INTERNATIONAL STANDARD

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Second edition
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Steel sheet and strip for welded gas cylinders

Produit en acier laminé à plat pour bouteilles à gaz soudées

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.

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 of 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 www.iso.org/iso/foreword.html.

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

This second edition cancels and replaces the first edition ISO 4978:1983, which has been technically revised. The following main changes have been made:

— the title has been changed from "flat rolled steel products" to "steel sheet and strip";

— the Scope has been changed from "flat rolled steel products with a thickness up to 6 mm" to "hot-rolled steel sheet and strip with a thickness up to 12 mm";

— the normative references have been updated;

— a new option c) for maximum carbon equivalent value has been added to the list of options for the purchaser in 4.2;

— statements concerning the surface condition under 6.5.1 and internal quality under 6.5.3 have been revised;

— the tables and statements concerning chemical composition, mechanical properties, testing and assessment of non-metallic inclusions have been completely revised or added;

— the Bibliography has been added.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Steel sheet and strip for welded gas cylinders

1 Scope

This document specifies the characteristics of hot-rolled steel sheet and strip with a thickness up to 12 mm inclusive of the non-alloyed steels listed in Table 1, which are intended for welded gas cylinders in accordance with ISO 4706.

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 148-1, *Metallic materials — Charpy pendulum impact test — Part 1: Test method*

ISO 377, *Steel and steel products — Location and preparation of samples and test pieces for mechanical testing*

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

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

ISO 4706, *Gas cylinders — Refillable welded steel cylinders — Test pressure 60 bar and below*

ISO 4967:2013, *Steel — Determination of content of non-metallic inclusions — Micrographic method using standard diagrams*

ISO 6892-1, *Metallic materials — Tensile testing — Part 1: Method of test at room temperature*

ISO 7438, *Metallic materials — Bend test*

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

ISO 16160, *Hot-rolled steel sheet products — Dimensional and shape tolerances*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

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

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

3.1
normalizing rolling
rolling process in which the final deformation process is carried out in a certain temperature range, leading to a material condition equivalent to that obtained after normalizing so that the specified values of the mechanical properties are retained even after normalizing

4 Information to be supplied by the purchaser

4.1 The following information shall be supplied by the purchaser at the time of enquiry and order:

a) the dimensions and tolerances of the product (see 6.6);

b) the steel grade (see Table 1);

c) the inspection procedures and type of the documents required.

4.2 A number of options are specified in this document and are listed below. If the purchaser does not indicate any of these options at the time of enquiry and order, products shall be supplied at the discretion of the manufacturer:

a) heat treatment condition of supply (see 5.2);

b) if a product analysis is required (see 6.1.2 and 9.1.2);

c) maximum carbon equivalent value (see 6.1.3);

d) surface condition of supply (see 6.5);

e) others (see 6.7).

5 Manufacturing process

5.1 Steelmaking

5.1.1 Unless otherwise stated at the time of enquiry and order, the steelmaking process and the deoxidation practice within the provisions of 5.1.2 and 5.1.3 shall be left to the discretion of the manufacturer.

5.1.2 The steel shall be produced by electric or one of the basic oxygen processes. Other steelmaking processes may be used by agreement between the parties concerned. On request, the purchaser shall be informed of the steelmaking process used.

NOTE Other parties include the user, purchaser and manufacturer of the equipment, the producer of the material supplied and the inspection and/or certifying authority.

5.1.3 The deoxidation procedure shall ensure that the steel has acceptable non-aging properties. The steel shall therefore be killed with aluminium so that Al_{sol} is equal to or greater than 0,015 %. However, other elements which, by binding the nitrogen, have a similar effect may also be used instead of, or in addition to, aluminium (see also Table 1).

If the manufacturer intends, however, to supply steels with such additions in contents higher than 0,05 %, this addition shall conform to the restriction given in ISO 4706 for the niobium, titanium and vanadium content.

5.2 Delivery condition

5.2.1 The delivery condition shall be agreed at the time of enquiry and order.

5.2.2 The most usual delivery condition is “hot rolled”. The product may, however, also be delivered in other conditions such as:

— hot rolled and normalized;

— normalizing rolling.

6 Technical requirements

6.1 Chemical composition

6.1.1 The chemical composition determined by heat analysis shall comply with the values specified in Table 1.

Table 1 — Chemical composition of heat analysis (%, by mass[a])

Grade	C	Si	Mn	P	S	Al_{sol}[b]
P235	≤ 0,16	≤ 0,15	≤ 0,80	≤ 0,025	≤ 0,015	≥ 0,015
P265	≤ 0,19	≤ 0,20	≤ 0,80			
P295	≤ 0,19	≤ 0,25	≤ 1,00			
P325	≤ 0,20	≤ 0,35	≤ 1,50			
P345	≤ 0,20	≤ 0,45	≤ 1,50			
P365	≤ 0,20	≤ 0,45	≤ 1,50			

[a] Microalloying elements may be added in order to improve the mechanical properties. The steel may show a Nb content of max.0,05 %, a V content of max. 0,10 % and a Ti content of max. 0,03 %, The total content of Nb and V shall not exceed 0,12 %.

