INTERNATIONAL STANDARD

ISO 9328-2

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Steel flat products for pressure purposes — Technical delivery conditions —

Part 2: Non-alloy and alloy steels with specified elevated temperature properties

Produits plats en acier pour service sous pression — Conditions techniques de livraison —

Partie 2: Aciers non alliés et aciers alliés avec caractéristiques spécifiées à température élevée

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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 9328-2 was prepared by Technical Committee ISO/TC 17, *Steel*, Subcommittee SC 10, *Steel for pressure purposes*.

This third edition cancels and replaces the second edition (ISO 9328-2:2004), which has been technically revised.

ISO 9328 consists of the following parts, under the general title *Steel flat products for pressure purposes — Technical delivery conditions*:

— *Part 1: General requirements*

— *Part 2: Non-alloy and alloy steels with specified elevated temperature properties*

— *Part 3: Weldable fine grain steels, normalized*

— *Part 4: Nickel-alloy steels with specified low temperature properties*

— *Part 5: Weldable fine grain steels, thermomechanically rolled*

— *Part 6: Weldable fine grain steels, quenched and tempered*

— *Part 7: Stainless steels*

The clauses marked by a point (•) contain information relating to agreements that shall be made at the time of enquiry and order. The clauses marked by two points (••) contain information relating to agreements that may be made at the time of enquiry and order.

Steel flat products for pressure purposes — Technical delivery conditions —

Part 2: Non-alloy and alloy steels with specified elevated temperature properties

1 Scope

This part of ISO 9328 specifies the technical delivery conditions for plates and strip for pressure equipment made of non-alloy and alloy steels as specified in Tables A.1 and B.1. The requirements and definitions of ISO 9328-1 also apply to this part of ISO 9328.

2 Normative references

The following normative 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 4948-1:1982, *Steels — Classification — Part 1: Classification of steels into unalloyed and alloy steels based on chemical composition*

ISO 4948-2:1981, *Steels — Classification — Part 2: Classification of unalloyed and alloy steels according to main quality classes and main property or application characteristics*

ISO 9328-1:2011, *Steel flat products for pressure purposes — Technical delivery conditions — Part 1: General requirements*

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

EN 10229:1998, *Evaluation of resistance of steel products to hydrogen induced cracking (HIC)*

EN 10314, *Method for the derivation of minimum values of proof strength of steel at elevated temperatures*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 9328-1 apply.

4 Classification and designation

4.1 Classification

In accordance with ISO 4948-1 and ISO 4948-2, the steel grades P235GH, P265GH, P295GH and P355GH (see Annex A) and PT410GH, PT450GH and PT480GH (see Annex B) are non-alloy-quality steels. All other grades are alloyed special steels.

4.2 Designation

See ISO 9328-1.

NOTE 1 Non-alloy grades in Annex A are classified in accordance with their yield strength, non-alloy grades in Annex B are classified in accordance with their tensile strength.

NOTE 2 Information on the designation of comparable steel grades in national or regional standards is given in Annex C.

5 Information to be supplied by the purchaser

5.1 Mandatory information

See ISO 9328-1 and 6.2.3.

5.2 Options

A number of options are specified in this part of ISO 9328. These are listed below under a) to t). Additionally, the relevant options of ISO 9328-1 apply. If the purchaser does not indicate a wish to implement any of these options at the time of enquiry and order, the products shall be supplied in accordance with the basic specification (see ISO 9328-1):

a) tests in the simulated normalized condition (see 6.2.2);

b) products delivered untreated (see 6.2.4 and 6.2.5);

c) maximum carbon-equivalent value for P235GH, P265GH, P295GH and P355GH (see 6.3.3);

d) specification of an impact energy value of 40 J (see Table A.2, footnote h);

e) test on simulated heat-treated samples (see 6.7.2);

f) hydrogen-induced cracking (HIC) test in accordance with Annex G (see 6.10);

g) step cooling test in accordance with Annex H (see 6.11);

h) mid-thickness test pieces for the impact test and/or tensile test (see Clause 8);

i) lower copper content and maximum tin content (see Table A.1, footnote b);

j) minimum chromium content of 0,80 % (see Table A.1, footnote f);

k) maximum carbon content of 0,17 % for product thicknesses greater than 150 mm (see Table A.1, footnote g);

l) maximum contents of Al ($\leqslant$ 0,020 %), Ti ($\leqslant$ 0,01 %) and Zr ($\leqslant$ 0,01 %) (see Table A.1, footnote i);

m) mechanical properties for product thicknesses $>$ 250 mm (see Table A.2, footnote a);

n) specification of the delivery condition +QT where the usual delivery condition is +NT (see Table A.2, footnote c and Table A.3, footnote c);

o) additional impact energy values (see Table A.2, footnote i);

p) 0,2 % proof strength ($R_{p0,2}$) values at elevated temperature for increased product thicknesses (see Table A.3, footnote b);

q) increased carbon content for grades PT410GH, PT450GH and PT480GH (see Table B.1, footnote c);

r) Al additions not permitted (see Table B.1, footnote d);

s) specification of the delivery condition +NT for the grade 14CrMo9-10 and of the delivery condition +QT for the grades 14CrMoV9-10 and 13CrMoV12-10 (see Table B.2, footnote j);

t) requirement for impact tests and values (see Table B.2, footnote l);

5.3 Example for ordering

An order of 10 plates with nominal dimensions thickness = 50 mm, width = 2 000 mm, length = 10 000 mm, made of a steel grade with the name 16Mo3 as specified in ISO 9328-2, to be delivered normalized, with inspection document 3.1.B as specified in ISO 10474:1991 is designated as follows:

10 plates – 50 × 2 000 × 10 000 – ISO 9328-2 16Mo3 – Inspection document 3.1.B

6 Requirements

6.1 Steelmaking process

See ISO 9328-1.

6.2 Delivery condition

6.2.1 Unless otherwise agreed at the time of enquiry and order, the products covered by this part of ISO 9328 shall be supplied in the usual conditions given in Tables A.2 and B.2.

6.2.2 •• Normalizing may, at the discretion of the manufacturer, be replaced with normalizing rolling for the steel grades P235GH, P265GH, P295GH and P355GH (see Annex A). In this case, additional tests in the simulated normalized condition with an agreed frequency of testing may be agreed upon at the time of enquiry and order to verify that the obtained properties also comply with the standard requirements.

6.2.3 • For products made of steel grades PT410GH, PT450GH, PT480GH, 19MnMo4-5, 19MnMo5-5 and 19MnMoNi5-5 (see Table B.2), the requested delivery condition normalized (+N) or untreated (+AR) (but see 6.2.5) or, where applicable, quenched and tempered (+QT) shall be specified at the time of enquiry and order.

6.2.4 •• If so agreed at the time of enquiry and order, products made of steel grades P235GH, P265GH, P295GH, P355GH and 16Mo3 (see Table A.2) may also be delivered in the untreated condition (but see 6.2.5). Products made of one of the other alloy grades may be supplied in the tempered or normalized condition or in the untreated condition, if so agreed.

NOTE Annex D contains heat treatment information for the purchaser.

6.2.5 For products delivered untreated in accordance with 6.2.3 and 6.2.4, testing shall be carried out on test pieces in the usual delivery condition as indicated in Tables A.2 and B.2.

NOTE Tests in a simulated heat-treated condition are made to verify the suitability of the delivered product in the delivery condition +N, or +NT or +QT, as appropriate. However, they do not discharge the processor from the obligation of providing proof of the specified properties in the finished product when adequately heat treated.

6.3 Chemical composition

6.3.1 The requirements of Tables A.1 and B.1 shall apply for the chemical composition according to the cast (heat) analysis.

6.3.2 The product analysis shall not deviate from the values for the cast (heat) analysis specified in Tables A.1 and B.1 by more than the values given in Table 1.

