

TITANIUM Grade 1

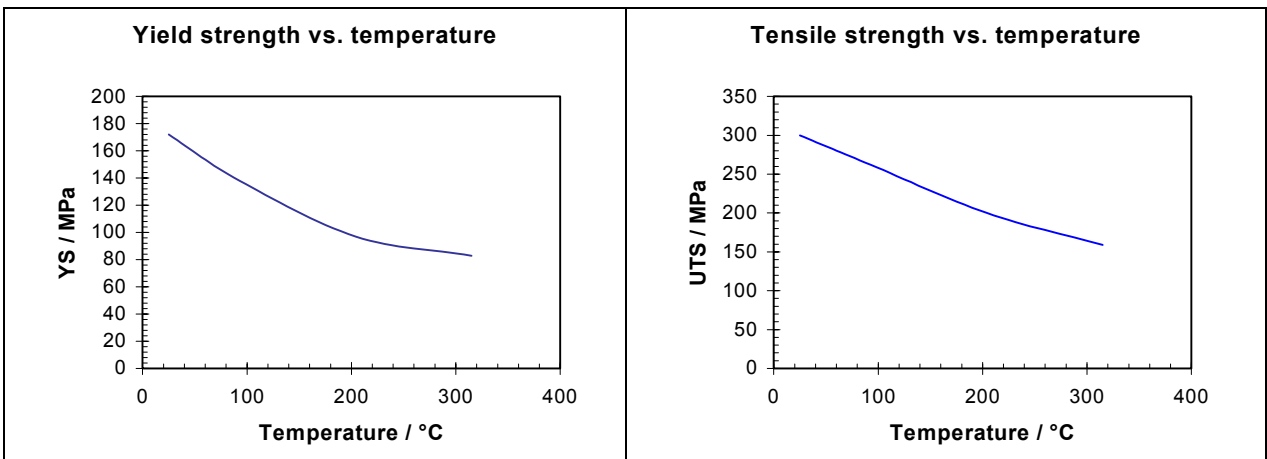
Commercial pure titanium

The data given is for information not for design

Chemical composition (weight %) (Maximum values unless range is shown)										
O	N	C	H	Fe	Al	V	Ni	Mo	Others	Residuals
0.18	0.03	0.08	0.015	0.2						0.4

Unalloyed titanium offering optimum ductility and cold formability with useful strength, high-impact toughness, and excellent weldability. Highly corrosion resistant in oxidizing and mildly reducing environments, including chlorides.

Mechanical properties at room temperature		
	Minimum values	Typical values
Yield Strength	170 MPa	220 MPa
Ultimate Strength	240 MPa	345 MPa
Elongation in 50 mm, A5	25 %	37 %
Reduction in Area	30 %	%
Hardness		115 HV
Modulus of elasticity		103 GPa
Charpy V-Notch Impact		95-162 J



Fatigue properties at room temperature (Stress to cause failure in 10^7 Cycles)		
Rotating bend		
Smooth	$K_t=1$	193 MPa
Notch	$K_t=3$	123 MPa

Physical properties	
Melting point, ± 15 °C	1670 °C
Density	4.51 g/cm ³
Beta transus, ± 15 °C	890 °C
Thermal expansion, 20 - 100 °C	8.6 *10 ⁻⁶ K ⁻¹
Thermal expansion, 0 - 300 °C	9.2 *10 ⁻⁶ K ⁻¹
Thermal conductivity, room temperature	20.8 W/mK
Thermal conductivity, 400 °C	14 W/mK
Specific heat, room temperature	0.56 J/gK
Specific heat, 400 °C	0.60 J/gK
Electrical resistivity, room temperature	52 μW*cm
Poisson's ratio	0.34-0.40

Heat treating			
		Temperature	Time
Annealing	air-cooled	650-760 °C	6 min - 2 hours
Stress relieving	air-cooled	480-595 °C	15 min - 4 hours

Weldability – excellent

Grade 1 has very good weldability. Being substantially single-phase material, the microstructure of the alpha phase is not affected greatly by thermal treatments or welding temperatures. Therefore, the mechanical properties of a correctly welded joint are equal to, or exceed those of the parent metal and show good ductility

Available mill products

Bar, billet, ingot, extrusions, plate, sheet, strip, tubing, wire, pipe, forging

Typical Applications

For corrosion resistance in the chemical and marine industries; in airframe construction where maximum ease of formability is desired

Industry specifications	ASTM Gradel, JIS Grade , TIA, RMI 25, TIMETAL 35A, ST-40
Sheet and plate	ASTM B265 Gr1, Mil-T-9046 CP-4
Bars and billets	ASTM B348 Gr1
Tube	ASTM B337 Gr1, ASTM B338 Gr1
Forging	ASTM B381 Gr1
Casting	ASTM F467 Gr1 ASTM F468 Gr1 DIN 3.7025 BSTA 1

TITANIUM Grade 2

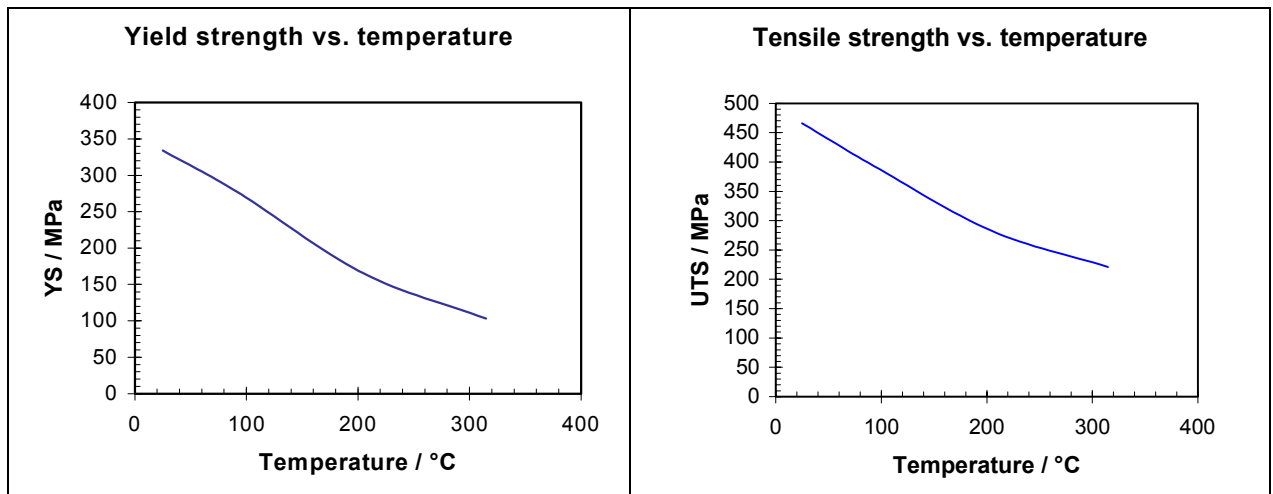
Commercial pure titanium

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Chemical composition (weight %) (Maximum values unless range is shown)										
O	N	C	H	Fe	Al	V	Ni	Mo	Others	Residuals
0.25	0.03	0.08	0.015	0.3						0.4

Grade 2 is the most widely used titanium alloy in all product forms for industrial service, offering an excellent balance of moderate strength and reasonable ductility. Highly corrosion-resistant in highly oxidizing and mildly reducing environments, including chlorides.

Mechanical properties at room temperature		
	Minimum values	Typical values
Yield Strength	275 MPa	350-450 MPa
Ultimate Strength	345 MPa	485 MPa
Elongation in 50 mm, A5	20 %	28 %
Reduction in Area	30 %	55 %
Hardness		160-200 HV
Modulus of elasticity		103 GPa
Charpy V-Notch Impact		40-82 J



Fatigue properties at room temperature (Stress to cause failure in 10^7 Cycles)		
Rotating bend		
Smooth	$K_t=1$	230 MPa
Notch	$K_t=3$	155 MPa

Physical properties	
Melting point, ± 15 °C	1660 °C
Density	4.51 g/cm ³
Beta transus, ± 15 °C	910 °C
Thermal expansion, 20 - 100 °C	8.6 *10 ⁻⁶ K ⁻¹
Thermal expansion, 0 - 300 °C	9.7 *10 ⁻⁶ K ⁻¹
Thermal conductivity, room temperature	20.8 W/mK
Thermal conductivity, 400 °C	15 W/mK
Specific heat, room temperature	0.52 J/gK
Specific heat, 400 °C	0.60 J/gK
Electrical resistivity, room temperature	56 μW*cm
Poisson's ratio	0.34-0.40

Heat treating			
		Temperature	Time
Annealing	air-cooled	650-760 °C	6 min - 2 hours
Stress relieving	air-cooled	480-595 °C	15 min - 4 hours

Weldability – excellent

Grade 2 has very good weldability. Being substantially single phase material, the microstructure of the alpha phase is not affected greatly by thermal treatments or welding temperatures. Therefore, the mechanical properties of a correctly welded joint are equal to, or exceed those of the parent metal and show good ductility

Available mill products

Bar, billet, ingot, extrusions, plate, sheet, strip, tubing, wire, pipe, forging, casting

Typical Applications

For corrosion resistant in the chemical and offshore industries, in aircraft construction where a certain strength level and ease of formability is desired. Also used in heat exchangers, hypochlorite systems, fire water systems, ballast water systems, risers, fittings, flanges, fasteners, forgings, pumps, valves.