[b] If the total aluminium content is determined, a content of not less than 0,018 % shall be deemed to fulfil the requirement of not less than 0,015 % Al_{sol}.

6.1.2 If a product analysis is required, the permissible deviations, relative to the limiting value of heat analysis (see Table 1), are given in Table 2.

If a product analysis for acceptance purpose is required, it shall be stated at the time of enquiry and order.

Table 2 — Permissible product analysis deviations on the limiting values (mass fraction, %)

Element	Specified value (see Table 1) %, by mass	Permissible deviations of the product analysis %, by mass
C	≤ 0,20	+0,02
Si	≤ 0,35	+0,03
	> 0,35	+0,05
Mn	≤ 0,80	+0,03
	> 0,80	+0,05
P	≤ 0,035	+0,005
S	≤ 0,035	+0,005
Al_{sol}	≥ 0,015	−0,003

6.1.3 A maximum carbon-equivalent value of 0,45 % based on heat analysis may be agreed upon at the time of enquiry and order. In this case, the Formula (1) shall apply for the calculation of the carbon-equivalent value (CEV):

$$CEV = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15} \quad (1)$$

6.2 Mechanical properties

6.2.1 The mechanical properties shall comply with the values in Table 3.

Table 3 — Mechanical properties at room temperature

Grade	Tensile test[a]				Impact test[a]	
	YS, R_{eH} MPa[b]	TS, R_m MPa[b]	Elongation after fracture, %		KV_2, J	
			A_{80mm} L_0 = 80 mm, b = 20 mm	A	5 mm × 10 mm × 55 mm	7,5 mm × 10 mm × 55 mm
			a < 3 mm	a ≥ 3 mm		
P235	≥ 235	380 to 500	≥ 23	≥ 29	≥ 23	≥ 29
P265	≥ 265	410 to 520	≥ 21	≥ 27		
P295	≥ 295	440 to 560	≥ 20	≥ 26		
P325	≥ 325	490 to 600	≥ 18	≥ 22		
P345	≥ 345	510 to 620	≥ 17	≥ 21		
P365	≥ 365	540 to 660	≥ 14	≥ 20		

[a] Applicable for transverse direction.

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

6.2.2 For the impact test, the averaged value of three test pieces shall comply with Table 3. One individual value may be below the specified value, provided that it is not less than 70 % of that value.

6.2.3 Impact tests shall be specified for sheet and strip over 6 mm in thickness. Sub-sized test pieces of 5 mm × 10 mm × 55 mm and 7,5 mm × 10 mm × 55 mm shall be used in the case of nominal product thickness of 6 mm ≤ t ≤ 8 mm and 8 mm < t ≤ 12 mm, respectively.

6.3 Grain size

The steel shall have a structure with ferritic grain size according to Index 6 or finer when determined in accordance with ISO 643.

6.4 Weldability

The steels covered by this document are weldable by the usual fusion welding processes. For the requirement of carbon equivalent value, see 6.1.3.

6.5 Surface condition and soundness

6.5.1 Depending on the specified surface condition, the sheet or strip shall be supplied either in the rolled condition or in the chemically or mechanically descaled and oiled condition.

6.5.2 Any special requirements for free from defects shall be agreed between the parties concerned at the time of enquiry and order.

6.5.3 The general technical delivery requirements for the surface and internal quality are given in ISO 404.

6.6 Dimensions and tolerances

The dimensions and tolerances of the products shall comply with the requirements agreed at the time of enquiry and order. The agreement shall be based on ISO 16160.

6.7 Other requirements

6.7.1 The following test items may be required by the purchaser. In this case, it shall be specified at the time of enquiry and order.

6.7.2 The ratio of yield strength to tensile strength shall not exceed 0,8.

6.7.3 The impact test may be carried out at −40 °C. The minimum values of impact energy are 18 J for 5 mm × 10 mm × 55 mm test piece and 23 J for 7,5 mm × 10 mm × 55 mm test piece.

6.7.4 For bend test, crack shall not appear in the test piece when it is bent around a former through 180°. The ratio n of the diameter of bend test former D to the thickness of test pieces a shall not exceed the values specified in Table 4. This test may not be carried out if manufacturer can guarantee the property of bend test.

Table 4 — Ratio of the diameter of former to the thickness of test piece

Grade	Bend test, $n = D/a$
P235	1,5
P265	1,5
P295	2,0
P325	2,0
P345	2,0
P365	2,0

6.7.5 The non-metallic inclusion shall comply with Table 5.

Table 5 — Non-metallic inclusion assessment according to Method A in ISO 4967

Type	A		B		C		D		DS
	Fine	Thick	Fine	Thick	Fine	Thick	Fine	Thick	
Index	≤ 2,0	≤ 2,0	≤ 2,0	≤ 2,0	≤ 2,0	≤ 2,0	≤ 2,0	≤ 2,0	≤ 2,0

7 Inspection

7.1 Types of inspection and inspection documents

7.1.1 The purchaser shall state the required type of inspection documents in accordance with ISO 10474 at the time of enquiry and order.

