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TOYOTA ENGINEERING STANDARD

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TITLE : HARDNESS TEST METHODS FOR METALS

CLASS : C2

PUBLICATION RECORD

This standard has been revised in consequence of the following changes:
(1) terms and explanations have been modified in part.
(2) the International System of Units (SI) has been used as a sole basis of units and numerical values.

Engineering Information
Planning Dept.
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HARDNESS TEST METHODS FOR METALS

1. Scope

This standard covers general rules in the hardness tests of automobile metallic materials and parts.

Remark:
For sintered metals (sintered materials and parts), refer to TSG2500G.

2. Classification of Hardness

Hardness is classified into the three types listed in Table 1. For research, process control and other purposes, any other appropriate types of hardness may be used.

Table 1 Classification

Classification		Code
Vickers hardness		HV
Brinell hardness		HB
Rockwell hardness	Scale-B	HRB
	Scale-C	HRC

3. Hardness Test Methods

3.1 Vickers Hardness Test Method

3.1.1 Test Procedure

The test procedure is as follows:

(1) Carry out the test using the tester specified in Appendixes 1 and 2 under the test conditions specified in Table 2.

Table 2 Vickers Hardness Test

Item	Test condition	Remark
Indenter	Diamond pyramidal penetrator with interfacial angle of 136°	---
Test load	Normal-type vickers hardness tester (Appendix 1) (9.8), 49, 98, 196, 294, 490 N	Loads shown in ( ) are not preferably used.
	Vickers microhardness tester (Appendix 2) (0.49), (0.98), 1.96, 2.94, 4.90, 9.8 N	
Load increase time (s)	4 to 8	---
Load retention time (s)	Normally 10	
Test temperature (℃)	10 to 35	

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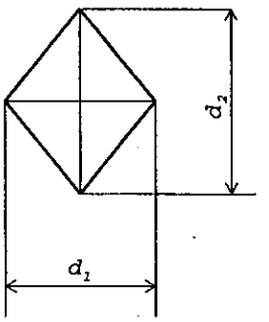
(2) After removal of the test load, measure the diagonal width of the permanent indentation on the test surface d_1 and d_2 (Fig. 1) using a measuring microscope, and find the mean value d (mm).



Mean value $d = \frac{d_1 + d_2}{2}$

Fig. 1 Measurement of Indentation

Calculate the Vickers hardness (HV) using the following equation (1) by dividing the load by the surface area of the indentation. The quotient has a dimension of N/mm^2, but express it as an absolute number.

$$HV = \frac{2P}{9.8d^2} \sin\frac{\alpha}{2} = 0.18909\frac{P}{d^2} \text{ ---------- (1)}$$

where,
P: test load (N)
α: interfacial angle of penetrator (=136 °)

The hardness is generally obtained from P and d on the quick reference table.

(3) Precautions in implementing the test are listed below:
(a) The test surface should be flat. It is desirable to form a very small plane to be used as the test surface even if the test specimen is cylindrical or spherical.
(b) It is desirable to prepare the test surface to a finish as fine as or finer than #600 emery paper finish (for Vickers hardness test) or wet buffing finish (for Vickers microhardness test).
(c) Grease or other substances that may alter the coefficient of friction shall be absent on the test surface and the penetrator surface.
(d) The inclination of the test surface with respect to the tester table surface shall be 2 ° or less.
(e) The test load should be as heavy as possible unless there is a limitation.
(f) No vibration shall be applied during the application of the test load.
(g) The removal of the test load shall be done gently without causing shock.

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(h) The size of the specimen and the location of the indentation shall meet the specifications in Table 3, where *d* (mm) represents the mean value of a diagonal width of the indentation.

Table 3 Size of Specimen and Location of Indentation

Thickness of specimen	Width of specimen	Center-to-center distance between indentations	Distance between specimen edge and center of indentation
1.5*d* min.	5*d* min.	2.5*d* min.	

(i) The measuring microscope may be used to measure the diagonal length of the indentation within the range 20 to 70 % of the field of vision.

(j) Make sure that the zero-point of the measuring counter is properly adjusted and that the micrometer ocular is in place.

(k) To find the Vickers hardness number on the quick reference table, it is desirable that the mean diagonal length *d* (mm) of the indentation be obtained to 0.0005 mm, then the hardness number calculated by proportional interpolation. When finding the Vickers microhardness number on the quick reference table, it is desirable that *d* (mm) be obtained to 0.0001 mm.

3.1.2 Reporting

(1) The Vickers hardness shall be denoted in the order of the digits of hardness value followed by the symbol of hardness. The symbol of hardness consists of the two English capital letters representing Vickers hardness, HV, followed by a numerical value proportional to the test load. Table 4 shows the symbols of hardness representing different test loads.

Table 4 Correspondence between Symbols of Hardness and Test Loads

Symbol of hardness	HV0.05	HV0.1	HV0.2	HV0.3	HV0.5	HV1	HV5	HV10	HV20	HV30	HV50
Test load (N)	0.49	0.98	1.96	2.94	4.90	9.8	49	98	196	294	490

Example:
700 HV0.1 ---- Hardness value 700, test load 0.98 N
300 HV30 ---- Hardness value 300, test load 294 N

(2) If the test load is obvious or if the hardness indication is not dependent on the test load, it may be omitted.

Remark:
The Vickers hardness test result is not dependent on the test load if the surface and inside of the specimen are homogeneous. However, for the measurement of a thin hardened layer, decarburized layer, or restricted area, an appropriate test load should be selected.

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(3) Round the number according to Table 5:

Table 5 Rounding the Number (HV)

Hardness	Rounding	Example
100 HV min.	Round to the nearest whole number	251 HV
50 HV and over to 100 HV excl.	Round to the nearest tenth	85.5 HV
Under 50 HV		49.1 HV

(4) If the test conditions are different from those specified by the standard and the difference appears to affect the test results, report the conditions used.