Industry specifications ASTM Grade 2, AMS 4902, JIS Grade 2, TIB, RMI 40, ST-50

Sheet and plate	ASTM B265 Gr2, MIL-T-9046 CP-3, AMS 4900
Bars and billets	ASTM B348 Gr2
Tube	ASTM B337 Gr2, ASTM B338 Gr2
Forging	ASTM B381 Gr2
Casting	ASTM B367 Gr2, ASTM F467 Gr2, ASTM F468 Gr2

TITANIUM Grade 3

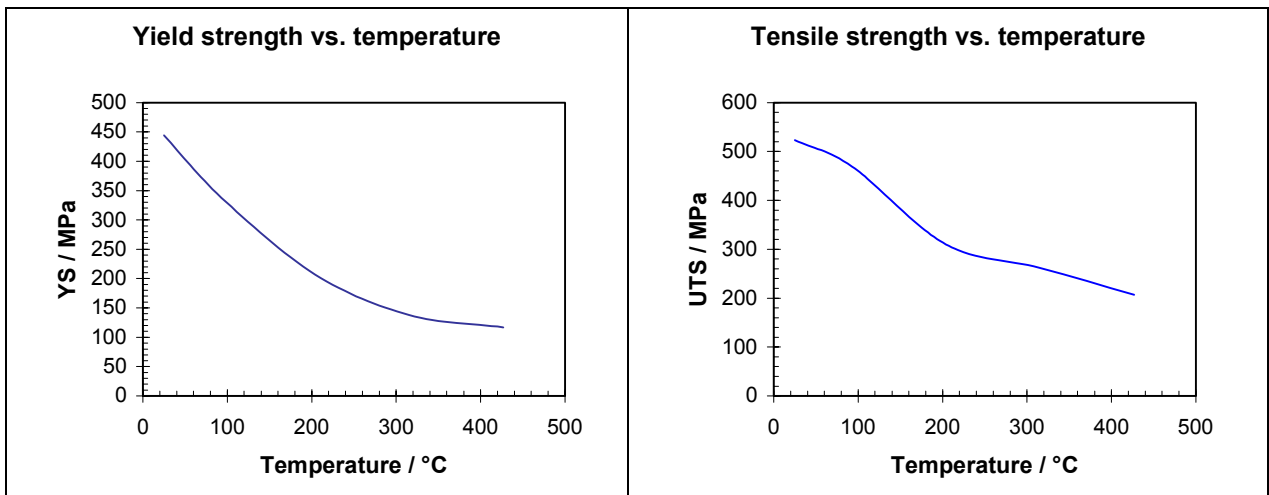
Commercial pure titanium

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Chemical composition (weight %) (Maximum values unless range is shown)										
O	N	C	H	Fe	Al	V	Ni	Mo	Others	Residuals
0.35	0.05	0.08	0.015	0.30						0.4

Unalloyed titanium offering optimum ductility and cold formability with useful strength, high-impact toughness, and excellent weldability. Highly corrosion resistant in oxidizing and mildly reducing environments, including chlorides.

Mechanical properties at room temperature		
	Minimum values	Typical values
Yield Strength	380 MPa	460 MPa
Ultimate Strength	450 MPa	595 MPa
Elongation in 50 mm, A5	18 %	25 %
Reduction in Area	30 %	%
Hardness		180-220 HV
Modulus of elasticity		103 GPa
Charpy V-Notch Impact		24-48 J



Fatigue properties at room temperature (Stress to cause failure in 10^7 Cycles)				
Rotating bend			Direct stress limit	
Smooth	$K_t=1$	380 MPa	Smooth	$K_t=1$ 280 MPa
Notch	$K_t=3$	165 MPa	Notch	$K_t=3$ 123 MPa

Physical properties	
Melting point, ± 15 °C	1680 °C
Density	4.51 g/cm ³
Beta transus, ± 15 °C	920 °C
Thermal expansion, 20 - 100 °C	8.6 *10 ⁻⁶ K ⁻¹
Thermal expansion, 0 - 300 °C	9.2 *10 ⁻⁶ K ⁻¹
Thermal conductivity, room temperature	17 W/mK
Thermal conductivity, 400 °C	16 W/mK
Specific heat, room temperature	0.54 J/gK
Specific heat, 400 °C	0.60 J/gK
Electrical resistivity, room temperature	56 μW*cm
Poisson's ratio	0.34-0.40

Heat treating			
		Temperature	Time
Annealing	air-cooled	650-760 °C	6 min - 2 hours
Stress relieving	air-cooled	480-595 °C	15 min - 4 hours

Weldability – excellent

Grade 3 has very good weldability. Being substantially single phase material, the microstructure of the alpha phase is not affected greatly by thermal treatments or welding temperatures. Therefore, the mechanical properties of a correctly welded joint are equal to, or exceed those of the parent metal and show good ductility

Available mill products

Bar, billet, ingot, extrusions, plate, sheet, strip, tubing, wire, pipe, forging, casting

Typical Applications

Equivalent to Grade 1 and 2, and eminently suitable where high strength is needed

Industry specifications	ASTM Grade 3, AMS 4900, JIS Grade 3, TIC, RMI 55, ST-70
Sheet and plate	ASTM B265 Gr3, MIL-T-9046 CP-2, AMS 4900
Bars and billets	ASTM B348 Gr3
Tube	ASTM B337 Gr3, ASTM B338 Gr2
Forging	ASTM B381 Gr3
Casting	ASTM B367 Gr3, ASTM F467 Gr3 ASTM F468 Gr3, DIN 3.7055

TITANIUM Grade 4

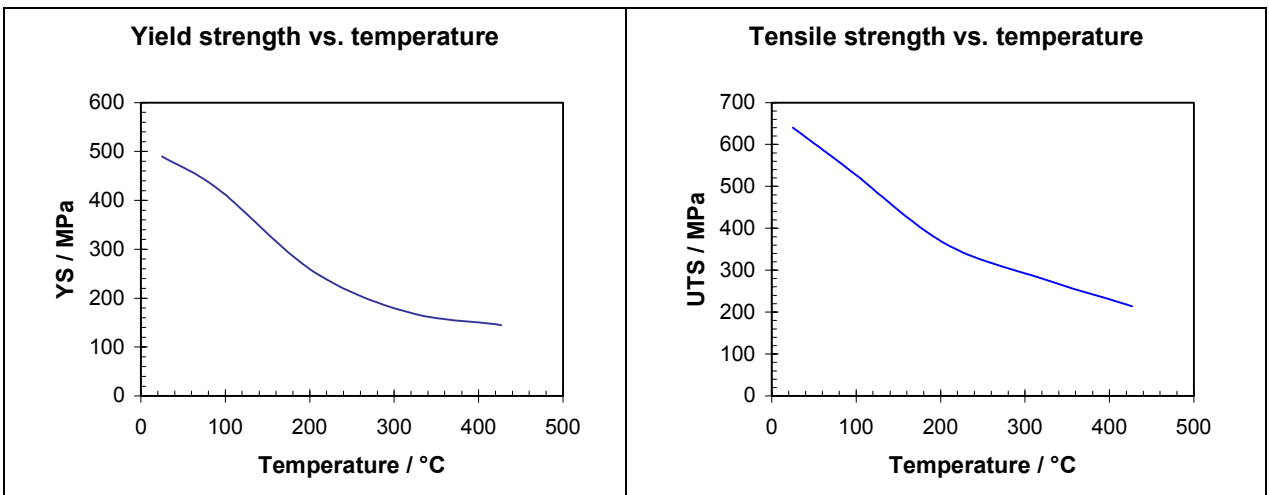
Commercial pure titanium

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Chemical composition (weight %) (Maximum values unless range is shown)										
O	N	C	H	Fe	Al	V	Ni	Mo	Others	Residuals
0.40	0.05	0.08	0.015	0.50						0.4

Unalloyed titanium offering reasonable high strength with good weldability. Good corrosion resistance in neutral to oxidizing environments, including chlorides.

