BRITISH STANDARD

BS 903 :
Part A26 : 1995
ISO 48 : 1994

Physical testing of rubber

Part A26. Method for determination of hardness (hardness between 10 IRHD and 100 IRHD)

BSI STANDARDS

Committees responsible for this British Standard

The preparation of this British Standard was entrusted to Technical Committee PRI/22, Physical testing of rubber, upon which the following bodies were represented:

British Railways Board
British Rubber Manufacturers' Association Ltd.
GAMBICA (BEAMA Ltd.)
Malaysian Rubber Producers' Research Association
Ministry of Defence
RAPRA Technology Ltd.
SATRA Footwear Technology Centre
Coopted member

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Contents

National foreword

This Part of BS 903 has been prepared by Technical Committee PRI/22. It is identical with ISO 48 : 1994 *Rubber, vulcanized or thermoplastic — Determination of hardness (hardness between 10 IRHD and 100 IRHD)*, published by the International Organization for Standardization (ISO). This edition supersedes BS 903 : Part A26 : 1969 which is withdrawn.

This edition of BS 903 : Part A26 differs from the 1969 edition as follows.

a) The apparent hardness of rubber-covered rollers is now the subject of BS 7442 : Section 3.1.

b) Hardness is expressed and reported to the nearest whole number on the entire hardness range (see clause **12**).

Cross-references

International standard	Corresponding British Standard
	BS 903 *Physical testing of rubber*
ISO 471 :	Part A35 : 1985 *Temperatures, humidities and times for conditioning and testing of pieces* (Identical)
ISO 3383 : 1985	Part A32 : 1988 *General directions for achieving elevated or subnormal temperatures for test purposes* (Identical)
ISO 4661 : 1993	Part A36 : 1995 *Preparation of samples and test pieces* (Identical)

The Technical Committee has reviewed the provisions of ISO 1826 : 1981 and ISO/TR 9272 : 1986, to which normative reference is made in the text, and has decided that they are acceptable for use in conjunction with this standard.

A British Standard related to ISO 1826 : 1981 is BS 903 : Part A19 : 1986 *Methods of testing vulcanized rubber Part A19. Heat resistance and accelerated ageing.*

ISO 7267-1 : 1986, ISO 7267-2 : 1986 and ISO 7267-3 : 1988 on the apparent hardness of rubber-covered rollers are identical with BS 7442 : Section 3.1 : 1991, BS 7442 : Section 3.2 : 1991 and BS 7442 : Section 3.3 : 1992 respectively.

Additional information In the UK the standard temperature (see clause **9**) is 23 °C ± 2 °C.

NOTE. The 'standard temperature' is commonly referred to as the 'standard laboratory temperature'.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Introduction

The hardness test specified in this International Standard is intended to provide a rapid measurement of rubber stiffness, unlike hardness tests on other materials which measure resistance to permanent deformation.

Hardness is measured from the depth of indentation of a spherical indentor, under a specified force, into a rubber test piece. An empirical relationship between depth of indentation and Young's modulus for a perfectly elastic isotropic material has been used to derive a hardness scale which may conveniently be used for most rubbers.

When it is required to determine the value of Young's modulus itself, an appropriate test method should be used, for example that described in ISO 7743:1989, *Rubber, vulcanized or thermoplastic — Determination of compression stress-strain properties*, for determination of compression stress-strain properties.

Rubber, vulcanized or thermoplastic — Determination of hardness (hardness between 10 IRHD and 100 IRHD)

1 Scope

This International Standard specifies four methods for the determination of the hardness of vulcanized or thermoplastic rubbers on flat surfaces:

Method N	Normal test
Method H	High-hardness test
Method L	Low-hardness test
Method M	Microtest

and four methods for the determination of apparent hardness of curved surfaces using methods N, H, L and M, respectively:

Methods CN, CH, CL and CM.

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 figure 1.

Method N: The normal test for hardness is the appropriate method for test pieces of thickness greater than or equal to 4 mm and is preferably used for rubbers in the range 35 IRHD to 85 IRHD but may be used for those in the range 30 IRHD to 95 IRHD.

