USER'S MANUAL

HR SERIES PORTABLE ROCKWELL
SUPERFICIAL ROCKWELL HARDNESS TESTER
HBR SERIES PORTABLE BRINELL&ROCKWELL HARDNESS TESTER




Cautions

The magnetic type hardness tester has strong magnets which are active when the magnetic switch is set at "Attract" and inactive when the magnetic switch is set at "Release". In order to ensure safety, before testing, when you put the tester on the work piece or iron base, and then you can set the magnetic switch at" Attract", otherwise, it is not permitted to set the magnetic switch at"Attract". Because there will be intense attraction between the tester and ferrous objects, which may result in injury to operator or tester damage

Content

1. Introduction

This operation manual is applied to: HR series portable Rockwell hardness testers, HR series portable superficial Rockwell Hardness testers and HBR series portable Brines & Rockwell hardness testers.

PHR series portable Rockwell and superficial Rockwell hardness testers comply with the basic designing principles of Rockwell hardness testing in accordance with international standard ISO6508, American Standard ASTM E18 and ASTM E110.

PHR series hardness testers which consist of four kinds: regular, C-shape, chain clamp and magnetic type, altogether 15 models (refer to Appendix C), can test a variety of metal materials and work pieces with thickness $>$0.2mm and diameter $>$2.5mm. They can test the hardness of different kinds of metals form very soft aluminum to very hard steels, hard alloy etc.

The hardness values can be read directly from the Rockwell and superficial Rockwell hardness testers after rapid and accurate operations. It can be considered as a non-destructive testing with very small indentations. This kind of testers can be used at site to test the finished or semi-finished work pieces piece by piece in batches. Rockwell hardness testers are mostly applied in the metal-processing enterprises.

The PHBR series portable Briness & Rockwell hardness testers are designed and developed based on the PHR series testers according to Brinell and Rockwell hardness testing methods. The test principle, test conditions and test accuracy are all up to the international standard ISO6508/6506.

The PHBR series portable Brinell & Rockwell hardness testers have 5 models in 4 series: regular, C-shape, chain clamp and magnetic type (refer to Appendix C).Used as a Brinell hardness tester, it is suitable for testing castings, forgings, steels, nonferrous metals and iron and steel parts after being treated by annealing, normalizing and tempering of different sizes.

The PHBR series hardness tester can work as both Rockwell hardness tester and Brinell hardness tester. They can solve most of the hardness testing problems in the industry. HBR series Brinell & Rockwell hardness testers have a higher testing accuracy. The test results meet most requirements of product standard or drawings and can be well accepted in international trade.

2. Principle and Structure

2.1 Principle of Rockwell Hardness Test

As illustrated in Fig.1, the indenter is pressed (diamond cone or hard alloy ball) into the test piece surface in two steps. After maintaining the pressure for a predetermined period of time, unload the major test force F_1, and measure the remaining indentation depth h under initial test force F0.

Rockwell hardness value is:

$$HR = N - \frac{h}{s} \qquad \cdots\cdots\cdots (1)$$

In this equation:

N— a constant related to scales; for A, C, D, N and T scales, N=100; for B, E, F, G, H and V scales, N=130.

S— unit indentation depth, for Rockwell hardness it is 0.002mm, for superficial Rockwell hardness it is 0.001mm.

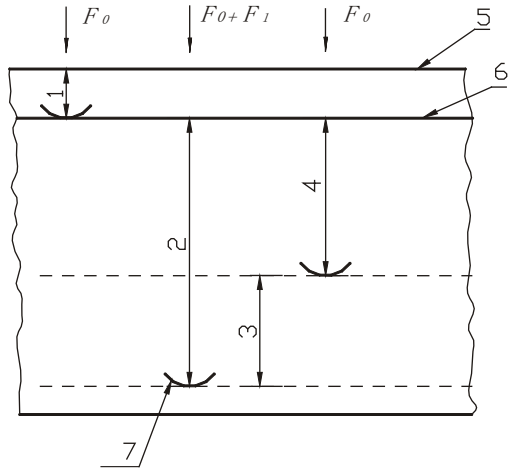

Fig. 1 Principle of Rockwell Hardness Testing

1—indentation depth under initial test forces F_0;
2—indentation depth under total test forces F_0+F_1;
3—elastic recovery depth when major test force F_1 is removed;
4—remaining indentation depth h; 5—test piece surface;
6—datum plane; 7—position of indenter

Rockwell hardness testers are designed according to the basic principle of Rockwell hardness test. The main differences from the bench-type lie in: the test force is applied by a screw and a calibrated U-shape spring; two indicators are installed on the tester: one indicating dial indicates the test force value by measuring the deformation of the elastomer and one precision screw micrometer used for testing the indentation depth; one barrel dial installed on the micrometer shows the hardness values. The principle and structure of this device is in accordance with the American Standard ASTM E110.

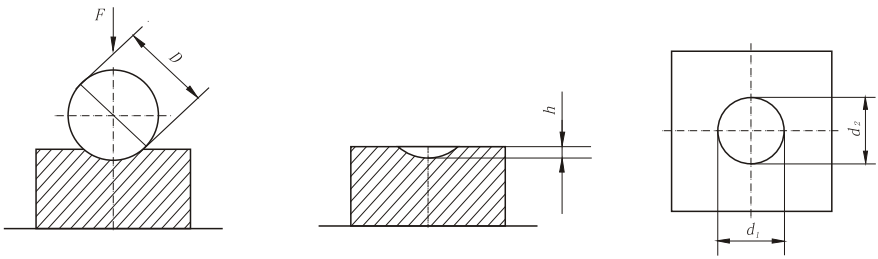

Fig. 2 Principle of Brinell Hardness Testing

2.2 Principle of Brinell Hardness Testing

Apply a standard test force F to the hard alloy ball indenter with a diameter of D and press it into the test piece surface; keep on pressing for a set period of time, then remove the test force F and a round indentation with depth h is obtained on the surface of the test piece. Measure the indentation's average diameter d, the Brinell hardness can be calculated by the quotient of test force divided by indentation's surface area.

$$HBW=F/S \quad \cdots\cdots (2)$$

$$=F/\pi Dh \quad \cdots\cdots (3)$$

$$=0.102\times 2F / [\pi D (D-\sqrt{D^2-d^2}\ )] \quad \cdots\cdots (4)$$

2.3 Structure of Regular Hardness Testers

Fig.3 Regular Hardness Tester.

2.4 Structure of C-shape Hardness Testers

Fig.4 C-shape Hardness Tester.

2.5 Structure of Chain Clamp Hardness Testers

Fig.5 Chain Clamp Hardness Tester.

2.6 Structure of Magnetic Type Hardness Testers

Fig.6 Structure of Magnetic Type Hardness Tester.

2.7 Comparison between Brinell 7 Rockwell Hardness Tester and Rockwell Hardness Tester

PHBR series Brinell & Rockwell hardness testers have the same appearance as the corresponding types of Rockwell hardness testers. The structrural and configurational differences are as follows:three force scales marks-187.5kg, 125kg and 62.5kg-are added on the dial of Brinell & Rockwell hardness testers;two hard alloy indenters with 2.5mm and 5mm diameters are added; Brinell hardness blocks are added;and a reading microscope is added to read the indentation diameter

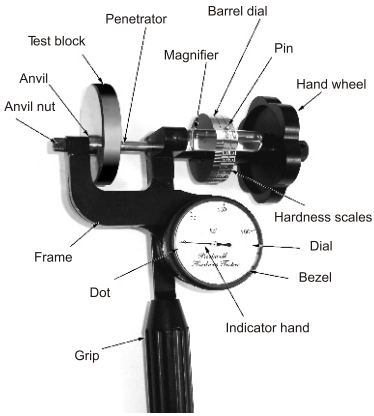

Fig. 3 Regular Hardness Tester

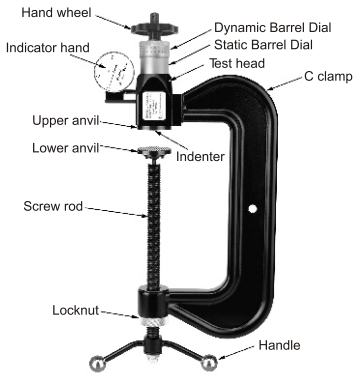

Fig. 4 Large Hardness Tester

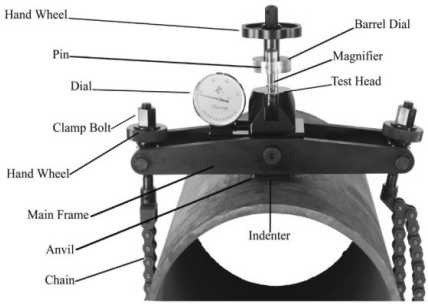

Fig. 5 Chain Clamp Hardness Tester

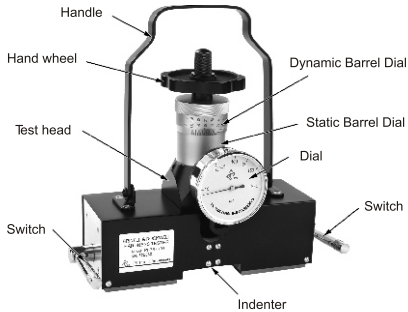

Fig. 6 Magnetic Type Hardness Tester

3. Main Technical Parameters

Rockwell Initial test force:	Superficial Rockwell hardness	3kg
	Rockwell hardness	10kg
Rockwell Total test force:	Superficial Rockwell hardness	15kg, 30kg, 45kg
	Rockwell hardness	60kg, 100kg, 150kg
Brinell test force:	62.5Kg, 125Kg, 187.5Kg	
Maximum magnetic force:	>350kg (for magnetic type hardness testers)	
Force applying method:	by screw	
Indenter:	120° diamond cone Φ 1.588mm, Φ2.5mm, Φ5mm hard alloy balls	
Testing Items:	Superficial Rockwell hardness	HR15N、HR30N、HR45N、HR15T、HR30T、HR45T, altogether 6 scales
	Rockwell hardness	HRC, HRB, HRA etc., 15 scales
	Brinell hardness	HBW 30, HBW 10, HBW 5, HBW 2.5, four testing conditions
Resolution:	for Rockwell hardness: 0.5HR; for Brinell hardness: 0.01mm (indentation diameter)	
Accuracy:	Meets the requirements of ISO6508/6506 and ASTM E18/E10	
Application:	All common use metals, including steel, forged steel, cast iron, copper, copper alloy, aluminum, aluminum alloy and hard alloys etc.	

4. Selection of Indenter, Test Force and Anvil

In order to test the metallic materials of different qualities, hardness and thickness, 3 different indenters and 3 different test forces are applied, resulting in 9 combinations corresponding to the 9 scales of Rockwell hardness. 2 kinds of indenters and 3 kinds of testing force are applied in the superficial Rockwell hardness testing, resulting in 6 combinations corresponding to 6 scales of superficial Rockwell hardness, refer to Appendix A. (The application of regular and C–shape hardness tester can be expanded to 15 scales of Rockwell hardness or 15 scales of superficial Rockwell hardness, which realizes the softer metals being tested).