Mechanical properties at room temperature		
	Minimum values	Typical values
Yield Strength	485 MPa	560 MPa
Ultimate Strength	550 MPa	685 MPa
Elongation in 50 mm, A5	15 %	23 %
Reduction in Area	30 %	%
Hardness		250 HV
Modulus of elasticity		104 GPa
Charpy V-Notch Impact		13-27 J



Fatigue properties at room temperature (Stress to cause failure in 10^7 Cycles)	
	Direct stress limit
	Smooth $K_t=1$ 375 MPa

Physical properties	
Melting point, ± 15 °C	1660 °C
Density	4.54 g/cm ³
Beta transus, ± 15 °C	950 °C
Thermal expansion, 20 - 100 °C	8.6 *10 ⁻⁶ K ⁻¹
Thermal expansion, 0 - 300 °C	9.2 *10 ⁻⁶ K ⁻¹
Thermal conductivity, room temperature	17.3 W/mK
Thermal conductivity, 400 °C	W/mK
Specific heat, room temperature	0.54 J/gK
Specific heat, 400 °C	0.40 J/gK
Electrical resistivity, room temperature	60 μW*cm
Poisson's ratio	0.34-0.40

Heat treating			
		Temperature	Time
Annealing	air-cooled	650-760 °C	6 min - 2 hours
Stress relieving	air-cooled	480-595 °C	6 min - hours

Weldability – excellent

Grade 4 has very good weldability. Being substantially single-phase material, the microstructure of the alpha phase is not affected greatly by thermal treatments or welding temperatures. Therefore, the mechanical properties of a correctly welded joint are equal to, or exceed those of the parent metal and show good ductility

Available mill products

Bar, billet, ingot, extrusions, plate, sheet, strip, tubing, wire, pipe, forging, casting

Typical Applications

For corrosion resistance in the chemical and marine industries and for aircraft construction

Industry specifications	ASTM Grade 4, JIS Grade 4, TID, RMI 70
Sheet and plate	AMS 4901, MIL-T-9046 CP-1
Bars and billets	ASTM B348 Gr4
Forging	ASTM B381 Gr4
Bar, forging and circular forging	AMS 4921
Bar, billet and forging blank	ASTM F467 Gr4, ASTM F468 Gr4
	DIN 3.7065
	BSTA 6,7,8,9

TITANIUM Grade 5

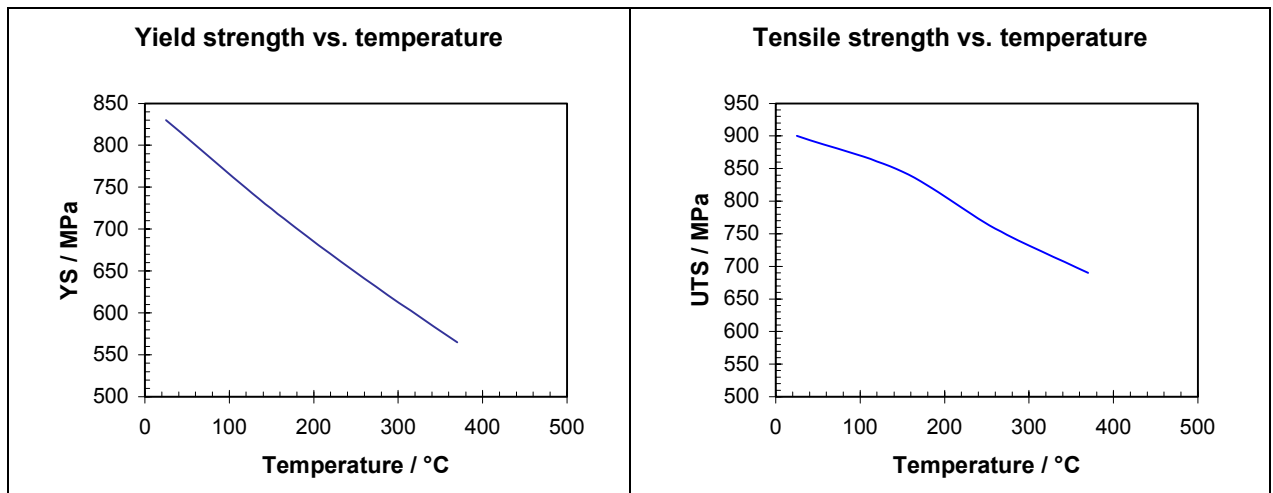
Ti - 6Al - 4V Alpha-beta alloy

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Chemical composition (weight %) (Maximum values unless range is shown)										
O	N	C	H	Fe	Al	V	Ni	Mo	Others	Residuals
0.20	0.05	0.08	0.015	0.40	5.5-6.75	3.5-4.5				0.4

This is the most widely used titanium alloy. It has very high strength but relatively low ductility. The main application of this alloy is in aircraft and spacecraft. Offshore use is growing. The alloy is weldable and can be precipitation hardened.

Mechanical properties at room temperature		
	Minimum values	Typical values
Yield Strength	825 MPa	910 MPa
Ultimate Strength	895 MPa	1000 MPa
Elongation in 50 mm, A5	10 %	18 %
Reduction in Area	20 %	%
Hardness		330-390 HV
Modulus of elasticity		114 GPa
Charpy V-Notch Impact		20-27 J



Fatigue properties at room temperature (Stress to cause failure in 10^7 Cycles)					
Rotating bend			Direct stress limit		
Smooth	$K_t=1$	430-520 MPa	Smooth	$K_t=1$	376 MPa
Notch	$K_t=3$	MPa	Notch	$K_t=3$	270 MPa

Physical properties	
Melting point, ± 15 °C	1650 °C
Density	4.43 g/cm ³
Beta transus, ± 15 °C	995 °C
Thermal expansion, 20 - 100 °C	9.0 *10 ⁻⁶ K ⁻¹
Thermal expansion, 0 - 300 °C	9.5 *10 ⁻⁶ K ⁻¹
Thermal conductivity, room temperature	6.6 W/mK
Thermal conductivity, 400 °C	13 W/mK
Specific heat, room temperature	0.57 J/gK
Specific heat, 400 °C	0.65 J/gK
Electrical resistivity, room temperature	171 μW*cm
Poisson's ratio	0.30-0.33

Heat treating		
	Temperature	Time
Solution treating temperature	950-970°C	1 hour
Ageing temperature	480-595°C	4-8hours
Annealing	710-790°C	1-4hours
Stress relieving	480-650°C	1-4hours

Weldability – good

Since the two-phase microstructure of alpha-beta titanium alloys responds to thermal treatment, the temperatures encountered during the welding cycle can affect the material being welded.

Available mill products

Bar, billet, extrusions, plate, sheet, strip, wire

Typical Applications

Compressor blades, discs and rings for jet engines, aircraft components, pressure vessels, rocket engine cases, offshore pressure vessels.

Industry specifications

ASTM Grade5, ST-AI40, AMS4911D, MIL-T-9047G

Sheet and plate

ASTM B265 Gr5, AMS 4911

Bars and billets

ASTM B348 Gr5

Bars, billets and forging (+circular forging)

AMS 4928, AMS 4965, AMS 4967

Extruded products

AMS 4935

Castings

ASTM B367 Gr5

TITANIUM Grade 6

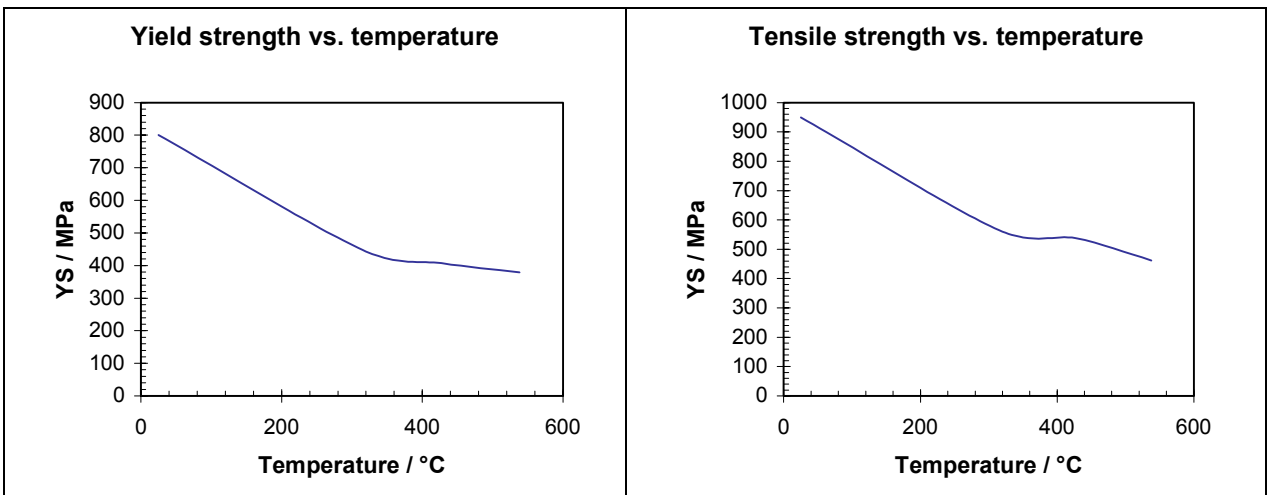
Ti-5Al-2.5Sn

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Chemical composition (weight %) (Maximum values unless range is shown)										
O	N	C	H	Fe	Al	V	Sn	Mo	Others	Residuals
0.20	0.05	0.08	0.02	0.50	4.0-6.0		2.0-3.0			0.40

An alloy for airframe and jet engine applications requiring good weldability, stability and strength at elevated temperatures.