3.2 Brinell Hardness Test Method

3.2.1 Test Procedure

The test procedure is as follows:

(1) Carry out the test using the tester specified in Appendix 3 under the test conditions specified in Table 6.

Table 6 Brinell Hardness Test

Item	Test condition
Penetrator	Tungsten carbide alloy ball with 10 mm diameter, normally
Test load (N)	29400
Load increase time (s)	4 to 8
Load retention time (s)	Normally 10
Test temperature (℃)	10 to 35

(2) After removal of the test load, measure the diameter of the permanent indentation on the test surface in two perpendicular directions d_1 and d_2 (Fig. 2) using a measuring instrument, and find the mean value d (mm). Calculate the Brinell hardness (HB) using the following equation (2) by dividing the load by the surface area of the indentation. The quotient has a dimension of N/mm^2, but express it as an absolute number.

$$HB = \frac{2P}{\pi D\left(D-\sqrt{D^2-d^2}\right)\times 9.8} \quad \text{---------} \quad (2)$$

where,

P: test load (N)

D: diameter of penetrator (mm)

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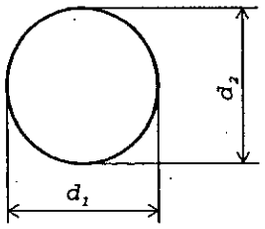

Fig. 2 Measurement of Indentation

The hardness is generally obtained from P, D and d on the quick reference table.

(3) Precautions in implementing the test are listed below:

(a) The test surface should be flat.

(b) The test surface shall be machined or polished to a smooth finish.

(c) Grease or other substances that may alter the coefficient of friction shall be absent on the test surface and the penetrator surface.

(d) The diameter of the permanent indentation d should be 0.2 to 0.5 times the diameter of the penetrator D. Especially hard objects that may cause a permanent deformation of the penetrator shall not be tested. Due to this restriction on indentation size, the lower limit for the specimen hardness is 140 HB. The upper limit is 600 HB even for cemented carbide balls.

(e) The specimen size and the spacings of indentation should meet the specifications in Table 7, where d represents the mean value of a diameter of the penetrator:

Table 7 Size of Specimen and Location of Indentation

Thickness of specimen	Width of specimen	Center-to-center distance between indentations	Distance between specimen edge and center of indentation
1.5d min.	5d min.	2.5d min.	

(f) Do not apply vibration during the application of test load

(g) Measuring instruments with a minimum scale of 0.05 mm are generally used for the measurement of indentation diameter, but it is desirable to use a measuring instrument with a minimum scale of 0.01 mm.

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3.2.2 Reporting

(1) The reporting method shall be as follows:

○○○HB

To clarify the penetrator diameter or the test load, they shall be indicated as in the following example:

Example:

○○○HB5/750 ----- with 5 mm ball and 7350 N load

If the test conditions are different from those specified by the standard and the difference appears to affect the test results, report the conditions used.

(2) Round the number according to Table 8:

Table 8 Rounding the Number (HB)

Hardness	Rounding	Example
100 HB min.	Round to the nearest whole number	211 HB
50 HB and over to 100 HB excl.	Round to the nearest tenth	58.5 HB
Under 50 HB		46.1 HB

3.3 Rockwell Hardness Test Method

3.3.1 Test Procedure

The test procedure is as follows:

(1) Carry out the test using the tester specified in Appendix 4 under the test conditions specified in Table 9.

Table 9 Rockwell Hardness Test

Item	Test condition	
	Scale-C	Scale-B
Penetrator	Diamond spheroconical penetrator forming an angle of 120 ° with an apex 0.2 mm in radius	Steel ball 1.588 mm in diameter
Standard load (N)	98	
Test load (N)	1470	980
Load increase time (s)	4 to 8	
Load retention time (s)	Normally 10	
Test temperature (℃)	10 to 35	

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(2) Under the standard load, measure the difference in the indentation depth before and after the test load application h (mm) (Fig. 3).

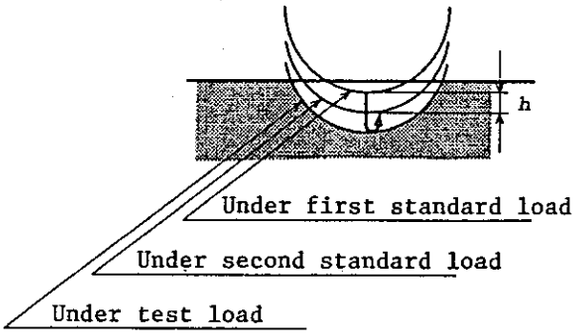

Fig. 3 Measurement of Deformation

Calculate the Rockwell hardness (HRC and HRB) from h (mm) using the following equations (3) and (4). The results have a dimension of length, but express them as an absolute number.

$$HRC = 100-500h \quad \text{---------- (3)}$$

$$HRB = 130-500h \quad \text{---------- (4)}$$

Testers in service give the hardness as ther indication of the pointer interlocked with the penetrator motion. When using such a tester, read the hardness number to the first decimal place.

(3) Precautions in implementing the test are listed below:

(a) The test surface and the opposite surface should be flat and parallel. If the opposite surface is not flat enough, use a spot anvil with a small contact surface.

(b) The test surface shall not displace during the measurement of the Rockwell hardness since the measurement is taken directly from the displacement of the penetrator. Therefore, supporting the specimen by using a vice or jig or by embedding in resin, or tests on the outer circumference of circular objects (ring tube, not, etc.) should be avoided since the rigidity and the setting condition of the specimen affect the hardness number significantly.

(c) The test surface shall be polished (the finish may be rougher than required for Vickers hardness). It is also desirable to polish the opposite surface to a similar fineness.

(d) The inclination of the test surface with respect to the table surface shall be 1 ° or less.

(e) Grease or other substances that may alter the coefficient of friction shall be absent on the test surface and the penetrator surface.

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(f) It is recommended that the specimen size and the location of indentation meet the specifications in Table 10, where *d* (mm) represents the mean value of a diameter of the indentation.

