# INTERNATIONAL STANDARD

# ISO 18265

First edition
2003-11-01

## Metallic materials — Conversion of hardness values

*Matériaux métalliques — Conversion des valeurs de dureté*



Reference number
ISO 18265:2003(E)

**PDF disclaimer**

This PDF file may contain embedded typefaces. In accordance with Adobe's licensing policy, this file may be printed or viewed but shall not be edited unless the typefaces which are embedded are licensed to and installed on the computer performing the editing. In downloading this file, parties accept therein the responsibility of not infringing Adobe's licensing policy. The ISO Central Secretariat accepts no liability in this area.

Adobe is a trademark of Adobe Systems Incorporated.

Details of the software products used to create this PDF file can be found in the General Info relative to the file; the PDF-creation parameters were optimized for printing. Every care has been taken to ensure that the file is suitable for use by ISO member bodies. In the unlikely event that a problem relating to it is found, please inform the Central Secretariat at the address given below.





ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

# Contents

Page

# Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 18265 was prepared by Technical Committee ISO/TC 164, *Mechanical testing of metals*, Subcommittee SC 3, *Hardness testing*.

## Introduction

The hardness conversion values given in Table A.1 were obtained in interlaboratory tests by the *Verein Deutscher Eisenhüttenleute* (VDEh) (German Iron and Steel Institute) using verified and calibrated hardness testing machines. Statistically reliable information cannot be given on the uncertainty of these values because the test conditions were not reproducible, and the number of results used to calculate the mean hardness values is not known. The conversion values in Table A.1 are in accordance with the information presented in IC No. 3 (1980) and IC No. 4 (1982) of the European Coal and Steel Community, as well as in ISO 4964:1984 and ISO/TR 10108:1989.

Annexes C, D and E contain — in a revised format — the extensive results on the conversion of hardness values presented in TGL 43212/02 to 43212/04, standards published by the former East German standards body, the *Amt für Standardisierung, Meßwesen und Warenprüfung* (ASMW). The values presented in Annex B had also been determined by the ASMW, but were published in a report of the *Physikalisch-Technische Bundesanstalt* (PTB) [1], the German national institute for science and technology, not in a TGL standard.

The converted hardness values in the above-mentioned TGL standards were obtained in statistically reliable hardness and tensile tests. The hardness tests were performed using ASMW normal testing machines on plane-parallel, polished specimens of various materials in different heat treatment conditions. Tensile strength was tested on machines whose force measuring and extension measuring systems had been calibrated immediately before testing. The tensile test method used is equivalent to that specified in ISO 6892, and the calibration procedures conform with those specified in ISO 7500-1 and ISO 9513.



Users of this International Standard should take note of Clause 3, especially the concluding warning.

# Metallic materials — Conversion of hardness values

## 1 Scope

This International Standard specifies the principles of the conversion of hardness values and gives general information on the use of conversion tables.

The conversion tables in Annexes A to F apply to

- unalloyed and low-alloy steels and cast iron;
- steels for quenching and tempering;
- cold working steels;
- high speed steels;
- hardmetals;
- non-ferrous metals and alloys.



NOTE The conversion tables in Annexes B to E are based on empirical results which were evaluated by means of regression analysis. Such analysis was not possible in the case of the values given in Annex A because a sufficient number of results was not available.



## 2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 6506-1:1999, *Metallic materials — Brinell hardness test — Part 1: Test method*

ISO 6507-1:1997, *Metallic materials — Vickers hardness test — Part 1: Test method*

ISO 6507-2:1997, *Metallic materials — Vickers hardness test — Part 2: Verification of testing machines*

ISO 6508-1:1999, *Metallic materials — Rockwell hardness test — Part 1: Test method (scales A, B, C, D, E, F, G, H, K, N, T)*

ISO 6508-2:1999, *Metallic materials — Rockwell hardness test — Part 2: Verification and calibration of testing machines (scales A, B, C, D, E, F, G, H, K, N, T)*

