Standard Test Method for Rubber Property—International Hardness[1]

This standard is issued under the fixed designation D 1415; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This test method describes a procedure for measuring the hardness of rubber. The hardness is obtained by the difference in penetration depth of a specified dimension ball under two conditions of contact with the rubber: (*1*) with a small initial force and (*2*) with a much larger final force. The differential penetration is taken at a specified time and converted to a hardness scale value.

1.2 This test method is identical in substance with ISO 48.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 1349 Practice for Rubber—Standard Temperatures for Testing[2]

D 2240 Test Method for Rubber Property—Durometer Hardness[2]

D 4483 Practice for Determining Precision for Test Method Standards in the Rubber and Carbon Black Industries[2]

2.2 *ISO Standard:*

ISO/48 Vulcanized Rubbers—Determination of Hardness (Hardness between 30 and 85 IRHD)[3]

3. Summary of Test Methods

3.1 Two procedures are given to accommodate specimens of different dimensions. The standard test is intended to be used on specimens greater than 4 mm in thickness, preferably 8 to 10 mm. The micro-tester is used on specimens less than 4 mm in thickness, on specimens thicker than 4 mm having lateral dimensions less than those specified for the standard test, or on rubber articles that do not have flat surfaces suitable for making the standard test. In both procedures, the hardness in International Rubber Hardness Degrees (IRHD) is derived from the difference in penetrations and a table or graph constructed from the table. In the micro-tester procedure, the difference in penetration must first be multipled by scale factor 6. Alternatively, the penetration-measuring instrument may be calibrated directly in IRHD.

4. Significance and Use

4.1 The International Hardness test is based on measurement of the penetration of a rigid ball into the rubber specimen under specified conditions. The measured penetration is converted into International Rubber Hardness Degrees, the scale of degrees being so chosen that 0 represents a material having an elastic modulus of zero, and 100 represents a material of infinite elastic modulus. The scale chosen also fulfills the following conditions over most of the normal range of hardness: one International Rubber Hardness Degree range represents approximately the same proportionate difference in Young's modulus, and for rubber vulcanizates in the usual range of resilience, readings in International Rubber Hardness Degrees are comparable with those given by a Type A durometer (Test Method D 2240) when testing standard specimens. The term "usual range of resilience'' is used to exclude those compounds that have unusually high rates of stress relaxation or deformational hysteresis. For such compounds, differences in the dwell time in the two hardness tests result in differences in hardness values. Readings may not be comparable when testing curved or irregularly shaped test pieces.

4.1.1 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, although for markedly plastic or anisotropic rubbers the relationship will be less precisely known.

4.1.2 The relation between the difference of penetration and the hardness expressed in International Rubber Hardness Degrees is based on the following:

4.1.2.1 The relation[4] between penetration and Young's modulus for a perfectly elastic isotropic material:

$$F/M = 1.9\, R^2 (P/R)^{1.35} \qquad (1)$$

where:
F = indenting force,

[1] This test method is under the jurisdiction of ASTM Committee D-11 on Rubber and is the direct responsibility of Subcommittee D11.10 on Physical Testing.

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[2] *Annual Book of ASTM Standards*, Vol 09.01.

[3] Available from American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036.

[4] This relation is approximate and is included as an indication.

M = Young's modulus, MPa,
R = radius of ball, mm, and
P = penetration, mm.

4.1.2.2 Use of a probit (integrated normal error) curve to relate $\log_{10} M$ and hardness in International Rubber Hardness Degrees, as shown in Fig. 1. This curve is defined as follows:

4.1.2.3 The value of $\log_{10} M$ corresponding to the midpoint of the curve is equal to 0.364, that is, M = 2.31 MPa or 335 psi.

4.1.2.4 The maximum slope is equal to 57 International Rubber Hardness Degrees per unit increase in $\log_{10} M$.

5. Apparatus

5.1 The essential parts of the apparatus are as follows, the appropriate dimensions and loads being given in Table 1:

5.1.1 *Vertical Plunger*, terminating in a rigid ball.

5.1.2 *Force Applicator*—for applying a minor force and a major force to the ball the mass of the plunger and of any fittings attached to it and the force of any spring acting on it shall be included in determining the minor and major forces. This is in order that the forces actually applied to the ball shall be as specified.

5.1.3 *Measuring Device*—A mechanical, optical, or electrical device graduated either in standard units of length or in International Rubber Hardness Degrees for measuring the increase in depth of penetration of the plunger caused by the major load.

