Designation: E140 – 12b$^{\varepsilon 1}$

# Standard Hardness Conversion Tables for Metals Relationship Among Brinell Hardness, Vickers Hardness, Rockwell Hardness, Superficial Hardness, Knoop Hardness, Scleroscope Hardness, and Leeb Hardness[1]

This standard is issued under the fixed designation E140; 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 ($\varepsilon$) indicates an editorial change since the last revision or reapproval.

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

$\varepsilon^1$ NOTE—Eq A10.1 and Eq A10.2 were editorially corrected in August 2013.

## 1. Scope*

1.1 Conversion Table 1 presents data in the Rockwell C hardness range on the relationship among Brinell hardness, Vickers hardness, Rockwell hardness, Rockwell superficial hardness, Knoop hardness, and Scleroscope hardness of non-austenitic steels including carbon, alloy, and tool steels in the as-forged, annealed, normalized, and quenched and tempered conditions provided that they are homogeneous.

1.2 Conversion Table 2 presents data in the Rockwell B hardness range on the relationship among Brinell hardness, Vickers hardness, Rockwell hardness, Rockwell superficial hardness, Knoop hardness, and Scleroscope hardness of non-austenitic steels including carbon, alloy, and tool steels in the as-forged, annealed, normalized, and quenched and tempered conditions provided that they are homogeneous.

1.3 Conversion Table 3 presents data on the relationship among Brinell hardness, Vickers hardness, Rockwell hardness, Rockwell superficial hardness, and Knoop hardness of nickel and high-nickel alloys (nickel content over 50 %). These hardness conversion relationships are intended to apply particularly to the following: nickel-aluminum-silicon specimens finished to commercial mill standards for hardness testing, covering the entire range of these alloys from their annealed to their heavily cold-worked or age-hardened conditions, including their intermediate conditions.

1.4 Conversion Table 4 presents data on the relationship among Brinell hardness, Vickers hardness, Rockwell hardness, and Rockwell superficial hardness of cartridge brass.

1.5 Conversion Table 5 presents data on the relationship between Brinell hardness and Rockwell B hardness of austenitic stainless steel plate in the annealed condition.

1.6 Conversion Table 6 presents data on the relationship between Rockwell hardness and Rockwell superficial hardness of austenitic stainless steel sheet.

1.7 Conversion Table 7 presents data on the relationship among Brinell hardness, Vickers hardness, Rockwell hardness, Rockwell superficial hardness, and Knoop hardness of copper.

1.8 Conversion Table 8 presents data on the relationship among Brinell hardness, Rockwell hardness, and Vickers hardness of alloyed white iron.

1.9 Conversion Table 9 presents data on the relationship among Brinell hardness, Vickers hardness, Rockwell hardness, and Rockwell superficial hardness of wrought aluminum products.

1.10 Conversion Table 10 presents data in the Rockwell C hardness range on the relationship among Leeb (Type D) hardness, Brinell hardness, Vickers hardness, and Rockwell hardness of non-austenitic steels including carbon, alloy, and tool steels, in the as-forged, annealed, normalized, and quenched and tempered conditions provided that they are homogeneous.

1.11 Many of the conversion values presented herein were obtained from computer-generated curves of actual test data. Most Rockwell hardness numbers are presented to the nearest 0.1 or 0.5 hardness number to permit accurate reproduction of these curves.

1.12 Annex A1-Annex A10 contain equations to convert from one hardness scale to another. The equations given in Annex A1-Annex A9 were developed from the data in Tables 1 to 9, respectively. The equations given in Annex A10 were developed at the time the Leeb hardness test was invented (see Appendix X2). The data in Table 10 was calculated from the Annex A10 equations.

1.13 Conversion of hardness values should be used only when it is impossible to test the material under the conditions specified, and when conversion is made it should be done with discretion and under controlled conditions. Each type of

[1] These conversion tables are under the jurisdiction of ASTM Committee E28 on Mechanical Testing and are the direct responsibility of Subcommittee E28.06 on Indentation Hardness Testing.

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[3] A Summary of Changes section appears at the end of this standard

hardness test is subject to certain errors, but if precautions are carefully observed, the reliability of hardness readings made on instruments of the indentation type will be found comparable. Differences in sensitivity within the range of a given hardness scale (for example, Rockwell B) may be greater than between two different scales or types of instruments. The conversion values, whether from the tables or calculated from the equations, are only approximate and may be inaccurate for specific application.

## 2. Referenced Documents

2.1 *ASTM Standards:*[2]

A956 Test Method for Leeb Hardness Testing of Steel Products

E10 Test Method for Brinell Hardness of Metallic Materials

E18 Test Methods for Rockwell Hardness of Metallic Materials

E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E92 Test Method for Vickers Hardness of Metallic Materials (Withdrawn 2010)[3]

E384 Test Method for Knoop and Vickers Hardness of Materials

E448 Practice for Scleroscope Hardness Testing of Metallic Materials

## 3. Methods for Hardness Determinations

3.1 The hardness readings used with these conversion tables shall be determined in accordance with one of the following ASTM test methods:

3.1.1 *Brinell Hardness*—Test Method E10.

3.1.2 *Rockwell Hardness*—Test Method E18 Scales A, B, C, D, E, F, G, H, K, 15-N, 30-N, 45-N, 15-T, 30-T, 45-T, 15-W.

3.1.3 *Vickers Hardness and Knoop Hardness*—Test Method E384.

3.1.4 *Scleroscope*[4] *Hardness*—Practice E448.

3.1.5 *Leeb Hardness*—Test Method A956.

NOTE 1—The comparative hardness test done to generate the conversion tables in this standard were performed in past years using ASTM test methods in effect at the time of testing. In some cases, the standards have changed in ways that could affect the final results. For example, currently both the Rockwell and Brinell hardness standards (Test MethodE10 and E18, respectively) allow or require the use of tungsten carbide ball indenters; however, all of the ball scale Rockwell hardness tests (HRB, HR30T, etc.) and most of the Brinell hardness tests preformed to develop these tables used hardened steel ball indenters. The use of tungsten carbide balls will produce slightly different hardness results than steel balls. Therefore, the user is cautioned to consider these differences and to keep in mind the approximate nature of these conversions when applying them to the results of tests using tungsten carbide balls.

## 4. Apparatus and Reference Standards

4.1 The apparatus and reference standards shall conform to the description in Test Methods A956, E10, E18, E384, and Practice E448.

## 5. Principle of Method of Conversion

5.1 Tests have proved that even the most reliable data cannot be fitted to a single conversion relationship for all metals. Indentation hardness is not a single fundamental property but a combination of properties, and the contribution of each to the hardness number varies with the type of test. The modulus of elasticity has been shown to influence conversions at high hardness levels; and at low hardness levels conversions between hardness scales measuring depth and those measuring diameter are likewise influenced by differences in the modulus of elasticity. Therefore separate conversion tables are necessary for different materials.

NOTE 2—Hardness conversion values for other metals based on comparative test on similar materials having similar mechanical properties will be added to this standard as the need arises.

## 6. Significance and Use

6.1 The conversion values given in the tables, or calculated by the equations given in the appendixes, should only be considered valid for the specific materials indicated. This is because conversions can be affected by several factors, including the material alloy, grain structure, heat treatment, etc.

6.2 Since the various types of hardness tests do not all measure the same combination of material properties, conversion from one hardness scale to another is only an approximate process. Because of the wide range of variation among different materials, it is not possible to state confidence limits for the errors in using a conversion chart. Even in the case of a table established for a single material, such as the table for cartridge brass, some error is involved depending on composition and methods of processing.

6.3 Because of their approximate nature, conversion tables must be regarded as only an estimate of comparative values. It is recommended that hardness conversions be applied primarily to values such as specification limits, which are established by agreement or mandate, and that the conversion of test data be avoided whenever possible (see Note 1).

## 7. Reporting of Hardness Numbers

7.1 Historically when reporting converted hardness numbers, the measured hardness and test scale were also reported in parentheses. This is still an acceptable practice as in the following:

$$353\ HBW\ (38\ HRC) \quad (1)$$

where 353 HBW is the converted hardness value and 38 HRC is the original measurement value and test scale.

7.2 Other formats for reporting converted hardness values, such as data tables, may be used; however, the original measurement value and test scale shall also be reported and clearly identified.

7.3 Since all converted hardness values must be considered approximate, all converted hardness numbers shall be rounded

[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] The last approved version of this historical standard is referenced on www.astm.org.

[4] Registered trademark of the Shore Instrument and Manufacturing Co., Inc.

in accordance with Practice E29 and should have no more significant digits than is given for the data in the applicable table.

## 8. Keywords

8.1 conversion; hardness scale; metallic

**TABLE 1 Approximate Hardness Conversion Numbers for Non-Austenitic Steels (Rockwell C Hardness Range)[A, B]**

| Rockwell C Hardness Number 150 kgf (HRC) | Vickers Hardness Number (HV) | Brinell Hardness Number[C] 10-mm Standard Ball, 3000-kgf (HBS) | Brinell Hardness Number[C] 10-mm Carbide Ball, 3000-kgf (HBW) | Knoop Hardness, Number 500-gf and Over (HK) | Rockwell Hardness Number A Scale, 60-kgf (HRA) | Rockwell Hardness Number D Scale, 100-kgf (HRD) | Rockwell Superficial Hardness Number 15-N Scale, 15-kgf (HR 15-N) | Rockwell Superficial Hardness Number 30-N Scale, 30-kgf (HR 30-N) | Rockwell Superficial Hardness Number 45-N Scale, 45-kgf (HR 45-N) | Scleroscope Hardness Number[D] | Rockwell C Hardness Number 150 kgf (HRC) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 68 | 940 | ... | ... | 920 | 85.6 | 76.9 | 93.2 | 84.4 | 75.4 | 97.3 | 68 |
| 67 | 900 | ... | ... | 895 | 85.0 | 76.1 | 92.9 | 83.6 | 74.2 | 95.0 | 67 |
| 66 | 865 | ... | ... | 870 | 84.5 | 75.4 | 92.5 | 82.8 | 73.3 | 92.7 | 66 |
| 65 | 832 | ... | (739) | 846 | 83.9 | 74.5 | 92.2 | 81.9 | 72.0 | 90.6 | 65 |
| 64 | 800 | ... | (722) | 822 | 83.4 | 73.8 | 91.8 | 81.1 | 71.0 | 88.5 | 64 |
| 63 | 772 | ... | (705) | 799 | 82.8 | 73.0 | 91.4 | 80.1 | 69.9 | 86.5 | 63 |
| 62 | 746 | ... | (688) | 776 | 82.3 | 72.2 | 91.1 | 79.3 | 68.8 | 84.5 | 62 |
| 61 | 720 | ... | (670) | 754 | 81.8 | 71.5 | 90.7 | 78.4 | 67.7 | 82.6 | 61 |
| 60 | 697 | ... | (654) | 732 | 81.2 | 70.7 | 90.2 | 77.5 | 66.6 | 80.8 | 60 |
| 59 | 674 | ... | 634 | 710 | 80.7 | 69.9 | 89.8 | 76.6 | 65.5 | 79.0 | 59 |
| 58 | 653 | ... | 615 | 690 | 80.1 | 69.2 | 89.3 | 75.7 | 64.3 | 77.3 | 58 |
| 57 | 633 | ... | 595 | 670 | 79.6 | 68.5 | 88.9 | 74.8 | 63.2 | 75.6 | 57 |
| 56 | 613 | ... | 577 | 650 | 79.0 | 67.7 | 88.3 | 73.9 | 62.0 | 74.0 | 56 |
| 55 | 595 | ... | 560 | 630 | 78.5 | 66.9 | 87.9 | 73.0 | 60.9 | 72.4 | 55 |
| 54 | 577 | ... | 543 | 612 | 78.0 | 66.1 | 87.4 | 72.0 | 59.8 | 70.9 | 54 |
| 53 | 560 | ... | 525 | 594 | 77.4 | 65.4 | 86.9 | 71.2 | 58.6 | 69.4 | 53 |
| 52 | 544 | (500) | 512 | 576 | 76.8 | 64.6 | 86.4 | 70.2 | 57.4 | 67.9 | 52 |
| 51 | 528 | (487) | 496 | 558 | 76.3 | 63.8 | 85.9 | 69.4 | 56.1 | 66.5 | 51 |
| 50 | 513 | (475) | 481 | 542 | 75.9 | 63.1 | 85.5 | 68.5 | 55.0 | 65.1 | 50 |
| 49 | 498 | (464) | 469 | 526 | 75.2 | 62.1 | 85.0 | 67.6 | 53.8 | 63.7 | 49 |
| 48 | 484 | 451 | 455 | 510 | 74.7 | 61.4 | 84.5 | 66.7 | 52.5 | 62.4 | 48 |
| 47 | 471 | 442 | 443 | 495 | 74.1 | 60.8 | 83.9 | 65.8 | 51.4 | 61.1 | 47 |
| 46 | 458 | 432 | 432 | 480 | 73.6 | 60.0 | 83.5 | 64.8 | 50.3 | 59.8 | 46 |
| 45 | 446 | 421 | 421 | 466 | 73.1 | 59.2 | 83.0 | 64.0 | 49.0 | 58.5 | 45 |
| 44 | 434 | 409 | 409 | 452 | 72.5 | 58.5 | 82.5 | 63.1 | 47.8 | 57.3 | 44 |
| 43 | 423 | 400 | 400 | 438 | 72.0 | 57.7 | 82.0 | 62.2 | 46.7 | 56.1 | 43 |
| 42 | 412 | 390 | 390 | 426 | 71.5 | 56.9 | 81.5 | 61.3 | 45.5 | 54.9 | 42 |
| 41 | 402 | 381 | 381 | 414 | 70.9 | 56.2 | 80.9 | 60.4 | 44.3 | 53.7 | 41 |
| 40 | 392 | 371 | 371 | 402 | 70.4 | 55.4 | 80.4 | 59.5 | 43.1 | 52.6 | 40 |
| 39 | 382 | 362 | 362 | 391 | 69.9 | 54.6 | 79.9 | 58.6 | 41.9 | 51.5 | 39 |
| 38 | 372 | 353 | 353 | 380 | 69.4 | 53.8 | 79.4 | 57.7 | 40.8 | 50.4 | 38 |
| 37 | 363 | 344 | 344 | 370 | 68.9 | 53.1 | 78.8 | 56.8 | 39.6 | 49.3 | 37 |
| 36 | 354 | 336 | 336 | 360 | 68.4 | 52.3 | 78.3 | 55.9 | 38.4 | 48.2 | 36 |
| 35 | 345 | 327 | 327 | 351 | 67.9 | 51.5 | 77.7 | 55.0 | 37.2 | 47.1 | 35 |
| 34 | 336 | 319 | 319 | 342 | 67.4 | 50.8 | 77.2 | 54.2 | 36.1 | 46.1 | 34 |
| 33 | 327 | 311 | 311 | 334 | 66.8 | 50.0 | 76.6 | 53.3 | 34.9 | 45.1 | 33 |
| 32 | 318 | 301 | 301 | 326 | 66.3 | 49.2 | 76.1 | 52.1 | 33.7 | 44.1 | 32 |
| 31 | 310 | 294 | 294 | 318 | 65.8 | 48.4 | 75.6 | 51.3 | 32.5 | 43.1 | 31 |
| 30 | 302 | 286 | 286 | 311 | 65.3 | 47.7 | 75.0 | 50.4 | 31.3 | 42.2 | 30 |
| 29 | 294 | 279 | 279 | 304 | 64.8 | 47.0 | 74.5 | 49.5 | 30.1 | 41.3 | 29 |
| 28 | 286 | 271 | 271 | 297 | 64.3 | 46.1 | 73.9 | 48.6 | 28.9 | 40.4 | 28 |
| 27 | 279 | 264 | 264 | 290 | 63.8 | 45.2 | 73.3 | 47.7 | 27.8 | 39.5 | 27 |
| 26 | 272 | 258 | 258 | 284 | 63.3 | 44.6 | 72.8 | 46.8 | 26.7 | 38.7 | 26 |
| 25 | 266 | 253 | 253 | 278 | 62.8 | 43.8 | 72.2 | 45.9 | 25.5 | 37.8 | 25 |
| 24 | 260 | 247 | 247 | 272 | 62.4 | 43.1 | 71.6 | 45.0 | 24.3 | 37.0 | 24 |
| 23 | 254 | 243 | 243 | 266 | 62.0 | 42.1 | 71.0 | 44.0 | 23.1 | 36.3 | 23 |
| 22 | 248 | 237 | 237 | 261 | 61.5 | 41.6 | 70.5 | 43.2 | 22.0 | 35.5 | 22 |
| 21 | 243 | 231 | 231 | 256 | 61.0 | 40.9 | 69.9 | 42.3 | 20.7 | 34.8 | 21 |
| 20 | 238 | 226 | 226 | 251 | 60.5 | 40.1 | 69.4 | 41.5 | 19.6 | 34.2 | 20 |

