UDC 669.14.018.23:620.1 April 1988

Free-cutting steels
Technical delivery conditions

DIN 1651

Automatenstähle; technische Lieferbedingungen

Supersedes April 1970 edition.

In keeping with current practice in standards published by the International Organization for Standardization (ISO), a comma has been used throughout as the decimal marker.

See Explanatory notes for connection with draft International Standard ISO/DIS 683/9 – 1987 published by the International Organization for Standardization (ISO) and with EURONORM 87-70 published by the European Coal and Steel community (ECSC).

The clauses and subclauses marked • give specifications which are to be agreed upon at the time of ordering, those marked •• give specifications which are optional and may be agreed upon at the time of ordering.

1 Field of application

1.1 This standard applies to

semi-finished products (e.g. blooms, slabs, billets),

hot rolled wire,

hot rolled steel bars (round, square, hexagonal, octagonal and flat steel bars), and

bright steel,

made from free-cutting steels as specified in table 2.

Table 1 lists the combinations of surface conditions and heat treatment conditions in which the steels may be supplied (see subclause 7.2.2 for special surface finish).

1.2 In addition to the requirements specified in this standard, the general technical delivery conditions for steel and steel products given in DIN 17 010 shall apply unless otherwise specified in this standard.

2 Concepts

2.1 Free-cutting steels

For the purposes of this standard, free-cutting steels are steels characterized by good machinability and chip-breaking characteristics, essentially obtained by high contents of sulfur and, where applicable, of other elements (e.g. lead).

2.2 Product forms

The definitions given in EURONORM 79 shall apply for the product forms.

2.3 Types of heat treatment

The terminology used in DIN 17 014 Part 1 shall apply for the types of heat treatment referred to in this standard.

3 • Dimensions, limit deviations and form tolerances

3.1 The nominal sizes, limit deviations and, where applicable, form tolerances for the products shall be agreed at the time of ordering, reference being made, if possible, to the appropriate dimensional standards (see appendix B).

3.2 It is the customer's responsibility to specify the machining allowances that are to apply in the manufacture of bright steel and for its further processing, allowance being made for the limit deviations for the final product concerned.

4 Mass

The mass of the steels covered in this standard has been calculated taking the density as 7,85 kg/dm^3.

5 Designation and ordering

5.1 The standard designation for steel as covered in this standard shall give in the following order:

the name of product (steel);

the number of this standard;

the symbol or material number identifying the steel grade (see table 2)[1];

the code letters designating the surface condition and the heat treatment condition (see table 1 and subclause 7.2.1).

Example:

Steel DIN 1651 – 9 SMn 28 K+S

or

Steel DIN 1651 – 1.0715 K+S

5.2 The specifications given in the relevant dimensional standard shall apply for the standard designation of products.

5.3 The order shall provide any information necessary for a clear description of the required products including their condition and the test methods to be applied. In cases where the designations as in subclauses 5.1 and 5.2 are not adequate for this purpose, for example in the case of agreements as provided for in the clauses and subclauses marked • or ••, the necessary information shall be added to these designations.

[1] *DIN-Normenheft* (DIN Standardization booklet) No. 3 provides information on how the designations and material numbers for steels are formed.

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6 Classification into grades

6.1 Steel grades

6.1.1 This standard covers the steel grades not intended for heat treatment and those suitable for case hardening and for quenching and tempering, as listed in table 2.

6.1.2 9 SMn 28 and 9 SMnPb 28 steels are suitable for case hardening under specific conditions, it being the customer's responsibility to ascertain whether these steels are suitable for the intended application.

7 Requirements

7.1 Manufacturing process

The steelmaking process, the casting process and the process for hot working the products shall be at the manufacturer's discretion.

•• In special cases, however, an agreement on this may be made at the time of ordering.

7.2 Heat treatment condition and surface finish of material on delivery

7.2.1 •• Heat treatment condition

The possible heat treatment conditions are as listed in table 1. Unless otherwise agreed at the time of ordering, the products shall be supplied in the untreated condition.

7.2.2 •• Special surface finish

If agreed at the time of ordering, the products may be provided with one of the following surface finishes (not listed in table 1):

a) hot formed and pickled;

b) hot formed and abrasive blasted;

c) other surface finishes (with the details to be agreed).

7.3 Chemical composition and mechanical properties

Table 1 summarizes usual combinations of surface conditions and heat treatment conditions of the material on delivery and indicates which requirements apply to the mechanical properties. See subclauses 7.3.1 and 7.3.2 for requirements regarding the chemical composition.

•• Unless otherwise agreed, the requirements given in columns 2 to 4 of table 1 for the relevant combinations of surface condition and heat treatment condition of the material on delivery shall apply.

7.3.1 Table 2 shall apply for the chemical composition determined by ladle analysis.

7.3.2 The specifications given in table 3 (see also footnote 3 to table 7) shall apply for the limit deviations in the product analysis from the limiting values specified for the ladle analysis (see table 2).

7.3.3 The specifications given in table 4 shall apply for the mechanical properties of the material in the heat treatment condition listed in columns 2 to 4 of table 1.

Note. The nominal size of the products shall be taken as the thickness, i.e. the diameter in the case of round steel bars, the side length in the case of square steel bars, the width across flats in the case of hexagonal steel bars and the smaller side in the case of flat steel bars (see also clause A.2). For other cross sections, the thickness shall be determined as appropriate.