Method H: The appropriate method for test pieces of thickness greater than or equal to 4 mm and hardness in the range 85 IRHD to 100 IRHD.

Method L: The appropriate method for test pieces of thickness greater than or equal to 6 mm and hardness in the range 10 IRHD to 35 IRHD.

NOTE 1 The value of hardness obtained by method N within the ranges 85 IRHD to 95 IRHD and 30 IRHD to 35 IRHD may not agree precisely with that obtained using method H or method L, respectively. The difference is not normally significant for technical purposes.

Method M: The microtest for hardness is essentially a scaled-down version of the normal test method N, permitting the testing of thinner and smaller test pieces. It is the appropriate method for test pieces of thickness less than 4 mm and is preferably used for rubbers in the range 35 IRHD to 85 IRHD but may be used for those in the range 30 IRHD to 95 IRHD.

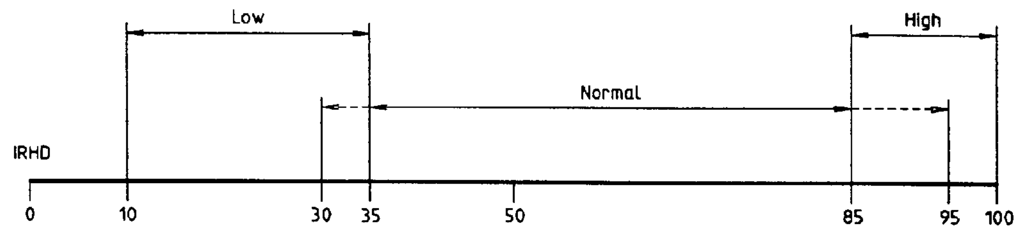

Figure 1 — Range of applicability

NOTE 2 Because of various surface effects in the rubber and of any slight surface roughness (produced, for example, by buffing), the microtest will not always give results agreeing with those obtained by the normal test.

Methods CN, CH, CL and CM: Apparent-hardness tests on curved surfaces.

These methods are modifications of methods N, H, L and M for cases where the rubber surface tested is curved. Two cases exist, depending whether

a) the test piece or article tested is large enough for the hardness instrument to rest upon it;

b) it is small enough for both the test piece and the instrument to rest upon a common support.

A variant of b) 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 pieces but cover some of the commonest types such as "O" rings. Determination of the apparent hardness of rubber-covered rollers is dealt with separately in ISO 7267-1:1986, *Rubber-covered rollers — Determination of apparent hardness — Part 1: IRHD method*, ISO 7267-2:1986, *Rubber-covered rollers — Determination of apparent hardness — Part 2: Shore-type durometer method* and ISO 7267-3:1988, *Rubber-covered rollers — Determination of apparent hardness — Part 3: Pusey and Jones method.*

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 471:—[1], *Rubber — Times, temperatures and humidities for conditioning and testing.*

ISO 1826:1981, *Rubber, vulcanized — Time-interval between vulcanization and testing — Specification.*

ISO 3383:1985, *Rubber — General directions for achieving elevated or subnormal temperatures for test purposes.*

ISO 4661-1:1993, *Rubber, vulcanized or thermoplastic — Preparation of samples and test pieces — Part 1: Physical tests.*

ISO/TR 9272:1986, *Rubber and rubber products — Determination of precision for test method standards.*

3 Principle

The hardness test consists in measuring the difference between the depths of indentation of a ball into the rubber under a small contact force and a large total force. From this difference, multiplied when using the microtest by the scale factor 6, the hardness in international rubber hardness degrees (IRHD) is obtained by using tables 3 to 5 or on graphs based on these tables or a scale, reading directly in international rubber hardness degrees, calculated from the tables and fitted to the indentation-measuring instrument. These tables and curves are derived from the empirical relationship between indentation depth and hardness given in annex A.

4 Definitions

For the purposes of this International Standard, the following definitions apply.

4.1 international rubber hardness degrees (IRHD): A hardness scale chosen so that "0" represents the hardness of material having a Young's modulus of zero and "100" represents the hardness of a material of infinite Young's modulus, with the following conditions being fulfilled over most of the normal range of hardness:

a) one international rubber hardness degree always represents approximately the same proportionate difference in the Young's modulus;

b) for highly elastic rubbers, the scales of IRHD and the Shore A durometer are comparable.

