
**Heat-treatable steels, alloy steels and
free-cutting steels —**

Part 4:
Free-cutting steels

*Aciers pour traitement thermique, aciers alliés et aciers pour
décolletage —*

Partie 4: Aciers pour décolletage

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received. www.iso.org/patents

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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

The committee responsible for this document is ISO/TC 17, *Steel*, Subcommittee SC 4, *Heat treatable and alloy steels*.

This first edition cancels and replaces ISO 683-9:1988, which has been technically revised.

ISO 683 consists of the following parts, under the general title *Heat-treatable steels, alloy steels and free-cutting steels*:

- *Part 1: Non-alloy steels for quenching and tempering*
- *Part 2: Alloy steels for quenching and tempering*
- *Part 3: Case hardening steels*
- *Part 4: Free-cutting steels*
- *Part 5: Nitriding steels*
- *Part 14: Hot-rolled steels for quenched and tempered springs*
- *Part 15: Valve steels for internal combustion engines*
- *Part 17: Ball and roller bearing steels*
- *Part 18: Bright steel products*

Heat-treatable steels, alloy steels and free-cutting steels —

Part 4: Free-cutting steels

1 Scope

This part of ISO 683 gives the technical delivery requirements for semi-finished products (e.g. blooms, billets, slabs), bars, and wire rod, manufactured from the free-cutting steels listed in [Table 2](#) and supplied in one of the treatment conditions given for the different types of products in [Table 1](#), rows 2 to 4.

This part of ISO 683 covers three groups of free-cutting steels for mechanical purposes as listed in [Table 2](#), namely

- a) not intended for heat treatment,
- b) suitable for case-hardening, and
- c) suitable for quenching and tempering.

Free-cutting steels are often used as bright bars. For these products please refer to ISO 683-18.

In special cases, variations in these technical delivery requirements or additions to them can form the subject of an agreement at the time of enquiry and order (see [Annex B](#)).

In addition to this part of ISO 683, the general technical delivery requirements of ISO 404 are applicable.

2 Normative references

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

ISO 377, *Steel and steel products — Location and preparation of samples and test pieces for mechanical testing*

ISO 404, *Steel and steel products — General technical delivery requirements*

ISO 643, *Steels — Micrographic determination of the apparent grain size*

ISO 4885, *Ferrous products — Heat treatments — Vocabulary*

ISO 4948-1, *Steels — Classification — Part 1: Classification of steels into unalloyed and alloy steels based on chemical composition*

ISO 4948-2, *Steels — Classification — Part 2: Classification of unalloyed and alloy steels according to main quality classes and main property or application characteristics*

ISO 6506-1, *Metallic materials — Brinell hardness test — Part 1: Test method*

ISO 6892-1, *Metallic materials — Tensile testing — Part 1: Method of test at room temperature*

ISO 6929, *Steel products — Vocabulary*

ISO 9443, *Heat-treatable and alloy steels — Surface quality classes for hot-rolled round bars and wire rods — Technical delivery conditions*

ISO 10474, *Steel and steel products — Inspection documents*

ISO 14284, *Steel and iron — Sampling and preparation of samples for the determination of chemical composition*

ISO/TR 9769, *Steel and iron — Review of available methods of analysis*

ISO/TS 4949, *Steel names based on letter symbols*

3 Terms and definitions

For the purposes of this document, the definitions given in ISO 377, ISO 4885, ISO 4948-1, ISO 4948-2, ISO 6929, and ISO 14284, and the following apply.

3.1 ruling section

section for which the specified mechanical properties shall apply

Note 1 to entry: Independent of the actual shape and dimensions of the cross-section of the product, the size of its ruling section is always given by a diameter. This corresponds to the diameter of an "equivalent round bar". That is a round bar which, at the position of its cross-section specified for taking the test pieces for the mechanical tests, will, when being cooled from austenitizing temperature, show the same cooling rate as the actual ruling section of the product concerned at its position for taking the test pieces.

3.2 free-cutting steels

steels characterized by good machinability, i.e. high metal removal rate, mostly obtained by higher than normal contents of sulfur

Note 1 to entry: Other elements besides sulfur can be added for further improving the machinability.

4 Classification and designation

4.1 Classification

The classification of the relevant steel grades is allocated in accordance with ISO 4948-1 and ISO 4948-2. All steels covered by this part of ISO 683 are classified as non-alloy quality steels.

4.2 Designation

For the steel grades covered by this part of ISO 683, the steel names given in the relevant tables are allocated in accordance with ISO/TS 4949.

5 Information to be supplied by the purchaser

5.1 Mandatory information

The manufacturer shall obtain the following information from the purchaser at the time of enquiry and order:

- a) the quantity to be delivered;
- b) the designation of the product form (e.g. slab, bloom, billet, round bar, wire rod);
- c) either the designation of the dimensional standard and the dimensions and tolerances selected from this (see 7.7) or the designation of the drawing or any other document, covering the dimensions and tolerances required for the product;

- d) a reference to this part of ISO 683 (i.e. ISO 683-4);
- e) the designation of the steel grade given in [Table 2](#);
- f) standard designation for a test report 2.2 or, if required, any other type of inspection document in accordance with ISO 10474.