7.3.4 In the ring expanding test as described in table 7, 9 SMn 28, 9 SMnPb 28, 15 S 10, 10 S 20 and 10 SPb 20 steels, for surface condition/heat treatment condition combinations U–SH and K+S, shall reach a minimum elongation of 5 % in the transverse direction. The mean value of three tests shall be taken as the test result provided that none of the values is lower than 3 %.

7.4 Technological properties

7.4.1 Machinability

Free-cutting steels shall exhibit machining and chip-breaking characteristics consistent with their grade and treatment condition, killed free-cutting steels intended for case hardening or quenching and tempering being generally less suitable for machining. Furthermore, machinability generally decreases with increasing carbon, silicon and manganese contents, while cold working improves machinability of low carbon steels.

7.4.2 Weldability

Because of their high sulfur and phosphorus content, free-cutting steels are weldable to a limited extent only.

7.5 Internal soundness

7.5.1 •• Requirements regarding internal soundness, based, for example, on non-destructive testing, may be agreed at the time of ordering.

7.5.2 Sulfide inclusions and segregation streaks, characteristic of free-cutting steels, shall not be considered material defects.

7.5.3 Steel grades 15 S 10 to 60 SPb 20 (as listed in table 2) suitable for case hardening or quenching and tempering and intended to be cast killed are less susceptible to segregation than steel grades 9 SMn 28 to 9 SMnPb 36.

7.6 Surface finish

7.6.1 General

7.6.1.1 The products shall have a smooth surface consistent with the shaping process used.

Isolated minor surface imperfections, such as small pores, pitting, flaking and, in the case of bright free-cutting steels, marks from drawing, peeling or polishing, are permitted.

7.6.1.2 In the case of hot rolled free-cutting steel, imperfections, such as scabs, scores, laps and cracks, may be removed using appropriate means. The resulting depressions shall be flattened out, taking into account the limit deviations for thickness and the machining allowances.

7.6.2 •• Permissible depth of crack

It may be agreed at the time of ordering that a specified depth of crack shall not be exceeded.

Specification of a permissible depth of crack, in the case of hot rolled steel bars and rods of circular cross section, shall be in accordance with quality class 1 or 2 as defined in *Stahl-Eisen-Lieferbedingungen* (Iron and steel delivery conditions) 055.

In the case of bright steel, the specifications given in table 8 and in *Stahl-Eisen-Lieferbedingungen* 055 (e.g. with regard to test conditions and possible agreements on permitted imperfections) shall apply.

7.7 Form of material on delivery

7.7.1 Hot rolled free-cutting steel covered in this standard shall be supplied, subject to agreement, as semi-finished product, or in the form of bars or in coils, without packaging.

7.7.2 •• Bright free-cutting steel shall be supplied in the form of bars or in coils, slightly greased, without packaging, unless otherwise specified by the customer or the carrier.

7.7.3 •• The usual slight greasing of bright steel using a commercial grease does not provide adequate rust protection and is certainly not adequate to protect against condensation water. The use of rust-preventive compounds may be agreed at the time of ordering.

7.8 Separation of products by casts

Within one consignment, the products shall be separated by casts.

8 Testing

8.1 General

The manufacturer shall be responsible for devising and implementing a quality control system for his production so as to ensure that the requirements specified in clause 7 are met.

•• The issue of a certificate as specified in DIN 50 049 for materials testing carried out at the manufacturer's works or by independent inspectors may be agreed at the time of ordering.

8.2 •• Materials testing certificates issued by the manufacturer's works

8.2.1 If a test report (DIN 50 049 – 2.2) is to be issued in accordance with agreements made at the time of ordering, this report shall specify the results of the cast analysis for all the elements listed in table 2 for the relevant steel grades.

8.2.2 • If a manufacturer's test certificate (DIN 50 049 – 2.3) is to be issued, the required tests shall be agreed.

The document shall give the following details:

a) the results of a ladle analysis for all the elements listed in table 2 for the relevant steel grade;

b) the results of the agreed tests.

8.3 •• Materials testing certificates issued by independent inspectors

These certificates (inspection certificate 3.1 A, 3.1 B or 3.1 C, or inspection report 3.2 A or 3.2 C) shall be issued on the basis of acceptance inspection.

• The required tests or the tests to be carried out in keeping with official regulations and the relevant codes of practice shall be subject to agreement.

•• If acceptance inspection is not to be carried out by a works expert, the body responsible for acceptance inspection or the inspector shall be named.

The document shall give the following details:

a) the information referred to in subclause 8.2.2;

b) the mark identifying the inspector.

8.4 Scope of test programme for acceptance inspection, sampling, preparation of samples and test procedure

8.4.1 Chemical composition and mechanical properties

Where tests have to be carried out, the test conditions specified in table 7 shall apply.

8.4.2 •• Internal soundness

In cases where testing of the products for their internal soundness has been agreed, but the testing programme has not been specified, the scope of test programme, test conditions and test criteria shall be at the manufacturer's discretion.

8.4.3 •• Surface defects

8.4.3.1 If bright steel tested for cracks has been ordered, the products shall be tested for surface cracks by suitable non-destructive test methods.