Mechanical properties at room temperature		
	Minimum values	Typical values
Yield Strength	795 MPa	900 MPa
Ultimate Strength	825 MPa	970 MPa
Elongation in 50 mm, A5	10 %	16 %
Reduction in Area	25 %	%
Hardness		330-350 HV
Modulus of elasticity		110 GPa
Charpy V-Notch Impact		14 J



Physical properties	
Melting point, ± 15 °C	1600 °C
Density	4.48 g/cm ³
Beta transus, ± 15 °C	1040 °C
Thermal expansion, 20 - 100 °C	9.4 *10 ⁻⁶ K ⁻¹
Thermal expansion, 0 - 300 °C	9.5 *10 ⁻⁶ K ⁻¹
Thermal conductivity, room temperature	7.8 W/mK
Thermal conductivity, 400 °C	W/mK
Specific heat, room temperature	0.53 J/gK
Specific heat, 400 °C	J/gK
Electrical resistivity, room temperature	160 μW*cm
Poisson's ratio	

Heat treating				
		Temperature	Time	
Annealing	air-cooled	650-760 °C	6 min -	2 hours
Stress relieving	air-cooled	480-595 °C	15 min -	4 hours

Weldability – good

Grade 6 has good weldability

Available mill products

Bar, billett, ingot, plate, sheet, strip, wire, pipe, forging, casting

Typical Applications

Weldable alloy for forgings and sheet metal parts such as aircraft engine compressor blades and ducting, steam turbine blades, rocket engine, ordnance components. Good oxidation resistance and strength at 315-540 °C. Good stability at elevated temperatures. Can be cold-worked and used only in annealed condition

Industry specifications

ASTM Grade6, AMS 4966B, RMI 5Al-2.4Sn, TIMETAL 5-2.5, TITA2

Sheet and plate

AMS 4910, MIL-T-9046 A-1, ASTM B265 Gr6

Bars and billets

ASTM B348 Gr6

Forging

ASTM B381 Gr6, AMS 4966

Bar, forging and circular forgings

AMS 4926

Bar, billett and forging blank

MIL-T-9047

Casting

ASTM B367 Gr6

TITANIUM Grade 7

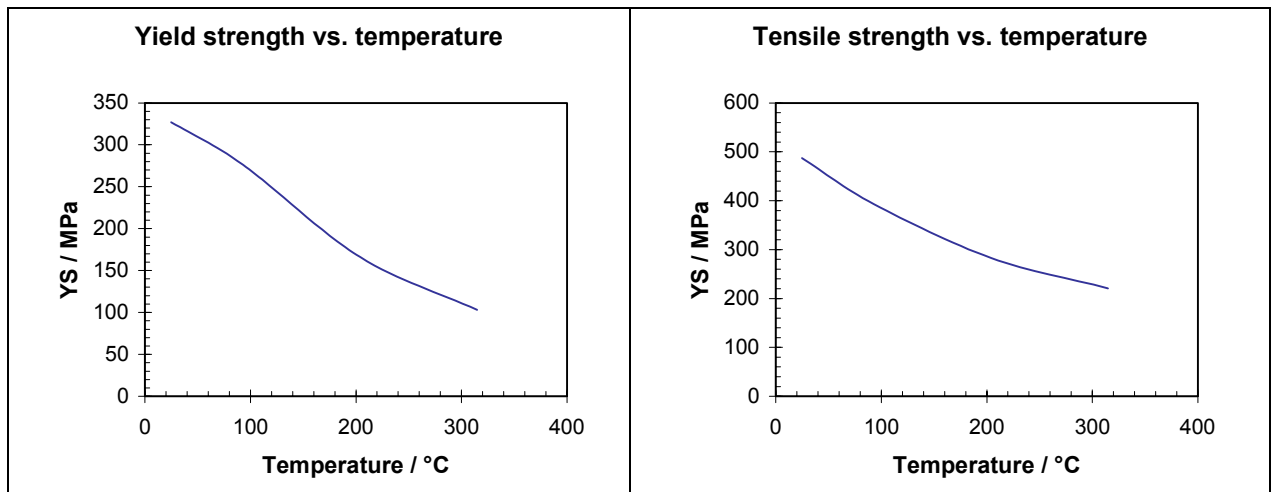
Commercial pure titanium - 0.15%Pd

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Chemical composition (weight %) (Maximum values unless range is shown)										
O	N	C	H	Fe	Al	V	Ni	Mo	Pd	Residuals
0.25	0.03	0.08	0.015	0.30					0.12-0.25	0.40

Most corrosion-resistant titanium alloy offering outstanding resistance to general and localized crevice corrosion in a wide range of oxidizing and reducing acid environments including chlorides, with a good balance of moderate strength, reasonable ductility and excellent weldability. Physical and mechanical properties equivalent to Grade 2.

Mechanical properties at room temperature		
	Minimum values	Typical values
Yield Strength	275 MPa	350 MPa
Ultimate Strength	345 MPa	485 MPa
Elongation in 50 mm, A5	20 %	28 %
Reduction in Area	30 %	%
Hardness		150 HV
Modulus of elasticity		103 GPa
Charpy V-Notch Impact		40-82 J



Physical properties	
Melting point, ± 15 °C	1660 °C
Density	4.51 g/cm ³
Beta transus, ± 15 °C	915 °C
Thermal expansion, 20 - 100 °C	8.6 *10 ⁻⁶ K ⁻¹
Thermal expansion, 0 - 300 °C	9.2 *10 ⁻⁶ K ⁻¹
Thermal conductivity, room temperature	20.8 W/mK
Thermal conductivity, 400 °C	16 W/mK
Specific heat, room temperature	0.52 J/gK
Specific heat, 400 °C	0.60 J/gK
Electrical resistivity, room temperature	56 μW*cm
Poisson's ratio	

Heat treating				
		Temperature	Time	
Annealing	air-cooled	650-760 °C	6 min -	2 hours
Stress relieving	air-cooled	480-595 °C	15 min -	4 hours

Weldability – excellent

Grade 7 has very good weldability. Being substantially single phase material, the microstructure of the alpha phase is not affected greatly by thermal treatments or welding temperatures. Therefore, the mechanical properties of a correctly welded joint are equal to, or exceed those of the parent metal and show good ductility.

Available mill products

Bar, billet, ingot, extrusions, plate, sheet, strip, tubing, wire, pipe, forging, casting

Typical Applications

Good corrosion resistance for chemical processing industry applications in which the liquid medium is mildly reducing or varies between oxidizing and reducing.

Palladium improves resistance to crevice corrosion. Grade 7 has good formability.

Industry specifications **ASTM Grade7, RMI 0.2 % Pd, TIMETAL 50A Pd, ST-50Pd**

Sheet and plate	ASTM B265 Gr7
Bars and billets	ASTM B348 Gr7
Forging	ASTM B381 Gr7
Casting	ASTM B367 Gr7
Tube	ASTM B337 Gr7, ASTM B338 Gr7

