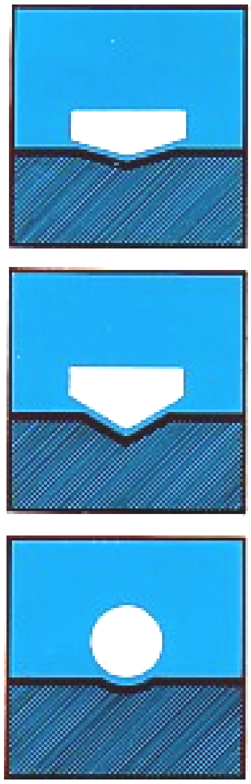

GUIDE TO HARDNESS TESTING

This is a basic introductory guide to the hardness testing of metals.
It does not quote or explain the technical aspects in great detail but is intended only as a guide for many dealers and operators of the ERNST range of equipment.

For whoever is interested in looking more deep into the argument, the most important DIN normes taken in consideration are the following:

Härteprüfung nach Rockwell C, A, B, F	50 103 T1
Härteprüfung nach Rockwell N und T	50 103 T2
Härteprüfung nach Vickers	50 133
Härteprüfung nach Brinell	50 351
Richtlinien for die Gestaltung und Anwendung von Aufnahmevorrichtungen	51 200
Umwertungstabellen	50 150
Härtevergleichsplatten	51 303

N.B. The reference points (1), (2), ecc... included in the text are reported in the appendix.

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GENERAL NOTES ON HARDNESS TESTING

Within all types of measuring systems, that must be carried out in a workshop, the one concerning the hardness control, is without doubt the most various.
Testings can be made with 3'000 kp (29'430 N) load or with few hundreds of grams. When it comes to laboratories the measuring can even be carried out with the gram. It is therefore possible to check the hardness of heavy castings or pins for horology, from the hardest sintered to the softest alloys.
There are several principles to follow and a certain quantity of scales to be used. Hence, it is normal that even a person with an extensive workshop experience can be in difficulty or confused, when facing such problems.
The electronics have brought a considerable and almost indispensable improvement of hardness testing.
It allows in fact greater precision and reliability when it comes to reading results, storing and the possibility of analysing statistics, grafics, data etc...
It is to be understood that the electronics finds its main application within the reading of the results and eventually the control of the functions, while the original mechanical principles, remain always valid and indispensable.
The following notes are a good indication to solve the problem:
Advantages and limitations concerning the Rockwell, Brinell and Vickers principle will be amply considered later.
It is however useful to examine first the most relevant aspects concerning the characteristics of the instruments such as: 1) testing load, 2) operating hardness field, 3) accuracy of results, 4) adabtability of the instrument to the form and dimensions of the specimens 5) financial aspect.
We will now see these five aspects one by one in function of the different possible occuring situations.

1) **Test load** - As a general rule, it should be used a higher possible load; this in order to obtain greater precision and also because the surface of the specimen is normally subject to decarburization during treatment. Furthermore, when using a high load, tests result less sensible to the surface refining. However, it is important that the load must not cause a penetration more than 1/10 of the specimen to be tested or the hardened surface (in case of surface preparation) this to avoid false results. The choice of the load depends on the material's homogeneity: a typical example is cast iron, normally checked with high load.

2) **Hardness field** - Over a hardness of 50 HRC (steel of approx. 485 HB 30) it is better to use a diamond penetrator, instead of a steel or carbide one (to be used for lower hardnesses).
Since the Brinell test does not use a diamond penetrator, the measuring of tempered steel is not possible. Rockwell, being more universal, can make use of a conical diamond as well as steel penetrators. The Vickers test, uses a pyramid diamond penetrator and it is good for all hardness fields, even though it finds its best application in laboratories rather than in workshops.

3) **Degree of precision** - This, depends on the accuracy of the test: surfaces well prepared, steady measuring time, frequent and regular tests of the instrument with reliable test blocks.
Usually, it is better to make use of a static system instead of dynamic ones. These latter in fact, are more sensible to the mass and to the stiffness of the specimen.
When measuring with very low loads, the accuracy and precision of the test becomes more difficult.

4) **Adaptability of the instrument to the form and dimensions of the specimens**
It is possible to bring the specimen under the instrument as well as the instrument over the specimen. The first example concerns bench instruments, which can hold and possibly even lock the specimen during the test; these instruments are more suitable for the control of pieces with small and medium dimensions (1). The second example, is referred to portable instruments which can be locked to the specimen (2) (buckle, chain, etc.), or used only on very large or difficult shaped specimens. Those working with high loads must be only dynamics (3) while for low loads also static ones exists (4).
There are other types of tests on particular and difficult surfaces that must be studied from time to time.

5) **Financial aspect** - Includes: purchase price, employment possibilities, measuring time and attention required by the user. The first two aspects are relevant when it comes to measuring parts with difficult shapes or treatments, ex. handycrafts or low volumes of work. Where tests must be carried out on large batches, the speed and possibility of employing staff, not particularly qualified, becomes most important.