For Brinell hardness testing, 2 indenters and 3 test forces with outcome of 4 combinations correspond to relevant 4 testing conditions for Brinell hardness testing. Choose appropriate test conditions for different hardness ranges.

4.1 Indenters Selection for Rockwell / Superficial Rockwell Hardness

The indenters should be selected according to the hardness range of testing materials.

Select diamond indenters for tempered steel, quenched steel, surface hardening soft steel and hard alloys; ball indenters for soft metals; small ball indenters for harder metals; big ball indenters for softer metals and bigger ball indenters for even softer metals; refer to Appendix D.

When the hardness of test samples cannot be estimated, a diamond indenter should be used first to test HRC or HRN scale. When the hardness value is smaller than a certain relevant testing range, the ball indenter can be applied instead.

The following requirements should also be taken into account:

Do not use the ball indenter to test quenched steel and hard alloys.

Choose the suitable ball indenters based on the hardness of test pieces when testing soft metals so as to make the test results lie within the valid measuring range of relevant scales. Prevent the indenter from damaging the anvil when testing thin materials.

The diamond indenter and the diamond spot anvil are forbidden to be used meanwhile.

4.2 Test Force Selection for Rockwell Hardness / Superficial Rockwell Hardness

The test force should be selected according to the thickness of the test piece. Apply big test force to thick test pieces, small test force to thin test pieces and use superficial Rockwell hardness tester to test thinner test pieces. Refer to Appendix D and Appendix E.

Also follow the principles below when choosing test forces:

When different test forces are applicable for a certain test piece, choose the biggest test force among them, because big test force can make deep indentations and the accuracy will be relatively higher.

When testing thin test pieces, no visible deformation trace should be observed on the back side of test pieces, otherwise, it means the test force is overloaded with measuring anvil effect .In this occasion, there would be a large measuring deviation, so the test force should be reduced.

When testing the hard alloy, only HRA scale is permitted to be applied. Do not use HRC scale to test hard alloys in the big test force. Otherwise, the diamond indenter will be damaged.

4.3 Selection of Indenter and Test Force for Brinell Hardness

Four testing conditions can be selected for Brinell hardness testing, correspondingly the values of $0.102F/D^2$ are 30, 10, 5, 2.5, refer to Appendix I. The testing range of hardness is from 20HBW to 650HBW.

For steel, forged steel, cast iron, nickel alloy, titanium alloy and bronze, choose the ball indenter with diameter of 2.5mm, apply 187.5kg test force, thus $0.102F/D^2 =30$; for soft cast iron, brass and hard aluminum alloy, choose the ball indenter with diameter of 2.5mm, apply 62.5kg test force, accordingly $0.102F/D^2$

= 10; for soft brass, pure copper, soft aluminum alloy and pure aluminum, choose the ball indenter with diameter of 5mm, and apply 125kg test force, then $0.102F/D^2$ =5; for pure aluminum and other soft metals, choose the ball indenter of 5mm diameter and apply 62.5kg test force, therefore $0.102F/D^2$ =2.5. Refer to Appendix J for selection of the testing conditions of Brinell hardness.

A pre–test should be carried out after the test force is determined. The relationship of indenter diameter D and indentation diameter d should satisfy $0.24D \leqslant d \leqslant 0.6D$, if not, change the test force and retest.

4.4 Selection of Anvil

The anvil should be selected according to the shape of the test piece.

Flat anvils are adopted by flat test pieces.

V–shape anvils are used to test the test pieces with a cylindrical surface thick wall pipes, round bars and wires.

For tubing with inner diameter > 30mm, apply the regular Rockwell hardness tester and use the spot anvil by inserting its left side into the tube to test the external surface hardness, or by exchanging the positions of indenter and anvil to test its internal surface hardness.

For tubing with inner diameter < 30mm, cut one piece from the test piece of tubing and use the flat anvil to test its internal surface.

For the soft metal thin–wall tubing with inner diameter >4.8mm, use the model PHR–1ST superficial Rockwell hardness tester.

The spot anvil can be applied to test small test pieces and those with uneven bottom surface. For small–size, deformed punching parts, the slender spot anvil can be selected.

For the bent sheets, use the flat anvil or the spot anvil and have the convex surface rest on the anvil.

For such thin and soft metal sheets as tinplates, cold–rolled thin steel sheets and thin copper strips, the best choice is diamond spot anvil together with Superficial Rockwell Hardness Tester.

4.5 Application of Adapters for Magnetic Type Hardness Testers

The magnetic type hardness testers could be applied to test the test pieces of flat surfaces and cylindrical surfaces directly. For those irregular or certain component parts could not be tested directly due to length, width, thickness or curvature reasons, they could be tested by adding specialized adapters. The end–user could send back the drawings or photographs to the manufacturer, who should design and manufacture the specialized adapters for the component parts.

5.Operation

5.1 Rockwell/Superficial Rockwell Hardness Tester’s Operation

5.1.1 Preparations

Be sure to have chosen the proper indenter and anvil before testing. This device is equipped with the diamond indenter and flat anvil before leaving factory. When changing the indenter and anvil, be sure to have the screws fastened tight. When using a hardness tester with an opening size >1 inch to test small test pieces, an extension should be adopted and also fixed tight. After the indenter and anvil are changed or the extension is installed, a pretest should be made before the formal test. The result of the pretest should be neglected.

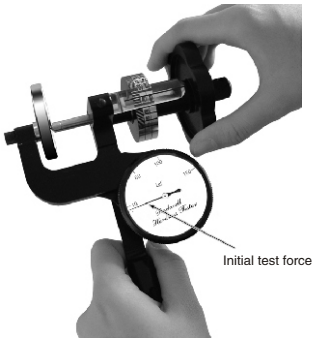

Fig. 7 Apply initial test force

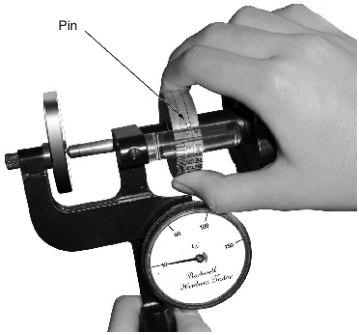

Fig. 8 Adjust the barrel dial

5.1.2 Set the load dial to "0"

Check the indicator hand. It should rest exactly on the red dot "0" on the indicator dial. If it doesn't, adjust the dial by turning the bezel to locate the red dot under the pointer.

5.1.3 Fix the test piece

Put the test piece into the opening of the tester with its back side contacting the anvil tight, and be sure to keep its testing surface vertical to the principal axis of the indenter. Turn the hand wheel to make the main shaft of the tester move to the left, and the indenter is made to hit on the test piece surface.

5.1.4 Apply initial test force

Slowly turn the hand wheel clockwise to bring the indicator hand to the position of initial force F0 (for Rockwell Hardness Tester F0=10Kg, for superficial Rockwell hardness tester F0=3 Kg), refer to Fig. 7.

Fig. 9 Apply major test force

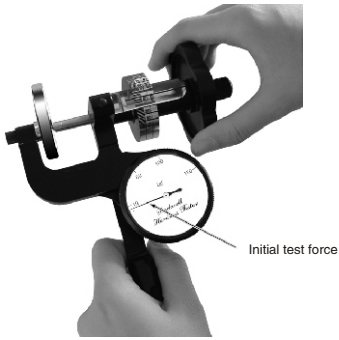

Fig. 10 Take the reading

5.1.5 Set reading line in magnifier aligned with full–scale line in barrel dial

Rotate the barrel dial anticlockwise until its pin rests against the upper edge of the magnifier; refer to Fig. 8. Meanwhile, the operator should adjust the observing

angle to make the full–scale benchmark line on the fixed drum dial (the red scale mark 130, black scale mark 100) exactly aligned beneath the reading scale mark of the magnifier. The operator should keep this viewing angle also known as the viewing angle for reading the hardness value until the test is finished.

5.1.6 Load and unload major test force

Rotate the hand wheel stably clockwise to bring the indicator hand to the position of total test force F=F0+F1 (e.g., for HRC scale, F=150kg). The indicator hand should be aligned exactly to the marked scale of the selected test force, refer to Fig. 9. If the pointer goes beyond the scale mark, the testing should be considered as failure. Then unload the test force and choose a new point on the test piece to make a new test.

The time duration from loading initial test force to loading total test force should be no more than 8 seconds.

After loading total test force, the test force should be maintained 3 to 5 seconds. Then completely unload major test force within 2 seconds to bring the indicator hand back to the position of initial test force F0.

5.1.7 Take the reading

Looking through the magnifier, determine the superposition of reading line of the barrel dial aligned with that of the magnifier, the value of which represents the hardness value of this test. Each long scale mark on the rotational drum dial represents 10 hardness units, and the value is shown above the mark. Between every two long scale marks there are 5 (or 10) graduations, each of which indicates 2 (or 1) hardness units. The midpoint of every 2 short marks indicates 1 (or 0.5) hardness unit. The 1/4 point between 2 short marks indicates 0.5 (or 0.25) hardness unit. The reading value should be estimated to 0.5 hardness unit as shown in Fig. 10.

For Rockwell hardness testers:

Read the black numbers under C on the rotational drum dial for Scales HRA, HRC, HRD with a diamond indenter; read the red numbers under B on the rotational drum dial for Scales HRB, HRE, HRF, HRG, HRH, HRK with a ball indenter.

For superficial Rockwell hardness testers:

Read the N–T graduations on the rotational drum.

5.2 Operation of C–shape Rockwell Hardness Tester

5.2.1 Preparation

Be sure to have chosen the proper indenter and anvil before testing. This device is equipped with the diamond indenter and flat anvil before leaving factory. Before using the tester, check if the indenter has retracted into the upper anvil. If not, turn the hand wheel to bring the indenter back into the upper anvil. Otherwise, the indenter will be damaged when fixing the tester and the work piece.

5.2.2 Fix the tester

The tester can be used in a horizontal or tilting way on condition that it can be fixed on the work piece smoothly and stably with the test surface of the work piece vertical to the indenter axis for easy operation and reading. If possible, it's better to use the tester in a horizontal way to operate and get the reading easily. Fix the tester as below:

First select the test part of the work piece and place the work piece vertically on one side to put the test part on the operator's right side. Hold the device

horizontally in the palm to make the test head rest on the operator’ s right side. Regulate the handle tight and fix the test piece. Press the test head firmly onto the work piece with over 200kgf. Finally screw the locknut tight.

5.2.3 Apply initial test force

Slowly turn the hand wheel clockwise to bring the indicator hand to the position of initial force 10Kg.

5.2.4Set reading line in static barrel dial aligned with full–scale line in dynamic barrel dial

Rotate the dynamic barrel dial anticlockwise and make reading line(only one long black line) in static barrel dial aligned with full–scale line(the C scale mark 130, and B scale mark 100)in dynamic barrel dial.