TITANIUM Grade 9

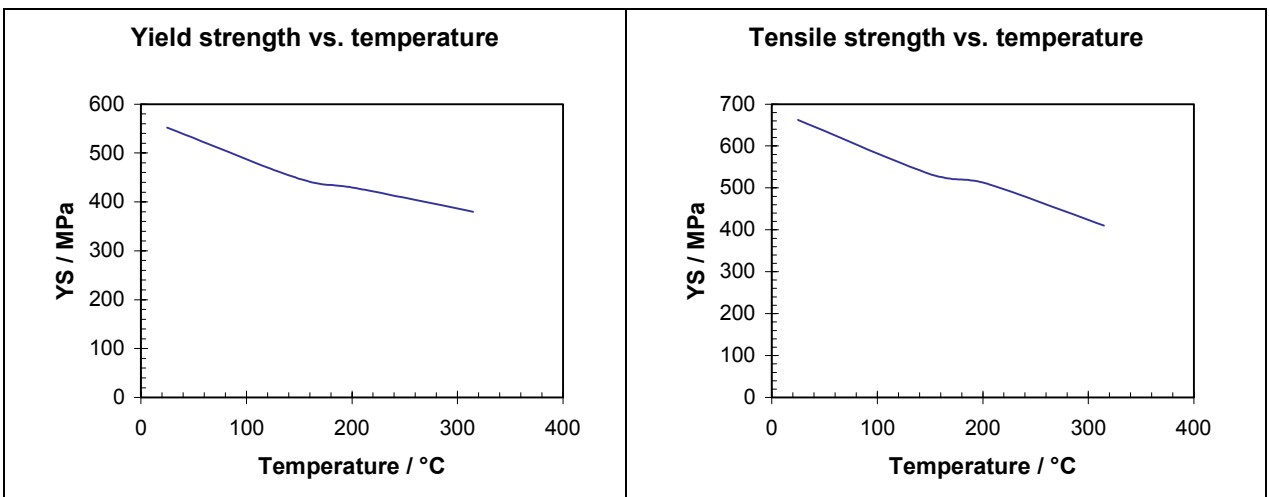
Ti-3Al-2-5V

The data given is for information not for design

Chemical composition (weight %) (Maximum values unless range is shown)										
O	N	C	H	Fe	Al	V	Ni	Mo	Others	Residuals
0.15	0.02	0.08	0.015	0.25	2.5-3.5	2.0-3.0				0.4

This alloy is sometimes referred to as "half 6-4". It offers 20-50% higher strength than C.P. grades, but is more formable and weldable than Ti-6Al-4V. Grade 9 combines strength, weldability and formability. The alloy has excellent formability plus higher tensile strength than the strongest unalloyed grade.

Mechanical properties at room temperature		
	Minimum values	Typical values
Yield Strength	485 MPa	610 MPa
Ultimate Strength	620 MPa	740 MPa
Elongation in 50 mm, A5	15 %	17 %
Reduction in Area	25 %	%
Hardness		260-320 HV
Modulus of elasticity		107 GPa
Charpy V-Notch Impact		48-102 J



Fatigue properties at room temperature (Stress to cause failure in 10^7 Cycles)	
Rotating bend	
Smooth $K_t=1$	373 MPa
Notch $K_t=3$	MPa

Physical properties	
Melting point, ± 15 °C	1700 °C
Density	4.48 g/cm ³
Beta transus, ± 15 °C	935 °C
Thermal expansion, 20 - 100 °C	9.5 *10 ⁻⁶ K ⁻¹
Thermal expansion, 0 - 300 °C	9.9 *10 ⁻⁶ K ⁻¹
Thermal conductivity, room temperature	8.3 W/mK
Thermal conductivity, 400 °C	W/mK
Specific heat, room temperature	0.54 J/gK
Specific heat, 400 °C	J/gK
Electrical resistivity, room temperature	126 μW*cm
Poisson's ratio	0.34

Heat treating			
		Temperature	Time
Annealing	air-cooled	595-760 °C	1 - 3 hours
Stress relieving	air-cooled	315-650 °C	1 - 3 hours

Weldability – good

Grade 9 has good weldability. Since the two-phase microstructure of alpha-beta titanium alloys respond to thermal treatment, the temperatures encountered during the welding cycle can affect the material being welded. A properly chosen filler rod can improve the toughness and ductility of alpha-beta welds.

Available mill products

Billet, ingot, plate, sheet, strip, tubing (welded), wire, pipe

Typical Applications

Grade 9 is used in aircraft hydraulic tubing and fittings, foil. It is principally used as tubing in aircraft and engine hydraulic systems, for high strength corrosion resisting applications such as pipes and vessels and as foil for honeycomb applications.

Industry specifications ASTM Grade9, TIMETAL 3 - 2.5

Sheet and plate	ASTM B265 Gr9, MIL-T-9046 AB-5
Bars and billets	ASTM B348 Gr9
Bar, billet and forging blank	MIL-T-9047
Forging	ASTM B381 Gr9
Tube	ASTM B337 Gr9, ASTM B338 Gr9, AMS 4943, AMS 4944

TITANIUM Grade 12

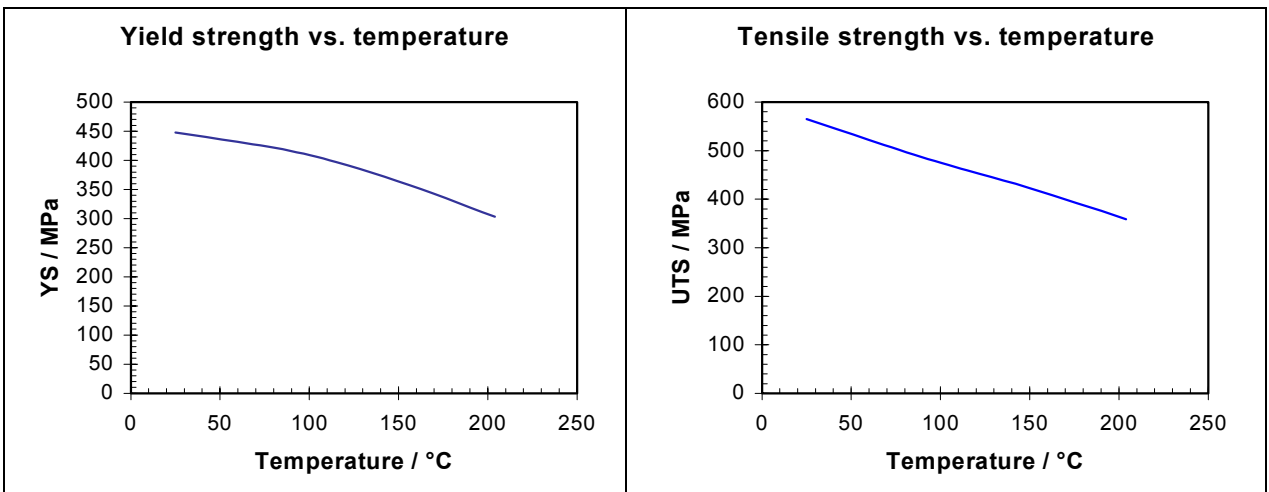
Ti - 0.3Mo - 0.8Ni

The data given is for information not for design

Chemical composition (weight %) (Maximum values unless range is shown)										
O	N	C	H	Fe	Al	V	Ni	Mo	Others	Residuals
0.25	0.03	0.08	0.015	0.30			0.6-0.9	0.2-0.4		0.4

Highly weldable, near-alpha titanium alloy exhibiting improved strength and optimum ASME Code design allowable at increased temperatures, combined with superior crevice corrosion resistance, and excellent resistance under oxidizing to mildly reducing conditions, especially chlorides.

Mechanical properties at room temperature		
	Minimum values	Typical values
Yield Strength	345 MPa	465 MPa
Ultimate Strength	485 MPa	610 MPa
Elongation in 50 mm, A5	18 %	22 %
Reduction in Area	25 %	%
Hardness		170-240 HV
Modulus of elasticity		103 GPa
Charpy V-Notch Impact		16-27 J



Physical properties	
Melting point, ± 15 °C	1660 °C
Density	4.51 g/cm ³
Beta transus, ± 15 °C	890 °C
Thermal expansion, 20 - 100 °C	9.5 *10 ⁻⁶ K ⁻¹
Thermal expansion, 0 - 300 °C	9.6 *10 ⁻⁶ K ⁻¹
Thermal conductivity, room temperature	19 W/mK
Thermal conductivity, 400 °C	W/mK
Specific heat, room temperature	0.54 J/gK
Specific heat, 400 °C	J/gK
Electrical resistivity, room temperature	52 μW*cm
Poisson's ratio	

Heat treating		
		Temperature
Annealing	air-cooled	730-815 °C
Stress relieving	air-cooled	540-650 °C

Weldability – excellent

Grade 12 has very good weldability. Being substantially single-phase material, the microstructure of the alpha phase is not affected greatly by thermal treatments or welding temperatures. Therefore, the mechanical properties of a correctly welded joint are equal to, or exceed those of the parent metal and show good ductility.

Available mill products

Billet, ingot, plate, sheet, strip, tubing (welded), wire, pipe, forging

Typical Applications

Grade 12 is developed specifically for the process industries and is similar to the Ti-Pd alloys. Grade 12 has improved resistance to crevice corrosion in hot brines, and extends titanium's usefulness in harsh environments.