ROCKWELL PRINCIPLE

The following steps concerning the Rockwell principle, for a clearer understanding, have been numbered and indicated in fig. 1, in which also appears the dial indicator that in connection with the penetrator registers all big displacement differences.

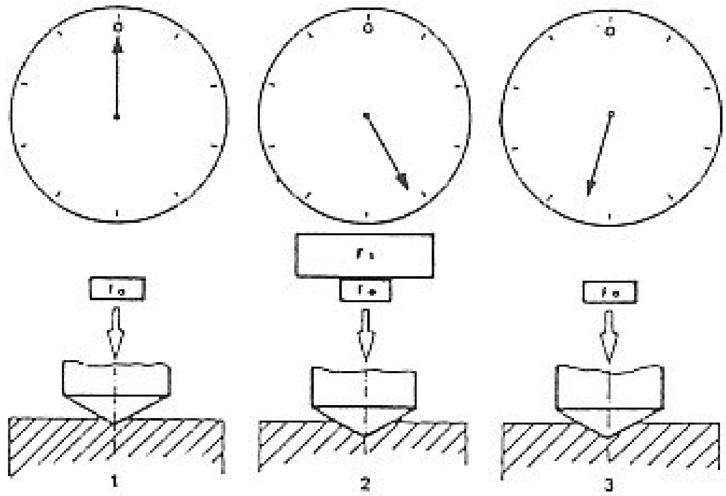


FIG. 1 - Drawing of the Rockwell principle

1) The surface to be tested must be brought into contact with the penetrator, after the application of an initial load Fo (preload) a first little indentation is determined; after which, the dial indicator must be reset to zero.

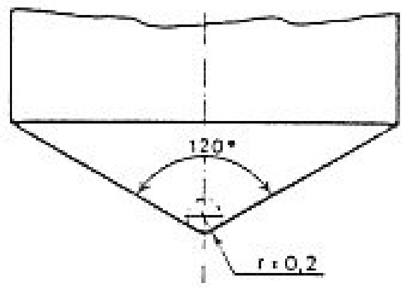
2) An additional load F1 must be gradually applied and without shocks, which added to the preload is called test load (F). The penetrator, under this load, will penetrate the material according to its hardness.
In this position we have to wait until the penetration is completed (on hard materials, it is almost immediate, while on softer ones it is necessary to wait few seconds).
The penetration is shown by the movement of the dial indicator pointer.

3) The additional load F1 is removed, returning back to the preload conditions; in this way the penetrator will remain into the indentation made under the load, eliminating all elastic deformations caused by the load itself. The dial indicator will therefore indicate the penetration difference within preload and load.
In the Rockwell principle, penetrators, preloads, loads and the unit of measurement are standardized in two groups: normal Rockwell and superficial Rockwell.

NORMAL ROCKWELL (5)

In the normal Rockwell principle only a conical diamond indenter is used with a 120° included angle and a 0,2 mm. radius on the point (see fig. 2) and several ball carbide indenters which diameters are always expressed in inches:
1/16" - 1/8" - 1/4" 1/2".

FIG. 2 Penetrator profile of the Rockwell conical diamond



The preload is constant: 10 kp. (98,1 N).

The test loads (preload + additional load) are: 60 - 100 - 150 kp (N 588,4 - 980,7 - 1471). According to the present DIN standards, preload and load of the various Rockwell, Brinell and Vickers principles, must be only expressed in N (Newton), however, for practical reasons we use the old indications in kp (kilo pound).
The normal Rockwell unit of measurement corresponds to a penetration of 0,002 mm. The hardness values must obviously increase with the hardness.
Hence the indentation difference between preload and load decreases as the hardness itself rises. The Rockwell hardness number is obtained by subtracting from 100 (with diamond penetrator) or 130 (with any other ball indenter) the difference of penetration in units of 0,002 mm.
Example: With diamond indenter and penetration difference of 0,082 mm we have 100 - (82 : 2) = 59 Rockwell; with the same hardness difference but with a ball indenter we have instead 130 - (82:2) = 89 Rockwell.
In the instruments with a dial indicator, showing the penetration displacements, generally is divided into 100 levels in order that the complete revolution corresponds to 0,2 mm; the numbers are divided in two series: the black ones for measurements with diamond indenter, and red ones for ball indenters.
The 0 setting, must always be made on the black numbers (0 black 130 red).
When using electronics, results are directly shown on the display at the end of the entire cycle.
With the various indenters and loads it is possible to obtain a large choice of different scales. Each one is indicated by a letter, as shown in

table nr. 1 here below.