5.2.5 Load and unload major test force

Rotate the hand wheel stably clockwise to bring the indicator hand to the position of total test force F=F0+F1 (e.g., for HRC scale, F=150kg). The indicator hand should be aligned exactly to the marked scale of the selected test force, refer to Fig. 9. If the pointer goes beyond the scale mark, the testing should be considered as failure. Then unload the test force and choose a new point on the test piece to make a new test.

The time duration from loading initial test force to loading total test force should be no more than 8 seconds.

After loading total test force, the test force should be maintained 3 to 5 seconds. Then completely unload major test force within 2 seconds to bring the indicator hand back to the position of initial test force F0.

5.2.6 Take the reading of hardness

Find the corresponding position of value reading line on the fixed drum dial to the pin of the rotational drum. The number of this position showing is the measuring hardness of this test. The reading value should be estimated to 0.5 hardness value at least.

5.2.7 Withdraw the indenter

After testing, turn the hand wheel in a reverse direction until the pin of the rotational drum dial leaving the red dot of the magnifier, then the indenter returns into the upper anvil.

5.2.8 Remove the tester

Loosen both the locknut and the handle to take off the tester from the work piece.

5.2.9 Replace the indenter and anvil

The indenter probably needs to be changed following the change of the test scales. The V anvil needs to be changed during the test of curved surface test pieces. Below is the operating method:

Slightly turn the upper anvil, pull the anvil downwards off and the indenter appears. Rotate the hand wheel to make the indenter show out more. The indenter is connected to the tester by screw threads and it can be taken down by unscrewing the threads. Screw on the threads tight after replacing a new indenter, and slightly push the upper anvil upwards to replace the anvil.

After the indenter is replaced, 1 or 2 pretests should be made first before the formal test.

5.3 Operation of Chain Clamp Rockwell Hardness Tester

Test with chain clamp Rockwell hardness tester might be operated by 2 operators.

5.3.1 Preparation

Be sure to have chosen the proper indenter and anvil before testing. This device is equipped with the diamond indenter and V–shape anvil before leaving factory. Before using the tester, check if the indenter has been returned into the upper anvil. If not, turn the hand wheel to bring the indenter back into the upper anvil. Otherwise, the indenter will be damaged when fixing the tester and the work piece.

5.3.2 Fix the tester

Horizontally put the testing frame across the test piece. One operator holds the testing frame, and the other holds the chain to make it in order round the test piece, then pull it tight and hang it up on the hook at the right side of the testing frame.

Pull the chain tight by alternately turning the hand wheels on the tension bolts. During this course be careful not to incline the testing frame.

Use the wrench equipped for the tester to screw tight alternately the tension bolts on both the left and right sides. The chain should be pulled tight until the test head could be pressed on the test piece with more than 200Kgf. The fix screws should not be tighten too much, otherwise it could cause breaking off of the pothook

5.3.3 Operation

Reffer to the steps in 5.1.2~5.1.7.

5.3.4 Pull back the indenter

After testing, turn the hand wheel in a reverse direction to bring the pin of the rotational drum dial to the red dot of the magnifier, then the indenter returns into the upper anvil.

5.3.5 Take off the tester

Unscrew the tension bolt reversely and alternately, and take down the chain to take off the tester from the work piece.

5.3.6 Replace the indenter and anvil

The indenter probably needs to be changed following the change of the test scales. Below is the operating method:

Slightly turn the anvil, pull it downwards off and the indenter appears. Adjust the hand wheel to make the indenter show up more. The indenter is connected to the tester by screw threads and it can be taken down by unscrewing the threads. Screw on the threads tight after replacing a new indenter, slightly turning the anvil and push it upwards to replace the anvil.

After the indenter is replaced, 1 or 2 pretests should be made first before the formal test.

5.4 Operation of Magnetic Type Rockwell Hardness Testers

5.4.1 Test Conditions

5.4.1.1 Magnetic Type Rockwell Hardness Testers can be used only for testing iron and steel.

5.4.1.2 When testing on flat surface test piece, its area should be greater than 60mm × 180mm, the thickness should be thicker than 5 mm; for testing on curved surface test piece, its length should be longer than 180mm, diameter should be greater than 50mm; for tubing test piece, its wall thickness should be thicker than 8mm.

5.4.1.3 The test side of the device should have a surface contact with the test

pieces. Adapters of relevant sizes should be installed when testing on the curved surface test pieces.

5.4.1.4 The surface of test piece should be smooth because the rough surface can reduce the magnetic force and test precision. It does not matter if there are some shallow cutting lines on the test piece surface, but the rough surface by casting and forging ought to be polished smoothly before testing.

5.4.2 Preparations

This device has strong magnets. The magnetic switch should be set at "Release" when it is idle and the magnet is inactive. Only when the device is firmly placed on the ferrous test piece and ready for test, can the magnetic switch be set at "Attract". Otherwise, the device can be damaged and bodily injury may happen.

Check the magnetic switch before test and ensure it is set at "Release". If not, place the magnetic switch at "Release" immediately.

Also confirm that the proper indenters are selected before test. Diamond indenters are used for testing the quenched, tempered ferrous parts; ball indenters are used for testing annealed, normalized ferrous parts. The device is installed with a diamond indenter before leaving factory.

5.4.3 Fix the Device

Place the device onto the test piece firmly. Spin two magnetic switches by 180° to position Attract separately, keep the hand shank covering on the word "Attract", then the device should be attracted onto the test piece firmly.

5.4.4 Set "0" to the Force Indicator

Check the position of the indicator hand; it should rest on the red "0" point. If it does not rest on the red point, turn the dial bezel and bring it to the red point.

5.4.5 Applying Initial Test Force

Rotate the hand wheel clockwise to bring the indicator hand to the initial test force "10kg".

5.4.6 Set the full scale line to "0"

Rotate the rotational drum dial anticlockwise to bring the full scale marks of it (the red line 130 and the black line 100) exactly aligned with the scale marks of the fixed drum.

5.4.7 Applying and Removing the Main Test Force

Steadily rotate the hand wheel clockwise to bring the indicator hand to the total test force F (for HRC scale, F=150kg).

The time duration from applying the initial test force to applying the total test force should be no more than 8 seconds.

After loading total test force, the test force should be maintained 3 to 5 seconds. Then completely unload major test force within 2 seconds to bring the indicator hand back to the position of initial test force F0 (10kg).

5.4.8 Take the Hardness Reading

The hardness number from where the scale mark on the rotational drum dial is aligned with that of the fixed drum dial represents the hardness value of this test. Read the number and estimate the reading to 0.5 hardness value.

For HRA and HRC scales with the diamond indenters, take the reading on the black HRC scale of the rotational drum.

For HRB scale with the ball indenter, take the reading on the red HRB scale of the rotational drum.

5.4.9 Withdraw the Indenter

Rotate the hand wheel in a reverse direction after the test is finished to

withdraw the indenter until the rotational drum dial retreats to where the red point on the fixed drum dial is shown. Otherwise, the indenter could be damaged in next test.

5.4.10 Remove the Device

Set the two magnetic switches to "Release" position to remove the device. Attention: The switch handle should be turned by full 180 and exactly rest on the "Release" mark when setting the switch to "Release". Then the magnets of the device are completely inactive to the external objects.

5.4.11 Replace the Indenter

The indenter needs to be replaced following the change of the test scales. Below is the operating method:

Rotate the hand wheel clockwise to show the parts of the indenter as many as possible.

Replace and screw tight the indenter. Rotate the hand wheel anticlockwise to move the rotational drum dial upward until the red point on the fixed drum dial is shown out.

After the indenter is replaced, 1 or 2 pretests should be made first before the formal test.

5.4.12 Cautions

This device has strong magnets which are active when the magnetic switch is set at "Attract" and inactive when the magnetic switch is set at "Release". In order to ensure safety, DO NOT set the magnetic switch at "Attract" when stored or transported at normal times after using the device, otherwise there will be intense attraction between the device and iron and steel component parts, which may result in injury to the operator's hands or malfunction to precision devices like the wrist watch.

5.5 Operation of Brinell Hardness Testers

The operations of regular, C–shape, Chain Clamp and magnetic type Brinell hardness testers are similar to those of the relevant types of Rockwell hardness testers, shown as follows:

5.5.1 Check the indenter

Be sure to have replaced the indenter with Φ2.5mm or Φ5mm ball indenter.

5.5.2 Increase the tightening force

Due to the biggest test force for Rockwell hardness testers is 150kgf, and for Brinell hardness testers it is 187.5kg, so when using the C–shape or Chain Clamp Brinell & Rockwell hardness testers to test Brinell scales, if with the 2.5mm ball indenter and applying 187.5kg test force, press the test head onto the test piece with the force over 250kg, otherwise, the result is invalid.

5.5.3 Apply the test force

The value in red on the indicator dial shows the test force of Rockwell hardness tester. Turn the hand wheel and apply the test force. Look at the pointer on the dial and bring it to the desired marked force according to section 4.3. Be sure that the pointer rests on the exact scale mark of the test force. If not, the test should be considered as failure and a retest should be made in a new position.

5.5.4 Maintain the test force

The test force should be maintained for some time as stated, for instance, 10–15 seconds in steels testing and 30 seconds in nonferrous metals testing.

5.5.5 Unload the test force

Turn the hand wheel in a reverse direction to unload the test force.

5.5.6 Withdraw the indenter

For C–shape, chain clamp or magnetic type hardness testers, keep on turning the hand wheel in a reverse direction to bring the pin of the rotational drum dial to the red dot of the magnifier, or move the rotational drum dial upward until the red point on the fixed drum dialis shown out.

5.5.7 Remove the tester

Remove the tester from the test piece or remove the test piece.

5.5.8 Measure the indentation diameter

Measure the indentation diameter with the 40x reading microscope equipped for the tester. Get the two mutually vertical indentation diameters and take the average value. The reading should be accurate to 0.01mm.

5.5.9 Look up table and read hardness values

Look up Appendix G and read the hardness values.

5.6 Usage Method of the reading microscope

5.6.1 Look into the ocular and turn the rotational barrel dial to make the vertical lens line aligned with the "0" scale of the horizontal line, Meanwhile look at the barrel outside, the long black scale mark should rest on "0" scale of the rotational drum dial

5.6.2 Put the reading microscope on the test piece to locate the indentation in the centre of the viewing field of the microscope. Move the microscope to make the vertical line tangential to the left edge of the indentation. Press the bottom of the reading microscope firmly, turn the rotational drum dial and make the vertical line tangential to the right edge of the indentation.

5.6.3 Read the integer part (mm) of the indentation diameter from the horizontal scale mark, then read the 2–digit decimal part of the indentation diameter from the rotational drum, accurate to 0.01mm.