5.2 Options/Supplementary or special requirements

A number of options are specified in this part of ISO 683 and listed below. If the purchaser does not indicate the wish to implement any of these options, the products will be supplied in accordance with the basic specification of this part of ISO 683 (see [5.1](#)).

- a) if a heat-treatment condition other than the untreated condition is required, the symbol for this other condition (see [Table 1](#), column 2)
- b) any supplementary requirement that shall comply with the symbol and, where necessary, the details of this supplementary requirement (see [Annex B](#))
- c) suitability of bars and rod for bright drawing (see [7.6.4](#))
- d) any requirement relating to removal of surface defects (see [7.6.5](#))

EXAMPLE 50 hot-rolled round bars according to ISO 1035-1, with a nominal diameter of 40 mm and a nominal length of 8 000 mm, with diameter tolerance according to class S, and with length tolerance according to class L2 of ISO 1035-4, made of steel grade ISO 683-4, 35S20 (see [Table 2](#)) in the heat-treatment condition +U (see [Table 1](#)), product analysis/option B.5 with a test report 2.2 in accordance with ISO 10474.

**50 round bars ISO 1035 – 40,0S x 8 000L2
steel grade ISO 683-4 – 35S20 option B.5.
Inspection document ISO 10474 – 2.2**

6 Manufacturing process

6.1 General

The manufacturing process of the steel and of the products is, with the restrictions given by the requirements in [6.2](#) and [6.3](#) left to the discretion of the manufacturer.

For minimum reduction ratio or minimum thickness deformation ratio of rolled and forged products, see [B.6](#).

6.2 Heat treatment and surface condition at delivery

6.2.1 Normal condition at delivery

Unless otherwise agreed at the time of enquiry and order, the products shall be delivered in the untreated condition that means “as hot-worked”.

6.2.2 Particular heat-treatment condition

If so agreed at the time of enquiry and order, the products shall be delivered in one of the particular heat-treatment conditions given in [Table 1](#), rows 3 and 4.

6.3 Traceability of the cast

Each product shall be traceable to the cast (see [Clause 10](#)).

7 Requirements

7.1 Chemical composition, hardness, and mechanical properties

7.1.1 General

[Table 1](#) gives a survey of combinations of usual treatment conditions at delivery, product forms, and requirements according to [Tables 2](#) to [6](#) (chemical composition, maximum hardness, mechanical properties).

7.1.2 Chemical composition

The chemical composition determined by cast analysis shall comply with the values in [Table 2](#).

Permissible deviations between the limiting values for cast analysis and the values for product analysis are given in [Table 3](#).

The product analysis shall be carried out when specified at the time of the enquiry and order (see [B.5](#)).

WARNING — Due to hazardous effects to health and environmental problems of Pb, it is recommended to instead use steels only with sulfur and other innocuous free-cutting element additions.

7.1.3 Mechanical properties

Mechanical properties for free-cutting steels are given in [Tables 4](#) to [6](#).

7.2 Machinability

The steels covered by this part of ISO 683 have good machinability and chip-breaking characteristics. However, the machinability decreases with increasing carbon, silicon, and manganese contents, while cold reduction improves the machinability of the steels not intended for heat treatment and steel 10S20.

NOTE Non-leaded steels with comparable chemical composition generally have identical mechanical properties, but often lower machinability than leaded steels.

7.3 Weldability

Because of their high sulfur and phosphorus content, free-cutting steels are normally not recommended for welding.

7.4 Grain size

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 for case-hardening steels or steels for quenching and tempering, the special requirement in [B.3](#) shall be ordered.

If direct hardening treatment is used for case-hardening steels, a fine grain structure should be ordered.

7.5 Internal soundness

Where appropriate, requirements relating to the internal soundness of the products shall be agreed at the time of enquiry and order (see [B.4](#)).

7.6 Surface quality

7.6.1 All products shall have a smooth surface finish appropriate to the manufacturing processes applied.

7.6.2 Minor surface imperfections, which can occur under normal manufacturing conditions, such as prints originating from rolled-in scale, are not to be regarded as defects.

7.6.3 Bars and wire rod are delivered with surface class A according to ISO 9443, unless otherwise agreed at the time of enquiry and order.

NOTE It is more difficult to detect and eliminate surface discontinuities in coiled products than in cut lengths. This should be taken into account when agreements on surface quality are made.

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

7.6.5 The removal of surface defects by welding is not permitted.

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

7.7 Shape, dimensions, and tolerances

The shape, dimensions, and tolerances of the products shall comply with the requirements agreed at the time of enquiry and order. The agreements shall, as much as possible, be based on corresponding International Standards (see [Annex D](#)), or otherwise on suitable national standards.

8 Inspection

8.1 Testing procedures and types of documents

8.1.1 Products complying with this part of ISO 683 shall be ordered and delivered with one of the inspection documents specified in ISO 10474. 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 2.2 shall be issued.

8.1.2 If, in accordance with the agreements made at the time of enquiry and order, a test report 2.2 is to be provided, this shall cover the following information:

- a) confirmation that the material complies with the requirements of the order;
- b) results of the cast analysis of the concerned cast for all elements specified in [Table 2](#) for the steel grade.

8.1.3 If in accordance with the agreements in the order an inspection certificate [3.1](#) or [3.2](#) is to be provided, the specific inspections and tests described in [8.2](#), [8.3](#), and [Clause 9](#) shall be carried out and the results shall be confirmed in the inspection certificate.