6.3.3 •• A maximum value for the carbon equivalent may be agreed upon at the time of enquiry and order for steel grades P235GH, P265GH, P295GH and P355GH (see Annex A) and PT410GH, PT450GH and PT480GH (see Annex B). In this case, the following formula shall apply for calculation of the carbon-equivalent value (CEV):

$$CEV = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

Table 1 — Permissible product analysis tolerances on the limiting values given in Tables A.1 and B.1 for the cast (heat) analysis

Element	Specified value in the cast (heat) analysis according to Tables A.1 and B.1 % by mass	Permissible deviation of the product analysis[a] % by mass
C[b]	⩽ 0,31	±0,02
Si	⩽ 0,35	±0,05
	> 0,35 to ⩽ 1,00	±0,06
Mn	⩽ 1,00	±0,05
	> 1,00 to ⩽ 1,70	±0,10
P[b]	⩽ 0,015	+0,003
	> 0,015 to ⩽ 0,030	+0,005
S[b]	⩽ 0,010	+0,003
Al	⩾ 0,010	±0,005
B	⩽ 0,003	±0,000 5
Ca	0,015	+0,003
N	⩽ 0,020	+0,002
	> 0,020 to ⩽ 0,070	±0,005
Cr	⩽ 2,00	±0,05
	> 2,00 to ⩽ 10,00	±0,10
Cu	⩽ 0,30	±0,05
	> 0,30 to ⩽ 0,80	±0,10
Mo	⩽ 0,35	±0,03
	> 0,35 to ⩽ 1,10	+0,04
Nb	⩽ 0,10	±0,01
Ni	⩽ 0,30	+0,05
	> 0,30 to ⩽ 1,30	±0,10
Cr+Cu+Mo+Ni	⩽ 1,00	+0,05
Ti	⩽ 0,035	±0,01
V	⩽ 0,05	±0,01
	> 0,05 to ⩽ 0,30	±0,03

[a] If several product analyses are carried out on one cast, and the contents of an individual element determined lie outside the permissible range of the chemical composition specified for the cast analysis, then it is only allowed to exceed the permissible maximum value or fall short of the permissible minimum value, but not both for one cast.

[b] In the case of steel grades specified in Annex B, the maximum values listed in Table B.1 also apply for the product analysis.

6.4 Mechanical properties

6.4.1 The values given in Tables A.2, A.3 and B.2 (see also ISO 9328-1) shall apply.

6.4.2 Annex F gives, for the grades in Annex A, mean values as preliminary data for the purchaser on the strength for 1 % (plastic) creep strain and creep rupture.

6.5 Surface condition

See ISO 9328-1.

6.6 Internal soundness

See ISO 9328-1.

6.7 Weldability

6.7.1 The steel grades specified in this part of ISO 9328 shall be suitable for welding processes in current use (see also the Note to 6.7.2).

6.7.2 Information on welding can be found in appropriate documents, e.g. EN 1011-1 and EN 1011-2 or IIS/IIW 382-71.

NOTE Excessive post-weld heat treatment (PWHT) conditions can decrease the mechanical properties. When in stress relieving, the intended time-temperature parameter

$$P = T_{\mathrm{s}}(20 + \lg t) \times 10^{-3}$$

where

T_{s} is the stress relieving temperature, in kelvins;

t is the holding time, in hours;

exceeds the critical ($P_{\mathrm{crit.}}$) values in Annex E, or where regarded as necessary in the case of Annex B steel grades, the purchaser should, in his enquiry and order, inform the manufacturer accordingly.

•• Where appropriate, tests on simulated heat-treated samples may be agreed at the time of enquiry and order to check whether, after such a treatment, the properties specified in this part of ISO 9328 can still be regarded as valid.

6.8 Dimensions and tolerances on dimensions

See ISO 9328-1.

6.9 Calculation of mass

See ISO 9328-1.

6.10 Resistance to hydrogen-induced cracking

Carbon and low-alloy steels may be susceptible to cracking when exposed to corrosive H_2S-containing environments, usually referred to as “sour service”.

•• A test to evaluate the resistance to hydrogen-induced cracking in accordance with Annex G or another test method may be agreed at the time of enquiry and order.

6.11 Embrittlement of CrMo steels

CrMo steels may tend to become brittle in service at temperatures between approximately 400 °C and 500 °C. This possible tendency for embrittlement can be simulated in the laboratory with the so-called step cooling test. In this test, a specimen is exposed to a temperature-time cycle as given in Figure H.1. The shift of a transition curve before and after the step cooling test is a measure for the embrittlement.

●● A step cooling test in accordance with Annex H may be agreed upon at the time of enquiry and order.

NOTE The step cooling test is primarily applicable to the weld metal and the heat-affected zone.

7 Inspection

7.1 Types of inspection and inspection documents

See ISO 9328-1.

7.2 Tests to be carried out

See ISO 9328-1 and 6.10 and 6.11.

7.3 Retests

See ISO 9328-1.

8 Sampling

See ISO 9328-1.

●● For the impact test and/or the tensile test, deviating from ISO 9328-1:2011, Table 3, footnote e, by preparing test pieces taken from the mid-thickness may be agreed upon at the time of enquiry and order. In this case, test temperatures and minimum impact energy values shall also be agreed upon.

9 Test methods

9.1 See ISO 9328-1, and Annexes D and E.

9.2 For the steel grades specified in Annex B, the impact test shall only be carried out if so agreed at the time of enquiry and order. Requirements and test conditions shall then also be agreed (see Table B.2, footnote l).

10 Marking

See ISO 9328-1.

Annex A
(normative)

Chemical composition and mechanical properties of products based on European standards

Table A.1 — Chemical composition [cast (heat) analysis]

Steel grade	% by mass[a]														
	C	Si	Mn	P max.	S max.	Al_{total}	N	Cr	Cu[b]	Mo	Nb	Ni	Ti max.	V	Others
P235GH	⩽ 0,16	⩽ 0,35	0,60[c] to 1,20	0,025	0,010	⩾ 0,020[d]	⩽ 0,012[d]	⩽ 0,30	⩽ 0,30	⩽ 0,08	⩽ 0,020	⩽ 0,30	0,03	⩽ 0,02	—
P265GH	⩽ 0,20	⩽ 0,40	0,80 to 1,40	0,025	0,010	⩾ 0,020[d]	⩽ 0,012[d]	⩽ 0,30	⩽ 0,30	⩽ 0,08	⩽ 0,020	⩽ 0,30	0,03	⩽ 0,02	Cr+Cu+Mo +Ni: ⩽0,70
P295GH	0,08 to 0,20	⩽ 0,40	0,90 to 1,50	0,025	0,010	⩾ 0,020[d]	⩽ 0,012[d]	⩽ 0,30	⩽ 0,30	⩽ 0,08	⩽ 0,020	⩽ 0,30	0,03	⩽ 0,02	
P355GH	0,10 to 0,22	⩽ 0,60	1,10 to 1,70	0,025	0,010	⩾ 0,020[d]	⩽ 0,012[d]	⩽ 0,30	⩽ 0,30	⩽ 0,08	⩽ 0,040	⩽ 0,30	0,03	⩽ 0,02	
16Mo3	0,12 to 0,20	⩽ 0,35	0,40 to 0,90	0,025	0,010	[e]	⩽ 0,012	⩽ 0,30	⩽ 0,30	0,25 to 0,35	—	⩽ 0,30	—	—	—
18MnMo4-5	⩽0,20	⩽ 0,40	0,90 to 1,50	0,015	0,005	[e]	⩽ 0,012	⩽ 0,30	⩽ 0,30	0,45 to 0,60	—	⩽ 0,30	—	—	—
20MnMoNi4-5	0,15 to 0,23	⩽ 0,40	1,00 to 1,50	0,020	0,010	[e]	⩽ 0,012	⩽ 0,20	⩽ 0,20	0,45 to 0,60	—	0,40 to 0,80	—	⩽ 0,02	—
15NiCuMoNb5-6-4	⩽ 0,17	0,25 to 0,50	0,80 to 1,20	0,025	0,010	⩾ 0,015	⩽ 0,020	⩽ 0,30	0,50 to 0,80	0,25 to 0,50	0,015 to 0,045	1,00 to 1,30	—	—	—
13CrMo4-5	0,08 to 0,18	⩽ 0,35	0,40 to 1,00	0,025	0,010	[e]	⩽ 0,012	0,70[f] to 1,15	⩽ 0,30	0,40 to 0,60	—	—	—	—	—
13CrMoSi5-5	⩽ 0,17	0,50 to 0,80	0,40 to 0,65	0,015	0,005	[e]	⩽ 0,012	1,00 to 1,50	⩽ 0,30	0,45 to 0,65	—	⩽ 0,30	—	—	—
10CrMo9-10	0,08 to 0,14[g]	⩽ 0,50	0,40 to 0,80	0,020	0,010	[e]	⩽ 0,012	2,00 to 2,50	⩽ 0,30	0,90 to 1,10	—	—	—	—	—
12CrMo9-10	0,10 to 0,15	⩽ 0,30	0,30 to 0,80	0,015	0,010	0,010 to 0,040	⩽ 0,012	2,00 to 2,50	⩽ 0,25	0,90 to 1,10	—	⩽ 0,30	—	—	—
X12CrMo5	0,10 to 0,15	⩽ 0,50	0,30 to 0,60	0,020	0,005	[e]	⩽ 0,012	4,00 to 6,00	⩽ 0,30	0,45 to 0,65	—	⩽ 0,30	—	—	—

