NATIONAL ACCREDITATION BOARD FOR TESTING AND CALIBRATION LABORATORIES

SPECIFIC CRITERIA for CALIBRATION LABORATORIES IN MECHANICAL DISCIPLINE : Verification of Hardness Testing Machine

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1 General Requirement

- The purpose of this document is to specify requirements with which a laboratory has to operate and demonstrate its competency to carry out calibration in accordance with ISO/IEC 17025:2005.

- To achieve uniformity between the laboratories, assessors and assessment process in terms of maximum permissible error, CMC, measurement uncertainty etc in line with National/International standards.

- To achieve uniformity in selection of equipment's, calibration methods, maintaining required environmental conditions, personnel with relevant qualification and experience.

1.1 Scope

This specific criteria lays down the specific requirements in verification of Hardness Testing Machine under mechanical discipline. This part of the document thus amplifies the generic requirements for verification of Hardness Testing Machine and supplements the requirements of ISO/IEC 17025:2005.

1.2 Calibration and Measurement Capability (CMC)

1.2.1 CMC is one of the parameters that is used by NABL to define the scope of an accredited calibration laboratory, the others being parameter/quantity measured, standard/master used, calibration method used and measurement range. The CMC is expressed as "the smallest uncertainty that a laboratory can achieve when calibrating the best existing device". It is an expanded uncertainty estimated at a confidence level of approximately 95% corresponding to a coverage factor k=2.

1.2.2 For evaluation of CMC laboratories shall follow NABL 143 - Policy on Calibration and Measurement Capability (CMC) and Uncertainty in Calibration.

1.3 Personnel, Qualification and Training

1.3.1 Technical Personnel:

1.3.1.1 Qualification required for carrying out calibration activity:

The following are the specific requirements. However, qualification and experience will not be the only criteria for the required activity. They have to prove their skill, knowledge and competency in their specific field of calibration activity.

a) B.E / B.Tech or M.Sc. (having Physics as one of the subject) degree with 3 months experience in Verification of Hardness Testing Machine.

b) B.Sc (with Physics as one of the subject) or Diploma with 6 months experience in Verification of Hardness Testing Machine.

c) ITI with 1 year of experience in Verification of Hardness Testing Machine.

1.3.1.2 Training and experience required:

a) Training may be external/ internal depending on the expertise available in the field.

b) Training in Verification of Hardness Testing machine and in Uncertainty Measurements, CMC including statistical analysis for Technical Manager.

c) Experience and competence in Verification of Hardness Testing Machine.

d) Sufficient knowledge about handling of reference equipment, maintenance, traceability, calibration procedure and effect of environmental conditions on the results of calibration.

e) During training calibration activity should be done under supervision.

1.3.2 Authorised Signatory

1.3.2.1 Qualification required for interpretation of results and signing the calibration certificates:

The following are the specific requirements. However, qualification and experience will not be the only criteria for the required activity. They have to prove their skill, knowledge and competency in analysis and interpretation of calibration results.

a) B.E / B.Tech or M.Sc. (with having Physics as one of the subject) degree with 6 months experience in Verification of Hardness Testing Machine.

b) B.Sc. (with Physics as one of the subject) or Diploma with 1 year experience in Verification of Hardness Testing Machine.

c) Qualification & experience of a person may be relaxed based on verification of skill, knowledge and competency in the specific field of his/her activity.

1.3.2.2 Training and experience required:

a) Training may be external/ internal depending on the expertise available in the field

b) Training, Experience and Competence in Verification of Hardness Testing machine and Training in Uncertainty Measurements, CMC including statistical analysis for Technical Manager.

c) Sufficient knowledge and competence in effective implementation of ISO/IEC 17025, specific criteria and NABL guidelines.

d) Competency in reviewing of results, giving opinion and interpretations.

e) During training the relevant activity has to be done under supervision.

1.4 Accommodation and Environmental Conditions

A Laboratory may be offering calibration services under different categories

i. Permanent laboratory service

ii. Onsite service

The above category of laboratories may provide following types of services.

a) Service that intended primarily for measurement standards, reference equipments which are further used for calibration purposes or high accuracy measurements which requires high degree of accuracy and better CMC.

b) Service that intended primarily for calibration and adjustment of test, measurement and diagnostic equipments to use in such areas as product testing, manufacturing and servicing.

