METHODS OF TESTING VULCANIZED RUBBER

PART A26. DETERMINATION OF HARDNESS

BS 903 : Part A26 : 1969

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BRITISH STANDARDS INSTITUTION

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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
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BRITISH STANDARD

METHODS OF TESTING VULCANIZED RUBBER

Part A26. Determination of Hardness

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. Certain revisions have also been made to methods N and M in order to bring these standards into line with the appropriate recommendations of the International Organization for Standardization (ISO). 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.

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.

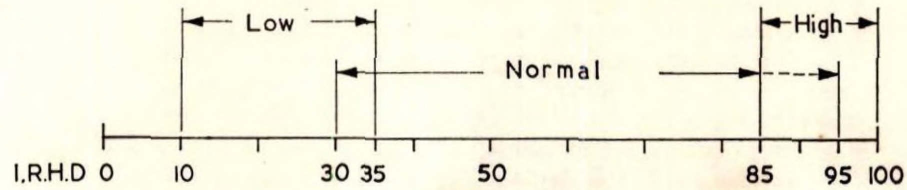


Fig. 1. Range of applicability

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 indentor 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 indentor 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 indentor 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 indentor 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 indentor 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.

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 indentor, 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 indentor, having a lower surface (the datum surface) that is flat and normal to the indentor axis. The foot and its attachments shall allow free passage of the indentor, 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 0·30 ± 0·05 bar. The force shall remain constant to within ±0·1 N during the test. The requisite force is most simply achieved by appropriate deadweight loading of the foot and its attachments.

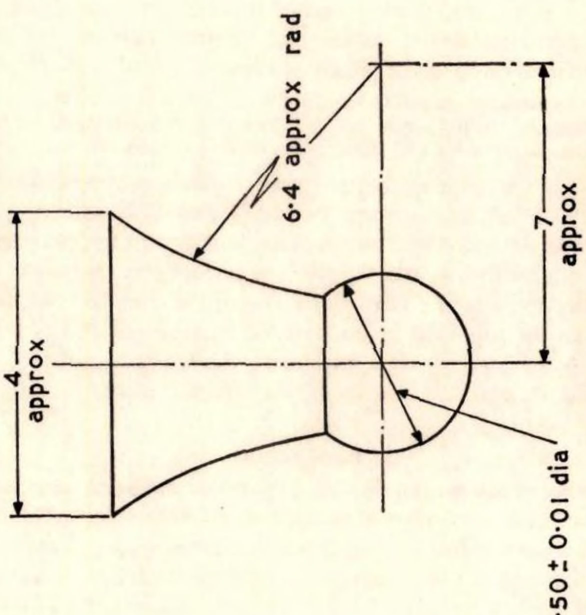
2.2.4 Means for supporting the indentor so that, except when an indentation measurement is actually being made as in 2.2.5 and 2.2.6, the lowest extremity of the indentor is always at least 0·5 mm above the datum surface of the foot.

2.2.5 Means for lowering the indentor 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 ± 0·005 N during the test.

TABLE 1. SPECIFIED DIMENSIONS AND FORCES

Test	Diameters	Force on ball			Force on foot
		Contact	Indenting increment	Total	
	mm	N	N	N	N
Normal Method 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
High hardness Method H	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
Low hardness Method L	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

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.



Dimensions are in millimetres

Fig. 2. Preferred indentor for Method N

2.2.6 Means, which may be mechanical, optical or electrical, for measuring the vertical movement of the indentor relative to the foot either in units of 0·01 mm (0·02 mm for Method L) or directly in International Rubber Hardness Degrees. If the scale reads directly in hardness degrees the relationship between the scale and the pointer shall be capable of manual adjustment.

The calibration of instruments reading directly in International Rubber Hardness Degrees shall be based on the indentation-hardness relations given in Tables 2 to 7.

NOTE. A dial gauge having a travel of 2 mm per revolution for Method N, 0·5 mm per revolution for Method H or 4 mm per revolution for Method L is suggested.

2.2.7 Means, e.g. an electrically-operated buzzer, for gently vibrating the apparatus to overcome any slight residual friction. This may be omitted in instruments where friction is completely eliminated.

NOTE. In order to maintain machine accuracy it is essential that as far as is practicable all moving parts, especially the dial gauge, should be kept free of grease, dust, talc and the like. Serious errors have arisen in the past from failure to observe these precautions.

2.2.8 A means of maintaining the test piece at the appropriate temperature if tests are made at temperatures other than 20°C. For sub-zero temperatures this shall be a chamber equipped with means of maintaining the test piece temperature at the desired value within $\pm$ 2 degC or such higher accurac yas may be necessary. The foot and indentor extend through the top of the chamber and the portions passing through the top shall be constructed from a material of low thermal conductivity. A sensing device for measuring the temperature shall be located within the chamber near or at the location of the test piece.

2.3 PROCEDURE

2.3.1 Preparation of sample (applicable only where moulded sheet is not available). If fabric is attached to or embedded in the rubber sample, it shall be removed before cutting the test pieces. The method of removal shall preferably avoid the use of a swelling liquid, but benzene, chloroform or carbon tetrachloride may be used to wet the contacting surfaces if necessary. Care shall be taken to avoid stretching the rubber during the separation from the fabric, and liquid, if used, shall be allowed to evaporate completely from the rubber surfaces after separation. Cloth-marked surfaces shall be made smooth by buffing and a rubber sample which is of uneven thickness, or of thickness above the maximum specified for the test pieces which are to be cut from it, shall also be buffed as necessary. A fine abrasive (No. 60 or No. 80 grit) shall be used for the final buffing and undue heating of the rubber shall be avoided throughout the operation.

