BS EN ISO 18265:2013

BSI Standards Publication

Metallic materials — Conversion of hardness values (ISO 18265:2013)

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National foreword

This British Standard is the UK implementation of EN ISO 18265:2013. It supersedes BS EN ISO 18265:2003 which is withdrawn.

The UK committee is aware that the common need to convert from one hardness test scale to another has led to the creation of various International Standards (EN ISO 18265:2013, ASTM E140 12b). These standards take measurements from a small number of example materials using different static hardness tests and present a conversion between static hardness scales in the form of comparison tables and graphs of the relevant static hardness test results. However, different materials have different hardness responses and so the comparison tables in these standards are strictly only applicable to the same material as that used to derive the tables. The UK committee is of the opinion that these standards should not be used to provide any conversion from a dynamic indentation test to a different hardness scale, static or dynamic. The recommended method for determining a hardness scale conversion is to generate a set of comparison results for the exact material and scale conversions required.

Using this standard to convert between static hardness scales for test results obtained on materials different from the example materials in the standard will introduce additional and possibly large uncertainties (see clause 1). Even for the same or similar materials the uncertainty is variable. For this reason, all converted hardness values obtained by comparison with the specific conversion tables acquired for the example materials quoted in this document should be treated as estimated or indicative values only. Attention is therefore also drawn to clause 2 which states that "a measurement made according to the correct hardness (or tensile) standard for the scale being reported shall always take precedence over a hardness (or strength) value derived from a conversion table".

The UK participation in its preparation was entrusted by Technical Committee ISE/101, Test methods for metals to Subcommittee ISE/101/5, Indentation hardness testing.

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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EUROPEAN STANDARD

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EN ISO 18265

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English Version

Metallic materials - Conversion of hardness values (ISO 18265:2013)

Matériaux métalliques - Conversion des valeurs de dureté (ISO 18265:2013)

Metallische Werkstoffe - Umwertung von Härtewerten (ISO 18265:2013)

This European Standard was approved by CEN on 3 August 2013.

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Foreword

This document (EN ISO 18265:2013) has been prepared by Technical Committee ISO/TC 164 "Mechanical testing of metals" in collaboration with Technical Committee ECISS/TC 101 “Test methods for steel (other than chemical analysis)” the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by April 2014, and conflicting national standards shall be withdrawn at the latest by April 2014.

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

This document supersedes EN ISO 18265:2003.

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Endorsement notice

The text of ISO 18265:2013 has been approved by CEN as EN ISO 18265:2013 without any modification.

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2. www.iso.org/directives

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT), see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 164, *Mechanical testing of metals*, Subcommittee SC 3, *Hardness testing*.

This second edition cancels and replaces the first edition (ISO 18265:2003) which has been technically revised.

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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 this table 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 6892-1, and the calibration procedures conform with those specified in ISO 7500-1 and ISO 9513.

Annex G contains the results on the conversion of hardness values of two tool steels with the assistance of the *Verein Deutscher Eisenhüttenleute* (VDEh) which were obtained in the year 2007.

Users of this International Standard should take note of Clause 2, especially the concluding warning.

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Metallic materials — Conversion of hardness values

1 Scope

This International Standard specifies the principles of the conversion of hardness values to equivalent values in other hardness scales and to estimates of tensile strength. It gives general information on the use of the conversion tables.

The conversion tables in Annexes A to G apply to

— unalloyed and low alloy steels and cast steel,

— steels for quenching and tempering,

— steels for cold working,

— high speed steels,

— tool steels,

— hardmetals, and

— non-ferrous metals and alloys.

NOTE 1 The conversion tables in Annexes B to G 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.

NOTE 2 Annex H gives information about the effects of changes of the test procedure in the standards specifying the hardness tests.

Converted values obtained using this International Standard are only directly applicable to the exact material tested. For all other materials, they provide an indicator only. In all cases, the converted values are not intended as replacements for values obtained by the correct standard method. In particular, tensile strength estimates are the least reliable converted values in this International Standard.

Sections of this International Standard are reprinted, with permission of ASTM International, from ASTM E140 *Standard Hardness Conversion Tables for Metals Relationship among Brinell Hardness, Vickers Hardness, Rockwell Hardness, Superficial Harness, Knoop Hardness, and Scleroscope Hardness*.

2 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.

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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.

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 drawn for hardness-to-hardness conversions. This may be done as long as the following conditions are fulfilled.

— The hardness test method used is only employed internally, and the results obtained will 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 shall have been derived from a sufficiently large number of parallel experiments using both scales and carried out on the material in question.

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

However, the conversion values in this International Standard are informative only. A measurement made according to the correct hardness (or tensile) standard for the scale being reported shall always take precedence over a hardness (or strength) value derived from a conversion table within this International Standard. Similarly, a value derived by conversion shall not provide sufficient grounds either for a complaint or for proof of meeting an acceptance criterion.

WARNING — In practice, an attempt is often made to establish a strong relationship between the original and converted values without taking the characteristics of the material under test into consideration. 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 References [2] and [3]).