Table 1 - Standard Rockwell scales

LOAD kp	**HR SCALE**				
150 100 60	C D A	G B F	K E H	P M L	V S R
INDENTER	diamond	ball 1 / 16"	ball 1 /8"	ball 1/4"	ball 1/2"
NUMBERS	black	red			

Example: Using a diamond indenter penetrator and a 150 kp load, the denomination will be HRC, "H" represents the hardness in general, "R" the principle (Rockwell) and "C" relative scale. The hardness number appears always before the initials. Example: 60 HRC.

SUPERFICIAL ROCKWELL (6)

The indenters used in the Superficial Rockwell principle are the same as in the standard principle. The conical diamond penetrator however, even though it has geometrically the same profile, requires a greater precision on the angle and radius, as in this principle the low loads cause a very little penetration.
Consequently a little imperfection of the point would affect the results.
The preload is constant: 3 kp (29,43 N); the loads (preload and additional load) are: 15-30-45 kp. (147,1 - 294,2 - 441,3 N).
The Superficial Rockwell unit of measurement corresponds to a penetration of 0,001 mm.
Compared to the standard Rockwell, in the Superficial Rockwell principle the 0 setting must always be carried out on nr. 100 (0 in the dial indicator), whether with a diamond or ball indenter. In fact, dial indicators have usually only one series of numbers. The dials are divided in 100 levels, one whole revolution corresponds to 0,1 mm. Example: With a diamond or ball indenter and a difference of penetration of 0,082 mm, we have 100 - 82 = 18 Superficial Rockwell.
The Superficial Rockwell scales, obtainable with the various penetrators and load combinations, are indicated by a letter following a number, which specifies the test load, see table nr. 2.

Table 2 - Superficial Rockwell scales.

LOAD kp	HR SCALE				
45 30 15	45 N 30 N 15 N	45 T 30 T 15 T	45 W 30 W 15 W	45 X 30 X 15 X	45 Y 30 Y 15 Y
INDENTER	diamond	ball 1/16”	ball 1/8"	ball 1/4"	ball 1/2"

APPLICATION FIELD OF THE VARIOUS ROCKWELL SCALES

As we have noticed, as a whole, Rockwell and Superficial Rockwell scales are noteworthy: the choice of one or the other depends on the material hardness, minimum thickness of the specimen or hardened coat (in the case of superficial treatments, such as: cementing, nitriding etc..).
The material hardness determines the choice of the penetrator: conical diamond or ball indenter.
The conical diamond indenter is used only for tempered steels and for hard metals; it is not recommended for steels having a resistance below 785 N/mm^2.
Steel ball penetrators are used for softer materials: soft materials require a larger ball diameter and lower loads. For example with the HRB scale (ball indenter 1/16" - 100 kp load), it is not possible to control soft materials as with HRL scale (ball indenter 1/4" - 60 kp load).
Larger ball indenters, are in fact used only for the testing of plastic materials or similar.
With the Rockwell principle, it is possible to test plastic materials even under load.
When testing sheet or superficially hardened thin pieces, the indentation left by the penetrator under load, influences a very extended area of the material, all around the indentation itself. If the deformation reaches the limit of the piece itself, the results would be false. Therefore, for the control of a thin piece, the load to be used must not cause deformations larger than the minimum thickness of the specimen, breaking through on the opposite side. This is a general rule for all hardness measuring principles.
For each kind of test a minimum measurable thickness always exists.
However, there are no precise rules, as much depends from the different types of materials. The minimum measurable thickness conventionally considered must be at least 10 times the penetration depth (see table nr. 3).

Same thing for hardened surface layers (cementing, etc.), in fact, the scale usually used for controlling cemented pieces is HRA (conical diamond - 60 kp).

Table 3 - Minimum measurable thickness for the Rockwell tests with diamond indenter.

F	HRC					
kp	**20**	**30**	**40**	**so**	**60**	**70**
15	0.41	0.33	0.26	0.19	0.14	0.09
30	0.69	0.58	0.47	0.36	0.26	0.17
45	0.91	0.77	0.63	0.50	0.37	0.25
60	1.0	0.9	0.8	0.7	0.6	0.5
150	1.8	1.6	1.4	1.2	1.0	0.8

The most common Rockwell scales are:

HRC (conical diamond - 150 kp) is the most typical of the Rockwell scales, used to check tempered, hardened and tempered or deeply cemented pieces.
Usually the mention of Rockwell hardness refers to HRC scale.
This, can however cause a certain confusion, as sometimes a HRC hardness is wrongly requested, even when, because of the small dimensions, it is not possible to use a load of 150 kp.
In these cases other Rockwell scales or principles of measurement must be employed. There is always the possibility to convert HRC values by means of conversion tables that, as we will see later, but are to be considered approximations only.

HRA (conical diamond - 60 kp) principally used for cemented and hard metal pieces, where the high consistence of carbides, could cause the splitting of the diamond . Therefore, high loads are not suggested.

HRB (ball indenter 1/16" - 100 kp) generally used in Europe, for brass alloys (copper, bronze etc..), in the USA, for ferrous alloys until approx. 686 N/mm^2.

