

Steels for quenching and tempering —

Part 2: Technical delivery conditions for non alloy steels

The European Standard EN 10083-2:2006 has the status of a
British Standard

National foreword

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Foreword

This document (EN 10083-2:2006) has been prepared by Technical Committee ECISS/TC 23 "Steels for heat treatment, alloy steels and free-cutting steels - Qualities and dimensions", the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by February 2007, and conflicting national standards shall be withdrawn at the latest by February 2007.

This document supersedes EN 10083-2:1991.

Together with Part 1 and Part 3 of this standard, this Part 2 is a revision of the following European Standards:

EN 10083-1:1991 +A1:1996, *Quenched and tempered steels – Part 1: Technical delivery conditions for special steels*

EN 10083-2: 1991 +A1:1996, *Quenched and tempered steels – Part 2: Technical delivery conditions for unalloyed quality steels*

EN 10083-3:1995, *Quenched and tempered steels – Part 3: Technical delivery conditions for boron steels*

and of

EURONORM 86-70, *Flame and induction hardening steels – Quality specifications*

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

1 Scope

This part of EN 10083, in addition to Part 1, specifies the technical delivery requirements for:

- semi-finished products, hot formed, e.g. blooms, billets, slabs (see NOTES 2 and 3 in EN 10083-1:2006, Clause 1),
- bars (see NOTE 2 in EN 10083-1:2006, Clause 1),
- rod,
- wide flats,
- hot-rolled strip and sheet/plate,
- forgings (see NOTE 2 in EN 10083-1:2006, Clause 1),

manufactured from the direct hardening non alloy steels for quenching and tempering and the non alloy flame and induction hardening steels and supplied in one of the heat treatment conditions given for the different types of products in Table 1, lines 2 to 7, and in one of the surface conditions given in Table 2.

The steels are generally intended for the manufacture of quenched and tempered, flame or induction hardened machine parts, but can also be used in the normalized condition.

The requirements for mechanical properties given in this document are restricted to the sizes given in Table 9 and Table 10.

NOTE This document does not apply for bright steel products. For bright steel products EN 10277-1 and EN 10277-5 apply.

In special cases, variations in these technical delivery requirements or additions to them may be agreed at the time of enquiry and order (see Annex A).

2 Normative references

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

EN 10002-1, *Metallic materials – Tensile testing – Part 1: Method of test at ambient temperature*

EN 10020, *Definition and classification of grades of steel*

EN 10027-1, *Designation systems for steels – Part 1: Steel names*

EN 10027-2, *Designation systems for steel – Part 2: Numerical system*

EN 10045-1, *Metallic materials – Charpy impact test – Part 1: Test method*

EN 10083-1:2006, *Steels for quenching and tempering – Part 1: General technical delivery conditions*

EN 10160, *Ultrasonic testing of steel flat product of thickness equal or greater than 6 mm (reflection method)*

EN 10163-2, *Delivery requirements for surface condition of hot-rolled steel plates, wide flats and sections – Part 2: Plate and wide flats*

EN 10204, *Metallic products – Types of inspection documents*

EN 10221, *Surface quality classes for hot-rolled bars and rods – Technical delivery conditions*

CR 10261, *ECISS Information Circular 11 – Iron and steel – Review of available methods of chemical analysis*

EN 10308, *Non destructive testing – Ultrasonic testing of steel bars*

EN ISO 377, *Steel and steel products – Location and preparation of samples and test pieces for mechanical testing (ISO 377:1997)*

EN ISO 642, *Steel – Hardenability test by end quenching (Jominy test) (ISO 642:1999)*

EN ISO 643, *Steels – Micrographic determination of the apparent grain size (ISO 643:2003)*

EN ISO 3887, *Steels – Determination of depth of decarburization (ISO 3887:2003)*

EN ISO 6506-1, *Metallic materials – Brinell hardness test – Part 1: Test method (ISO 6506-1:2005)*

EN ISO 6508-1:2005, *Metallic materials – Rockwell hardness test – Part 1: Test method (scales A, B, C, D, E, F, G, H, K, N, T) (ISO 6508-1:2005)*

EN ISO 14284, *Steel and iron – Sampling and preparation of samples for the determination of chemical composition (ISO 14284:1996)*

EN ISO 18265, *Metallic materials – Conversion of hardness values (ISO 18265:2003)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 10083-1:2006 apply.

4 Classification and designation

4.1 Classification

Steel grades C35, C40, C45, C55 and C60 are classified according to EN 10020 as non alloy quality steels and the other steel grades as non alloy special steels.

4.2 Designation

4.2.1 Steel names

For the steel grades covered by this document, the steel names as given in the relevant tables are allocated in accordance with EN 10027-1.

4.2.2 Steel numbers

For the steel grades covered by this document, the steel numbers as given in the relevant tables are allocated in accordance with EN 10027-2.

5 Information to be supplied by the purchaser

5.1 Mandatory information

See EN 10083-1:2006, 5.1.

5.2 Options

A number of options are specified in this document (listed below). If the purchaser does not indicate his wish to implement any of these options, the supplier shall act in accordance with the basic specification.

- a) any particular heat treatment condition (see 6.3.2);
- b) any particular surface condition (see 6.3.3);
- c) any verification of the product analysis (see 7.1.2.2 and A.6);
- d) any requirement to the hardenability (+H, +HH, +HL) for special steels (see 7.1.3) and if agreed the information concerning calculating hardenability (see 10.3.2);
- e) any verification of mechanical properties of reference test pieces in the quenched and tempered (+QT) or normalized (+N) condition (see A.1 and A.2);
- f) any fine grain requirements (see 7.4 and A.3);
- g) any requirements for the verification of non-metallic inclusion content of special steels (see 7.4 and A.4);
- h) any requirement for internal soundness (see 7.5 and A.5);
- i) any requirement relating to surface quality (see 7.6.3);
- j) any requirement regarding the permissible depth of decarburization of special steels (see 7.6.4);
- k) suitability of bars and rod for bright drawing (see 7.6.5);
- l) any requirement relating to removal of surface defects (see 7.6.6);
- m) inspection of surface condition and dimensions shall be carried out by the purchaser at the manufacturer's works (see 8.1.4);
- n) any requirement concerning special marking of the products (see Clause 11 and A.7).

EXAMPLE

20 round bars with the nominal diameter 20 mm and the nominal length of 8000 mm according to EN 10060 made of steel grade C45E (1.1191), according to EN 10083-2 in the heat treatment condition +A, inspection certificate 3.1 as specified in EN 10204.

20 round bars EN 10060 - 20x8000
EN 10083-2 – C45E+A
EN 10204 - 3.1

or

20 round bars EN 10060 - 20x8000
EN 10083-2 – 1.1191+A
EN 10204 - 3.1

6 Manufacturing process

6.1 General

The manufacturing process of the steel and of the products is left to the discretion of the manufacturer with the restrictions given by the requirements in 6.2 to 6.4.

6.2 Deoxidation

All steels shall be killed.

6.3 Heat treatment and surface condition at delivery

6.3.1 Untreated condition

Unless otherwise agreed at the time of enquiry and order, the products shall be delivered in the untreated, i.e. hot worked, condition.