Accommodation and environmental conditions adversely affect the results of calibration and measurement accuracy unless they are controlled and monitored. Hence, they play a very important role.

The influencing parameters may be one or more of the following i. e. temperature, relative humidity, atmospheric pressure, vibration, acoustic noise, dust particle, air currents/draft, illumination(wherever applicable), voltage fluctuations, electrical earthing and direct sunlight etc., depending on the nature of calibration services provided. The variables described above can play a major factor on calibration results.

The main difference between the permanent laboratory and onsite calibration services has to do with environmental conditions only. Since the onsite calibration relies on where the service is provided, it affects the results of calibration (refer NABL 130).

The laboratories are advised to follow the requirement of accommodation and environment depending on the types of services provided as recommended

- By the manufacturers of the reference equipment.
- By the manufacturers of the Unit under calibration.
- As specified in the National/ International Standards or guidelines followed for the calibration.

The environmental monitoring equipments used should also meet the requirement of manufacturers' recommendations and specifications as per the relevant standards followed.

If, accommodation and environmental conditions are not specified either by manufacturer or by National/International standards / guidelines, the laboratory shall follow the below recommendations.

1.4.1 Vibration

The calibration area shall be free from vibrations generated by central air-conditioning plants, vehicular traffic and other sources to ensure consistent and uniform operational conditions. The laboratory shall take all special/ protective precautions like mounting of sensitive apparatus on vibration free tables and pillars etc., isolated from the floor, if necessary.

1.4.2 Acoustic Noise

Acoustic noise level in the laboratory shall be maintained to facilitate proper performance of calibration work. Noise level shall be maintained less than 60 dBA, wherever it affects adversely the required accuracy of measurement.

1.4.3 Illumination

The calibration area shall have adequate level of illumination. Where permissible, fluorescent lighting is preferred to avoid localized heating and temperature drift. The recommended level of illumination is 250-500 lux on the working table.

1.4.4 Environmental Conditions and Monitoring

The environmental conditions for the activity of the laboratory shall be such as not to adversely affect the required accuracy of measurement. Facilities shall be provided whenever necessary for recording temperature, pressure and humidity values prevailing during calibration. The atmospheric conditions maintained in the laboratory during calibration shall be reported in the calibration report/ certificate.

1.5 Special Requirements of Laboratory

1.5.1 The calibration laboratory shall make arrangements for regulated and uninterrupted power supply of proper rating. The recommended voltage regulation level is ±2% or better, and Frequency variation ± 2.5 Hz or better on the calibration bench.

1.5.2 The reference standards shall be maintained at temperatures specified for their maintenance on order to ensure their conformance to the required level of operation.

1.5.3 The laboratory shall take adequate measures against dust and external air pressure.

1.6 Safety Precautions

1.6.1 Relevant fire extinguishing equipment for possible fire hazards shall be available in the corridors or convenient places in the laboratory. Adequate safety measures against electrical, chemical fire hazards must be available at the work place. Laboratory rooms/ areas where highly inflammable.

1.7 Other Important Points

1.7.1 **Entry to the Calibration Area:** As far as possible, only the staff engaged in the calibration activity shall permitted entry inside the calibration area.

1.7.2 **Space in Calibration Area**: The calibration Laboratory shall ensure adequate space for calibration activity without adversely affecting the results.

1.8 Proficiency Testing

To give further assurance to the accuracy or Uncertainty of measurements, a laboratory will be required to participate, from time to time, in Proficiency Testing Program. The laboratory shall remain prepared to participate in the Proficiency Testing Program through inter-laboratory, inter-comparison schemes wherever it is technically feasible. (Ref. NABL 162, 163 and 164 for further details)

2 Specific Requirements – Verification of Hardness Testing Machine

2.1 Scope: Verification of Hardness Testing Machine

Sl. No.	Description	Relevant Standard	Permanent Facility	Onsite Calibration	Mobile Facility
1	Rockwell Hardness	ISO 6508-2	√*	√	X
2	Brinell Hardness	ISO 6506-2	√*	√	X
3	Vickers Hardness	ISO 6507-2	√*	√	X
4	Knoop hardness	ISO 4545-2	√*	√	X
5	Rubber - Calibration and Verification of Hardness Testers - Durometers	ISO 18898-2012, ASTM-D-2240-05	√	X	X

***Note 1:** Verification of Hardness Testing Machine at permanent facility is acceptable. However, verification of performance shall be carried out after installation and commissioning of Hardness Testing Machine at site.

