INTERNATIONAL STANDARD

ISO 683-15

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

Part 15:
Valve steels for internal combustion engines

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

Partie 15: Aciers pour soupapes de moteurs à combustion interne

Reference number
ISO 683-15:1992(E)

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.

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.

International Standard ISO 683-15 was prepared by Technical Committee ISO/TC 17, *Steel*, Sub-Committee SC 4, *Heat treatable and alloy steels*.

This second edition cancels and replaces the first edition (ISO 683-15:1976), of which it constitutes a technical revision.

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

— *Part 1: Direct-hardening unalloyed and low-alloyed wrought steel in form of different black products*

— *Part 9: Wrought free-cutting steels*

— *Part 10: Wrought nitriding steels*

— *Part 11: Wrought case-hardening steels*

— *Part 13: Wrought stainless steels*

— *Part 14: Hot-rolled steels for quenched and tempered springs*

— *Part 15: Valve steels for internal combustion engines*

— *Part 16: Precipitation hardening stainless steels*

— *Part 17: Ball and roller bearing steels*

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— *Part 18: Bright products of unalloyed and low alloy steels*

Annex A of this part of ISO 683 is for information only.

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

Part 15:
Valve steels for internal combustion engines

1 Scope

1.1 This part of ISO 683 applies to the grades of wrought high-alloy materials listed in table 1. These valve materials are used for intake and exhaust valves in reciprocating internal combustion engines.

It is applicable to bars, wire, wire rod and forgings and for the surface finishes listed in note 3 of 6.2.

1.2 This part of ISO 683 does not apply to alloys resistant to wear and corrosion which are used to protect valve seat surfaces.

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 standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 683. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 683 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 286-1:1988, *ISO system of limits and fits — Part 1: Bases of tolerances, deviations and fits.*

ISO 377-1:1989, *Selection and preparation of samples and test pieces of wrought steels — Part 1: Samples and test pieces for mechanical test.*

ISO 377-2:1989, *Selection and preparation of samples and test pieces of wrought steels — Part 2: Samples for the determination of the chemical composition.*

ISO 404:1992, *Steel and steel products — General technical delivery requirements.*

ISO 643:1983, *Steels — Micrographic determination of the ferritic or austenitic grain size.*

ISO 783:1989, *Metallic materials — Tensile testing at elevated temperature.*

ISO 1035-1:1980, *Hot-rolled steel bars — Part 1: Dimensions of round bars.*

ISO 1035-4:1982, *Hot-rolled steel bars — Part 4: Tolerances.*

ISO 6506:1981, *Metallic materials — Hardness test — Brinell test.*

ISO 6508:1986, *Metallic materials — Hardness test — Rockwell test (scales A - B - C - D - E - F - G - H - K).*

ISO 6892:1984, *Metallic materials — Tensile testing.*

ISO 8457-1:1989, *Steel wire rod — Part 1: Dimensions and tolerances.*

ISO 9443:1991, *Heat-treatable and alloy steels — Surface quality classes for hot-rolled round bars and wire rods — Technical delivery conditions.*

ISO/TR 9769:1991, *Steel and iron — Review of available methods of analysis.*

ISO 10474:1991, *Steel and steel products — Inspection documents.*

3 Definition

For the purposes of this part of ISO 683, the following definition applies.

3.1 valve materials: Steels and non-ferrous metal alloys which exhibit, to varying degrees, resistance to:

— heat,

— thermal cycling,

— corrosion,

— oxidation,

— fatigue loading,

— impact,

— adhesive and abrasive wear.

Valve materials are therefore used for the manufacture of intake and exhaust valves in reciprocating internal combustion engines.

4 Grade classification and categorization

4.1 The materials listed in this part of ISO 683 are classified according to their chemical composition (see table 1).

4.2 Valve materials are divided into two categories based upon structure, which is itself determined by the general chemical composition:

— martensitic steels which are primarily used for intake valves and the stem portion of exhaust valves;

— austenitic alloys, which are primarily used for exhaust valves.

