Designation: B294 – 10

Standard Test Method for Hardness Testing of Cemented Carbides[1]

This standard is issued under the fixed designation B294; 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.

1. Scope

1.1 This test method covers the hardness testing of cemented carbides by use of a Rockwell hardness tester performing tests in the Rockwell HRA scale (regular scale, diamond indenter, 10 kgf (98.07 N) preliminary test force, and 60 kgf (588.4 N) load) in the range of Rockwell 80 HRA and above. Also covered are the procedures for the testing and selection of diamond indenters, the management and traceability of the four levels of standardized test blocks, and the making and calibration of Primary, Secondary, and Working standardized test blocks.

1.2 The Rockwell hardness tester is a convenient and reliable means of measuring the hardness of cemented carbides. A hardness value is obtained easily, but it is subject to considerable error unless certain precautions are observed.

1.3 The latest version of Test Methods E18 shall be followed except where otherwise indicated in this test method.

1.4 The values stated in SI units are to be regarded as standard except that force and length values associated with the Rockwell hardness testers will comply with E18 with force values specified as N (kgf) and indenter length values specified as mm.

1.5 *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]

E18 Test Methods for Rockwell Hardness of Metallic Materials

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

2.2 *ISO Standards:*[3]

ISO/IEC 17011 Conformity Assessment—General Requirements for Accreditation Bodies Accrediting Conformity Assessment Bodies

ISO/IEC 17025 General Requirements for the Competence of Testing and Calibration Laboratories

3. Significance and Use

3.1 Rockwell hardness testing is one of the more important methods used to evaluate cemented carbides. For compositional groups of cemented carbides, hardness is an indication of wear resistance and toughness. Lower hardness grades usually indicate less wear resistance but greater toughness. For a specific grade of cemented carbide, hardness is an indication of the metallurgical quality of the material. In no case is Rockwell hardness testing the only test method to be considered in evaluating cemented carbides.

4. Apparatus

4.1 *Tester*—All hardness tests shall be performed using a Rockwell hardness tester that meets the requirements defined in the latest version of Test Method E18 except where otherwise indicated in this test method. Testers shall comply with the requirements of Annex A3 of this test method.

4.2 *Scale*—All tests shall be performed using the carbide Rockwell HRA scale (a carbide diamond indenter, 10 kgf (98.07 N) preliminary force, and 60 kgf (588.4 N) total test force.

4.3 *Effect of Vibration*—The Rockwell hardness tester should be located in a vibration-free area in order to avoid erroneous results. If this is not possible, the tester shall be mounted so as to minimize vibrations, since vibrations tend to cause erratic readings.

4.4 *Indenter*—The indenters used shall conform to the requirements defined in Annex A2 of this test method.

4.5 *Anvils*—Select an anvil suitable for the specimen to be tested. The test piece should be supported rigidly, with the test

[1] This test method is under the jurisdiction of ASTM Committee B09 on Metal Powders and Metal Powder Products and is the direct responsibility of Subcommittee B09.06 on Cemented Carbides.

Current edition approved May 1, 2010. Published June 2010. Originally approved in 1954. Last previous edition approved in 2009 as B294 – 09 (2009). DOI: 10.1520/B0294-10.

[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, http://www.ansi.org.

surface perpendicular to the line of travel of the indenter. For the best accuracy, flat test pieces should be tested on a flat spot anvil of approximately 6-mm diameter. The surface of the anvil that contacts the sample should have a Rockwell hardness of at least 58 HRC, and shall be polished smooth and be free of pits and heavy scratches that could affect the test results. The mounting surface of the anvil support and the mating surface of the anvil should be clean. Dust, dirt, grease, or scale should not be allowed to accumulate on any part of the apparatus, as this will affect the results. Seat the anvil securely.

4.6 *Test Blocks*—Standardized test blocks used to verify the performance of the tester shall comply with the requirements in Annex A1 of this test method.

5. Test Specimens

5.1 *Size of Specimens*—A minimum thickness of 1.6 mm is recommended. With thinner specimens, breakage may occur, resulting in damage to the anvil, the indenter, or both. Specimens that have enough overhang to cause imbalance shall be supported properly. The 6-mm anvil will support flat test specimens up to approximately 113 g and will also support the standard test blocks recommended previously.