Note 2: This technical requirement is based on the above mentioned standards**.** Lab may follow any relevant standard, however care shall be taken to follow the requirements in totality.

2.2 National/ International Standards, References and Guideline

- ISO 6508-2:2005- Metallic material-Rockwell Hardness Test- part-2 –verification and calibration of the testing machine.
- ISO 6506-2:2005 – Metallic material-Brinell Hardness Test -part-2 –Verification and calibration of the testing machine.
- ISO 6507-2:2005 – Metallic material-Vickers Hardness Test -part-2 –Verification and calibration of the testing machine.
- ISO 4545-2:2005– Metallic material-Knoop Hardness Test -part-2 - Verification and calibration of the testing machine.
- ISO 18898 – Rubber - Calibrations and Verification of Hardness Tester.
- ISO 18899 – Rubber – Guide to the Calibration of Test Equipment.
- ASTM-D-2240-05 – Standard test method for Rubber Property – Durometer Hardness.

2.3 Metrological Requirements

2.3.1 The condition of indenters should be monitored by visually checking the aspect of the indentation on a reference block, each day the testing machine is used.

2.3.2 The verification of the indenter is no longer valid when the indenter shows defects, reground or otherwise repaired indenters shall be verified.

2.3.3 In the case of direct verification of hardness testing machine each measurement force applied shall be within ± 1.0% of accuracy.

2.3.4 The force shall be measured by means of a force proving instrument in accordance with ISO 376 - class1or IS 4169 - class 0. By balancing against a force, accurate to ± 0.2 %, applied by means of calibrated masses or another method with the same accuracy.

2.3.5 For indirect verification, the reference blocks shall be calibrated in accordance with ISO 6506-3 (For Brinell), ISO 6507-3 (For Vickers), ISO 6508-3 (For Rockwell) & ISO 4545-3 (For Knoop Hardness).

2.3.6 For indirect verification, the difference between the mean measured value and the certified mean diameter shall not exceed 0.5%.

2.3.7 The error of the measuring device, expressed as a percentage of the assigned length of the mean indentation diagonal of each reference indentation, shall be not more than 1%.

2.3.8 IS 4545-2 for verification and Calibration of Knoop Hardness Testing machine covers test forces from 0.09807 N to 19.614 N.

2.3.9 Three readings shall be taken for each test force. Immediately before each reading is taken, the indenter shall be moved in the same direction as during the test. All readings shall be within the tolerances defined in Table 1.

2.3.10 The indenter (Diamond) shall be calibrated, conforming to the requirements of geometrical deviations.

2.3.11 On each reference block, five indentations shall be made & measured.

2.3.12 For the calibration and verification of Hardness Testers- Durometers the measurands of indenter and pressure foot for the instruments to be calibrated are depicted in figures 1 to 6 of ISO 18898 (table 1 to 9).

2.4 Terms and Definitions

Brinell Hardness Testing Machine

- The **Brinell Scale** characterizes the indentation hardness of materials through the scale of penetration of an indenter, loaded on a material test-piece.

Rockwell Hardness Testing Machine

- The **Rockwell Scale** is a hardness scale based on indentation hardness of a material. The Rockwell test determines the hardness by measuring the depth of penetration of an indenter under a large load compared to the penetration made by a preload. There are different scales, denoted by a single letter, that use different loads or indenters. The result is a dimensionless number noted as HRA, where A is the scale letter.

Vickers Hardness Testing Machine

- **Vickers** is as an alternative to the Brinell method to measure the hardness of materials. The Vickers test is often easier to use than other hardness tests since the required calculations are independent of the size of the indenter, and the indenter can be used for all materials irrespective of hardness. The unit of hardness given by the test is known as the Vickers Pyramid Number (HV) or Diamond Pyramid Hardness (DPH).