ISO 6892:1998, *Metallic materials — Tensile testing at ambient temperature*

ISO 7500-1:—[1)], *Metallic materials — Verification of static uniaxial testing machines — Part 1: Tension/compression testing machines — Verification and calibration of the force-measuring system*

ISO 9513:1999, *Metallic materials — Calibration of extensometers used in uniaxial testing*

[1)] To be published. (Revision of ISO 7500-1:1999)

## 3 Principles of conversion

Hardness testing is a form of materials testing that provides information on the mechanical properties of a material with limited destruction of the specimen and within a relatively short period of time. In practice, it is often desirable to use hardness results to draw conclusions on the tensile strength of the same material if tensile testing is too involved or the piece to be examined is not to be destroyed.

Since the means of loading in hardness testing is considerably different from that in tensile testing, it is not possible to derive a reliable functional relationship between these two characteristic values on the basis of a model. Nevertheless, hardness values and tensile strength values are positively correlated, and so it is possible to draw up empirical relationships for limited applications.

Often it is necessary to check a given hardness value against a value gained by a different test method. This is especially the case if only a certain method can be used due to the particular specimen or coating thickness, the size of the object to be tested, surface quality, or the availability of hardness testing machines.

Conversion of hardness values to tensile values makes it possible to carry out hardness measurement in place of the measurement of tensile strength taking into account that these tensile strength values must be seen as being the least reliable form of conversion. Likewise, with conversion between hardness scales, a hardness value can be replaced with a value obtained using the desired method.

NOTE Sometimes a conversion relationship is drawn on a single-case basis to gain information on properties other than hardness, most often to obtain a good estimate of tensile strength. Special relationships are sometimes also drawn for hardness-to-hardness conversions. This may be done as long as the following conditions are fulfilled.

— The hardness test method is only used internally, and the results obtained not be compared with those of other methods, or the details of the test procedure are defined precisely enough so that results can be reproduced by another laboratory or at another time.



— The conversion tables used have been derived from a sufficiently large number of parallel experiments using both scales and carried out on the material in question.



— Complaints may not be made on the basis of converted values.

— Converted results are expressed in such a manner that it is clear which method was used to determine the original hardness value.

**WARNING — In practice, an attempt is often made to establish a strong relationship between the original and converted values without taking into consideration the characteristics of the material under test. As Figures 1 and 2 show, this is not possible. Therefore, users of this International Standard should ensure that all conditions for conversion are met (see also [2] and [3]).**

