BMS BULUT® MAKİNA
SANAYİ VE TİCARET LTD. ŞTİ.

OPERATION MANUAL

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1. Forewords

1.1. History

The Leeb measuring method was first brought into measurement technology in 1978. It is defined as the quotient of an impact body's rebound velocity over its impact velocity, multiplied by 1000. Harder materials produce a higher rebound velocity than softer materials. For a specific group of material (e.g. steel, aluminum. etc.), Leeb hardness value represents a direct relationship to its hardness properties. For ordinary metal, conversion curves of hardness HL versus other standard static hardness (HB, HV, HRC, etc.) are available, enabling you to convert HL into other hardness values.

1.2. Leeb Hardness Test (definition)

An impact body with a spherical test tip made of tungsten carbide is propelled against the sample surface by a spring force and then rebounds back. At a distance of 1mm from the sample surface, the impact and rebound velocity of the impact body are measured by the following method: A permanent magnet embedded in the impact body, when passing through the coil in its coil holder, induces in the coil an electric voltage proportional to the velocities of the magnet. Leeb hardness is expressed by the following formula:

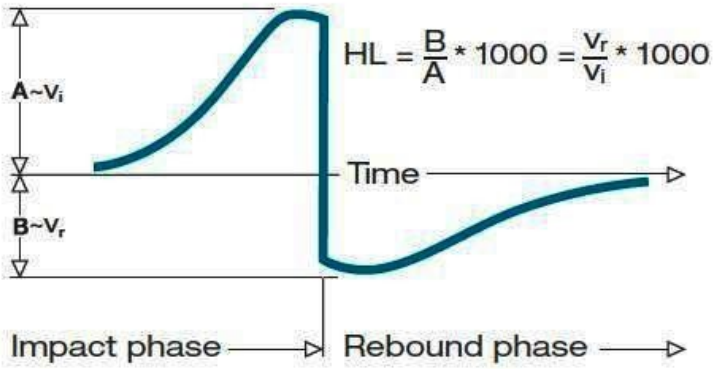
$$HL = \frac{Vr}{Vi} * 1000$$

Where: HL is Leeb Hardness

V_r is the rebound velocity of the impact body

V_i is the impact velocity of the impact body

The voltage characteristic of output signal, when the impact body passes through the induction coil is illustrated in the following figure:



Voltage characteristic of output signal

A Leeb's Hardness Tester measures the hardness of sample material in terms of Hardness Leeb (HL), which can be converted into other Hardness units (Rockwell B and C, Vickers, Brinell and Shore D).

1.3. Notation of Leeb's Hardness

When measuring the hardness of a sample material using the traditional static hardness testing method, a change of applied pressure will result in a change in the hardness reading. This will also happen during a Leeb's Hardness test when one changes the impact device. In hardness measurement of the same test sample with different impact devices, the Leeb's hardness values obtained will vary.

For example: 720HLD≠720HLC

Because different converting curves are obtained from different impact devices, when converting hardness HL into another hardness values, the notation for the converted hardness value should include the impact device used.

For example:

Hardness HV converted from hardness HL using impact device D+15 should be written as 22, 8 HV LD+15.

Where: 22=Hardness value HL

8=Hardness value HV

L=Leeb's Method

D+15=Impact device

Hardness HRC converted from hardness L using impact device D should be written as 35, 9 HRCLD.

Where: 35=Hardness value HL

9=Hardness value HRC

L=Leeb's Method

D=Impact device

2. Features and Applications

2.1. Introduction

HARTIP 2000 is an innovative portable Leeb hardness tester with our new patent technology which makes HARTIP 2000 a universal impact direction hardness tester. It is no need to set up impact direction when taking measurement by any angle. Therefore, HARTIP 2000 offers a linear accuracy comparing to the angle compensating method. HARTIP 2000 is also a cost saving hardness tester and has many other features.

2.2. Specifications

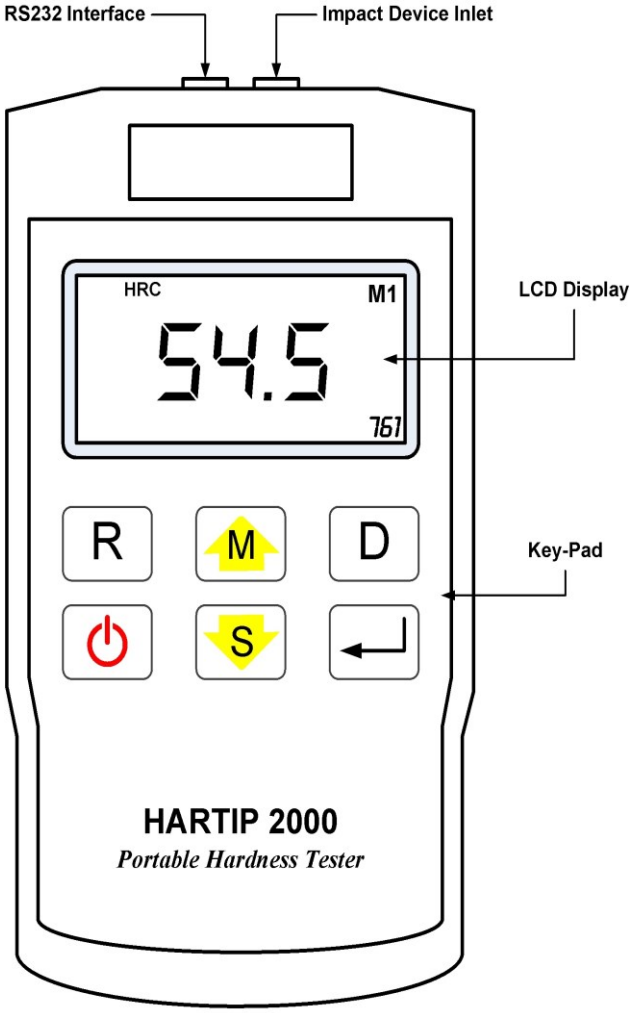
Principle Leeb hardness measurement
Accuracy ±0.3% @ HL=800
Repeatability ±2HL
Display Digital LCD with backlight
Impact direction Universal angle type
Hardness scale HL/HRC/HRB/HB/HV/HS/HRA/σb
Measuring range HL100-960 / HRC0.9-79.2 / HRB1.0-140 / HB1-1878 / HV1-1698 / HS0.5-1370 / HRA1.0-88.5 / σb (rm)1-6599N/mm^2
Impact device D (External) /DC, DL, D+15, G, C, E (External, optional)
Materials 10 common metal materials
Memory 300 data can be stored and re-readable
Statistics Calculated automatically
Recalibration Allowed by user
Indicator Low battery
Communication interface RS232 to micro-printer, Bluetooth (optional) to Bluetooth micro-printer
Auto power off Auto
Power supply 1.5V AA alkaline battery x 2
Working environment-10ºC ~+45ºC
Dimension (mm) 124x67x30
Net weight (g) 240
Standards Conforming to ASTM A956, DIN50156, GB/T 17394-1998