Table 10 Size of Specimen and Location of Indentation

Thickness of specimen	Width of specimen	Center-to-center distance between indentations	Distance between specimen edge and center of indentation
1.5*d* min.	5*d* min.	2.5*d* min.	

(g) When the penetrator is replaced, carry out a preliminary operation (same as the measuring procedure of hardness) before using for a test.

(h) In setting the minor load, if the pointer stands within 5 divisions from the upper center of the scale, regard the load as 98 N and set the scale to zero without fine adjustment. If the pointer has overreached by 5 divisions or more, readjustment is ineffectual and the measurement is invalidated.

(i) Do not apply vibration during the application of the loads.

(j) The load increase time is the duration after the needle starts moving until it stops moving quickly, not until the lever is completely tilted.

(k) The load retention time is the time after the needle stops moving quickly until the load is removed.

3.3.2 Reporting

(1) The reporting method shall be as follows:

○○HRC ----- Scale-C hardness

○○HRB ----- Scale-B hardness

If the test conditions are different from those specified by the standard and the difference appears to affect the test results, report the conditions used.

(2) Round the number according to Table 11:

Table 11 Rounding the Number (HR)

Hardness	Rounding	Example
50 HRC min.	Round to the nearest tenth	53.5 HRC
Under 50 HRC	Round to the nearest whole number	48 HRC
HRB		63 HRB

Applicable Standard

TSG2500G Hardness Test Method for Sintered Metal Materials

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APPENDIX 1 VICKERS HARDNESS TESTING MACHINES (BASED ON JIS B 7725)

1. Scope

This Appendix 1 covers the Vickers hardness testing machines, hereinafter referred to as the "testing machines", for measuring Vickers hardness according to the load in the range of 9.807 to 490.3 N.

2. Construction

The testing machine shall be composed of machine frame, sample holder, loading apparatus, and measuring microscope and be provided with a indenter.

3. Performances

3.1 Functions

The testing machine shall be the machine of which axis of indenter is mounted perpendicularly to the sample receiving stand, and which is capable of carrying out adequately the application, retention removing of load, formation of accurate indentation and measuring of indentation.

3.2 Loading Apparatus

The loading apparatus shall be in accordance with the following:

(1) The loading apparatus shall not be accompanied with shock, vibration, etc., and be to apply, retain and remove the specified load at or from the tip of the indenter.

(2) The mean value of the loads and dispersion shall comply with following (a) and (b):

(a) The tolerances of mean value of loads shall be within ±1.0 % relative to the nominal load. Provided that the error of the mean value of loads shall be in accordance with equation (1):

$$\text{Error of mean value}\ (\%) = \frac{\text{Mean value of loads - Nominal load}}{\text{Nominal load}} \times 100 \quad \text{----- (1)}$$

(b) The permissible value of dispersion of repeating loads shall be within 0.5 % of nominal load. Provided that the dispersion shall be in accordance with the equation (2):

$$\text{Dispersion}\ (\%) = \frac{\text{Maximum value - Minimum value}}{\text{Nominal load}} \times 100 \quad \text{----- (2)}$$

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3.3 Indenter

3.3.1 Shape of Indenter

The shape of indenter shall be as follows:

(1) The tip of the indenter shall be a right pyramid with a square base having the angle between the opposite faces of $136 \pm 0.5^\circ$.

(2) The difference to each other of inclination of four faces relative to the central axis of the indenter shall be within 0.5°.

(3) The four faces shall meet in a point at the vertex and the length of any line of junction generated by the opposite faces shall be not more than 1 μm.

3.3.2 Finish of Indenter

The part of diamond of indenter to come in contact with sample shall be of sufficiently polished faces and be free from cracks or surface flaws. The edges on surfaces must be sharp.

3.4 Measuring Microscope

The measuring microscope shall be as follows:

(1) The measuring microscope to measure the length of diagonals of indentation shall be capable of offering a clear shape of indentation and taking accurate measurements of the length of diagonals of indentation.

(2) The permissible error of the scale of measuring microscope shall be within ± 0.5 % relative to the measuring length. However, in the range of measuring length of not more than 200 μm, it shall be within ± 1 μm.

Remark:

In the case where the measuring length ℓ (μm) is not more than 200 μm, it is desirable that the permissible error of scale is $\pm(0.2 \pm 0.004\ell)$ μm.

3.5 Overall Error of Testing Machine

The overall error of testing machine shall be evaluated according to the measurement of hardness of the standardized block. The tolerances (permissible value of error, reliability of 95 %) of mean value relative to the hardness of standardized block and the permissible value of dispersion shall be the value as given in Appendix 1 Table 1. Provided that the measurement of hardness shall be carried out at three points. Further, the error of the mean value and the dispersion shall be in accordance with equations (3) and (4):

$$\text{Error of mean value } (\%) = \frac{\text{Mean value - Hardness of standardized block}}{\text{Hardness of standardized block}} \times 100 \quad \text{----- (3)}$$

$$\text{Dispersion } (\%) = \frac{\text{Maximum value - Minimum value}}{\text{Mean value}} \times 100 \quad \text{-----(4)}$$

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Appendix 1 Table 1 Tolerances on Mean Value and Permissible Value of Dispersion

Test load F (N)	$9.807 \leqq F < 49.03$	$49.03 \leqq F < 196.1$	$196.1 \leqq F \leqq 294.2$	$294.2 < F$
Tolerances on mean value (%)	±4	±3	±2	
Permissible value of dispersion (%)	10	5.5	2.5	
Permissible value of dispersion of mean value (%) (reference)	4	3	2	

Remark:
It is desirable that the permissible value of dispersion of mean value on three point of repeated measurement is the value as shown in reference of Appendix 1 Table 1. Provided that the repetition is about three times. Further, the dispersion of mean value shall be in accordance with the equation (5):

$$\text{Dispersion of mean value } (\%) = \frac{\text{Maximum mean value - Minimum mean value}}{\text{Overall mean value}} \times 100 \quad \text{-----(5)}$$

4. Inspection

4.1 Inspection on Functions
For inspection on functions, indentations shall be made on the adequate samples by the maximum and the minimum loads of the testing machine, and the actuations of each part of testing machine and of measuring microscope shall be confirmed to be adequate.