5.6.4 In routine use, when you look into the ocular, let the vertical line is aligned with the "0" scale mark of the horizontal line, but in the outside barrel if the "0" scale mark of the rotational drum dial does not align with the long black scale mark, it means the microscope is inaccurate. Adjustment should be made as follow:

a. Make the vertical lens line aligned with the "0" scale mark of the horizontal line.
b. Loosen the three screws on the rotational drum dial.
c. Make the "0" scale mark on rotational drum dial exactly aligned with the long reading mark.
d. Fasten the three screws.

6. Inspection of Hardness Testers

Daily inspection and regular inspection should be made to the hardness tester with the standardized hardness blocks.

6.1 Verification of Rockwell / superficial Rockwell hardness tester

6.1.1 Daily Inspection

If the tester is used every day, it should be inspected daily; otherwise, it should be inspected every time before using. Daily inspection could be applied to only one scale to be used with one standardized hardness block. Choose the standardized hardness block with its hardness most close to the hardness value of the test piece. When the daily inspection is carried out, test 5 times on the hardness block, neglect the first 2 data and take the average of the rest 3 data. The difference

between the average value and the standardized hardness block value should comply with Appendix B.

6.1.2 Regular Inspection

A periodic inspection should be made to this device in no more than 6 months at most. Regular inspections should be applied to each scale which could be used and the standard hardness blocks to be used in the inspection should have as many specifications as possible.

Only the front face could be used when testing the hardness blocks. After 2 times of "pretest", on the 5 evenly–distributed dots measure the hardness values H_1, H_2, H_3, H_4, H_5 arranged in the increasing order by size.

Note: "H"is the hardness value of the standardized hardness block.

Mean Hardness: $$\overline{H} = \frac{H_1 + H_2 + H_3 + H_4 + H_5}{5} \quad \cdots\cdots\cdots\cdots (5)$$

Repeatability: $$H_5 - H_1 \quad \cdots\cdots\cdots\cdots (6)$$

Error: $$\overline{H} - H \quad \cdots\cdots\cdots\cdots (7)$$

The repeatability and error of the hardness tester should meet with the requirements of Appendix B.

6.2 Inspection of Brinell Hardness Tester

6.2.1 Daily Inspection

The tester in use should be inspected once per day. The tester not used frequently should be inspected every time before using. During the inspection, carry out 2 times of pretest before begin the formal test.

Standardized hardness block should be used in the daily inspection and its hardness value should be close to that of the test piece. The difference between the test value and the hardness value of the hardness block should accord with Appendix H.

6.2.2 Regular Inspection

A periodic inspection should be made to this device in no more than 6 months at most. Regular inspections should use two hardness blocks within the high, middle and low scopes. After 2 times of "pretest", on the 5 evenly–distributed dots make the indentations by pressing. The average diameters of the indentations d_1, d_2, d_3, d_4, d_5 are arranged in the increasing order by size.

Repeatability of the Brinell hardness tester is determined by:

$$d_5 - d_1 \quad \cdots\cdots\cdots\cdots (8)$$

Error is determined by:

$$\overline{H} - H \quad \cdots\cdots\cdots\cdots (9)$$

Note: "$\overline{H}$" is the mean hardness value of the 5 indentations:

$$\overline{H} = \frac{H_1 + H_2 + H_3 + H_4 + H_5}{5} \quad \cdots\cdots\cdots\cdots (10)$$

Note: H is the hardness value of the standardized hardness block.
Repeatability and error of Brinell hardness tester should conform to Appendix H.]

6.3 Cautions

Use the flat anvil when calibrating the hardness blocks for small, C–shape and chain clamp hardness testers; and use the special hardness block of diameter 50mm for the magnetic type hardness testers.

7. Cautions in Use

7.1 For Rockwell hardness testers, except under normal testing, in any case the diamond indenters should not be pressed against the anvil, extension and test piece. Otherwise, it can be damaged.

7.2 Indentations should not appear on the bearing surface of the hardness block or work surface of the anvil.

7.3 During the test the direction of testing force must be vertical to the test piece testing surface, and when applying test force the test piece should not move or slide on the anvil.

7.4 The process of applying force should be slow at even pace. The dial pointer should rise smoothly. If the pointer is found to be uncontrollably dithering or sliding down, the following reasons may explain and relevant measures should be taken:

a. improper selection of the anvil
b. the supporting of the test piece is not stable

8. Factors Affecting Testing Accuracy

8.1 Surface of test pieces

The surface of the test piece should be smooth and flat without oxide coating, without decarburized layer or dirt. The rough surface of the test piece will cause the testing value to go on the low side and will increase the data dispersion.

For forgings and castings without smooth surfaces, the surface of the test piece should be burnished smooth by the portable grinding machine.

8.2 Thickness of test pieces

The test piece should be thick enough, otherwise the hardened and deformed area at the bottom of the indentation will be diffused to the interface with the anvil and the surface will be deformed which will result in accurate testing results. According to ISO6508, different scales or testing conditions should be applied to the test pieces with different thickness; after testing, the back side of the test piece should not be seen with naked eyes any trace of deformation. during Rockwell hardness testing, when the diamond indenter is used, the thickness of the test piece should not be smaller than 10 times the remnant indentation depth, for a steel ball indenter, it should be no less than 15 times; during the Brinell hardness testing, the thickness of the test piece should not be smaller than 8 times the indentation depth. The relationship between the minimum thickness of the test piece and Rockwell hardness specified in ISO6508 refers to Appendix E.

Refer to Appendix X for reference of the minimum test piece thickness in Brinell hardness testing.

8.3 Test piece with curved surface

There will be a deviation in the hardness value obtained from the curved–surface test piece compared with that of the flat–surface test piece. Therefore, the test result should be added or subtracted by a correction value. A correction value should be added when the test is made on the convex cylindrical surface, while a correction value should be subtracted when the test is made on the concave cylindrical surface. Refer to Appendix F.

8.4 Test piece position

When choosing the anvil and placing the test piece, ensure that the test surface is vertical to the indenter axis. Avoid any displacement of the test piece, partial elastic deformation and tilted force direction.

For the flat–surface test piece, in order to ensure applying the force vertically, there must be a certain parallelism between the bearing surface and the test surface. Otherwise, it will affect the test result, especially for HRC.

Flat anvil should be used for warped plates. Its convex surface should lean against the anvil in order to avoid suspending bearing surface of the testing point which otherwise will result in the elastic deformation under the test force.

For tubing test pieces, proper anvils should be chosen as per the diameter and wall thickness of the tubing to avoid the moving and elastic deformation of the test piece. Thin–wall tubing materials may be affected by the elastic deformation, which may result in errors caused by incorrect indentation depth during the test.

During Brinell hardness testing, a little elastic deformation of the test piece is permitted.

8.5 Invalidation of hardness blocks

The hardness block can only be used on its front surface. Infinite times of testing on the blocks are impossible, when the surface is full of indentations, a new block should be replaced. If the block is rusty and the test result is inaccurate, a new block should also be replaced.

Different devices are equipped with different hardness blocks. Superficial Rockwell hardness testers are equipped with HRN, HRT superficial Rockwell hardness blocks, Rockwell hardness testers with HRA, HRB, HRC Rockwell hardness blocks, and Brinell hardness testers with HBW 2.5/187.5 hardness blocks. The blocks should not be shared in common, otherwise the testing is invalid.

8.6 Incorrectly applying force

During the test, applying force should be slow and even to bring the indicator hand aligned exactly with relevant scale marks. The accuracy will be affected by both not–reaching–up or beyond the scale marks.

Different test force should be applied to different testing conditions and different scales. The test force of Rockwell hardness is marked in black, and that of Brinell hardness tester is in red. The testing will be invalid if the wrong test force is chosen.

8.7 Incorrect Reading

During the Rockwell, superficial Rockwell hardness testing, when operating the instrument, the visual angle of the operator should be maintained unchanged. The position of reading should be consistent to that of the barrel dial adjustment. Otherwise it will cause error reading.

The indentation diameter of Brinell hardness should be accurate to 0.01mm. Error of each 0.01mm will cause an error of a few HBWs.

8.8 Damage of Indenter

The indenter can be damaged by wearing, impact or testing very hard materials. When the tester has been used for a long time or its accuracy is going down, the indenter should be inspected with an 8-10x magnifier. When the diamond indenter has some cracks, cicatrices or defects and the ball indenter has been deformed, it should be replaced with a new one.

9. Maintenance

This tester is a precision instrument, the service life of which depends on correct usage and timely maintenance. This tester can be used for 20 years under proper maintenance and inspection conditions. Users should read carefully this instruction manual, master the inspection rules and operating methods after receive it. The tester should be inspected correctly, handled carefully, stored properly and used by a special person. It should be put in the carrying case after used.

Pay special attention to the following points:

9.1 Anti-rust

Though all the parts of this instrument have been treated anti-rust, some parts still can be rusted by improper storage or maintenance, especially in the coastal areas.

The instrument has been fully lubricated before leaving the factory, so no lubricating should be made in use. It should be often wiped with a piece of soft cloth. Be careful to keep the anvil, indenter, extension and the hardness block dry and clean.The testing surface of the hardness block is not allowed to touch by hand.

9.2 Avoid falling off

This instrument is made up of many precision components, impact or falling off of it will result in the permanent damage to some parts, even worse the instrument can be discarded as useless. The magnifier of this instrument is made of synthetic glass, and it can be broken by impact. Disassemble and store the magnifier separately during transportation to protect it. The force indicator should be protected from impact in use and during transportation as an important part of the tester. For the instrument with opening size of 1 inch, move away the hardness block which is nearest to the force indicator during transportation.

9.3 Disassembly forbidden

The testing accuracy of this instrument is guaranteed by the good collaboration of some of the precision parts. This collaboration is not easy for the nonprofessional people to master. Consequently, disassembly of the parts is not allowed except for parts, such as the indenter, anvil and the extension, otherwise this will result in inaccurate instrument or

some parts damaged, and the warranty will be void.