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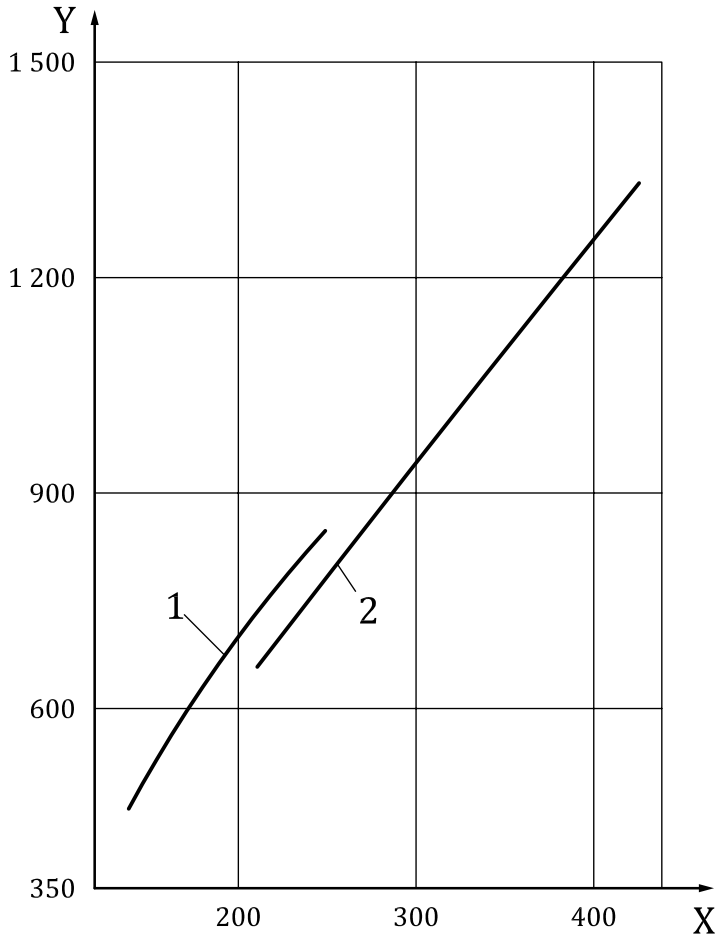

Key

X Hardness HV 30

Y Tensile strength, R_m in MPa

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

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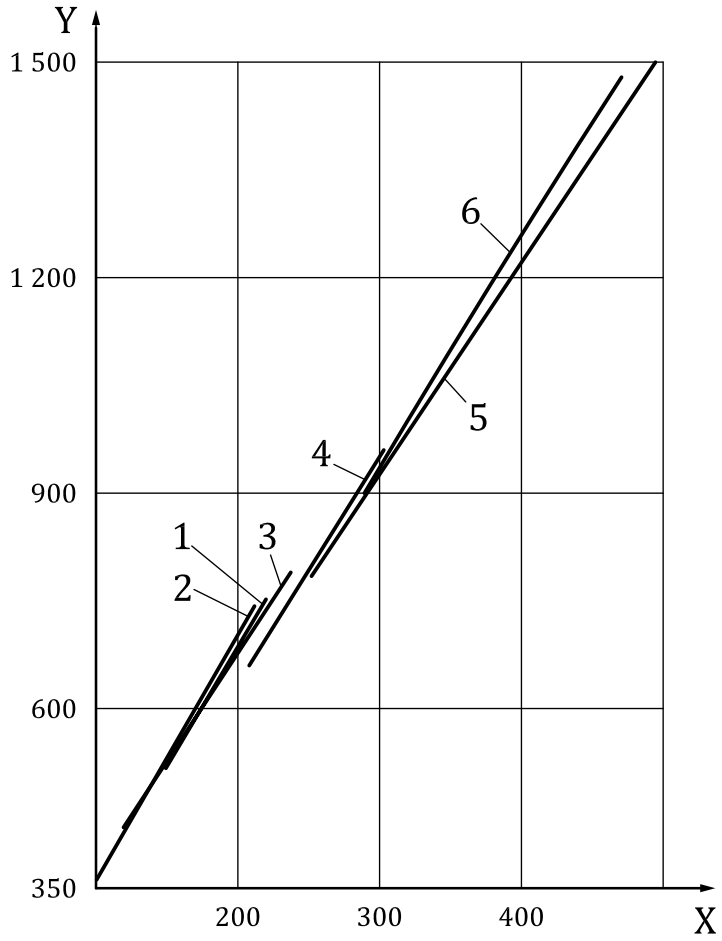

Key

X	Hardness HV30	3	R_e/R_m=0,70 to 0,79 normal annealed
Y	Tensile strength, R_m in MPa	4	R_e/R_m=0,70 to 0,79 heat treated
1	R_e/R_m=0,45 to 0,59	5	R_e/R_m=0,80 to 0,89
2	R_e/R_m=0,60 to 0,69	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

3 Application of conversion tables

3.1 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 elastic and plastic deformation. For this reason, the given conversion relationship provides greater equivalency 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 equivalency 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.

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Measurement best practice shall be defined by the hardness test adopted.

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. Different geometry indentations are affected differently by these effects and so conversions from one hardness scale to another may no longer be consistent even in the same sample.

Hardness values shall only be converted when the prescribed test method cannot be used, for example 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.

Converted values shall not be used as the basis for proof of compliance (or not) to a specification or contract (any necessary exceptions therefore require specific agreement between the parties concerned).

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 (ISO 6506-1, ISO 6507-1, ISO 6508-1) used.

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 sufficiently smooth; depending on the hardness test method and the test force a suitable method of surface preparation has to be selected, e.g. machine-finishing (for macro hardness) up to polishing (for low-force and micro hardness).

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, in which case the converted values are to be established on the basis of the mean of five individual values.