Table A.1 (*continued*)

Steel grade	% by mass[a]														
	C	Si	Mn	P max.	S max.	Al_{total}	N	Cr	Cu[b]	Mo	Nb	Ni	Ti max.	V	Others
13CrMoV9-10	0,11 to 0,15	⩽ 0,10	0,30 to 0,60	0,015	0,005	e	—	2,00 to 2,50	⩽ 0,20	0,90 to 1,10	⩽ 0,07	⩽ 0,25	0,03	0,25 to 0,35	⩽ 0,002 B ⩽ 0,015 Ca
12CrMoV12-10	0,10 to 0,15	⩽ 0,15	0,30 to 0,60	0,015	0,005	e	⩽0,012	2,75 to 3,25	⩽ 0,25	0,90 to 1,10	⩽ 0,07[h]	⩽ 0,25	0,03[h]	0,20 to 0,30	⩽ 0,003 B[h] ⩽ 0,015 Ca[h]
X10CrMoVNb9-1	0,08 to 0,12	⩽ 0,50	0,30 to 0,60	0,020	0,005	⩽ 0,040[i]	0,030 to 0,070	8,00 to 9,50	⩽ 0,30	0,85 to 1,05	0,06 to 0,10	⩽ 0,30	i	0,18 to 0,25	—

[a] Elements not listed in this table shall not be intentionally added to the steel without the agreement of the purchaser, except for finishing the cast. All appropriate measures shall be taken to prevent the addition from scrap or other materials used in steelmaking of these elements which may affect the mechanical properties and usability.

[b] •• A lower maximum copper content and/or a maximum sum of copper and tin content, e.g. (Cu + 6Sn) ⩽ 0,33 %, may be agreed upon at the time of enquiry and order, e.g. with regard to hot formability for the grades where only a maximum copper content is specified.

[c] For product thicknesses <6 mm, a minimum manganese content of 0,20 % lower than specified is permitted.

[d] A ratio Al:N ⩾ 2 shall apply.

[e] The Al content of the cast shall be determined and given in the inspection document.

[f] •• If resistance to pressurized hydrogen is of importance, a minimum content of 0,80 % Cr may be agreed upon at the time of enquiry and order.

[g] •• For product thicknesses greater than 150 mm, a maximum content of 0,17 % C may be agreed upon at the time of enquiry and order.

[h] This grade may be produced with additions of either Ti + B or Nb + Ca. The following minimum contents shall apply: ⩾0,015 % Ti and ⩾0,001 % B in the case of additions of Ti + B, ⩾0,015 % Nb and ⩾0,000 5 % Ca in the case of additions of Nb + Ca.

[i] •• If so agreed at the time of enquiry and order, the Al content shall be ⩽0,020 %, the Ti content shall be ⩽0,01 %, and a Zr content of ⩽0,01 % is specified.

Table A.2 — Mechanical properties (applicable to the transverse direction)[a]

Steel grade	Usual delivery condition[b,c]	Product thickness	Tensile properties at room temperature			Impact energy		
			Yield strength	Tensile strength	Elongation after fracture	KV J min. at a temperature in °C of		
		t mm	R_{eH} MPa[g] min.	R_m MPa[g]	A % min.	–20	0	+20
P235GH	+N[d,e]	$\leqslant 16$	235	360 to 480	24	27[h]	34[h]	40
		$16 < t \leqslant 40$	225					
		$40 < t \leqslant 60$	215					
		$60 < t \leqslant 100$	200					
		$100 < t \leqslant 150$	185	350 to 480				
		$150 < t \leqslant 250$	170	340 to 480				
P265GH	+N[d,e]	$\leqslant 16$	265	410 to 530	22	27[h]	34[h]	40
		$16 < t \leqslant 40$	255					
		$40 < t \leqslant 60$	245					
		$60 < t \leqslant 100$	215					
		$100 < t \leqslant 150$	200	400 to 530				
		$150 < t \leqslant 250$	185	390 to 530				
P295GH	+N[d,e]	$\leqslant 16$	295	460 to 580	21	27[h]	34[h]	40
		$16 < t \leqslant 40$	290					
		$40 < t \leqslant 60$	285					
		$60 < t \leqslant 100$	260					
		$100 < t \leqslant 150$	235	440 to 570				
		$150 < t \leqslant 250$	220	430 to 570				
P355GH	+N[d,e]	$\leqslant 16$	355	510 to 650	20	27[h]	34[h]	40
		$16 < t \leqslant 40$	345					
		$40 < t \leqslant 60$	335					
		$60 < t \leqslant 100$	315	490 to 630				
		$100 < t \leqslant 150$	295	480 to 630				
		$150 < t \leqslant 250$	280	470 to 630				
16Mo3	+N[e,f]	< 16	275	440 to 590	22	i	i	31[h]
		$16 < t \leqslant 40$	270					
		$40 < t \leqslant 60$	260					
		$60 < t \leqslant 100$	240	430 to 560				
		$100 < t \leqslant 150$	220	420 to 570				
		$150 < t \leqslant 250$	210	410 to 570				
18MnMo4-5	+NT	$\leqslant 60$	345	510 to 650	20	27[h]	34[h]	40
		$60 < t \leqslant 150$	325					
	+QT	$150 < t \leqslant 250$	310	480 to 620				
20MnMoNi4-5	+QT	$\leqslant 40$	470	590 to 750	18	27[h]	40	50
		$40 < t \leqslant 60$	460	590 to 730				
		$60 < t \leqslant 100$	450	570 to 710				
		$100 < t \leqslant 150$	440					
		$150 < t \leqslant 250$	400	560 to 700				

Table A.2 (*continued*)

