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Titanium and titanium alloys — Strip for welded tubes — Technical delivery conditions

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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 79, *Light metals and their alloys*, Subcommittee SC 11, *Titanium*.

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.

Introduction

This document was developed in response to worldwide demand for stabilizing the quality assurance for the strip for welded tubes by common regulations worldwide.

Determining condition concerning such technical delivery conditions for strips of titanium and titanium alloys used for welded tubes as chemical composition, mechanical properties and dimensional tolerance is extremely important to promote commerce of titanium and titanium alloys products in the global market.

The International Organization for Standardization (ISO) draws attention to the fact that it is claimed that compliance with this document may involve the use of patents concerning the titanium alloys given in Tables 1 and 2.

ISO takes no position concerning the evidence, validity and scope of these patent rights.

The holders of these patent rights have assured ISO that they are willing to negotiate licences under reasonable and non-discriminatory terms and conditions with applicants throughout the world. In this respect, the statement of the holders of these patent rights is registered with ISO. Information may be obtained from the patent database available at www.iso.org/patents.

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

Titanium and titanium alloys — Strip for welded tubes — Technical delivery conditions

1 Scope

This document specifies general requirements for the manufacture and technical delivery conditions of strips made from titanium and titanium alloys for welded tubes.

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

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

ISO 7438, *Metallic materials — Bend test*

ISO 9712, *Non-destructive testing — Qualification and certification of NDT personnel*

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

ISO 28401, *Light metals and their alloys — Titanium and titanium alloys — Classification and terminology*

ASTM E8/E8M, *Standard Test Methods for Tension Testing of Metallic Materials*

ASTM E539, *Standard Test Method for Analysis of Titanium Alloys by Wavelength Dispersive X-Ray Fluorescence Spectrometry*

ASTM E1409, *Standard Test Method for Determination of Oxygen and Nitrogen in Titanium and Titanium Alloys by Inert Gas Fusion*

ASTM E1447, *Standard Test Method for Determination of Hydrogen in Titanium and Titanium Alloys by Inert Gas Fusion Thermal Conductivity/Infrared Detection Method*

ASTM E1941, *Standard Test Method for Determination of Carbon in Refractory and Reactive Metals and Their Alloys by Combustion Analysis*

ASTM E2371, *Standard Test Method for Analysis of Titanium and Titanium Alloys by Direct Current Plasma and Inductively Coupled Plasma Atomic Emission Spectrometry (Performance-Based Test Methodology)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 28401 and the following apply.

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

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

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

3.1
strip
flat rolled product of rectangular cross-section with uniform thickness of 0,30 mm or more and less than 4,5 mm supplied in coils usually with slit edges with width of 20 to 610 mm

Note 1 to entry: The thickness does not exceed one-tenth of the width.

3.2
burr height
deformation height raised by slitting at the edges of the strip

3.3
wave
ratio of the wave height (H) for the suitable length (L) of the length of the strip in the longitudinal direction

Note 1 to entry: H is the maximum height difference between the peak and valley of the wave in the longitudinal direction of the strip.

Note 2 to entry: L is the arbitrary length of periodic distortion or arbitrary length of localized distortion.

3.4
camber
maximum horizontal curve between a reference line of 2 000 mm long placed between any two points on the cut edge of the strip

3.5
lot
set of products with the same nominal size produced with the same ingot, processing, heat treatment and chemical treatment

4 Information to be supplied by the purchaser

4.1 General information

The purchase order shall include the following information:

a) quantity (e.g. total mass or total length of the strip);

b) designation;

c) thickness and width;

d) packaging;

e) inspection;

f) certification.

4.2 Options

A number of options are specified in this document:

a) restrictive chemistry (see 6.2);

b) product analysis (see 6.2);

c) special mechanical properties (see 6.3 and 6.4);

d) special tolerance (see 6.5);

e) method of manufacture and finish (see Clause 5 and 6.6).

In the event that the purchaser does not indicate a wish to implement any of these options at the time of enquiry and order, the strip shall be supplied in accordance with the basic specification.

