



A Guide to Selecting the Right Hardness Testing Method

Zwick / Roell



The best hardness test method and corresponding load depend on the material to be tested, the component shape, application, and the customer requirements. After process of elimination, there are often only a few options left. In this white paper we provide the necessary details to make your decision easier.

Hardness Methods:

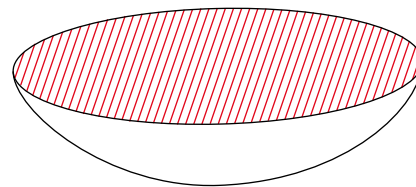
There are several frequently used methods to measure the hardness of metals, including:

1 Rockwell Hardness

The Rockwell hardness test measures the depth of penetration of an indenter into a material under a known load. It provides a hardness value based on the depth of penetration.

2 Brinell Hardness

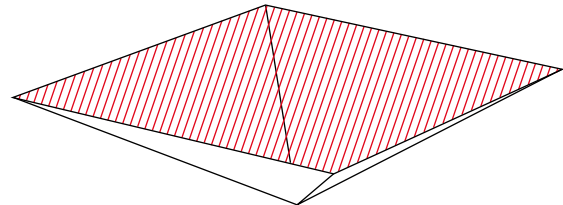
The Brinell hardness test involves indenting a material with a hard sphere under a specific load. Two diameters (x and y axis) of the indentation are measured, and the hardness value is determined based on the load applied.



Brinell belongs to the optical methods. [Learn more here.](#)

3 Vickers Hardness

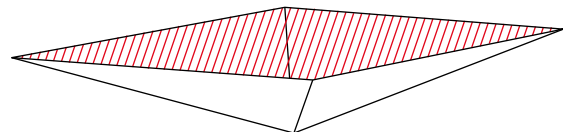
The Vickers hardness test utilizes a pyramidal diamond indenter to create an indentation on the material's surface. The diagonals (x and y axis) of the indentation are measured, and the hardness value is calculated based on the applied load and the indentation size.



Vickers belongs to the optical methods. [Learn more here.](#)

4 Knoop Hardness

The Knoop hardness test is similar to the Vickers test but uses a rhombic-based diamond indenter instead of a pyramid. It is commonly used for measuring the hardness of thin coatings or materials with a small indentation requirement.



Knoop belongs to the optical methods. [Learn more here.](#)

Each method has its advantages and limitations, and the choice of method depends on the material being tested and the specific requirements of the application. In the following pages we will examine the individual methods in more depth.



Rockwell



In certain cases, Rockwell offers compelling advantages. Fast, rough, affordable, and less surface treatment represent some of the key descriptors of this testing method. Rockwell is the most common procedure and offers accurate results.

1.1

Applications for Rockwell Methods

The Rockwell method is the most widely used on the American market. There are different reasons for this: Rockwell hardness testers are usually less costly than optical hardness testers, the test itself is quick and easy, surface finish of the material is not critical, and the Rockwell scale is a commonly accepted value when purchasing products.

■ Industrial Application

The Rockwell hardness test is widely used in various industrial applications, such as manufacturing, engineering, and quality control. It provides a quick and reliable measure of hardness, making it suitable for routine hardness testing on the production floor.

■ Surface Roughness

The Rockwell hardness test is less affected by surface roughness compared to other methods such as the Vickers or Brinell tests. It can provide reliable hardness measurements even on surfaces with moderate roughness, making it a practical choice for a wide range of materials and surface conditions.

■ Hardened Materials

The Rockwell test is particularly suitable for measuring the hardness of hardened metals and alloys. These materials often have high hardness levels and require higher applied loads to create an indentation. The Rockwell C scale (HRC) is commonly used for harder materials.

■ Portable Testing

Portable Rockwell hardness testers are available, which allow for on-site or field hardness testing. This is advantageous for applications where it is not feasible to transport samples to a laboratory or for situations that require immediate hardness assessment.



1.2

Rockwell Methods

- Brinell load ranges: 15 kg, 35 kg, 45 kg, 60 kg, 100 kg, 150 kg
- Cone indenter: 120°
- Ball sizes of the indenters: 1/16", 1/8", 1/4", 1/2"
- Method: Depth difference method
- Standards: EN ISO 6507 / ASTM E18

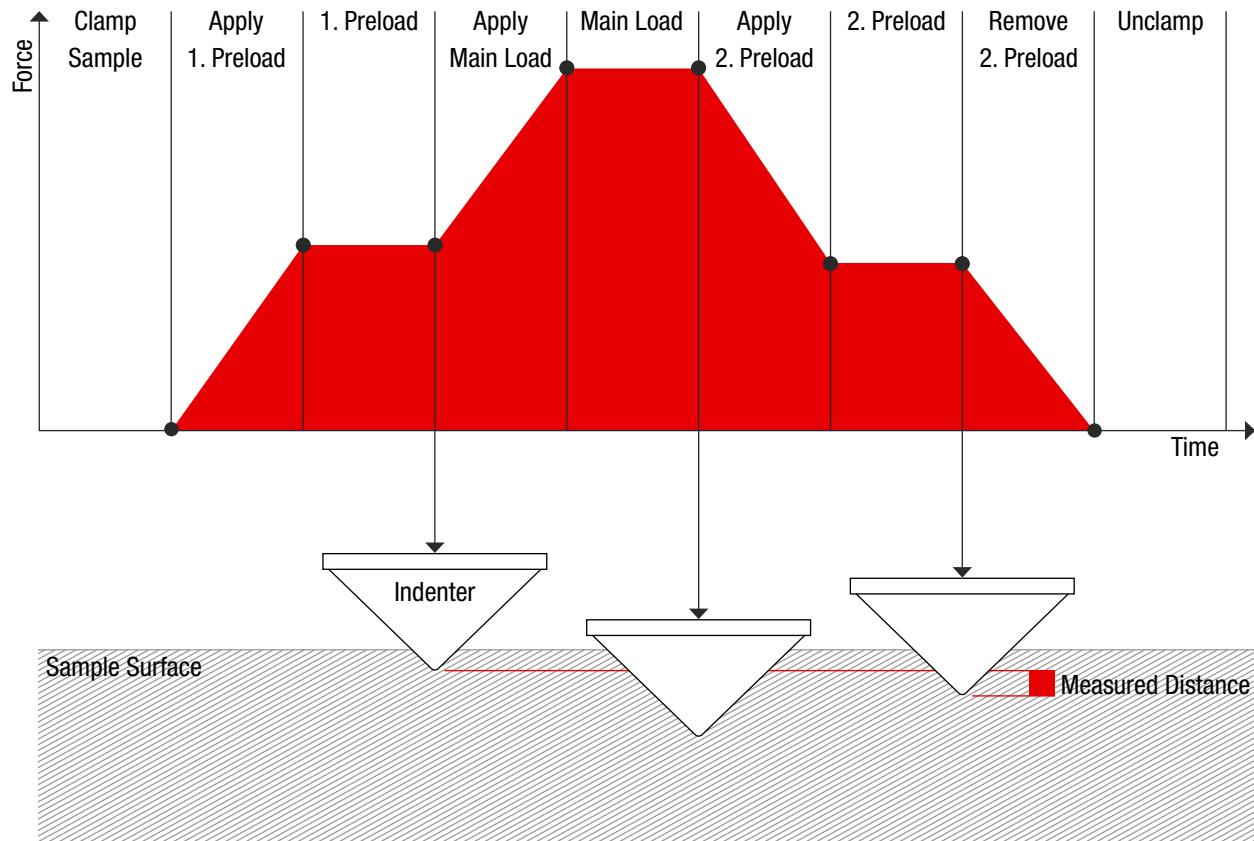
Rockwell Methods	Cone 	1/16" 	1/8" 	1/4" 	1/2" 
150 kg	HRC	HRGW	HRKW	HRPW	HRVW
100 kg	HRD	HRBW	HREW	HRMW	HRSW
60 kg	HRA	HRFW	HRHW	HRLW	HRRW
45 kg (Superficial)	HR45N	HR45TW	HR45WW	HR45XW	HR45YW
30 kg (Superficial)	HR30N	HR30TW	HR30WW	HR30XW	HR30YW
15 kg (Superficial)	HR15N	HR15TW	HR15WW	HR15XW	HR15YW



1.3

Test Cycle for Depth Difference Methods

Rockwell is a depth difference method and measures a distance by applying different loads to a sample. Regardless of the indenter and test load, the testing cycle always follows the same pattern.