The surfaces produced by this buffing treatment lead to slightly different values for hardness from those with a smooth mould finish, the magnitude of the effect depending on the type of rubber.

2.3.2 Conditioning and temperature of test. For all test purposes the minimum time between vulcanization and testing shall be 16 hours and for evaluations intended to be comparable the tests should, as far as possible, be carried out after the same time interval from vulcanization.

The test is normally carried out at a temperature of 20 ± 2°C. When a test is made at this standard laboratory temperature, the test pieces shall be maintained at the conditions of test for at least three hours before testing. When tests are made at higher or lower temperatures, the test pieces shall be maintained at the conditions of test for a period of time sufficient to reach temperature equilibrium with the testing environment or for the period of time required by the specification covering the material or product being tested.

Samples and test pieces shall be protected from light as completely as possible during the interval between vulcanization and testing. If the preparation of the samples or test pieces involves buffing, the interval between buffing and testing shall not exceed 72 hours.

2.3.3 Effect of thickness. Tests intended to be comparable should be made on test pieces of similar thickness. As an approximate guide, the disparity in thickness (expressed in mm) between any two test pieces should not exceed $T^2/30$ (T being the mean thickness in mm) if the hardness readings on these test pieces are to be comparable within 1 IRHD and should be proportionately smaller for more closely comparable readings.

2.3.4 Method of measurement. The upper and lower surfaces of the test piece shall be lightly dusted with talc, any excess removed and the test piece supported on a horizontal rigid surface. The apparatus vibrator shall be switched on, and the foot shall then be lowered so that it presses on the test piece with the requisite force. Immediately afterwards the indentor shall be lowered so that it presses on the test piece with the contact force, and this force shall be maintained for 5 seconds. At the end of this period the force shall be increased immediately by the amount denoted as the indenting force increment, and this increased force shall be maintained for 30 seconds.

If the gauge for measuring the indentor penetration is graduated directly in International rubber hardness degrees, the relationship between the pointer and the scale shall be adjusted (in the case of a dial gauge this entails a rotation of the bezel) during the above-mentioned 5 seconds period so that at the end of this period the pointer indicates 100 (care being taken not to exert any vertical force on the indentor). The hardness reading indicated by the pointer shall then be taken at the end of the above-mentioned 30 seconds period.

If the gauge is graduated in units of 0·01 mm (0·02 mm for Method L) the readings indicated by the pointer shall be taken at the ends of the above-mentioned 5 seconds and 30 seconds periods respectively. The difference between these two readings shall be converted to International Rubber Hardness Degrees by using Table 3, 5 or 7 or graphs constructed from Table 2, 4 or 6. Alternatively, if the gauge is adjustable, it may be adjusted (care being taken not to exert any vertical force on the indentor) so as to read zero at the end of the above-mentioned 5 seconds period, and the reading at the end of the above-mentioned 30 seconds period shall be converted to International rubber hardness degrees.

2.3.5 Number of readings. One measurement shall be made at each of three or five different points distributed over the test piece and the median of the results shall be taken (i.e. the middle value when these are arranged in increasing order).

2.4 REPORT

2.4.1 Hardness shall be reported to the nearest whole number for Methods N and L, or the nearest 0·2 IRHD for Method H, as the median result of the measurements expressed in International Rubber Hardness Degrees (indicated by the degree sign °), followed by

(1) *either* ' S ' for tests on the standard test piece *or* the thickness and smallest lateral dimension (in mm) for tests on non-standard test pieces (the result then being **apparent hardness**);

(2) the code letter (N, H or L) denoting the test method used.

2.4.2 Examples

Normal test on disk 9 mm thick, 50 mm dia.: 58°/S/N.
Low hardness test on slab 5 mm thick × 25 mm × 15 mm: 16°/5 × 15/L.
High hardness test on disk 6·3 mm thick, 12·5 mm dia.: 90·6°/6 × 13/H.

2.4.3 The following additional information shall be given:

(1) whether the test piece is composed of one or two layers;

(2) temperature of test, if other than 20 ± 2°C;

(3) type of surface, if not moulded (e.g. buffed).

3. METHOD M. DETERMINATION OF HARDNESS—MICROTEST

3.1 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 0·5 mm thick) may be superimposed to obtain the necessary thickness.

The standard test piece shall be 2 ± 0·5 mm thick, and its lateral dimensions shall be such that no test is made at a distance from the edge of less than 2 mm.

Only test pieces of these standard dimensions give the **standard hardness** of the rubber as measured by the microtest. This **standard hardness** is approximately equivalent to the **standard hardness** as measured by the Normal test (see 2.3).

NOTE. It is permissible to use non-standard test pieces, but they should not be thinner than 1 mm and should not normally be thicker than 4 mm. 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 less than 2 mm. Results on non-standard test pieces give only an **apparent hardness**; the hardness value will be either lower or higher than the **standard hardness** depending on whether the thickness is greater or less than standard.

3.2 APPARATUS

The essential parts and mode of action of the apparatus are as follows, the specified dimensions and forces being as shown in 3.2.8.

3.2.1 An indentor, 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 so as to avoid coming into contact with the rubber.

