

BS EN 4800-002:2010



BSI Standards Publication

Aerospace series — Titanium and titanium alloys — Technical specification

Part 002: Bar and section

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EUROPEAN STANDARD

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Aerospace series - Titanium and titanium alloys - Technical specification - Part 002: Bar and section

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Luft- und Raumfahrt - Titan und Titanlegierungen
Knetzeugnisse - Technische Lieferbedingungen - Teil
002: Stangen und Profile

This European Standard was approved by CEN on 20 February 2010.

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Foreword

This document (EN 4800-002:2010) has been prepared by the Aerospace and Defence Industries Association of Europe - Standardization (ASD-STAN).

After enquiries and votes carried out in accordance with the rules of this Association, this Standard has received the approval of the National Associations and the Official Services of the member countries of ASD, prior to its presentation to CEN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by May 2011, and conflicting national standards shall be withdrawn at the latest by May 2011.

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

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

Introduction

This standard is part of the series of EN metallic material standards for aerospace applications. The general organization of this series is described in EN 4258.

1 Scope

This standard defines the requirements for the ordering, manufacture, testing, inspection and delivery of titanium and titanium alloy bar and section. It shall be applied when referred to and in conjunction with the EN material standard unless otherwise specified on the drawing, order or inspection schedule.

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.

EN 2002-001, *Aerospace series — Metallic materials — Test methods — Part 001: Tensile testing at ambient temperature*

EN 2002-002, *Aerospace series — Metallic materials — Test methods — Part 002: Tensile testing at elevated temperature*

EN 2002-005, *Aerospace series — Test methods for metallic materials — Part 005: Uninterrupted creep and stress-rupture testing*

EN 2002-16, *Aerospace series — Metallic materials — Test methods — Part 16: Non-destructive testing — Penetrant testing*¹⁾

EN 2032-1, *Aerospace series — Metallic materials — Part 1: Conventional designation*

EN 2032-2, *Aerospace series — Metallic materials — Part 2: Coding of metallurgical condition in delivery condition*

EN 2078, *Aerospace series — Metallic materials — Manufacturing schedule, inspection schedule, inspection and test report — Definition, general principles, preparation and approval*

EN 2954-002, *Aerospace series — Macrostructure of titanium and titanium alloy wrought products — Part 002: Macrostructure of bar, section, forging stock and forgings*

EN 2955, *Aerospace series — Recycling of titanium and titanium alloy scrap*

EN 3114-001, *Aerospace series — Test method — Microstructure of ($\alpha + \beta$) titanium alloy wrought products — Part 001: General requirements*

EN 3114-002, *Aerospace series — Test method — Microstructure of ($\alpha + \beta$) titanium alloy wrought products — Part 002: Microstructure of bars, sections, forging stock and forgings*

EN 3238, *Aerospace series — Metallic materials — Test method — Shear test for wires and rivets*

EN 3683, *Aerospace series — Test methods — Titanium alloy wrought products — Determination of primary α content — Point count method and line intercept method*

EN 3684, *Aerospace series — Test methods — Titanium alloy wrought products — Determination of β transus temperature — Metallographic method*

EN 3874, *Aerospace series — Test method for metallic materials — Constant amplitude force-controlled low cycle fatigue testing*¹⁾

1) In preparation at the date of publication of this standard.

EN 3976, *Aerospace series — Titanium and titanium alloys — Test method — Chemical analysis for the determination of hydrogen content*

EN 3987, *Aerospace series — Test methods for metallic materials — Constant amplitude force-controlled high cycle fatigue testing*

EN 3988, *Aerospace series — Test method for metallic materials — Constant amplitude strain-controlled low cycle fatigue testing* ²⁾

EN 4050-1, *Aerospace series — Test method for metallic materials — Ultrasonic inspection of bars, plates, forging stock and forgings — Part 1: General requirement* ²⁾

EN 4050-4, *Aerospace series — Test method for metallic materials — Ultrasonic inspection of bars, plates, forging stock and forgings — Part 4: Acceptance criteria* ²⁾

EN 4258, *Aerospace series — Metallic materials — General organization of standardization — Links between types of EN standards and their use*

EN 4259, *Aerospace series — Metallic materials — Definition of general terms* ²⁾

EN 9100, *Quality Management Systems — Requirements for Aviation, Space and Defense Organizations*

EN 9133, *Aerospace series — Quality management systems — Qualification procedure for aerospace standard parts*

EN ISO 643, *Steels — Micrographic determination of the apparent grain size (ISO 643:2003)*

EN ISO 4288, *Geometrical product specifications (GPS) — Surface texture: Profile method — Rules and procedures for the assessment of surface texture (ISO 4288:1996)*

EN ISO 6892-1, *Metallic materials — Tensile testing — Part 1: Method of test at room temperature (ISO 6892-1:2009)*

prEN ISO 6892-2, *Metallic materials — Tensile testing — Part 2: Method of test at elevated temperature (ISO/DIS 6892-2:2009)*

TR 2410, *Aerospace series — Metallic materials — Relationship between dimensional standards and material standards* ³⁾

AMS 2750, *Pyrometry* ⁴⁾

ASTM E 399, *Standard test method for linear-elastic plane-strain fracture toughness K_{Ic} of metallic materials* ⁴⁾

2) In preparation at the date of publication of this standard.

3) Published as ASD-STAN Technical Report at the date of publication of this standard.

4) Published by: American Society for Testing and Materials (ASTM), 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA, 19428-2959 USA.

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 4259 apply.