8.4.3.2 If products not tested for cracks have been ordered, and unless otherwise agreed at the time of ordering, the method of testing products for surface defects, the scope of test programme and the test criteria shall be at the manufacturer's discretion.

8.4.4 •• Visual examination and check of dimensions

Unless otherwise agreed at the time of ordering, the procedure for visual examination and check of dimensions shall be at the manufacturer's discretion.

8.4.5 Retests

The specifications given in DIN 17 010 shall apply for retests.

9 Marking

9.1 The manufacturer shall mark the products or the bundles or packets, as far as possible in compliance with DIN 1599, so that it is possible to identify the cast, the steel grade and the source of the consignment.

9.2 If the consignments are to be accompanied by documents covering acceptance inspection, the marking shall additionally include the test piece number and the inspector's mark.

9.3 •• Any further requirements with regard to the marking of the products may be agreed at the time of ordering.

10 Heat treatment

Tables 5 and 6 give details on the temperatures for case hardening and quenching and tempering.

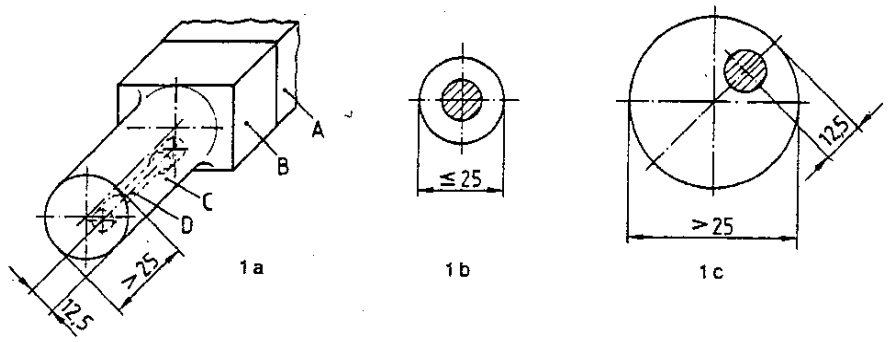
11 Complaints

11.1 Under current law, warranty claims may only be raised against defective products if the defects impair their processing and use to a more than negligible extent. This shall apply unless otherwise agreed at the time of ordering.

11.2 It is normal and practical for the purchaser to give the supplier the opportunity to judge whether the complaints are justified, if possible by submitting the product objected to or samples of the products supplied.

Dimensions in mm

Circular cross sections



A = sample product
B = sample section
C = test bar (sample after reduction of cross section to size in which is to be heat treated)
D = test piece

Rectangular cross sections

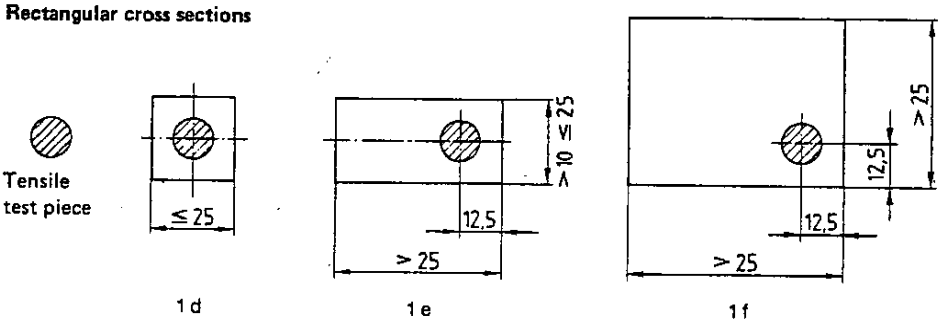


Figure 1. Points at which tensile test pieces are to be taken from the product

Table 1. **Combinations of surface conditions and heat treatment conditions** [1])

1	2	3	4
Heat treatment condition (symbol) / Surface condition [symbol]	Untreated (U)	Stress-relieved (S)	Quenched and tempered (V)
Hot worked [U]	X (Table 4, column 3) [2])	–	–
Peeled[3]), [4]) [SH]	X (Table 4, column 3) [2])	X (Table 4, column 5)	X (Table 4, column 6)
Cold drawn[5]) [K]	X (Table 4, column 4)	X (Table 4, column 5)	X (Table 4, column 6)

[1]) An X in columns 2 to 4 indicates the usual combination of surface condition and heat treatment condition in which the steels are supplied. The reference and parameters beneath the X indicate in which column of table 4 the relevant requirements regarding the maximum hardness and mechanical properties for the steel grade concerned are to be found.

[2]) After proper heat treatment, steels supplied in surface conditions U and SH shall have the mechanical properties specified in column 6 of table 4 for the quenched and tempered condition.

[3]) Products with a minimum diameter of 16 mm may generally be peeled, the supplier may, however, rough-grind the products instead of peeling them.

[4]) •• At the time of ordering, stress relieving to remove surface hardening may be agreed for 45 S 20, 45 SPb 20, 60 S 20 and 60 SPb 20 steels.

[5]) Round steel bars exceeding 50 mm in diameter are normally not suitable for cold drawing, but may only be peeled.