4.2 standard hardness (denoted by the letter S): The hardness, reported to the nearest whole number in international rubber hardness degrees, obtained using the procedures described in methods N, H, L and M on test pieces of the standard thickness and not less than the minimum lateral dimensions specified.

4.3 apparent hardness: The hardness, reported to the nearest whole number in international rubber

1) To be published. (Revision of ISO 471:1983)

hardness degrees, obtained using the procedures described in methods N, H, L and M on test pieces of non-standard dimensions, as well as hardness values obtained using methods CN, CH, CL and CM.

NOTE 3 Values obtained by methods CN, CH, CL and CM are always given as apparent hardness since tests are commonly made on the complete article where the thickness of the rubber will vary, 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 do not in general coincide with readings obtained on standard test pieces as defined in methods N, H, L and M or on a flat parallel-faced slab of the same thickness as the article. Moreover, the readings may depend appreciably on the method of support of the article and whether or not a presser foot is used.

It should, therefore, be recognized that results obtained on curved surfaces are arbitrary values applicable only to test pieces or articles of one particular shape and of particular dimensions, and supported in one particular way, and in extreme cases such values may differ from the standard hardness by as much as 10 IRHD. Furthermore, surfaces that have been buffed or otherwise prepared to remove cloth markings, etc., will give slightly different hardness values from those with a smooth, moulded finish.

5 Apparatus

5.1 Methods N, H, L and M

The essential parts of the apparatus are as follows, the appropriate dimensions and forces being shown in table 1.

5.1.1 Vertical plunger, having a rigid ball or spherical surface on the lower end, and **means for supporting the plunger** so that the spherical tip is kept slightly above the surface of the annular foot prior to applying the contact force.

5.1.2 Means for applying a contact force and an additional indenting force to the plunger, making allowance for the mass of the plunger, including any fittings attached to it, and for the force of any spring acting on it, so that the forces actually transmitted through the spherical end of the plunger are as specified.

5.1.3 Means for measuring the increase in depth of indentation of the plunger caused by the indenting force, either in metric units or reading directly in IRHD. The means employed may be mechanical, optical or electrical.

Table 1 — Forces and dimensions of apparatus

Test	Diameters	Force on ball: Contact	Force on ball: Indenting	Force on ball: Total	Force on foot
	mm	N	N	N	N
Method N (normal test)	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
Method H (high hardness)	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
Method L (low hardness)	Ball 5,00 ± 0,01 Foot 22 ± 1 Hole 10 ± 1	0,30 ± 0,02	5,40 ± 0,01	5,70 ± 0,03	8,3 ± 1,5
Method M (microtest)	mm	mN	mN	mN	mN
	Ball 0,395 ± 0,005 Foot 3,35 ± 0,15 Hole 1,00 ± 0,15	8,3 ± 0,5	145 ± 0,5	153,3 ± 1,0	235 ± 30

5.1.4 Flat annular foot, normal to the axis of the plunger and having a central hole for the passage of the plunger. The foot rests on the test piece and exerts a pressure on it of 30 kPa ± 5 kPa[2)] provided that the total load on the foot does not fall outside the values given in table 1. The foot shall be rigidly connected to the indentation-measuring device, so that a measurement is made of the movement of the plunger relative to the foot (i.e. the top surface of the test piece, not relative to the surface supporting the test piece).

5.1.5 Means for gently vibrating the apparatus, for example an electrically operated buzzer, to overcome any slight friction. (This may be omitted in instruments where friction is completely eliminated.)

5.1.6 Chamber for the test piece, when tests are made at temperatures other than a standard temperature. This chamber shall be equipped with a means of maintaining the temperature within 2 °C of the desired value. The foot and vertical plunger shall extend through the top of the chamber, and the portion passing through the top shall be constructed from a material having a low thermal conductivity. A sensing device shall be located within the chamber near or at the location of the test piece, for measuring the temperature (see ISO 3383).