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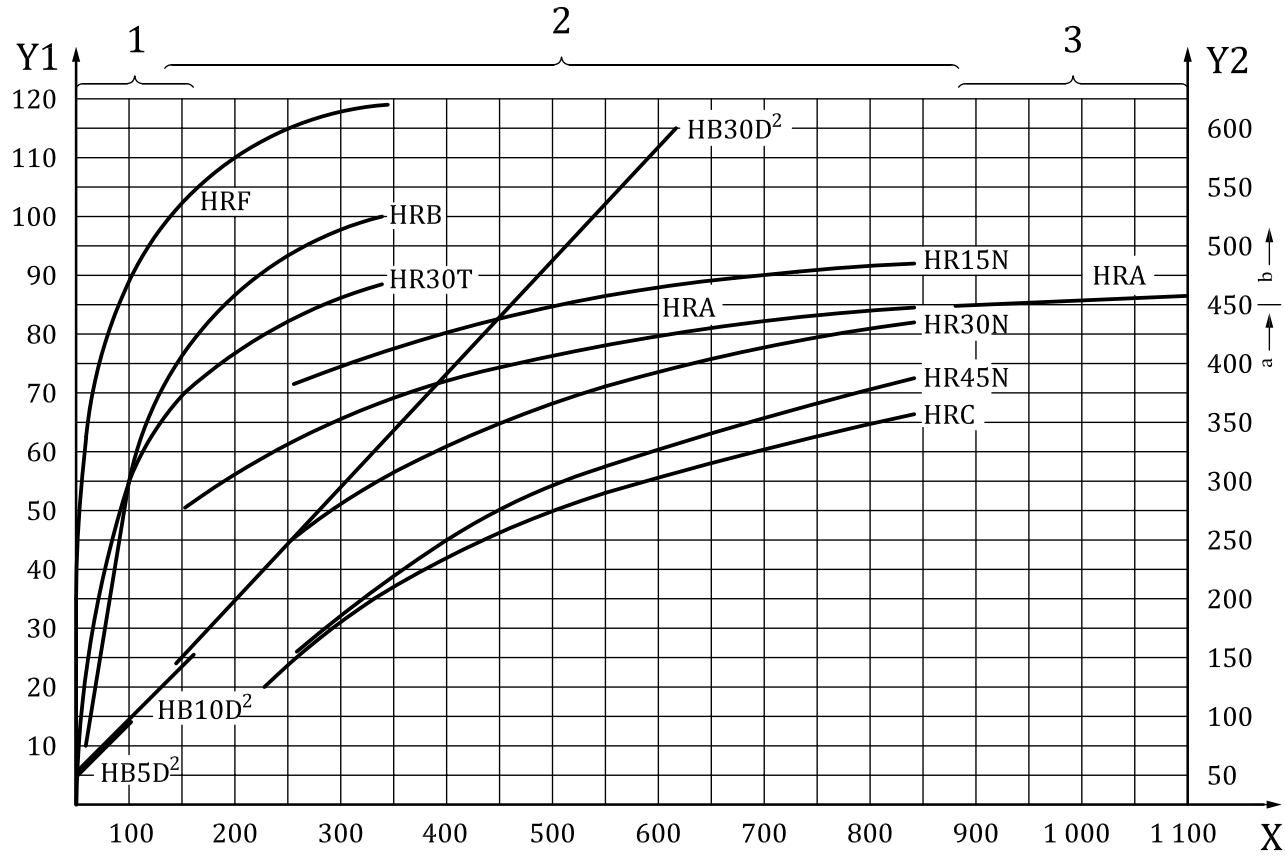

Key

X	Vickers hardness HV30	1	non-ferrous metal
Y_1	Rockwell hardness	2	steel
Y_2	Brinell hardness	3	hardmetal
a	Brinell hardness, determined with steel ball (HBS)		
b	Brinell hardness, determined with hardmetal ball (HBW)		

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

NOTE The designation "HB5D^2" corresponds to the force-diameter ratio according to ISO 6506-1.

Figure 3 — Various hardness scales compared to the Vickers scale

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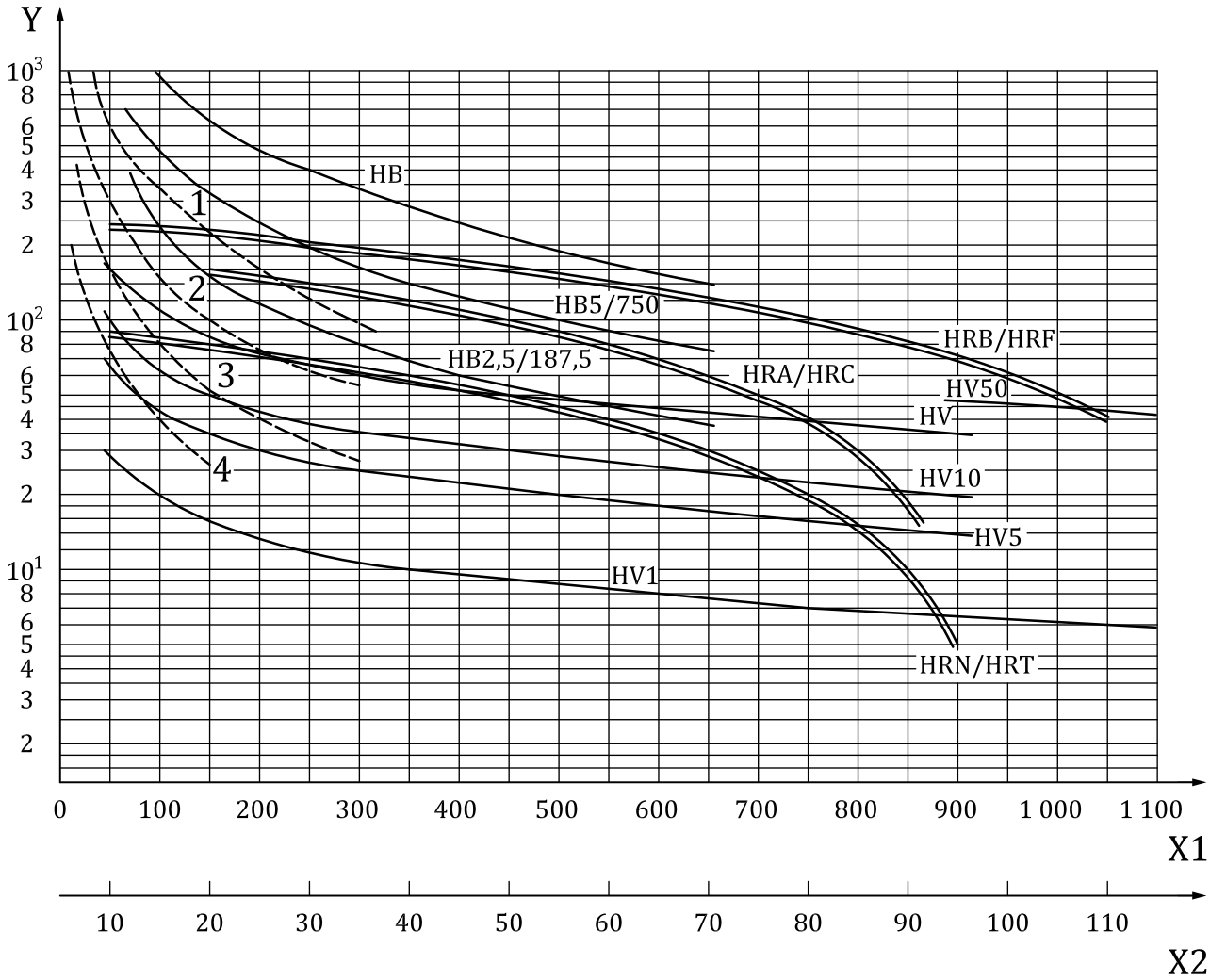