4.2 Inspection on Load
For the load inspection, the measurements shall be repeated three times at the positions of indenter axis when the hardness tests are carried out, and the fact that the mean value and dispersion comply with Section 3.2 (2) shall be affirmed.

Remark:
In the inspection on load, the load due to the mass of indenter shall be corrected.

4.3 Inspection on Indenter
The inspection on indenter shall be carried out as follows:
(1) The inspection device on the shape of indenter shall be able to carry out the measurements of angle of each face or each line of junction relative to the central axis if indenter and shall have such accuracy as to assure the tolerances on the shape.
(2) For the inspection on indenter, the fact that it satisfies the requirements of Section 3.3 shall be confirmed.

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4.4 Inspection on Measuring Microscope

The inspection on measuring microscope shall be carried out as follows:

(1) The standard ruler to be used for inspection shall be calibrated with an accuracy of ±0.1 % in measuring length. However, where the measuring length is less than 200 μm, the ruler shall be calibrated with an accuracy of ± 0.2 μm.

(2) For the inspection on graduation, the fact that the lengths corresponding to the graduations at not less than five positions containing zero point satisfy the requirements of Section 3.4 (2) shall be confirmed.

5. Inspection on Overall Error of Testing Machine

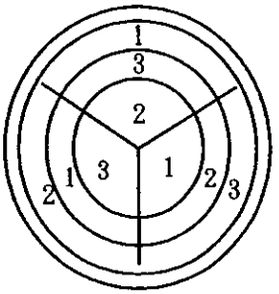
The inspection on overall error of testing machine shall be carried out as follows.

(1) In the inspection on overall error, it shall be confirmed that the requirements of Section 3.5 are satisfied by measuring the hardness of standardized block.

(2) The measurement of hardness shall be carried out on three points.

Remark 1:
The measuring person shall carry out the measurement of standardized indentation or that equivalent thereto, as required, and correct the personal error on indentation reading. The indentation equivalent to the standardized indentation is the indentation of which lengths of diagonals are determined by comparison measurement with the standardized indentation.

Remark 2:
The measuring positions of three points shall be selected from the three compartments apart from each other, by dividing in layers the using surface of the standardized block into 9 compartments of equal area as shown in Appendix 1 Fig. 1.



Appendix 1 Fig. 1 Division on Layers on Standardized Block

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Remark 3:
Concerning the dispersion of mean values of three points on repeated measurements, it si desirable to verify that the reference in Appendix 1 Table 1 in Section 3.5 is satisfied. Provided that the repeated measurements shall be approximately three times, and three points in each repeated measurement shall be compartments of 1, 2 and 3 as the numbers in 9 compartments shown in Appendix 1 Fig. 1 for the first repetition, the second, and the third respectively. When the repeated measurements are carried out, the fact that the overall mean value satisfies the tolerances on mean value in Appendix 1 Table 1 in Section 3.5 shall be varified.

(3) The hardness of the standardized block to be used for inspection shall be such that the lengths of diagonals of the indentation become, as a rule, not less than 200 μm.
(4) The loads for carrying out the inspection shall, as a rule, be of two kinds.

6. Marking
The testing machine shall be marked with the following items. The indenter shall be marked with the manufacturing number.
(1) Manufacturer's name or its abbreviation
(2) Manufacturing number
(3) Year and month of manufact

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APPENDIX 2 MICRO HARDNESS TESTING MACHINES FOR VICKERS AND KNOOP HARDNESS (BASED ON JIS B 7734)

1. Scope

This Appendix 2 covers the micro hardness testing machines, hereinafter referred to as the "testing machines", for measuring Vickers by the load in the range of 98.07 mN to 9.807 N.

2. Construction

The testing machine shall be composed of machine frame, sample holder, loading apparatus and measuring microscope and be provided with a indenter.

3. Performances

3.1 Functions

The testing machine shall be such that its indenter axis is attached perpendicularly to the sample receiving stand and be able to carry out adequately the application, retention, removing of load, formation of accurate indentation, and measurement of indentation.

3.2 Loading Apparatus

The loading apparatus shall be as follows:

(1) The loading apparatus shall not be accompanied by shock, vibration, etc., and be capable of application, retention, and removing of the specified load at the tip of indenter.

(2) The mean value of loads and the dispersion shall comply with following (a) and (b):

(a) The tolerances of mean value of loads shall be ±1.0 % for the load not less than 1.961 N relative to the nominal load, and ±1.5 % for the load less than 1.961 N. Provided that the error of mean value of loads shall be in accordance with equation (1):

$$\text{Error of mean value}\ (\%) = \frac{\text{Mean value of loads - Nominal load}}{\text{Nominal load}} \times 100 \quad \text{----- (1)}$$

(b) The permissible value of dispersion of repeated loads shall be 1.0 % for the load not less than 1.961 N, and 1.5 % for the load less than 1.961 N. Provided that the dispersion shall be in accordance with equation (2):

$$\text{Dispersion}\ (\%) = \frac{\text{Maximum value - Minimum value}}{\text{Nominal load}} \times 100 \quad \text{-----(2)}$$

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3.3 Indenter

3.3.1 Shape of Indenter

The indenter shall be as follows:

(1) The tip of indenter shall be a diamond in the form of a right pyramid with a square base having the angle between the opposite faces at the vertex of 136 ° ±0 ° 30 '.

(2) The difference to each other of inclinations of four faces to the central axis of indenter shall be not more than 0 ° 30 '.

(3) The four faces shall meet at a point at their vertex and the length of line of junction generated by the opposite faces shall be not more than 0.5 μm.

3.3.2 Finish of Indenter

The part of diamond for the indenter to be in contact with the sample shall be of highly polished surface and free from cracks or surface flaws. The edges on surfaces must be sharp.