Steel grade	Usual delivery condition[b,c]	Product thickness	Tensile properties at room temperature			Impact energy		
			Yield strength	Tensile strength	Elongation after fracture	KV J min. at a temperature in °C of		
		t mm	R_{eH} MPa[g] min.	R_m MPa[g]	A % min.	–20	0	+20
15NiCuMoNb5-6-4	+NT	$\leqslant 40$	460	610 to 780	16	27[h]	34[h]	40
		$40 < t \leqslant 60$	440					
		$60 < t \leqslant 100$	430	600 to 760				
	+NT or +QT	$100 < t \leqslant 150$	420	590 to 740				
	+QT	$150 < t \leqslant 200$	410	580 to 740				
13CrMo4-5	+NT	$\leqslant 16$	300	450 to 600	19	i	i	31[h]
		$16 < t \leqslant 60$	290					
		$60 < t \leqslant 100$	270	440 to 590			i	27[h]
	+NT or +QT	$100 < t \leqslant 150$	255	430 to 580				
	+QT	$150 < t \leqslant 250$	245	420 to 570				
13CrMoSi5-5	+NT	$\leqslant 60$	310	510 to 690	20	i	27[h]	34[h]
		$60 < t \leqslant 100$	300	480 to 660				
	+QT	$\leqslant 60$	400	510 to 690		27[h]	34[h]	40
		$60 < t \leqslant 100$	390	500 to 680				
		$100 < t \leqslant 250$	380	490 to 670				
10CrMo9-10	+NT	$\leqslant 16$	310	480 to 630	18	i	i	31[h]
		$16 < t \leqslant 40$	300					
		$40 < t \leqslant 60$	290					
	+NT or +QT	$60 < t \leqslant 100$	280	470 to 620	17	i	i	27[h]
	+QT	$100 < t \leqslant 150$	260	460 to 610				
		$150 < t \leqslant 250$	250	450 to 600				
12CrMo9-10	+NT or +QT	$\leqslant 250$	355	540 to 690	18	27[h]	40	70
X12CrMo5	+NT	$\leqslant 60$	320	510 to 690	20	27[h]	34[h]	40
		$60 < t \leqslant 150$	300	480 to 660				
	+QT	$150 < t \leqslant 250$	300	450 to 630				
13CrMoV9-10	+NT	$\leqslant 60$	455	600 to 780	18	27[h]	34[h]	40
		$60 < t \leqslant 150$	435	590 to 770				
	+QT	$150 < t \leqslant 250$	415	580 to 760				
12CrMoV12-10	+NT	$\leqslant 60$	455	600 to 780	18	27[h]	34[h]	40
		$60 < t \leqslant 150$	435	590 to 770				
	+QT	$150 < t \leqslant 250$	415	580 to 760				
X10CrMoVNb9-1	+NT	$\leqslant 60$	445	580 to 760	18	27[h]	34[h]	40
		$60 < t \leqslant 150$	435	550 to 730				
	+QT	$150 < t \leqslant 250$	435	520 to 700				

[a] •• For product thicknesses > 250 mm (except for grades 12CrMo9-10 and 15NiCuMoNb5-6-4), property values may be agreed upon.

[b] As rolled (untreated) by agreement, see 6.2.4; +N: normalized; +NT: normalized and tempered; +QT: quenched and tempered.

[c] •• For product thicknesses where the usual delivery condition is +NT, higher strength and impact energy values may be agreed for the delivery condition +QT.

[d] See 6.2.2.

[e] See 6.2.4.

[f] This steel may also be supplied in the +NT condition at the discretion of the manufacturer.

[g] 1 MPa = 1 N/mm^2.

[h] •• An impact energy value of 40 J may be agreed upon at the time of enquiry and order.

[i] •• A value may be agreed upon at the time of enquiry and order.

Table A.3 — Minimum values for the 0,2 % proof strength at elevated temperatures[a]

Steel grade	Product thickness[b,c] t	Minimum 0,2 % proof strength, $R_{p0,2}$ MPa[f] at a temperature in °C of									
	mm	50	100	150	200	250	300	350	400	450	500
P235GH[d]	$\leqslant 16$	227	214	198	182	167	153	142	133	—	—
	$16 < t \leqslant 40$	218	205	190	174	160	147	136	128	—	—
	$40 < t \leqslant 60$	208	196	181	167	153	140	130	122	—	—
	$60 < t \leqslant 100$	193	182	169	155	142	130	121	114	—	—
	$100 < t \leqslant 150$	179	168	156	143	131	121	112	105	—	—
	$150 < t \leqslant 250$	164	155	143	132	121	111	103	97	—	—
P265GH[d]	$\leqslant 16$	256	241	223	205	188	173	160	150	—	—
	$16 < t \leqslant 40$	247	232	215	197	181	166	154	145	—	—
	$40 < t \leqslant 60$	237	223	206	190	174	160	148	139	—	—
	$60 < t \leqslant 100$	208	196	181	167	153	140	130	122	—	—
	$100 < t \leqslant 150$	193	182	169	155	142	130	121	114	—	—
	$150 < t \leqslant 250$	179	168	156	143	131	121	112	105	—	—
P295GH[d]	$\leqslant 16$	285	268	249	228	209	192	178	167	—	—
	$16 < t \leqslant 40$	280	264	244	225	206	189	175	165	—	—
	$40 < t \leqslant 60$	276	259	240	221	202	186	172	162	—	—
	$60 < t \leqslant 100$	251	237	219	201	184	170	157	148	—	—
	$100 < t \leqslant 150$	227	214	198	182	167	153	142	133	—	—
	$150 < t \leqslant 250$	213	200	185	170	156	144	133	125	—	—
P355GH[d]	$\leqslant 16$	343	323	299	275	252	232	214	202	—	—
	$16 < t \leqslant 40$	334	314	291	267	245	225	208	196	—	—
	$40 < t \leqslant 60$	324	305	282	259	238	219	202	190	—	—
	$60 < t \leqslant 100$	305	287	265	244	224	206	190	179	—	—
	$100 < t \leqslant 150$	285	268	249	228	209	192	178	167	—	—
	$150 < t \leqslant 250$	271	255	236	217	199	183	169	159	—	—
16Mo3	$\leqslant 16$	273	264	250	233	213	194	175	159	147	141
	$16 < t \leqslant 40$	268	259	245	228	209	190	172	156	145	139
	$40 < t \leqslant 60$	258	250	236	220	202	183	165	150	139	134
	$60 < t \leqslant 100$	238	230	218	203	186	169	153	139	129	123
	$100 < t \leqslant 150$	218	211	200	186	171	155	140	127	118	113
	$150 < t \leqslant 250$	208	202	191	178	163	148	134	121	113	108
18MnMo4-5[e]	$\leqslant 60$	330	320	315	310	295	285	265	235	215	—
	$60 < t \leqslant 150$	320	310	305	300	285	275	255	225	205	—
	$150 < t \leqslant 250$	310	300	295	290	275	265	245	220	200	—
20MnMoNi4-5	$\leqslant 40$	460	448	439	432	424	415	402	384	—	—
	$40 < t \leqslant 60$	450	438	430	423	415	406	394	375	—	—
	$60 < t \leqslant 100$	441	429	420	413	406	398	385	367	—	–
	$100 < t \leqslant 150$	431	419	411	404	397	389	377	359	—	—
	$150 < t \leqslant 250$	392	381	374	367	361	353	342	327	—	—

Table A.3 (*continued*)