3.2.2 A rigid foot in the form of an annulus of rectangular cross section, concentric with the indentor, having a lower surface (the datum surface) that is flat and normal to the indentor axis. The foot and its attachments shall allow free passage of the indentor, and shall be capable of substantially frictionless vertical movement. The foot shall press vertically on the test piece with the specified force.

3.2.3 Means for supporting the indentor so that, except when an indentation measurement is actually being made, as in 3.2.4 and 3.2.5, the lowest extremity of the indentor is always at least 0·1 mm above the datum surface of the foot.

3.2.4 Means for bringing the indentor into contact with the test piece 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.

3.2.5 Means, which may be mechanical, electrical or optical, for measuring the vertical movement of the indentor relative to the foot either in metric units or directly in International rubber hardness degrees. If the scale reads directly in hardness degrees the relationship between the scale and the pointer shall be capable of adjustment.

3.2.6 Means, e.g. an electrically-operated buzzer, for gently vibrating the apparatus to overcome any residual friction. This may be omitted in instruments where friction is completely eliminated.

NOTE. In order to maintain the accuracy of the instrument it is essential that as far as is practicable all moving parts should be kept free of grease, dust, talc and the like. Serious errors have arisen in the past from failure to observe these precautions.

3.2.7 A means of maintaining the test piece at the appropriate temperature if tests are made at temperatures other than 20°C. For sub-zero temperatures this shall be a chamber equipped with means of maintaining the test piece temperature at the desired value within ± 2°C or such higher accuracy as may be necessary. The foot and indentor extend through the top of the chamber and the portions passing through the top shall be constructed from a material of low thermal conductivity. A sensing device for measuring the temperature shall be located within the chamber near or at the location of the test piece.

3.2.8 Dimensions and forces

Diameter of indentor ball	0·395 ± 0·005 mm
External diameter of annular foot	3·35 ± 0·05 mm
Internal diameter of annular foot	1·00 ± 0·05 mm
Minimum dimension of foot in vertical direction	1 mm
Indentor contact force	8·3 ± 0·5 mN
Indenting force increment	145 ± 0·5 mN
Force exerted by foot	235 ± 30 mN (See Note)

The calibration of instruments reading directly in International Rubber Hardness Degrees shall be based on the indentation-hardness relation shown in Table 2 (see also 2.3).

NOTE. In tests using instruments in which the test piece table is pressed upwards by a spring, the value of the force on foot is that acting during the period of application of the total indenting force. Before the indenting force increment of 145 mN is applied, the force on the foot is greater by this amount, and hence is 380 ± 30 mN.

3.3 PROCEDURE

3.3.1 Preparation of sample (applicable only where moulded sheet is not available). If fabric is attached to or embedded in the rubber sample, it shall be removed before cutting the test pieces. The method of removal shall preferably avoid the use of a swelling liquid, but benzene, chloroform or carbon tetrachloride may be used to wet the contacting surfaces if necessary. Care shall be taken to avoid stretching the rubber during the separation from the fabric, and the liquid, if used, shall be allowed to evaporate completely from the rubber surfaces after separation. Cloth-marked surfaces shall be made smooth by buffing and a rubber sample which is of uneven thickness shall also be buffed as necessary. A fine abrasive (No. 120 grit) shall be used for the final buffing and undue heating of the rubber shall be avoided throughout the operation.

The surfaces produced by this buffing treatment lead to slightly different values for hardness from those with a smooth mould finish, the magnitude of the effect depending on the type of rubber.

3.3.2 Conditioning and temperature of test. For all test purposes the minimum time between vulcanization and testing shall be 16 hours and for evaluations intended to be comparable the tests shall, as far as possible, be carried out after the same time interval from vulcanization.

The test is normally carried out at a temperature of 20 ± 2°C. When a test is made at this standard laboratory temperature, the test pieces shall be maintained at the conditions of test for at least three hours immediately before testing. When tests are made at higher or lower temperatures, the test pieces shall be maintained at the conditions of test for a period of time sufficient to reach temperature equilibrium with the testing environment or for the period of time required by the specification covering the material or product being tested.

Samples and test pieces shall be protected from light as completely as possible during the interval between vulcanization and testing. If the preparation of the samples involves buffing, the interval between buffing and testing shall not exceed 72 hours.

3.3.3 Effect of thickness. Tests intended to be comparable shall be made on test pieces of similar thickness. As an approximate guide, the disparity in thickness (expressed in mm) between any two test pieces shall not exceed $T^2/6$ (T being the mean thickness in mm) if the hardness readings on these test pieces are to be comparable within 1 IRHD and shall be proportionately smaller for more closely comparable readings.

3.3.4 Method of measurement. The upper and lower surfaces of the test piece shall be lightly dusted with talc, any excess removed and the test piece supported on a horizontal rigid surface. The apparatus vibrator shall be switched on, and the foot shall then be lowered so that it presses on the test piece with the requisite force. Immediately afterwards the indentor shall be brought into contact with the test piece with the contact force, and this force shall be maintained for 5 seconds. At the end of this period the force shall be increased immediately by the amount denoted as the indenting force increment, and this increased force shall be maintained for 30 seconds.

If the device for measuring the depth of indentation reads directly in International rubber hardness degrees, it shall be adjusted (without exerting any net vertical force on the indentor) so that it indicates 100 at the end of the above-mentioned 5 seconds period, and the hardness reading indicated by the device at the end of the above-mentioned 30 seconds period shall then be taken.