In addition, the inspection certificate shall cover the following:

- a) confirmation that the material complies with the requirements of the order;
- b) results of the cast analysis of the concerned cast for all elements specified in [Table 2](#) for the steel grade;

- c) the result of all inspections and tests ordered by supplementary requirements (see [Annex B](#));
- d) the symbol letters or numbers relating the inspection certificate, test pieces, and products to each other.

8.2 Frequency of testing

The amount of testing, the sampling conditions, and the test methods to be applied for the verification of compliance with the requirements shall be in accordance with the prescriptions of [Table 7](#).

8.3 Specific inspection and testing

8.3.1 Verification of the hardness and mechanical properties

The hardness requirements and/or mechanical properties given for the relevant treatment condition in [Table 1](#), column 6, sub-column 6.2, shall be verified, with the following exception. The requirements given in footnote a to [Table 1](#) (mechanical properties of reference test pieces), shall only be verified if the supplementary requirement given in [B.2](#), is ordered.

8.3.2 Visual and dimensional inspection

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

9 Test methods

9.1 Chemical analysis

The choice of a suitable physical or chemical analytical method for the analysis shall be at the discretion of the manufacturer. In cases of dispute, the method for product analysis used shall be agreed taking into account the relevant existing International Standards.

The list of available International Standards on chemical analysis is given in ISO/TR 9769.

9.2 Hardness and mechanical tests

9.2.1 Hardness

For products in the untreated condition, the hardness shall be measured in accordance with ISO 6506-1.

9.2.2 Mechanical tests

The tensile test shall be carried out in accordance with ISO 6892-1.

For the specified yield strength in the tables of mechanical properties in this part of ISO 683 the upper yield strength (R_{eH}) shall be determined.

If a yield phenomenon is not present, the 0,2 % proof strength ($R_{p0,2}$) shall be determined.

9.3 Retests

Retests for steels for quenching and tempering and criteria should be as specified in ISO 404.

10 Marking

The manufacturer shall mark the products or the bundles or boxes containing the products in a suitable way, so that the identification of the cast, the steel name, and the origin of the delivery is possible (see B.7).

Table 1 — Combinations of usual heat-treatment conditions at delivery, product forms, and requirements according to Tables 2 to 6

| | 1 | 2 | 3 | 4 | 5 | 6 | | |
|---|--------------------------------------|--|------------------------|------|----------|--|--|--|
| 1 | Heat-treatment condition at delivery | Symbol | x = applicable for | | | 6.1 | Applicable requirements | |
| | | | Semi-finished products | Bars | Wire rod | | 6.2 | |
| 2 | Untreated | None or +U | x | x | x | Chemical composition according to Tables 2 and 3 | Maximum Brinell hardness or (in the case of dispute) the tensile strength according to Table 4 in the case of steels not intended for heat treatment or Table 5 in the case of case-hardening steels or Table 6 in the case of steels for quenching and tempering ^a | |
| 3 | Quenched and tempered | +QT | — | x | — | | Mechanical properties according to Table 6 in the case of steels for quenching and tempering | |
| 4 | Others | Other treatment conditions, for example the stress relieved condition, can be agreed at the time of enquiry and order. | | | | | | |

^a The mechanical properties specified in Table 6 for the quenched + tempered condition shall be achievable after appropriate heat treatment if so agreed at the time of enquiry and order (see B.2).

Table 2 — Steel grades and chemical composition (cast analysis)

| Steel name | % mass fraction ^a | | | | | |
|--|------------------------------|-------------------|--------------|-------------------|--------------|--------------|
| | C | Si | Mn | P | S | Pb |
| Steels not intended for heat treatment | | | | | | |
| 9S20 | 0,13 | 0,05 ^b | 0,60 to 1,20 | 0,11 ^c | 0,15 to 0,25 | — |
| 11SMn30 | 0,14 | 0,05 ^b | 0,90 to 1,30 | 0,11 ^c | 0,27 to 0,33 | — |
| 11SMnPb30 | | | | | | 0,20 to 0,35 |
| 11SMn37 | 0,14 | 0,05 ^b | 1,00 to 1,50 | 0,11 ^c | 0,34 to 0,40 | — |
| 11SMnPb37 | | | | | | 0,20 to 0,35 |
| Case-hardening steels | | | | | | |
| 10S20 | 0,07 to 0,13 | 0,40 | 0,70 to 1,10 | 0,060 | 0,15 to 0,25 | — |
| 10SPb20 | | | | | | 0,20 to 0,35 |
| 15SMn13 | 0,12 to 0,18 | 0,40 | 0,90 to 1,30 | 0,060 | 0,08 to 0,18 | — |
| 17SMn20 | 0,14 to 0,20 | 0,40 | 1,20 to 1,60 | 0,060 | 0,15 to 0,25 | — |
| Steels for quenching and tempering | | | | | | |
| 35S20 | 0,32 to 0,39 | 0,40 | 0,70 to 1,10 | 0,060 | 0,15 to 0,25 | — |
| 35SPb20 | | | | | | 0,15 to 0,35 |
| Elements not quoted 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 materials used in manufacture which affect the mechanical properties and applicability. However, if agreed, the manufacturer can add elements such as Ca, Se, Te, etc. for the purpose of improving the machinability. These elements have to be reported in the inspection document. | | | | | | |
| ^a Maximum values unless otherwise indicated. | | | | | | |
| ^b Since silicon has an adverse effect on machinability, it is not intentionally added to specified limits, but if the formation of special oxides is guaranteed, a Si-content of 0,10 to 0,40 % can be agreed. | | | | | | |
| ^c At the time of enquiry and order, it can be agreed that either a grade with 0,06 to 0,11 % P or a grade with max. 0,05 % P shall be delivered. | | | | | | |

