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Steel flat products for pressure purposes — Technical delivery conditions —

Part 5: Weldable fine grain steels, thermomechanically rolled

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

Partie 5: Aciers soudables à grains fins, laminés thermomécaniquement

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Foreword

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

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

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

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

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 17, *Steel*, Subcommittee SC 10, *Steel for pressure purposes*.

This fourth edition cancels and replaces the third edition (ISO 9328-5:2011), which has been technically revised. The following changes have been made:

— the term “product thickness” has been replaced with “nominal thickness”;

— the example of ordering has been revised;

— the content of the document has been generally updated.

— in Table B.1, “B ≤ 0,0010” has been added and the specifications of “P” and “S” have been changed.

A list of all the parts in the ISO 9328 series can be found on the ISO website.

Steel flat products for pressure purposes — Technical delivery conditions —

Part 5: Weldable fine grain steels, thermomechanically rolled

1 Scope

This document specifies the requirements for flat products for pressure equipment, made of thermomechanically rolled weldable fine grain steels as specified in Tables A.1 and B.1. The steels are not suitable for hot forming.

Until now, no sufficient data for the standardization of the elevated temperature properties of these steels are available. If their use at such temperatures is intended, the conditions for this are specially agreed upon between the interested parties.

The requirements and definitions of ISO 9328-1 also apply to this document.

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 document offers the possibility of specifying products in accordance with European design codes and ASME-type design codes.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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, *Steels — Classification — Part 1: Classification of steels into unalloyed and alloy steels based on chemical composition*

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

ISO 9328-1:2018, *Steel flat products for pressure purposes — Technical delivery conditions — Part 1: General requirements*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at https://www.iso.org/obp

4 Classification and designation

4.1 Classification

In accordance with ISO 4948-1 and ISO 4948-2, all steel grades covered by this document are alloyed special steels.

4.2 Designation

Shall be in accordance with ISO 9328-1.

This document covers the steel grades specified in Annexes A and B in four series:

a) basic series (P...M, PT...M);

b) series with low temperature properties down to −40 °C (P...ML1, PT...ML1);

c) series with low temperature properties down to −50 °C (P...ML2 – grades of Annex A only);

d) series with low temperature properties down to −60 °C (PT...ML3 – grades of Annex B only).

NOTE 1 The steel grades in Annex A are classified in accordance with their yield strength; the steel 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

Shall be in accordance with 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.4, footnote [a]).

5.2 Options

A number of options are specified in this document. These are listed below under a) to g). 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) specification of an impact energy of 40 J (see Note to 6.4 and Table A.4);

c) decreased minimum Al_{total} content (see Table B.1, footnote [b]);

d) increased maximum carbon content for the grade PT550ML1 (see Table B.1, footnote [c]);

e) increased maximum silicon content for the grade PT550M (see Table B.1, footnote [d]);

f) other test requirements for the impact test (see Table B.4, footnote [b]);

g) tests on simulated heat-treated samples (see 6.7.2).

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 P355ML2 as specified in this document, with inspection certificate 3.1 as specified in ISO 10474, is designated as follows:

10 plates – 50 × 2 000 × 10 000 – ISO 9328-5 P355ML2 – Inspection certificate 3.1

6 Requirements

6.1 Steelmaking process

Shall be in accordance with ISO 9328-1.

6.2 Delivery condition

The products complying with this document are supplied in the thermomechanically rolled condition.

6.3 Chemical composition

6.3.1 The requirements in Table A.1 and Table 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 Table A.1 and Table B.1 by the values given in Table 1.

6.3.3 For steel grades covered by this document, a carbon-equivalent value according to Table A.2 (for steel grades in Annex A) or Table B.2 (for steel grades in Annex B) may be agreed upon at the time of enquiry and order.

Table 1 — Permissible deviations of the chemical composition from 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[c]	≤ 0,20	+0,02
Si	≤ 0,75	+0,06
Mn	≤ 2,00	+0,10
P[c]	≤ 0,030	+0,005
S[c]	≤ 0,010	+0,003
	> 0,010 to ≤ 0,030	+0,005
Al	≥ 0,020	−0,005
N	≤ 0,020	+0,002
Mo	≤ 0,20	+0,03
Nb	≤ 0,05	+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 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] Only specified for grades in Annex A.

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

Table 1 *(continued)*

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
Ni	≤ 0,50	+0,05
Ti	≤ 0,05	+0,01
V	≤ 0,10	+0,01
B	≤ 0,001 0	+0,000 5
Cr + Cu + Mo[b]	≤ 0,60	+0,10
V + Nb + Ti[b]	≤ 0,15	+0,03

[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 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] Only specified for grades in Annex A.