3.4 Measuring Microscope

The measuring microscope shall be as follows:

(1) The measuring microscope to measure the length of diagonals of indentation shall be capable of offering a clear shape of indentation and taking accurate measurements of the length of diagonals of indentation.

(2) The permissible error of the scale of measuring microscope shall be ±(0.2± 0.004ℓ) μm. Where, ℓ is the measured length (μm).

3.5 Overall Error of Testing Machine

The overall error of testing machine shall, as a rule, be evaluated according to the measurement of hardness of the standardized block. The tolerances (permissible value of error, reliability of 95 %) of mean value relative to the hardness of standardized block shall be the value of Appendix 2 Table 1. Provided that the measurement of hardness shall be carried out at three points, and the error of the mean value shall be in accordance with equation (3):

$$\text{Error of mean value } (\%) = \frac{\text{Mean value - Hardness of standardized block}}{\text{Hardness of standardized block}} \times 100 \quad \text{----- (3)}$$

Appendix 2 Table 1 Tolerances on Mean Value

Test load F (mN)	$98.07 \leqq F < 490.3$	$490.3 \leqq F < 1961$	$1961 \leqq F < 4903$	$4903 \leqq F \leqq 9807$
Tolerances on mean value (%)	±20	±15	±7	±4

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4. Inspection

4.1 Inspection on Functions

For inspection on functions, indentations shall be made on the adequate samples by the maximum and the minimum loads of the testing machine, and the actuations of each part of testing machine and of measuring microscope shall be confirmed to be adequate.

4.2 Inspection on Load

4.2.1 Inspection Device for Load

The inspection device for load shall be as follows:

(1) The inspection device for load shall be that correctly calibrated by weight or the like.

(2) The dispersion on the indicated values of inspection device for load shall be not more than 0.5 % relative to the mean value of indicated values. Provided that the repetition of calibrations shall be three times.

(3) The balance to be used for mass inspection on attached weight for load shall be able to assure the measurement value with an accuracy of ±0.2 %.

4.2.2 Inspection on Load

The inspection on load shall be carried out as follows:

(1) In the inspection on load, the load applied to the indenter shall be directly measured.

(2) The inspection on load shall, as a rule, be carried out on all loads to be used.

(3) For the load inspection, the measurements shall be repeated three times at the positions of indenter axis when the hardness tests are carried out, and the fact that the mean value and dispersion comply with Section 3.2 (2) shall be affirmed.

4.3 Inspection on Indenter

4.3.1 Shape of Inspection Device

The inspection device on the shape of indenter shall be able to carry out the measurements of angle of each face or each line of junction relative to the central axis of indenter and shall have such accuracy as to assure the tolerances on the shape.

4.3.2 Indenter

For the inspection on indenter, the fact that it satisfies the requirements of Section 3.3.1 shall be confirmed.

Remark:
For the inspection on the line of junction generated by the opposite faces at indenter tip, it should be preferable that a small indentation is made on a suitable sample and it is measured by the method using a microscope.

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4.4 Inspection on Measuring Microscope

The inspection on measuring microscope shall be carried out as follows:

(1) The standard ruler to be used for inspection shall be calibrated with an accuracy of ±0.1 % in measuring length. However, where the measuring length is not more than 200 μm, the ruler shall be calibrated with an accuracy of ±0.2 μm.

(2) For the inspection on graduations at not less than four positions containing zero point in the effective working range satisfy the requirements of Section 3.4 (2) shall be confirmed.

5. Inspection on Overall Error of Testing Machine

The inspection on overall error of testing machine shall be carried out as follows.

(1) In the inspection on overall error, it shall be confirmed that the requirements of Section 3.5 are satisfied by measuring the Vickers hardness of standardized block.

(2) The measurement of hardness shall be carried out on three points.

Remark 1:
The measuring person shall carry out the measurement of standardized indentation or that equivalent thereto, as required, and correct the personal error on indentation reading. The indentation equivalent to the standardized indentation is the indentation of which lengths of diagonals are determined by comparison measurement with the standardized indentation.
Remark 2:
The measuring positions of three points shall be able to represent the working surface of the standardized block.

(3) The loads for carrying out the inspection shall be of two kinds and, as a rule, be of 1.961 N and 9.807 N.

Remark 1:
Concerning the stability of the testing machine, it is desirable that the dispersion of mean values when the three points are measured repeatedly is within the control limit given in Appendix 2 Table 2. The control limit (2σ) of mean value shall be as given in equation (4):

$$\text{Control limit (\%)} = \pm\frac{2}{\bar{\bar{x}}}\sqrt{\frac{\sum\left(\bar{x}i - \bar{\bar{x}}\right)^2}{n-1}} \times 100 \quad \text{---------(4)}$$

where,

$\bar{x}i$: mean value of three point measurements at ith time

$\bar{\bar{x}}$: overall mean

n : number of times of repeated measurements

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Remark 2:
The calculated values of errors integrated with only each error factor of the testing machine are shown in Appendix 2 Table 2.

Appendix 2 Table 2 Control Limit of Mean Value and Overall Error

Test load F (mN)	$98.07 \leqq F < 490.3$	$490.3 \leqq F < 1961$	$1961 \leqq F < 4903$	$4903 \leqq F \leqq 9807$
Control limits of mean value (%)	±10	±7	±3.5	±2.5
Overall error of testing machine only (%)	±6	±5		±3

6. Marking

The testing machine shall be marked with the following items. The indenter shall be marked with the manufacturing number.

(1) Manufacturer's name or its abbreviation
(2) Manufacturing number
(3) Year and month of manufacture

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APPENDIX 3 BRINELL HARDNESS TESTING MACHINES (BASED ON JIS B 7724)

1. Scope

This Appendix 3 covers the testing machine for measuring the Brinell hardnesses, hereinafter to be referred to as the "testing machine".