Table 2 (continued)

| Steel name | % mass fraction ^a | | | | | |
|------------|------------------------------|------|--------------|-------|--------------|--------------|
| | C | Si | Mn | P | S | Pb |
| 36SMn14 | 0,32 to 0,39 | 0,40 | 1,30 to 1,70 | 0,060 | 0,10 to 0,18 | — |
| 36SMnPb14 | | | | | | 0,15 to 0,35 |
| 35SMn20 | 0,32 to 0,39 | 0,40 | 0,90 to 1,40 | 0,060 | 0,15 to 0,25 | — |
| 35SMnPb20 | | | | | | 0,15 to 0,35 |
| 38SMn28 | 0,35 to 0,40 | 0,40 | 1,20 to 1,50 | 0,060 | 0,24 to 0,33 | — |
| 38SMnPb28 | | | | | | 0,15 to 0,35 |
| 44SMn28 | 0,40 to 0,48 | 0,40 | 1,30 to 1,70 | 0,060 | 0,24 to 0,33 | — |
| 44SMnPb28 | | | | | | 0,15 to 0,35 |
| 46S20 | 0,42 to 0,50 | 0,40 | 0,70 to 1,10 | 0,060 | 0,15 to 0,25 | — |
| 46SPb20 | | | | | | 0,15 to 0,35 |

Elements not quoted 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 materials used in manufacture which affect the mechanical properties and applicability. However, if agreed, the manufacturer can add elements such as Ca, Se, Te, etc. for the purpose of improving the machinability. These elements have to be reported in the inspection document.

^a Maximum values unless otherwise indicated.

^b Since silicon has an adverse effect on machinability, it is not intentionally added to specified limits, but if the formation of special oxides is guaranteed, a Si-content of 0,10 to 0,40 % can be agreed.

^c At the time of enquiry and order, it can be agreed that either a grade with 0,06 to 0,11 % P or a grade with max. 0,05 % P shall be delivered.

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

| Element | Permissible maximum content according to cast analysis | Permissible deviations ^a |
|---------|--|-------------------------------------|
| | % mass fraction | % mass fraction |
| C | ≤0,30 | ±0,02 |
| | 0,30 < C ≤ 0,50 | ±0,03 |
| Si | ≤0,05 | ±0,01 |
| | 0,05 < Si ≤ 0,40 | ±0,03 |
| Mn | ≤1,00 | ±0,04 |
| | 1,00 < Mn ≤ 1,70 | ±0,06 |
| P | ≤ 0,06 | ±0,008 |
| | 0,06 < P ≤ 0,11 | ±0,02 |
| S | ≤0,33 | ±0,03 |
| | 0,33 < S ≤ 0,40 | ±0,04 |
| Pb | ≤0,35 | +0,03 -0,02 |

^a ± means that, in one cast, the deviation can occur over the upper value or under the lower value of the specified range in this table, but not both at the same time.

Table 4 — Mechanical properties of free-cutting steels not intended for heat treatment^a

| Steel name ^b | Diameter mm | Hardness ^a HBW max. | Untreated |
|-------------------------|--------------------|-----------------------------------|----------------------------------|
| | | | Tensile Strength R_m MPa |
| 9S20 | $d \leq 16$ | 154 | 330 to 520 |
| | $16 < d \leq 40$ | 154 | 330 to 520 |
| | $40 < d \leq 63$ | 154 | 320 to 520 |
| | $63 < d \leq 100$ | 140 | 310 to 470 |
| 11SMn30 | $5 \leq d \leq 10$ | 169 | 380 to 570 |
| 11SMnPb30 | $10 < d \leq 16$ | 169 | 380 to 570 |
| 11SMn37 | $16 < d \leq 40$ | 169 | 380 to 570 |
| 11SMnPb37 | $40 < d \leq 63$ | 169 | 370 to 570 |
| | $63 < d \leq 100$ | 154 | 360 to 520 |

^a In cases of dispute, the tensile strength values are the decisive factor.

^b In this table, grades alloyed with further elements for better machinability are not explicitly mentioned, but the mechanical properties are also valid for them (see Table 2).