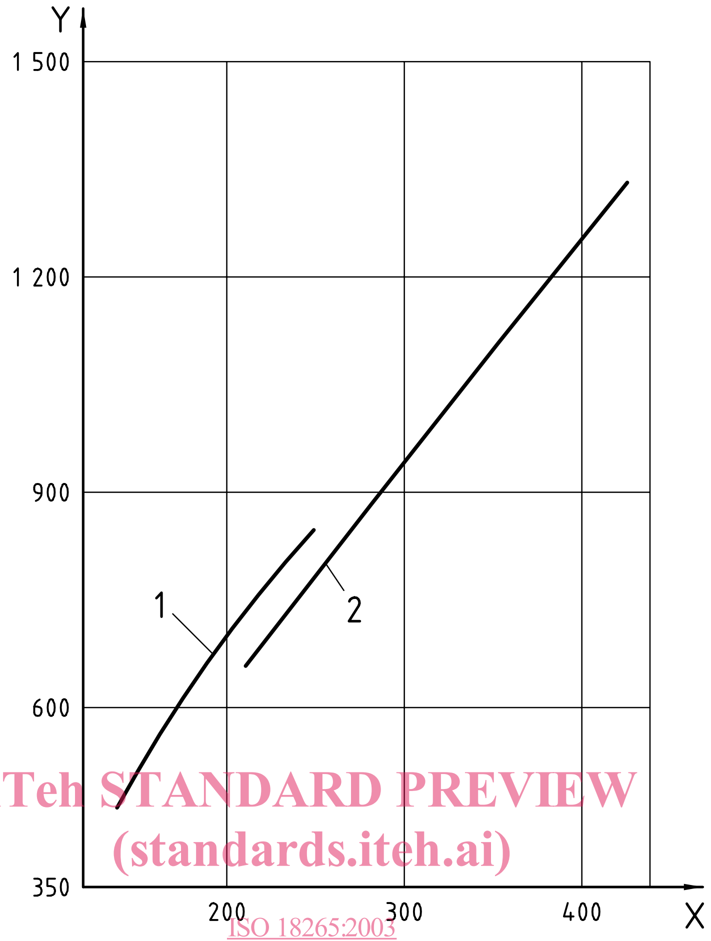
## 4 Application of conversion tables

### 4.1 General

Conversion from one hardness value to another, or from a hardness value to a tensile strength value, involves uncertainties which must be taken into account. Extensive investigations have shown that it is not possible to establish universally applicable conversion relationships between hardness values obtained by different methods, no matter how carefully the tests had been carried out. This lies in the fact that there is a complex relationship between the indentation behaviour of a material and its elasticity. For this reason, the given conversion relationship provides greater equivalence the more similarity there is between the elasticity of the tested material and that of the material used to establish the relationship. Likewise, a better equivalence can be expected for methods with similar indentation processes (i.e. where the differences in the force application-indentation procedures and the test parameters is minimal). Therefore, conversion from hardness values to tensile values must be seen as being the least reliable form of conversion.

NOTE In many cases, the yield strength or the 0,2 % proof strength provides information on the elastic behaviour of a material.






X Hardness, HV 30

Y Tensile strength, $R_m$, MPa

**Key**

1 untreated, soft annealed, normalized

2 quenched and tempered

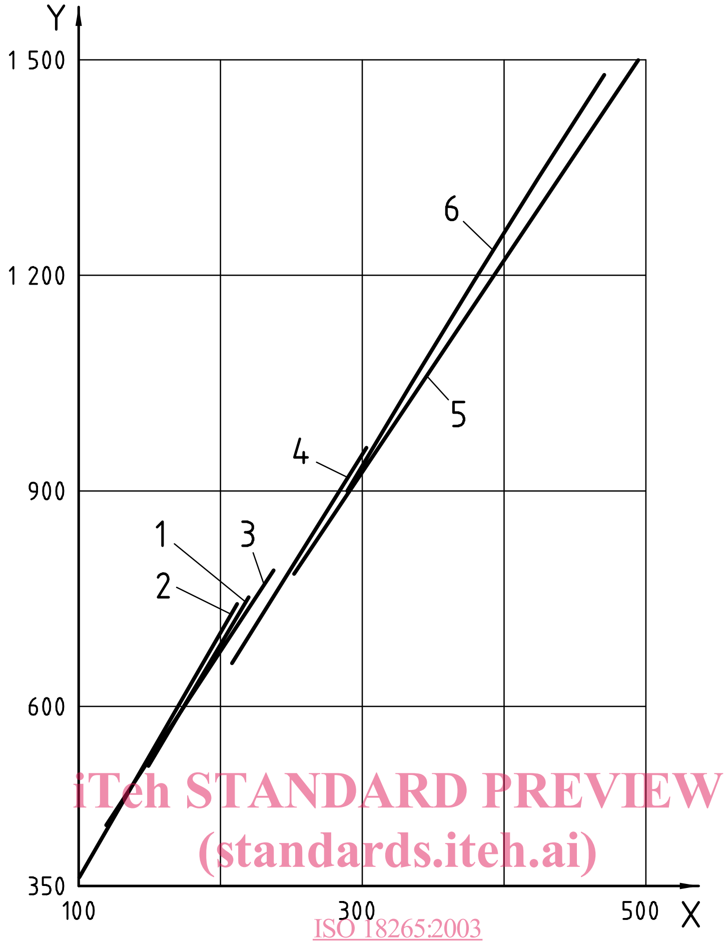
**Figure 1 —HV 30/$R_m$ curves for quenching and tempering steels in various heat treatment conditions**

It should be noted that each hardness determination is only applicable to the immediate area of the indentation. Where hardness varies, e.g. at an increasing distance from the surface, Brinell or Vickers hardness values, or even tensile strength values can deviate from the converted values solely as a result of the different rate of elongation within the area under consideration.

