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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.

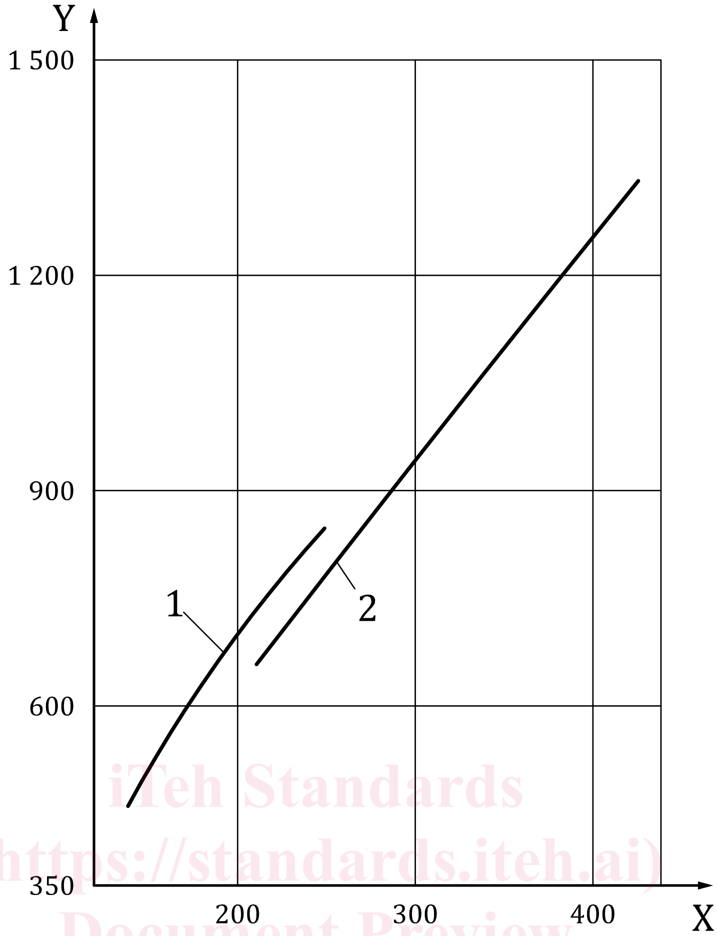
— The hardness test method used is only employed internally, and the results obtained will not be compared with those of other methods, or the details of the test procedure are defined precisely enough so that results can be reproduced by another laboratory or at another time.

— 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

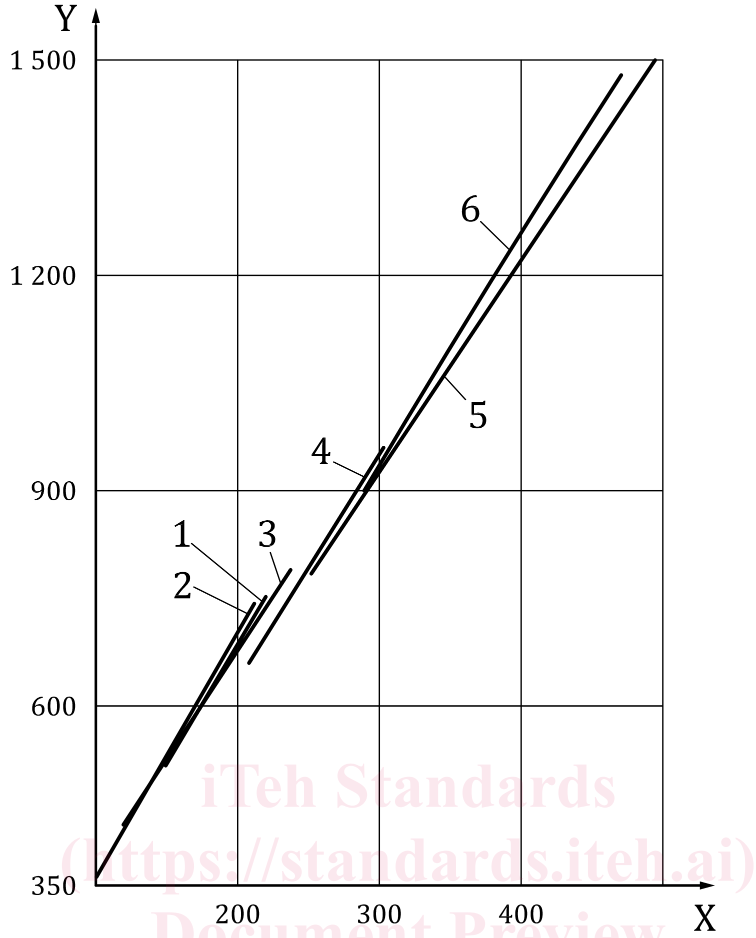
X Hardness HV 30

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

Y Tensile strength, R_m in MPa

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

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

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

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

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

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

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

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.