Industry specifications

ASTM Grade12, TIMETAL Code12

Sheet and plate	ASTM B265 Gr12
Bars and billets	ASTM B348 Gr12
Forging	ASTM B381 Gr12
Tube	ASTM B337 Gr12, ASTM B338 Gr12

TITANIUM Grade 16

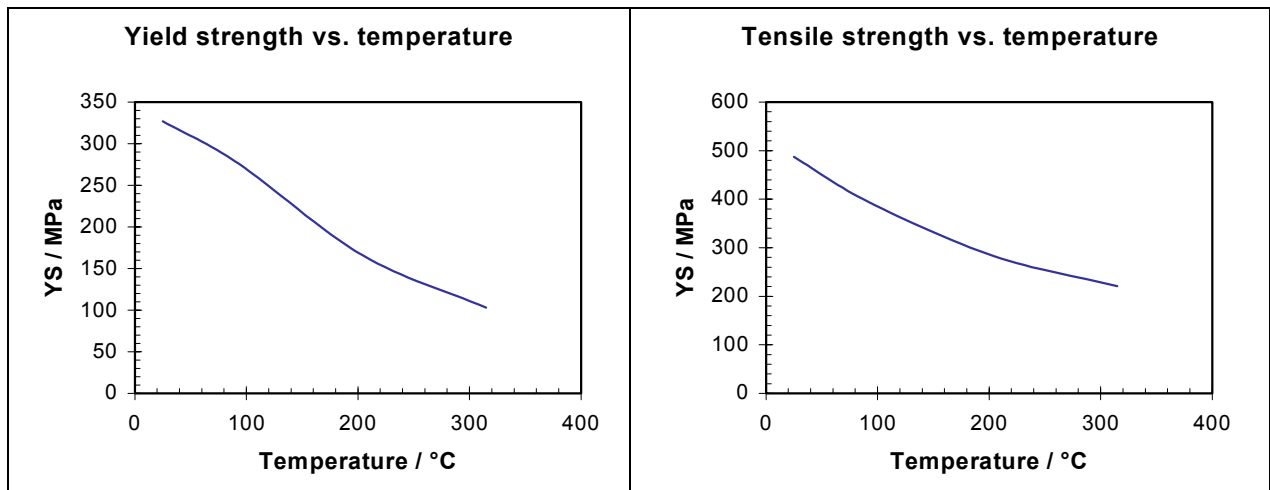
Commercial pure titanium - 0.05%Pd (Grade 2 with Pd)

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Chemical composition (weight %) (Maximum values unless range is shown)										
O	N	C	H	Fe	Al	V	Ni	Mo	Pd	Residuals
0.25	0.03	0.08	0.015	0.30					0.04-0.08	0.40

Corrosion-resistant titanium alloy offering outstanding resistance to general and localized crevice corrosion in a wide range of oxidizing and reducing acid environments including chlorides. Has a good balance of moderate strength, reasonable ductility and excellent weldability.

Mechanical properties at room temperature		
	Minimum values	Typical values
Yield Strength	275 MPa	350 MPa
Ultimate Strength	345 MPa	485 MPa
Elongation in 50 mm, A5	20 %	28 %
Reduction in Area	%	%
Hardness		150 HV
Modulus of elasticity		103 GPa
Charpy V-Notch Impact		40-82 J



Physical properties	
Melting point, ± 15 °C	1660 °C
Density	4.51 g/cm ³
Beta transus, ± 15 °C	915 °C
Thermal expansion, 20 - 100 °C	8.6 *10 ⁻⁶ K ⁻¹
Thermal expansion, 0 - 300 °C	9.2 *10 ⁻⁶ K ⁻¹
Thermal conductivity, room temperature	20.8 W/mK
Thermal conductivity, 400 °C	16 W/mK
Specific heat, room temperature	0.52 J/gK
Specific heat, 400 °C	0.60 J/gK
Electrical resistivity, room temperature	56 μW*cm
Poisson's ratio	0.34-0.40

Heat treating			
		Temperature	Time
Annealing	air-cooled	650-760 °C	6 min - 2 hours
Stress relieving	air-cooled	480-595 °C	15 min - 4 hours

Weldability – excellent

Grade 16 has very good weldability. Being substantially single phase material, the microstructure of the alpha phase is not affected greatly by thermal treatments or welding temperatures. Therefore, the mechanical properties of a correctly welded joint are equal to, or exceed those of the parent metal and show good ductility.

Available mill products

Bar, billet, ingot, extrusions, plate, sheet, strip, tubing, wire, pipe, forging, casting

Typical Applications

Good corrosion resistance for chemical processing industry applications in which the liquid medium is mildly reducing or varies between oxidizing and reducing.

Palladium improves resistance to crevice corrosion. Grade 16 has good formability.

Industry specifications ASTM Grade16

Sheet and plate	ASTM B265
Bars and billets	ASTM B348
Forging	ASTM B381
Casting	ASTM B367
Tube	ASTM B337, ASTM B338

TITANIUM Grade 17

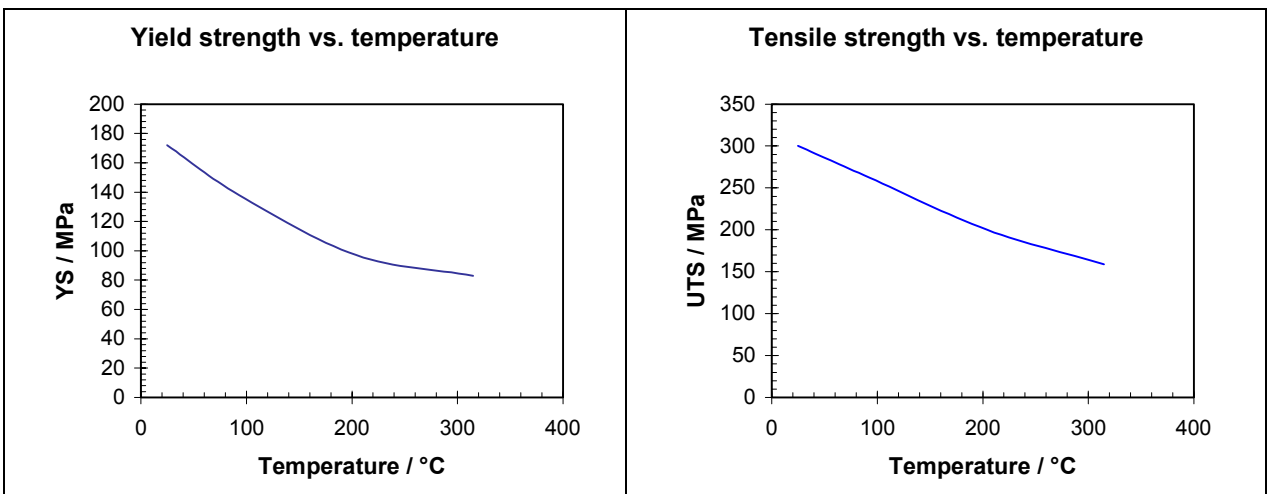
Commercial pure titanium with 0.05%Pd (Grade 1 with Pd)

The data given is for information not for design

Chemical composition (weight %) (Maximum values unless range is shown)										
O	N	C	H	Fe	Al	V	Ni	Mo	Pd	Residuals
0.18	0.03	0.08	0.015	0.2					0.04-0.08	0.4

This alloy is the same as Grade 1, but with Pd for better corrosion resistance. Grade 17 has optimum ductility and cold formability with useful strength, high-impact toughness, and excellent weldability. Very resistant to crevice corrosion.

Mechanical properties at room temperature		
	Minimum values	Typical values
Yield Strength	170 MPa	220 MPa
Ultimate Strength	240 MPa	345 MPa
Elongation in 50 mm, A5	25 %	37 %
Reduction in Area	35 %	%
Hardness		115 HV
Modulus of elasticity		103 GPa
Charpy V-Notch Impact		95-162 J



Fatigue properties at room temperature (Stress to cause failure in 10^7 Cycles)		
Rotating bend		
Smooth	$K_t=1$	193 MPa
Notch	$K_t=3$	123 MPa

Physical properties	
Melting point, ± 15 °C	1670 °C
Density	4.51 g/cm ³
Beta transus, ± 15 °C	890 °C
Thermal expansion, 20 - 100 °C	8.6 *10 ⁻⁶ K ⁻¹
Thermal expansion, 0 - 300 °C	9.2 *10 ⁻⁶ K ⁻¹
Thermal conductivity, room temperature	20.8 W/mK
Thermal conductivity, 400 °C	W/mK
Specific heat, room temperature	0.52 J/gK
Specific heat, 400 °C	0.60 J/gK
Electrical resistivity, room temperature	54 μW*cm
Poisson's ratio	0.34-0.40

Heat treating			
		Temperature	Time
Annealing	air-cooled	650-760 °C	6 min - 2 hours
Stress relieving	air-cooled	480-595 °C	15 min - 4 hours

Weldability – excellent

Grade 17 has very good weldability. Being substantially single-phase material, the microstructure of the alpha phase is not affected greatly by thermal treatments or welding temperatures. Therefore, the mechanical properties of a correctly welded joint are equal to, or exceed those of the parent metal and show good ductility

Available mill products

Bar, billet, ingot, extrusions, plate, sheet, strip, tubing, wire, pipe, forging

Typical Applications

Very good corrosion resistance for chemical processing industry applications in which the liquid medium is mildly reducing or varies between oxidizing and reducing. Palladium improves resistance to crevice corrosion. Grade 11 has good formability.