[A] In the table headings, *force* refers to total test forces.

[B] Annex A1 contains equations converting determined hardness scale numbers to Rockwell C hardness numbers for non-austenitic steels. Refer to 1.12 before using conversion equations.

[C] The Brinell hardness numbers in parentheses are outside the range recommended for Brinell hardness testing in 9.1 of Test Method E10.

[D] These Scleroscope hardness conversions are based on Vickers—Scleroscope hardness relationships developed from Vickers hardness data provided by the National Bureau of Standards for 13 steel reference blocks, Scleroscope hardness values obtained on these blocks by the Shore Instrument and Mfg. Co., Inc., the Roll Manufacturers Institute, and members of this institute, and also on hardness conversions previously published by the American Society for Metals and the Roll Manufacturers Institute.

TABLE 2 Approximate Hardness Conversion Numbers for Non-Austenitic Steels (Rockwell B Hardness Range)[A, B]

| Rockwell B Hardness Number, 100-kgf (HRB) | Vickers Hardness Number (HV) | Brinell Hardness Number, 3000-kgf, (HBS) | Knoop Hardness Number, 500-gf, and Over (HK) | Rockwell A Hardness Number, 60-kgf, (HRA) | Rockwell F Hardness Number, 60-kgf, (HRF) | Rockwell Superficial Hardness Number | | | Rockwell B Hardness Number, 100-kgf, (HRB) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 15-T Scale, 15-kgf, (HR 15-T) | 30-T Scale, 30-kgf, (HR 30-T) | 45-T Scale, 45-kgf, (HR 45-T) | |
| 100 | 240 | 240 | 251 | 61.5 | ... | 93.1 | 83.1 | 72.9 | 100 |
| 99 | 234 | 234 | 246 | 60.9 | ... | 92.8 | 82.5 | 71.9 | 99 |
| 98 | 228 | 228 | 241 | 60.2 | ... | 92.5 | 81.8 | 70.9 | 98 |
| 97 | 222 | 222 | 236 | 59.5 | ... | 92.1 | 81.1 | 69.9 | 97 |
| 96 | 216 | 216 | 231 | 58.9 | ... | 91.8 | 80.4 | 68.9 | 96 |
| 95 | 210 | 210 | 226 | 58.3 | ... | 91.5 | 79.8 | 67.9 | 95 |
| 94 | 205 | 205 | 221 | 57.6 | ... | 91.2 | 79.1 | 66.9 | 94 |
| 93 | 200 | 200 | 216 | 57.0 | ... | 90.8 | 78.4 | 65.9 | 93 |
| 92 | 195 | 195 | 211 | 56.4 | ... | 90.5 | 77.8 | 64.8 | 92 |
| 91 | 190 | 190 | 206 | 55.8 | ... | 90.2 | 77.1 | 63.8 | 91 |
| 90 | 185 | 185 | 201 | 55.2 | ... | 89.9 | 76.4 | 62.8 | 90 |
| 89 | 180 | 180 | 196 | 54.6 | ... | 89.5 | 75.8 | 61.8 | 89 |
| 88 | 176 | 176 | 192 | 54.0 | ... | 89.2 | 75.1 | 60.8 | 88 |
| 87 | 172 | 172 | 188 | 53.4 | ... | 88.9 | 74.4 | 59.8 | 87 |
| 86 | 169 | 169 | 184 | 52.8 | ... | 88.6 | 73.8 | 58.8 | 86 |
| 85 | 165 | 165 | 180 | 52.3 | ... | 88.2 | 73.1 | 57.8 | 85 |
| 84 | 162 | 162 | 176 | 51.7 | ... | 87.9 | 72.4 | 56.8 | 84 |
| 83 | 159 | 159 | 173 | 51.1 | ... | 87.6 | 71.8 | 55.8 | 83 |
| 82 | 156 | 156 | 170 | 50.6 | ... | 87.3 | 71.1 | 54.8 | 82 |
| 81 | 153 | 153 | 167 | 50.0 | ... | 86.9 | 70.4 | 53.8 | 81 |
| 80 | 150 | 150 | 164 | 49.5 | ... | 86.6 | 69.7 | 52.8 | 80 |
| 79 | 147 | 147 | 161 | 48.9 | ... | 86.3 | 69.1 | 51.8 | 79 |
| 78 | 144 | 144 | 158 | 48.4 | ... | 86.0 | 68.4 | 50.8 | 78 |
| 77 | 141 | 141 | 155 | 47.9 | ... | 85.6 | 67.7 | 49.8 | 77 |
| 76 | 139 | 139 | 152 | 47.3 | ... | 85.3 | 67.1 | 48.8 | 76 |
| 75 | 137 | 137 | 150 | 46.8 | 99.6 | 85.0 | 66.4 | 47.8 | 75 |
| 74 | 135 | 135 | 147 | 46.3 | 99.1 | 84.7 | 65.7 | 46.8 | 74 |
| 73 | 132 | 132 | 145 | 45.8 | 98.5 | 84.3 | 65.1 | 45.8 | 73 |
| 72 | 130 | 130 | 143 | 45.3 | 98.0 | 84.0 | 64.4 | 44.8 | 72 |
| 71 | 127 | 127 | 141 | 44.8 | 97.4 | 83.7 | 63.7 | 43.8 | 71 |
| 70 | 125 | 125 | 139 | 44.3 | 96.8 | 83.4 | 63.1 | 42.8 | 70 |
| 69 | 123 | 123 | 137 | 43.8 | 96.2 | 83.0 | 62.4 | 41.8 | 69 |
| 68 | 121 | 121 | 135 | 43.3 | 95.6 | 82.7 | 61.7 | 40.8 | 68 |
| 67 | 119 | 119 | 133 | 42.8 | 95.1 | 82.4 | 61.0 | 39.8 | 67 |
| 66 | 117 | 117 | 131 | 42.3 | 94.5 | 82.1 | 60.4 | 38.7 | 66 |
| 65 | 116 | 116 | 129 | 41.8 | 93.9 | 81.8 | 59.7 | 37.7 | 65 |
| 64 | 114 | 114 | 127 | 41.4 | 93.4 | 81.4 | 59.0 | 36.7 | 64 |
| 63 | 112 | 112 | 125 | 40.9 | 92.8 | 81.1 | 58.4 | 35.7 | 63 |
| 62 | 110 | 110 | 124 | 40.4 | 92.2 | 80.8 | 57.7 | 34.7 | 62 |
| 61 | 108 | 108 | 122 | 40.0 | 91.7 | 80.5 | 57.0 | 33.7 | 61 |
| 60 | 107 | 107 | 120 | 39.5 | 91.1 | 80.1 | 56.4 | 32.7 | 60 |

**TABLE 2** *(continued)*

| Rockwell B Hardness Number, 100-kgf, (HRB) | Vickers Hardness Number (HV) | Brinell Hardness Number, 3000-kgf, 10-mm Ball | Knoop Hardness Number, 500-gf and Over | Rockwell A Hardness Number, 60-kgf, Diamond Penetrator | Rockwell F Hardness Number, 60-kgf, 1⁄16-in. (1.588-mm) Ball | Rockwell Superficial Hardness Number | | | Rockwell B Hardness Number, 100-kgf, 1⁄16-in. (1.588-mm) Ball |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 15-T Scale, 15-kgf, 1⁄16-in. (1.588-mm) Ball | 30-T Scale, 30-kgf, 1⁄16-in. (1.588-mm) Ball | 45-T Scale, 45-kgf, 1⁄16-in. (1.588-mm) Ball | |
| 59 | 106 | 106 | 118 | 39.0 | 90.5 | 79.8 | 55.7 | 31.7 | 59 |
| 58 | 104 | 104 | 117 | 38.6 | 90.0 | 79.5 | 55.0 | 30.7 | 58 |
| 57 | 103 | 103 | 115 | 38.1 | 89.4 | 79.2 | 54.4 | 29.7 | 57 |
| 56 | 101 | 101 | 114 | 37.7 | 88.8 | 78.8 | 53.7 | 28.7 | 56 |
| 55 | 100 | 100 | 112 | 37.2 | 88.2 | 78.5 | 53.0 | 27.7 | 55 |
| 54 | ... | ... | 111 | 36.8 | 87.7 | 78.2 | 52.4 | 26.7 | 54 |
| 53 | ... | ... | 110 | 36.3 | 87.1 | 77.9 | 51.7 | 25.7 | 53 |
| 52 | ... | ... | 109 | 35.9 | 86.5 | 77.5 | 51.0 | 24.7 | 52 |
| 51 | ... | ... | 108 | 35.5 | 86.0 | 77.2 | 50.3 | 23.7 | 51 |
| 50 | ... | ... | 107 | 35.0 | 85.4 | 76.9 | 49.7 | 22.7 | 50 |
| 49 | ... | ... | 106 | 34.6 | 84.8 | 76.6 | 49.0 | 21.7 | 49 |
| 48 | ... | ... | 105 | 34.1 | 84.3 | 76.2 | 48.3 | 20.7 | 48 |
| 47 | ... | ... | 104 | 33.7 | 83.7 | 75.9 | 47.7 | 19.7 | 47 |
| 46 | ... | ... | 103 | 33.3 | 83.1 | 75.6 | 47.0 | 18.7 | 46 |
| 45 | ... | ... | 102 | 32.9 | 82.6 | 75.3 | 46.3 | 17.7 | 45 |
| 44 | ... | ... | 101 | 32.4 | 82.0 | 74.9 | 45.7 | 16.7 | 44 |
| 43 | ... | ... | 100 | 32.0 | 81.4 | 74.6 | 45.0 | 15.7 | 43 |
| 42 | ... | ... | 99 | 31.6 | 80.8 | 74.3 | 44.3 | 14.7 | 42 |
| 41 | ... | ... | 98 | 31.2 | 80.3 | 74.0 | 43.7 | 13.6 | 41 |
| 40 | ... | ... | 97 | 30.7 | 79.7 | 73.6 | 43.0 | 12.6 | 40 |
| 39 | ... | ... | 96 | 30.3 | 79.1 | 73.3 | 42.3 | 11.6 | 39 |
| 38 | ... | ... | 95 | 29.8 | 78.6 | 73.0 | 41.6 | 10.6 | 38 |
| 37 | ... | ... | 94 | 29.5 | 78.0 | 72.7 | 41.0 | 9.6 | 37 |
| 36 | ... | ... | 93 | 29.1 | 77.4 | 72.3 | 40.3 | 8.6 | 36 |
| 35 | ... | ... | 92 | 28.7 | 76.9 | 72.0 | 39.6 | 7.6 | 35 |
| 34 | ... | ... | 91 | 28.2 | 76.3 | 71.7 | 39.0 | 6.6 | 34 |
| 33 | ... | ... | 90 | 27.8 | 75.7 | 71.4 | 38.3 | 5.6 | 33 |
| 32 | ... | ... | 89 | 27.4 | 75.2 | 71.0 | 37.6 | 4.6 | 32 |
| 31 | ... | ... | 88 | 27.0 | 74.6 | 70.7 | 37.0 | 3.6 | 31 |
| 30 | ... | ... | 87 | 26.6 | 74.0 | 70.4 | 36.3 | 2.6 | 30 |

[A] In table headings, kgf refers to total test force.

[B] Annex A2 contains equations converting determined hardness numbers to Rockwell B hardness numbers for non-austenitic steels. Refer to 1.12 before using conversion equations.

## TABLE 3 Approximate Hardness Conversion Numbers for Nickel and High-Nickel Alloys[A, B, C]

NOTE 1—See Supplement to Table 3.