In the microtest when using instruments in which the test piece table is pressed upwards by a spring, the values of the foot pressure and the force on the foot are those acting during the period of application of the total force. Before the indenting force of 145 mN is applied, the force on the foot is greater by this amount, and hence equals 380 mN ± 30 mN.

NOTE 4 Not all possible combinations of dimensions and forces in table 1 will meet the pressure requirements of 5.1.4.

5.2 Methods CN, CH, CL and CM

The apparatus used shall be essentially that described in 5.1 but differing in the following respects.

5.2.1 Cylindrical surfaces of radius greater than 50 mm

The base of the instrument shall have a hole below the plunger, allowing free passage of the annular foot such that measurement may be made above or below the base.

The lower surface of the base shall be in the form of two cylinders parallel to each other and the plane of the base. The diameter of the cylinders and their distance apart shall be such as to locate and support the instrument on the curved surface to be tested. Alternatively, the modified base may be fitted with feet movable in universal joints so that they adapt themselves to the curved surface.

5.2.2 Surfaces with double curvature of large radius greater than 50 mm

The instrument specified in 5.2.1 with adjustable feet shall be used.

5.2.3 Cylindrical surfaces of radius 4 mm to 50 mm or small test pieces with double curvature

On surfaces too small to support the instrument, the test piece or article shall be supported by means of special jigs or V blocks so that the indentor is vertically above the test surface. Wax may be used to fix small items to the test piece table.

NOTES

5 In general, an instrument as described for method M should be used only where the thickness of the rubber tested is less than 4 mm.

6 Instruments for method M in which the test piece table is pressed upwards by a spring are not suitable for use on large test pieces or articles with a large radius of curvature.

5.2.4 Small "O" rings and articles of radius of curvature less than 4 mm

These shall be held in suitable jigs or blocks or secured by wax to the instrument table. Measurements shall be made using the instrument for method M. No test shall be made if the smallest radius is less than 0,8 mm.

6 Test pieces

Test pieces shall be prepared in accordance with ISO 4661-1.

6.1 Methods N, H, L and M

6.1.1 General

The test pieces shall have their upper and lower surfaces flat, smooth and parallel to one another.

Tests intended to be comparable shall be made on test pieces of the same thickness.

2) 1 kPa = 10^3 N/m^2

6.1.2 Thickness

6.1.2.1 Methods N and H

The standard test piece shall be 8 mm to 10 mm thick and shall be made up of one, two or three layers of rubber, the thinnest of which shall not be less than 2 mm thick. All surfaces shall be flat and parallel. Non-standard test pieces may be either thicker or thinner but not less than 4 mm thick.

6.1.2.2 Method L

The standard test piece shall be 10 mm to 15 mm thick and shall be made up of one, two or three layers of rubber, the thinnest of which shall not be less than 2 mm thick. All surfaces shall be flat and parallel. Non-standard test pieces may be either thicker or thinner but not less than 6 mm thick.

6.1.2.3 Method M

The standard test piece shall have a thickness of 2 mm ± 0,5 mm. Thicker or thinner test pieces may be used, but in no case less than 1 mm thick. On such test pieces, the readings will not in general agree with those obtained on the standard test piece.

6.1.3 Lateral dimensions

6.1.3.1 Methods N, H and L

The lateral dimensions of both standard and non-standard test pieces shall be such that no test is made at a distance from the edge of the test piece less than the appropriate distance shown in table 2.

Table 2 — Minimum distance of point of contact from test piece edge

Dimensions in millimetres

Total thickness of test piece	Minimum distance from point of contact to edge of test piece
4	7,0
6	8,0
8	9,0
10	10,0
15	11,5
25	13,0

6.1.3.2 Method M

The lateral dimensions shall be such that no test is made at a distance from the edge of less than 2 mm.

When test pieces thicker than 4 mm are tested on the microtest instrument because the lateral dimensions or the available flat area do not permit testing on a normal instrument, the test shall be made at a distance from the edge as great as possible.

6.2 Methods CN, CH, CL and CM

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 properly supported during the hardness test. If the surface on which the test is to be made is cloth-marked, it shall be buffed prior to testing. Test pieces shall be allowed to recover at a standard temperature (see ISO 471) for at least 16 h after buffing and shall be conditioned in accordance with clause 8. The conditioning period may form part of the recovery period.

