INTERNATIONAL STANDARD

ISO 9328-5

Second edition
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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

Reference number
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Foreword

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

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

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

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 9328-5 was prepared by Technical Committee ISO/TC 17, *Steel*, Subcommittee SC 10, *Steel for pressure purposes*.

This second edition of ISO 9328-5 is a newly elaborated part of ISO 9328. The first edition (ISO 9328-5:1991) has been cancelled and replaced by ISO 9328-7.

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*

NOTE 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.

Introduction

This part of ISO 9328 was newly elaborated on the basis of European Standard EN 10028-5:1996 including additional steel grades. In comparison with EN 10028-5, it takes into consideration partly deviating and additional requirements, thus offering the possibility of specifying products in accordance with European design codes and ASME type design codes.

Steel flat products for pressure purposes — Technical delivery conditions —

Part 5: Weldable fine grain steels, thermomechanically rolled

1 Scope

This part of ISO 9328 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 shall be specially agreed upon between the interested parties.

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

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

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 9328-1:2003, *Steel plates and strips 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 purpose 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 in 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...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 Steel grades in Annex A are classified according to their yield strength; 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.4, footnote a).

5.2 Options

A number of options is specified in this part of ISO 9328. These are listed below under a) to e). 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) decreased minimum Al_{total} content (see Table B.1, footnote b);

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

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

e) other test requirements for the impact test (see Table B.4, 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 P355ML2 as specified in ISO 9328-5, inspection document 3.1.B as specified in ISO 10474:1991 is designated as follows:

10 plates – 50 × 2 000 × 10 000 – ISO 9328-5 P355ML2 – 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 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 analysis.

6.3.2 The product analysis may deviate from the specified values of the cast 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 part of ISO 9328, a carbon equivalent value according to Table A.2 (steel grades in Annex A) or Table B.2 (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 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	⩽ 0,20	+ 0,02
Si	⩽ 0,75	+ 0,06
Mn	⩽ 1,70	+ 0,10
P	⩽ 0,030	+ 0,005
S	⩽ 0,015	+ 0,003
	> 0,015 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
Ni	⩽ 0,50	+ 0,05
Ti	⩽ 0,05	+ 0,01
V	⩽ 0,10	+ 0,01
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 fall short of the permissible minimum value, but not both for one cast.

[b] Only specified for grades in Annex A..

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).

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 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 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.

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

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

where

T_s is the stress relieving temperature in Kelvin and

t is holding time in hours

exceeds the critical P value of $P_{crit} = 17$ (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 and, where appropriate, tests on simulated post-weld heat-treated samples may be agreed upon in 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

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, deviating from ISO 9328-1:2003, Table 3, footnote c, the preparation of 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.

9 Test methods

See ISO 9328-1.

• Impact tests for verification of impact energy values in Tables A.4 and B.4 shall be carried out on transverse test pieces (steel grades in accordance with Annex A) or on test pieces specified in the order (steel grades in accordance with Annex B. See Table B.4 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

Steel grade	% by mass[a]												
	C max.	Si max.	Mn max.	P max.	S max.	Al_{total}[b] min.	N max.	Mo[d] max.	Nb[e] max.	Ni max.	Ti[e] max.	V[e] max.	Others
P355M	0,14	0,50	1,60	0,025	0,020	0,020[c]	0,015	0,20	0,05	0,50	0,05	0,10	[d]
P355ML1				0,020	0,015								
P355ML2													
P420M	0,16	0,50	1,70	0,025	0,020		0,020						
P420ML1				0,020	0,015								
P420ML2													
P460M	0,16	0,60	1,70	0,025	0,020								
P460ML1				0,020	0,015								
P460ML2													

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

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

[d] (Cr + Cu + Mo) $\leqslant$ 0,60 %.

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

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

Steel grade	CEV[b] max. for specified product thickness t in mm		
	$t \leqslant 16$	$16 < t \leqslant 40$	$40 < t \leqslant 63$
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] $\text{CEV} = \text{C} + \frac{\text{Mn}}{6} + \frac{\text{Cr+Mo+V}}{5} + \frac{\text{Ni+Cu}}{15}$.

Table A.3 — Tensile properties at room temperature

Steel grade	Yield strength[a] R_{eH} for specified product thickness in mm N/mm² [a] min.			Tensile strength R_m N/mm²	Elongation after fracture A % min.
	$t \leqslant 16$	$16 < t \leqslant 40$	$40 < t \leqslant 63$		
P355M P355ML1 P355ML2	355		345	450 to 610	22
P420 P420ML1 P420ML2	420	400	390	500 to 660	19
P460M P460ML1 P460ML2	460	440	430	530 to 720	17

[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 $R_{p0,2}$.

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

Steel grades of the following series	Product thickness t mm	Impact energy KV J min. at a temperature in °C of				
		− 50	− 40	− 20	0	+ 20
P...M	5 [a] ⩽ t ⩽ 63	–	–	27	40	60
P...ML1		–	27	40	60	
P...ML2		27	40	60	80	

[a] See ISO 9328-1.

Annex B
(normative)

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

Table B.1 — Chemical composition (cast analysis)

Steel grade	% by mass[a]												
	C	Si	Mn	P	S	Al_{total}[b]	Cr	Cu	Mo	Nb	Ni	Ti	V
	max.	max.		max.	max.	min.	max.	max.	max.	max.	max.	max.	max.
PT440M	0,18	0,55	⩽ 1,60	0,030	0,030	0,020	0,30	0,40	0,20	0,05	0,50	0,05	0,10
PT440ML1	0,16	0,55	0,70 to ⩽ 1,60	0,025	0,020	0,020	0,30	0,40	0,20	0,05	0,50	0,05	0,10
PT440ML3													
PT490M	0,18	0,55	⩽ 1,60	0,030	0,030	0,020	0,30	0,40	0,20	0,05	0,50	0,05	0,10
PT490ML1	0,16	0,55	0,70 to ⩽ 1,60	0,025	0,020	0,020	0,30	0,40	0,20	0,05	0,50	0,05	0,10
PT490ML3													
PT520M	0,18	0,55	⩽ 1,60	0,030	0,030	0,020	0,30	0,40	0,20	0,05	0,50	0,05	0,10
PT520ML1	0,16	0,55	0,70 to ⩽ 1,60	0,025	0,020	0,020	0,30	0,40	0,20	0,05	0,50	0,05	0,10
PT520ML3													
PT550M	0,18	0,55[d]	⩽ 1,60	0,030	0,030	0,020	0,30	0,40	0,20	0,05	0,50	0,05	0,10
PT550ML1	0,18[c]	0,55	0,70 to ⩽ 1,60	0,025	0,020	0,020	0,30	0,40	0,20	0,05	0,50	0,05	0,10

[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 vales from the cast analysis
(if agreed upon at the time of enquiry and order) [a]

Steel grade	CEV[b] max. for specified product thickness t in mm		
	$6 \leqslant t \leqslant 50$	$50 < t \leqslant 100$	$100 < t \leqslant 150$
PT440M	0,37	0,40	0,42
PT440ML1/ML3	0,37	—	—
PT490M	0,38	0,41	0,43
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] $\text{CEV} = \text{C} + \frac{\text{Mn}}{6} + \frac{\text{Cr+Mo+V}}{5} + \frac{\text{Ni+Cu}}{15}$