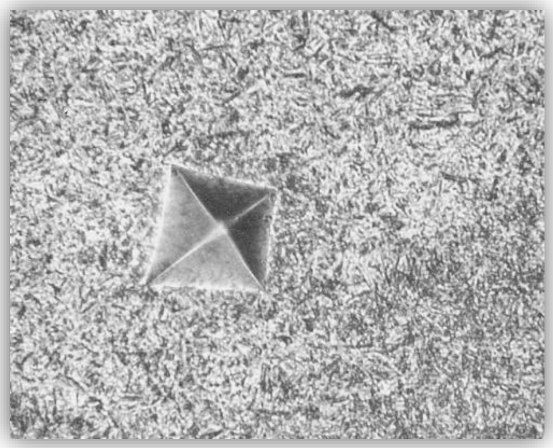
Knoop hardness should be reported as, for example, 400 HK 0.5, which means a Knoop hardness of 400 obtained by using a 0.5 kgf test force.

The **Vickers hardness test** was invented at Vickers, Ltd. In the UK during the 1920's by two engineers. The Vickers method is similar to Knoop except the diamond indenter is of a square shape. Hardness is proportional to the test force divided by the projected indentation area after removal of the test force. The advantages of using this method are that the hardness values are extremely accurate and a single indenter is used for all types of materials, both soft and hard. ASTM E92 *Standard Test Method for Vickers Hardness and Knoop Hardness of Metallic Materials* provides requirements and procedures for this test. Note that very thin specimens may be examined by testing microhardness, which is not interchangeable with standard Vickers hardness.

The Vickers indenter is highly polished, pointed, and has the form of a pyramid with a square base and an angle of 136° between opposite faces. Test force varies between 1gf and 100kgf, although common loads are 5 kg, 10 kg, 30 kg, and 50 kg. The load is applied for 10-15 seconds. The image below (right) shows the post-test view of the indentation on the sample material.







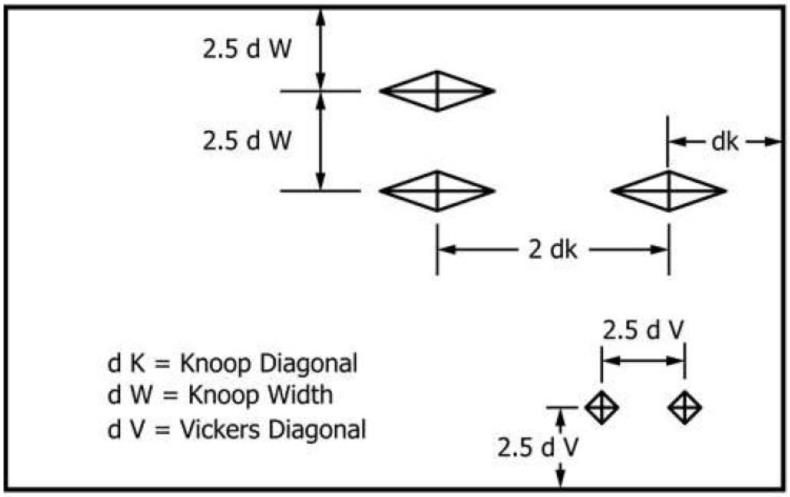
To calculate Vickers hardness, the diagonals of the indentation left in the surface are measure with a microscope and averaged. Then, the Vickers hardness value (HV) is calculated by the following equations, based on a load with units of kgf:

$$HV = \frac{Test\ Force}{Surface\ Area} \text{ where } A_s = \frac{d^2}{2sin\frac{\alpha}{2}}$$