10. Standard package

Below is the list of standard package for Rockwell/ superficial Rockwell hardness testers:

1 Tester
1 Bench stand (small)
1 Diamond indenter
1 Ball indenter (Φ 1.588mm)
3 Rockwell hardness blocks
1 Flat anvil (small, large and chain clamp)
1 V anvil (small, large and chain clamp)
1-2 Extensions (small)
1 Wrench (chain clamp)
1 Spare magnifier (large, chain clamp)
1 Carrying case

List of standard package for Brinell & Rockwell hardness testers, see below:

1 Tester
1 Bench stand (small)
1 Diamond indenter
1 Ball indenter (Φ 1.588mm)
1 Ball indenter (Φ 2.5mm)
3 Rockwell hardness blocks
1 Brinell hardness block
1 Reading microscope (40x)
1 Flat anvil (small, large and chain clamp)
1 V anvil (small, large and chain clamp)
1-2 Extensions (small)
1 Wrench (chain clamp)
1 Spare magnifier (large, chain clamp)
4 V adapters (magnetic type)
1 Carrying case

11. Optional

Rockwell standard hardness block:	HRC (high), HRC (medium), HRC (low),HRA, HRB, HR15T, HR30T, HR45T, HR15N,HR30N, HR45N
Brinell standard hardness block:	HBW (high), HBW (medium), HBW (low)
Diamond indenter:	120° cone
Tungsten carbide ball indenter:	Φ 1.588mm, Φ 2.5mm, Φ 3.175mm, Φ 5mm
Steel ball indenter:	Φ 1.588mm, Φ 6.35mm, Φ 12.7mm
Flat anvil:	1/2", 1"
V anvil:	1/4", 1/2", 1", 1-1/2"
Concave cylindrical anvil:	1/2", 3/4", 1"
Convex cylindrical anvil:	1/2", 3/4", 1"
Raised spot anvil:	1/2", 1"
Thin raised spot anvil:	Φ 1.5 x 11mm, Φ 2.0 x 11mm, Φ 2.5 x 11mm
Anvil for testing ball:	1/2", 1", 1-1/3"
Diamond raised spot anvil:	(sheet metal such as tinplate)
Spare magnifier:	(small, large and chain clamp)
Reading microscope:	40 times(Brinell & Rockwell)
Adapters for tubular specimens:	(Magnetic Type)

Appendix A: Technical Conditions for Rockwell, Superficial Rockwell Hardness Scales

Rockwell Hardness Scales / Initial Test Force ：10kg（98.07N）

Rockwell Hardness Scale	Hardness Symbol	Indenter Type	Total Test Force kg(N)	Applicable Range
A	HRA	Diamond cone	60kg（588.4N）	20～88HRA
B	HRB	Steel ball Φ1.588mm	100kg（980.7N）	20～100HRB
C	HRC	Diamond cone	150kg（1471N）	20～70HRC
D	HRD	Diamond cone	100kg（980.7N）	40～77HRD
E	HRE	Steel ball Φ3.175mm	100kg（980.7N）	70～100HRE
F	HRF	Steel ball Φ1.588mm	60kg（588.4N）	60～100HRF
G	HRG	Steel ball Φ1.588mm	150kg（1471N）	30～94HRG
H	HRH	Steel ball Φ3.175mm	60kg（588.4N）	80～100HRH
K	HRK	Steel ball Φ3.175mm	150kg（1471N）	40～100HRK

In accordance with International Standard: ISO6508-1999 Note: 9.8N=1kg

Superficial Rockwell Hardness Scales / Initial Test Force ：3kg（29.4N）

Superficial Rockwell Hardness Scales	Hardness Symbol	Indenter Type	Total Test Force kg(N)	Applicable Range
15N	HR15N	Diamond cone	15kg（147.1）	70～94HR15N
30N	HR30N		30kg（294.2）	42～86HR30N
45N	HR45N		45kg（441.3）	20～77HR45N
15T	HR15T	Steel ball Φ1.588mm	15kg（147.1）	67～93HR15T
30T	HR30T		30kg（294.2）	29～82HR30T
45T	HR45T		45kg（441.3）	10～72HR45T

In accordance with International Standard: ISO6508-1999 Note: 9.8N=1kg

Appendix B: Allowable Error and Repeatability of Rockwell Hardness Tester

Rockwell Hardness Scale	Hardness Range of Standard Block	Allowable Error for Rockwell Hardness Unit	Allowable Repeatability
A	20HRA～≤75HRA >75HRA～≤88HRA	±2HRA ±1.5HRA	≤0.02（100－$\overline{H}$）or 0.8 Rockwell unit [b]
B	20HRB～≤45HRB >45HRB～≤80HRB >80HRB～≤100HRB	±4HRB ±3HRB ±2HRB	≤0.04（130－$\overline{H}$）or 1.2 Rockwell unit [b]
C	20HRC～≤70HRC	±1.5HRC	≤0.02（100－$\overline{H}$）or 0.8 Rockwell unit [b]
D	40HRD～≤70HRD >70HRD～≤77HRD	±2HRD ±1.5HRD	≤0.02（100－$\overline{H}$）or 0.8 Rockwell unit [b]
E	70HRE～≤90HRE >90HRE～≤100HRE	±2.5HRE ±2HRE	≤0.04（130－$\overline{H}$）or 1.2 Rockwell unit [b]
F	60HRF～≤90HRF >90HRF～≤100HRF	±3HRF ±2HRF	≤0.04（130－$\overline{H}$）or 1.2 Rockwell unit [b]
G	30HRG～≤50HRG >50HRG～≤75HRG >75HRG～≤94HRG	±6HRG ±4.5HRG ±3HRG	≤0.04（130－$\overline{H}$）or 1.2 Rockwell unit [b]
H	80HRH～≤100HRH	±2HRH	≤0.04（130－$\overline{H}$）or 1.2 Rockwell unit [b]
K	40HRK～≤60HRK >60HRK～≤80HRK >80HRK～≤100HRK	±4HRK ±3HRK ±2HRK	≤0.04（130－$\overline{H}$）or 1.2 Rockwell unit [b]
N		±2HRN	≤0.04（100－$\overline{H}$）or 1.2 Rockwell unit [b]
T		±3HRT	≤0.06（100－$\overline{H}$）or 2.4 Rockwell unit [b]

a: "$\overline{H}$" is the average hardness value. b: The greater value is valid.

In accordance with International Standard: ISO6508-1999

Appendix C: Models and Dimensions

Series	Name	Model	Opening Size/W × D Specimen Dimensions /mm	weight /kg
Regular	Rockwell hardness tester	HR-1	25×25	0.8
		HR-2	50×50	1.2
		HR-4-2	100×50	1.6
		HR-4-4	100×100	2.5
	Superficial Rockwell hardness tester	HR-1S	25×25	0.8
		HR-2S	50×50	1.1
		HR-4-2S	100×50	1.5
	Superficial Rockwell hardness tester for pipes	HR-1ST	25×25	0.8
	Brinell & Rockwell hardness tester	HBR-2	50×50	1.2
		HBR-4-2	100×50	1.6
Large	Large Rockwell hardness tester	HR-8-4	200×100	4.0
		HR-8-10	200×250	5.5
		HR-20-10	500×300	7.8
	Large Brinell & Rockwell hardness tester	HBR-8-4	200×100	4.0
		HBR-8-10	200×250	5.5
		HBR-20-12	500×300	7.8
Chain clamp	Chain clamp Rockwell hardness tester	HR-16	200-450（diameter）	4.8
		HR-32	400-850（diameter）	6.8
		HR-64	800-1600（diameter）	11.5
	Chain clamp Brinell & Rockwell hardness tester	HBR-16	200-450（diameter）	4.8
		HBR-32	400-850（diameter）	6.8
		HBR-64	800-1600（diameter）	11.5
Magnetic Type	Rockwell	HR-100	>60mm×180mm >Φ 100mm	4.7
	Brinell & Rockwell	HBR-100		

Description: the first digit in model numbers denotes the opening width of the instrument (in inch), the second one indicates the opening depth (in inch), “S” represents superficial Rockwell hardness testers, and “ST” means the superficial Rockwell hardness testers for pipes. The number in the model number of chain clamp hardness testers indicates the maximum diameter of the specimen (in inch). The digits in the model number of magnetic type hardness testers implicate that the specimen size can be infinity.

Appendix D: Rockwell Hardness Scale Selection（according to sort of materials and thickness）

Specimen Materials	Scale	Indenter	Test Force (kg)	Barrel Dial Scale
High hardness or thin hard materials such as tungsten carbides, thin hard steel slice and High hardness or thin hard materials such as	HRA	Diamond cone	60	C
Materials of medium and low hardness such as annealed mild steel, stainless steel, copperalloy, super-hard aluminum alloy, forgeable cast iron etc., a kind of widely-applied Rockwell hardness scale	HRB	Steel ball Φ1.588mm	100	B
Quenched and low temperature tempered ordinary steels, cold and hard cast iron, pearlitic forgeable cast iron, titanium alloy, thick-layer carburized steel and the materials with hardness > HRB 100, a kind of widely-used Rockwell hardness scale	HRC	Diamond cone	150	C
Medium surface hardening steel, thin hard steel slice, pearlitic forgeable cast iron	HRD	Diamond cone	100	C
Cast iron, aluminum alloy, magnesium alloy, bearing alloy	HRE	Steel ball Φ 3.175mm	100	B
Annealed brass, red copper, aluminum alloy, thin soft steel sheets	HRF	Steel ball Φ1.588mm	60	B
Materials with HRB value close to 100 such as berylium bronze, phosphorbronze, forgeable cast iron etc.	HRG	Steel ball Φ1.588mm	150	B
Soft steels such as aluminum zinc, lead, tin etc.	HRH	Steel ball Φ 3.175mm	60	B
Soft sheet metal, bearing alloy	HRK	Steel ball Φ 3.175mm	150	B
The shallow surface hardening steel pieces such as carbruized steel, nitrided steel etc. which cannot be tested by regular Rockwell hardness testers easily, small parts, hard steel slice of the thin thickness up to 0.15 mm and work pieces of high hardness requiring indentations as small as possible	HR15N	Diamond cone	15	N－T
	HR30N	Diamond cone	30	N－T
	HR45N	Diamond cone	45	N－T
Mild steel, stainless steel, copper alloy, thin sheet and strap of aluminum alloy, thin-wall tubing, small parts and work pieces of medium, low hardness requiring indentations as small as possible	HR15T	Steel ball Φ1.588mm	15	N－T
	HR30T	Steel ball Φ1.588mm	30	N－T
	HR45T	Steel ball Φ1.588mm	45	N－T

Notes: Scale N is used for the similar materials as tested by Rockwell hardness scales C, A and D, applicable to test the thin and small specimens and those with shallow hardening depth.
Scale T is used for the similar materials as tested by Rockwell hardness scales B, F and G, applicable to test the thin and small specimens of softer metals.

Appendix E: Selection of Rockwell Hardness Scales（according to thickness and hardness of specimens）

For any given thickness value in the table, the corresponding Rockwell hardness value is the minimum acceptable measured value; for any given hardness value in the table, any test piece with its thickness greater than its corresponding minimum thickness can be tested on the specified scale.

Table 1 Minimum Thickness Value of Specimens （Scale A and C）

Minimum Specimen Thickness		Rockwell Scale		
		HRA		HRC
inch	mm	Dial reading	Approximate hardness，Scale C[a]	Dial reading
0.014	0.36	-	-	-
0.016	0.41	86	69	-
0.018	0.46	84	65	-
0.020	0.51	82	61.5	-
0.022	0.56	79	56	69
0.024	0.61	76	50	67
0.026	0.66	71	41	65
0.028	0.71	67	32	62
0.030	0.76	60	19	57
0.032	0.81	-	-	52
0.034	0.86	-	-	45
0.036	0.91	-	-	37
0.038	0.96	-	-	28
0.040	1.02	-	-	20

a – the approximate hardness value in the table is only used for selecting the proper scale, can not be used for hardness conversion, if needed, refer to ASTM E140 The Conversion Table for Standard Metal hardness.

