

METHODS OF TESTING VULCANIZED RUBBER

PART A26. DETERMINATION OF HARDNESS

BS 903 : Part A26 : 1969



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The Institution desires to call attention to the fact that this British Standard does not purport to include all the necessary provisions of a contract.

In order to keep abreast of progress in the industries concerned, British Standards are subject to periodical review. Suggestions for improvements will be recorded and in due course brought to the notice of the committees charged with the revision of the standards to which they refer.

A complete list of British Standards, numbering over 5000, fully indexed and with a note of the contents of each, will be found in the British Standards Yearbook. The B.S. Yearbook may be consulted in many public libraries and similar institutions.

British Standards are revised, when necessary, by the issue either of amendment slips or of revised editions. It is important that users of British Standards should ascertain that they are in possession of the latest amendments or editions.

The following BSI references relate to the work on this standard:
Committee references RUC/10, RUC/10/4
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CO-OPERATING ORGANIZATIONS

The Rubber Industry Standards Committee, under whose supervision this British Standard was prepared, consists of representatives from the following Government and scientific and industrial organizations:

- British Association of Synthetic Rubber Manufacturers
- *British Rubber Manufacturers Association Ltd.
- *Institution of the Rubber Industry
- *Ministry of Technology
 - Natural Rubber Bureau
- *Natural Rubber Producers' Research Association
- *Rubber and Plastics Research Association of Great Britain
- Rubber Growers' Association
- *Society of Motor Manufacturers and Traders Ltd.
- Tyre Manufacturers Conference Ltd.

The Government department and scientific and industrial organizations marked with an asterisk in the above list, together with the following, were directly represented on the committee entrusted with the preparation of this British Standard:

- British Railways Board
- British Rubber and Resin Adhesive Manufacturers' Association
- British Society of Rheology
- Chemical Industries Association
- Electrical Research Association
- Institution of Mechanical Engineers
- Institution of Mechanical Engineers (Automobile Divn.)
- Institution of Municipal Engineers
- Institution of Water Engineers
- Ministry of Defence (Air Force Dept.)
- Ministry of Defence (Army Dept.)
- Ministry of Defence (Navy Dept.)
- Ministry of Housing and Local Government
- National College of Rubber Technology
- National Physical Laboratory (Ministry of Technology)
- Post Office
- Royal Institute of Chemistry

BRITISH STANDARD
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VULCANIZED RUBBER

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FOREWORD

This British Standard has been published with the Authority of the Rubber Industry Standards Committee. This standard brings together in one volume methods of test previously published as Parts A7, A20 and A22 of BS 903 relating to the normal hardness test, the microtest and the test for the apparent hardness of curved surfaces respectively. Two new methods for high and low hardness have been included.

This standard at present comprises five methods:

Method N	Determination of hardness (Normal test)		
Method H	"	"	(High hardness test)
Method L	"	"	(Low hardness test)
Method M	"	"	(Microtest)
Methods CN, CH, CL, CM	Determination of apparent hardness of curved surfaces using methods N, H, L and M respectively.		

Further methods may be issued later to cover microtests for rubbers of high and low hardness.

Recommendations of the International Organization for Standardization (ISO) with which methods in this standard are now in agreement, are as follows:

ISO/R No.	Title of Recommendation	Method
48	Determination of hardness of vulcanized rubbers	N and M
1400	Determination of hardness of vulcanized rubbers of high hardness (85 to 100 IRHD)	H
1818	Determination of hardness of vulcanized rubbers of low hardness (10 to 35 IRHD)	

In addition the procedure given in all the methods in this standard concerning the time interval between vulcanization and testing agrees with that described in ISO/R 1826, 'Time lapse between vulcanization and testing of rubbers'. It should be noted, however, that there are no equivalent ISO methods on the determination of apparent hardness of curved surfaces for which methods are given in this standard.

METHODS OF TEST

1. GENERAL

1.1 SCOPE

This British Standard lays down methods for determining the hardness of vulcanized rubber.

1.2 DEFINITIONS

For the purposes of this British Standard the following definitions, which are common to all methods of rubber hardness testing, apply:

Stress. The average force per unit area of the original cross section.

Strain. The alteration of the shape or dimensions resulting from stress, this alteration being expressed as a fraction of the original dimension.

Young's modulus. Young's modulus, as applied to vulcanized rubber, is the ratio of either compressive stress to compressive strain, or tensile stress to tensile strain, when the strain is very small.

Standard hardness. The hardness of the rubber as measured by standard test methods on standard test pieces.

Apparent hardness. The hardness of the rubber as measured on non-standard test pieces..

