**Designation: ~~A956 – 06~~ A956 – 12**

# Standard Test Method for Leeb Hardness Testing of Steel Products[1]

This standard is issued under the fixed designation A956; 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*~~Scope

1.1 This test method covers the determination of the Leeb hardness of steel, cast steel, and cast iron (Part A), including the methods for the verification of Leeb hardness testing instruments (Part B), and the calibration of standardized test blocks (Part C).

NOTE 1—The original title of this standard was "Standard Test Method for Equotip Hardness Testing of Steel Products."[1]

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

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

## 2. Referenced Documents

2.1 *ASTM Standards:*[2]

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

## 3. Terminology

3.1 *Definitions:*

3.1.1 *calibration*—determination of the values of the significant operating parameters of the instrument by comparison with values indicated by a reference instrument or by a set of reference standards.

3.1.2 *Leeb hardness number*—a number equal to the ratio of the rebound velocity to the impact velocity of a 3-mm or 5-mm (based on the type of impact device) diameter ~~tungsten carbide ball~~ spherically shaped tungsten carbide, silicon nitride, or diamond tipped impact body, multiplied by 1000.

$$L = \frac{\text{Rebound Velocity}}{\text{Impact Velocity}} \times 1000$$

The Leeb hardness number is followed by the symbol *HL* with one or more suffix characters representing the type of impact device.

3.1.3 *Leeb hardness test*—a dynamic hardness test method using a calibrated instrument that impacts a spherically shaped ~~carbide ball~~ tungsten carbide, silicon nitride, or diamond tipped body with a fixed velocity (generated by a spring force) onto a surface of the material under test. The ratio of the rebound velocity to the impact velocity of the impact body is a measure of the hardness of the material under test.

3.1.4 *surface finish*—all references to surface finish in this test method are defined as surface roughness (that is, *Ra* = average roughness value, *AA* = arithmetic average).

3.1.5 *verification*—checking or testing the instrument to ensure conformance with this test method.

## 4. Summary of Test Method

4.1 During a hardness test, an impact body with a spherically shaped tungsten ~~carbide~~ carbide, silicon nitride, or diamond tip impacts under spring force, the test surface from which it rebounds. The impact and rebound velocities are measured when the

[1] This test method is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.06 on Steel Forgings and Billets.

Current edition approved ~~Sept. 1, 2006~~Nov. 15, 2012. Published ~~September 2006~~December 2012. Originally approved in 1996. Last previous edition approved in ~~2002~~2006 as ~~A956 – 02.~~A956 – 06.

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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.

***A Summary of Changes section appears at the end of this standard**

impact body is approximately 1 mm from the test surface. This is accomplished by means of a permanent magnet mounted in the impact body which, during the test, moves through a coil in the impact device and induces an electric voltage on both the impact and rebound movements. These induced voltages are proportional to the respective impact and rebound velocities. The quotient of these measured voltage values derived from the impact and rebound velocities, multiplied by the factor 1000 produces a number which constitutes the Leeb hardness value.

## 5. Significance and Use

5.1 Hardness of a material is a poorly defined term that may have many meanings depending on the type of test performed and the expectations of the person involved. The Leeb hardness test is of the dynamic or rebound type, which primarily depends both on the plastic and on the elastic properties of the material being tested. The results obtained are indicative of the strength and dependent on the heat treatment of the material tested.

5.2 The Leeb hardness test is a superficial determination only measuring the condition of the surface contacted. The results generated at that location do not represent the part at any other surface location and yield no information about the material at subsurface locations.

## A. GENERAL DESCRIPTION OF INSTRUMENTS AND TEST PROCEDURE FOR LEEB HARDNESS TEST

## 6. Apparatus

6.1 The instrument used for Leeb hardness testing consists of (*1*) an impact device that is equipped with a ~~tungsten carbide ball~~ spherically shaped tungsten carbide, silicon nitride, or synthetic diamond tipped impact body, an induction coil velocity measuring assembly, and a support ring, and (*2*) an electronic digital display hardness indicating device.