2. Construction

The testing machine shall be composed of a frame, sample holder, loading apparatus, mounting shaft of indenter, and indentation measuring apparatus, hereinafter referred to as the "measuring apparatus" and be provided with indenters.

Remark:
The measuring apparatus need not be integrated with the testing machine.

3. Performances

3.1 Functions

The testing machine shall be so built that the mounting shaft of indenter is mounted vertical to the sample bearer, and is capable of appropriately performing the manifold functions of loading, holding and unloading of the load, formation of normal indentations and measurement.

3.2 Frame and Sample Holder

The frame and sample holder shall have a sufficient rigidity in measurement to withstand the maximum working load they should be subjected to.

Remark:
When a load of 29.42 kN is applied to C-shaped frame type testing machine of nominal load 29.42 kN, the deformation of the frame measured on the central line of the mounting shaft of indenter should preferably be 0.5 mm or under.

3.3 Loading Apparatus

The loading apparatus shall be in accordance with the following:

(1) The loading appartus shall be capable of applying the specified load to the contact point of the indenter, maintaining the load there and removing the load without causing accompanying impact, vibration or the like.

(2) The tolerance on the average load value and the tolerance on the dispersion of the load measurements shall comply with both of (a) and (b) as follows:

(a) The tolerance on the average value of load shall be ± 1.0 % of the nominal load. The error in the average value of load shall be calculated by equation (1).

$$\text{Error in the average value } (\%) = \frac{\text{Average value of load - Nominal load}}{\text{Nominal load}} \times 100 \quad \text{----- (1)}$$

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(b) The tolerance on the dispersion of repeatedly measured load shall be 0.5 % or under of the nominal load. The dispersion shall be calculated by equation (2).

$$\text{Dispersion (\%)} = \frac{\text{Greatest load value - Smallest load value}}{\text{Nominal load}} \times 100 \text{ ----- (2)}$$

(3) Dispersion of masses of the additional additional weights used to make up the same nominal load shall be 0.1 % or under when calculated from equation (3):

$$R\,(\%) = \frac{W_{max} - W_{min}}{\overline{W}} \times 100 \text{ ---------- (3)}$$

where,

R: dispersion of masses (%)

W_{max} : value of the greatest mass

W_{min} : value of the smallest mass

$\overline{W}$: average value of masses

(4) The load indicator mounted to the testing machine shall be in accordance with the follwoing:

(a) When a test load is applied through an indenter, the load indicator shall behave smoothly and the test load shall be read off with ease.

(b) The dial scale plate of the load indicator shall generally be marked with the nominal load in units of N.

3.4 Indenters

The indenters shall conform to the following:

(1) The indenter shall be steel ball or of cemented carbide ball.

(2) The tolerance on diameter of spherical indenter newly to be used shall be ±0.015 mm, and sphericity shall be 0.0015 mm or under.

Reference:
For indenters of a diameter 2.5 mm or smaller, the tolerance on diameter should preferably be ±0.003 mm and the sphericity 0.001 mm or under.

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3.5 Measuring Apparatus

The measuring apparatus shall be in accordance with the following:

(1) The measuring apparatus shall be capable of clearly discerning the shape of indentation.

(2) The scale interval of a measuring apparatus shall be such that the diameter of an indentation will be determined to 0.5 %.

Remark:
The scale interval of a measuring apparatus, where readings to the extent of 0.05 mm are required, shall be 0.05 mm or under.

(3) The tolerance on the scale of a measuring apparatus shall be ±0.5 % of the length to be measured.

Remark:
The tolerance on the scale of a measuring apparatus, where readings to the extent of 0.05 mm are required, shall be ±0.02 mm.

3.6 Overall Errors

The overall error of a testing machine shall be evaluated with standard hardness samples. In that case, the tolerance on the average value for a standard test piece shall be ±3 %. However, for those testing machines that are referred to in the two remarks of Section 3.5, one in (2) and the other in (3), the tolerance shall be ±4 %.

4. Inspection

4.1 Functional Inspection

In the functional inspection, it shall be confirmed that the testing machine works smoothly and normally by making indentations on the test surface of a suitable sample with the indenter under the maximum working load of the testing machine.

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4.2 Loading Inspection

The loading inspection shall be carried out in accordance with the following:

(1) In the loading inspection, the load applied to the extreme end of the mounting shaft of indenter shall be directly measured.

(2) In the loading inspection, three measurements shall be conducted for each of the nominal loads to be used in that testing machine, and it shall be confirmed that the average value and the dispersion of measurements satisfy the requirements of Section 3.3 (2).

Remark 1:
In carrying out the loading inspection, the working conditions, such as the travelling range of the mounting shaft of indenter and positions of additional weights, shall be taken into consideration according to the mechanism of loading apparatus.

Remark 2:
In the loading inspection of a loading apparatus whose mechanism is likely to change the load in the course of holding the load, as in the case of a testing machine using oil hydraulic pressure for loading, it shall be confirmed that the variation of load, in the duration of 1 min after application of the specified load, is kept within 1 % of the nominal load.

4.3 Inspection on Additional Weights

In the inspection on the additional weights, it shall be confirmed that the differences between masses with respect to the interchangeable weights (or combination of weights) are within the tolerances specified in Section 3.3 (3).

4.4 Inspection on Indenter

In the inspection on the indenter, it shall be confirmed that the indenter satisfies the requirements specified in Section 3.4.

4.5 Inspection on Measuring Apparatus

In the inspection of the measuring apparatus, the scale shall be tested for error in three different places within the working range by the use of a standard scale calibrated to an accuracy of ± 0.2 % of the length to be measured, and it shall be confirmed that the results are within the tolerances specified in Section 3.5 (3).

4.6 Inspection on Overall Error of Testing Machine

As for the inspection on the overall error of a testing machine, the value of hardness to be inspected shall be one kind arfitrarily chosen.

Remark:
Where there is no specification, either a hardness of 225 HB or thereabout or that which will give rise to an indentation of about 4 mm in diameter is preferred.