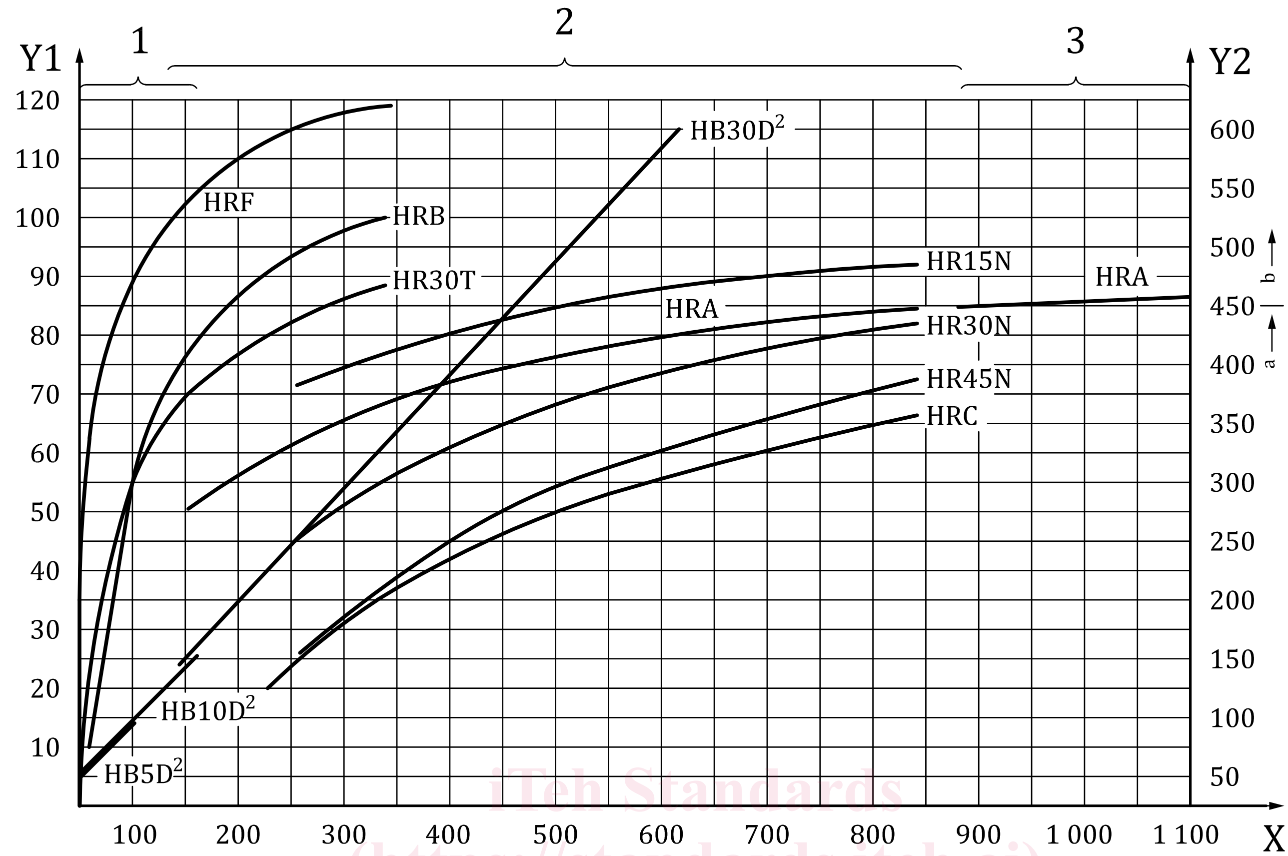
To ensure an acceptable uncertainty of measurement, the specimen surfaces shall be sufficiently smooth; depending on the hardness test method and the test force a suitable method of surface preparation has to be selected, e.g. machine-finishing (for macro hardness) up to polishing (for low-force and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

Y_1 Rockwell hardness

Y_2 Brinell hardness

a Brinell hardness, determined with steel ball (HBS)

b Brinell hardness, determined with hardmetal ball (HBW)