Table 5 — Mechanical properties of case-hardening free-cutting steels

| Steel name ^b | Diameter mm | Hardness ^a HBW max. | Untreated |
|-------------------------|--------------------|-----------------------------------|----------------------------------|
| | | | Tensile strength R_m MPa |
| 10S20 10SPb20 | $5 \leq d \leq 10$ | 156 | 360 to 530 |
| | $10 < d \leq 16$ | 156 | 360 to 530 |
| | $16 < d \leq 40$ | 156 | 360 to 530 |
| | $40 < d \leq 63$ | 156 | 360 to 530 |
| | $63 < d \leq 100$ | 146 | 350 to 490 |
| 15SMn13 | $5 \leq d \leq 10$ | 181 | 430 to 610 |
| | $10 < d \leq 16$ | 178 | 430 to 600 |
| | $16 < d \leq 40$ | 178 | 430 to 600 |
| | $40 < d \leq 63$ | 172 | 430 to 580 |
| | $63 < d \leq 100$ | 160 | 420 to 540 |
| 17SMn20 | $5 \leq d \leq 10$ | 181 | 430 to 610 |
| | $10 < d \leq 16$ | 178 | 430 to 600 |
| | $16 < d \leq 40$ | 178 | 430 to 600 |
| | $40 < d \leq 63$ | 172 | 430 to 580 |
| | $63 < d \leq 100$ | 160 | 420 to 540 |

^a In cases of dispute, the tensile strength values are the decisive factor.

^b In this table, grades alloyed with further elements for better machinability are not explicitly mentioned, but the mechanical properties are also valid for them (see Table 2).

Table 6 — Mechanical properties of free-cutting steels for quenching and tempering

| Steel name ^b | Diameter mm | Untreated | | Quenched and tempered | | |
|-------------------------|----------------|-----------------------------------|----------------------------------|-----------------------|--------------|---------------|
| | | Hardness ^a HBW max. | Tensile strength R_m MPa | R_e min. MPa | R_m MPa | A min. % |
| 35S20 35SPb20 | 5 ≤ d ≤ 10 | 210 | 550 to 720 | 430 | 630 to 780 | 15 |
| | 10 < d ≤ 16 | 204 | 550 to 700 | 430 | 630 to 780 | 15 |
| | 16 < d ≤ 40 | 198 | 520 to 680 | 380 | 600 to 750 | 16 |
| | 40 < d ≤ 63 | 196 | 520 to 670 | 320 | 550 to 700 | 17 |
| | 63 < d ≤ 100 | 190 | 500 to 650 | 320 | 550 to 700 | 17 |
| 36SMn14 36SMnPb14 | 5 ≤ d ≤ 10 | 225 | 580 to 770 | 480 | 700 to 850 | 14 |
| | 10 < d ≤ 16 | 225 | 580 to 770 | 460 | 700 to 850 | 14 |
| | 16 < d ≤ 40 | 219 | 560 to 750 | 420 | 670 to 820 | 15 |
| | 40 < d ≤ 63 | 216 | 560 to 740 | 400 | 640 to 790 | 16 |
| | 63 < d ≤ 100 | 216 | 550 to 740 | 360 | 570 to 720 | 17 |
| 35SMn20 35SMnPb20 | 5 ≤ d ≤ 10 | 225 | 580 to 770 | — | — | — |
| | 10 < d ≤ 16 | 225 | 580 to 770 | 420 | 620 to 820 | 14 |
| | 16 < d ≤ 40 | 219 | 560 to 750 | 365 | 590 to 790 | 16 |
| | 40 < d ≤ 63 | 216 | 560 to 740 | 335 | 540 to 740 | 17 |
| | 63 < d ≤ 100 | 216 | 550 to 740 | — | — | — |
| 38SMn28 38SMnPb28 | 5 ≤ d ≤ 10 | 228 | 580 to 780 | 480 | 700 to 850 | 15 |
| | 10 < d ≤ 16 | 219 | 580 to 750 | 460 | 700 to 850 | 15 |
| | 16 < d ≤ 40 | 213 | 560 to 730 | 420 | 700 to 850 | 15 |
| | 40 < d ≤ 63 | 213 | 560 to 730 | 400 | 700 to 850 | 16 |
| | 63 < d ≤ 100 | 204 | 550 to 700 | 380 | 630 to 800 | 16 |
| 44SMn28 44SMnPb28 | 5 ≤ d ≤ 10 | (266) | 630 to 900 | 520 | 700 to 850 | 16 |
| | 10 < d ≤ 16 | (252) | 630 to 850 | 480 | 700 to 850 | 16 |
| | 16 < d ≤ 40 | 241 | 630 to 820 | 420 | 700 to 850 | 16 |
| | 40 < d ≤ 63 | 231 | 620 to 790 | 410 | 700 to 850 | 16 |
| | 63 < d ≤ 100 | 228 | 610 to 780 | 400 | 700 to 850 | 16 |
| 46S20 46SPb20 | 5 ≤ d ≤ 10 | 234 | 590 to 800 | 490 | 700 to 850 | 12 |
| | 10 < d ≤ 16 | 228 | 590 to 780 | 490 | 700 to 850 | 12 |
| | 16 < d ≤ 40 | 222 | 590 to 760 | 430 | 650 to 800 | 13 |
| | 40 < d ≤ 63 | 213 | 580 to 730 | 370 | 630 to 780 | 14 |
| | 63 < d ≤ 100 | 207 | 560 to 710 | 370 | 630 to 780 | 14 |

^a In cases of dispute, the tensile strength values are the decisive factor.

^b In this table, grades alloyed with further elements for better machinability are not explicitly mentioned, but the mechanical properties are also valid for them (see [Table 2](#)).