Hardness values should only be converted when the prescribed test method cannot be used, e.g. because a suitable machine is not available, or if the required samples cannot be taken. A suitable test method can be selected with the aid of Figures 3 and 4. Values obtained by conversion may only be taken as the basis of complaints if so agreed in the delivery contract.

If hardness or tensile strength values are determined by conversion in accordance with this International Standard, this shall be stated, as shall the hardness test method used (see ISO 6506-1, ISO 6507-1, ISO 6508-1).






X Hardness, HV 30

Y Tensile strength, $R_m$, MPa

**Key**

1 $R_e/R_m$ = 0,45 to 0,59

2 $R_e/R_m$ = 0,60 to 0,69

3 $R_e/R_m$ = 0,70 to 0,79 normal annealed

4 $R_e/R_m$ = 0,70 to 0,79 heat treated

5 $R_e/R_m$ = 0,80 to 0,89

6 $R_e/R_m$ = 0,90 to 0,99

**Figure 2 — Mean HV 30/$R_m$ curves for quenching and tempering steels with different $R_e/R_m$ ratios**

The basis of conversion shall be the mean of at least three individual hardness values.

To ensure an acceptable uncertainty of measurement, the specimen surfaces shall be machine-finished.

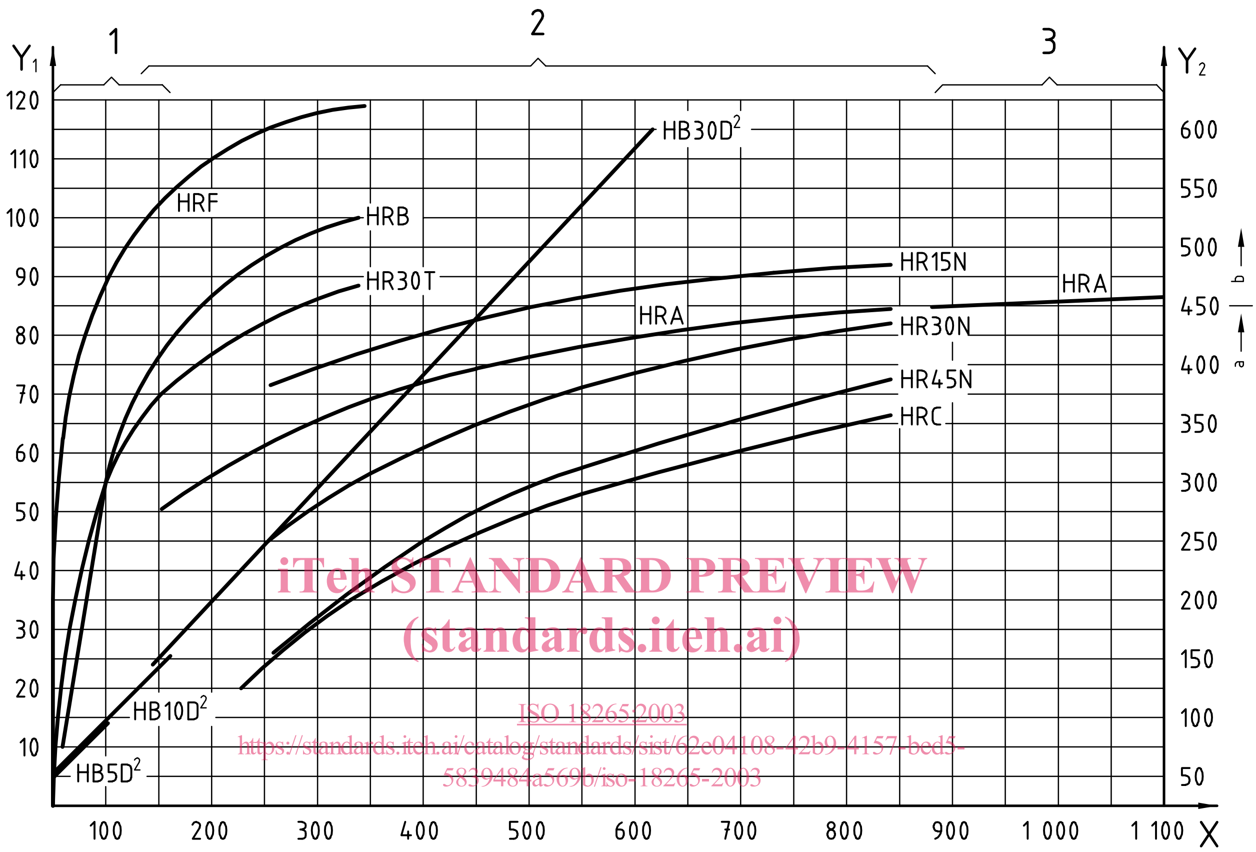
The uncertainties of the values given in the conversion tables here comprise the confidence interval of the hardness conversion curves calculated by means of regression analysis, and the uncertainty of the hardness or tensile strength value to be converted. The confidence interval of the regression function is a parameter that cannot be influenced by the user and is calculated as a function of hardness.