Knoop Hardness Testing Machine

- The **Knoop Hardness Test** is a micro hardness test – a test for mechanical hardness used particularly for very brittle materials or thin sheets, where only a small indentation may be made for testing purposes.

2.5 Selection of Reference Standard

- Rockwell Hardness Blocks
- Brinell Hardness Blocks
- Vickers Hardness Blocks
- Knoop hardness Blocks

2.6 Calibration Interval

Reference Equipment	Recommended Interval
Rockwell Hardness Blocks	2 year
Brinell Hardness Blocks	2 year
Vickers Hardness Blocks	2 year
Knoop hardness Blocks	2 year
Load Cell	26 Months
Mass	3 Years
Depth Measuring Instruments	1 Year

Also, Calibration Interval with valid traceability will be accepted.

2.7 Environmental conditions required for calibration and requirement of Environmental monitoring System

2.7.1 Ambient temperature may have considerable influence on the results of hardness measurements, especially if small lengths have to be determined. The lower limit for Vickers indentations is 20 µm, and the minimum depth for Rockwell scales N and T is only 6 µm to 7 µm & for Knoop hardness indentations with diagonals ≥ 0.020 mm. According to the relevant standards, the temperature ranges are (23±5) °C.

2.7.2 Vibrations, electrical interference and lack of cleanliness, can cause significant problems that are difficult to quantify. Micro hardness measurements of course require an absolutely vibration-free environment, whereas vibration requirements for test forces above 200 mN are not so critical.

2.7.3 For the calibration and verification of Hardness Testers- Durometer the ambient temperature of the measurement room in which the calibration or verification is carried out shall be 18 °C to 25 °C.

2.7.4 Recommended Environmental monitoring equipment:

- Temperature with a resolution of 0.1°C.
- Humidity with a resolution of 1% RH.

However, laboratory should evaluate the requirement of accuracy, resolution and uncertainty depending on the CMC aimed at.

2.8 Methods for Verification

The requirements for a comprehensive service to meet the needs of industry for the established scales of hardness, together with the specific requirements of current Standards, have been divided into two categories as follows:

2.8.1 Indirect verification of testing machines

For each scale of hardness a laboratory will require requisite sets of standardized test blocks and standard indenters, together with the apparatus necessary to carry out the preliminary inspection of the testing machine. The standardized test blocks and indenters will require periodic re-standardization.

2.8.2 Direct verification of testing machines

Direct verification of testing machines, which have passed indirect verification, requires verification of loads, indenters and the measuring device.

2.9 Measurement Uncertainty

2.9.1 A procedure for the estimation of uncertainty in hardness measurement by the indirect calibration method:

Step 1. Identifying the Parameters for Which Uncertainty is to be estimated

The first step is to list the quantities (measurands) for which the uncertainties must be calculated. Table 1 shows the parameters that are usually reported in hardness measurements by the indirect calibration method. None of these measurands are measured directly, but are determined from others quantities (or measurements).

Table 1 Measurands, their units and symbols

Measurands	Units and Symbol
Rockwell hardness	HR (Scale)
Brinell hardness	HBW
Vickers hardness	HV
Knoop hardness	KH

Table 2 Measurements, their units and symbols

Measurements	Units	Symbol
Permanent increase in depth of penetration under preliminary test force after removal of additional force	0.002mm (regular scale) 0.001mm (superficial scale)	H
Single diameter of the indention	Mm	d1(HB) , d2(HB)
Single diagonal of the indention	mm	d1(HV) , d2(HV)

Step 2. Identifying all Sources of Uncertainty in the Test

- Uncertainty due to calibration of reference blocks
- Uncertainty of maximum permissible error according the standards
- Uncertainty due to repeatability at certain test conditions

2.9.2 Mathematical Formulae for Estimating Uncertainties in Hardness Measurement by the Indirect Calibration Method:

Procedure:

2.9.2.1 Certified value of the CRM (Certified Reference Material)

CRM ... Mean value of five measurements

CRM ... Uncertainty of the mean value calculated by the calibration laboratory. It is the 2-Sigma uncertainty (confidence level: 95%).