7 Time-interval between vulcanization and testing

Unless otherwise specified for technical reasons, the following requirements shall be observed (see ISO 1826).

For all normal test purposes, the minimum time between vulcanization and testing shall be 16 h. In cases of arbitration, the minimum time shall be 72 h.

For non-product tests, the maximum time between vulcanization and testing shall be 4 weeks and, for evaluations intended to be comparable, the tests, as far as possible, shall be carried out after the same time-interval.

For product tests, whenever possible, the time between vulcanization and testing shall not exceed 3 months. In other cases, tests shall be made within 2 months of the date of receipt by the purchaser of the product.

8 Conditioning of test pieces

8.1 When a test is made at a standard temperature (see ISO 471), the test pieces shall be maintained at the conditions of test for at least 3 h immediately before testing.

8.2 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, and then immediately tested.

9 Temperature of test

The test shall normally be carried out at standard temperature (see ISO 471). When other temperatures are used, these shall be selected from the list of preferred temperatures as specified in ISO 471.

10 Procedure

Condition the test piece as specified in clause 8. Lightly dust the upper and lower surfaces of the test piece with dusting powder. Place the test piece on a horizontal rigid surface. Bring the foot into contact with the surface of the test piece. Press the plunger and indenting ball for 5 s on to the rubber, the force on the ball being the contact force.

If the gauge is graduated in international rubber hardness degrees (IRHD), it shall be adjusted to read 100 at the end of the 5 s period; the additional indenting force shall be then be applied and maintained for 30 s, when a direct reading of the hardness in international rubber hardness degrees is obtained.

If the gauge is graduated in metric units, the differential indentation D (in hundredths of a millimetre) of the plunger caused by the additional indenting force, applied for 30 s, shall be noted. This (after multiplying by the scale factor of 6 when using the apparatus for the microtest) shall be converted into international rubber hardness degrees by using tables 3 to 5 or a graph constructed therefrom.

During the loading periods, the apparatus shall be gently vibrated unless it is completely free of friction.

11 Number of readings

One measurement shall be made at a minimum of three 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.

12 Expression of results

Hardness shall be expressed to the nearest whole number as the median of the individual measurements in international rubber hardness degrees (indicated by the degree sign °) followed by

a) either the letter S for the standard test piece thickness or the thickness and smallest lateral dimension (in millimetres) for tests on non-standard test pieces (the result then being an apparent hardness);

b) the code-letter for the method, i.e. N for normal test, H for high, L for low and M for microtest;

c) for tests on curved surfaces, the prefix letter C.

13 Precision

13.1 General

The precision calculations to provide repeatability and reproducibility values were performed in accordance with ISO/TR 9272. Consult this for precision concepts and nomenclature. Annex B gives guidance on the use of repeatability and reproducibility values.

13.2 Programme details

13.2.1 Five interlaboratory test programmes (ITPs) were organized and conducted by Statens Provningsanstalt (Sweden) between 1985 and 1989. Cured test pieces were prepared in one laboratory and sent to all the participants. The details of the five ITPs are as follows:

Medium-hardness rubbers, method N: Four rubber compounds, nominal hardness range 30 IRHD to 85 IRHD, 26 laboratories. Three determinations (measurements) of hardness on each compound on each of two days, one week apart, using method N. The median of the three used as the "test result" for the precision analysis.

Medium-hardness rubbers, method M: Four rubber compounds, nominal hardness range 30 IRHD to 85 IRHD, 26 laboratories. Three determinations (measurements) of hardness on each of two days, one week apart, using method M. The median of the three used as the "test result" for the precision analysis.

High-hardness rubbers, method N: Three rubber compounds, nominal hardness range 85 IRHD to 100 IRHD, 12 laboratories. Five determinations (measurements) of hardness on each of two days, one week apart, using method N. The median of the five used as the "test result" for the precision analysis.