The uncertainty associated with the hardness values to be converted is influenced by the repeatability of the testing machine, the quality of the specimen surface, the uniformity of the specimen's hardness and the number of indentations used to determine hardness. It is thus dependent on the test conditions of the person doing the conversion. This conversion is to be carried out on the basis of the tables given in this International Standard for various groups of materials. These tables give hardness values for various scales and, in some cases, the relevant tensile strength.

When only comparing the values in these tables without actually carrying out hardness testing, the uncertainty of the converted value is reduced to the confidence interval of the calculated hardness conversion curve.

When using the tables, it is not significant which value is taken as the measured value and which as the converted one.

The determination of the uncertainty of converted values, as well as the specification of a permissible level of uncertainty may be agreed upon, in which case the converted values are to be established on the basis of the mean of five individual values.






X Vicker hardness, HV 30

$Y_1$ Rockwell hardness

$Y_2$ Brinell hardness

**Key**

1 non-ferrous metal

2 steel

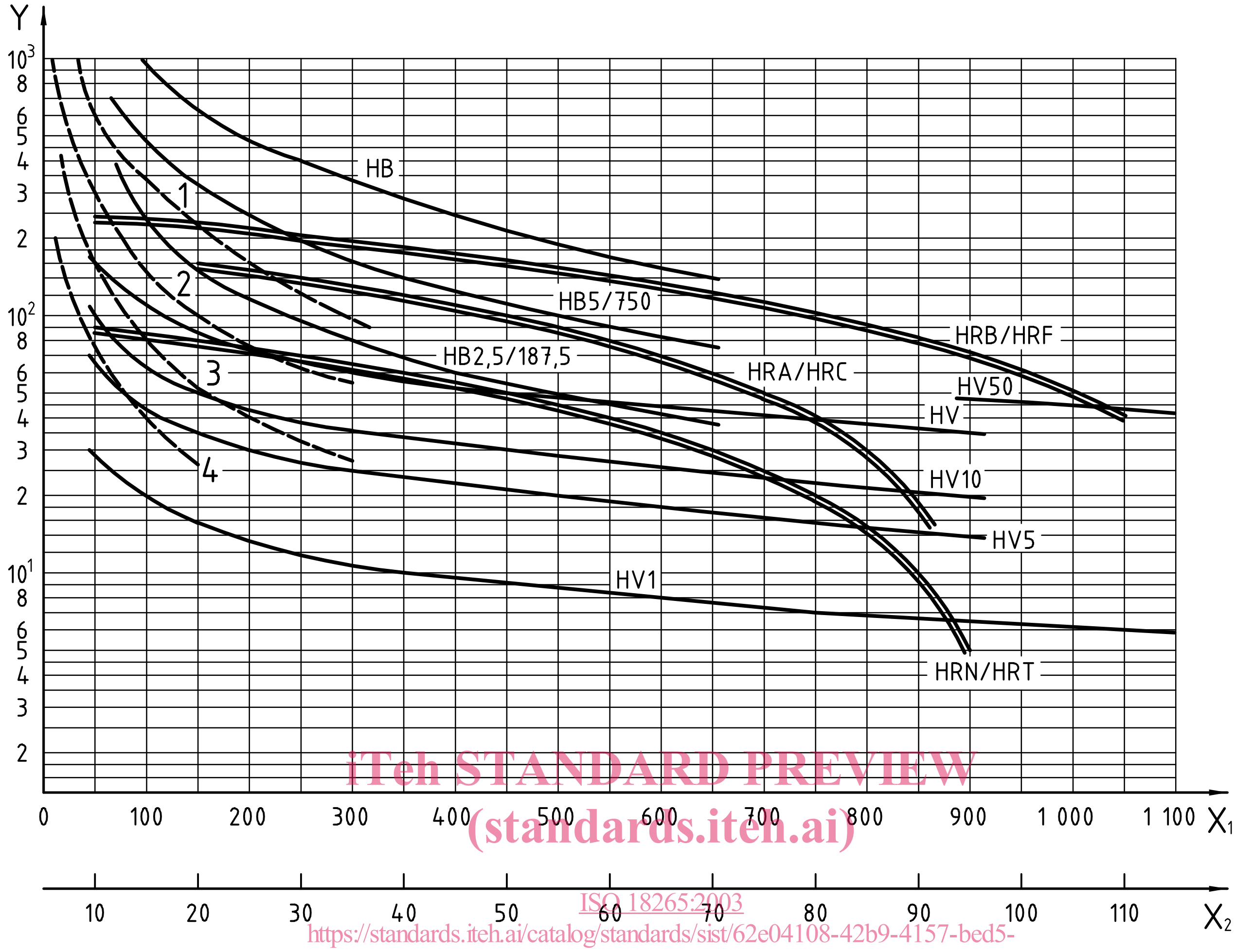
3 hardmetal

NOTE This figure is intended only as an aid in selecting an alternative test method and is not to be used for conversion purposes.

[a] Determined with a steel ball (HBS).

[b] Determined with a hardmetal ball (HBW).

**Figure 3 — Various hardness scales compared to the Vickers scale**






$X_1$ Brinell hardness/Vicker hardness

$X_2$ Rockwell hardness, (according to its different scales)

Y Indentation depth, µm

**Key**

1 HB10/1 000

2 HB10/500 and HB 5/250

3 HB5/125 and HB 2,5/62,5

4 HB2,5/62,5

**Figure 4 — Indentation depth as a function of hardness for various test methods**

## 4.2 Converting values

### 4.2.1 Limits of error

Depending on the measurement conditions in practice, measured value/converted value pairs (e.g. HV/HRC, HRC/HV, HRA/HRN, HB/$R_m$) can be taken from the tables in Annexes B to F. Essential criteria which should be taken into account when selecting a hardness test method are discussed in this clause.

The example below illustrates the conversion of values together with their limits of error using Table C.2.