5.2 *Preparation of Test Specimens:*

5.2.1 The finish of the test surface is of major importance. The surface to be tested should be prepared to obtain a roughness of Ra ≤0.2 µm. A coarser finish will provide a wider range of readings. Preparation shall be conducted in such a way that alteration of the surface due to heat or cold-working is minimized. A 220-grit medium hardness resinoid bond diamond wheel, downfed 0.01 mm per pass with abundant flow of coolant, should provide the desired surface. The thickness of the layer removed from an as-sintered surface to be tested shall be not less than 0.2 mm.

5.2.2 The test and anvil surfaces of the test specimen shall be parallel within 0.01 mm/mm in general practice, but within 0.001 mm/mm when critical comparisons are being made. The surface in contact with the anvil shall be free of any irregularity (for example, a previous hardness indentation). Taper that results in the test surface not being normal to the axis of the indenter, or irregularity that causes instability during the test, will result in error.

5.2.3 When determining the hardness of a test specimen with a curved surface, the radius of curvature shall not be less than 15 mm. If less, then a flat surface at least 3 mm wide shall be prepared on which to conduct the test, and there shall be an opposite flat surface such that the specimen conforms to the requirements of 5.2 and 5.3. If the test surface is curved or the opposite surface must be supported in a V-anvil, the repeatability and reproducibility limits of 8.2 and 8.3 may not apply.

5.3 *Preparation of Mounted Carbides*—Remove mounted carbides from the steel body by heating or some other convenient method. All braze metal or other bond material shall be removed from both the test surface and the opposite face. The specimen should then be prepared as described in 5.1 and 5.2.

6. Procedure

6.1 Rockwell hardness tests should be carried out at an ambient temperature within the limits of 10 to 35°C. Users of the Rockwell hardness test are cautioned that the temperature of the test material and the temperature of the hardness tester may affect test results. Consequently, users should ensure that the test temperature does not adversely affect the hardness measurement.

6.2 Procedures that are not described in this test method shall conform to those of Test Method E18.

6.3 Disregard the first two readings after an indenter or anvil has been newly mounted.

6.4 *Test Cycle Time*

6.4.1 The application time for the additional test force (major load) shall be 2 to 6 s.

6.4.2 The total test force (major load) shall be maintained for 2 to 4 s.

NOTE 1—On manual machines, the abrupt actuation of the total test force (major load) application trip lever may affect the hardness value obtained. In addition the abrupt actuation of the total test force (major load) removal lever may significantly affect the hardness value obtained.

6.5 The Rockwell HRA hardness value is read after the total test force (major load) has been removed and while the preliminary test force (minor load) is still applied.

6.6 Hardness should be read or estimated to at least the nearest 0.1 HRA. Calculations should be carried to two decimal places.

6.7 The distance between the centers of any two adjacent indentations, and the distance between the center of any indentation and the edge of a test specimen, shall be at least 1.5 mm.

6.8 Make two trial determinations of the hardness of the test specimen. This action also reassures that the indenter is seated properly. Disregard the results and perform the following steps.

6.8.1 Select a standardized test block that complies with Annex A1 having a value closest to the trial hardness of the test specimen. Determine the Rockwell HRA hardness at three points on the block.

6.8.2 If the arithmetic mean of the three determinations differs from the certified hardness value of the standardized test block by more than ±0.5 HRA, check the diamond indenter and the testing equipment, and eliminate the cause of the error. Repeat the determinations.

6.8.3 If the arithmetic mean of the three determinations differs from the certified hardness value of the standardized test block by ±0.5 HRA or less, record the difference, giving due regard to the algebraic sign. This difference will be used to correct the arithmetic mean of the hardness of the test specimens.

6.8.4 Determine the Rockwell HRA hardness of the test specimen, with determinations at three or more locations chosen at random, or as dictated by the purpose of the test.

6.8.5 Calculate the arithmetic mean of the hardness determinations. Apply the correction determined as in 6.8.3, giving due regard to the algebraic sign.

6.8.6 Report the corrected arithmetic mean of the hardness determinations, rounded in accordance with Practice E29[4] to the nearest 0.1 HRA.

7. Report

7.1 Report the following information:

7.1.1 All details necessary for identification of the test specimen,

7.1.2 The corrected mean hardness and the amount of correction including the algebraic sign,

7.1.3 The range of hardness determinations,

7.1.4 The number of hardness determinations,

7.1.5 The smallest division of readout or graduation of the hardness test machine and whether it is digital or analog,

7.1.6 The identification and original source of calibration for the standardized test blocks used,

7.1.7 A reference to this test method, and

7.1.8 Details of any deviations from this test method, of optional procedures used, and of any conditions and occurrences that may have affected the results.

