INTERNATIONAL STANDARD

ISO 9328-6

Second edition
2011-05-01

Steel flat products for pressure purposes — Technical delivery conditions —

Part 6: Weldable fine grain steels, quenched and tempered

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

Partie 6: Aciers soudables à grains fins, trempés et revenus

Reference number
ISO 9328-6:2011(E)

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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 9328-6 was prepared by Technical Committee ISO/TC 17, *Steel*, Subcommittee SC 10, *Steel for pressure purposes*.

This second edition cancels and replaces the first edition (ISO 9328-6:2004), of which it constitutes a minor revision.

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 with a point (•) contain information relating to agreements which 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 6: Weldable fine grain steels, quenched and tempered

1 Scope

This part of ISO 9328 specifies the requirements for flat products for pressure equipment made of quenched and tempered weldable fine grain steels as listed in Tables A.1 and B.1. The requirements and definitions in ISO 9328-1 also apply to this part of ISO 9328.

NOTE 1 Fine grain steels are understood to be steels with a ferritic grain size of 6 or finer when tested in accordance with ISO 643.

NOTE 2 This part of ISO 9328 offers the possibility of specifying products in accordance with European design codes and ASME-type design codes.

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 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*

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, all steel grades covered by this part of ISO 9328 are alloyed special steels.

4.2 Designation

See ISO 9328-1.

This part of ISO 9328 covers the steel grades specified in Annexes A and B in four series:

a) basic series (P...Q; PT…Q);

b) series with elevated temperature properties (P...QH, PT…QH);

c) series with low temperature properties down to −40 °C (P...QL1);

d) series with low temperature properties down to −60 °C (P...QL2, PT…QL2).

NOTE 1 The steel grades in Annex A are classified according to their yield strength; the steel grades in Annex B are classified according to 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.

Additionally, for steel grades in accordance with Annex B, the test direction for the impact test shall be agreed upon (see Clause 9 and Table B.3, footnote a).

5.2 Options

A number of options are specified in this part of ISO 9328. These are listed below under a) to i). 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) carbon-equivalent value (see 6.3.3);

b) tensile properties at elevated temperatures for steel grades PT…QH (see 6.4);

c) specification of an impact energy of 40 J (see the Note to 6.4 and Table A.3);

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

e) mechanical properties for thicknesses > 150 mm (see Table A.2, footnote b);

f) applicability of elevated temperature values for QL grades (see Table A.4, footnote b);

g) increased maximum carbon content for the grade PT520Q (see Table B.1, footnote c);

h) increased maximum carbon content for the grade PT550QL2 (see Table B.1, footnote d);

i) other test requirements for the impact test (see Table B.3, footnote b).

5.3 Example for ordering

10 plates with nominal dimensions thickness = 50 mm, width = 2 000 mm, length = 10 000 mm, made of a steel grade with the name P355QL2 as specified in ISO 9328-6, with inspection document 3.1.B as specified in ISO 10474:1991 is designated as follows:

10 plates – 50 × 2 000 × 10 000 – ISO 9328-6 P355QL2 — Inspection document 3.1.B

6 Requirements

6.1 Steelmaking process

See ISO 9328-1.

6.2 Delivery condition

The products complying with this part of ISO 9328 are supplied in the quenched and tempered condition.

6.3 Chemical composition

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

6.3.2 The product analysis may deviate from the specified values of the cast (heat) analysis given in Tables A.1 and B.1 by the values given in Table 1.

6.3.3 •• For the steel grades covered by this part of ISO 9328, a carbon-equivalent value (CEV) may be specified at the time of enquiry and order. This shall be based on the formula:

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

6.4 Mechanical properties

The values given in Tables A.2 to A.4, as well as in Tables B.2 and B.3, apply (see also ISO 9328-1).

•• Additionally, for PT…QH steels (see Annex B), tensile properties at elevated temperatures may be agreed upon at the time of enquiry and order.

NOTE Optionally, a minimum impact energy value of 40 J can be specified for temperatures where lower minimum values are specified (see Table A.3, footnote a).

6.5 Surface condition

See ISO 9328-1.

6.6 Internal soundness

See ISO 9328-1.

6.7 Weldability

6.7.1 The steels specified in this part of ISO 9328 shall be suitable for welding processes in current use (see the 4th paragraph of 6.7.2).

6.7.2 The manufacturer shall, if requested, provide the purchaser with data on suitable welding conditions determined on the basis of weld procedure tests.

