BS EN 4632-006:2013

BSI Standards Publication

Aerospace series — Weldability and brazeability of materials in aerospace constructions

Part 006: Homogeneous assemblies of titanium alloys

National foreword

This British Standard is the UK implementation of EN 4632-006:2013.

The UK participation in its preparation was entrusted to Technical Committee ACE/61, Metallic materials for aerospace purposes.

A list of organizations represented on this committee can be obtained on request to its secretary.

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ISBN 978 0 580 67022 0

ICS 49.025.01

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 April 2013.

Amendments issued since publication

Date	Text affected

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 4632-006

March 2013

ICS 49.025.01

English Version

Aerospace series - Weldability and brazeability of materials in aerospace constructions - Part 006: Homogeneous assemblies of titanium alloys

Série aérospatiale - Soudabilité et brasabilité des matériaux pour constructions aérospatiales - Partie 006 : Assemblages homogènes des alliages de titane

Luft- und Raumfahrt - Schweißbarkeit und Lötbarkeit von Werkstoffen im Luft- und Raumfahrzeugbau - Teil 006: Gleichartige Verbindungen aus Titanbasislegierungen

This European Standard was approved by CEN on 19 January 2013.

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COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

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Foreword

This document (EN 4632-006:2013) 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of an identical text or by endorsement, at the latest by September 2013, and conflicting national standards shall be withdrawn at the latest by September 2013.

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.

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This standard is part 6 of a series of 8 standards, with:

— EN 4632-001, *Aerospace series — Welded and brazed assemblies for aerospace constructions — Weldability and brazeability of materials — Part 001: General requirements*

— EN 4632-002, *Aerospace series — Welded and brazed assemblies for aerospace constructions — Weldability and brazeability of materials — Part 002: Homogeneous assemblies aluminium and aluminium alloys*

— EN 4632-003, *Aerospace series — Weldability and brazeability of materials in aerospace constructions — Part 003: Welding and brazing of homogeneous assemblies of unalloyed and low alloy steels*

— EN 4632-004, *Aerospace series — Welded and brazed assemblies for aerospace constructions — Weldability and brazeability of materials — Part 004: Homogeneous assemblies highly alloyed steels*

— EN 4632-005, *Aerospace series — Weldability and brazeability of materials in aerospace constructions — Part 005: Homogeneous assemblies of heat resisting Ni or Co base alloys*

— *EN* 4632-007, *Aerospace series — Weldability and brazeability of materials in aerospace constructions — Part 007: Homogeneous assemblies of miscellaneous alloys*

1 Scope

This European Standard defines degrees of weldability and brazeability for materials or families of materials used in the aerospace applications.

It comprises a series of sheets, by materials or by material family, which:

— indicate the main titles, the typical chemical composition and the main characteristics,

— contain recommendations for welding and brazing,

— indicate a degree of weldability or brazeability for a given process under defined conditions.

It is applicable without restriction for the manufacturing of new parts or for repair.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 3120, *Aerospace series — Titanium alloy TI-P64003 — Cold worked and stress relieved — Seamless tube for pressure systems — 4 mm ≤ D ≤ 51 mm — 690 MPa ≤ R_m ≤ 1 030 MPa*

EN 3310, *Aerospace series — Titanium alloy TI-P64001 (Ti-6Al-4V) — Not heat treated — Forging stock, for annealed forgings — D_e ≤ 360 mm*

EN 3311, *Aerospace series — Titanium alloy TI-P64001 (Ti-6Al-4V) — Annealed — Bar for machining — D < 110 mm*

EN 3312, *Aerospace series — Titanium alloy Ti-6Al-4V — Annealed — Forgings — D_e ≤ 150 mm*

EN 3313, *Aerospace series — Titanium alloy TI-P64001 — Not heat treated — Grade 2 forging stock, for solution treated and aged forgings — a or D ≤ 360 mm* [1)]

EN 3314, *Aerospace series — Titanium alloy TI-P64001 — Solution treated and aged — Bar for machining — D ≤ 75 mm* [1)]

EN 3315, *Aerospace series — Titanium alloy TI-P64001 — Solution treated and aged — Forgings — D_e ≤ 75 mm* [1)]

EN 3321, *Aerospace series — Titanium alloy TI-P65001 — As forged — Grade 1 forging stock, for solution treated and aged forgings — a or D ≤ 360 mm* [1)]

EN 3322, *Aerospace series — Titanium alloy TI-P65001 — Solution treated and aged — Grade 1 — Forgings — D_e ≤ 75 mm* [1)]

EN 3354, *Aerospace series — Titanium alloy TI-P64001 (Ti-6Al-4V) — Annealed — Sheet for superplastic forming — a ≤ 6 mm* [1)]

1) Published as ASD-STAN Prestandard at the date of publication of this standard (www.asd-stan.org).

