

Australian Standard[®]

**Metallic materials—Vickers
hardness test**

This Australian Standard was prepared by Committee MT/6, Mechanical Testing of Metals. It was approved on behalf of the Council of Standards Australia on 28 June 1991 and published on 7 October 1991.

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Bureau of Steel Manufacturers of Australia
Division of Applied Physics, CSIRO
Confederation of Australian Industry
Department of Defence
Federal Chamber of Automotive Industries
Metal Trades Industry Association of Australia
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Calibrating organizations
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Metallic materials—Vickers hardness test

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PREFACE

This Standard was prepared under the direction of the Standards Australia Committee on Mechanical Testing of Metals to supersede AS 1817, *Method for Vickers hardness test*, Part 1—1976, *Testing of metals* and Part 2—1976, *Calibration of the testing machine*.

This edition was prepared at the request of the National Association of Testing Authorities, Australia, to alleviate problems associated with calibration in relation to availability and cost of certified diamond indenters, and cost, adequacy and range of hardness blocks available for user checks.

In this edition, the testing and calibration requirements have been combined into the one Standard for simplification and to avoid duplication.

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CONTENTS

	<i>Page</i>
SECTION 1 SCOPE AND GENERAL	
1.1 SCOPE	4
1.2 REFERENCED DOCUMENTS	4
1.3 DEFINITIONS	4
1.4 VICKERS TEST PRINCIPLE	4
1.5 DESIGNATION OF VICKERS HARDNESS	5
1.6 TABLES OF HARDNESS VALUES	5
1.7 HARDNESS CONVERSIONS	5
SECTION 2 TESTING OF METALS	
2.1 SCOPE OF SECTION	6
2.2 TESTING MACHINE	6
2.3 INDENTER	6
2.4 MEASURING APPARATUS	7
2.5 ANVIL	7
2.6 PERFORMANCE OF MACHINE	7
2.7 MAINTENANCE OF THE TESTING MACHINE BY THE USER	7
2.8 TEST PIECE	7
2.9 TEST PROCEDURE	8
2.10 RECORD OF TEST RESULTS	10
2.11 TEST REPORT	10
SECTION 3 COMPLETE CALIBRATION OF THE TESTING MACHINE	
3.1 GENERAL	11
3.2 PRELIMINARY INSPECTION	11
3.3 INDENTING FORCES	11
3.4 INDENTER	11
3.5 MEASURING APPARATUS	11
3.6 PERFORMANCE TEST	12
3.7 RECORD OF RESULTS	12
3.8 REPORT OF COMPLETE CALIBRATION	12
SECTION 4 PARTIAL CALIBRATION OF THE TESTING MACHINE	
4.1 GENERAL	13
4.2 PRELIMINARY INSPECTION	13
4.3 INDENTING PROCEDURE	13
4.4 ASSESSMENT OF PERFORMANCE	13
4.5 RECORD OF RESULTS	14
4.6 REPORT OF PARTIAL CALIBRATION	14
SECTION 5 CALIBRATION OF STANDARD HARDNESS BLOCKS	
5.1 GENERAL	15
5.2 REQUIREMENTS FOR STANDARD HARDNESS BLOCKS	15
5.3 CALIBRATION OF STANDARD HARDNESS BLOCKS	15
5.4 STANDARDIZING MACHINE	16
SECTION 6 REQUIREMENTS FOR STANDARD INDENTERS	
6.1 GENERAL	18
6.2 CONDITION	18
6.3 DIMENSIONS	18
APPENDICES	
A TABLES OF VICKERS HARDNESS VALUES	19
B TABLES OF CORRECTION FACTORS FOR USE IN TESTS MADE ON SPHERICAL OR CYLINDRICAL SURFACES	40

STANDARDS AUSTRALIA

Australian Standard

Metallic materials—Vickers hardness test

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE This Standard sets out methods for measuring the Vickers hardness of metals and metal products using forces between 9.8 N and 980 N inclusive. It does not apply for the use of forces below 9.8 N. It includes requirements for the installation and calibration of the testing machine, and recommendations for its maintenance by the user.

This Standard does not apply to portable hardness testing machines.

