INTERNATIONAL STANDARD

ISO 683-1

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

Part 1: Non-alloy steels for quenching and tempering

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

Partie 1: Aciers non alliés pour trempe et revenu

Reference number
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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 683-1 was prepared by Technical Committee ISO/TC 17, *Steel*, Subcommittee SC 4, *Heat treatable and alloy steels*.

This second edition cancels and replaces the first edition (ISO 683-1:1987) 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 9: Wrought free-cutting steels*

— *Part 10: Wrought nitriding steels*

— *Part 11: Case-hardening 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 products of unalloyed and low alloy steels*

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

Part 1:
Non-alloy steels for quenching and tempering

1 Scope

1.1 This part of ISO 683 specifies the technical delivery requirements for

— semi-finished products, hot formed, e.g. blooms, billets, slabs (see Note 1),

— bars (see Note 1),

— wire rod,

— finished flat products,

— hammer or drop forgings (see Note 1)

manufactured from the direct hardening non-alloy steels and the non-alloy flame- and induction-hardening steels listed in Table 3 and supplied in one of the heat-treatment conditions given for the different types of products in Table 1 and in one of the surface conditions given in Table 2.

The steels are, in general, intended for the manufacture of quenched and tempered or austempered (see 3.2 and Note 2) and flame- or induction-hardened machine parts (see Tables 9 and 11), but can also be partly used in the normalized condition (see Table 10).

The requirements for mechanical properties given in this part of ISO 683 are restricted to the sizes given in the relevant Tables 9 and 10.

NOTE 1 Hammer-forged semi-finished products (blooms, billets, slabs, etc.), seamless rolled rings and hammer-forged bars are in the following covered under semi-finished products or bars and not under the term “hammer and drop forgings”.

NOTE 2 For the purposes of simplification, the term “quenched and tempered” is, unless otherwise indicated, used in the following also for the austempered condition.

NOTE 3 For International Standards relating to steels complying with the requirements for the chemical composition in Table 3, however, supplied in other product forms or treatment conditions than given above or intended for special applications, and for other related International Standards, see the Bibliography.

NOTE 4 This part of ISO 683 does not apply to bright products and bars and wire rod for cold heading. For such products, see ISO 683-18 and ISO 4954.

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

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

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.

ISO 148-1, *Metallic materials — Charpy pendulum impact test — Part 1: Test method*

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 642, *Steel — Hardenability test by end quenching (Jominy test)*

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

ISO 3887, *Steels — Determination of depth of decarburization*

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

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

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

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

ISO 6929, *Steel products — Vocabulary*

ISO 4967, *Steel — Determination of content of nonmetallic inclusions — Micrographic method using standard diagrams*

ISO 7788, *Steel — Surface finish of hot-rolled plates and wide flats — Delivery requirements*

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

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

ISO 10474, *Metallic products — Inspection documents*

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

ISO 18265, *Metallic materials — Conversion of hardness values*

3 Terms and definitions

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

NOTE For deviations from these terms and definitions, see Notes 1 and 2 to the Scope.

3.1
ruling section
section for which the specified mechanical properties apply

NOTE 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, shows the same cooling rate as the actual ruling section of the product concerned at its position for taking the test pieces.

3.2
austempering
austenitization of a steel with a subsequent cooling to a temperature in the Bainite region and holding at this temperature until a desired degree of transformation is obtained

NOTE The subsequent cooling to room temperature can be carried out in any manner desired.

3.3
non-alloy steel
non-alloy steel as defined in ISO 4948-1

3.4
special steel
special steel as defined in ISO 4948-2

4 Classification and designation

4.1 Classification

The classification of the relevant steel grades is in according to ISO 4948-1 and ISO 4948-2. Steel grades C25, C35, C40, C45, C50, C55 and C60 are non-alloy quality steels. All other steel grades covered by this part of ISO 683 are non-alloy special steels.

4.2 Designation

For the steel grades covered by this part of ISO 683, the steel names, as 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 (slab, bloom, billet, round bar, wire rod, wide flat, sheet, plate, strip, forging, etc.)

c) either the designation of the dimensional standard and the dimensions and tolerances selected from this (see 7.9) or, for example in the case of drop forgings, the designation of the drawing or any other document covering the dimensions and tolerances required for the product;

d) reference to this part of ISO 683, i.e. ISO 683-1;

e) the designation of the steel grade, as given in Table 3;

f) standard designation for a test report 2.2 or, if required, any other type of inspection document in accordance with ISO 10474 or another standard (e.g. regional standards EN 10204 or JIS G 0415).