EN 3355, *Aerospace series — Titanium alloy TI-P64001 (Ti-6Al-4V) — Annealed — Extruded section — D_e ≤ 150 mm — 900 MPa ≤ R_m ≤ 1 160 MPa*

EN 3442, *Aerospace series — Titanium TI-P99002 — Annealed — Sheet and strip, hot rolled — a ≤ 6 mm — 390 MPa ≤ R_m ≤ 540 MPa* [1)]

EN 3443, *Aerospace series — Titanium TI-P99003 — Annealed — Sheet and strip, hot rolled — a ≤ 6 mm — 570 MPa ≤ R_m ≤ 730 MPa* [1)]

EN 3451, *Aerospace series — Titanium TI-P99002 — Not heat treated — Grade 2 forging stock, for annealed forgings — a or D ≤ 300 mm* [1)]

EN 3453, *Aerospace series — Titanium TI-P99003 — Not heat treated — Grade 2 forging stock, for annealed forgings — a or D ≤ 300 mm* [1)]

EN 3454, *Aerospace series — Titanium alloy TI-P19001 — Not heat treated — Grade 2 forging stock, for annealed forgings — a or D ≤ 300 mm* [1)]

EN 3455, *Aerospace series — Titanium alloy TI-P19001 — Not heat treated — Grade 2 forging stocks, for solution treated and aged forgings — a or D ≤ 300 mm* [1)]

EN 3456, *Aerospace series — Titanium alloy TI-P64001 (Ti-6Al-4V) — Annealed — Sheet and strip, hot rolled — a ≤ 6 mm*

EN 3460, *Aerospace series — Titanium TI-P99002 — Annealed — Bar for machining — a or D ≤ 150 mm — R_m ≥ 390 MPa* [1)]

EN 3461, *Aerospace series — Titanium TI-P99003 — Annealed — Bar for machining — D ≤ 150 mm — 540 MPa ≤ R_m ≤ 740 MPa* [1)]

EN 3462, *Aerospace series — Titanium alloy TI-P19001 — Annealed — Bar for machining — D ≤ 150 mm* [1)]

EN 3463, *Aerospace series — Titanium alloy TI-P19001 — Solution treated and aged — Bar for machining — D ≤ 75 mm* [1)]

EN 3464, *Aerospace series — Titanium alloy TI-P64001 (Ti-6Al-4V) — Annealed — Plate — 6 mm < a ≤ 100 mm*

EN 3494, *Aerospace series — Titanium alloy TI-P19001 — Grade 2 — Solution treated and aged — Forgings — D_e ≤ 75 mm* [1)]

EN 3495, *Aerospace series — Titanium alloy TI-P19001 — Grade 2 — Annealed — Forgings — D_e ≤ 150 mm* [1)]

EN 3496, *Aerospace series — Titanium TI-P99003 — Grade 2 — Annealed — Forgings — D_e ≤ 150 mm* [1)]

EN 3498, *Aerospace series — Titanium TI-P99002 — Annealed — Sheet and strip, cold rolled — a ≤ 6 mm — 390 MPa ≤ R_m ≤ 540 MPa* [1)]

EN 3499, *Aerospace series — Titanium TI-P99003 — Annealed — Sheet and strip, cold rolled — a ≤ 6 mm — 570 MPa ≤ R_m ≤ 730 MPa* [1)]

EN 3735, *Aerospace series — Titanium alloy TI-P65002 — Solution treated and aged — Bar for machining — D ≤ 75 mm* [1)]

EN 3736, *Aerospace series — Titanium alloy TI-P65002 — Grade 2 — Solution treated and aged — Forgings — D_e ≤ 75 mm* [1)]

EN 3737, *Aerospace series — Titanium alloy TI-P65002 — Not heat treated — Grade 2 forging stock, for solution treated and aged forgings — a or D ≤ 360 mm* [1)]