1.2 REFERENCED DOCUMENTS The following documents are referred to in this Standard:

AS

1816 Metallic materials—Brinell hardness test

2193 Methods for calibration and grading of force-measuring systems of testing machines

ISO

4964 Steel—Hardness conversions

1.3 DEFINITIONS For the purpose of this Standard, the definitions below apply.

1.3.1 Arithmetic mean deviation (R_a)—the arithmetic average of the deviation of a profile above and below the reference curve or line. This parameter has the dimensions of length and is used for surface roughness measurement.

1.3.2 Calibration—all the operations for determining the values of the errors of a Vickers hardness testing machine (and, if necessary, for determining other metrological properties).

1.3.3 Calibrating authority—any approved person or organization qualified and equipped to perform the tests set out in Section 3 or 4, or both.

NOTE: The National Association of Testing Authorities, Australia, registers laboratories for performance of these calibrations.

1.3.4 Hardness test blocks—metal blocks for the purpose of maintaining surveillance of the performance of hardness testing machines between periodic calibrations.

1.3.5 Indenter—a diamond indenter used for routine hardness tests, usually assigned to a hardness testing machine and evaluated in conjunction with it.

1.3.6 Indenter, reference—a diamond indenter which is maintained by the Australian standardizing authority and whose performance has been compared with reference indenters maintained by other national standardizing authorities.

1.3.7 Indenter, standard—a diamond indenter which is maintained by a calibrating authority for assessing the performance of hardness testing machines in the field, in the event of non-complying results being obtained when using the indenters assigned to the machine.

1.3.8 Standard hardness blocks—metal blocks having a calibration traceable to a national standard scale of hardness, which is recognized by the Australian standardizing authority, for verifying the performance of hardness testing machines.

1.3.9 Standardizing authority—an authority which maintains the standard of Vickers hardness.

NOTE: In Australia the standardizing authority is the National Measurement Laboratory, Division of Applied Physics, CSIRO.

1.3.10 Test piece—a prepared piece for testing made from a test specimen by some mechanical operation.

1.3.11 Test specimen—a portion of material or a single item taken from the sample for applying a particular test.

NOTE: Vickers hardness tests can be made on test pieces or test specimens, the latter often being in the form of finished products or components.

1.4 VICKERS TEST PRINCIPLE The test consists of pressing a diamond indenter into the surface of a test piece under a force. After removal of the force, two diagonals, d_1 and d_2 , of the indentation are measured and the mean value d is determined. The sloping area of the indentation is estimated from the mean length ' d ' of the two diagonals d_1 and d_2 .

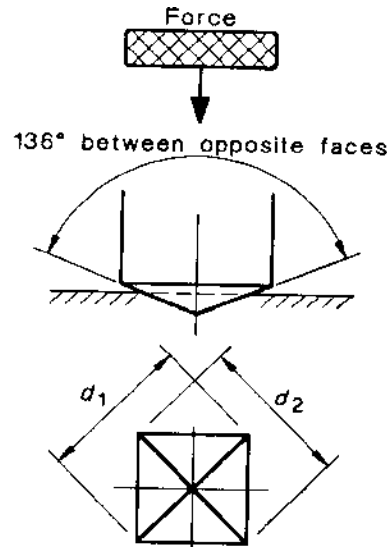


FIGURE 1.1 VICKERS PRINCIPLE

The indenter is a right pyramid with a square base and an angle of 136° between opposite faces (see Figure 1.1).

The Vickers hardness is the quotient obtained by dividing the test force by 9.806 65 times the sloping area of the indentation. This may be expressed by the following equations:

$$\text{HV} = \frac{2F \sin \frac{136^\circ}{2}}{9.806\ 65d^2} \quad \dots 1.4(1)$$

$$= 0.1891 \frac{F}{d^2} \text{ approximately} \quad \dots 1.4(2)$$

where

HV = Vickers hardness

F = force, in newtons

d = mean diagonal of indentation, in millimetres

For the requirements for a Vickers hardness machine, see Clause 2.2.1.

1.5 DESIGNATION OF VICKERS HARDNESS The symbol HV is preceded by the hardness value and followed by a number indicating the nominal force used in the test.