Steel grade	Product thickness[b,c] t	Minimum 0,2 % proof strength, $R_{p0,2}$ MPa[f] at a temperature in °C of									
	mm	50	100	150	200	250	300	350	400	450	500
15NiCuMoNb5-6-4	$\leqslant 40$	447	429	415	403	391	380	366	351	331	—
	$40 < t \leqslant 60$	427	410	397	385	374	363	350	335	317	—
	$60 < t \leqslant 100$	418	401	388	377	366	355	342	328	309	—
	$100 < t \leqslant 150$	408	392	379	368	357	347	335	320	302	—
	$150 < t \leqslant 200$	398	382	370	359	349	338	327	313	295	—
13CrMo4-5	$\leqslant 16$	294	285	269	252	234	216	200	186	175	164
	$16 < t \leqslant 60$	285	275	260	243	226	209	194	180	169	159
	$60 < t \leqslant 100$	265	256	242	227	210	195	180	168	157	148
	$100 < t \leqslant 150$	250	242	229	214	199	184	170	159	148	139
	$150 < t \leqslant 250$	235	223	215	211	199	184	170	159	148	139
13CrMoSi5-5+NT	$\leqslant 60$	299	283	268	255	244	233	223	218	206	—
	$60 < t \leqslant 100$	289	274	260	247	236	225	216	211	199	—
13CrMoSi5-5+QT	$\leqslant 60$	384	364	352	344	339	335	330	322	309	—
	$60 < t \leqslant 100$	375	355	343	335	330	327	322	314	301	—
	$100 < t \leqslant 250$	365	346	334	326	322	318	314	306	293	
10CrMo9-10	$\leqslant 16$	288	266	254	248	243	236	225	212	197	185
	$16 < t \leqslant 40$	279	257	246	240	235	228	218	205	191	179
	$40 < t \leqslant 60$	270	249	238	232	227	221	211	198	185	173
	$60 < t \leqslant 100$	260	240	230	224	220	213	204	191	178	167
	$100 < t \leqslant 150$	250	237	228	222	219	213	204	191	178	167
	$150 < t \leqslant 250$	240	227	219	213	210	208	204	191	178	167
12CrMo9-10	$\leqslant 250$	341	323	311	303	298	295	292	287	279	g
X12CrMo5	$\leqslant 60$	310	299	295	294	293	291	285	273	253	222
	$60 < t \leqslant 250$	290	281	277	275	275	273	267	256	237	208
13CrMoV9-10[e]	$\leqslant 60$	410	395	380	375	370	365	362	360	350	—
	$60 < t \leqslant 250$	405	390	370	365	360	355	352	350	340	—
12CrMoV12-10[e]	$\leqslant 60$	410	395	380	375	370	365	362	360	350	—
	$60 < t \leqslant 250$	405	390	370	365	360	355	352	350	340	—
X10CrMoVNb9-1	$\leqslant 60$	432	415	401	392	385	379	373	364	349	324
	$60 < t \leqslant 250$	423	406	392	383	376	371	365	356	341	316

[a] The values correspond to the lower band of the relevant trend curve determined in accordance with EN 10314 with a confidence limit of about 98 % (2 s).

[b] •• For product thicknesses exceeding the specified maximum thicknesses, $R_{p0,2}$ values at elevated temperatures may be agreed upon.

[c] Delivery condition as given in Table A.2 (but see footnote c to Table A.2).

[d] The values reflect the minimum values for furnace-normalized test pieces.

[e] $R_{p0,2}$ not determined in accordance with EN 10314. These are minimum values of the scatter band considered up until now.

[f] 1 MPa = 1 N/mm^2.

Annex B
(normative)

Chemical composition and mechanical properties of products based on ASTM/ASME or JIS standards

Table B.1 — Chemical composition [cast (heat) analysis]

Steel grade	% by mass[a]													
	C[b] max.	Si	Mn	P[b] max.	S[b] max.	Al_{total}	Cr	Cu max.	Mo	Nb max.	Ni	Ti max.	V	Others
PT410GH	0,20[c]	⩽ 0,40	0,40 to 1,40	0,025	0,025	⩾ 0,020[d]	⩽ 0,30	0,40	⩽ 0,12	0,02	⩽ 0,40	0,03	⩽ 0,03	Cr+Cu+Mo+Ni: ⩽ 1,00
PT450GH	0,20[c]	⩽ 0,40	0,60 to 1,60	0,025	0,025	⩾ 0,020[d]	⩽ 0,30	0,40	⩽ 0,12	0,02	⩽ 0,40	0,03	⩽ 0,03	Cr+Cu+Mo+Ni: ⩽ 1,00
PT480GH	0,20[c]	⩽ 0,55	0,60 to 1,60	0,025	0,025	⩾ 0,020[d]	⩽ 0,30	0,40	⩽ 0,12	0,02	⩽ 0,40	0,03	⩽ 0,03	Cr+Cu+Mo+Ni: ⩽ 1,00
19MnMo4-5	0,25	⩽ 0,40	0,95 to 1,30	0,025	0,025	—	⩽ 0,30	0,40	0,45 to 0,60	0,02	⩽ 0,40	0,03	⩽ 0,03	—
19MnMo5-5	0,25	⩽ 0,40	0,95 to 1,50	0,025	0,025	—	⩽ 0,30	0,40	0,45 to 0,60	0,02	⩽ 0,40	0,03	⩽ 0,03	—
19MnMo6-5	0,25	⩽ 0,40	1,15 to 1,50	0,025	0,025	—	⩽ 0,30	0,40	0,45 to 0,60	0,02	⩽ 0,40	0,03	⩽ 0,03	—
19MnMoNi5-5	0,25	⩽ 0,40	0,95 to 1,50	0,025	0,025	—	⩽ 0,30	0,40	0,45 to 0,60	0,02	0,40 to 0,70	0,03	⩽ 0,02	—
19MnMoNi6-5	0,25	⩽ 0,40	1,15 to 1,50	0,025	0,025	—	⩽ 0,20	0,40	0,45 to 0,60	0,02	0,40 to 0,70	0,03	⩽ 0,02	—
14CrMo4-5[e]	0,17	⩽ 0,40	0,40 to 0,65	0,025	0,025	—	0,80 to 1,15	0,40	0,45 to 0,65	0,02	⩽ 0,40	0,03	⩽ 0,03	—
14CrMoSi5-6[e]	0,17	0,50 to 0,80	0,40 to 0,65	0,025	0,025	—	1,00 to 1,50	0,40	0,45 to 0,60	0,02	⩽ 0,40	0,03	⩽ 0,03	—
13CrMo9-10[e]	0,17	⩽ 0,50	0,30 to 0,60	0,025	0,025	—	2,00 to 2,50	0,40	0,90 to 1,10	0,02	⩽ 0,40	0,03	⩽ 0,03	—
14CrMo9-10	0,17	⩽ 0,50	0,30 to 0,60	0,015	0,015	—	2,00 to 2,50	0,40	0,90 to 1,10	0,02	⩽ 0,40	0,03	⩽ 0,03	—
14CrMoV9-10	0,17	⩽ 0,10	0,30 to 0,60	0,015	0,010	–	2,00 to 2,50	0,40	0,90 to 1,10	0,07	⩽ 0,40	0,035	0,25 to 0,35	⩽ 0,003 B; ⩽ 0,015 Ca, ⩽ 0,015 REM[f]

Table B.1 (*continued*)

Steel grade	% by mass[a]													
	C[b] max.	**Si**	**Mn**	**P[b] max.**	**S[b] max.**	**Al_{total}**	**Cr**	**Cu max.**	**Mo**	**Nb max.**	**Ni**	**Ti max.**	**V**	**Others**
13CrMoV12-10	0,17	⩽ 0,15	0,30 to 0,60	0,015	0,010	—	2,75 to 3,25	0,40	0,90 to 1,10	0,07	⩽ 0,40	0,035	0,20 to 0,30	⩽ 0,003 B; ⩽ 0,015 Ca, ⩽ 0,015 REM[f]
X9CrMoVNb9-1	0,08 to 0,12	⩽ 0,50	0,30 to 0,60	0,020	0,010	⩽ 0,040	8,00 to 9,50	0,40	0,85 to 1,05	0,06 to 0,10	⩽ 0,40	0,03	0,18 to 0,25	—

[a] Elements not listed in this table shall not intentionally be added to the steel without agreement of the purchaser, except for finishing the cast. All appropriate measures shall be taken to prevent the addition from scrap or other materials used in steelmaking of these elements which may affect the mechanical properties and usability.

[b] The maximum values also apply to the product analysis.

[c] •• By agreement at the time of enquiry and order, the maximum carbon content may be increased up to 0,31 % in the case of PT410GH, 0,33 % in the case of PT450GH and 0,35 % in the case of PT480GH.

[d] On cast analysis, the aluminium content shall not be less than 0,020 % total aluminium or, alternately, 0,015 % acid soluble aluminium.

•• If so agreed at the time of enquiry and order, aluminium shall not be used in order to restrain graphitization.

[e] See Table B.2 for complete steel names.

[f] REM: Rare earth metals.