Key

X_1	Brinell hardness HB/ Vickers hardness HV	1	HB10/1 000
X_2	Rockwell hardness, HR according to its different scales	2	HB10/500 and HB 5/250
Y	Indentation, depth, µm	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

3.2 Converting values

3.2.1 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 A to G. Essential criteria which should be taken into account when selecting a hardness test method are discussed in this clause.

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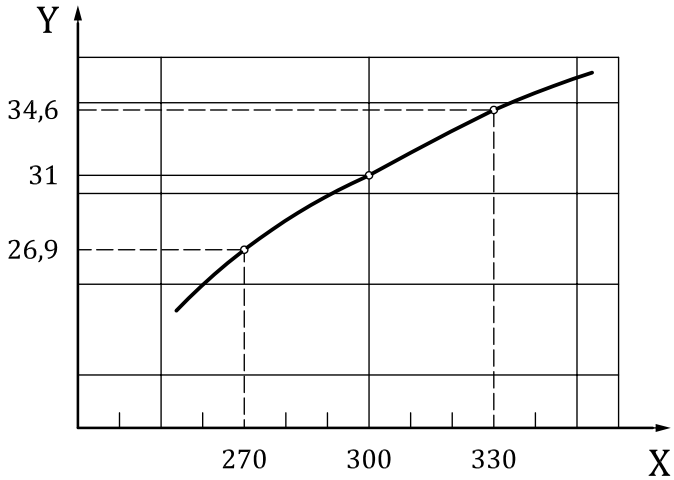
The example below illustrates the conversion of values together with their limits of error using Table C.2.

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.



Key

X HV 30

Y HRC

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

3.2.2 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 neighboring curves is possible. The reproducibility, R, is to be calculated on the basis of five measurements as shown in 3.4.2 for various hardness test methods.

The uncertainty curves only take account of the effects of the random errors of the measured value on the converted value. However, they do not take account of 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 3.4. For this reason, hardness testing machines are to 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

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hardness testing. Figure 6 illustrates the determination of the uncertainty, u, of a converted hardness value (dashed line) according to the example below.

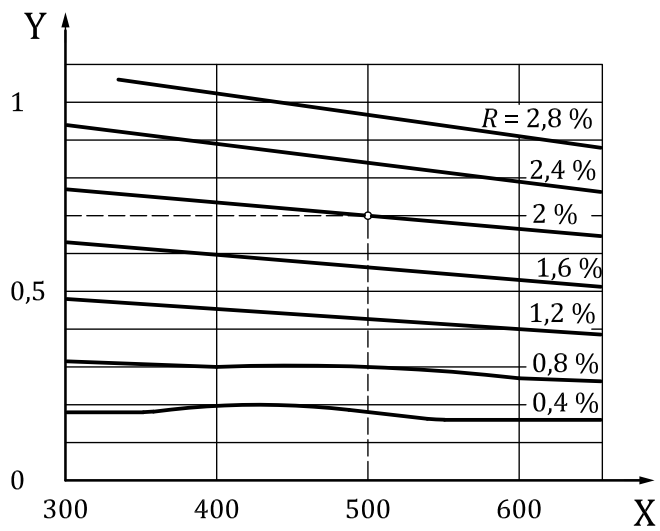
EXAMPLE

— 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



Key

X $\bar{H}_K$ in HV 30

Y u in HRC

Figure 6 — Determining uncertainty of a converted hardness value (example)

3.3 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

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

Conversion ISO 18265 – (60,2 ±1,0) HRC – C.2 – HV 30

Standard number

Converted hardness value, with uncertainty

Table used for conversion

Original hardness test method used

EXAMPLE 3 Conversions into tensile strength values are 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

3.4 Notes on use of conversion tables

3.4.1 Selection of alternative hardness test methods

3.4.1.1 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 (y-axes), 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.

3.4.1.2 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.

3.4.1.3 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.

3.4.2 Calculating the reproducibility limit, *R*

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

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For HRB and HRF testing:

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

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

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

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:

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

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.