5 Manufacturing

The strip shall be manufactured by cold-rolling of the hot-stripped mill product followed by the appropriate surface conditioning and heat treatment. The strip shall be edge-cut by slitting in the requested width.

6 Requirements

6.1 General

When supplied in the delivery condition indicated in 4.1 and inspected in accordance with Clause 6, the strip shall conform to the requirements of this document.

6.2 Chemical composition

The titanium and titanium alloys strip shall conform to the chemical requirements given in Table 1.

The elements listed in Table 1 are either intentional alloy additions or elements that are inherent to the manufacture of titanium sponge, ingot or mill product.

The content of any element intentionally added to the formulation of heat shall be reported.

Other elements are those not specified in the relevant designated material, such as Cr and Mo of Ti1-0,18Pd, and those not originally specified in Table 1, such as Co and Hf. The choice of element taken as the other element shall be agreed between the purchaser and the manufacturer.

Other elements need not be reported unless the concentration is greater than 0,1 % for each, or 0,4 % for the total.

When agreed upon between the manufacturer and the purchaser and specified in the purchase order, other specific residual elements not listed in Table 1 may be added, and their content shall be reported.

The chemical analysis shall be conducted by the standard techniques normally utilized by the manufacturer and the purchaser. In case of disagreement, the test methods given in ASTM E2371 or ASTM E539 shall be used as the referee method, except for carbon, oxygen and hydrogen, which are not covered in those standards. The test methods given in ISO 22960, ISO 22961 or ISO 22962 may be used as the referee method for iron instead of those given in ASTM E2371 or ASTM E539. The test method given in ASTM E1409 shall be used as the referee method for oxygen and nitrogen. ISO 22963 may be used as the referee method for oxygen. The test method given in ASTM E1447 shall be used as a referee method for hydrogen. The test method given in ASTM E1941 shall be used as the referee method for carbon.

Table 1 — Chemical composition (% mass fraction)

Designation	C max.	O max.	N max.	H max.	Fe max. range	Al	V	Ru	Pd	Mo	Ni	Cr	Co	Si	Other elements max.	
															each	total
Ti1	0,08	0,18	0,03	0,015	0,20										0,1	0,4
Ti1H	0,08	0,18	0,03	0,015	0,20										0,1	0,4
Ti2L	0,08	0,20	0,03	0,015	0,25										0,1	0,4
Ti2	0,08	0,25	0,03	0,015	0,30										0,1	0,4
Ti3	0,08	0,35	0,05	0,015	0,30										0,1	0,4
Ti3H	0,08	0,35	0,05	0,015	0,30										0,1	0,4
Ti2L-0,18Pd	0,08	0,20	0,03	0,015	0,25				0,12 to 0,25						0,1	0,4
Ti2-0,18Pd	0,08	0,25	0,03	0,015	0,30				0,12 to 0,25						0,1	0,4
Ti-3Al-2,5V	0,08	0,15	0,03	0,015	0,25	2,5 to 3,5	2,0 to 3,0								0,1	0,4
Ti3-0,3Mo-0,75Ni	0,08	0,25	0,03	0,015	0,30					0,2 to 0,4	0,6 to 0,9				0,1	0,4
Ti-0,06Pd	0,08	0,25	0,03	0,015	0,30				0,04 to 0,08						0,1	0,4
Ti2-0,06Pd	0,08	0,25	0,03	0,015	0,30				0,04 to 0,08						0,1	0,4
Ti2-0,11Ru	0,08	0,25	0,03	0,015	0,30			0,08 to 0,14							0,1	0,4
Ti-0,5Co-0,06Pd	0,08	0,25	0,03	0,015	0,30				0,04 to 0,08				0,20 to 0,80		0,1	0,4
Ti2-0,45Ni-0,15Cr-0,015Pd-0,03Ru	0,08	0,25	0,03	0,015	0,30			0,02 to 0,04	0,01 to 0,02		0,35 to 0,55	0,10 to 0,20			0,1	0,4
Ti-1,5Al	0,08	0,25	0,03	0,015	0,30	1,0 to 2,0									0,1	0,4
Ti-0,25Fe-0,4Si	0,08	0,15	0,03	0,015	0,15 to 0,40									0,30 to 0,50	0,1	0,4

6.3 Tensile properties

The room temperature tensile properties of the strip in both longitudinal and transverse directions of final rolling shall conform to the requirements given in Table 2.