Table 2. **Chemical composition of free-cutting steels (ladle analysis)**

Steel grade		Chemical composition, % by mass [1]					
Symbol	Material number	C	Si	Mn	P max.	S	Pb [2]
		General purpose free-cutting steels [3]					
9 SMn 28	1.0715	≤ 0,14	≤ 0,05	0,90 to 1,30	0,100 [4]	0,27 to 0,33	–
9 SMnPb 28	1.0718	≤ 0,14	≤ 0,05	0,90 to 1,30	0,100 [4]	0,27 to 0,33	0,15 to 0,35
9 SMn 36	1.0736	≤ 0,15	≤ 0,05	1,10 to 1,50	0,100 [4]	0,34 to 0,40	–
9 SMnPb 36	1.0737	≤ 0,15	≤ 0,05	1,10 to 1,50	0,100 [4]	0,34 to 0,40	0,15 to 0,35
		Case hardening free-cutting steels [3], [5], [6]					
15 S 10	1.0710	0,12 to 0,18	0,10 to 0,30	0,70 to 1,10	0,060	0,080 [7] to 0,130	–
10 S 20	1.0721	0,07 to 0,13	0,10 to 0,30	0,70 to 1,10	0,060	0,18 to 0,25	–
10 SPb 20	1.0722	0,07 to 0,13	0,10 to 0,30	0,70 to 1,10	0,060	0,18 to 0,25	0,15 to 0,35
		Quenched and tempered free-cutting steels [8]					
35 S 20	1.0726	0,32 to 0,39	0,10 to 0,30	0,70 to 1,10	0,060	0,18 to 0,25	–
35 SPb 20	1.0756	0,32 to 0,39	0,10 to 0,30	0,70 to 1,10	0,060	0,18 to 0,25	0,15 to 0,35
45 S 20	1.0727	0,42 to 0,50	0,10 to 0,30	0,70 to 1,10	0,060	0,18 to 0,25	–
45 SPb 20	1.0757	0,42 to 0,50	0,10 to 0,30	0,70 to 1,10	0,060	0,18 to 0,25	0,15 to 0,35
60 S 20	1.0728	0,57 to 0,65	0,10 to 0,30	0,70 to 1,10	0,060	0,18 to 0,25	–
60 SPb 20	1.0758	0,57 to 0,65	0,10 to 0,30	0,70 to 1,10	0,060	0,18 to 0,25	0,15 to 0,35

[1] Elements not listed in this table shall not be intentionally added to the steel except for finishing the cast, unless the element has been added for improving the machinability, subject to the customer's approval.

[2] The values apply to the product analysis.

[3] 9 SMn 28 and 9 SMnPb 28 steels are suitable for case hardening under specific conditions, it being the customer's responsibility to ascertain whether these steels are suitable for the intended application.

[4] •• The nitrogen content may, without further verification, be assumed to be not less than 0,006 %. At the time of ordering it may be agreed that the phosphorus and nitrogen content shall not exceed 0,050 % and 0,007 %, respectively, taking into account that this limitation may affect the mechanical properties in the work-hardened condition.

[5] C 10 Pb (1.0302) and C 15 Pb (1.0403) steels are covered in DIN 17 210.

[6] •• A fine-grained melt may be agreed at the time of ordering, i.e. the grain size index of the austenite is to be 5 and/or finer when determined in accordance with DIN 50 601.

[7] If the material is intended for making tubes, a minimum sulfur content of 0,070 % shall apply.

[8] Steels C 22 Pb (1.0404), C 25 Pb (1.0411), C 30 Pb (1.0598), C 35 Pb (1.0502), C 40 Pb (1.0512), C 45 Pb (1.0504), C 50 Pb (1.0542), C 55 Pb (1.0537) and C 60 Pb (1.0602) steels are covered in DIN 17 200, March 1987 edition (see footnote 5 to table 2 of that standard).

Table 3. **Amounts by which the chemical composition as determined by the product analysis may deviate from the limiting values specified in table 2 for the ladle analysis** (Applies to products which, when supplied, have a cross section not exceeding 10 000 mm².)

Element	Maximum permissible content in the ladle analysis % by mass	Limit deviations in the product analysis from the limiting values specified for the ladle analysis [1] % by mass
C	≤ 0,55	0,02
	> 0,55 ≤ 0,65	0,03
Si	≤ 0,05	0,01
	> 0,05 ≤ 0,30	0,03
Mn	≤ 1,00	0,04
	> 1,00 ≤ 1,50	0,05
P	≤ 0,060	0,005
	> 0,060 ≤ 0,100	0,010
S	≤ 0,13	0,02
	> 0,13 ≤ 0,33	0,03
	> 0,33 ≤ 0,40	0,04
Pb	≤ 0,35	See footnote 2 to table 2.

[1] If several product analyses are to be carried out, the deviations shown by an element within one cast shall lie either only above the upper limit or below the lower limit of the range specified for the ladle analysis.