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5. Marking

The testing machine shall be marked with the following information on one portion of the body:

(1) Manufacturer's name or its abbreviation
(2) Manufacturing number
(3) Year and month of manufacture

Remark:
The testing machine should preferably be marked with the limit of travelling range of its mounting shaft of indenter.

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APPENDIX 4 ROCKWELL AND ROCKWELL SUPERFICIAL HARDNESS TESTING MACHINES (BASED ON JIS B 7726)

1. Scope

This Appendix 4 covers the Rockwell and Rockwell superficial hardness testing machines, hereinafter referred to as the "testing machines", for measuring the Rockwell hardness either of B and C scales.

2. Composition

The testing machine shall be composed of a machine frame, supporting anvil, loading loading device and hardness indicating apparatus, and shall be provided with the indenter.

3. Performance

3.1 Functions

The testing machine shall be capable of carrying out applying, holding and removing of the load appropriately. Furthermore, it shall be capable of measuring the displacements of the indenter appropriately.

3.2 Machine Frame and Supporting Anvil

The performances of the machine frame and supporting anvil shall be as the following:

(1) The machine frame and supporting anvil shall have sufficient rigidity in measurement, even if these are loaded with the maximum load.

(2) The sample seating face of the anvil shall generally be a plane normal to the center line of the indenter mounting shaft.

(3) The difference of magnitudes of deformation, in loading direction of the machine frame and the supporting anvil, between the two time loadings under the standard load before and after, when the loads have been varied, as in the same manner as a normal hardness test, from the standard load, through test load to the standard load again, placing the indenter mounting shaft directly in contact with the anvil or interposing an auxiliary jig between the indenter mounting shaft and the anvil, shall be assumed as the return deformation; the permissible value of this return deformation shall be within the permissible value given in Appendix 4 Table 1. However, the measurements shall be made five times.

Appendix 4 Table 1 Permissible Values of Return Deformation

Applicable hardness	Permissible value	
	For each measured value	Dispersion
Rockwell hardness	±0.5	0.4

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3.3 Loading Device

The loading device shall be so constructed that it will not cause any shock and vibration in carrying out the loading of the standard load and loading, holding and removing of the test load, and the values for the standard loads, test loads to be applied to the indenter tip and their permissible values shall conform to Appendix 4 Table 2. However, the measurements shall be made three times.

Appendix 4 Table 2 Loads on Testing Machine and Their Permissible Value (Unit: N)

Standard load and test load	Permissible value	
	Mean value-Nominal load	Dispersion
98.07	±1.96	2.0
588.4	±4.9	5.0
980.7	±6.4	6.0
1471.0	±8.8	9.0
29.42	±0.59	0.6
147.10	±0.98	1.0
294.2	±2.0	2.0
441.3	±2.9	3.0

3.4 Hardness Indicating Apparatus

The performance of the hardness indicating apparatus shall be as the following:

(1) The effective operating range of the hardness indicating apparatus shall conform to Appendix 4 Table 3.

Remark:
The effective operating range shall be the value converted into the displacement of the indenter mounting shaft.

Appendix 4 Table 3 Effective Operating Range of Hardness Indicating Apparatus

Applicable hardness	Effective operating range (mm)
Rockwell hardness	0 to 0.2 for diamond indenter
	0 to 0.26 for ball indenter

(2) The scale or indication number of the hardness indicating apparatus shall be the value of the hardness.

(3) The tolerances for the hardness indicating apparatus shall conform to ± 0.5 in the value of the hardness.

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3.5 Indenter

3.5.1 Diamond Indenter

The performance of the diamond indenter shall be as the following (see Appendix 4 Fig. 1):

(1) The tip shall have a curved surface of which conical part blends smoothly with the spherical part.

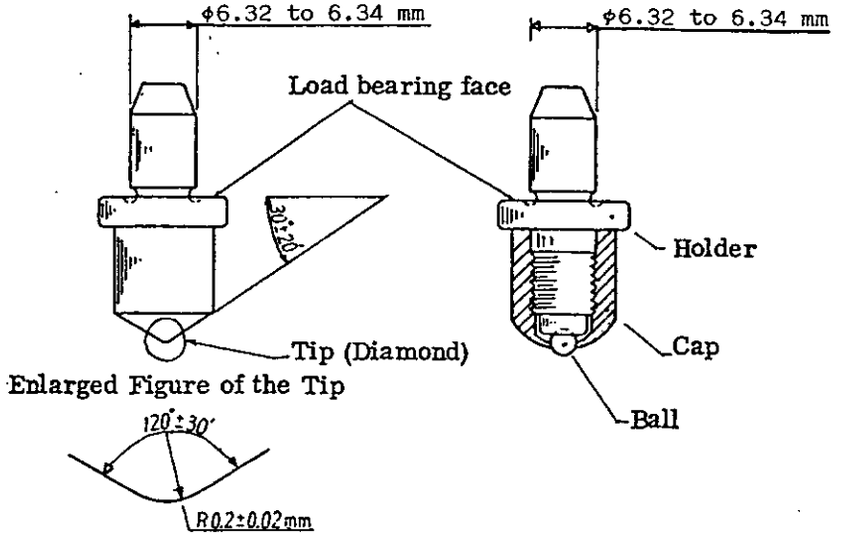
(2) The included angle of the cone of the tip shall be 120 ° ±30 '.

(3) The angle between the generator of the cone of the tip and the load bearing face of the insert shall be 30 ° ±20 '.

(4) The radius of curvature of the spherical part of the tip shall be 0.2±0.02 mm.

3.5.2 Ball Indenter

The ball indenter shall be classified into two types of steel ball and cemented carbide alloy ball, and their performances shall be as the following (see Appendix 4 Fig. 2): The diameter of the ball indenter shall be 1.5875±0.0030 mm or 3.175± 0.004 mm. Furthermore, the sphericity shall each be 0.003 mm or 0.004 mm.