8. Precision and Bias[5]

8.1 The following statements regarding the repeatability and reproducibility of hardness (HRA) measurements of cemented carbide test specimens shall apply only within the hardness range established for the indenter in accordance with A2.3.4.5 or A2.3.4.6.

8.2 The repeatability limit (r) is 0.3 HRA. On the basis of test error alone, the difference in absolute value of two test results obtained in the same laboratory on the same test specimen will be expected to exceed 0.3 HRA only approximately 5 % of the time. The repeatability standard deviation (S_r) is 0.1 HRA.

8.3 The reproducibility limit (R) between or among laboratories is 0.4 HRA when each has calibrated its machine, indenter, and operator system with a standard test block that has itself been calibrated to the same superior test block used to calibrate the test blocks of the other laboratories. On the basis of test error alone, the difference in absolute value of the test results obtained in different laboratories on the same test specimen will be expected to exceed 0.4 HRA only approximately 5 % of the time. The reproducibility standard deviation (S_R) is 0.14 HRA.

8.4 Neither the data of the interlaboratory study nor theoretical considerations suggest a bias in this test procedure.

8.5 If the test specimens are of a hardness substantially outside the hardness ranges of the standard test blocks on which the indenter has been performance tested, and if interlaboratory reproducibility is critical, the same indenter and standard test blocks should be used by each laboratory.

9. Keywords

9.1 cemented carbides; hardness; indenters; Rockwell hardness test; Scale HRA; test blocks

[4] When the second decimal place is less than 0.05, leave the first decimal place unchanged. When the second decimal place is more than 0.05, increase the first decimal place by 0.1. When the second decimal place is exactly 5 and the first decimal place is odd, increase the first decimal by 0.1. If the first decimal place is even, leave it unchanged.

[5] The statements of repeatability and reproducibility in this section are based on an interlaboratory study conducted by the Cemented Carbide Producers Association. Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:B09-1016.

ANNEXES

(Mandatory Information)

A1. PREPARATION, CALIBRATION, AND CONTROL OF STANDARDIZED TEST BLOCKS USED IN THE PERFORMANCE OF THE PROCEDURES OF THIS TEST METHOD

A1.1 Scope and Field of Application

A1.1.1 The Rockwell hardness levels of cemented carbides are established by sets of Master test blocks that were developed by the Cemented Carbide Producers Association (CCPA). This Annex specifies how those Master blocks are utilized to provide a traceable Rockwell hardness standard to the user of this test method. It specifies the preparation and calibration of Primary, Secondary, and Working standard test blocks that are traceable to the Master blocks.

A1.1.2 Standardized test blocks complying with this Annex are required for Rockwell hardness testing of cemented carbides by the procedures defined in this test method.

A1.1.3 The requirements for marking and a verification report for the standardized test blocks will also be defined.

A1.2 Hierarchy and Availability of Standardized Test Blocks

A1.2.1 The Rockwell HRA scale hardness levels for cemented carbides are established and transferred by using a series of standardized test blocks. There are four levels of standardized test blocks: Master, Primary, Secondary, and Working.

A1.2.2 Master standardized test block sets were created by the CCPA. (See ASTM Research Report RR:B09-1016.[5])

A1.2.3 To provide traceability to the Master standardized test blocks, the CCPA has released a set of the Master standardized test blocks to the authorized calibrating agency. Secondary standardized test blocks, and the calibration or recalibration services for secondary standardized test blocks,

that are traceable to the Master blocks are available from the authorized calibrating agency.[6]

A1.3 Manufacture and Calibration of Standardized Test Blocks

A1.3.1 All standardized test blocks shall conform to the following conditions:

A1.3.1.1 The blocks shall be comprised of hardmetals composed substantially of tungsten carbide and cobalt without other carbides. The attention of the manufacturer of test blocks is drawn to use material and a manufacturing process which will give the necessary homogeneity, stability of structure, and uniformity of surface hardness.

A1.3.1.2 The blocks shall have a top surface that is not larger than 1600 mm^2 and a thickness that is not less than 6 mm. The bottom surface edge shall have a chamfer that is approximately 0.8 mm by 45°.

A1.3.1.3 All blocks shall be ground on the top and bottom surfaces. Preparation shall be conducted in such a way that alteration of the surface due to heat or cold-working is minimized. A 220-grit medium hardness resinoid bond diamond wheel, downfed 0.01 mm per pass with abundant flow of coolant, should provide the desired surface.