Table 4. **Mechanical properities of steels as a function of the treatment condition**

1		2		3		4			5	6		
Steel grade		Thickness, in mm		Surface condition and heat treatment condition [1], [2]								
				U or U+SH [3]		K [4], [5]			K+S [3]	SH+V or K+V		
Symbol	Material number	Over	Up to	Maximum hardness HB	Tensile strength, in N/mm²	Minimum yield strength, in N/mm²	Tensile strength, in N/mm²	Minimum elongation after fracture ($L_0=5d_0$), in %	Maximum tensile strength, in N/mm²	Minimum yield strength, in N/mm²	Tensile strength, in N/mm²	Minimum elongation after fracture ($L_0=5d_0$), in %
9 SMn 28 9 SMnPb 28	1.0715 1.0718		10	170	380 to 570	440	560 to 810	6	550	–	–	–
		10	16	170	380 to 570	410	510 to 760	7				
		16	40	159	380 to 570	375 [6]	460 to 710 [7]	8				
		40	63	159	380 to 570	305	410 to 660	9				
		63	100	156	360 to 520	245	380 to 630	10				
9 SMn 36 9 SMnPb 36	1.0736 1.0737		10	174	390 to 590	440	560 to 800	6	550	–	–	–
		10	16	174	390 to 580	430	540 to 780	7				
		16	40	163	380 to 550	390	490 to 740	8				
		40	63	159	370 to 540	315	430 to 680	9				
		63	100	156	360 to 520	265	390 to 640	10				
15 S 10	1.0710		10	175	420 to 600	420	520 to 820	6	580	–	–	–
		10	16	176	410 to 600	400	500 to 780	7				
		16	40	166	400 to 560	360	450 to 720	8				
		40	63	162	380 to 550	300	400 to 650	9				
		63	100	162	360 to 550	250	380 to 620	10				
10 S 20 10 SPb 20	1.0721 1.0722		10	159	360 to 530	410	540 to 780	7	550	–	–	–
		10	16	159	360 to 530	390	490 to 740	8				
		16	40	149	360 to 530	355 [6]	460 to 710 [7]	9				
		40	63	149	360 to 530	295	390 to 640	10				
		63	100	146	350 to 490	235	360 to 610	11				
35 S 20 35 SPb 20	1.0726 1.0756		10	197	490 to 660	480	640 to 880	6	680	420	620 to 760	13
		10	16	197	490 to 660	400	590 to 830	7		420	620 to 760	14
		16	40	192	490 to 660	315	540 to 740	8		365	580 to 730	16
		40	63	192	490 to 640	285	510 to 710	9		325	540 to 690	17
		63	100	187	480 to 630	255	480 to 680	10	–	–	–	–
45 S 20 45 SPb 20	1.0727 1.0757		10	229	590 to 760	570	740 to 980	5	750	480	700 to 840	10
		10	16	229	590 to 760	470	690 to 930	6		480	700 to 840	11
		16	40	223	590 to 760	375	640 to 830	7		410	660 to 800	13
		40	63	223	590 to 740	325	610 to 800	8		375	620 to 760	14
		63	100	217	580 to 730	305	580 to 770	9	–	–	–	–
60 S 20 60 SPb 20	1.0728 1.0758		10	269	670 to 880	645 [8]	830 to 1080 [8]	5 [8]	850	570	830 to 980	7
		10	16	269	670 to 880	540 [8]	780 to 1030 [8]	6 [8]		570	830 to 980	8
		16	40	261	660 to 870	430 [8]	740 to 930 [8]	7 [8]		490	780 to 930	10
		40	63	261	650 to 860	355 [8]	710 to 900 [8]	8 [8]		450	740 to 880	11
		63	100	255	640 to 840	335 [8]	640 to 880 [8]	9 [8]	–	450	740 to 880	11

[1] See table 1 for meaning of letter symbols.

[2] It is usual, for order purposes, to specify the surface condition first and then the heat treatment to be carried out (e.g. 'K+V'). When this order is reversed, in particular in the case of 45 S 20, 45 SPb 20, 60 S 20 and 60 SPb 20 steels, the values to be maintained shall be agreed.

[3] For the ring expanding test, for 9 SMn 28, 9 SMnPb 28, 15 S 10, 10 S 20 and 10 SPb 20 steels produced to the surface condition/heat treatment condition combinations U+SH and K+S, a minimum percentage elongation in the transverse direction has been specified (see subclause 7.3.4 and table 7).

[4] Round steel bars exceeding 50 mm in diameter are normally supplied in the peeled and not in the cold drawn condition.

[5] See footnote 4 to table 2.

[6] •• At the time of ordering it may be agreed that the steels have a minimum yield strength of 390 N/mm².

[7] •• At the time of ordering it may be agreed that the steels have a minimum tensile strength of 490 N/mm².

[8] •• The values specified for condition K shall apply only if the steels are untreated or have been normalized.

Table 5. **Usual case-hardening temperatures for steel grades 15 S 10, 10 S 20 and 10 SPb 20 (guideline values)**

Carburizing temperature[1] °C	Hardening from core-hardening temperature[2] °C	Hardening from case-hardening temperature[2] °C	Quenching agent	Tempering °C
880 to 980	880 to 920	780 to 820	Taking the required properties of the component into account, the choice of the quenching agent depends on the hardenability or case hardenability of the steel used, on the geometry and cross section of the workpiece to be hardened and on the effect of the quenching agent.	150 to 200

[1] The main criteria to be considered when choosing the carburizing temperature are the time desired for carburization, the carburizing medium, the plant available for carburization, details of the hardening process and the material structure required. When applying the direct method, carburizing shall normally be effected at temperatures below 950 °C, which may, however, exceed 1000 °C in special cases.

[2] When applying the direct method, the steel is to be quenched when its temperature has sunk to the carburizing temperature or a lower temperature, this lower hardening temperatures being given preference in particular when there is risk of distortion.

