

ASTM E140: The Comprehensive Technical Guide to Hardness Conversion Tables for Metals

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In the complex landscape of materials science and mechanical engineering, the ability to quantify and compare the resistance of a material to localized plastic deformation—commonly known as hardness—is paramount. However, hardness is not a fundamental physical property like mass or density; rather, it is a result of a specific measurement procedure involving varied indenters, loads, and timing. Consequently, engineers frequently encounter data expressed in different scales, such as Brinell, Rockwell, or Vickers. This is where **ASTM E140**, officially titled the **Standard Hardness Conversion Tables for Metals**, becomes an indispensable tool for technical professionals globally. This standard provides the empirical relationship among these disparate scales, facilitating communication across supply chains and ensuring quality control in manufacturing processes.

The Fundamental Importance of Hardness Conversion

Hardness testing is perhaps the most utilized mechanical test in industry because it is relatively non-destructive, cost-effective, and provides a reliable proxy for other mechanical properties, such as tensile strength. Despite its utility, the proliferation of testing methods often leads to data fragmentation. A component might be specified in **Rockwell C (HRC)**, yet the available testing equipment in a remote facility might only support **Brinell (HB)** testing. **ASTM E140** serves as the bridge, allowing for the translation of these values based on rigorous empirical data gathered over decades of metallurgical research.

It is critical to understand that these conversions are not based on universal mathematical constants. Instead, they are derived from experimental correlations performed on specific materials. This is because different metals react differently to the geometry of the indenter and the magnitude of the applied force. For example, the elastic modulus and the work-hardening characteristics of an alloy significantly influence how an indentation is formed and recovered once the load is removed. ASTM E140 addresses this by providing separate conversion tables for various material groups, including carbon steels, stainless steels, aluminum alloys, and copper alloys.

Core Hardness Scales and Their Methodology

To effectively utilize the **ASTM E140** conversion tables, one must first grasp the technical nuances of the primary scales it covers. Each method employs a unique combination of indenter geometry and load application, which results in different localized stress states within the material.

1. The Rockwell Hardness Test (ASTM E18)

The Rockwell test is arguably the most common due to its speed and direct-reading capability. It measures the **permanent depth of indentation** produced by a force on an indenter. The test involves two stages: a preliminary test force (minor load) followed by an additional test force (major load). There are several Rockwell scales (A, B, C, D, etc.), each using different indenters—such as a 120° diamond cone for Scale C or a 1/16-inch diameter steel ball for Scale B.

2. The Brinell Hardness Test (ASTM E10)

The Brinell method involves pressing a hardened steel or tungsten carbide ball (usually 10 mm in diameter) into the

material surface with a specified load (typically 3000 kgf for steels). The **Brinell Hardness Number (HBW)** is calculated by dividing the applied load by the surface area of the resulting indentation. Because it creates a relatively large impression, it is excellent for measuring materials with non-homogeneous microstructures, such as castings and forgings.

3. The Vickers Hardness Test (ASTM E92)

The Vickers test uses a square-based diamond pyramid indenter with an angle of 136° between opposite faces. Unlike Brinell, the Vickers scale is continuous and can be used for all materials, from very soft to extremely hard. The **Vickers Hardness (HV)** is determined by measuring the diagonals of the square impression using a microscope. It is highly precise and frequently used in laboratory research and for measuring thin sections or coatings.

4. The Knoop Hardness Test (ASTM E384)

Similar to Vickers, Knoop is a microhardness test but uses a rhombic-based (elongated) diamond indenter. It is particularly useful for measuring very brittle materials or thin layers, as the shallow indentation minimizes the risk of cracking the specimen.

Technical Analysis of ASTM E140 Tables

The **ASTM E140-12b** and its subsequent revisions (such as **E140-12be1**) categorize metals into distinct tables to ensure the highest possible conversion accuracy. A common error among junior engineers is applying a steel conversion table to an aluminum alloy, which leads to significant discrepancies due to the differences in **Young's Modulus**.

