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Metallic materials — Conversion of hardness values

Matériaux métalliques — Conversion des valeurs de dureté

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Foreword

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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.

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.

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.

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.

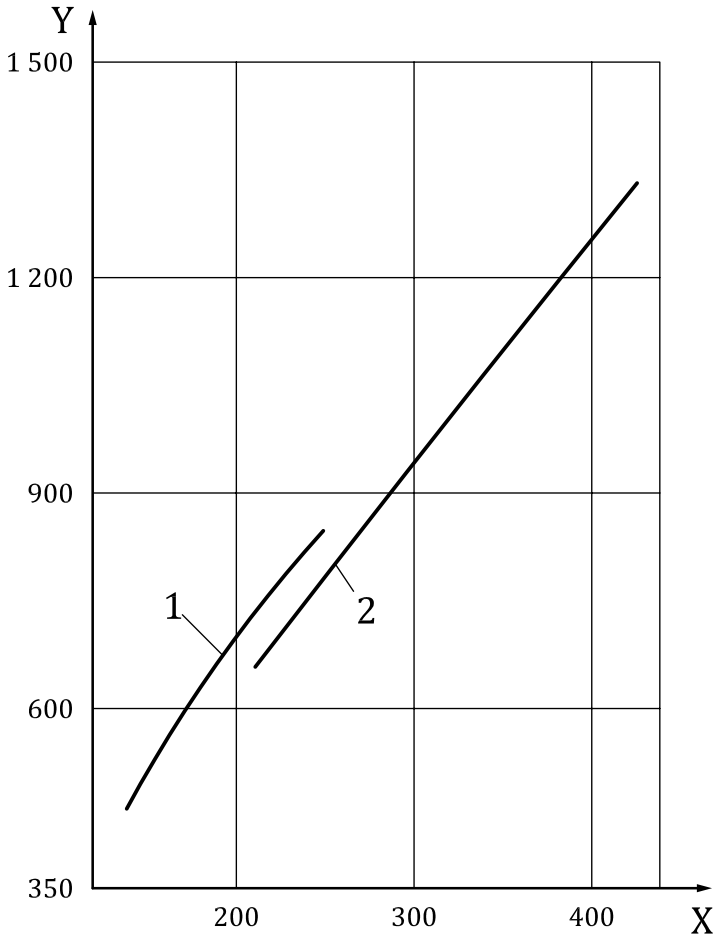
— The hardness test method used is only employed internally, and the results obtained will not be compared with those of other methods, or the details of the test procedure are defined precisely enough so that results can be reproduced by another laboratory or at another time.

— 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]).



Key

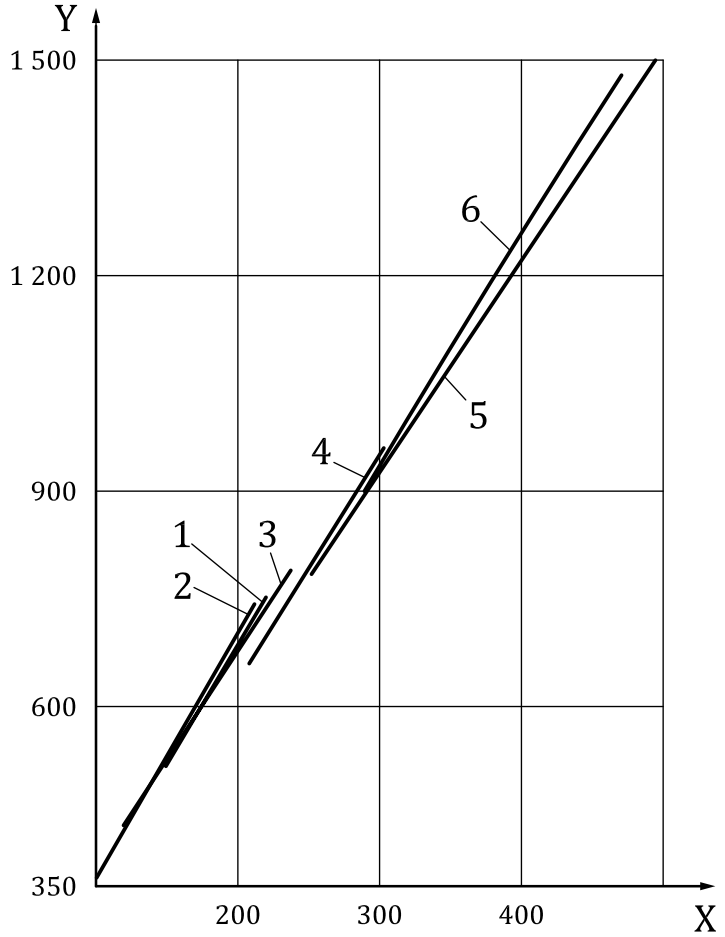
X Hardness HV 30

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



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.

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.

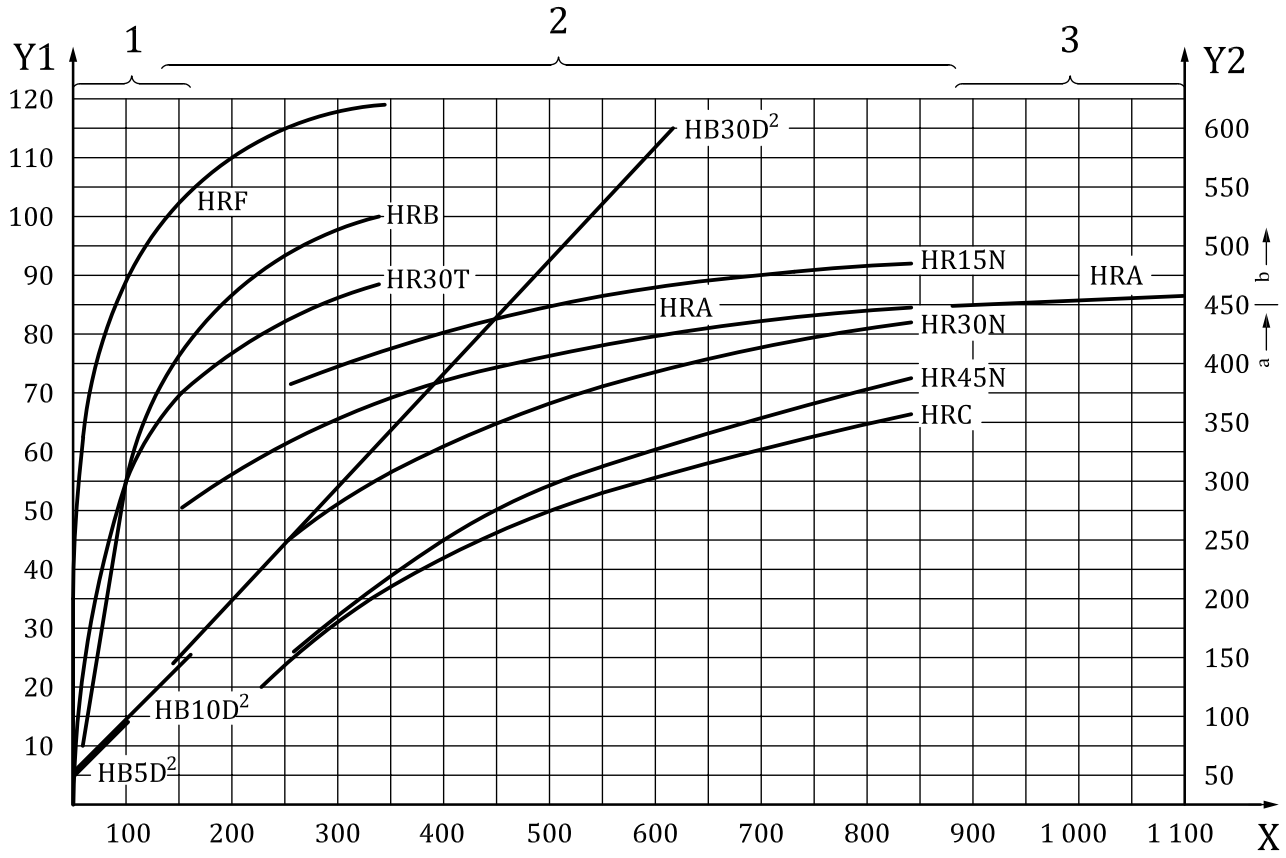
To ensure an acceptable uncertainty of measurement, the specimen surfaces shall be sufficiently smooth; depending on the hardness test method and the test force a suitable method of surface preparation has to be selected, e.g. machine-finishing (for macro hardness) up to polishing (for low-force and 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.



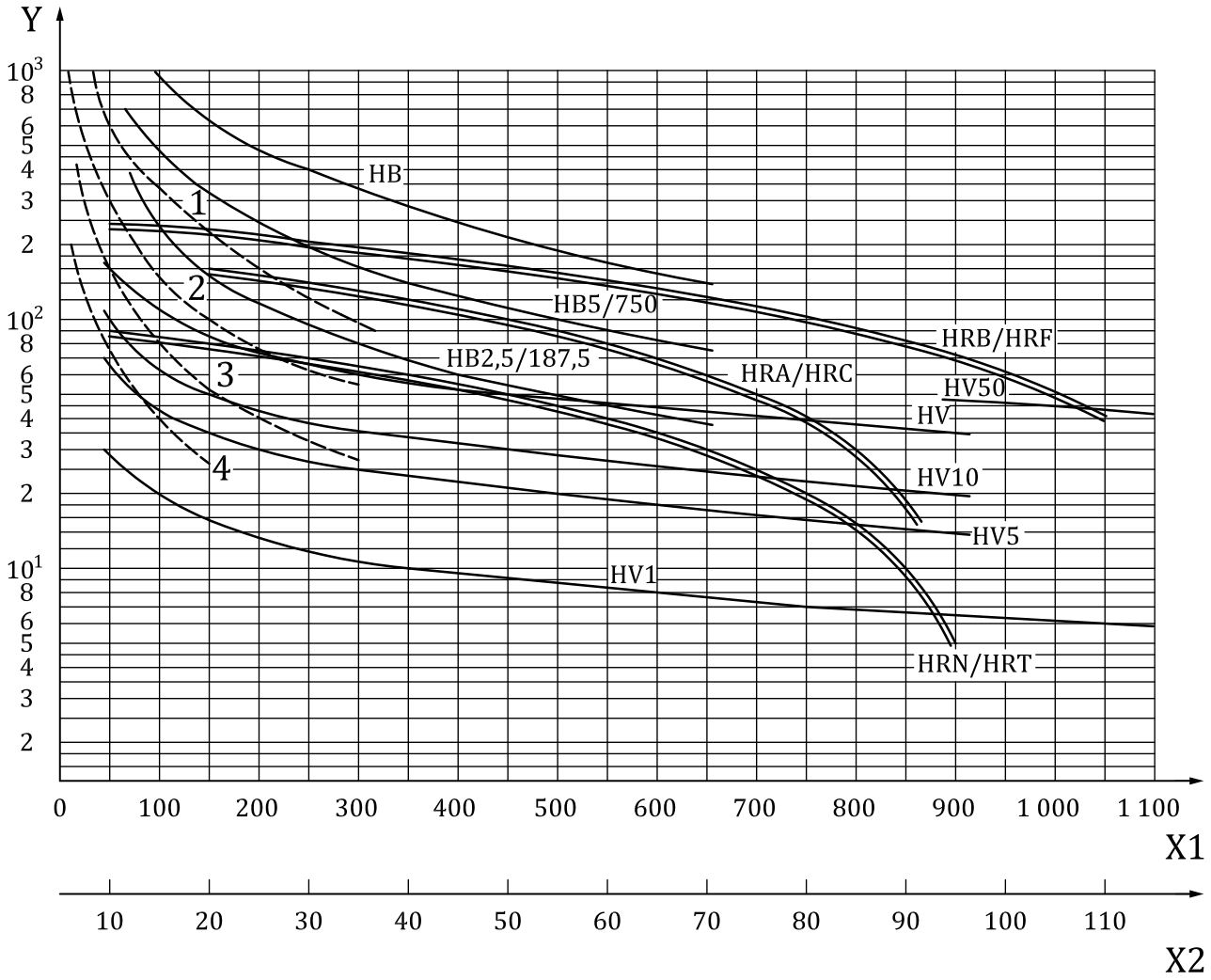
Key

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



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

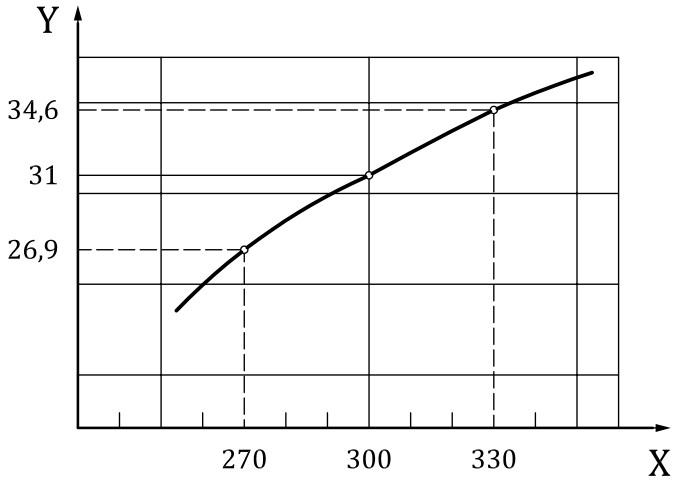
3.2.1 Limits of error

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.

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

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

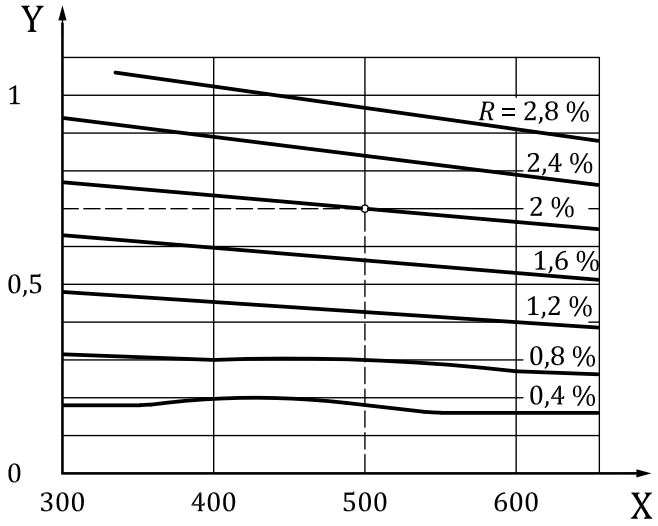
EXAMPLE

— 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

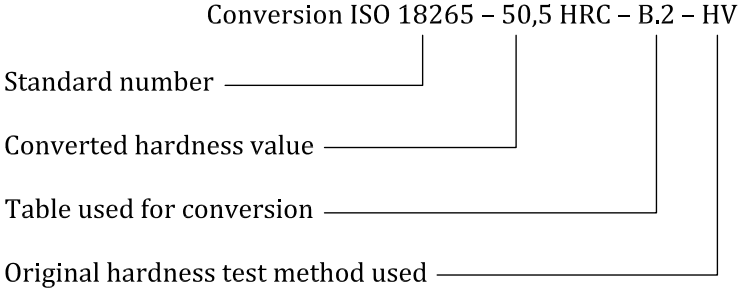
Y u in HRC

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

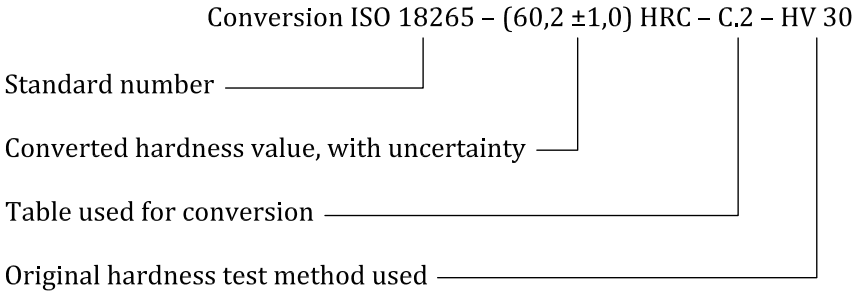
3.3 Designation of conversion results

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.

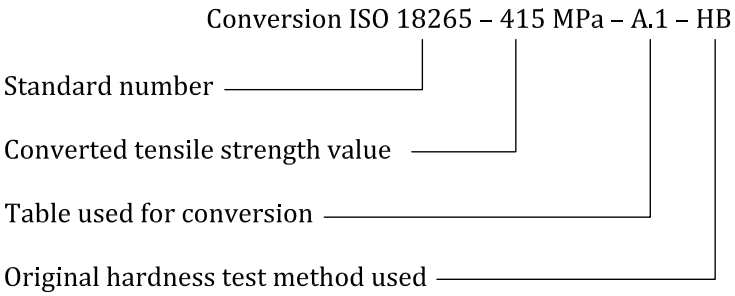
EXAMPLE 1



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:



EXAMPLE 3 Conversions into tensile strength values are expressed as follows:



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).

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.

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.

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

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

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

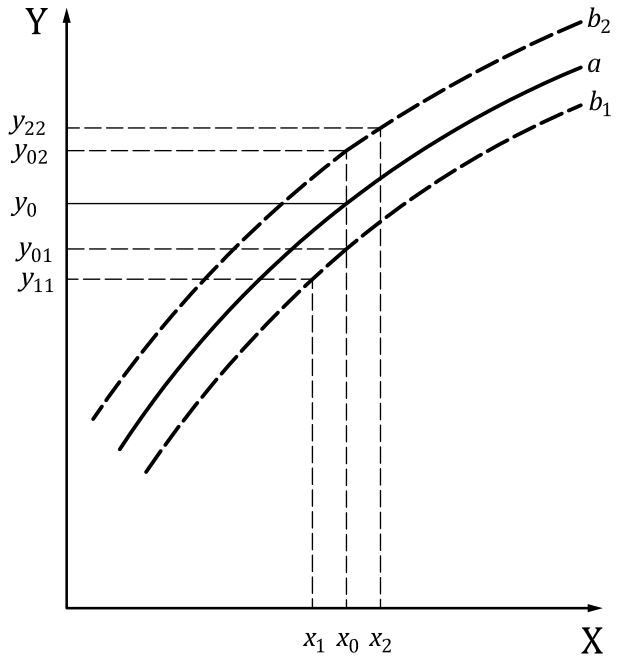
Table A.1 *(continued)*

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)

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.

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.

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.

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.

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.

Table B.4 — Conversion of hardness-to-hardness values for quenching and tempering steels in the quenched condition

HV	HBW	HRC	HRA	HR45N	HR30N	HR15N
580	572	54,0	78,1	59,5	71,4	87,2
590	576	54,4	78,4	59,6	71,9	87,4
600	580	54,8	78,6	59,9	72,3	87,6
610	585	55,2	78,8	60,2	72,8	87,8
620	591	55,6	79,1	60,5	73,2	88,0
630	597	56,1	79,3	60,9	73,6	88,2
640	604	56,5	79,6	61,4	74,1	88,4
650	611	56,9	79,8	61,8	74,5	88,7
660	619	57,4	80,1	62,4	75,0	88,9
670	627	57,8	80,3	63,0	75,4	89,1
680	636	58,3	80,6	63,6	75,8	89,4
690	646	58,7	80,9	64,2	76,2	89,6
700	656	59,2	81,1	64,9	76,7	89,8
710	666	59,7	81,4	65,6	77,1	90,1
720	677	60,1	81,7	66,4	77,5	90,3
NOTE If only HV is given without a number, then most probably HV30 is meant.						

Table B.5 — Uncertainty curves to be used for conversion as in Table B.2

To obtain uncertainty u, in	of conversion from/to	use
HB	HV/HB	Figure B.1
HV	HB/HV	Figure B.2
HRC	HV/HRC	Figure B.3
HV	HRC/HV	Figure B.4
HRA	HV/HRA	Figure B.5
HV	HRA/HV	Figure B.6
HR45N	HV/HR45N	Figure B.7
HV	HR45N/HV	Figure B.10
HR30N	HV/HR30N	Figure B.8
HV	HR30N/HV	Figure B.11
HR15N	HV/HR15N	Figure B.9
HV	HR15N/HV	Figure B.12
HRB	HV/HRB	Figure B.13
HV	HRB/HV	Figure B.14
HRF	HV/HRF	Figure B.15
HV	HRF/HV	Figure B.16
HR45T	HV/HR45T	Figure B.17
NOTE If only HV is given without a number, then most probably HV30 is meant.		

Table B.5 *(continued)*

To obtain uncertainty u, in	of conversion from/to	use
HV	HR45T/HV	Figure B.18
HR30T	HV/HR30T	Figure B.19
HV	HR30T/HV	Figure B.20
HR15T	HV/HR15T	Figure B.21
HV	HR15T/HV	Figure B.22
HRC	HRA/HRC	Figure B.23
HRC	HR30N/HRC	Figure B.24
HRB	HRF/HRB	Figure B.25
HRB	HR30T/HRB	Figure B.26
MPa	HV/R_m	Figure B.63
MPa	HB/R_m	Figure B.64
MPa	HRC/R_m	Figure B.65
NOTE If only HV is given without a number, then most probably HV30 is meant.		

Table B.6 — Uncertainty curves to be used for conversion as in Table B.3

To obtain uncertainty u, in	of conversion from/to	use
HB	HV/HB	Figure B.27
HV	HB/HV	Figure B.28
HRC	HV/HRC	Figure B.29
HV	HRC/HV	Figure B.30
HRA	HV/HRA	Figure B.31
HV	HRA/HV	Figure B.32
HR45N	HV/HR45N	Figure B.33
HV	HR45N/HV	Figure B.34
HR30N	HV/HR30N	Figure B.35
HV	HR30N/HV	Figure B.36
HR15N	HV/HR15N	Figure B.37
HV	HR15N/HV	Figure B.38
HRB	HV/HRB	Figure B.39
HV	HRB/HV	Figure B.40
HRF	HV/HRF	Figure B.41
HV	HRF/HV	Figure B.42
HR45T	HV/HR45T	Figure B.43
HV	HR45T/HV	Figure B.44
HR30T	HV/HR30T	Figure B.45
HV	HR30T/HV	Figure B.46
HR15T	HV/HR15T	Figure B.47
HV	HR15T/HV	Figure B.48
HRC	HR30N/HRC	Figure B.49
HRB	HR30T/HRB	Figure B.50
MPa	HV/R_m	Figure B.66
MPa	HB/R_m	Figure B.67
MPa	HRC/R_m	Figure B.68
NOTE If only HV is given without a number, then most probably HV30 is meant.		

Table B.7 — Uncertainty curves to be used for conversion as in Table B.4

To obtain uncertainty *u*, in	of conversion from/to	use
HB	HV/HB	Figure B.51
HV	HB/HV	Figure B.52
HRC	HV/HRC	Figure B.53
HV	HRC/HV	Figure B.54
HRA	HV/HRA	Figure B.55
HV	HRA/HV	Figure B.56
HR45N	HV/HR45N	Figure B.57
HV	HR45N/HV	Figure B.58
HR30N	HV/HR30N	Figure B.59
HV	HR30N/HV	Figure B.60
HR15N	HV/HR15N	Figure B.61
HV	HR15N/HV	Figure B.62
NOTE If only HV is given without a number, then most probably HV30 is meant.		

