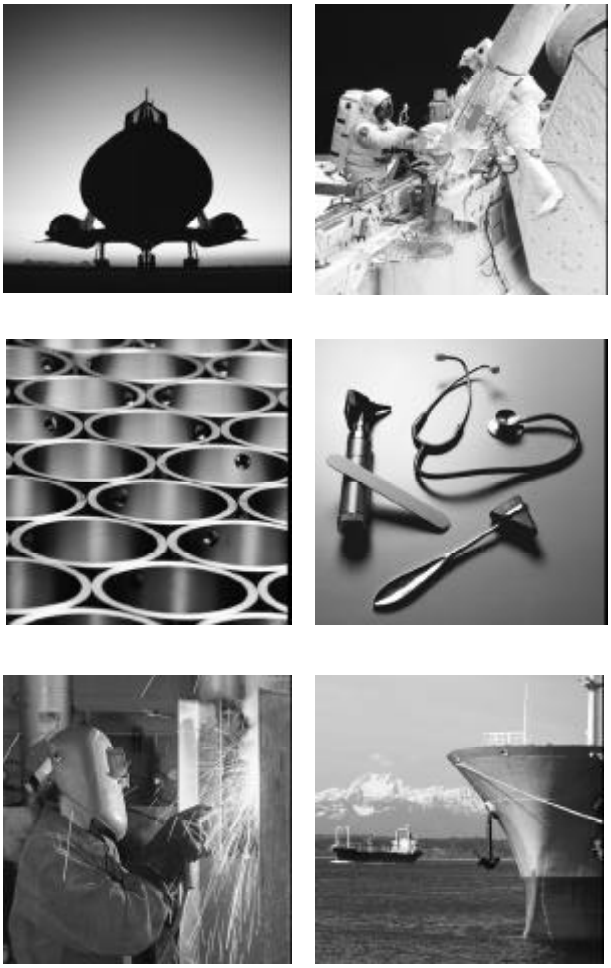
International Titanium Association



Specifications Book

Fourth Edition - 2005

About the Specifications Book

The Specifications Book is designed to assist people considering using titanium for a specific application, and will be most useful to those organizations that do not have extensive experience with titanium applications. The book contains a selection of commonly utilized titanium alloys, and will assist in the selection of possible alloy choices for most commercial applications.

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UNALLOYED TITANIUM

Unalloyed titanium typically contains between 99%-99.5% titanium, with the balance being made up of iron and the interstitial impurity elements hydrogen, nitrogen, carbon, and oxygen. The microstructure of unalloyed titanium consists of grains of alpha phase, with the possibility of small amounts of beta phase. The “unalloyed” grades of titanium are generally less expensive, and are easier to fabricate than alloyed, and generally stronger grades of titanium.

ALPHA AND NEAR-ALPHA ALLOYS

Titanium alloys have a fully alpha structure only if they contain alpha stabilizers such as aluminum, tin, and oxygen. These elements also act as solid solution strengtheners. The typical all-alpha alloy is Ti-5Al-2.5Sn. Near-alpha alloys include Ti-8Al-1Mo-1V, Ti-6Al-2Sn-4Zr-2Mo.

ALPHA-PLUS BETA ALLOYS

These alloys contain both alpha stabilizers and beta stabilizers. These alloys can be heat treated to develop a range of microstructures. The “lean” alpha-beta alloys are moderately heat treatable and weldable, while the “rich” alpha-beta alloys have greater hardenability, and thus can be through-hardened in thicker section by heat treatment, but are more difficult to weld. The most important “lean” alloy is Ti-6Al-4V. The “rich” alloys include Ti-6Al-6V-2Sn and Ti-6Al-2Sn-4Zr-6Mo.

BETA ALLOYS

Beta alloys contain a balance of beta stabilizers to alpha stabilizers, which is sufficiently high that a fully beta phase microstructure can be retained on cooling. Their generally high strength, high toughness, and improved formability, as compared with alpha-beta alloys, provides an attractive combination of properties. However, processing and material costs are often quite high. Ti-3Al-8V-6Cr-4Zr-4Mo is an example of a commonly utilized beta alloy.

Table of Contents

Table of Contents

Specifications Book 2005

Common Name: CP Grade 1
Titanium Grade 1

UNS Number: R50350

General Information: Titanium Alloy Grade 1 is "unalloyed" titanium offering optimum ductility and cold formability. The material has high impact toughness and is readily weldable. The material is capable of deep drawing, and used for plate, frame, and tube heat exchangers, and also is used as plate for explosive bonding for clad plate. The material is castable and is sometimes utilized "as cast" in dental applications. The alloy is available as castings, wire, welded tube, bar, plate, sheet, forgings, and billet.

Common Specifications:

Specification:	Product Form:
ASTM B265 (Grade 1)	Strip, Sheet, and Plate
ASTM B338 (Grade 1)	Seamless Welded Tubes
ASTM B348 (Grade 1)	Bar and Billet
ASTM B363 (Grade 1)	Fittings
ASTM B367 (Grade 1)	Castings
ASTM B381 (Grade 1)	Forgings
ASTM B861 (Grade 1)	Seamless Pipe
ASTM B862 (Grade 1)	Welded Pipe
ASTM F67 (Grade 1)	Unalloyed Titanium for Surgical Implants
AWS A5.16 (ERTi-1)	Weld Wire
ISO 5832-2 (Grade 1)	Unalloyed Titanium for Surgical Implants

Chemistry Requirements: % Maximum unless given as a range.

N	C	H	Fe	O	Residuals Each Max.	Residuals Max. Total	Ti
0.03	0.1	0.015	0.20	0.18	0.1	0.4	balance

Minimum Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA*
As specified (shape)	35 (240)	20 (138)	24	30

Typical Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA
As provided	50(345)	32 (221)	37	-

Note: Typical properties are not to be utilized as a requirement, but are only listed for guidance. These properties may or may not be attainable in all circumstances.

** %Ra not required by all specifications*

Specifications Book 2005

Common Name: CP Grade 11 Ti - Palladium
CP Grade 1with Palladium

UNS Number: R52252

General Information: Titanium Grade 11 is the equivilent of Grade 1 but with a palladium addition which imparts a significant improvement in resistance to general and localized crevice corrosion in a wide range of reducing acid environments, including chlorides, and where low pH and high temperatures above 180° F (83° C) to 500° F (260° C) are prevalent. The alloy is available as castings, wire, bar, plate, sheet, forgings, pipe, tubing and billet.

Common Specifications:

Specification:	Product Form:
ASME SB-265	Sheet, Strip, and Plate
ASME SB-337	Pipe, Seamless and Welded
ASME SB-338	Tube, Seamless and Welded
ASME SB-348	Bar and Billet
ASTM B265 (Grade 11)	Strip, Sheet and Plate
ASTM B348 (Grade 11)	Bar and Billet
ASTM B367 (Grade 11)	Castings.
ASTM B861 (Grade 11) *	Seamless Pipe
ASTM B862 (Grade 11) *	Welded Pipe
AWS A5.16 (ERTi-11)	Weld Wire
AWS A5.16 (ERTi-17)	Weld Wire

* Replacing ASTM B337

Chemistry Requirements: % Maximum unless given as a range.

N	C	H	Fe	O	Pd	Residuals Each Max.	Residuals Max. Total	Ti
0.03	0.08	0.015	0.20	0.18	0.12-0.25	0.1	0.4	Balance

Note: Chemical requirements are not consistent between specifications. Check referenced specifications.

Minimum Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA*
As specified (shape)	35 (240)	20 (138)	24	30

Typical Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA
As provided	50 (345)	32 (221)	37	-

Note: Typical properties are not to be utilized as a requirement, but are only listed for guidance. These properties may or may not be attainable in all circumstances.

** %Ra not required by all specifications*

Common Name: CP Grade 17 | Ti – 0.06 Pd
Titanium Grade 17 | CP Grade 1 w/ Lower Palladium

UNS Number: R52252

General Information: Titanium Alloy Grade 17 is "alloyed" titanium offering optimum ductility and cold formability, with properties similar to Grade 1 and Grade 11. Grade 17 is like Grade 11 but with lower palladium. The material is readily weldable. This material is very corrosion resistant in highly oxidizing and mildly reducing environments. The material is castable and may be utilized in cast valves and fittings. The alloy is available as castings, wire, welded tube, pipe, plate, sheet, strip, forgings, bar, and billet.

Common Specifications:

Specification:	Product Form:
ASTM B265 (Grade 17)	Strip, Sheet, and Plate
ASTM B348 (Grade 17)	Bar and Billet
ASTM B367 (Grade 17)	Castings
ASTM B381 (Grade 17)	Forgings

Chemistry Requirements: % Maximum unless given as a range.

N	C	H	Fe	O	Pd	Residuals Each Max.	Residuals Max. Total	Ti
0.03	0.08	0.015	0.20	0.18	0.04-0.08	0.1	0.4	Balance

Minimum Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA*
As specified (shape)	35 (240)	25 (170)	24	30

Typical Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA
As provided	50 (345)	34 (221)	37	-

Note: Typical properties are not to be utilized as a requirement, but are only listed for guidance. These properties may or may not be attainable in all circumstances.