4 Wording of order

The order shall clearly indicate:

- quantities to be supplied;
- dates of delivery;
- material standard number;
- delivery condition and metallurgical code of products;
- dimensions and tolerances or reference to an appropriate dimensional standard;
- product designation, when required;
- forwarding address;
- nature and type of packing, if required;
- definition and frequency of any special tests and their retest procedures, if required.

5 Health and safety

The products in the delivery condition shall fulfil the health and safety laws of the area of the country when and where it is to be delivered.

A product safety data sheet shall be available.

6 Technical requirements

6.1 General

The product shall be manufactured in accordance with the requirements of the relevant material standard and the applicable requirements of this specification. A manufacturing schedule shall be established and applied in accordance with EN 2078.

Product shall satisfy the requirements of the material standard and/or order and shall be free from irregularities prejudicial to the subsequent manufacture or use of this product.

Notwithstanding previous acceptance complying with this material standard, any product that is found, at a later stage, to contain such defects shall be rejected.

Unless otherwise specified, the requirements in Tables 1 and 2 shall apply in conjunction with those of the relevant material standard. Table 1 relates to lines 1 to 29 (inclusive) of the material standard and Table 2 relates to lines 30 onwards in which the sub-line format is also used. Lines 2 to 98 may also be opened in line 100 if the material standard details specific qualification requirements. If a specific line number is not shown in Tables 1 and 2, the requirement is stated in the material standard and/or order.

The requirements of the order and/or material standard shall over-ride the requirements of the technical specification.

6.2 Qualification requirements

Qualification requirements when invoked by the material standard and/or order are detailed in Tables 1 and 2. Unless otherwise agreed between the manufacturer and purchaser the qualification phase shall be run on the first three batches, coming from three different ingots.

6.3 Release requirements

6.3.1 Release tests

Release testing shall be the responsibility of the manufacturer.

The purchaser reserves the right to perform any of the inspections and/or tests required by the material standard and/or order.

The test samples shall be representative of the product.

When required the manufacturer shall inform the purchaser of the planned dates for extraction of samples and release testing in order that these operations may be witnessed.

Tables 1 and 2 detail the requirements for each line of the material standard. Unless otherwise specifically requested by the purchaser, a particular inspection and/or test for release shall be carried out if corresponding acceptance criteria and/or values are stated in the applicable material standard, but see also in 6.3.5.

6.3.2 Retests

If the test procedure or test piece preparation is faulty, testing shall be re-applied at the original frequency after rectification of the original cause of failure.

When failure cannot be attributed to faulty testing, or test piece preparation, further test samples shall be selected at twice the original frequency from the product, one of which shall be that on which the original results were obtained unless already withdrawn by the manufacturer after suitable identification of the cause of failure. If all retest results are satisfactory, the batch shall be accepted. If one or more tests are unsatisfactory, the batch shall be:

- rejected; or
- 100 % retested and the conforming products accepted; or
- partially or fully re-heat treated if heat treatment can rectify the cause of the failure and tested as a completely new batch except for chemical composition, for which redetermination of hydrogen content is required. No product or test sample shall be re-heat treated more than twice.

6.3.3 Rejection

Any failure to meet the requirements of the material standard shall be cause for rejection.

6.3.4 Special tests

Special tests may be required by the purchaser. In such cases, the nature of the test, method, frequency and technical requirements shall be specified on the order or inspection schedule and shall be mutually agreed by the manufacturer and purchaser.

6.3.5 Capability clause

Where capability clause is invoked and where sufficient statistical evidence exists, the test shall not be carried out (unless specifically requested by the purchaser). However, this in no way reduces the obligations of the manufacturer to fulfil the requirements. If subsequent testing indicates that the product does not comply with the requirements, the batch shall be rejected.

If sufficient statistical evidence does not exist, the test shall be carried out at a frequency agreed between the manufacturer and the purchaser.

6.3.6 Statistical process control

Reduction in the extent of release testing, other than that defined in 6.3.5 above, may be negotiated with the purchaser on the basis of appropriate statistical process control and/or statistical data.

6.3.7 Inspection and test report

The manufacturer shall furnish, with each delivery, a report conforming to the requirements of EN 2078 stating the following:

- manufacturer's name and address and, if appropriate, identification of the plant;
- order number;
- material standard number;
- delivery condition and metallurgical code of the product;
- quantity and dimensions;
- manufacturing and inspection schedule reference;
- cast and batch number;
- batch and/or test samples heat treatment condition;
- results of the tests and retests if any.

6.4 Traceability

Each product shall be traceable to the cast, production batch and/or heat treatment batch at all stages of manufacture, testing and delivery.

Table 1 — Technical requirements for lines 1 to 29, where appropriate

Material standard line reference		Requirements	Frequency of testing	
			Qualification	Release
No	Title			
1	Material designation	See EN 2032-1.	—	—
2	Chemical composition	The test samples used for chemical analysis shall be representative of the product and shall be taken from location corresponding to top and bottom of each ingot produced after the final melting stage. The method of chemical analysis shall be at the discretion of the manufacturer unless otherwise stated in the material standard or order. In cases of dispute, the method of chemical analysis shall be agreed between the manufacturer and purchaser preferably using existing chemical analysis standards. The measured chemical composition shall be stated on the inspection certificate.	2 per cast	2 per cast
		Specific requirements for hydrogen content: The hydrogen content shall be determined on each batch in the delivery condition in accordance with EN 3976.	1 per batch	1 per batch
3	Method of melting	Method of melting consists of multiple melt using combination of non-consumable electrode, consumable electrode and cold hearth (electron beam or plasma arc) melting practices. Some of the following requirements are dependent on the actual melting route non-consumable electrode melting should be used for consolidation purpose only. 1 <u>Raw material:</u> Raw materials shall be purchased only from suppliers approved by the manufacturer and registered in his list of approved suppliers. Approval of suppliers shall be made in accordance with written procedures contained within the quality assurance system of the manufacturer. <u>Titanium sponge and alloying elements:</u> The requirements shall be specified by the manufacturer who shall also establish the following procedures for the evaluation and acceptance testing of each batch: — titanium sponge: manufacturing method, level of impurities, particle size, freedom from surface contamination; — alloying elements: chemical composition including level of impurities, particle size, freedom from foreign particles.	—	—

continued

Table 1 — Technical requirements for lines 1 to 29, where appropriate (continued)