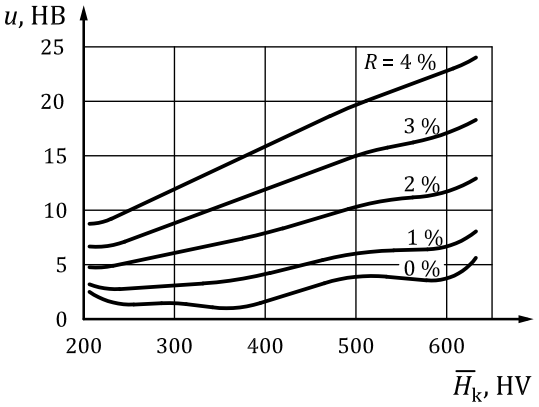


Figure B.1

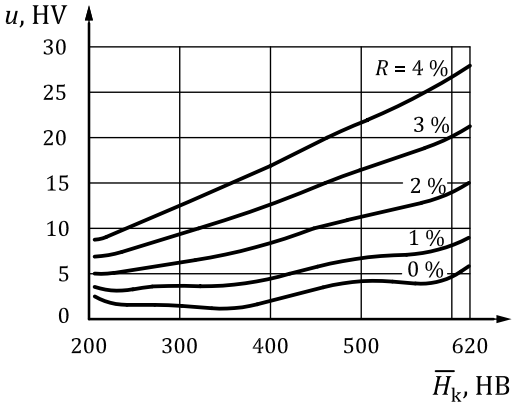


Figure B.2

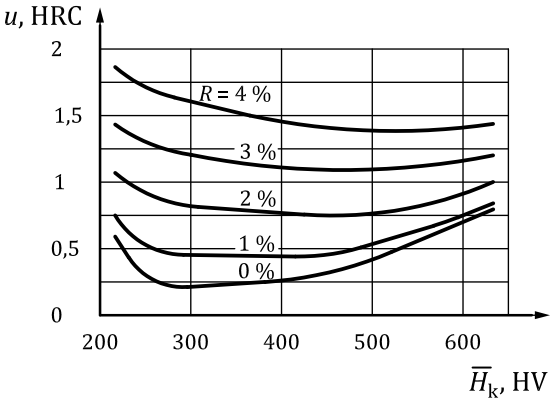


Figure B.3

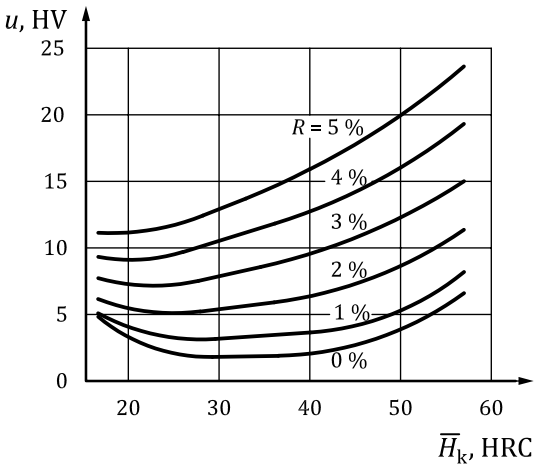


Figure B.4

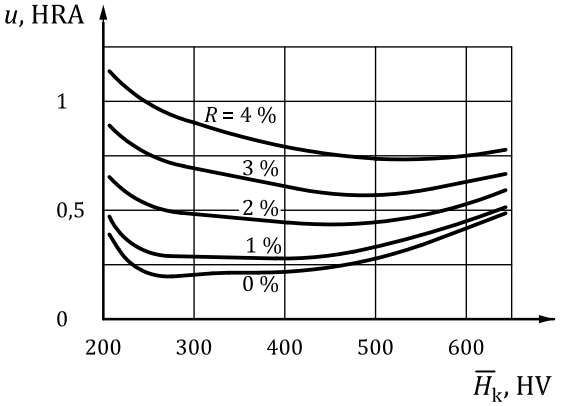


Figure B.5

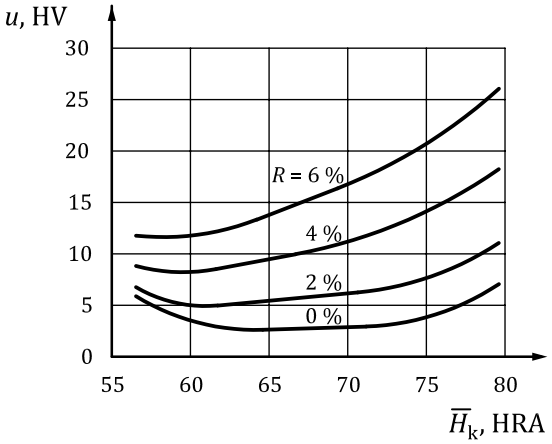
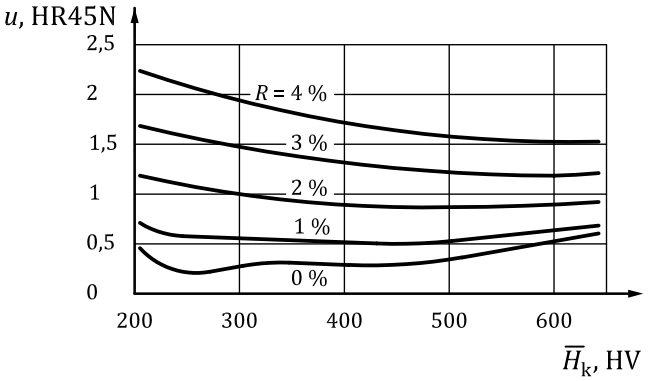


Figure B.6



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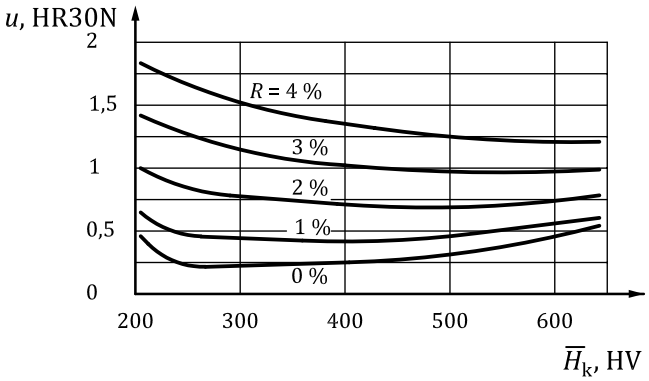

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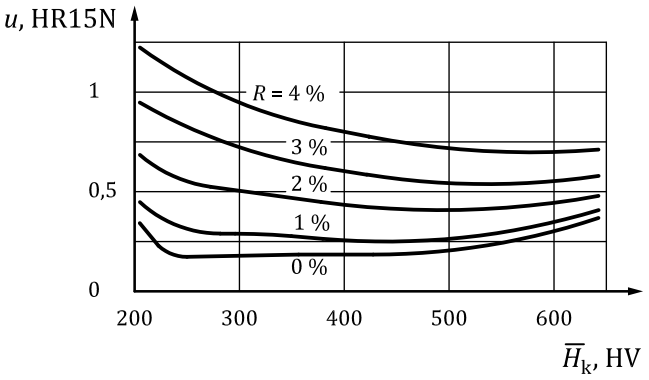

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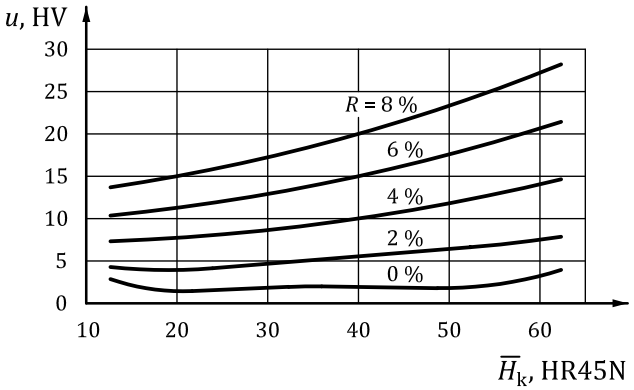

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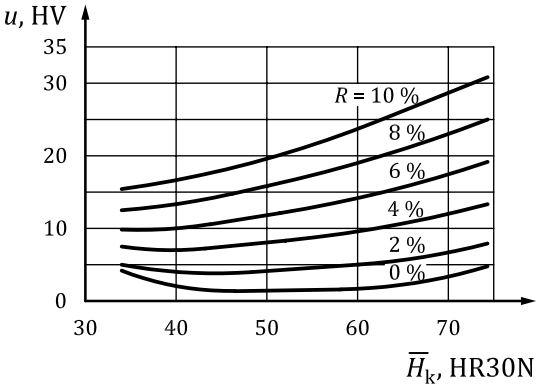

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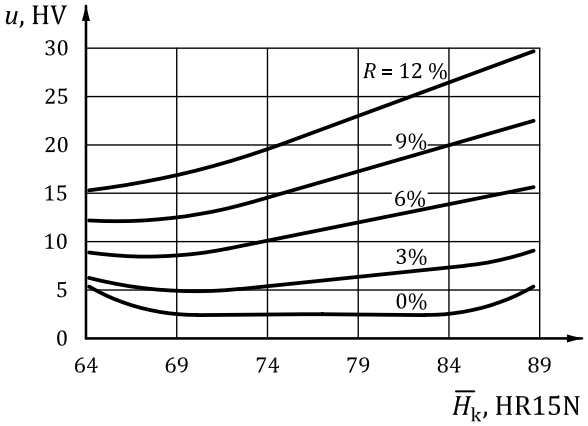

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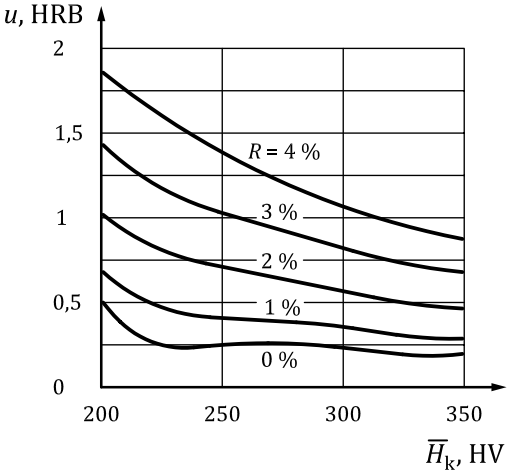

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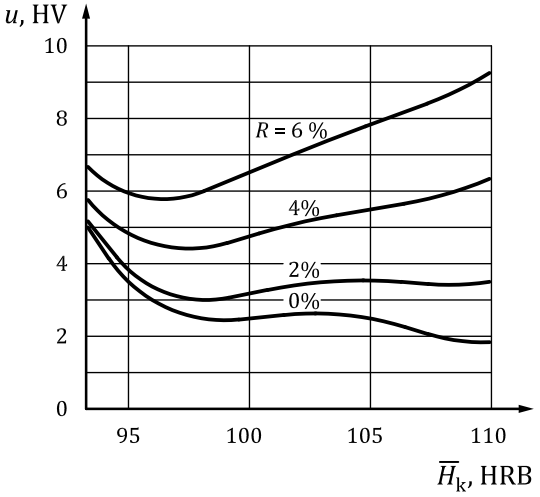

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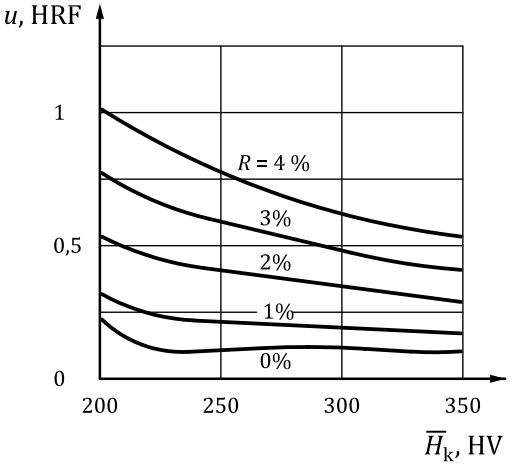

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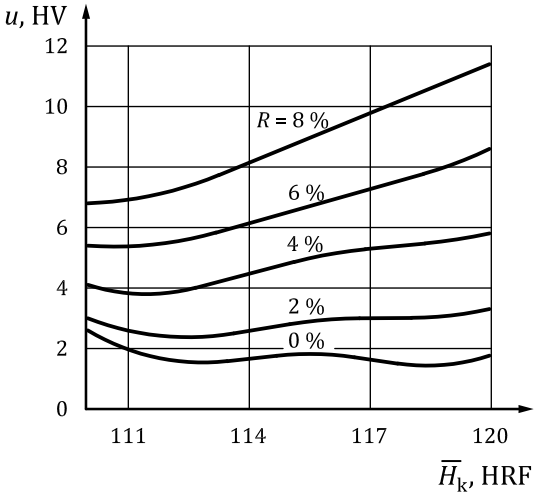

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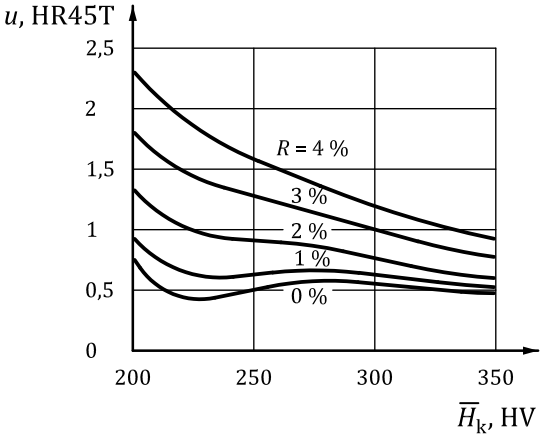

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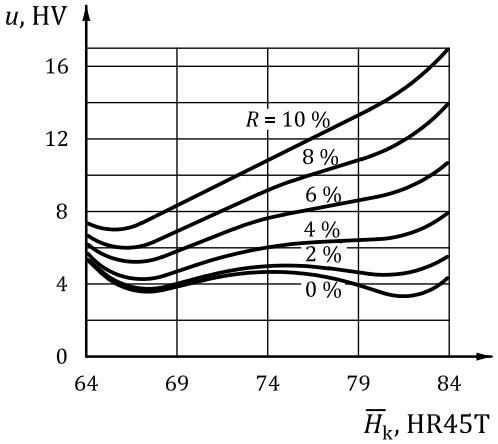

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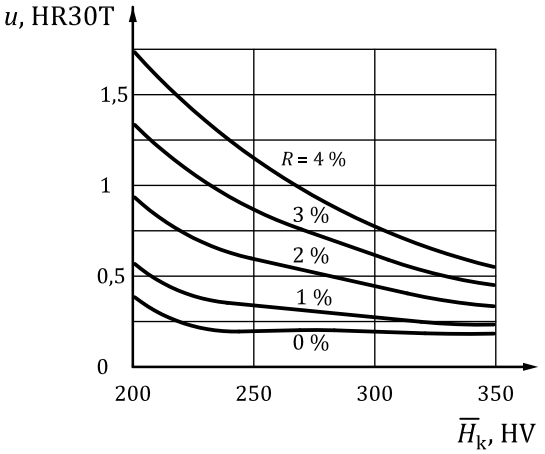

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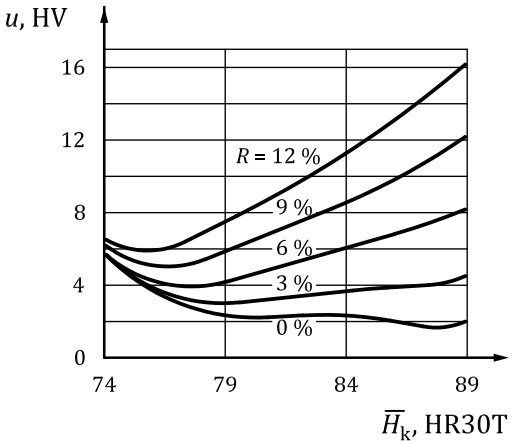

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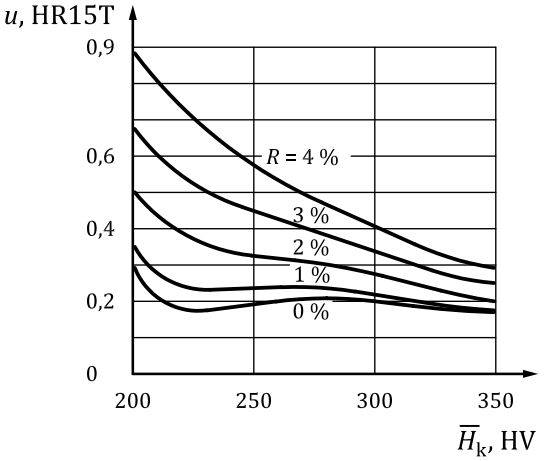

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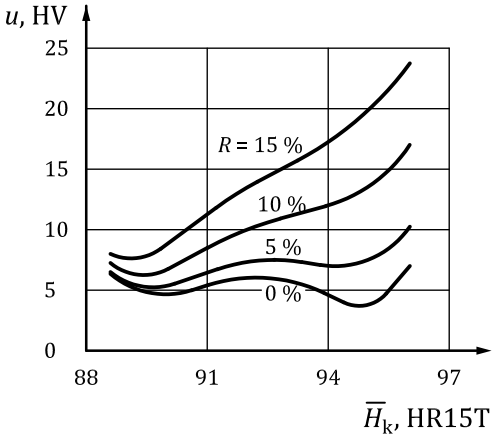

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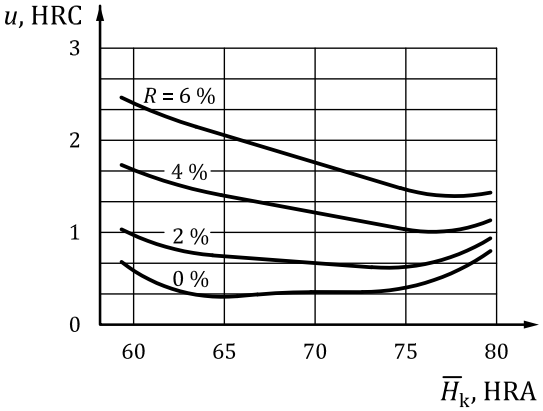

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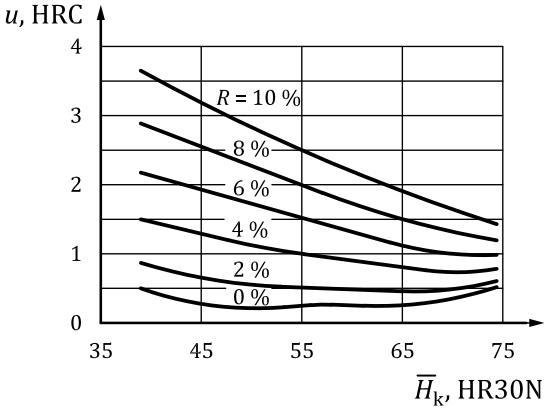

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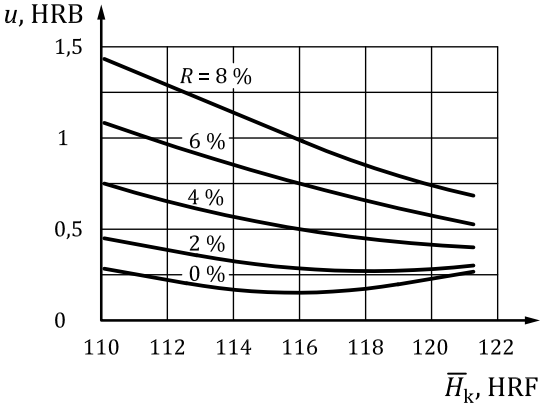

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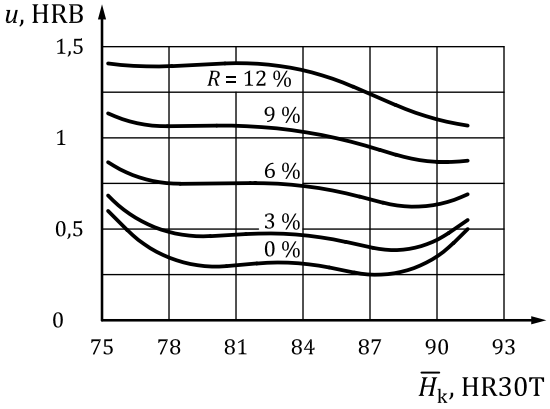

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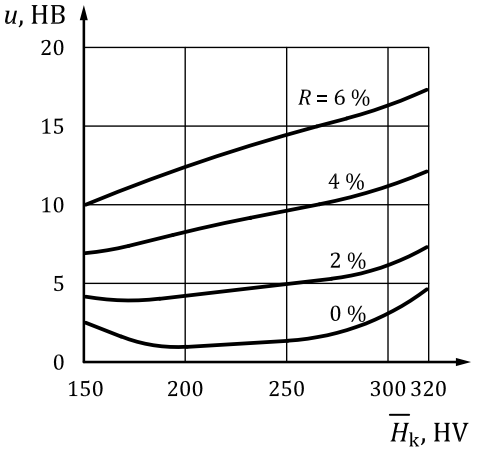

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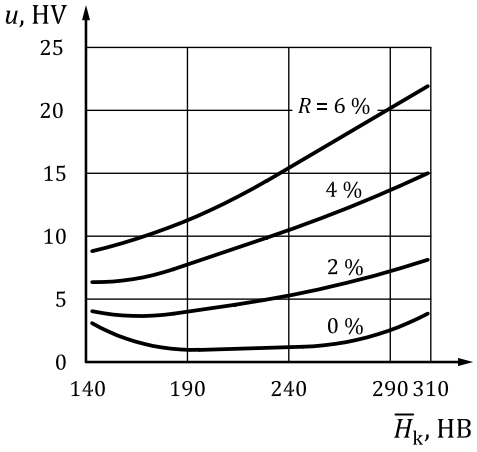

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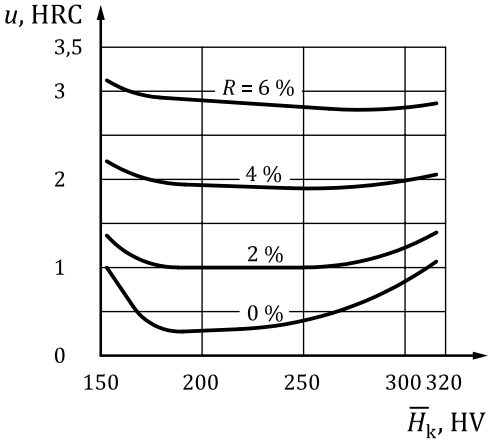