NOTE 2—The use of hardness scales for hardness values shown in parentheses is not recommended since they are beyond the ranges recommended for accuracy. Such values are shown for comparative purposes only, where comparisons may be desired and the recommended machine and scale are not available.

| Vickers Hardness Number | Brinell Hardness Number | Rockwell Hardness Number | | | | | | | | Rockwell Superficial Hardness Number | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vickers Indenter 1, 5, 10, 30-kgf (HV) | 10-mm Standard Ball, 3000-kgf (HBS) | A Scale 60-kgf Diamond Penetrator (HRA) | B Scale 100-kgf 1/16-in. (1.588-mm) Ball (HRB) | C Scale 150-kgf Diamond Penetrator (HRC) | D Scale 100-kgf Diamond Penetrator (HRD) | E Scale 100-kgf 1/8-in. (3.175-mm) Ball (HRE) | F Scale 60-kgf 1/16-in. (1.588-mm) Ball (HRF) | G Scale 150-kgf 1/16-in. (1.588-mm) Ball (HRG) | K Scale 150-kgf 1/8-in. (3.175-mm) Ball (HRK) | 15-N Scale 15-kgf Superficial Diamond Penetrator (HR 15-N) | 30-N Scale 30-kgf Superficial Diamond Penetrator (HR 30-N) | 45-N Scale 45-kgf Superficial Diamond Penetrator (HR 45-N) | 15-T Scale 15-kgf 1/16-in. (1.588-mm) Ball (HR 15-T) | 30-T Scale 30-kgf 1/16-in. (1.588-mm) Ball (HR 30-T) | 45-T Scale 45-kgf 1/16-in. (1.588-mm) Ball (HR 45-T) |
| 513 | (479) | 75.5 | ... | 50.0 | 63.0 | ... | ... | ... | ... | 85.5 | 68.0 | 54.5 | ... | ... | ... |
| 481 | 450 | 74.5 | ... | 48.0 | 61.5 | ... | ... | ... | ... | 84.5 | 66.5 | 52.5 | ... | ... | ... |
| 452 | 425 | 73.5 | ... | 46.0 | 60.0 | ... | ... | ... | ... | 83.5 | 64.5 | 50.0 | ... | ... | ... |
| 427 | 403 | 72.5 | ... | 44.0 | 58.5 | ... | ... | ... | ... | 82.5 | 63.0 | 47.5 | ... | ... | ... |
| 404 | 382 | 71.5 | ... | 42.0 | 57.0 | ... | ... | ... | ... | 81.5 | 61.0 | 45.5 | ... | ... | ... |
| 382 | 363 | 70.5 | ... | 40.0 | 55.5 | ... | ... | ... | ... | 80.5 | 59.5 | 43.0 | ... | ... | ... |
| 362 | 346 | 69.5 | ... | 38.0 | 54.0 | ... | ... | ... | ... | 79.5 | 58.0 | 41.0 | ... | ... | ... |
| 344 | 329 | 68.5 | ... | 36.0 | 52.5 | ... | ... | ... | ... | 78.5 | 56.0 | 38.5 | ... | ... | ... |
| 326 | 313 | 67.5 | ... | 34.0 | 50.5 | ... | ... | ... | ... | 77.5 | 54.5 | 36.0 | ... | ... | ... |
| 309 | 298 | 66.5 | (106) | 32.0 | 49.5 | ... | (116.5) | 94.0 | ... | 76.5 | 52.5 | 34.0 | 94.5 | 85.5 | 77.0 |
| 285 | 275 | 64.5 | (104) | 28.5 | 46.5 | ... | (115.5) | 91.0 | ... | 75.0 | 49.5 | 30.0 | 94.0 | 84.5 | 75.0 |
| 266 | 258 | 63.0 | (102) | 25.5 | 44.5 | ... | (114.5) | 87.5 | ... | 73.5 | 47.0 | 26.5 | 93.0 | 83.0 | 73.0 |
| 248 | 241 | 61.5 | 100 | 22.5 | 42.0 | ... | (113.0) | 84.5 | ... | 72.0 | 44.5 | 23.0 | 92.5 | 81.5 | 71.0 |
| 234 | 228 | 60.5 | 98 | 20.0 | 40.0 | ... | (112.0) | 81.5 | ... | 70.5 | 42.0 | 20.0 | 92.0 | 80.5 | 69.0 |
| 220 | 215 | 59.0 | 96 | (17.0) | 38.0 | ... | (111.0) | 78.5 | 100.0 | 69.0 | 39.5 | 17.0 | 91.0 | 79.0 | 67.0 |
| 209 | 204 | 57.5 | 94 | (14.5) | 36.0 | ... | (110.0) | 75.5 | 98.0 | 68.0 | 37.5 | 14.0 | 90.5 | 77.5 | 65.0 |
| 198 | 194 | 56.5 | 92 | (12.0) | 34.0 | ... | (108.5) | 72.0 | 96.5 | 66.5 | 35.5 | 11.0 | 89.5 | 76.0 | 63.0 |
| 188 | 184 | 55.0 | 90 | (9.0) | 32.0 | (108.5) | (107.5) | 69.0 | 94.5 | 65.0 | 32.5 | 7.5 | 89.0 | 75.0 | 61.0 |
| 179 | 176 | 53.5 | 88 | (6.5) | 30.0 | (107.0) | (106.5) | 65.5 | 93.0 | 64.0 | 30.5 | 5.0 | 88.0 | 73.5 | 59.5 |
| 171 | 168 | 52.5 | 86 | (4.0) | 28.0 | (106.0) | (105.0) | 62.5 | 91.0 | 62.5 | 28.5 | 2.0 | 87.5 | 72.0 | 57.5 |
| 164 | 161 | 51.5 | 84 | (2.0) | 26.5 | (104.5) | (104.0) | 59.5 | 89.0 | 61.5 | 26.5 | (–0.5) | 87.0 | 70.5 | 55.5 |
| 157 | 155 | 50.0 | 82 | ... | 24.5 | (103.0) | (103.0) | 56.5 | 87.5 | ... | ... | ... | 86.0 | 69.5 | 53.5 |
| 151 | 149 | 49.0 | 80 | ... | 22.5 | (102.0) | (101.5) | 53.0 | 85.5 | ... | ... | ... | 85.5 | 68.0 | 51.5 |
| 145 | 144 | 47.5 | 78 | ... | 21.0 | (100.5) | (100.5) | 50.0 | 83.5 | ... | ... | ... | 84.5 | 66.5 | 49.5 |
| 140 | 139 | 46.5 | 76 | ... | (19.0) | 99.5 | 99.5 | 47.0 | 82.0 | ... | ... | ... | 84.0 | 65.5 | 47.5 |
| 135 | 134 | 45.5 | 74 | ... | (17.5) | 98.0 | 98.5 | 43.5 | 80.0 | ... | ... | ... | 83.0 | 64.0 | 45.5 |
| 130 | 129 | 44.0 | 72 | ... | (15.0) | 97.0 | 97.0 | 40.5 | 78.0 | ... | ... | ... | 82.5 | 62.5 | 43.5 |
| 126 | 125 | 43.0 | 70 | ... | (14.5) | 95.5 | 96.0 | 37.5 | 76.5 | ... | ... | ... | 82.0 | 61.0 | 41.5 |
| 122 | 121 | 42.0 | 68 | ... | (13.0) | 94.5 | 95.0 | 34.5 | 74.5 | ... | ... | ... | 81.0 | 60.0 | 39.5 |
| 119 | 118 | 41.0 | 66 | ... | (11.5) | 93.0 | 93.5 | 31.0 | 72.5 | ... | ... | ... | 80.5 | 58.5 | 37.5 |
| 115 | 114 | 40.0 | 64 | ... | (10.0) | 91.5 | 92.5 | ... | 71.0 | ... | ... | ... | 79.5 | 57.0 | 35.5 |
| 112 | 111 | 39.0 | 62 | ... | (8.0) | 90.5 | 91.5 | ... | 69.0 | ... | ... | ... | 79.0 | 56.0 | 33.5 |
| 108 | 108 | ... | 60 | ... | ... | 89.0 | 90.0 | ... | 67.5 | ... | ... | ... | 78.5 | 54.5 | 31.5 |
| 106 | 106 | ... | 58 | ... | ... | 88.0 | 89.0 | ... | 65.5 | ... | ... | ... | 77.5 | 53.0 | 29.5 |
| 103 | 103 | ... | 56 | ... | ... | 86.5 | 88.0 | ... | 63.5 | ... | ... | ... | 77.0 | 51.5 | 27.5 |
| 100 | 100 | ... | 54 | ... | ... | 85.5 | 87.0 | ... | 62.0 | ... | ... | ... | 76.0 | 50.5 | 25.5 |
| 98 | 98 | ... | 52 | ... | ... | 84.0 | 85.5 | ... | 60.0 | ... | ... | ... | 75.5 | 49.0 | 23.5 |
| 95 | 95 | ... | 50 | ... | ... | 83.0 | 84.5 | ... | 58.0 | ... | ... | ... | 74.5 | 47.5 | 21.5 |
| 93 | 93 | ... | 48 | ... | ... | 81.5 | 83.5 | ... | 56.5 | ... | ... | ... | 74.0 | 46.5 | 19.5 |

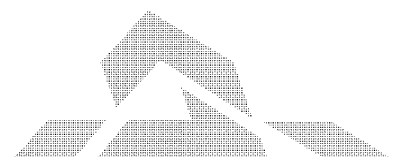

TABLE 3 *Continued*

| Vickers Hardness Number | Brinell Hardness Number | Rockwell Hardness Number | | | | | | | | Rockwell Superficial Hardness Number | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vickers Indenter 1, 5, 10, 30-kgf (HV) | 10-mm Standard Ball, 3000-kgf (HBS) | A Scale 60-kgf Diamond Penetrator (HRA) | B Scale 100-kgf 1/16-in. (1.588-mm) Ball (HRB) | C Scale 150-kgf Diamond Penetrator (HRC) | D Scale 100-kgf Diamond Penetrator (HRD) | E Scale 100-kgf 1/8-in. (3.175-mm) Ball (HRE) | F Scale 60-kgf 1/16-in. (1.588-mm) Ball (HRF) | G Scale 150-kgf 1/16-in. (1.588-mm) Ball (HRG) | K Scale 150-kgf 1/8-in. (3.175-mm) Ball (HRK) | 15-N Scale 15-kgf Superficial Diamond Penetrator (HR 15-N) | 30-N Scale 30-kgf Superficial Diamond Penetrator (HR 30-N) | 45-N Scale 45-kgf Superficial Diamond Penetrator (HR 45-N) | 15-T Scale 15-kgf 1/16-in. (1.588-mm) Ball (HR 15-T) | 30-T Scale 30-kgf 1/16-in. (1.588-mm) Ball (HR 30-T) | 45-T Scale 45-kgf 1/16-in. (1.588-mm) Ball (HR 45-T) |
| 91 | 91 | ... | 46 | ... | ... | 80.5 | 82.0 | ... | 54.5 | ... | ... | ... | 73.5 | 45.0 | 17.0 |
| 89 | 89 | ... | 44 | ... | ... | 79.0 | 81.0 | ... | 52.5 | ... | ... | ... | 72.5 | 43.5 | 14.5 |
| 87 | 87 | ... | 42 | ... | ... | 78.0 | 80.0 | ... | 51.0 | ... | ... | ... | 72.0 | 42.0 | 12.5 |
| 85 | 85 | ... | 40 | ... | ... | 76.5 | 79.0 | ... | 49.0 | ... | ... | ... | 71.0 | 41.0 | 10.0 |
| 83 | 83 | ... | 38 | ... | ... | 75.0 | 77.5 | ... | 47.0 | ... | ... | ... | 70.5 | 39.5 | 7.5 |
| 81 | 81 | ... | 36 | ... | ... | 74.0 | 76.5 | ... | 45.5 | ... | ... | ... | 70.0 | 38.0 | 5.5 |
| 79 | 79 | ... | 34 | ... | ... | 72.5 | 75.5 | ... | 43.5 | ... | ... | ... | 69.0 | 36.5 | 3.0 |
| 78 | 78 | ... | 32 | ... | ... | 71.5 | 74.0 | ... | 42.0 | ... | ... | ... | 68.5 | 35.5 | 1.0 |
| 77 | 77 | ... | 30 | ... | ... | 70.0 | 73.0 | ... | 40.0 | ... | ... | ... | 67.5 | 34.0 | (–1.5) |

**TABLE 3** *(continued)*

| Vickers Hardness Number | Knoop Hardness Number |
|---|---|
| Vickers Indenter 1,5,10,30-kgf (HV) | Knoop Indenter 500 and 1000-gf (HK) |
| 382 | 436 |
| 362 | 413 |
| 344 | 392 |
| 326 | 372 |
| 309 | 352 |
| 295 | 335 |
| 280 | 304 |
| 248 | 283 |
| 234 | 267 |
| 220 | 251 |
| 209 | 239 |
| 198 | 226 |
| 188 | 215 |
| 179 | 204 |
| 171 | 195 |
| 164 | 187 |
| 157 | 179 |
| 151 | 173 |
| 145 | 166 |
| 140 | 160 |
| 135 | 154 |
| 130 | 149 |
| 126 | 144 |
| 122 | 140 |
| 119 | 136 |

[A] In table headings, kgf or gf refers to total test force.

[B] Annex A3 contains equations converting determined hardness scale numbers to Vickers hardness numbers for nickel and high-nickel alloys. Refer to 1.12 before using conversion equations.

[C] Note that in Table 5 of Test Method E10 (appears in the *Annual Book of ASTM Standards*, Vol 03.01), the use of a 3000-kgf force is recommended (but not mandatory) for material in the hardness range from 96 to 600 HV, and a 1500-kgf force is recommended (but not mandatory) for material in the hardness range from 48 to 300 HV. These recommendations are designed to limit impression diameters to the range from 2.50 to 6.0 mm. The Brinell hardness numbers in this conversion table are based on tests using a 3000-kgf force. When the 1500-kgf force is used for the softer nickel and high-nickel alloys, these conversion relationships do not apply.