5.2 Options and/or 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 specifications 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) if another surface condition than “hot worked” or a special surface quality is required, the surface condition (see Table 2) and the surface quality (see 7.7);

c) any requirement for the hardenability (+H, +HH, +HL) for special steels (see 7.1.4 and Tables 5 to 7);

d) any supplementary requirement that shall be complied with, the symbol and, where necessary, the details of this supplementary requirement (see Annex B);

e) any requirement for the verification of non-metallic inclusion content (see 7.5);

f) verification of hardenability and, if agreed, the information about calculation of the hardenability (see 9.3.2);

g) any requirement regarding the permissible depth of decarburization (see 7.8);

h) suitability of bars and rod for bright drawing (see 7.7.4);

i) any requirement relating to the removal of surface defects (see 7.7.5);

j) hardness testing instead of tensile testing for normalized finished flat products in thicknesses > 10 mm for plates or > 100 mm for bars (see 7.1.3). In this case, hardness limits should be agreed.

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 683-1 C45E (see Table 3) in the heat treatment condition +N (see Table 1), surface blast cleaned (+BC) (see Table 2), product analysis/option B.5 with an inspection certificate 3.1 according to ISO 10474:

50 round bars ISO 1035 - 40,0S × 8 000L2

ISO 683-1 – C45E+N+BC option B.5

ISO 10474 – 3.1

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 to 6.4 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 Deoxidation

All steels shall be deoxidized.

6.3 Heat-treatment condition and surface condition at delivery

6.3.1 Normal condition at delivery

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

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 conditions

If so agreed at the time of enquiry and order, the products shall be delivered in one of the particular surface conditions given in Table 2, lines 3 to 6.

6.4 Traceability of the cast

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

7 Requirements

7.1 Chemical composition, mechanical properties and hardenability

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 11.

Except where steels are ordered in the quenched and tempered condition, this part of ISO 683 makes for the steel types 23Mn6, 28Mn6, 36Mn6 and 42Mn6, and for the non-alloy special steels with carbon contents equal to or higher than the contents of type C35 provisions to be supplied with or without hardenability requirements (see Table 1, columns 8 and 9).

7.1.2 Chemical composition

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

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 B.5).

7.1.3 Mechanical properties

Where the steel is ordered without hardenability requirements, the requirements for mechanical properties specified in Tables 8, 9 or 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 Figure 2 or Figures 3 and 4 (see also footnote a to Table 1).

For steel plates of thickness > 10 mm and bars > 100 mm in 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 the sample for the tensile test piece would be taken from. The hardness test should be performed and, from this, the tensile strength values can be calculated according to ISO 18265. The calculated tensile strength shall comply with Table 10.

7.1.4 Hardenability

Where the steel is ordered using the designations given in Table 5, 6 or 7 to normal (see Table 5) or to narrowed (see Tables 6 and 7) hardenability requirements, the values of hardenability given in Table 5, 6 or 7, respectively, apply in addition to the requirements cited in Table 1, columns 9.1 and 9.2. (See footnote b to Table 3.)

7.1.5 Surface hardness

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

7.2 Machinability

All steels are machinable in the condition “soft annealed”. Where improved machinability is required, grades with a specified sulfur range and/or with a specific treatment should be ordered to improve machinability (see also Table 1, line 7).

7.3 Cold shearability

7.3.1 Under suitable shearing conditions (avoiding local stress peaks, preheating, application of blades with a profile adapted to that of the product, etc.), all steels are cold shearable in the soft annealed (+A) condition.

7.3.2 Steel grades C45, C50, C55, C60, 28Mn6, 36Mn6 and 42Mn6 and the corresponding E-, R-, +H-, +HH- and +HL grades (see Tables 3 and 5 to 7) are, under suitable conditions, also cold shearable when being delivered in the condition “treated to improve shearability (+S)” with the hardness requirements given in Table 8.

7.3.3 Steels C25, C30, C35, C40 and 23Mn6 and the corresponding E-, R-, +H-, +HH- and +HL-grades (see Tables 3 and 5 to 7) are, under suitable conditions, cold shearable when being delivered in the untreated condition.

Cold shearablity may also be assumed for the various grades of steel C45, in sizes of 80 mm and greater in the untreated condition.

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 in accordance with a reference treatment, special requirement B.3 shall be ordered.