NOTE: For historical reasons, the designation expresses the test force in kilograms force whereas the units of actual measurement of the force are newtons (1 kgf is approximately equivalent to 10 N).

Example of Vickers hardness designation

400 HV 30 denotes a Vickers hardness of 400 determined with a test force of 294 N (30 kgf). If a duration of test outside the normal time range of 10 s to 15 s is used, the actual duration, in seconds, is indicated by adding a number to the hardness designation, e.g. 400 HV 30/20 for a test of 20 seconds duration.

1.6 TABLES OF HARDNESS VALUES The Vickers hardness may be calculated using either Equation 1.4(1) or 1.4(2), or by the use of tables. Appendix A contains suitable tables which have been calculated using Equation 1.4(1).

The tables, which are primarily intended for use with the values of force given in Table 2.1, may be adapted for other values of force as described in Appendix A.

The hardness values given in the tables apply directly to tests made on flat surfaces. For tests on curved surfaces, it is necessary to correct the values obtained from the tables (see Clause 2.9(g)).

1.7 HARDNESS CONVERSIONS As there is no general procedure for accurately converting Vickers hardness into other scales of hardness, it is recommended that such conversions should be avoided except in instances where a reliable basis for the conversion has been established beforehand by direct tests on the material concerned.

NOTE: Charts for approximate comparison of hardness scales for steels are given in ISO 4964.

SECTION 2 TESTING OF METALS

2.1 SCOPE OF SECTION This Section specifies the requirements for the testing machine and sets out the methods for measuring the Vickers hardness of metals and metal products.

2.2 TESTING MACHINE

2.2.1 General The machine shall perform the test in accordance with the Vickers test principle (see Clause 1.4), and shall comply with the requirements of this Clause.

2.2.2 Installation The machine shall be set up in accordance with the manufacturer's instructions, on a rigid foundation on a site which is free from vibration, and not subject to gritty or dusty conditions, or excessive temperature changes. Damp or fume-laden atmospheres should be avoided.

2.2.3 Calibration

2.2.3.1 Calibration on installation On completion of installation the machine shall be given a complete calibration, by a calibrating authority, in accordance with Section 3.

2.2.3.2 Routine recalibration of the testing machine The machine shall be recalibrated, by a calibrating authority, in accordance with Sections 3 and 4.

NOTE: For machines in good order and used under favourable conditions, it is recommended that a complete calibration be carried out at intervals not exceeding 3 years and a partial calibration at intervals not exceeding 1 year.

2.2.3.3 Additional recalibration of the testing machine If there is any reason to doubt the accuracy of the results, the machine shall be checked in accordance with Clause 2.7. If after this check there is still reason to doubt the accuracy of the machine, it shall be recalibrated. The decision as to whether a complete or partial recalibration is to be carried out shall rest with the calibrating authority.

2.2.4 Indenting forces The nominal value of the indenting force shall lie within the range 9.8 to 980 N. The indenting force shall not deviate from the nominal value by more than 1 percent. The most commonly used nominal forces, i.e. those for which the tables of hardness values have been included (see Appendix A), are given in Table 2.1, together with the corresponding hardness symbols.

The force shall be applied along the axis of the indenter and normal to the surface of the test piece.

The mechanism controlling the application and removal of the force shall ensure that the force is applied and removed without shock or vibration, and that the full force is maintained for the duration of the test.

NOTE: During normal operation the test duration is not less than 10 s nor greater than 15 s.

TABLE 2.1
INDENTING FORCES AND HARDNESS SYMBOLS

Nominal force N	Hardness symbol
9.8	HV 1
19.6	HV 2
24.5	HV 2.5
29.4	HV 3
39.2	HV 4
49	HV 5
98	HV 10
196	HV 20
294	HV 30
392	HV 40
490	HV 50
588	HV 60
784	HV 80
980	HV 100

2.3 INDENTER The indenter shall comprise a diamond in the form of a right pyramid with a square base, and a suitable holder in which the diamond is rigidly mounted (see Figure 1.1). The holder shall have a plane bearing surface through which the indenting force is applied by the carrier.

The tip of the pyramid shall lie on the axis of the indenter.

2.4 MEASURING APPARATUS

2.4.1 Illumination The illumination shall be uniform over the field of view and shall provide adequate contrast between the indentation and the test surface.