6.2 *Impact Devices*—There are ~~six~~eight types of impact devices used in Leeb hardness testing. These are the *D, DC, D*+15, *DL,G, C, S,* and the *E* impact units. Brief descriptions of the types of devices and their common applications are given in Appendix X1.

6.3 See 8.1.1 when using replacement machine components.

## 7. Test Piece

7.1 *Form*—The Leeb hardness test is acceptable for steel, cast steel, and cast iron with varying shapes and sizes.

7.2 *Thickness and Weight*—The thickness and weight of the test piece shall be considered when selecting the impact device to be employed. The following guidelines are offered as minimum weights and sizes of test pieces for selecting the proper test equipment. Test pieces of weights less than the minimum or pieces of any weight with sections less than the minimum thickness require rigid support and coupling to a thick, heavier non-yielding surface to resist the impact of the device. Failure to provide adequate support and coupling will produce test results lower than the true hardness value.

| Impact Device | Weight (min) or | Thickness (min) |
|---|---|---|
| *D, DC, D*+15, *DL,S, E* | 15 lb (5 kg) | ⅛ in. (3 mm) |
| *G* | 40 lb (15 kg) | ⅜ in. (10 mm) |
| *C* | 4 lb (1.5 kg) | 1/32 in. (1 mm) |

7.3 *Curvature*—Test pieces with curved surfaces may be tested on either the convex or concave surfaces providing that this radius of curvature of the specimens is matched to the size of the support ring and is not less than 2 in. (50 mm) for the *G* impact device or 1 3/16 in. (30 mm) for other impact devices.

7.4 *Surface Finish/Preparation*—The test surface shall be carefully prepared to avoid any alterations in hardness caused by heating during grinding or by work hardening during machining. Any paint, scale, pits, or other surface coatings shall be completely removed. The surfaces to be tested shall be smooth. Failure to provide adequate surface finish will produce questionable test results. Coarse finishes will tend to lower the measured value. It is recommended that the test surface be machined or ground and polished to the following finishes. (The grinding wheel grit size shown for each finish is offered for guidance in achieving the finish noted.)

| Impact Device | Surface Finish—Ra (max) | Grit Size (Approx.) |
|---|---|---|
| *D, DC, D*+15, *DL,S, E* | 63 µin. (2 µm) | 200 |
| *G* | 250 µin. (7 µm) | 65 |
| *C* | 16 µin. (0.4 µm) | 500 |

7.5 *Magnetic Fields*—Performance of the Leeb hardness test on parts with a residual magnetic field may affect the results. It is recommended that any residual magnetic field be less than 4 G.

7.6 *Vibration*—Vibration of the test specimen may affect the results of the Leeb hardness test. It is recommended that this test be performed with the test piece at rest.

7.7 *Temperature*—The temperature of the test piece may affect the results of the test. In addition, this effect may be different for different materials. Testing to this procedure shall be performed with the temperature of the test piece between 40°F (4°C) and 100°F (38°C). At temperatures outside this range, the user shall develop a temperature correction for the specific material being tested.

## 8. Verification of Apparatus

8.1 *Verification Method*—Prior to each shift, work period, or use, and following a period of extended continuous use (1000 impacts), the instrument shall be verified as specified in Part B. Any instrument not meeting the requirements of Part B shall not be employed for the acceptance testing of product.

8.1.1 Cautionary note: When replacement parts are used in a Leeb hardness tester it is important that they be fully compatible with the original equipment, otherwise incorrect hardness readings may be obtained. Calibration using a single standard test block may indicate acceptable results, but additional calibration tests using blocks of differing hardness may yield unacceptable results. If replacement, non-original equipment parts are used, multiple block calibration verification is strongly advised. Specifically, one calibration block of a hardness equal to or lower than the minimum expected hardness of the material being tested, one calibration block of a hardness equal to or greater than the maximum expected hardness of the material being tested, and one calibration block near the middle of the range should be used.