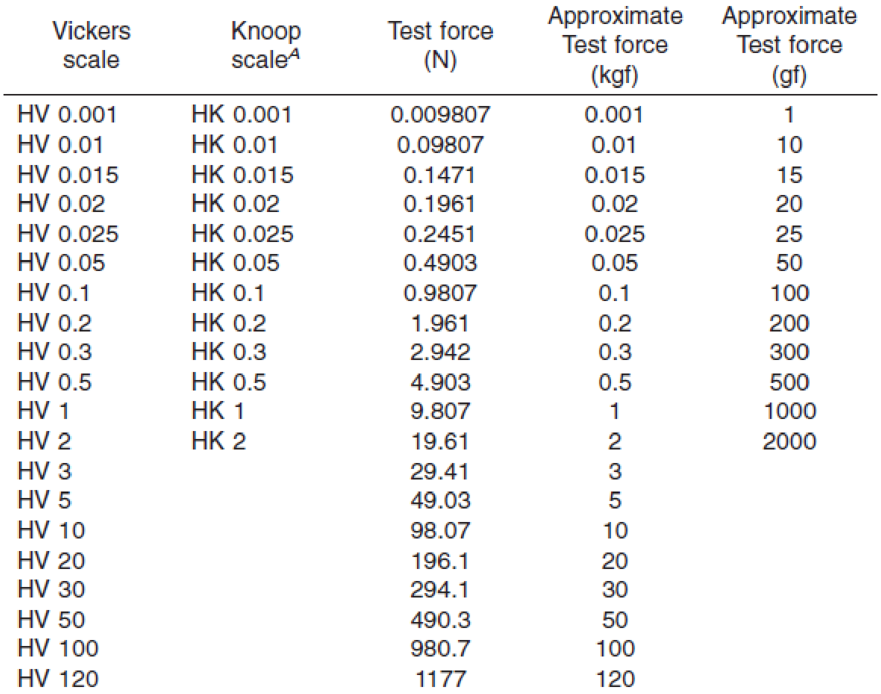
$$HV = \frac{2Fsin\left(\frac{136^0}{2}\right)}{d^2} \text{ which simplifies to } HV = 1.854\frac{F}{d^2}$$

Modern digital hardness testers calculate this value and report the result automatically. Vickers hardness should be reported as, for example, 725 HV 10, which means a Vickers hardness of 650 obtained by using a 10 kgf test force.

Recommended spacing between indentations for both Knoop and Vickers tests are shown in this graphic:



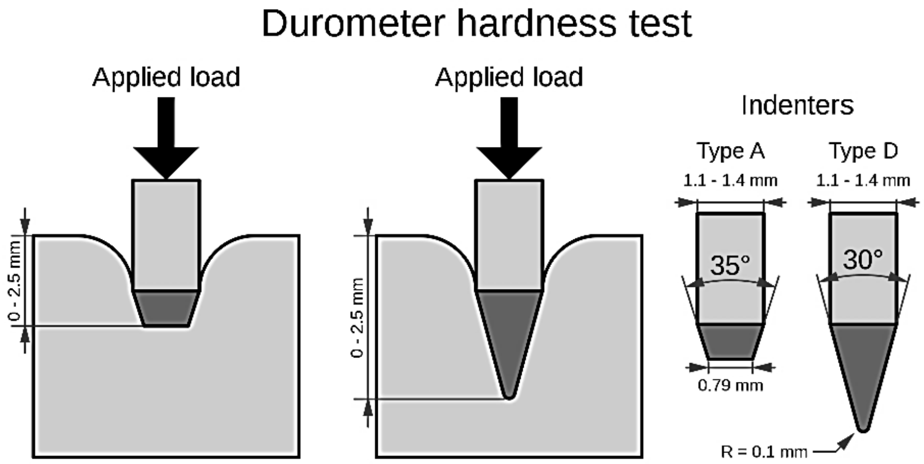
This table specifies the standard hardness scales and test forces for Vickers and Knoop:



Vickers scale	Knoop scale^A	Test force (N)	Approximate Test force (kgf)	Approximate Test force (gf)
HV 0.001	HK 0.001	0.009807	0.001	1
HV 0.01	HK 0.01	0.09807	0.01	10
HV 0.015	HK 0.015	0.1471	0.015	15
HV 0.02	HK 0.02	0.1961	0.02	20
HV 0.025	HK 0.025	0.2451	0.025	25
HV 0.05	HK 0.05	0.4903	0.05	50
HV 0.1	HK 0.1	0.9807	0.1	100
HV 0.2	HK 0.2	1.961	0.2	200
HV 0.3	HK 0.3	2.942	0.3	300
HV 0.5	HK 0.5	4.903	0.5	500
HV 1	HK 1	9.807	1	1000
HV 2	HK 2	19.61	2	2000
HV 3		29.41	3	
HV 5		49.03	5	
HV 10		98.07	10	
HV 20		196.1	20	
HV 30		294.1	30	
HV 50		490.3	50	
HV 100		980.7	100	
HV 120		1177	120	

Shore Hardness

Shore hardness defines the solidarity of non-metallic materials (generally polymers, elastomers, and rubbers) via indentation. Named after Albert F. Shore, the inventor, the Shore hardness test was developed in the 1920's and uses a device called a Durometer to measure resistance to indentation, hence the synonymity of the terms 'Shore' and 'Durometer'. Although Shore hardness is an accurate way to measure resistance to indentation, it should not be used as a sole means of categorizing a material. Other properties such as abrasion, strength, and scratch resistance cannot be predicted by a hardness test.



There are 12 different Shore scales: A, B, C, D, E M, 0, 00, D0, 000, and 000-S, although only A, D, and 00 are the three commonly used. A higher Shore number means a harder material, regardless of which scale is used.

The 00 scale has a spring force of 113g and is used for very soft materials such as gum, marshmallows, and gummy bears. The need for an engineer to measure edible food hardness remains unknown.

The A scale is used for medium soft flexible rubbers materials like a rubber band or a shoe heel and uses a 822g spring force. Silicone products are generally measure with Shore A.

The D scale used with harder plastic materials. Casting resins, urethanes, HDPE, and truck tires usually fall into the Shore D category.

The variables that change with each scale include indenter configuration/diameter, extension, and applied spring force. ASTM D2240 *Standard Test Method for Rubber Property – Durometer Hardness* provides requirements and procedures for this test. Depth of indenter penetration depends on four properties:

1. Material hardness
2. Viscoelastic properties
3. Shape of indenter
4. Duration of the test

Examples of materials with various Shore harnesses are shown here:

Material	Durometer	Scale
Bicycle gel seat	15–30	OO
Chewing gum	20	OO
Rubber band	25	A
Door seal	55	A
Automotive tire tread	70	A
Soft wheels of roller skates and skateboard	78	A
Hydraulic O-ring	70–90	A
Pneumatic O-ring	65–75	A
Hard wheels of roller skates and skateboard	98	A
Ebonite rubber	100	A
Solid truck tires	50	D
Hard hat (typically HDPE)	75	D
Cast urethane plastic	80	D

Good Hardness Testing Practices

- For Rockwell testing, if an unknown material is to be tested, it is good practice to begin with a diamond indenter rather than a ball indenter. A diamond indenter is not likely to be damaged in a soft material, whereas a ball indenter could flatten if the material is too hard.

- Testing too thin of material can damage the anvil and distort the reading. Follow specification guidelines to prevent damage and inaccurate testing.

- Avoid stacking multiple specimens when testing.

- Indenters must be handled with care and prevented from sharply striking the anvil or specimen.

- Reference blocks should be handled and stored carefully. The accuracy of the test machine largely depends on the integrity of reference blocks.

- The anvil must be properly seated before hardness testing to prevent inaccurate measurements. A proper anvil should be selected and routinely cleaned to ensure reliable data collection.

- A clean, well-supported material specimen is critical to an accurate hardness test.

- In circumstances where the user wants to compare measurements with previously obtained hardness data, the same scale should be chosen as was used for the previous testing as long as a valid test can be obtained. This is preferred to testing on one scale and then converting the data to another scale by way of conversion tables.

- **Converted data is never as accurate as the original measurement and should only be considered approximations. Avoid where possible.**

- Follow machine instructions to complete direct & indirect verification tests and calibration requirements.

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