Table B.2 — Mechanical properties

Steel grade	Usual delivery condition[a]	Product thickness t mm	Tensile properties at room temperature[b,c] Yield strength R_{eH} MPa[d] min.	Tensile strength R_m MPa[d]	Elongation after fracture A % min.	Impact energy KV J
PT410GH	+AR	$6 \leqslant t \leqslant 50$	225	410 to 550	21	
	+N	$6 \leqslant t \leqslant 200$				
PT450GH	+AR	$6 \leqslant t \leqslant 50$	245	450 to 590	19	
	+N	$6 \leqslant t \leqslant 200$				
PT480GH	+AR	$6 \leqslant t \leqslant 50$	265	480 to 620	17	
	+N	$6 \leqslant t \leqslant 200$				
19MnMo4-5	+N, +AR	$6 \leqslant t \leqslant 50$	315	520 to 660	17	
	+N[e]	$50 \leqslant t \leqslant 200$				
19MnMo5-5	+N, +QT[f], +AR	$6 \leqslant t \leqslant 50$	345	550 to 690	17	
	+N[e], +QT[f]	$6 \leqslant t \leqslant 200$				
19MnMo6-5	+QT[f]	$6 \leqslant t \leqslant 200$	480	620 to 790	15	
19MnMoNi5-5	+N, +QT[c], +AR	$6 \leqslant t \leqslant 50$	345	550 to 690	17	l
	+N[e], +QT[f]	$50 \leqslant t \leqslant 200$				
19MnMoNi6-5	+QT[f]	$6 \leqslant t \leqslant 50$	480	620 to 790	15	
		$50 \leqslant t \leqslant 200$				
14CrMo4-5+NT1	+NT[g]	$6 \leqslant t \leqslant 200$	225	380 to 550	20	
14CrMo4-5+NT2	+Nt[g]	$6 \leqslant t \leqslant 200$	275	450 to 590	20	
14CrMoSi5-6+NT1	+N[g]	$6 \leqslant t \leqslant 200$	235	410 to 590	20	
14CrMoSi5-6+NT2	+NT[g]	$6 \leqslant t \leqslant 200$	315	520 to 690	20	
13CrMo9-10+NT1	+NT[g]	$6 \leqslant t \leqslant 300$	205	410 to 590	17	
13CrMo9-10+NT2	+NT[g]	$6 \leqslant t \leqslant 300$	315	520 to 690	17	
14CrMo9-10	+QT[h] (+NT[i])[j]	$6 \leqslant t \leqslant 300$	380	580 to 760	17	
14CrMoV9-10	+NT[i] (+QT[g])[j]	$6 \leqslant t \leqslant 300$	415	580 to 760	17	
13CrMoV12-10	+NT[i] (+QT[g])[j]	$6 \leqslant t \leqslant 300$	415	580 to 760	17	
X9CrMoVNb9-1	+NT[k]	$6 \leqslant t \leqslant 300$	415	585 to 760	17	

[a] +AR = as rolled (untreated), see 6.2.3 and 6.2.5; +N: normalized; +NT: normalized and tempered; +QT: quenched and tempered. For products delivered untreated, 6.2.5 applies.

[b] Applicable for transverse direction.

[c] The reduction of area shall not be less than 45 % for steel grades 13CrMo9-10+NT1, 13CrMo9-10+NT2, 14CrMo9-10 and 13CrMoV12-10.

[d] 1 MPa = 1 /mm^2.

[e] Normalizing for steel plate > 100 mm may include accelerated cooling and subsequent tempering in the temperature range of 595 °C to 705 °C.

[f] Plates shall be quenched and tempered, and the tempering temperature shall be a suitable temperature to produce the specific properties, but shall not be less than 595 °C.

[g] In normalizing, accelerated cooling to obtain the specified mechanical properties may be performed by liquid quenching, air blasting or other methods. Minimum tempering temperature shall be 620 °C for steel grades 14CrMo4-5 and 14CrMoSi5-6 and 650 °C for steel grade 13CrMo9-10.

[h] Minimum tempering temperature shall be 675 °C. The purchaser shall inform the manufacturer of his intention to use this tempering temperature of 675 °C. In this case, the manufacturer may perform tempering at temperatures lower than 675 °C, but not lower than 625 °C.

[i] Minimum tempering temperature shall be 675 °C. The purchaser shall inform the manufacturer of his intention to use this tempering temperature of 675 °C. In this case, the manufacturer may perform tempering at temperatures lower than 675 °C, but not lower than 625 °C.

[j] •• By agreement at the time of enquiry and order, the products may be delivered in the condition +NT (14CrMo9-10) or +QT(14CrMoV9-10 and 13CrMoV12-10).

[k] Minimum tempering temperature shall be 730 °C.

l •• Impact tests with agreed minimum impact energy value(s) and test temperature(s) may be agreed at the time of enquiry and order.

Annex C
(informative)

Steel designations in accordance with this part of ISO 9328 and designation of comparable steel grades in national or regional standards

Table C.1 — Steel designations in accordance with this part of ISO 9328[a] and designation of comparable[b] steel grades in national or regional standards

Steel designation in			
ISO 9328-2	EN 10028-2[c]	ASTM A302, A387, A515, A516, A533, A542, A832	JIS G3103, G3118, G3119, G3120, G4109
P235GH	1.0345		
P265GH	1.0425		
P295GH	1.0481		
P355GH	1.0473		
PT410GH		A515-60, A516-60	SB410, SGV410
PT450GH		A515-65, A516-65	SB450, SGV450
PT480GH		A515-70, A516-70	SB480, SGV480
16Mo3	1.5415		
18MnMo4-5	1.5414		
19MnMo4-5		A302A	SBV1A
19MnMo5-5		A302B, A533A1	SBV1B, SQV1A
19MnMo6-5		A533A2	SQV1B
20MnMoNi4-5	1.6311		
19MnMoNi5-5		A302C, A533B1	SBV2, SQV2A
19MnMoNi6-5		A533B2	SQV2B
15NiCuMoNb5-6-4	1.6368		
13CrMo4-5	1.7335		
14CrMo4-5+NT1		A387-12-1	SCMV2-1
14CrMo4-5+NT2		A387-12-2	SCMV2-2
13CrMoSi5-5	1.7336		
14CrMoSi5-6+NT1		A387-11-1	SCMV3-1
14CrMoSi5-6+NT2		A387-11-2	SCMV3-2
10CrMo9-10	1.7380		
12CrMo9-10	1.7375		
13CrMo9-10+NT1		A387-22-1	SCMV4-1
13CrMo9-10+NT2		A387-22-2	SCMV4-2
14CrMo9-10		A542B4	SCMQ4E
X12CrMo5	1.7362		
13CrMoV9-10	1.7703		
14CrMoV9-10		A542D4a, A832-22V	SCMQ4V
12CrMoV12-10	1.7767		
13CrMoV12-10		A542E4a	SCMQ5V
X9CrMoVNb9-1		A387-91	
X10CrMoVNb9-1	1.4903		

[a] In accordance with ISO/TS 4949.

[b] "Comparable" covers both identical or similar steel grades.

[c] In addition to the steel name (identical to the corresponding steel name used in this part of ISO 9328), the listed steel number is specified.

Annex D
(informative)

Guidelines for heat treatment

Tables D.1 and D.2 give reference data for heat treatment temperatures. For stress relief annealing, see Annex E.

NOTE In addition to the temperature, there are other parameters, such as type of heating, heating rate, holding time and cooling method which have to be taken into account.