■ Preload

1. The preload is applied to the sample and held for a specific time. For Rockwell methods the preload is 10 kg. For Superficial Rockwell methods the preload is 3 kg.

■ Main Load

2. In the second step, the main force is applied to the sample. Most of the time the main force is held for 7 seconds. Depending on the method chosen, the forces used may be different.

■ Back to Preload

3. In the third step, the force is returned to the previous force. After a certain holding time, the hardness value can be read from the hardness tester.

Semi-automatic and fully automatic hardness testers run this test cycle automatically and thereby reduce operator influences.



Brinell testing uses a relatively large, spherical indenter. This results in a larger and more visible indentation on the material's surface, which makes it easier to measure and less sensitive to surface roughness. Since the indentation is relatively large, it represents an average hardness over a larger area. This can provide a more representative measurement of the material's overall hardness compared to some other hardness testing methods.

2.1

Applications for Brinell Methods

The Brinell hardness testing method is used in various cases where large or rough surfaces, coarse-grained materials, or high loads are involved. It is particularly well-suited for testing the hardness of materials with relatively low hardness ranges, such as non-ferrous metals, castings, and softer steels. Specific cases where Brinell hardness testing is applied:

■ Soft Materials

Brinell testing is suitable for measuring the hardness of relatively soft materials, including low-carbon steels, aluminum, lead, copper, and some plastics. The use of a large indenter and high load helps to minimize the effect of surface irregularities and yields more accurate hardness values.

■ Casting Industry

Brinell hardness testing is extensively used in the casting industry to assess the hardness and quality of cast materials, such as cast iron, aluminum alloys, and bronze. It provides a reliable measurement of the material's hardness, which is crucial for evaluating its strength and durability.

■ Large Forgings

Forged components, especially those with large dimensions, can be effectively tested using the Brinell method. The high test load and a large spherical indenter allow for accurate measurements on the rough surfaces of forgings.

■ Coarse-Grained Materials

Brinell testing is often preferred for materials with a coarse grain structure, such as certain types of castings, because it provides an average hardness value over a larger indentation area. This helps to account for the potential variation in hardness across the grains.



It is important to note that Brinell hardness testing may not be suitable for materials with very high hardness or thin and small components where a smaller indentation size is desired. In such cases, alternative hardness testing methods like Knoop or Vickers may be more appropriate.

2.2

Brinell Methods

- Brinell load ranges: 1 kg – 3000 kg
- Ball sizes of the indenters: 1 mm, 2.5 mm, 5 mm and 10 mm
- Method: Optical
- Standards: DIN EN ISO 6506 / ASTM E10

Method	Indenter	Load F kgf	Load F N	Load Factor 0.102 x F/D ²	Hardness Range HBW*	Material
HBW 1/30	1 mm	30 kgf	294.2 N	30	95.5-653	Steel/Iron
HBW 2.5/187.5	2.5 mm	187.5 kgf	1.839 kN	30	95.5-653	
HBW 5/750	5 mm	750 kgf	7.355 kN	30	95.5-653	
HBW 10/3000	10 mm	3000 kgf	29.42 kN	30	95.5-653	
HBW 1/10	1 mm	10 kgf	98.07 N	10	31.8-218	Light Metal Copper Aluminium
HBW 2.5/62.5	2.5 mm	62.5 kgf	612.9 N	10	31.8-218	
HBW 5/250	5 mm	250 kgf	2.452 kN	10	31.8-218	
HBW 10/1000	10 mm	1000 kgf	9.807 kN	10	31.8-218	
HBW 1/5	1 mm	5 kgf	49.03 N	5	15.9-109	Light Metal Copper Aluminium
HBW 2.5/31.25	2.5 mm	31.25 kgf	306.5 N	5	15.9-109	
HBW 5/125	5 mm	125 kgf	1.226 kN	5	15.9-109	
HBW 10/500	10 mm	500 kgf	4.903 kN	5	15.9-109	
HBW 1/2.5	1 mm	2.5 kgf	24.52 N	2.5	7.96-54.5	Light Metal
HBW 2.5/15.625	2.5 mm	15.625 kgf	153.2 N	2.5	7.96-54.5	
HBW 5/62.5	5 mm	62.5 kgf	612.9 N	2.5	7.96-54.5	
HBW 10/250	10 mm	250 kgf	2.452 kn	2.5	7.96-54.5	
HBW 1/1	1 mm	1 kgf	9.807 N	1	3.18-21.8	Light Metal Lead/Tin
HBW 2.5/6.25	2.5 mm	6.25 kgf	61.29 N	1	3.18-21.8	
HBW 5/25	5 mm	25 kgf	245.2 N	1	3.18-21.8	
HBW 10/100	10 mm	100 kgf	980.7 N	1	3.18-21.8	

*Recommended hardness range according to EN ISO 6506-4, table 2

2.3

Functional and Calculation Principle for Brinell

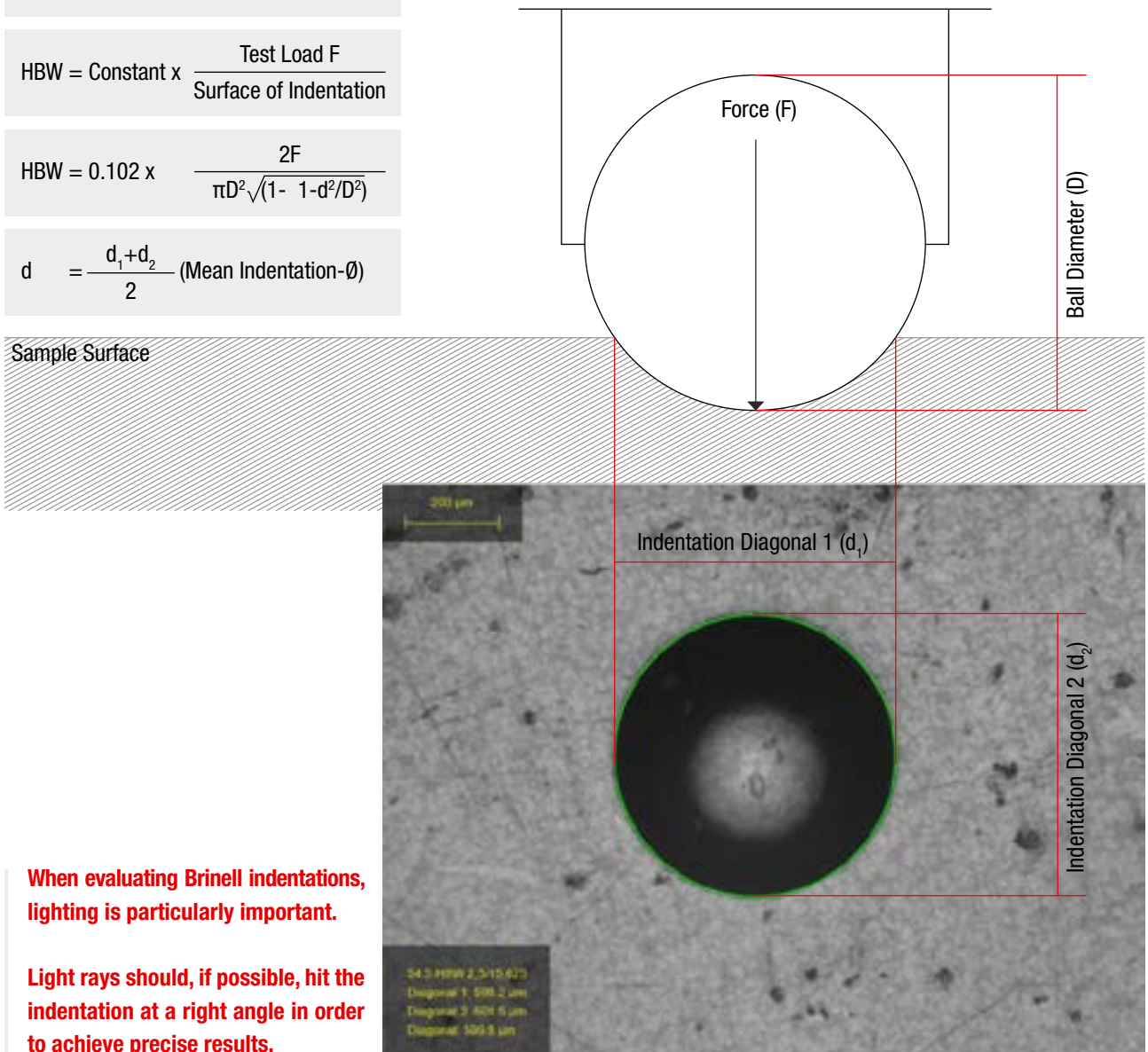
The result of a Brinell method depends on the tested material, force, ball size and dwell time. An indentation is measured using a magnifying lens. The larger the measured diagonals, the softer the material is.