3. Applications

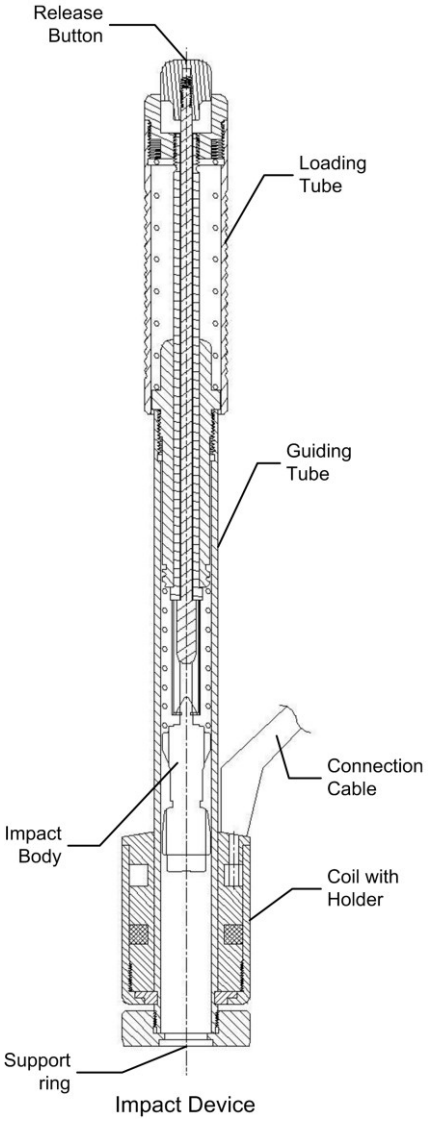
Hardness tests on installed machines or steel structures: e.g. on heavy and large work-piece or on permanently installed system parts.
Rapid testing of multiple measuring areas for examination of hardness variations over larger regions.
Measuring hardness for produced parts at production line.
Identifying metallic material stored in a warehouse.
Ineffectiveness analysis of permanent parts, pressure -vessel, turbo generator.

4. Layout and Key-pad Description

4.1. Layout of HARTIP 2000



HARTIP 2000 MAIN UNIT



PROBE

4.2. Function of Key

R	: Read the memory		: Power On Power Off
M	: Menu Increase the value Turn the page forth	S	: Change parameter Decrease the value Turn the page back
D	: Delete the current reading Delete the stored values Press for 3 seconds to activate/deactivate direction indicator		: Confirm the setup View the statistics values

4.3. Special Features of Impact Devices

Type	Brief description	
D	Universal standard unit for majority of hardness testing assignments.	
DC	Extremely short impact device, other specs identical with type D.	
	Application:	- highly confined spaces - holes and cylinders - internal measurements on assembled machines
D+15	Slim front section	
	Application:	- grooves and recessed surfaces.
DL	Extremely slim front section	
	Application:	- extremely confined spaces - base of grooves
C	Reduced impact energy (compared with type D).	
	Application:	- surface hardened components, coatings - minimum layer thickness: 0.2mm. -thin walled or impact sensitive components (small measuring indentation).
E	Synthetic diamond test tip (approx.5000 HV).	
	Application:	- extremely high hardness measurement such as high carbon steel up to 1200 HV
G	Increased impact energy(approx. 9 times that of type D)	
	Application:	- Brinell hardness range only - heavy cast and forged parts with lower demands on surface finish.

5. Symbols and Illustrations

5.1. Symbols and Illustrations

Symbol	Meaning
LD	Leeb hardness value obtained with impact device D
LDC	Leeb hardness value obtained with impact device DC
LG	Leeb hardness value obtained with impact device G
LC	Leeb hardness value obtained with impact device C
LD15	Leeb hardness value obtained with impact device D+15
LE	Leeb hardness value obtained with impact device E
LDL	Leeb hardness value obtained with impact device DL

Symbol	Meaning
HL	Leeb hardness value
HRC	Rockwell C hardness value
HRB	Rockwell B hardness value
HB	Brinell hardness value
HV	Vickers hardness value
HS	Shore hardness value
HRA	Rockwell A hardness value
SGM	Intensity of tension

5.2. Measurement and Conversion Table

Range for measurement and conversion:

PROBE D/DC			HLD: 100-960				
MATERIALS	HRC	HRB	HB	HV	HS	HRA	σb(N/mm²)
STEEL/CAST STEEL	1-74.7	1.2-140	28-1027	45-1230	4.0-112	7-88.5	118-3315
ALLOY TOOL STEEL	0.9-78.7	*	*	32-1698	*	*	79-6599
STAINLESS STEEL	3.7-62.4	8.3-101.7	85-655	36-802	*	*	108-1725
GREY CAST IRON-GG	*	*	35-570	*	*	*	*
NODULAR CAST IRON	*	*	62-857	*	*	*	*
CAST ALUMINUM	*	24-85	19-445	*	*	*	*
COPPER-ZINC BRASS	*	1.5-99.6	32-477	*	*	*	*
COPPER ALUMINIUM BRONZE	*	*	15-505	*	*	*	*
WEOUGHT COPPER	*	*	39-569	*	*	*	*
FORGING STEEL	*	*	50-1060	*	*	*	*

PROBE DL		DL: 100-980					
MATERIALS	HRC	HRB	HB	HV	HS	HRA	σb(N/mm²)
STEEL/CAST STEEL	1-73	1.5-109.5	1-1026	1-1167	0.5-100	*	*

PROBE E		HLE: 100-960					
MATERIALS	HRC	HRB	HB	HV	HS	HRA	σb(N/mm²)
STEEL/CAST STEEL	6.3-78.5	*	24-1144	24-1369	3.6-121	*	*
ALLOY TOOL STEEL	10.5-83.2	*	*	24-1659	*	*	*

PROBE G		HLG: 100-900					
MATERIALS	HRC	HRB	HB	HV	HS	HRA	σb(N/mm²)
STEEL/CAST STEEL	*	1-133	10-946	*	*	*	*
GREY CAST IRON-GG	*	*	5-804	*	*	*	*
NODULAR CAST IRON	*	*	5-998	*	*	*	*