TABLE 4 Approximate Hardness Conversion Numbers for Cartridge Brass (70 % Copper 30 % Zinc Alloy)[A,B]

| Vickers Hardness Number (HV) | Rockwell Hardness Number | | Rockwell Superficial Hardness Number | | | Brinell Hardness Number |
|---|---|---|---|---|---|---|
| | B Scale, 100-kgf, 1/16-in. (1.588-mm) Ball (HRB) | F Scale, 60-kgf 1/16-in. (1.588-mm) Ball (HRF) | 15-T Scale, 15-kgf,1/16-in. (1.588-mm) Ball (HR 15-T) | 30-T Scale, 30-kgf, 1/16-in. (1.588-mm) Ball (HR 30-T) | 45-T Scale, 45-kgf, 1/16-in. (1.588-mm) Ball (HR 45-T) | 500-kgf, 10-mm Ball (HBS) |
| 196 | 93.5 | 110.0 | 90.0 | 77.5 | 66.0 | 169 |
| 194 | ... | 109.5 | ... | ... | 65.5 | 167 |
| 192 | 93.0 | ... | ... | 77.0 | 65.0 | 166 |
| 190 | 92.5 | 109.0 | ... | 76.5 | 64.5 | 164 |
| 188 | 92.0 | ... | 89.5 | ... | 64.0 | 162 |
| 186 | 91.5 | 108.5 | ... | 76.0 | 63.5 | 161 |
| 184 | 91.0 | ... | ... | 75.5 | 63.0 | 159 |
| 182 | 90.5 | 108.0 | 89.0 | ... | 62.5 | 157 |
| 180 | 90.0 | 107.5 | ... | 75.0 | 62.0 | 156 |
| 178 | 89.0 | ... | ... | 74.5 | 61.5 | 154 |
| 176 | 88.5 | 107.0 | ... | ... | 61.0 | 152 |
| 174 | 88.0 | ... | 88.5 | 74.0 | 60.5 | 150 |
| 172 | 87.5 | 106.5 | ... | 73.5 | 60.0 | 149 |
| 170 | 87.0 | ... | ... | ... | 59.5 | 147 |
| 168 | 86.0 | 106.0 | 88.0 | 73.0 | 59.0 | 146 |
| 166 | 85.5 | ... | ... | 72.5 | 58.5 | 144 |
| 164 | 85.0 | 105.5 | ... | 72.0 | 58.0 | 142 |
| 162 | 84.0 | 105.0 | 87.5 | ... | 57.5 | 141 |
| 160 | 83.5 | ... | ... | 71.5 | 56.5 | 139 |
| 158 | 83.0 | 104.5 | ... | 71.0 | 56.0 | 138 |
| 156 | 82.0 | 104.0 | 87.0 | 70.5 | 55.5 | 136 |
| 154 | 81.5 | 103.5 | ... | 70.0 | 54.5 | 135 |
| 152 | 80.5 | 103.0 | ... | ... | 54.0 | 133 |
| 150 | 80.0 | ... | 86.5 | 69.5 | 53.5 | 131 |
| 148 | 79.0 | 102.5 | ... | 69.0 | 53.0 | 129 |
| 146 | 78.0 | 102.0 | ... | 68.5 | 52.5 | 128 |
| 144 | 77.5 | 101.5 | 86.0 | 68.0 | 51.5 | 126 |
| 142 | 77.0 | 101.0 | ... | 67.5 | 51.0 | 124 |
| 140 | 76.0 | 100.5 | 85.5 | 67.0 | 50.0 | 122 |
| 138 | 75.0 | 100.0 | ... | 66.5 | 49.0 | 121 |
| 136 | 74.5 | 99.5 | 85.0 | 66.0 | 48.0 | 120 |
| 134 | 73.5 | 99.0 | ... | 65.5 | 47.5 | 118 |
| 132 | 73.0 | 98.5 | 84.5 | 65.0 | 46.5 | 116 |
| 130 | 72.0 | 98.0 | 84.0 | 64.5 | 45.5 | 114 |
| 128 | 71.0 | 97.5 | ... | 63.5 | 45.0 | 113 |
| 126 | 70.0 | 97.0 | 83.5 | 63.0 | 44.0 | 112 |
| 124 | 69.0 | 96.5 | ... | 62.5 | 43.0 | 110 |
| 122 | 68.0 | 96.0 | 83.0 | 62.0 | 42.0 | 108 |
| 120 | 67.0 | 95.5 | ... | 61.0 | 41.0 | 106 |
| 118 | 66.0 | 95.0 | 82.5 | 60.5 | 40.0 | 105 |
| 116 | 65.0 | 94.5 | 82.0 | 60.0 | 39.0 | 103 |
| 114 | 64.0 | 94.0 | 81.5 | 59.5 | 38.0 | 101 |
| 112 | 63.0 | 93.0 | 81.0 | 58.5 | 37.0 | 99 |
| 110 | 62.0 | 92.5 | 80.5 | 58.0 | 35.5 | 97 |
| 108 | 61.0 | 92.0 | ... | 57.0 | 34.5 | 95 |
| 106 | 59.5 | 91.2 | 80.0 | 56.0 | 33.0 | 94 |
| 104 | 58.0 | 90.5 | 79.5 | 55.0 | 32.0 | 92 |
| 102 | 57.0 | 89.8 | 79.0 | 54.5 | 30.5 | 90 |
| 100 | 56.0 | 89.0 | 78.5 | 53.5 | 29.5 | 88 |
| 98 | 54.0 | 88.0 | 78.0 | 52.5 | 28.0 | 86 |
| 96 | 53.0 | 87.2 | 77.5 | 51.5 | 26.5 | 85 |
| 94 | 51.0 | 86.3 | 77.0 | 50.5 | 24.5 | 83 |
| 92 | 49.5 | 85.4 | 76.5 | 49.0 | 23.0 | 82 |
| 90 | 47.5 | 84.4 | 75.5 | 48.0 | 21.0 | 80 |
| 88 | 46.0 | 83.5 | 75.0 | 47.0 | 19.0 | 79 |
| 86 | 44.0 | 82.3 | 74.5 | 45.5 | 17.0 | 77 |
| 84 | 42.0 | 81.2 | 73.5 | 44.0 | 14.5 | 76 |
| 82 | 40.0 | 80.0 | 73.0 | 43.0 | 12.5 | 74 |
| 80 | 37.5 | 78.6 | 72.0 | 41.0 | 10.0 | 72 |
| 78 | 35.0 | 77.4 | 71.5 | 39.5 | 7.5 | 70 |
| 76 | 32.5 | 76.0 | 70.5 | 38.0 | 4.5 | 68 |
| 74 | 30.0 | 74.8 | 70.0 | 36.0 | 1.0 | 66 |
| 72 | 27.5 | 73.2 | 69.0 | 34.0 | ... | 64 |
| 70 | 24.5 | 71.8 | 68.0 | 32.0 | ... | 63 |
| 68 | 21.5 | 70.0 | 67.0 | 30.0 | ... | 62 |
| 66 | 18.5 | 68.5 | 66.0 | 28.0 | ... | 61 |
| 64 | 15.5 | 66.8 | 65.0 | 25.5 | ... | 59 |
| 62 | 12.5 | 65.0 | 63.5 | 23.0 | ... | 57 |
| 60 | 10.0 | 62.5 | 62.5 | ... | ... | 55 |

**TABLE 4** *Continued*

| Vickers Hardness Number (HV) | Rockwell Hardness Number | | Rockwell Superficial Hardness Number | | | Brinell Hardness Number |
|---|---|---|---|---|---|---|
| | B Scale, 100-kgf, 1/16-in. (1.588-mm) Ball (HRB) | F Scale, 60-kgf 1/16-in. (1.588-mm) Ball (HRF) | 15-T Scale, 15-kgf,1/16-in. (1.588-mm) Ball (HR 15-T) | 30-T Scale, 30-kgf, 1/16-in. (1.588-mm) Ball (HR 30-T) | 45-T Scale, 45-kgf, 1/16-in. (1.588-mm) Ball (HR 45-T) | 500-kgf, 10-mm Ball (HBS) |
| 58 | ... | 61.0 | 61.0 | 18.0 | ... | 53 |
| 56 | ... | 58.8 | 60.0 | 15.0 | ... | 52 |
| 54 | ... | 56.5 | 58.5 | 12.0 | ... | 50 |
| 52 | ... | 53.5 | 57.0 | ... | ... | 48 |
| 50 | ... | 50.5 | 55.5 | ... | ... | 47 |
| 49 | ... | 49.0 | 54.5 | ... | ... | 46 |
| 48 | ... | 47.0 | 53.5 | ... | ... | 45 |
| 47 | ... | 45.0 | ... | ... | ... | 44 |
| 46 | ... | 43.0 | ... | ... | ... | 43 |
| 45 | ... | 40.0 | ... | ... | ... | 42 |

[A] In table headings, kgf or gf refers to total test force.

[B] Annex A4 contains equations converting determined hardness scale numbers to Vickers hardness numbers for cartridge brass. Refer to 1.12 before using conversion equations.

**TABLE 5 Approximate Brinell-Rockwell B Hardness Conversion Numbers for Austenitic Stainless Steel Plate in Annealed Condition[A,B]**

| Rockwell Hardness Number, B Scale (100-kgf, 1/16-in. (1.588-mm) ball) (HRB) | Brinell Hardness Number (3000-kgf, 10-mm ball) (HBS) |
|---|---|
| 100 | 256 |
| 99 | 248 |
| 98 | 240 |
| 97 | 233 |
| 96 | 226 |
| 95 | 219 |
| 94 | 213 |
| 93 | 207 |
| 92 | 202 |
| 91 | 197 |
| 90 | 192 |
| 89 | 187 |
| 88 | 183 |
| 87 | 178 |
| 86 | 174 |
| 85 | 170 |
| 84 | 167 |
| 83 | 163 |
| 82 | 160 |
| 81 | 156 |
| 80 | 153 |
| 79 | 150 |
| 78 | 147 |
| 77 | 144 |
| 76 | 142 |
| 75 | 139 |
| 74 | 137 |
| 73 | 135 |
| 72 | 132 |
| 71 | 130 |
| 70 | 128 |
| 69 | 126 |
| 68 | 124 |
| 67 | 122 |
| 66 | 120 |
| 65 | 118 |
| 64 | 116 |
| 63 | 114 |
| 62 | 113 |
| 61 | 111 |
| 60 | 110 |

[A] In table headings, kgf or gf refers to total test force.

[B] Annex A5 contains an equation converting determined Brinell hardness numbers to Rockwell B hardness numbers for austenitic steel plate in the annealed condition. Refer to 1.12 before using this conversion equation.

**TABLE 6 Approximate Rockwell Hardness Conversion Numbers for Austenitic Stainless Steel Sheet[A,B]**

NOTE 1—These conversions are based on interlaboratory tests conducted on the following grades: Types 201, 202, 301, 302, 304, 304L, 305, 316, 316L, 321, and 347. Tempers ranged from annealed to extra hard for Type 301, with a smaller range of tempers for the other types. Test coupon thicknesses ranged from approximately 0.1 in. (2.5 mm) to 0.050 in. (1.27 mm).

| Rockwell Hardness Number | | Rockwell Superficial Hardness Number | | |
|---|---|---|---|---|
| C Scale, 150-kgf Diamond Penetrator (HRC) | A Scale, 60-kgf, Diamond Penetrator (HRA) | 15-N Scale, 15-kgf, Superficial Diamond Penetrator (HR 15-N) | 30-N Scale, 30-kgf, Superficial Diamond Penetrator (HR 30-N) | 45-N Scale, 45-kgf, Superficial Diamond Penetrator (HR 45-N) |
| 48 | 74.4 | 84.1 | 66.2 | 52.1 |
| 47 | 73.9 | 83.6 | 65.3 | 50.9 |
| 46 | 73.4 | 83.1 | 64.5 | 49.8 |
| 45 | 72.9 | 82.6 | 63.6 | 48.7 |
| 44 | 72.4 | 82.1 | 62.7 | 47.5 |
| 43 | 71.9 | 81.6 | 61.8 | 46.4 |
| 42 | 71.4 | 81.0 | 61.0 | 45.2 |
| 41 | 70.9 | 80.5 | 60.1 | 44.1 |
| 40 | 70.4 | 80.0 | 59.2 | 43.0 |
| 39 | 69.9 | 79.5 | 58.4 | 41.8 |
| 38 | 69.3 | 79.0 | 57.5 | 40.7 |
| 37 | 68.8 | 78.5 | 56.6 | 39.6 |
| 36 | 68.3 | 78.0 | 55.7 | 38.4 |
| 35 | 67.8 | 77.5 | 54.9 | 37.3 |
| 34 | 67.3 | 77.0 | 54.0 | 36.1 |
| 33 | 66.8 | 76.5 | 53.1 | 35.0 |
| 32 | 66.3 | 75.9 | 52.3 | 33.9 |
| 31 | 65.8 | 75.4 | 51.4 | 32.7 |
| 30 | 65.3 | 74.9 | 50.5 | 31.6 |
| 29 | 64.8 | 74.4 | 49.6 | 30.4 |
| 28 | 64.3 | 73.9 | 48.8 | 29.3 |
| 27 | 63.8 | 73.3 | 47.9 | 28.2 |
| 26 | 63.3 | 72.8 | 47.0 | 27.0 |
| 25 | 62.8 | 72.4 | 46.2 | 25.9 |
| 24 | 62.3 | 71.9 | 45.3 | 24.8 |
| 23 | 61.8 | 71.3 | 44.4 | 23.6 |
| 22 | 61.3 | 70.8 | 43.5 | 22.5 |
| 21 | 60.8 | 70.3 | 42.7 | 21.3 |
| 20 | 60.3 | 69.8 | 41.8 | 20.2 |

| B Scale, 100-kgf, 1/16-in. (1.588-mm) Ball (HRB) | A Scale, 60-kgf, Diamond Penetrator (HRA) | F Scale, 60-kgf, 1/16-in. (1.588-mm) Ball[C] (HRF) | 15-T Scale, 15-kgf, 1/16-in. (1.588-mm) Ball (HR 15-T) | 30-T Scale, 30-kgf, 1/16-in. (1.588-mm) Ball (HR 30-T) | 45-T Scale, 45-kgf, 1/16-in. (1.588-mm) Ball (HR 45-T) |
|---|---|---|---|---|---|
| 100 | 61.5 | (113.9) | 91.5 | 80.4 | 70.2 |
| 99 | 60.9 | (113.2) | 91.2 | 79.7 | 69.2 |
| 98 | 60.3 | (112.5) | 90.8 | 79.0 | 68.2 |
| 97 | 59.7 | (111.8) | 90.4 | 78.3 | 67.2 |
| 96 | 59.1 | (111.1) | 90.1 | 77.7 | 66.1 |
| 95 | 58.5 | (110.5) | 89.7 | 77.0 | 65.1 |
| 94 | 58.0 | (109.8) | 89.3 | 76.3 | 64.1 |
| 93 | 57.4 | (109.1) | 88.9 | 75.6 | 63.1 |
| 92 | 56.8 | (108.4) | 88.6 | 74.9 | 62.1 |
| 91 | 56.2 | (107.8) | 88.2 | 74.2 | 61.1 |
| 90 | 55.6 | (107.1) | 87.8 | 73.5 | 60.1 |
| 89 | 55.0 | (106.4) | 87.5 | 72.8 | 59.0 |
| 88 | 54.5 | (105.7) | 87.1 | 72.1 | 58.0 |
| 87 | 53.9 | (105.0) | 86.7 | 71.4 | 57.0 |
| 86 | 53.3 | (104.4) | 86.4 | 70.7 | 56.0 |
| 85 | 52.7 | (103.7) | 86.0 | 70.0 | 55.0 |
| 84 | 52.1 | (103.0) | 85.6 | 69.3 | 54.0 |
| 83 | 51.5 | (102.3) | 85.2 | 68.6 | 52.9 |
| 82 | 50.9 | (101.7) | 84.9 | 67.9 | 51.9 |
| 81 | 50.4 | (101.0) | 84.5 | 67.2 | 50.9 |
| 80 | 49.8 | (100.3) | 84.1 | 66.5 | 49.9 |
| 79 | 49.2 | 99.6 | 83.8 | 65.8 | 48.9 |
| 78 | 48.6 | 99.0 | 83.4 | 65.1 | 47.9 |
| 77 | 48.0 | 98.3 | 83.0 | 64.4 | 46.8 |
| 76 | 47.4 | 97.6 | 82.6 | 63.7 | 45.8 |
| 75 | 46.9 | 96.9 | 82.3 | 63.0 | 44.8 |
| 74 | 46.3 | 96.2 | 81.9 | 62.4 | 43.8 |
| 73 | 45.7 | 95.6 | 81.5 | 61.7 | 42.8 |
| 72 | 45.1 | 94.9 | 81.2 | 61.0 | 41.8 |
| 71 | 44.5 | 94.2 | 80.8 | 60.3 | 40.7 |
| 70 | 43.9 | 93.5 | 80.4 | 59.6 | 39.7 |
| 69 | 43.3 | 92.8 | 80.1 | 58.9 | 38.7 |
| 68 | 42.8 | 92.2 | 79.7 | 58.2 | 37.7 |