If the device measures the depth of indentation in metric units, the readings at the ends of the above-mentioned 5 seconds and 30 seconds periods shall be taken. Alternatively, if the relationship between the pointer and scale is adjustable, the device may be adjusted (without exerting any net vertical force on the indentor) so that its reading is zero at the end of the above-mentioned 5 seconds period, and the reading at the end of the above-mentioned 30 seconds period shall then be taken. The difference between the two readings or the final reading (as appropriate), after multiplication as necessary by the scaling factor 6 (see 1.3.5), shall be converted to International Rubber Hardness Degrees by using Table 3 or a graph constructed from Table 2.

3.3.5 Number of readings. One measurement shall be made at each of three or five different points distributed over the test piece, and the median of the results shall be taken (i.e. the middle value when these are arranged in increasing order).

3.4 REPORT

3.4.1 Hardness shall be reported to the nearest whole number as the median result of the three or five measurements expressed in International Rubber Hardness Degrees (indicated by the degree sign °), followed by

(1) *either* ' S ' for tests on the standard test piece *or* the thickness and smallest lateral dimension (in mm) for tests on non-standard test pieces (the result then being **apparent hardness**);
(2) the code letter M.

3.4.2 Examples

Test on slab 2·2 mm thick × 20 mm × 10 mm	62°/S/M
Test on strip 3 mm thick × 4 mm wide	73°/3 × 4/M
Test on disk 1·5 mm thick, 3 mm diameter	48°/1·5 × 3/M

3.4.3 The following additional information shall be given:

(1) whether the test piece is composed of one or two layers;
(2) temperature of test, if other than 20 ± 2°C;
(3) type of surface, if not moulded (e.g. buffed).

4. METHODS CN, CH, CL AND CM—APPARENT HARDNESS OF CURVED SURFACES

4.1 TEST PIECE

The test piece shall be either a complete article or a piece cut therefrom. The underside of a cut piece shall be such that it can be well supported during the hardness test. Throughout this standard the term ' test piece ' includes a complete article. If the surface on which the test is to be made is cloth-marked it shall be buffed as described in 2.3.1 or 3.3.1.

4.2 PROCEDURE

Tests shall be made in accordance with Method N, H L or M, with exceptions as indicated below. The presser foot shall not be used for concave surfaces.

4.2.1 Cylindrical surfaces of large radius. The test instrument, substantially in accordance with 2.2 or 3.2, shall be so constructed as to rest firmly on the rubber surface and to permit the presser foot and indentor to make vertical contact with this surface. This is conveniently done in one of the ways indicated in 4.2.1.1 and 4.2.1.2.

In general an instrument as described in Method M shall be used only when the thickness of rubber tested is less than 4 mm.

4.2.1.1 The instrument is fitted with feet movable in universal joints so that they adapt themselves to the curved surface.

4.2.1.2 The base of the instrument is fitted with two parallel rods A and A′ at a distance apart depending on the curvature of the surface (see Fig. 3). This method can be used on surfaces with radius of curvature down to 20 mm.

4.2.2 Surfaces with double curvature of large radius. An instrument substantially as in 2.2 or 3.2, with movable feet, as described in 4.2.1.1, shall be used. In general an instrument as described in 3.2 shall be used only when the thickness of rubber tested is less than 4 mm.

4.2.3 Cylindrical surfaces of small radius. On surfaces with too small a radius of curvature for the procedures described in 4.2.1 the test piece shall be supported, on the same rigid base as the hardness instrument, in such a way as to minimize bodily movement of the rubber surface when the indenting force increment is applied to the indentor and so that the indentor is vertically above the axis of the test piece. Suitable procedures are as follows.

4.2.3.1 For rubber-covered rollers: by resting in a groove or trough in a metal jig (see Fig. 4*a*). (Here, bodily movement of the rubber surface is due to compression of the rubber between the metal core and the jig.)

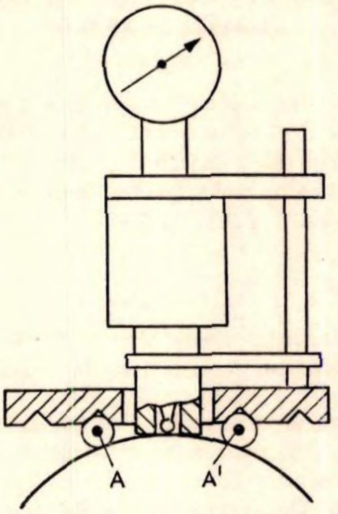


Fig. 3. Testing surfaces of large radius

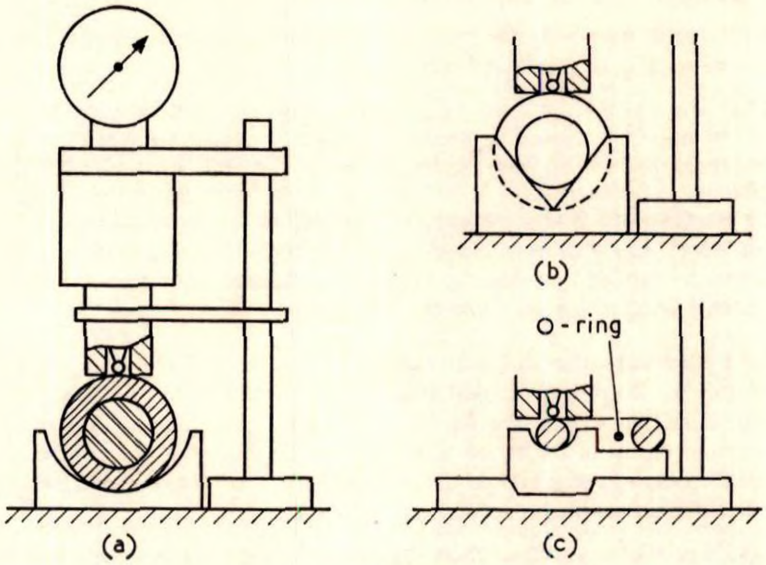


Fig. 4. Test jigs

4.2.3.2 For rubber-covered rollers: by resting the ends of the metal core in V-blocks (see Fig. 4*b*). (Here, bodily movement of the rubber surface is due to bending of the roller.)