5 Ordering

The purchaser shall state in his enquiry and order

a) the quantity to be delivered;

b) the designation of the product form (e.g. "bar", see 1.1);

c) the number of the product standard, the dimensions and, where these are not specified in the standard, the surface finish (see 6.2, note 3) and the tolerances (see 6.6);

d) the designation "valve material";

e) the number of this part of ISO 683;

f) the alloy grade (see table 1);

g) the heat-treatment condition on delivery (see 6.2);

h) all other necessary details including the intended method of processing (hot extrusion or upsetting with electric resistance heating);

i) the required type of document (see 7.1).

6 Requirements

6.1 Manufacturing process

6.1.1 Unless otherwise agreed in the order, the type of melting process (see 6.1.2) and the type of process used in making the product are left to the discretion of the manufacturer.

6.1.2 The non-ferrous metal alloys NiCr 15 Fe 7 TiAl, NiFe 25 Cr 20 NbTi and NiCr 20 TiAl are usually produced by remelting processes.

6.2 Heat-treatment condition and surface finish at the time of delivery

The heat-treatment condition and surface finish of the products at the time of delivery shall be agreed when ordering.

NOTES

1 Valve materials intended for subsequent processing by metal forming are normally ordered in one of the heat-treatment conditions indicated in table 3.

2 When they have become finished components, the materials are used, depending on their chemical composition, in the quenched and tempered or the precipitation-hardened condition (see tables A.1 and A.5).

3 Valve materials are mainly supplied in bar form, with one of the following surface finishes:

— peeled and polished;

— peeled and ground;

— ground;

— ground and polished;

— peeled and ground, then polished;

— as rolled.

6.3 Chemical composition

6.3.1 The chemical composition of the materials, as given by the cast analysis, shall conform to the specifications in table 1.

6.3.2 Slight deviations from the specified limits may be permitted by the purchaser, if the characteristics in use are only affected to a negligible extent.

6.3.3 At the time of ordering, it may be agreed that the result of the product analysis, with the permissible deviations given in table 2, shall serve as proof that the limiting values for the cast analysis in table 1 have been complied with.

6.4 Mechanical properties

Table 3 specifies values of the mechanical properties at room temperature for the soft annealed and quenched and tempered conditions of martensitic steels and for the controlled cooled and/or quenched conditions of austenitic materials (see also tables A.1 to A.4).

6.5 Internal and external condition

6.5.1 Any limitations on non-metallic inclusions for valve materials shall be agreed upon at the time of enquiry and order.

NOTE 4 In connection with agreements of the type described in this subclause, it should be borne in mind that, in the case of open melting, the percentage of non-metallic inclusions will be high because of the high alloy contents of the materials complying with this part of ISO 683 and also that an irregular distribution of the non-metallic inclusions is to be expected.

6.5.2 The valve materials shall not have internal bursts, open centreline, or any other kind of internal void apparent on a polished cross-section at 100 × magnification.

6.5.3 The NiCr 20 TiAl alloy shall have a grain size of 4 and/or finer when tested in accordance with ISO 643, but occasional coarser grains shall be tolerated.

6.5.4 In the case of bars which were peeled or ground during finishing (see 6.2, note 3), the depth of surface defects shall not exceed the tolerance class h11 of ISO 286-1.

6.5.5 In all other cases, the requirements governing surface quality shall be agreed upon at the time of enquiry and order.

For round bars and wire rods to be delivered in the hot-rolled surface condition, these requirements should where appropriate be based on ISO 9443.

6.6 Dimensions and tolerances

The dimensions and tolerances of the product shall comply with the requirements agreed upon at the time of enquiry and order. The agreements shall, as far as possible, be based on corresponding International Standards or otherwise on suitable national Standards.

NOTE 5 The following International Standards cover dimensions and/or tolerances for products included in this part of ISO 683:

— for as-rolled bars: ISO 1035-1 and ISO 1035-4,

— for as-rolled wire rod: ISO 8457-1.

7 Testing

7.1 Agreement between tests and documents

7.1.1 For each delivery, the issue of one of the documents listed in 7.6 may be agreed upon at the time of enquiry and order.

7.1.2 If, in accordance with the agreements at the time of enquiry and order, a test report is to be provided, this shall cover the results of the cast analysis for all elements specified for the steel type supplied.