A1.3.1.4 The top surface on which indentations are to be made shall have had a minimum of 0.35 mm ground off of the as-sintered surface and shall have a surface finish of Ra ≤0.2 µm, and it may be polished. The maximum deviation in flatness of the top and bottom surfaces shall not exceed 0.010 mm. The bottom of the blocks shall not be convex. The maximum deviation in parallelism between the top and bottom surfaces shall not exceed 0.0004 mm/mm.

A1.3.2 Primary and Secondary standardized test blocks shall be calibrated in a laboratory that meets the requirements defined in E18, Annex A2, using a Rockwell Hardness Standardizing tester that meets the requirements of E18, Annex A2, and 6.4 of this test method. The indenters used shall meet the requirements of Annex A2 of this test method. Primary and Secondary test blocks shall be calibrated for hardness by following the requirements of A1.4, or A1.5 respectively.

A1.3.3 Working standardized test blocks shall be calibrated for hardness by following the requirements of section A1.6.

A1.4 Primary Standardized Test Block Sets

A1.4.1 Primary standardized test blocks shall be prepared and calibrated in sets of blocks with five different hardness levels. A minimum of one block shall be included at each of the following nominal levels: 93, 92, 91, 88.5, and 85.5 HRA.

A1.4.2 Primary standardized test blocks shall be reserved for use by the calibrating agency to calibrate Secondary standardized test blocks.

A1.4.3 The following calibration procedures shall be followed:

A1.4.3.1 Perform three Rockwell HRA scale tests on any piece of hard metal to seat the indenter and the anvil.

A1.4.3.2 Select a Master standardized test block with hardness nearest to that of the candidate Primary standardized test block to be calibrated. Perform ten (10) Rockwell tests evenly spaced on the Master block's test surface and calculate the arithmetic mean of the results to the nearest 0.01 HRA. Subtract the mean from the certified hardness of the Master test block. The result is the correction for the given combination of testing machine and indenter for that hardness level.

A1.4.3.3 If the correction is greater than 0.20 HRA absolute, the machine and indenter shall be examined to ascertain the cause, and the test shall then be repeated. Separate diamonds for each hardness level may be used to satisfy these tolerances.

A1.4.3.4 If the correction is ≤0.20 HRA absolute, perform ten (10) Rockwell tests evenly spaced around the surface of the candidate Primary standardized test block.

A1.4.3.5 Calculate the standard deviation (SD) of the ten tests using the Eq A1.1.

$$SD = \sqrt{\frac{\sum (x - \bar{x})^2}{n - 1}} \qquad \text{(A1.1)}$$

where:

x = the individual hardness result,
$\bar{x}$ = the arithmetic mean of hardness results in the sample, and
n = the number of hardness results in the sample.

A1.4.3.6 If the standard deviation (S) is ≤0.07, HRA, the block is acceptable for use as a Primary standardized test block. The arithmetic mean of the ten results shall be calculated to the nearest 0.01 HRA and corrected for the error of machine and indenter obtained above. The results shall be rounded off to the nearest 0.01 HRA and recorded as the hardness of the Primary standardized test block.

NOTE A1.1—When calibrating a number of Primary standardized test blocks of the same nominal hardness in an uninterrupted series, the correction may be determined only at the commencement of the series, unless there is reason to believe that the correction may have changed.

A1.4.4 Repeat section A1.4.3 for each block to be calibrated.

A1.4.5 Each block shall be marked with the letter *P*, the year of calibration and an appropriate code such that it can be related unmistakably to a record of its most recent calibration.

A1.4.6 To identify regrinding of the test surface, the thickness of the Primary standardized test block shall be measured and recorded or as an alternative, a permanent mark which will be obliterated if the surface is reground may be placed on the test surface. The test surface of the Primary standardized test blocks may be reground provided a minimum of 0.35 mm is removed and the reground block meets all of the requirements of A1.3. The reground block shall then be recalibrated using the procedure defined in this section.

A1.5 Secondary Standardized Test Blocks

A1.5.1 Secondary standardized test blocks may be prepared in sets of from one to five, so as to have one or all of the following nominal hardnesses: 93, 92, 91, 88.5, and 85.5 HRA.

A1.5.2 Secondary standardized test blocks shall be used to calibrate Working standardized test blocks, and indenters that

[6] The Cemented Carbide Producers Association has authorized Instron/Wilson Instruments, 825 University Ave, Norwood, MA 02062, to be the calibrating agency.