1 non-ferrous metal

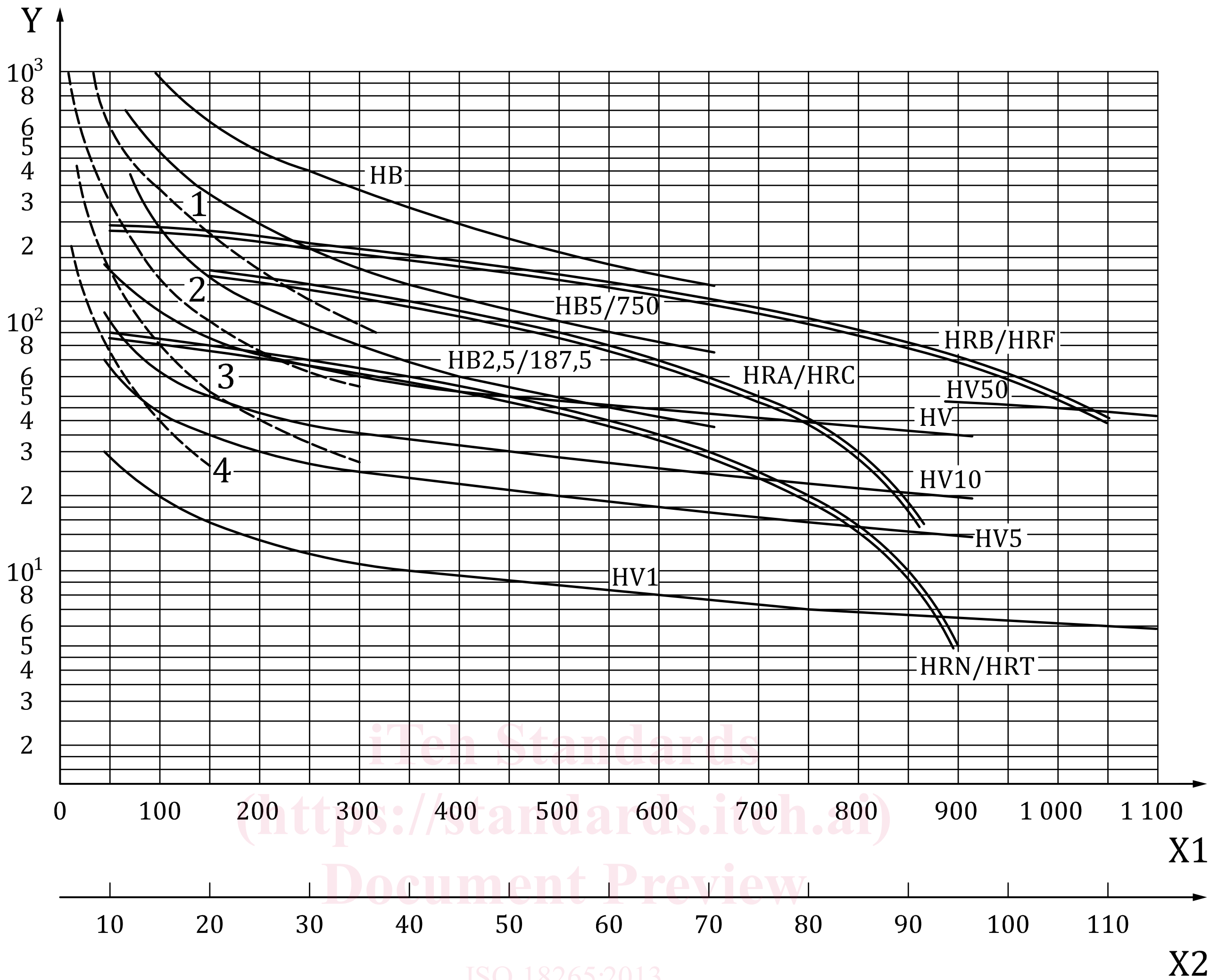
2 steel

3 hardmetal

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

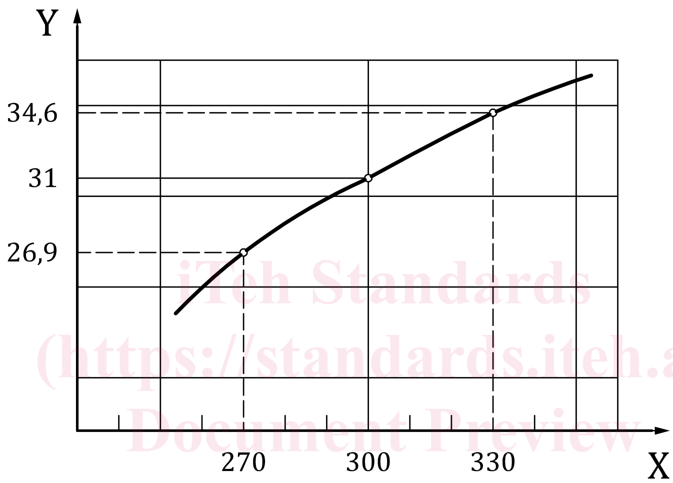
3.2.1 Limits of error

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