2.9.2.2 Determination of users machine repeatability

a) Mean value

$$H= \frac{H_1+H_2+H_3+H_4+H_5}{5} \qquad (3)$$

b) Repeatability according EN ISO 6506, 6507, and 6508

d_5 - d_1 (Vickers; EN ISO 6507 and Brinell; EN ISO 6506) (4)

c) Empirical standard deviation of a single value

$$s_n = \sqrt{\frac{1}{(n-1)}\sum_{i=1}^{n}(Hi - \overline{H})2} \;, n=5 \qquad (5)$$

2.9.2.3 Assessment according EN ISO 6506, 6507, and 6508

a) Estimation of the error (E) of a laboratory testing device by n repeated measurements on the same CRM

$$E = X\ CRM - \overline{H} \qquad (6)$$

The error (E) shall not exceed the values given in Table 2 of EN ISO 6506-2, Table 5 of EN ISO 6507-2, and Table 5 of EN ISO 6508-2.

b) Permissible repeatability values given in Table 2 of EN ISO 6506-2, Table 4 of EN ISO 6507-2, and Table 5 of EN ISO 6508-2.

2.9.2.4 Measure on a material by n1 repetition

a) Mean Value

$$\overline{X} = \frac{\sum_{i=1}^{n} x_i}{n_i} \qquad (7)$$

b) Empirical standard deviation of a single value

$$s_n = \sqrt{\frac{1}{(n_1-1)}\sum_{i=1}^{n1}(x_i - \overline{x})^2} \qquad (8)$$

2.9.2.5 In order to estimate the uncertainty of the mean value, x, following mathematical model has been used.

Combined uncertainty

$$u_{C\overline{X}}^{\;2} = E_w^{\;2} + u_{CRM(i\sigma)}^{\;2} + u_{\overline{H}}^{\;2} + u_{\overline{x}}^{\;2} + \cdots \qquad (9)$$

Expanded uncertainty

$u(\bar{x}) = k\,u_c(\bar{x})$; k = 2 (10)

a) The permissible error (E 2σ) is a 2-Sigma error (normal distribution is assumed), therefore

$$E1\sigma = \frac{E_{2\sigma}}{2} \quad (11)$$

b) The uncertainty uCRM is a 2-Sigma uncertainty, therefore

$$u_{CRM(}1\sigma) = \frac{u_{CRM(2\sigma)}}{2}$$

(12)

c) The uncertainty of $\bar{H}$ (mean value of users machine on CRM)

$$u_{\bar{H}} = \frac{t s_{\bar{H}}}{\sqrt{n}} \quad (13)$$

t ... Student coefficient for 'n' and P = 68.27%

d) The uncertainty of $\bar{x}$ (measurements on a material)

$$u_{\bar{x}} = \frac{t s_x}{\sqrt{n_1}} \quad (14)$$

t ... Student coefficient for 'n1' and P = 68.27%
n1 ... at least 5 repetitions; Eqn. 14 would be valid for n1 ≥ 2

Where

ci	sensitivity coefficient
CoP	Code of Practice
d(x)	diameter or diagonal of the indention (i.e. d1(HB))
dv	divisor used to calculate the standard uncertainty
E	exactness of impact testing machine
F_1	additional force
F_o	preliminary test force
h	permanent increase in depth
HB	Brinell hardness
hM	measurement for the difference in depth
HR	Rockwell hardness
HV	Vickers hardness
k	coverage factor used to calculate expanded uncertainty (normally corresponding to 95% confidence level)
N	number of input parameters xi on which the measurand depends
n	number of repeat measurements
p	confidence level
s	experimental standard deviation (of a random variable) determined from a limited number of measurements, n
U	expanded uncertainty
u	standard uncertainty
uc	combined standard uncertainty
V	value of the measurand
xi	estimate of input quantity
x	arithmetic mean of the values of the random variable xi
y	test (or measurement) mean result

Contribution to uncertainty of measurement (Knoop Hardness Testing Machine):

1) Direct Verification:

- Uncertainty due to measurement of the hardness testing machine (Type A).
- Uncertainty due to force transducer (From calibration certificate).
- Uncertainty due to test force generated by the hardness testing machine.
- Uncertainty due to temperature.
- Uncertainty due to long-term stability.
- Uncertainty due to interpolation deviation.
- Uncertainty due to object micrometer/optical measuring system (from calibration certificate).
- Uncertainty due to the resolution of the measuring system.