7.1.3 If, in accordance with the agreements at the time of enquiry and order, an inspection certificate or an inspection report is to be provided, the specifications in 7.2 to 7.5 are to be observed.

7.2 Number of tests

7.2.1 Mechanical tests

7.2.1.1 The test unit shall consist of products from the same cast, the same type of manufacturing process and the same heat-treatment batch; all products of the test unit shall have cross-sections of the same form and nominal dimensions.

7.2.1.2 For the purpose of verifying the mechanical properties given in table 3, unless otherwise agreed at the time of ordering, one sample per 10 t shall be taken from the test units as described in 7.2.1.1. As far as possible, the hardness shall be determined, otherwise the tensile test shall be carried out.

7.2.2 Other tests

Where, in addition to the tests in 7.2.1, other tests are to be carried out and certified in an inspection certificate or inspection report, this shall be agreed upon at the time of enquiry and order together with the necessary details on the test unit and the number of tests.

7.3 Selection and preparation of samples and test pieces

7.3.1 Product analysis

For product analysis, the selection and preparation of samples shall be carried out in accordance with the requirements of ISO 377-2.

If the spectrographic analysis method is used, testing may be carried out on the surface of the product. However, in cases of doubt, it will be necessary to carry out several analyses evenly distributed over the cross-section of the product and to average their results.

7.3.2 Tensile and hardness tests

7.3.2.1 The test pieces for the tensile test shall be taken in the longitudinal direction of the products (in accordance with figure 1) and be prepared in accordance with ISO 377-1 and ISO 6892.

7.3.2.2 The hardness test shall be made in the cross-sectional area from which the tensile test pieces are to be taken, in accordance with figure 1. The test pieces for the hardness test shall be prepared in accordance with ISO 6506 or ISO 6508.

7.3.3 Grain size

The instructions given in ISO 643 shall apply to the sampling and preparation of test pieces for determining the austenitic grain size.

7.3.4 Surface testing

In accordance with ISO 9443, in cases of dispute, transverse microsections shall be prepared for the microscopic examination of the surface quality (see also 7.4.5).

7.4 Test methods

7.4.1 Chemical analysis

The chemical composition shall be determined in accordance with the appropriate International Standards listed in ISO/TR 9769 or prepared since the publication of ISO/TR 9769.

7.4.2 Tensile test

The tensile test shall be performed in accordance with ISO 6892.

7.4.3 Hardness test

The Rockwell C hardness test shall be performed in accordance with ISO 6508, the Brinell hardness test shall be performed in accordance with ISO 6506.

7.4.4 Grain size

The austenitic grain size shall be determined in accordance with ISO 643.

Unless otherwise agreed, the choice between the various methods specified in ISO 643 is left to the discretion of the manufacturer.

7.4.5 Surface defects

In cases of dispute, the depth of surface defects shall, in accordance with ISO 9443, be determined by metallography on a transverse microsection. If this is not possible, the defective spot shall be filed until the defect disappears, in order to determine the depth of the defect by suitable means.

7.5 Retests

ISO 404 shall apply for retests.

7.6 Certification of the tests

ISO 10474 is valid, acceptable documents being:

— a test report,

— an inspection certificate, or

— an inspection report.

8 Marking

8.1 Each coil of wire or bundle of bars shall be identified by means of a securely affixed label, featuring

— the manufacturer's mark or name,

— the grade of material,

— the cast number,

— the nominal size.

Marking which identifies the surface finish and/or indicates the coil or bundle weight may be agreed upon.

8.2 The marking on the label shall remain clearly legible even after prolonged outdoor exposure of the coil or bundle.

8.3 In the case of bars with diameters not smaller than 30 mm or with a cross-section of equivalent area, the manufacturer shall also ensure that one bar per bundle is marked as a guide bar. This requires painting its front end white and affixing the manufacturer's mark, the material grade and the

cast number on the front end, either by engraving (die-stamping), or by printing (rubber stamping), or by means of adhesive tape.

In the case of diameters smaller than 30 mm, or cross-sections of equivalent area, a second label giving information about the manufacturer, the material grade and the cast number shall be provided.

9 Complaints

The conditions for dealing with complaints specified in ISO 404 shall apply.