7.1.2 If, in accordance with the agreements in the order, an inspection certificate is to be provided, the specific inspections and tests described in 7.2 and Clauses 8 and 9 shall be carried out and the results shall be confirmed in the inspection certificate.

In addition, the inspection certificate shall contain the following information:

a) confirmation that the material complies with the requirements of the order;

b) results of the heat analysis for all elements specified in Table 1 for the steel grade concerned;

c) the symbol, letters or numbers relating the inspection certificate, test pieces and products to each other.

7.2 Test frequency

The amount of testing, the sampling conditions to be applied for the verification of the requirements shall be in accordance with the requirements of Table 6.

Table 6 — Type of test, sampling amount, sampling method

No.	Type of test	Test unit[a]	Number of test pieces	Mandatory test[b]	Optional test[b]
1	Chemical composition	C	1 per cast	×	
2	Tensile test	C+D+T	2 per 80t	×	
3	Impact test	C+D+T	3 per 80t	× (at RT[c])	× (at −40 °C)
4	Bend test	C+D+T	1 per 80t		×
5	Grain size	C+D+T	1 per 80t	×	
6	Non-metallic inclusion	C+D+T	1 per 80t		×

[a] The test should be carried out separately for each cast (symbol C), or for each cast and each dimension (symbol C+D),or for each cast, each dimension and each treatment (symbol C+D+T).

[b] Only if an inspection document in accordance with ISO 10474 is ordered.

[c] Room temperature.

7.3 Visual inspection

Every sheet and strip shall be inspected.

8 Sampling

8.1 The identification and preparation of sample and test pieces shall conform to ISO 377.

8.2 The steel sheet and strip shall be accepted in test unit. The test unit shall have a mass of no greater than 80 tons and shall consist of material from the same cast. Other requirements for the formation of test unit, such as same rolling unit and same thickness, shall be as specified in ISO 404.

8.3 The position from which the sample is to be taken shall lie halfway between the edge and the axis of the product and, in the case of coils, at the outer end of the coil. In cases of dispute, the distance between the outer end of the coil and the position from which the sample is taken shall be 1 m or greater.

8.4 From each test sample, one tensile test piece, three impact test pieces and one bend test piece (if agreed) shall be prepared with the direction transverse to final rolling. If the thickness is 3 mm or greater, tensile test piece shall be of rectangular section with dimensions in accordance with the requirements of ISO 6892-1. The width of the parallel portion shall not exceed 30 mm. The thickness shall be that of the product. If the thickness is less than 3 mm, the dimensions of the test pieces shall be those given in ISO 6892-1 for a gauge length of 80 mm.

9 Test methods

9.1 Chemical analysis

9.1.1 Unless otherwise agreed at the time of enquiry and order, the choice of a suitable physical or chemical analytical method for the heat analysis shall be left to the discretion of the manufacturer. In cases of dispute, the analysis shall be carried out by a laboratory approved by both parties. In this case, the analysis method to be used shall be agreed upon, if possible, with reference to the corresponding International Standards. If no International Standard is available, the method to be used shall be agreed between the parties concerned.

9.1.2 If a product analysis is required, the number of test pieces to be taken shall be agreed between the parties concerned. The test pieces shall be taken either from the samples used for the verification of the mechanical properties, or from the whole thickness of the product at the same location as for the mechanical test pieces.

9.2 Tensile test

The tensile test shall be carried out in accordance with ISO 6892-1. Transverse test pieces shall be taken at the 1/4 point (halfway between the edge and mid-width).

The tensile strength R_m, the yield strength R_{eH} and the elongation after fracture A shall be determined, and the results obtained shall meet the requirements given in Table 3.

For the yield strength, either the upper yield stress R_{eH} or the 0,2 % proof stress (plastic extension) $R_{p0,2}$ may be determined.

9.3 Impact test

The impact test shall be carried out in accordance with ISO 148-1. The test piece shall be in the transverse direction and the test shall be a Charpy V-notch test.

9.4 Bend test

The bend test shall be carried out in accordance with ISO 7438. The former shall be placed in the centre of the test piece while the test is being performed and remained in that position until the end of the test. The values for bend test apply to transverse test pieces.

9.5 Grain size

The test of grain size shall conform to ISO 643.

9.6 Non-metallic inclusion

The test of non-metallic inclusion shall conform to ISO 4967, Method A. If agreed between purchaser and manufacturer, alternative methods may be used, such as ASTM E45, Method A.

9.7 Retests

Retests shall be as specified in ISO 404.

10 Marking

The requirements of ISO 404 shall apply. The manufacturer shall mark the products in a suitable way, so that the identification of the cast, the steel grade and the origin of the delivery is applicable.