EN 3859, *Aerospace series — Titanium alloy TI-P19001 — Annealed — Sheet and strip, hot rolled — a ≤ 6 mm* [1)]

EN 3860, *Aerospace series — Titanium alloy TI-P19001 — Annealed — Sheet and strip, cold rolled — a ≤ 6 mm* [1)]

EN 3870, *Aerospace series — Titanium alloy TI-P19001 — Solution treated and aged — Sheet and strip, hot rolled — a ≤ 6 mm* [1)]

EN 3871, *Aerospace series — Titanium alloy TI-P19001 — Solution treated and aged — Sheet and strip, cold rolled — a ≤ 6 mm* [1)]

EN 3892, *Aerospace series — Titanium alloy TI-W64001 — Filler metal for welding*

EN 3965, *Aerospace series — Titanium alloy TI-B17001 — Filler metal for brazing — Rolled foil*

EN 4632-001:2008, *Aerospace series — Welded and brazed assemblies for aerospace constructions — Weldability and brazeability of materials — Part 001: General requirements*

EN 4632-007, *Aerospace series — Weldability and brazeability of materials in aerospace constructions — Part 007: Homogeneous assemblies of miscellaneous alloys* [2)]

EN 10052, *Vocabulary of heat treatment terms for ferrous products*

EN ISO 4063:2009, *Welding and allied processes — Nomenclature of processes and reference numbers (ISO 4063:2009)*

EN ISO 24034, *Welding consumables — Solid wires and rods for fusion welding of titanium and titanium alloys — Classification (ISO 24034:2010)*

AMS 4897, *Titanium alloy, sheet, strip, and plate 77 Ti — 15Mo - 3.0Al - 2.8Cb - 0.20Si* [3)]

AMS 4911, *Titanium alloy, sheet, strip, and plate 6Al - 4V annealed* [3)]

AMS 4920, *Titanium alloy, forgings 6Al - 4V alpha-beta or beta processed, annealed* [3)]

AMS 4928, *Titanium alloy bars, wire, forgings, rings, and drawn shapes, 6Al - 4V, annealed* [3)]

AMS 4930, *Titanium alloy bars, wire, forgings, and rings, 6Al - 4V, extra low interstitial, annealed* [3)]

AMS 4934, *Titanium alloy, extrusions and flash welded rings, 6Al - 4V, solution heat treated and aged* [3)]

AMS 4935, *Titanium alloy, extrusions and flash welded rings 6Al - 4V annealed beta processed* [3)]

AMS 4965, *Titanium alloy, bars, wire, forgings, and rings 6.0Al - 4.0V solution heat treated and aged* [3)]

AMS 4966, *Titanium alloy, forgings 5Al - 2.5Sn annealed, 110 ksi (758 MPa) yield strength* [3)]

AMS 4967, *Titanium alloy, bars, wire, forgings, and rings, 6.0Al - 4.0V, annealed, heat treatable* [3)]

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2) In preparation at the date of publication.

3) Published by: SAE National (US) Society of Automotive Engineers http://www.sae.org/.

AMS 4981, *Titanium alloy bars, wire, and forgings — 6.0Al - 2.0Sn - 4.0Zr - 6.0Mo — solution and precipitation heat treated* [3)]

AMS 4985, *Titanium alloy, investment castings 6Al 4V 130 Uts, 120 Ys, 6 % El hot isostatically pressed anneal optional or when specified* [3)]

AMS 4991, *Titanium alloy castings, investment 6Al - 4V hot isostatic pressed, annealed optional* [3)]

AMS 4995, *Billets and preforms 5Al - 2Sn - 2Zr - 4Cr - 4M - 0.100 premium quality, powder-metallurgy product* [3)]

ASTM B 265, *Standard specification for titanium and titanium alloy strip, sheet, and plate* [4)]

AWS A5.16, *Specification for titanium and titanium alloy welding electrodes and rods* [5)]

3 Terms, definitions, symbols and abbreviations

For the purposes of this document, the terms, definitions, symbols and abbreviations given in EN 4632-001:2008 and EN ISO 4063:2009 apply.