2.4.2 Measuring scale The measuring device shall permit the measurement of intervals to the following accuracy:

- (a) For intervals up to and including 200 μm : $\pm 1 \mu\text{m}$.
- (b) For intervals exceeding 200 μm : ± 0.5 percent.

2.5 ANVIL The anvil on which the test piece is supported shall be suitable for the form of the test piece and shall be of sufficient hardness and rigidity to prevent significant deformation in use.

2.6 PERFORMANCE OF MACHINE The performance of the machine shall be in accordance with the requirements of Clause 4.4.1.

2.7 MAINTENANCE OF THE TESTING MACHINE BY THE USER

2.7.1 General The user shall ensure that the machine is maintained in satisfactory working order and condition during the intervals between calibrations carried out in accordance with Sections 3 and 4. It is necessary that the procedures given in Clauses 2.7.2 and 2.7.3 be followed.

2.7.2 Inspection of components and operation The machine shall be inspected frequently to ascertain that—

- (a) the test piece support and the bearing surfaces of the indenter carrier are in good order, i.e. clean and free from corrosion and burrs;
- (b) the indenter is free from damage and is correctly secured in the carrier (see Note);
- (c) the forces are applied and removed without shock or vibration and the full force is maintained for not less than 10 s or greater than 15 s, or for other durations for which the machine is required to be used;
- (d) where applicable, the zero reading of the measuring apparatus is correctly adjusted;
- (e) where the measuring apparatus is integral with the machine, the indentation is in the centre of the field of view;
- (f) the illumination is uniform over the field of view and gives adequate contrast between the indentation and the surface of a suitably prepared test piece; and
- (g) indentations on a hardness test block have diagonals equal within 2 percent.

NOTE: Periodic examination of the indenter for defects is strongly recommended. These are usually clearly reproduced in the indentations and can be detected by carefully scrutinizing an indentation whilst viewing it through the measuring apparatus.

2.7.3 Performance check tests by the user

2.7.3.1 General The user shall conduct performance tests to establish that the machine is continuing to operate satisfactorily at the force or forces to be used, with the indenter to be used, and at the hardness level appropriate to the work being performed.

Testing may be carried out without commencing with a check test, provided that a check test at the appropriate hardness level, using the same force and indenter, is carried out within one week prior to the test. The force is deemed to be checked if check tests are undertaken at higher and lower forces than the force used during the test.

2.7.3.2 Routine checking procedure The procedure consists of checking the machine and indenter combination using one or more hardness test blocks (see Clause 1.3.4).

The indenters used shall be those assigned to the machine.

2.7.4 Record of user tests A record of results obtained in all user checks should be kept, preferably in graphical form. Any gradual or sudden change in level of hardness reading should be investigated.

2.7.5 Assessment of results of user tests As a guide to the user in assessing the acceptability of the machine for subsequent use, a machine meeting the requirements of this Standard is expected to give hardness readings within ± 2 percent of the assigned value of the hardness test blocks used, for tests in which the diagonals of the indentation are not less than 0.150 mm (see also Clauses 2.2.3.3 and 2.6).

2.8 TEST PIECE

2.8.1 Preparation of test piece The surface finish of the test area shall permit accurate measurement of the diagonals of the indentation.

Precautions shall be taken to ensure that the surface tested is representative and that its hardness is not affected by any unsuitable machining, grinding or polishing process applied to it during preparation.

2.8.2 Thickness of test piece The thickness of the test piece or of the layer under test should be at least 1.5 times the length of the diagonal of the indentation. In any event, no evidence of indentation shall be visible at the back of the test piece after the test.

Figure 2.1 shows the minimum thickness of the test piece corresponding to 1.5 times the length of the diagonal of the indentation for different combinations of hardness value and nominal force.

NOTE: When testing metal in thin sheet or strip form, special care is required if erroneous hardness values are to be avoided. If the thickness is at least 1.5 times the length of the diagonal of the indentation, it is unlikely that hardness measurements on either ferrous or non-ferrous metals will be faulty provided that the bearing surface of the test piece is smooth and in intimate contact with the support. If it becomes necessary in particular circumstances to accept a ratio of thickness to length of diagonal of less than 1.5, the hardness value may be influenced by the indenting nominal force and by the size and hardness of the anvil. A special investigation may be needed to establish what influence these factors exert on these hardness values.