HBW = Brinell Hardness

$$HBW = \text{Constant} \times \frac{\text{Test Load } F}{\text{Surface of Indentation}}$$

$$HBW = 0.102 \times \frac{2F}{\pi D^2 \sqrt{1 - 1 - d^2/D^2}}$$

$$d = \frac{d_1 + d_2}{2} \text{ (Mean Indentation-}\emptyset\text{)}$$



When evaluating Brinell indentations, lighting is particularly important.

Light rays should, if possible, hit the indentation at a right angle in order to achieve precise results.



The Vickers hardness testing method offers advantages such as a small indentation size, accurate hardness measurements, and applicability to a wide range of materials. Series measurements or mappings are very often carried out using this method. However, it may not be suitable for very soft or highly textured materials, while alternative hardness testing methods like Brinell or Rockwell may be more appropriate in such cases.

3.1

Vickers Method

The Vickers hardness testing method is widely used in various cases where precise and accurate hardness measurements are required. It is applicable to a broad range of materials, including metals, ceramics, composites, and thin coatings. Here are some specific cases where Vickers hardness testing is commonly employed:

General Material Testing

Vickers hardness testing is a versatile method used for measuring the hardness of a wide range of materials, including metals, alloys, ceramics, and plastics. It provides reliable and repeatable results for assessing material hardness and evaluating material properties.

Hardened Steels

Vickers hardness testing is often utilized to measure the hardness of hardened steels, including heat-treated and case-hardened steels. It provides accurate and precise measurements of surface hardness, allowing for evaluation of the material's response to heat treatment processes.

An application example is the case hardness depth (CHD). A certain hardness value is determined by a series of Vickers test points. The distance from the edge to the desired hardness value is measured. Typically, this is the point where the hardness is 550 HV.

Quality Control & Characterization

Vickers hardness testing is commonly employed in quality control and material characterization processes. It allows for rapid and accurate hardness assessment, ensuring the compliance of materials with specified hardness requirements and providing valuable data for material selection and comparison.

Microhardness Testing

Vickers hardness testing is particularly suitable for microhardness testing, which involves measuring the hardness of small and localized areas, thin sections, or near-surface regions. It is commonly used for analyzing microstructures, thin films, coatings, and small components. Welds or gears are examples of components that are usually tested using the Vickers method.

Brittle Materials

Vickers hardness testing is well-suited for measuring the hardness of brittle materials like ceramics, glass, and certain types of composites. These materials typically exhibit low ductility, making traditional indentation methods like Rockwell less suitable.

In some cases, the lengths of cracks that appear after the test can also be measured. Cracks appear at the four peaks of the indentation. The cracks can also be measured and evaluated for further assessment of the material quality.

Research and Development

Vickers hardness testing is frequently used in research and development activities to investigate material behavior, study phase transformations, analyze material properties, and evaluate the effectiveness of various processing techniques.



3.2

Knoop Method

The Knoop hardness testing method is primarily used in cases where the material being tested is thin, small, or has anisotropic properties. It is particularly suitable for measuring the hardness of brittle materials, thin coatings, and individual microscopic features. Here are some specific cases where Knoop hardness testing is commonly employed:

Thin Films and Coatings

Knoop hardness testing is widely used for measuring the hardness of thin films and coatings, such as metal platings, ceramics, and hard coatings. The elongated diamond-shaped indenter allows for precise indentation and accurate hardness measurements on thin layers without significant substrate influence.

Anisotropic Materials

Anisotropic materials, which exhibit different mechanical properties in different crystallographic directions, can be effectively tested using the Knoop method. By aligning the indentation with a specific crystallographic direction, the Knoop test provides hardness measurements along specific orientations.

Micro Indentation

Knoop hardness testing is commonly utilized for micro indentation testing, where small and localized areas are tested. It is particularly effective for characterizing individual grains, phases, or microstructures within a material.

Ceramic Materials

Knoop hardness testing is commonly employed for measuring the hardness of brittle materials like ceramics, including ceramics used in engineering applications, advanced ceramics, and ceramic coatings. The method accounts for the inherent brittleness of these materials.

Composite Materials

Knoop hardness testing is suitable for measuring the hardness of composite materials, where different phases or components have varying hardness values. It allows for targeted hardness assessments on individual constituents within the composite.

Research and Development

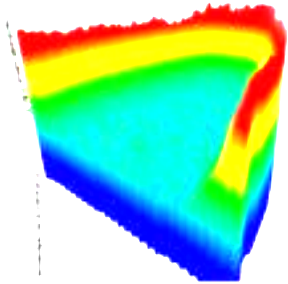
Knoop hardness testing is often used in research and development activities for materials characterization, failure analysis, and mechanical property investigations. It provides valuable insights into the microstructural properties and mechanical behavior of materials.