Table 6. **Quenching and tempering temperatures for 35 S 20, 35 SPb 20, 45 S 20, 45 SPb 20, 60 S 20 and 60 SPb 20 steels (guideline values)**

Steel grade (symbol)	Temperature of quenching in water[1] °C	Temperature of quenching in oil[1] °C	Tempering temperature[2] °C
35 S 20, 35 SPb 20	840 to 870	850 to 880	540 to 680
45 S 20, 45 SPb 20	820 to 850	830 to 860	540 to 680
60 S 20, 60 SPb 20	800 to 830	810 to 840	540 to 680

[1] The quenching agent is to be selected as a function of workpiece shape and size.

[2] Cooling in air.

Table 7. **Test conditions for verifying compliance with the requirements**[1]

1	2		3	4	5	6	7
No.	Property	See tables	Test unit[2]	Number of test pieces per test unit	Number of tests per test piece	Sampling and preparation of samples	Test method to be used
1	Chemical composition	2 and 3	S	The manufacturer shall inform the customer of the results of the ladle analysis. See footnote[3] as to whether a product analysis is to be carried out.			
2	Hardness in condition U	4	S+A	1	1	In cases of arbitration, the hardness shall be determined as close as possible to the product surface, at a distance of one diameter from one end, or in the case of squares or flats, at a distance of 0,25 times the product thickness from a longitudinal edge. Sample preparation as described in DIN 50 351.	As described in DIN 50 351.
3	Mechanical properties in conditions U, K, S or V	4	S+A+W	1	1	The tensile test pieces shall be taken as shown in figure 1.	The tensile test shall be carried out as described in DIN 50 145, generally using the short proportional test piece specified in DIN 50 125.
4	Ring expanding test for 9 SMn 28, 9 SMnPb 28, 15 S 10, 10 S 20 and 10 SPb 20 steels for surface condition/heat treatment condition combinations U+SH and K+S	4	S+A+W	3	1	For the ring expanding test to determine the percentage elongation in transverse direction, crack-free test pieces of a height equal to 0,5 d (d being the diameter or width across flats of the product) shall be taken, the hole diameter being 0,6 d.	The test pieces shall be widened using a lubricated test mandrel (with a 1 : 100 taper), with the force being applied slowly and steadily along their axis. The values specified in subclause 7.3.4 and referring to the expansion of the hole shall be reached without the test piece cracking.

[1] Verification is only necessary for products for which the individual requirement referred to in table 1 is deemed to apply and the relevant method of test has been agreed.

[2] Key to symbols:

S – only products of one cast may be combined.

A – only products of the same nominal size may be combined.

W – only products of the same heat treatment batch may be combined.

[3] •• If subsequent checking of the chemical composition has been agreed at the time of ordering, one product analysis shall be carried out per cast and per consignment, unless otherwise specified. The specifications given in *Stahl-Eisen-Prüfblatt* (Iron and steel test sheet) 1805 shall apply for sampling and preparation of samples. The composition may be determined by chemical or spectrochemical methods of analysis. For the analytical procedure, the specifications given in *Handbuch für das Eisenhüttenlaboratorium* (Handbook for the ferrous metallurgy laboratory) shall apply. In cases of arbitration, the method to be applied shall be agreed.

Table 8. **Permissible depth of crack for bright steel**

Thickness[1], in mm		Permissible depth of longitudinal surface crack, in mm, as measured on the actual product, in the case of			
		drawn	drawn and crack tested	peeled	peeled and ground
Over	Up to	round, square, hexagonal and flat steel bars		round steel bars	
3	10	0,20	Depth of crack as agreed.[2]	–	–
10	18	0,25		0,15[3]	0,10[3]
18	30	0,30		0,20	0,15
30	50	0,50			
50	80	0,70			
80	100	By agreement.		By agreement.	By agreement.

[1] See note in subclause 7.3.3.
[2] • The permissible depth of cracks shall be agreed at the time of ordering (cf. subclause 8.4.3.2).
[3] Applies to diameters not less than 16 mm.

Appendix A

Equivalent diameter for the mechanical properties

A.1 Concept

The ruling section of a product is the cross section to which the values specified for the mechanical properties refer. Irrespective of the actual shape and dimensions of the product, the size of the ruling section is always expressed as a diameter ('equivalent diameter'). This diameter is that of an 'equivalent round steel bar', meaning a round bar which, at the position in the cross section specified for taking the test pieces for mechanical testing, on cooling from the austenitizing temperature, has a cooling rate equivalent to that of the ruling section of the product concerned at the location specified for sampling.

A.2 Determining the equivalent diameter

A.2.1 In the case of round steel bars, the equivalent diameter is equal to the nominal diameter of the product.

A.2.2 In the case of hexagonal and octagonal steel bars, the equivalent diameter is equal to the nominal distance between two opposite parallel sides.

A.2.3 In the case of square steel and flat steel bars, the equivalent diameter shall be determined as shown in the example in figure A.1.

A.2.4 • For all other product forms, the equivalent diameter shall be agreed.