## 9. Procedure

9.1 *Test Method*—To perform a hardness test, the impact device is connected to the indicator device and the instrument is turned on. The impact device, while not in contact with the test piece, is held firmly with one hand and the charging tube is depressed with the other hand until contact is felt. The charging tube is allowed to slowly return to the starting position. The impact body is now in its loaded or locked position. After placing the impact device on the test surface, trigger the impact body by exerting a light pressure on the release button. The Leeb hardness value is read on the indicator device.

9.2 *Alignment*—To prevent errors resulting from misalignment, the base support ring of the impact device shall be held snugly and perpendicular to the surface of the test piece.

9.3 *Impact Direction*—The impact device is calibrated for the down vertical impact direction (perpendicular to a horizontal surface). For other impact directions such as 45° from the horizontal plane or from underneath, the measured hardness values will require adjustment (see 10.2). Some newer models automatically compensate for test direction.

9.4 *Spacing Indentations*—The distance between any two impact points shall not be less than two diameters edge-to-edge. The distance between the impact point and a specimen edge shall not be less than three diameters edge-to-edge. No point shall be impacted more than once.

9.5 *Reading the Leeb Instrument*—Hardness values in Leeb units are read directly on the electronic display of the indicator device. The indicated value is automatically replaced with the next test impact result.

9.6 *Number of Impacts*—Five impacts in an area of approximately 1 in.$^2$ (645 mm$^2$) shall constitute a test. If the material being tested is considered to be nonhomogeneous (for example, cast iron) ten impacts in an area shall be made to constitute a test.

## 10. Calculation of Hardness Result

10.1 The hardness test result shall be the arithmetic average of the five individual impact readings in the measuring area.

10.2 ~~*Correction*~~*Compensation for Test Direction*—When using an Leeb instrument without automatic compensation for test direction, the ~~correction~~compensation value for direction of test impact is to be subtracted from the average value determined for the measuring area. This ~~correction~~compensation value can be determined in accordance with Tables 1-6~~8~~.

## 11. Conversion to Other Hardness Scales or Tensile Strength Values

11.1 There is no direct correlation between the Leeb hardness test principle and other hardness methods or a tensile strength test. All such conversions are, at best, approximations and therefore conversions should be avoided except for special cases where a reliable basis for the approximate conversion and the accuracy of the conversion has been obtained by comparison testing. No conversions shall be employed without specific agreement between the party specifying this test method and the party performing the hardness test.

## 12. Report

12.1 Report the following information:

12.1.1 The average Leeb hardness number for each test area with the impact device indicated (for example, xxx *HLD* or xxx *HLD*+15).

12.1.2 When hardness values converted from the Leeb number are reported, the instrument used shall be reported in parentheses, for example, *HB* ( *HLG*).

**TABLE 1 ~~Correction~~Compensation Values for Other Impact Directions: Device D**

| $L_D$ |  |  |  |  |
|---|---|---|---|---|
| 300 | -6 | -12 | -20 | -29 |
| 350 | -6 | -12 | -19 | -27 |
| 400 | -5 | -11 | -18 | -25 |
| 450 | -5 | -10 | -17 | -24 |
| 500 | -5 | -10 | -16 | -22 |
| 550 | -4 | -9 | -15 | -20 |
| 600 | -4 | -8 | -14 | -19 |
| 650 | -4 | -8 | -13 | -18 |
| 700 | -3 | -7 | -12 | -17 |
| 750 | -3 | -6 | -11 | -16 |
| 800 | -3 | -6 | -10 | -15 |
| 850 | -2 | -5 | -9 | -14 |
| 900 | | | | |



**TABLE 2 ~~Correction~~Compensation Values for Other Impact Directions: Device D + 15**

| $L_{D+15}$ |  |  |  |  |
|---|---|---|---|---|
| 300 | -7 | -14 | -26 | -38 |
| 350 | -7 | -13 | -25 | -36 |
| 400 | -6 | -12 | -23 | -34 |
| 450 | -6 | -12 | -22 | -32 |
| 500 | -6 | -11 | -21 | -30 |
| 550 | -6 | -11 | -20 | -28 |
| 600 | -5 | -10 | -19 | -27 |
| 650 | -5 | -10 | -18 | -25 |
| 700 | -5 | -9 | -17 | -24 |
| 750 | -4 | -9 | -16 | -22 |
| 800 | -4 | -8 | -15 | -21 |
| 850 | -4 | -8 | -14 | -20 |
| 900 | | | | |



