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Standard Test Methods for Vickers Hardness and Knoop Hardness of Metallic Materials[1]

This standard is issued under the fixed designation E92; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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

1. Scope

1.1 These test methods cover the determination of the Vickers hardness and Knoop hardness of metallic materials by the Vickers and Knoop indentation hardness principles. This standard provides the requirements for Vickers and Knoop hardness machines and the procedures for performing Vickers and Knoop hardness tests.

1.2 This standard includes additional requirements in annexes:

Verification of Vickers and Knoop Hardness Testing Machines	Annex A1
Vickers and Knoop Hardness Standardizing Machines	Annex A2
Standardization of Vickers and Knoop Indenters	Annex A3
Standardization of Vickers and Knoop Hardness Test Blocks	Annex A4
Correction Factors for Vickers Hardness Tests Made on Spherical and Cylindrical Surfaces	Annex A5

1.3 This standard includes nonmandatory information in an appendix which relates to the Vickers and Knoop hardness tests:

Examples of Procedures for Determining Vickers and Knoop Hardness Uncertainty	Appendix X1

1.4 This test method covers Vickers hardness tests made utilizing test forces ranging from 9.807×10^{-3} N to 1176.80 N (1 gf to 120 kgf), and Knoop hardness tests made utilizing test forces from 9.807×10^{-3} N to 19.613 N (1 gf to 2 kgf).

1.5 Additional information on the procedures and guidance when testing in the microindentation force range (forces ≤ 1 kgf) may be found in Test Method E384, Test Method for Microindentation Hardness of Materials.

1.6 *Units*—When the Vickers and Knoop hardness tests were developed, the force levels were specified in units of grams-force (gf) and kilograms-force (kgf). This standard specifies the units of force and length in the International System of Units (SI); that is, force in Newtons (N) and length in mm or µm. However, because of the historical precedent and continued common usage, force values in gf and kgf units are provided for information and much of the discussion in this standard as well as the method of reporting the test results refers to these units.

NOTE 1—The Vickers and Knoop hardness numbers were originally defined in terms of the test force in kilogram-force (kgf) and the surface area or projected area in millimetres squared (mm^2). Today, the hardness numbers are internationally defined in terms of SI units, that is, the test force in Newtons (N). However, in practice, the most commonly used force units are kilogram-force (kgf) and gram-force (gf). When Newton units of force are used, the force must be divided by the conversion factor 9.80665 N/kgf.

1.7 The test principles, testing procedures, and verification procedures are essentially identical for both the Vickers and Knoop hardness tests. The significant differences between the two tests are the geometries of the respective indenters, the method of calculation of the hardness numbers, and that Vickers hardness may be used at higher force levels than Knoop hardness.

NOTE 2—While Committee E28 is primarily concerned with metallic materials, the test procedures described are applicable to other materials. Other materials may require special considerations, for example see C1326 and C1327 for ceramic testing.

1.8 *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]

C1326 Test Method for Knoop Indentation Hardness of Advanced Ceramics
C1327 Test Method for Vickers Indentation Hardness of Advanced Ceramics
E3 Guide for Preparation of Metallographic Specimens
E6 Terminology Relating to Methods of Mechanical Testing
E7 Terminology Relating to Metallography

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

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

E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E74 Practice of Calibration of Force-Measuring Instruments for Verifying the Force Indication of Testing Machines
E140 Hardness Conversion Tables for Metals Relationship Among Brinell Hardness, Vickers Hardness, Rockwell Hardness, Superficial Hardness, Knoop Hardness, Scleroscope Hardness, and Leeb Hardness
E175 Terminology of Microscopy
E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods
E384 Test Method for Knoop and Vickers Hardness of Materials
E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

2.2 *ISO Standards:*[3]
ISO 6507-1 Metallic Materials—Vickers hardness Test—Part 1: Test Method
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. Terminology and Equations

3.1 *Definitions of Terms*—For the standard definitions of terms used in this test method, see Terminology E6 and Terminology E7.

3.1.1 *indentation hardness, n*—the hardness as evaluated from measurements of area or depth of the indentation made by forcing a specified indenter into the surface of a material under specified static loading conditions.