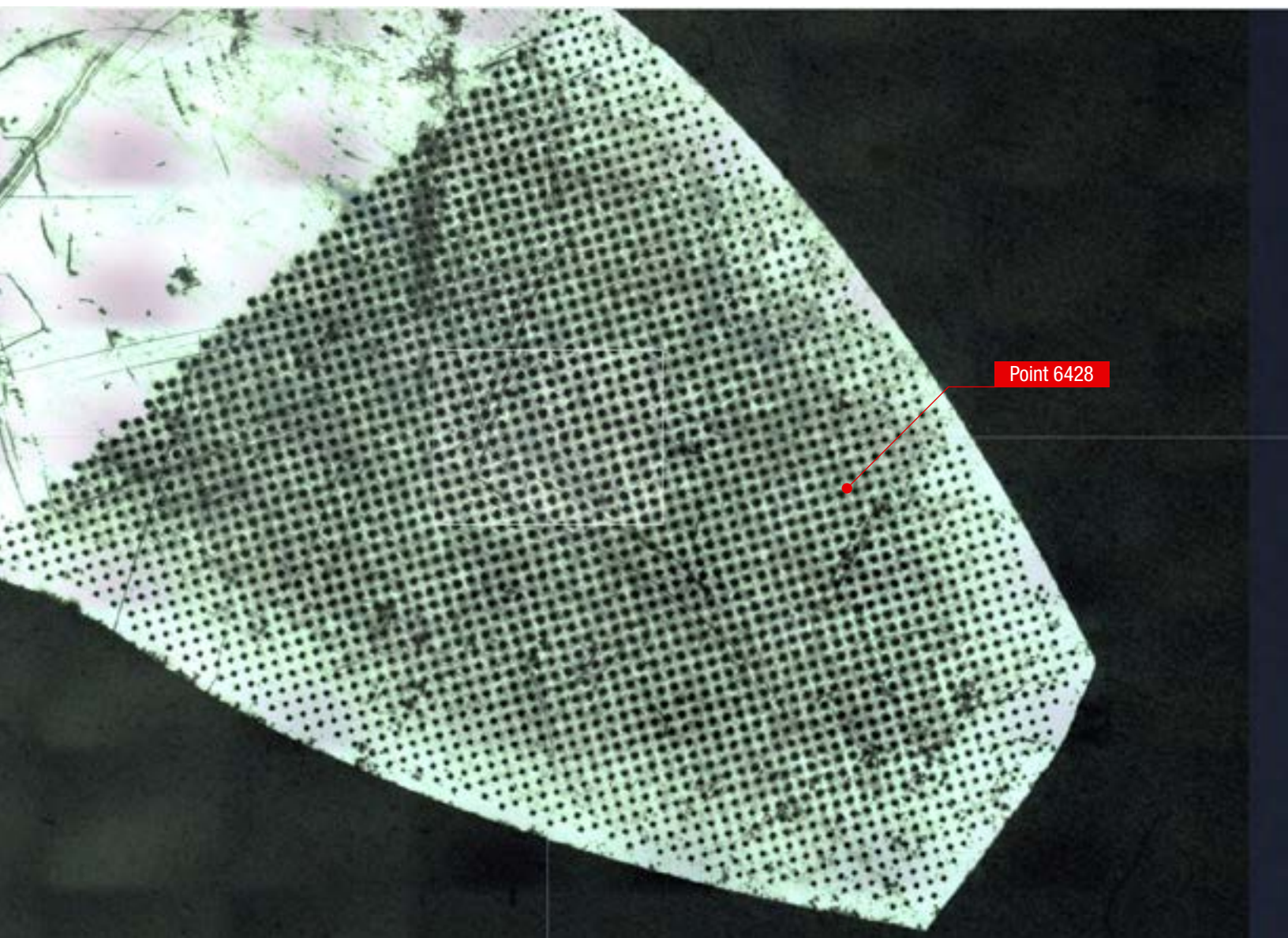
3.3

Mapping

Mapping is used to get a holistic overview of a specific area and its hardness. Vickers is particularly suitable for mapping because the small indentations allow for a high density of test points.



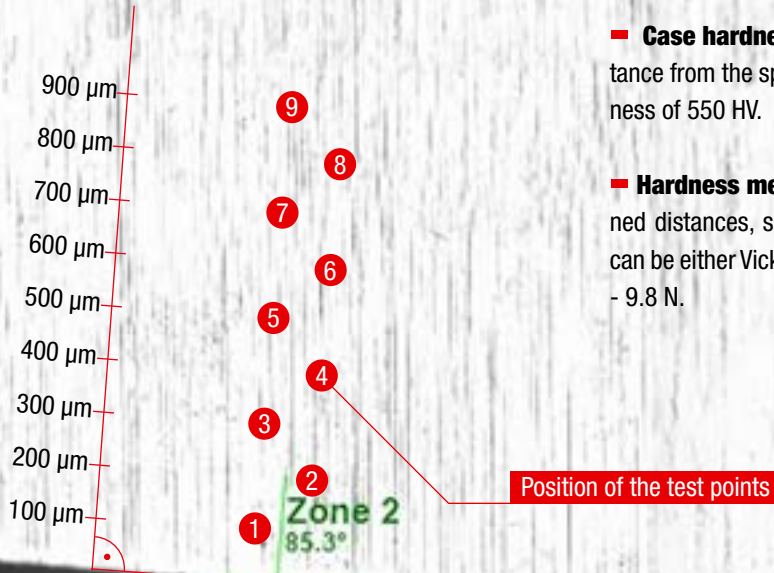
- **Up to 10000 test points:** hardness mapping refers to the creation of a comprehensive hardness curve for a specimen or a specific area. The hardness curve can be determined through the equal distribution of test points across the entire specimen. The result – the hardness map – can either be shown as a 2D color image or a 3D diagram.



3.4

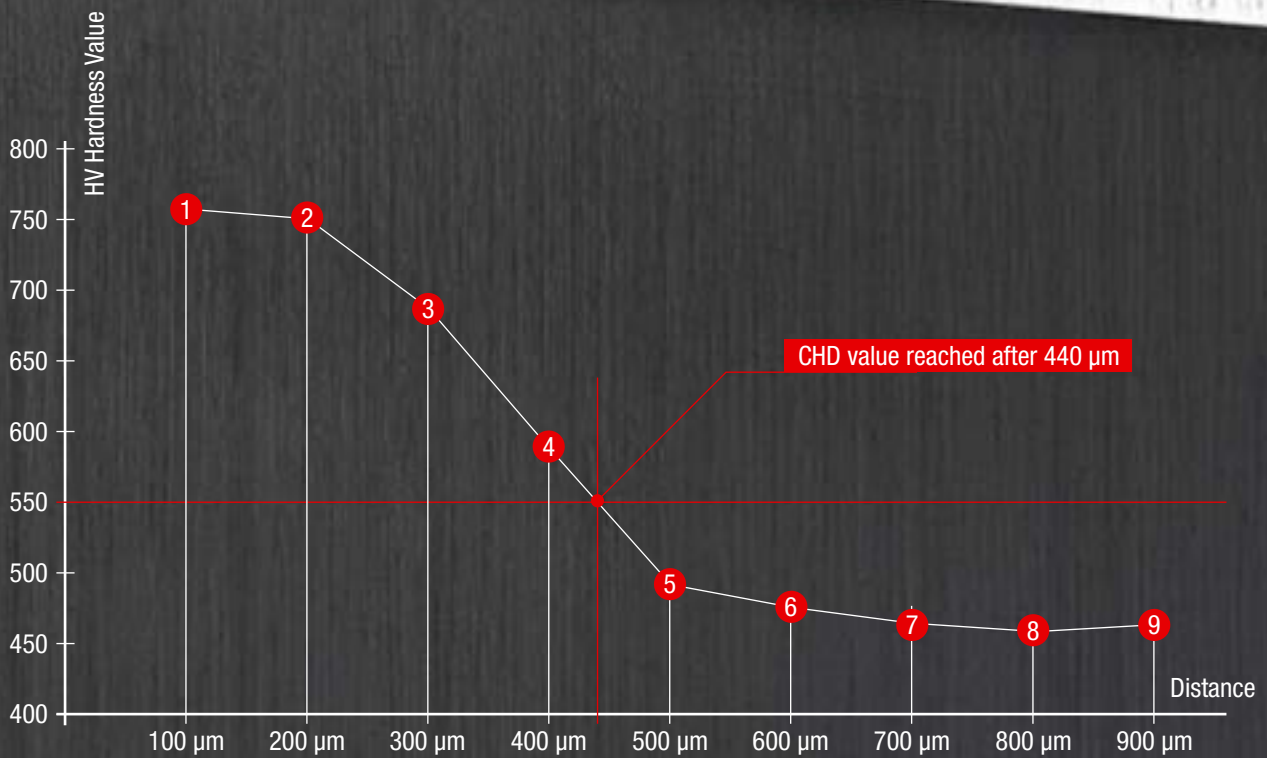
Case Hardness Depth (CHD)

Case-hardened components are heat-treated steel workpieces. Here the workpiece is carburized, hardened, then tempered. This produces a hard, wear-resistant surface, while the core remains relatively soft and tough.



■ **Case hardness depth (CHD)** describes the vertical distance from the specimen surface to a layer with a limit hardness of 550 HV.



■ **Hardness method:** indents are applied at precisely defined distances, see illustration. The test method to be used can be either Vickers or Knoop with a test force between 0.98 - 9.8 N.