** %Ra not required by all specifications*

Specifications Book 2005

Common Name: CP Grade 27 Ti 0.1 Ru
Titanium Grade 1 + 0.1%Ruthenium TIRU-27™

UNS Number:

General Information: Titanium Grade 27 has excellent weldability, formability with mechanical properties equivalent to those of Grade 1 titanium. Titanium Grade 27 is alloyed with 0.1 ruthenium to provide expanded resistance essentially (equivalent to Ti Grades 11, 17) at lower cost to acidic general and crevice corrosion in mildly reducing at pH's <1 and temps >200○C. The alloy is available as strip, sheet, plate, tubing, forgings, bar, and billet.

Common Specifications:

Specification:	Product Form:
ASTM B265	Strip, Sheet, and Plate
ASTM B338	Tubing
ASTM B348	Bar and Billet
ASTM B363	Fittings
ASTM B381	Forgings
ASTM B861	Seamless Pipe
ASTM B862	Welded Pipe

Chemistry Requirements: % Maximum unless given as a range.

N	C	H	Fe	O	Pd	Residuals Each Max.	Residuals Max. Total	Ti
0.03	0.08	0.015	0.20	0.18	0.08-0.14	0.1	0.4	Balance

Minimum Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA*
As specified (shape)	35 (240)	25 (170)	24	30

Typical Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA
As provided	56 (386)	37 (255)	36	-

Note: Typical properties are not to be utilized as a requirement, but are only listed for guidance. These properties may or may not be attainable in all circumstances.

** %Ra not required by all specifications*

Specifications Book 2005

Common Name: CP Grade 2
Titanium Grade 2

UNS Number: R50400

General Information: Titanium Alloy Grade 2 is “unalloyed” titanium offering an excellent balance of strength and ductility. The material has good toughness and is readily weldable. This material is very corrosion resistant in highly oxidizing and mildly reducing environments. The material is castable and is often utilized in cast valves and fittings. In plate form, the alloy is also used explosively boned to make clad plate. The alloy is available as castings, wire, welded tube, pipe, plate, sheet, strip, forgings, bar, and billet.

Common Specifications:

Specification:	Product Form:
AMS 4902	Strip, Sheet, and Plate
AMS 4941	Welded Tubing
AMS 4942	Seamless Tubing
AMS 4951	Wire, Welding
ASME SB265	Sheet, Strip, and Plate
ASME SB348	Bar and Billet
ASME SB367	Casting
ASME SB381	Forgings
ASTM B265 (Grade 2)	Strip, Sheet, and Plate
ASTM B338	Tube, Seamless and Welded
ASTM B348 (Grade 2)	Bar and Billet
ASTM B363	Fittings
ASTM B367 (Grade 2)	Castings
ASTM B381	Forgings
ASTM B861	Seamless Pipe
ASTM B862	Welded Pipe
ASTM B863	Wire
ASTM B831	Forgings
ASTM F67 (Grade 2)	Unalloyed Titanium for Surgical Implants
AWS A5.16 ERTi-2	Weld Wire
ISO 5832-2 (Grade 2)	Unalloyed Titanium for Surgical Implants

Chemistry Requirements: % Maximum unless given as a range.

N	C	H	Fe	O	Residuals Each Max.	Residuals Max. Total	Ti
0.03	0.08	0.015	0.3	0.25	0.1	0.4	Balance

Minimum Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA*
As specified (shape)	50 (345)	40 (275)	20	30

Typical Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA
As provided	70 (483)	51 (352)	28	-

Note: Typical properties are not to be utilized as a requirement, but are only listed for guidance. These properties may or may not be attainable in all circumstances.

** %Ra not required by all specifications*

Specifications Book 2005

Common Name: CP Grade 7 | Ti-0.15PD
CP Grade 2 with Palladium | Titanium Grade 7

UNS Number: R52400

General Information: Titanium Alloy Grade 7 with 0.1% palladium is similar to Grade 2, but with improved resistance to general and localized crevice corrosion in a wide range of reducing acid environments, including chlorides, and where low pH and high temperatures above 180ºF (83ºC) to 500ºF (260ºC) are prevalent. The alloy is available as castings, wire, welded tube, pipe, plate, sheet, strip, forgings, bar, and billet.

Common Specifications:

Specification:	Product Form:
ASME SB-265	Sheet, Strip, and Plate
ASME SB-337	Pipe, Seamless and Welded
ASME SB-338	Tube, Seamless and Welded
ASME SB-348	Bar and Billet
ASTM B265 (Grade 7)	Sheet, Strip, and Plate
ASTM B348 (Grade 7)	Bar and Billet
ASTM B367 (Grade 7)	Castings
ASTM B861*	Seamless Pipe
ASTM B862*	Welded Pipe
AWS A5.16 (ERTi-7)	Weld Wire

* Replacing ASTM B337

Chemistry Requirements: % Maximum unless given as a range.

N	C	H	Fe	O	Pd	Residuals Each Max.	Residuals Max. Total	Ti
0.03	0.08	0.015	0.30	0.25	0.12- 0.25	0.1	0.4	Balance

Note: Chemical requirements are not consistent between specifications. Check referenced specifications.

Minimum Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA*
As specified (shape)	50 (345)	40 (275)	20	30

Typical Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA
As provided	70 (438)	51 (352)	28	-

Note: Typical properties are not to be utilized as a requirement, but are only listed for guidance. These properties may or may not be attainable in all circumstances.

** %Ra not required by all specifications*

Specifications Book 2005

Common Name: CP Grade 16 | Ti- - 0.05% Pd
CP Grade 2 with Lower Palladium | Titanium Grade 16

UNS Number: R52402

General Information: Titanium Alloy Grade 16 with lower palladium (0.1Pd) is similar to Grade 2 and Grade 7, but has lower palladium. Lower palladium may reduce the cost, without significant effect on the resistance to general and localized crevice corrosion. The alloy is available as castings, wire, welded tube, pipe, plate, sheet, strip, forgings, bar, and billet.

Common Specifications:

Specification:	Product Form:
ASME SB-265	Sheet, Strip, and Plate
ASME SB-338	Seamless and Welded Tube
ASTM B265 (Grade 16)	Sheet, Strip, and Plate
ASTM B348 (Grade 16)	Bars and Billets
ASTM B367 (Grade Ti-Pd 16)	Castings
AWS A5.16 ERTi-16	Weld Wire

Chemistry Requirements: % Maximum unless given as a range.

N	C	H	Fe	O	Pd	Residuals Each Max.	Residuals Max. Total	Ti
0.03	0.08	0.015	0.30	0.25	0.04-0.08	0.4	0.4	Balance

Minimum Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA*
As specified (shape)	50 (345)	40 (275)	20	30

Typical Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA
As provided	70 (483)	51 (352)	28	-

Note: Typical properties are not to be utilized as a requirement, but are only listed for guidance. These properties may or may not be attainable in all circumstances.

** %Ra not required by all specifications*

Specifications Book 2005

Common Name: CP Grade 26, Titanium Grade 26, Ti-0.1 Ru, TIRU-26™

UNS Number: R52404

General Information: Titanium Grade 26 with (0.1Ru) has equivalent (similar) mechanical properties to those of Grade 2 titanium. Ti-Grade 26 offers equivalent corrosion resistance to Grades 7 and 16 titanium, in mildly reducing acidic environments to pH's <1 and temps >200○C. The alloy is available as sheet, strip, plate, tubing, forgins, bar, and billet.

Common Specifications:

Specification:	Product Form:
ASTM B265 (Grade 16)	Sheet, Strip, and Plate
ASTM B338	Tubing
ASTM B348	Bar, Billet
ASTM B363	Fittings
ASTM B381	Forgings
ASTM B861	Seamless Pipe
ASTM B862	Welded Pipe

Chemistry Requirements: % Maximum unless given as a range.

N	C	H	Fe	O	Ru	Residuals Each Max.	Residuals Max. Total	Ti
0.03	0.08	0.015	0.30	0.25	0.08-0.14	0.1	0.4	Balance

Minimum Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA*
As specified (shape)	50 (345)	40 (275)	20	30

Typical Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA
As provided	64 (441)	44 (303)	32	-

Note: Typical properties are not to be utilized as a requirement, but are only listed for guidance. These properties may or may not be attainable in all circumstances.

** %Ra not required by all specifications*

Specifications Book 2005

Common Name: CP Grade 3
Titanium Grade 3

UNS Number: R50550

General Information: Titanium Alloy Grade 3 is "unalloyed" titanium offering improved strength, moderate ductility, and ASME Code design allowables. The material is readily weldable. This material is very corrosion resistant in highly oxidizing and mildly reducing environments. The material is castable and is often utilized in cast valves and fittings. The alloy is available as castings, wire, welded tube, pipe, plate, sheet, strip, forgings, bar, and billet.