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

6.4 Mechanical properties

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

NOTE Optionally, a minimum impact energy value of 40 J can be specified for temperatures where lower minimum values are specified (see Table A.4, footnote [a]).

6.5 Surface condition

Shall be in accordance with ISO 9328-1.

6.6 Internal soundness

Shall be in accordance with ISO 9328-1.

6.7 Weldability

6.7.1 The steels specified in this document shall be suitable for welding processes in current use (see Note to 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 nominal 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 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 nominal 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 can decrease the mechanical properties. When, on stress relieving, the intended time-temperature parameter shown by Formula (1):

$$P = T_s\,(20 + \lg\, t) \times 10^{-3} \tag{1}$$

where

T_s is the stress relieving temperature, in kelvins;

t is the holding time, in hours;

exceeds the critical P-value of $P_{crit.}$ = 17,3 (for steel grades in accordance with Annex A) 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 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 document can still be regarded as valid (see 5.2, Option 7).

6.8 Dimensions and tolerances

Shall be in accordance with ISO 9328-1.

6.9 Calculation of mass

Shall be in accordance with ISO 9328-1.

7 Inspection

7.1 Types of inspection and inspection documents

Shall be in accordance with ISO 9328-1.

7.2 Tests to be carried out

Shall be in accordance with ISO 9328-1.

7.3 Retests, sorting and reprocessing

Shall be in accordance with ISO 9328-1.

8 Sampling

Shall be in accordance with ISO 9328-1.

For an impact test (and/or the tensile test), that deviates from ISO 9328-1:2018, Table 3, footnote [e], 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 Shall be in accordance with ISO 9328-1.

9.2 Impact tests for verification of impact energy values in Tables A.4 and B.4 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.4, footnote [a]).

10 Marking

Shall be in accordance with 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

Steel grade	% by mass[a]												
	C max.	**Si** max.	**Mn**[b] max.	**P** max.	**S** max.	**Al_{total}**[c] min.	**N** max.	**Mo**[e] max.	**Nb**[f] max.	**Ni** max.	**Ti**[f] max.	**V**[f] max.	**Others**
P355M	0,14	0,50	1,60	0,025	0,010	0,020[d]	0,015	0,20	0,05[g]	0,50	0,05	0,10	[e]
P355ML1				0,020	0,008								
P355ML2					0,005								
P420M	0,16	0,50	≤ 1,70	0,025	0,010		0,020						
P420ML1				0,020	0,008								
P420ML2					0,005								
P460M	0,16	0,60	1,70	0,025	0,010								
P460ML1				0,020	0,008								
P460ML2					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 For each reduction of 0,02 % lower than the maximum carbon content, an increase of 0,05 % Mn above the specified maximum value is permitted, up to a maximum of 2,00 % Mn.

c The total Al content of the cast shall be determined and given in the inspection document.

d The minimum value for Al_{total} does not apply if adequate contents of other nitrogen-fixing elements are present.

e (Cr + Cu + Mo) ≤ 0,60 %.

f The total of V + Nb + Ti shall not exceed a value of 0,15 %.

g If the carbon content is restricted to ≤ 0,07 %, a maximum niobium content of 0,10 % is permitted. In this case, special care has be taken to avoid problems in the heat-affected zone at operation temperatures of −40 °C and below after PWHT.

Table A.2 — Maximum carbon-equivalent value (CEV) based on the cast (heat) analysis (if agreed upon at the time of enquiry and order)[a]

Steel grade	CEV[b] max. for specified nominal thickness t in mm		
	$t \leq 16$	$16 < t \leq 40$	$40 < t \leq 63$
P355M/ML1/ML2	0,39	0,39	0,40
P420M/ML1/ML2	0,43	0,45	0,46
P460M/ML1/ML2	0,45	0,46	0,47

NOTE The values for the carbon equivalent are based on the percentage by mass and relate to the mechanical properties specified for the delivery condition.

[a] See 6.3.3.

[b] $$\text{CEV} = \text{C} + \frac{\text{Mn}}{6} + \frac{\text{Cr} + \text{Mo} + \text{V}}{5} + \frac{\text{Ni} + \text{Cu}}{15}.$$

Table A.3 — Tensile properties at room temperature

Steel grade	Yield strength[a] R_{eH} MPa[b] min. for specified nominal thickness in mm			Tensile strength R_m MPa[b]	Elongation after fracture A % min.
	$t \leq 16$	$16 < t \leq 40$	$40 < t \leq 63$		
P355M	355		345	450 to 610	22
P355ML1					
P355ML2					
P420M	420	400	390	500 to 660	19
P420ML1					
P420ML2					
P460M	460	440	430	530 to 720	17
P460ML1					
P460ML2					

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

Table A.4 — Minimum impact energy values (valid for transverse V-notched test pieces)