4.2.3.3 For O-rings: by resting in a jig supported on the specimen table of the instrument and so designed as to ensure that the underside of the ring beneath the indentor is firmly in contact with the base of the jig and hence does not move when the indenting force increment is applied (see Fig. 4*c*). The jig may be so constructed as to permit lateral adjustment of the test piece to bring its centre exactly beneath the indentor.

4.2.3.4 For O-rings: by fixing to the specimen table with wax.

4.2.4 Small test pieces with double curvature. These shall be held either in a jig that avoids movement of the underside when the indenting force increment is applied and ensures the indentor being exactly vertically above the centre of the curvature, or fixed in wax.

4.2.5 Minimum dimensions. In cases 4.2.3 and 4.2.4, using instruments substantially as in 2.2, the smallest radius of curvature of the surface shall be at least 4 mm. For smaller radii the instrument described in 3.2 shall be used, but no test shall be made if the smallest radius is less than 0·8 mm.

4.3 NUMBER OF READINGS

One measurement is made at each of three or more different points distributed over the test piece. The median of the results shall be taken (i.e. the middle value when these are arranged in increasing order).

4.4 CONDITIONING AND TEMPERATURE OF TEST

For all test purposes the minimum time between vulcanization and testing shall be 16 hours and for evaluations intended to be comparable the tests shall, as far as possible, be carried out at the same time interval.

The test is normally carried out at a temperature of 20 ± 2°C. When a test is made at this standard laboratory temperature, the test pieces shall be maintained at the conditions of test for at least three hours immediately before testing. When tests are made at higher or lower temperatures, the test pieces shall be maintained at the conditions of test for a period of time sufficient to reach temperature equilibrium with the testing environment or for the period of time required by the specification covering the material or product being tested.

4.5 REPORT

4.5.1 The report shall state the **apparent hardness** of the test piece expressed in International rubber hardness degrees (indicated by the degree sign °) followed by:

(1) for circular-section rings and straight cylinders: the cross-sectional diameter (dia.) (in mm);
for rubber-covered rollers: the thickness of rubber and the diameter (dia.) of the roller (in mm).

NOTE. Code designations for dimensions are not proposed for other types of curved surfaces, as in all cases dimensions will be recorded as in 4.5.3(1).

(2) the code letter (N, H, L or M) denoting the test method used, preceded by 'C' (curved).

4.5.2 Examples

Microtest on O-ring, 4 mm sectional diameter: 56°/4 dia./CM.
Normal test on roller with 8 mm thick rubber, diameter 40 mm:
75°/8 × 40 dia./CN.
High hardness test on rubber ball 30 mm diameter: 90·4°/CH.

4.5.3 The report shall give the individual readings and the median, together with the following information:

(1) Description and dimensions of test piece, together with an indication of the positions where hardness measurements were made.
(2) Method of supporting or holding the test piece.
(3) Whether used with or without foot.
(4) Test temperature, if other than 20°C.
(5) Type of surface, if not moulded (e.g. buffed).

TABLES 2 AND 3. RELATION BETWEEN INTERNATIONAL RUBBER HARDNESS DEGREES AND THE INDENTATION INCREMENT (*D*) PRODUCED BY AN INDENTING FORCE INCREMENT OF 5·40 N ON A 2·50 mm BALL OR OF 5·23 N ON A 2·38 mm BALL, WITH 0·30 N CONTACT FORCE

Table 2 gives the exact International Rubber Hardness Degrees for use with Methods N and M in constructing conversion graphs or in graduating dials to read in International rubber hardness degrees.

Table 3 enables any reading to be converted to the corresponding reading on the other scale to the accuracy necessary for practical use.

In the case of Method M the values of *D* shown in Tables 2 and 3 represent the actual indentation increment multiplied by the scaling factor 6.

TABLE 2

Hardness IRHD	*D** 0·01 mm	Hardness IRHD	*D** 0·01 mm
30	180	70	51·7
35	153	75	43·3
40	130·5	80	35·3
45	112	85	28
50	96·4	90	20·8
55	83	95	13·5
60	71·2	98	8·3
65	61	99	6

* For dials calibrated in thousandths of an inch use conversions shown in BS 350, ' Conversion factors and tables '.