The tensile test shall be carried out in accordance with ISO 6892-1 or ASTM E8/E8M.

For measurement of the 0,2 % proof strength or yield strength, the strain increase rate on the gauge length shall be 0,3 %/min to 0,7 %/min. For measurement of the tensile strength after that of 0,2 % proof strength or yield strength, the strain increase rate estimated from the crosshead displacement rate shall be approximately 10 %/min to 40 %/min.

Mechanical properties for conditions other than those given in Table 2 may be agreed between the manufacturer and the purchaser.

Table 2 — Tensile properties at room temperature

Designation	Tensile strength (R_m) MPa		0,2 % Proof strength ($R_{p0,2}$)[a] MPa		Elongation in 50 mm[b] %
	min.	max.	min.	max.	min.
Ti1	240	—	138	310	24
Ti1H	270	410	165	—	24
Ti2L	340	510	215	—	23
Ti2	345	—	275	450	20
Ti3	450	—	380	550	18
Ti3H	480	620	345	—	18
Ti2L-0,18Pd	340	510	215	—	23
Ti2-0,18Pd	345	—	275	450	20
Ti-3Al-2,5V	620	—	483	—	12
Ti3-0,3Mo-0,75Ni	483	—	345	—	12
Ti-0,06Pd	345	515	275	—	20
Ti2-0,06Pd	345	—	275	450	20
Ti2-0,11Ru	345	—	275	450	20
Ti-0,5Co-0,06Pd	345	515	275	—	20
Ti2-0,45Ni-0,15Cr-0,015Pd-0,03Ru	345	—	275	450	20
Ti-1,5Al	345	—	215	450	20
Ti-0,25Fe-0,4Si	515	—	410	620	20

[a] 0,2 % proof strength is specified. When specific yielding point is exhibited, the yield strength (R_e) shall satisfy the specified strength.

[b] Elongation value when using a test piece with a gauge length different from 50 mm shall be agreed between the manufacturer and the purchaser.

6.4 Bend test

The room temperature bend test of the strip in the longitudinal direction of the final rolling shall be carried out in accordance with ISO 7438.

The strip, when subjected to the bending test under the conditions specified in Table 3, shall not generate any cracks outside the bent portion.

Table 3 — Bend test at room temperature

Designation	Bending angles Degrees °	Inside radius	
		Under 1,8 mm in thickness	1,8 mm to 4,5 mm in thickness
Ti1	105	1,5T	2T
Ti1H	105	1,5T	2T
Ti2L	105	2T	2,5T
Ti2	105	2T	2,5T
Ti3	105	2T	2,5T
Ti3H	105	2T	2,5T
Ti2L-0,18Pd	105	2T	2,5T
Ti2-0,18Pd	105	2T	2,5T
Ti-3Al-2,5V	105	2,5T	3T
Ti3-0,75Ni-0,3Mo	105	2T	2,5T
Ti-0,06Pd	105	1,5T	2T
Ti2-0,06Pd	105	2T	2,5T
Ti2-0,11Ru	105	2T	2,5T
Ti-0,5Co- 0,06Pd	105	2T	2,5T
Ti2-0,015Pd-0,03Ru-0,45Ni-0,15Cr	105	2T	2,5T
Ti-1,5Al	105	2T	2,5T
Ti-0,25Fe-0,4Si	105	1,5T	2T
Key T: thickness of the bend test specimen NOTE Upon request of the purchaser, the bend test may be carried out at 180°.			

6.5 Dimensional tolerance

6.5.1 Tolerance of thickness

The tolerance of thickness for the strip shall conform to Table 4.