With increasing product thickness and strength level, cold cracking can occur. Cold cracking is caused by the following factors in combination:

— the amount of diffusible hydrogen in the weld metal;

— brittle structure of the heat-affected zone;

— tensile stress concentrations in the welded joint.

When using recommendations as laid down in appropriate documents, e.g. EN 1011-1 and EN 1011-2 or IIS/IIW 382-71, the recommended welding conditions and the various welding ranges of the steel grades can be determined depending on the product thickness, the applied welding energy, the design requirements, the electrode efficiency, the welding process and the weld metal properties.

Excessive post-weld heat treatment (PWHT) conditions may decrease the mechanical properties. The purchaser should, in his enquiry and order, inform the manufacturer accordingly.

●● Where appropriate, tests on simulated post-weld heat-treated samples may be agreed upon 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.

Table 1 — Permissible deviations of the chemical composition in the results of the product analysis from the specified values applicable to the cast (heat) analysis

Element	Specified value in the cast analysis according to Tables A.1 and B.1 % by mass	Permissible deviation[a] of the product analysis % by mass
C[b]	⩽ 0,24	+0,02
Si	⩽ 0,80	+0,05
Mn	⩽ 1,70	+0,10
P[b]	⩽ 0,030	+0,005
S[b]	⩽ 0,010	+0,003
	> 0,010 to ⩽ 0,030	+0,005
Al	⩽ 0,020	–0,005
B	⩽ 0,005	+0,000 5
N	⩽ 0,020	+0,002
Cr	⩽ 1,50	+0,10
Cu	⩽ 0,40	+0,05
Mo	⩽ 0,70	+0,04
Nb	⩽ 0,06	+0,01
Ni	⩽ 2,50	+0,10
Ti	⩽ 0,05	+0,01
V	⩽ 0,12	+0,01
Zr	⩽ 0,15	+0,01

[a] If several product analyses are carried out on one cast, and the contents of an individual element, as determined, lie outside the permissible range of the chemical composition specified for the cast (heat) analysis, then it is allowed either to exceed the permissible maximum value or to 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.

6.8 Dimensions and tolerances

See ISO 9328-1.

6.9 Calculation of mass

See ISO 9328-1.

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.

7.3 Retests

See ISO 9328-1.

8 Sampling

See ISO 9328-1.

●● For the impact test and/or 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

See ISO 9328-1.

● Impact tests for verification of impact energy values in Tables A.3 and B.3 shall be carried out on transverse test pieces (for steel grades in accordance with Annex A) or on test pieces as specified in the order (for steel grades in accordance with Annex B; see Table B.3, footnote a).

10 Marking

See ISO 9328-1.

Annex A
(normative)

Chemical composition and mechanical properties of products delivered in accordance with European design codes

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

Steel grade	Maximum contents % by mass[b]														
	C	Si	Mn	P	S	N	B	Cr	Mo	Cu[c]	Nb[d]	Ni	Ti[d]	V[d]	Zr[d]
P355Q, P355QH	0,16	0,40	1,50	0,025	0,010	0,015	0,005	0,30	0,25	0,30	0,05	0,50	0,03	0,06	0,05
P355QL1				0,020	0,008										
P355QL2					0,005										
P460Q, P460QH	0,18	0,50	1,70	0,025	0,010	0,015	0,005	0,50	0,50	0,30	0,05	1,00	0,03	0,08	0,05
P460QL1				0,020	0,008										
P460QL2					0,005										
P500Q, P500QH	0,18	0,60	1,70	0,025	0,010	0,015	0,005	1,00	0,70	0,30	0,05	1,50	0,05	0,08	0,15
P500QL1				0,020	0,008										
P500QL2					0,005										
P690Q, P690QH	0,20	0,80	1,70	0,025	0,010	0,015	0,005	1,50	0,70	0,30	0,06	2,50	0,05	0,12	0,15
P690QL1				0,020	0,008										
P690QL2					0,005										

[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 of these elements from scrap and other materials used in steelmaking, which may adversely affect the mechanical properties and usability.

[b] The manufacturer may add one or several alloying element(s) up to the maximum values specified in the order, as a function of the product thickness and the steelmaking conditions, in order to attain the specified properties. The chemical composition range for each manufacturer's analysis shall be given in the offer and confirmation of order.

[c] •• For reasons of hot formability, a lower copper content and a maximum tin content may be agreed upon at the time of enquiry and order.