High-hardness rubbers, method H: Three rubber compounds, nominal hardness range 85 IRHD to 100 IRHD, 12 laboratories. Three determinations (measurements) of hardness on each of two days, one week apart, using method H. The median of the three used as the "test result" for the precision analysis.

Low-hardness rubber, method L: One rubber compound of nominal low hardness, five laboratories. Three determinations (measurements) of hardness on each of two days, one week apart, using method L. The median of the three used as the "test result" for the precision analysis.

13.2.2 The precision assessments are type 1 (cured, prepared test pieces circulated) and the time for repeatability and reproducibility is on a scale of days. For the low-hardness rubber, method L, due to the small number of laboratories in the precision evaluation programme, the tabulated precision results should be used with caution.

13.3 Precision results

The precision results are given in table 6 for medium-hardness rubbers using method N, table 7 for medium-hardness rubbers using method M, table 8 for high-hardness rubbers using method N, table 9 for high-hardness rubbers using method H, and table 10 for the low-hardness rubber using method L.

The symbols r, (r), R and (R) as used in the table of results are defined as follows:

r = absolute repeatability, in measurement units;

(r) = relative repeatability, in percent;

R = absolute reproducibility, in measurement units;

(R) = relative reproducibility, in percent.

14 Test report

The test report shall include the following particulars:

a) a reference to this International Standard and the method used;

b) the form of the test piece, the number of layers and the dimensions of the thinnest layer plus, in the case of curved or irregularly shaped test pieces, the test piece description, the method of mounting and the method of applying the test force;

c) the temperature of test;

d) the type of surface tested, i.e. moulded, buffed or other;

e) the hardness, expressed as in clause 12;

f) any deviation from the procedure specified.

Table 3 — Conversion of values of *D* to international rubber hardness degrees (IRHD) for use in method N

D = differential indentation, in hundredths of a millimetre, with 2,5 mm indentor

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

Table 4 — Conversion of values of *D* into international rubber hardness degrees (IRHD) for use in method H

D = differential indentation, in hundreths of a millimetre, with 1 mm indentor

D	IRHD	*D*	IRHD	*D*	IRHD
0	100,0	15	97,3	30	91,1
1	100,0	16	97,0	31	90,7
2	100,0	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

Table 5 — Conversion of values of *D* into international rubber hardness degrees (IRHD) for use in method L

D = differential indentation, in hundreths of a millimetre, with 5 mm indentor

D	IRHD	*D*	IRHD	*D*	IRHD
110	34,9	180	21,3	250	14,1
112	34,4	182	21,1	252	14,0
114	33,9	184	20,8	254	13,8
116	33,4	186	20,6	256	13,7
118	32,9	188	20,3	258	13,5
120	32,4	190	20,1	260	13,4
122	31,9	192	19,8	262	13,3
124	31,4	194	19,6	264	13,1
126	30,9	196	19,4	266	13,0
128	30,4	198	19,2	268	12,8
130	30,0	200	18,9	270	12,7
132	29,6	202	18,7	272	12,6
134	29,2	204	18,5	274	12,5
136	28,8	206	18,3	276	12,3
138	28,4	208	18,0	278	12,2
140	28,0	210	17,8	280	12,1
142	27,6	212	17,6	282	12,0
144	27,2	214	17,4	284	11,8
146	26,8	216	17,2	286	11,7
148	26,4	218	17,0	288	11,6
150	26,1	220	16,8	290	11,5
152	25,7	222	16,6	292	11,4
154	25,4	224	16,4	294	11,3
156	25,0	226	16,2	296	11,2
158	24,7	228	16,0	298	11,1
160	24,4	230	15,8	300	11,0
162	24,1	232	15,6	302	10,9
164	23,8	234	15,4	304	10,8
166	23,5	236	15,3	306	10,6
168	23,1	238	15,1	308	10,5
170	22,8	240	14,9	310	10,4
172	22,5	242	14,8	312	10,3
174	22,2	244	14,6	314	10,2
176	21,9	246	14,4	316	10,1
178	21,6	248	14,3	318	9,9