PROBE C		HLC: 100-960					
MATERIALS	HRC	HRB	HB	HV	HS	HRA	σb(N/mm²)
STEEL/CAST STEEL	5-72.5	*	23-953	23-1125	5-111	*	*
ALLOY TOOL STEEL	4-77.2	*	*	43-1566	*	*	*

PROBE D+15		HLD+15: 100-960					
MATERIALS	HRC	HRB	HB	HV	HS	HRA	σb(N/mm²)
STEEL/CAST STEEL	1-69.8	*	12-999	12-1221	2-112	*	*
ALLOY TOOL STEEL	1.3-78	*	*	2.0-1485	*	*	*

6. Preparation before Measuring

6.1. Requirements for the sample

The surface temperature of sample should be less than 120 °C.
The samples must feature a metallic smooth, ground surface, in order to eliminate erroneous measurements brought about by coarse grinding or lathe scoring. Roughness of the finished surface should not exceed values shown in following table:

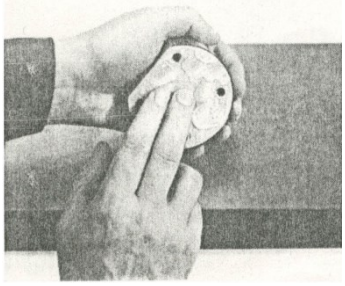
Types of impact devices	Max surface roughness of sample Ra
D/DC/D+15/DL/E	2μm
G	7μm
C	0.4μm

6.2. Requirements for the weight of the sample

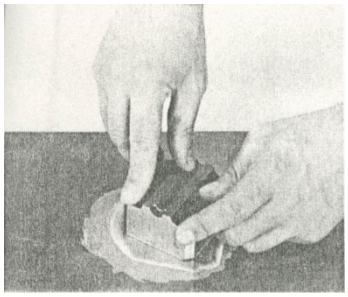
For samples weighing over 5 kg and of compact shape, no support is needed.
Samples weighing between 2-5 kg, and also for heavier samples with protruding parts or thin walls, should be placed on a solid support in such a manner that they do not bend or move by the impact force.
Samples weighing less than 2 kg should be firmly coupled with a stable support weighing over 5 kg.
For coupling purposes,
The coupling surface between the sample and base plate should be flat, plane parallel and ground.
A thin proper layer of coupling paste is to be applied to the contact surface of the sample.
The sample should be firmly pressed against the surface of the base plate by moving it with a circular motion.
The direction of impact should be perpendicular to the coupling surface.
For the coupling operation, the following prerequisites must be fulfilled:
The contact surface of the sample and the surface of the base plate must be flat, plane parallel and ground.
The direction of the test impact must be perpendicular to the coupled surface.
Minimum thickness of the sample for coupling under various impact devices are shown in following table:

Types of impact devices	Minimum thickness
D/DC/D+15/DL/E	3mm
G	10mm
C	1mm

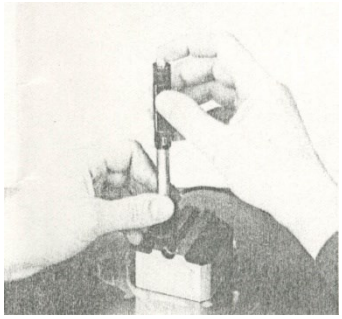
Proper Coupling:
Proper coupling requires a little experience. Insufficiently coupled samples produce large variations of individual measurements, L-values which are too low and the operation is characterized by a rattling noise upon impact of the test tip.
Example for coupling a test piece with a base plate:



Application of the coupling paste



Mutual rubbing of both parts while firmly press the sample against the base plate.



A particular advanced of coupling is the possibility of obtaining a very uniform, rigid connection between the sample and the support, totally eliminating stresses at the sample surface. The resulting variation in measured values is very low.

6.3. Requirement for the surface hardened layer of the sample

Surface-hardened steels, especially case-hardened steels, produce L-values which are too low when case-hardening depth is small because of their soft core .When measuring with impact devices D, D+15 or DL, depth of the hardened layer should be no less than 0.8 mm. When measuring with impact device C, the depth of the hardened layer should be no less than 0.2 mm.

Types of impact devices	Min. layer thickness for surface hardening
D/DC/D+15/DL/E	0.8mm
C	0.2mm

Surface of the test sample should not be magnetic.
For test sample of curving surface with radius of curvature R less than 30mm, a small support ring should be used.

6.4. Supporting the Samples during Testing

Types of impact devices	Classification of samples		
	Heavy-weight	medium-weight	light-weight
D/DC/D+15/DL/E	>5kg	2 - 5kg	0.05 – 2kg
G	>15 kg	5 - 15kg	0.5 – 5kg
C	>1.5kg	0.5 - 1.5kg	0.02 - 0.5kg

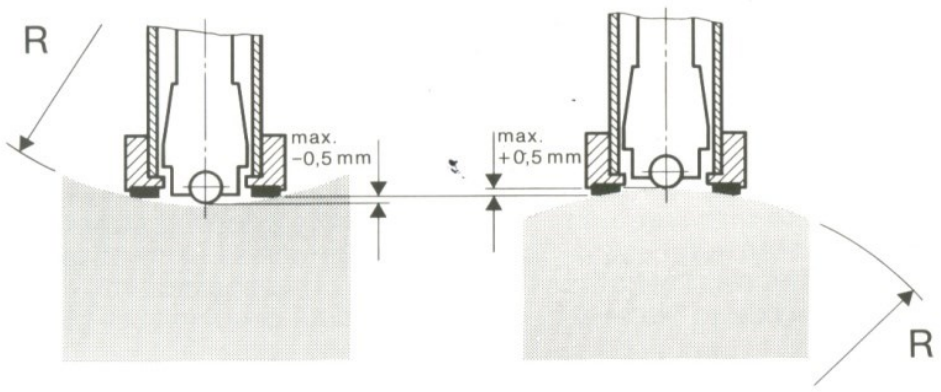
When measuring hardness with HARTIP 2000, the following has to be noticed: Despite the low mass of the impact body and low impact energy, a relatively large impact force within short duration is generated when the impact body hits the measuring surface.