Table 2 Minimum Thickness Value of Specimen （Scale B, F）

Minimum Specimen Thickness		Rockwell Scale		
		HRF		HRB
inch	mm	Dial reading	Approximate hardness，Scale B[a]	Dial reading
0.022	0.56	-	-	-
0.024	0.61	98	72	94
0.026	0.66	91	60	87
0.028	0.71	85	49	80
0.030	0.76	77	35	71
0.032	0.81	69	21	62
0.034	0.86	-	-	52
0.036	0.91	-	-	40
0.038	0.96	-	-	28
0.040	1.02	-	-	-

a – the approximate hardness value in the table is only used for selecting the proper scale, can not be used for hardness conversion, if needed, refer to ASTM E140 The Conversion Table for Standard Metal hardness.

Table 3 Minimum Thickness Value of Specimen（Scale N）

Minimum Specimen Thickness		Superficial Rockwell Scale					
		HR15N		HR30N		HR45N	
inch	mm	Dial reading	Approximate hardness Scale C[a]	Dial reading	Approximate hardness Scale C[a]	Dial reading	Approximate hardness Scale C[a]
0.006	0.15	92	65	-	-	-	-
0.008	0.20	90	60	-	-	-	-
0.010	0.25	88	55	-	-	-	-
0.012	0.30	83	45	82	65	77	69.5
0.014	0.35	76	32	78.5	61	74	67
0.016	0.41	68	18	74	56	72	65
0.018	0.46	-	-	66	47	68	61
0.020	0.51	-	-	57	37	63	57
0.022	0.56	-	-	47	26	58	52.5
0.024	0.61	-	-	-	-	51	47
0.026	0.66	-	-	-	-	37	35
0.028	0.71	-	-	-	-	20	20.5
0.030	0.76	-	-	-	-	-	-

a – the approximate hardness value in the table is only used for selecting the proper scale, can not be used for hardness conversion, if needed, refer to ASTM E140 The Conversion Table for Standard Metal hardness.

Table 4 Minimum Thickness Value of Specimen （Scale T）

Minimum Specimen Thickness		Superficial Rockwell Scale					
		HR15T		HR30T		HR45T	
inch	mm	Dial reading	Approximate hardness Scale B[a]	Dial reading	Approximate hardness Scale B[a]	Dial reading	Approximate hardness Scale B[a]
0.010	0.25	91	93	-	-	-	-
0.012	0.30	86	78	-	-	-	-
0.014	0.35	81	62	79	96	-	-
0.016	0.41	75	44	73	74	71	99
0.018	0.46	68	24	64	71	62	90
0.020	0.51	-	-	55	58	53	80
0.022	0.56	-	-	45	43	43	70
0.024	0.61	-	-	34	28	31	58
0.026	0.66	-	-	-	-	18	45
0.028	0.71	-	-	-	-	4	32
0.030	0.76	-	-	-	-	-	-

a — the approximate hardness value in the table is only used for selecting the proper scale, can not be used for hardness conversion, if needed, refer to ASTM E140 The Conversion Table for Standard Metal hardness.

Appendix F: Correction Chart of Rockwell Hardness for Convex Cylindrical Specimens

Table 1 Rockwell Hardness Correction Value （Scale A, C, D）

Rockwell Hardness Reading	Radius of Curved Surface (mm)								
	3	5	6.5	8	9.5	11	12.5	16	19
20				2.5	2	1.5	1.5	1	1
25			3	2.5	2	1.5	1	1	1
30			2.5	2	1.5	1.5	1	1	
35		3	2	1.5	1.5	1	1	0.5	0.5
40		2.5	2	1.5	1	1	1	0.5	0.5
45	3	2	1.5	1	1	1	0.5	0.5	0.5
50	2.5	2	1.5	1	1	0.5	0.5	0.5	0.5
55	2	1.5	1	1	0.5	0.5	0.5	0.5	0.5
60	1.5	1	1	0.5	0.5	0.5	0.5	0	0
65	1.5	1	1	0.5	0.5	0.5	0.5	0	0
70	1	1	0.5	0.5	0.5	0.5	0.5	0	0
75	1	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
Note: the error of correction value > 3HR is too big to be specified in this table.									

Table 2 Rockwell Hardness Correction Value （Scale B, F, G）

Rockwell Hardness Reading	Radius of Curved Surface (mm)						
	3	5	6.5	8	9.5	11	12.5
20				4.5	4	3.5	3
30			5	4.5	3.5	3	2.5
40			4.5	4	3	2.5	2.5
50			4	3.5	3	2.5	2
60		5	3.5	3	2.5	2	2
70		4	3	2.5	2	2	1.5
80	5	3.5	2.5	2	1.5	1.5	1.5
90	4	3	2	1.5	1.5	1.5	1
100	3.5	2.5	1.5	1.5	1	1	0.5
Note: the error of correction value >5HR is too big to be specified in this table.							

In accordance with International Standard ISO6508-1999

Table 3 Correction Value of Superficial Rockwell Hardness (Scale N)[a, b]

Superficial Rockwell Hardness Reading	Radius of Curved Surface[c]/mm					
	1.6	3.2	5	6.5	9.5	12.5
20	(6)[d]	3	2	1.5	1.5	1.5
25	(5.5)[d]	3	2	1.5	1.5	1
30	(5.5)[d]	3	2	1.5	1	1
35	(5)[d]	2.5	2	1.5	1	1
40	(4.5)[d]	2.5	1.5	1.5	1	1
45	(4)[d]	2	1.5	1	1	1
50	(3.5)[d]	2	1.5	1	1	1
55	(3.5)[d]	2	1.5	1	0.5	0.5
60	3	1.5	1	1	0.5	0.5
65	2.5	1.5	1	0.5	0.5	0.5
70	2	1	1	0.5	0.5	0.5
75	1.5	1	0.5	0.5	0.5	0
80	1	0.5	0.5	0.5	0	0
85	0.5	0.5	0.5	0.5	0	0
90	0	0	0	0	0	0

a – The correction value is an approximate value, which represents the real measured average value obtained from test of curved surface specified in this table, and it is accurate to 0.5 unit of superficial Rockwell hardness.

b – The test result on the cylindrical surface is affected by such integrated factors as the coaxiality of the main shaft, V-anvil and the indenter, surface roughness of the specimen and curvature of the cylindrical surface.

c – The correction values of the other radiuses in this table can be calculated by linear difference method.

d – The correction value in brackets should be used only after discussion.

Table 4 Correction Value of Superficial Rockwell Hardness（Scale T）[a, b]

Superficial Rockwell Hardness Reading	Radius of Curved Surface[c]/mm						
	1.6	3.2	5	6.5	8	9.5	12.5
20	(13)[d]	(9)[d]	(6)[d]	(4.5)[d]	(3.5)[d]	3	2
30	(11.5)[d]	(7.5)[d]	(5)[d]	(4)[d]	(3.5)[d]	2.5	2
40	(10)[d]	(6.5)[d]	(4.5)[d]	(3.5)[d]	3	2.5	2
50	(8.5)[d]	(5.5)[d]	(4)[d]	3	2.5	2	1.5
60	(6.5)[d]	(4.5)[d]	3	2.5	2	1.5	1.5
70	(5)[d]	(3.5)[d]	2.5	2	1.5	1	1
80	3	2	1.5	1.5	1	1	0.5
90	1.5	1	1	0.5	0.5	0.5	0.5

a – The correction value is an approximate value, which represents the real measured average value obtained from test of curved surface specified in this table, and it is accurate to 0.5 unit of superficial Rockwell hardness.
b – The test result on the cylindrical surface is affected by such integrated factors as the coaxiality of the main shaft, V-anvil and the indenter, surface roughness of the specimen and curvature of the cylindrical surface.
c – The correction values of the other radiuses in this table can be calculated by linear difference method.
d – The correction value in brackets should be used only after discussion.

In accordance with International Standard ISO6508-1999

Appendix G: Brinell Hardness Table

Ball Diameter D/mm		$0.102F/D^2$			
		30	10	5	2.5
		Test Force F/kgf(N)			
5	2.5	187.5 (1839 N)	62.5 (612.9 N)	125 (1226 N)	62.5 (612.9 N)
Indentation Diameter d/mm		Brinell Hardness (HBW)			
1.20	0.60	653	218	109	54.5
1.22	0.61	632	211	105	52.7
1.24	0.62	611	204	102	50.9
1.26	0.63	592	197	98.6	49.3
1.28	0.64	573	191	95.5	47.8
1.30	0.65	555	185	92.6	46.3
1.32	0.66	538	179	89.7	44.9
1.34	0.67	522	174	87.0	43.5
1.36	0.68	507	169	84.4	42.2
1.38	0.69	492	164	81.9	41.0
1.40	0.70	477	159	79.6	39.8
1.42	0.71	464	155	77.3	38.7
1.44	0.72	451	150	75.1	37.6
1.46	0.73	438	146	73.0	36.5
1.48	0.74	426	142	71.0	35.5
1.50	0.75	415	138	69.1	34.6
1.52	0.76	404	135	67.3	33.6
1.54	0.77	393	131	65.5	32.7
1.56	0.78	383	128	63.8	31.9
1.58	0.79	373	124	62.1	31.1
1.60	0.80	363	121	60.5	30.3
1.62	0.81	354	118	59.0	29.5
1.64	0.82	345	115	57.5	28.8
1.66	0.83	337	112	56.1	28.1
1.68	0.84	329	110	54.8	27.4
1.70	0.85	321	107	53.4	26.7
1.72	0.86	313	104	52.2	26.1
1.74	0.87	306	102	50.9	25.5
1.76	0.88	298	99.5	49.7	24.9

Ball Diameter D/mm		$0.102F/D^2$			
		30	10	5	2.5
		Test Force F/kgf(N)			
5	2.5	187.5(1839N)	62.5(612.9N)	125(1226N)	62.5(612.9N)
Indentation Diameter d/mm		Brinell Hardness (HBW)			
1.78	0.89	292	97.2	48.6	24.3
1.80	0.90	285	95.0	47.5	23.7
1.82	0.91	278	92.8	46.4	23.2
1.84	0.92	272	90.7	45.4	22.7
1.86	0.93	266	88.7	44.4	22.2
1.88	0.94	260	86.8	43.4	21.7
1.90	0.95	255	84.9	42.4	21.2
1.92	0.96	249	83.0	41.5	20.8
1.94	0.97	244	81.3	40.6	20.3
1.96	0.98	239	79.5	39.8	19.9
1.98	0.99	234	77.9	38.9	19.5
2.00	1.00	229	76.3	38.1	19.1
2.02	1.01	224	74.7	37.3	18.7
2.04	1.02	219	73.2	36.6	18.3
2.06	1.03	215	71.7	35.8	17.9
2.08	1.04	211	70.2	35.1	17.6
2.10	1.05	207	68.8	34.4	17.2
2.12	1.06	202	67.5	33.7	16.9
2.14	1.07	198	66.2	33.1	16.5
2.16	1.08	195	64.9	32.4	16.2
2.18	1.09	191	63.6	31.8	15.9
2.20	1.10	187	62.4	31.2	15.6
2.22	1.11	184	61.2	30.6	15.3
2.24	1.12	180	60.1	30.0	15.0
2.26	1.13	177	59.0	29.5	14.7
2.28	1.14	174	57.9	28.9	14.5
2.30	1.15	170	56.8	28.4	14.2
2.32	1.16	167	55.8	27.9	13.9
2.34	1.17	164	54.8	27.4	13.7
2.36	1.18	161	53.8	26.9	13.4
2.38	1.19	158	52.8	26.4	13.2