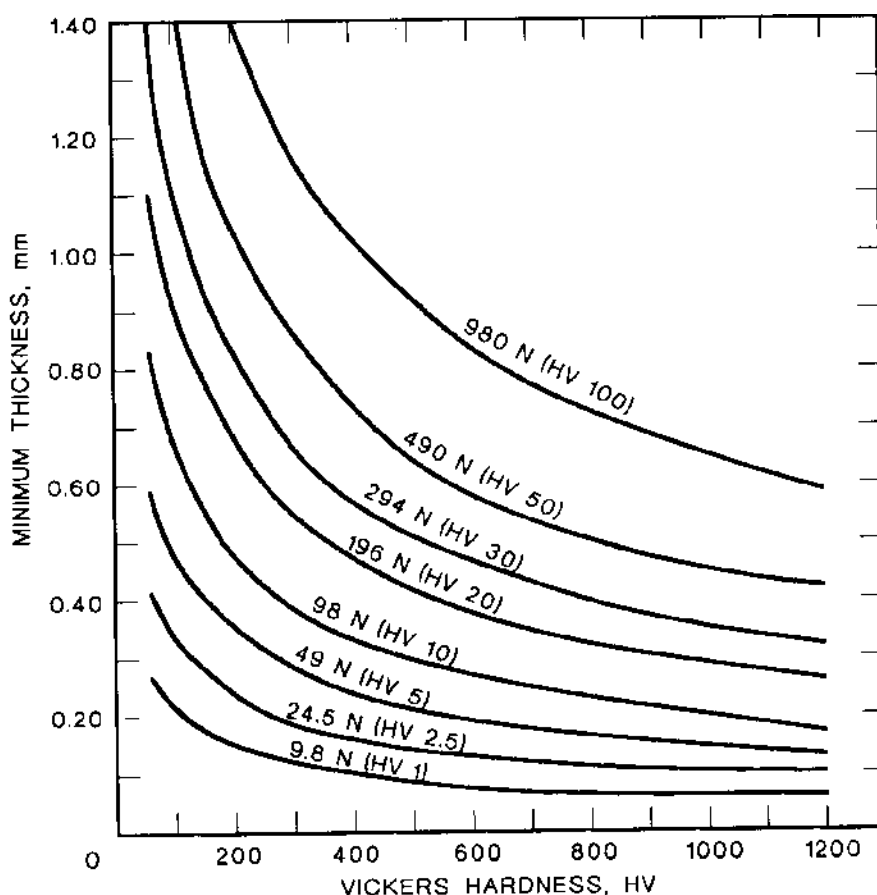


FIGURE 2.1 RECOMMENDED MINIMUM THICKNESSES OF TEST PIECE OR LAYER UNDER TEST WITH DIFFERENT COMBINATIONS OF HARDNESS VALUE AND FORCE

2.9 TEST PROCEDURE The procedure to perform a Vickers hardness test shall be as follows:

- (a) *Pre-test inspection* Inspect the machine and inspect the performance check results (see Clause 2.7).
- (b) *Selection of indenting force* Select the indenting force taking into account the following factors:
 - (i) The indenting force used should be related both to the form and dimensions of the test piece, and to its material, condition, and anticipated hardness.
 - (ii) Where the value of nominal force is stated in the product specification, that value shall be used. When not specified, the force used should be sufficiently large to produce an indentation of optimum size (see Notes 1 and 2).

NOTES:

- 1 In general, a maximum nominal force of 294 N is recommended. Repeated use of large forces on hard metals may damage the indenter.
- 2 Small indentations on metals of coarse microstructure, such as may occur in some cast irons, tend to give the hardness of individual constituents in the metal and not a representative hardness. In such cases it is advisable, where practicable, to use the Brinell method (see AS 1816).