PJHT : Post joining (brazing or diffusion brazing) heat treatment

PWHT : Post welding heat treatment

FSW : Friction stir welding

15 : Plasma arc welding

21 : Resistance spot welding

22 : Resistance seam welding

24 : Resistance flash welding

42 : Inertia friction welding

45 : Diffusion welding

51 : Electron beam welding

522 : Gas laser welding

91 : Brazing

111 : Shielded metal arc welding

131 : Gas metal arc welding

141 : Gas tungsten arc welding

919 : Diffusion brazing

924 : Vacuum brazing

4) Published by: ASTM National (US) American Society for Testing and Materials http://www.astm.org/.

5) Published by: AWS, 550 N.W. LeJeune Road, Miami, Florida 33126.

4 Use of this standard

The index of material sheets contained in this standard, classified by family based on the main element used in the chemical composition and on the alloy structure, is given in Clause 6 of this standard.

The degree of weldability or brazeability to be used is the value indicated by the material sheet considered for the process chosen. In the operating cycle, preferably select thermal states that give the lowest degree.

If two degrees are indicated, the responsible person must select the degree that is most appropriate for the definition of the assembly.

5 Updating of this standard

See EN 4632-001.

6 List of titanium alloys sheets

See Sheets 7.1 to 7.8.

Sheet	Materials	
	Old designation	**Chemical designation**
7.1	T40 - T60	Ti Grade 2 - Ti Grade 4
7.2	TU2 - TA5E	Ti-2,5Cu – Ti-5Al -2,5Sn
7.3	TA6V - TA3V2,5	Ti-6Al-4V - Ti-3Al-2,5V
7.4	TA6Zr5D - TA6Zr4DE	Ti-6Al-5Zr-Mo - Ti-6Al-4Zr-4Mo-2Sn
7.5	—	Ti-15Mo-3Nb-3Al
7.6	TAD6Zr4E	Ti-6Al-6Mo-4Zr-2Sn
7.7	TA5CD4	Ti-5Al-4Cr-4Mo-2Sn-2Zr
7.8	TAD4E	Ti-4Al-4Mo-2Sn-0,5Si

7 Material sheets

7.1 Ti Grade 2 - Ti Grade 4

7.1.1 Designation

EN	:	EN 3442, EN 3451, EN 3460, EN 3498	EN 3443, EN 3453, EN 3461, EN 3496, EN 3499
Chemical	:	Ti Grade 2	Ti Grade 4
Current	:	–	–
ASD STAN	:	Ti-P99002	Ti-P99003
Other standards	:	Grade 2 according to ASTM B 265	Grade 4 according to ASTM B 265

7.1.2 Typical chemical composition (w.%)

Grade	Ti	O	N	H	Fe	C
Ti Grade 2	base	— 0,25	— 0,05	— 0,0125	— 0,25	— 0,08

Grade	Ti	O2	N2	H2	Fe	C
Ti Grade 4	base	— 0,40	— 0,05	— 0,0125	— 0,35	— 0,08

7.1.3 Structure

α structure

7.1.4 Particular characteristics

Chemical pickling recommended: welding within 12 hours, otherwise storage under gaseous protection with a neutral gas in a confined environment after chemical pickling.

Chemical pickling may be omitted on mechanical preparations with very good R_a and thorough cleaning.

Improvement of gaseous protection for 141, 15, 52 processes.

For single-run welding without re-start of weld (141, 15, 52) a straw-colouring of the melted zone or/and heat affected zone may be acceptable. For multi-runs welding, this straw-colouring is not permitted between runs.

7.1.5 Forms

Ti-P99002: Hot rolled sheet (EN 3442) – Cold rolled sheet (EN 3498) – Forging stock (EN 3451) – Bars (EN 3460).

Ti-P99003: Hot rolled sheet (EN 3443) – Cold rolled sheet (EN 3499) – Forging stock (EN 3453) – Bar (EN 3461) – Forgings (EN 3496).

Recommendations for welding and filling Ti Grade 2 and Ti Grade 4

Process EN ISO 4063 reference number	Thickness range mm	State before welding	PWHT	Degree of weldability	Joint efficiency	Comments and bibliographic references [ ]
141	< 10	–	Stress relieving	1 to 2 [a]	1	Filler metal: Ti Grade 2 according to EN ISO 24034 ERTi-2 according to AWS A5.16 Automatic GTAW Pulsed without filler metal: $t < 2$ mm
15	< 6	–	Stress relieving	2 [a]	1	
131	All	–	Stress relieving	3	–	–
51	All	Annealed	Without or Stress relieving	1 to 2 [b]	1	–
522	< 5	–	Without or Stress relieving	1 to 2 [a, b]	1	The use of a filler metal of 0,8 mm diameter allows to accommodate clearances up to 0,3 mm for 1 mm by butt welding [1]
21	< 3	–	Annealing	2	–	–
22	< 3	–	Annealing	2	–	–
24	All	Annealed	Annealing	1	–	Without chemical pickling on mechanical preparation (cleaning)

[a] The degree of weldability 2 is given because of the risk of weld embrittlement due to a lack of gaseous protection.