Table 7 — Test conditions for verification of compliance with the various requirements

| No | 1 | | 2 | 3 | 4 | 5 | 6 |
|----|---|--------------------|------------------------|---|--------------------------|---|--|
| | Requirements | | Amount of testing | | | Sampling ^b | Test method |
| | | See Tables | Test unit ^a | Sample products per test unit | Tests per sample product | | |
| 1 | Chemical composition | Tables 2 and 3 | C | (The cast analysis is given by the manufacturer; for product analysis, see B.5) | | | |
| 2 | Hardness in the untreated condition (as rolled) | Tables 4, 5, and 6 | C + D | 1 | 1 | The hardness shall be measured, if possible, at the circumference of the product at a distance of 1 × diameter from one end and, in cases of products with square or rectangular cross-section, at a distance of 0,25 × w (width of the product) from one longitudinal edge. In cases of dispute, the tensile test is to be done. | According to ISO 6506-1 |
| 3 | Mechanical properties of products in the untreated or quenched and tempered condition | Tables 4, 5, and 6 | C + D + T | 1 ^c | 1 | The test pieces for the tensile test shall be taken in accordance with Figure 1. | The tensile test shall be carried out in accordance with ISO 6892-1 on proportional test pieces having a gauge length of $L_0 = 5,65 \sqrt{S_0}$ (S_0 = area of the cross-section of the test piece.) |

NOTE Verification of the requirements is only necessary if an inspection certificate is ordered.

^a The tests shall be carried out separately for each cast as indicated by “C”, each dimension as indicated by “D”, and each heat-treatment batch as indicated by “T”.

Products with different thicknesses can be grouped if the thicknesses lie in the same dimensional range for mechanical properties and if the differences in thickness do not affect the properties. In case of doubt, the thinnest and the thickest product shall be tested.

^b The general conditions for selection and preparation of test samples and test pieces shall be in accordance with ISO 377.

^c If the products are continuously heat treated, one sample product shall be taken for each 25 t or part thereof, but at least one sample product for each cast.

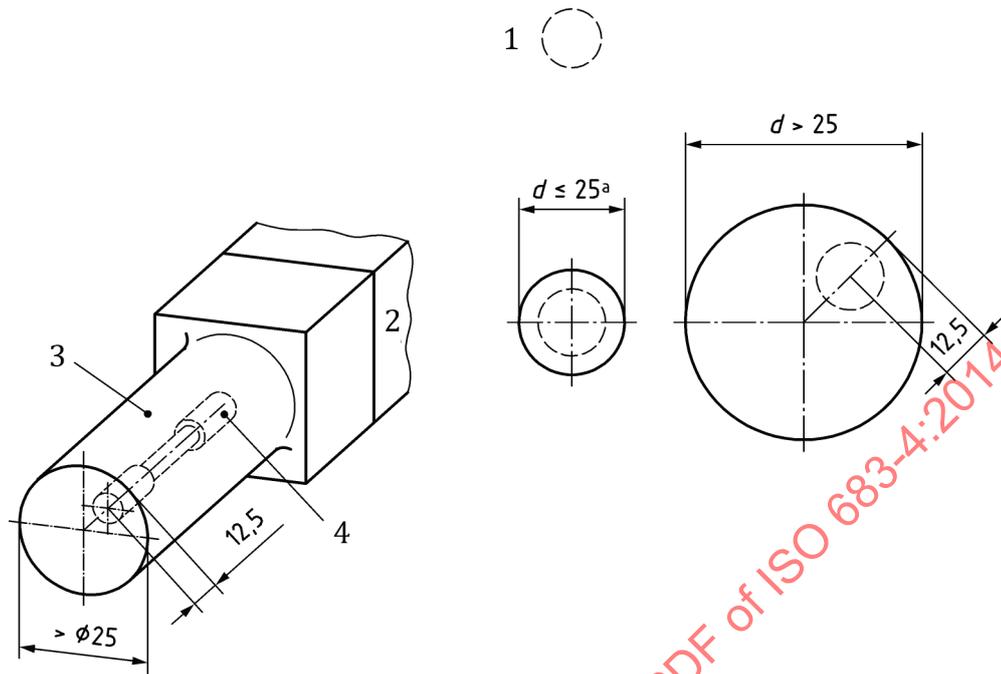
Table 8 — Conditions for heat treatment of case-hardening free-cutting steels^a

| Steel name ^e | Carburizing temperature ^b °C | Direct and simple hardening temperature °C | Double hardening | | Quenching agent | Tempering ^d °C |
|--|--|---|----------------------------------|----------------------------------|-----------------------------------|------------------------------|
| | | | Core-hardening temperature °C | Case-hardening temperature °C | | |
| 10S20 10SPb20 15SMn13 17SMn20 | 880 to 980 | 830 to 870 | 880 to 920 | 780 to 820 | Water, oil, emulsion ^c | 150 to 200 |
| <p>^a The temperatures given for carburizing, direct and simple hardening, core hardening, case hardening, and tempering are for guidance; the actual temperatures chosen shall be those that will give the properties required.</p> <p>^b The carburizing temperature will depend on the chemical composition of the steel, the mass of the product, and the carburizing medium. If the steels are direct hardened, in general a temperature of 950 °C is not exceeded. For special procedures, for example under vacuum, higher temperatures, for example 1 020 °C to 1 050 °C, are not unusual.</p> <p>^c The kind of quenching agent depends, for example, on the shape of the products, the cooling conditions and the quantity of furnace filling.</p> <p>^d Time for tempering as a guide: 1 h minimum.</p> <p>^e In this table, grades alloyed with further elements for better machinability are not explicitly mentioned, but the heat-treatment conditions are also valid for them (see Table 2).</p> | | | | | | |