3.1.2 *Knoop hardness number,* HK, *n*—the calculated result from a Knoop hardness test, which is proportional to the test force applied to the Knoop indenter divided by the projected area of the permanent indentation made by the indenter after removal of the test force.

3.1.2.1 *Discussion*—The projected area of the permanent indentation made by the Knoop indenter is calculated based partly on the measured length of the long diagonal of the projected area of the indentation.

3.1.3 *Knoop hardness test, n*—an indentation test in which a Knoop rhombic-based pyramidal diamond indenter having specified edge angles, is forced under specified conditions into the surface of the test material, and, after removal of the test force, the length of the long diagonal of the projected area of the indentation is measured to calculate the Knoop hardness number.

3.1.4 *Vickers hardness number,* HV, *n*—the calculated result from a Vickers hardness test, which is proportional to the test force applied to the Vickers indenter divided by the surface area of the permanent indentation made by the indenter after removal of the test force.

3.1.4.1 *Discussion*—The surface area of the permanent indentation made by the Vickers indenter is calculated based partly on the measured mean length of the two diagonals of the projected area of the indentation.

3.1.5 *Vickers hardness test, n*—an indentation test in which a Vickers square-based pyramidal diamond indenter having specified face angles is forced under specified conditions into the surface of the test material, and, after removal of the test force, the lengths of the two diagonals of the projected area of the indentation are measured to calculate the Vickers hardness number.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *standardization, n*—to bring in conformance to a known standard through verification or calibration.

3.2.2 *microindentation hardness test, n*—a hardness test, normally in the Vickers or Knoop scales, using test forces in the range of 9.807×10^{-3} to 9.807 N (1 to 1000 gf).

3.2.3 *macroindention hardness test, n*—a hardness test using test forces normally higher than 9.807 N (1 kgf). Macroindentation tests include Vickers, Rockwell and Brinell.

NOTE 3—Use of the term microhardness should be avoided because it implies that the hardness, rather than the force or the indentation size, is very low.

3.2.4 *scale, n*—a specific combination of indenter (Knoop or Vickers) and the test force (kgf).

3.2.4.1 *Discussion*—For example, HV 10 is a scale defined as using a Vickers indenter and a 10 kgf test force and HK 0.1 is a scale defined as using a Knoop indenter and a 100 gf test force. See 5.10 for the proper reporting of the hardness level and scale.

3.2.5 *as-found condition, n*—the state of the hardness machine as reflected by the initial verification measurements made prior to performing any cleaning, maintenance, adjustments or repairs associated with an indirect verification.

3.2.6 *hardness machine, n*—a machine capable of performing a Vickers or Knoop hardness test.

3.2.7 *hardness testing machine, n*—a Vickers or Knoop hardness machine used for general testing purposes.

3.2.8 *hardness standardizing machine, n*—a Vickers or Knoop hardness machine used for the standardization of Vickers or Knoop hardness test blocks.

3.2.8.1 *Discussion*—A hardness standardizing machine differs from a hardness testing machine by having tighter tolerances on certain parameters.

3.3 *Equations:*

3.3.1 The average $\bar{d}$ of a set of n diagonal length measurements $d_1, d_2, \ldots, d_n$ is calculated as:

$$\bar{d} = \frac{d_1 + d_2 + \ldots + d_n}{n} \tag{1}$$

where each of the individual diagonal measurements $d_1, d_2, \ldots, d_n$ is the mean of the two diagonal length measurements in the case of a Vickers indentation, or is the long diagonal length measurement in the case of a Knoop indentation.

3.3.2 The repeatability R in the performance of a Vickers or Knoop hardness machine at each hardness level, under the

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

particular verification conditions, is determined from n diagonal measurements made on a standardized test block as part of a performance verification. The repeatability is estimated as the percent range of n diagonal measurements with respect to the measured average hardness value as:

$$R = 100 \times \left(\frac{d_{max} - d_{min}}{\bar{d}} \right) \quad (2)$$

where:

d_{max} = the longest diagonal length measurement made on the standardized test block,

d_{min} = the shortest diagonal length measurement made on the standardized test block, and

$\bar{d}$ = the average (see 3.3.1) of the n diagonal length measurements made on the standardized test block.