2) Indirect Verification:

- Uncertainty due to measurement of the hardness testing machine (Type A).
- Uncertainty due to reference hardness block (From calibration certificate).
- Uncertainty due to the resolution of the hardness testing machine.

2.9.3 Uncertainty components for Indentation Depth:

- Uncertainty of length measuring device.
- Standard deviation of length measurements.

2.9.4 Uncertainty components for Force Verification:

- Uncertainty of applied force.
- Standard deviation of force measurements.

2.10 Evaluation of CMC

2.10.1 Refer NABL 143 for CMC evaluation.

2.10.2 CMC value is not the same as expanded uncertainty reported in the calibration Certificate/Report. CMC values exclude the uncertainties which are attributed to the UUT (Unit under test/calibration).

2.10.3 For the purpose of CMC evaluation the following components shall be considered.

- Uncertainty of the applied torque.
- Repeatability of the artifact (10 reading at 3 rotation of position for minimum and maximum value of the range).

2.11 Sample Scope

Sample Recommended Scope: An illustrative example

Laboratory: XYZ							Date(s) of Visit:
Discipline: Mechanical							
Sl	**Parameter* / Device under calibration**	**Master equipment used**	**Range(s) of measurement**	**Calibration and Measurement Capability ****			**Remarks+/ Method used**
				Claimed by Laboratory	**Observed by Assessor**	**Recommended by Assessor**	
1	Rockwell Hardness Testing Machine	Standard Blocks	HRA HRB HRC	0.9 HRA 0.9 HRB 0.9 HRC	1.0 HRA 1.0 HRB 1.0 HRC	1.0 HRA 1.0 HRB 1.0 HRC	Using Standard Blocks by Indirect method As per ISO 6508-2-2005
2	Brinell Hardness Testing Machine	Standard Blocks	HBW 2.5/187.5 HBW 5/750 HBW 10/3000	1.0 % 1.0 % 1.0 %	1.2 % 1.2 % 1.2 %	1.2% 1.2% 1.2%	Using Standard Blocks by Indirect method As per ISO 6506-2:2005
3	Vickers Hardness Testing Machine	Standard Blocks	HV 5 HV 10 HV 20 HV 30 HV 50	1.6 % 1.4 % 1.6 % 1.6 % 1.6 %	1.7% 1.6% 2.2% 1.7% 1.7%	1.7% 1.6% 2.2% 1.7% 1.7%	Using Standard Blocks by Indirect method As per ISO 6507-2:2005

* *Only for Electro-technical discipline; scope shall be recommended parameter wise (where applicable) and the ranges may be mentioned frequency wise.*

** *NABL 143 shall be referred for the recommendation of CMC*

+ *Remarks shall also include whether the same scope is applicable for site calibration as well. NABL 130 shall be referred while recommending the scope for site calibration.*

Signature, Date & Name of Lab Representative	Signature, Date & Name of Assessor(s)	Signature, Date & Name of Lead Assessor

2.12 Key Points

Demonstration of any CMC values doesn't automatically qualify for granting accreditation until the lab satisfies the stipulated requirement given in this document.

ANNEXURE-I

Table-1: Brinell Hardness Testing Machine (HBW): Repeatability and Error of the Testing Machine

Hardness of the reference block HBW	Permissible repeatability of the testing machine %	Permissible Error, of the testing machine % of H
≤ 125	3.0	± 3.0
125 < HBW ≤ 225	2.5	± 2.5
>225	2.0	± 2.0