Common Specifications:

Specification:	Product Form:
AMS 4900	Sheet, Strip, and Plate
ASME SB-265	Sheet, Strip, and Plate
ASME SB-348	Bar and Billet
ASTM 337	Seamless and Welded Pipe
ASTM B265 (Grade 3)	Strip, Sheet, and Plate
ASTM B348 (Grade 3)	Bars and Billets
ASTM B367 (Grade 3)	Castings
ASTM B381	Forgings
ASTM B861	Seamless Pipe
ASTM B862	Welded Pipe
ASTM F67 (Grade 3)	Unalloyed Titanium for Surgical Implants
AWS A5.16 (ERTi-3)	Weld Wire
ISO 5832-3	Unalloyed Titanium for Surgical Implants

Chemistry Requirements: % Maximum unless given as a range.

N	C	H	Fe	O	Residuals Each Max.	Residuals Max. Total	Ti
0.05	0.08	0.015	0.30	0.35	0.1	0.4	Balance

Minimum Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA*
As specified (shape)	64 (450)	55 (380)	18	30

Typical Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA
As provided	86 (593)	67 (462)	25	-

Note: Typical properties are not to be utilized as a requirement, but are only listed for guidance. These properties may or may not be attainable in all circumstances.

** %Ra not required by all specifications*

Specifications Book 2005

Common Name: CP Grade 4
Titanium Grade 4

UNS Number: R50700

General Information: Titanium Alloy Grade 4 is "unalloyed" titanium offering improved strength, moderate ductility. The material is readily weldable. This material is very corrosion resistant in highly oxidizing and mildly reducing environments. The material is castable and is often utilized in cast valves and fittings. The alloy is available as castings, wire, plate, sheet, strip, forgings, bar, and billet. Used mostly in aerospace applications.

Common Specifications:

Specification:	Product Form:
AMS 4901	Sheet, Strip, and Plate
AMS 4921	Bars, wire, forgings, and rings
ASTM B265 (Grade 4)	Strip, Sheet, and Plate
ASTM B348 (Grade 4)	Bars and Billets
ASTM B367 (Grade 4)	Castings
ASTM B381	Forgings
ASTM F67 (Grade 4)	Unalloyed Titanium for Surgical Implants
ISO 5832-2 Grade 4	Unalloyed Titanium for Surgical Implants
MIL-T-9047 Ti-CP-70	Bars for forging
MIL-T-9046	

Chemistry Requirements: % Maximum unless given as a range.

N	C	H	Fe	O	Residuals Each Max.	Residuals Max. Total	Ti
0.05	0.08	0.015	0.50	0.4	0.1	0.4	Balance

Minimum Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA*
As specified (shape)	(80 (550)	70 (483)	15	25

Typical Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA
As provided	86 (593)	75 (571)	20	-

Note: Typical properties are not to be utilized as a requirement, but are only listed for guidance. These properties may or may not be attainable in all circumstances.

** %Ra not required by all specifications*

Specifications Book 2005

Common Name: Titanium Grade 12 Ti-CODE 12™
Ti-0.3Mo-0.8Ni

UNS Number: R53400

General Information: Titanium Alloy Grade 12 is lightly alloyed near-alpha alloy offering improved strength at elevated temperatures and optimum ASME Code design allowables. The material is readily weldable, and has superior crevice corrosion resistance. This material is very corrosion resistant in highly oxidizing and mildly reducing environments. The alloy is available as wire, plate, sheet, strip, forgings, bar, and billet.

Common Specifications:

Specification:	Product Form:
AMS 4902	
ASME B861 (Grade 12)*	Seamless Pipe
ASME B862 (Grade 12)*	Welded Pipe
ASME SB-381	Forgings
ASME SB-348	Bars and Billets
ASTM B265 (Grade 12)	Sheet, Strip, and Plate
ASTM B338	
ASTM B348 (Grade 12)	Bars and Billets
ASTM B337 (Grade 12)	Welded and Seamless Pipe
ASTM B381 (Grade 12)	Forgings
ASTM B861	
ASTM B862	
AWS A5.16 (ERTi-12)	Weld Wire

*replacing ASTM B337

Chemistry Requirements: % Maximum unless given as a range.

N	C	H	Fe	O	Mo	Ni	Residuals Each Max.	Residuals Max Total	Ti
0.03	0.08	0.015	0.30	0.25	0.2-0.4	0.6-0.9	0.1	0.4	Balance

Minimum Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA*
As specified (shape)	70 (483)	50 (345)	18	25

Typical Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA
As provided	88 (607)	67 (462)	22	-

Note: Typical properties are not to be utilized as a requirement, but are only listed for guidance. These properties may or may not be attainable in all circumstances.

** %Ra not required by all specifications*

Specifications Book 2005

Common Name: Ti–2.5Cu
Ti 230

UNS Number: None assigned

General Information: Ti 230 combines the formability and weldability of unalloyed titanium with improved mechanical properties, particularly at elevated temperatures (up to 662°F (350°C)). The alloy may be used in the annealed condition as sheet, forgings and extrusions; it is used both in the airframe and in components such as bypass ducts for gas-turbine engines. Ageing can be used to raise the room temperature tensile properties by ~25% and nearly double the elevated temperature properties (eg creep @ 392°F(200°C)). Such a material is particularly attractive since it can be formed in the soft condition, thus lowering fabrication costs.

Common Specifications:

Specification:	Product Form:
MSRR 8603	Sheet (Annealed)
MSRR 8602/8605	Forging stock, forgings
TA 58	Plate
TA52, MSRR8606	Sheet (SHT)
WL 3.7124, TA 53	Bar

Chemistry Requirements: % Maximum unless given as a range.

N	C	H	Fe	O	Cu	Ti
0.03	0.08	0.01	0.20	0.2	20.-3.0	Balance

Minimum Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA*
As specified (shape)	88 (610)	71 (490)	10	25

Typical Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA
Sheet ST	90 (620)	77 (530)	24 (on 2"(50mm))	
Sheet STA	112 (770)	96 (660)	20 (on 2"(50mm))	
Bar & Rod ST	91 (630)	72 (500)	27	45
Bar & Rod STA	107 (740)	84 (580)	22	41
Extrusions ST	91 (630)	72 (500)	30	40
Extrusions STA	115 (790)	97 (670)	28	30

Note: Typical properties are not to be utilized as a requirement, but are only listed for guidance. These properties may or may not be attainable in all circumstances.

** %Ra not required by all specifications*

Common Name: Titanium Grade 9 Ti-3-2.5
Ti-3Al-2.5V

UNS Number: R56320

General Information:

Ti-3Al-2.5V alloy is an alpha alloy that is strengthened by cold working. The material exhibits good ductility and toughness. It is used in a wide range of tubular products from aircraft ducting to golf club shafts and bicycle frames. The alloy is available as wire, bar, sheet, seamless and welded tubing. ASME code approved.

Common Specifications:

Specification:	Product Form:
AMS 4943	Seamless Tubing, Annealed
AMS 4944	Seamless Tubing, Cold Worked, Stress Relieved
AMS 4945	Seamless Tubing, Texture Controlled, Cold Worked, Stress Relieved
ASTM B265	Sheet, Strip, Plate
ASTM B338	Tubing
ASTM B348 (Grade 9)	Wire, Bar, Sheet, and Plate
ASTM B381	
ASTM B861	Seamless Pipe
ASTM B862	Welded Pipe
AWS A5.16 (ERTi-9)	Weld Wire

Chemistry Requirements: % Maximum unless given as a range.

N	C	H	Fe	O	Al	V	Ti
0.03	0.08	0.015	0.25	0.15	2.5-3.5	2.0-3.0	Balance

Note: Chemical requirements are not consistent between specifications. Check referenced specifications.

Minimum Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA*
As specified (shape)	90 (620)	70 (483)	15	25

Typical Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA
Annealed	100 (690)	75 (515)	18	40
Solution Treated and Aged	132 (910)	120 (830)	11	-
Cold Worked, Stress Relieved	125 (860)	105 (723)	8	-

Note: Typical properties are not to be utilized as a requirement, but are only listed for guidance. These properties may or may not be attainable in all circumstances.

** %Ra not required by all specifications*

Common Name: Ti-3Al-2.5V with 0.1% Ruthenium Ti-3-2.5Ru
Titanium Grade 28

UNS Number: R56323

General Information: Ti-3Al-2.5V alloy is a near alpha alloy that is strengthened by cold working. This modified material incorporates a ruthenium addition for enhanced corrosion resistance. The alloy is available as wire, bar, sheet, seamless and welded tubing.

Common Specifications:

Specification:	Product Form:
ASTM B265 (Grade 28)	Strip, Sheet, and Plate
ASTM B338	
ASTM B348 (Grade 28)	Bars and Billets, Annealed
ASTM B363 (Grade 28)	Seamless and Welded Fittings
ASTM B383 (Grade 28)	Wire
ASTM B861	
ASTM B862	

Chemistry Requirements: % Maximum unless given as a range.

N	C	H	Fe	O	Al	V	Ru	Ti
0.03	0.08	0.015	0.25	0.15	2.5-3.5	2.0-3.0	0.08-0.14	Balance

Minimum Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA*
Annealed	90 (620)	70 (483)	15	25

Typical Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA
Annealed	100 (690)	75 (515)	18	40

Note: Typical properties are not to be utilized as a requirement, but are only listed for guidance. These properties may or may not be attainable in all circumstances.