Table 6 — Type 1 precision, medium-hardness rubbers, method N

Material	Average value	Within lab		Between labs	
		r	(*r*)	*R*	(*R*)
A	31,5	1,29	4,08	2,98	9,47
B	47,1	1,23	2,61	2,68	5,68
C	66,6	1,65	2,48	4,47	6,71
D	86,5	2,32	2,68	3,49	4,03
Pooled values	58,3	1,68	2,89	3,49	5,99

Table 7 — Type 1 precision, medium-hardness rubbers, method M

Material	Average value	Within lab		Between labs	
		r	(*r*)	*R*	(*R*)
A	36,6	1,57	4,29	5,82	15,9
B	50,9	2,31	4,55	5,44	10,7
C	64,9	4,89	7,54	7,47	11,5
D	88,6	4,76	5,38	6,80	7,68
Pooled values	60,3	3,71	6,16	6,43	10,7

Table 8 — Type 1 precision, high-hardness rubbers, method N

Material	Average value	Within lab		Between labs	
		r	(*r*)	*R*	(*R*)
A	85,8	0,78	0,91	3,53	4,11
B	93,4	1,11	1,19	2,96	3,17
C	98,5	0,33	0,34	1,45	1,47
Pooled values	92,6	0,81	0,87	2,86	3,09

Table 9 — Type 1 precision, high-hardness rubbers, method H

Material	Average value	Within lab		Between labs	
		r	(*r*)	*R*	(*R*)
A	87,0	0,96	1,03	3,12	3,41
B	94,2	1,00	1,07	2,15	2,31
C	98,7	0,71	0,76	1,03	1,10
Pooled values	93,3	0,75	0,90	2,29	2,46

Table 10 — Type 1 precision, low-hardness rubber, method L

Material	Average value	Within lab		Between labs	
		r	(r)	R	(R)
A	33,0	0,20	0,61	2,00	6,04

Annex A
(normative)

Empirical relationship between indentation and hardness

The relationship between the differential indentation and the hardness expressed in international rubber hardness degrees is based on

a) the known relationship, for a perfectly elastic isotropic material, between indentation D, expressed in millimetres, and Young's modulus E, expressed in megapascals, viz:

$$\frac{F}{E} = 0{,}0038\, r^{0{,}65} \times D^{1{,}35}$$

where

F is the indenting force, in newtons,

r is the radius of the ball, in millimetres;

b) the use of a probit (integrated normal error) curve to relate $\log_{10}E$ to the hardness in international rubber hardness degrees, as shown in figures A.1, A.2 and A.3. This curve is defined in terms of

1) the value of $\log_{10}E$ corresponding to the mid-point of the curve: 0,364 (E being expressed in megapascals),

2) the maximum slope: 57 IRHD per unit increase in $\log_{10}E$.

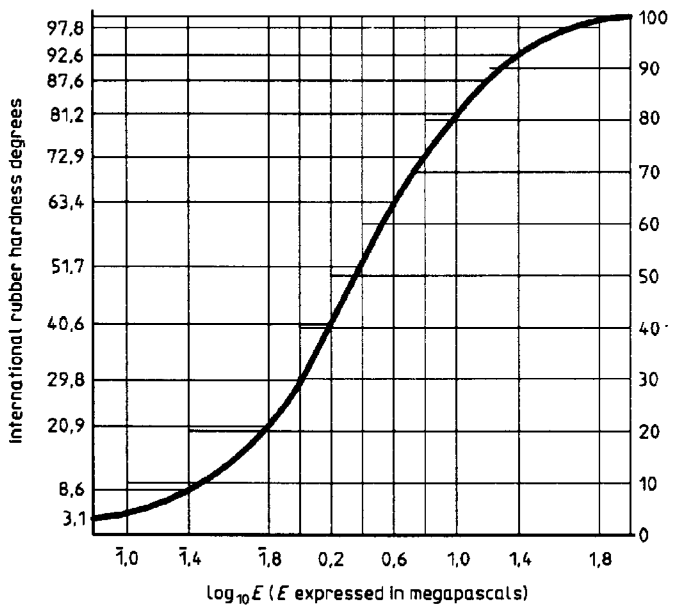

Figure A.1 — Relationship between $\log_{10}E$ and hardness in IRHD from 3 to 100