[b] The degree of weldability 2 is given because of controlling the slope down beam from producing lack of fusion, gas cavity, spiking defects.

7.2

Designation:

EN	:	EN 3454, EN 3455, EN 3462, EN 3463, EN 3494, EN 3495, EN 3859, EN 3860, EN 3870, EN 3871	–
Chemical	:	Ti-2,5Cu	Ti-5Al-2,5Sn
Current	:	–	–
ASD STAN	:	Ti-P19001	–
Other standards	:	–	Grade 6 according to ASTM B265, AMS 4966

Typical chemical composition (w. %):

Grade	Ti	Cu	O	N	H	Fe	C
Ti-2,5Cu	base	2,0 3,0	– 0,2	– 0,05	– 0,01	– 0,2	– 0,08

Grade	Ti	Al	Sn	O2	N2	H2	Fe	C
Ti-5Al-2,5Sn	base	4,0 6,0	2,0 3,0	0,2	0,05	0,020	0,50	0,08

Structure:

α structure

Particular characteristics:

Chemical pickling recommended: welding within 12 hours, otherwise storage under gaseous protection with a neutral gas in a confined environment after chemical pickling.

Chemical pickling may be omitted on mechanical preparations with a very good R_a and thorough cleaning.

Improvement of gaseous protection for 141, 15, 52 processes.

For single-run welding without re-start of weld (141, 15, 52) a straw-colouring of the melted zone or/and heat affected zone may be acceptable. For multi-runs welding, this straw-colouring is not permitted between runs.

Forms:

Ti-P19001: Hot rolled sheet (EN 3859, EN 3870) – Cold rolled sheet (EN 3860, EN 3871) – Forging stock (EN 3454, EN 3455) – Bar (EN 33462, EN 3463) – Forgings (EN 3494, EN 3495).

Recommendations for welding and filling Ti-2,5Cu and Ti-5Al-2,5Sn

Process EN ISO 4063 reference number	Thickness range mm	State before welding	PWHT	Degree of weldability	Joint efficiency	Comments and bibliographic references [ ]
141	< 10	–	Stress relieving	1 to 2 [a]	–	Filler metal: Ti Grade 2 according to EN ISO 24034 ERTi-2 according to AWS A5.16 Automatic GTAW Pulsed without filler metal: t< 2 mm
15	< 6	–	Stress relieving	2 [a]	–	
131	All	–	Stress relieving	3	–	–
51	All	Annealed	Without or Stress relieving	1 to 2 [b]	–	–
522	< 5	–	Without or Stress relieving	1 to 2 [a, b]	–	–
21	< 3	–	Annealing	2	–	–
22	< 3	–	Annealing	2	–	–
24	All	Annealed	Annealing	1	–	Without chemical pickling on mechanical preparation (cleaning)

[a] The degree of weldability 2 is given because of the risk of weld embrittlement due to a lack of gaseous protection.

[b] The degree of weldability 2 is given because of the difficulty of controlling the slope down beam from producing lack of fusion, gas cavity, spiking defects.

7.3

Designation:

EN	:	EN 3310, EN 3311, EN 3312, EN 3313, EN 3314, EN 3315, EN 3354, EN 3355, EN 3456, EN 3464	EN 3120
Chemical	:	Ti-6Al-4V	Ti-3Al-2,5V
Current	:	Ti 6.4	Ti 3.2,5
ASD STAN	:	Ti-P 64001	Ti-P64003
Other standards	:	Grade 5 according to ASTM B 265, AMS 4911, AMS 4920, AMS 4928, AMS 4930, AMS 4934, AMS 4935, AMS 4965, AMS 4967, AMS 4985, AMS 4991	Grade 9 according to ASTM B 265

Typical chemical composition (w. %):

Grade	Ti	Al	V	O	N	H	Fe	C
Ti-6Al-4V	base	5,5 6,75	3,5 4,5	– 0,2	– 0,05	– 0,0125	– 0,3	– 0,08

Grade	Ti	Al	V	O	N	H	Fe	C
Ti-3Al-2,5V	base	2,5 3,5	2,0 3,0	– 0,120	– 0,020	– 0,015	– 0,30	– 0,05

Structure:

α + β structure

Particular characteristics:

Chemical pickling recommended: welding within 12 hours, otherwise storage under gaseous protection with a neutral gas in a confined environment after chemical pickling.