** %Ra not required by all specifications*

Specifications Book 2005

Common Name: Ti-5Al-2.5Sn A-110AT Ti-5-2.5
Titanium Grade 6 MMA-5137

UNS Number: R54520

General Information: Ti-5Al-2.5Al has good weldability and shows stability and oxidation resistance at elevated temperatures (600 - 1000°F). Applications are forgings and sheet metal parts such as jet turbine compressor blades, ducting, and steam turbine blades. The alloy is a more difficult alloy to forge with a narrow forgeability range and greater yield loss. This alpha alloy is available in bar, billet, castings, extrustions, plate, sheet, and wire.

Common Specifications:

Specification:	Product Form:
AMS 4910	Strip, Sheet, and Plate, Annealed
AMS 4926	Bar and Ring, Annealed
AMS 4966	Forgings, Annealed
ASTM B265 (Grade 6)	Strip, Sheet, and Plate
ASTM B348 (Grade 15)	Bar and Billet
ASTM B381 (Grade 15)	Forgings
MIL-T-9046	Strip, Sheet, and Plate
MIL-T-9047	Bar, Re-forging
MIL-T-81556	Extrusions
MIL-F-83142	Forgings

Chemistry Requirements: % Maximum unless given as a range.

N	C	H	Fe	O	Al	Sn	Y	Residuals Each Max.	Residuals Max. Total	Ti
0.05	0.08	0.020	0.50	0.20	4.5-5.75	2.0-3.0	0.005	0.1	0.4	Balance

Note: Chemical requirements are not consistent between specifications. Check referenced specifications.

Minimum Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% Ra*	Size
Forged Bars	115 (792)	110 (758)	10	25	<4"

Typical Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% Ra*	Size
Sheet and Plate, Annealed	120 (827)	113 (779)	10	-	<1.5"

Note: Typical properties are not to be utilized as a requirement, but are only listed for guidance. These properties may or may not be attainable in all circumstances.

** %Ra not required by all specifications*

Specifications Book 2005

Common Name: 5-2.5Sn ELI 5-2.5 Extra Low Interstitial
A-95AT

UNS Number: R54521

General Information: Ti-5Al-2.5Sn ELI alloy's most common use is for cryogenic applications. It is used for the main booster pumps (liquid oxygen and hydrogen) on the space shuttle. This alpha alloy is available in bar, billet, castings, extrusions, plate, sheet, and wire.

Common Specifications:

Specification:	Product Form:
AMS 4909	Strip, Sheet, and Plate
AMS 4924	Bar, Ring, and Forgings

Chemistry Requirements: % Maximum unless given as a range.

N	C	H	Fe	O	Y	Al	Sn	Residuals Each Max.	Residuals Max.Total	Ti
0.035	0.05	0.013	0.25	0.12	0.01	4.5-5.75	2.0-3.0	0.1	0.4	Balance

Minimum Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA*	Size
Forgings	100 (689)	90 (620)	10	25	<3"

Typical Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA
Bar, Forged	118 (815	103 (710)	19	34
Casting	115 (795)	105 (725)	10	17

Note: Typical properties are not to be utilized as a requirement, but are only listed for guidance. These properties may or may not be attainable in all circumstances.

** %Ra not required by all specifications*

Specifications Book 2005

Common Name: Ti-6Al-4V Titanium Grade 5
Ti-6-4

UNS Number: R56400

General Information: Ti-6Al-4V alloy is the most widely used titanium alloy of the alpha-plus-beta class, and is also the most common of all titanium alloys. The alloy is castable and is utilized "as cast" in sporting goods. The wrought material is used in aerospace, medical, and other applications where moderate strength, good strength to weight, and favorable corrosion properties are required. The alloy is available as castings, wire, bar, plate, sheet, forgings, rings, and billet.

Common Specifications:

Specification:	Product Form:
AMS 4911	Strip, Sheet, and Plate, Annealed
AMS 4920	Forgings, Alpha-Beta or Beta Processed, Annealed
AMS 4928	Bar, Wire, Forgings, Ring, Annealed
AMS 4965, AMS 4963, and AMS 4967 (Capable of)	Bar, Wire, Forgings, Ring, Solution Treated & Aged
AMS-T-9047	
ASTM B348 (Grade 5)	Bar and Billet, Annealed
ASTM B367 (Grade 5)	Castings
ASTM F1472	Wrought Alloy for Surgical Implants
AWS A5.16 (ERTi-5)	Weld Wire

Chemistry Requirements: % Maximum unless given as a range.

N	C	H	Fe	O	Al	V	Y	Ti
0.05	0.08	0.125	0.40	0.2	5.5-6.75	3.5-4.5	0.005	Balance

Note: Chemical requirements are not consistent between specifications. Check referenced specifications.

Minimum Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA*
As specified (shape)	130 (895)	120 (828)	10	25
Solution Treated and Aged	160 (1103)	150 (1034)	10	20
Castings	130 (895)	120 (828)	6	10

Note: Mechanical properties vary with diameter. Check referenced specifications.

Typical Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA
Annealed	145 (1000)	132 (910)	18	40
Solution Treated and Aged	161 (1110)	141 (970)	15	45
Castings	145 (1000)	130 (895)	5	15

Note: Typical properties are not to be utilized as a requirement, but are only listed for guidance. These properties may or may not be attainable in all circumstances.

** %Ra not required by all specifications*

Common Name: Ti-6Al-4V ELI Ti 6-4ELI
Grade 23 Titanium

UNS Number: R56407

General Information: Ti-6Al-4V alloy is the most widely used titanium alloy of the alpha-plus-beta class, and is also the most common of all titanium alloys. This modification incorporates extra low interstitials (ELI). The wrought material is used in applications where moderate strength, good strength to weight, and favorable corrosion properties are required. This alloy is commonly used in medical implants where strength is important. The alloy is available as castings, wire, bar, plate, sheet, forgings, rings, and billet.

Common Specifications:

Specification:	Product Form:
AMS 4907	Sheet, Strip, and Plate
AMS 4956	Wire
ASTM B265 (Grade 23)	Strip, Sheet, and Plate
ASTM B348 (Grade 23)	Bars and Billets; annealed
ASTM B363 (Grade 23)	Seamless and welded fittings
ASTM B381	Forgings
ASTM B861	Seamless Pipe
ASTM B862	Welded Pipe
ASTM B863 (Grade 23)	Wire
ASTM F136	Wrought Alloy for Surgical Implants
AWS A5.16 (ERTi-23)	Weld Wire

Chemistry Requirements: % Maximum unless given as a range.

N	C	H	Fe	O	V	Al	Ti
0.03	0.08	0.02	0.25	0.13	3.5-4.5	5.5-6.75	Balance

Minimum Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA*
Beta-Annealed	120 (828)	110 (759)	10	25

Typical Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA
Annealed	132 (910)	120 (828)	10	40

Note: Typical properties are not to be utilized as a requirement, but are only listed for guidance. These properties may or may not be attainable in all circumstances.

** %Ra not required by all specifications*

Common Name: 6Al-4V ELI with 0.1% Ruthenium Ti-6-4 Ru
Titanium Grade 29

UNS Number: R56404

General Information: Ti-6Al-4V alloy is the most widely used titanium alloy of the alpha-plus-beta class, and is also the most common of all titanium alloys. This modification incorporates extra low interstitials (ELI) and also has a ruthenium addition to enhance the corrosion properties. The wrought material is used in applications where moderate strength, good strenght to weight, and favorable corrosion properties are required. The alloy is available as castings, wire, bar, plate, sheet, forgings, rings, and billet.

Common Specifications:

Specification:	Product Form:
ASTM B265 (Grade 29)	Strip, Sheet, and Plate
ASTM B348 (Grade 29)	Bar and Billet, Annealed
ASTM B363 (Grade 29)	Seamless and Welded Fittings
ASTM B381	Forgings
ASTM B861(Grade 29)	Seamless Pipe
ASTM B862 (Grade 29)	Welded Pipe
ASTM B863 (Grade 29)	Wire
AWS A5.16 (ERTi-29)	Weld Wire

Chemistry Requirements: % Maximum unless given as a range.

N	C	H	Fe	O	Al	V	Ru	Ti
0.03	0.08	0.015	0.25	0.13	5.5-6.5	3.5-4.5	0.08-0.14	Balance

Minimum Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA*
As specified (shape)	120 (828)	110 (759)	10	25

Typical Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA
As provided	132 (910)	120 (828)	18	40

Note: Typical properties are not to be utilized as a requirement, but are only listed for guidance. These properties may or may not be attainable in all circumstances.

** %Ra not required by all specifications*

Common Name: Ti-6Al-7Nb

UNS Number: R56700

General Information: Ti-6Al-7Nb is a high strenght titanium alloy used 1° for medical implants.

Common Specifications:

Specification:	Product Form:
ASTM - F1295	Bar
ISO 5832-11	

Chemistry Requirements: % Maximum unless given as a range.

