Designation: D1415 – 06 (Reapproved 2012)

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

This standard is issued under the fixed designation D1415; 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 U.S. Department of Defense.

1. Scope

1.1 This test method covers a procedure for measuring the hardness of vulcanized or thermoplastic 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 technically similar to 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:*[2]

D1349 Practice for Rubber—Standard Conditions for Testing

D2240 Test Method for Rubber Property—Durometer Hardness

D4483 Practice for Evaluating Precision for Test Method Standards in the Rubber and Carbon Black Manufacturing Industries

2.2 *International Standard:*[3]

ISO 48 Rubber, Vulcanized or Thermoplastic—Determination of Hardness (Hardness between 10 and 100 IRHD)

3. Summary of Test Methods

3.1 Four procedures are given to accommodate specimens of different dimensions hardness of vulcanized or thermoplastic rubbers on flat surfaces:

Type S1 and S2, Standard hardness tests;
Type M, Micro-hardness tests;
Type L, Low hardness test;
Type H, High hardness test.

3.1.1 *Types S1 and S2 (refer to Table 1)*—The standard test for hardness is the appropriate method for specimens having a thickness described in Section 6, and is appropriate for those having a hardness of 35 IRHD to 85 IRHD. It may be used for those in the range of 30 IRHD to 95 IRHD.

NOTE 1—The hardness values obtained by Types S and S1, within the ranges of 85 IRHD to 95 IRHD and 30 IRHD to 35 IRHD may not agree with those obtained using Types H or L. The differences are not generally considered significant.

3.1.2 *Type M (refer to Table 1)*—The micro-hardness test is a scaled-down version of Type S1 and S2, which permit testing of thinner and smaller specimens. It is applicable for specimens having a thickness described in Section 6, and a hardness of 35 IRHD to 85 IRHD. It may be used for those in the range of 30 IRHD to 95 IRHD.

NOTE 2—The hardness values obtained by Type M may not agree with those obtained using Types S1 or S2 due to the effects of surface variations or specimen configuration.

3.1.3 *Type L*—The appropriate method for specimens having a thickness described in Section 6, and a hardness of 10 IRHD to 35 IRHD.

3.1.4 *Type H*—The appropriate method for specimens having a thickness described in Section 6, and a hardness of 85 IRHD to 100 IRHD.

3.2 In all 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 multiplied by scale factor 6. Alternatively, the penetration measuring instrument may be calibrated directly in IRHD.

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

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

TABLE 1 Apparatus Requirements

NOTE 1—In Type M micro-hardness 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*.

	Type S1	Type S2	Type M	Type L	Type H
Diameter of ball, mm	2.38 ± 0.01	2.50 ± 0.01	0.395 ± 0.005	5.0 ± 0.01	1.0 ± 0.01
Minor force on ball, N[A]	0.30 ± 0.02	0.29 ± 0.02	0.0083± 0.0005	0.3 ± 0.02	0.3 ± 0.02
Major force on ball, N[A]	5.23 ± 0.01	5.4 ± 0.01	0.1455 ± 0.0005	5.4 ± 0.01	5.4 ± 0.01
Total force on ball, N[A]	5.53 ± 0.03	5.7 ± 0.03	0.153 ± 0.001	5.7 ± 0.03	5.7 ± 0.03
Outside diameter of foot, mm	20 ± 1	20 ± 1	3.35± 0.15	22 ± 1.0	20 ± 1.0
Inside diameter of foot, mm	6 ± 1	6 ± 1	1.00± 0.15	10 ± 1.0	6 ± 1.0
Force on foot, N[B]	8.3 ± 1.5	8.3 ± 1.5	0.235± 0.03[C]	8.3 ± 1.5	8.3 ± 1.5

[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.

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 IRHD, 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.

4.1.1 The scale also fulfills the following conditions over most of the normal range of hardness: one IRHD range represents approximately the same proportionate difference in Young's modulus, and for rubber vulcanizates in the usual range of resilience, readings in IRHD are comparable with those given by a Type A durometer (Test Method D2240) when testing standard specimens.

4.1.1.1 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 (Test Methods D2240 and D1415) result in differences in hardness values. Readings may not be comparable when testing curved or irregularly shaped test specimens.

4.1.2 For substantially elastic isotropic materials like well-vulcanized natural rubbers, the hardness in IRHD bears a known relation to Young's modulus, although for markedly plastic or anisotropic rubbers the relationship will be less precisely known.