Chemical pickling may be omitted on mechanical preparations with a very good R_a and thorough cleaning.

Improvement of gaseous protection for 141, 15, 52 processes.

For single-run welding without re-start of weld (141, 15, 52) a straw-colouring of the melted zone or/and heat affected zone may be acceptable. For multi-runs welding, this straw-colouring is not permitted between runs.

Temperature for prolonged use: 350 °C.

Temperature for short time use: 400 °C.

Forms:

Ti-P 64001: Hot rolled sheet (EN 3456) – Sheet (EN 3354) – Forging stock (EN 3310, EN 3313) – Bar (EN 3311, EN 3314) – Forgings (EN 3312, EN 3315) – Plates (EN 3464) – Extruded profiles (EN 3355).

Ti-P64003: Hydraulic tubing (EN 3120).

Recommendations for welding and filling Ti-6Al-4V and Ti-3Al-2,5V

Process EN ISO 4063 reference number	Thickness range mm	State before welding	PWHT	Degree of weldability	Joint efficiency	Comments and bibliographic references [ ]
141	< 10	Annealed	Stress relieving [c]	1 to 2 [a]	1	Filler metal: Ti-6Al-4V according to EN ISO 24034 TI-W64001 according to EN 3892 ERTi-5 according to AWS A5.16 Automatic GTAW Pulsed without filler metal: $t < 2$ mm [2]
15	< 6	–	Without or Stress relieving [c]	2 [a]	–	
131	All	–	aged	3	–	–
51	All	Annealed	aged	1 to 2 [b]	1	[3]
		Solution heat treated and aged	Without or Stress relieving [c]	1 to 2 [b]	0,95	[8]
42	< 10	Solution heat treated and aged	Stress relieving [c]	–	1	[10]
522	< 10	Annealed	Without or Stress relieving [c]	1 to 2 [a, b]	1	[4] [5]
522	< 2	Annealed	Without	1 to 2 [a, b]	–	
21	< 3	–	Annealing	2	–	–
22	< 3	–	Annealing	2	–	–
24	All	Annealed	Annealing	1	–	Without chemical pickling on mechanical preparation (cleaning)

[a] The degree of weldability 2 is given because of the risk of weld embrittlement due to a lack of gaseous protection.

[b] The degree of weldability 2 is given because of the difficulty of controlling the slope down beam from producing lack of fusion, gas cavity, spiking defects.

[c] 600 °C to 750 °C during 2 hours.

Recommendations for brazing and diffusion brazing joints

Process EN ISO 4063 reference number	State before joining	Joining temperature °C	PJHT	Filler metals		Flux	Degree of brazeability or weldability	Comments
				family	form			
DB 919 vacuum furnace	Annealed	970	–	Ti	foil	–	1	Filler metal: Ti-Cu-Ni according to EN 3965 [7]
DW 45	Annealed	750 to 950	without	–	–	–	1 to 2 [a]	[16]

[a] The brazeabitlity degree 2 is given because of the process sensitivity to the state of surface preparation and environment.

7.4

Designation:

EN	:	EN 3321, EN 3322	EN 3735, EN 3736, EN 3737
Chemical	:	Ti-6Al-5Zr-Mo	Ti-6Al-4Zr-4Mo-2Sn
Current	:	–	Ti-6.2.4.2
ASD STAN	:	Ti-P65001	Ti-P65002
Other standards	:	–	–

Typical chemical composition (w. %):

Grade	Ti	Al	Mo	Zr	Si	O	N	H	Fe	C	Y
Ti-6Al-5Zr-Mo	base	5,7 6,3	0,25 0,75	4,5 6,0	0,1 0,40	0,09 0,19	– 0,03	– 0,0125	– 0,05	– 0,08	– 0,005

Grade	Ti	Al	Mo	Zr	Si	O+2N	N	H	Fe	C	Sn
Ti-6Al-4Zr-4Mo-2Sn	base	5,5 6,5	1,8 2,2	3,6 4,4	0,06 0,12	– 0,25	– 0,03	– 0,0125	– 0,10	– 0,05	1,8 2,2

Structure:

α + small quantity β structure

Particular characteristics:

Chemical pickling recommended: welding within 12 hours, otherwise storage under gaseous protection with a neutral gas in a confined environment after chemical pickling.