Material standard line reference		Requirements	Frequency of testing																																					
No	Title		Qualification	Release																																				
3	Method of melting (continued)	<p>Recycling of scrap:</p> <p>See EN 2955.</p> <p>The categories and sub-categories of scrap which may be used by the manufacturer are given in the following table.</p> <table><tr><th>Scrap categories and sub-categories (see EN 2955)</th><th>Melting method which includes cold hearth</th><th>VAR-only melt method</th></tr><tr><td>1</td><td>allowed</td><td>allowed</td></tr><tr><td>2</td><td>allowed</td><td>allowed</td></tr><tr><td>3</td><td>allowed</td><td>allowed</td></tr><tr><td>4.1</td><td>allowed ^a</td><td>allowed ^a</td></tr><tr><td>4.2.1</td><td>allowed ^{a b}</td><td>allowed ^a</td></tr><tr><td>4.2.2</td><td>allowed ^{a b}</td><td>not allowed ^a</td></tr><tr><td>4.3.1</td><td>allowed ^{a b}</td><td>allowed ^a</td></tr><tr><td>4.3.2</td><td>allowed ^{a b}</td><td>not allowed ^a</td></tr><tr><td>5.1</td><td>allowed</td><td>allowed</td></tr><tr><td>5.2</td><td>not allowed</td><td>not allowed</td></tr><tr><td>6</td><td>not allowed</td><td>not allowed</td></tr></table> <p>^a Only turnings produced by the melter shall be used, unless otherwise agreed by the purchaser.</p> <p>^b X-ray inspection not required.</p> <p>Foundry scrap, castings, bolts or used components shall not be used.</p> <p>The manufacturer shall maintain a list of his approved scrap processors. The list shall indicate the categories of scrap for which the processors are approved.</p> <p>Each order for scrap shall refer to EN 2955, specify the category and, if necessary, the sub-category of the scrap. In the case of turnings the limits for O₂, C and H₂ shall also be specified.</p>	Scrap categories and sub-categories (see EN 2955)	Melting method which includes cold hearth	VAR-only melt method	1	allowed	allowed	2	allowed	allowed	3	allowed	allowed	4.1	allowed ^a	allowed ^a	4.2.1	allowed ^{a b}	allowed ^a	4.2.2	allowed ^{a b}	not allowed ^a	4.3.1	allowed ^{a b}	allowed ^a	4.3.2	allowed ^{a b}	not allowed ^a	5.1	allowed	allowed	5.2	not allowed	not allowed	6	not allowed	not allowed	—	—
Scrap categories and sub-categories (see EN 2955)	Melting method which includes cold hearth	VAR-only melt method																																						
1	allowed	allowed																																						
2	allowed	allowed																																						
3	allowed	allowed																																						
4.1	allowed ^a	allowed ^a																																						
4.2.1	allowed ^{a b}	allowed ^a																																						
4.2.2	allowed ^{a b}	not allowed ^a																																						
4.3.1	allowed ^{a b}	allowed ^a																																						
4.3.2	allowed ^{a b}	not allowed ^a																																						
5.1	allowed	allowed																																						
5.2	not allowed	not allowed																																						
6	not allowed	not allowed																																						

continued

Table 1 — Technical requirements for lines 1 to 29, where appropriate (continued)

Material standard line reference		Requirements	Frequency of testing	
			Qualification	Release
No	Title			
3	Method of melting (continued)	<p>2 <u>Charge preparation:</u></p> <p>The melter shall establish procedures for the charge make up which shall include, if appropriate:</p> <ul style="list-style-type: none">— scrap categories and sub-categories to be used;— amount of recycled scrap;— charge composition;— requirements for recording the constitution of each charge;— compaction. <p>The scrap shall be of the same alloy, or compatible with the final alloy composition.</p> <p>3 <u>Electrode constitution (if appropriate):</u></p> <p>Build up of electrodes and attachment of their stubs shall be carried out under a vacuum or inert gas atmosphere in accordance with the procedure defined by the manufacturer.</p> <p>4 <u>Welding:</u></p> <p>The welding method to be used for fabricating electrodes, joining electrodes and joining stubs to the electrode shall be Metal Inert Gas (MIG) or Plasma in an inert gas atmosphere or Electron Beam (EB) under vacuum. In addition stubs may be attached to electrodes by electric arc in a VAR furnace.</p> <p>5 <u>Melting:</u></p> <p>Melting process consists of:</p> <ul style="list-style-type: none">— a first melting using a consumable electrode or a cold hearth process, (non consumable electrode is no longer in use as a first melt);— at least one consumable electrode remelting, except where a cold hearth melting route is used for commercially pure titanium. <p>Scrap may only be used during the first melt, except for striking the arc.</p> <p>The stub weld interface shall not be melted during the second or subsequent melts. The stub weld interface may be melted during the first melting operation if the stub is of the same alloy and the weld has been made without filler metal, in a vacuum or inert gas atmosphere.</p>	—	—

continued

Table 1 — Technical requirements for lines 1 to 29, where appropriate (continued)