Appendix 4 Fig. 1 Diamond Indenter

Appendix 4 Fig. 2 Ball Indenter

Remark 1:
Appendix 4 Figs. 1 and 2 give the principal shapes, but these do not give detailed shapes.

Remark 2:
Diameter of the insert shaft of the indenter shall generally be 6.32 to 6.34 mm.

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Remark 3:
The shape of the load bearing face of the insert part shall be so shaped as to fit closely with the indenter mounting shaft, when the diamond indenter or the holder of the ball indenter has been inserted into the indenter mounting shaft.
Remark 4:
The holder and ball of the ball indenter shall be so shaped as to fit closely each other.

3.6 Overall Errors on Testing Machine

The overall errors on the testing machine shall be assessed by the hardness measurements. The permissible value for the mean value and dispersion (the maximum value-the minimum value) on each hardness range shall conform to Appendix 4 Table 4. However, the measurements shall be made five times.

Appendix 4 Table 4 Overall Errors (C and B Scales) (Unit: hardness value)

Hardness range	Permissible value	
	Mean value-Standard value	Dispersion
60 to 65 HRC	±0.8	0.8
45 to 50 HRC		
30 to 35 HRC	±1.2	1.0
90 to 95 HRB		1.5
30 to 35 HRB	±2.0	2.0

4. Inspection

4.1 General

The testing machine shall be examined on all items of Sections 4.2 to 4.7. However, where only the overall error of the testing machine is to be examined, the inspections on Sections 4.3, 4.4, 4.5 and 4.6 may be omitted.

4.2 Inspection on Functions

In the inspection of functions, the testing machine shall be confirmed that it functions appropriately by carrying out the hardness measuring procedures using adequate two test pieces which are different in hardness.

Remark:
For the testing machine of the Rockwell hardness, the test pieces of hardness range given in Appendix 4 Table 4 should be used.

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4.3 Inspection on Machine Frame and Test Piece Supporting Anvil

The inspection on the machine frame and test piece supporting anvil shall be as the following:

(1) In the inspection on the machine frame and test piece supporting anvil, the inspection on the return deformation for the machine frame and test piece supporting anvil specified in Section 3.2 (3) shall be carried out.

(2) The measurement of the return deformation shall be made under the maximum load to be used on this testing machine.

(3) The measurement of the return deformation shall be made carrying out five times of measurement after two times of preliminary procedures have been made, and it shall be confirmed that each measurement value and dispersion (the maximum value-the minimum value) are within the permissible values given in Appendix 4 Table 1 of Section 3.2.

(4) The return deformation shall be the value presented on the hardness indicating apparatus, and its value be given as the formula (1):

$$\text{Return deformation} = \begin{pmatrix}\text{Indicated value under}\\ \text{the loading condition}\\ \text{of standard load at}\\ \text{the second time}\end{pmatrix} - \begin{pmatrix}\text{Indicated value under}\\ \text{the loading condition}\\ \text{of standard load at}\\ \text{the first time}\end{pmatrix} \quad \text{----- (1)}$$

4.4 Inspection on Loading Machine

The inspection on the loading machine shall be as the following:

(1) In the inspection on the loading machine, the standard load and the test load shall be examined. In the inspection on the standard load and the test load, the measurement of the loads shall be carried out three times repeatedly and be ascertained that their mean values and dispersions (the maximum value - the minimum value) shall be within the permissible values given in Appendix 4 Table 2 of Section 3.3.

(2) In the measurement of the load, the load which is applied at the extreme point of the indenter mounting shaft shall be measured directly. If required, the measured value shall be corrected for the mass of the indenter.

(3) The measurement of the standard load shall be made at the position of the indenter mounting shaft where the hardness indicating apparatus indicates the the datum position.

(4) The measurement of the test load shall be made at two places near the both ends of the operating range of the indenter mounting shaft.

Remark:
The two positions where the loads are to be measured should be determined as the following positions on the hardness indicating apparatus:
Positions of approximately 70 HRC(100 HRB) and 0 HRB(-30 HRC) in hardness value, for Rockwell hardness.

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4.5 Inspection on Hardness Indicating Apparatus

The inspection on the hardness indicating apparatus shall be as the following:

(1) In the inspection on the hardness indicating apparatus, errors on the indicated values shall be inspected giving direct displacements to the indenter mounting shaft.

(2) In the inspection on the hardness indicating apparatus, it shall be ascertained that the errors on the indicated values shall be within tolerances of Section 3.4 (3).

(3) The errors on the indicated values shall be as the formulas (2) to (3):

$$\text{Error} = \text{Indicated value} - (100 - 500h),\ h \leqq 0.2 \text{ mm} \quad \text{----- (2)}$$

$$\text{Error} = \text{Indicated value} - (130 - 500h),\ h > 0.2 \text{ mm} \quad \text{----- (3)}$$

where,
h being a displacement (mm) corresponding to the datum position given on the indenter mounting shaft.

(4) The hardness scales at which the inspection is carried out shall be as the scales of 0 HRB, 0, 20, 40, 60 and 80 HRC.

4.6 Inspection on Indenter

The inspection on the indenter shall be as the following:

(1) Diamond indenter
In the inspection on the diamond indenter, it shall be ascertained that the indenter is conforming to each item of Section 3.5.1, using the toolmaker's microscope or the optical projecter.

(2) Ball indenter
In the inspection on the ball indenter, it shall be ascertained that the indenter conforms to Section 3.5.2.

4.7 Inspection on Overall Error of Testing Machine

The inspection on the overall error of the testing machine shall be as the following:

(1) The inspection on the overall error shall be carried out by the hardness measurements.

(2) The hardness measurements shall be made five times repeatedly after the preliminary procedures have been carried out on each sample, and it shall be ascertained that the mean value and dispersion (the maximum value-the minimum value) are within the permissible values given in Appendix 4 Table 4.

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5. Marking

The testing machine shall be marked with the following information on a part of the body:

(1) Manufacturer's name or its abbreviation

(2) Manufacturing number

(3) Year and month of manufacture

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