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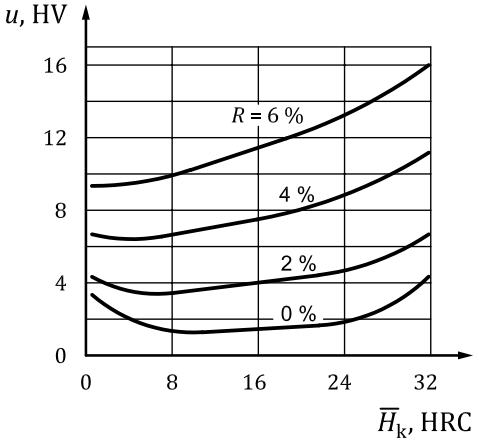

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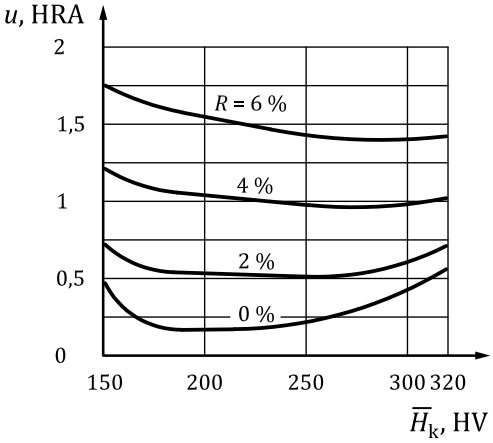

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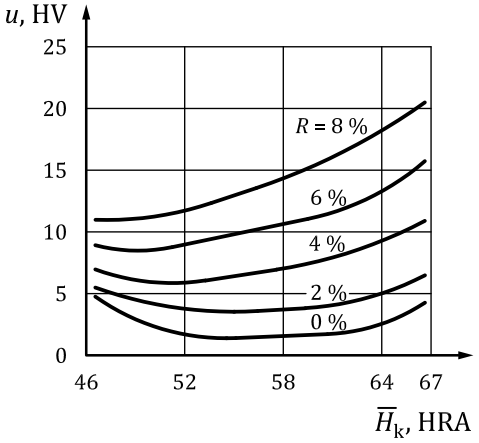

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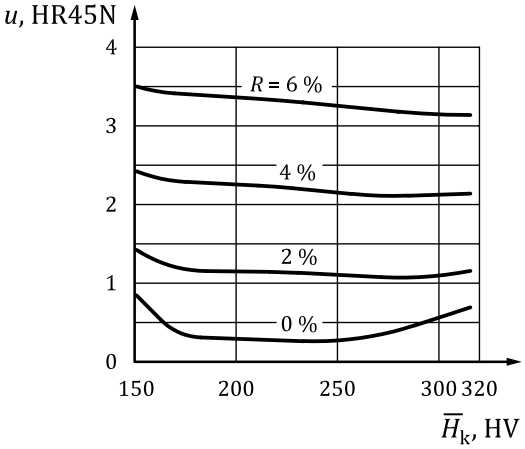

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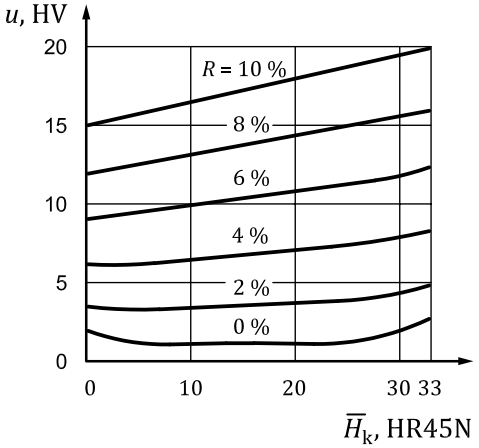

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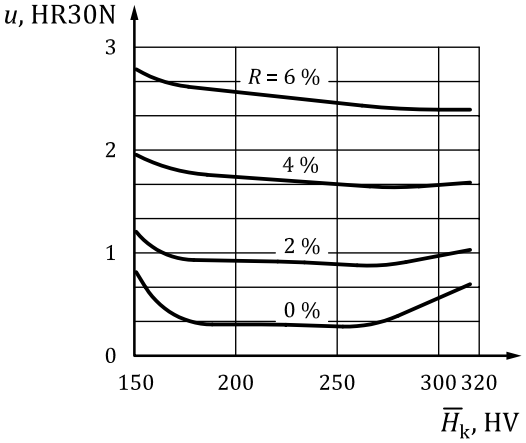

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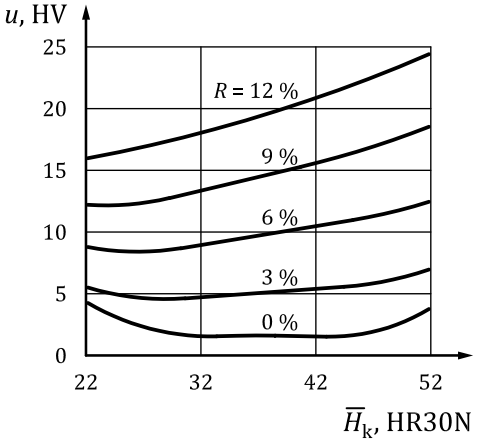

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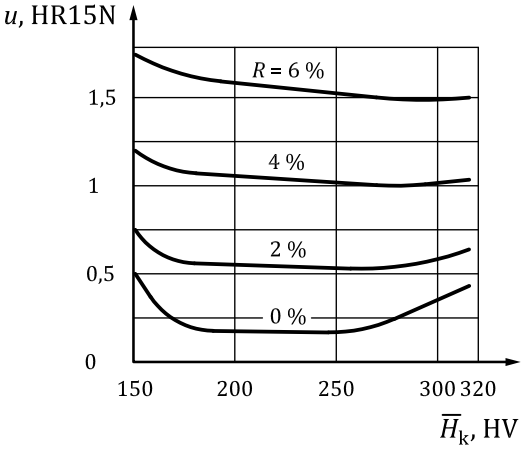

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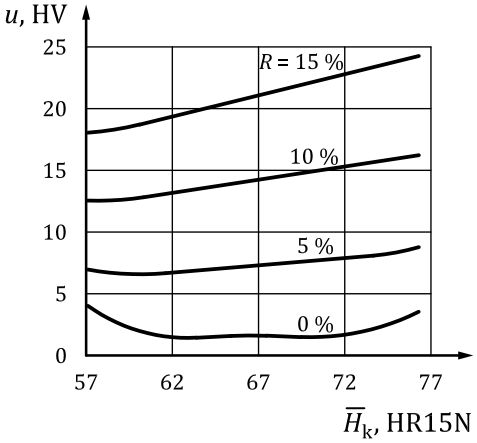

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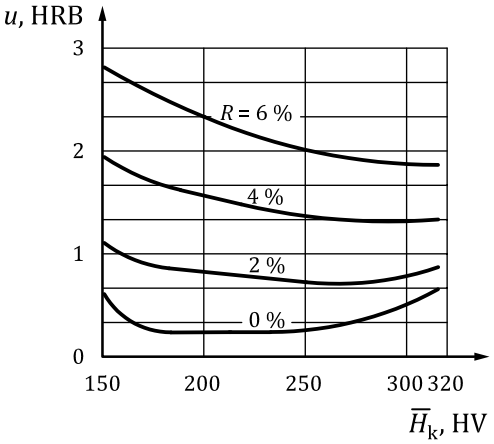

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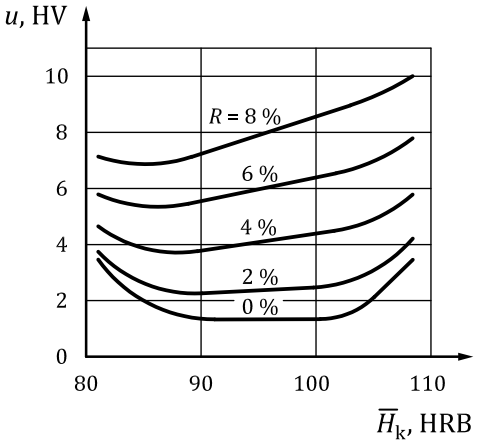

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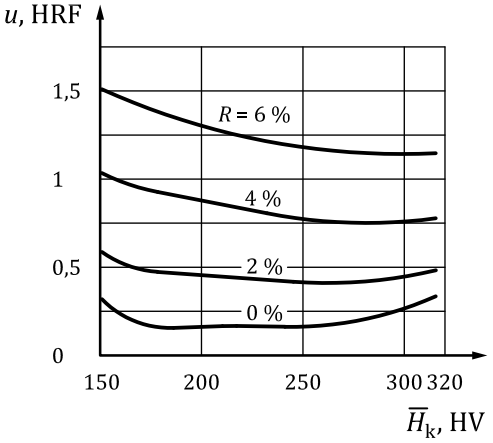

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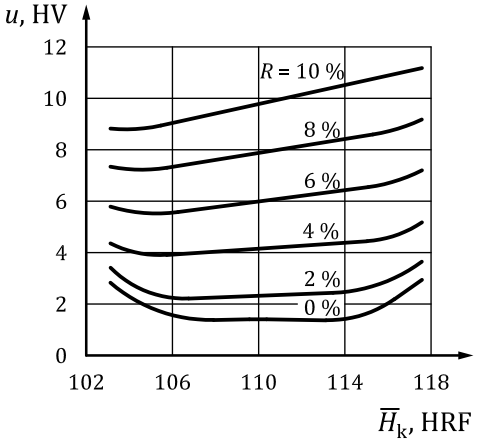

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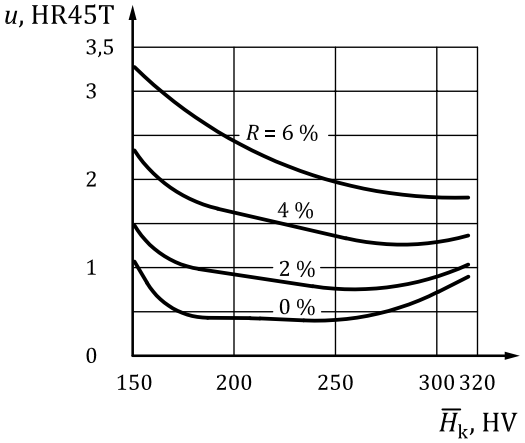

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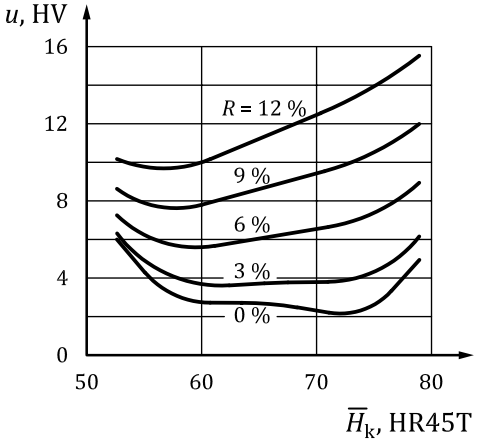

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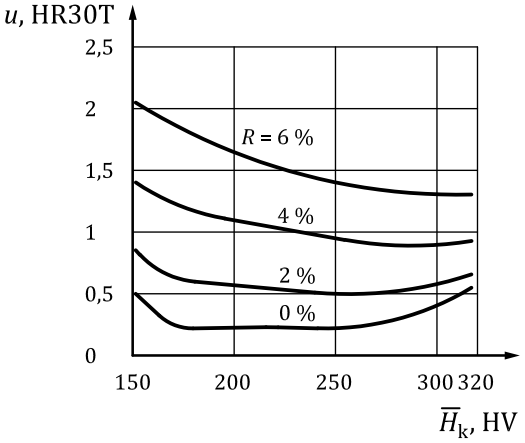

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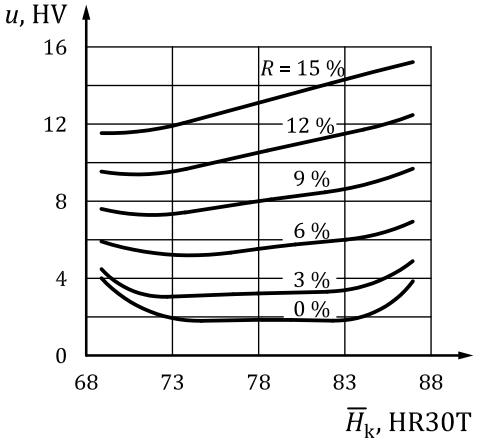

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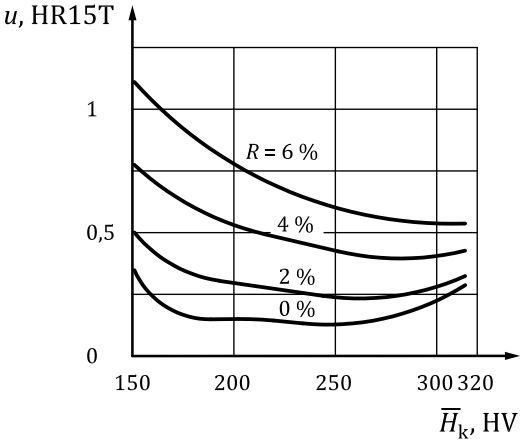

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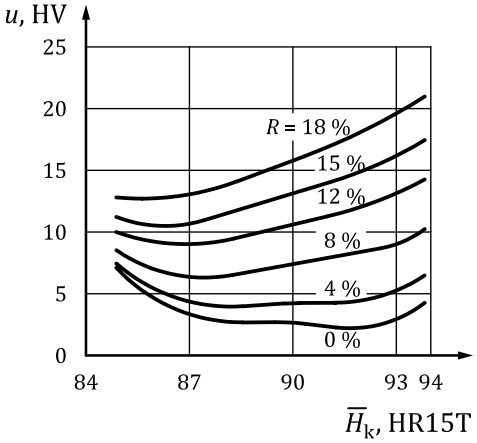

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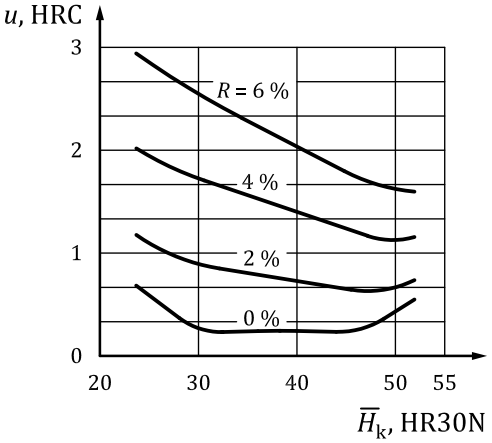

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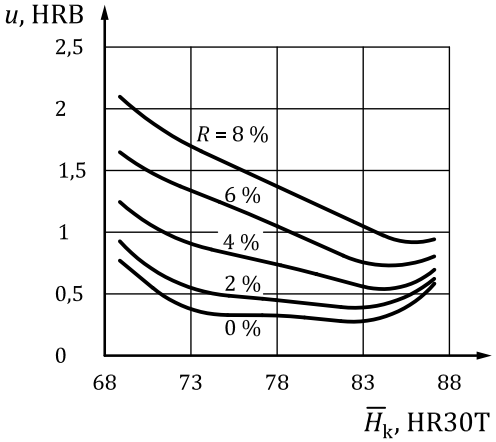

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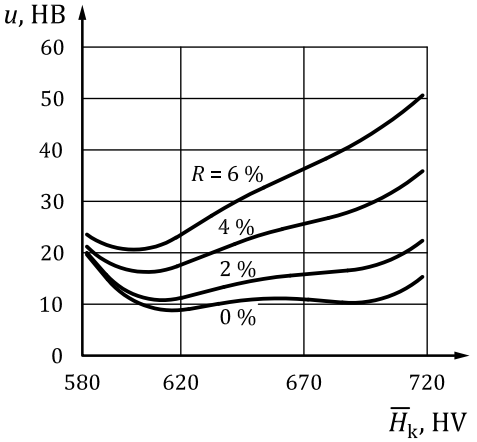

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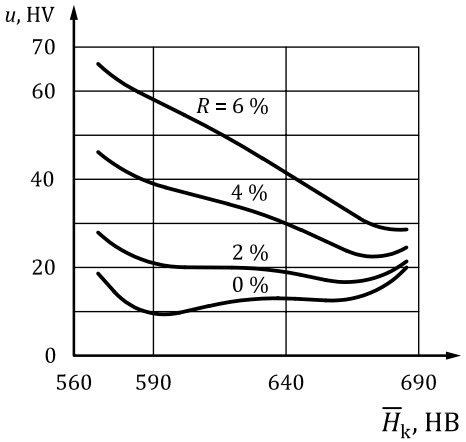

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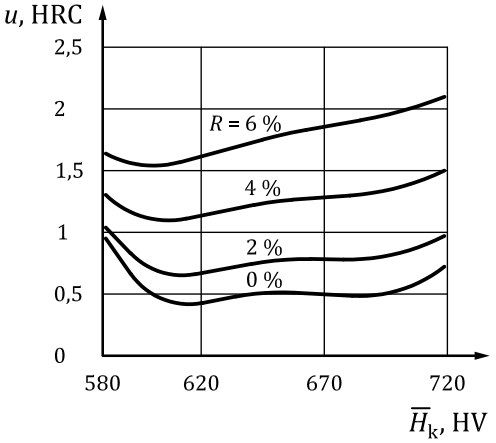

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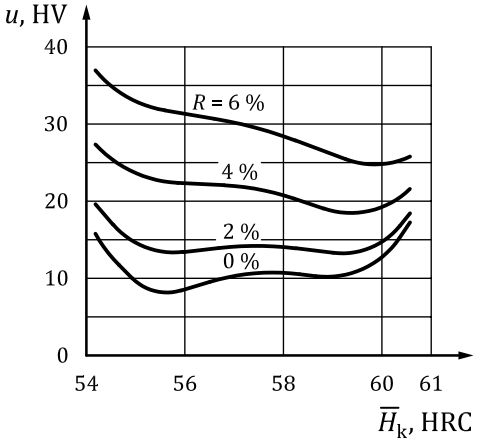

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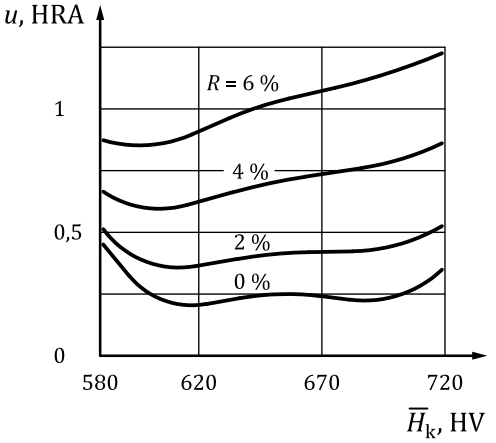

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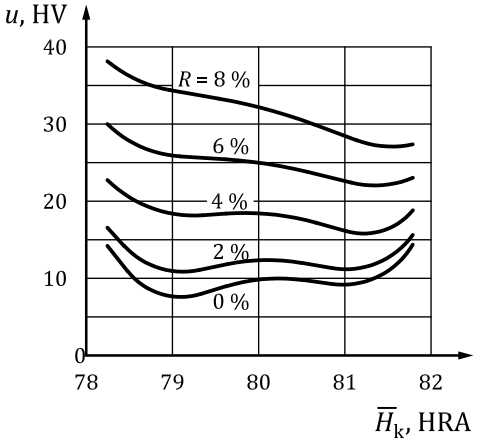

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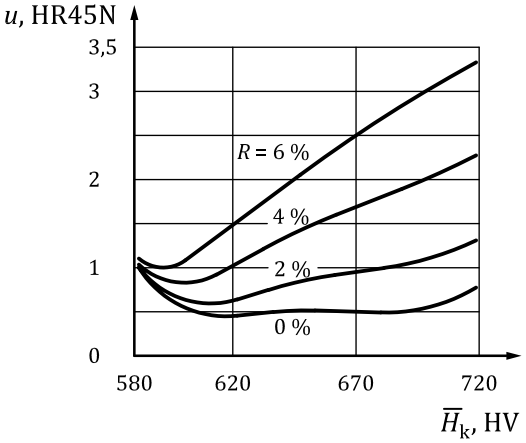

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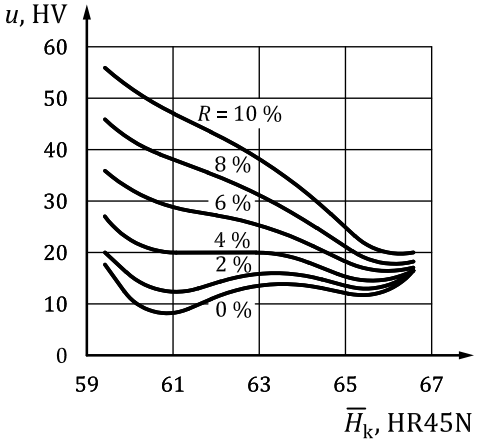

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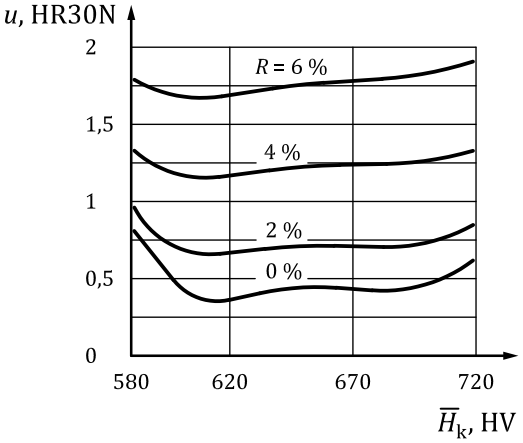
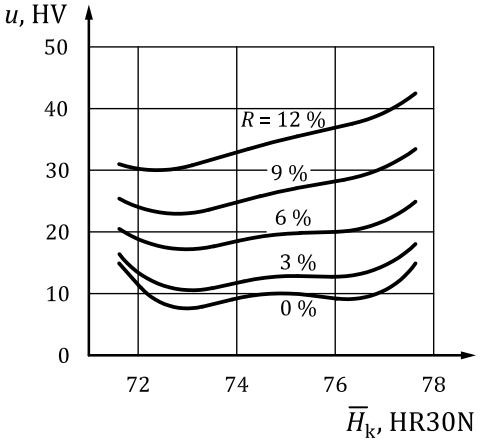


Figure B.59



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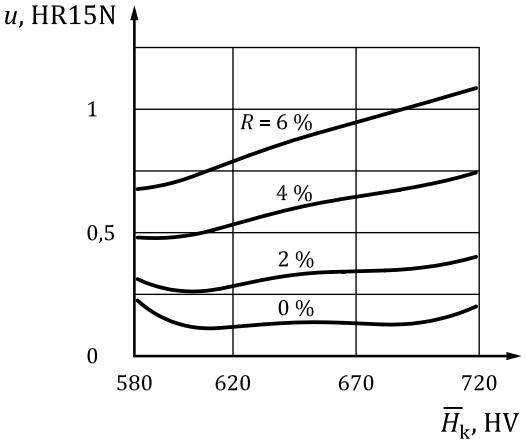