NOTE Depending on product shape and dimensions, not all steel grades can be delivered in the hot worked untreated condition (e. g. steel grade C60).

6.3.2 Particular heat treatment condition

If so agreed at the time of enquiry and order, the products shall be delivered in one of the heat-treatment conditions given in Table 1, lines 3 to 7.

6.3.3 Particular surface condition

If so agreed at the time of enquiry and order, the products shall be delivered with one of the particular surface conditions given in Table 2, lines 3 to 7.

6.4 Cast separation

The products shall be delivered separated by cast.

7 Requirements

7.1 Chemical composition, hardenability and mechanical properties

7.1.1 General

Table 1 shows the combinations of usual heat-treatment conditions at delivery, product forms and requirements as specified in Tables 3 to 10.

Except where special steels are ordered in the quenched and tempered condition, the special steels may be supplied with or without hardenability requirements (see Table 1, columns 8 and 9).

7.1.2 Chemical composition

7.1.2.1 The chemical composition determined by cast analysis shall comply with the values in Table 3.

7.1.2.2 Permissible deviations between the limiting values for cast analysis and the values for product analysis are given in Table 4.

The product analysis shall be carried out when specified at the time of the enquiry and order (see A.6).

7.1.3 Hardenability

Where the steel is ordered by using the symbols for normal (+H) or restricted (+HL, +HH) hardenability requirements, the hardenability values given in Table 5, Table 6 or Table 7 shall apply.

7.1.4 Mechanical properties

Where the steel is ordered without hardenability requirements, the requirements for mechanical properties specified in Table 9 or Table 10 apply as appropriate for the particular heat treatment condition.

In this case, the hardenability values given in Table 5 for special steels are for guidance purposes only.

The mechanical property values given in Table 9 and Table 10 apply to test pieces in the quenched and tempered or normalized condition, which have been taken and prepared in accordance with EN 10083-1:2006, Figure 1 or Figures 2 and 3 (see also footnote a in Table 1).

For steel plates > 10 mm thickness and bars > 100 mm diameter in the normalized condition (+N), it may be agreed at the time of enquiry and order that instead of the tensile test the hardness test is performed at the same region, where otherwise the sample for the tensile test piece would be taken from. The hardness test should be performed and from this so that the tensile strength values can be calculated according to EN ISO 18265. The calculated tensile strength shall comply to Table 10.

7.1.5 Surface hardness

For the surface hardness of special steels after flame and induction hardening, the specifications in Table 11 apply.

7.2 Machinability

All steels delivered in the soft annealed (+A) condition are machinable. Where improved machinability is required, the grades with a specified sulphur range should be ordered and/or with a specific treatment to improve machinability (e.g. Ca treatment), see also Table 3, footnote c.

7.3 Shearability of semi-finished products and bars

7.3.1 Under suitable conditions (avoiding local stress peaks, pre-heating, application of blades with a profile adapted to that of the product, etc.), all steels are shearable in the soft-annealed (+A) and normalized (+N) condition.

7.3.2 Steel grades C45, C45E, C45R, C50E, C50R, C55, C55E, C55R, C60, C60E, C60R and 28Mn6 (see Table 8) and the corresponding grades with requirements on hardenability (see Tables 5 to 7) are also shearable under suitable conditions if they are supplied in the "treated to improve shearability (+S)" condition with the hardness requirements as specified in Table 8.

7.3.3 Under suitable conditions, steel grades C22E, C22R, C35, C35E, C35R, C40, C40E and C40R (see Table 8) and the corresponding grades with hardenability requirements (see Tables 5 to 7) are shearable in the untreated condition.

Shearability may also be assumed for steel grades C45, C45E and C45R with dimensions greater than 80 mm and in the untreated condition.

7.4 Structure

7.4.1 Unless otherwise agreed at the time of enquiry and order, the grain size shall be left to the discretion of the manufacturer. If a fine grain structure is required in accordance with a reference treatment, special requirement A.3 shall be ordered.

If steels C35E, C35R, C45E, C45R, C50E, C50R, C55E and C55R are intended for flame or induction hardening, special requirement A.3 shall be ordered in any case.

7.4.2 The special steels shall have a degree of cleanness corresponding to the special steel quality (see A.4 and EN 10083-1:2006, Annex E).

7.5 Internal soundness

Where appropriate, requirements relating to the internal soundness of products shall be agreed at the time of enquiry and order, if possible with reference to European standards. EN 10160 specifies requirements of ultrasonic testing of flat products of thickness equal to or greater than 6 mm and EN 10308 specifies requirements of ultrasonic testing of steel bars (see A.5).

7.6 Surface quality

7.6.1 All products shall have a smooth finish appropriate to the manufacturing processes applied, see also 6.3.3..

7.6.2 Minor surface imperfections which may also occur under normal manufacturing conditions, such as scores originating from rolled-in scale in the case of hot-rolled products, shall not be regarded as defects.

7.6.3 Where appropriate, requirements relating to the surface quality of the products shall be agreed on at the time of enquiry and order, if possible with reference to European standards.

Sheet/plate and wide flats are delivered with surface class A, subclass 1 according to EN 10163-2 unless otherwise agreed at the time of enquiry and order.

Bars and rods are delivered with surface class A according to EN 10221 unless otherwise agreed at the time of enquiry and order.

7.6.4 Requirements relating to the permissible depth of decarburization may be agreed at the time of enquiry and order for special steels.

The depth of decarburization shall be determined in accordance with the micrographic method specified in EN ISO 3887.

7.6.5 If suitability of bars and rods for bright drawing is required, this shall be agreed at the time of enquiry and order.

7.6.6 The removal of surface defects by welding shall only be permitted with the approval of the customer or his or her representative.

If surface discontinuities are repaired, the method and maximum depth of removal shall be agreed at the time of enquiry and order.

7.7 Dimensions, tolerances on dimensions and shape

The nominal dimensions, tolerances on dimensions and shape for the product shall be agreed at the time of enquiry and order, if possible, with reference to the dimensional standards applicable (see EN 10083-1:2006, Annex D).

8 Inspection

8.1 Testing procedures and types of documents

8.1.1 Products complying with this document shall be ordered and delivered with one of the inspection documents as specified in EN 10204. The type of document shall be agreed upon at the time of enquiry and order. If the order does not contain any specification of this type, a test report shall be issued.

8.1.2 For information to be included in a test report, see EN 10083-1:2006, 8.1.2.

8.1.3 For information to be included in an inspection certificate, see EN 10083-1:2006, 8.1.3.

8.1.4 Unless otherwise agreed at the time of the order, inspection of the surface quality and dimensions shall be carried out by the manufacturer.

8.2 Frequency of testing

8.2.1 Sampling

Sampling shall be in accordance with Table 12.

8.2.2 Test units

The test units and the extent of testing shall be in accordance with Table 12.

8.3 Tests to be carried out for specific inspection

8.3.1 Verification of hardenability, hardness and mechanical properties

For steels being ordered without hardenability requirements, i.e. without the symbol +H, +HH or +HL in the designation, the hardness requirements or mechanical properties given for the relevant heat-treatment condition in Table 1, Column 8, subclause 2, shall with the following exception be verified. The requirement given in Table 1, footnote a (mechanical properties of reference test pieces), is only to be verified if supplementary requirement A.1 or A.2 is ordered.