Dimensions in millimetres

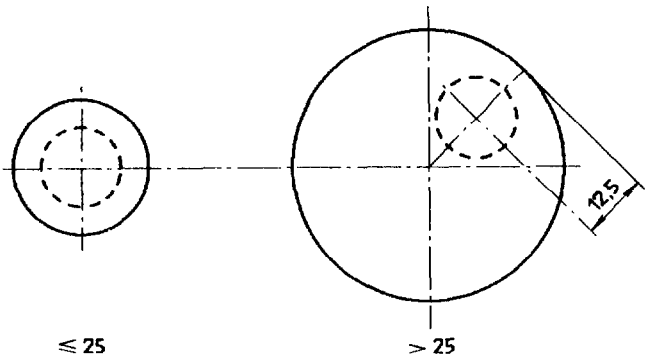

Figure 1 — Location of tensile test pieces

Table 1 — Types of valve materials and specified chemical composition (applicable to cast analysis)

Material designation	Comparable type in ISO 683-15:1976	Chemical composition [% (*m/m*)] C	Si	Mn	P max.	S max	Cr	Mo	Ni	Others
Martensitic steels										
X 50 CrSi 8 2	-	0,45 to 0,55	1,0 to 2,0	max. 0,60	0,030	0,030	7,5 to 9,5		max. 0,60	
X 45 CrSi 9 3	1	0,40 to 0,50	2,7 to 3,3	max. 0,80	0,040	0,030	8,0 to 10,0		max. 0,60	
X 85 CrMoV 18 2	3	0,80 to 0,90	max. 1,0	max. 1,5	0,040	0,030	16,5 to 18,5	2,0 to 2,5		0,30 to 0,60 V
Austenitic materials										
X 55 CrMnNiN 20 8	—	0,50 to 0,60	max. 0,25	7,0 to 10,0	0,050	0,030	19,5 to 21,5		1,5 to 2,75	0,20 to 0,40 N
X 53 CrMnNiN 21 9	8,9	0,48 to 0,58	max. 0,25	8,0 to 10,0	0,050	0,030	20,0 to 22,0		3,25 to 4,5	0,35 to 0,50 N
X 50 CrMnNiNbN 21 9	--	0,45 to 0,55	max. 0,45	8,0 to 10,0	0,050	0,030	20,0 to 22,0		3,5 to 5,5	0,80 to 1,50 W 1,80 to 2,50 Nb + Ta 0,40 to 0,60 N
X 53 CrMnNiNbN 21 9	--	0,48 to 0,58	max. 0,45	8,0 to 10,0	0,050	0,030	20,0 to 22,0		3,25 to 4,5	0,38 to 0,50 N C + N > 0,90 2,00 to 3,00 Nb + Ta
X 33 CrNiMnN 23 8	--	0,28 to 0,38	0,50 to 1,00	1,5 to 3,5	0,050	0,030	22,0 to 24,0	max. 0,50	7,0 to 9,0	max. 0,50 W 0,25 to 0,35 N
NiCr 15 Fe 7 TiAl	---	0,03 to 0,10	max. 0,50	max. 0,50	0,015	0,015	14,0 to 17,0	max. 0,50	Remainder	1,10 to 1,35 Al 5,0 to 9,0 Fe 0,70 to 1,20 Nb + Ta 2,0 to 2,6 Ti
NiFe 25 Cr 20 NbTi	---	max. 0,10	max. 1,0	max. 1,0	0,030	0,015	18,0 to 21,0		Remainder	0,30 to 1,00 Al 23,0 to 28,0 Fe 1,0 to 2,0 Nb + Ta 1,0 to 2,0 Ti max. 0,008 B
NiCr 20 TiAl	11	0,04 to 0,10	max. 1,0	max. 1,0	0,020	0,015	18,0 to 21,0		min. 65	max. 3,0 Fe max. 0,2 Cu max. 2,0 Co max. 0,008 B 1,0 to 1,8 Al 1,8 to 2,7 Ti

Table 2 — Product analysis — Permissible deviations from the specified cast analysis (see table 1)