4.1.3 The relation between the difference of penetration and the hardness expressed in IRHD is based on the following:

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

$$D = 61.5\,R^{-0.48}\left(\left[F/E\right]^{0.74} - \left[f/E\right]^{0.74}\right) \quad (1)$$

where:

D = known relationship for a perfectly elastic isotropic material, between indentation,
R = radium of the ball, mm,
F = total indenting force,
E = Young's modulus expressed in megapascals, and
f = contact force

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

4.1.3.3 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.

4.1.3.4 The maximum slope is equal to 57 IRHD 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 IRHD 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

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

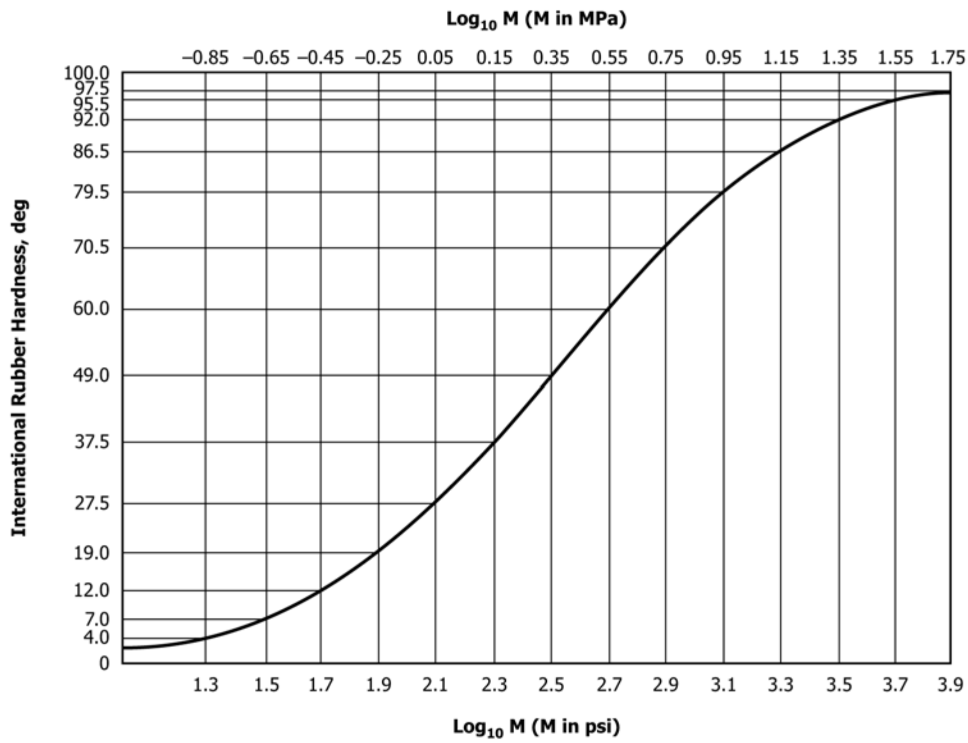

FIG. 1 Point Curve to Relate $\log_{10}$ M and the Hardness in IRHD

parallel upper and lower surfaces. Up to three specimens may be plied to obtain the required thickness. The dimensions of the specimen depend on the test type being used to measure the hardness.

6.2 *Types S1 and S2*—The Types S1 and S2 specimens shall be between 8 and 10 mm in thickness. Nonstandard specimens may be either thicker or thinner but in no case less than 2 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 the specimen less than the appropriate distance shown in Table 2.

6.3 *Type M*—The Type M specimen micro-hardness tests shall be 2 ± 0.5 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-hardness tester if the specimens are mounted in such a manner as to prevent movement during the test, but the values obtained may not be comparable to those obtained with flat specimens.

TABLE 2 Minimum Distance from Edge of Specimen at Which Test is Made (All types except M)

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	13.0	0.50

6.4 *Type L*—The Type L specimens shall be 10 to 15 mm in thickness. Standard specimens may be either thicker or thinner but in no case less than 2 mm. Nonstandard specimens may be either thicker or thinner but in no case less than 6 mm. The lateral dimensions of both standard and nonstandard specimens shall be such that no test is made at a distance from the edge of the specimen less than the appropriate distance shown in Table 2.

6.5 *Type H*—Refer to 6.2 (Types S1 and S2).