SUPERFICIAL ROCKWELL OR SUPER ROCKWELL

Scales HR 15N - HR 30N - HR 45N (conical diamond) are suggested for the control of parts with thin cementation; scales HR 15T - HR 30T - HR 45T (ball indenter 1/16") for thin plates.
Instruments working according to the Rockwell principle can also be used for the direct reading in Brinell points, as shown in the relative chapter (see pag. 19).

CONTROL OF CYLINDRICAL SURFACES

It is clear that the conditions are different when measuring on cylindrical surfaces instead of flat ones. On large diameters the differences are not too relevant, but on small ones, a compensation must be carried out, adding a determined quantity to the obtained results according to the hardness and diameter of the piece, as indicated in table no. 4.

Table 4 Correction values for Rockwell tests on cylindrical surfaces with diamond indenter (to be added to the result on display or dial indicator).

		DIAMETER OF THE CYLINDRICAL SURFACE mm						
		3	**6**	**10**	**12**	**15**	**20**	**25**
VALUES HR C - D - A	80		0.5	0.5	0.5	0	0	0
	70		1.0	1.0	0.5	0.5	0.5	0
	60		1.5	1.0	1.0	0.5	0.5	0.5
	50		2.5	2.0	1.5	1.0	1.0	0.5
	40		3.5	2.5	2.0	1.5	1.0	1.0
	30		5.0	3.5	2.5	2.0	1.5	1.0
	20		6.0	4.5	3.5	2.5	2.0	1.5
VALUES HR 15 N - 30 N - 45 N	9 0	0.5	0.5	0	0	0	0	0
	80	1.0	0.5	0.5	0.5	0	0	0
	70	2.0	1.0	1.0	0.5	0.5	0.5	0.5
	60	3.0	1.5	1.0	1.0	0.5	0.5	0.5
	50	3.5	2.0	1.5	1.0	1.0	1.0	0.5
	40	4.5	3.0	2.0	1.5	1.0	1.0	1.0

ADVANTAGES AND LIMITATIONS OF THE ROCKWELL PRINCIPLE

The Rockwell principle is well known and the only one that allows a direct reading of the hardness number without requiring optical measurements, like Brinell and Vickers. It is therefore the most rapid and the only one that can be fully automated.
Instruments working according to the Rockwell principle are the most popular, as they are less subject to personal influences.
Even though the surface to be tested must be accurately smoothened, between the various principles this is the less sensitive to the surface roughness.
The most important limitations comes from the fact that between maximum load (150 kp) and minimum (15 kp) there is a ratio of only 10 times. In workshops and foundries (excluding laboratories working with grams), the hardness testing often requires test loads that range from 3000 to 1 kp.
For instance, a Rockwell scale suitable for the control of cast iron or steel sheets for springs, thickness under 0,15 mm, does not exist.

Instruments working according to the Rockwell principle, with preload and load, are manufactured operating with much lower loads, not standardized, in order to supply this limit.
For a range of important materials, such as untreated steels, although there are many scales, a Rockwell one does not exist. In these cases it is better to use an instrument with Rockwell principle with Brinell loads and penetrators (see relative heading, pag. 19).

VARIANT TO THE ROCKWELL PRINCIPLE

The traditional instruments for measuring Rockwell have a disadvantage, due to the fact that the precision of the measurement depends mostly on the perfect contact between the piece to be tested and its support (usually called anvil).
When removing the additional load and returning to the preload conditions, in this way eliminating the elastic deformations (as per Rockwell principle indicated at point no. 3), the only deformation registered by the dial indicator should be the indentation itself.
This only occurs if there is a perfect support between the piece and the anvil.
If there is a slight coat of oil, grease or other, under load a little movement occurs, which, added to the indentation depth, alters the results decreasing the hardness indication.
It is not always possible to operate in ideal conditions, therefore, in heat treatment or workshops this is an obvious disadvantage.
For overcoming this problem, there are instruments with the Rockwell principle, (as nearly all the instruments of our production program: AT 180, AT 130, BRE AUT, TER, COMPUTEST, DYNATEST, ME), represented in fig. no. 3, in which the measure of the penetration is given by a support on the surface to be tested.
Hence, any movement of the piece, elevating screw or other parts of the stand itself, does not influence the result: in this way obtaining the same advantages as per Brinell and Vickers principle.
- Continued.