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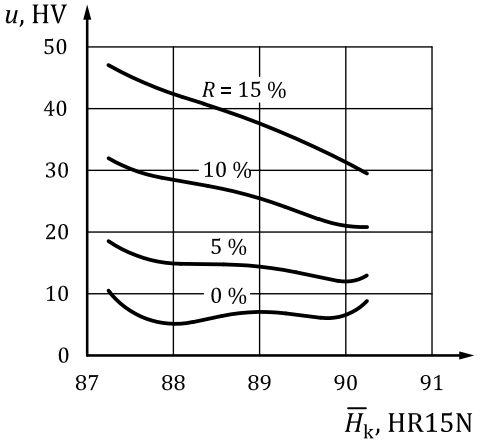

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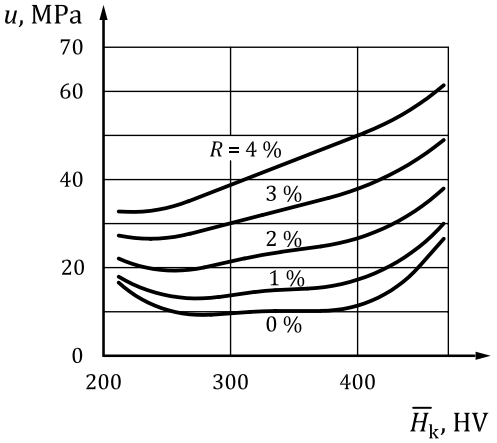

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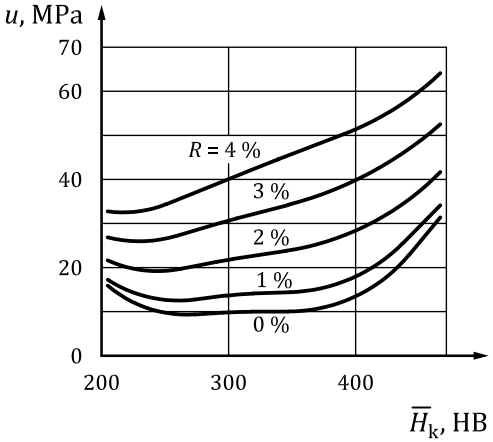

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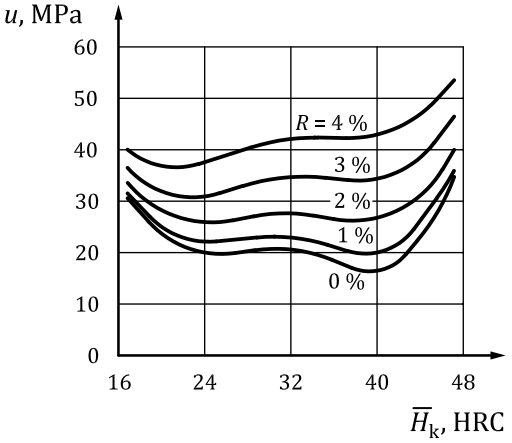


Figure B.65

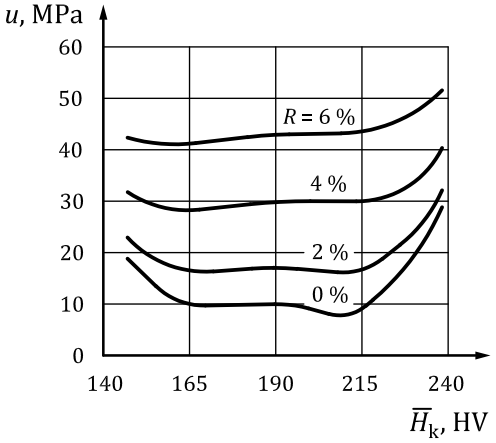


Figure B.66

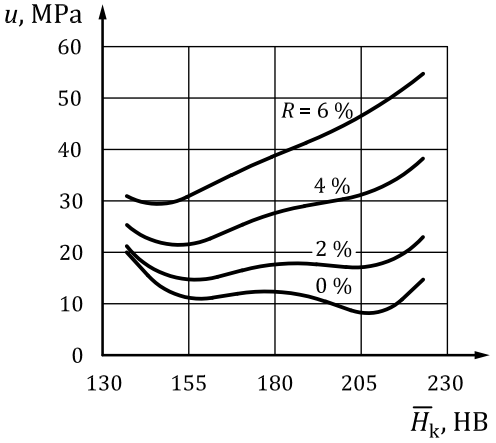


Figure B.67

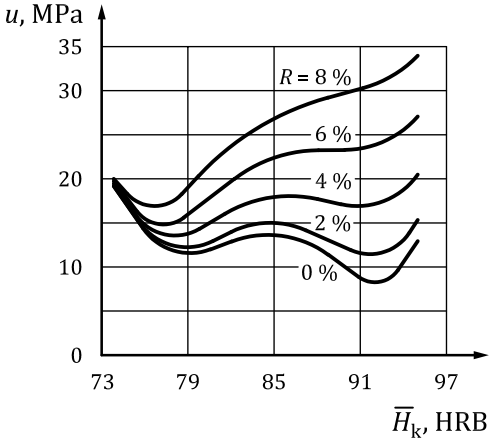


Figure B.68

Annex C
(informative)

Conversion tables for steels for cold working

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.

This Annex presents conversion values for steels for cold working that have been quenched and tempered. These values are based on results of testing carried out on steels as specified in TGL 4393. The steel grades that were tested are listed in Table C.1, which also provides an overview of the former designations used in the TGL standard along with the corresponding designations as in ISO 4957. Table C.2 lists the conversion values, while Table C.3 gives an overview of the uncertainty curves presented in Figures C.1 to C.28 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.

Table C.1 — Cold working steels tested

Steel grade (as in TGL 4393)	Steel grade (as in ISO 4957)	
	Material no.	Name
85CrMo7.2	1.2304	85CrMo7
UR85CrMo7.2	1.2304	85CrMo7
90MnV8	1.2842	90MnCrV8
101Cr6	1.3514	101Cr6LW
UR101Cr6	1.3505 [a]	100Cr6
125CrSi5	1.2109	125CrSi5
X125WMo6.5	1.3344 [a]	S6-5-3
210Cr46	1.2080	X210Cr12
210CrW46	1.2436	X210CrW12
[a] Chemical composition roughly equivalent to that specified in TGL 4393.		

Table C.2 — Conversion of hardness-to-hardness values for cold working steels

HV	HV 5	HB [a]	HRC	HRA	HR45N	HR30N	HR15N	HRB	HRF	HR45T	HR30T	HR15T
210	212	205	–	–	–	–	–	95,6	(110,7)	66,9	78,0	90,2
220	222	215	(18,8)	59,4	(16,4)	(38,8)	(67,0)	97,2	(111,6)	68,6	79,1	90,7
230	232	225	20,6	60,3	(18,7)	(40,5)	(68,2)	98,6 [b]	(112,5)	70,2	80,1	91,2
240	242	235	22,2	61,2 [b]	20,9	42,2	(69,3)	100,0 [b]	(113,3)	71,6	81,0	91,7
250	252	245	23,9	62,1 [b]	23,0	43,8 [b]	70,3	(101,4)	(114,0)	(72,9)	81,9	92,1
260	262	255	25,4	62,8	24,9	45,3	71,3	(102,6)	(114,7)	(74,1)	(82,7)	92,5
270	272	265	26,9	63,6	26,8	46,8	72,2	(103,7)	(115,3)	(75,2)	(83,5)	92,9
280	282	275	28,3	64,4	28,6	48,2	73,1	(104,7)	(115,9)	(76,3)	(84,2)	(93,3)
290	293	285	29,7 [b]	65,1	30,2	49,5	73,9	(105,6)	(116,4)	(77,3)	(84,8)	(93,6)
300	303	295	31,0	65,8	31,9	50,7	74,7	(106,5)	(116,9)	(78,2)	(85,5)	(93,9)
310	313	304	32,3	66,4	33,4	51,9	75,4	(107,3)	(117,4)	(79,1)	(86,0)	(94,2)
320	323	314	33,5	67,1	34,9	53,0	76,1	(108,1)	(117,8)	(79,9)	(86,6)	(94,5)
330	333	324	34,6	67,7	36,3	54,1	76,8	(108,8)	(118,2)	(80,6)	(87,1)	(94,8)
340	343	334	35,8	68,3	37,6	55,2	77,4	(109,5)	(118,6)	(81,4)	(87,6)	(95,0)
350	353	344	36,8	68,8	39,0	56,2	78,0	–	–	–	–	–
360	363	354	37,9	69,4	40,2	57,2	78,6					
370	373	363	38,9	69,9	41,4	58,1	79,2					
380	383	373	39,9	70,4	42,6	59,0	79,7					
390	393	383	40,8	71,0	43,7	59,9	80,2					
400	404	392	41,7	71,4	44,8	60,7	80,7					
410	414	402	42,6	71,9	45,8	61,5	81,2					
420	424	412	43,5	72,4	46,9	62,3	81,6					
430	434	422	44,3	72,8	47,8	63,1	82,1					
440	444	431	45,1	73,3	48,8	63,8	82,5					
450	454	441	45,9	73,7	49,7	64,5	82,9					
460	464	450	46,7	74,1	50,5	65,2	83,3					
470	474	460	47,4	74,5	51,4	65,8	83,7					
480	484	469	48,2	74,9	52,2	66,5	84,0					
490	494	479	48,9	75,3	53,1	67,1	84,4					
500	505	488	49,5	75,6	53,9	67,7	84,7					
510	515	498	50,2	76,0	54,6	68,3	85,1					
520	525	507	50,9	76,4	55,4	68,9	85,4					

[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.

[b] Recalculated in 2012 by interpolation.

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

Table C.2 *(continued)*

HV	HV 5	HB [a]	HRC	HRA	HR45N	HR30N	HR15N	HRB	HRF	HR45T	HR30T	HR15T
530	535	517	51,6	76,7	56,2	69,5	85,7					
540	545	526	52,1	77,0	56,8	70,0	86,0					
550	555	535	52,7	77,4	57,6	70,6	83,3					
560	565	545	53,3	77,7	58,2	71,1	86,6					
570	575	554	53,9	78,0	58,9	71,6	86,9					
580	585	563	54,5	78,3	59,6	72,1	87,1					
590	595	572	55,0	78,6	60,2	72,6	87,4					
600	606	582	55,6	78,9	60,8	73,0	87,7					
610	616	591	56,1	79,2	61,4	73,5	87,9					
620	626	600	56,6	79,5	62,0	74,0	88,2					
630	636	-	57,1	79,8	62,6	74,4	88,4					
640	646	-	57,6	80,0	63,2	74,8	88,6					
650	656	-	58,1	80,3	63,7	75,3	88,8					
660	666		58,6	80,6	64,3	75,7	89,1					
670	676		59,0	80,8	64,8	76,1	89,3					
680	686		59,5	81,0	65,3	76,5	89,5					
690	697		59,9	81,3	65,8	76,9	89,7					
700	707		60,4	81,5	66,3	77,3	89,9					
710	717		60,8	81,8	66,8	77,7	90,1					
720	727		61,2	82,0	67,3	78,0	90,3					
730	737		61,6	82,2	67,8	78,4	90,5					
740	747		62,0	82,5	68,2	78,8	90,7					
750	757		62,4	82,7	68,7	79,1	90,8					
760	767		62,8	82,9	69,1	79,4	91,0					
770	777		63,2	83,1	69,6	79,8	91,2					
780	788		63,6	83,3	70,0	80,1	91,4					
790	798		64,0	83,5	70,4	80,4	91,5					
800	808		64,4	83,7	70,8	80,8	91,7					
810	818		64,7	83,9	71,3	81,1	91,9					
820	828		65,1	84,1	71,7	81,4	92,0					
830	838		65,4	84,3	72,1	81,7	92,2					
840	848		65,8	84,5	72,4	82,0	92,3					

[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.

[b] Recalculated in 2012 by interpolation.

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

Table C.3 — Uncertainty curves to be used for conversion as in Table C.2

To obtain uncertainty u, in	of conversion from/to	use
HV 10; HV 5	HV/HV 10, HV/HV 5	Figure C.1
HV	HV 10/HV, HV 5/ HV	Figure C.2
HB	HV/HB	Figure C.3
HV	HB/HV	Figure C.4
HRC	HV/HRC	Figure C.5
HV	HRC/HV	Figure C.6
HRA	HV/HRA	Figure C.7
HV	HRA/HV	Figure C.8
HR45N	HV/HR45N	Figure C.9
HV	HR45N/HV	Figure C.10
HR30N	HV/HR30N	Figure C.11
HV	HR30N/HV	Figure C.12
HR15N	HV/HR15N	Figure C.13
HV	HR15N/HV	Figure C.14
HRB	HV/HRB	Figure C.15
HV	HRB/HV	Figure C.16
HRF	HV/HRF	Figure C.17
HV	HRF/HV	Figure C.18
HR45T	HV/HR45T	Figure C.19
HV	HR45T/HV	Figure C.20
HR30T	HV/HR30T	Figure C.21
HV	HR30T/HV	Figure C.22
HR15T	HV/HR15T	Figure C.23
HV	HR15T/HV	Figure C.24
HRB	HRF/HRB	Figure C.25
HRB	HR30T/HRB	Figure C.26
HRC	HR30N/HRC	Figure C.27
HRC	HRA/HRC	Figure C.28
NOTE If only HV is given without a number, then most probably HV30 is meant.		