3.4.3 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 50. 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 50, 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 still would lead to a deviation of 130 HV 50 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.

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Annex A
(informative)

Conversion table for unalloyed, low alloy steels and cast steel

WARNING — Hardness conversions are no substitute for direct measurements. These tables should be used with caution and only in accordance with the principles of conversions, see Clause 2.

The values in this table are considered to be estimates for indication only. The hardness values lie outside the defined conditions of the relevant hardness test standard. The tensile strength values were not obtained under reproducible conditions and it is now impossible to determine the uncertainty of the data.

A.1 Hardness-to-hardness conversion

When considering the confidence level of converted hardness values, the uncertainty of the hardness test method as well as the width of the conversion scatterband must be taken into account, as shown in Figure A.1. Curve a characterizes the mean conversion relationship upon which the values given in this Annex are based. Curves b_1 and b_2 delineate the areas on either side of a which take into consideration the different elasticities of the steels tested. In an ideal conversion, the hardness value x_0 becomes y_0. Taking account of the scatterband between b_1 and b_2, practically every hardness value between y_{01} and y_{02} is obtainable. It should be borne in mind that, because the hardness value x_0 is associated with the uncertainty of the relevant test method, the actual hardness can fluctuate between x_1 and x_2 and thus the converted value will lie between y_{11} and y_{22}.

NOTE In the interlaboratory tests carried out by the VDEh (see the Introduction), the evaluation of about 700 results for the conversion between HV10 values and HB values produced (graphically depicted) scatterband widths of ±24 HV10 and ±23 HB, respectively. Regression analysis was not performed.

A.2 Hardness-to-tensile-strength conversion

While hardness-to-hardness conversion involves considerable scatter and systematic errors, conversion of hardness to tensile strength values produces even greater scattering. One reason for this is that a great uncertainty can be affected by microstructural changes (e.g. resulting from heat treatment or cold working) within even the same type of steel.

The tensile strength values given in Table A.1 are therefore only approximate values which cannot take the place of the results of tensile testing.

NOTE 1 In the interlaboratory tests carried out by the VDEh (see Introduction), the evaluation of about 700 results for the conversion from HV10 values to tensile strength values produced (graphically depicted) scatterband widths of ± 25 HV10 and ± 85 N/mm^2, respectively. It was also shown that systematic deviations from the mean were possible for particular steel groups. For instance, for pearlitic steels within the hardness range of 300 HV10 to 500 HV10, it was found that the converted tensile values were, on the average, about 100 MPa higher than those listed in Table A.1. Regression analysis was not performed.

NOTE 2 Since high-strength structural steels are now being tested at an increasing rate, the tensile strengths in Table A.1 were extended up to 2 180 MPa. The tensile strength values in this table are based on results of extensive interlaboratory tests by the VDEh in the hardness range up to about 420 HV10, and on the results from Reference [4] which are gradually approached by the values in the range above 420 HV10.

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Table A.1 — Conversion of hardness-to-hardness or hardness-to-tensile-strength values for unalloyed and low alloy steels and cast steel

Tensile strength	Vickers hardness	Brinell hardness	Rockwell hardness							
MPa	HV10	HB [a]	HRB	HRF	HRC	HRA	HRD	HR15N	HR30N	HR45N
255	80	76,0								
270	85	80,7	41,0							
285	90	85,5	48,0	82,6						
305	95	90,2	52,0							
320	100	95,0	56,2	87,0						
335	105	99,8								
350	110	105	62,3	90,5						
370	115	109								
385	120	114	66,7	93,6						
400	125	119								
415	130	124	71,2	96,4						
430	135	128								
450	140	133	75,0	99,0						
465	145	138								
480	150	143	78,7	101,4						
495	155	147								
510	160	152	81,7	103,6						
530	165	156								
545	170	162	85,0	105,5						
560	175	166								
575	180	171	87,1	107,2						
595	185	176								
610	190	181	89,5	108,7						
625	195	185								
640	200	190	91,5	110,1						
660	205	195	92,5							
675	210	199	93,5	111,3						
690	215	204	94,0							
705	220	209	95,0	112,4						
720	225	214	96,0							

[a] Brinell hardness values up to 450 HB were determined using a steel ball indenter, those above this value were determined with a hardmetal ball.

NOTE 1 Values in parentheses are those lying outside the defined range of the standard test method but which may used as estimates.

NOTE 2 The value of the tension test are not based on method A (10.3 Testing rate based on close-loop control at the rate of the extension) in ISO 6892-1:2009