TABLE 3

*D** 0·01 mm	IRHD	*D** 0·01 mm	IRHD	*D** 0·01 mm	IRHD	*D** 0·01 mm	IRHD	*D** 0·01 mm	IRHD
0	100	40	77·0	80	56·2	120	42·7	160	33·6
1	100	41	76·4	81	55·8	121	42·5	161	33·4
2	99·9	42	75·8	82	55·4	122	42·2	162	33·2
3	99·8	43	75·2	83	55·0	123	41·9	163	33·0
4	99·6	44	74·5	84	54·6	124	41·7	164	32·8
5	99·3	45	73·9	85	54·2	125	41·4	165	32·6
6	99·0	46	73·3	86	53·8	126	41·1	166	32·4
7	98·6	47	72·7	87	53·4	127	40·9	167	32·3
8	98·1	48	72·2	88	53·0	128	40·6	168	32·1
9	97·7	49	71·6	89	52·7	129	40·4	169	31·9
10	97·1	50	71·0	90	52·3	130	40·1	170	31·7
11	96·5	51	70·4	91	52·0	131	39·9	171	31·6
12	95·9	52	69·8	92	51·6	132	39·6	172	31·4
13	95·3	53	69·3	93	51·2	133	39·4	173	31·2
14	94·7	54	68·7	94	50·9	134	39·1	174	31·1
15	94·0	55	68·2	95	50·5	135	38·9	175	30·9
16	93·4	56	67·6	96	50·2	136	38·7	176	30·7
17	92·7	57	67·1	97	49·8	137	38·4	177	30·5
18	92·0	58	66·6	98	49·5	138	38·2	178	30·4
19	91·3	59	66·0	99	49·1	139	38·0	179	30·2
20	90·6	60	65·5	100	48·8	140	37·8	180	30·0
21	89·8	61	65·0	101	48·5	141	37·5		
22	89·2	62	64·5	102	48·1	142	37·3		
23	88·5	63	64·0	103	47·8	143	37·1		
24	87·8	64	63·5	104	47·5	144	36·9		
25	87·1	65	63·0	105	47·1	145	36·7		
26	86·4	66	62·5	106	46·8	146	36·5		
27	85·7	67	62·0	107	46·5	147	36·2		
28	85·0	68	61·5	108	46·2	148	36·0		
29	84·3	69	61·1	109	45·9	149	35·8		
30	83·6	70	60·6	110	45·6	150	35·6		
31	82·9	71	60·1	111	45·3	151	35·4		
32	82·2	72	59·7	112	45·0	152	35·2		
33	81·5	73	59·2	113	44·7	153	35·0		
34	80·9	74	58·8	114	44·4	154	34·8		
35	80·2	75	58·3	115	44·1	155	34·6		
36	79·5	76	57·9	116	43·8	156	34·4		
37	78·9	77	57·5	117	43·5	157	34·2		
38	78·2	78	57·0	118	43·3	158	34·0		
39	77·6	79	56·6	119	43·0	159	33·8		

*** For dials calibrated in thousandths of an inch use conversions shown in BS 350, ' Conversion factors and tables '.**

TABLES 4 AND 5. RELATION BETWEEN INTERNATIONAL RUBBER HARDNESS DEGREES AND THE INDENTATION INCREMENT (*D*) PRODUCED BY AN INDENTING FORCE INCREMENT OF 5·40 N ON A 1·00 mm BALL WITH 0·30 N CONTACT FORCE

Table 4 gives the exact International Rubber Hardness Degrees for use with Method H in constructing conversion graphs or in graduating dials to read IRHD.

Table 5 enables any reading to be converted to the corresponding reading on the other scale to the accuracy necessary for practical use.

TABLE 4

Hardness IRHD	*D** 0·01 mm	Hardness IRHD	*D** 0·01 mm
85	43·6	94	23·5
88	36·8	96	18·5
90	32·4	98	13·0
92	28·0	99	9·3

TABLE 5

*D** 0·01 mm	IRHD	*D** 0·01 mm	IRHD	*D** 0·01 mm	IRHD
0	100	15	97·3	30	91·1
1	100	16	97·0	31	90·7
2	100	17	96·6	32	90·2
3	99·9	18	96·2	33	89·7
4	99·9	19	95·8	34	89·3
5	99·8	20	95·4	35	88·8
6	99·6	21	95·0	36	88·4
7	99·5	22	94·6	37	87·9
8	99·3	23	94·2	38	87·5
9	99·1	24	93·8	39	87·0
10	98·8	25	93·4	40	86·6
11	98·6	26	92·9	41	86·1
12	98·3	27	92·5	42	85·7
13	98·0	28	92·0	43	85·3
14	97·6	29	91·6	44	84·8

* For dials calibrated in thousandths of an inch use conversions shown in BS 350, ' Conversion factors and tables '.

TABLES 6 AND 7. RELATION BETWEEN INTERNATIONAL RUBBER HARDNESS DEGREES AND THE INDENTATION INCREMENT (*D*) PRODUCED BY AN INDENTING FORCE INCREMENT OF 5·40 N ON A 5·0 mm BALL WITH 0·30 N CONTACT FORCE

Table 6 gives the exact International Rubber Hardness Degrees for use with Method L in constructing conversion graphs or in graduating dials to read in IRHD.

Table 7 enables any reading to be converted to the corresponding reading on the other scale to the accuracy necessary for practical use.

TABLE 6

Hardness IRHD	*D** 0·01 mm	Hardness IRHD	*D** 0·01 mm
10	318	22	175·3
12	282	24	162·7
14	252	26	150·5
16	228	28	140·0
18	208	30	130·0
20	190·7	32	121·6

* For dials calibrated in thousandths of an inch use conversions shown in BS 350, 'Conversion factors and tables'.