Material standard line reference		Requirements	Frequency of testing	
No	Title		Qualification	Release
3	Method of melting (concluded)	<p>Arc breaks during the final melting operation shall not exceed 60 s during steady state melting.</p> <p>An appropriate system shall be provided for the control, checking and verification of the voltage, pressure, and either current or melt rate.</p> <p>The manufacturer shall establish written procedures which define (if appropriate):</p> <ul style="list-style-type: none"> — the cleaning of furnace and ingot-moulds; — the purity of inert gas used; — the current, the voltage and the maximum allowed pressure during melting; — the maximum allowed leak rate in the furnace; — the hot topping cycle at the end of the final melt; — the inspection of the stub weld interface after melting. 	—	—
4.1	Form	Bar and section	—	—
4.2	Method of production	<p>Mechanical hot working:</p> <p>The manufacturer shall establish a procedure for mechanical hot working.</p> <p>This procedure shall define:</p> <ul style="list-style-type: none"> — the homogenisation thermal cycle; — the thermo-mechanical working processes; — the manufacturing schedule for each process: the temperatures and durations of pre-heating; the maximum time of each working process; the dimensions of the products at each step and conditions for heat treatment between operations. <p>Mechanical cold working:</p> <p>The manufacturer shall establish a procedure for the mechanical cold working.</p> <p>This procedure shall define:</p> <ul style="list-style-type: none"> — the mechanical working processes; — the manufacturing schedule for each process; the dimensions of the products at each step and heat treatment conditions between operations. <p>Final conversion shall be done by hot or cold rolling according to material standard.</p>		

continued

Table 1 — Technical requirements for lines 1 to 29, where appropriate (continued)

Material standard line reference		Requirements	Frequency of testing	
			Qualification	Release
No	Title			
4.2	Method of production (concluded)	<p>Straightening:</p> <p>Straightening and stress relieving operations shall be indicated in the manufacturing schedule and shall not cause any defects prejudicial to the intended use.</p> <p>Surface finishing:</p> <p>Products shall be supplied in the descaled condition. For products in the machined condition, all additional requirements shall be defined on the order. The surface finish shall allow the satisfactory performance of the inspection operation specified.</p> <p>The method used for removal of defects such as cracks, burrs, etc. from the edges and ends of products shall be agreed between manufacturer and purchaser.</p>	—	—
4.3	Limit dimension(s)	Minimum and/or maximum size of the product expressed as the nominal thickness a , or nominal thicknesses for multi-legged/flanged sections, or as a nominal diameter, D , of round bar or as equivalent diameter D_e of non circular or non rectangular section products.	—	—
5	Technical specification	Reference to this technical specification EN 4800-002. In cases of conflict, the requirements of the material standard shall take precedence over those of this technical specification.	—	—
6.1	Delivery condition	<p>Product shall be supplied in the delivery condition specified in this line in the material standard and/or as stated on the order.</p> <p>Marking:</p> <p>The method of marking used shall not cause corrosion, crack initiation, contamination or unacceptable deformation. The marking shall remain permanently visible after handling and contact with protective products.</p> <p>Unless otherwise specified, the nature and colour of marking ink and type of marking characters shall be left to the discretion of the manufacturer. The marking inks shall be removable with cleaning products which do not leave a residue which could affect further processing. The cleaning products shall not give rise to corrosion.</p>	—	—

continued

Table 1 — Technical requirements for lines 1 to 29, where appropriate (continued)

Material standard line reference		Requirements	Frequency of testing													
No	Title		Qualification	Release												
6.1	Delivery condition	<p>All lengths shall be marked legibly as indicated in the following tables unless otherwise agreed between the manufacturer and purchaser:</p> <table><tr><th colspan="2">Products of diameter or major sectional dimension, a or $D \geq 12,5$ mm</th></tr><tr><th>Continuous marking ^a</th><th>End marking ^b</th></tr><tr><td><ul style="list-style-type: none">Material standardNominal dimensions in millimetres or part/drawing no.Delivery condition codeManufacturer/plant identification</td><td>—</td></tr><tr><td colspan="2">^a Ink or similar product shall be used. All information shall be repeated at least every 500 mm. ^b Hard stamping on one end of the length.</td></tr></table> <table><tr><th colspan="2">Products of diameter or major sectional dimension, a or $D < 12,5$ mm</th></tr><tr><td colspan="2"><ul style="list-style-type: none">The information stated in the above table shall be indelibly marked on a durable label attached to each bundle or products.</td></tr></table> <p>Packing:</p> <p>All necessary precautions shall be taken to prevent damage to the product, especially where the delivered surface finish shall be maintained.</p> <p>The packing shall be suitable for the type of transportation used.</p> <p>The exterior of the packing shall bear the following information:</p> <ul style="list-style-type: none">— name and address of recipient;— mass;— order number and sufficient information to enable the contents to be related to the relevant documentation. <p>Shipment:</p> <p>The responsibility for shipping shall be detailed in a transport contract.</p>	Products of diameter or major sectional dimension, a or $D \geq 12,5$ mm		Continuous marking ^a	End marking ^b	<ul style="list-style-type: none">Material standardNominal dimensions in millimetres or part/drawing no.Delivery condition codeManufacturer/plant identification	—	^a Ink or similar product shall be used. All information shall be repeated at least every 500 mm. ^b Hard stamping on one end of the length.		Products of diameter or major sectional dimension, a or $D < 12,5$ mm		<ul style="list-style-type: none">The information stated in the above table shall be indelibly marked on a durable label attached to each bundle or products.		—	—
Products of diameter or major sectional dimension, a or $D \geq 12,5$ mm																
Continuous marking ^a	End marking ^b															
<ul style="list-style-type: none">Material standardNominal dimensions in millimetres or part/drawing no.Delivery condition codeManufacturer/plant identification	—															
^a Ink or similar product shall be used. All information shall be repeated at least every 500 mm. ^b Hard stamping on one end of the length.																
Products of diameter or major sectional dimension, a or $D < 12,5$ mm																
<ul style="list-style-type: none">The information stated in the above table shall be indelibly marked on a durable label attached to each bundle or products.																