Types of impact devices	D/DC/D+15/DL/E	G	C
Max. impact force	900N	2500N	500N

No particular precautions are necessary for heavy-weight samples with compact shape.
Smaller and lighter samples or workpieces may yield or flex under this force, producing too-low L-values with excessively large variation. Even with big or heavy workpieces, it is possible for thin-wall regions or thinner protruding parts to yield upon impact. Depending on the frequency of the resilient yielding action, the measured L-value may be abnormally low or high. Under many situation, potential problems can be checked in the following manner:
a) Medium-weight samples and also heavier samples with protruding parts or thin walls should be placed on a solid support in such a manner that they do not move or flex during the test impact.
b) Light-weight samples should be rigidly “coupled” with a non-yielding support such as a heavy base plate. Clamping in a vice is of no value, since the samples become exposed to stress and because complete rigidity is never attained. As a rule, the measured L-values would be too small and show excessive variations.

6.5. Samples with Curved Surfaces

Impact testers only work properly, if the impact body has a certain position in the guide tube at the moment of impacting the test surface. In the normal position, automatically present when testing flat and convex-cylindrical samples (such as round samples), the spherical test tip is located exactly at the end of the guide tube.
However, when testing spherically or cylindrically shaped concave surfaces, the impact body remains further within the guide tube or protrudes further therefore. Thus, with such types of curved surfaces, it is to be observed that radii of curvature do not drop below the values indicated in the following Fig.
Curved surfaces should always be tested with the small support ring.



Impact device types D, D+15, C and E Rmin =30mm
Impact device type G Rmin =50mm
For impact devices D, D+15, C and E, special support rings are available to accommodate smaller radii on convex or concave surface.

Types of impact devices	Support Ring	Radius for Curved Surface (mm)
D/DC, D+15,C,E	Standard support ring	>60
	Small support ring	60-30
C	Standard support ring	>100
	Small support ring	100-50

7. Menu Operation

Press the key  to switch on the tester and press the key  again to switch off the tester. When the tester is switched on, the tester will enter into measuring mode.

In the measuring mode, press and hold key  to enter MENU mode.

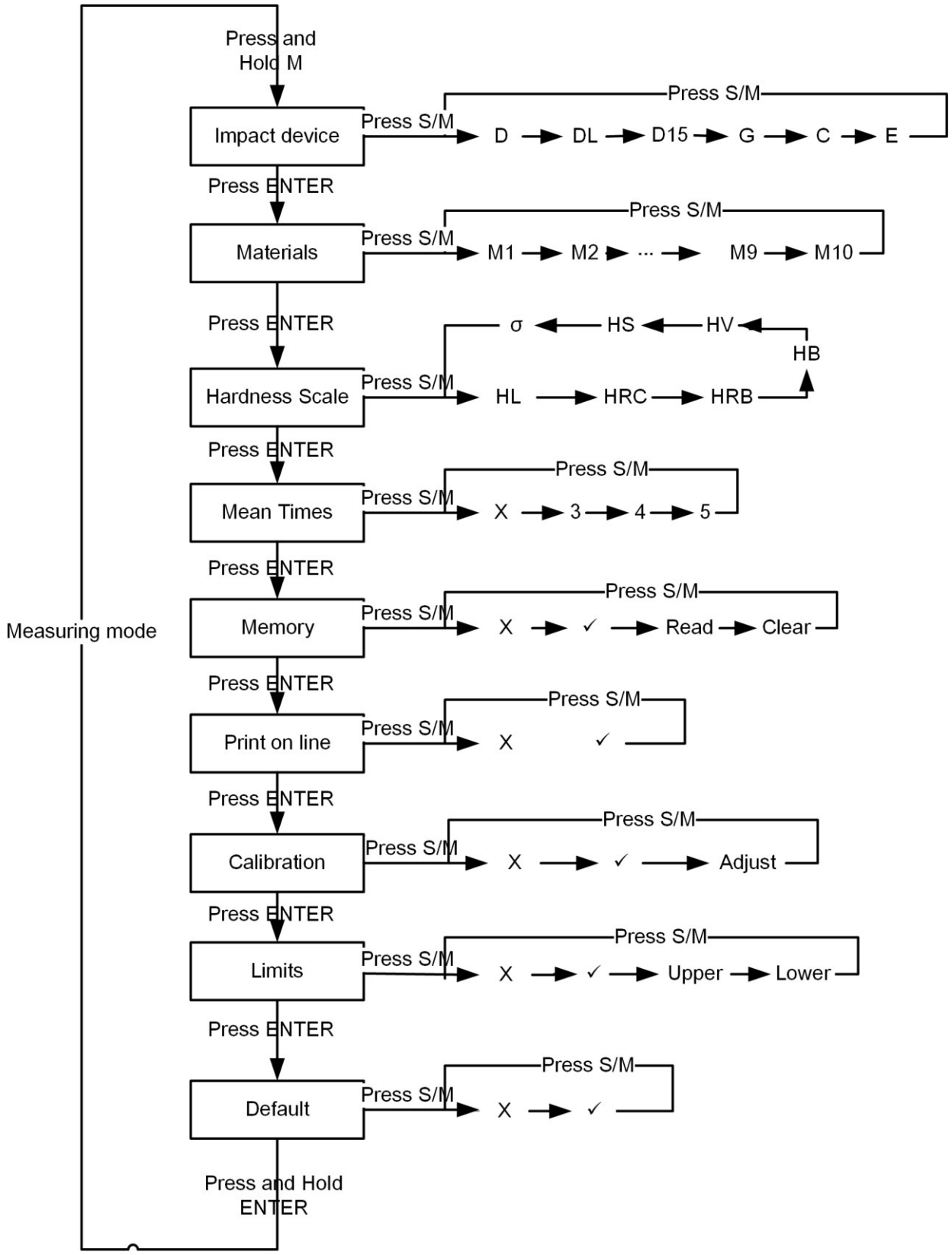
Press  or  to change parameters in the current MENU item.

Press key  to confirm the setting and enter next menu.

Press and hold key  to exit the menu mode and return to the measuring mode.

7.1. Parameter Setup

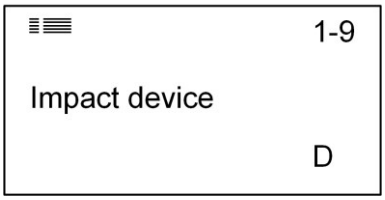
Operation Diagram



7.2. Impact Device (Probe) Setup

Press and hold key M to enter the MENU mode, the first menu is IMPACT DEVICE.

Press key S or M to change probe between D, DL, D15, G, C and E.