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Table A.1 *(continued)*

Tensile strength	Vickers hardness	Brinell hardness	Rockwell hardness							
MPa	HV10	HB [a]	HRB	HRF	HRC	HRA	HRD	HR15N	HR30N	HR45N
740	230	219	96,7	113,4						
755	235	223								
770	240	228	98,1	114,3	20,3	60,7	40,3	69,6	41,7	19,9
785	245	233			21,3	61,2	41,1	70,1	42,5	21,1
800	250	238	99,5	115,1	22,2	61,6	41,7	70,6	43,4	22,2
820	255	242			23,1	62,0	42,2	71,1	44,2	23,2
835	260	247	(101)		24,0	62,4	43,1	71,6	45,0	24,3
850	265	252			24,8	62,7	43,7	72,1	45,7	25,2
865	270	257	(102)		25,6	63,1	44,3	72,6	46,4	26,2
880	275	261			26,4	63,5	44,9	73,0	47,2	27,1
900	280	266	(104)		27,1	63,8	45,3	73,4	47,8	27,9
915	285	271			27,8	64,2	46,0	73,8	48,4	28,7
930	290	276	(105)		28,5	64,5	46,5	74,2	49,0	29,5
950	295	280			29,2	64,8	47,1	74,6	49,7	30,4
965	300	285			29,8	65,2	47,5	74,9	50,2	31,1
995	310	295			31,0	65,8	48,4	75,6	51,3	32,5
1 030	320	304			32,2	66,4	49,4	76,2	52,3	33,9
1 060	330	314			33,3	67,0	50,2	76,8	53,6	35,2
1 095	340	323			34,4	67,6	51,1	77,4	54,4	36,5
1 125	350	333			35,5	68,1	51,9	78,0	55,4	37,8
1 155	360	342			36,6	68,7	52,8	78,6	56,4	39,1
1 190	370	352			37,7	69,2	53,6	79,2	57,4	40,4
1 220	380	361			38,8	69,8	54,4	79,8	58,4	41,7
1 255	390	371			39,8	70,3	55,3	80,3	59,3	42,9
1 290	400	380			40,8	70,8	56,0	80,8	60,2	44,1
1 320	410	390			41,8	71,4	56,8	81,4	61,1	45,3
1 350	420	399			42,7	71,8	57,5	81,8	61,9	46,4
1 385	430	409			43,6	72,3	58,2	82,3	62,7	47,4
1 420	440	418			44,5	72,8	58,8	82,8	63,5	48,4
1 455	450	428			45,3	73,3	59,4	83,2	64,3	49,4

[a] Brinell hardness values up to 450 HB were determined using a steel ball indenter, those above this value were determined with a hardmetal ball.

NOTE 1 Values in parentheses are those lying outside the defined range of the standard test method but which may used as estimates.

NOTE 2 The value of the tension test are not based on method A (10.3 Testing rate based on close-loop control at the rate of the extension) in ISO 6892-1:2009

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Table A.1 *(continued)*

Tensile strength	Vickers hardness	Brinell hardness	Rockwell hardness							
MPa	HV10	HB [a]	HRB	HRF	HRC	HRA	HRD	HR15N	HR30N	HR45N
1 485	460	437			46,1	73,6	60,1	83,6	64,9	50,4
1 520	470	447			46,9	74,1	60,7	83,9	65,7	51,3
1 555	480	456			47,7	74,5	61,3	84,3	66,4	52,2
1 595	490	466			48,4	74,9	61,6	84,7	67,1	53,1
1 630	500	475			49,1	75,3	62,2	85,0	67,7	53,9
1 665	510	485			49,8	75,7	62,9	85,4	68,3	54,7
1 700	520	494			50,5	76,1	63,5	85,7	69,0	55,6
1 740	530	504			51,1	76,4	63,9	86,0	69,5	56,2
1 775	540	513			51,7	76,7	64,4	86,3	70,0	57,0
1 810	550	523			52,3	77,0	64,8	86,6	70,5	57,8
1 845	560	532			53,0	77,4	65,4	86,9	71,2	58,6
1 880	570	542			53,6	77,8	65,8	87,2	71,7	59,3
1 920	580	551			54,1	78,0	66,2	87,5	72,1	59,9
1 955	590	561			54,7	78,4	66,7	87,8	72,7	60,5
1 995	600	570			55,2	78,6	67,0	88,0	73,2	61,2
2 030	610	580			55,7	78,9	67,5	88,2	73,7	61,7
2 070	620	589			56,3	79,2	67,9	88,5	74,2	62,4
2 105	630	599			56,8	79,5	68,3	88,8	74,6	63,0
2 145	640	608			57,3	79,8	68,7	89,0	75,1	63,5
2 180	650	618			57,8	80,0	69,0	89,2	75,5	64,1
	660				58,3	80,3	69,4	89,5	75,9	64,7
	670				58,8	80,6	69,8	89,7	76,4	65,3
	680				59,2	80,8	70,1	89,8	76,8	65,7
	690				59,7	81,1	70,5	90,1	77,2	66,2
	700				60,1	81,3	70,8	90,3	77,6	66,7
	720				61,0	81,8	71,5	90,7	78,4	67,7
	740				61,8	82,2	72,1	91,0	79,1	68,6
	760				62,5	82,6	72,6	91,2	79,7	69,4
	780				63,3	83,0	73,3	91,5	80,4	70,2
	800				64,0	83,4	73,8	91,8	81,1	71,0

[a] Brinell hardness values up to 450 HB were determined using a steel ball indenter, those above this value were determined with a hardmetal ball.

NOTE 1 Values in parentheses are those lying outside the defined range of the standard test method but which may used as estimates.

NOTE 2 The value of the tension test are not based on method A (10.3 Testing rate based on close-loop control at the rate of the extension) in ISO 6892-1:2009

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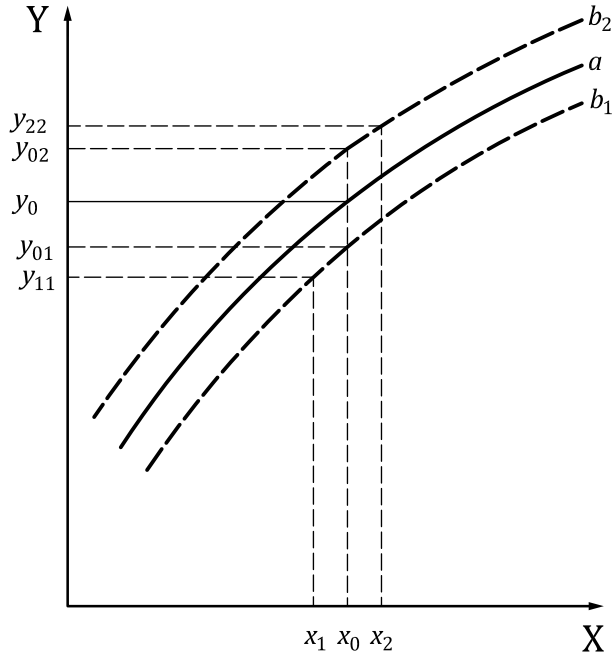
Table A.1 *(continued)*