continued

Table 1 — Technical requirements for lines 1 to 29, where appropriate (continued)

Material standard line reference		Requirements	Frequency of testing																															
No	Title		Qualification	Release																														
6.1	Heat treatment	<p>Thermal and/or thermomechanical operations shall be applied to the product as specified in the material standard and are listed in the same order as they are to be applied. No product shall be re-solution heat treated more than once without the agreement of the purchaser. Abbreviations and symbols used in the material standard are shown in the following table: all other terms are written in full.</p> <table><tr><th>Term</th><th>Abbreviation/Symbol</th><th>Term</th><th>Abbreviation/Symbol</th></tr><tr><td>temperature</td><td>θ</td><td>water quench</td><td>WQ</td></tr><tr><td>time</td><td>t</td><td>oil quench</td><td>OQ</td></tr><tr><td>hour</td><td>h</td><td>forced air quench</td><td>AQ</td></tr><tr><td rowspan="2">minute</td><td rowspan="2">min</td><td>air cool</td><td>AC</td></tr><tr><td>furnace cool</td><td>FC</td></tr></table> <p>AMS 2750 to be used unless otherwise agreed between customer and supplier.</p> <p>If a specific temperature (value and tolerance) is stated in the material standard or order, that temperature shall be mandatory. If a temperature range is stated, a temperature within that range, reduced by the tolerances of the furnace, shall be selected. The total volume of the charge shall be maintained at the temperature selected, subject to the furnace tolerances in the following table, for the period stated in the material standard:</p> <table><tr><th>Heat treatment</th><th>Tolerance °C</th></tr><tr><td>Solution treatment</td><td rowspan="3">± 15</td></tr><tr><td>Annealing</td></tr><tr><td>Stress relieving</td></tr><tr><td>Ageing</td><td>± 10</td></tr></table> <p>When the duration of the heat treatment is stated as a fixed value, the tolerance shall be: $\left(\begin{smallmatrix} +20 \\ 0 \end{smallmatrix} \right) \%$.</p> <p>When the duration of the heat treatment stage is stated as a range, a time within that range shall be selected. When the duration is not specified, it shall be at the discretion of the manufacturer.</p>	Term	Abbreviation/Symbol	Term	Abbreviation/Symbol	temperature	θ	water quench	WQ	time	t	oil quench	OQ	hour	h	forced air quench	AQ	minute	min	air cool	AC	furnace cool	FC	Heat treatment	Tolerance °C	Solution treatment	± 15	Annealing	Stress relieving	Ageing	± 10	–	–
Term	Abbreviation/Symbol	Term	Abbreviation/Symbol																															
temperature	θ	water quench	WQ																															
time	t	oil quench	OQ																															
hour	h	forced air quench	AQ																															
minute	min	air cool	AC																															
		furnace cool	FC																															
Heat treatment	Tolerance °C																																	
Solution treatment	± 15																																	
Annealing																																		
Stress relieving																																		
Ageing	± 10																																	
6.2	Delivery condition code	See EN 2032-2.	–	–																														

continued

Table 1 — Technical requirements for lines 1 to 29, where appropriate (continued)

Material standard line reference		Requirements	Frequency of testing																														
No	Title		Qualification	Release																													
7	Use condition	The use condition treatment of the product is stated in the material standard.	—	—																													
	Heat treatment	<p>If the delivery condition is the use condition, no further heat treatment shall be applied to the product.</p> <p>If the delivery condition is not the use condition, the product shall be subject to heat treatment(s) in the same order as those specified in the material standard. Abbreviations and symbols used in the material standard are shown in the following table: all other terms are written in full.</p> <table><tr><th>Term</th><th>Abbreviation/Symbol</th><th>Term</th><th>Abbreviation/Symbol</th></tr><tr><td>temperature</td><td>θ</td><td>water quench</td><td>WQ</td></tr><tr><td>time</td><td>t</td><td>oil quench</td><td>OQ</td></tr><tr><td>hour</td><td>h</td><td>forced air quench</td><td>AQ</td></tr><tr><td rowspan="2">minute</td><td rowspan="2">min</td><td>air cool</td><td>AC</td></tr><tr><td>furnace cool</td><td>FC</td></tr></table> <p>AMS 2750 to be used unless otherwise agreed between customer and supplier.</p> <p>If a specific temperature (value and tolerance) is stated in the material standard or order, that temperature shall be mandatory. If a temperature range is stated, a temperature within that range, reduced by the tolerances of the furnace, shall be selected. The total volume of the charge shall be maintained at the temperature selected, subject to the furnace tolerances in the following table, for the period stated in the material standard:</p> <table><tr><th>Heat treatment</th><th>Tolerance °C</th></tr><tr><td>Solution treatment</td><td rowspan="3">± 15</td></tr><tr><td>Annealing</td></tr><tr><td>Stress relieving</td></tr><tr><td>Ageing</td><td>± 10</td></tr></table> <p>When the duration of the heat treatment is stated as a fixed value, the tolerance shall be: $(\begin{smallmatrix} +20 \\ 0 \end{smallmatrix})$ %.</p> <p>When the duration of the heat treatment stage is stated as a range, a time within that range shall be selected. When the duration is not specified, it shall be at the discretion of the manufacturer.</p>	Term	Abbreviation/Symbol	Term	Abbreviation/Symbol	temperature	θ	water quench	WQ	time	t	oil quench	OQ	hour	h	forced air quench	AQ	minute	min	air cool	AC	furnace cool	FC	Heat treatment	Tolerance °C	Solution treatment	± 15	Annealing	Stress relieving	Ageing	± 10	—
Term	Abbreviation/Symbol	Term	Abbreviation/Symbol																														
temperature	θ	water quench	WQ																														
time	t	oil quench	OQ																														
hour	h	forced air quench	AQ																														
minute	min	air cool	AC																														
		furnace cool	FC																														
Heat treatment	Tolerance °C																																
Solution treatment	± 15																																
Annealing																																	
Stress relieving																																	
Ageing	± 10																																
8.1	Test sample(s)	<p>This line relates to test samples for the test defined in lines 12 to 26.</p> <p>Test samples shall not be worked after removal from the product they represent.</p> <p>Test samples and associated test pieces shall be marked in such a manner that their identity, location and orientation with respect to the product and batch are maintained.</p>	—	—																													