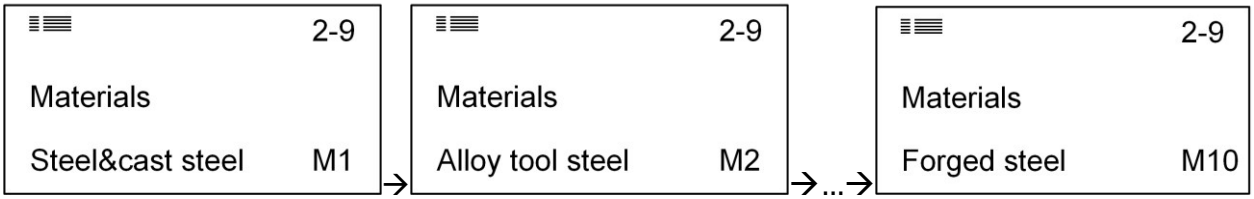
Press key ↵ to confirm the setting and enter next menu - Materials. Press and hold key ↵ to exit the menu mode and return to the measuring mode.

7.3. Materials Selection

The material selected is prior to the conversion from HL value to other scales.

Press and hold key M to enter the MENU mode, then press ↵ to enter the next menu - MATERIALS.

Press key S or M to change material from M1→M2→M3→ ... →M10.



Press key ↵ to confirm the setting and enter next menu. Press and hold key ↵ to exit the menu mode and return to the measuring mode.

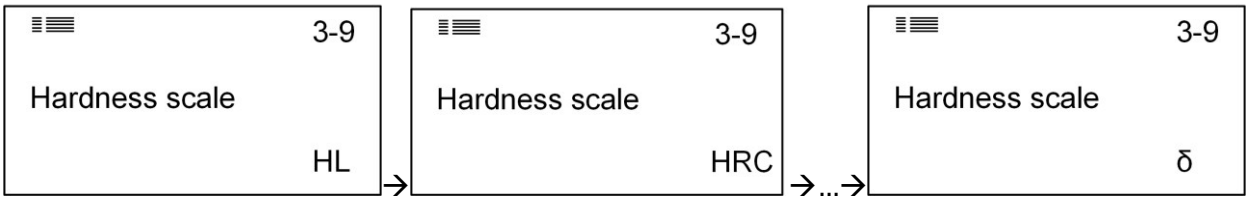
M1:	Steel & Cast Steel
M2:	Cold Work Tool Steel
M3:	Stainless Steel & High-temp. Resistant Steel
M4:	Cast Iron with Lamellar Graphite (GG)
M5:	Cast Iron with Nodular Graphite (GGG)
M6:	Cast Aluminum Alloys
M7:	Copper-Zinc Alloys (Brass)
M8:	Copper-Aluminum / Copper-Tin Alloys (Bronze)
M9:	Wrought Copper Alloys
M10:	Forging Steel

7.4. Hardness Scale (Conversion)

Hardness scale is based on the material selected. Not every material has same conversion. For example, for steel, it has conversions to HRC, HRB, HB, HV, HS; but for cast iron, only has conversions to HB.
The material selected is prior to the conversion from HL value to other scales.

Press and hold key M to enter the MENU mode, then press ↵ consecutively to enter the menu – HARDNESS SCALE.

Press key S or M to change hardness scale from HL→HRC→HRB→HB→HV→HS→HRA→σb.



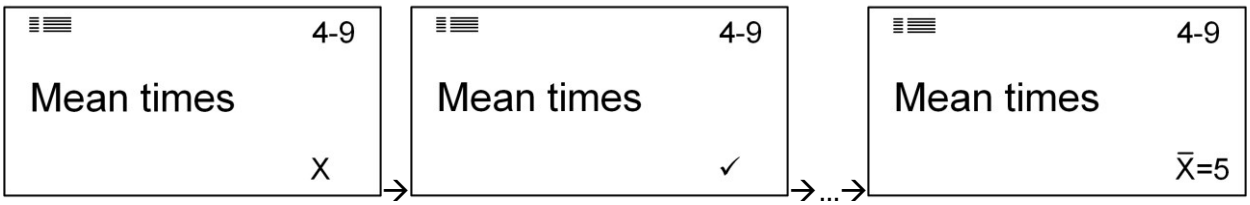
Press key [↵] to confirm the setting and enter next menu. Press and hold key [↵] to exit the menu mode and return to the measuring mode.

7.5. Mean Time

With HARTIP2000, the statistics values can be calculated automatically after setup mean time.

Press and hold key [M] to enter the MENU mode, then press [↵] consecutively to enter the menu – MEAN TIME.

Press key [S] or [M] to select mean time from X→ ✓→3→4→5.



Press key [↵] to confirm the setting and enter next menu. Press and hold key [↵] to exit the menu mode and return to the measuring mode.

Delete measured values

After mean time is set, in order to avoid the error caused by abnormal values involving in calculation, you can delete the current values by pressing key [D].

Read statistics info

After setting the meantime, an indicator will be showed on the measuring mode. When measuring times reach setting times, press [↵] to display average, min. and max. value. Press [↵] again to go back to measuring mode.

7.6. Memory

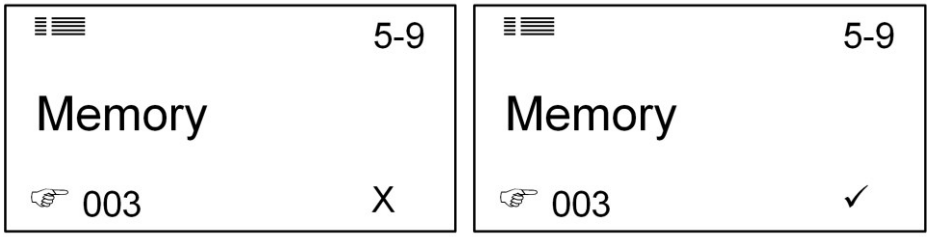
The HARTIP2000 has a memory capacity of 300 data. The stored values can be re-readable on LCD.

Press and hold key [M] to enter the MENU mode, then press [↵] consecutively to enter the menu – MEMORY.

Press key [S] or [M] to select from X→ ✓→Read→Clear.

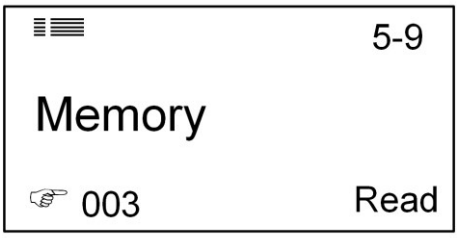
- Memory Off / On

In memory mode, press [S] or [M] to select "X" or "✓", then press [↵] to confirm.



- **Data review**

In memory mode, press [S] or [M] to select "Read". Press [↵] to enter "Read data" mode. In this mode, press [S] or [M] to turn the page forth or back.