For special steels being ordered with the symbol +H, +HH or +HL in the designation (see Tables 5 to 7), unless otherwise agreed, only hardenability requirements according to Tables 5, 6 or 7 shall be verified.

8.3.2 Visual and dimensional inspection

A sufficient number of products shall be inspected to ensure compliance with the specification.

9 Preparation of samples and test pieces

9.1 Selection and preparation of samples for chemical analysis

The preparation of samples for product analysis shall be in accordance with EN ISO 14284.

9.2 Location and orientation of samples and test pieces for mechanical tests

9.2.1 Preparation of samples

Preparation of samples shall be in accordance with Table 12 and EN 10083-1:2006, 9.2.1.

9.2.2 Preparation of test pieces

Preparation of test pieces shall be in accordance with Table 12 and EN 10083-1:2006, 9.2.2.

9.3 Location and preparation of samples for hardness and hardenability tests

See Table 12.

9.4 Identification of samples and test pieces

Samples and test pieces shall be marked so that the original products and their location and orientation in the product is known.

10 Test methods

10.1 Chemical analysis

See EN 10083-1:2006, 10.1.

10.2 Mechanical tests

See Table 12 and EN 10083-1:2006, 10.2.

10.3 Hardness and hardenability tests

10.3.1 Hardness in treatment conditions +A and +S

For products in treatment conditions +A (soft annealed) and +S (treated to improve shearability), the hardness shall be measured in accordance with EN ISO 6506-1.

10.3.2 Verification of hardenability

As far as available the manufacturer has the option to verify the hardenability by calculation. The calculation method is left to the discretion of the manufacturer. If agreed at the time of enquiry and order, the manufacturer shall give sufficient information about the calculation for the customer to confirm the result.

If a calculation formula is not available or in the case of a dispute an end quench hardenability test shall be carried out in accordance with EN ISO 642. The temperature for quenching shall comply with Table 13. The hardness values shall be determined in accordance with EN ISO 6508-1, scale C.

10.3.3 Surface hardness

The surface hardness of steels after flame or induction hardening (see Table 11) shall be determined in accordance with EN ISO 6508-1, scale C.

10.4 Retests

See EN 10083-1:2006, 10.4

11 Marking, labelling, packaging

The manufacturer shall mark the products or the bundles or boxes in a suitable way so that it is possible to determine the cast, the steel grade and the origin of the delivery (see A.7).

Table 1 — Combinations of usual heat-treatment conditions at delivery, product forms and requirements as specified in Tables 3 to 10

[illegible]

Table 2 — Surface condition at delivery

	1	2	3	4	5	6	7	8	9
1	Surface condition at delivery		Symbol	x indicates in general applicable for Semi-finished products (such as blooms, billets) Bars Rod Flat products Hammer and drop forgings (see Note 2 in EN 10083-1:2006, Clause 1)					Notes
2	Unless otherwise agreed	Hot worked	None or +HW	x	x	x	x	x	-
3	Particular conditions supplied by agreement	Unformed continuously cast	+CC	x	-	-	-	-	-
4		Hot worked and pickled	+PI	x	x	x	x	x	^a
5		Hot worked and blast cleaned	+BC	x	x	x	x	x	^a
6		Hot worked and rough machined	+RM	-	x	x	-	x	-
7		Others							
^a In addition, it may be agreed that the products be oiled or, where appropriate, limed or phosphated.									

Table 3 — Steel grades and chemical composition (cast analysis)

Steel designation		Chemical composition (% by mass) ^{a,b,c}								
Name	Number	C ^d	Si max.	Mn	P max.	S	Cr max.	Mo max.	Ni max.	Cr + Mo + Ni max. ^d
Quality steels										
C35	1.0501	0,32 to 0,39	0,40	0,50 to 0,80	0,045	max. 0,045	0,40	0,10	0,40	0,63
C40	1.0511	0,37 to 0,44	0,40	0,50 to 0,80	0,045	max. 0,045	0,40	0,10	0,40	0,63
C45	1.0503	0,42 to 0,50	0,40	0,50 to 0,80	0,045	max. 0,045	0,40	0,10	0,40	0,63
C55	1.0535	0,52 to 0,60	0,40	0,60 to 0,90	0,045	max. 0,045	0,40	0,10	0,40	0,63
C60	1.0601	0,57 to 0,65	0,40	0,60 to 0,90	0,045	max. 0,045	0,40	0,10	0,40	0,63
Special steels										
C22E	1.1151	0,17 to 0,24	0,40	0,40 to 0,70	0,030	max. 0,035 ^e	0,40	0,10	0,40	0,63
C22R	1.1149					0,020 to 0,040				
C35E	1.1181	0,32 to 0,39	0,40	0,50 to 0,80	0,030	max. 0,035 ^e	0,40	0,10	0,40	0,63
C35R	1.1180					0,020 to 0,040				
C40E	1.1186	0,37 to 0,44	0,40	0,50 to 0,80	0,030	max. 0,035 ^e	0,40	0,10	0,40	0,63
C40R	1.1189					0,020 to 0,040				
C45E	1.1191	0,42 to 0,50	0,40	0,50 to 0,80	0,030	max. 0,035 ^e	0,40	0,10	0,40	0,63
C45R	1.1201					0,020 to 0,040				
C50E	1.1206	0,47 to 0,55	0,40	0,60 to 0,90	0,030	max. 0,035 ^e	0,40	0,10	0,40	0,63
C50R	1.1241					0,020 to 0,040				
C55E	1.1203	0,52 to 0,60	0,40	0,60 to 0,90	0,030	max. 0,035 ^e	0,40	0,10	0,40	0,63
C55R	1.1209					0,020 to 0,040				
C60E	1.1221	0,57 to 0,65	0,40	0,60 to 0,90	0,030	max. 0,035 ^e	0,40	0,10	0,40	0,63
C60R	1.1223					0,020 to 0,040				
28Mn6	1.1170	0,25 to 0,32	0,40	1,30 to 1,65	0,030	max. 0,035 ^e	0,40	0,10	0,40	0,63

^a Elements not quoted in this table shall not be intentionally added to the steel without the agreement of the purchaser, other than for the purpose of finishing the heat. All reasonable precautions shall be taken to prevent the addition of such elements from scrap or other material used in the manufacture which affect the hardenability, mechanical properties and applicability.

^b Where requirements are made on hardenability of special steels (see Tables 5 to 7), slight deviations from the limits for the cast analysis are permissible, except for the elements carbon (see footnote d), phosphorus and sulphur; the deviations shall not exceed the specifications of Table 4.

^c Steels with improved machinability as a result of the addition of higher sulphur contents up to around 0,10% S (including resulphurized steels with controlled inclusion content (e.g. Ca-treatment)) may be supplied upon request. In this case, the upper limit for the manganese content may be increased by 0,15 %.

^d If special steels are ordered without hardenability requirements (symbols +H, +HH, +HL) or without mechanical property requirements in the quenched and tempered or normalized condition, a restriction in the carbon range to 0,05 % and/or the total sum of the elements Cr, Mo and Ni to ≤ 0,45 % may be agreed at the time of ordering.

^e If agreed at the time of enquiry and order, for flat products, sulphur is restricted to maximum 0,010 % by mass.