**TABLE 6** *Continued*

| B Scale, 100-kgf, 1/16-in. (1.588-mm) Ball (HRB) | A Scale, 60-kgf, Diamond Penetrator (HRA) | F Scale, 60-kgf, 1/16-in. (1.588-mm) Ball [C] (HRF) | 15-T Scale, 15-kgf, 1/16-in. (1.588-mm) Ball (HR 15-T) | 30-T Scale, 30-kgf, 1/16-in. (1.588-mm) Ball (HR 30-T) | 45-T Scale, 45-kgf, 1/16-in. (1.588-mm) Ball (HR 45-T) |
|---|---|---|---|---|---|
| 67 | 42.2 | 91.5 | 79.3 | 57.5 | 36.7 |
| 66 | 41.6 | 90.8 | 78.9 | 56.8 | 35.7 |
| 65 | 41.0 | 90.1 | 78.6 | 56.1 | 34.7 |
| 64 | 40.4 | 89.5 | 78.2 | 55.4 | 33.6 |
| 63 | 39.8 | 88.8 | 77.8 | 54.7 | 32.6 |
| 62 | 39.3 | 88.1 | 77.5 | 54.0 | 31.6 |
| 61 | 38.7 | 87.4 | 77.1 | 53.3 | 30.6 |
| 60 | 38.1 | 86.8 | 76.7 | 52.6 | 29.6 |
| Standard deviation[C] | 1.44 | 2.75 | 2.29 | 1.67 | 1.57 |

[A] In table headings, kgf or gf refers to total test force.
[B] Annex A6 contains equations converting determined hardness numbers to Rockwell C and Rockwell B hardness numbers for austenitic stainless steel sheet. Refer to 1.12 before using conversion equations.
[C] Observed standard deviation of the interlaboratory test data about the indicated conversion line.
[D] Rockwell F hardness numbers in parentheses are above the maximum hardness recommended and are presented for information only.

TABLE 7 Approximate Hardness Conversion Numbers for Copper, No. 102 to 142 Inclusive[A, B]

| Vickers Hardness Number | | Knoop Hardness Number | | Rockwell Superficial Hardness Number | | | Rockwell Hardness Number | | Rockwell Superficial Hardness Number | | | Brinell Hardness Number | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1-kgf (HV) | 100-gf (HV) | 1-kgf (HK) | 500-gf (HK) | 15-T Scale, 15-kgf 1/16-in. (1.588-mm) Ball (HR 15-T) | 15-T Scale, 15-kgf 1/16-in. (1.588-mm) Ball (HR 15-T) | 30-T Scale, 30-kgf 1/16-in. (1.588-mm) Ball (HR 30-T) | B Scale, 100-kgf 1/16-in. (1.588-mm) Ball (HRB) | F Scale, 60-kgf 1/16-in. (1.588-mm) Ball (HRF) | 15-T Scale, 15-kgf 1/16-in. (1.588-mm) Ball (HR 15-T) | 30-T Scale, 30-kgf 1/16-in. (1.588-mm) Ball (HR 30-T) | 45-T Scale, 45-kgf 1/16-in. (1.588-mm) Ball (HR 45-T) | 500-kgf, 10-mm Diameter Ball (HBS) | 20-kgf 2-mm Diameter Ball (HBS) |
| | | | | 0.010-in. (0.25-mm) Strip | | 0.020-in. (0.51-mm) Strip | | | 0.040-in. (1.02-mm) Strip and Greater | | | 0.080-in. (2.03-mm) Strip | 0.040-in. (1.02-mm) Strip |
| 130 | 127.0 | 138.7 | 133.8 | ... | 85.0 | ... | 67.0 | 99.0 | ... | 69.5 | 49.0 | ... | 119.0 |
| 128 | 125.2 | 136.8 | 132.1 | 83.0 | 84.5 | ... | 66.0 | 98.0 | 87.0 | 68.5 | 48.0 | ... | 117.5 |
| 126 | 123.6 | 134.9 | 130.4 | ... | 84.0 | ... | 65.0 | 97.0 | ... | 67.5 | 46.5 | 120.0 | 115.0 |
| 124 | 121.9 | 133.0 | 128.7 | 82.5 | 83.5 | ... | 64.0 | 96.0 | 86.0 | 66.5 | 45.0 | 117.5 | 113.0 |
| 122 | 121.1 | 131.0 | 127.0 | ... | 83.0 | ... | 62.5 | 95.5 | 85.5 | 66.0 | 44.0 | 115.0 | 111.0 |
| 120 | 118.5 | 129.0 | 125.2 | 82.0 | 82.5 | ... | 61.0 | 95.0 | ... | 65.0 | 42.5 | 112.0 | 109.0 |
| 118 | 116.8 | 127.1 | 123.5 | 81.5 | ... | ... | 59.5 | 94.0 | 85.0 | 64.0 | 41.0 | 110.0 | 107.5 |
| 116 | 115.0 | 125.1 | 121.7 | ... | 82.0 | ... | 58.5 | 93.0 | ... | 63.0 | 40.0 | 107.0 | 105.5 |
| 114 | 113.5 | 123.2 | 119.9 | 81.0 | 81.5 | ... | 57.0 | 92.5 | 84.5 | 62.0 | 38.5 | 105.0 | 103.5 |
| 112 | 111.8 | 121.4 | 118.1 | 80.5 | 81.0 | ... | 55.0 | 91.5 | ... | 61.0 | 37.0 | 102.0 | 102.0 |
| 110 | 109.9 | 119.5 | 116.3 | 80.0 | ... | ... | 53.5 | 91.0 | 84.0 | 60.0 | 36.0 | 99.5 | 100.0 |
| 108 | 108.3 | 117.5 | 114.5 | ... | 80.5 | ... | 52.0 | 90.5 | 83.5 | 59.0 | 34.5 | 97.0 | 98.0 |
| 106 | 106.6 | 115.6 | 112.6 | 79.5 | 80.0 | ... | 50.0 | 89.5 | ... | 58.0 | 33.0 | 94.5 | 96.0 |
| 104 | 104.9 | 113.5 | 110.1 | 79.0 | 79.5 | ... | 48.0 | 88.5 | 83.0 | 57.0 | 32.0 | 92.0 | 94.0 |
| 102 | 103.2 | 111.5 | 108.0 | 78.5 | 79.0 | ... | 46.5 | 87.5 | 82.5 | 56.0 | 30.0 | 89.5 | 92.0 |
| 100 | 101.5 | 109.4 | 106.0 | 78.0 | 78.0 | ... | 44.5 | 87.0 | 82.0 | 55.0 | 28.5 | 87.0 | 90.0 |
| 98 | 99.8 | 107.3 | 104.0 | 77.5 | 77.5 | ... | 42.0 | 85.5 | 81.0 | 53.5 | 26.5 | 84.5 | 88.0 |
| 96 | 98.0 | 105.3 | 102.1 | 77.0 | 77.0 | ... | 40.0 | 84.5 | 80.5 | 52.0 | 25.5 | 82.0 | 86.5 |
| 94 | 96.4 | 103.2 | 100.0 | 76.5 | 76.5 | ... | 38.0 | 83.0 | 80.0 | 51.0 | 23.0 | 79.5 | 85.0 |
| 92 | 94.7 | 101.0 | 98.0 | 76.0 | 75.5 | ... | 35.5 | 82.0 | 79.0 | 49.0 | 21.0 | 77.0 | 83.0 |
| 90 | 93.0 | 98.9 | 96.0 | 75.5 | 75.0 | ... | 33.0 | 81.0 | 78.0 | 47.5 | 19.0 | 74.5 | 81.0 |
| 88 | 91.2 | 96.9 | 94.0 | 75.0 | 74.5 | ... | 30.5 | 79.5 | 77.0 | 46.0 | 16.5 | ... | 79.0 |
| 86 | 89.7 | 95.5 | 92.6 | 74.5 | 73.5 | ... | 28.0 | 78.0 | 76.0 | 44.0 | 14.0 | ... | 77.0 |
| 84 | 87.9 | 92.3 | 90.0 | 74.0 | 73.0 | ... | 25.5 | 76.5 | 75.0 | 43.0 | 12.0 | ... | 75.0 |
| 82 | 86.1 | 90.1 | 87.9 | 73.5 | 72.0 | ... | 23.0 | 74.5 | 74.5 | 41.0 | 9.5 | ... | 73.0 |
| 80 | 84.5 | 87.9 | 85.6 | 72.5 | 71.0 | ... | 20.0 | 73.0 | 73.5 | 39.5 | 7.0 | ... | 71.5 |
| 78 | 82.8 | 85.7 | 84.0 | 72.0 | 70.0 | ... | 17.0 | 71.0 | 72.5 | 37.5 | 5.0 | ... | 69.5 |
| 76 | 81.0 | 83.5 | 81.9 | 71.5 | 69.5 | ... | 14.5 | 69.0 | 71.5 | 36.0 | 2.0 | ... | 67.5 |
| 74 | 79.2 | 81.3 | 79.9 | 71.0 | 68.5 | ... | 11.5 | 67.5 | 70.0 | 34.0 | ... | ... | 66.0 |
| 72 | 77.6 | 79.3 | 78.7 | 70.0 | 67.5 | ... | 8.5 | 66.0 | 69.0 | 32.0 | ... | ... | 64.0 |
| 70 | 75.8 | 76.8 | 75.6 | 69.5 | 66.5 | ... | 5.0 | 64.0 | 67.5 | 30.0 | ... | ... | 62.0 |
| 68 | 74.3 | 74.1 | 74.4 | 69.0 | 65.5 | ... | 2.0 | 62.0 | 66.0 | 28.0 | ... | ... | 60.5 |
| 66 | 72.6 | 71.9 | 73.0 | 68.0 | 64.5 | ... | ... | 60.0 | 64.5 | 25.5 | ... | ... | 58.5 |
| 64 | 70.9 | 69.5 | 70.0 | 67.5 | 63.5 | ... | ... | 58.0 | 63.5 | 23.5 | ... | ... | 57.0 |
| 62 | 69.1 | 67.0 | 67.9 | 66.5 | 62.0 | ... | ... | 56.0 | 61.0 | 21.0 | ... | ... | 55.0 |
| 60 | 67.5 | 64.6 | 65.9 | 66.0 | 61.0 | ... | ... | 54.0 | 59.0 | 18.0 | ... | ... | 53.0 |
| 58 | 65.8 | 62.0 | 63.8 | 65.0 | 60.0 | ... | ... | 51.5 | 57.0 | 15.5 | ... | ... | 51.5 |
| 56 | 64.0 | 59.8 | 61.8 | 64.5 | 58.5 | ... | ... | 49.0 | 55.0 | 13.0 | ... | ... | 49.5 |
| 54 | 62.3 | 57.4 | 59.5 | 63.5 | 57.5 | ... | ... | 47.0 | 53.0 | 10.0 | ... | ... | 48.0 |
| 52 | 60.7 | 55.0 | 57.2 | 63.0 | 56.0 | ... | ... | 44.0 | 51.5 | 7.5 | ... | ... | 46.5 |
| 50 | 58.9 | 52.8 | 55.0 | 62.0 | 55.0 | ... | ... | 41.5 | 49.5 | 4.5 | ... | ... | 44.5 |
| 48 | 57.3 | 50.3 | 52.7 | 61.0 | 53.5 | ... | ... | 39.0 | 47.5 | 1.5 | ... | ... | 42.0 |
| 46 | 55.8 | 48.0 | 50.2 | 60.5 | 52.0 | ... | ... | 36.0 | 45.0 | ... | ... | ... | 41.0 |
| 44 | 53.9 | 45.9 | 47.8 | 59.5 | 51.0 | ... | ... | 33.5 | 43.0 | ... | ... | ... | ... |
| 42 | 52.2 | 43.7 | 45.2 | 58.5 | 49.5 | ... | ... | 30.5 | 41.0 | ... | ... | ... | ... |
| 40 | 51.3 | 40.2 | 42.8 | 57.5 | 48.0 | ... | ... | 28.0 | 38.5 | ... | ... | ... | ... |

[A] In table headings, kgf or gf refers to total test force.

[B] Annex A7 contains equations converting determined hardness scale numbers to Vickers hardness numbers for copper, numbers 102 to 142 inclusive. Refer to 1.12 before using conversion equations.