Table D.1 — Heat treatment temperatures (steel grades of Annex A)

Steel grade	Temperature, °C		
	Normalizing	Austenitizing	Tempering[b]
P235GH	890 to 950[a]	—	—
P265GH	890 to 950[a]	—	—
P295GH	890 to 950[a]	—	—
P355GH	890 to 950[a]	—	—
16Mo3	890 to 950[a]	—	[c]
18MnMo4-5	890 to 950		600 to 640
20MnMoNi4-5	—	870 to 940	610 to 690
15NiCuMoNb5-6-4	880 to 960		580 to 680
13CrMo4-5	890 to 950		630 to 730
13CrMoSi5-5	890 to 950		650 to 730
10CrMo9-10	920 to 980		650 to 750
12CrMo9-10	920 to 980		650 to 750
X12CrMo5	920 to 970		680 to 750
13CrMoV9-10	930 to 990		675 to 750
12CrMoV12-10	930 to 1 000		675 to 750
X10CrMoVNb9-1	1 040 to 1 100		730 to 780

[a] When normalizing, after the required temperatures have been attained over the whole cross-section, no further holding is necessary and should be generally avoided.

[b] When tempering, the specified temperatures shall, when they have been attained over the whole cross-section, be maintained for an appropriate time.

[c] In certain cases, tempering at 590 °C may be necessary.

Table D.2 — Heat treatment temperatures (steel grades of Annex B)

Steel grade	Temperature, °C		
	Normalizing	Austenitizing	Tempering
PT410GH	880 to 950	—	—
PT450GH	880 to 950	—	—
PT480GH	880 to 950	—	—
19MnMo4-5	880 to 950	—	—
19MnMo5-5	880 to 950	880 to 950	595 to 690
19MnMo6-5	—	880 to 950	595 to 690
19MnMoNi5-5	880 to 950	880 to 950	595 to 690
19MnMoNi6-5	—	880 to 950	595 to 690
14CrMo4-5+NT1	880 to 980	—	620 to 710
14CrMo4-5+NT2	880 to 980	—	620 to 710
14CrMoSi5-6+NT1	880 to 980	—	620 to 710
14CrMoSi5-6+NT2	880 to 980	—	620 to 720
13CrMo9-10+NT1	900 to 980	—	650 to 760
13CrMo9-10+NT2	900 to 980	—	650 to 760
14CrMo9-10	900 to 980	900 to 980	620 to 760
14CrMoV9-10	900 to 1 000	900 to 1 000	675 to 760
13CrMoV12-10	900 to 1 000	900 to 1 000	675 to 760
X9CrMoVNb9-1	1 040 to 1 095	—	730 to 780

Annex E
(informative)

Critical time-temperature parameter $P_{crit.}$ and possible combinations of stress relieving temperature and holding time

Examples for stress relieving temperatures and the corresponding maximum holding time calculated on the basis of the equation in 6.7 for a given critical time-temperature parameter $P_{crit.}$ are given in Table E.1.

Table E.1 — $P_{crit.}$ value and permissible holding time for a given stress relieving temperature

Steel type or steel grade	$P_{crit.}$	$P_{crit.}$ condition fulfilled with stress relieving temperature in °C for a holding time[a] of	
		1 h	2 h
C, CMn steels	17,3	580	575
16Mo3	17,5	590	585
18MnMo4-5	17,5	590	585
20MnMoNi4-5	17,5	590	585
15NiCuMoNb5-6-4	17,5	590	585
13CrMo4-5	18,5	640	630
13CrMoSi5-5	18,7	650	640
10CrMo9-10	19,2	675	665
12CrMo9-10	19,3	680	670
X12CrMo5	19,5	690	680
13CrMoV9-10	19,4	685	675
12CrMoV12-10	19,4	685	675
X10CrMoVNb9-1	20,5	740	730

[a] Selected pairs of stress relieving temperature and holding time for guidance.

Annex F
(informative)

Reference data relating to strength for 1 % (plastic) creep strain and creep rupture

NOTE The values given in Table F.1 have been derived as mean values in accordance with ISO 6303 with a scatter band of ±20 %.

The strength values for 1 % (plastic) creep strain and creep rupture given up to the elevated temperatures listed in Table F.1 do not mean that the steels can be used in continuous duty up to these temperatures. The governing factor is the total stressing during operation. Where relevant, the oxidation conditions should also be taken into account.

Table F.1 — Strength for 1 % (plastic) creep strain and creep rupture

Steel grade	Temperature	Strength for 1 % (plastic) creep strain in MPa for		Creep rupture strength in MPa for		
	°C	10 000 h	100 000 h	10 000 h	100 000 h	200 000 h
P235GH, P265GH	380	164	118	229	165	145
	390	150	106	211	148	129
	400	136	95	191	132	115
	410	124	84	174	118	101
	420	113	73	158	103	89
	430	101	65	142	91	78
	440	91	57	127	79	67
	450	80	49	113	69	57
	460	72	42	100	59	48
	470	62	35	86	50	40
	480	53	30	75	42	33
P295GH, P355GH	380	195	153	291	227	206
	390	182	137	266	203	181
	400	167	118	243	179	157
	410	150	105	221	157	135
	420	135	92	200	136	115
	430	120	80	180	117	97
	440	107	69	161	100	82
	450	93	59	143	85	70
	460	83	51	126	73	60
	470	71	44	110	63	52
	480	63	38	96	55	44
	490	55	33	84	47	37
	500	49	29	74	41	30

Table F.1 (*continued*)

Steel grade	Temperature	Strength for 1 % (plastic) creep strain in MPa for		Creep rupture strength in MPa for		
	°C	10 000 h	100 000 h	10 000 h	100 000 h	200 000 h
16Mo3	450	216	167	298	239	217
	460	199	146	273	208	188
	470	182	126	247	178	159
	480	166	107	222	148	130
	490	149	89	196	123	105
	500	132	73	171	101	84
	510	115	59	147	81	69
	520	99	46	125	66	55
	530	84	36	102	53	45
18MnMo4-5	425	392	314	421	343	
	430	383	302	407	330	
	440	360	272	380	300	
	450	333	240	353	265	
	460	303	207	325	230	
	470	271	176	295	196	
	480	239	148	263	166	
	490	207	124	229	140	
	500	177	103	196	118	
	510	150	84	165	98	
	520	127	64	141	79	
	525	118	54	132	69	
20MnMoNi4-5	450			290	240	
	460			272	211	
	470			251		
	480			225		
	490			194		
15NiCuMoNb5-6-4	400	324	294	402	373	
	410	315	279	385	349	
	420	306	263	368	325	
	430	295	245	348	300	
	440	281	227	328	273	
	450	265	206	304	245	
	460	239	180	274	210	
	470	212	151	242	175	
	480	180	120	212	139	
	490	145	84	179	104	
	500	108	49	147	69	

Table F.1 (*continued*)

Steel grade	Temperature	Strength for 1 % (plastic) creep strain in MPa for		Creep rupture strength in MPa for		
	°C	10 000 h	100 000 h	10 000 h	100 000 h	200 000 h
13CrMo4-5	450	245	191	370	285	260
	460	228	172	348	251	226
	470	210	152	328	220	195
	480	193	133	304	190	167
	490	173	116	273	163	139
	500	157	98	239	137	115
	510	139	83	209	116	96
	520	122	70	179	94	76
	530	106	57	154	78	62
	540	90	46	129	61	50
	550	76	36	109	49	39
	560	64	30	91	40	32
	570	53	24	76	33	26
13CrMoSi5-5	450		209		313	
	460		200		300	
	470		185		278	
	480		141		212	
	490		119		179	
	500		113		169	
	510		81		122	
	520		66		99	
	530		41		62	
	540		33		50	
	550		27		40	
	560		23		35	
	570		21		31	
10CrMo9-10	450	240	166	306	221	201
	460	219	155	286	205	186
	470	200	145	264	188	169
	480	180	130	241	170	152
	490	163	116	219	152	136
	500	147	103	196	135	120
	510	132	90	176	118	105
	520	119	78	156	103	91
	530	107	68	138	90	79
	540	94	58	122	78	68
	550	83	49	108	68	58
	560	73	41	96	58	50
	570	65	35	85	51	43
	580	57	30	75	44	37
	590	50	26	68	38	32
	600	44	22	61	34	28

Table F.1 (*continued*)