Table 4 — Permissible deviations between the product analysis and the limiting values given in Table 3 for the cast analysis

Element	Permissible maximum content in the cast analysis % by mass	Permissible deviation ^a % by mass
C	$\leq 0,55$	$\pm 0,02$
	$> 0,55$ $\leq 0,65$	$\pm 0,03$
Si	$\leq 0,40$	$+ 0,03$
Mn	$\leq 1,00$	$\pm 0,04$
	$> 1,00$ $\leq 1,65$	$\pm 0,05$
P	$\leq 0,045$	$+ 0,005$
S	$\leq 0,045$	$+ 0,005^b$
Cr	$\leq 0,40$	$+ 0,05$
Mo	$\leq 0,10$	$+ 0,03$
Ni	$\leq 0,40$	$+ 0,05$
^a $\pm$ means that in one cast, the deviation may occur over the upper value or under the lower value of the specified range in Table 3, but not both at the same time. ^b For steels with a specified sulphur range (0,020% to 0,040% according to cast analysis) the permissible deviation is $\pm 0,005\%$.		

Table 5 — Limiting values for the "C" scale Rockwell hardness for special steel grades with (normal) hardenability requirements (+H grades)

[illegible]

Table 6 — Limiting values for the "C" scale Rockwell hardness for special steel grades with restricted hardenability scatter bands (+HH and +HL grades)

Steel designation		Symbol	Distance in mm from the quenched end		
Name	Number		HRC hardness		
			1	4	5
C35E	1.1181	+HH4	-	34 to 53	-
		+HH14	51 to 58	34 to 53	-
C35R	1.1180	+HL4	-	24 to 43	-
		+HL14	48 to 55	24 to 43	-
C40E	1.1186	+HH4	-	38 to 57	-
		+HH14	54 to 60	38 to 57	-
C40R	1.1189	+HL4	-	27 to 46	-
		+HL14	51 to 57	27 to 46	-
C45E	1.1191	+HH4	-	41 to 60	-
		+HH14	57 to 62	41 to 60	-
C45R	1.1201	+HL4	-	30 to 49	-
		+HL14	55 to 60	30 to 49	-
C50E	1.1206	+HH5	-	-	40 to 58
		+HH15	58 to 63	-	40 to 58
C50R	1.1241	+HL5	-	-	31 to 49
		+HL15	56 to 61	-	31 to 49
C55E	1.1203	+HH5	-	-	42 to 60
		+HH15	60 to 65	-	42 to 60
C55R	1.1209	+HL5	-	-	33 to 51
		+HL15	58 to 63	-	33 to 51
C60E	1.1221	+HH5	-	-	44 to 62
		+HH15	62 to 67	-	44 to 62
C60R	1.1223	+HL5	-	-	35 to 53
		+HL15	60 to 65	-	35 to 53

Table 7 — Limiting values for the "C" scale Rockwell hardness for special steel grade 28Mn6 with restricted hardenability scatter bands (+HH and +HL grades)

[illegible]

Table 8 — Maximum hardness for products to be supplied in the "treated to improve shearability (+S)" or "soft annealed (+A)" condition

Steel designation ^a		Max. HBW in condition ^b	
Name	Number	+S	+A
Quality steels			
C35	1.0501	- ^c	-
C40	1.0511	- ^c	-
C45	1.0503	255 ^c	207
C55	1.0535	255 ^d	229
C60	1.0601	255 ^d	241
Special steels			
C22E, C22R	1.1151, 1.1149	- ^c	-
C35E, C35R	1.1181, 1.1180	- ^c	-
C40E, C40R	1.1186, 1.1189	- ^c	-
C45E, C45R	1.1191, 1.1201	255 ^c	207
C50E, C50R	1.1206, 1.1241	255	217
C55E, C55R	1.1203, 1.1209	255 ^d	229
C60E, C60R	1.1221, 1.1223	255 ^d	241
28Mn6	1.1170	255	223
^a The values apply also for the special steel grades with hardenability requirements (+H-, +HH- and +HL grades) covered in Tables 5 to 7; see, however, footnote d. ^b The values are not applicable to slabs which have been continuously cast and not further deformed. ^c See 7.3.3. ^d Depending on the chemical composition of the cast, and on the dimensions, particularly in the case of the +HH-grades, soft annealing may be necessary.			

Table 9 — Mechanical properties^a at room temperature in the quenched and tempered condition (+QT)

Steel designation		Mechanical properties for the ruling section (see EN 10083-1:2006, Annex A) with a diameter (d) or for flat products thickness (t) of					40 mm < d ≤ 100 mm 20 mm < t ≤ 60 mm				
		16 mm < d ≤ 40 mm 8 mm < t ≤ 20 mm									
Name	Number	R _e min.	R _m	A min.	Z min.	KV ^b min.	R _e min.	R _m	A min.	Z min.	KV ^b min.
Quality steels											
C35	1.0501	430	630 to 780	17	40	-	380	600 to 750	19	45	-
C40	1.0511	460	650 to 800	16	35	-	400	630 to 780	18	40	-
C45	1.0503	490	700 to 850	14	35	-	430	650 to 800	16	40	-
C55	1.0535	550	800 to 950	12	30	-	490	750 to 900	14	35	-
C60	1.0601	580	850 to 1 000	11	25	-	520	800 to 950	13	30	-
Special steels											
C22E	1.1151	340	500 to 650	20	50	-	290	470 to 620	22	50	-
C22R	1.1149										
C35E	1.1181	430	630 to 780	17	40	-	380	600 to 750	19	45	35
C35R	1.1180										
C40E	1.1186	460	650 to 800	16	35	-	400	630 to 780	18	40	30
C40R	1.1189										
C45E	1.1191	490	700 to 850	14	35	-	430	650 to 800	16	40	25
C45R	1.1201										
C50E	1.1206	520	750 to 900	13	30	-	460	700 to 850	15	35	-
C50R	1.1241										
C55E	1.1203	550	800 to 950	12	30	-	490	750 to 900	14	35	-
C55R	1.1209										
C60E	1.1221	580	850 to 1 000	11	25	-	520	800 to 950	13	30	-
C60R	1.1223										
28Mn6	1.1170	590	800 to 950	13	40	-	490	700 to 850	15	45	40

^a R_e: Upper yield strength or, if no yield phenomenon occurs, the 0,2 % proof strength R_{0,2}.
R_m: Tensile strength.
A: Percentage elongation after fracture (gauge length L₀ = 5,65 √S₀; see Table 12, column 7a, line T4).
Z: Reduction in cross-section on fracture.
KV: Impact strength of longitudinal Charpy V-notch test pieces (average of 3 individual values shall meet the minimum specified in the table; no individual value shall be lower than 70% of the minimum shown in the table).