5.1.4 *Foot*—A flat annular-shaped foot that is rigidly fastened to the penetration-measuring device and normal to the axis of the plunger, and which during the test is forced against the specimen in order to determine accurately the position of the upper surface.

5.1.5 *Vibrating Device*—For example, an electrically operated buzzer, for gently vibrating the apparatus to overcome any slight friction; this should not exceed 5 % of the minor load. This device may be omitted on apparatus without any friction.

6. Test Specimen

6.1 Tests intended to be comparable must be made on specimens of the same thickness that have smooth, flat, and parallel upper and lower surfaces. Two pieces of rubber, but not more than two, may be superimposed to obtain the required thickness. The dimensions of the specimen depend on the tester used to measure the hardness.

6.2 *Standard Tester*—The standard specimen shall be between 8 and 10 mm in thickness; nonstandard specimens may be either thicker or thinner but in no case less than 4 mm thick. The lateral dimensions of both standard and nonstandard specimens shall be not less than 20 mm, and no test shall be made at a distance from the edge of the specimen less than the appropriate distance shown in Table 2.

6.3 *Micro Tester*—The standard specimen for the micro test procedure shall be between 2 and 2.5 mm in thickness; nonstandard specimens may be either thicker or thinner but in no case less than 1 mm thick. The lateral dimensions of both standard and nonstandard specimens shall be such that no test is made at a distance from the edge of less than 2 mm. When specimens thicker than 4 mm are tested on the micro tester because lateral dimensions or area of flatness do not permit testing on a standard tester, the test shall be made at a distance from the edge as great as possible. Curved specimens, for example, O-rings, may be tested with the micro tester if the specimens are mounted in such a manner as to prevent movement during the test, but the values obtained may not be

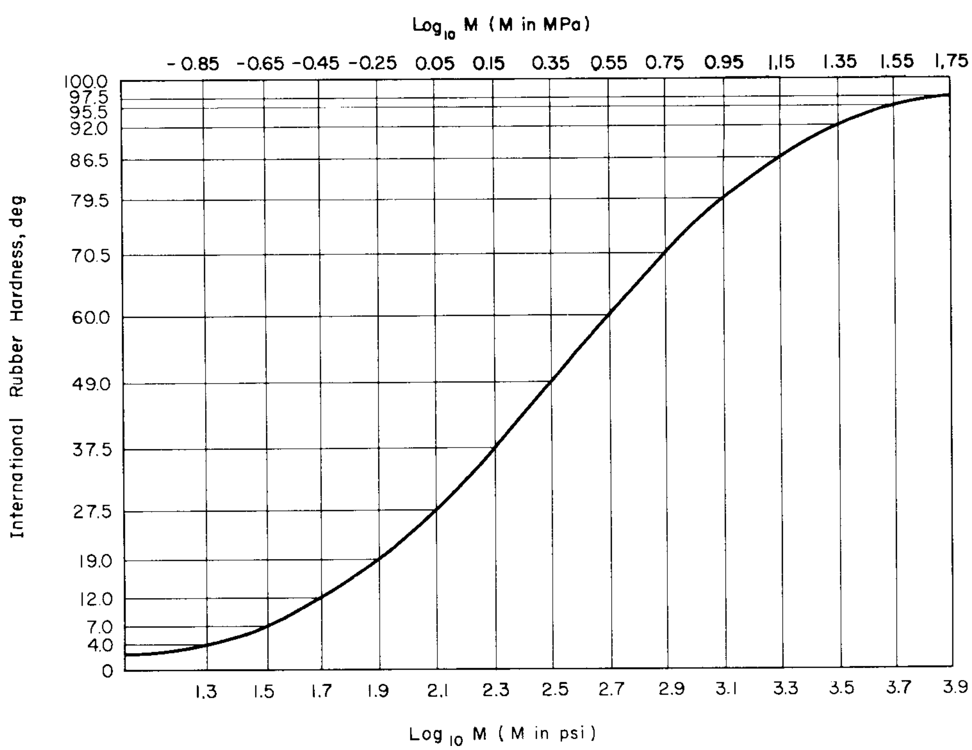

FIG. 1 Point Curve to Relate Log_{10} M and the Hardness in International Rubber Hardness Degrees

TABLE 1 Apparatus Requirements

NOTE 1—In micro testing 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 0.145 *N* is applied, the force on the foot is greater by this amount, and hence is 0.38 ± 0.03 *N*.