Ball Diameter D/mm		$0.102F/D^2$			
		30	10	5	2.5
		Test Force F/kgf(N)			
5	2.5	187.5 (1839 N)	62.5 (612.9 N)	125 (1226 N)	62.5 (612.9 N)
Indentation Diameter d/mm		Brinell Hardness (HBW)			
2.40	1.20	156	51.9	25.9	13.0
2.42	1.21	153	51.0	25.5	12.7
2.44	1.22	150	50.1	25.0	12.5
2.46	1.23	148	49.2	24.6	12.3
2.48	1.24	145	48.3	24.2	12.1
2.50	1.25	143	47.5	23.8	11.9
2.52	1.26	140	46.7	23.4	11.7
2.54	1.27	138	45.9	23.0	11.5
2.56	1.28	135	45.1	22.6	11.3
2.58	1.29	133	44.4	22.2	11.1
2.60	1.30	131	43.7	21.8	10.9
2.62	1.31	129	42.9	21.5	10.7
2.64	1.32	127	42.2	21.1	10.6
2.66	1.33	125	41.5	20.8	10.4
2.68	1.34	123	40.9	20.4	10.2
2.70	1.35	121	40.2	20.1	10.1
2.72	1.36	119	39.6	19.8	9.89
2.74	1.37	117	38.9	19.5	9.73
2.76	1.38	115	38.3	19.2	9.58
2.78	1.39	113	37.7	18.9	9.43
2.80	1.40	111	37.1	18.6	9.28
2.82	1.41	110	36.5	18.3	9.14
2.84	1.42	108	36.0	18.0	8.99
2.86	1.43	106	35.4	17.7	8.85
2.88	1.44	105	34.9	17.4	8.72
2.90	1.45	103	34.3	17.2	8.59
2.92	1.46	101	33.8	16.9	8.45
2.94	1.47	99.9	33.3	16.7	8.33
2.96	1.48	98.4	32.8	16.4	8.20
2.98	1.49	96.9	32.3	16.2	8.08
3.00	1.50	95.5	31.8	15.9	7.96

Source: International Standard ISO6508-1999

Appendix H: Repeatability and Error of Brinell Hardness Testers

Hardness value of Standard Block (HBW)	Allowable Max. Repeatability of Hardr Testers (mm)	Allowable Max. Error of Hardness Testers / % (relative to H)
≤125	0.030 $\bar{d}$	±3
125 <HBW≤225	0.025 $\bar{d}$	±2.5
>225	0.020 $\bar{d}$	±2
$\bar{d}$ – mean diameter of indentations		

In accordance with International Standard ISO6508-1999

Appendix I: Testing Conditions of Brinell Hardness

Hardness Symbol	Ball Diameter D/mm	Test Force F/kg	$0.102F/D^2$
HBW 2.5/187.5	2.5	187.5	30
HBW 2.5/62.5	2.5	62.5	10
HBW 5/125	5	125	5
HBW 5/62.5	5	62.5	2.5

Note: The hardness symbol HBW 2.5/187.5 denotes using a carbide ball indenter with 2.5mm diameter and applying 187.5kg test force.

Appendix J: Selection of Testing Conditions for Brinell Hardness Testers

Material	Hardness (HBW)	Ball Diameter D/mm	Test Force F/kg	$0.102F/D^2$
Steel		2.5	187.5	30
Cast Iron	≥140 < 140	2.5	187.5 62.5	30 10
Bronze	> 200	2.5	187.5	30
Brass, red copper, aluminum alloy	80-200	2.5	62.5	10
Red copper, aluminum alloy aluminum	35-80	5	125	5
aluminum	< 35	5	62.5	2.5

In accordance with International Standard ISO6508-1999

Appendix K: Minimum Thickness of Specimens for Brinell Hardness Testing

Indenter D/mm	Test Force F/kg	F/D^2	Brinell Hardness (HBW)								
			40	60	80	100	150	200	300	400	500
			Minimum Thickness of Specimens (mm)								
2.5	187.5	30	—	—	—	2.40	1.60	1.20	0.80	0.60	0.48
5	125	5	2.0	1.3	1.0	0.8	0.53	—	—	—	—

Appendix L: Conversion of Brinell Hardness and Tensile Strength

Material	Brinell Hardness (HBW)	Tensile Strength (MN/m^2)
Steel	>175 125-175	$\sigma_b \approx 3.63HBW$ $\sigma_b \approx 3.43HBW$
Quenched brass, quenched bronze	—	$\sigma_b \approx 4.0HBW$
Annealed brass, annealed bronze	—	$\sigma_b \approx 5.5HBW$
Cast aluminum alloy	—	$\sigma_b \approx 2.6HBW$

Appendix M: Conversion Value of Hardness and Strength of Ferrous Metal

Table A Conversion Value of Hardness and Tensile Strength of Steels

Hardness								Tensile Strength σ_b/ MPa								
Rockwell		Superficial Rockwell			Vickers	Brinell ($F/D^2=30$)		Carbon steel	Chrome steel	Chrome-vanadium steel	Chrome nickel steel	Chrome molybdenum steel	Cr-Ni-Mo steel	Cr-Mn-Si steel	Super high strength steel	Stainless steel
HRC	HRA	HR15N	HR30N	HR45N	HV	HBS	HBW									
20.0	60.2	68.8	40.7	19.2	226	225		774	742	736	782	747		781		740
20.5	60.4	69.0	41.2	19.8	228	227		784	751	744	787	753		788		749
21.0	60.7	69.3	41.7	20.4	230	229		793	760	753	792	760		794		758
21.5	61.0	69.5	42.2	21.0	233	232		803	769	761	797	767		801		767
22.0	61.2	69.8	42.6	21.5	235	234		813	799	770	803	774		809		777
22.5	61.5	70.0	43.1	22.1	238	237		823	788	779	809	781		816		786
23.0	61.7	70.3	43.6	22.7	241	240		833	798	788	815	789		824		796
23.5	62.0	70.6	44.0	23.3	244	242		843	808	797	822	797		832		806
24.0	62.2	70.8	44.5	23.9	247	245		854	818	807	829	805		840		816
24.5	62.5	71.1	45.0	24.5	250	248		864	828	816	836	813		848		826
25.0	62.8	71.4	45.5	25.1	253	251		875	838	826	843	822		856		837
25.5	63.0	71.6	45.9	25.7	256	254		886	848	837	851	831	850	865		847
26.0	63.3	71.9	46.4	26.3	259	257		897	859	847	859	840	859	874		858
26.5	63.5	72.2	46.9	26.9	262	260		908	870	858	867	850	869	883		868
27.0	63.8	72.4	47.3	27.5	266	263		919	880	869	876	860	870	893		879
27.5	64.0	72.7	47.8	28.1	269	266		930	891	880	885	870	890	902		890
28.0	64.3	73.0	48.3	28.7	273	269		942	902	892	894	880	901	912		901
28.5	64.6	73.3	48.7	29.3	276	273		954	914	903	904	891	912	922		913
29.0	64.8	73.5	49.2	29.9	280	276		965	925	915	914	902	923	933		924
29.5	65.1	73.8	49.7	30.5	284	280		977	937	928	924	913	935	943		936
30.0	65.3	74.1	50.2	31.1	288	283		989	948	940	935	924	947	954		947
30.5	65.6	74.4	50.6	31.7	292	287		1002	960	953	946	936	959	965		959
31.0	65.8	74.7	51.1	32.3	296	291		1014	972	966	957	948	972	977		971
31.5	66.1	74.9	51.6	32.9	300	294		1027	984	980	969	961	985	989		983
32.0	66.4	75.2	52.0	33.5	304	298		1039	996	993	981	974	999	1001		996
32.5	66.6	75.5	52.5	34.1	308	302		1052	1009	1007	994	987	1012	1013		1008

Hardness								Tensile Strength σ_b/ MPa								
Rockwell		Superficial Rockwell			Vickers	Brinell ($F/D^2=30$)		Carbon steel	Chrome steel	Chrome-vanadium steel	Chrome nickel steel	Chrome molybdenum steel	Cr-Ni-Mo steel	Cr-Mn-Si steel	Super high strength steel	Stainless steel
HRC	HRA	HR15N	HR30N	HR45N	HV	HBS	HBW									
33.0	66.9	5.87	53.0	34.7	313	306		1065	1022	1022	1007	1001	1027	1026		1021
33.5	67.1	76.1	53.4	35.3	317	310		1078	1034	1036	1020	1015	1041	1039		1034
34.0	67.4	76.4	53.9	35.9	321	314		1092	1048	1051	1034	1029	1056	1052		1047
34.5	67.7	76.7	54.4	36.5	326	318		1105	1064	1067	1048	1043	1071	1066		1060
35.0	67.9	77.0	54.8	37.0	331	323		1119	1074	1082	1063	1058	1087	1079		1074
35.5	67.9	77.0	55.3	37.6	335	327		1133	1088	1098	1078	1074	1103	1094		1087
36.0	68.4	77.5	55.8	38.2	340	332		1147	1102	1114	1093	1090	1119	1108		1101
36.5	68.7	77.8	56.2	38.8	345	336		1162	1116	1131	1109	1106	1136	1123		1116
37.0	69.0	78.1	56.7	39.4	350	341		1117	1131	1148	1125	1122	1153	1139		1130
37.5	69.2	78.4	57.2	40.0	355	345		1192	1146	1165	1142	1139	1171	1155		1145
38.0	69.5	78.7	57.6	40.6	360	350		1207	1161	1183	1159	1157	1189	1171		1161
38.5	69.7	79.0	58.1	41.2	365	355		1222	1176	1201	1177	1174	1207	1187	1170	1176
39.0	70.0	79.3	58.6	41.8	371	360		1238	1192	1219	1195	1192	1226	1204	1195	1193
39.5	70.3	79.6	59.0	42.4	376	365		1254	1208	1238	1214	1211	1245	1222	1219	1209
40.0	70.5	79.9	59.5	43.0	381	370	370	1271	1225	1257	1233	1230	1265	1240	1243	1226
40.5	70.8	80.2	60.0	43.6	387	375	375	1288	1242	1276	1252	1249	1285	1258	1267	1244
41.0	71.1	80.5	60.4	44.2	393	380	381	1305	1260	1296	1273	1269	1306	1277	1290	1262
41.5	71.3	80.8	60.9	44.8	398	385	386	1322	1278	1317	1293	1289	1327	1296	1313	1280
42.0	71.6	81.1	61.3	45.4	404	391	392	1340	1296	1337	1314	1310	1348	1316	1336	1299
42.5	71.8	81.4	61.8	45.9	410	396	397	1359	1315	1358	1336	1331	1370	1336	1359	1319
43.0	72.1	81.7	62.3	46.5	416	401	403	1378	1335	1380	1358	1353	1392	1357	1381	1339
43.5	72.4	82.0	62.7	47.1	422	407	409	1397	1355	1401	1380	1375	1415	1378	1404	1361
44.0	72.6	82.3	63.2	47.7	428	413	415	1417	1376	1424	1404	1397	1439	1400	1427	1383
44.5	72.9	82.6	63.6	48.3	435	418	422	1438	1398	1446	1427	1420	1462	1422	1450	1405
45.0	73.2	82.9	64.1	48.9	441	424	428	1459	1420	1469	1451	1444	1487	1445	1473	1429
45.5	73.4	83.2	64.6	49.5	448	430	435	1481	1444	1493	1476	1468	1512	1469	1496	1453
46.0	73.7	83.5	65.0	50.1	454	436	441	1503	1468	1517	1502	1492	1537	1493	1520	1479
46.5	73.9	83.7	65.5	50.7	461	442	448	1526	1493	1541	1527	1517	1563	1517	1544	1505