continued

Table 1 — Technical requirements for lines 1 to 29, where appropriate (continued)

Material standard line reference				Requirements	Frequency of testing													
					Qualification	Release												
No	Title																	
8.2	Test piece(s)			This line relates to test pieces for the test defines in lines 12 to 26. Test pieces shall be machined from the test samples taken in accordance with the requirements of line 8.1 of this technical specification. Test piece type and dimensions shall be as specified for the appropriate test/line number in the material standard and/or this technical specification and/or test method.	–	–												
8.3	Heat treatment			The heat treatment shall be as specified in the material standard. If the delivery condition is the use condition, further heat treatment shall not be applied.	–	–												
9	Dimensions concerned			Nominal thickness, <i>a</i> , or nominal diameter <i>D</i> , of the product to which the properties, in lines 11 to 26 of the material standard, relate.	–	–												
10	Thickness of cladding on each face			Not used for titanium alloys.														
11	Direction of test piece			As specified in the material standard and relates to the direction of the test piece used for tensile and creep testing.	–	–												
Tensile test				Lines 12 to 16	–	–												
12	Temperature	<i>θ</i>	°C	As specified in the material standard and relates to the temperature at which the tensile tests are carried out.	–	–												
13	Proof stress <i>R</i> _{p0.2}	MPa		Tensile testing shall be carried out in accordance with EN 2002-001 for testing at ambient temperature and EN 2002-002 for testing at elevated temperature. EN ISO 6892-1 and prEN ISO 6892-2 are also applicable subject to agreement between customer and supplier on the test method (A or B method) The tensile test specimen direction and position within the product shall be in accordance with the following table: <table><tr><th>Minor transverse dimension of product mm</th><th>Direction of test piece</th><th>Location of test piece</th></tr><tr><td>≤ 25</td><td>Longitudinal</td><td>Centre</td></tr><tr><td>25 < <i>D</i> ≤ 75</td><td>Longitudinal</td><td>At 12,5 mm from the surface</td></tr><tr><td>> 75</td><td>Longitudinal or transverse</td><td>Mid radius</td></tr></table>	Minor transverse dimension of product mm	Direction of test piece	Location of test piece	≤ 25	Longitudinal	Centre	25 < <i>D</i> ≤ 75	Longitudinal	At 12,5 mm from the surface	> 75	Longitudinal or transverse	Mid radius	1 specimen per batch	1 specimen per batch
Minor transverse dimension of product mm	Direction of test piece	Location of test piece																
≤ 25	Longitudinal	Centre																
25 < <i>D</i> ≤ 75	Longitudinal	At 12,5 mm from the surface																
> 75	Longitudinal or transverse	Mid radius																
14	Strength	<i>R</i> _m	MPa															
15	Elongation	<i>A</i>	%															
16	Reduction of area	<i>Z</i>	%															
17	Hardness			Not normally used for titanium alloys.	–	–												

continued

Table 1 — Technical requirements for lines 1 to 29, where appropriate (*concluded*)

Material standard line reference				Requirements	Frequency of testing													
No	Title				Qualification	Release												
18	Shear strength			Test in accordance with EN 3238.	1 specimen per batch	1 specimen per batch												
19	Bending			Not used for this type of product.	–	–												
20	Impact strength			Not normally used for titanium alloys.	–	–												
Creep parameters				Lines 21-26	–	–												
21	Temperature	θ	°C	As specified in the material standard and relates to the temperature at which the creep and/or stress rupture tests are carried out.	–	–												
22	Time		h															
23	Stress	σ_a	MPa	Test in accordance with EN 2002-005. The test piece definition and position within the product shall be agreed between the manufacturer and purchaser. The test specimen orientation shall be in accordance with the following table: <table><tr><th>Minor transverse dimension of product mm</th><th>Direction of test piece</th><th>Location of test piece</th></tr><tr><td>≤ 25</td><td>Longitudinal</td><td>Centre</td></tr><tr><td>$25 < D \leq 75$</td><td>Longitudinal</td><td>At 12,5 mm from the surface</td></tr><tr><td>> 75</td><td>Longitudinal or transverse</td><td>Mid radius</td></tr></table>	Minor transverse dimension of product mm	Direction of test piece	Location of test piece	≤ 25	Longitudinal	Centre	$25 < D \leq 75$	Longitudinal	At 12,5 mm from the surface	> 75	Longitudinal or transverse	Mid radius	1 specimen per batch	1 specimen per batch
Minor transverse dimension of product mm	Direction of test piece	Location of test piece																
≤ 25	Longitudinal	Centre																
$25 < D \leq 75$	Longitudinal	At 12,5 mm from the surface																
> 75	Longitudinal or transverse	Mid radius																
24	Elongation	a	%															
25	Rupture stress	σ_R	MPa															
26	Elongation at rupture	A	%															
27	Notes			List of indices appearing on page 4 of the material standard which relate to normative and/or interpretative notes which are subsequently explained in line 98 of the material standard.	–	–												
29	Reference heat treatment			When required, reference heat treatment is applied to the test samples, see line 8.3.	–	–												