	Standard Testers		Micro Tester
Diameter of ball, mm	2.38 ± 0.01	2.50 ± 0.01	0.395 ± 0.005
Minor force on ball, N[A]	0.30 ± 0.02	0.29 ± 0.02	0.0083± 0.0005
Major force on ball, N[A]	5.23 ± 0.01	5.4 ± 0.01	0.1455 ± 0.0005
Total force on ball, N[A]	5.53 ± 0.03	5.7 ± 0.03	0.153 ± 0.001
Outside diameter of foot, mm	20 ± 1	20 ± 1	3.35± 0.15
Inside diameter of foot, mm	6 ± 1	6 ± 1	1.00± 0.15
Force on foot, N[B]	8.3 ± 1.5	8.3 ± 1.5	0.235± 0.03[C]

[A] Includes frictional forces in apparatus.
[B] The force should be adjusted within these limits to the actual area of the foot so that the pressure in the specimen is 30 ± 0.5 kPa.
[C] Force on foot during application of total force on ball; force on foot during application of minor force on ball, 0.2 N minimum, 0.4 N maximum.

TABLE 2 Minimum Distance from Edge of Specimen at Which Test is Made

Total Thickness of Specimen		Minimum Distance from Edge	
mm	in.	mm	in.
4	0.16	7.0	0.28
6	0.25	8.0	0.31
8	0.3	9.0	0.35
10	0.4	10.0	0.40
15	0.6	11.5	0.45
25	1.0	12.5	0.50

comparable to those obtained with flat specimens.

7. Test Temperature

7.1 The test shall be normally carried out at 23 ± 2°C (73.4 ± 3.6°F). The specimens shall be maintained at the test temperature for at least 3 h immediately prior to testing. Specimens that are affected by atmosphere moisture shall be conditioned in an atmosphere controlled to 50± 5 % relative humidity for at least 24 h. When tests are made at higher or lower temperatures, the specimens shall be maintained at the conditions of test for a period of time sufficient to reach temperature equilibrium with the testing chamber, and the temperatures shall be chosen from those specified in Practice D 1349.

8. Procedure

8.1 Condition the specimen in accordance with 7.1. Slightly dust the upper and lower surfaces of the test specimen with talc. Support the specimen on a horizontal rigid surface, and lower the foot to rest on the surface of the specimen. Press the plunger, with the minor force on the indenting ball, vertically onto the specimen for 5 s.

8.2 If the gage is graduated directly in International Rubber Hardness Degrees, turn the bezel of the gage so that the pointer indicates 100 (exercise care to avoid exerting any vertical pressure on the gage). Add the major force to the plunger and maintain the total force on the ball for 30 s (Note 1). Record the reading on the gage as the hardness in International Rubber Hardness Degrees.

NOTE 1—During the loading periods the apparatus shall be gently vibrated to overcome any friction.

8.3 If the measuring device is graduated in metric or inch units, record the movement of the plunger caused by application of the major load for 30 s. If the micro tester is used, multiply this movement by the scale factor of 6. Convert the value obtained into International Rubber Hardness Degrees by using Table 3 or a graph constructed therefrom.

8.4 Make one measurement at each of three or five different points distributed over the specimen. Take the median of these measurements rounded to the nearest IRHD for the hardness value.

9. Report

9.1 The report shall include the following:

9.1.1 Hardness expressed in International Rubber Hardness Degrees (IRHD). Values from curved or irregularly shaped specimens shall be quoted as apparent hardness,

9.1.2 Dimensions of specimen and number of pieces, that is, one or two. In the case of curved or irregularly shaped specimens: specimen description, method of mounting, and method of applying test,

9.1.3 Type of surface tested, that is, molded, buffed, or otherwise,

9.1.4 Type of tester used, that is, standard or micro, and

9.1.5 Temperature of test.

10. Precision and Bias [5]

10.1 This precision and bias section has been prepared in accordance with Practice D 4483. Refer to this practice for terminology and other statistical calculation details.

10.2 *Precision*—A Type 1 (interlaboratory) test program to determine precision was evaluated in 1981. Both repeatability and reproducibility are short term. A period of a few days separates replicate test results. A test result is the median value, as specified by this test method, obtained on five determinations or measurements of hardness.

10.3 Four different materials were used in the interlaboratory program. These were tested in six laboratories on two different days. The results of the precision calculations for repeatability and reproducibility are given in Table 4, in ascending order of material average or level, for each of the materials evaluated.

10.4 The precision of this test method may be expressed in the format of the following statements, which use an appropriate value of *r* or *R*, that is, that value to be used in decisions

[5] Supporting data are available from ASTM Headquarters. Request RR: D11-1024.