TABLE 7

D* 0·01 mm	IRHD	D* 0·01 mm	IRHD	D* 0·01 mm	IRHD	D* 0·01 mm	IRHD
110	34·9	170	22·8	230	15·8	290	11·5
2	34·4	2	22·5	2	15·6	2	11·4
4	33·9	4	22·2	4	15·4	4	11·3
6	33·4	6	21·9	6	15·3	6	11·2
8	32·9	8	21·6	8	15·1	8	11·1
120	32·4	180	21·3	240	14·9	300	11·0
2	31·9	2	21·1	2	14·8	2	10·9
4	31·4	4	20·8	4	14·6	4	10·8
6	30·9	6	20·6	6	14·4	6	10·6
8	30·4	8	20·3	8	14·3	8	10·5
130	30·0	190	20·1	250	14·1	310	10·4
2	29·6	2	19·8	2	14·0	2	10·3
4	29·2	4	19·6	4	13·8	4	10·2
6	28·8	6	19·4	6	13·7	6	10·1
8	28·4	8	19·2	8	13·5	8	10·0
140	28·0	200	18·9	260	13·4	320	9·9
2	27·6	2	18·7	2	13·3		
4	27·2	4	18·5	4	13·1		
6	26·8	6	18·3	6	13·0		
8	26·4	8	18·0	8	12·8		
150	26·1	210	17·8	270	12·7		
2	25·7	2	17·6	2	12·6		
4	25·4	4	17·4	4	12·5		
6	25·0	6	17·2	6	12·3		
8	24·7	8	17·0	8	12·2		
160	24·4	220	16·8	280	12·1		
2	24·1	2	16·6	2	12·0		
4	23·8	4	16·4	4	11·8		
6	23·5	6	16·2	6	11·7		
8	23·1	8	16·0	8	11·6		

* For dials calibrated in thousandths of an inch use conversions shown in BS 350, 'Conversion factors and tables'.

APPENDIX A

RELATION BETWEEN IRHD AND YOUNG'S MODULUS

An approximate form of the relation between the depth of indentation *P* (in units of 0·01 mm) and Young's modulus *M* (in bar) for elastic isotropic rubbers is:

$$F/M = 0{\cdot}00038 . R^{0\cdot65} P^{1\cdot35}$$

where *F* is the indenting force (N) and *R* is the radius of the ball (mm). The IRHD scale is based on a probit (integrated normal error) curve relating $\log_{10} M$ and hardness degrees, the curve being defined by the conditions that $\log_{10} M = 1{\cdot}364$ (*M* expressed in bar) at 50 IRHD and the maximum slope = 57 IRHD per unit increase in $\log_{10} M$. The curves shown in Figs. 5, 6 and 7 are those for the full range of hardness with enlargements of the high and low hardness ends.

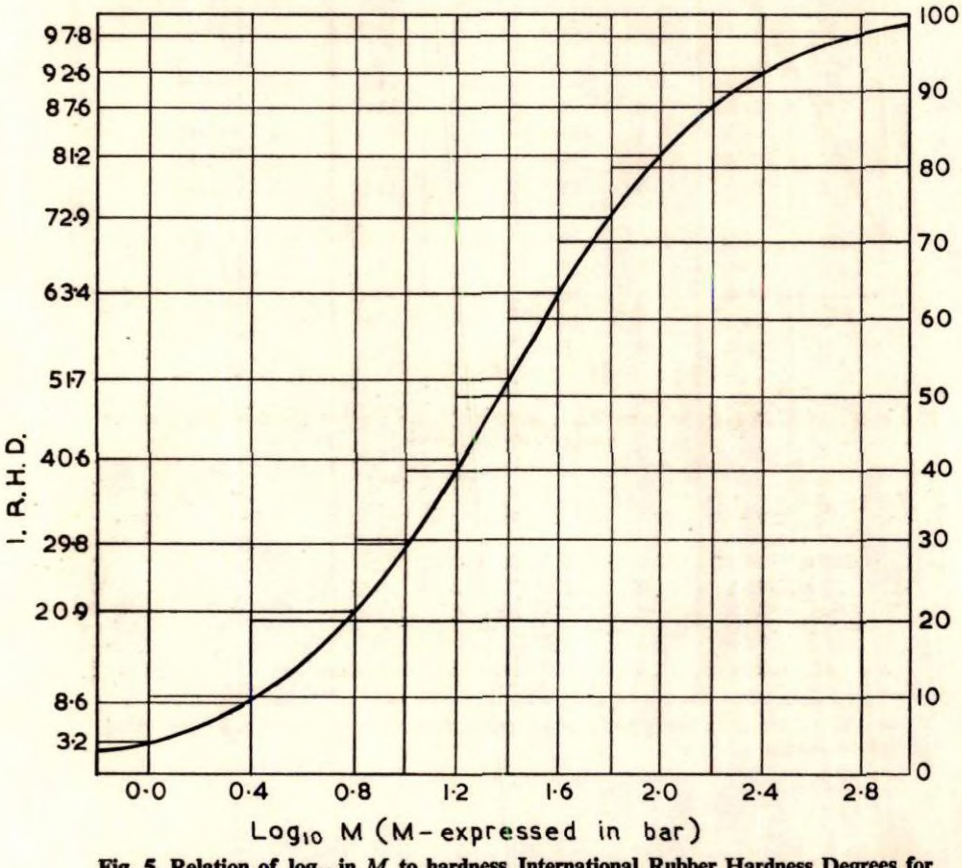


Fig. 5. Relation of $\log_{10}$ in *M* to hardness International Rubber Hardness Degrees for hardness from 0° to 100°