Element	Cast analysis (specified limits) % (*m*/*m*)	Permissible deviations[1) 2)] from the specified composition % (*m*/*m*)
C	< 0,20	± 0,01
	⩾ 0,20 < 0,60	± 0,02
	⩾ 0,60 ⩽ 0,90	± 0,03
Si	⩽ 1,0	± 0,05
	> 1,0 ⩽ 3,3	± 0,10
Mn	< 1,0	± 0,03
	⩾ 1,0 ⩽ 2,0	± 0,04
	> 2,0 ⩽ 10,0	± 0,06
P	⩽ 0,040	+ 0,005
	> 0,040 ⩽ 0,050	+ 0,010
S	⩽ 0,030	+ 0,005
N	⩽ 0,60	± 0,02
Cr	⩾ 7,5 ⩽ 10,0	± 0,10
	> 10,0 ⩽ 15,0	± 0,15
	> 15,0 ⩽ 20,0	± 0,20
	> 20,0 ⩽ 24,0	± 0,25
Mo	< 1,75	± 0,05
	⩾ 1,75 ⩽ 2,5	± 0,10
Ni	< 5,0	± 0,07
	⩾ 5,0 ⩽ 9,0	± 0,10
Nb (+ Ta)	⩾ 1,8 ⩽ 3,0	± 0,05
V	⩾ 0,30 ⩽ 0,60	± 0,03
W	⩽ 1,50	± 0,05

1) The permissible deviations for the NiCr 20 TiAl, NiFe 25 Cr 20 NbTi and NiCr 15 Fe 7 TiAl alloys shall be agreed upon at the time of ordering, if required.

2) "±" means that in one cast, and in more than one product analysis, the deviation may occur over the upper value or under the lower value of the specified range in table 1, but not both at the same time.

Table 3 — Mechanical properties at room temperature in the heat-treatment condition on delivery

Material designation	Heat-treatment condition on delivery	Hardness[1] HB	Tensile strength[1] N/mm² [2]
Martensitic steels			
X 50 CrSi 8 2	Soft annealed (TA)	max. 300	—
	Quenched and tempered (TQ + T)	See table A.1	
X 45 CrSi 9 3	Soft annealed (TA)	max. 300	—
	Quenched and tempered (TQ + T)	See table A.1	
X 85 CrMoV 18 2	Soft annealed (TA)	max. 300	—
Austenitic materials			
X 55 CrMnNiN 20 8	Controlled cooled[3]	approx. 385	approx. 1 300
	Quenched at 1 000 °C to 1 100 °C [4]	max. 385	max. 1 300
X 53 CrMnNiN 21 9	Controlled cooled[3]	approx. 385	approx. 1 300
	Quenched at 1 000 °C to 1 100 °C [4]	max. 385	max. 1 300
X 50 CrMnNiNbN 21 9	Controlled cooled[3]	approx. 385	approx. 1 300
	Quenched at 1 000 °C to 1 100 °C [4]	max. 385	max. 1 300
X 53 CrMnNiNbN 21 9	Controlled cooled[3]	approx. 385	approx. 1 300
	Quenched at 1 000 °C to 1 100 °C [4]	max. 385	max. 1 300
X 33 CrNiMnN 23 8	Controlled cooled[3]	approx. 360	approx. 1 250
	Quenched at 1 000 °C to 1 100 °C [4]	max. 360	max. 1 200
NiCr 15 Fe 7 TiAl	Quenched at 930 °C to 1 030 °C	max. 325	max. 1 100
NiFe 25 Cr 20 NbTi	Quenched at 930 °C to 1 030 °C	max. 295	max. 1 000
NiCr 20 TiAl	Quenched at 930 °C to 1 030 °C	max. 325	max. 1 100

1) In the case of austenitic materials, the tensile strength values shall be decisive in cases of dispute.

2) 1 $N/mm^2 = 1$ MPa

3) This heat-treatment condition is suitable for processing by hot extrusion.

4) This heat-treatment condition is suitable for processing by upsetting with electric resistance heating.

Annex A
(informative)

Technical supplement

A.1 General

Property values contained in the main text of this part of ISO 683 are requirements of delivery. Property values indicated in this annex are not requirements of delivery (with the exception indicated in table A.1, footnote 3) because they are the result of processing after delivery. The data in this annex are provided only as a guide to the relative performance of the different materials covered in this part of ISO 683.