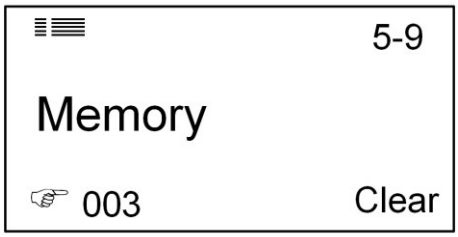


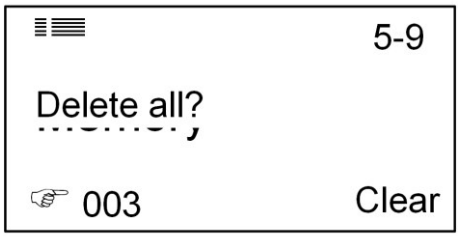
Press ↵ to exit "Read data" mode and go back to "Memory" menu.

Memory clear

In memory mode, press S or M to select "Clear". Press ↵ then "Delete all?" is displayed, press ↵ again to delete all stored data.

In "Read data" mode, press and hold D, "Delete all?" will also be displayed, press ↵ to delete all stored data.



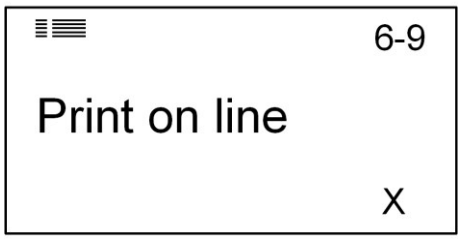


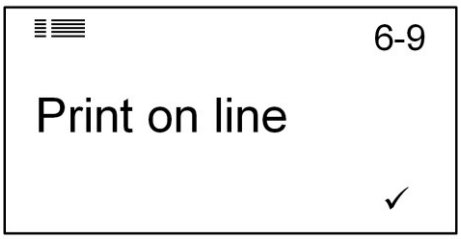
Press key ↵ to confirm the setting and enter next menu. Press and hold key ↵ to exit the menu mode and return to the measuring mode.

7.7. Print on line

Press and hold key M to enter the MENU mode, then press ↵ consecutively to enter the menu – PRINT ON LINE.

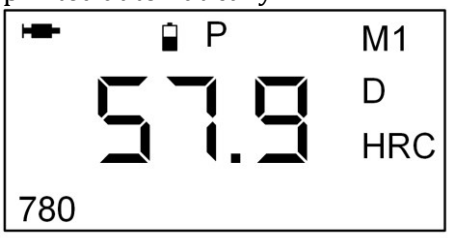
Press key S or M to select X or ✓.





Press key ↵ to confirm the setting and go to next item of menu. Press and hold key ↵ to exit the menu mode and return to the measuring mode.

When PRINT ON LINE is turned on, a "P" will be displayed on the top of the LCD. After the printer is connected correctly, every measurement will be printed automatically.



Please note PRINT ON LINE function will be disabled after the tester is turned off. If you need to print, please enable it again.

7.8. Compensation (Calibration)

- Compensation Description

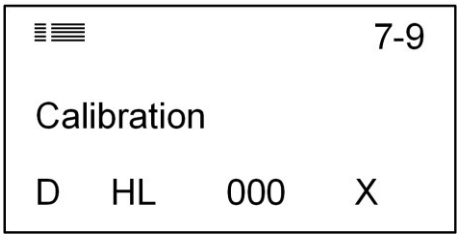
The measurement compensation is used for calibration of the instrument. After the instrument is used for some time, the ball tip on impact body may be worn out which would lead inaccuracy. In order to compensate such error, the tester is designed to be re-calibrated by user.

- Calibration

Set hardness scale to be calibrated.

Press and hold key M to enter the MENU mode, then press ↵ consecutively to enter the menu – CALIBRATION.

Press key S or M to select from X→ ✓→Adjust.

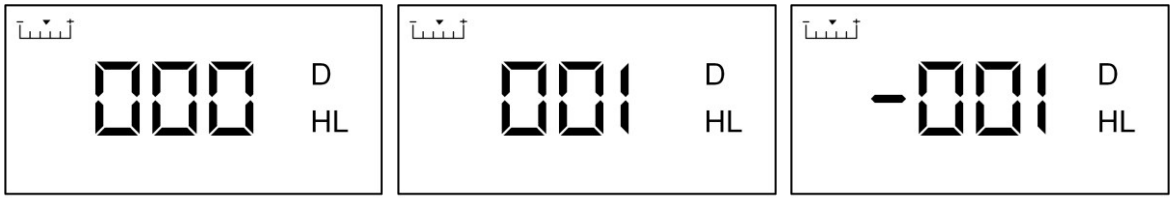


Press key ↵ to confirm the setting and go to next item of menu. Press and hold key ↵ to exit the menu mode and return to the measuring mode.

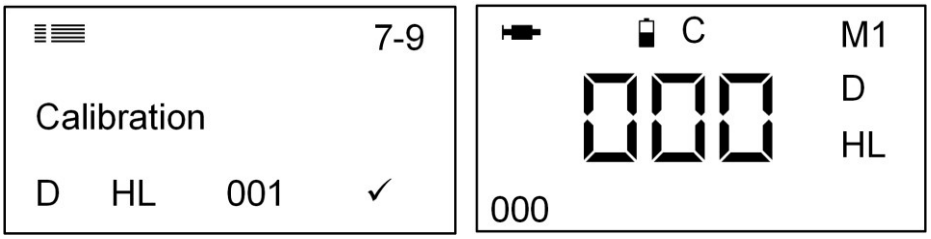
- Adjust

In calibration menu, press S or M to select Adjust, then press ↵ to enter Adjust mode.

Press M or S to adjust compensation value till it meets your actual difference.



After finishing adjustment, press ↵ to confirm modifying and press ↵ again to go to next menu. The compensation value will be saved automatically. An indicator "C" will be displayed in LCD.



Note: The user calibration procedure should be done every half year, if you don't use the tester for long time, before start to use it, you should also do a calibration.

- Calibration off

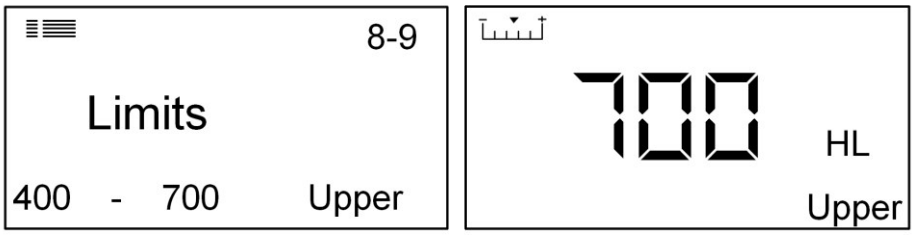
In calibration menu, press S or M to select "X", then press ↵ to confirm and enter next menu. After calibration is disabled, the indicator "C" will disappear.