^b For sampling see EN 10083-1:2006 figure 1 and figure 3

^c 1 MPa = 1 N/mm²

Table 10 — Mechanical properties^a at room temperature in the normalized condition (+N)

Steel designation		Mechanical properties for products with a diameter (d) or, for flat products, a thickness (t) of								
		$d \leq 16 \text{ mm}$ $t \leq 16 \text{ mm}$			$16 \text{ mm} < d \leq 100 \text{ mm}$ $16 \text{ mm} < t \leq 100 \text{ mm}$			$100 \text{ mm} < d \leq 250 \text{ mm}$ $100 \text{ mm} < t \leq 250 \text{ mm}$		
Name	Number	R_e min. MPa ^c	R_m min. MPa ^c	A min. %	R_e min. MPa ^c	R_m min. MPa ^c	A min. %	R_e min. MPa ^c	R_m min. MPa ^c	A min. %
Quality steels										
C35	1.0501	300	550	18	270	520	19	245	500	19
C40	1.0511	320	580	16	290	550	17	260	530	17
C45	1.0503	340	620	14	305	580	16	275	560	16
C55	1.0535	370	680	11	330	640	12	300	620	12
C60	1.0601	380	710	10	340	670	11	310	650	11
Special steels ^b										
C22E	1.1151	240	430	24	210	410	25	-	-	-
C22R	1.1149									
C35E	1.1181	300	550	18	270	520	19	245	500	19
C35R	1.1180									
C40E	1.1186	320	580	16	290	550	17	260	530	17
C40R	1.1189									
C45E	1.1191	340	620	14	305	580	16	275	560	16
C45R	1.1201									
C50E	1.1206	355	650	13	320	610	14	290	590	14
C50R	1.1241									
C55E	1.1203	370	680	11	330	640	12	300	620	12
C55R	1.1209									
C60E	1.1221	380	710	10	340	670	11	310	650	11
C60R	1.1223									
28Mn6	1.1170	345	630	17	310	600	18	290	590	18

^a R_e : Upper yield strength or, if no yield phenomenon occurs, the 0,2 % proof strength $R_{p0.2}$.
 R_m : Tensile strength.
 A : Percentage elongation after fracture (gauge length $L_0 = 5,65 \sqrt{S_0}$; see Table 12, column 7a, line T4).

^b The values also apply for the special steel grades with hardenability requirements (+H, +HH and +HL grades) as specified in Tables 5 to 7.

^c 1 MPa = 1 N/mm².

Table 11 — Surface hardness for special steels after flame or induction hardening

Steel designation		Surface hardness ^a
Name	Number	HRC min.
C35E/C35R	1.1181/1.1180	48
C45E/C45R	1.1191/1.1201	55
C50E/C50R	1.1206/1.1241	56
C55E/C55R	1.1203/1.1209	58
^a The above values apply to cross sections up to 100 mm for the condition existing after quenching and tempering and surface hardening according to the conditions given in Table 13, followed by stress relieving at 150 °C to 180 °C for about 1h. The same values may also be agreed for the condition after normalizing and surface hardening, subject to the same conditions, for cross-sections up to 100 mm diameter. It should be noted that surface decarburization may lead to lower hardness values in the surface.		

Table 12 — Test conditions for the verification of the requirements given in column 2

1 No.	2 Requirements	3 Test unit ^a	4 Extent of testing Number of products per test unit	5 Number of tests per product	6 Sampling and sample preparation (see in the supplement to this table, line T1 and line ...)	7 Test method to be applied	(Supplement to Table 12, columns 6 and 7)	
							6a Sampling and sample preparation	7a Test method to be applied
		See Table					Line	
1	Chemical composition	3 + 4	(The cast analysis is given by the manufacturer, for product analysis see clause A.6 in Annex A)				T1	General conditions The general conditions for selection and preparation of test samples and test pieces for steel shall be in accordance with EN ISO 377 and EN ISO 14284.
2	Hardenability	5 to 7		1	T2		T2	End quench hardenability test. In the case of dispute if possible the sampling method given below shall be used: — the test piece shall be produced by machining in the case of diameters ≤ 40 mm; — the bar shall be reduced by forging to a diameter of 40 mm in the case of diameters $> 40 \leq 150$ mm; — in the case of diameters > 150 mm the test piece shall be taken such that, its axis lies 20 mm below the surface. In all other cases, the sampling method which starts from separately cast and subsequently hot worked test ingots or from cast and not hot worked samples is, unless otherwise agreed at the time of enquiry and order, left to the discretion of the manufacturer.

Table 12 - (continued)

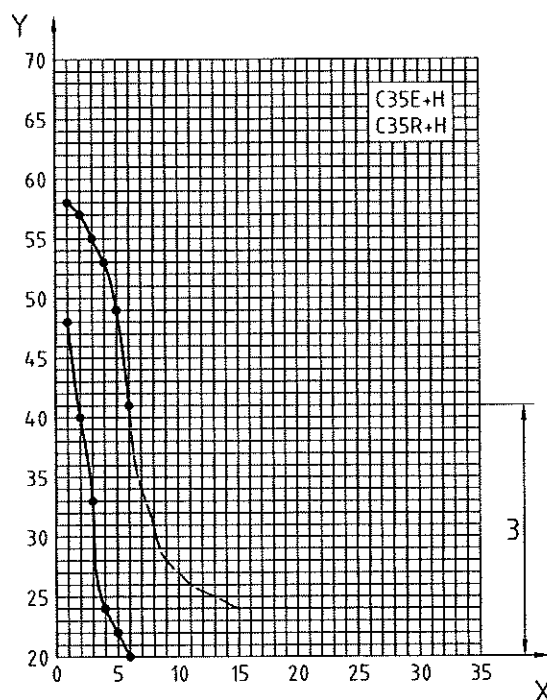
1	2	3	4	5	6	7	(Supplement to Table 12, columns 6 and 7)		
							6a	7a	
No.	Requirements	Test unit ^a	Extent of testing Number of products per test unit	Number of tests per product	Sampling and sample preparation (see in the supplement to this table, line T1 and line ...)	Test method to be applied	Line	Sampling and sample preparation	Test method to be applied
3	Hardness				T3		T3	Hardness tests	In accordance with EN ISO 6506-1.
3a	in the condition 8 +S or +A	C +D +T	1	1	T3a		T3a	In cases of dispute, the hardness shall, where possible, be determined at the following point on the surface: — at a distance of 1x diameter from one end of the bar in the case of round bars; — at a distance of 1 x thickness from one end and 0,25 x thickness from one longitudinal edge of the product in the case of bars with square or rectangular cross-section and also in the case of flat products. If it should be impossible to comply with the above, e.g. in the case of hammer or drop forgings, the most appropriate position for the hardness indentations shall be agreed at the time of ordering. Specimen preparation shall be in accordance with EN ISO 6506-1.	
3b	Surface hardness	C	1	1	T3b		T3b	The test shall be carried out on a surface which is smooth and even, free from oxide scale and foreign matter. Preparation shall be carried out in such a way that any alteration of the surface hardness is minimized. This shall be taken into account particularly in the case of low-depth indentations (in accordance with EN ISO 6508-1:2005, clause 6).	In accordance with EN ISO 6508-1

Table 12 – (continued)