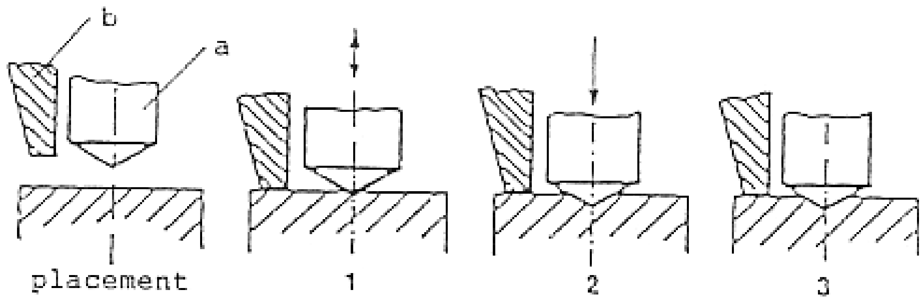


Fig. 3 - Drawing of the variant to the Rockwell principle
(measure reference and penetrator)

Placement of the specimen: on the resting position the penetrator point (a) streches out from the penetrator shroud (b).

1) Together (a - b) come down to the testing piece and the penetrator draws back with a resistance equivalent to the preload value. The zero setting is automatic.
2) The load is applied.
3) The load must be removed, the penetration displacement is readable, from (a) to (b).

If the piece to be measured gives way, relation between (a) and (b) remains constant, avoiding the typical mistake of the original Rockwell measuring.
This same principle is also used for measuring Rockwell Superficial.

In our instruments there is a third element that must not be confused with the penetrator shroud (b). This element, in the instruments with stand, is called clamping shield and in many cases it is used to tighten the piece to be tested, avoiding this way to add further special supports, it can be easily taken away if not needed.
In the portable instruments it is called base, it is interchangeable and helps to create an efficient support on the piece to be measured.

BRINELL PRINCIPLE (8)

In the Brinell principle a carbide ball indenter (of various diameters in mm, Rockwell always in inches) must be applied on the surface to be tested (flat and smooth) with a specific load and a specific time (usually 15"). From the resulting indentation, rounded shape, the diameter will be measured with optical instruments (microscopes or profile projectors); if the indentation is not perfectly round the medium value must be read

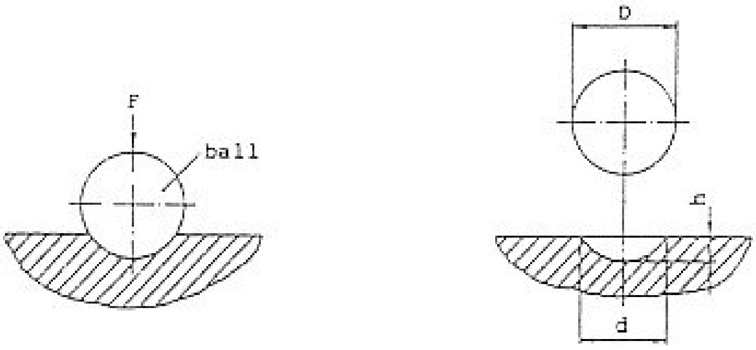


Fig. 4- Drawing of the Brinell principle

The Brinell hardness (HB) is given from the relation between the applied load and the rounded shape resulted on the test piece, according to the formula:

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

F represents the Load in kp, **D** the ball diameter in mm and **d** the print diameter in mm.

Knowing the load, the ball diameter and the indentation diameter, by means of tables it is possible to read directly the Brinell hardness number.
The balls usually used in the Brinell principle have diameters of - 2,5 - 5 and 10 mm.
Test loads are: 3000 - 1000 - 750 - 250 - 187,5 - 125 - 62,5 - 31,25 kp (29420 - 9807 -7355 - 4903 - 2452 - 1839 - 1226 - 612,9 - 306,5 N).
For proceeding with the Brinell testing the following steps are to be considered:

1) The standards require that the indentation diameter must be within 0,25 and 0,6 of the ball diameter. In order to satisfy this condition, a certain relation between the ball diameter and the load is necessary, suitable to the type of material to be tested.

When a high load is applied with a ball indenter of small diameter, on a soft material, the resulting indentation will be too deep. Instead, if a low load is applied on a ball indenter of large diameter, on a hard material, the resulting indentation will be smaller than 0,25 mm respect the ball diameter; the indentation will be practically unreadable.

2) In the Brinell principle there is a basic relation: F/D^2, between load (kp) and diameter (mm) of the ball square, that is characteristic of each single Brinell test.
The ratio usually is: 30 - 10 - 5 - 2,5 (in case of softer material, lower ratio can also be used).
For instance with a ball indenter 10 mm diameter and load of 3000 kp, the ratio is 30.
In fact, $3000 : 10^2 = 30$
With ball indenter 5 mm diameter and load of 125 kp, ratio is 5.
The harder the material, the higher will be the ratio to be used.

3) The relation F/D^2 is important since different results are obtained according to the ratio used. The same material controlled with a ball indenter 10 mm and load 1000 kp (ratio HB 10) gives a different Brinell hardness if tested with a 10 mm ball indenter and a load 500 kp (ratio HB 5)
Furthermore. it the same material is tested with a ball indenter 2,5 mm and load 62.5 kp (ratio HB 10). the result will be the same as the first test since both cases have used the same ratio (it the material is homogeneous and without layers of different hardnesses)

DENOMINATION OF THE BRINELL TESTS

The HB denomination means Brinell hardness, H = hardness in general and B = Brinell. The Brinell hardness number comes before the indication HB and ball indenter in mm, as well as the load in kp (or N) and the loading time in seconds.