7.9. Limits

The upper and lower limits can be set by user.

Press and hold key M to enter the MENU mode, then press ↵ consecutively to enter the menu – LIMITS.

Press key S or M to select from X→ ✓→Upper→Lower.

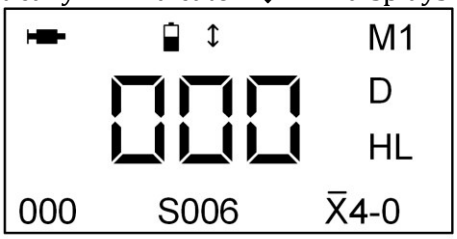


In Limit menu, press S or M to select upper or lower, then press ↵ to enter Adjust mode.

Press M or S to adjust Upper or lower value till it meets your actual requirements.

After finishing adjustment, press ↵ to confirm modifying and press ↵ again to go to next menu.

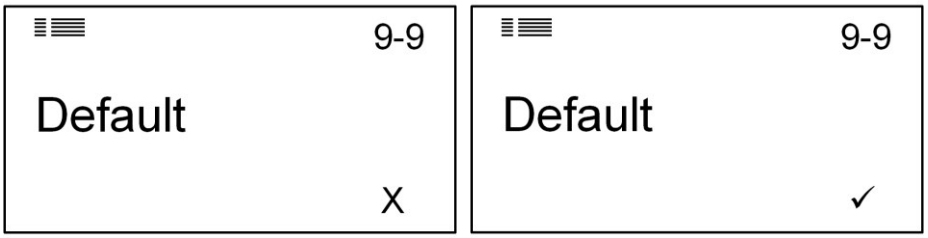
The limits value will be saved automatically. An indicator "↕" will displays in LCD.



7.10. Factory default

Press and hold key M to enter the MENU mode, then press ↵ consecutively to enter the menu – DEFAULT.

Press key S or M to select X or ✓. Press ↵ to confirm and press ↵ again to exit the menu mode and return to the measuring mode.



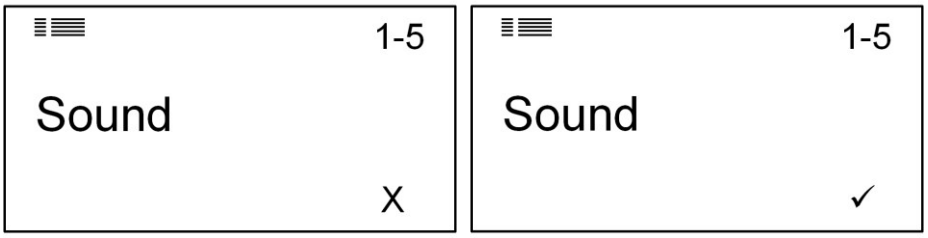
Default settings:
Hardness scale: HL
Materials: M1
Mean time: Off
Memory: Off
Print on line: Off
Calibration: Off
Limits: Off
Factory default: No

7.11. Configuration Menu

In the measuring mode, press and hold key S to enter the Configuration mode.

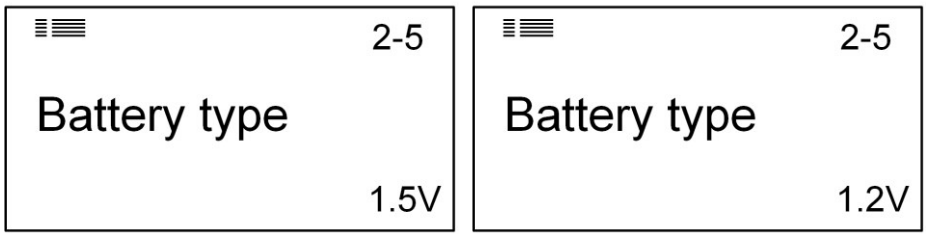
- Sound

In the measuring mode, press and hold key S to enter the Configuration mode, first item is SOUND. Press key S or M to select X or ✓.



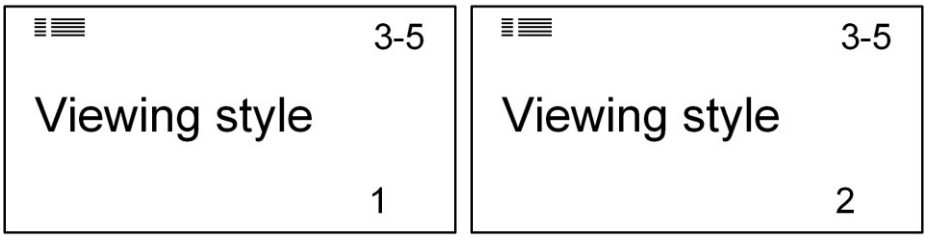
- Battery type

In the measuring mode, press and hold key S to enter the Configuration mode, then press ↵ consecutively to enter the menu – BATTERY TYPE. Press key S or M to select 1.5V or 1.2V. Press ↵ to enter next menu.



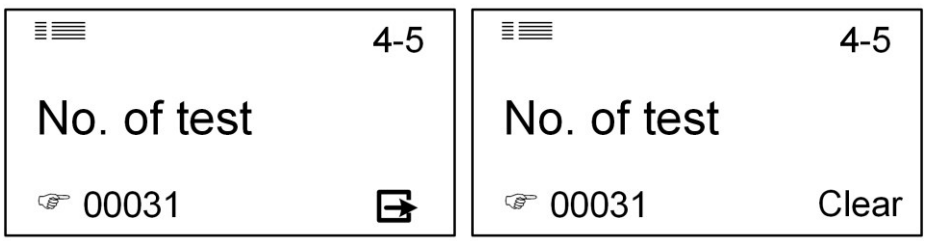
- Viewing style

In the measuring mode, press and hold key S to enter the Configuration mode, then press ↵ consecutively to enter the menu – VIEWING STYLE. Press key S or M to select 1 or 2. Press ↵ to enter next menu.



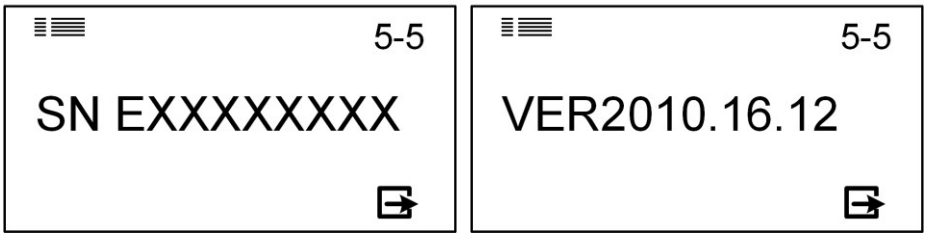
- No. of test

In the measuring mode, press and hold key S to enter the Configuration mode, then press ↵ consecutively to enter the menu – NO. OF TEST. Press key S or M to view number or clear the number. Press ↵ to enter next menu.