3.3.3 The error E in the performance of a Vickers or Knoop hardness machine at each hardness level, relative to a standardized reference value, is calculated as a percent error determined as:

$$E = 100 \times \left(\frac{\bar{d} - d_{ref}}{d_{ref}} \right) \quad (3)$$

where:

$\bar{d}$ = the average (see 3.3.1) of n diagonal length measurements made on a standardized test block as part of a performance verification, and

d_{ref} = the certified diagonal length reported for the standardized test block.

4. Significance and Use

4.1 Vickers and Knoop hardness tests have been found to be very useful for materials evaluation, quality control of manufacturing processes and research and development efforts. Hardness, although empirical in nature, can be correlated to tensile strength for many metals, and is an indicator of wear resistance and ductility.

4.2 Microindentation hardness tests extend testing to materials that are too thin or too small for macroindentation hardness tests. Microindentation hardness tests also allow specific phases or constituents and regions or gradients too small for macroindentation hardness testing to be evaluated. Recommendations for microindentation testing can be found in Test Method E384.

4.3 Because the Vickers and Knoop hardness will reveal hardness variations that may exist within a material, a single test value may not be representative of the bulk hardness.

4.4 The Vickers indenter usually produces essentially the same hardness number at all test forces when testing homogeneous material, except for tests using very low forces (below 25 gf) or for indentations with diagonals smaller than about 25 µm (see Test Method E384). For isotropic materials, the two diagonals of a Vickers indentation are equal in length.

4.5 The Knoop indenter usually produces similar hardness numbers over a wide range of test forces, but the numbers tend to rise as the test force is decreased. This rise in hardness number with lower test forces is often more significant when testing higher hardness materials, and is increasingly more significant when using test forces below 50 gf (see Test Method E384).

4.6 The elongated four-sided rhombohedral shape of the Knoop indenter, where the length of the long diagonal is 7.114 times greater than the short diagonal, produces narrower and shallower indentations than the square-based pyramid Vickers indenter under identical test conditions. Hence, the Knoop hardness test is very useful for evaluating hardness gradients since Knoop indentations can be made closer together than Vickers indentations by orienting the Knoop indentations with the short diagonals in the direction of the hardness gradient.

5. Principle of Test and Apparatus

5.1 *Vickers and Knoop Hardness Test Principle*—The general principle of the Vickers and Knoop indentation hardness test consists of two steps.

5.1.1 *Step 1*—The applicable specified indenter is brought into contact with the test specimen in a direction normal to the surface, and the test force F is applied. The test force is held for a specified dwell time and then removed.

5.1.2 *Step 2*—For the Vickers hardness test, the lengths of the two diagonals are measured and the mean diagonal length is calculated, which is used to derive the Vickers hardness value. For the Knoop hardness test, the length of the long diagonal is measured, which is used to derive the Knoop hardness value.

5.1.3 Most materials will exhibit some elastic recovery when the indenter is removed after the loading cycle. However, for the purposes of calculating the hardness results from the indentation diagonal lengths, it is assumed that the indentation retains the shape of the indenter after the force is removed. In Knoop testing, it is assumed that the ratio of the long diagonal to the short diagonal of the indentation is the same as for the indenter.

5.2 *Testing Machine*—The testing machine shall support the test specimen and control the movement of the indenter into the specimen under a preselected test force, and should have a light optical microscope to select the desired test location and to measure the size of the indentation produced by the test. The plane of the surface of the test specimen should be perpendicular to the axis of the indenter which is the direction of the force application.

5.2.1 See the equipment manufacturer's instruction manual for a description of the machine's characteristics, limitations, and respective operating procedures.

5.3 *Indenters:*

5.3.1 Indenters for general Vickers or Knoop hardness testing shall comply with the requirements of a Class B indenter or better in accordance with Annex A3.

5.3.2 *Vickers Indenter*—The ideal Vickers indenter (see Fig. A3.1) is a highly polished, pointed, square-based pyramidal diamond with face angles of 136° 0'.

5.3.3 *Knoop Indenter*—The ideal Knoop indenter (see Fig. A3.2) is a highly polished, pointed, rhombic-based, pyramidal diamond. The included longitudinal edge angles are 172° 30' and 130° 0'.