3.5

Vickers & Knoop Methods

- Vickers load ranges: 0.00025 kg – 150 kg
- Vickers load ranges: 0.00025 kg – 2 kg
- Method: Optical
- Standards: Vickers - DIN EN ISO 6507 / ASTM E384 / ASTM E92
Knoop - DIN EN ISO 4545 / ASTM E384 / ASTM E92

Vickers & Knoop Methods		Vickers 136° 	Knoop 172.5° 
0.00025 kg	0.002 N	HV 0.00025	HK 0.00025
0.0005 kg	0.005 N	HV 0.0005	HK 0.0005
0.001 kg	0.01 N	HV 0.001	HK 0.001
0.002 kg	0.02 N	HV 0.002	HK 0.002
0.003 kg	0.029 N	HV 0.003	HK 0.003
0.005 kg	0.049 N	HV 0.005	HK 0.005
0.01 kg	0.098 N	HV 0.01	HK 0.01
0.02 kg	0.196 N	HV 0.02	HK 0.02
0.025 kg	0.245 N	HV 0.025	HK 0.025
0.05 kg	0.491 N	HV 0.05	HK 0.05
0.1 kg	0.981 N	HV 0.1	HK 0.1
0.2 kg	1.962 N	HV 0.2	HK 0.2
0.3 kg	2.943 N	HV 0.3	HK 0.3
0.5 kg	4.905 N	HV 0.5	HK 0.5
1 kg	9.81 N	HV 1	HK 1
2 kg	19.62 N	HV 2	HK 2
2.5 kg	24.53 N	HV 2.5	
3 kg	29.43 N	HV 3	
5 kg	49.05 N	HV 5	
10 kg	98.1 N	HV 10	
20 kg	196.2 N	HV 20	
30 kg	294.3 N	HV 30	
50 kg	490.5 N	HV 50	
60 kg	588.6 N	HV 60	
100 kg	981 N	HV 100	
120 kg	1177.2 N	HV 120	
125 kg	1226.3 N	HV 125	
150 kg	1471.5 N	HV 150	

3.6

Functional and Calculation Principle for Vickers

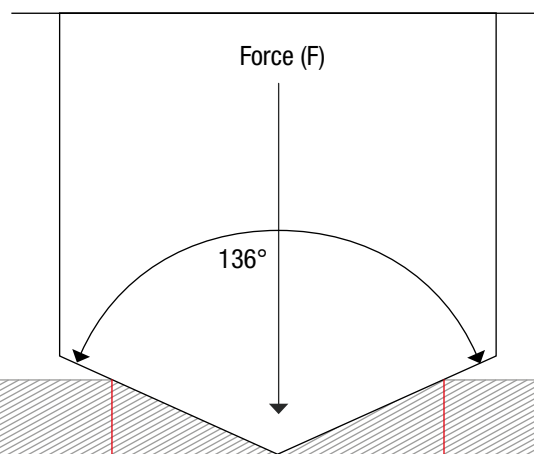
The result of a Vickers method depends on the tested material, force, and dwell time. An indentation is measured using a magnifying lens. The larger the measured diagonals, the softer the material is.

HV = Vickers Hardness

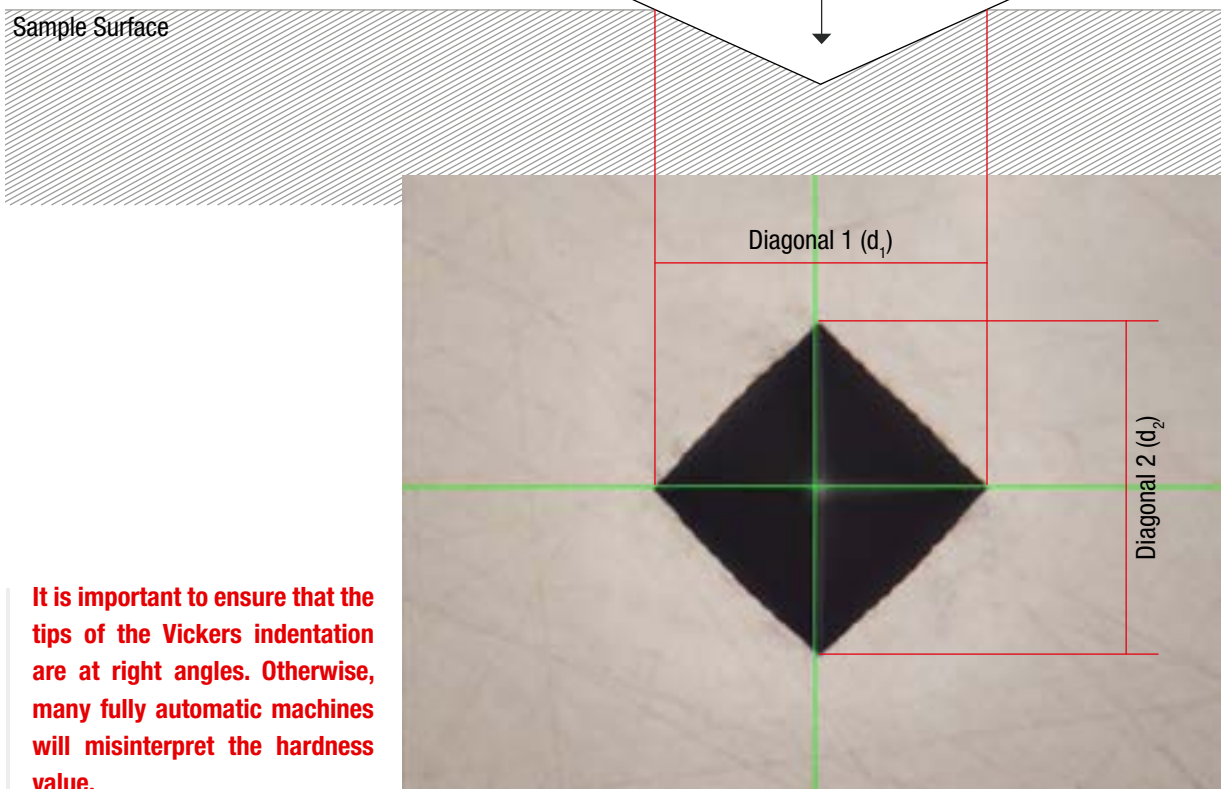
$$HV = \text{Constant} \times \frac{\text{Test Load } F}{\text{Surface of the Indentation}}$$

$$HV = 0.102 \times \frac{2F \sin \frac{136^\circ}{2}}{d^2} \approx 0.178 \times \frac{F}{d^2}$$

$$d = \frac{d_1 + d_2}{2} \text{ (Mean Diagonal Length)}$$



Sample Surface



It is important to ensure that the tips of the Vickers indentation are at right angles. Otherwise, many fully automatic machines will misinterpret the hardness value.