Tensile strength	Vickers hardness	Brinell hardness	Rockwell hardness							
MPa	HV10	HB [a]	HRB	HRF	HRC	HRA	HRD	HR15N	HR30N	HR45N
	820				64,7	83,8	74,3	92,1	81,7	71,8
	840				65,3	84,1	74,8	92,3	82,2	72,2
	860				65,9	84,4	75,3	92,5	82,7	73,1
	880				66,4	84,7	75,7	92,7	83,1	73,6
	900				67,0	85,0	76,1	92,9	83,6	74,2
	920				67,5	85,3	76,5	93,0	84,0	74,8
	940				68,0	85,6	76,9	93,2	84,4	75,4

[a] Brinell hardness values up to 450 HB were determined using a steel ball indenter, those above this value were determined with a hardmetal ball.

NOTE 1 Values in parentheses are those lying outside the defined range of the standard test method but which may used as estimates.

NOTE 2 The value of the tension test are not based on method A (10.3 Testing rate based on close-loop control at the rate of the extension) in ISO 6892-1:2009



Key

X determined hardness value

Y converted value

CAUTION — There may be very large scatter bands in the conversions of different kinds of cast steel.

Figure A.1 — Scatter band for hardness-to-hardness conversion (schematic)

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Annex B
(informative)

Conversion tables for steels for quenching and tempering

WARNING — Hardness conversions are no substitute for direct measurements. These tables should be used with caution and only in accordance with the principles of conversions, see Clause 2.

The values and curves presented in this Annex are based on a report of the *Physikalisch-Technische Bundesanstalt* (PTB),[1] the German national institute for science and technology, and are reproduced with their permission (see also the Introduction for further information).

The values in these conversion tables are based on the results of testing carried out on steels as in TGL 6547 that have been quenched and tempered. The steel grades that were tested are listed in Table B.1, which also provides an overview of the former designations used in the TGL standard along with the corresponding designations as in EN 10083-1. Tables B.2 to B.4 give conversion values for the steels in various heat treatment conditions, while Tables B.5 to B.7 give an overview of the uncertainty curves presented in Figures B.1 to B.68 which are to be used in conjunction with the conversion tables.

NOTE A useful reference book is [24]. It provides information for the comparison of different national and international steel designations with regard to their compositions.

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Table B.1 — Quenching and tempering steels tested

Steel grade (as in TGL 6547)	Steel grade (as in EN 10083-1)	
	Material no.	Name
C25	1.1158	C25E
C35	1.1180	C35R
CK45	1.1191	C45E
CK55[a]	1.1203	C55E
C60	1.1223	C60R
CK67 [b]	[c]	[c]
24CrMoV5.5 [a]	[c]	[c]
30CrMoV9	1.7707	30CrMoV9 [d]
30Mn5	1.1165	30Mn5 [d]
34Cr4	1.7033	34Cr4
37MnSi5	1.5122	37MnSi5 [d]
38CrSi6	1.7038	37CrS4
40Cr4	1.7035	41Cr4
42CrMo4	1.7225	42CrMo4
42MnV7	1.5223	42MnV7 [d]
50CrV4	1.8159	51CrV4
50MnSi4	1.5131	50MnSi4 [d]
60CrMo4 [a]	1.7228	50CrMo4

[a]Not included in TGL 6547.

[b]As in TGL 7975.

[c]Not included in EN 10083-1 and in DIN 17200.

[d]According to DIN 17200:1987-03 (withdrawn, replaced by EN 10083-1) but not included in EN 10083-1.

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Table B.2 — Conversion of hardness-to-hardness and hardness-to-tensile-strength values for quenching and tempering steels in the quenched tempered conditions

HV	HBW	HRC	HRA	HR45N	HR30N	HR15N	HRB	HRF	HR45T	HR30T	HR15T	R_m
210	205	15,3	57,2	13,4	36,1	65,2	94,8	110,4	65,4	76,8	89,2	651
220	215	17,4	58,4	15,9	38,1	66,5	96,7	111,4	67,6	78,5	90,0	683
230	225	19,3	59,6	18,2	40,4	67,8	98,4	112,4	69,6	80,0	90,8	716
240	235	21,2	60,6	20,4	41,8	68,9	100,0	113,3	71,4	81,4	91,4	748
250	245	22,9	61,6	22,5	43,4	70,0	101,4	114,1	73,0	82,5	92,0	781
260	255	24,6	62,5	24,4	45,0	71,0	102,7	114,9	74,4	83,6	92,5	813
270	266	26,2	63,4	26,3	46,5	72,0	103,9	115,6	75,7	84,5	90,0	845
280	276	27,7	64,3	28,1	47,9	72,9	105,0	116,2	76,9	85,4	90,8	877
290	286	29,1	65,0	29,8	49,3	73,7	106,0	116,8	77,9	86,1	91,4	909
300	296	30,5	65,8	31,4	50,5	74,5	106,9	117,3	78,9	86,8	92,0	940
310	306	31,8	66,5	32,9	51,8	75,3	107,7	117,8	79,7	87,4	94,3	972
320	316	33,1	67,2	34,4	52,9	76,0	108,5	118,3	80,5	88,0	94,6	1 003
330	326	34,3	67,8	35,8	54,0	76,7	109,2	118,8	81,2	88,4	94,8	1 035
340	336	35,4	68,5	37,2	55,1	77,3	109,9	119,2	81,9	88,9	95,0	1 070
350	345	36,5	69,1	38,4	56,1	78,0	110,5	119,6	82,5	89,3	95,2	1 097
360	355	37,6	69,6	39,7	57,1	78,6	111,1	119,9	83,0	89,6	95,4	1 128
370	365	38,6	70,2	40,9	58,0	79,1	111,7	120,3	83,5	89,9	95,5	1 159
380	375	39,6	70,7	42,0	58,9	79,7	112,2	120,6	84,0	90,2	95,6	1 189
390	385	40,6	71,2	43,2	59,8	80,2	112,7	120,9	84,4	90,5	95,7	1 220
400	395	41,5	71,7	44,2	60,6	80,7	113,1	121,2	84,8	90,7	95,8	1 250
410	405	42,4	72,2	45,3	61,4	81,2	113,6	121,5	85,1	90,9	95,9	1 281
420	414	43,2	72,6	46,3	62,2	81,6						1 311
430	424	44,1	73,0	47,2	63,0	82,1						1 341
440	434	44,9	73,5	48,2	63,7	82,5						1 371
450	444	45,7	73,9	49,1	64,4	82,9						1 401
460	453	46,4	74,3	50,0	65,1	83,3						1 430
470	463	47,2	74,6	50,8	65,8	83,7						1 460
480	473	47,9	75,0	51,7	66,4	84,1						
490	482	48,6	75,4	52,5	67,0	84,4						
500	492	49,2	75,7	53,2	67,6	84,8						
510	501	49,9	76,0	54,0	68,2	85,1						
520	511	50,5	76,4	54,8	68,8	85,4						