- System information

In the measuring mode, press and hold key S to enter the Configuration mode, then press ↵ consecutively to enter the menu – 5-5. Press key S or M to view serial number, firmware or other system information. Press ↵ to exit configuration menu.

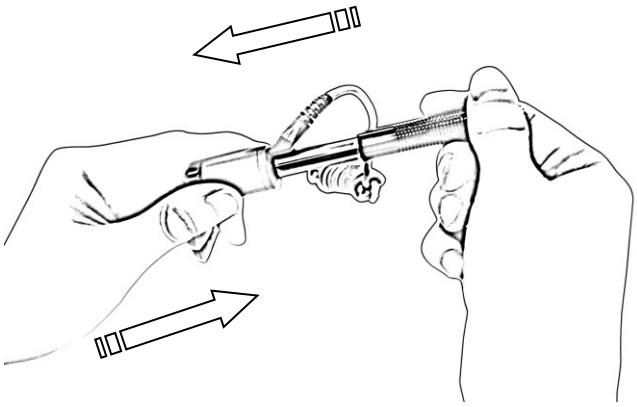


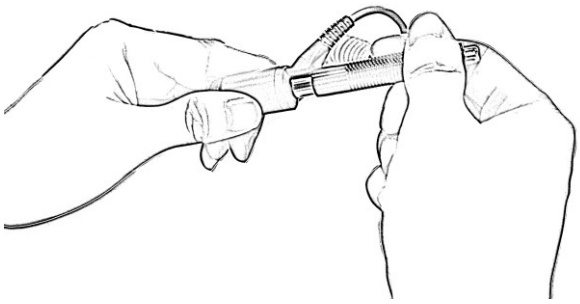
8. Measuring

Press the key  to switch on the tester and press the key  again to switch off the tester. When t
If the parameters are needed to change.

8.1. Take measurements

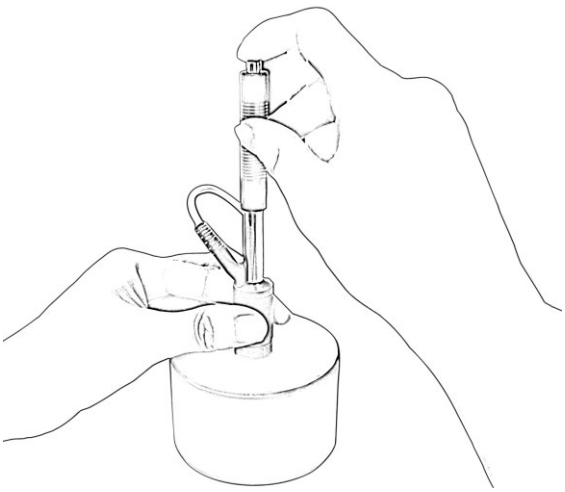
- Load spring force





Hold the impact device with left hand while push the loading tube with right hand toward to the end. Then loose the force and let the loading tube back to original position.

- Release



Place the impact device against the object to be measured. Then press the release button on top of the impact device with finger of right hand. The measuring value will be displayed on LCD.
Please note：During the measurement, the impact device must be placed vertically with a little force against the surface of workpiece. Otherwise, it may affect the accuracy.

8.2. Data storing and review

This tester has a memory capacity of 300 data. The stored values can be re-readable on LCD.
Switch on the memory function from the menu. Memory, then all measured data will be stored automatically. In measuring mode, press R to enter data review mode, in this mode, you can review stored data, press S or M to turn the page forth or back. Press ↵ to exit “Read data” mode and go back to the measuring mode. For more detailed information.

8.3. Print-out (Optional)

If the tester is integrated with a wireless module, it can be equipped with a wireless printer to print the measurement in real time. Switch on the print function from the menu. Print on line. The measuring data will be printed automatically; if the mean time is set, when measuring times reach setting times, the average value, max. value and min. value will also be printed automatically. To cancel printing, return to the menu to disable print on line.

9. Maintenance and Repair

Do your best to avoid shock, heavy dust, damp, strong magnetic field, and oil stain.

9.1. Maintenance of the Impact Device

The devices do not require any particular care other than periodic cleaning of the impact body and the guide tube after performing approximately 1000-2000 tests. During cleaning, the following procedures need to be observed:

Unscrew support ring and remove impact body from guide tube.
Clean off any dirt and metallic dust from the impact body and the spherical test tip.
Clean guide tube with the special brush provided.
Do not apply oil to any parts for the impact device.
Please make sure to keep the spring of impact device at releasing position, do not let the spring pressed by locking impact body after working and being storage.

10. Optional Accessories

Support Rings for Impact Device D

Part designation and dimensions:		Suitable for the following test surfaces	
D6	Φ 19.5×5.5mm	R≥60mm	plane cylindrical hollow-cylindrical spherical hollow-spherical
			
D6a	Φ 13.5×5.5mm	R≥30mm	plane cylindrical hollow -cylindrical spherical hollow-spherical
			
		cylindrical	
Z 10-15	20×20×7.5mm	R 10mm-15mm	
Z 14.5-30	20×20×6.5mm	R 14.5mm-30mm	
Z 25-50	20×20×6.5mm	R 25mm-50mm	
		R<10mm not possible R≥30mm D6/D6a	
		hollow-cylindrical	
HZ 11-13	20×18×5mm	R 11mm-13mm	
HZ 12.5-17	20×20×5mm	R 12.5mm-17mm	
HZ 16.5-30	20×20×5mm	R 16.5mm-30mm	
		R<11mm not possible R≥30mm D6a	
		spherical	
K 10-15	Φ 20×7.7mm	R 10mm-13mm	
K 14.5-30	Φ 20×6.7mm	R 14.5mm-30mm	
		R<10mm not possible R≥30mm D6/D6a	
		hollow-spherical	
HK 11-13	Φ 17×5mm	R 11mm-13mm	
HK 12.5-17	Φ 18×5mm	R 12.5mm-17mm	
HK 16.5-30	Φ 20×5mm	R 16.5mm-30mm	
		R<11mm not possible R≥30mm D6a	
UN	Φ 52×20×16mm