1.3 SUMMARY AND EXPLANATORY NOTES

1.3.1 The British Standard rubber hardness tests are based on measurement of the indentation of a rigid ball into the rubber test piece under specified conditions. The measured indentation is converted into International Rubber Hardness Degrees, the scale being so chosen that 0 represents a material having a Young's modulus of zero, and 100 represents a material of infinite Young's modulus. The term International Rubber Hardness Degrees (IRHD) denotes the hardness scale recommended by the International Organization for Standardization (ISO).

For substantially elastic isotropic materials like well vulcanized natural rubbers, the hardness in International Rubber Hardness Degrees bears a known relation to Young's modulus (see Appendix A), although for markedly plastic or anisotropic rubbers the relationship will be less precisely known. A difference of one International Rubber Hardness Degree represents approximately the same proportionate difference in Young's modulus over most of the usual range of hardness.

The hardness test consists in measuring the increase in the depth of indentation of the ball into the rubber (the indentation increment) when the force exerted by the ball is increased from a small initial value to a larger final value, the depths of indentation being measured in all cases relative to a foot resting on the surface of the rubber, except in those instances in Methods CN, CH, CL and CM where the use of a foot is impracticable or inappropriate. The relation between the indentation increment and International Rubber Hardness Degrees for each method of test is given in an associated conversion table, e.g. Tables 2 and 3 in the case of Method N. Most instruments are calibrated, on the basis of the conversion table, to read directly in International rubber hardness degrees. Where instruments are not thus calibrated the indentation increment readings are individually converted to International Rubber Hardness Degrees by the use of the table or a graph based on the table.

The hardness value is dependent on the dimensions of the test piece, the thickness usually being the most critical dimension. Test pieces of standard

dimensions are therefore specified for the measurement of 'standard hardness'. Results obtained on non-standard test pieces will in general differ from standard hardness and are denoted as 'apparent hardness'.

The hardness value decreases as the test piece dimensions are increased and approaches asymptotically a lower limiting value as the dimensions become large in comparison with the diameter of the indenting ball and the depth of the indentation. The sensitivity of the hardness value to variations in the size of the test piece is consequently greater for small test pieces than for large test pieces.

The conflicting requirements of high sensitivity in the measurement of hardness and of low sensitivity to the effects of test piece size and surface skin on the rubber are not easily reconciled. Several test methods are therefore necessary to cover the complete technical range in hardness (10–100 IRHD) and an adequate range in test piece size. The methods differ primarily in the diameter of the indenting ball and the magnitude of the indenting force, these being chosen to suit the particular application. The range of applicability of each is indicated in Fig. 1.

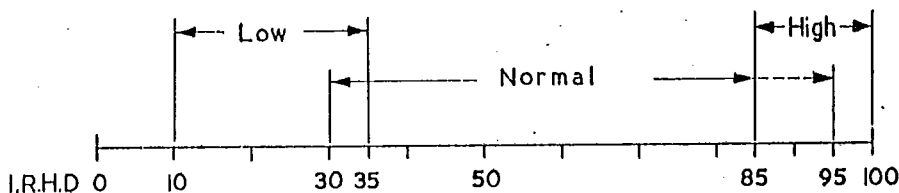


Fig. 1. Range of applicability

It has been found that in the ranges where the normal test overlaps the low and high hardness tests, i.e. 30 to 35 and 85 to 95 IRHD respectively (see Fig. 1), there may be a small difference between the readings by the normal and low hardness, or normal and high hardness tests. Consequently in these ranges comparison should not be made between readings obtained by different forms of test. For referee purposes when results obtained in the normal hardness test fall below 35 or above 85 a subsequent test should be made by either the low hardness test or the high hardness test as applicable, and the result of this test reported.



1.3.2 Method N. Normal test. The normal test for hardness is essentially as described in the summary above. This method conforms to the corresponding method of the International Organization for Standardization (ISO). It is the appropriate method for test pieces of thickness greater than 4 mm and is preferably used for rubbers in the range 30-85 IRHD but may be used for those in the range 30-95 IRHD. The preferred indenter is a ball of 2.5 mm diameter.

The relation between the indentation increment and International Rubber Hardness Degrees for this test is given in Tables 2 and 3.

1.3.3 Method H. High hardness test. The high hardness test for hardness is essentially as described in the summary above. This method conforms to the corresponding method of the International Organization for Standardization (ISO). It is the appropriate method for test pieces of thickness greater than 4 mm

and of hardness in the range 85–100 IRHD. The indenter is a ball of 1.0 mm diameter.

The relation between the indentation increment and International Rubber Hardness Degrees for this test is given in Tables 4 and 5.

1.3.4 Method L. Low hardness test. The low hardness test for hardness is essentially as described in the summary above. This method conforms to the corresponding method of the International Organization for Standardization (ISO). It is the appropriate method for test pieces of thickness greater than 6 mm and of hardness in the range 10–35 IRHD. The indenter is a ball of 5.0 mm diameter.