1		2		3	4	5	6	7	(Supplement to Table 12, columns 6 and 7)	
No.	Requirements	Test unit ^a	Extent of testing		Sampling and sample preparation (see in the supplement to this table, line T1 and line ...)	Test method to be applied	Line	Sampling and sample preparation	Test method to be applied	
			Number of products per test unit	Number of tests per product						
4	Mechanical properties of						T4	Tensile test and impact tests		
4a	quenched and tempered products	9	1	1 tensile and 3 Charpy-V-notch impact tests	T4a		T4a and T4b	The test pieces for tensile test, and where applicable, the Charpy-V-notch impact tests shall be taken as follows: — for bars and rod in accordance with EN 10083-1:2006, Figure 1; — for flat products in accordance with EN 10083-1:2006, Figures 2 and 3; — in the case of hammer and drop forgings (see note 2 in EN 10083-1:2006, Clause 1), the test pieces shall be taken from a position agreed at the time of ordering in such a way that their longitudinal axis lies in the direction of principal grain flow. The tensile test pieces shall be prepared in accordance with EN 10002-1, the impact test pieces in accordance with EN 10045-1.	In cases of dispute the tensile test shall be carried out on proportional test pieces having a gauge length of $L_0 = 5.65 \sqrt{S_0}$ (where S_0 is the original cross-sectional area). Where this is not possible – i.e. for flat products with thickness of < 3 mm – a test piece with constant gauge length as specified in EN 10002-1 shall be agreed at the time of enquiry and order. In this case the minimum elongation value to be obtained for these test pieces shall also be agreed. The impact test shall be carried out on Charpy-V-notch test pieces in accordance with EN 10045-1.	
4b	normalized products ^c	10	1 ^b	1 tensile test	T4b					
NOTE Verification of the requirements is only necessary if an inspection certificate is ordered and if the requirement is applicable according to Table 1, column 8 or 9.										
^a The tests shall be carried out separately for each cast indicated by "C" – and for each heat treatment batch as indicated by "T". Products of different thicknesses may be grouped if the thicknesses lie in the same dimension range for mechanical properties and if the differences do not affect the properties.										
^b If the product is continuously heat treated, one test piece shall be taken for each 25 t or part thereof, but at least one test piece shall be taken per cast.										
^c See 7.1.4, last paragraph for a hardness test instead of the tensile test.										

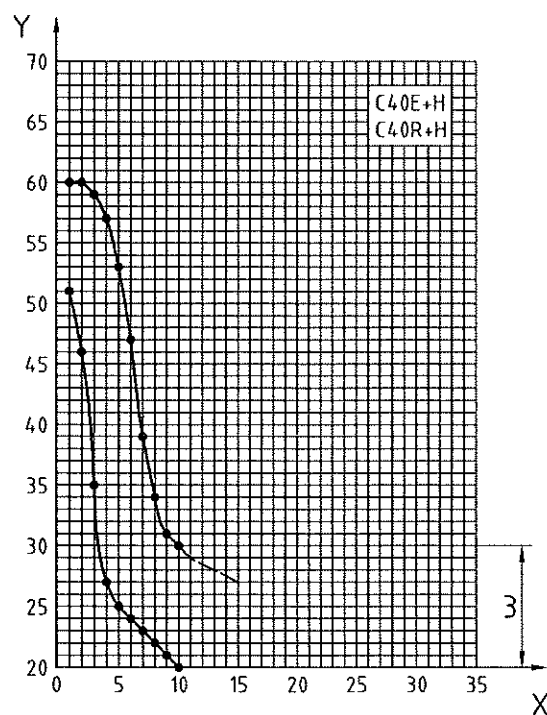
Table 13 — Heat treatment^a

Steel designation		Quenching ^{b,c}	Quenching ^d	Tempering ^e	End quench test	Normalizing ^c		
Name	Number	°C	agent	°C	°C	°C		
Quality steels								
C35	1.0501	840 to 880	Water or oil	550 to 660	-	860 to 920		
C40	1.0511	830 to 870			-	850 to 910		
C45	1.0503	820 to 860			-	840 to 900		
C55	1.0535	810 to 850	Oil or water		-	825 to 885		
C60	1.0601	810 to 850			-	820 to 880		
Special steels ^f								
C22E	1.1151	860 to 900	Water	550 to 660	-	880 to 940		
C22R	1.1149							
C35E	1.1181	Water or oil	870 ± 5		860 to 920			
C35R	1.1180							
C40E	1.1186				830 to 870	870 ± 5	850 to 910	
C40R	1.1189							
C45E	1.1191	820 to 860			850 ± 5	840 to 900		
C45R	1.1201							
C50E	1.1206	810 to 850			Oil or water	850 ± 5	830 to 890	
C50R	1.1241							
C55E	1.1203					810 to 850	830 ± 5	825 to 885
C55R	1.1209							
C60E	1.1221					810 to 850	830 ± 5	820 to 880
C60R	1.1223							
28Mn6	1.1170	840 to 880	Water or oil	540 to 680		850 ± 5	850 to 890	
^a The conditions given in this table are for guidance. However, the temperatures specified for the end quench test are mandatory.								
^b The temperatures at the lower end of the range are generally applicable to quenching in water and those at the upper end for quenching in oil.								
^c Austenitizing period: at least 30 min (guide value).								
^d When choosing the quenching agent the influence of other parameters, such as shape, dimensions, and quenching temperature on properties and crack susceptibility should be taken into account. Other quenching agents such as synthetic quenchants may also be used.								
^e Tempering period: at least 60 min (guide value).								
^f This table also applies for the special steel grades with specified hardenability (+H-, +HH- and +HL-grades) covered in Tables 5 to 7.								

**Key**

- X Distance from quenched end of test piece, mm
 Y Hardness, HRC
 3 H-grade

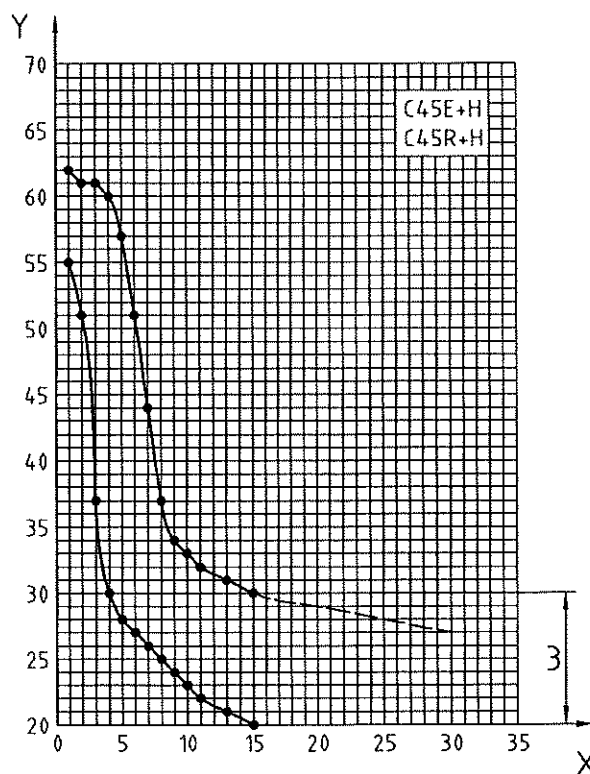
Figure 1a — Scatter bands for the Rockwell-C hardness in the end quench hardenability test