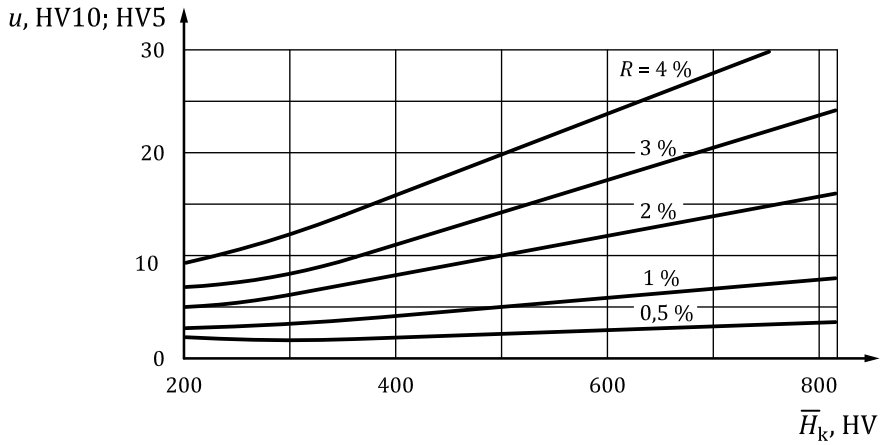


Figure C.1

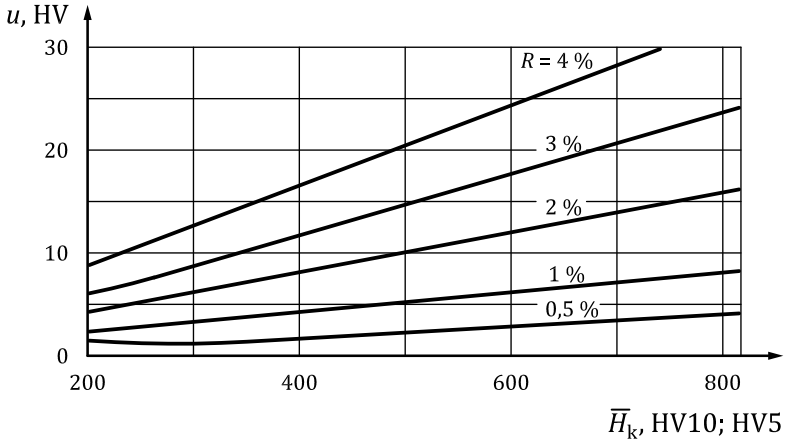


Figure C.2

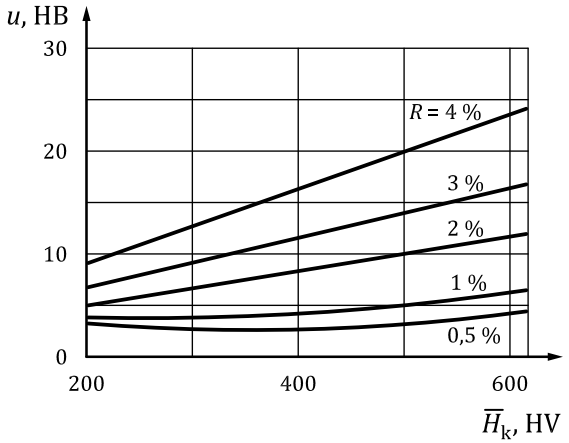


Figure C.3

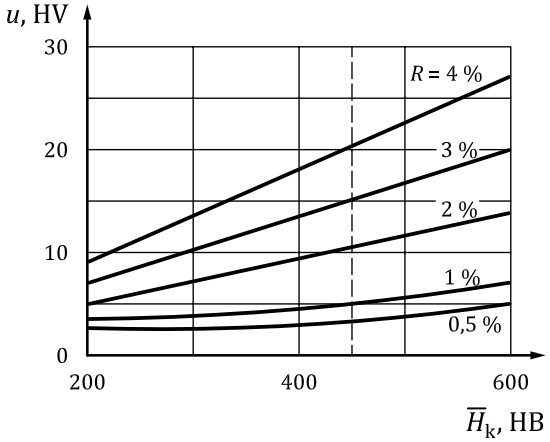


Figure C.4

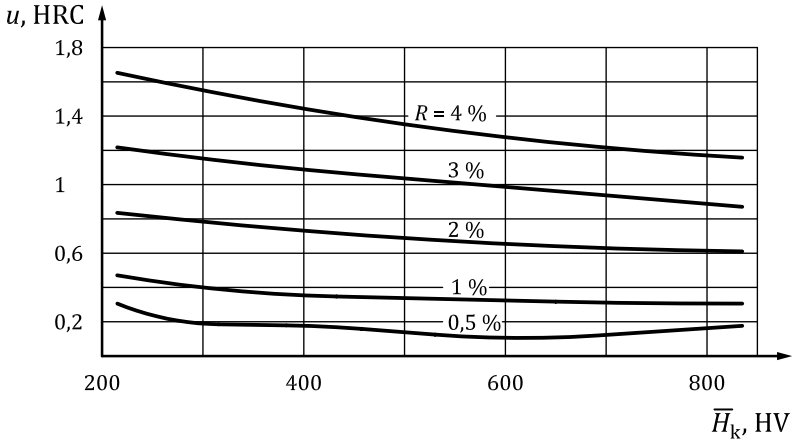


Figure C.5

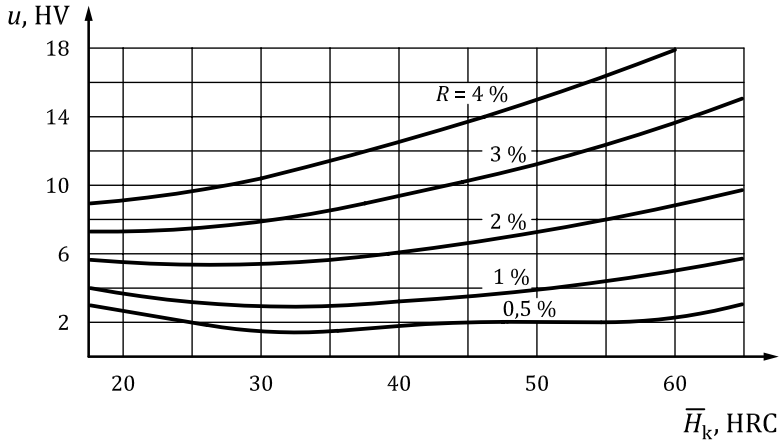


Figure C.6

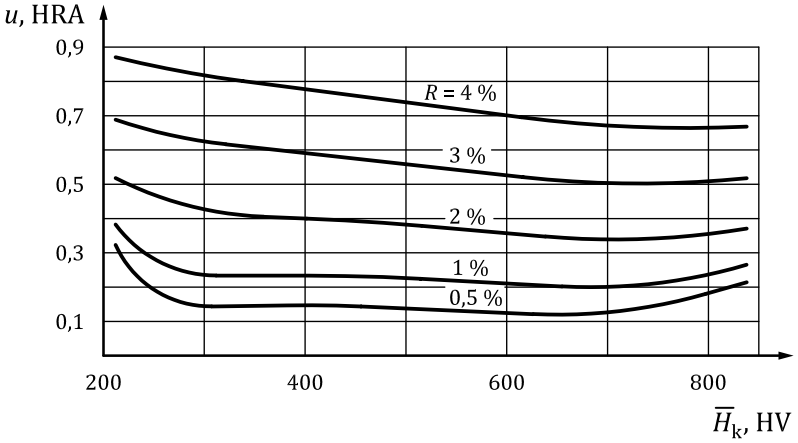


Figure C.7

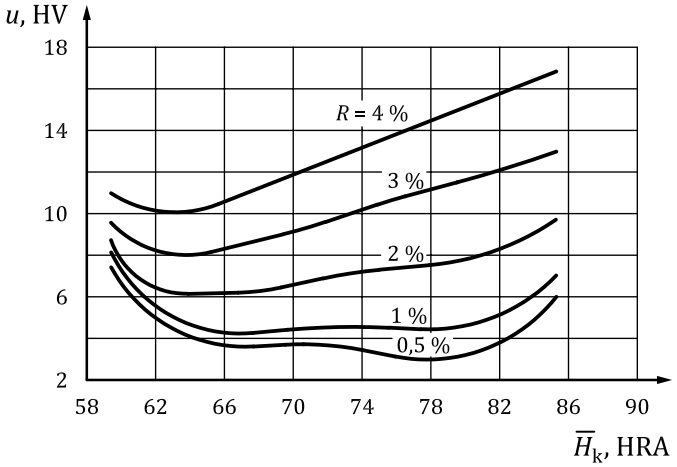


Figure C.8

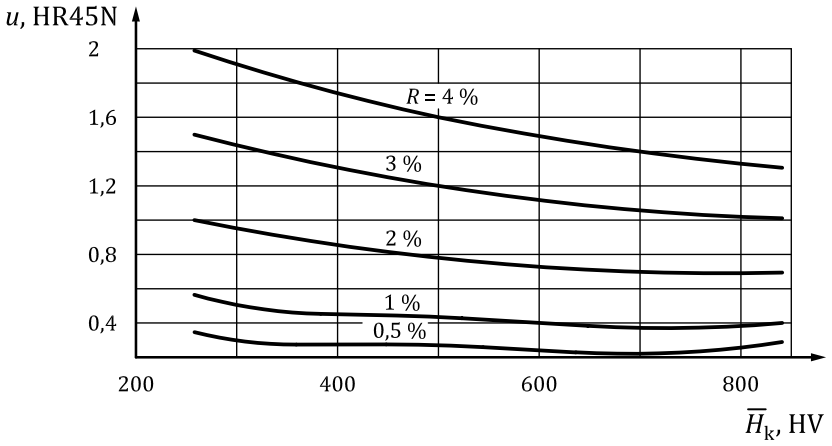


Figure C.9

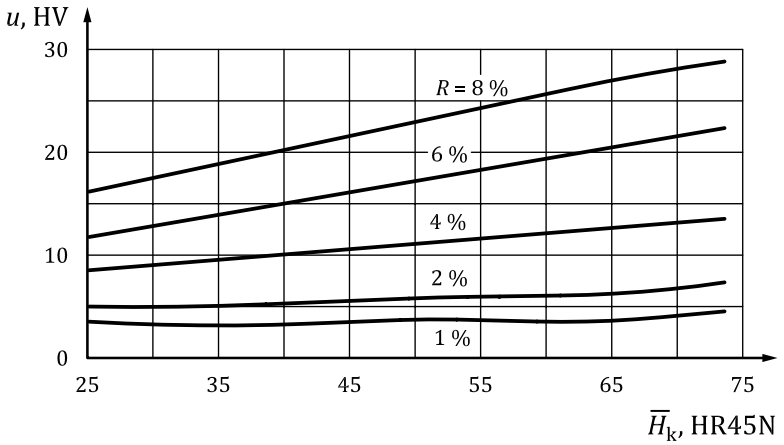


Figure C.10

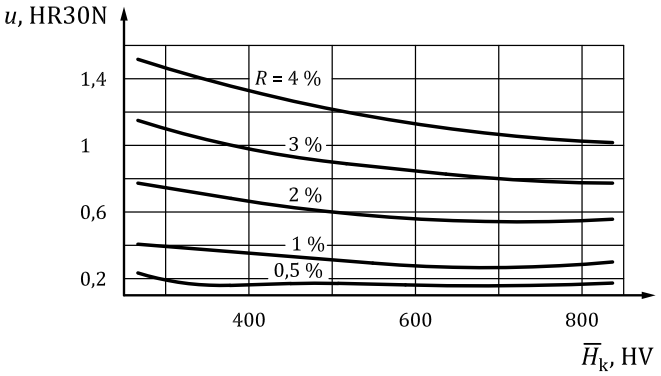


Figure C.11

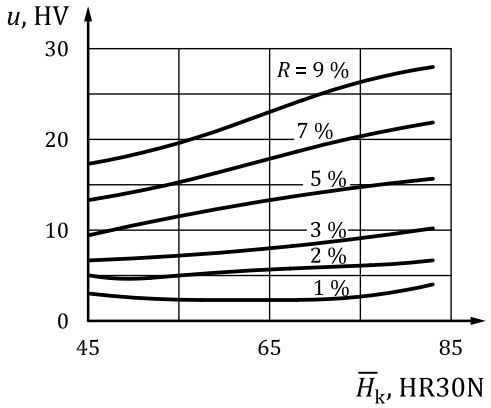


Figure C.12

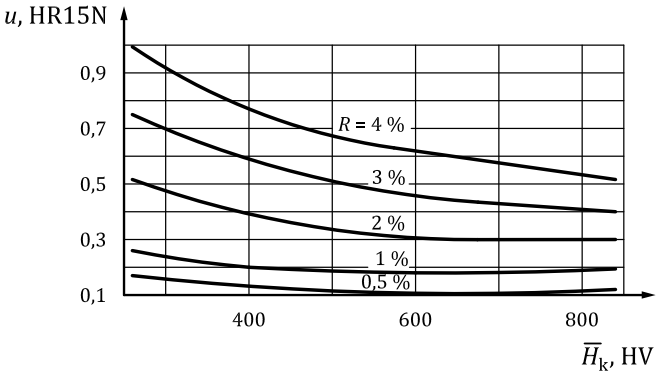


Figure C.13

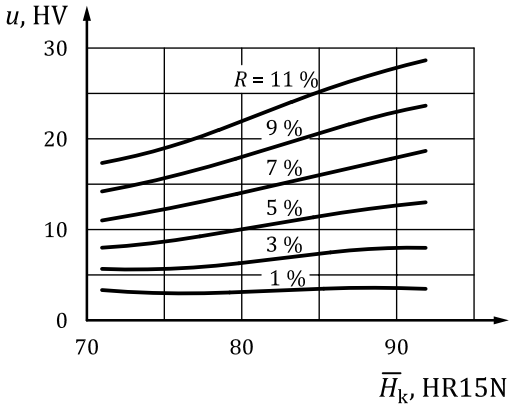


Figure C.14

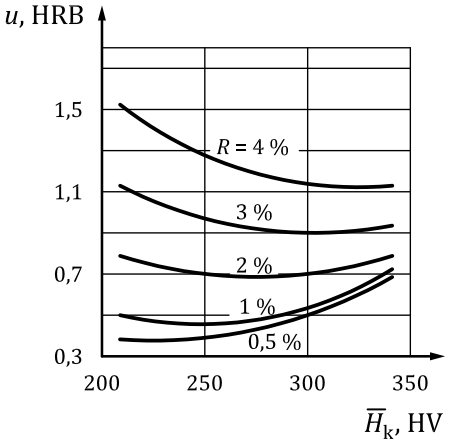


Figure C.15

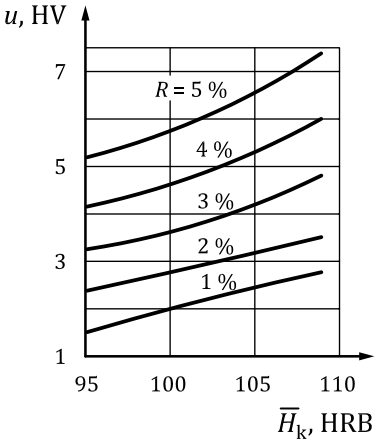


Figure C.16

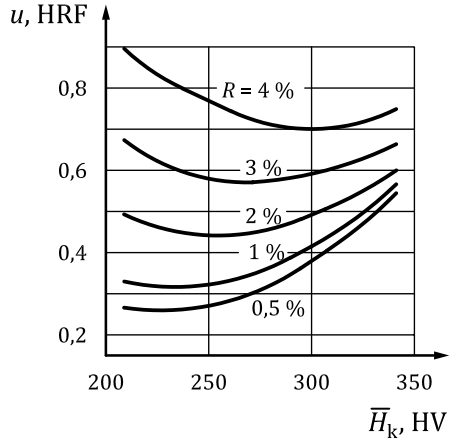


Figure C.17

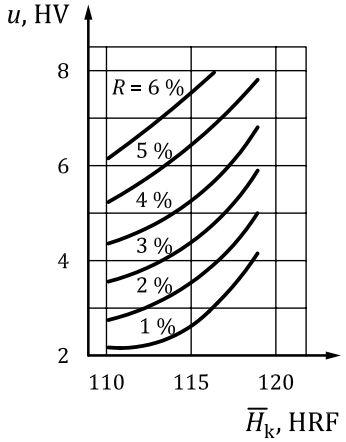


Figure C.18

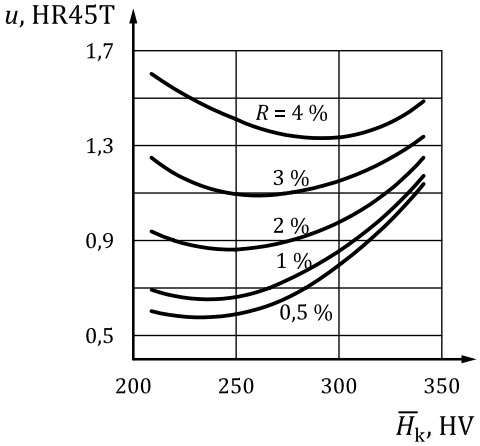


Figure C.19

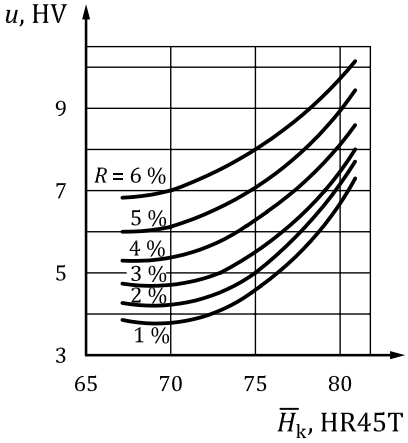


Figure C.20

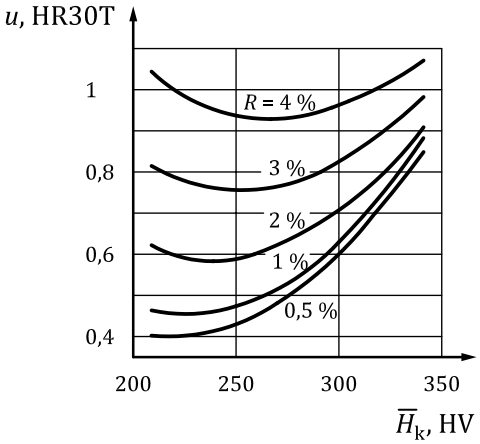


Figure C.21

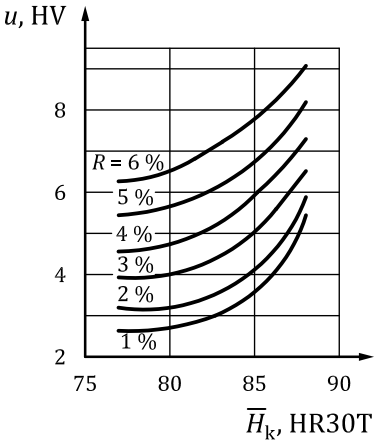


Figure C.22

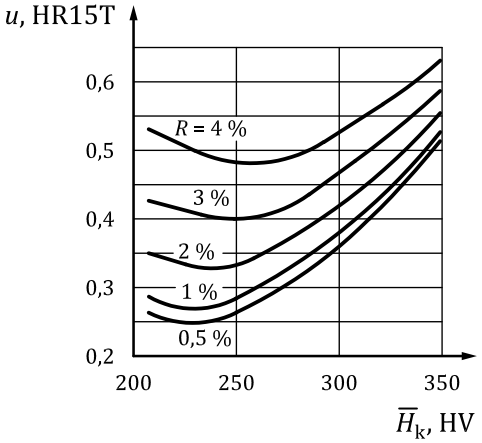


Figure C.23

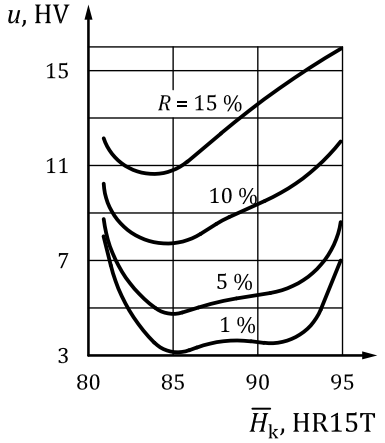


Figure C.24

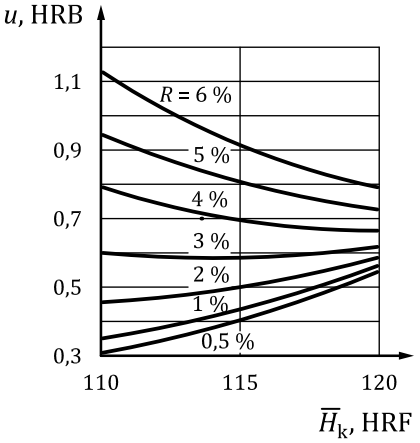


Figure C.25

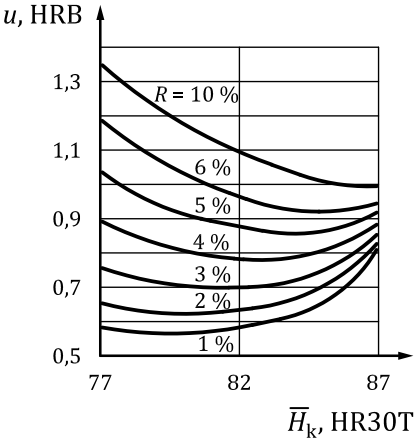


Figure C.26

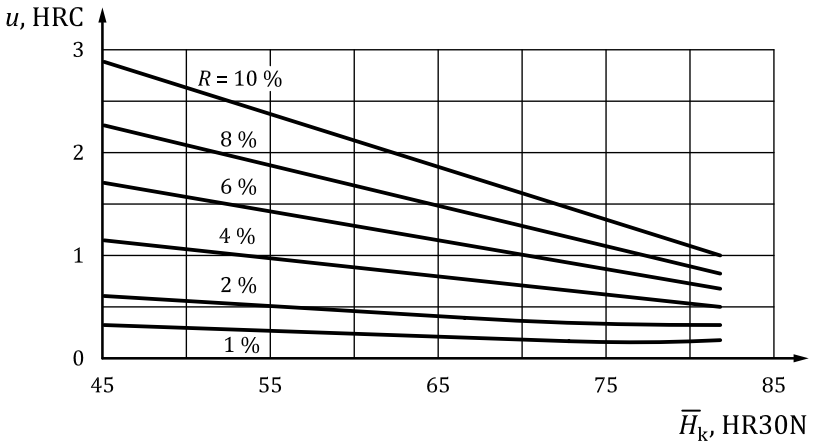


Figure C.27

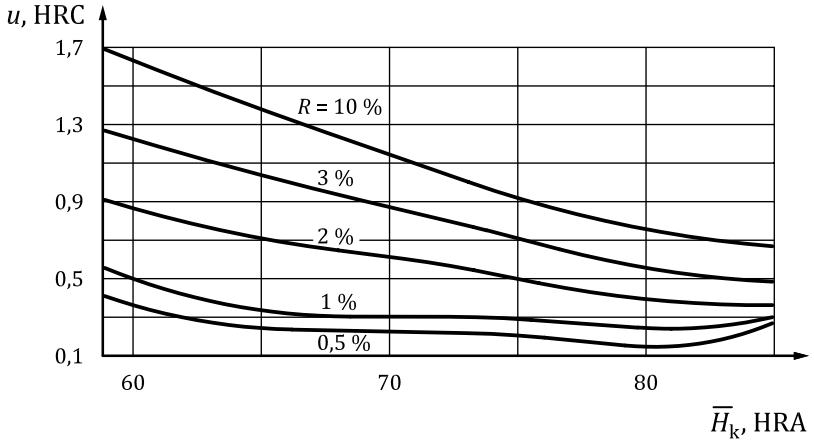


Figure C.28

Annex D
(informative)

Conversion tables for high speed steels

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.

This Annex presents conversion values for high speed steels that have been quenched and tempered above the secondary hardening peak. These values are based on results of testing carried out on the high speed steel grades as in TGL 7571, listed in Table D.1, which also provides an overview of the former designations used in the TGL standard along with the corresponding designations as in ISO 4957. Tables D.2, D.4, D.6 and D.8 list the conversion values, while Tables D.3, D.5, D.7 and D.9 give an overview of the uncertainty curves presented in Figures D.1 to D.30 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.

Table D.1 — High speed steels tested

Steel grade (as in TGL 7571)	Steel grade (as in ISO 4957)	
	Material no.	Name
X80WMo6.5		X80WMo6.5
X82WMo6.5		X82WMo6.5
X90WMo6.5	1.3343	X90WMo6.5
X97WMo3.3		X97WMo3.3
X100WMo6.5	1.3342	X100WMo6.5
X85WMoCo6.5.5	1.3243	X85WMoCo6.5.5
X105WMoCo6.5.5	1.3355	X105WMoCo6.5.5
X79WCo18.5	1.3255	X79WCo18.5
X110MoCo9.8	1.3247	X110MoCo9.8

NOTE Where no material number is listed, no equivalent number could be found in ISO 4957.

Table D.2 — Conversion of hardness-to-hardness values for high speed steels of steel grades X80WMo6.5, X82WMo6.5, X90WMo6.5, X97WMo3.3, X100WMo6.5, X85WMoCo6.5.5, X105WMoCo6.5.5 and X79WCo18.5

Vickers hardness HV 30	Rockwell hardness				
	HRC	HRA	HR45N	HR30N	HR15N
580	54,2	77,9	58,8	71,7	87,1
590	54,7	78,2	59,4	72,2	87,4
600	55,2	78,5	60,0	72,6	87,6
610	55,7	78,7	60,6	73,1	87,8
620	56,2	79,0[a]	61,1	73,5	88,1

[a] Recalculated in 2012 by interpolation

Table D.2 *(continued)*

Vickers hardness HV 30	Rockwell hardness				
	HRC	HRA	HR45N	HR30N	HR15N
630	56,6	79,3	61,7	74,0	88,3
640	57,1	79,6	62,2	74,4	88,5
650	57,6	79,8	62,8	74,8	88,7
660	58,0	80,1	63,3	75,2	88,9
670	58,5	80,3	63,8	75,6	89,1
680	58,9	80,6	64,3	76,0	89,3
690	59,3	80,8	64,8	76,4	89,5
700	59,7	81,0	65,3	76,7	89,7
710	60,2	81,3	65,8	77,1	89,9
720	60,6	81,5	66,3	77,4	90,1
730	61,0	81,7	66,7	77,8	90,2
740	61,4	82,0	67,2	78,1	90,4
750	61,8	82,2	67,6	78,5	90,6
760	62,1	82,4	68,1	78,8	90,7
770	62,5	82,6	68,5	79,1	90,9
780	62,9	82,8	68,9	79,5	91,0
790	63,3	83,0	69,4	79,8	91,2
800	63,6	83,2	69,8	80,1	91,3
810	64,0	83,5	70,2	80,4	91,5
820	64,3	83,6	70,6	80,7	91,6
830	64,7	83,8	71,0	81,0	91,8
840	65,0	84,0	71,4	81,3	91,9
850	65,4	84,2	71,7	81,6	92,0
860	65,7	84,4	72,1	81,8	92,2
870	66,0	84,6	72,5	82,1	92,3
880	66,3	84,8	72,8	82,4	92,4
890	66,7	85,0	73,2	82,7	92,5
900	67,0	85,0	73,6	82,9	92,6
910	67,3	85,3	73,9	83,2	92,8
920	67,6	85,5	74,2	83,4	92,9

[a] Recalculated in 2012 by interpolation

Table D.3 — Uncertainty curves to be used for conversion as in Table D.2

To obtain uncertainty u, in	of conversion from/to	use
HRC	HV/HRC	Figure D.1
HV	HRC/HV	Figure D.2
HRA	HV/HRA	Figure D.3
HV	HRA/HV	Figure D.4
HR45N	HV/HR45N	Figure D.5
HR30N	HV/HR30N	Figure D.6
HR15N	HV/HR15N	Figure D.7
HV	HR45N/HV	Figure D.8
HV	HR30N/HV	Figure D.9
HV	HR15N/HV	Figure D.10
HRC	HRA/HRC	Figure D.11
HRC	HR30N/HRC	Figure D.12
NOTE If only HV is given without a number, then most probably HV30 is meant.		

Table D.4 — Conversion between various Vickers hardness scales for high speed steels of steel grades X80WMo6.5, X82WMo6.5, X90WMo6.5, X97WMo3.3, X100WMo6.5, X85WMoCo6.5.5 and X105WMoCo6.5.5

HV	HV 10	HV 5	HV	HV 10	HV 5
580	587	589	750	760	762
590	598	599			
600	608	609	760	770	772
			770	780	782
610	618	620	780	790	792
620	628	630	790	801	802
630	638	640	800	811	813
640	648	650	810	821	823
650	658	660	820	831	833
			830	841	843
660	669	670	840	851	853
670	679	681	850	862	863
680	689	691			
690	699	701	860	872	874
700	709	711	870	882	884
			880	892	894
710	719	721	890	902	904
720	730	731	900	912	914
730	740	742	910	923	924
740	750	752	920	933	935
NOTE If only HV is given without a number, then most probably HV30 is meant.					

Table D.5 — Uncertainty curves to be used for conversion as in Table D.4

To obtain uncertainty u, in	of conversion from/to	use
HV 10, HV 5	HV/HV 10, HV/HV5	Figure D.13
HV	HV 10/HV, HV5/HV	Figure D.14
NOTE If only HV is given without a number, then most probably HV30 is meant.		

Table D.6 — Conversion between various Vickers hardness scales for high speed steels of steel grade X79WCo18.5

HV	HV 10	HV 5
790	795	794
800	806	805
810	817	816
820	828	826
830	839	837
840	850	847
850	861	858
860	872	868
870	883	879
880	894	890
890	905	900
900	916	911
910	927	921
920	938	932
NOTE If only HV is given without a number, then most probably HV30 is meant.		

Table D.7 — Uncertainty curves to be used for conversion as in Table D.6

To obtain uncertainty u, in	of conversion from/to	use
HV 10	HV/HV 10	Figure D.15
HV	HV 10/HV	Figure D.16
HV 5	HV/HV 5	Figure D.17
HV	HV 5/HV	Figure D.18
NOTE If only HV is given without a number, then most probably HV30 is meant.		

Table D.8 — Conversion of hardness-to-hardness values for high speed steels of steel grade X110MoCo9.8

Vickers hardness			Rockwell hardness				
HV	HV 10	HV 5	HRC	HRA	HR45N	HR30N	HR15N
740	–	–	–	82,0	67,8	77,9	90,7
750	–	–	–	82,2	68,1	78,3	90,8
760	–	–	–	82,5	68,4	78,6	90,9
770	768	759	63,2	82,7	68,8	79,0	91,0
780	779	770	63,5	82,9	69,1	79,3	91,1
790	790	781	63,9	83,1	69,4	79,6	91,2
800	801	791	64,2	83,3	69,7	79,9	91,3
810	812	802	64,5	83,5	70,0	80,2	91,4
820	822	813	64,8	83,7	70,3	80,5	91,6
830	833	823	65,1	83,8	70,6	80,8	91,7
840	844	834	65,4	84,0	71,0	81,0	91,8
850	855	845	65,7	84,2	71,3	81,3	91,9
860	866	856	66,0	84,4	71,6	81,5	92,0
870	876	866	66,3	84,5	71,9	81,8	92,1
880	887	877	66,6	84,7	72,2	82,0	92,2
890	898	888	66,9	84,8	72,5	82,3	92,4
900	909	899	67,1	85,0	72,8	82,5	92,5
910	920	909	67,4	85,1	73,1	82,7	92,6
920	931	920	67,6	85,3	73,4	83,0	92,7
930	942	931	67,9	85,4	73,7	83,2	92,8
940	–	–	68,2	85,5	74,0	83,4	92,9
950	–	–	–	85,7	74,3	83,6	93,0

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

Table D.9 — Uncertainty curves to be used for conversion as in Table D.8

To obtain uncertainty u, in	of conversion from/to	use
HV10	HV/HV10	Figure D.15
HV	HV10/HV	Figure D.16
HV5	HV/HV5	Figure D.17
HV	HV5/HV	Figure D.18
HRC	HV/HRC	Figure D.19
HV	HRC/HV	Figure D.20
HRA	HV/HRA	Figure D.21
HV	HRA/HV	Figure D.22
HR45N	HV/HR45N	Figure D.23
HV	HR45N/HV	Figure D.24
HR30N	HV/HR30N	Figure D.25
HV	HR30N/HV	Figure D.26
HR15N	HV/HR15N	Figure D.27
HV	HR15N/HV	Figure D.28
HRC	HRA/HRC	Figure D.29
HRC	HR30N/HRC	Figure D.30
NOTE If only HV is given without a number, then most probably HV30 is meant.		