Steel grade	Temperature	Strength for 1 % (plastic) creep strain in MPa for		Creep rupture strength in MPa for		
	°C	10 000 h	100 000 h	10 000 h	100 000 h	200 000 h
12CrMo9-10	400			382	313	
	410			355	289	
	420			333	272	
	430			312	255	
	440			293	238	
	450			276	221	
	460			259	204	
	470			242	187	
	480			225	170	
	490			208	153	
	500			191	137	
	510			174	122	
	520			157	107	
X12CrMo5	450	107				
	460	96				
	470	87		147 (475°C)		
	480	83		139		
	490	78		123		
	500	70		108		
	510	56		94		
	520	50		81		
	530	44		71		
	540	39		61		
	550	35		53		
	560	31		47		
	570	27		41		
	580	24		36		
	590	21		32		
	600	18		27		
	610	16				
	620	14				
	625	13				
13CrMoV9-10	400			430	383	
	410			414	365	
	420			397	346	
	430			380	327	
	440			362	309	
	450			344	290	
	460			326	271	
	470			308	253	
	480			290	235	
	490			272	218	
	500			255	201	

Table F.1 (*continued*)

Steel grade	Temperature	Strength for 1 % (plastic) creep strain in MPa for		Creep rupture strength in MPa for		
	°C	10 000 h	100 000 h	10 000 h	100 000 h	200 000 h
13CrMoV9-10	510			237	184	
	520			221	169	
	530			204	144	
	540			188	126	
	550			173	108	
12CrMoV12-10	400			430	383	
	410			414	365	
	420			397	346	
	430			380	327	
	440			362	309	
	450			344	290	
	460			326	271	
	470			308	253	
	480			290	235	
	490			272	218	
	500			255	201	
	510			237	184	
	520			221	169	
	530			204	144	
	540			188	126	
	550			173	108	
X10CrMoVNb 9-1	500			289	258	246
	510			271	239	227
	520			252	220	208
	530			234	201	189
	540			216	183	171
	550			199	166	154
	560			182	150	139
	570			166	134	124
	580			151	120	110
	590			136	106	97
	600			123	94	86
	610			110	83	75
	620			99	73	65
	630			89	65	57
	640			79	56	49
	650			70	49	42
	660			62	42	35
	670			55	36	—

Annex G
(normative)

Evaluation of resistance to hydrogen-induced cracking

G.1 A test to evaluate the resistance of steel products to hydrogen-induced cracking shall be performed.

G.2 The test procedure specified in EN 10229 or another appropriate procedure with specified acceptance criteria (e.g. in accordance with NACE TM0284) shall be applied.

G.3 The procedure to be applied, the test solution and the corresponding acceptance criteria shall be agreed upon at the time of enquiry and order.

In the case of the procedure specified in EN 10229, the acceptance criteria for the test solution A (with pH ≈ 3) apply for the classes indicated in Table G.1 where the given values are mean values from three individual test results.

Table G.1 — Acceptance classes for the HIC test (test solution A)

Acceptance class	CLR[a] %	CTR[a] %	CSR[a] %
I	⩽ 5	⩽ 1,5	⩽ 0,5
II	⩽ 10	⩽ 3	⩽ 1
III	⩽ 15	⩽ 5	⩽ 2

[a] CLR: crack length ratio, CTR: crack thickness ratio, CSR: crack sensitivity ratio.

Annex H
(normative)

Step cooling test

For the step cooling test, a procedure to check step cooling embrittlement shall be agreed. This procedure shall include temperatures, T, and holding times, t, to be considered. The procedure given in Figure H.1 is recommended.

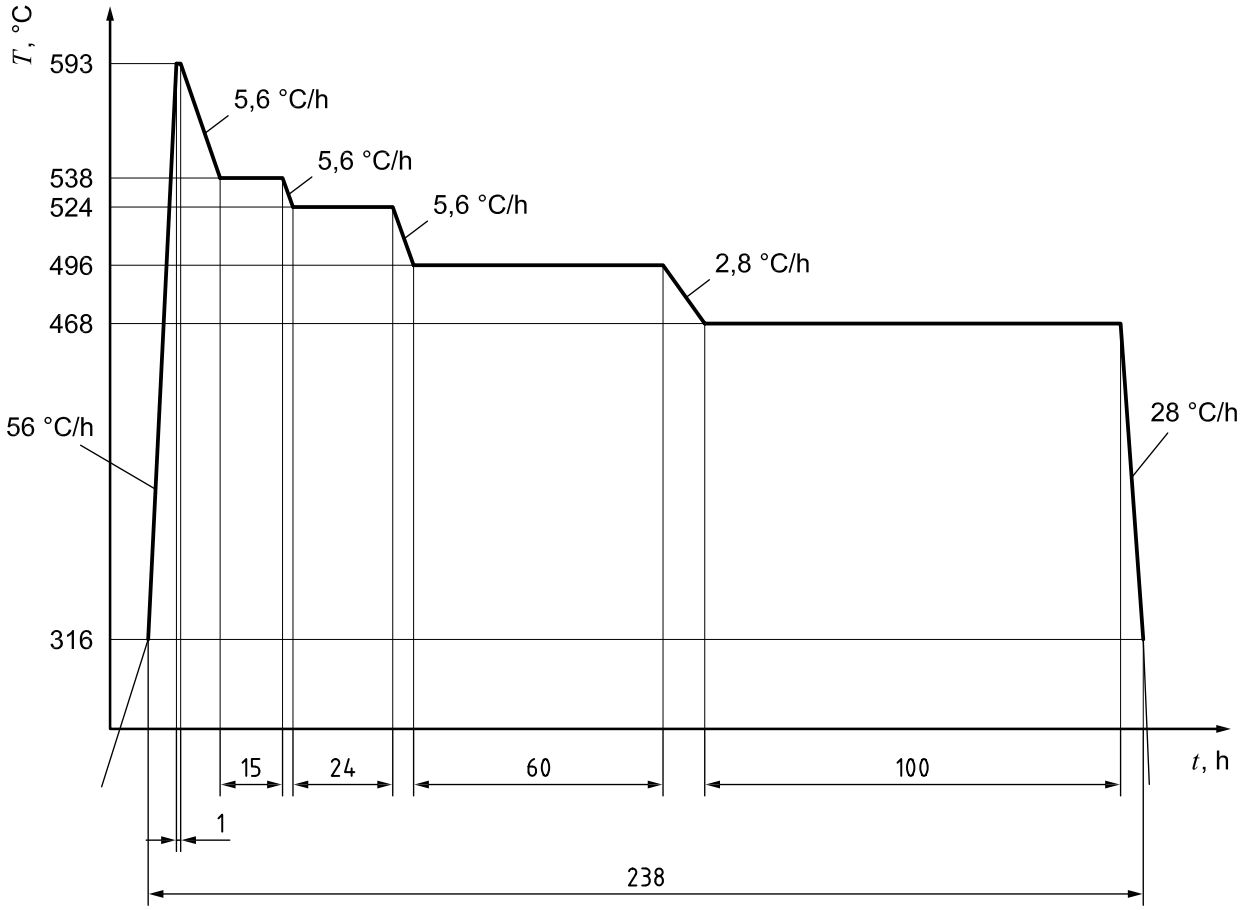

Figure H.1 — Recommended procedure for the step cooling test

Bibliography

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

[2] ISO 6303, *Pressure vessel steels not included in ISO 2604, Parts 1 to 6 — Derivation of long-time stress rupture properties*

[3] EN 1011-1, *Welding — Recommendations for welding of metallic materials — Part 1: General guidance for arc welding*

[4] EN 1011-2, *Welding — Recommendations for welding of metallic materials — Part 2: Arc welding of ferritic steels*

[5] IIS/IIW 382-71*, Guide to the welding and weldability of C-Mn steels and C-Mn microalloyed steels*

[6] NACE TM0284:2003*, Standard test method — Evaluation of pipeline and pressure vessel steels for resistance to hydrogen-induced cracking*

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