- 3 In industrial tests carried out in accordance with this Standard, using testing machines in good order, the principal limitation to the accuracy achieved will arise in the measurement of the diagonals of the indentation. For many machines it is unlikely that the accuracy of determination of the mean diagonal length will be better than $\pm 1 \mu\text{m}$. The corresponding error in the resulting hardness value may be obtained from Figure 2.2, which shows the change of hardness value equivalent to a change of $1 \mu\text{m}$ in the length of the mean diagonal for various forces at different levels of hardness. The broken line in the figure represents ± 2 percent error in HV.

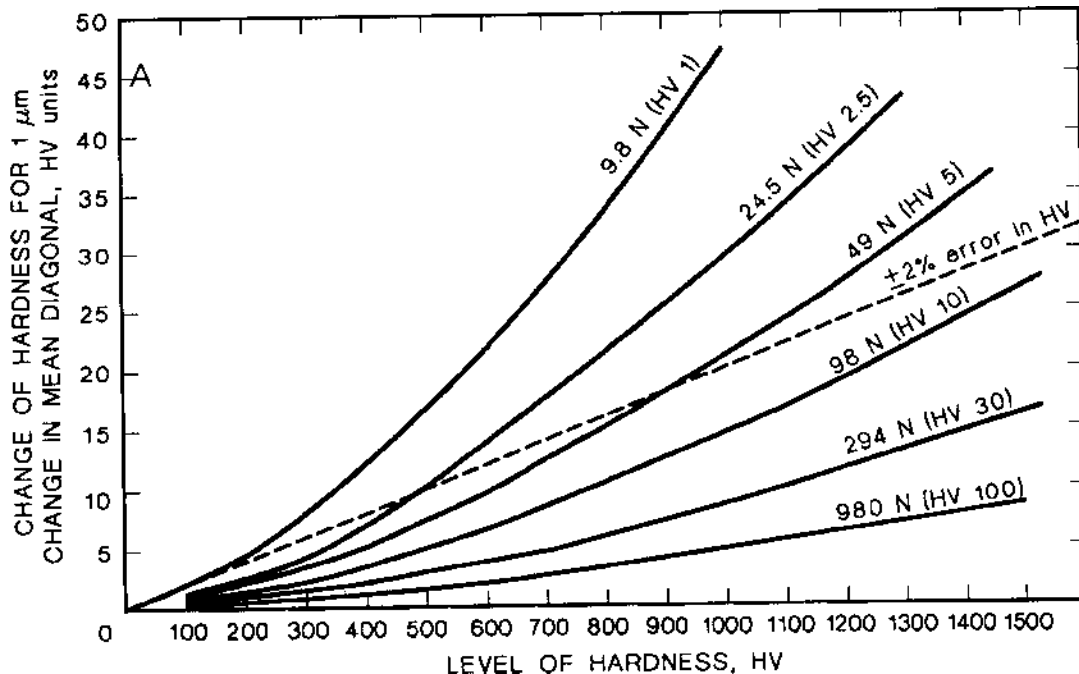


FIGURE 2.2 CHANGE OF HARDNESS FOR $1 \mu\text{m}$ CHANGE IN MEAN DIAGONAL FOR DIFFERENT NOMINAL FORCES AT DIFFERENT LEVELS OF HARDNESS

- (c) *Preparation of test piece* Prepare the test piece in accordance with the requirements of Clause 2.8.1.
- (d) *Method of supporting test piece* Support or clamp the test piece by a suitable method to provide rigidity and to ensure that the test surface of the test piece is normal to the axis of the indenter. Where the test piece rests directly on the support, ensure that its bearing surface and that of the anvil is clean and free from foreign matter, corrosion, and burrs likely to affect the test results.

With some forms of test piece it may be necessary to use an auxiliary support to accommodate the bearing surface of the test piece. It may also be necessary to make provision for supporting the overhanging portion of a long test piece or to provide a special jig, e.g. to support a gear wheel when testing gear teeth. The use of auxiliary supports requires additional care to ensure that the test piece does not move when the indenting force is applied.

NOTES:

- 1 Asymmetrical indentations usually indicate a tilted test piece and may give unreliable results. The error in hardness is not likely to exceed 1 percent if the angle of tilt is less than 2 degrees, particularly if the results of several indentations are averaged.
- 2 For test pieces in which the test surface is inaccessible to the normal indenter and measuring microscope, e.g. gear teeth, recesses, or internal surfaces of tubes, it is necessary for the indenter holder to be of special form or for special attachments to be fitted between the indenter carrier and the indenter, and the measuring device. Some of these indenter fittings require compensation for their weight and should only be used on machines with special provision for them.