**TABLE 8 Approximate Hardness Conversion Numbers for Alloyed White Irons [A, B, C]**

| Vickers Hardness, HV 50 | Brinell Hardness, HBW | Rockwell C Hardness, HRC | Vickers Hardness, HV 50 | Brinell[D] Hardness, HBW | Rockwell C Hardness, HRC |
|---|---|---|---|---|---|
| 1000 | (903)[E] | 70 | 680 | 621 | 57 |
| 980 | (886) | 69 | 660 | 604 | 56 |
| 960 | (868) | 68 | 640 | 586 | 55 |
| 940 | (850) | 68 | 620 | 569 | 54 |
| 920 | (833) | 67 | 600 | 551 | 53 |
| 900 | (815) | 66 | 580 | 533 | 52 |
| 880 | (798) | 66 | 560 | 516 | 51 |
| 860 | (780) | 65 | 540 | 498 | 50 |
| 840 | (782) | 64 | 520 | 481 | 48 |
| 820 | (745) | 63 | 500 | 463 | 47 |
| 800 | (727) | 62 | 480 | 445 | 45 |
| 780 | (710) | 62 | 460 | 428 | 44 |
| 760 | (692) | 61 | 440 | 410 | 42 |
| 740 | (674) | 60 | 420 | 393 | 40 |
| 720 | (657) | 59 | 400 | 375 | 38 |
| 700 | (639) | 58 | 380 | 357 | 35 |

[A] Data were generated in an interlaboratory comparison program conducted by American Foundrymen's Society Special Irons Subcommittee, 5-D. Supporting data available on loan from ASTM Headquarters. Request RR:E28-1003.
[B] In table headings, kgf or gf refers to total test force.
[C] Annex A8 contains equations converting determined hardness scale numbers to Vickers hardness numbers for alloyed white irons. Refer to 1.12 before using conversion equations.
[D] Ten-millimetre tungsten carbide ball.
[E] Brinell hardness numbers in parentheses are above the maximum hardness recommended by Test Method E10 and are presented for information only.

**TABLE 9 Approximate Hardness Conversion Numbers for Wrought Aluminum Products[A, B, C]**

| Brinell Hardness Number 500-kgf, (10-mm Ball) (HBS) | Vickers Hardness Number 15-kgf, (HV) | Rockwell Hardness Number | | | Rockwell Superficial Hardness Number | | |
|---|---|---|---|---|---|---|---|
| | | B Scale 100-kgf, 1/16-in. Ball (HRB) | E Scale 100-kgf, 1/8-in. Ball (HRE) | H Scale 60-kgf, 1/8-in. Ball (HRH) | 15-T Scale 15-kgf, 1/16-in. Ball (HR 15-T) | 30-T Scale 30-kgf, 1/16-in. Ball (HR 30-T) | 15-W Scale 15-kgf, 1/8-in. Ball (HR 15-W) |
| 160 | 189 | 91 | ... | ... | 89 | 77 | 95 |
| 155 | 183 | 90 | ... | ... | 89 | 76 | 95 |
| 150 | 177 | 89 | ... | ... | 89 | 75 | 94 |
| 145 | 171 | 87 | ... | ... | 88 | 74 | 94 |
| 140 | 165 | 86 | ... | ... | 88 | 73 | 94 |
| 135 | 159 | 84 | ... | ... | 87 | 71 | 93 |
| 130 | 153 | 81 | ... | ... | 87 | 70 | 93 |
| 125 | 147 | 79 | ... | ... | 86 | 68 | 92 |
| 120 | 141 | 76 | ... | ... | 86 | 67 | 92 |
| 115 | 135 | 72 | 101 | ... | 86 | 65 | 91 |
| 110 | 129 | 69 | 100 | ... | 85 | 63 | 91 |
| 105 | 123 | 65 | 99 | ... | 84 | 61 | 91 |
| 100 | 117 | 60 | 98 | ... | 83 | 59 | 90 |
| 95 | 111 | 56 | 96 | ... | 82 | 57 | 90 |
| 90 | 105 | 51 | 94 | 108 | 81 | 54 | 89 |
| 85 | 98 | 46 | 91 | 107 | 80 | 52 | 89 |
| 80 | 92 | 40 | 88 | 106 | 78 | 50 | 88 |
| 75 | 86 | 34 | 84 | 104 | 76 | 47 | 87 |
| 70 | 80 | 28 | 80 | 102 | 74 | 44 | 86 |
| 65 | 74 | ... | 75 | 100 | 72 | ... | 85 |
| 60 | 68 | ... | 70 | 97 | 70 | ... | 83 |
| 55 | 62 | ... | 65 | 94 | 67 | ... | 82 |
| 50 | 56 | ... | 59 | 91 | 64 | ... | 80 |
| 45 | 50 | ... | 53 | 87 | 62 | ... | 79 |
| 40 | 44 | ... | 46 | 83 | 59 | ... | 77 |

[A] Data were generated in an interlaboratory test program conducted by ASTM Subcommittee E28.06. Supporting data available from ASTM Headquarters. Request RR:E28-1005.
[B] In table headings, kgf or gf refers to total test force.
[C] Annex A9 contains equations converting determined hardness scale numbers to Brinell numbers for wrought aluminum products. Refer to 1.12 before using conversion equations.

TABLE 10 Approximate Leeb (Type D) Hardness Conversion Numbers for Non-Austenitic Steels (Rockwell C Hardness Range)[A,B]

| Leeb Hardness, Type D Impact Device (HLD) | Rockwell C Hardness Number 150 kgf (HRC) | Vickers Hardness Number (HV 10) | Brinell Hardness Number, 10-mm Steel Ball 3000kgf (HBS)[C] | Leeb Hardness, Type D Impact Device (HLD) |
|---|---|---|---|---|
| 828 | 62 | 762 | (721) | 828 |
| 819 | 61 | 737 | (699) | 819 |
| 809 | 60 | 711 | (675) | 809 |
| 800 | 59 | 688 | (654) | 800 |
| 791 | 58 | 667 | 634 | 791 |
| 782 | 57 | 645 | 614 | 782 |
| 773 | 56 | 625 | 595 | 773 |
| 764 | 55 | 605 | 577 | 764 |
| 755 | 54 | 586 | 559 | 755 |
| 746 | 53 | 568 | 542 | 746 |
| 737 | 52 | 550 | 526 | 737 |
| 729 | 51 | 534 | 511 | 729 |
| 720 | 50 | 517 | 496 | 720 |
| 712 | 49 | 503 | 482 | 712 |
| 703 | 48 | 487 | 467 | 703 |
| 695 | 47 | 473 | 455 | 695 |
| 687 | 46 | 460 | 442 | 687 |
| 679 | 45 | 447 | 430 | 679 |
| 671 | 44 | 434 | 418 | 671 |
| 663 | 43 | 422 | 407 | 663 |
| 655 | 42 | 410 | 395 | 655 |
| 647 | 41 | 398 | 385 | 647 |
| 640 | 40 | 388 | 375 | 640 |
| 632 | 39 | 377 | 365 | 632 |
| 625 | 38 | 368 | 356 | 625 |
| 618 | 37 | 358 | 347 | 618 |
| 611 | 36 | 349 | 338 | 611 |
| 603 | 35 | 339 | 328 | 603 |
| 596 | 34 | 330 | 320 | 596 |
| 590 | 33 | 323 | 313 | 590 |
| 583 | 32 | 314 | 305 | 583 |
| 576 | 31 | 306 | 297 | 576 |
| 570 | 30 | 299 | 291 | 570 |
| 563 | 29 | 291 | 283 | 563 |
| 557 | 28 | 284 | 276 | 557 |
| 551 | 27 | 277 | 270 | 551 |
| 545 | 26 | 271 | 264 | 545 |
| 539 | 25 | 264 | 258 | 539 |
| 533 | 24 | 258 | 252 | 533 |
| 527 | 23 | 251 | 246 | 527 |
| 521 | 22 | 245 | 240 | 521 |
| 516 | 21 | 240 | 235 | 516 |
| 510 | 20 | 234 | 229 | 510 |

[A] In the table headings, kgf refers to total test forces.
[B] Annex A10 contains equations converting from Leeb hardness numbers to desired hardness scale numbers for non-austenitic steels (see 1.11).
[C] The Brinell hardness numbers in parentheses are outside the range recommended for Brinell hardness testing in Test Method E10.

## ANNEXES

**(Mandatory Information)**

### A1. HARDNESS CONVERSION EQUATIONS FOR NON-AUSTENITIC STEELS (DETERMINED HARDNESS SCALE NUMBERS TO ROCKWELL C HARDNESS NUMBERS)

A1.1 The following equations were generated from the specific hardness numbers contained in Table 1 and should not be used for converting numbers outside of the defined hardness range. Due to inherent inaccuracies in the conversion process, the converted number should be rounded to the nearest whole number in accordance with Practice E29.

A1.1.1 From Vickers hardness to Rockwell C hardness:

$$HRC = +3.14900E+01+7.96683E\text{-}02(HV) - 3.55432E\text{-}05(HV)^2 - 6.72816E+03(HV)^{-1} \quad (A1.1)$$

A1.1.2 From Brinell hardness (10-mm diameter steel ball, 3000-kgf force) to Rockwell C hardness:

$$HRC = +8.35260E+01 - 8.68203E\text{-}02(HBS) + 1.44229E\text{-}04(HBS)^2 - 1.15905E+04(HBS)^{-1} \quad (A1.2)$$

A1.1.3 From Brinell hardness (10-mm diameter tungsten carbide ball, 3000-kgf force) to Rockwell C hardness:

$$HRC = +1.81673E+01 + 1.20388E-01(HBW) - 6.94388E-05(HBW)^2 - 4.88327E+03(HBW)^{-1} \quad (A1.3)$$

A1.1.4 From Knoop hardness (500-gf force and greater) to Rockwell C hardness:

$$HRC = +6.43102E+01 + 7.59497E-03(HK_{500-1000}) + 1.13729E-05(HK_{500-1000})^2 - 1.17515E+04(HK500 - 1000)^{-1} \quad (A1.4)$$

A1.1.5 From Rockwell A hardness to Rockwell C hardness:

$$HRC = -1.25501E+02 + 2.76747E+00(HRA) - 5.94178E-03(HRA)^2 \quad (A1.5)$$

A1.1.6 From Rockwell D hardness to Rockwell C hardness:

$$HRC = -3.20806E+01 + 1.30193E+00(HRD) \quad (A1.6)$$

A1.1.7 From Rockwell 15N hardness to Rockwell C hardness:

$$HRC = -3.74666E+02 + 1.27582E+01(HR15N) - 1.48317E-01(HR15N)^2 + 6.88816E-04(HR15N)^3 \quad (A1.7)$$

A1.1.8 From Rockwell 30N hardness to Rockwell C hardness:

$$HRC = -2.60390E+01 + 1.11079E+00(HR30N) \quad (A1.8)$$

A1.1.9 From Rockwell 45N hardness to Rockwell C hardness:

$$HRC = +3.18978E+00 + 8.54135E-01(HR45N) \quad (A1.9)$$

A1.1.10 From Scleroscope hardness to Rockwell C hardness:

$$HRC = +1.14708E+01 + 9.61667E-01(HSc) - 3.15195E-03(HSc)^2 - 6.97208E+02(HSc)^{-1} \quad (A1.10)$$

## A2. HARDNESS CONVERSION EQUATIONS FOR NON-AUSTENITIC STEELS (DETERMINED HARDNESS SCALE NUMBERS TO ROCKWELL B HARDNESS NUMBERS)

A2.1 The following equations were generated from the specific hardness numbers contained in Table 2 and should not be used for converting numbers outside of the defined hardness range. Due to inherent inaccuracies in the conversion process, the converted number should be rounded to the nearest whole number in accordance with Practice E29.

A2.1.1 From Vickers hardness to Rockwell B hardness:

$$HRB = +1.14665E+02 + 8.82795E-02(HV) - 1.41855E-04(HV)^2 - 6.69528E+03(HV)^{-1} \quad (A2.1)$$

A2.1.2 From Brinell hardness (10-mm diameter steel ball, 3000-kgf force) to Rockwell B hardness:

$$HRB = +1.14665E+02 + 8.82795E-02(HBS) - 1.41855E-04(HBS)^2 - 6.69528E+03(HBS)^{-1} \quad (A2.2)$$

A2.1.3 From Knoop hardness (500-gf force and greater) to Rockwell B hardness:

$$HRB = +1.75357E+02 - 2.37706E-01(HK_{500-1000}) + 4.56743E-04(HK_{300-1000})^2 - 1.12480E+04(HK_{500-1000})^{-1} \quad (A2.3)$$

A2.1.4 From Rockwell A hardness to Rockwell B hardness:

$$HRB = -4.82350E+01 + 3.33354E+00(HRA) - 1.50107E-02(HRA)^2 \quad (A2.4)$$

A2.1.5 From Rockwell F hardness to Rockwell B hardness:

$$HRB = -9.99816E+01 + 1.75617E+00(HRF) \quad (A2.5)$$

A2.1.6 From Rockwell 15T hardness to Rockwell B hardness:

$$HRB = -1.86934E+02 + 3.08173E+00(HR15T) \quad (A2.6)$$

A2.1.7 From Rockwell 30T hardness to Rockwell B hardness:

$$HRB = -2.42568E+01 + 1.49484E+00(HR30T) \quad (A2.7)$$

A2.1.8 From Rockwell 45T hardness to Rockwell B hardness:

$$HRB = +2.74135E+01 + 9.95874E-01(HR45T) \quad (A2.8)$$

## A3. HARDNESS CONVERSION EQUATIONS FOR NICKEL AND HIGH-NICKEL ALLOYS (DETERMINED HARDNESS SCALE NUMBERS TO VICKERS HARDNESS NUMBERS)

A3.1 The following equations were generated from the specific hardness numbers contained in Table 3 and should not be used for converting numbers outside of the defined hardness range. Due to inherent inaccuracies in the conversion process, the converted number should be rounded to the nearest whole number in accordance with Practice E29.