Steel grades of the following series	Nominal thickness *t* mm	Impact energy *KV* J min. at a temperature in °C of				
		−50	−40	−20	0	+20
P...M	≤ 63	—	—	27[a]	40	60
P...ML1		—	27[a]	40	60	—
P...ML2		27[a]	40	60	80	—

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

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 max.	Si max.	Mn	P max.	S max.	Al_{total}[b] min.	Cr max.	Cu max.	Mo max.	Nb max.	Ni max.	Ti max.	V max.	B max.
PT440M	0,18	0,55	≤ 1,60	0,020	0,020	0,020	0,30	0,40	0,20	0,05	0,50	0,05	0,10	0,001 0
PT440ML1	0,16	0,55	0,70 to ≤ 1,60	0,015	0,010	0,020	0,30	0,40	0,20	0,05	0,50	0,05	0,10	0,001 0
PT440ML3														
PT490M	0,18	0,55	≤ 1,60	0,020	0,020	0,020	0,30	0,40	0,20	0,05	0,50	0,05	0,10	0,001 0
PT490ML1	0,16	0,55	0,70 to ≤ 1,60	0,015	0,010	0,020	0,30	0,40	0,20	0,05	0,50	0,05	0,10	0,001 0
PT490ML3														
PT520M	0,18	0,55	≤ 1,60	0,020	0,020	0,020	0,30	0,40	0,20	0,05	0,50	0,05	0,10	0,0010
PT520ML1	0,16	0,55	0,70 to ≤ 1,60	0,015	0,010	0,020	0,30	0,40	0,20	0,05	0,50	0,05	0,10	0,001 0
PT520ML3														
PT550M	0,18	0,55[d]	≤ 1,60	0,020	0,020	0,020	0,30	0,40	0,20	0,05	0,50	0,05	0,10	0,001 0
PT550ML1	0,18[c]	0,55	0,70 to ≤ 1,60	0,015	0,010	0,020	0,30	0,40	0,20	0,05	0,50	0,05	0,10	0,001 0

[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 analysis, the aluminium content shall be not less than 0,020 % total aluminium or, alternatively, 0,015 % acid-soluble aluminium. By agreement at the time of enquiry and order, the (total or soluble) aluminium content may fall short of this minimum, if niobium, titanium or vanadium are additionally used for nitrogen binding.

[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 silicon content may be increased to 0,75 %.

Table B.2 — Maximum carbon-equivalent values (CEV) from the cast (heat) analysis (if agreed upon at the time of enquiry and order)[a]

Steel grade	CEV[b] max. for specified nominal thickness t in mm		
	$6 \le t \le 50$	$50 < t \le 100$	$100 < t \le 150$
PT440M	0,37	0,40	0,42
PT440ML1/ML3	0,37	—	—
PT490M	0,38	0,41	0,43

NOTE The values for the carbon equivalent are based on the percentage by mass and relate to the mechanical properties specified for the delivery condition.

[a] See 6.3.3.

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

Table B.2 *(continued)*

Steel grade	CEV[b] max. for specified nominal thickness t in mm		
	$6 \le t \le 50$	$50 < t \le 100$	$100 < t \le 150$
PT490ML1	0,38	0,41	—
PT490ML3	0,38	—	—
PT520M	0,40	0,42	0,44
PT520ML1	0,40	0,42	—
PT520ML3	0,40	—	—
PT520M	0,42	0,45	—
PT520ML1	0,42	0,45	—

NOTE The values for the carbon equivalent are based on the percentage by mass and relate to the mechanical properties specified for the delivery condition.

[a] See 6.3.3.

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

Table B.3 — Tensile properties at room temperature[a]

Steel grade	Nominal thickness t mm	Yield strength[b] R_{eH} MPa[c] min.	Tensile strength R_m MPa[c]	Elongation after fracture A % min.
PT440M	$6 \le t \le 50$	270	440 to 560	20
	$50 < t \le 100$	250		
	$100 < t \le 150$	230		
PT440ML1/ML3	$6 \le t \le 38$	325	440 to 560	19
PT490M	$6 \le t \le 50$	315	490 to 610	19
	$50 < t \le 100$	295		
	$100 < t \le 150$	275		
PT490ML1	$6 \le t \le 65$	345	490 to 620	19
	$65 < t \le 100$	310	460 to 590	
PT490ML3	$6 \le t \le 38$	365	490 to 610	17
PT520M	$6 \le t \le 50$	355	520 to 640	17
	$50 < t \le 100$	335		
	$100 < t \le 150$	315		
PT520ML1	$6 \le t \le 50$	385	520 to 640	17
	$50 < t \le 100$	365		
PT520ML3	$6 \le t \le 38$	410	520 to 640	16

[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.