They are not intended for use in the purchase, design, development, manufacture or usage of any item. Users must assure themselves of the properties actually obtained in practice.

A.2 Mechanical properties

A.2.1 For the reference heat-treatment condition (see table A.5), reference values for mechanical properties at room temperature are given in table A.1.

A.2.2 For the reference heat-treatment condition (see table A.5), reference values for tensile strength and 0,2 %-proof stress at elevated temperatures are given in tables A.2 and A.3 respectively.

A.2.3 Reference values for the creep strength after 1 000 h are given in table A.4.

NOTE 6 An International Standard on creep rupture testing of metallic materials is in preparation and should be applied as soon as it is available, because the results of creep tests are very dependent on differences in the testing conditions.

A.2.4 If the mechanical properties covered in tables A.1 to A.3 are to be checked, then the relevant reference heat treatment indicated in table A.5 should be carried out before the mechanical properties are tested. In addition, for tests at room temperature the specifications of 7.3.2, 7.4.2 and 7.4.3 shall be applied. For tests at elevated temperatures, those of figure 1 and ISO 783 should be applied.

A.3 Physical properties

Table A.6 contains reference values relating to the physical properties of the materials complying with this part of ISO 683.

A.4 Subsequent processing and heat treatment

A.4.1 Shaping and heat treatment

All the materials listed in this part of ISO 683 are suitable for hot forming. As a general rule, hot forming becomes more difficult as the alloy content increases, because of the reduced capacity for flow. Consequently, abrupt reductions in cross-section during any single forging pass should be avoided.

When establishing parameters for heating prior to forging, the low thermal conductivity of austenitic alloys should be borne in mind. Any temperature gradients in valve alloys can cause tremendous internal stresses during forging and working, which result in internal ruptures and surface cracks.

Guideline temperatures for hot forming and heat treatment are given in table A.5.

A.4.2 Machining

Machining is possible but difficult in the case of austenitic materials, due to their high strength, toughness and strain hardening characteristics. To prevent cracks from occurring during grinding operations, appropriate grinding conditions should be chosen.

Table A.1 — Reference values for the mechanical properties at room temperature (for diameters up to 40 mm) (applicable to the reference heat-treatment condition in accordance with table A.5)

Material designation	Reference heat treatment condition[1]	Hardness		0,2 %-proof stress[2] N/mm² [3]	Tensile strength N/mm² [3]	Elongation after fracture ($L_0 = 5\ D_0$)[2] %	Reduction in area after fracture[2] %
		HB	HRC[2]				
Martensitic steels							
X 50 CrSi 8 2	TQ + T[4]	266 to 325		685	900 to 1 100	14	40
X 45 CrSi 9 3	TQ + T[4]	266 to 325		700	900 to 1 100	14	40
X 85 CrMoV 18 2	TQ + T	296 to 355		800	1 000 to 1 200	7	12
Austenitic materials							
X 55 CrMnNiN 20 8	ST + P	—	28[5]	550	900 to 1 150	8	10
X 53 CrMnNiN 21 9	ST + P	—	30[5]	580	950 to 1 200	8	10
X 50 CrMnNiNbN 21 9	ST + P	—	30[5]	580	950 to 1 150	12	15
X 53 CrMnNiNbN 21 9	ST + P	—	30[5]	580	950 to 1 150	8	10
X 33 CrNiMnN 23 8	ST + P	—	25[5]	550	850 to 1 100	20	30
NiCr 15 Fe 7 TiAl	ST + P	—	32	750	1 100 to 1 300	12	20
NiFe 25 Cr 20 NbTi	ST + P	—	28	500	900 to 1 100	25	30
NiCr 20 TiAl	ST + P	—	32	725	1 100 to 1 400	15	25

1) TQ = quenched; T = tempered; ST = solution treated; P = precipitation hardened.

2) The values given here are situated near the lower limit of the scatter range.

3) 1 N/mm² = 1 MPa

4) Also possible as delivery condition, in which case the values shall apply as true requirements.