A3.1.1 From Brinell hardness (10-mm diameter steel ball, 3000-kgf force) to Vickers hardness (1.5, 10, and 30-kgf forces):

$$HV\,1.5,10,30 = +8.52592E\text{-}02 + 9.82889E\text{-}01(HBS) + 1.89707E\text{-}04(HBS)^2 \quad (A3.1)$$

A3.1.2 From Rockwell A hardness to Vickers hardness (1.5, 10, and 30-kgf forces):

$$(HV\,1.5,10,30)^{-1} = +2.13852E\text{-}02 - 3.84341E\text{-}04(HRA) + 1.67455E\text{-}06(HRA)^2 \quad (A3.2)$$

A3.1.3 From Rockwell B hardness to Vickers hardness (1.5, 10, and 30-kgf forces):

$$(HV\,1.5,\,10,\,30)^{-1} = +1.69552E\text{-}02 - 1.29200E\text{-}04(HRB) \quad (A3.3)$$

A3.1.4 From Rockwell C hardness to Vickers hardness (1.5, 10, and 30-kgf forces):

$$(HV\,1.5,\,10,\,30)^{-1} = +6.24553E\text{-}03 - 1.08014E\text{-}04(HRC) + 4.32021E\text{-}07(HRC)^2 \quad (A3.4)$$

A3.1.5 From Rockwell D hardness to Vickers hardness (1.5, 10, and 30-kgf forces):

$$(HV\,1.5,\,10,\,30)^{-1} = +1.04408E\text{-}02 - 1.86498E\text{-}04(HRD) + 8.16952E\text{-}07(HRD)^2 \quad (A3.5)$$

A3.1.6 From Rockwell E hardness to Vickers hardness (1.5, 10, and 30-kgf forces):

$$(HV\,1.5,\,10,\,30)^{-1} = +2.72286E\text{-}02 - 2.01093E\text{-}04(HRE) \quad (A3.6)$$

A3.1.7 From Rockwell F hardness to Vickers hardness (1.5, 10, and 30-kgf forces):

$$(HV\,1.5,\,10,\,30)^{-1} = +2.94130E\text{-}02 - 2.23861E\text{-}04(HRF) \quad (A3.7)$$

A3.1.8 From Rockwell G hardness to Vickers hardness (1.5, 10, and 30-kgf forces):

$$(HV\,1.5,\,10,\,30)^{-1} = +1.10239E\text{-}02 - 8.27628E\text{-}05(HRG) \quad (A3.8)$$

A3.1.9 From Rockwell K hardness to Vickers hardness (1.5, 10, and 30-kgf forces):

$$(HV\,1.5,\,10,\,30)^{-1} = +1.87458E\text{-}02 - 1.41851E\text{-}04(HRK) \quad (A3.9)$$

A3.1.10 From Rockwell 15N hardness to Vickers hardness (1.5, 10, and 30-kgf forces):

$$(HV\,1.5,\,10,\,30)^{-1} = +2.59838E\text{-}02 - 4.31479E\text{-}04(HR15N) + 1.75469E\text{-}06(HR15N)^2 \quad (A3.10)$$

A3.1.11 From Rockwell 30N hardness to Vickers hardness (1.5, 10, and 30-kgf forces):

$$(HV\,1.5,\,10,\,30)^{-1} = +9.85078E\text{-}03 - 1.58346E\text{-}04(HR30N) + 6.16727E\text{-}07(HR30N)^2 \quad (A3.11)$$

A3.1.12 From Rockwell 45N hardness to Vickers hardness (1.5, 10, and 30-kgf forces):

$$(HV\,1.5,\,10,\,30)^{-1} = +6.03882E\text{-}03 - 9.51201E\text{-}05(HR45N) + 3.63345E\text{-}07(HR45N)^2 \quad (A3.12)$$

A3.1.13 From Rockwell 15T hardness to Vickers hardness (1.5, 10, and 30-kgf forces):

$$(HV\,1.5,\,10,\,30)^{-1} = +3.71482E\text{-}02 - 3.49957E\text{-}04(HR15T) - 8.92693E\text{-}08(HR15T)^2 \quad (A3.13)$$

A3.1.14 From Rockwell 30T hardness to Vickers hardness (1.5, 10, and 30-kgf forces):

$$(HV\,1.5,\,10,\,30)^{-1} = +1.94133E\text{-}02 - 1.85296E\text{-}04(HR30T) - 4.01798E\text{-}08(HR30T)^2 \quad (A3.14)$$

A3.1.15 From Rockwell 45T hardness to Vickers hardness (1.5, 10, and 30-kgf forces):

$$(HV\,1.5,\,10,\,30)^{-1} = +1.29736E\text{-}02 - 1.14693E\text{-}04(HR45T) - 1.61879E\text{-}07(HR45T)^2 \quad (A3.15)$$

A3.1.16 From Knoop hardness (500 and 1000-gf forces) to Vickers hardness (1.5, 10, and 30-kgf forces):

$$HV\,1.5,\,10,\,30 = -5.08687E\text{-}01 + 8.78046E\text{-}01(HK_{500,1000}) \quad (A3.16)$$

## A4. HARDNESS CONVERSION EQUATIONS FOR CARTRIDGE BRASS (DETERMINED HARDNESS SCALE NUMBERS TO VICKERS HARDNESS NUMBERS)

A4.1 The following equations were generated from the specific hardness numbers contained in Table 4 and should not be used for converting numbers outside of the defined hardness range. Due to inherent inaccuracies in the conversion process, the converted number should be rounded to the nearest whole number in accordance with Practice E29.

A4.1.1 From Rockwell B hardness to Vickers hardness:

$$(HV)^{-1} = +1.77793E\text{-}02 - 1.31112E\text{-}04(HRB) - 3.77903E\text{-}07(HRB)^2 + 3.55271E\text{-}09(HRB)^3 \quad (A4.1)$$

A4.1.2 From Rockwell F hardness to Vickers hardness:

$$(HV)^{-1} = +2.95966E\text{-}02 - 1.03725E\text{-}04(HRF) - 2.31669E\text{-}06(HRF)^2 + 1.12203E\text{-}08(HRF)^3 \quad (A4.2)$$

A4.1.3 From Rockwell 15T hardness to Vickers hardness:

$$(HV)^{-1} = +7.65595E\text{-}02 - 1.79133E\text{-}03(HR15T) + 1.84105E\text{-}05(HR15T)^2 - 8.14318E\text{-}08(HR15T)^3 \quad (A4.3)$$

A4.1.4 From Rockwell 30T hardness to Vickers hardness:

$$(HV)^{-1} = +2.08924E\text{-}02 - 2.03448E\text{-}04(HR30T) - 2.80441E\text{-}08(HR30T)^2 + 1.33185E\text{-}10(HR30T)^3 \quad (A4.4)$$

A4.1.5 From Rockwell 45T hardness to Vickers hardness:

$$(HV)^{-1} = +1.36295E\text{-}02 - 1.03553E\text{-}04(HR45T) - 9.70546E\text{-}07(HR45T)^2 + 8.77834E\text{-}09(HR45T)^3 \quad (A4.5)$$

A4.1.6 From Brinell hardness (10-mm diameter steel ball, 500-kgf force) to Vickers hardness:

$$HV = -5.60725E{+}00 + 1.19007E{+}00(HBS\ 10/500/15) \quad (A4.6)$$

## A5. HARDNESS CONVERSION EQUATION FOR ANNEALED AUSTENITIC STAINLESS STEEL PLATE (DETERMINED BRINELL HARDNESS NUMBERS TO ROCKWELL B HARDNESS NUMBERS)

A5.1 The following equation was generated from the specific hardness numbers contained in Table 5 and should not be used for converting numbers outside of the defined hardness range. Due to inherent inaccuracies in the conversion process, the converted number should be rounded to the nearest whole number in accordance with Practice E29.

A5.1.1 From Brinell hardness (10-mm steel diameter ball, 3000-kgf force) to Rockwell B hardness:

$$HRB = +1.29998E{+}02 - 7.66860E{+}03(HBS)^{-1} \quad (A5.1)$$

## A6. HARDNESS CONVERSION EQUATIONS FOR AUSTENITIC STAINLESS STEEL SHEET (DETERMINED HARDNESS SCALE NUMBERS TO ROCKWELL C OR ROCKWELL B HARDNESS NUMBERS

A6.1 The following equations were generated from the specific hardness numbers contained in Table 6 and should not be used for converting numbers outside of the defined hardness range. Due to inherent inaccuracies in the conversion process, the converted number should be rounded to the nearest whole number in accordance with Practice E29.

A6.1.1 From Rockwell A hardness to Rockwell C hardness:

$$HRC = -9.94148E{+}01 + 1.98137E{+}00(HRA) \quad (A6.1)$$

A6.1.2 From Rockwell 15N hardness to Rockwell C hardness:

$$HRC = -1.16608E{+}02 + 1.95692E{+}00(HR15N) \quad (A6.2)$$

A6.1.3 From Rockwell 30N hardness to Rockwell C hardness:

$$HRC = -2.79663E{+}01 + 1.14752E{+}00(HR30N) \quad (A6.3)$$

A6.1.4 From Rockwell 45N hardness to Rockwell C hardness:

$$HRC = +2.25782E{+}00 + 8.78362E\text{-}01(HR45N) \quad (A6.4)$$

A6.1.5 From Rockwell A hardness to Rockwell B hardness:

$$HRB = -5.16024E{+}00 + 1.71080E{+}00(HRA) \quad (A6.5)$$

A6.1.6 From Rockwell F hardness to Rockwell B hardness:

$$HRB = -6.79918E{+}01 + 1.47539E{+}00(HRF) \quad (A6.6)$$

A6.1.7 From Rockwell 15T hardness to Rockwell B hardness:

$$HRB = -1.47089E{+}02 + 2.69928E{+}00(HR15T) \quad (A6.7)$$

A6.1.8 From Rockwell 30T hardness to Rockwell B hardness:

$$HRB = -1.56777E{+}01 + 1.43818E{+}00(HR30T) \quad (A6.8)$$

A6.1.9 From Rockwell 45T hardness to Rockwell B hardness:

$$HRB = +3.08896E+01+9.84321E-01(HR45T) \quad (A6.9)$$

## A7. HARDNESS CONVERSION EQUATIONS FOR COPPER, NOS. 102 TO 142 INCLUSIVE (DETERMINED HARDNESS SCALE NUMBERS TO VICKERS HARDNESS NUMBERS)

A7.1 The following equations were generated from the specific hardness numbers contained in Table 7 and should not be used for converting numbers outside of the defined hardness range. Due to inherent inaccuracies in the conversion process, the converted number should be rounded to the nearest whole number in accordance with Practice E29.

A7.1.1 From Vickers hardness (100-gf force) to Vickers hardness (1-kgf force):

$$HV\ 1 = -1.94066E+01+1.17624E+00(HV_{100}) \quad (A7.1)$$

A7.1.2 From Knoop hardness (1-kgf force) to Vickers hardness (1-kgf force):

$$HV\ 1 = +1.1858E+01+6.42195E-01(HK_{1000}) + 1.50709E-03(HK_{1000})^2 \quad (A7.2)$$

A7.1.3 From Knoop hardness (500 gf force) to Vickers hardness (1-kgf force):

$$HV\ 1 = +4.04249E+00+7.73167E-01(HK_{500}) + 1.22866E-03(HK_{500})^2 \quad (A7.3)$$

A7.1.4 From Rockwell 15T hardness to Vickers hardness (1-kgf force) for 0.010-in. (0.25-mm) strip:

$$(HV\ 1)^{-1} = +3.37918E-01 - 1.15500E-02(HR15T) + 1.40059E-04(HR15T)^2 - 5.88157E-07(HR15T)^3 \quad (A7.4)$$

A7.1.5 From Rockwell 15T hardness to Vickers hardness (1-kgf force) for 0.020-in. (0.51-mm) strip:

$$(HV\ 1)^{-1} = +1.25038E-01 - 3.80747E-03(HR15T) + 4.54150E-05(HR15T)^2 - 1.98661E-07(HR15T)^3 \quad (A7.5)$$

A7.1.6 From Rockwell B hardness to Vickers hardness (1-kgf force) for 0.040-in. (1.02-mm) and greater strip:

$$(HV\ 1)^{-1} = +1.49881E-02 - 1.39326E-04(HRB) + 8.82686E-07(HRB)^2 - 6.30498E-09(HRB)^3 \quad (A7.6)$$

A7.1.7 From Rockwell F hardness to Vickers hardness (1-kgf force) for 0.040-in. (1.02-mm) and greater strip:

$$(HV\ 1)^{-1} = +4.03378E-02 - 7.12218E-04(HRF) + 6.46922E-06(HRF)^2 - 2.64942E-08(HRF)^3 \quad (A7.7)$$

A7.1.8 From Rockwell 15T hardness to Vickers hardness (1-kgf force) for 0.040-in. (1.02-mm) and greater strip:

$$(HV\ 1)^{-1} = +6.91162E-02 - 1.89938E-03(HR15T) + 2.43142E-05(HR15T)^2 - 1.21657E-07(HR15T)^3 \quad (A7.8)$$

A7.1.9 From Rockwell 30T hardness to Vickers hardness (1-kgf force) for 0.040-in. (1.02-mm) and greater strip:

$$(HV\ 1)^{-1} = +2.12081E-02 - 2.79029E-04(HR30T) + 1.85833E-06(HR30T)^2 - 9.41015E-09(HR30T)^3 \quad (A7.9)$$

A7.1.10 From Rockwell 45T hardness to Vickers hardness (1-kgf force) for 0.040-in. (1.02-mm) and greater strip:

$$(HV\ 1)^{-1} = +1.33602E-02 - 1.16936E-04(HR45T) - 2.02801E-07(HR45T)^2 + 4.40268E-09(HR45T)^3 \quad (A7.10)$$

A7.1.11 From Brinell hardness (10-mm diameter steel ball, 500-kgf force) to Vickers hardness (1-kgf force) for 0.080- in. (2.03-mm) strip:

$$HV\ 1 = +2.77693E+01+8.62258E-01(HBS\ 10/500/15) - 3.66858E-04(HBS\ 10/500/15)^2 \quad (A7.11)$$

A7.1.12 From Brinell hardness (2-mm diameter steel ball, 20-kgf force) to Vickers hardness (1-kgf force) for 0.040 in. (1.02-mm) strip:

$$HV\ 1 = -1.01087E+00+1.18352E+00(HBS\ 2/20/15) - 7.02625E-04(HBS\ 2/20/15)^2 \quad (A7.12)$$

## A8. HARDNESS CONVERSION EQUATIONS FOR ALLOYED WHITE IRON (DETERMINED HARDNESS SCALE NUMBERS TO VICKERS HARDNESS NUMBERS)

A8.1 The following equations were generated from the specific hardness numbers contained in Table 8 and should not be used for converting numbers outside of the defined hardness range. Due to inherent inaccuracies in the conversion process, the converted number should be rounded to the nearest whole number in accordance with Practice E29.