Key

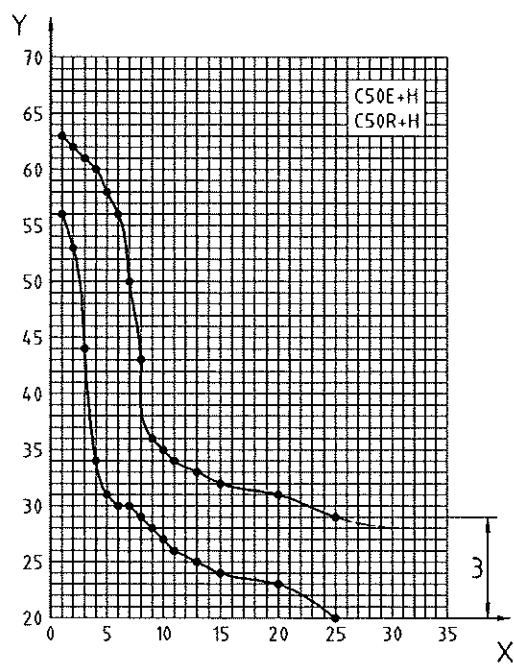
- X Distance from quenched end of test piece, mm
- Y Hardness, HRC
- 3 H-grade

Figure 1b — Scatter bands for the Rockwell-C hardness in the end quench hardenability test

**Key**

- X Distance from quenched end of test piece, mm
Y Hardness, HRC
3 H-grade

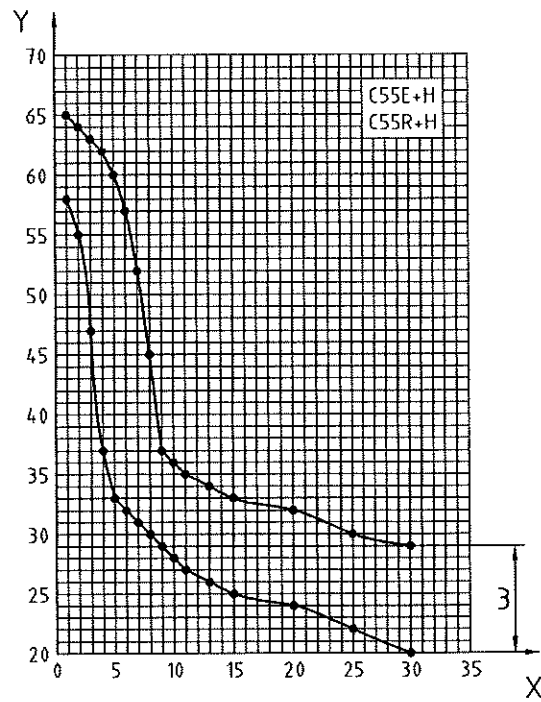
Figure 1c — Scatter bands for the Rockwell-C hardness in the end quench hardenability test



Key

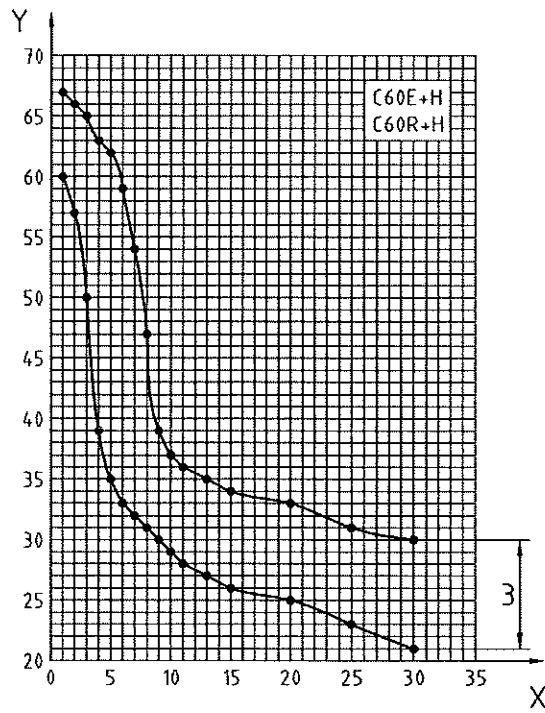
- X Distance from quenched end of test piece, mm
- Y Hardness, HRC
- 3 H-grade

Figure 1d — Scatter bands for the Rockwell-C hardness in the end quench hardenability test

**Key**

- X Distance from quenched end of test piece, mm
- Y Hardness, HRC
- 3 H-grade

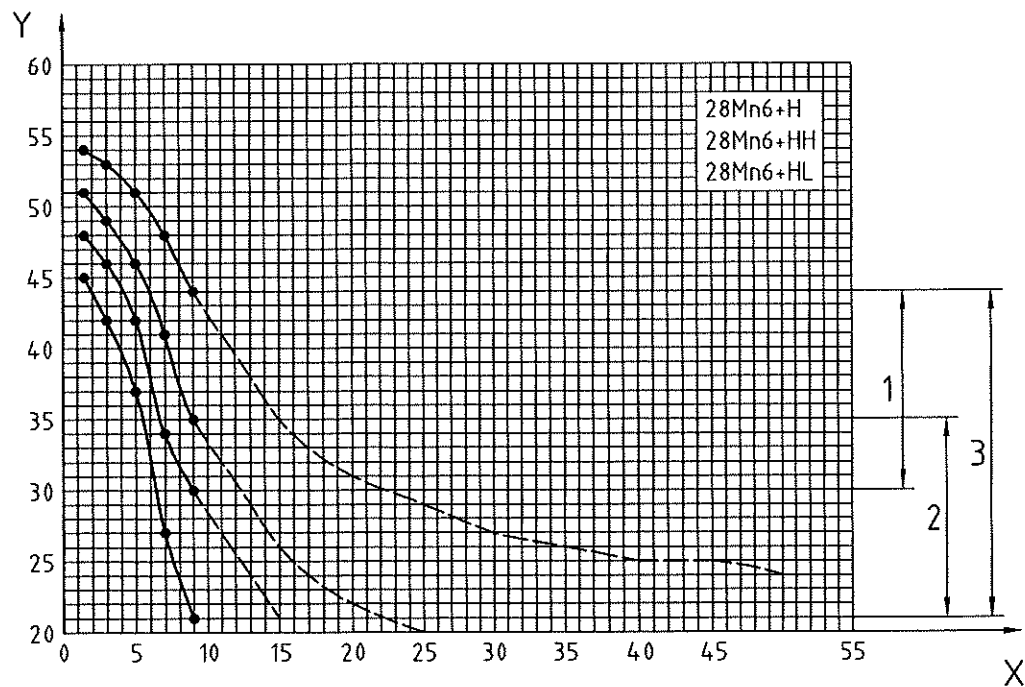
Figure 1e — Scatter bands for the Rockwell-C hardness in the end quench hardenability test



Key

- X Distance from quenched end of test piece, mm
- Y Hardness, HRC
- 3 H-grade

Figure 1f — Scatter bands for the Rockwell-C hardness in the end quench hardenability test

**Key**

- X Distance from quenched end of test piece, mm
- Y Hardness, HRC
- 1 HH-grade
- 2 HL-grade
- 3 H-grade

Figure 1g — Scatter bands for the Rockwell-C hardness in the end quench hardenability test

Annex A **(normative)**

Options

NOTE One or more of the following supplementary or special requirements may be agreed upon at the time of enquiry and order. The details of these requirements may be agreed upon between the manufacturer and purchaser at the time of enquiry and order if necessary.