Table-2: Hardness Testing Machine (HRW): Maximum Permissible Error

Rockwell Hardness Scale	Hardness Range of the Standardized Block		Maximum Permissible Error Rockwell Units
	Up to and including		
(1)	**(2)**	**(3)**	**(4)**
A	20	75 HRA	± 2 HRA
	>75	88 HRA	± 1.5 HRA
B	20	45 HRB	± 4 HRB
	>45	80 HRB	± 3 HRB
	>80	100 HRB	± 2 HRB
C	20	70 HRC	± 1.5 HRC
D	40	70 HRD	± 2.5 HRD
	>70	77 HRD	± 1.5 HRD
E	70	90 HRE	± 2.5 HRE
	>90	100 HRE	± 2 HRE
F	60	90 HRF	± 3 HRF
		100 HRF	± 2 HRF
G	30	50 HRG	± 6 HRG
	>50	75 HRG	± 4.5 HRG
	>75	94 HRG	± 3 HRG
H	80	100 HRH	± 2 HRH
K	40	60 HRK	± 4 HRK
	>60	80 HRK	± 3 HRK
	>80	100 HRK	± 2 HRK
15 N	70	90 HR 15 N	± 1.5
30 N	42	80 HR 30 N	± 1.5
45 N	20	70 HR 45 N	± 1.5
15 T	73	93 HR 15 T	± 2.5
30 T	43	82 HR 30 T	± 2.5
45 T	12	72 HR 45 T	± 2.5

Table-3: Vickers Hardness Testing Machine: Maximum Permissible Error (in %)

Hardness	Hardness, HV															
Symbol	**50**	**100**	**150**	**200**	**250**	**300**	**350**	**400**	**450**	**500**	**600**	**700**	**800**	**900**	**1000**	**1500**
HV 0.01																
HV 0.015	10															
HV 0.02	8															
HV 0.025	8	10														
HV 0.05	6	8	9	10												
HV 0.1	5	6	7	8	8	9	10	10	11							
HV 0.2		4		6		8		9		10	11	11	12	12		
HV 0.3		4		5		6		7		8	9	10	10	11	11	
HV 0.5		3		5		5		6		6	7	7	8	8	9	11
HV 1		3		4		4		4		5	5	5	6	6	6	8
HV 2		3		3		3		4		4	4	4	4	5	5	6
HV 3		3		3		3		3		3	4	4	4	4	4	5
HV 5		3		3		3		3		3	3	3	3	3	4	4
HV 10		3		3		3		3		3	3	3	3	3	3	3
HV 20		3		3		3		3		3	3	3	3	3	3	3
HV 30		3		3		2		2		2	2	2	2	2	2	2
HV 50		3		3		2		2		2	2	2	2	2	2	2
HV 100				3		2		2		2	2	2	2	2	2	2

NOTES

1. Values are not given when the length of the indentation diagonal is less than 0.020 mm.

2. For intermediate values, the maximum permissible error may be obtained by interpolation.

3. The values for micro hardness testing machines are based on a maximum permissible error of 0.001 mm or 2% of the mean diagonal length of indentation, whichever is the greater.

Table-4: Knoop Hardness Testing Machine (KH):

Direct Verification	Recommended Test forces	
Hardness scale	**Test force value, *F***	
	N	**approximate kgf[a] equivalent**
HK 0,001	0,0098 07	0,001
HK 0,002	0,0196 1	0,002
HK 0,005	0,0490 3	0,005
HK 0,01	0,098 07	0,010
HK 0,02	0,196 1	0,020
HK 0,025	0,245 2	0,025
HK 0,05	0,490 3	0,050
HK 0,1	0,980 7	0,100
HK 0,2	1,961	0,200
HK 0,3	2,942	0,300
HK 0,5	4,903	0,500
HK 1	9,807	1,000
HK 2	19,614	2,000

[a] Not an SI unit.

Direct Verification **Test–Force Tolerances:**

Table-5

Test Force 'N'	Tolerance %
0.09807 ≤ F < 1.961	**± 1.5**
1.961 ≤ F ≤ 19.614	**± 1.0**

<u>Indirect Verification</u> - Relative Repeatability:

Table-6

Hardness range of standardized test blocks	**Test Force 'N'**	**Maximum Permissible Error 'r ref' %**
100 ≤ HK ≤ 250 250 < HK ≤ 650 HK > 650	0.09807 ≤ F ≤ 4.903	9 5 4
100 ≤ HK ≤ 250 250 < HK ≤ 650 HK > 650	4.903 < F ≤ 19.614	8 5 4

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