A8.1.1 From Brinell hardness (10-mm diameter tungsten carbide ball, 3000-kgf force) to Vickers hardness (50-kgf force):

$$HV\ 50 = -2.61008E{+}01 + 1.13635E{+}00(HBW) \quad (A8.1)$$

A8.1.2 From Rockwell C hardness to Vickers hardness (50-kgf force):

$$HV\ 50 = +5.72753E{+}02 - 1.71996E{+}01(HRC) + 3.33893E{-}01(HRC)^2 \quad (A8.2)$$

## A9. HARDNESS CONVERSION EQUATIONS FOR WROUGHT ALUMINUM PRODUCTS (DETERMINED HARDNESS SCALE NUMBERS TO BRINELL HARDNESS NUMBERS)

A9.1 The following equations were generated from the specific hardness numbers contained in Table 9 and should not be used for converting numbers outside of the defined hardness range. Due to inherent inaccuracies in the conversion process, the converted number should be rounded to the nearest whole number in accordance with Practice E29.

A9.1.1 From Vickers hardness (15-kgf force) to Brinell hardness (10-mm diameter steel ball, 500-kgf force):

$$HBS\ 10/500/15 = +3.76211E{+}00 + 8.25366E{-}01(HV\ 15) \quad (A9.1)$$

A9.1.2 From Rockwell B hardness to Brinell hardness (10-mm diameter steel ball, 500-kgf force):

$$(HBS\ 10/500/15)^{-1} = +2.09261E{-}02 - 3.13747E{-}04(HRB) + 3.24720E{-}06(HRB)^2 - 1.71476E{-}08(HRB)^3 \quad (A9.2)$$

A9.1.3 From Rockwell E hardness to Brinell hardness (10-mm diameter steel ball, 500-kgf force):

$$(HBS\ 10/500/15)^{-1} = +6.91185E{-}02 - 1.57873E{-}03(HRE) + 1.66991E{-}05(HRE)^2 - 6.90196E{-}08(HRE)^3 \quad (A9.3)$$

A9.1.4 From Rockwell H hardness to Brinell hardness (10-mm diameter steel ball, 500-kgf force):

$$(HBS\ 10/500/15)^{-1} = +4.00460E{-}01 - 1.06615E{-}02(HRH) + 1.02525E{-}04(HRH)^2 - 3.44242E{-}07(HRH)^3 \quad (A9.4)$$

A9.1.5 From Rockwell 15T hardness to Brinell hardness (10-mm diameter steel ball, 500-kgf force):

$$(HBS\ 10/500/15)^{-1} = +3.35165E{-}01 - 1.16197E{-}02(HR15T) + 1.44778E{-}04(HR15T)^2 - 6.26187E{-}07(HR15T)^3 \quad (A9.5)$$

A9.1.6 From Rockwell 30T hardness to Brinell hardness (10-mm diameter steel ball, 500-kgf force):

$$(HBS\ 10/500/15)^{-1} = +4.66560E{-}02 - 1.24964E{-}03(HR30T) + 1.45528E{-}05(HR30T)^2 - 6.71447E{-}08(HR30T)^3 \quad (A9.6)$$

A9.1.7 From Rockwell 15W hardness to Brinell hardness (10-mm diameter steel ball, 500-kgf force):

$$(HBS\ 10/500/15) = -7.10127E{+}03 + 2.71267E{+}02(HR15W) - 3.46213E{+}00(HR15W)^2 + 1.48551E{-}02(HR15W)^3 \quad (A9.7)$$

## A10. HARDNESS CONVERSION EQUATIONS FOR NON-AUSTENITIC STEELS (DETERMINED LEEB HARDNESS NUMBERS TO HARDNESS SCALE NUMBERS)

A10.1 The following equations were developed at the time the Leeb hardness test was invented and based upon a variety of low alloy and unalloyed carbon steels (see Appendix X2). The data in Table 10 was calculated from these equations. The equations should not be used for converting numbers outside of the data ranges given in Table 10. Due to inherent inaccuracies in the conversion process, the converted number should be rounded to the nearest whole number in accordance with Practice E29.

A10.1.1 From Leeb D hardness to Rockwell C hardness:

$$HRC = -2.2872E{+}02 + 1.0137E{+}00(HLD) - 1.5593E{-}03(HLD)^2 + 1.225E{-}06(HLD)^3 - 3.7227E{-}10(HLD)^4 \quad (A10.1)$$

A10.1.2 From Leeb D hardness to Brinell hardness (10-mm diameter steel ball, 3000-kgf force):

$$HBS(10/3000) = 7.2862E{+}02 - 2.3014E{+}00(HLD) + 7.8978E{-}03(HLD)^2 - 9.5946E{-}06(HLD)^3 + 5.0641E{-}09(HLD)^4 \quad (A10.2)$$

A10.1.3 From Leeb D hardness to Vickers hardness:

$$HV10 = 2.9085E{+}02 - 2.4113E{+}00(HLD) + 8.2399E{-}03(HLD)^2 - 1.0056E{-}05(HLD)^3 + 5.3754E{-}09(HLD)^4 \quad (A10.3)$$

## APPENDIXES

**(Nonmandatory Information)**

## X1. EFFECT OF STRAIN HARDENING ON HARDNESS CONVERSION RELATIONSHIPS

X1.1 For ferrous and nonferrous metals softer than 240 HB, a single set of hardness conversion relationships inevitably introduces large errors because of the wide difference that may exist in the amount of cold working before testing, as well as the amount that occurs during the test itself. This dependence on strain-hardening characteristics can be demonstrated by the Rockwell scales 15-T, 30-T, 45-T, F, and B, in which forces ranging from 15 to 100 kgf are applied on a ¹⁄₁₆-in. (1.588-mm) diameter ball indenter. As higher forces are used, the increased strain raises the hardness by an amount that depends on the pretest capacity of the metal for strain hardening. An annealed metal of high capacity for strain hardening will harden much more in the test than will a cold-worked metal. For example, an annealed iron and a cold-rolled aluminum alloy may have hardnesses of 71 and 72 HR 15T, respectively. The hardnesses are 31 HRB for the soft annealed iron and 71 HRB for the cold-rolled aluminum alloy.

X1.2 On the other hand, if materials have Brinell or Rockwell hardness values that are approximately equal in the annealed state as well as after heavy cold deformation, these materials will have similar hardness conversion relationships for all degrees of strain hardening. This is true of yellow brasses and low-carbon steels and irons. The limiting conditions can usually be identified by the appearance of the hardness indentations themselves. Soft annealed metals have characteristic "sinking" type indentation contours when indenters of the ball type are used. On the other hand, heavily cold-worked metals have sharp "ridging" type indentations. While annealed metals are being progressively cold worked, the indentation contours pass through a "flat" stage in which the lip of the indentation is neither round nor sharply ridged. It is necessary to base hardness conversions on comparative tests of similar materials that also have very similar mechanical properties.

## X2. CONFIRMATION OF THE LEEB HARDNESS CONVERSIONS GIVEN IN Table 10 AND Annex A10

X2.1 The Annex A10 conversion equations were developed at the time the Leeb hardness test method was invented and are based upon a variety of low alloy and unalloyed carbon steels.[5] These established conversions are currently in wide use by industry. ASTM subcommittee E28.06 conducted a round-robin study to confirm the established conversion equations. Comparisons of the round-robin data to the conversion equations is presented in Figs. X2.1-X2.3, and are provided for informational purposes only. The $R^2$ value, or the coefficient of determination, given with the figures is a statistical measure of how well the regression line approximates the real data points. The $R^2$ value varies between 0 and 1 with $R^2 = 1$ indicating that the line equation represents a perfect fit to the data. Some deviations of the round-robin data from the conversion equation lines can be attributed to the range of steels used in creating the original conversion data. The details of the round

[5] The conversion equations were developed by a single manufacturer of Leeb hardness equipment in 1977.

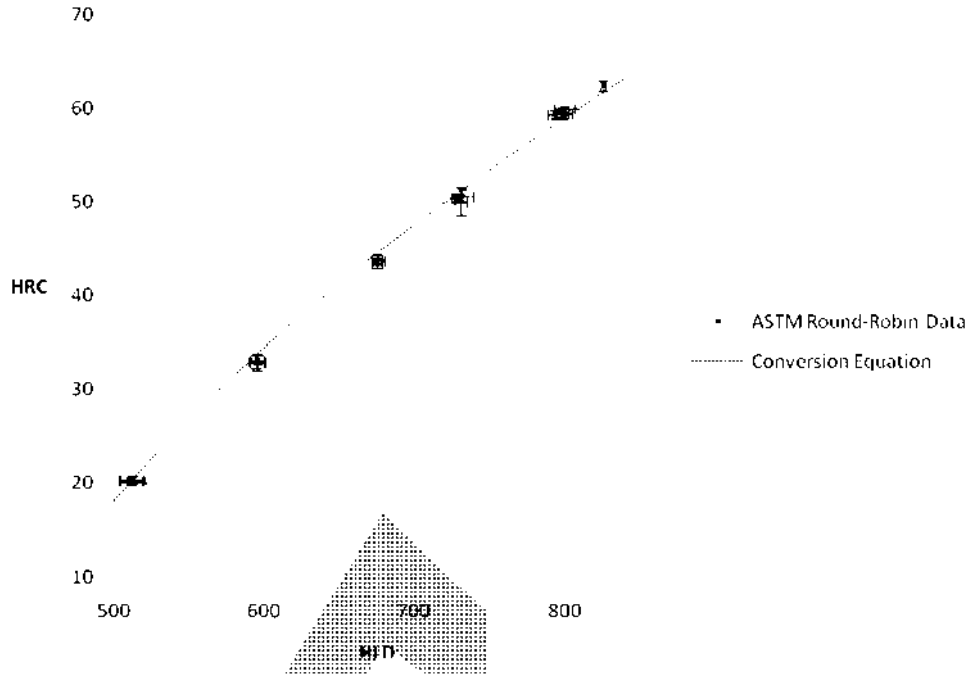


FIG. X2.1 Comparison of Mean Values of Subcommittee E28.06 Round-Robin Data to Conversion Eq A10.1 (Conversions from Leeb D hardness to Rockwell C hardness). The standard deviation of subcommittee E28.06 round-robin data is shown as error bars for each respective data point. $R^2$=0.9909 for the data shown in this figure.

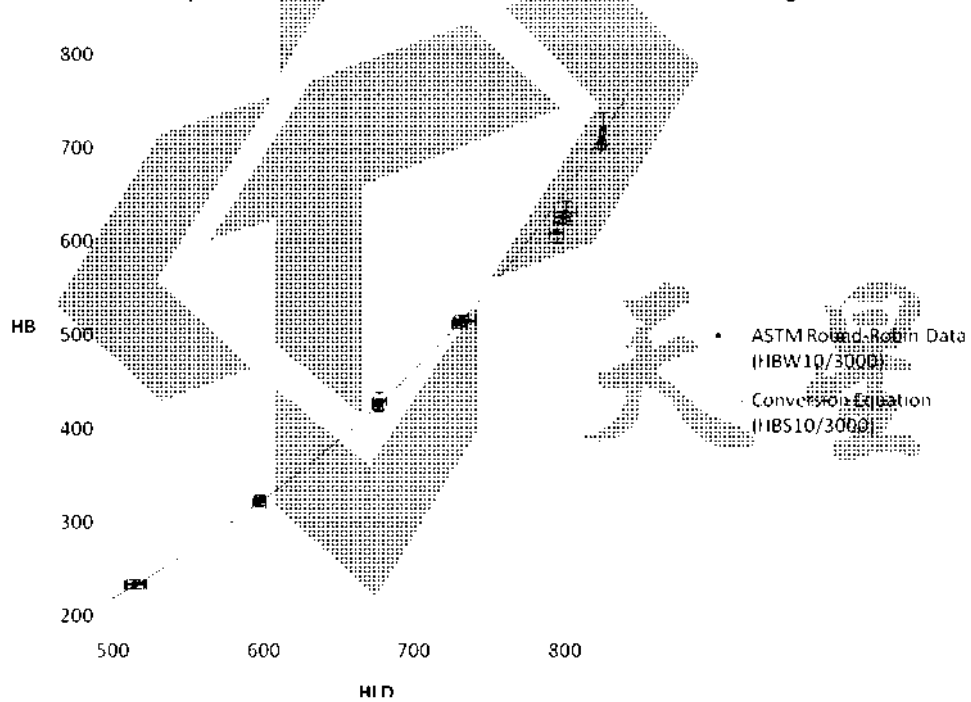


FIG. X2.2 Comparison of Mean Values of Subcommittee E28.06 Round-Robin Data to Conversion Eq A10.2 (Conversions from Leeb D hardness to Brinell hardness). The standard deviation of subcommittee E28.06 round-robin data is shown as error bars for each respective data point. The conversion equation was developed using HBS 10/3000 and the round-robin data was acquired using HBW 10/3000.$R^2$=0.9915 for the data shown in this figure.

robin study can be found in ASTM research report RR:E28-1044.[6]

[6] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:E28-1044. Contact ASTM Customer Service at service@astm.org.

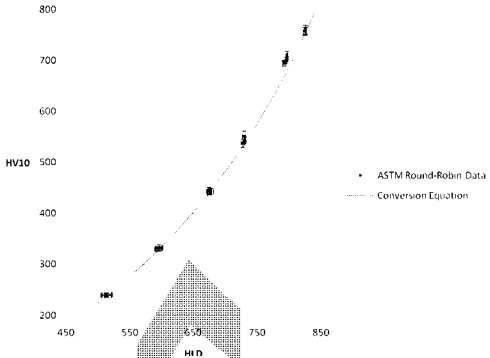


FIG. X2.3 Comparison of Mean Values of Subcommittee E28.06 Round-Robin Data to Conversion Eq A10.3 (Conversions from Leeb D hardness to Vickers hardness). The standard deviation of subcommittee E28.06 round-robin data is shown as error bars for each respective data point. $R^2$=0.9931 for the data shown in this figure.

## SUMMARY OF CHANGES

Committee E28 has identified the location of selected changes to this standard since the last issue (E140–12a) that may impact the use of this standard. (Approved Dec. 1, 2012.)

*(1)* Sections 1.11, 1.12, and Section 7 were revised.

Committee E28 has identified the location of selected changes to this standard since the last issue (E140–12) that may impact the use of this standard. (Approved Sept. 1, 2012.)

*(1)* The title was revised.
*(2)* Test Method A956 was added and referenced in 1.11.
*(3)* Sections 1 and 3 were revised.
*(4)* Table 10 was added.
*(5)* Annex A10 was added.
*(6)* Appendix X2 was added.

Committee E28 has identified the location of selected changes to this standard since the last issue (E140–07) that may impact the use of this standard. (Approved August 15, 2012.)

*(1)* The $R^2$ value was removed from the equations in Annex A1-Annex A9.