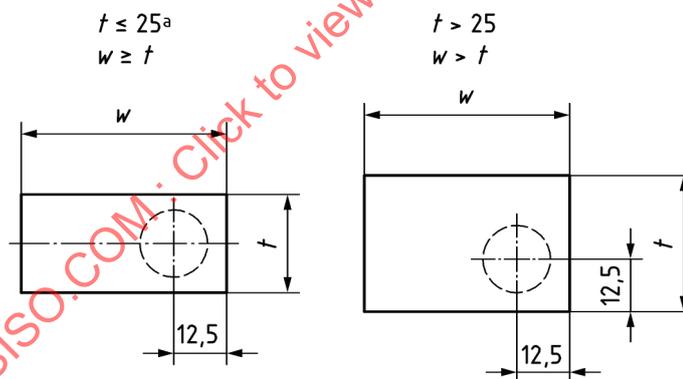
Table 9 — Conditions for heat treatment of free-cutting steels for quenching and tempering^a

| Steel name ^d | Quenching ^b | | Tempering ^c °C |
|---|------------------------|--------------|------------------------------|
| | °C | Medium | |
| 35S20 35SPb20 | 860 to 890 | Water or oil | 540 to 680 |
| 36SMn14 36SMnPb14 35SMn20 35SMnPb20 | 850 to 880 | Water or oil | 540 to 680 |
| 38SMn28 38SMnPb28 44SMn28 44SMnPb28 46S20 46SPb20 | 840 to 870 | Water or oil | 540 to 680 |
| <p>^a The temperature are for guidance, but the actual temperatures chosen shall be those that will give the properties required.</p> <p>^b Time for austenitizing as a guide: 0,5 h minimum.</p> <p>^c Time for tempering as a guide: 1 h minimum.</p> <p>^d In this table, grades alloyed with further elements for better machinability are not explicitly mentioned, but the heat-treatment conditions are also valid for them (see Table 2).</p> | | | |

Dimensions in millimetres



a) Round and similar shaped sections



b) Rectangular and square sections

Key

- 1 tensile test piece
- 2 sample
- 3 rough specimen
- 4 test piece

a For small products (d or $w \leq 25$ mm), the test piece shall, if possible, consist of an un-machined part of the bar.

Figure 1 — Location of the test pieces in bars and rods

Annex A (normative)

Ruling sections for mechanical properties

A.1 Definition

See 3.1.

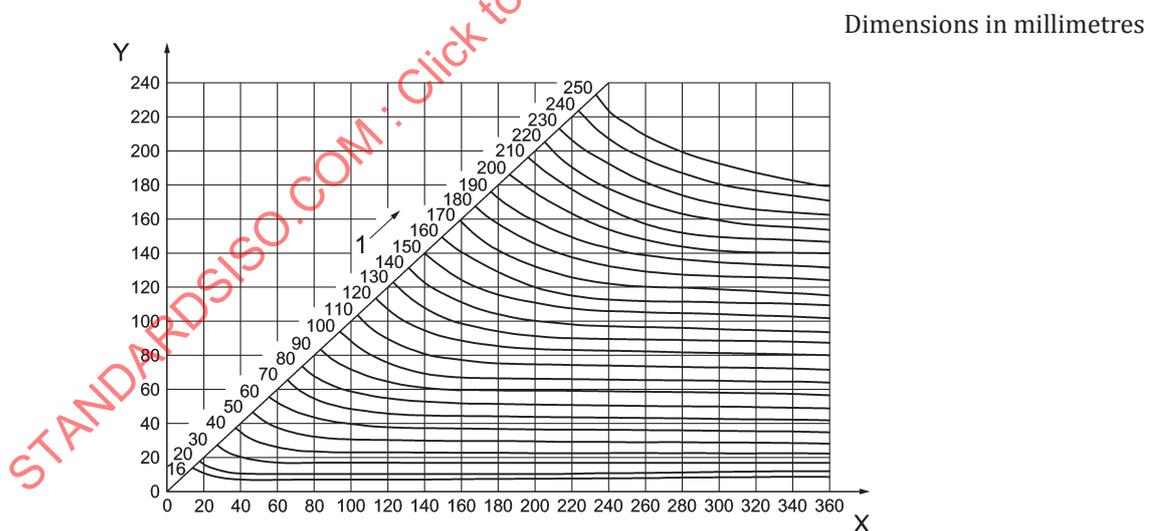
A.2 Determination of the diameter of the equivalent ruling section

A.2.1 If the test pieces are taken from products with simple cross-sections and from positions with quasi two-dimensional heat flow, A.2.1.1 to A.2.1.3 shall apply.

A.2.1.1 For rounds, the nominal diameter of the product (not comprising the machining allowance) shall be taken as the diameter of the ruling section.

A.2.1.2 For hexagons and octagons, the nominal distance between two opposite sides of the cross-section shall be taken as the diameter of the ruling section.

A.2.1.3 For square and rectangular bars, the diameter of the ruling section shall be determined in accordance with the example shown in Figure A.1.