A.1 Mechanical properties of reference test pieces in the quenched and tempered condition

For deliveries in a condition other than quenched and tempered or normalized, the requirements for the mechanical properties in the quenched and tempered condition shall be verified on a reference test piece.

In the case of bars and rods, the sample to be quenched and tempered shall, unless otherwise agreed, have the cross-section of the product. In all other cases the dimensions and the manufacture of the sample shall be agreed at the time of enquiry and order, where appropriate, while taking into consideration the indications for the determination of the ruling section given in EN 10083-1:2006, Annex A. The samples shall be quenched and tempered in accordance with the conditions given in Table 13 or as agreed at the time of enquiry and order. The details of the heat treatment shall be given in the inspection document. The test pieces shall, unless otherwise agreed, be taken in accordance with EN 10083-1:2006, Figure 1 for bars and rods and in accordance with EN 10083-1:2006, Figure 3 for flat products.

A.2 Mechanical properties of reference test pieces in the normalized condition

For deliveries in a condition other than quenched and tempered or normalized, the requirements for the mechanical properties in the normalized condition shall be verified on a reference test piece.

In the case of bars and rods, the sample to be normalized shall, unless otherwise agreed, have the cross-section of the product. In all other cases the dimensions and the preparation of the sample shall be agreed at the time of enquiry and order.

The details of the heat treatment shall be given in the inspection document. The test pieces shall, unless otherwise agreed, be taken in accordance with EN 10083-1:2006, Figure 1 in the case of bars and rods and with EN 10083-1:2006, Figure 3 in the case of flat products.

A.3 Fine grain steel

When tested in accordance with EN ISO 643, the steel shall have an austenite grain size of 5 or finer. If specific testing is ordered, it shall also be agreed whether this grain size requirement is to be verified by determining the aluminium content or micrographically. In the first case, the aluminium content shall also be agreed.

In the second case, one test piece shall be inspected per cast for the determination of the austenitic grain size. Sampling and sample preparation shall be as specified in EN ISO 643.

Unless otherwise agreed at the time of enquiry and order, the quenched grain size shall be determined. Hardening shall be carried out under the following conditions for the purposes of determining the quenched grain size:

- for steels with a lower carbon content limit $< 0,35 \%$: $(880 \pm 10) ^\circ\text{C}$, 90 min/water;
- for steels with a lower carbon content limit $\geq 0,35 \%$: $(850 \pm 10) ^\circ\text{C}$, 90 min/water.

In cases of dispute, pretreatment at $1150 ^\circ\text{C}$ for 30 min/air shall be carried out in order to produce a uniform starting condition.

A.4 Non-metallic inclusion content of special steels

This requirement is applicable to special steels. The microscopically determined non-metallic inclusion content shall be within agreed limits when tested according to a procedure to be agreed at the time of enquiry and order (see EN 10083-1:2006, Annex E).

NOTE 1 The requirements for non-metallic inclusion content apply in every case, however, verification requires a special agreement.

NOTE 2 For steels with a specified minimum sulphur content the agreements should only concern the oxides.

A.5 Non-destructive testing

Steel flat products of thickness equal to or greater than 6 mm shall be tested ultrasonically in accordance with EN 10160 and steel bars shall be tested ultrasonically in accordance with EN 10308. Other products shall be non-destructively tested in accordance with a method to be agreed at the time of enquiry and order and to acceptance criteria also to be agreed at the time of enquiry and order.

A.6 Product analysis

One product analysis shall be carried out per cast for elements for which values are specified for the cast analysis of the steel type concerned.

The conditions for sampling shall be in accordance with EN ISO 14284. In the case of dispute about the analytical method, the chemical composition shall be determined in accordance with a reference method taken from one of the European Standards in CR 10261.

A.7 Special agreements for marking

The products shall be specially marked (e.g. by bar coding in accordance with EN 606) in a way agreed upon at the time of enquiry and order.

Annex B

(informative)

Comparison of steel grades specified in this European Standard and ISO 683-1:1987 and other steel grades previously standardized nationally

Table B.1 — Comparison of steel grades

EN 10083-2		ISO 683-1:1987 ^a		Germany ^a		United Kingdom ^a		France ^a		Italy ^a		Sweden SS - steel		Spain ^a	
Name	Number			Name	Number									Name	Number
C35	1.0501	(C35)		C 35	1.0501		-	[AF55C35]		(C35)		-		-	-
C40	1.0511	(C40)		C 40	1.0511		-	[AF60C40]		(C40)		-		-	-
C45	1.0503	(C45)		C 45	1.0503		(080M46)	[AF65C45]		(C45)		-		-	-
C55	1.0535	(C55)		C 55	1.0535		-	[AF70C55]		(C55)		-		-	-
C60	1.0601	(C60)		C 60	1.0601		-	-		(C60)		-		-	-
C22E	1.1151	-		(Ck 22)	(1.1151)		(070M20)	[XC 18]		(C25)		-		-	-
C22R	1.1149	-		(Cm 22)	(1.1149)		-	[XC 18u]		(C25)		-		-	-
C35E	1.1181	(C 35 E4)		(Ck 35)	(1.1181)		(080M36)	[XC 38 H1]		(C35)		1572		C35K	F1130
C35R	1.1180	(C 35 M2)		Cm 35	1.1180		-	[XC 38 H1u]		(C35)		-		C35K1	F1135(1)
C40E	1.1186	(C 40 E4)		(Ck 40)	(1.1186)		(080M40)	[XC 42 H1]		(C40)		-		-	-
C40R	1.1189	(C 40 M2)		Cm 40	1.1189		-	[XC 42 H1u]		(C40)		-		-	-
C45E	1.1191	(C 45 E4)		(Ck 45)	(1.1191)		(080M46)	[XC 48 H1]		(C45)		1672		C45K	F1140
C45R	1.1201	(C 45 M2)		Cm 45	1.1201		-	[XC 48 H1u]		(C45)		-		C45K1	F1145(1)
C50E	1.1206	(C 50 E4)		(Ck 50)	(1.1206)		(080M50)	-		(C50)		1674		-	-
C50R	1.1241	(C 50 M2)		Cm 50	1.1241		-	-		(C50)		-		-	-
C55E	1.1203	(C 55 E4)		(Ck 55)	(1.1203)		(070M55)	[XC 55 H1]		(C55)		-		C55K	F1150
C55R	1.1209	(C 55 M2)		Cm 55	1.1209		-	[XC 55 H1u]		(C55)		-		C55K1	F1155(1)
C60E	1.1221	(C 60 E4)		(Ck 60)	(1.1221)		(070M60)	-		(C60)		-		-	-
C60R	1.1223	(C 60 M2)		Cm 60	1.1223		-	-		(C60)		-		-	-
28Mn6	1.1170	(28Mn6)		(28 Mn 6)	(1.1170)		(150M28)	-		-		-		-	-

^a If a steel grade is given in round brackets, this means that the chemical composition differs only slightly from EN 10083-2. If it is given in square brackets, this means that greater differences exist in the chemical composition compared with EN 10083-2. If there are no brackets around the steel grade, this means that there are practically no differences in the chemical composition compared with EN 10083-2.

Bibliography

- [1] EN 10021, *General technical delivery requirements for steel and iron products*

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