[d] The percentage of grain-refining elements shall be at least 0,015 %. Aluminium is also included in these elements. The minimum content of 0,015 % applies here to dissolved aluminium. This value is regarded as attained if the total aluminium content is at least 0,018 %; in cases of dispute, the dissolved aluminium content shall be determined.

Table A.2 — Mechanical properties at room temperature

Steel grade	Yield strength[a] R_{eH} MPa[c] min. for product thickness, t, in mm			Tensile strength R_m MPa[c] for product thickness, t, in mm		Elongation after fracture A % min.
	$t \leqslant 50$	$50 < t \leqslant 100$	$100 < t \leqslant 150$[b]	$t \leqslant 100$	$100 < t \leqslant 150$[b]	
P355Q, P355QH, P355QL1, P355QL2	355	335	315	490 to 630	450 to 590	22
P460Q, P460QH, P460QL1, P460QL2	460	440	400	550 to 720	500 to 670	19
P500Q, P500QH, P500QL1, P500QL2	500	480	440	590 to 770	540 to 720	17
P690Q, P690QH, P690QL1, P690QL2	690	670	630	770 to 940	720 to 900	14

[a] The yield strength to be determined shall be the upper yield strength R_{eH} or, if this is not pronounced, the 0,2 % proof strength $R_{p0,2}$.

[b] •• Other product thicknesses may be agreed upon at the time of enquiry and order.

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

Table A.3 — Impact energy (valid for transverse V-notched test pieces)

Steel grades of the series	Product thickness t	Impact energy KV J Min. at a temperature in °C of				
		–60	–40	–20	0	+20
P...Q, P...QH	$\leqslant 150$	—	—	27[a]	40	60
P...QL1		—	27[a]	40	60	
P...QL2		27[a]	40	60	80	

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

Table A.4 — Minimum 0,2 % proof strength $R_{p0,2}$ at elevated temperatures[a]

Steel grade[b]	Minimum proof strength values[c] $R_{p0,2}$ MPa[d] at a temperature in °C of					
	50	100	150	200	250	300
P355QH	340	310	285	260	235	215
P460QH	445	425	405	380	360	340
P500QH	490	470	450	420	400	380
P690QH	670	645	615	595	575	570

[a] The values shall be proven on request (see ISO 9328-1) for the specified service temperature.

[b] •• If agreed upon at the time of enquiry and order, these values also apply to the grades P...QL with specified low temperature properties.

[c] These values are valid for product thicknesses $t \leqslant 50$ mm. For larger specified thicknesses, the minimum 0,2 % proof strength values are reduced by

20 MPa for 50 mm $< t \leqslant$ 100 mm, and by

60 MPa for $t >$ 100 mm.

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

Annex B
(normative)

Chemical composition and mechanical properties of products delivered in accordance with ASME-type design codes

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

Steel grade	% by mass[a]													
	C	Si	Mn	P	S	Al_{total}[b]	B	Cr	Cu	Mo	Nb	Ni	Ti	V
	max.	max.		max.	max.	min.	max.	max.	max.	max.	max.	max.	max.	max.
PT440QL2	0,16	0,55	0,70 to 1,60	0,025	0,020	0,020	0,005	0,30	0,40	0,25	0,05	0,50	0,03	0,06
PT490Q, PT490QH	0,18	0,55	⩽ 1,60	0,030	0,030	0,020	0,005	0,30	0,40	0,25	0,05	0,50	0,03	0,06
P490QL2	0,18	0,55	0,70 to 1,60	0,025	0,020	0,020	0,005	0,30	0,40	0,25	0,05	0,50	0,03	0,06
PT520Q, PT520QH	0,18[c]	0,55	⩽ 1,60	0,030	0,030	0,020	0,005	0,30	0,40	0,25	0,05	0,50	0,03	0,06
PT520QL2	0,18	0,55	0,70 to 1,60	0,025	0,020	0,020	0,005	0,30	0,40	0,25	0,05	0,50	0,03	0,06
PT550Q, PT550QH	0,18	0,75	⩽ 1,60	0,030	0,030	0,020	0,005	0,30	0,40	0,50	0,05	0,50	0,03	0,08
PT550QL2	0,18[d]	0,50	0,70 to 1,60	0,025	0,020	0,020	0,005	0,30	0,40	0,50	0,05	1,00	0,03	0,08
PT570Q, PT570QH	0,18	0,75	⩽ 1,60	0,030	0,030	0,020	0,005	0,30	0,40	0,50	0,05	1,00	0,03	0,08
PT610Q, PT610QH	0,18	0,75	⩽ 1,60	0,030	0,030	0,020	0,005	0,30	0,40	0,50	0,05	1,00	0,03	0,08

[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 of these elements from scrap and other materials used in steelmaking, which may adversely affect the mechanical properties and usability.