Given hardness value: (300 ± 30) HV

Desired scale: HRC

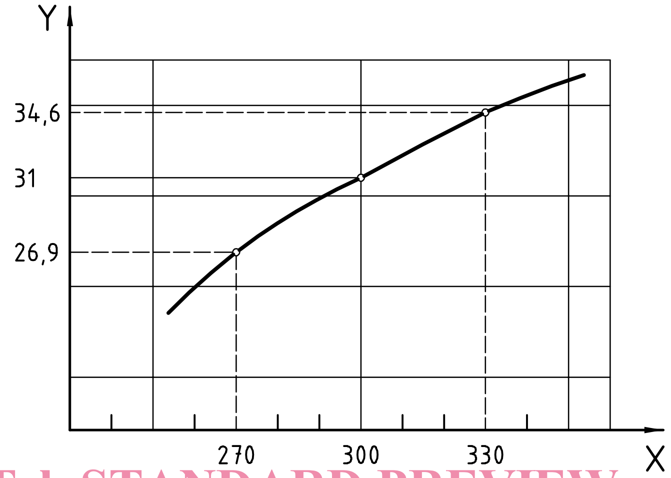
 

Converted values from table: 270 HV ≙ 26,9 HRC

300 HV ≙ 31,0 HRC

330 HV ≙ 34,6 HRC

The converted value, $31^{+3,6}_{-4,1}$ HRC, for the nominal value 300 HV no longer represents the mean of the upper and lower limits in HRC because of the nonlinear relationship between HV and HRC values (see Figure 5). The confidence interval of the hardness conversion curve may be disregarded for such estimations.




X HV
Y HRC



**Figure 5 — Shift of the nominal value when converting hardness values**



### 4.2.2 Uncertainty

The uncertainty of a converted value should be taken from the curves associated with the conversion table used, as shown in the figures in Annexes B to E for various types of material.

The families of curves given in the annexes represent the uncertainty, *u*, for a probability level of 95 % as a function of the hardness value $\bar{H}_K$ for various reproducibility limits, *R*. ($\bar{H}_K$ is the corrected arithmetic mean of five individual values.) The curves have been arranged so that interpolation between neighbouring curves is possible. The reproducibility, *R*, is to be calculated on the basis of five measurements as shown in 4.4.2 for various hardness test methods.

The uncertainty curves only take into account the effects of the random errors of the measured value on the converted value. However, they do not take into account the systematic error of the testing machine used, as this can lead to exceedingly high errors in the converted result, even if the systematic error lies within the permissible range specified for the machine; this is explained in 4.4. For this reason, hardness testing machines shall be verified, using calibrated blocks, at least within the time interval specified in the relevant standards. The systematic error determined in this manner is to be compensated by correcting the measured mean hardness value. This is especially important in the case of Rockwell hardness testing. Figure 6 illustrates the determination of the uncertainty, *u*, of a converted hardness value (dashed line) according to the example below.