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 sensitive to atmospheric moisture shall be conditioned in an atmosphere controlled to 50 ± 5 % relative humidity (RH%) 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 D1349, or as otherwise agreed upon between customer and supplier.

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 gauge is graduated directly in IRHD, turn the bezel of the gauge so that the pointer indicates 100 (exercise care to avoid exerting any vertical pressure on the gauge). Add the major force to the plunger and maintain the total force on the ball for 30 s (Note 3). Record the reading on the gauge as the hardness in IRHD.

NOTE 3—During the loading periods, the apparatus shall be gently vibrated to overcome any friction.

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

8.4 If the measuring device is graduated in metric units, the differential indentation, *D*, (in hundredths of a millimetre) of the plunger caused by the additional indenting force (the major load) for 30 s, shall be noted. If the Type M micro-hardness tester is used, multiply this movement by the scale factor of 6, as given in Table 3 (a) for Types S1 and S2, Table 3 (b) for Type H, and Table 3 (c) for Type L. Convert the value obtained into IRHD by using Table 3 (a-c) or a graph constructed therefrom.

8.5 Make one measurement at each of three or five different points distributed evenly over the specimen. Take the median of these measurements rounded to the nearest displayed unit of IRHD (whole numbers for analog instruments and 0.1 units for digital instruments, if so equipped), and record the result as the hardness value.

TABLE 3 Relationship of IRHD and Penetrations Differences Types S1, S2, and Type M

NOTE 1—Table 3 is applicable for instruments reading in inches. In Type M micro-hardness, the values are to be multiplied by a factor of 6.

IRHD	Movement of Plunger	IRHD	Movement of Plunger	IRHD	Movement of Plunger	IRHD	Movement of Plunger
	mils		mils		mils		mils
28	76.1	47	41.5	66	23.2	85	11.0
29	73.5	48	40.3	67	22.5	86	10.5
30	71.0	49	39.1	68	21.7	87	9.9
31	68.6	50	38.0	69	21.0	88	9.3
32	66.4	51	36.8	70	20.3	89	8.8
33	64.2	52	35.8	71	19.6	90	8.2
34	62.1	53	34.7	72	18.9	91	7.7
35	60.1	54	33.7	73	18.3	92	7.1
36	58.2	55	32.7	74	17.6	93	6.5
37	56.4	56	31.7	75	17.0	94	5.9
38	54.7	57	30.8	76	16.3	95	5.3
39	53.0	58	29.8	77	15.7	96	4.7
40	51.4	59	28.9	78	15.1	97	4.0
41	49.8	60	28.1	79	14.5	98	3.3
42	48.3	61	27.2	80	13.9	99	2.4
43	46.9	62	26.4	81	13.3	100	0.0
44	45.5	63	25.5	82	12.7		
45	44.1	64	24.7	83	12.2		
46	42.8	65	24.0	84	11.6		

TABLE 3 (a) Conversion of values of *D* to IRHD Types S1 and S2 (*D* = differential indentation with a 2.38 or 2.5-mm indentor, given in hundredths of a millimetre)

D	IRHD	*D*	IRHD	*D*	IRHD	*D*	IRHD
0	100	46	73.3	92	51.6	138	38.2
1	100	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

TABLE 3 *Continued*

D	IRHD	*D*	IRHD	*D*	IRHD	*D*	IRHD
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 3 (b) Conversion of Values of *D* to IRHD
Type H (*D* = differential indentation with a 1.0-mm indentor, given in hundredths of a millimetre)

D	IRHD	*D*	IRHD	*D*	IRHD
0	100.00	15	97.3	30	91.1
1	100.00	16	97.0	31	90.7
2	100.00	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 3 (c) Conversion of Values of *D* to IRHD
Type L = (*D* = differential indentation with a 5.0-mm indentor, given in hundredths of a millimetre)

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

TABLE 3 *Continued*

D	IRHD	*D*	IRHD	*D*	IRHD
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	10.0

9. Report

9.1 Report the following information:

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

9.1.2 Dimensions of the specimen, if a singular entity; the number of pieces, that is, one, two, or three; and their individual dimensions when plied. 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, Type S1, S2, Type M, Type H, or Type L,

9.1.5 Date, time, RH%, and temperature of test, and

9.1.6 Pertinent details that would be deemed important to future replication of the test or as agreed upon between customer and supplier.

10. Precision and Bias[5]

10.1 This precision and bias section has been prepared in accordance with Practice D4483. 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 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.

[5] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D11-1024.

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.