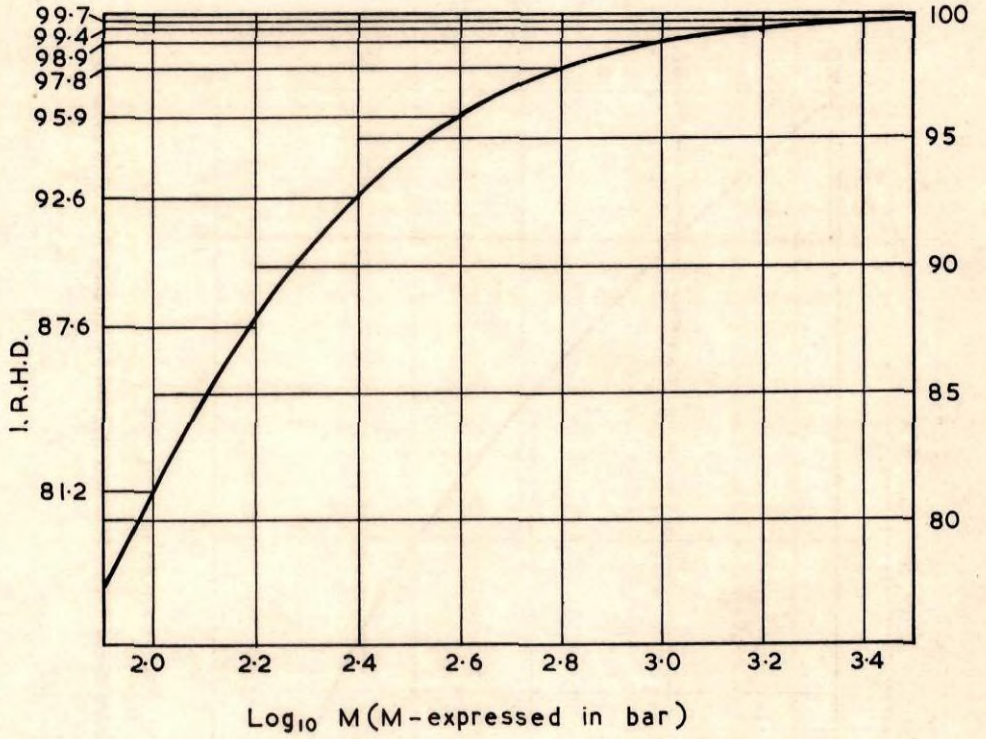


Fig. 6. Relation of $\log_{10} M$ to hardness in International Rubber Hardness Degrees for hardness 80° to 100°

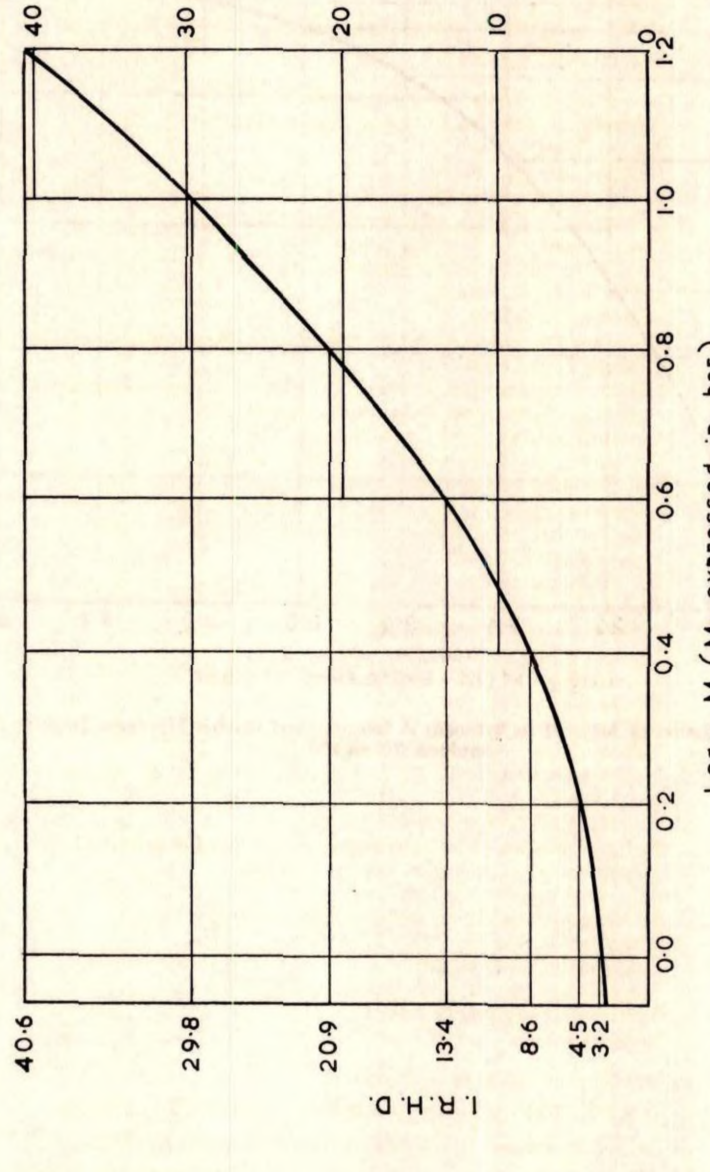


Fig. 7. Relation of $\log_{10} M$ to hardness in International Rubber Hardness Degrees for hardness from 3° to about 40°

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