The relation between the indentation increment and International Rubber Hardness Degrees for this test is given in Tables 6 and 7.

1.3.5 Method M. Microtest. The microtest for hardness is essentially a scaled-down version of the normal test described in Method N, permitting the testing of thinner and smaller test pieces. The method conforms to the corresponding method of the International Organization for Standardization (ISO). It is the appropriate method for test pieces of thickness less than 4 mm and is preferably used for rubbers in the range 30–85 IRHD but may be used for those in the range 30–95 IRHD. The indenter is a ball of 0.395 mm diameter.

The relation between the indentation increment and International Rubber Hardness Degrees for this test is as given in Tables 2 and 3 except that the indentation increments of this table represent in this case the actual indentation increment multiplied by the scaling factor 6 (which is approximately the ratio of the diameters of the indenting balls used in the normal test and microtest respectively). In some instruments the scaling factor is automatically applied so that the indicated indentation increment is six times the actual increment. In such cases Tables 2 and 3 are used directly (without further application of a scaling factor) either to convert the individual indentation increment readings into International Rubber Hardness Degrees or to calibrate the instrument to read directly in International Rubber Hardness Degrees. In all other cases allowance must be made for the scaling factor in using Table 2 or 3 to convert individual indentation increment readings or to calibrate the instrument in International Rubber Hardness Degrees.

Provided the test piece has flat parallel surfaces large enough to permit the test to be made well away from the edges, the reading obtained in the microtest is comparable with that obtained in the normal test on a test piece about five times the thickness of that used in the microtest. Theoretically, equivalence between normal tests and microtests should be obtained with test piece thicknesses in the ratio 6 : 1, but in practice the ratio varies, being reduced by surface hardening of the rubber and increased if the surface is buffed. A ratio of 5 : 1 seems most likely to give equivalence but this will not always be exact.

1.3.6 Methods CN, CH, CL and CM. Apparent hardness tests on curved surfaces. These methods describe modifications of the procedures given in Methods N, H, L and M for cases where the rubber surface tested is curved. It is convenient to distinguish broadly between two cases dependent on whether (i) the test piece or article tested is big enough for the hardness instrument to rest upon it, or (ii) small enough for both the test piece and the instrument to rest upon a common support. A variant of (ii) would be where the test piece rests on the specimen table of the instrument. The procedures described cannot provide for all possible shapes and dimensions of test piece but cover some of the commonest types such as rubber-covered rollers and O-rings.

As the test is commonly made on a complete article the thickness of the rubber will vary greatly and in many cases the lateral dimensions will not provide the minimum distance between the indenter and the edge necessary to eliminate edge effects. The readings obtained, therefore, will not in general coincide with the reading on a standard test piece as defined in Methods N, H, L or M, or even on a flat parallel-faced slab of the same thickness as the article.

Moreover, the reading may depend appreciably on the method of support, i.e. on the freedom of the rubber to deform in various directions. Thus a ring may give different readings according to whether it rests on a flat surface allowing free lateral deformation, or in a groove of 'U' or 'V' shape which will restrict lateral deformation. The reading will also depend on whether a presser foot has been used or not.

It must, therefore, be recognized that test results on curved surfaces are arbitrary values applicable only to test pieces or articles of one particular shape and dimensions supported in one particular way, and in extreme cases may differ from the standard hardness by as much as 10 IRHD. Moreover, surfaces that have been buffed, e.g. to remove cloth marking, will give slightly different hardness values from those with a smooth mould finish. For these reasons the test results will in general be an apparent hardness and not the standard hardness of the rubber.

2. METHODS N, H AND L. DETERMINATION OF HARDNESS

2.1 TEST PIECE

The test piece shall, wherever possible, be from moulded sheet. It shall have its upper and lower surfaces flat, smooth and parallel to one another. Two pieces of the rubber (but not more than two, neither of which shall be less than 2 mm thick) may be superimposed to obtain the necessary thickness.

If the two pieces are of different thickness the thicker piece shall be placed on top.

The standard test piece for Methods N and H shall be between 8 mm and 10 mm thick and for Method L shall be between 10 mm and 15 mm thick. No other dimension shall be less than 25 mm for Methods N and H, or less than

30 mm for Method L. Only test pieces of these standard dimensions give the **standard hardness** of the rubber as measured by these tests (see also 2.3.3).