Example: 305 HB 2,5/187,5/15. With the portable instruments that work with not standard load, the indication HB is used followed by the relation F/D^2 only to indicate the type of scale. Example 305 HB 30.

For the different standard relation F/D^2 see table no. 5.

Table 5 - Brinell tests and relation F/D^2

BALL DIAMETER mm	LOAD kp			
10 5 2.5	3000 750 187.5	1000 250 62.5	500 125 31.2	250 62.5 15.6
RELATION	**HB 30**	**HB10**	**H65**	**HB 2.5**

When a hard metal ball indenter (Widia) is used, (testings on semi hard steel) it will be indicated with HBW and special tables.

USE OF THE VARIOUS TESTS IN THE BRINELL FIELD

The material hardness establishes the ratio to be used according to the previous point no. 1. Once the ratio has been determined, the load will be chosen according to the following elements: 1) minimum thickness of the piece to be tested. Considerations made in the chapter regarding the Rockwell principle are still valid; the minimum measurable thickness must correspond to 10 times the print depth. (see table 6).

Table 6 - Minimum measurable thickness for Brinell tests

●	F	HB								
mm	**kp**	40	60	80	100	150	200	300	400	500
2.5	187.5	HB/30			2.40	1.60	1.20	0.80	0.60	0.48
5	125	2.0	1.3	1.0	0.80	0.53			HB/5	HB/5
10	1000	8.0	5.3	4.0	3.2	2.1	1.6		HB/10	HB/10
10	3000	HB/30			9.6	6.3	4.8	3.2	2.4	1.9

2) The material homogeneity. For materials not very homogeneous it is better to use a higher load.

3) The facility of reading the diameter indentation, whether with a microscope or profile projector, will be easier on a larger indentation than on a little one.

Here follow all Brinell tests employed for the different materials:

Steel: always HB 30. The Brinell test is very important for steels because there is a precise constant relation, between Brinell hardness and tensile strength (with a ratio of 0,36 for carbon steels, chrome and chrome-manganese; 0,34 for nickel-chrome steels).

Example - 225 HB 30 X 0,36 X 9,807 = 794,3 N/mm^2

This is the only way to determine the tensile strength of a steel without damaging the testing piece. For tempered steels however, the Brinell principle is not suitable, as it does not make use of a diamond penetrator, generally used for hardened and tempered steels over 1765 N. Soft iron is usually controlled with HB 30 on the condition that the indentation diameter exceedes half of the ball diameter.

Cast iron: Uses always HB 30. Due to its scarce homogeneity, it is suggested to use the highest possible load, compatible with the minimum thickness of the piece. Usually 3000 kp.

Light alloys: Uses HB 10 or HB 5, for alloys particularly soft even HB 2,5.
Having various possibilities of testing when the type of test (relation F/D^2) to be carried out is not clear, it could cause confusion .

Copper alloys: Uses HB 10 for bronze (if particularly hard also HB 30) and HB 5 or HB 10 for brasses.

ADVANTAGES AND LIMITATIONS OF THE BRINELL PRINCIPLE

The main advantages of the Brinell principle are that high loads particularly can be used with ruggued and simple constructed instruments. Furthermore, the resulting indentation can be measured by means of a simple microscope or even with a magnifier. It provides accurate measurements even when the positionning of the piece is not ideal, since, unlike the Rockwell principle, slight deflections do not influence the result.

Multiplying the Brinell value by a coefficient, specific for each material, the tensile strength value will be obtained. Eventual indentation bucklings can emphasize the already existing stress in the controlled material. The most evident limitation is that the measurement of the indentation diameter must be carried out optically and therefore is subject to the evaluation errors of the user. Besides, even though using high loads, the smooth surface preparation is essential. This allows an accurate measurement of the indentation. For these reasons Brinell testing is slow and not suitable for testing in production lines.

To overcome this problem, often the Rockwell principle is used, but with Brinell penetrators and loads (see following chapter). (9) The testing of round surfaces is not possible. Therefore, it is essential to create a flat surface before the test is made.

TESTS WITH BRINELL PENETRATORS AND LOADS ACCORDING TO THE ROCKWELL PRINCIPLE

As mentioned before, to overcome the various inconveniences of the Brinell tests, and to make more use of the Rockwell instruments, the latter are used to carry out tests with Brinell penetrators and loads. In fact, the majority of these instruments besides having Rockwell loads have also: 62,5 - 125 - 187,5 kp loads (612,9 - 1226 -1839 N), standard for the Brinell tests. The indentation measure is carried out by measuring the penetration difference between preload and load, according to the Rockwell principle, rather than on the diameter, according to the Brinell principle. The results are directly shown on display or on dial indicator in Rockwell lines, then converted into Brinell numbers with the relative tables. However, this principle is not a real Brinell test , since it would require the optical measuring of the indentation. In fact the results that are obtained from the conversion by means of tables, are not the same for all materials (for instance the steel conversion is not the same as the cast iron one).