3.7

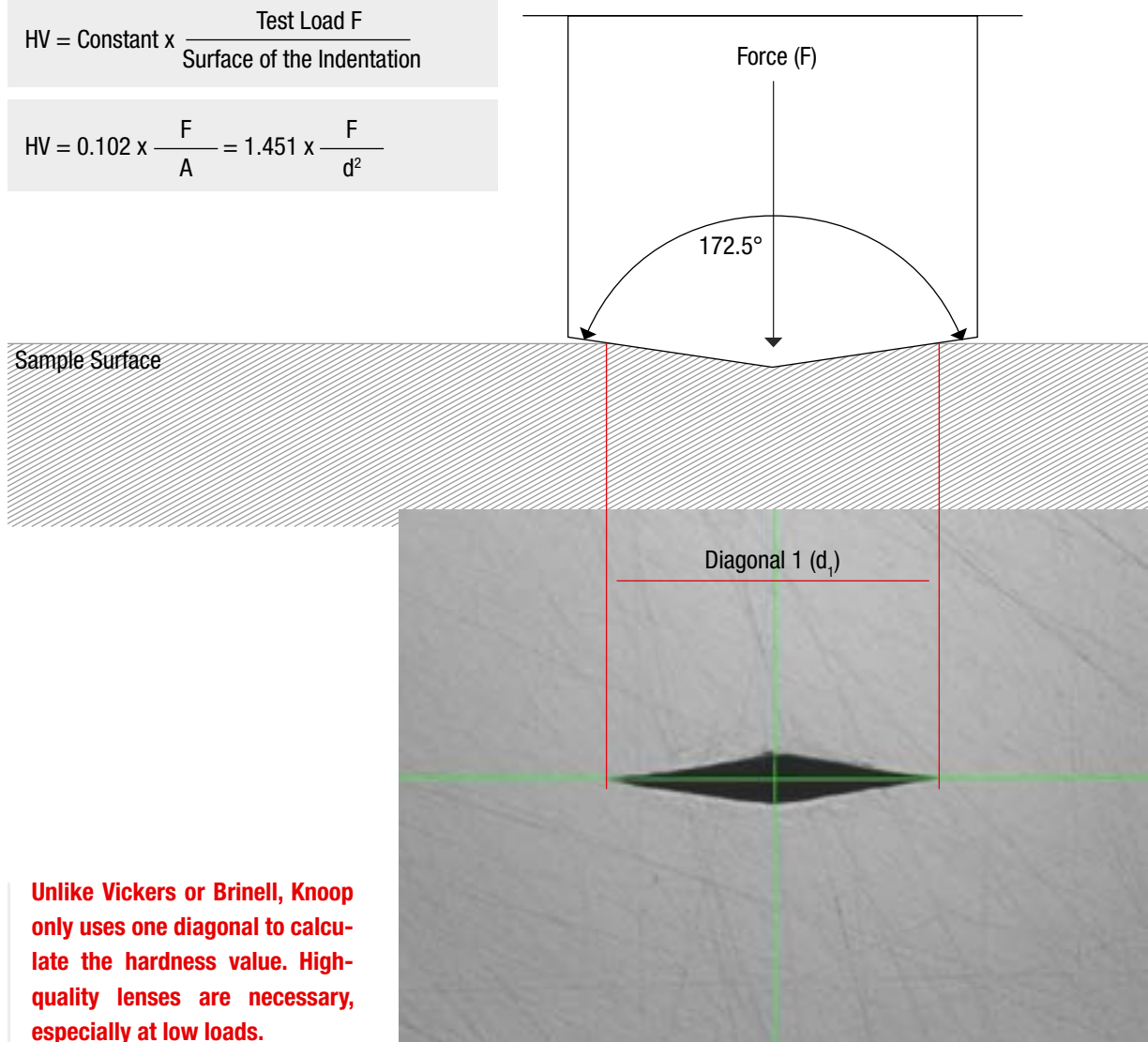
Functional and Calculation Principle for Knoop

The result of a Knoop test depends on the tested material, force, and dwell time. An indentation is measured using a magnifying lens. The larger the measured diagonal, the softer the material is.

HK = Knoop Hardness

$$HV = \text{Constant} \times \frac{\text{Test Load } F}{\text{Surface of the Indentation}}$$

$$HV = 0.102 \times \frac{F}{A} = 1.451 \times \frac{F}{d^2}$$



Unlike Vickers or Brinell, Knoop only uses one diagonal to calculate the hardness value. High-quality lenses are necessary, especially at low loads.

The Right Load?

When deciding which load to choose for Vickers, Brinell, or Knoop hardness testing, there are several factors to consider. The load selection depends on the material being tested, the desired indentation size, and the specific requirements of the application.

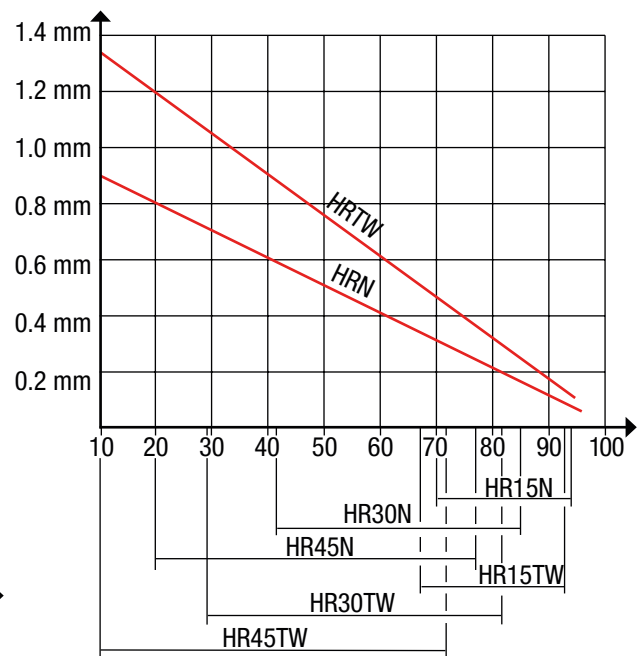
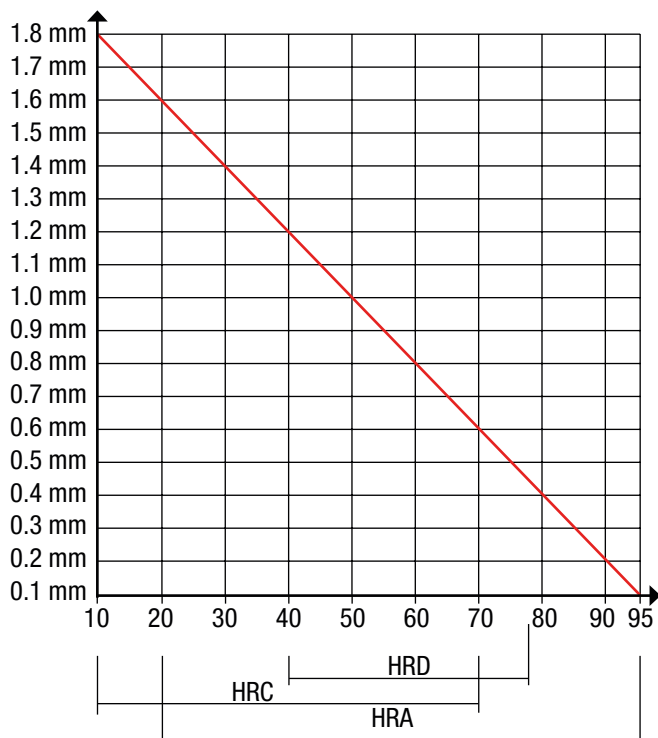
Basically, it is recommended to choose the highest possible load. This minimizes the influence of the surface treatment on mounted, cut or sanded samples. It is possible that with lower loads (e.g., HV 0.01) harder values are generated than with the next higher load (HV0.02). Also, with a higher load, metallographic structure becomes more irrelevant.

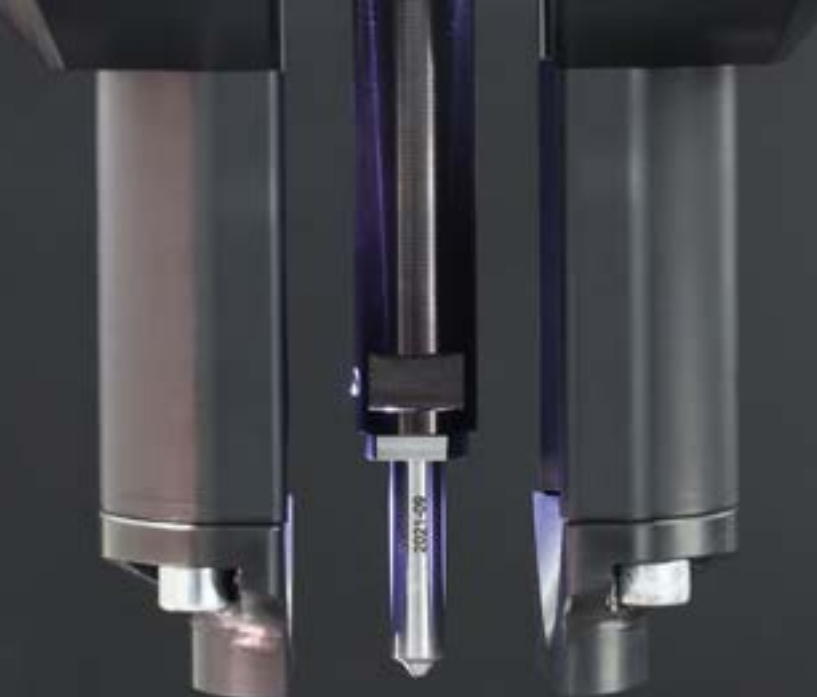
■ **Material thickness:** the thickness of the material can affect the load selection. For thin materials or coatings, lighter loads are often preferred to minimize the risk of deformation or damage. Thicker materials can accommodate higher loads without significant issues.