TABLE 3 Relation Between International Rubber Hardness Degrees (IRHD) and Penetrations Differences

IRHD	Movement of Plunger		IRHD	Movement of Plunger		IRHD	Movement of Plunger		IRHD	Movement of Plunger	
	mm	mils		mm	mils		mm	mils		mm	mils
28	1.934	76.1	47	1.055	41.5	66	0.589	23.2	85	0.280	11.0
29	1.867	73.5	48	1.024	40.3	67	0.570	22.5	86	0.266	10.5
30	1.803	71.0	49	0.994	39.1	68	0.552	21.7	87	0.251	9.9
31	1.743	68.6	50	0.964	38.0	69	0.534	21.0	88	0.237	9.3
32	1.685	66.4	51	0.936	36.8	70	0.516	20.3	89	0.223	8.8
33	1.630	64.2	52	0.908	35.8	71	0.498	19.6	90	0.209	8.2
34	1.578	62.1	53	0.881	34.7	72	0.481	18.9	91	0.195	7.7
35	1.528	60.1	54	0.855	33.7	73	0.464	18.3	92	0.180	7.1
36	1.479	58.2	55	0.830	32.7	74	0.447	17.6	93	0.166	6.5
37	1.433	56.4	56	0.805	31.7	75	0.431	17.0	94	0.151	5.9
38	1.389	54.7	57	0.781	30.8	76	0.415	16.3	95	0.135	5.3
39	1.346	53.0	58	0.758	29.8	77	0.399	15.7	96	0.119	4.7
40	1.305	51.4	59	0.735	28.9	78	0.384	15.1	97	0.102	4.0
41	1.265	49.8	60	0.713	28.1	79	0.368	14.5	98	0.083	3.3
42	1.227	48.3	61	0.691	27.2	80	0.353	13.9	99	0.060	2.4
43	1.190	46.9	62	0.670	26.4	81	0.338	13.3	100	0.000	0.0
44	1.155	45.5	63	0.649	25.5	82	0.323	12.7			
45	1.120	44.1	64	0.629	24.7	83	0.309	12.2			
46	1.087	42.8	65	0.609	24.0	84	0.294	11.6			

TABLE 4 Type 1 Precision Results (IRHD)

Material	Average	Within Laboratory[A]			Between Laboratory[A]		
		S_r	r	$(r)^B$	S_R	R	$(R)^B$
Material 1	41.51	0.1140	0.3227	0.777	3.1126	8.8087	21.221
Material 2	52.67	0.4143	1.1725	2.226	2.7121	7.6752	14.573
Material 3	65.09	0.3617	1.0236	1.573	2.8652	8.1086	12.457
Material 4	75.08	0.5236	1.4818	1.974	2.8091	7.9497	10.589
Pooled values[C]	58.59	0.3915	1.1079	1.891	2.9055	8.2225	14.035

[A] S_r = repeatability standard deviation.
r = repeatability = 2.83 times the square root of the repeatability variance.
(r) = repeatability (as a percent of material average).
S_R = reproducibility standard deviation.
R = reproducibility = 2.83 times the square root of the reproducibility variance.
(R) = reproducibility (as a percent of material average).
[B] Because the hardness scale is not a linear scale, use caution in interpreting (*r*) and (*R*).
[C] No values omitted.

about test results (obtained with the test method). The appropriate value is that value of *r* or *R* associated with a mean level in Table 4 closest to the mean level under consideration at any given time for any given material in routine testing operations.

10.5 *Repeatability*—The repeatability, *r*, of this test method has been established as the appropriate value tabulated in Table 4. Two single test results, obtained under normal test procedures, that differ by more than this tabulated *r* (for any given level) must be considered as derived from different or nonidentical sample populations.

10.6 *Reproducibility*—The reproducibility, *R*, of this test method has been established as the appropriate value tabulated in Table 4. Two single test results obtained in two different laboratories, under normal test procedures, that differ by more than the tabulated *R* (for any given level) must be considered to have come from different or nonidentical sample populations.

10.7 Repeatability and reproducibility expressed as a percentage of the mean level, (*r*) and (*R*), have equivalent application statements as above for *r* and *R*. For the (*r*) and (*R*) statements, the difference in the two single test results is expressed as a percent of the arithmetic mean of the two test results.

10.8 *Bias*—In test method terminology, bias is the difference between an average test value and the reference (or true) test property value. Reference values do not exist for this test method since the value (of the test property) is exclusively defined by the test method. Bias, therefore, cannot be determined.