Chemical pickling may be omitted on mechanical preparations with a very good R_a and thorough cleaning.

Improvement of gaseous protection for 141, 15, 52 processes.

For single-run welding without re-start of weld (141, 15, 52) a straw-colouring of the melted zone or/and heat affected zone may be acceptable. For multi-runs welding, this straw-colouring is not permitted between runs.

Forms:

Ti-P65001: Forging stock (EN 3321) – Forgings (EN 3322).

Ti-P65002: Forging stock (EN 3737) – Bar (EN 3735) – Forgings (EN 3736).

Recommendations for welding and filling Ti-6Al-5Zr-Mo

Process EN ISO 4063 reference number	Thickness range mm	State before welding	PWHT	Degree of weldability	Joint efficiency	Comments and bibliographic references [ ]
141	–	Solution heat treated and aged	aged	1 to 2	–	Filler metal: Ti-6Al-4V according to EN ISO 24034 TI-W64001 according to EN 3892 ERTi-5 according to AWS A5.16
51	< 6 mm	Solution heat treated and aged	aged	1 to 2	1	[8]

Recommendations for welding and filling Ti-6Al-4Zr-4Mo-2Sn

Process EN ISO 4063 reference number	Thickness range mm	State before welding	PWHT	Degree of weldability	Joint efficiency	Comments and bibliographic references [ ]
141	< 3 mm	Solution heat treated and aged	aged	1	0,97	[9]
51	All	Solution heat treated or Solution heat treated and aged	Stress relieving or aged	1 to 2	–	–
24	–	Solution heat treated	Solution heat treating and aged	1	–	–

Recommendations for brazing and diffusion brazing joints

Process EN ISO 4063 reference number	State before joining	Joining temperature °C	PJHT	Filler metals		Flux	Degree of brazeability or weldability	Comments
				family	form			
924	–	950	900 °C 2 h to 8 h	Ti	powder, foil	–	2	–

7.5

Designation:

EN : –

Chemical : Ti-15Mo-3Nb-3Al

ASD STAN : –

Other standards : AMS 4897 Grade 21 (according to ASTM)

Typical chemical composition (w. %):

Grade	Ti	Al	Mo	Nb	Si	Fe	O	C
Ti-15Mo-3Nb-3Al	base	2,5 3,5	14 16	2,4 3,2	0,15 0,25	0,20 0,40	0,11 0,15	– 0.05

Structure:

β metastable structure

Particular characteristics:

Chemical pickling recommended: welding within 12 hours, otherwise storage under gaseous protection with a neutral gas in a confined environment after chemical pickling.

Chemical pickling may be omitted on mechanical preparations with a very good R_a and thorough cleaning.

Improvement of gaseous protection for 141, 15, 52 processes.

For single-run welding without re-start of weld (141, 15, 52) a straw-colouring of the melted zone or/and heat affected zone may be acceptable. For multi-runs welding, this straw-colouring is not permitted between runs.

High resistance to hydraulic fluid oxidizing.

Good mechanical resistance to high temperatures up to 590 °C and to creep.

Good hot formability.

Forms:

—

Recommendations for welding and filling Ti-15Mo-3Nb-3Al

Process EN ISO 4063 reference number	Thickness range mm	State before welding	PWHT	Degree of weldability	Joint efficiency	Comments and bibliographic references [ ]
141	< 3	Solution heat treated	Without	1	1	Filler metal : Same composition of parent metal is recommended to avoid porosities. [14]
		Solution heat treated	Aged [a]	1	1	
51	< 2	Solution heat treated	Without	1	1	[11]
		Solution heat treated	Aged [b]	1	0,68	
		Solution heat treated and aged	Without	1	0,63	
		Solution heat treated and aged	Aged [b]	1	0,84	
522	< 2	Solution heat treated	Aged [c]	1	1	[17]
FSW	–	Solution heat treated	Without	2	1	[15]
	–	Solution heat treated	Aged [b]	2	0,6	

[a] Aged at 690 °C for 8 h.