■ **Standard recommendations:** for specific materials or applications, there may be standard recommendations or specifications that suggest suitable loads. Industry standards or material-specific guidelines can provide valuable information on load selection.

Minimum Material Thickness for Rockwell

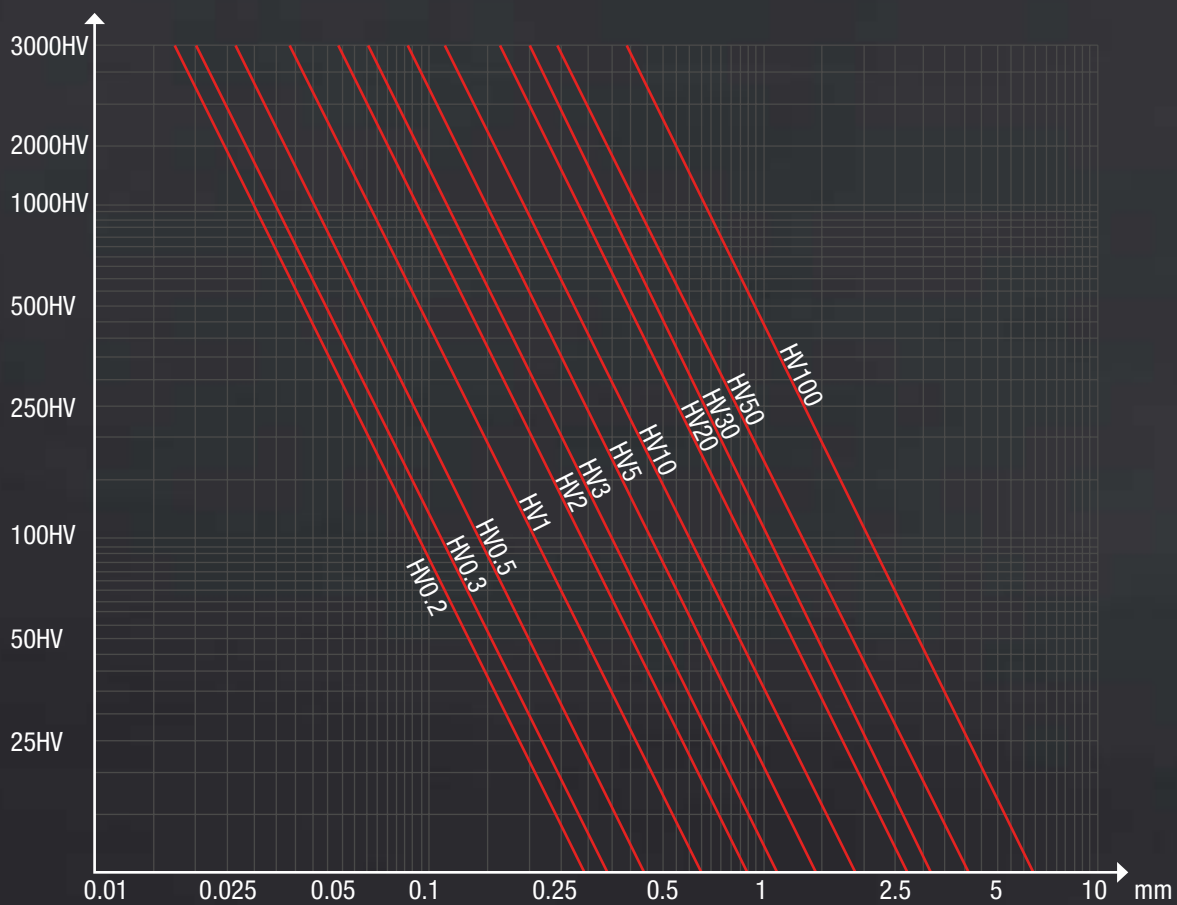
Minimum thickness (hardness coat) of the sample in relation to Rockwell hardness







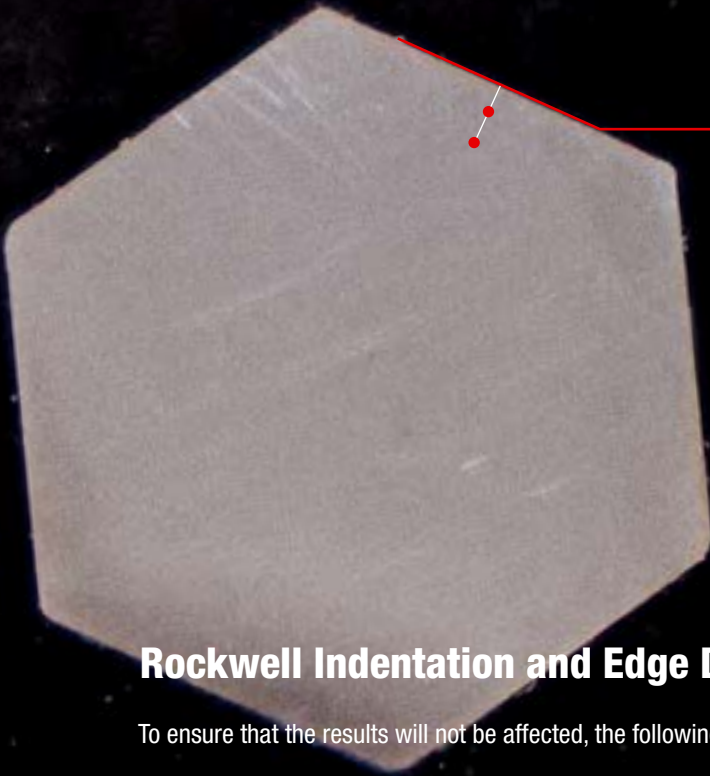
Vickers Minimum Material Thickness

Minimum thickness (hardness coat) of the sample in relation to the test load and to the hardness for Vickers



Brinell Minimum Material Thickness

Mean Indentation Ø	Minimum Thickness of Sample			
	1 mm 	2.5 mm 	5 mm 	10 mm 
0.2 mm	0.12 mm			
0.3 mm	0.18 mm			
0.4 mm	0.33 mm			
0.5 mm	0.54 mm			
0.6 mm	0.80 mm	0.29 mm		
0.7 mm		0.40 mm		
0.8 mm		0.53 mm		
0.9 mm		0.67 mm		
1.0 mm		0.83 mm		
1.1 mm		1.02 mm		
1.2 mm		1.23 mm	0.58 mm	
1.3 mm		1.46 mm	0.69 mm	
1.4 mm		1.72 mm	0.80 mm	
1.5 mm		2.00 mm	0.92 mm	
1.6 mm			1.05 mm	
1.7 mm			1.19 mm	
1.8 mm			1.34 mm	
1.9 mm			1.50 mm	
2.0 mm			1.67 mm	
2.2 mm			2.04 mm	
2.4 mm			2.45 mm	1.17 mm
2.6 mm			2.92 mm	1.38 mm
2.8 mm			3.43 mm	1.60 mm
3.0 mm			4.00 mm	1.84 mm
3.2 mm				2.10 mm
3.4 mm				2.38 mm
3.6 mm				2.68 mm
3.8 mm				3.00 mm
4.0 mm				3.34 mm
4.4 mm				4.08 mm
4.8 mm				4.91 mm
5.2 mm				5.83 mm
5.6 mm				6.86 mm
6.0 mm				8.00 mm



Rockwell Indentation and Edge Distance

To ensure that the results will not be affected, the following distances have to be maintained:

Sample Surface

Test point distance:

The test point distance in Rockwell hardness testing may vary depending on the specific scale or application. Generally, it is recommended to maintain a distance of at least three times the depth of the indentation between adjacent test points.