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

7.5 Non-metallic inclusions

7.5.1 Microscopic inclusions

The special steels shall have a certain degree of cleanness; however, verification of the non-metallic inclusion content requires a special agreement. If there is such an agreement at the time of enquiry and order, the microscopic non-metallic inclusion content shall be determined to an agreed procedure and within agreed limits in accordance with ISO 4967 or another standard (e.g. regional standards EN 10247 or JIS G 0555).

For grades with specified minimum sulfur content, the agreement should not include sulfides.

7.5.2 Macroscopic inclusions

This requirement is applicable to the verification of the macroscopic inclusions in special steels. If verification is agreed, the method and acceptance limits shall be agreed at the time of enquiry and order.

7.6 Internal soundness

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

7.7 Surface quality

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

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

7.7.3 Bars and wire rod shall be delivered with surface class A according to ISO 9443 and hot-rolled plates and wide flats shall be delivered with surface according to ISO 7788, unless otherwise agreed at the time of enquiry and order.

Where no International Standard on the surface quality of steel products exists, detailed requirements referring to this characteristic shall, where appropriate, be agreed at the time of enquiry and order.

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

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

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

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

7.8 Decarburization

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

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

7.9 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 far as possible, be based on corresponding International Standards (see Annex D); 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 as specified in ISO 10474 (or according to another regional standard, e.g. EN 10204 or JIS G 0415). 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 for all elements specified in Table 3 for the steel grade concerned.

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 8.3 and Clause 9 shall be carried out and the results shall be confirmed in the inspection certificate.

In addition, the inspection certificate shall cover:

a) confirmation that the material complies with the requirements of the order;

b) results of the cast analysis for all elements specified in Table 3 for the steel grade concerned;

c) results 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 the requirements shall be in accordance with the requirements of Table 12.

8.3 Specific inspection and testing

8.3.1 Verification of the 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 requirements given in Table 1, footnote a (mechanical properties of reference test pieces), shall only be verified if a supplementary requirement specified in (clause) B.1 or B.2 is ordered.

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

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.

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

9.2 Mechanical tests

9.2.1 Tensile test

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.

9.2.2 Impact test

The impact test shall be carried out in accordance with ISO 148-1.

The average values of a set of three test pieces shall be equal to or greater than the specified value. One individual value may be below the specified value, provided it is not less than 70 % of that value.

If these conditions are not satisfied, the sample product is rejected and retests may be carried out on the remainder of the test unit.

9.3 Hardness and hardenability tests

9.3.1 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 ISO 6506-1.

9.3.2 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 dispute, an end quench hardenability test shall be carried out in accordance with ISO 642. The temperature for quenching shall comply with the relevant tables in this part of ISO 683. The hardness values shall be determined in accordance with ISO 6508-1, scale C.

9.3.3 Surface hardness

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

9.4 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 type 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 as specified in Tables 3 to 10

1		2	3	4	5	6	7	8			9		
1	Heat-treatment condition at delivery	Symbol	x indicates applicable to					Applicable requirements if the steel is ordered with the designation given in					
								Table 3			Table 5, 6 or 7		
			Semi-finished products	Bars	Wire rod	Flat products	Hammer and drop forgings	8.1	8.2		9.1	9.2	9.3
2	Untreated	none or +U	x	x	x	x	x	Chemical composition according to Tables 3 and 4	– [a]		As in column 8.1 and 8.2		Hardenability values according to Table 5, 6 or 7
3	Treated to improve shearability	+S	x	x	-	-	-		Maximum hardness according to	Table 8 column +S[a]			
4	Soft annealed	+A	x	x	x	x[b]	x			Table 8 column +A[a]			
5	Normalized[b]	+N	-	x	-	x[b]	x		Mechanical properties according to	Table 10			
6	Quenched and tempered	+QT	-	x	-	x[b]	x			Table 9			Not applicable
7	Others	Other treatment conditions, for example certain annealing conditions to achieve a certain structure, may be agreed at the time of enquiry and order. The condition “annealed to achieve a spheroidization of the carbides”, as required for cold heading and cold extrusion, is covered in ISO 4954.											

[a] The mechanical properties specified in Table 9 for the quenched and tempered condition and in Table 10 for the normalized condition shall be achievable after appropriate heat treatment, if so agreed at the time of enquiry and order [for reference test pieces, see (clauses) B.1 and B.2].

[b] Normalizing may be replaced by normalizing forming.