Material Classification in ASTM E140

The standard is structured into several tables, each optimized for a specific alloy family:

- Table 1: Hardness Conversion Numbers for Non-Austenitic Steels (Carbon, Alloy, and Tool Steels in the as-forged, annealed, or quenched and tempered conditions).
- Table 2: Hardness Conversion Numbers for Non-Austenitic Steels (Alternative Table).
- Table 3: Hardness Conversion Numbers for Austenitic Steels (Stainless Steels).
- Table 4: Hardness Conversion Numbers for Quick-Reference (General Steel).
- Table 5: Hardness Conversion Numbers for Aluminum and Aluminum Alloys.
- Table 6: Hardness Conversion Numbers for Copper Alloys.
- Table 7: Hardness Conversion Numbers for Nickel and High-Nickel Alloys.

Mathematical Limitations and Empirical Errors

According to **ASTM E140-12b**, hardness conversion is subject to certain errors. The standard explicitly warns that conversions are **empirical**. When a value is converted from one scale to another, it introduces a degree of uncertainty that would not be present if the material were tested directly using the target scale. Factors such as surface finish, parallelism of the specimen, and the thickness of the material (the "anvil effect") can all skew results.

Comprehensive Conversion Matrix (Representative Data)

The following table provides a simplified excerpt of the relationships defined in ASTM E140 for **Non-Austenitic Steels**. This table demonstrates how the scales track against one another across a range of hardness levels.

Vickers (HV)	Brinell (HBW, 3000kg)	Rockwell C (HRC)	Rockwell B (HRB)	Tensile Strength (Approx. ksi)
800	(712)	64.0	-	-
700	627	60.1	-	320
600	542	55.2	-	278
500	456	49.1	-	230
400	371	40.8	-	185
300	285	29.8	105	138
200	190	(11.5)	91.5	93
150	143	-	78.7	71

Note: Values in parentheses are beyond the recommended range for the scale but are provided for reference in ASTM E140.

Step-by-Step Procedure for Accurate Hardness Conversion

To ensure technical compliance with **ASTM E140**, engineering teams should follow a standardized workflow. Deviating from these steps often results in non-conforming parts or inaccurate material characterization.

1. Identify the Material Family: Determine the exact alloy type. Do not use Table 1 (Steel) for Table 5 (Aluminum) applications.
2. Verify the Original Measurement: Ensure the initial hardness test was performed according to its respective ASTM standard (e.g., E10 for Brinell). Check for minimum thickness requirements to avoid the anvil effect.
3. Locate the Relevant ASTM E140 Table: Find the column corresponding to the "measured scale" and the row corresponding to the "measured value."
4. Read the Converted Value: Identify the target scale in the adjacent columns.
5. Report with Disclosure: When documenting converted values, always indicate that the value was converted and specify the original scale. For example: "40.8 HRC (Converted from 400 HV per ASTM E140)."

Factors Affecting Conversion Accuracy

Even when using the latest **ASTM E140-12b(2019)** revision, several technical variables can degrade the reliability of a conversion. A **Senior Technical Writer** must emphasize that the conversion is only as good as the primary test.

Surface Preparation and Roughness

Hardness tests rely on measuring microscopic indentations. If the surface is rough, the indenter may rest on "peaks" or slip into "valleys," resulting in a false reading. Brinell testing is more forgiving of surface roughness than Rockwell or Vickers, but all require a smooth, flat surface perpendicular to the indenter.

Material Homogeneity

If a material has undergone surface hardening (e.g., carburizing or nitriding), the hardness will vary with depth. In such cases, converting a surface Rockwell reading to a bulk Brinell value is fundamentally flawed, as the two tests sample different volumes of material.

Elastic Recovery

All materials undergo some degree of elastic recovery when the test load is removed. The **Vickers** and **Brinell** methods measure the indentation after recovery, whereas the **Rockwell** method measures the depth while the minor load is still applied. This mechanical difference is a primary reason why conversion tables must be used instead of simple linear equations.