- (e) *Operation of the testing machine* Operate the machine in accordance with the manufacturer's instructions.

With the machine set up with the selected nominal force and the test piece correctly supported, apply the force and maintain it for not less than 10 s or longer than 15 s, unless otherwise specified in the product specification. Remove the force and measure the lengths of diagonals of the indentation. The mean value of the two measurements of diagonals is used in the determination of the hardness value.

Wherever possible, carry out a minimum of three tests on each test piece, unless otherwise specified in the product specification.

For metals that show time-dependent plasticity during the test, the product specification should specify the time for which the force is to be applied.

- (f) *Spacing of indentations* Ensure that the distance between the centre of any indentation and the edge of the test piece is at least 2.5 times the mean diagonal of the indentation in the case of steel, copper and copper alloys, and at least 3 times the mean diagonal of the indentation in the case of light metals, lead and tin and their alloys.

Also ensure that the distance between the centres of two adjacent indentations is at least 3 times the mean diagonal of the indentation in the case of steel, copper and copper alloys, and at least 6 times the mean diagonal in the case of light metals, lead and tin and their alloys. If two adjacent indentations differ in size the spacing is based on the mean diagonal of the larger indentation.

- (g) *Tests on curved surfaces* Unless otherwise stated in the product specification, apply a correction when the test surface is spherical or cylindrical. Tables giving the correction factors applicable when tests are made on convex or concave surfaces, both spherical and cylindrical, are given in Appendix B.

NOTES:

- 1 These correction factor tables have been calculated on the basis of the geometry of intersecting surfaces and take no account of other factors (see Clause 2.8.1 for precautions to be taken in preparing the test surface).
- 2 When indenting curved surfaces, special precautions are necessary to ensure that the axis of the indenter is normal to the test surface.

2.10 RECORD OF TEST RESULTS A record of test results shall be made and shall be capable of providing the following information:

- (a) Identification of the laboratory.
- (b) Identification of the testing machine.
- (c) Identification of the indenter and any attachments used.
- (d) Identification of auxiliary supports.
- (e) Product description and test piece identification.
- (f) Reference number of product specification, where applicable.
- (g) Form of the test surface, e.g. whether the test surface is flat, cylindrical or spherical (concave or convex) and, where applicable, the diameter. If flat, whether the test area has been prepared on a curved surface.
- (h) Indenting force.
- (i) Duration of application of the full force, when other than 10 s to 15 s.
- (j) The measured value of each diagonal of each indentation and, where applicable, the correction table and factor for curvature of the test surface.
- (k) Each hardness value obtained.
- (l) Type of test, i.e. Vickers.
- (m) Name of the person who carried out test.
- (n) Reference number of this Australian Standard, i.e. AS 1817.
- (o) Date of test.

2.11 TEST REPORT The test report shall include the following information:

- (a) Description and identification of the test piece.
- (b) Type of test, i.e. Vickers.
- (c) Reference to this Australian Standard, i.e. AS 1817, and any relevant product specification.
- (d) If the test surface is curved, the correction that has been applied.
- (e) Each hardness value obtained, including the appropriate hardness symbol, e.g. 400 HV 30, 150 HV 30/20.
- (f) Compliance or otherwise with specified values, when applicable.
- (g) Report number and date.

SECTION 3 COMPLETE CALIBRATION OF THE TESTING MACHINE

3.1 GENERAL Complete calibration of hardness testing machines involves a preliminary inspection of the machine, calibration of the applied forces and the apparatus for measuring the diagonals of the indentations, together with an examination of the indenter and a performance test using each indenter assigned to the machine.