[b] Aged at 538 °C for 8 h.

[c] Aged at 600 °C for 8 h.

7.6

Designation:

EN : –

Chemical : Ti-6Al-6Mo-4Zr-2Sn

Current : Ti-6.2.4.6

ASD STAN : –

Other standards : AMS 4981

Typical chemical composition (w. %):

Grade	Ti	Al	Mo	Sn	Zr	Fe	O	C
Ti-6Al-6Mo-4Zr-2Sn	base	5,50 6,5	5,5 6,5	1,75 2,25	3,5 4,5	– 0,15	– 0,15	– 0,04

Structure:

β forged structure

Particular characteristics:

Chemical pickling recommended: welding within 12 hours, otherwise storage under gaseous protection with a neutral gas in a confined environment after chemical pickling.

Chemical pickling may be omitted on mechanical preparations with a very good R_a and thorough cleaning.

Improvement of gaseous protection for 141, 15, 52 processes.

For single-run welding without re-start of weld (141, 15, 52) a straw-colouring of the melted zone or/and heat affected zone may be acceptable. For multi-runs welding, this straw-colouring is not permitted between runs.

Temperature for prolonged use: 450 °C.

Temperature for short time use: 500 °C.

Forms:

Forged.

Recommendations for welding and filling Ti-6Al-6Mo-4Zr-2Sn

Process EN ISO 4063 reference number	Thickness range mm	State before welding	PWHT	Degree of weldability	Joint efficiency	Comments and bibliographic references [ ]
51	≤ 6	Solution heat treated and aged	Aged	1-2	1	[12]
42	≤ 6	Solution heat treated and aged	Aged	1	1	[12]

7.7

Designation:

EN : –

Chemical : Ti-5Al-4Cr-4Mo-2Sn-2Zr

ASD STAN : –

Other standards : AMS 4995

Typical composition (p. %):

Grade	Ti	Al	Mo	Sn	Zr	Fe	O	Cr	N	H
Ti-5Al-4Cr-4Mo-2Sn-2Zr	base	4,5 5,5	3,5 4,5	1,5 2,5	1,5 2,5	– 0,3	0,08 0,13	3,5 4,5	– 0,04	– 0,0125

Structure:

—

Particular characteristics:

Chemical pickling recommended: welding within 12 hours, otherwise storage under gaseous protection with a neutral gas in a confined environment after chemical pickling.

Chemical pickling may be omitted on mechanical preparations with a very good R_a and thorough cleaning.

Improvement of gaseous protection for 141, 15, 52 processes.

For single-run welding without re-start of weld (141, 15, 52) a straw-colouring of the melted zone or/and heat affected zone may be acceptable. For multi-runs welding, this straw-colouring is not permitted between runs.

Temperature for prolonged use: 350 °C.

Forms:

—

Recommendations for welding and filling Ti-5Al-4Cr-4Mo-2Sn-2Zr

Process EN ISO 4063 reference number	Thickness range mm	State before welding	PWHT	Degree of weldability	Joint efficiency	Comments and bibliographic references [ ]
51	–	Solution heat treated and aged	Aged	2-3	–	–
42	< 10	Solution heat treated and aged	Aged	1	1	[13]

7.8

Designation:

EN : EN 3351, EN 3459, EN 3465, EN 3466

Chemical : Ti-4Al-4Mo-2Sn-0,5Si

ASD STAN : Ti-P63001

Other standards : –

Typical chemical composition (w. %):

Grade	Ti	Al	Mo	Sn	Zr	Fe	O	N	H	C	Si
Ti-4Al-4Mo-2Sn-0,5Si	Base	3 5	3 5	1,5 2,5	0,3 0,7	– 0,2	– 0,25	– 0,02	– 0,0125	– 0,08	0,3 0,7

Structure:

—

Particular characteristics:

This alloy is not easily fusion welded.

Good creep characteristic up to 400 °C.

Forms:

—

Recommendations for welding and filling Ti-4Al-4Mo-2sn-0,5Si

Process EN ISO 4063 reference number	Thickness range mm	State before welding	PWHT	Degree of weldability	Joint efficiency	Comments and bibliographic references [ ]
51	< 6	Solution heat treated and aged	Aged	3	–	Slow welding speed recommended
42	< 10	Solution heat treated and aged	Aged	2	–	–

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