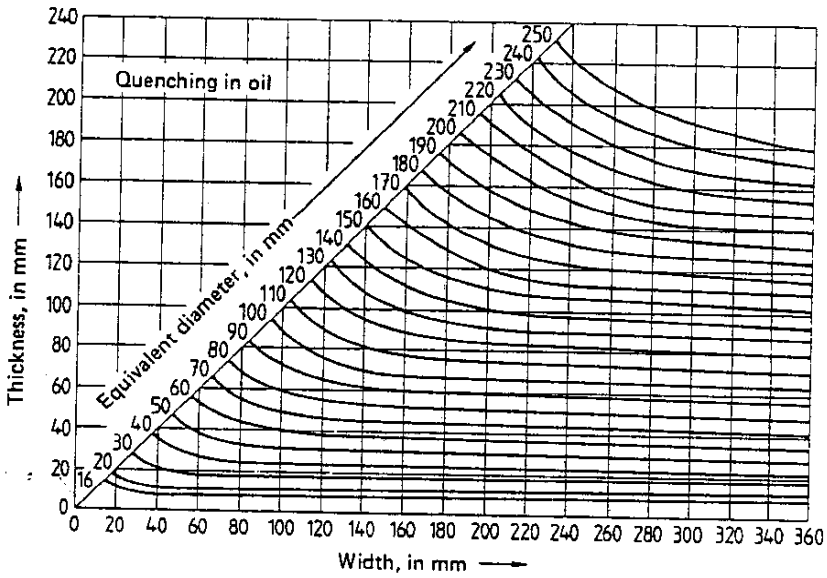


Figure A.1. Equivalent diameter for square and rectangular cross sections
Example: For a 40 mm x 60 mm flat steel, the equivalent diameter is 50 mm.

Appendix B

Dimensional standards relating to products covered by this standard

Hot rolled wire

DIN 59 110	Steel wire rod; dimensions, permissible deviations, mass
DIN 59 115	Steel wire rod for bolts, nuts and rivets; dimensions, permissible deviations, mass

Hot rolled bars

DIN 1013 Part 1	Steel bars; hot rolled round steel for general purposes; dimensions, permissible dimensional deviations and deviations of form
DIN 1013 Part 2	Steel bars; hot rolled round steel for special purposes; dimensions, permissible dimensional deviations and deviations of form
DIN 1014 Part 1	Steel bars; hot rolled squares for general purposes; dimensions, permissible dimensional deviations and deviations of form
DIN 1014 Part 2	Steel bars; hot rolled squares for special purposes; dimensions, permissible dimensional deviations and deviations of form
DIN 1015	Steel bars; hot rolled hexagons; dimensions, permissible deviations, mass
DIN 1017 Part 1	Steel bars; hot rolled flats for general purposes; dimensions, permissible deviations, mass
DIN 1017 Part 2	Steel bars; hot rolled flats for special applications (in bar drawing shops, screw works, etc.); dimensions, permissible deviations, mass
DIN 59 130	Steel bars; hot rolled round steel for bolts and rivets; dimensions, permissible dimensional deviations and deviations of form

Bright steel

DIN 174	Bright flat steel; dimensions, permissible deviations, mass
DIN 176	Bright hexagon steel; dimensions, permissible deviations, mass
DIN 178	Bright square steel; dimensions, permissible deviations, mass
DIN 668	Bright round steel; dimensions, permissible deviations according to ISO tolerance zone h11
DIN 670	Bright round steel; dimensions, permissible deviations according to ISO tolerance zone h8
DIN 671	Bright round steel; dimensions, permissible deviations according to ISO tolerance zone h9
DIN 59 360	Ground and polished bright round steel; dimensions, permissible deviations according to ISO tolerance zone h7
DIN 59 361	Ground and polished bright round steel; dimensions, permissible deviations according to ISO tolerance zone h6

Standards and other documents referred to

DIN 1599	Identification markings for steel
DIN 17 010	General technical delivery conditions for steel and steel products
DIN 17 014 Part 1	Heat treatment of ferrous materials; terminology
DIN 17 200	Steels for quenching and tempering; technical delivery conditions
DIN 17 210	Case hardening steels; technical delivery conditions
DIN 50 049	Materials testing certificates
DIN 50 125	Testing of metallic materials; tensile test pieces
DIN 50 145	Testing of metallic materials; tensile test
DIN 50 351	Testing of metallic materials; Brinell hardness test
DIN 50 601	Metallographic examination; determination of the ferritic or austenitic grain size of steel and ferrous materials
EURONORM 79	Terminology and classification of steel products by shape and size

Handbuch für das Eisenhüttenlaboratorium *) (in loose-leaf form)

DIN-Normenheft 3 *Kurznamen und Werkstoffnummern der Eisenwerkstoffe in DIN-Normen und Stahl-Eisen-Werkstoffblättern* (Symbols and material numbers for ferrous materials dealt with in DIN Standards and Iron and steel materials sheets)

Stahl-Eisen-Lieferbedingungen 055 *)
(at present at the stage of draft) *Warmgewalzter Stabstahl und Walzdraht mit rundem Querschnitt und nicht profilierter Oberfläche, Oberflächengüteklassen; technische Lieferbedingungen* (Hot rolled steel bars and wire rod of circular cross section and non-profiled surface; surface quality classes; technical delivery conditions)

Stahl-Eisen-Prüfblatt 1805 *)
Probenahme und Probenvorbereitung für die Stückanalyse bei Stählen (Sampling and preparation of samples for product analysis of steels)

See appendix B for other standards referred to.