Comparison of Hardness Testing Methods

The following table compares the operational characteristics of the major scales mentioned in **ASTM E140**.

Feature	Rockwell	Brinell	Vickers
Indenter Type	Diamond Cone / Steel Ball	Tungsten Carbide Ball	Diamond Pyramid
Measurement Basis	Depth of penetration	Surface area of impression	Diagonal length of impression
Speed	Very Fast	Slow	Moderate (Requires optics)
Primary Use Case	Production QC	Castings & Forgings	Laboratory & Precision parts

Case Study: Failure Analysis in Converted Values

Consider a scenario in an aerospace manufacturing plant where a landing gear component made of high-strength alloy steel (AISI 4340) was specified at **50-52 HRC**. The supplier provided a certificate showing **510-535 HBW**. Using **ASTM E140 Table 1**, the quality engineer discovers that 50 HRC converts to approximately 481 HBW, and 52 HRC converts to 512 HBW.

The supplier's range (510-535 HBW) actually converts to **51.8 to 53.5 HRC**. While the lower end of the range is compliant, the upper end exceeds the maximum hardness allowed (52 HRC). This excess hardness could indicate the material is too brittle, increasing the risk of hydrogen embrittlement or fatigue failure. This case study highlights why precise adherence to **ASTM E140** is critical: a simple oversight in conversion can lead to the acceptance of out-of-specification parts that pose a significant safety risk.

Common Troubleshooting Steps:

- **Discrepancy in Results:** If two laboratories provide different converted values, check if they used the same conversion table from ASTM E140. Standards are periodically updated (e.g., from E140-02 to E140-12).
- **Out-of-Range Errors:** If a measured value falls outside the bolded limits of the ASTM tables, the conversion is considered unreliable. In these instances, the material must be re-tested using the actual scale required by the specification.

The Evolution of ASTM E140 Standards

The standard has seen multiple iterations, such as **ASTM E140-12b1** and the 2019 reapproval. These updates often reflect improvements in the statistical analysis of the empirical data or the inclusion of new material tables. For example, older versions might not have had comprehensive data for high-nickel alloys used in modern turbine blades. Keeping a current subscription to the **ASTM International** portal ensures that engineering teams are not using obsolete conversion data that could jeopardize product integrity.

The digitization of these tables into Integrated Manufacturing Systems (IMS) and Enterprise Resource Planning (ERP) software has streamlined the process, but the underlying engineering principles remain the same. Automated systems must be programmed with the correct material-specific coefficients derived from the ASTM tables to prevent "blind" conversions that ignore material chemistry.

In summary, **ASTM E140** is more than just a set of tables; it is a vital communication protocol in the global engineering community. By understanding the mechanical basis of each hardness scale and the material-specific nature of their correlations, technical professionals can ensure accurate material characterization. Whether you are performing a failure analysis, a quality audit, or designing a new component, the **Standard Hardness Conversion**

Tables for Metals provide the empirical foundation necessary for precision and safety. Proper application of these tables, mindful of their inherent empirical limitations and material-specific scopes, remains a hallmark of competent metallurgical and engineering practice.

Baca Juga (Artikel Terkait)

- [The Ultimate Engineering Guide to ASTM A106 Seamless Carbon Steel Pipe: Specifications, Comparisons, and Industrial Applications](#)

URL: <http://www.alghafgolden.com/astm-a106-seamless-carbon-steel-pipe-technical-guide.pdf>

- [Comprehensive Engineering Guide to ASTM A350 LF2 and High-Performance Forged Alloys in Oil & Gas](#)

URL: <http://www.alghafgolden.com/engineering-guide-astm-a350-lf2-oil-gas-alloys.pdf>

- [A Comprehensive Engineering Guide to ASTM B337 Titanium Pipes: Specifications, Grades, and Industrial Applications](#)

URL: <http://www.alghafgolden.com/astm-b337-titanium-pipe-technical-guide.pdf>

- [The Definitive Guide to ASTM E8/E8M: Standard Test Methods for Tension Testing of Metallic Materials](#)

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