[b] On cast (heat) analysis, the aluminium content shall be not less than 0,020 % total aluminium or, alternatively, 0,015 % acid-soluble aluminium.

[c] •• By agreement at the time of enquiry and order, the maximum carbon content may be increased to 0,20 %.

[d] •• By agreement at the time of enquiry and order, the maximum carbon content may be increased to 0,24 %.

Table B.2 — Tensile properties at room temperature[a]

Steel grade	Product thickness t	Yield strength[b] R_{eH} MPa[c] min.	Tensile strength R_m MPa[c]	Elongation after fracture A % min.
PT440QL2	$6 \leqslant t \leqslant 38$	325	440 to 560	19
PT490Q, PT490QH	$6 \leqslant t \leqslant 50$	315	490 to 610	19
	$50 < t \leqslant 100$	295		
	$100 < t \leqslant 150$	275		
PT490QL2	$6 \leqslant t \leqslant 38$	365	490 to 610	17
PT520Q, PT520QH	$6 \leqslant t \leqslant 50$	355	520 to 640	17
	$50 < t \leqslant 100$	335		
	$100 < t \leqslant 150$	315		
PT520QL2	$6 \leqslant t \leqslant 38$	410	520 to 640	16
PT550Q, PT550QH	$6 \leqslant t \leqslant 50$	410	550 to 670	16
	$50 < t \leqslant 100$	390		
	$100 < t \leqslant 150$	370		
PT550QL2	$6 \leqslant t \leqslant 65$	415	550 to 690	16
	$65 < t \leqslant 100$	380	520 to 660	
	$100 < t \leqslant 150$	315	490 to 620	
PT570Q, PT570QH	$6 \leqslant t \leqslant 50$	450	570 to 700	16
	$50 < t \leqslant 100$	430		
	$100 < t \leqslant 150$	410		
PT610Q, PT610QH	$6 \leqslant t \leqslant 50$	490	610 to 740	16
	$50 < t \leqslant 100$	470		
	$100 < t \leqslant 150$	450		

[a] Applicable for transverse test pieces.

[b] The yield strength to be determined shall be the upper yield strength R_{eH} or, if this is not pronounced, the 0,2 % proof strength $R_{p0,2}$.

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

Table B.3 — Impact energy

Steel grade	Product thickness t mm	Impact energy[a,b] KV J min. at a temperature in °C of		
		−60	−10	0
PT440QL2, PT490QL2, PT520QL2	$6 \leqslant t \leqslant 38$	47	—	—
PT490Q, PT490QH, PT520Q, PT520QH	$6 \leqslant t \leqslant 150$	—	—	47
PT550QL2	$6 \leqslant t \leqslant 150$	47	—	—
PT550Q, PT550QH, PT570Q, PT570QH, PT610Q, PT610QH	$6 \leqslant t \leqslant 150$	—	47	—

[a] • For longitudinal or transverse test pieces, as agreed upon at the time of enquiry and order.

[b] •• Other test temperatures and minimum impact energy values may be agreed upon 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 9328-6	EN 10028-6[c]	ASTM A537, A734	JIS G3115, G3126
P355Q	1.8866		
P355QH	1.8867		
P355QL1	1.8868		
P355QL2	1.8869		
P460Q	1.8870		
P460QH	1.8871		
P460QL1	1.8872		
P460QL2	1.8864		
P500Q	1.8873		
P500QH	1.8874		
P500QL1	1.8875		
P500QL2	1.8865		
P690Q	1.8879		
P690QH	1.8880		
P690QL1	1.8881		
P690QL2	1.8888		
PT440QL2			SLA325B
PT490Q (...QH)			SPV315
PT490QL2			SLA365
PT520Q (...QH)		A734B	SPV355
PT520QL2			SLA410
PT550Q (...QH)			SPV410
PT550QL2		A537-2	
PT570Q (...QH)			SPV450
PT610Q (...QH)			SPV490

[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.

Bibliography

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

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

[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*

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