NOTE 1 The values of the tension tests are not based on method A (10.3 Testing rate based on close-loop control at the rate of the extension) in ISO 6892-1:2009.

NOTE 2 If only HV is given without a number, then most probably HV30 is meant.

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Table B.2 *(continued)*

HV	HBW	HRC	HRA	HR45N	HR30N	HR15N	HRB	HRF	HR45T	HR30T	HR15T	R_m
530	520	51,2	76,7	55,5	69,3	85,8						
540	530	51,8	77,0	56,2	69,9	86,1						
550	539	52,4	77,3	56,8	70,4	86,4						
560	549	52,9	77,6	57,5	70,9	86,6						
570	558	53,5	77,9	58,2	71,4	86,9						
580	568	54,0	78,2	58,8	71,9	87,2						
590	577	54,6	78,4	59,4	72,4	87,5						
600	586	55,1	78,7	60,0	72,8	87,7						
610	596	55,6	78,9	60,6	73,3	88,0						
620	605	56,1	79,2	61,2	73,7	88,2						
630	614	56,6	79,4	61,7	74,2	88,5						
640	623	57,1	79,7	62,3	74,6	88,7						
650	632	57,5	79,9	62,8	75,0	88,9						

NOTE 1 The values of the tension tests are not based on method A (10.3 Testing rate based on close-loop control at the rate of the extension) in ISO 6892-1:2009.

NOTE 2 If only HV is given without a number, then most probably HV30 is meant.

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Table B.3 — Conversion of hardness-to-hardness or hardness-to-tensile-strength values for quenching and tempering steels in the untreated, soft annealed or normalized conditions

HV	HBW	HRC	HRA	HR45N	HR30N	HR15N	HRB	HRF	HR45T	HR30T	HR15T	R_m
140												460
150	152	–	48,4	–	21,5	56,6	81,0	102,5	51,6	68,4	85,1	503
160	162	1,0	50,2	–	24,4	58,3	83,9	104,1	54,8	70,5	86,2	544
170	173	4,0	51,9	0,8	27,0	60,0	86,6	105,6	57,7	72,4	87,2	585
180	183	6,8	53,4	4,0	29,5	61,5	89,0	106,9	60,2	74,1	88,0	624
190	193	9,4	54,8	7,0	31,8	62,9	91,2	108,1	62,5	75,6	88,8	661
200	203	11,9	56,2	9,9	34,0	64,3	93,2	109,2	64,6	77,0	89,4	697
210	214	14,2	57,4	12,6	36,1	65,6	95,0	110,3	66,4	78,3	90,0	732
220	223	16,4	58,6	15,1	38,1	66,8	96,7	111,2	68,2	79,5	90,6	765
230	233	18,5	59,7	17,6	39,9	67,9	98,3	112,2	69,7	80,6	91,1	796
240	243	20,5	60,7	19,9	41,7	69,0	99,8	113,0	71,2	81,6	91,6	826
250	252	22,4	61,7	22,1	43,3	70,0	101,2	113,8	72,5	82,6	92,0	
260	262	24,3	62,6	24,2	44,9	71,0	102,5	114,6	73,7	83,5	92,4	
270	271	26,0	63,5	26,2	46,4	72,0	103,7	115,3	74,9	84,3	92,7	
280	280	27,7	64,3	28,1	47,9	72,9	104,9	116,0	75,9	85,1	93,0	
290	289	29,2	65,1	29,9	49,2	73,7	106,0	116,6	76,9	85,8	93,3	
300	298	30,8	65,8	31,6	50,6	74,6	107,0	117,2	77,9	86,5	93,6	
310	307	32,2	66,6	33,6	51,8	75,4	108,0	117,8	78,8	87,1	93,9	
320	316	33,6	67,2	35,0	53,0	76,1	108,9	118,4	79,6	87,8	94,1	

NOTE 1 The values of the tension tests are not based on method A (10.3 Testing rate based on close-loop control at the rate of the extension) in ISO 6892-1:2009.

NOTE 2 If only HV is given without a number, then most probably HV30 is meant.

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