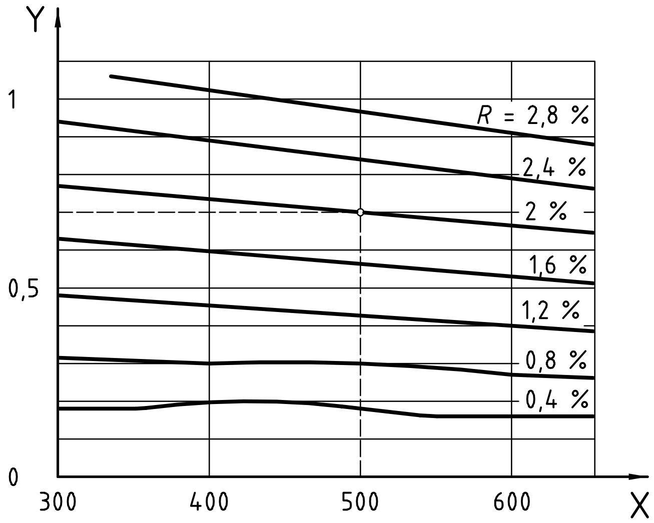
EXAMPLE

— Measured, corrected mean hardness $\bar{H}_K$ 500 HV

— Converted value as in Annex C 49,5 HRC

— Calculated reproducibility limit, $R$ 2,0 %

— Uncertainty of converted value, $u$ ± 0,7 HRC




X $\bar{H}_K$ in HV
Y $u$ in HRC

**Figure 6 — An example of the determination of uncertainty of a converted hardness value**

## 4.3 Designation of conversion results

Conversion results shall be reported in a manner that clearly indicates which method was used to determine the original hardness value. In addition, the relevant annex to this International Standard or the table used shall be given.



EXAMPLE 1

Conversion ISO 18265 - 50,5 HRC - B.2 - HV

Standard number
Converted hardness value
Table used for conversion
Original hardness test method used

EXAMPLE 2 If it is agreed that the uncertainty of the converted value is to be given, this shall be included in the result as follows:

Conversion ISO 18265 - (62,0 ±1,0) HRC - C.2 - HV

Standard number
Converted hardness value, with uncertainly
Table used for conversion
Original hardness test method used

EXAMPLE 3 Conversions into tensile strength values shall be expressed as follows:

Conversion ISO 18265 - 415 MPa - A.1 - HB

Standard number
Converted tensile strength value
Table used for conversion
Original hardness test method used

## 4.4 Notes on use of conversion tables

### 4.4.1 Selection of alternative hardness test methods

**4.4.1.1** In Figure 3 hardness scales for non-ferrous metals, hardmetals and selected steels are compared. The relationship of each scale to the Vickers scale is illustrated, and by comparison with Rockwell and Brinell scales (ordinates), information is gained as to the hardness ranges covered by each method. This figure is intended solely as an aid to selection and is not to be used for conversion purposes.

**4.4.1.2** Figure 4 shows indentation depths as a function of hardness for various test methods. This should facilitate selection of a suitable test method on the basis of specimen or coating thickness.

**4.4.1.3** Another criterion for selecting an alternative hardness test method is the uncertainty of the conversion results. Since this can vary greatly, the uncertainty curves given in this International Standard should also be used to determine which combination of methods is optimal for the application in question.

### 4.4.2 Calculating the reproducibility limit, $R$

The reproducibility limit, $R$, expressed as a percentage, shall be calculated for the different hardness test methods as shown in equations (1) to (3).

For HRB and HRF testing:

$$R = \frac{H_{max} - H_{min}}{130 - \bar{H}} \times 100 \qquad (1)$$



For HRC, HRA, HRD, HRN and HRT testing:

$$R = \frac{H_{max} - H_{min}}{100 - \bar{H}} \times 100 \qquad (2)$$



where

$H_{max}$, $H_{min}$ are the highest and lowest measured hardness values;

$\bar{H}$ is the mean of measured hardness values.

For HV, Vickers microhardness, and HB testing:

$$R = \frac{d_{max} - d_{min}}{\bar{d}} \times 100 \qquad (3)$$

where

$d_{max}$, $d_{min}$ are the largest and smallest measured indentation diagonals (Vickers) or the largest and smallest diameters (Brinell);

$\bar{d}$ is the mean of measured diagonals or diameters.

### 4.4.3 Effect of the systematic error

The effect of systematic errors of hardness values on conversion results is illustrated in the following example.

EXAMPLE According to Table E.2, a hardness value of 87,8 HRA corresponds to a converted value of 1 180 HV. In this hardness range, the limits of error of the testing machines (see ISO 6508-2 and ISO 6507-2) are ± 1,5 HRA and ± 23,6 HV, respectively (i.e. ± 2 % of the hardness value). A systematic error of a Rockwell testing machine of + 1,4 HRA lies within the permissible limits of error, although this would still lead to a deviation of 130 HV for the converted value if no correction is made before conversion. Deviations of this magnitude occur particularly when converting from Rockwell to Vickers or Brinell values.