Nevertheless, this principle is very convenient where tests in lines must be carried out, or optical reading of the indentation wants to be avoided. This also removes the requirement to create smooth surfaces necessary for optical reading. There is also the advantage, for steels, to make use of a scale especially calibrated for the direct reading of the tensile strength in kp/mm^2 - N/mm^2. In order to obtain a greater precision in the production testing, the ERNST instruments have the possibility to introduce a new and temporary calibration of-the Brinell scale. It must be used on a sample measure, previously obtained with the optical Brinell system.

VICKERS PRINCIPLE

The testing principle is the same as the Brinell one, but makes use of a pyramidal diamond penetrator with square base, having an angle of 136° between the faces. From the resulting indentation, the two diagonals will be measured, and since these are very seldom the same, the medium value will be the result.

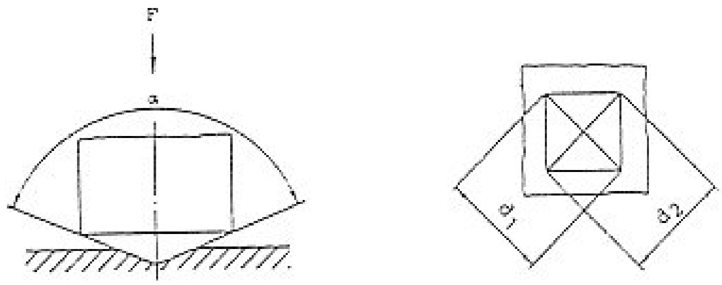


Fig. 5. Drawing of the Vickers principle

Likewise, to a Brinell number, the Vickers HV hardness number, is given by the relation between applied load and indentation surface according to the formula:

$$HV = \frac{2F}{d^2} \cdot \text{sen}\,\frac{136°}{2} = 1,854 \cdot \frac{F}{d^2}$$

F stands for the load in kp and **d** is the diagonal (or average of the diagonals) in mm. Obviously even in this case in order to establish the hardness, relative tables must be consulted.

The tests loads are various, but the most frequently used are: 1 - 2 - 5 10 - 30 kp (9,81 - 19,62 - 49,05 - 98,10 - 294, 30 N); it is also possible to use loads less than the kp (9,81), entering this way in the micro hardnesses field.
Their best application is to be found in the metallographic laboratories.

OPERATING FIELD OF THE VARIOUS VICKERS LOADS

The Vickers principle makes use of a penetrator and the Vickers number represents the specific load per mm 2 on the indentation. The obtained values according to the different loads are comparable between one another. For instance, if the test is carried out on the same material, with a load of 30 kp (294,30 N) and of I kp (9,81 N) the result will correspond, (this of course if the material is homogeneous and without layers of different hardnesses).

Even in. case of layers, the Vickers test can be conveniently used, by increasing the loads, to establish the superficial treatment thickness as in the case of the nitrogen-hardening. When test loads have a value under approx. 200 grams, there will be an increase of the hardness number, even if the material is homogeneous, because of the phenomenon manifestation of the superficial stress.

Even for the Vickers test, the minimum measurable thickness is considered equal to 10 times the penetration depth (see table no. 7)

Table no. 7 - Minimum measurable thickness for the Vickers tests

F	HV								
kp	**20**	**50**	**100**	**200**	**300**	**400**	**600**	**800**	**1000**
0.200	0.19	0.12	0.09	0.06	0.05	0.04	0.04	0.03	0.03
1	0.43	0.28	0.19	0.14	0.12	0.10	0.08	0.07	0.06
2	0.62	0.39	0.28	0.19	0.16	0.14	0.12	0.10	0.09
5	1.0	0.62	0.44	0.31	0.25	0.22	0.18	0.15	0.14
10	1.4	0.87	0.62	0.43	0136	0.31	0.25	0.22	0.19

The denomination of the Vickers tests is HV (H = hardness V = Vickers) followed by the test load. Example: 350 HV10.

The Vickers test is especially used for the control of small , thin or with superficial treated pieces, where there is a need of low loads.

It is to be avoided on materials not homogeneous, such as cast irons.

ADVANTAGES AND LIMITATIONS OF THE VICKERS PRINCIPLE

The great advantage of the Vickers principle is that it makes use of a scale that can range from the lowest hardnesses up to the highest. For this main reason, it is considered a foundamental research base for laboratories. Eventual indentation deformations can emphasize the structural characteristics of the material tested. As per the Brinell principle this is not influenced by eventual give ways.
The Vickers hardness number, unlike the Rockwell value (even more than in the Brinell number), has an evident meaning, it represents a specific load on a indentation always having the same shape.