Table 2 — Technical requirements for lines 30 onwards, where appropriate

30	Microstructure	
Test method	1	For alpha/beta alloys: — EN 3114-002 Other alloys: — To be agreed between the manufacturer and purchaser.
Frequency of testing	2	Qualification
		Release testing
		25 % of products per batch
		10 % of products per batch
Sample type	3	See EN 3114-002.
Test piece definition	4	One end. Longitudinal and transverse sections examined. Cut in the centre.
Heat treatment condition of test piece	5	Use condition or see material standard.
Testing condition	6	See EN 3114-001.
Acceptance criteria	7	See material standard.

30	Microstructure (Primary α content)	
Test method	1	EN 3683
Frequency of testing	2	Qualification
		Release testing
		1 per batch
		1 per batch
Sample type	3	Centre of product
Test piece definition	4	See EN 3683.
Heat treatment condition of test piece	5	Use condition or see material standard.
Testing condition	6	See EN 3683.
Acceptance criteria	7	See material standard.

continued

Table 2 — Technical requirements for lines 30 onwards, where appropriate (*continued*)

34	Grain size		
Test method	1	EN ISO 643	
Frequency of testing	2	Qualification	Release testing
		All macrostructure samples	2 samples from macrostructural examination. See line 51.
Sample type	3	Planes to examine: Longitudinal and transverse section	
Test piece definition	4	See EN ISO 643.	
Heat treatment condition of test piece	5	Use condition or see material standards	
Testing condition	6	See EN ISO 643.	
Acceptance criteria	7	See material standard.	

44	External defects		
Test method	1	Visual inspection	
Frequency of testing	2	Qualification	Release testing
		Each product 100 %	Each product 100 %
Sample type	3	—	
Test piece definition	4	Delivery condition after etching	
Heat treatment condition of test piece	5	Delivery condition	
Testing condition	6	—	
Acceptance criteria	7	<p>Product shall be clean and free from harmful defects (such as cracks, pits, score marks, indentations, inclusions, alpha case, etc.).</p> <p>Local dressing may be carried out by the manufacturer provided the dimensions of the product remain within the tolerance limits. It shall be carried out under the conditions agreed between the manufacturer and the purchaser. Local grinding shall not affect the sensitivity of any ultrasonic test which may be required. The ground area shall be reinspected to verify that the defects have been removed.</p>	

continued

Table 2 — Technical requirements for lines 30 onwards, where appropriate (continued)

44	External defects (penetrant) (normally for bar for fasteners)		
Test method	1	EN 2002-16	
Frequency of testing	2	Qualification	Release testing
		Each product 100 %	Each product 100 %
Sample type	3	-	
Test piece definition	4	After final surface finishing, except for ground bar, which shall be tested before final grinding.	
Heat treatment condition of test piece	5	Delivery condition	
Testing condition	6	-	
Acceptance criteria	7	Product shall be clean and free from harmful defects (such as cracks, laps, seams, corrosion, etc.). Local dressing may be carried out by the manufacturer provided the dimensions of the product remain within the tolerance limits. It shall be carried out under the conditions agreed between the manufacturer and the purchaser. Local grinding shall not affect the sensitivity of any ultrasonic test which may be required. The ground area shall be reinspected to verify that the defects have been removed.	

46	Fatigue														
Test method	1	EN 3874, EN 3987 or EN 3988 as appropriate													
Frequency of testing	2	Qualification	Release testing												
		1 per batch	Not normally used												
Sample type	3	Test specimen orientation and location shall be in accordance with: <table><tr><th>Minor transverse dimension of product mm</th><th>Direction of test piece</th><th>Location of test piece</th></tr><tr><td>≤ 25</td><td>Longitudinal</td><td>Centre</td></tr><tr><td>25 < D ≤ 75</td><td>Longitudinal</td><td>At 12,5 mm from the surface</td></tr><tr><td>> 75</td><td>Longitudinal</td><td>Mid radius</td></tr></table>		Minor transverse dimension of product mm	Direction of test piece	Location of test piece	≤ 25	Longitudinal	Centre	25 < D ≤ 75	Longitudinal	At 12,5 mm from the surface	> 75	Longitudinal	Mid radius
Minor transverse dimension of product mm	Direction of test piece	Location of test piece													
≤ 25	Longitudinal	Centre													
25 < D ≤ 75	Longitudinal	At 12,5 mm from the surface													
> 75	Longitudinal	Mid radius													
Test piece definition	4	See sub-line 1.													
Heat treatment condition of test piece	5	Use condition.													
Testing condition	6	See material standard or as agreed between the manufacturer and purchaser.													
Acceptance criteria	7	See material standard.													

continued

Table 2 — Technical requirements for lines 30 onwards, where appropriate (*continued*)