5) Austenitic grades X 55 CrMnNiN 20 8 to X 33 CrNiMnN 23 8 may show hardness values which cannot be converted into tensile strength values according to the standard tables commonly used in laboratories. Therefore, in cases of dispute only the tensile strength value shall be considered as valid.

Table A.2 — Reference values for the tensile strength at elevated temperatures

Material designation	Reference heat treatment condition[1]	Tensile strength[2], at N/mm² [3]						
		500 °C	550 °C	600 °C	650 °C	700 °C	750 °C	800 °C
Martensitic steels								
X 50 CrSi 8 2	TQ + T	500	360	230	160	105		
X 45 CrSi 9 3	TQ + T	500	360	250	170	110		
X 85 CrMoV 18 2	TQ + T	550	400	300	230	180	140	
Austenitic materials								
X 55 CrMnNiN 20 8	ST + P	640	590	540	490	440	360	290
X 53 CrMnNiN 21 9	ST + P	650	600	550	500	450	370	300
X 50 CrMnNiNbN 21 9	ST + P	680	650	610	550	480	410	340
X 53 CrMnNiNbN 21 9	ST + P	680	650	600	510	450	380	320
X 33 CrNiMnN 23 8	ST + P	600	570	530	470	400	340	280
NiCr 15 Fe 7 TiAl	ST + P	1 000	980	930	850	770	650	510
NiFe 25 Cr 20 NbTi	ST + P	800	800	790	740	640	500	340
NiCr 20 TiAl	ST + P	1 050	1 030	1 000	930	820	680	500

1) TQ = quenched; T = tempered; ST = solution treated; P = precipitation hardened.

2) The values given here are situated near the lower limit of the scatter range.

3) 1 N/mm² = 1 MPa

Table A.3 — Reference values for the 0,2 %-proof stress at elevated temperatures

Material designation	Reference heat treatment condition[1]	0,2 %-proof stress[2], at 500 °C	550 °C	600 °C	650 °C	700 °C	750 °C	800 °C
		N/mm² [3]						
Martensitic steels								
X 50 CrSi 8 2	TQ+T	400	300	220	110	75		
X 45 CrSi 9 3	TQ+T	400	300	240	120	80		
X 85 CrMoV 18 2	TQ+T	500	370	280	170	120	80	
Austenitic materials								
X 55 CrMnNiN 20 8	ST+P	300	280	250	230	220	200	170
X 53 CrMnNiN 21 9	ST+P	350	330	300	270	250	230	200
X 50 CrMnNiNbN 21 9	ST+P	350	330	310	285	260	240	220
X 53 CrMnNiNbN 21 9	ST+P	340	320	310	280	260	235	220
X 33 CrNiMnN 23 8	ST+P	270	250	220	210	190	180	170
NiCr 15 Fe 7 TiAl	ST+P	725	710	690	660	650	560	425
NiFe 25 Cr 20 NbTi	ST+P	450	450	450	450	430	380	250
NiCr 20 TiAl	ST+P	700	650	650	600	600	500	450

1) TQ = quenched; T = tempered; ST = solution treated; P = precipitation hardened.

2) The values given here are situated near the lower limit of the scatter range.

3) 1 N/mm² = 1 MPa

Table A.4 — Reference values for the creep strength after 1 000 h (applicable to the reference condition in accordance with table A.5)

Material designation	Creep strength[1] after 1 000 h, at 500 °C	650 °C	725 °C	800 °C
	N/mm² [2]			
Martensitic steels				
X 50 CrSi 8 2	190	—	—	—
X 45 CrSi 9 3	190	40	—	—
X 85 CrMoV 18 2	260	52	18	—
Austenitic materials				
X 55 CrMnNiN 20 8	—	160	85	45
X 53 CrMnNiN 21 9	—	200	110	50
X 50 CrMnNiNbN 21 9	—	220	120	55
X 53 CrMnNiNbN 21 9	—	215	115	50
X 33 CrNiMnN 23 8	—	235	130	60
NiCr 15 Fe 7 TiAl	—	475	260	125
NiFe 25 Cr 20 NbTi	—	400	180	60
NiCr 20 TiAl	—	500	290	150

1) Mean values of scatter range determined until now.