N	C	H	Fe	O	Al	Nb	Ta
0.05	0.08	0.009	0.25	0.2	5.5-6.5	6.5-7.5	0.5

Minimum Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA*
Bar	130.5 (900)	116 (800)	10	25

Typical Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA
0.25-0.75" diameter bar	148 (1021)	132 (910)	15	42

Note: Typical properties are not to be utilized as a requirement, but are only listed for guidance. These properties may or may not be attainable in all circumstances.

** %Ra not required by all specifications*

Specifications Book 2005

Common Name: Ti-6Al-6V-2Sn
Ti-6-6-2

UNS Number: R56620

General Information: Ti-6Al-6V-2Sn alloy is used for forgings and extrusions requiring greater strength thank Ti-6Al-4V. Typical uses include rocket engine cases, airframe applications, as well as fasteners. Fracture toughness and fatigue resistance are lower than Ti-6Al-4V. This alpha-beta alloy is available in bar, billet, extrusions, plate, sheet, and wire.

Common Specifications:

Specification:	Product Form:
AMS 4918	Sheet-Annealed, Strip, and Plate-Annealed
AMS 4936	Extrusions, Annealed
AMS 4971	Bar, Wire, Forgings, Ring-Annealed
AMS 4978	Wire, Forgings, Ring-Annealed
AMS 4979	Wire, Forgings, Ring-STA
MIL-T-9046	Sheet, Strip, and Plate
MIL-T-9047	Bar, Reforging
MIL-T-81556	Extrusions
MIL-T-83142	Forgings

Chemistry Requirements: % Maximum unless given as a range.

N	C	H	Fe	O	Cu	Y	Al	V	Sn	Residuals Each Max.	Residuals Max.Total
0.04	0.05	0.02	0.35-1.0	0.2	0.35-1.0	0.004	5.0-6.0	5.0-6.0	1.5-2.5	0.1	0.4

Minimum Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA*	Size
Forging	175 (1206)	160 (1103)	8	20	<1"
Annealed Forgings	150 (1035)	140 (965)	10	20	

Typical Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA	Size
Bar, Forged	160 (1103)	150 (1034)	15	40	1-2"
Casting	160 (1105)	140 (965)	6	11	

Note: Typical properties are not to be utilized as a requirement, but are only listed for guidance. These properties may or may not be attainable in all circumstances.

** %Ra not required by all specifications*

Specifications Book 2005

Common Name: Ti-6Al-2Sn-4Zr-2Mo
Ti-6-2-4-2

UNS Number: R54620

General Information: Ti-6Al-2Sn-4Zr-2Mo is used for forgings and rolled products in jet engines and airframe applications where high strength, toughness, and creep resistance are required. This near alpha alloy is available in bar, billet, castings, sheet, strip, and wire.

Common Specifications:

Specification:	Product Form:
AMS 4975	Bar, Wire, and Rings
AMS 4976	Forgings
MIL-T-9046	Sheet, Strip, and Plate
MIL-T-9047	Bar, Reforging
MIL-T-81915	Castings
MIL-T-83142	Forgings

Chemistry Requireme % Maximum unless given as a range.

N	C	H	Fe	Al	O	Y	Zr	Si	Sn	Mo	Residuals Each Max.	Residuals Max. Total	Ti
0.05	0.05	0.125	0.10	5.5-6.5	0.15	0.01	3.6-4.4	0.06-0.10	1.8-2.2	1.8-2.2	0.1	0.3	Balance

Minimum Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA*	Size
Annealed, Forgings	130 (896)	120 (827)	10	25	<3"

NOTE: Mechanical properties vary with diameter. Check referenced specifications.

Typical Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA	Size
Bar, Forged	145 (999)	135 (930)	14	33	1-2"
Castings	125 (861)	115 (792)	8	20	-

Note: Typical properties are not to be utilized as a requirement, but are only listed for guidance. These properties may or may not be attainable in all circumstances.

** %Ra not required by all specifications*

Common Name: Ti-6Al-2Sn-4Zr-6Mo
Ti-6-2-4-6

UNS Number: R56260

General Information: Ti-6Al-2Sn-4Zr-6Mo is a "rich" alpha-beta alloy which finds use in aircraft applications and in the oil and gas industry. The materials is more difficult to fabricate than the more "lean" Ti-6Al-2Sn-4Zr-2Mo alloy. The alloy is available as wire, bar, billet, and forgings.

Common Specifications:

Specification:	Product Form:
AMS 4981	Bar, Wire, Forgings, Heat Treated

Chemistry Requirements: % Maximum unless given as a range.

N	C	H	Fe	O	Al	V	Mo	Sn	Ti
0.04	0.04	0.125	0.15	0.15	5.5-6.5	3.6-4.4	5.5-6.5	1.75-2.25	Balance

Minimum Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% Ra*
Solution Treated & Aged	170 (1172)	160 (1103)	8-10	15-20

Note: Properties depend upon size, orientation, and condition. Refer to reference specification.

Typical Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% Ra*
Annealed	160 (1110)	148 (1020)	15	
Solution Treated & Aged (BSTA)	174 (1200)	152 (1050)	7	
Solution Treated & Aged (STA-1)	176 (1210)	163 (1120)	13	
Solution Treated & Aged (STA-2)	229 (1580)	204 (1410)	4	

Note: Typical properties are not to be utilized as a requirement, but are only listed for guidance. These properties may or may not be attainable in all circumstances.

** %Ra not required by all specifications*

Specifications Book 2005

Common Name: Ti-5Al-2Zr-2Sn-4Mo-4Cr

UNS Number: R58650

General Information: This near-beta, high strength, deep hardenable forging alloy was developed primarily for gas turbine applications such as discs for fan and compressor stages. In addition to offering superior strength properties over Ti-6Al-4V, the alloy also provides higher creep resistance in the intermediate temperature ranges.

Common Specifications:

Specification:	Product Form:
AMS 4995	Billet

Chemistry Requirements: % Maximum unless given as a range.

N	H	O	Al	Cr	Mo	Sn	Zr	Fe	Titanium
0.04	0.0125	0.08-0.13	4.5-5.5	3.5-4.5	3.5-4.5	1.5-2.5	1.5-2.5	0.3	Balance

Minimum Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA*
As specified (shape)	1165(169)	1110(161)	10	32

Typical Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA
	144(993)	122(841)	14	46

Note: Typical properties are not to be utilized as a requirement, but are only listed for guidance. These properties may or may not be attainable in all circumstances.

** %Ra not required by all specifications*

Specifications Book 2005

Common Name: Ti-7Al-4Mo, Ti-7-4, HA 146, C-135A Mo

UNS Number: R56740

General Information: Ti-7Al-4Mo bar and forgings are primarily used for jet engine discs, compressor blades, and spacers. This alpha-beta alloy is available in bar, billet, and extrusions.

Common Specifications:

Specification:	Product Form:
AMS 4970	Bar and Forgings
MIL-T-9047	Bar and Stock, Reforged
MIL-T-81556	Extrusions
MIL-T-83142	Forgings

Chemistry Requirement % Maximum unless given as a range.

N	C	H	Fe	O	Al	Mo	Y	Residuals Each Max.	Residuals Max.Total	Titanium
0.05	0.1	0.013	0.30	0.2	6.5-7.3	3.5-4.5	0.005	0.1	0.4	Balance

Minimum Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA*	Size
STA Forgings	170 (1172)	160 (1103)	8	15	<1"

Typical Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA	Size
Forged, Annealed	145 (1000)	135 (931)	10	20	<1"

Note: Typical properties are not to be utilized as a requirement, but are only listed for guidance. These properties may or may not be attainable in all circumstances.

** %Ra not required by all specifications*

Specifications Book 2005

Common Name: Ti-8Al-1Mo-1V
Ti-8-1-1-1

UNS Number: R54810

General Information: Ti-8Al-1Mo-1V is a "near alpha" alloy. It is primarily used in aircraft engine applications. The alloy is noted for being difficult to fabricate in larger sections. The alloy is available as wire (for welding), bar, billet, sheet, plate, extrusions, and forgings.

Common Specifications:

Specification:	Product Form:
AMS 4915	Sheet, Strip, and Plate, Single Annealed
AMS 4916	Sheet, Strip, and Plate, Duplex Annealed
AMS 4933	Extrusions and Rings, Heat Treated
AMS 4955	Weld Wire
AMS 4972	Bar, Wire, and Rings, Heat Treated

Chemistry Requirements: % Maximum unless given as a range.

N	C	H	Fe	O	Al	V	Mo	Ti
0.05	0.08	0.0125	0.30	0.15	7.35-8.35	0.75-1.25	0.75-1.25	Balance

Minimum Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% Ra*
Annealed	130 (895)	120 (828)	10	20
Heat Treated	170 (1180)	155 (1070)	10	20
Heat Treated, Tested at 800F	90 (620)	70 (480)	10	25

Typical Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% Ra*
Annealed	148 (1021)	134 (924)	19	40

Note: Typical properties are not to be utilized as a requirement, but are only listed for guidance. These properties may or may not be attainable in all circumstances.

** %Ra not required by all specifications*

Specifications Book 2005

Common Name: Ti-10V-2Fe-3Al
Ti-10-2-3

UNS Number: R56410

General Information: Ti-10V-2Fe-3Al is a near beta alloy capable of a wide range of strenghts depending on heat treatement applied. The alloy has excellent forgeability, high toughness and good hardenability which allows good properties in sections to 5" thick.