When requested by the purchaser, the thickness tolerance on only one side, either the plus or minus side, may be designated. In this case, the tolerance of the lower side or the upper side may be 0 mm within the same range of tolerance specified in Table 4.

Table 4 — Permissible variation in thickness

Nominal thickness mm	Permissible variation in thickness (with respect to the nominal thickness, t)
0,3 to 1,73 excluded	±10 %
1,73 to 2,5 excluded	
2,5 to 4,5 excluded	

6.5.2 Tolerance of width

The tolerance of width for the strip shall conform to Table 5.

The tolerance of widths not included in the specified range given in Table 5 is determined by the agreement between the producer and purchaser.

Table 5 — Permissible variation in width

Dimensions in millimetres

Nominal thickness mm	Width		
	20 mm to 200 mm excluded	200 mm to 400 mm excluded	400 mm to 610 mm excluded
0,3 to 1,73 excluded	±0,13	±0,25	±0,51
1,73 to 2,5 excluded	±0,20	±025	±0,51
2,5 to 4,5 excluded	±0,25	±0,41	±0,51

6.5.3 Tolerance of burr height

The tolerance of the burr height shall conform to Table 6.

Table 6 — Permissible variation in burr height

Nominal thickness mm	Burr height (with respect to the nominal thickness, t)
0,3 to 1,73 excluded	Less than 10 % of t
1,73 to 2,5 excluded	
2,5 to 4,5 excluded	

6.5.4 Tolerance of wave

The tolerance of the wave shall conform to Table 7.

Table 7 — Permissible variation in wave

Nominal thickness mm	Height	Steepness
	H mm	H/L %
0,3 to 1,73 excluded	Less than 6	Less than 3,0
1,73 to 2,5 excluded		
2,5 to 4,5 excluded		
Key H: height L: length		

6.5.5 Tolerance of camber

The tolerance of the camber shall conform to Table 8.

Table 8 — Permissible variation in camber (the maximum horizontal curve in mm per 2 000 mm length)

Nominal thickness mm	Width		
	20 mm to 40 mm excluded	40 mm to 80 mm excluded	80 mm to 610 mm excluded
0,3 to 2,5 excluded	Less than 15/2 000	Less than 8/2 000	Less than 4/2 000

6.6 Surface conditions, imperfections and defects

The finished strip shall be clean and free of foreign material, shall have smooth edge, and shall be free of injurious external and internal imperfections detrimental to use. Minor defects may be removed, provided the dimensional tolerances are not exceeded. The specific index value for defects and the treatment of defects detrimental to use shall be agreed between the purchaser and manufacturer.

6.7 Finish

The strip should be cut by slit-cutting. The cut edges shall be free from burrs and imperfections. The angle of cut of the edge of any strip may be at right angles to keep defect-free welded part.

The surface of the strip shall be smooth without lamination. The surface shall be treated by alkaline washing. Pickling, sandblasting and grinding for supply are permitted.

The surface quality for the strip shall be examined by visual inspection or by a defect inspector.

7 Inspection

7.1 Types of inspection and inspection documents

7.1.1 General

Compliance with the requirements of the purchase order shall be checked by specific inspection in accordance with ISO 10474.

Inspection documents shall be in a printed or electronic form such as an EDI (Electronic Data Interchange) transmission that conforms to any EDI agreement between the purchaser and the manufacturer.

7.1.2 Inspection documents

If agreed, the manufacturer shall provide inspection certificate 3.1 or 3.2 in accordance with ISO 10474.

7.2 Specific inspection

7.2.1 General

All tests and inspections required by this document shall be made at the place of manufacture prior to shipment and at the manufacturer's expense unless otherwise specified. They shall be conducted so as not to interfere unnecessarily with the operation of the works. When specified in the order, the manufacturer shall notify the purchaser in time so that the purchaser can have his/her inspector present to witness any part of the tests that are desired.

When agreed in writing between the manufacturer and the purchaser, a certification that the material conforms to the requirements of this document shall be the basis for acceptance of the material. Otherwise, the manufacturer shall report to the purchaser or his/her representative the results of the chemical analyses and mechanical tests made in accordance with this document.