Border edge distance:

The border edge distance should generally be at least two and a half times the depth of the indentation. This distance ensures that the indentation is far enough away from the edge to avoid any edge effects.





Brinell Indentation and Edge Distance

To ensure that the results will not be affected, the following distances have to be maintained:

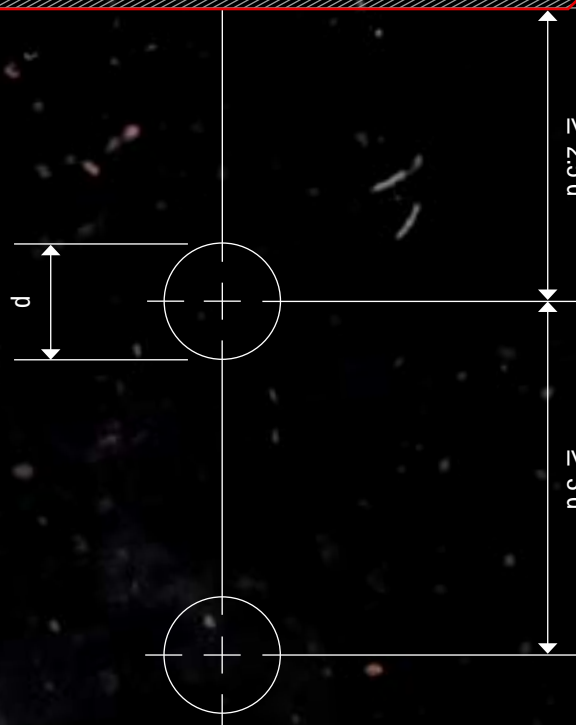
Sample Surface

Test point distance:

The distance between adjacent test points in Brinell hardness testing should generally be at least three times the diameter of the indentation. This spacing helps to ensure that the indentations do not interfere with each other and affect the accuracy of the measurements.

Border edge distance:

The distance between the indentation and the edge of the material should typically be at least two and a half times the diameter of the indentation. This allows for sufficient clearance and avoids any influence from the material's edge.



Vickers Indentation and Edge Distance

To ensure that the results will not be affected, the following distances have to be maintained:

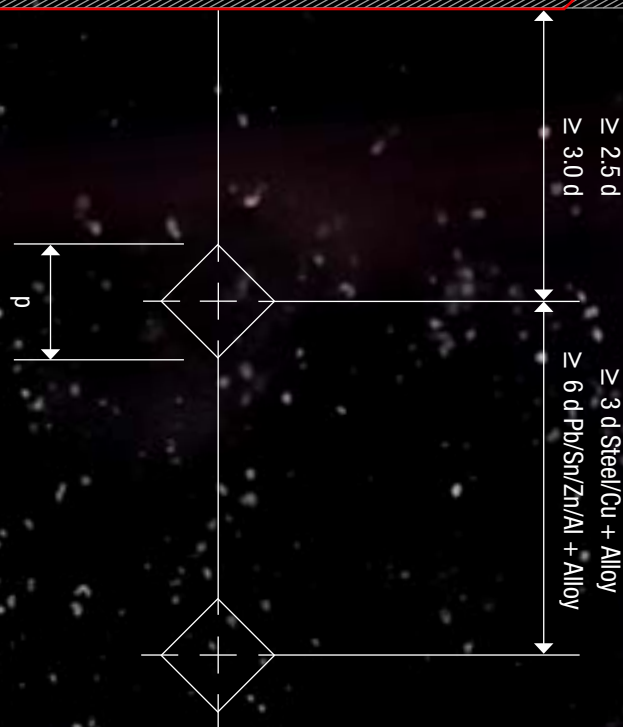
Sample Surface

Test point distance:

The test point distance in Vickers hardness testing should typically be at least three times the diagonal length of the indentation. With softer metals such as aluminum, lead, tin, and zinc, a distance of 6 diagonals must be maintained. This spacing helps to minimize any interference between adjacent indentations.

Border edge distance:

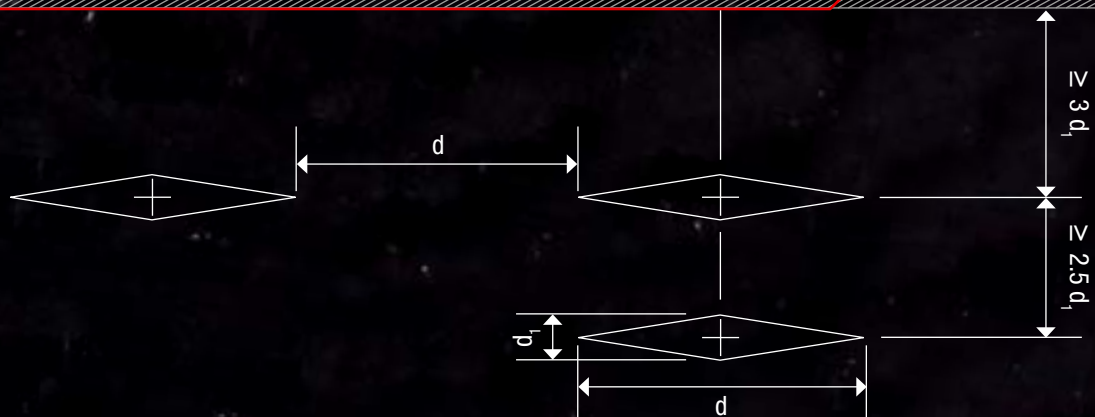
The border edge distance is generally recommended to be at least two and a half times the diagonal length of the indentation, and three times the diagonal for softer metals such as aluminum, lead, tin, zinc.



Knoop Indentation and Edge Distance

To ensure that the results will not be affected, the following distances have to be maintained:

Sample Surface



Test point distance:

For Knoop, a test point distance of two and a half times the diagonal on the short side and two times the diagonal on the long side must be maintained. These distances ensure that there is no influence of test points on each other.

Border edge distance:

The border edge distance is generally recommended to be at least three times the diagonal length of the indentation. This distance provides adequate clearance from the material's edge to prevent any edge effects.

Micro or Macro Hardness Tester?

The main difference between a micro hardness tester and a macro hardness tester lies in the scale of indentation and the level of magnification used for the hardness measurement. Here are the key distinctions:

■ **Test Load:** micro hardness testing involves applying a lower test load compared to macro hardness testing. Micro hardness testers typically use loads ranging from a few grams to a few kilograms, while macro hardness testers use heavier loads ranging from kilograms to tons.

The chosen load also influences the size of the indentation. In micro hardness testing, a smaller indentation is created, typically on the scale of micrometers. On the other hand, macro hardness testing involves creating larger indentations, typically on the scale of millimeters.

■ **Magnification:** micro hardness testing requires the use of high magnification to accurately measure the dimensions of the small indentation. The test indentation is examined and measured using a microscope or an optical system to determine the hardness value. In macro hardness testing, the indentation is typically observed and measured without the need for high magnification.

■ **Applications:** micro hardness testing is commonly used to examine small or thin samples, coatings, CHD rows, NHD rows, SHD rows, hardness mappings or localized areas of interest. It is widely employed in materials science, metallurgy, and research applications to study microstructures, phase transformations, and hardness variations within a material. Macro hardness testing, on the other hand, is suitable for larger samples and provides a more general measurement of hardness for quality control purposes, material selection, or assessing bulk properties.

■ **Test Method:** the test methods used for micro hardness and macro hardness testing can differ. Vickers and Knoop hardness tests are commonly employed for micro hardness testing due to their ability to produce small, precise indentations. For macro hardness testing, methods like Rockwell or Brinell hardness tests are often utilized due to their ability to apply heavier loads and create larger indentations.

ZwickRoell LP
1009 Market Center Dr NW, Kennesaw, GA 30144
United States
+1 770 420 6555

[> Questions? Contact us.](#)