NOTE. Results obtained on non-standard test pieces give only an **apparent hardness**; the hardness value will be lower or higher than the **standard hardness** depending on whether the thickness is greater or less than standard. The test piece should not be thinner than 4 mm for Methods N and H nor thinner than 6 mm for Method L and, in order to avoid edge effects, the lateral dimensions of the test piece should be such that no test is made at a distance from the edge of the test piece less than that indicated below. This requires a minimum lateral dimension of the test piece as indicated:

Thickness of test piece in mm	4	6	8	10	15	25
Minimum distance of test from edge in mm	7.0	8.0	9.0	10.0	11.5	13.0
Minimum lateral dimensions of test piece						
Methods N and H, in mm	25.0	25.0	25.0	27.0	30.0	33.0
Method L, in mm	—	30.0	30.0	30.0	30.0	33.0

2.2 APPARATUS

The essential parts and mode of action of the apparatus shall be as follows, the specified dimensions and forces being as shown in Table 1:

2.2.1 An indenter, comprising a vertical plunger terminating at its lower end in a rigid ball, and capable of substantially frictionless vertical movement. The part of the plunger immediately above the ball shall be substantially reduced in cross section, as shown in Fig. 2, so as to avoid coming into contact with the rubber.

2.2.2 A rigid foot in the form of an annulus of rectangular cross section, concentric with the indenter, having a lower surface (the datum surface) that is flat and normal to the indenter axis. The foot and its attachments shall allow free passage of the indenter, and shall be capable of substantially frictionless vertical movement.

2.2.3 Means for lowering the foot so that it presses vertically on the test piece with the specified stress of $30 \pm 5 \text{ kPa}^*$. The force shall remain constant to within $\pm 0.1 \text{ N}$ during the test. The requisite force is most simply achieved by appropriate deadweight loading of the foot and its attachments.

2.2.4 Means for supporting the indenter so that, except when an indentation measurement is actually being made as in 2.2.5 and 2.2.6, the lowest extremity of the indenter is always at least 0.5 mm above the datum surface of the foot.

2.2.5 Means for lowering the indenter so that it presses vertically on the test piece with the specified contact force and for increasing this force by the amount specified as the indenting force increment. The contact force and the total force (comprising the contact force plus the indenting force increment) shall each remain constant to within $\pm 0.005 \text{ N}$ during the test.

*1 kPa = 1 kN/m².

TABLE 1. SPECIFIED DIMENSIONS AND FORCES

Test	Diameters	Force on ball			Force on foot
		Contact	Indenting increment	Total	
Normal Method N	mm	N	N	N	N
	Preferred Ball 2.50 ± 0.01 Foot 20 ± 1 Hole 6 ± 1	0.30 ± 0.02	5.40 ± 0.01	5.70 ± 0.03	8.3 ± 1.5
	Alternative Ball 2.38 ± 0.01 Foot 20 ± 1 Hole 6 ± 1	0.30 ± 0.02	5.23 ± 0.01	5.53 ± 0.03	8.3 ± 1.5
	Ball 1.00 ± 0.01 Foot 20 ± 1 Hole 6 ± 1	0.30 ± 0.02	5.40 ± 0.01	5.70 ± 0.03	8.3 ± 1.5
High hardness Method H	Ball 5.00 ± 0.01 Foot 22 ± 2 Hole 10 ± 1	0.30 ± 0.02	5.40 ± 0.01	5.70 ± 0.03	8.3 ± 1.5
Low hardness Method L					

NOTE. All possible combinations of dimensions and forces in this table will not meet the stress requirements of 2.2.3. It is accordingly recommended that the foot and hole diameters should have a tolerance of ± 0.1 mm; this will ensure that the stress is within the limits specified.

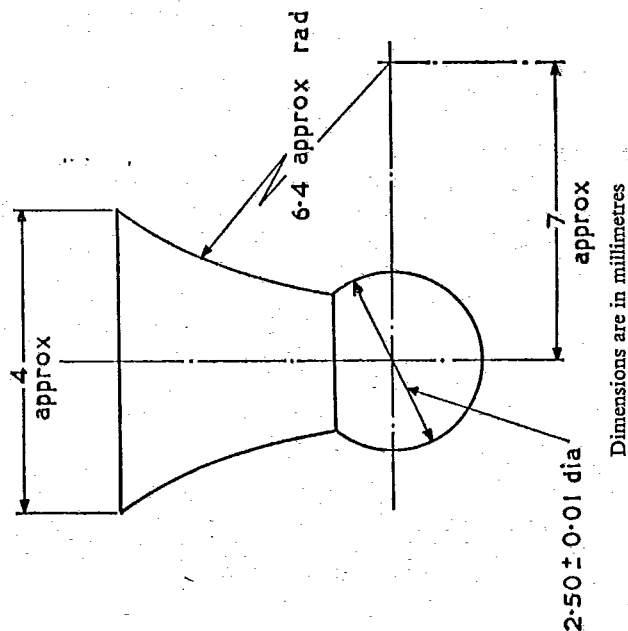


Fig. 2. Preferred indenter for Method N