## 13. Precision and Bias

13.1 *Precision:*

**TABLE 3 ~~Correction~~Compensation Values for Other Impact Directions: Device E**

| $L_E$ |  |  |  |  |
|---|---|---|---|---|
| 300 | -5 | -9 | -18 | -26 |
| 350 | -4 | -9 | -17 | -24 |
| 400 | -4 | -9 | -16 | -22 |
| 450 | -4 | -8 | -15 | -21 |
| 500 | -4 | -8 | -14 | -20 |
| 550 | -4 | -8 | -13 | -18 |
| 600 | -3 | -7 | -12 | -17 |
| 650 | -3 | -7 | -12 | -16 |
| 700 | -3 | -6 | -11 | -15 |
| 750 | -3 | -6 | -10 | -14 |
| 800 | -3 | -5 | -9 | -13 |
| 850 | -2 | -5 | -8 | -12 |
| 900 | | | | |



**TABLE 4 ~~Correction~~Compensation Values for Other Impact Directions: Device C**

| $L_C$ |  |  |  |  |
|---|---|---|---|---|
| 350 | -7 | -15 | [A] | [A] |
| 400 | -7 | -14 | | |
| 450 | -7 | -13 | | |
| 500 | -6 | -13 | | |
| 550 | -6 | -12 | | |
| 600 | -6 | -11 | | |
| 650 | -5 | -10 | | |
| 700 | -5 | -10 | | |
| 750 | -4 | -9 | | |
| 800 | -4 | -8 | | |
| 850 | -4 | -7 | | |
| 900 | -3 | -6 | | |
| 950 | | | | |



[A] Not permitted.

**TABLE 5 ~~Correction~~Compensation Values for Other Impact Directions: Device G (Steel)**

| $L_G$ |  |  |  |  |
|---|---|---|---|---|
| 300 | . . . | . . . | -12 | -18 |
| 350 | . . . | . . . | -11 | -17 |
| 400 | . . . | . . . | -11 | -16 |
| 450 | -2 | -5 | -10 | -15 |
| 500 | . . . | . . . | -9 | -14 |
| 550 | . . . | . . . | -9 | -13 |
| 600 | . . . | . . . | -8 | -12 |
| 650 | . . . | . . . | -8 | -11 |
| 700 | . . . | . . . | -7 | -10 |
| 750 | | | | |

**TABLE 6 ~~Correction~~Compensation Values for Other Impact Directions: Device G (Grey Cast Iron)**

| $L_G$ |  |  |  |  |
|---|---|---|---|---|
| 350 | . . . | . . . | -11 | -17 |
| 400 | . . . | . . . | -11 | -16 |
| 450 | -2 | -5 | -10 | -15 |
| 500 | . . . | . . . | -9 | -14 |
| 550 | . . . | . . . | -9 | -13 |
| 600 | | | | |



13.1.1 *Interlaboratory Test Program*—An interlaboratory test program was conducted in accordance with to develop information regarding the precision of the Leeb hardness measurements. Eight laboratories tested five certified test blocks. Each laboratory measured the hardness of each block 25 times.

13.1.2 *Test Result*—The precision information given below is the average of the five certified test blocks, each of a different hardness.

13.1.3 *Repeatability and Reproducibility:*

95 % Repeatability Limit (within laboratory) = 4.4 %
95 % Reproducibility Limit (between laboratories) = 8.8 %

13.1.3.1 The terms in 13.1.3 (repeatability limit and reproducibility limit) are used as specified in Practice E691. The respective standard deviations among test results, related to the above numbers by the factor 2.8, are:

Repeatability Standard Deviation = 1.6 %
Reproducibility Standard Deviation = 3.2 %

13.2 *Bias*—Since hardness is not an intrinsic property of a material, there is no basis on which to determine or assign an accepted reference value. Consequently, there is no basis for defining the bias of this test method.