Industry specifications ASTM Grade17

Sheet and plate	ASTM B265
Bars and billets	ASTM B348
Tube	ASTM B337, ASTM B338
Forging	ASTM B381

TITANIUM Grade 19

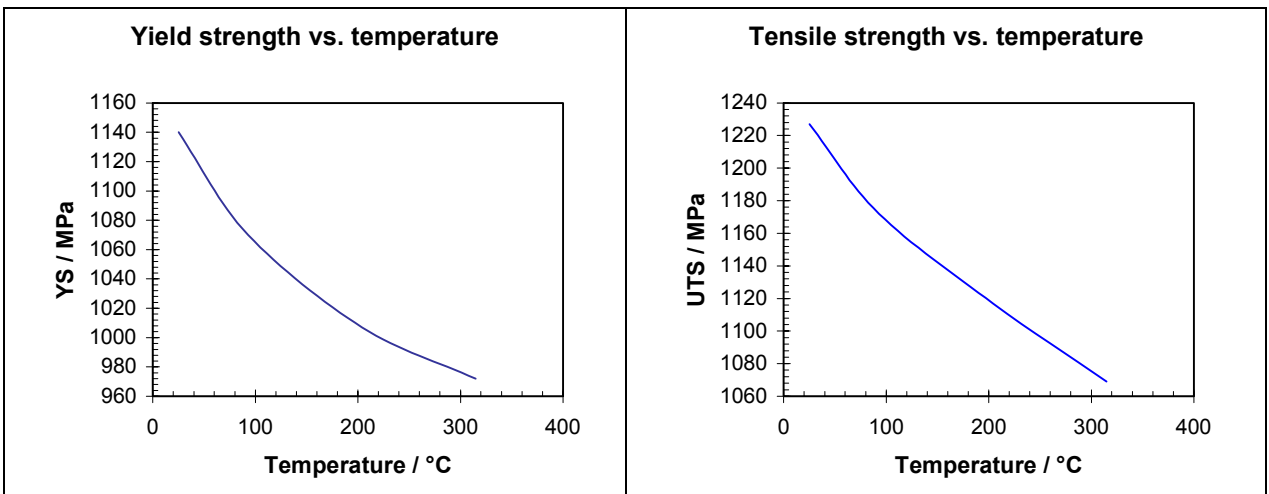
Beta-C

The data given is for information not for design

Chemical composition (weight %) (Maximum values unless range is shown)										
O	N	C	H	Fe	Al	V	Cr	Mo	Zr	Residuals
0.12	0.03	0.05	0.015	0.3	3.0-4.0	7.5-8.5	5.5-6.5	3.5-4.5	3.5-4.5	0.4

This metastable-beta alloy is strip-producible and cold-formable. The alloy is age-hardenable to a wide range of strengths. Beta-C is also being evaluated as extruded tubular for deep sour well applications. The alloy is superior resistant to general Corrosion pitting-, crevice- and stress Corrosion cracking in high temperature environments containing FeCl₃, NaCl, CO₂ and H₂S.

Mechanical properties at room temperature		
	Minimum values	Typical values
Yield Strength	1105 MPa	1150 MPa
Ultimate Strength	1170 MPa	1250 MPa
Elongation in 50 mm, A5	6 %	9 %
Reduction in Area	%	30 %
Hardness		360-420 HV
Modulus of elasticity		102 GPa
Charpy V-Notch Impact		11-16 J



Fatigue properties at room temperature (Stress to cause failure in 10 ⁷ Cycles)			
Direct stress fatigue limit			
Smooth	K _t =1	600	MPa
Notch	K _t =3	275	MPa

Physical properties	
Melting point, ± 15 °C	1650 °C
Density	4.82 g/cm ³
Beta transus, ± 15 °C	730 °C
Thermal expansion, 20 - 100 °C	8.3 *10 ⁻⁶ K ⁻¹
Thermal expansion, 0 - 300 °C	9.5 *10 ⁻⁶ K ⁻¹
Thermal conductivity, room temperature	6.2 W/mK
Thermal conductivity, 400 °C	W/mK
Specific heat, room temperature	0.52 J/gK
Specific heat, 400 °C	J/gK
Electrical resistivity, room temperature	160 μW*cm
Poisson's ratio	0.34

Heat treating				
		Temperature	Time	
Annealing	air-cooled/water	705-760°C	6min -	30min
Stress relieving	air-cooled	705-760°C	6min -	30min
Solution treating	water quench	815-925°C	1 hour	
Aging	air-cooled	455-540°C	8hours -	24hours

Weldability – fair

Beta - C is weldable in annealed or solution treated Condition. The weld has often low strength and good ductility. To gain fully strength in metastable alloys it is important to weld the alloy in annealed Condition. The welds have to be cold worked (sandblasting, hammering) after welding. At the end the welds goes through solution treatment and aging. This treatment usually gives the weld a satisfactory ductility.

Available mill products

Billet, billet, plate, sheet, ingot, wire, pipe, forging

Typical Applications

Heavy sections where deep hardening and high strength with good fracture toughness are required. The alloy has been used for springs, fasteners, torsion bars, sheet, rivets and foil applications. Tubing and casing down hole production equipment.

Industry specifications

Sheet and plate	MIL-T-909046 B-3
Bar, billett and forging blank	MIL-T-9047
	ASM 4957
	ASM 4958

TITANIUM Grade 21

Beta - 21S

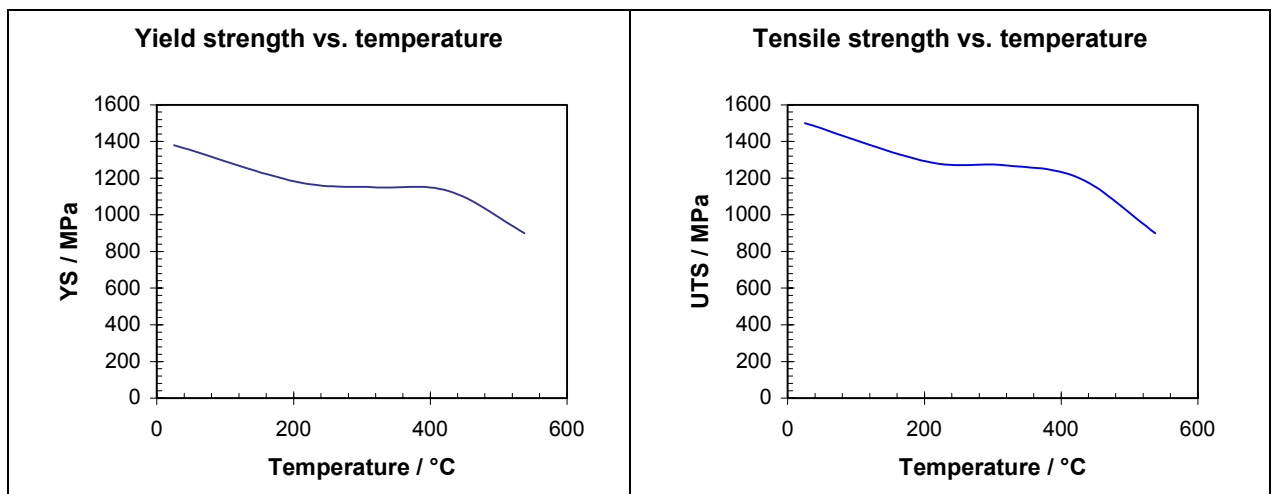
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Chemical composition (weight %) (Maximum values unless range is shown)										
O	N	C	H	Fe	Mo	Nb	Al	Si	Others	Residuals
0.15	0.05	0.05	0.015	0.4	14.0-16.0	2.2-3.2	2.3	3.5		0.4

Beta - 21S is a metastable beta alloy that offers high specific strength and good formability, and has been designed for improved oxidation resistance, elevated temperature strength, creep resistance and thermal stability. It is most useful for application above 300 °C. Because it can be economically rolled to foil and is compatible with most fibres, it is also well suited for metal matrix composites.