2) 1 N/mm² = 1 MPa

Table A.5 — Reference data for hot forming and heat treatment

Material designation	Hot forming °C	Soft annealing °C	Quenching or solution heat treatment °C	Quenching agent	Tempering or artificial ageing °C
Martensitic steels					
X 50 CrSi 8 2	1 100 to 900	780 to 820 / Air or water	1 000 to 1 050	Oil	720 to 820 / Air or water
X 45 CrSi 9 3	1 100 to 900	780 to 820 / Air or water	1 000 to 1 050	Oil	720 to 820 / Air or water
X 85 CrMoV 18 2	1 100 to 900	820 to 860 / Retarded cooling	1 050 to 1 080	Oil	720 to 820 / Air
Austenitic materials					
X 55 CrMnNiN 20 8	1 100 to 950		1 140 to 1 180	Water	760 to 815 / 4 h to 8 h Air
X 53 CrMnNiN 21 9	1 150 to 950		1 140 to 1 180	Water	760 to 815 / 4 h to 8 h Air
X 50 CrMnNiNbN 21 9	1 150 to 950		1 160 to 1 200	Water	760 to 815 / 4 h to 8 h Air
X 53 CrMnNiNbN 21 9	1 150 to 980		1 160 to 1 200	Water	760 to 850 / 6 h Air
X 33 CrNiMnN 23 8	1 150 to 980		1 150 to 1 170	Water	800 to 830 / 8 h Air
NiCr 15 Fe 7 TiAl	1 150 to 940		1 100 to 1 150	Air	840 / 24 h + 700 / 2 h Air
NiFe 25 Cr 20 NbTi	1 150 to 1 050		1 000 to 1 080	Air or water	690 to 710 / 16 h Air
NiCr 20 TiAl	1 150 to 1 050		1 000 to 1 080	Air or water	690 to 710 / 16 h Air

Table A.6 — Reference data relating to physical properties (applicable to the reference condition in accordance with table A.5)

Material designation	Density at 20 °C kg/dm³	Modulus of elasticity at 20 °C kN/mm² 1)	Thermal expansion coefficient between 20 °C and 100 °C $10^{-6} \cdot K^{-1}$	300 °C $10^{-6} \cdot K^{-1}$	500 °C $10^{-6} \cdot K^{-1}$	700 °C $10^{-6} \cdot K^{-1}$	Thermal conductivity at 20 °C W/(m·K)	Specific heat capacity at 20 °C J/kg·K	Magnetizability
Martensitic steels									
X 50 CrSi 8 2	7,7	210	10,9	11,2	11,5	11,8	21	500	Existent
X 45 CrSi 9 3	7,7	210	10,9	11,2	11,5	11,8	21	500	Existent
X 85 CrMoV 18 2	7,7	210	10,9	11,2	11,5	11,8	21	500	Existent
Austenitic materials									
X 55 CrMnNiN 20 8	7,8	205	15,5	17,5	18,5	18,8	14,5	500	Non-existent 2)
X 53 CrMnNiN 21 9	7,8	205	15,5	17,5	18,5	18,8	14,5	500	Non-existent 2)
X 50 CrMnNiNbN 21 9	7,8	205	15,5	17,5	18,5	18,8	14,5	500	Non-existent 2)
X 53 CrMnNiNbN 21 9	7,8	205	15,5	17,5	18,5	18,8	14,5	500	Non-existent 2)
X 33 CrNiMnN 23 8	7,8	205	16,5	17,1	17,3	17,4	14,5	500	Non-existent 2)
NiCr 15 Fe 7 TiAl	8,3	215	13,0	14,0	14,5	15,5	13	460	Non-existent
NiFe 25 Cr 20 NbTi	8,1	215	14,1	15,5	15,9	16,8	13	460	Non-existent
NiCr 20 TiAl	8,3	215	11,9	13,1	13,7	14,5	13	460	Non-existent

1) 1 $N/mm^2 = 1$ MPa

2) Austenitic steels may be slightly magnetizable in the aged condition. Their magnetizability may increase with extended cold forming.

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Descriptors: steels, heat treatable steels, alloy steels, free machining steels, internal combustion engines, engine valves, classification, specifications, mechanical properties, chemical composition, tests, mechanical tests, chemical analysis, designation, marking.

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