Additional requirements for strips for welded rolled tubes for heat exchanger or condenser application are specified in Annex A to guarantee the levels of quality and reliability.

7.2.2 Samples and test pieces for chemical composition and mechanical tests or product analysis

7.2.2.1 General

The preparation of test pieces for tensile testing requested by this document shall conform to ISO 377.

The test specimens and the tests for mechanical tests required by this document shall conform to those described in ISO 6892-1 or ASTM E8/E8M.

All routine mechanical tests shall be made at room temperature.

7.2.2.2 Number of tests

The chemical composition of a lot with the same nominal size shall be the ingot manufacturer's analysis, except for hydrogen, which shall be determined on each sample from the lot. Hydrogen determination shall be one strip analysis per lot with same ingot, heat treatment and thickness.

For the sample for mechanical testing, two samples shall be selected from strips of the same nominal size from a lot with the same ingot, rolling, heat treatment, heat process and chemical treatment. Samples shall be selected at both top and bottom portions of coil. The size of the lot may be either the manufactured lot or the purchased lot at the manufacturer's option.

One tension test in accordance with 6.3 shall be made on each sample.

One bend test in accordance with 6.4 shall be made on each sample.

If any test specimen shows defective machining or develops flaws due to preparation, the specimen may be discarded and another substituted.

If the per cent of elongation of any tension test specimen is less than specified in 6.3, and any part of the fracture is more than 19 mm (3/4 inch) away from the centre of the gage length as indicated by scratches marked on the specimen before testing, the specimen may be discarded and another substituted.

7.2.2.3 Retests

If the results of any chemical or mechanical property test lots are not in conformity with the requirements of this document, the lot may be retested at the option of the manufacturer. The frequency of the retest doubles the initial number of tests. If the results of the retest conform to this document, the retest values may be the test values for certification. Only original confirming test results or the conforming retest results shall be reported to the purchaser. If the results for the retest fail to conform to this document, the material shall be rejected.

8 Rounding-off procedure

For purposes of determining conformity with this document, an observed or calculated value shall be rounded off to the nearest unit in the last right-hand significant digit used to express the limiting value. This is in accordance with the round-off method of practice given in ASTM E29.

9 Reference test and analysis

In the event of a disagreement between the manufacturer and the purchaser on the conformity of the material to the requirements of this document, a mutually acceptable referee shall perform the tests in question. The referee's testing shall be used in determining conformity of the materials to this document.

10 Rejection

Material not conforming to this document nor to authorized modifications shall be subject to rejection unless otherwise specified. Rejected materials may be returned to the manufacturer at the manufacturer's expense, unless the purchaser receives within three weeks of notice of rejection other instructions for disposition.

11 Marking

11.1 General

The strip shall be marked by the manufacturer.

The strip shall be marked near the outside end of the coil.

The marking by labels attached on the packaging surface wrapping strip coil is permitted.

Additional markings, as desired by the manufacturer or as specified in the purchase order, may be applied.

The markings shall have no deleterious effects on the materials and performance. The marking characters shall be sufficiently stable to withstand ordinary handling.

11.2 Strip marking

Strip marking shall include the following information, as applicable.

a) Private name or identifying mark of the manufacturer of the strip (X).

b) Designation (see Table 1).

c) Heat number and lot number.

d) Specified thickness (t).

e) Specified width (w).

f) Mark of the customer's inspection representative (Y), if applicable.

EXAMPLE X Ti2 Heat N° Lot N° 0,35t x 72,5w mm

12 Packaging

The strip shall be packaged in accordance with the manufacturer's standard practice, unless otherwise agreed between the manufacturer and the purchaser and so stated in the purchase order.

13 Quality assurance

If certification is requested by the purchaser, the manufacturer shall supply at least one copy of his/her report certifying that the material supplied has been inspected and tested in accordance with the requirements of this document and that the results of chemical analyses and mechanical tests meet the requirements of this document for the appropriate designated material.