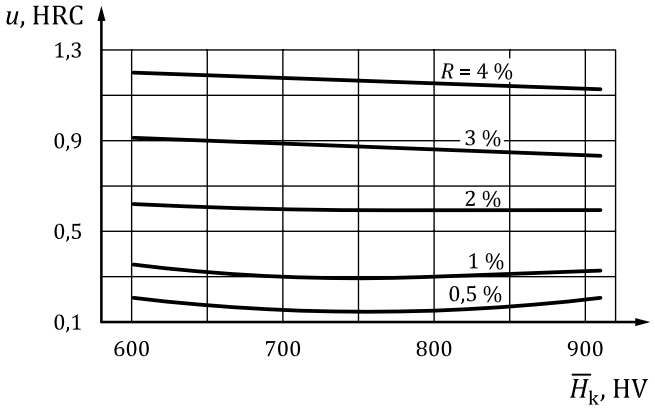


Figure D.1

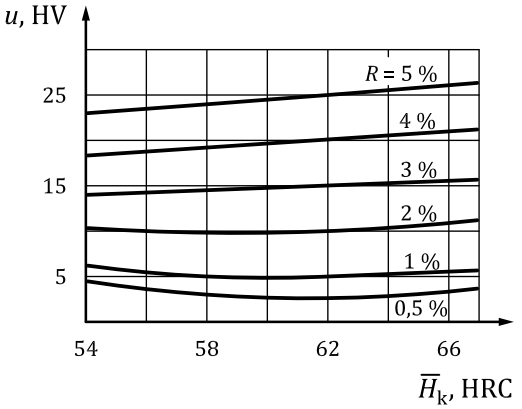


Figure D.2

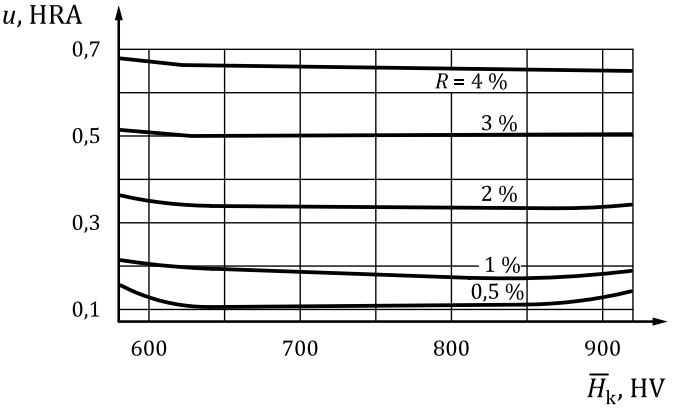


Figure D.3

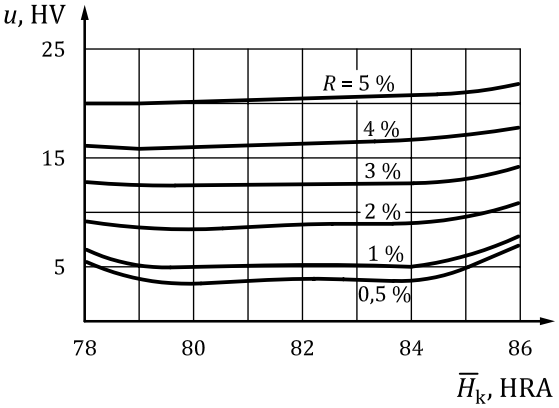


Figure D.4

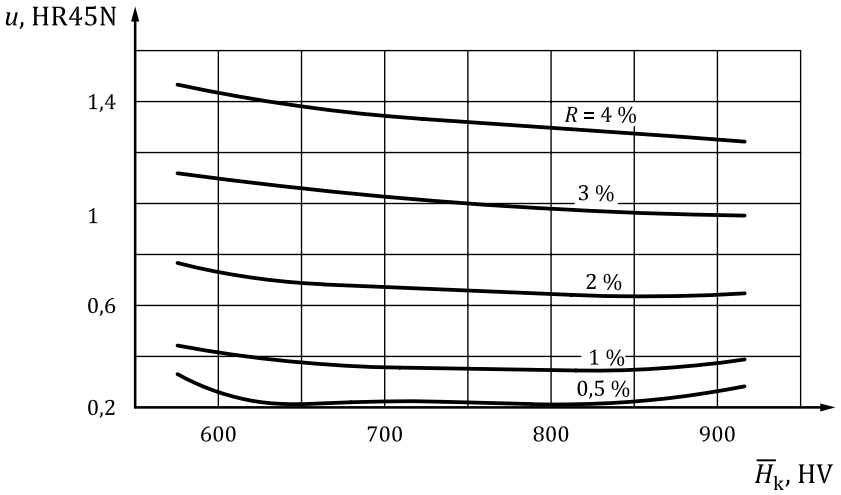


Figure D.5

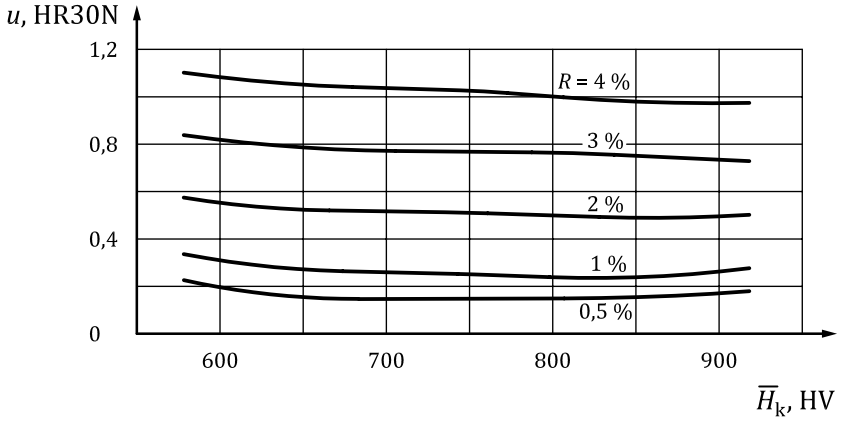


Figure D.6

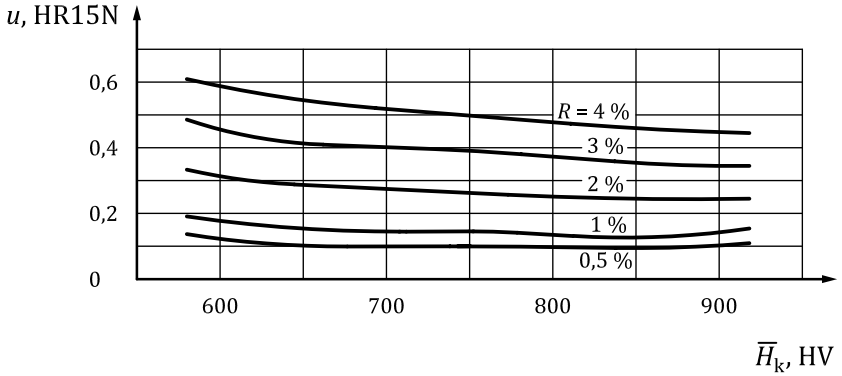


Figure D.7

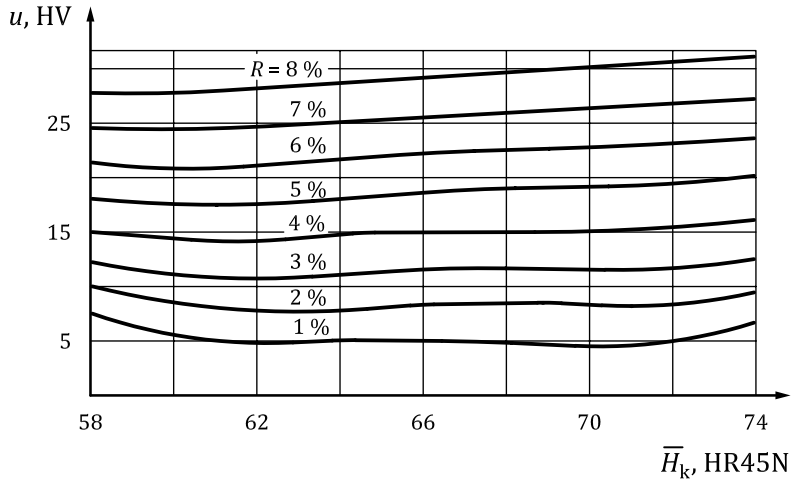


Figure D.8

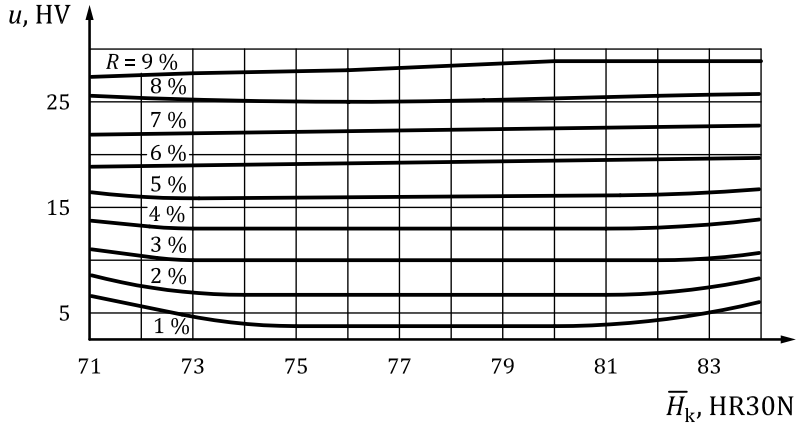


Figure D.9

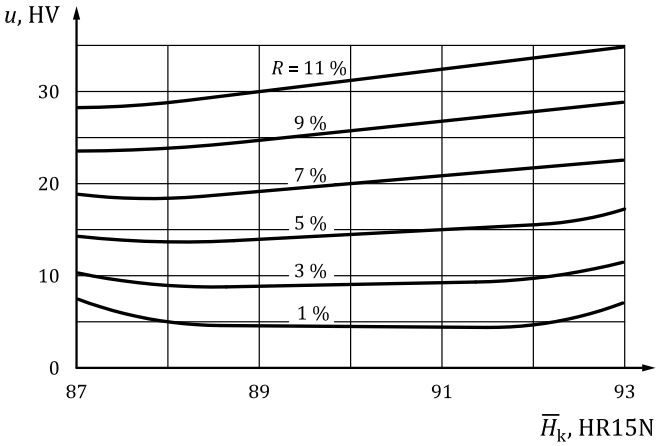


Figure D.10

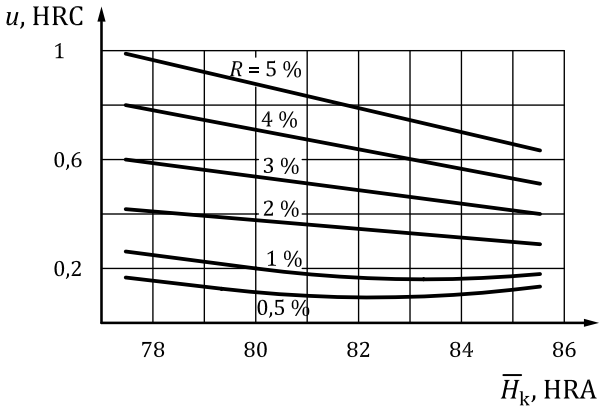


Figure D.11

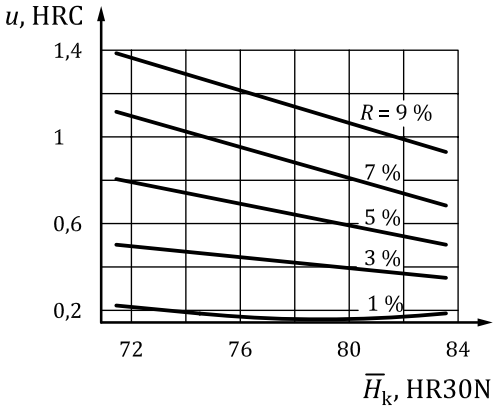


Figure D.12

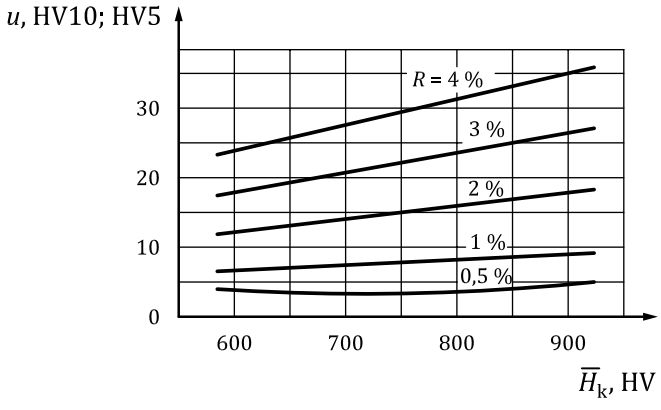


Figure D.13

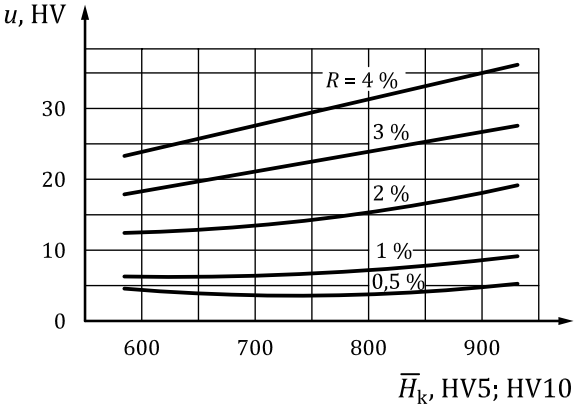


Figure D.14

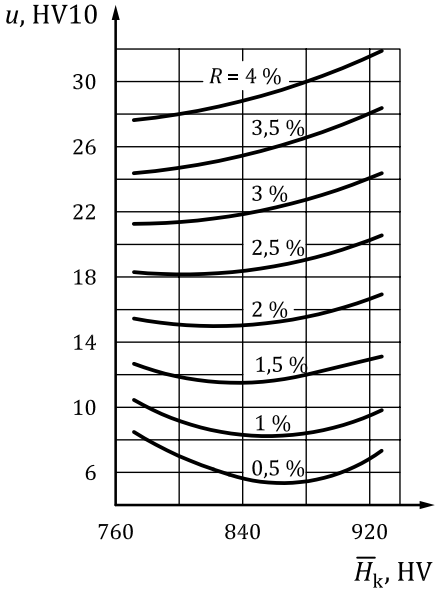


Figure D.15

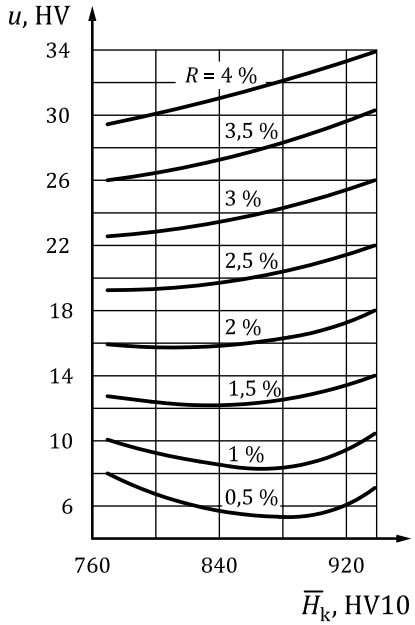


Figure D.16

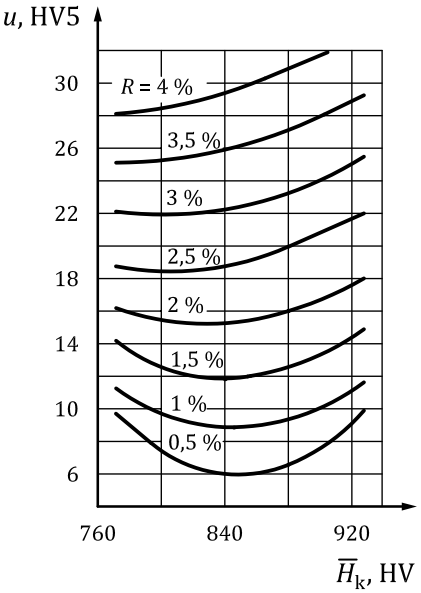


Figure D.17

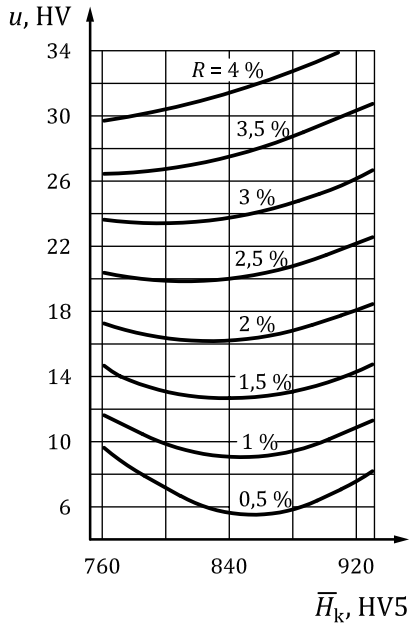


Figure D.18

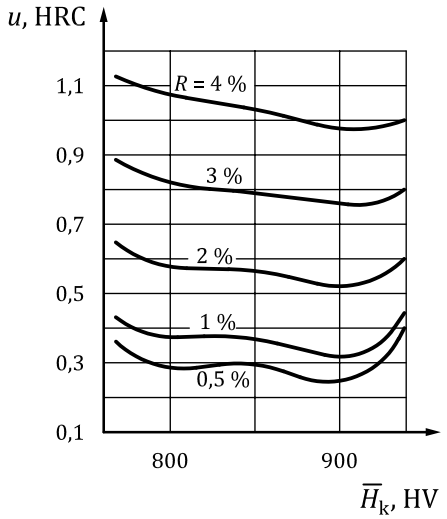


Figure D.19

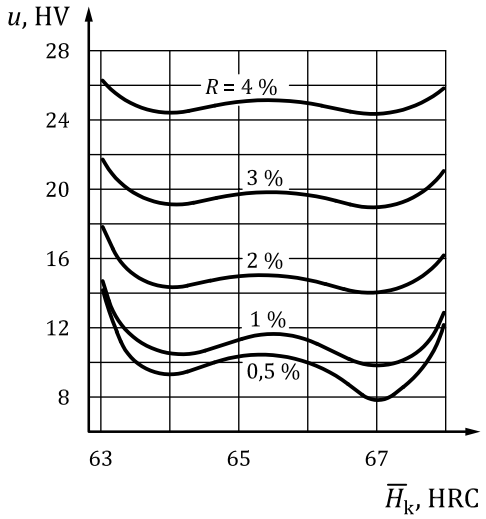


Figure D.20

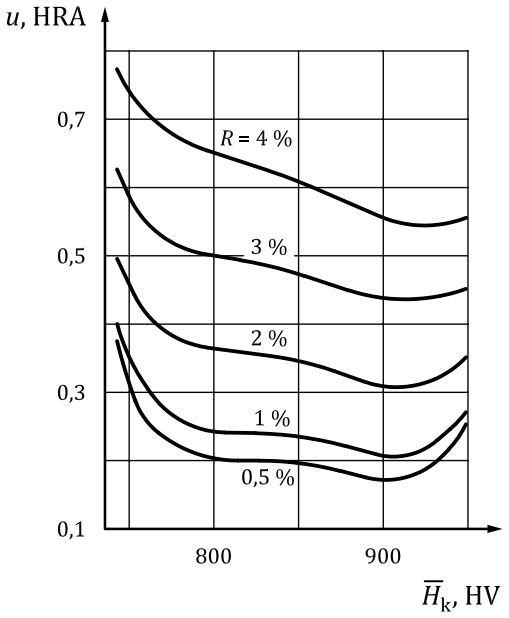


Figure D.21

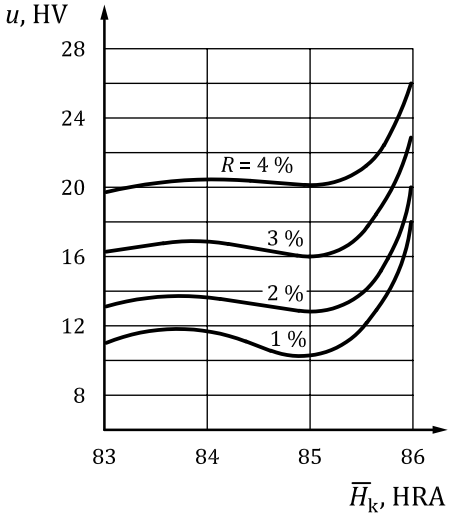


Figure D.22

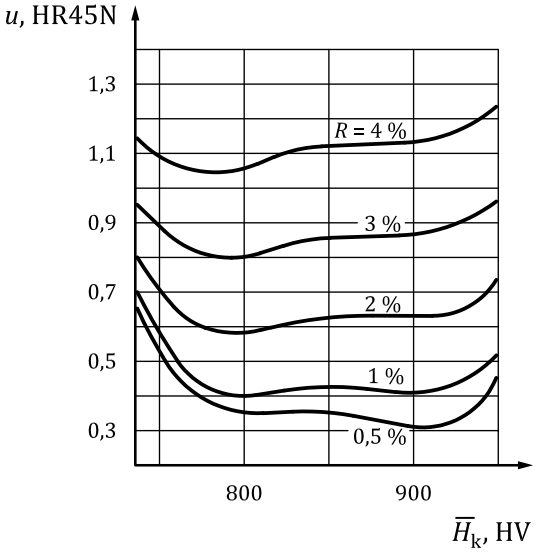


Figure D.23

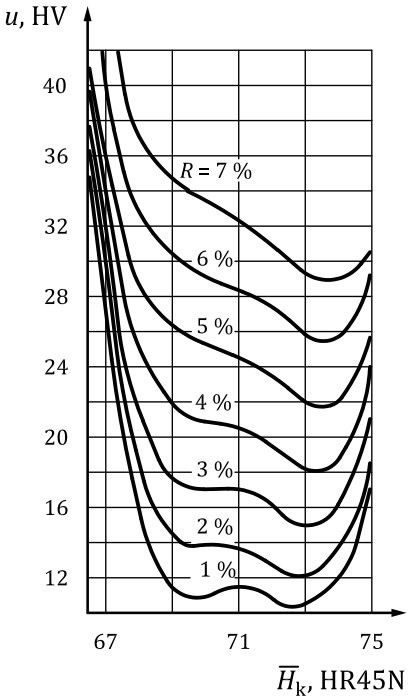


Figure D.24

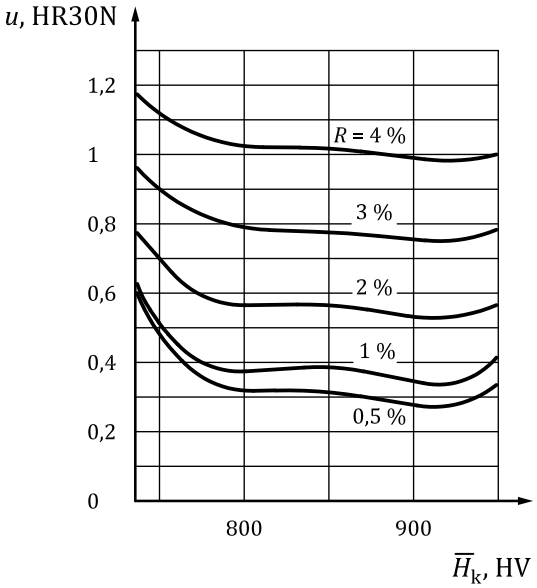


Figure D.25

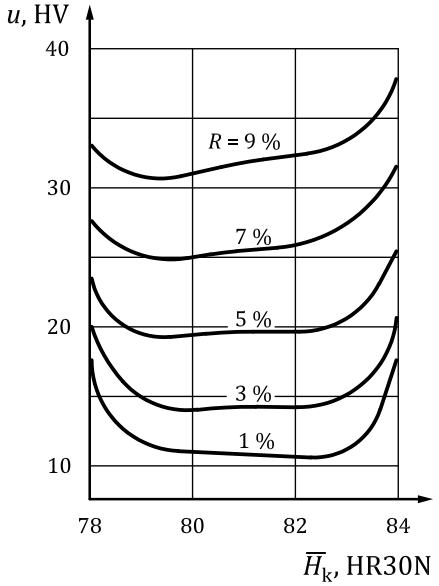


Figure D.26

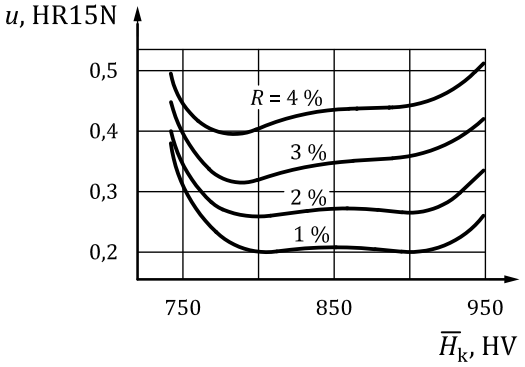


Figure D.27

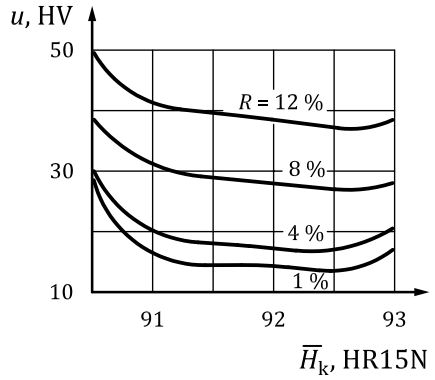


Figure D.28

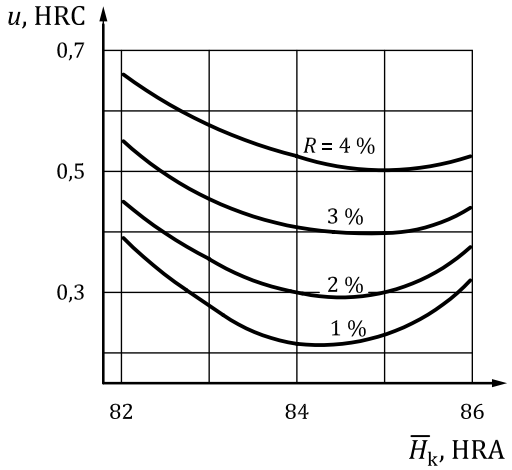


Figure D.29

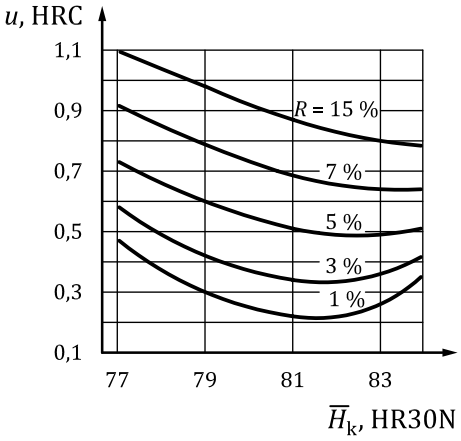


Figure D.30

Annex E
(informative)

Conversion tables for hardmetals

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 conversion values presented here for hardmetals are based on results of testing carried out on the hardmetals as in TGL 7965-02, listed in Table E.1. Table E.2 lists the conversion values, while Table E.3 gives an overview of the uncertainty curves presented in Figures E.1 and E.2 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.

Table E.1 — Designation and chemical composition of hardmetals tested

Hardmetal grade as in TGL 7965-02	WC content (% m/m)	TiC content (% m/m)	TaC and NbC (% m/m)	Co content (% m/m)
HS 021	65,8	23,0	8,0	3,2
HS 123	67,3	16,8	7,9	8,0
HS 10	69,0	17,0	8,0	6,0
HS 20	74,0	12,0	6,0	8,0
HS 25	76,0	5,0	10,0	9,0
HS 30	83,0	5,0	5,0	7,0
HS 345	76,9	7,2	7,2	8,7
HS 40	82,0	5,0	4,0	9,0
HS 50	80,0	5,0	3,0	12,0
HG 01	96,0			4,0
HG 110	94,0			6,0
HG 20	94,0			6,0
HG 30	91,5			8,5
HG 40	89,0			11,0
HG 50	85,0			15,0
HG 60	80,0			20,0
HU 10	79,0	10,0	5,0	6,0

Table E.2 — Conversion from HV 50 values to HRA values of hardmetals

Vickers hardness HV 50	Rockwell hardness HRA
780	82,5
800	82,8
820	83,1
840	83,4
860	83,7
880	84,0
900	84,2
920	84,5
940	84,8
960	85,1
980	85,3
1 000	85,6
1 020	85,8
1 040	86,1
1 060	86,4
1 080	86,6
1 100	86,8
1 120	87,1
1 140	87,3
1 160	87,6
1 180	87,8
1 200	88,0
1 220	(88,2)
1 240	(88,4)
1 260	(88,7)
1 280	(88,9)
1 300	(89,1)
1 320	(89,3)
1 340	(89,5)
1 360	(89,7)
1 380	(89,9)
1 400	(90,1)

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

Table E.2 *(continued)*

Vickers hardness HV 50	Rockwell hardness HRA
1 420	(90,3)
1 440	(90,5)
1 460	(90,7)
1 480	(90,9)
1 500	(91,0)
1 520	(91,2)
1 540	(91,4)
1 560	(91,6)
1 580	(91,8)
1 600	(91,9)
1 620	(92,1)
1 640	(92,3)
1 660	(92,4)
1 680	(92,6)
1 700	(92,8)
1 720	(92,9)
1 740	(93,1)
1 760	(93,2)

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

Table E.3 — Uncertainty curves to be used for conversion as in Table E.2

To obtain uncertainty u, in	of conversion from/to	use
HRA	HV 50/HRA	Figure E.1
HV 50	HRA/HV 50	Figure E.2

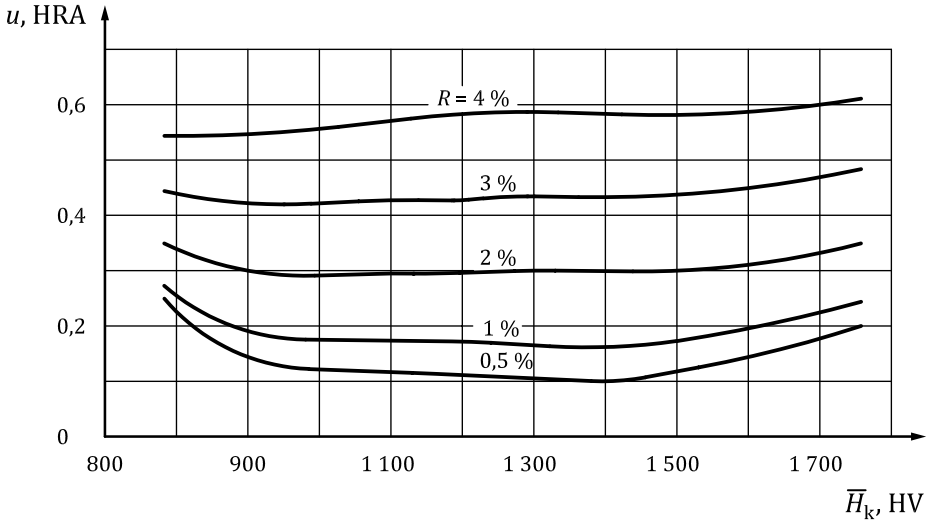


Figure E.1

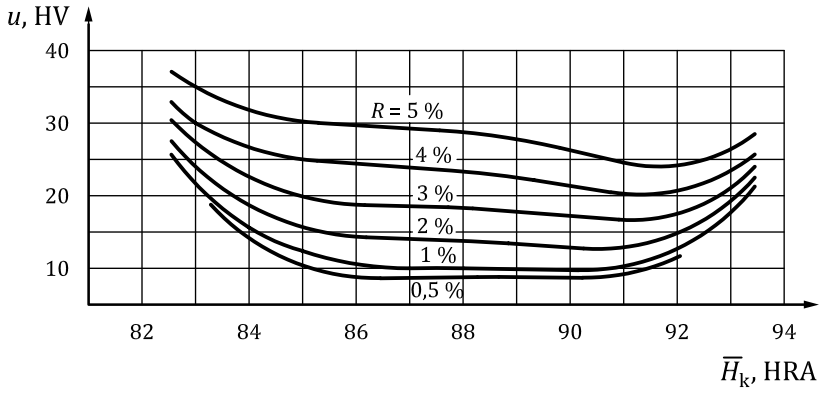


Figure E.2

Annex F
(informative)

Conversion tables for non-ferrous metals and alloys

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 user of Annex F should consider that the given metals and alloys in most cases are not specified with respect to their composition and treatment conditions.

The following tables are provided.

Table F.1 — Nickel and High-Nickel Alloys (ASTM E 140-97, Table 3)

HV	HB	Rockwell Hardness Number													HK
HV1, HV5, HV10, HV30	HBS 10/3000	HRA	HRB	HRC	HRD	HRE	HRF	HRG	HRK	HR15N	HR30N	HR45N	HR15T	HR30T	HR45T	HK0,5, HK1
513	(479)	75,5	…	50,0	63,0	…	…	…	…	85,5	68,0	54,5	…	…	…	…
481	450	74,5	…	48,0	61,5	…	…	…	…	84,5	66,5	52,5	…	…	…	…
452	425	73,5	…	46,0	60,0	…	…	…	…	83,5	64,5	50,0	…	…	…	…
427	403	72,5	…	44,0	58,5	…	…	…	…	82,5	63,0	47,5	…	…	…	…
404	382	71,5	…	42,0	57,0	…	…	…	…	81,5	61,0	45,5	…	…	…	…
382	363	70,5	…	40,0	55,5	…	…	…	…	80,5	59,5	43,0	…	…	…	436
362	346	69,5	…	38,0	54,0	…	…	…	…	79,5	58,0	41,0	…	…	…	413
344	329	68,5	…	36,0	52,5	…	…	…	…	78,5	56,0	38,5	…	…	…	392
326	313	67,5	…	34,0	50,5	…	…	…	…	77,5	54,5	36,0	…	…	…	372
309	298	66,5	(106)	32,0	49,5	…	(116,5)	94,0	…	76,5	52,5	34,0	94,5	85,5	77,0	352
285	275	64,5	(104)	28,5	46,5	…	(115,5)	91,0	…	75,0	49,5	30,0	94,0	84,5	75,0	325
266	258	63,0	(102)	25,5	44,5	…	(114,5)	87,5	…	73,5	47,0	26,5	93,0	83,0	73,0	304
248	241	61,5	100	22,5	42,0	…	(113,0)	84,5	…	72,0	44,5	23,0	92,5	81,5	71,0	283
234	228	60,5	98	20,0	40,0	…	(112,0)	81,5	…	70,5	42,0	20,0	92,0	80,5	69,0	267
220	215	59,0	96	(17,0)	38,0	…	(111,0)	78,5	100,0	69,0	39,5	17,0	91,0	79,0	67,0	251
209	204	57,5	94	(14,5)	36,0	…	(110,0)	75,5	98,0	68,0	37,5	14,0	90,5	77,5	65,0	239
198	194	56,5	92	(12,0)	34,0	…	(108,5)	72,0	96,5	66,5	35,5	11,0	89,5	76,0	63,0	226
188	184	55,0	90	(9,0)	32,0	(108,5)	(107,5)	69,0	94,5	65,0	32,5	7,5	89,0	75,0	61,0	215