Hardness								Tensile Strength σ_b/ MPa								
Rockwell		Superficial Rockwell			Vickers	Brinell ($F/D^2=30$)		Carbon steel	Chrome steel	Chrome-vanadium steel	Chrome nickel steel	Chrome molybdenum steel	Cr-Ni-Mo steel	Cr-Mn-Si steel	Super high strength steel	Stainless steel
HRC	HRA	HR15N	HR30N	HR45N	HV	HBS	HBW									
47.0	74.2	84.0	65.9	51.2	468	449	455	1550	1519	1566	1554	1542	1589	1543	1569	1533
47.5	74.5	84.3	66.4	51.8	475		463	1575	1546	1591	1581	1568	1616	1569	1594	1562
48.0	74.7	84.6	66.8	52.4	482		470	1600	1574	1617	1608	1595	1643	1595	1620	1592
48.5	75.0	84.9	67.3	53.0	489		478	1626	1603	1643	1636	1622	1671	1623	1646	1623
49.0	75.3	85.2	67.7	53.6	497		486	1653	1633	1670	1665	1649	1699	1651	1674	1655
49.5	75.5	85.5	68.2	54.2	504		494	1681	1665	1697	1695	1677	1728	1679	1702	1689
50.0	75.8	85.7	68.6	54.7	512		502	1710	1698	1724	1724	1706	1758	1709	1731	1725
50.5	76.1	86.0	69.1	55.3	520		510		1732	1752	1755	1735	1788	1739	1761	
51.0	76.3	86.3	69.5	55.9	527		518		1768	1780	1786	1764	1819	1770	1792	
51.5	76.6	86.6	70.0	56.5	535		527		1806	1809	1818	1794	1850	1801	1824	
52.0	76.9	86.8	70.4	57.1	544		535		1845	1839	1850	1825	1881	1834	1857	
52.5	77.1	87.1	70.9	57.6	552		544			1869	1883	1856	1914	1867	1892	
53.0	77.4	87.4	71.3	58.3	561		552			1899	1917	1888	1947	1901	1929	
53.5	77.7	87.6	71.8	58.8	569		561			1930	1951			1936	1966	
54.0	77.9	87.9	72.2	59.4	578		569			1961	1986			1971	2006	
54.5	78.2	88.1	72.6	59.9	587		577			1993	2022			2008	2047	
55.0	78.5	88.4	73.1	60.5	596		585			2026	2058			2045	2090	
55.5	78.7	88.6	73.5	61.1	606		593								2135	
56.0	79.0	88.9	73.9	61.7	615		601								2181	
56.5	79.3	89.1	74.4	62.2	625		608								2230	
57.0	79.5	89.4	74.8	62.8	635		616								2281	
57.5	79.8	89.6	75.2	63.4	645		622								2334	
58.0	80.1	89.8	75.6	63.9	655		628								2390	
58.5	80.3	90.0	76.1	64.5	666		634								2448	
59.0	80.6	90.2	76.5	65.1	676		639								2509	
59.5	80.9	90.4	76.9	65.6	687		643								2572	
60.0	81.2	90.6	77.3	66.2	698		647								2639	
60.5	81.4	90.8	77.7	66.8	710		650									

Hardness								Tensile Strength σ_b/ MPa								
Rockwell		Superficial Rockwell			Vickers	Brinell ($F/D^2=30$)		Carbon steel	Chrome steel	Chrome-vanadium steel	Chrome nickel steel	Chrome molybdenum steel	Cr-Ni-Mo steel	Cr-Mn-Si steel	Super high strength steel	Stainless steel
HRC	HRA	HR15N	HR30N	HR45N	HV	HBS	HBW									
61.0	81.7	91.0	78.1	67.3	721											
61.5	82.0	91.2	78.6	67.9	733											
62.0	82.2	91.4	79.0	68.4	745											
62.5	82.5	91.5	79.4	69.0	757											
63.0	82.8	91.7	79.8	69.5	770											
63.5	83.1	91.8	80.2	70.1	782											
64.0	83.3	91.9	80.6	70.6	795											
64.5	83.6	92.1	81.0	71.2	809											
65.0	83.9	92.2	81.3	71.7	822											
65.5	84.1				836											
66.0	84.4				850											
66.5	84.7				865											
67.0	85.0				879											
67.5	85.2				894											
68.0	85.5				909											

Table B Conversion Value of Hardness and Strength of Mild Steels

Hardness							Tensile Strength σ_b /MPa
Rockwell	Superficial Rockwell			Vickers	Brinell		
HRB	HR15T	HR30T	HR45T	HV	HBS		
					$F/D^2=10$	$F/D^2=30$	
60.0	80.4	56.1	30.4	105	102		375
60.5	80.5	56.4	30.9	105	102		377
61.0	80.7	56.7	31.4	106	103		379
61.5	80.8	57.1	31.9	107	103		381
62.0	80.9	57.4	32.4	108	104		382
62.5	81.1	57.7	32.9	108	104		384
63.0	81.2	58.0	33.5	109	105		386
63.5	81.4	58.3	34.0	110	105		388
64.0	81.5	58.7	34.5	110	106		390
64.5	81.6	59.0	35.0	111	106		393
65.0	81.8	59.3	35.5	112	107		395
65.5	81.9	59.6	36.1	113	107		397
66.0	82.1	59.9	36.6	114	108		399
66.5	82.2	60.3	37.1	115	108		402
67.0	82.3	60.6	37.6	115	109		404
67.5	82.5	60.9	38.1	116	110		407
68.0	82.6	61.2	38.6	117	110		409
68.5	82.7	61.5	39.2	118	111		412
69.0	82.9	61.9	39.7	119	112		415
69.5	83.0	62.2	40.2	120	112		418
70.0	83.2	62.5	40.7	121	113		421
70.5	83.3	62.8	41.2	122	114		424
71.0	83.4	63.1	41.7	123	115		427
71.5	83.6	63.5	42.3	124	115		430
72.0	83.7	63.8	42.8	125	116		433

Hardness							Tensile Strength σ_b /MPa
Rockwell	Superficial Rockwell			Vickers	Brinell		
HRB	HR15T	HR30T	HR45T	HV	HBS		
					$F/D^2=10$	$F/D^2=30$	
72.5	83.9	64.1	43.3	126	117		437
73.0	84.0	64.4	43.8	128	118		440
73.5	84.1	64.7	44.3	129	119		444
74.0	84.3	65.1	44.8	130	120		447
74.5	84.4	65.4	45.4	131	121		451
75.0	84.5	65.7	45.9	132	122		455
75.5	84.7	66.0	46.4	134	123		459
76.0	84.8	66.3	46.9	135	124		463
76.5	85.0	66.6	47.4	136	125		467
77.0	85.1	67.0	47.9	138	126		471
77.5	85.2	67.3	48.5	139	127		475
78.0	85.4	67.6	49.0	140	128		480
78.5	85.5	67.9	49.5	142	129		484
79.0	85.7	68.2	50.0	143	130		489
79.5	85.8	68.6	50.5	145	132		493
80.0	85.9	68.9	51.0	146	133		498
80.5	86.1	69.2	51.6	148	134		503
81.0	86.2	69.5	52.1	149	136		508
81.5	86.3	69.8	52.6	151	137		513
82.0	86.5	70.2	53.1	152	138		518
82.5	86.6	70.5	53.6	154	140		523
83.0	86.8	70.8	54.1	156		152	529
83.5	86.9	71.1	54.7	157		154	534
84.0	87.0	71.4	55.2	159		155	540
84.5	87.2	71.8	55.7	161		156	546
85.0	87.3	72.1	56.2	163		158	551
85.5	87.5	72.4	56.7	165		159	557
86.0	87.6	72.7	57.2	166		161	563

Hardness							Tensile Strength σ_b /MPa
Rockwell	Superficial Rockwell			Vickers	Brinell		
HRB	HR15T	HR30T	HR45T	HV	HBS		
					$F/D^2=10$	$F/D^2=30$	
86.5	87.7	73.0	57.8	168		163	570
87.0	87.9	73.4	58.3	170		164	576
87.5	88.0	73.7	58.8	172		166	582
88.0	88.1	74.0	59.3	174		168	589
88.5	88.3	74.3	59.8	176		170	596
89.0	88.4	74.6	60.3	178		172	603
89.5	88.6	75.0	60.9	180		174	609
90.0	88.7	75.3	61.4	183		176	617
90.5	88.8	75.6	61.9	185		178	624
91.0	89.0	75.9	62.4	187		180	631
91.5	89.1	76.2	62.9	189		182	639
92.0	89.3	76.6	63.4	191		184	646
92.5	89.4	76.9	64.0	194		187	654
93.0	89.5	77.2	64.5	196		189	662
93.5	89.7	77.5	65.0	199		192	670
94.0	89.8	77.8	65.5	201		195	678
94.5	89.9	78.2	66.0	203		197	686
95.0	90.1	78.5	66.5	206		200	695
95.5	90.2	78.8	67.1	208		203	703
96.0	90.4	79.1	67.6	211		206	712
96.5	90.5	79.4	68.1	214		209	721
97.0	90.6	79.8	68.6	216		212	730
97.5	90.8	80.1	69.1	219		215	739
98.0	90.9	80.4	69.6	222		218	749
98.5	91.1	80.7	70.2	225		222	758
99.0	91.2	81.0.	70.7	227		226	768
99.5	91.3	81.4	71.2	230		229	778
100.0	91.5	81.7	71.7	233		232	788