Ti-10V-2Fe-3Al is used for high strenght aircraft forgings. Its excellent forgeability allows it to be used in near-net shape forging applications. Ti-10V-2Fe-3Al is available in billet, bar and plate.

Common Specifications:

Specification:	Product Form:
AMS 4983A	Forging STA
AMS 4984	Forging STA
AMS 4986	Forging STOA
AMS 4987	Forging STOA

Chemistry Requirements: % Maximum unless given as a range.

N	C	H	Fe	O	Al	V	Ti
0.05	0.05	0.015	1.6-2.2	0.13	2.6-3.4	9.0-11.0	Balance

Minimum Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA*
STA	160	145	6	10
STOA	140 (965)	-	-	-

NOTE: Properties depend on form, heat treatment and size. Check referenced specifications.

Typical Tensile Properties:

	Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA	Klc ksi √ in
α+β Forged	STA	180-200	168-184	4-12	10-30	42-56
	STOA	140-150	130-140	20	45	93
	BAOA	145	135	17	46	100

Note: Typical properties are not to be utilized as a requirement, but are only listed for guidance. These properties may or may not be attainable in all circumstances.

** %Ra not required by all specifications*

Common Name: Ti-3Al-8V-6Cr-4Mo-4Zr 3-8-6-44
Ti Beta-C 38-6-4-4

UNS Number:

General Information: Ti-3Al-8V-6Cr-4Mo-4Zr is a beta alloy, which is capable of achieving a wide range of mechanical properties. In the solution annealed condition the alloy is very ductile and can be easily cold worked. High strength levels can be developed by cold working, solution treating, and aging, or a combination of these processes. This alloy also exhibits very good resistance to reducing acids. The alloy is commonly used for springs and fasteners for aircraft, tubing in oil and gas wells, and as wire in sporting goods and jewelry, and has limited availability in wire, bar, tubing, sheet, and plate.

Common Specifications:

Specification:	Product Form:
AMS 4957	Round Bar & Wire, Solution Treated & Cold Drawn
AMS 4958	Bar and Billet, Solution Treated & Solution Treated and Aged
ASTM B265 (Grade 19)	Strip, Sheet, and Plate
ASTM B348 (Grade 29)	Bar and Billet, Annealed

Chemistry Requirements: % Maximum unless given as a range.

N	C	H	Fe	O	Al	V	Y	Cr	Mo	Zr	Ti
0.03	0.05	0.03	0.30	0.12	3.0-4.0	7.5-8.5	0.005	5.5-6.5	3.5-4.5	3.5-4.5	Balance

Minimum Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA*
Annealed	115 (793)	110 (759)	15	n/a
Solution Treated and Aged	170 (1172)	160 (1103)	6	15

NOTE: mechanical properties vary with diameter. Check referenced specifications.

Typical Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA
Solution Treated	135 (931)	120 (827)	25	60
Solution Treated + Cold Work 25%	160 (1103)	145 (1000)	15	45
Solution Treated + Cold Work 25% +Age	185-195 (1276-1344)	175-185 (1207-1276)	15-Oct	30-40

Note: Typical properties are not to be utilized as a requirement, but are only listed for guidance. These properties may or may not be attainable in all circumstances.

** %Ra not required by all specifications*

Common Name: Ti-13V-11Cr-3Al, 13-11-3, Ti-13-11-3, B120VCA

UNS Number: R58010

General Information: Ti-13V-11Cr-3Al is a beta alloy used primarily for sheet products. The alloy is able to be cold worked and can be aged to high strengths. Typical aging times are substantially longer for the alloy than for other beta alloys. The alloy is commonly used for formed sheet metal components for aircraft and springs, and is available in sheet, wire, and bar.

Common Specifications:

Specification:	Product Form:
AMS 4917	Sheet, Strip, and Plate, Solution Treated
AMS 4959	Wire, Spring Temper

Chemistry Requirements: % Maximum unless given as a range.

N	C	H	Fe	O	Al	V	Cr	Ti
0.05	0.05	0.025	0.35	0.17	2.5-3.5	12.5-14.5	10-12	Balance

Minimum Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA*
Solution Treated	130 (896)	120 (827)	8	-
Sprint Temper	180 (1241)	n/a	6	2
STA	170 (1172)	160	4	-

Note: Mechanical properties vary with diameter. Check referenced specifications.

Typical Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA
Solution Treated	140 (965)	130 (896)	20	50
Solution Treated + Cold Work	175-185 (1207-1276)	160-170 (1103-1172)	8	30
Solution Treated + Cold Work + Age	210-220 (1448-1517)	n/a	5-8	n/a

Note: Typical properties are not to be utilized as a requirement, but are only listed for guidance. These properties may or may not be attainable in all circumstances.

** %Ra not required by all specifications*

Specifications Book 2005

Common Name: TIMETAL 21S
Ti-15Mo-3Nb-3Al-.2Si

UNS Number:

General Information: TIMETAL 21S is a metastable beta titanium alloy that offers substantial weight reductions over other engineering materials. It offers the high specific strength and good cold formability of a metastable beta alloy, but has been specifically designed for improved oxidation resistance, elevated temperature strength, creep resistance, and thermal stability.

Common Specifications:

Specification:	Product Form:
ASTM B265	Sheet, Strip, and Plate
ASTM B348	Bar and Billet
ASTM B363	Fittings
ASTM B381	Forgings
ASTM B861	Seamless Pipe
ASTM B862	Welded Pipe
ASTM B863	Wire
ASME SB-265	Sheet, Strip, and Plate
ASME SB-348	Bar and Billet
ASME SB-363	Fittings

Chemistry Requirements: % Maximum unless given as a range.

N	C	H	Fe	O	Si	Mo	Nb	Al	Residuals Each Max.	Residuals Max. Total	Ti
0.05	0.1	0.015	0.40	0.17	0.15-0.25	14.0-16.0	2.4-3.2	2.5-3.5	0.1	0.1	remainder

Minimum Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA*
Solution Treatment*	115 (793)	110 (759)	15	-

**ASTM B-265 minimums*

Typical Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA
Solution treatment + age	150 (1034)	140 (965)	6 min.	-

Note: Typical properties are not to be utilized as a requirement, but are only listed for guidance. These properties may or may not be attainable in all circumstances.

** %Ra not required by all specifications*

Common Name: Ti–4Al–4Mo–2Sn
Ti-550

UNS Number: None assigned

General Information: Ti 550 is a high strength, forgeable alpha beta alloy. In the solution treated and aged condition it has superior tensile and fatigue properties compared to Ti 6-4 combined with good elevated temperature tensile and creep properties up to 750°F (400°C). This alloy has applications in the aerospace industry both as aeroengine (eg compressor discs) and airframe components (eg flap tracks). Ti 550 has also found applications in high performance automotive engines. The alloy may be welded using electron beam or laser welding techniques. In sheet form, the alloy has good superplastic forming properties and an excellent balance of strength and toughness.

Common Specifications:

Specification:	Product Form:
MSRR 8626	Bar
MSRR 8663/8634	Discs, rotating components
TA 45/46	Rod/Bar
TA 47	Forging stock

Chemistry Requirements: % Maximum unless given as a range.

N	O+2	H	Fe	Al	Mo	Sn	Si	Ti
0.05	0.27	0.0125	0.20	3.0-5.0	3.0-5.0	1.5-2.5	0.3-0.7	Balance

Note: Chemical requirements are not wlways consistant between specifications

Minimum Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA*
Bar/Rod <1 in (25mm)	160 (1100)	139 (960)	9	20
Bar/Rod/Forgings 1-4 in (25-100mm)	152 (1050)	133 (920)	9	20
Bar/Rod/Forgings 4-6 in (100-150 mm)	145 (1000)	126 (870)	9	20
Plate 0.2-2.5 in (5-65 mm)	149 (1030)	130 (900)	9	20

Typical Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA
1 in (25mm) rod ST	157 (1080)	135 (930)	12	40
1 in (25mm) rod ST+A	174 (1200)	155 (1070)	14	42

Note: Typical properties are not to be utilized as a requirement, but are only listed for guidance. These properties may or may not be attainable in all circumstances.

** %Ra not required by all specifications*

Specifications Book 2005

Common Name: Ti-6Al-2Sn-2Zr-2Mo-2Cr-0.15Si
Ti-6-2-2-2-2

UNS Number: R56222

General Information: Ti-6Al-2Sn-2Zr-2Mo-2Cr-Si has been produced in a variety of mill products including sheet, plate, bar, and forgings. Triplex heat treatments allow damage tolerant properties to be minimized. Properties exceed those available in the less hard Ti-6Al-4V alloy. The alloy is available in sheet, plate, bar, and forgings.

Common Specifications:

Specification:	Product Form:
AMS 4898	Sheet Annealed

Chemistry Requirements: % Maximum unless given as a range.