179	176	53,5	88	(6,5)	30,0	(107,0)	(106,5)	65,5	93,0	64,0	30,5	5,0	88,0	73,5	59,5	204
171	168	52,5	86	(4,0)	28,0	(106,0)	(105,0)	62,5	91,0	62,5	28,5	2,0	87,5	72,0	57,5	195
164	161	51,5	84	(2,0)	26,5	(104,5)	(104,0)	59,5	89,0	61,5	26,5	(-0,5)	87,0	70,5	55,5	187
157	155	50,0	82	…	24,5	(103,0)	(103,0)	56,5	87,5	…	…	…	86,0	69,5	53,5	179
151	149	49,0	80	…	22,5	(102,0)	(101,5)	53,0	85,5	…	…	…	85,5	68,0	51,5	173
145	144	47,5	78	…	21.0	(100,6) [a]	(100,5)	50,0	83,5	…	…	…	84,5	66,5	49,5	166
140	139	46,5	76	…	(19,0)	99,5	99,5	47,0	82,0	…	…	…	84,0	65,5	47,5	160
135	134	45,5	74	…	(17,5)	98,0	98,5	43,5	80,0	…	…	…	83,0	64,0	45,5	154

[a] Recalculated in 2012 by interpolation

The use of the hardness scales for the hardness values shown in parentheses is not recommended since they are beyond the ranges recommended for accuracy. Such values are shown for comparative purposes only, where comparisons may be desired and the recommended machine and scale are not available.

Table F.1 *(continued)*

HV	HB	Rockwell Hardness Number														HK
HV1, HV5, HV10, HV30	HBS 10/3000	HRA	HRB	HRC	HRD	HRE	HRF	HRG	HRK	HR15N	HR30N	HR45N	HR15T	HR30T	HR45T	HK0,5, HK1
130	129	44,0	72	…	(16,0)	97,0	97,0	40,5	78,0	…	…	…	82,5	62,5	43,5	149
126	125	43,0	70	…	(14,5)	95,5	96,0	37,5	76,5	…	…	…	82,0	61,0	41,5	144
122	121	42,0	68	…	(13,0)	94,5	95,0	34,5	74,5	…	…	…	81,0	60,0	39,5	140
119	118	41,0	66	…	(11,5)	93,0	93,5	31,0	72,5	…	…	…	80,5	58,5	37,5	136
115	114	40,0	64	…	(10,0)	91,5	92,5	…	71,0	…	…	…	79,5	57,0	35,5	…
112	111	39,0	62	…	(8,0)	90,5	91,5	…	69,0	…	…	…	79,0	56,0	33,5	…
108	108	…	60	…	…	89,0	90,0	…	67,5	…	…	…	78,5	54,5	31,5	…
106	106	…	58	…	…	88,0	89,0	…	65,5	…	…	…	77,5	53,0	29,5	…
103	103	…	56	…	…	86,5	88,0	…	63,5	…	…	…	77,0	51,5	27,5	…
100	100	…	54	…	…	85,5	87,0	…	62,0	…	…	…	76,0	50,5	25,5	…
98	98	…	52	…	…	84,0	85,5	…	60,0	…	…	…	75,5	49,0	23,5	…
95	95	…	50	…	…	83,0	84,5	…	58,0	…	…	…	74,5	47,5	21,5	…
93	93	…	48	…	…	81,5	83,5	…	56,5	…	…	…	74,0	46,5	19,5	…
91	91	…	46	…	…	80,5	82,0	…	54,5	…	…	…	73,5	45,0	17,0	…
89	89	…	44	…	…	79,0	81,0	…	52,5	…	…	…	72,5	43,5	14,5	…
87	87	…	42	…	…	78,0	80,0	…	51,0	…	…	…	72,0	42,0	12,5	…
85	85	…	40	…	…	76,5	79,0	…	49,0	…	…	…	71,0	41,0	10,0	…
83	83	…	38	…	…	75,0	77,5	…	47,0	…	…	…	70,5	39,5	7,5	…
81	81	…	36	…	…	74,0	76,5	…	45,5	…	…	…	70,0	38,0	5,5	…
79	79	…	34	…	…	72,5	75,5	…	43,5	…	…	…	69,0	36,5	3,0	…
78	78	…	32	…	…	71,5	74,0	…	42,0	…	…	…	68,5	35,5	1,0	…
77	77	…	30	…	…	70,0	73,0	…	40,0	…	…	…	67,5	34,0		…

[a] Recalculated in 2012 by interpolation

The use of the hardness scales for the hardness values shown in parentheses is not recommended since they are beyond the ranges recommended for accuracy. Such values are shown for comparative purposes only, where comparisons may be desired and the recommended machine and scale are not available.

Table F.2 — Cartridge brass (70 % Copper, 30 % Zinc Alloy) (ASTM E 140-97, Table 4)

HV 30	Rockwell Hardness Number					HB
	HRB	HRF	HR15T	HR30T	HR45T	HBS10/500
196	93,5	110,0	90.0	77,5	66,0	169
194	...	109,5	...	...	65,5	167
192	93,0	...	...	77,0	65,0	166
190	92,5	109,0	...	76,5	64,5	164
188	92,0	...	89,5	...	64,0	162
186	91,5	108,5	...	76,0	63,5	161
184	91,0	...	...	75,5	63,0	159
182	90,5	108,0	89,0	...	62,5	157
180	90,0	107,5	...	74,5	62,0	156
178	89,0	...	...	...	61,5	154
176	88,5	107,0	...	...	61,0	152
174	88,0	...	88,5	74,0	60,5	150
172	87,5	106,5	...	73,5	60,0	149
170	87,0	...	...	...	59,5	147
168	86,0	106,0	88,0	73,0	59,0	146
166	85,5	...	...	72,5	58,5	144
164	85,0	105,5	...	72,0	58,0	142
162	84,0	105,0	87,5	...	57,5	141
160	83,5	...	...	71,5	56,5	139
158	83,0	104,5	...	71,0	56,0	138
156	82,0	104,0	87,0	70,5	55,5	136
154	81,5	103,5	...	70,0	54,5	135
152	80,5	103,0	...	...	54,0	133
150	80,0	...	86,5	69,5	53,5	131
148	79,0	102,5	...	69,0	53,0	129
146	78,0	102,0	...	68,5	52,5	128
144	77,5	101,5	86,0	68,0	51,5	126
142	77,0	101,0	...	67,5	51,0	124

[a]Recalculated in 2012 by interpolation

Table F.2 *(continued)*

HV 30	Rockwell Hardness Number					HB
	HRB	HRF	HR15T	HR30T	HR45T	HBS10/500
140	76,0	100,5	85,5	67,0	50,0	122
138	75,0	100,0	...	66,5	49,0	121
136	74,5	99,5	85,0	66,0	48,0	120
134	73,5	99,0	...	65,5	47,5	118
132	73,0	98,5	84,5	65,0	46,5	116
130	72,0	98,0	84,0	64,5	45,5	114
128	71,0	97,5	...	63,5	45,0	113
126	70,0	97,0	83,5	63,0	44,0	112
124	69,0	96,5	...	62,5	43,0	110
122	68,0	96,0	83,0	62,0	42,0	108
120	67,0	95,5	...	61,0	41,0	106
118	66,0	95,0	82,5	60,5	40,0	105
116	65,0	94,5	82,0	60,0	39,0	103
114	64,0	94,0	81,5	59,5	38,0	101
112	63,0	93,0	81,0	58,5	37,0	99
110	62,0	92,6	80,5	58,0	35,5	97
108	61,0	92,0	...	57,0	34,5	95
106	59,5	91,2	80,0	56,0	33,0	94
104	58,0	90,5	79,5	55,0	32,0	92
102	57,0	89,8	79,0	54,5	30,5	90
100	56,0	89,0	78,5	53,5	29,5	88
98	54,0	88,0	78,0	52,5	28,0	86
96	53,0	87,2	77,5	51,5	26,5	85
94	51,0	86,3	77,0	50,5	24,5	83
92	49,5	85,4	76,5	49,0	23,0	82
90	47,5	84,4	75,5	48,0	21,0	80
88	46,0	83,5	75,0	47,0	19,0	79
86	44,0	82,3	74,5	45,5	17,0	77

[a]Recalculated in 2012 by interpolation

Table F.2 *(continued)*

HV 30	Rockwell Hardness Number					HB
	HRB	HRF	HR15T	HR30T	HR45T	HBS10/500
84	42,0	81,2	73,5	44,0	14,5	76
82	40,0	80,0	73,0	43,0	12,5	74
80	37,5	78,6	72,0	41,0	10,0	72
78	35,0	77,4	71,5	39,5	7,5	70
76	32,5	76,0	70,5	38,0	4,5	68
74	30,0	74,8	70,0	36,0	1,0	66
72	27,5	73,2	69,0	34,0	…	64
70	24,5	71,8	68,0	32,0	…	63
68	21,5	70,0	67,0	30,0	…	62
66	18,5	68,5	66,0	27,8 [a]	…	61
64	15,5	66,8	65,0	25,5	…	59
62	12,5	65,0	63,5	23,0	…	57
60	10,0	62,5	62,5	…	…	55
58	…	61,0	61,0	18,0	…	53
56	…	58,8	60,0	15,0	…	52
54	…	56,5	58,5	12,0	…	50
52	…	53,5	57,0	…	…	48
50	…	50,5	55,5	…	…	47
48	…	49,0	54,5	…	…	46
47	…	47,0	53,5	…	…	45
46	…	45,0	…	…	…	44
45	…	40,0	…	…	…	42

[a] Recalculated in 2012 by interpolation

Table F.3 — Copper (ASTM E 140-97, Table 7)