51	Macrostructure																
Test method	1	EN 2954-002															
Frequency of testing	2	Qualification	Release testing														
		As below. Both ends of bars and sections	As below. One end of bars and sections														
		<p>A sample shall be selected at a convenient stage in manufacture from location corresponding to the top and bottom end of each ingot. In addition, samples shall subsequently be taken from finished bars and sections at the frequency.</p> <table><tr><td></td><td>Minor transverse dimension of product mm</td><td>Frequency</td></tr><tr><td rowspan="2">Bar for machining</td><td>$50 < D \leq 100$</td><td>10 %</td></tr><tr><td>$D > 100$</td><td>100 %</td></tr><tr><td>Bar for fasteners</td><td>$D > 20$</td><td>100 %</td></tr><tr><td>Sections</td><td>All</td><td></td></tr></table> <p>Alternatively, for release testing only at the option of the manufacturer, samples shall be taken from each end of each manufactured product prior to cutting to length.</p>			Minor transverse dimension of product mm	Frequency	Bar for machining	$50 < D \leq 100$	10 %	$D > 100$	100 %	Bar for fasteners	$D > 20$	100 %	Sections	All	
	Minor transverse dimension of product mm	Frequency															
Bar for machining	$50 < D \leq 100$	10 %															
	$D > 100$	100 %															
Bar for fasteners	$D > 20$	100 %															
Sections	All																
Sample type	3	Transverse section.															
Test piece definition	4	See EN 2954-002.															
Heat treatment condition of test piece	5	Delivery condition															
Testing condition	6	See EN 2954-002.															
Acceptance criteria	7	Samples shall be free from unsoundness, seams and detrimental segregation. Bar for fasteners shall be free from peripheral or localized coarse grain and oxide penetration. If any sample fails to meet the requirements, the corresponding end of the bar or section may be cut back and retested. If samples were originally selected at a frequency of less than 100 %, all the remaining bars shall be selected.															

continued

Table 2 — Technical requirements for lines 30 onwards, where appropriate (continued)

61	Internal defects		
Test method	1	EN 4050-1	
Frequency of testing	2	Qualification	Release testing
		Each product 100 %	Each product 100 %
Sample type	3	Products with diameter or minor sectional dimension > 35 mm shall be tested in the delivery condition. Products with diameter or minor sectional dimension ≤ 35 mm may optionally be ultrasonically tested at an intermediate stage of manufacture.	
Test piece definition	4	—	
Heat treatment condition of test piece	5	Delivery condition	
Testing condition	6	For a or D ≤ 100 mm, dead zone (surface resolution) shall be ≤ 3 mm. For a or D > 100 mm, dead zone shall be ≤ 6 mm, unless otherwise agreed between manufacturer and purchaser.	
Acceptance criteria	7	The test shall satisfy the requirements of Class 5 of EN 4050-4.	

64	Surface condition roughness		
Test method	1	EN ISO 4288	
Frequency of testing	2	Qualification	Release testing
		Each product 100 %	Each product 100 %
Sample type	3	—	
Test piece definition	4	—	
Heat treatment condition of test piece	5	Delivery condition	
Testing condition	6	—	
Acceptance criteria	7	See material standard.	

continued

Table 2 — Technical requirements for lines 30 onwards, where appropriate (*continued*)

74	Surface contamination		
Test method	1	EN 2003-009 (microexamination)	
Frequency of testing	2	Qualification	Release testing
		1 per batch	1 per batch
Sample type	3	Cut section perpendicular to the surface.	
Test piece definition	4	See EN 2003-009.	
Heat treatment condition of test piece	5	Delivery condition	
Testing condition	6	Test not required if machined all over to depth ≥ 6 mm	
Acceptance criteria	7	Sample shall be free from any α -stabilized layer.	

82	Batch uniformity		
Test method	1	The method used shall be at the discretion of the manufacturer.	
Frequency of testing	2	Qualification	Release testing
		Each product 100 %	Each product 100 %
Sample type	3	See sub-line 1.	
Test piece definition	4	—	
Heat treatment condition of test piece	5	Delivery condition	
Testing condition	6	The product shall be tested at final inspection.	
Acceptance criteria	7	The manufacturer has to guarantee that all the products belong to the same batch.	

continued

Table 2 — Technical requirements for lines 30 onwards, where appropriate (continued)

86	β-transus temperature		
Test method	1	EN 3684	
Frequency of testing	2	Qualification	Release testing
		3 samples per ingot representing top, middle and bottom of the ingot	2 representing top and bottom of the ingot
Sample type	3	See EN 3684.	
Test piece definition	4	See EN 3684.	
Heat treatment condition of test piece	5	Delivery condition	
Testing condition	6	See EN 3684.	
Acceptance criteria	7	See material standard.	

95	Marking inspection		
Test method	1	Visual inspection	
Frequency of testing	2	Qualification	Release testing
		Each product	The frequency adopted by the manufacturer shall be sufficient to permit him to certify compliance with the requirements
Sample type	3	—	
Test piece definition	4	—	
Heat treatment condition of test piece	5	—	
Testing condition	6	—	
Acceptance criteria	7	The requirements of line 6.1 shall be met.	

continued

Table 2 — Technical requirements for lines 30 onwards, where appropriate (*concluded*)

96	Dimensional inspection		
Test method	1	Measuring equipment and procedures suitable for the tolerances shall be used.	
Frequency of testing	2	Qualification	Release testing
		Each product	The frequency of the examination adopted by the manufacturer shall be sufficient to enable him to certify compliance with the requirements.
Sample type	3	—	
Test piece definition	4	—	
Heat treatment condition of test piece	5	—	
Testing condition	6	—	
Acceptance criteria	7	Dimensions and tolerances shall conform to the requirements of the dimensional standard stated on the order, or the relevant standard given in TR 2410.	

98	Notes	—	Normative and/or interpretive notes appearing on pages 4 and 5 of the material standard.
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99	Typical use	—	This line is not normally completed for titanium alloys.
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100	Qualification	—	For approval of the manufacturer's quality systems, see EN 9100. For product qualification, see EN 9133.
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