3.2 PRELIMINARY INSPECTION Before applying the procedure given in this Section, it shall be ascertained that —

- (a) the machine is level and correctly set up on a rigid foundation on a site which is free from vibration, and not subject to gritty or dusty conditions, or excessive temperature changes;
- (b) the test piece support and load bearing surfaces of the indenter and carrier are in good order, i.e. clean and free from corrosion and burrs;
- (c) the indenter is capable of being correctly secured in the carrier;
- (d) the forces are applied and removed without shock or vibration, and the force can be maintained for not less than 10 s nor greater than 15 s, and for other durations for which the machine is required to be used;
- (e) where applicable, the zero reading of the measuring apparatus is correctly adjusted;
- (f) where the measuring apparatus is integral with the machine, the indentation is in the centre of the field of view; and
- (g) the illumination is uniform over the field of view and provides adequate contrast between the indentation and the surface of a standard hardness block.

3.3 INDENTING FORCES The forces applied by the testing machine shall be calibrated by means of masses, proving levers, or elastic proving devices, and the equipment used shall conform to the requirements of AS 2193 for calibrating Grade A machines. If the machine is designed to provide an automatic time cycle, it shall be verified that the time for which the full force is maintained is not less than 10 s nor longer than 15 s. This shall be done before calibrating the forces.

It is necessary only to calibrate those forces required for testing.

NOTE: In order that the indenting forces may be calibrated under normal operating conditions, it is desirable that the deflection of the force measuring device under the applied force be less than the available travel of the indenter.

The calibration procedure should reproduce as closely as possible the conditions of normal use. Immediately before each reading of an applied force is taken, the indenter carrier shall have moved, under the control of the mechanism, in the same direction as occurs during a hardness test.

Measurements of each force shall be made at three or more positions of the indenter carrier covering the working range (where applicable), and each value obtained shall agree with its nominal value within ± 1 percent.

3.4 INDENTER

3.4.1 Description The indenter shall comply with the requirements of Clause 2.3.

3.4.2 Load test The diamond shall be subjected at least three times to a nominal force of 980 N or the maximum capacity of the machine, if this is lower, in an appropriate hardness test.

3.4.3 Condition The portion of the diamond that makes contact with the test piece shall be well polished and be free from cracks or other surface defects when examined at a magnification of 50 $\times$ to 100 $\times$ after being subjected to the load test. All edges shall be sharp.

NOTE: The area of the diamond in contact with the test piece depends on the indenting force applied and the hardness of the test piece, therefore, for a given machine, the polished area of the diamond should be adequate for the largest indentation which the machine is capable of producing. This information may be obtained by using the table of the hardness values in Appendix A corresponding to the maximum force applied by the machine. An indenter polished and free from cracks or other surface defects, within a distance of 300 μm from the tip, is suitable for all forces and hardness levels.

3.5 MEASURING APPARATUS The measuring device shall be calibrated by measurements made on a stage micrometer using a minimum of five intervals over its working range. At least two of the intervals shall be within the range 0 μm to 200 μm . The quality and spacing of the scale of the measuring device shall be such that when used to measure a stage micrometer, a change of half the maximum permissible error or less can be detected.

The measuring device shall be capable of measuring the intervals of the stage micrometer to the following accuracy:

- (a) For intervals up to and including 200 μm : ± 1 μm (maximum permissible error).
- (b) For intervals exceeding 200 μm : ± 0.5 percent (maximum permissible error).

Intervals of the stage micrometer shall be known to within ± 0.5 μm .

3.6 PERFORMANCE TEST A performance test using standard hardness blocks shall be carried out in accordance with Clauses 4.3 and 4.4.

3.7 RECORD OF RESULTS A record shall be kept of all readings taken during the calibration, all calculations made, and any other information required to produce a report as required by Clause 3.8.

3.8 REPORT OF COMPLETE CALIBRATION On completion of a complete calibration a report shall be issued. The report shall include the following information:

- (a) Manufacturer, type, serial number and location of machine.
- (b) Defects detected during the preliminary inspection and adjustments made.
- (c) Identification of the measuring apparatus, indenters and associated reports.
- (d) The range of calibration of the measuring apparatus.
- (e) Nominal values of the forces calibrated.
- (f) The assigned value of the standard hardness blocks, the mean hardness values obtained in the performance tests, and identification of the indenter used in the test.
- (g) Date of calibration.
- (h) Reference to this Australian Standard, i.e. AS 1817.
- (i) A statement of compliance or otherwise with the requirements of Section 3.
- (j) Recommended date of next calibration.