Vickers Hardness Number		Knoop Hardness Number		Rockwell Hardness Number								Brinell Hardness Number	
HV1	HV0,1	HK1	HK0,5	HR15T	HR15T	HR30T	HRB	HRF	HR15T	HR30T	HR45T	HBS 10/500	HBS 2/20
				Strip 0,25 mm	Strip 0,51 mm			Strip 1,02 mm and greater				Strip 2,03 mm	Strip 1,02 mm
130	127,0	138,7	133,8	...	85,0	...	67,0	99,0	...	69,5	49,0	...	119,0
128	125,2	136,8	132,1	83,0	84,5	...	66,0	98,0	87,0	68,5	48,0	...	117,5
126	123,6	134,9	130,4	...	84,0	...	65,0	97,0	...	67,5	46,5	120,0	115,0
124	121,9	133,0	128,7	82,5	83,5	...	64,0	96,0	86,0	66,5	45,0	117,5	113,0
122	121,1	131,0	127,0	...	83,0	...	62,5	95,5	85,5	66,0	44,0	115,0	111,0
120	118,5	129,0	125,2	82,0	82,5	...	61,0	95,0	...	65,0	42,5	112,0	109,0
118	116,8	127,1	123,5	81,5	...	...	59,5	94,0	85,0	64,0	41,0	110,0	107,5
116	115,0	125,1	121,7	...	82,0	...	58,5	93,0	...	63,0	40,0	107,0	105,5
114	113,5	123,2	119,9	81,0	81,5	...	57,0	92,5	84,5	62,0	38,5	105,0	103,5
112	111,8	121,4	118,1	80,5	81,0	...	55,0	91,5	...	61,0	37,0	102,0	102,0
110	109,9	119,5	116,3	80,0	...	...	53,5	91,0	84,0	60,0	36,0	99,5	100,0
108	108,3	117,5	114,5	...	80,5	...	52,0	90,5	83,5	59,0	34,5	97,0	98,0
106	106,6	115,6	112,6	79,5	80,0	...	50,0	89,5	...	58,0	33,0	94,5	96,0
104	104,9	113,5	110,1	79,0	79,5	...	48,0	88,5	83,0	57,0	32,0	92,0	94,0
102	103,2	111,5	108,0	78,5	79,0	...	46,5	87,5	82,5	56,0	30,0	89,5	92,0
100	101,5	109,4	106,0	78,0	78,0	...	44,5	87,0	82,0	55,0	28,5	87,0	90,0
98	99,8	107,3	104,0	77,5	77,5	...	42,0	85,5	81,0	53,5	26,5	84,5	88,0
96	98,0	105,3	102,1	77,0	77,0	...	40,0	84,5	80,5	52,0	25,5	82,0	86,6
94	96,4	103,2	100,0	76,5	76,5	...	38,0	83,0	80,0	51,0	23,0	79,5	85,0
92	94,7	101,0	98,0	76,0	75,5	...	35,5	82,0	79,0	49,0	21,0	77,0	83,0
90	93,0	98,9	96,0	75,5	75,0	...	33,0	81,0	78,0	47,5	19,0	74,5	81,0
88	91,2	96,9	94,0	75,0	74,5	...	30,5	79,5	77,0	46,0	16,5	...	79,0
86	89,7	95,5	92,0	74,5	73,5	...	28,0	78,0	76,0	44,0	14,0	...	77,0
84	87,9	92,3	90,0	74,0	73,0	...	25,5	76,5	75,0	43,0	12,0	...	75,0
82	86,1	90,1	87,9	73,5	72,0	...	23,0	74,5	74,5	41,0	9,5	...	73,0
80	84,5	87,9	86,0	72,5	71,0	...	20,0	73,0	73,5	39,5	7,0	...	71,5
78	82,8	85,7	84,0	72,0	70,0	...	17,0	71,0	72,5	37,5	6,0	...	69,5

Table F.3 *(continued)*

Vickers Hardness Number		Knoop Hardness Number		Rockwell Hardness Number								Brinell Hardness Number	
HV1	HV0,1	HK1	HK0,5	HR15T	HR15T	HR30T	HRB	HRF	HR15T	HR30T	HR45T	HBS 10/500	HBS 2/20
				Strip 0,25 mm	Strip 0,51 mm			Strip 1,02 mm and greater				Strip 2,03 mm	Strip 1,02 mm
76	81,0	83,5	81,9	71,5	69,5	...	14,5	69,0	71,5	36,0	2,0	...	67,5
74	79,2	81,1	79,9	71,0	68,5	...	11,5	67,5	70,0	34,0	...	...	66,0
72	77,6	78,9	78,7	70,0	67,5	...	8,5	66,0	69,0	32,0	...	...	64,0
70	75,8	76,8	76,6	69,5	66,5	...	5,0	64,0	67,5	30,0	...	...	62,0
68	74,3	74,1	74,4	69,0	65,5	...	2,0	62,0	66,0	28,0	...	...	60,5
66	72,6	71,9	71,9	68,0	64,5	...	...	60,0	64,5	25,5	...	...	58,5
64	70,9	69,5	70,0	67,5	63,5	...	...	58,0	63,5	23,5	...	...	57,0
62	69,1	67,0	67,9	66,5	62,0	...	...	56,0	61,0	21,0	...	...	55,0
60	67,5	64,6	65,9	66,0	61,0	...	...	54,0	59,0	18,0	...	...	53,0
58	65,8	62,0	63,8	65,0	60,0	...	...	51,5	57,0	15,5	...	...	51,5
56	64,0	59,8	61,8	64,5	58,5	...	...	49,0	55,0	13,0	...	...	49,5
54	62,3	57,4	59,5	63,5	57,5	...	...	47,0	53,0	10,0	...	...	48,0
52	60,7	55,0	57,2	63,0	56,0	...	...	44,0	51,5	7,5	...	...	46,5
50	58,9	52,8	55,0	62,0	55,0	...	...	41,5	49,5	4,5	...	...	44,5
48	57,3	50,3	52,7	61,0	53,5	...	...	39,0	47,5	1,5	...	...	42,0
46	55,8	48,0	50,2	60,5	52,0	...	...	36,0	45,0	...	...	...	41,0
44	53,9	45,9	47,8	59,5	51,0	...	...	33,5	43,0	...	...	...	...
42	52,2	43,7	45,2	58,5	49,5	...	...	30,5	41,0	...	...	...	...
40	51,3	40,2	42,8	57,5	48,0	...	...	28,0	38,5	...	...	...	...

Table F.4 — Wrought Aluminium Products (ASTM E 140-97, Table 9)

HBS10/500	HV15	Rockwell Hardness Number					
		HRB	HRE	HRH	HR15T	HR30T	HR15W
160	189	91	…	…	89	77	95
155	183	90	…	…	89	76	95
150	177	89	…	…	89	75	94
145	171	87	…	…	88	74	94
140	165	86	…	…	88	73	94
135	159	84	…	…	87	71	93
130	153	81	…	…	87		
125	147	79	…	…	86	68	92
120	141	76	…	…	86	67	92
115	135	72	101	…	86	65	91
110	129	69	100	…	85	63	91
105	123	65	99	…	84	61	91
100	117	60	98	…	83	59	90
95	111	56	96	…	82	57	90
90	105	51	94	108	81	54	89
85	98	46	91	107	80	52	89
80	92	40	88	106	78	50	88
75	86	34	84	104	76	47	87
70	80	28	80	102	74	44	86
65	74	…	75	100	72	…	85
60	68	…	70	97	70	…	83
55	62	…	65	94	67	…	82
50	56	…	59	91	64	…	80
45	50	…	53	87	62	…	79
40	44	…	46	83	59	…	77

Table F.5 — Aluminium and its Alloys (BS 860:1967, Table 1)

HV10	HB (0,102 F/D^2 = 5 or 10)	HRB
210	199,5	95,7
205	194,8	94,8
200	190,0	93,8
195	185,3	92,7
190	180,5	91,6
185	175,8	90,4
180	171,0	89,2
175	166,3	87,9
170	161,5	86,5
165	156,8	85,0
160	152,0	83,4
155	147,3	81,8
150	142,5	80,0
145	137,8	78,1
140	133,0	76,1
135	128,3	73,9
130	123,5	71,5
125	118,8	69,0
120	114,0	66,3
115	109,3	63,3
110	104,5	60,0
105	99,8	56,4
100	95,0	52,5
98	93,1	50,8
96	91,2	49,1
94	89,3	47,2
92	87,4	45,3
90	85,5	43,3
88	83,6	41,3
86	81,7	39,1
84	79,8	36,8
82	77,9	34,4
80	76,0	31,9
78	74,1	…
76	72,2	…
74	70,3	…
72	68,4	…
70	66,5	…
68	64,6	…
66	62,7	…

Table F.5 *(continued)*

HV10	HB (0,102 F/D^2 = 5 or 10)	HRB
64	60,8	…
62	58,9	…
60	57,0	…
58	55,1	…
56	53,2	…
54	51,3	…
52	49,4	…
50	47,5	…
48	45,6	…
46	43,7	…
44	41,8	…
42	39,9	…
40	38,0	…
38	36,1	…
36	34,2	…
34	32,3	…
32	30,4	…
30	28,5	…
28	26,6	…
26	24,7	…
24	22,8	…
22	20,9	…
20	19,0	…
18	17,1	…

Annex G
(informative)

Conversion tables for tool steels

The following conversion tables (Tables G.1 and G.2) for two tool steels were established in 2007 under application of the valid test conditions in ISO 6506-1, ISO 6507-1 and ISO 6508-1.

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.

Table G.1 — Conversion of hardness-to-hardness values and tensile strength for tool steel 1.1243

Tensile strength R_m, N/mm²	HBW2,5/187,5	HV30	HRA	HRC
950	297	305	65,9	31,2
960	300	308	66,1	31,5
970	303	311	66,2	31,8
980	306	314	66,4	32,0
990	309	316	66,5	32,3
1 000	312	319	66,7	32,6
1 010	315	322	66,8	32,9
1 020	318	325	67,0	33,2
1 030	321	328	67,1	33,4
1 040	324	331	67,3	33,7
1 050	327	333	67,4	34,0
1 060	330	336	67,6	34,3
1 070	333	339	67,7	34,6
1 080	335	342	67,9	34,8
1 090	338	345	68,0	35,1
1 100	341	347	68,2	35,4
1 110	344	350	68,3	35,7
1 120	347	353	68,5	36,0
1 130	350	356	68,6	36,2
1 140	353	359	68,8	36,5
1 150	356	362	68,9	36,8
1 160	359	364	69,1	37,1
1 170	362	367	69,2	37,4
1 180	365	370	69,4	37,6
1 190	368	373	69,5	37,9
1 200	371	376	69,7	38,2
1 210	374	378	69,8	38,5

NOTE 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

Table G.1 *(continued)*

Tensile strength R_m, N/mm²	HBW2,5/187,5	HV30	HRA	HRC
1 220	377	381	70,0	38,8
1 230	380	384	70,1	39,0
1 240	382	387	70,3	39,3
1 250	385	390	70,4	39,6
1 260	388	392	70,6	39,9
1 270	391	395	70,7	40,2
1 280	394	398	70,9	40,4
1 290	397	401	71,0	40,7
1 300	400	404	71,2	41,0
1 310	403	407	71,3	41,3
1 320	406	409	71,5	41,6
1 330	409	412	71,6	41,8
1 340	412	415	71,8	42,1
1 350	415	418	71,9	42,4
1 360	418	421	72,1	42,7
1 370	421	423	72,2	43,0
1 380	424	426	72,4	43,2
1 390	427	429	72,5	43,5
1 400	430	432	72,7	43,8
1 410	432	435	72,8	44,1
1 420	435	438	73,0	44,4
1 430	438	440	73,1	44,6
1 440	441	443	73,3	44,9
1 450	444	446	73,4	45,2
1 460	447	449	73,6	45,5
1 470	450	452	73,7	45,8
1 480	453	454	73,9	46,1
1 490	456	457	74,0	46,3
1 500	459	460	74,2	46,6
1 510	462	463	74,3	46,9
1 520	465	466	74,5	47,2
1 530	468	468	74,6	47,5
1 540	471	471	74,8	47,7
1 550	474	474	74,9	48,0
Function	R_m = f(HBW)	R_m = f(HV)	R_m=f(HRA)	R_m=f(HRC)
Standard deviation	15,7	16,4	20,6	23,3

NOTE 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

Table G.2 — Conversion of hardness-to-hardness values and tensile strength for tool steel 1.2714

Tensile strength R_m, N/mm²	HBW2,5/187,5	HV30	HRA	HRC
880	279	280	62,9	27,7
890	282	283	63,5	28,2
900	285	286	63,9	28,7
910	288	289	64,3	29,2
920	291	292	64,7	29,7
930	294	295	65,0	30,1
940	296	298	65,3	30,6
950	299	300	65,6	31,0
960	302	303	65,9	31,4
970	305	306	66,1	31,8
980	308	309	66,3	32,2
990	311	312	66,6	32,6
1 000	314	315	66,8	32,9
1 010	316	318	67,0	33,3
1 020	319	321	67,2	33,6
1 030	322	324	67,4	34,0
1 040	325	327	67,6	34,3
1 050	328	330	67,8	34,7
1 060	331	333	68,0	35,0
1 070	333	336	68,2	35,3
1 080	336	339	68,3	35,6
1 090	339	342	68,5	35,9
1 100	342	345	68,7	36,2
1 110	345	347	68,8	36,5
1 120	348	350	69,0	36,8
1 130	351	353	69,1	37,1
1 140	353	356	69,3	37,4
1 150	356	359	69,4	37,7
1 160	359	362	69,6	38,0
1 170	362	365	69,7	38,2
1 180	365	368	69,9	38,5
1 190	368	371	70,0	38,8
1 200	370	374	70,2	39,0
1 210	373	377	70,3	39,3
1 220	376	380	70,4	39,6
1 230	379	383	70,6	39,8
1 240	382	386	70,7	40,1
1 250	385	389	70,8	40,3

NOTE 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

Table G.2 *(continued)*

Tensile strength R_m, N/mm²	HBW2,5/187,5	HV30	HRA	HRC
1 260	388	392	71,0	40,6
1 270	390	395	71,1	40,8
1 280	393	397	71,2	41,0
1 290	396	400	71,3	41,3
1 300	399	403	71,4	41,5
1 310	402	406	71,6	41,7
1 320	405	409	71,7	42,0
1 330	407	412	71,8	42,2
1 340	410	415	71,9	42,4
1 350	413	418	72,0	42,7
1 360	416	421	72,1	42,9
1 370	419	424	72,3	43,1
Function	R_m = f(HBW)	R_m = f(HV)	R_m=f(HRA)	R_m=f(HRC)
Standard deviation	10,2	11,2	22,1	35,0
NOTE 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				

Annex H
(informative)

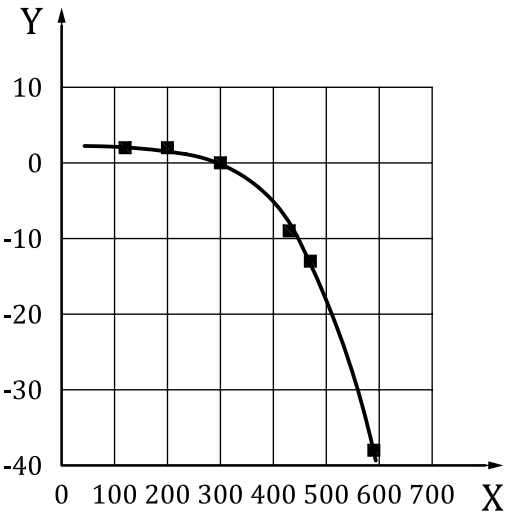
Remarks on the effect of the changed test conditions

Because the test conditions which were applied for the tables in the Annexes A to F (in the period from approximately 1950 until approximately 1990) are not further valid in the present ISO standards, effects on the converted hardness values should be considered. These changed test conditions refer to

a) the replacement of steel ball indenters by hardmetal ball indenters for the Rockwell and Brinell scales;

b) the introduction of a shorter test force duration time for the Rockwell scales, which was reduced from 30 s to (4 ± 2) s.

Preliminary investigations, which were carried out in Germany on hardness reference blocks (made from not or low alloyed steels), led to the results shown in Figures H.1 to H.5 for the effect of the changed test conditions.

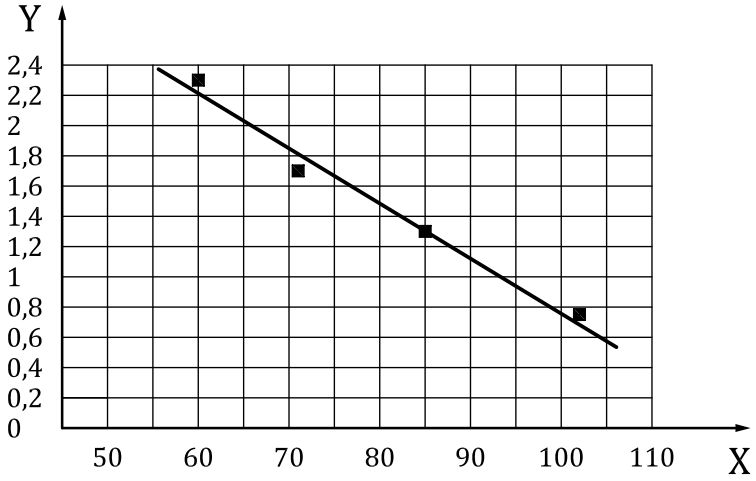


Key

X Brinell hardness in HB

Y Hardness difference in using a steel ball as a carbide ball

Figure H.1 — Influence of the material of Brinell indenter balls on hardness

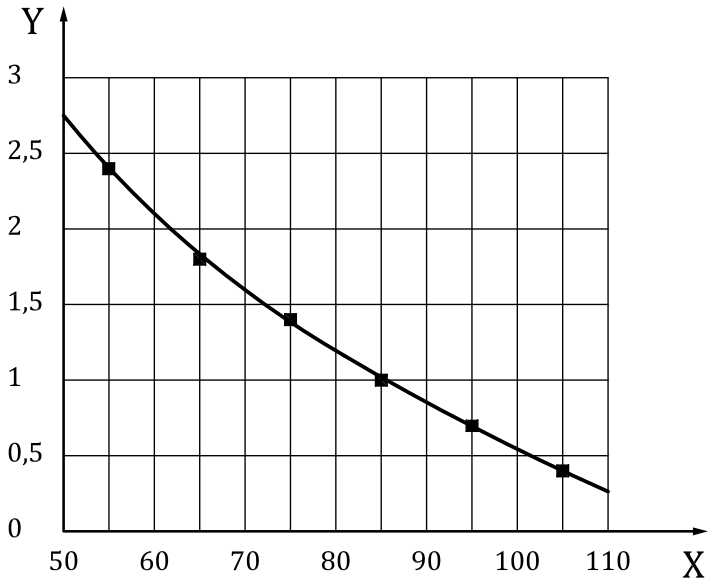


Key

X Rockwell hardness in HRB

Y Hardness difference in using a steel ball as a carbide ball

Figure H.2 — Influence of the material of Rockwell indenter balls on hardness

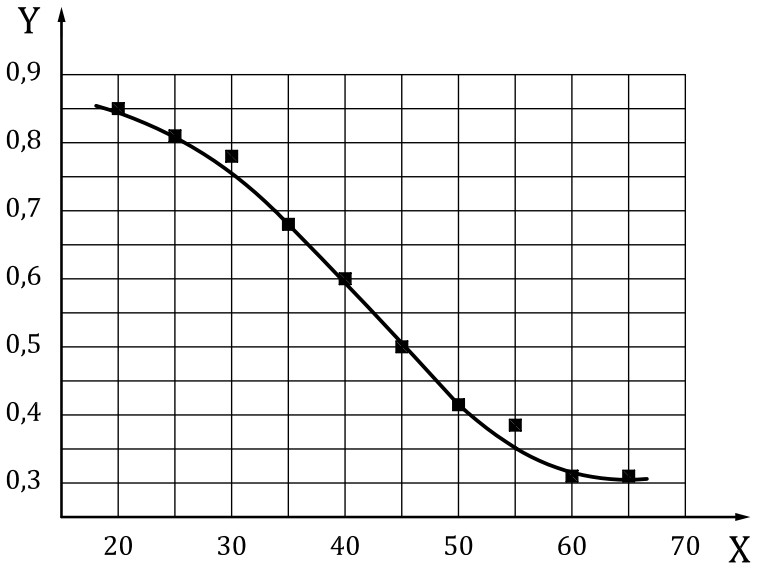


Key

X Rockwell hardness in HRB

Y Hardness difference in using 6 s as 30 s test force duration time

Figure H.3 — Influence of changed test force duration time at HRB



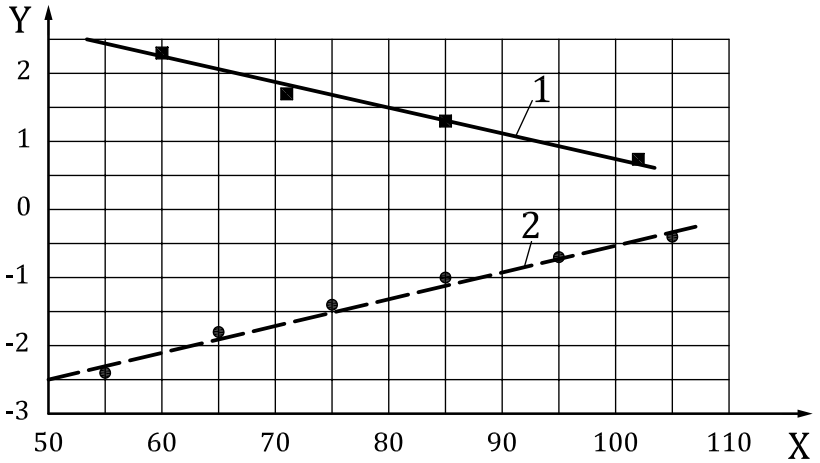
Key

X Rockwell hardness in HRC

Y Hardness difference in using 6 s as 30 s test force duration time

Figure H.4 — Influence of changed test force duration time at HRC

It should be noted that the combined influence of changed indenter ball material and of changed test force duration time at HRB obviously offset each other.



Key

X Rockwell hardness in HRB

Y Hardness difference in HRB

1 Hardness difference in using a steel ball as a carbide ball

2 Hardness difference in using 6 s as 30 s test force duration time

Figure H.5 — Influence of changed indenter ball material and of changed test force duration time at HRB

In summary, the following orders of magnitude of determined deviations due to changed test conditions for unalloyed or low alloyed steels were found in this investigation (see Table H.1).

Table H.1 — Order of magnitude of determined deviations due to changed test conditions for unalloyed or low alloyed steels found in this investigation

Hardness test method	HB 5/750	HRC	HRB
Changed indenter material	−40 HBW	-	2,3 HRB
Changed test force duration time	-	0,6 HRC	−2,0 HRB

These results are only intended to raise the consciousness of the user of this International Standard toward the effects of the changed test conditions on the converted hardness value. In each actual case, the user should carry out corresponding comparative measurements as shown above. Other studies have shown differing magnitudes in the differences of the test results due to the changes in the ball material and test force duration, likely due to testing different alloys or using different testing conditions.

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