Key

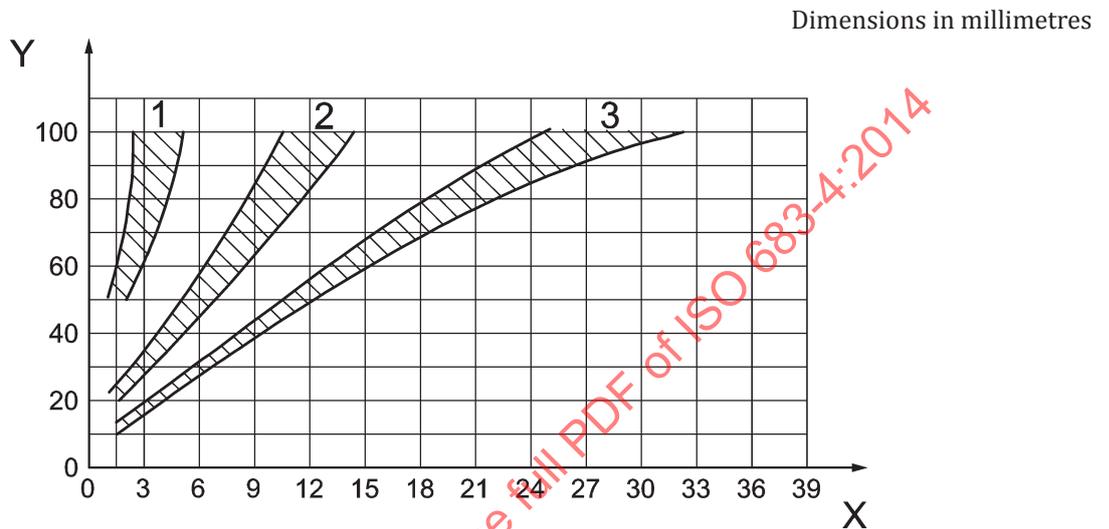
- X width
- Y thickness
- 1 diameter of the ruling cross-section

Figure A.1 — Diameter of the equivalent ruling section for square and rectangular sections for quenching in oil or water

EXAMPLE For a rectangular bar with a section of 40 mm × 60 mm, the diameter of the ruling section is 50 mm.

A.2.2 For other product forms, the ruling section shall be agreed at the time of enquiry and order.

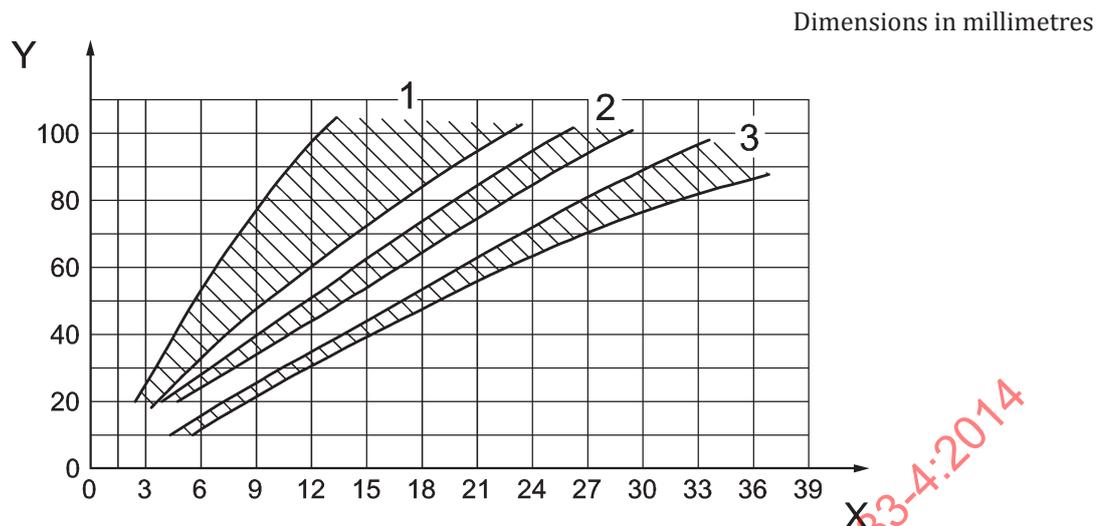
NOTE For this purpose, the following procedure can serve as a guideline. The product is hardened in accordance with usual practice. It is then cut so that the hardness and structure at the position of the ruling section provided for taking test pieces can be determined. From another product of the type under consideration and of the same cast, an end-quench piece is taken from the prescribed position and tested in the usual way. Then the distance is determined at which the end-quench test piece shows the same hardness and structure as the ruling section at the position provided for taking test pieces. On the basis of this distance, the diameter of the ruling section is then estimated using [Figures A.2](#) and [A.3](#).



Key

- X distance from the quenched end
- Y bar diameter
- 1 surface
- 2 3/4 radius
- 3 centre

Figure A.2 — Relationship between the cooling rates in end-quench test pieces (Jominy test pieces) and in quenched round bars in mildly agitated water (source: SAE J406c)



Key

- X distance from the quenched end
- Y bar diameter
- 1 surface
- 2 3/4 radius
- 3 centre

Figure A.3 — Relationship between the cooling rates in end-quench test pieces (Jominy test pieces) and in quenched round bars in mildly agitated oil (source: SAE J406c)

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