Previous editions

DIN 1651: 08.44, 08.54, 11.60, 04.70.

Amendments

The following amendments have been made to the April 1970 edition:

a) 9 S 20 (1.0711) steel is no longer specified. 9 SMn 28 (1.0715) steel may be supplied as an alternative.

b) The following steel grades have been included for the first time: 15 S 10 (1.0710), 35 SPb 20 (1.0756), 45 SPb 20 (1.0757) and 60 SPb 20 (1.0758).

c) The specifications regarding chemical composition have been amended (see Explanatory notes).

d) The treatment conditions are not identified by code letters only, as the numerical suffixes previously specified are normally used only inside the aircraft industry.

e) The 'normalized' treatment condition (including mechanical properties and heat treatment) and the 'spheroidized' treatment condition are no longer specified.

f) Maximum tensile strength values have been specified for the 'cold drawn + stress-relieved' condition.

g) The *Stahl-Eisen-Lieferbedingungen* 055 shall apply for the permissible depth of crack of hot rolled steel bars and rod of circular cross section.

h) The specifications regarding heat treatment have been harmonized with the revised editions of DIN 17 200 and DIN 17 210.

i) The graph permitting the determination of the equivalent diameter for square and rectangular steel bars on the basis of the values specified for round steel bars in the quenched and tempered condition has been replaced by one relating to steel bars quenched in oil.

j) The equivalent diameter for the mechanical properties is now dealt with in detail in appendix A.

*) Obtainable from *Verlag Stahleisen mbH*, Postfach 82 29, D-4000 Düsseldorf 1.

Explanatory notes

The form of the standard has been harmonized as far as possible with that of the revised edition of DIN 17 200.

The following amendments have been made to the chemical composition.

a) The sulfur content of 9 SMn 28 and 9 SMnPb 28 steels has been raised to values between 0,27 and 0,33 %.

b) In the case of 9 SMn 36 and 9 SMnPb 36 steels, the lower limit of manganese has been raised to 1,10 % and that of sulfur to 0,34 %.

c) The maximum silicon content of all case hardening and quenched and tempered steels has been reduced to 0,30 %.

d) The manganese content of case hardening and quenched and tempered steels has been raised to values between 0,70 and 1,10 %.

e) The minimum sulfur content of 10 S 20 and 10 SPb 20 steels has been raised to 0,18 %.

f) The maximum lead content of lead alloy steels has been raised to 0,35 %.

Although only relatively small quantities of 15 S 10 (1.0710) steel are currently being manufactured, it has been included in this standard as a viable substitute for other steel grades (e.g. a steel grade similar to C 15 but with a higher sulfur content) which, though commercially available, are difficult to produce owing to their unfavourable Mn/S ratio.

A request made by manufacturers of turned parts that subclause 7.8 should also specify that the (non-defined) machinability of products from different casts, in the same consignment, should at least be approximately equivalent could not be met, as it was objected that differences in machining properties cannot be mathematically formulated, because machinability is not only a function of chemical composition (sulfur content) but also of other factors, such as strength and structure.

It should be noted that, at a later date, the specifications of *Stahl-Eisen-Lieferbedingungen* 055 referred to in subclause 7.6.2 of this standard are to be harmonized with the relevant specifications given in table 8 and published in the final version of the *Stahl-Eisen-Lieferbedingungen* 055.

There is some connection between this standard and ISO/DIS 683/9 – 1987, Heat-treatable steels, alloy steels and free-cutting steels. Part 9: Wrought free-cutting steels, and to EURONORM 87-70, Free-cutting steels. The table below gives a survey of the steel grades covered in this standard and the international documentation for free-cutting steels.

Table 9.

Free-cutting steels specified in					
DIN 1651		EURONORM 87-70		ISO/DIS 683/9	
Symbol	Material number	Symbol	[1]	Symbol	[1]
–	–	10 S 22		9 S 20	
9 SMn 28	1.0715	11 SMn 28	O	11 SMn 28	O
9 SMnPb 28	1.0718	11 SMnPb 28	O	11 SMnPb 28	O
9 SMn 36	1.0736	12 SMn 35	O	12 SMn 35	O
9 SMnPb 36	1.0737	12 SMnPb 35	O	12 SMnPb 35	O
15 S 10	1.0710	–		–	
10 S 20	1.0721	10 S 20	O	10 S 20	O
10 SPb 20	1.0722	10 SPb 20	O	10 SPb 20	O
–	–	12 SMn 20		–	
–	–	17 S 20		–	
–	–	–		17 SMn 20	
35 S 20	1.0726	35 S 20	O	35 S 20	O
35 SPb 20	1.0756	–		[2]	
–	–	35 SMn 20		35 SMn 20	
45 S 20	1.0727	45 S 20	O	46 S 20	O
45 SPb 20	1.0757	–		[2]	
–	–	–		44 SMn 28	
60 S 20	1.0728	60 S 20	O	–	
60 SPb 20	1.0758	–		–	

[1] This column indicates the degree of correspondence with regard to the chemical composition, between the steels specified in this standard and those specified in international documentation, the symbol O meaning that there are significant differences between the documents.

[2] It may be agreed that a similar grade be supplied.

International Patent Classification

C 22 C 38/00