N	C	H	Fe	O	Al	Cr	Si	Zr	Mo	Sn	Ti
0.03	0.08	0.0125	0.15	0.15	2.25-6.25	1.75-2.25	0.12-0.20	1.75-2.25	1.75-2.25	1.75-2.25	Balance

Minimum Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA*
Sheet Annealed	155 (1069)	150 (1034)	5-8 *	n/a

*** depends on GA*

Typical Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% Ra*
STA	170 (1172)	160 (1103)	12	20

Note: Typical properties are not to be utilized as a requirement, but are only listed for guidance. These properties may or may not be attainable in all circumstances.

** %Ra not required by all specifications*

Common Name: Ti 834
Ti-5.8Al-4.0Sn-3.5Zr- 0.7Nb-0.5Mo-0.35Si-0.06C

UNS Number: None assigned

General Information: Ti 834 possesses the highest temperature capability of any commercial titanium alloy (up to 1112°F (600°C)) and is primarily used in aircraft engine applications. This "near alpha" alloy is weldable and possesses a fine grained alpha/beta microstructure that confers the best combination of tensile strength, fatigue and creep resistance. Furthermore, in comparison with other creep resistant Ti alloys, Ti 834 can be stress relieved at temperatures up to 1292°F (700°C).

Common Specifications:

Specification:	Product Form:
CP5238	Bar
CPW534	Billet
DMD 9003	Sheet
MSRR8679	Billet
MSRR8681	Bar
MTS1267	Bar/billet

Chemistry Requirements: % Maximum unless given as a range.

N	C	H	Fe	O	Al	Sn	Zr	Nb	Mo	Si	Ti
0.03	.04-.08	0.006	0.05	.075-.150	5.5-6.1	3.0-5.0	3.0-5.0	0.5-1.0	0.25-0.75	0.20-0.60	Balance

Minimum Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% Ra*
Forgings	149 (1030)	132 (910)	7.5	15
Forgings tested @1112˚F	85 (585)	65 (450)	11	20

Note: Properties depend upon form, heat treatment and size. Check referenced specifications.

Typical Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% Ra*
Forgings	155 (1067)	135 (931)	14	30
Forgings tested @1112˚F	102 (701)	78 (541)	20	58

Note: Typical properties are not to be utilized as a requirement, but are only listed for guidance. These properties may or may not be attainable in all circumstances.

** %Ra not required by all specifications*

Specifications Book 2005

Common Name: Ti-5Al-1Sn-1Zr-1V-0.8Mo
TIMETAL 5111

UNS Number:

General Information: TIMETAL 5111 is a near alpha titanium alloy of intermediate strength. This alloy has been designed for high toughness, good weldibility, stress corrosion cracking resistance, and room temperature creep resistance. TIMETAL 5111 is ideally suited for applications in marine environments where toughness and corrosion resistance are essential. The alloy has been produced on a commercial scale. Forging an dmachining characteristics of TIMETAL 5111 are very similar to TIMETAL 6-4.

Common Specifications:

Specification:	Product Form:
ASTM 468 (32)	
ASTM B265	Bar and Billet
ASTM B348	Bar and Billet
ASTM F467	
ASTM F467(32)	
ASTM F468	
ASTM Grade 32	

Chemistry Requirements % Maximum unless given as a range.

N	Al	H	Fe	O	Sn	V	Zr	Mo	Si	C	Ti
0.03	4.5-5.5	0.015	0.25	0.11	1.4	0.6-1.4	0.6-1.4	0.6-1.2	0.06-0.14	0.08	Remainder

Minimum Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA*
As specified (plate)	100 (689)	85 (586)	10	-

**ASTM B-265 minimum*

Typical Tensile Properties:

Condition	UTS ksi (Mpa)	0.2%YS ksi (MPA)	% El.	% RA
1" plate	121 (835)	104 (720)	13	28

Note: Typical properties are not to be utilized as a requirement, but are only listed for guidance. These properties may or may not be attainable in all circumstances.

** %Ra not required by all specifications*

International Specifications

USA Specifications	Type	ASTM	German DIN	Aerospace German WL	Russian	British Standards TA	Italian (UNI 10221)	Chinese	Japanese
GR-1	BPSTWF	1	3.7025	3.7024	BTI-0	1	Ti1-Type 1	TA0(C.P.Ti)	Gr-1
GR-2		2	3.7035	3.7034	BTI-0	2,3,4,5	Ti2-Type 2	TA1(C.P.Ti)	Gr-2
GR-3	BPSWFC	3	3.7055	-	-	-	Ti3-Type 3	TA2(C.P.Ti)	Cr-3
GR3 +Pd			3.7255	-	-	-	-	-	-
GR-4	BPSWFC	4	3.7065	3.7064	-	6,7,8,9	Ti4-Type 4	TA4(Ti-3A1)	Gr-4
GR-7	BPSTWFC	7	3.7235	-	Alloy 4200	-	Ti2Pd-Type 7	TA9 (Ti-0.2Pd)	Gr-13
GR-11			3.7225	-	-	-	**Ti1Pd-Type 11** C 0,10 max; Fe 0,15 max; O 0,15 max	TA9 (Ti-0.2Pd)	Gr-12
GR-12	BPSTWF	12	3.7105	-	-	-	TiNiMo-Type 12	TA10 (Ti-0.3Mo-0.8Ni)	
GR-5	BPSWFC	5	3.7165	3.7164	BT6, BT6S	10, 11, 12, 28, 56, 59	TiAl6V4-Type 5	TC4(Ti-6A1-4V)	Gr 6 0
GR-5ELI						-	**TiAl6V4ELI-Type 5.1** N 0,05 max; O 0,13 max; H 0,0125 max; C 0,08 max; Fe 0,25 max; Al 5,5-6,5; V 3,5-4,5	-	-
Ti-10Fe-2V-3Al (10-2-3)	BF		-	-	-	-	-	-	-
Ti-4Al-4 Mo-2.5Sn (550)	BPF		3.7185	3.7184	-	45-51, 57	-	-	-
Ti-15V-3Al-3 Cr-3Sn (15-3)	PSWT		-	-	-	-	-	-	-
Ti-6Al-2Sn 4Zr-2Mo (6-2-4-2)	BPSF		3.7145	3.7144	BT25, BT184*	-	-	-	-
T-6Al-2Sn-4Zr			-	-	-	-	-	-	-
Ti-3Al-2.5V (Grade 9)		9	3.7195	3.7194	PT3V*	-	TiAl3V2,5-Type 9	-	Gr 6 1
TI-3Al-2.5V with Ruthenium (Grade 28)		28	-	-	-	-	-	-	-
Ti-5Al-2.5Sn (Grade 6)		6	3.7115	3.7114	BT5-1	-	TiAl5Sn2,5-Type 6	TA7(Ti-5A1-2.5Sn)	-
Ti-5Al-2Sn ELI			-	-	BT5-1CH	-	-	-	-
Ti-6Al-4V ELI with Ruthenium (Grade 23)		23	-	-	-	-	-	-	Gr 6 0 E
Ti-6Al-4V ELI with Ruthenium (Grade 29)			-	-	-	-	-	-	-
Ti-6Al-6V-2Sn			3.7175	3.7174	-	-	-	-	-
Ti-6Al-2Sn-4Zr-6Mo			-	-	-	-	-	-	-
Ti-5Al-2Sn-2Zr-4Mo-4Cr			-	-	-	-	-	-	-
Ti-7Al-4Mo			-	-	BT8	-	-	-	-
Ti-8Al-1Mo-1V			-	3.7134	BT14*	-	-	-	-

International Specifications

USA Specifications	Type	ASTM	German DIN	Aerospace German WL	Russian	British Standards TA	Italian (UNI 10221)	Chinese	Japanese
Ti-10V-2Fe-3Al			-	-	-	-	-	-	-
Ti-3Al-8V-6Cr-4Mo-4Zr			-	-	-	-	-	-	-
Ti-13V-11Cr-3Al			-	-	TC6*	-	-	-	-
Ti-6Al-5Zr-0.5Mo-Si			3.7155	3.7154		-	-	-	-
Ti-5Al-2.5Fe			3.711			-	-	-	-
Ti-Cu2			-	3.7124		-	-	-	-
Ti-6Al-2Sn-4Zr-2Mo (+Si)			3.7145	3.7148		-	-	-	-
Ti-6Al-2Sn-4Zr-2Mo					BT2.5, BT18Y*	-	-	-	-
Ti6-4ELE					BT6CH	-	-	-	-
TiAl6V6Sn2-Type 13						-	N 0,04 max; C 0,05 max; Fe 0,35-1,0; O 0,20 max; H 0,015 max; Al 5,0-6,0; V 5,0-6,0; Sn 1,5-2,5; Cu 0,35-1,0	-	-
TiV10Al3Fe2-Type 14						-	N 0,05 max; C 0,05 max; Fe 1,6-2,2; O 0,13 max; H 0,015 max; Al 2,6-3,4; V 9,0-11,0	-	-

Russa * = similar to

Italian - UNI 10221: Chemical requirements for Titanium and Titanium alloys for ingots and semi-finished products

Types:

b -	bar	t -	tube
p -	plate	w -	wire
s -	sheet	f -	forgings
		c -	casting

Titanium Metal Terminology

FINISHED PRODUCT SHAPES

(Ready for fabrication into components)

Plate - Typically a hot finished flat rolled product with a width greater than 8" and a thickness greater than 0.125". Commonly available in 48" or 60" widths.