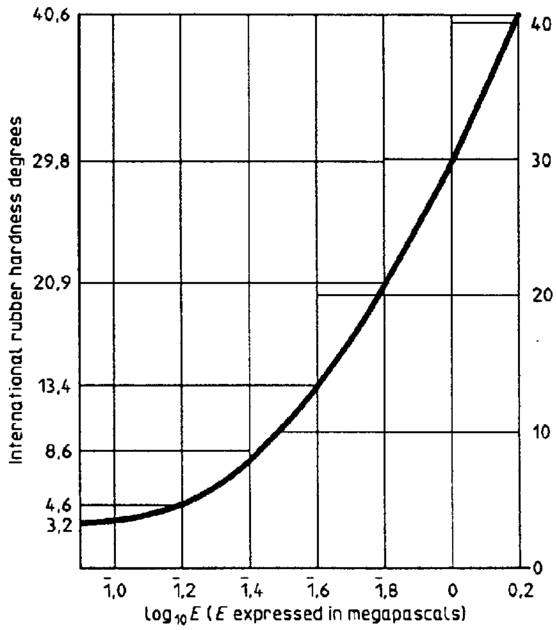

Figure A.2 — Relationship between $\log_{10}E$ and hardness in IRHD from 3 to 40

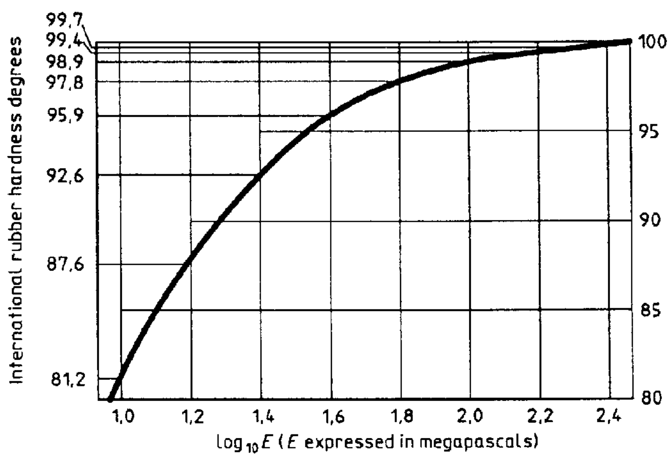

Figure A.3 — Relationship between $\log_{10}E$ and hardness in IRHD from 80 to 100

Annex B
(informative)

Guidance for using precision results

B.1 The general procedure for using precision results is as follows, with the symbol $|x_1 - x_2|$ designating a positive difference in any two measurement values (i.e. without regard to sign).

B.2 Enter the appropriate precision table (for whatever test parameter is being considered) at an average value (of the measured parameter) nearest to the "test" data average under consideration. This line will give the applicable r, (r), R or (R) for use in the decision process.

B.3 With these r and (r) values, the following general repeatability statements may be used to make decisions.

B.3.1 For an absolute difference: The difference $|x_1 - x_2|$ between two test (value) averages, found on nominally identical material samples under normal and correct operation of the test procedure, will exceed the tabulated repeatability r on average not more that once in twenty cases.

B.3.2 For a percentage difference between two test (value) averages: The percentage difference

$$[|x_1 - x_2|/(x_1 + x_2)/2] \times 100$$

between two test values, found on nominally identical material samples under normal and correct operation of the test procedure, will exceed the tabulated repeatability (r) on average not more than once in twenty cases.

B.4 With these R and (R) values, the following general reproducibility statements may be used to make decisions.

B.4.1 For an absolute difference: The absolute difference $|x_1 - x_2|$ between two independently measured test (value) averages, found in two laboratories using normal and correct test procedures on nominally identical material samples, will exceed the tabulated reproducibility R not more than once in twenty cases.

B.4.2 For a percentage difference between two test (value) averages: The percentage difference

$$[|x_1 - x_2|/(x_1 + x_2)/2] \times 100$$

between two independently measured test (value) averages, found in two laboratories using normal and correct test procedures on nominally identical material samples, will exceed the tabulated reproducibility (R) not more than once in twenty cases.

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