The limitations of the Vickers principle are due to its scarce rapidity, since the indentation measurement must be carried out optically (microscope or profile projector). The surface to be tested must be very carefully prepared and polished. Therefore, the perpendicularity with the penetrator axis becomes very important, as a little inclination causes irregularities on the indentation. For this main reason it is not suitable to control in lines. On some materials, the indentation results are hardly readable because of the irregular solicitation division, higher on the corners than on the faces of the pyramidal indentation. In conclusion it can be said that the Vickers principle is more suitable for laboratories than for workshops.

To overcome these limitations we have designed our instruments to read the Vickers hardness with faster and less stringent principles. (11)

SHORE PRINCIPLE (METALS)

Is based on the following principle: a ball (or rod with ball point) falls on the piece to be measured, rebounds in height more or less according to the hardness of the same. It is seldom used because even though being a simple principle, the precision depends from the mass of the piece to be measured and also from the perfect perpendicularity of the fall axis. The hardness measure is expressed in SHORE points and it is standardized for the measurements on large cylinders with high surface finishes.

KNOOP PRINCIPLE

It is similar to the Vickers principle, with a diamond penetrator, having a rhomboidal pyramid form with diagonals ratio 1:7.
It is only used in laboratories for measurements with few grams load.

USE OF THE COMPARATIVE TABLES

The equivalence between the different hardness scales are the result of the various empiric experiences, but no mathematics correlation exists between them. In fact, tables of different sources, often give differences, even notable ones .
Therefore, values deduced from conversion tables cannot be considered absolute but only orientatives.
Usually the comparative tables show also tensile strength values in N/mm^2 for steels or alloys with conversion ratios compared to the HB/30.

USE OF TEST BLOCKS

Generally, within the standard equipment of a hardness tester there are one or more test blocks. These must be of a very homogeneous material, conveniently treated, calibrated with particular care only on one side. It is important to often test the instruments with the test blocks in order to verify the accuracy and proper functioning. The minimum distance between the two centers indentation print or of the center and the edge of the test block must be as follows:

For Rockwell measurements, 3 mm.
For Rockwell N, 1 mm.
For Rockwell T, 2 mm.
For Brinell, from 2,5 to 6 times the diameter of the print, according to the hardness.

When tests have been carried to cover the complete surface of the test block, their reuse by smoothening them is not possible, because the material lying beneath has modified its structure and would therefore give false results.
With time the test blocks hardness can alter slightly. In fact, it has been experienced, that the hardness of some test blocks HRC 60 after approx. 5 years increased of 0,5-1 HRC point.

APPENDIX - REFERENCE INDICATED IN THE TEXT

For further information please consult our leaflets

(1) **ERNST *bench instruments such as:***

NR3 DR - This is a strong and simple digital instrument for Rockwell tests with preload and load standardized.
With Brinell loads.

NR3 DSR - As above, but Superficial Rockwell version.
With Brinell loads.

AT 130 DR - Fast and accurate digital hardness tester for Rockwell tests, working according to the variant. (See pages 13-14).
Preload and loads standardized.
With Brinell loads.
Choice of 4 differrent stands.

AT 130 ASR - As above, but Superficial Rockwell version.
With Brinell loads.

AT 200 DR - Similar to the AT 130 version but with a more powerful electronic, large graphic display and multifunction software: printing, statistics, 5 tolerances, minimum measurable thickness, round correction, histogramm and others.
Output RS 232.
Possibility of selecting various scales.
Also available in the motorized version.
Choice of 4 different stands.
With Brinell loads.

AT 200 DSR - As above, but Superficial Rockwell version.
With Brinell loads.

BRE-AUT - Instrument of big dimensions, for automatic Brinell measuring.
With loads from 500 to 3000 kp.
Easily connectable to complete plant projects or in production lines.

(2) (4) **ERNST** ***portable hardness testers (lean, press and read) such as.***

COMPUTEST	-	Portable instrument with a static load of 5 kp, direct digital reading on display. Very practical, with a selection of seven or more scales. Possibility of checking various types of metals with different shapes. With printing functions, statistics, tolerances and others, output RS 232.
DYNATEST	-	As above, but with a load over 100 kp. Selection of four or more scales. Enables to obtain approx. the same results as a bench instrument, this due to its high test load.
(3) **STE**	-	Static/Dynamic system with calibrated pins. Load of 1'580 kp. Indicated for foundries and steel plants. For Brinell HB/30 and tensile strength.
(5)	-	NR 3 DR - AT 130 DR - AT 200 DR see (1)*
(6)	-	NR 3 DSR - AT 130 DSR - AT 200 DSR see (1)*
(7)	-	COMPUTEST - DYNATEST see (2)*
(8)	-	
(9)	-	All our instruments
(10)	-	BRE AUT with grinder incorporated
(11)	-	All our instruments, except NR 3
(12)	-	Scale in Shore points available for almost each of our instruments

*Of this appendix