Sheet and Strip - Generally have thickness ranging from 0.025" to 0.125" and is produced by continuous rolling of large coils. It may then be cut into lengths and sold as sheet.

Bar - Refers to rounds, squares, hexagons and similar shapes measuring at least 3/8" in cross-section.

Wire Rod – Semi-finished product used for the manufacture of wire.

Wire - Usually cold drawn from wire rod.

Foil - May be any width but no more than 0.005" thick.

Tubular Product - Describes all hollow titanium products, usually cylindrical in shape such as condenser tubing.

HEAT TREATING

Heat Treating -Is the process of altering the properties of a metal by subjecting it to a controlled sequence of thermal cycles. The time of retention at a specific temperature and the rate of cooling are as important as the temperature itself. Heat treatment can be performed to improve machinability, increase toughness, improve cold forming characteristics, alter hardness ad tensile strength, up and down, and to relieve residual stress as well as improve shearability.

Annealing -Refers to a variety of operations involving heating and slow cooling to remove stresses and alter ductility and toughness. Annealing softens the titanium making it more workable for shearing, forming and machining.

Stress Relieving - Removes residual stresses from within the metal.

Quenching - Rapid cooling from a specific temperature.

Turning, Grinding and Polishing - Produces bars that are characterized by superior surface finish, dimensional precision and straightness.

METALLURGY

Acicular Alpha - A fine needle-like transformation product brought about through nucleation and growth.

Alpha - The low temperature allotrope of titanium with a hexagonal, close-packed crystal structure.

Alpha-Beta Structure - A microstructure that contains both alpha and beta as the principal phases.

Alpha Case - The oxygen-enriched, alpha-stabilized surface that results from elevated temperature air exposure.

Alpha-Prime (Martensitic Alpha) - A supersaturated, non-equilibrium phase formed by a diffusion-less transformationof beta phase which is lean in solute.

Alpha Stabilizer - An alloying element that dissolves preferentially in the alpha phase and raises the alpha-beta transformation temperature.

Alpha Two, (a_2) - An ordered alpha structure, such as Ti_3Al and Ti_3 (Al, Sn) found in highly stabilized alpha alloys.

Alpha Transus - The temperature that designates the phase boundary between the alpha and alpha-plus-beta fields.

Beta - The high temperature allotrope of titanium with a body-centered cubic crystal structure.

Beta Eutectoid - Beta stabilizing alloying elements that result in the decomposition of beta to eutectoid products, such as alpha and inter-metallic compounds.

Beta Isomorphous - Beta stabilizing alloying elements which are completely miscible in the beta phase.

Beta Stabilizer - An alloying element which dissolves preferentially in the beta phase and lowers the beta transformation temperature. Such elements promote the retention of beta at room temperature.

Beta Transus - The temperature which designates the phase boundary between the alpha-plus-beta and beta fields.

Elongated Alpha - A fibrous type of structure brought about by unidirectional fabrication.

Titanium Metal Terminology

Equiaxed Structure - A polygonal structure having approximately equal dimensions in all directions.

Hydride Phase - The phase TiH formed in titanium when the hydrogen content exceeds the solubility limit.

Interstitial Element - An element with a relatively small atom which can assume position in the interstices of the titanium lattice. These elements are oxygen, nitrogen and carbon.

Intergranular Beta - Beta situated between alpha grains.

Intermetallic Compound - An intermediate phase in an alloy system that has a narrow solubility range.

Matrix - The constituent which forms the continuous phase of a two phase microstructure.

Metastable Beta - A non-equilibrium phase that can be transformed to alpha or eutectoid products by heat or stress.

M_f - The temperature at which the martensite reaction is complete.

M_s - The maximum temperature at which alpha-prime begins to form from the beta phase on cooling.

Omega - A non-equilibrium, submicroscopic phase that forms during the nucleation and growth transformation of beta to alpha.

Ordered Structure - The orderly or periodic arrangement of solute atoms on the lattice sites of the solvent.

Plate-like Alpha - Alpha grains which form along preferred planes of beta during transformation of beta to alpha. Plate-like alpha is characterized by relatively long and wide grains.

Primary Alpha - Equilibrium alpha which remains untransformed on heating to temperatures below and for short times above
the beta transus.

Prior Beta Grain Size - The grain size of the beta phase prior to transformation to alpha.

Serrated Grain - Alpha grains which are characterized by irregular grain size and jagged grain boundaries.

Spheroidal Structure - Grains with a circular or globular appearance.

Substitutional Element - An alloying element with an atom size similar to the solvent which can replace or substitute for the solvent atoms in the lattice.

Transformed Beta - Products of unstable beta after transformation, e.g., alpha, beta and eutectoid products.

Widmanstatten Structure - A structure brought about by the formation of a new phase along preferred crystallographic planes of the prior phase. The Widmanstatten structure is a transformation product of the beta phase.

ROUGH PRODUCT SHAPES

Ingots - Cylindrical in shape with a 1.5 or more length to diameter ratio. A typical production ingot in 34" diameter by 96" long and weighs 14,000 pounds.

Bloom – Semi-finished billet, slab or bar of titanium that has been hammered, forged or rolled from an ingot.

Billet - Piece of semi-finished titanium square or nearly square in section, made by rolling an ingot or bloom.

Slab – Semi-finished titanium block having a rectangular cross-section in which the width is at least twice the thickness. Slab is also a cast product from EB or plasma melting.

TITANIUM SPONGE PRODUCTION

Titanium Ore - The most common ore used in the titanium metals industry is rutile which is a black beach sand containing +95% TiO_2. The alternate ore is ilmenite, which is only 55 to 60% TiO_2 with the remainder being iron oxides.

Chlorination - Rutile ore (TiO_2) reacts with chlorine gas at elevated temperatures to yield titanium tetrachloride, a colorless liquid.

Coke - The carbon feed material used in chlorination.

Chlorination - Titanium Tetrachloride, $TicCl_4$, Tickle - Titanium Tetrachloride is the product of chlorinating titanium dioxide "with Cl in the presence" of carbon to remove the oxygen and

Titanium Metal Terminology

produce $TiCl_4$. As used in the metals industry, it is a clear, colorless liquid at room temperature.

Titanium Dioxide - TiO_2 is a pure white material used as pigment in paint. Over 90% of all titanium ores that are mined end up as pigment. TiO_2 is also used in cosmetics such as lipstick.

Reduction - The process of converting $TiCl_4$ to titanium metal using a reducing agent such as magnesium or sodium.

Magnesium Reduction - Titanium tetrachloride combined with molten magnesium metal in a steel reactor under a controlled atmosphere yields titanium metal in sponge form and magnesium chloride ($MgCl_2$) as a by product. The pores in the spongy mass of titanium are filled with Mg or $MgCl_2$. This residual material is removed either by leaching or vacuum distillation.

Vacuum Distillation - For the vacuum distillation process, 366 stainless steel reactor pots are used. After the reduction is completed, the hot reactor pot is transferred to a cold wall vacuum furnace and the residual Mg-$MgCl_2$ is distilled over into a collection vessel for recovery.

Electrolytic Cell - Magnesium chloride ($MgCl_2$) is electrolyzed to recapture chlorine gas and magnesium metal, both of which are recycled through the process.

Sponge - A porous metal product of the chemical reduction of titanium tetrachloride to metal by the Kroll or Hunter process.

Kroll Process - A process for the production of titanium sponge metal where the reducing agent is magnesium.

Hunter Process - The Hunter Process uses sodium as the reducing agent. The sponge produced is purified by a weak acid leach. Between 1990 and 1994 all of the companies using the Hunter Process have gone out of business or shutdown that section of the plant.

Leaching - Titanium sponge passes through a rotary-leaching vessel (made from titanium) where aqua regia and water remove trace magnesium and other impurities.

Leached Sponge - A sponge metal that has been purified by using a weak acid to remove the impurities, such as unreacted reducing agent or by-product salt from the sponge.

Distilled Sponge - A sponge metal that has been purified by vacuum distillation instead of leaching. The impurities are removed from the pores of the sponge by vaporizing rather than digestion in leaching.

Sponge Mass - Is the 18,000-pound cylindrical block of sponge pushed out of the reactor vessel after the completion of reduction and distillation.

Titanium Crystals - A high purity titanium crystal produced by the iodide of electro-refining process. Normally in the 55 to 90 Bhn range.

Sodium - The agent used to reduce $TiCl_4$ to titanium metal in the Hunter Process.

Other Resources

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Email: infocentral@asme.org

American Society for Testing and Materials (ASTM)
100 Barr Harbor Drive
Conshohocken, PA 19428-2959 USA
Phone: (610) 832-9585
Fax: (610) 832-9555
Website: www.astm.org
Email: service@astm.org

American Welding Society (AWS)
550 Northwest LeJeune Road
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Fax: (305) 443-7559
Website: www.aws.org
Email: info@aws.org

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