Mechanical properties at room temperature*		
	Minimum values	Typical values
Yield Strength	965 MPa	1100 MPa
Ultimate Strength	1030 MPa	1150 MPa
Elongation in 50 mm, A5	6 %	10 %
Reduction in Area	%	%
Hardness		360-420 HV
Modulus of elasticity		72-85 GPa
Charpy V-Notch Impact		103-110 J

* Aged at 600 °C



Physical properties	
Melting point, ± 15 °C	°C
Density	4.9 g/cm ³
Beta transus, ± 15 °C	815 °C
Thermal expansion, 30 °C	7.1 *10 ⁻⁶ K ⁻¹
Thermal expansion, 200 °C	7.9 *10 ⁻⁶ K ⁻¹
Thermal conductivity, room temperature	7.6 W/mK
Thermal conductivity, 400 °C	16.9 W/mK
Specific heat, room temperature	0.5 J/gK
Specific heat, 400 °C	0.6 J/gK
Electrical resistivity, room temperature	135 μW*cm
Poisson's ratio	0.34

Heat treating			
		Temperature	Time
Annealing	air-cooled	815-845 °C	3-30 min
Stress relieving	air-cooled	510-650 °C	8-16 hours

Weldability – fair

Available mill products

Forging, tube

Typical Applications

Warm airframes of engine structures, honeycomb, fasteners, metal matrix composites. TIMETAL 21S is useful for applications from 230°C to 600°C. The alloy is resistant to aircraft hydraulic fluids. It is well suited for metal matrix composites because it can be economically rolled to foil, is compatible with most fibers, and is sufficiently stable up to 820°C.

Industry specifications

TIMETAL 21S

TITANIUM Grade 23

Ti - 6Al - 4V ELI (Extra low interstitials)

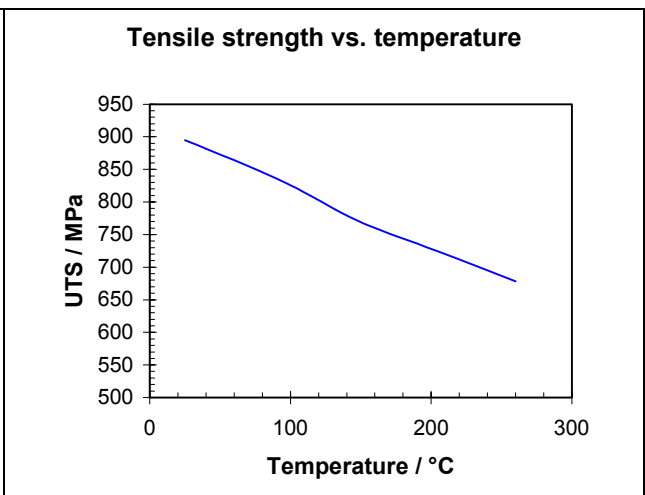
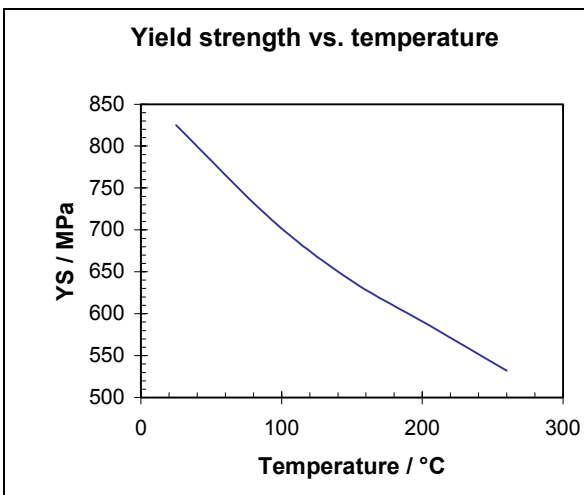
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Chemical composition (weight %) (Maximum values unless range is shown)										
O	N	C	H	Fe	Al	V	Ni	Mo	Others	Residuals
0.13	0.03	0.08	0.0125	0.25	5.5-6.5	3.5-4.5				0.4

An alpha-beta alloy based on Grade 5. The amount of interstitial elements (O, N, C) is reduced. Improved stress corrosion cracking (SCC) properties in seawater compared to Grade 5. Especially suited for thick wall highly stressed parts.

Mechanical properties at room temperature

	Minimum values	Typical values
Yield Strength	790(760) MPa	825 MPa
Ultimate Strength	860(825) MPa	895 MPa
Elongation in 50 mm, A5	10 (7.5) %	15 %
Reduction in Area	25 (15) %	%
Hardness		350 HV
Modulus of elasticity		114 GPa
Charpy V-Notch Impact		24-40 J



Fatigue properties at room temperature
 300 MPa unnotched
 140 MPa notched with stress concentration factor $K_t=3.1$

Physical properties	
Melting point, ± 15 °C	1650 °C
Density	4.43 g/cm ³
Beta transus, ± 15 °C	980 °C
Thermal expansion, 20 - 100 °C	9.2 *10 ⁻⁶ K ⁻¹
Thermal expansion, 0 - 300 °C	9.5 *10 ⁻⁶ K ⁻¹
Thermal conductivity, room temperature	7.3 W/mK
Thermal conductivity, 400 °C	W/mK
Specific heat, room temperature	0.57 J/gK
Specific heat, 400 °C	J/gK
Electrical resistivity, room temperature	165 μW*cm
Poisson's ratio	0.34

Heat treating				
		Temperature	Time	
Solution treating temperature	water quench	900-950°C	1 hour	
Ageing temperature		480-590°C	4hours	8hours
Full annealing	air-cooled	700-830°C	15 min -	2 hours
Stress relieving	air-cooled	480-650°C	60min -	4hours

Weldability – good

The same welding procedure as for Grade 5 can be used, but special filler metal required

Available mill products

Bar, billett, extrusions, plate, sheet, strip, wire

Typical Applications

Surgical implants, offshore- and seawater applications, high pressure cryogenic vessels down to - 195 °C. Improved stress corrosion resistance compared to Grade 5.

Industry specifications

ASTM - B265, B348, B363, B381, B861, B862 and F136

AMS - 4907, 4930 and 4956

TITANIUM Grade 26

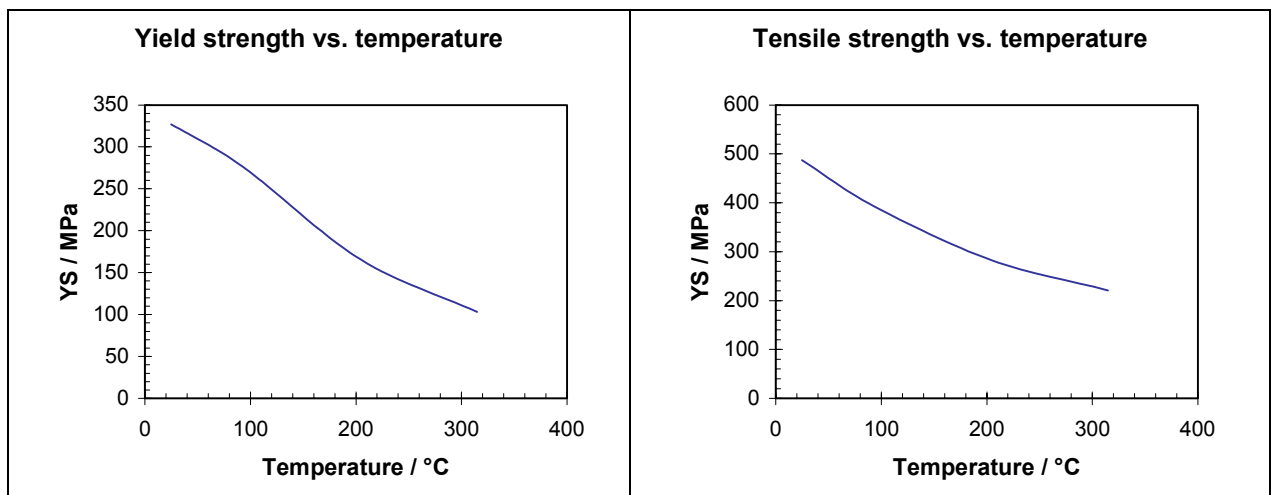
Commercial pure titanium - 0.1%Ru (Grade 2 with Ru)

The data given is for information not for design

Chemical composition (weight %) (Maximum values unless range is shown)										
O	N	C	H	Fe	Al	V	Ni	Mo	Ru	Residuals
0.25	0.03	0.08	0.015	0.30					0.08-0.14	0.40

Corrosion-resistant titanium alloy offering outstanding resistance to general and localized crevice corrosion in a wide range of oxidizing and reducing acid environments including chlorides, with a good balance of moderate strength, reasonable ductility and excellent weldability. Mechanical properties similar to Grade 2, but improved corrosion resistance.

Mechanical properties at room temperature		
	Minimum values	Typical values
Yield Strength	275 MPa	350 MPa
Ultimate Strength	345 MPa	485 MPa
Elongation in 50 mm, A5	20 %	28 %
Reduction in Area	30 %	%
Hardness		150 HV
Modulus of elasticity		103 GPa
Charpy V-Notch Impact		40-82 J



Physical properties	
Melting point, ± 15 °C	1660 °C
Density	4.51 g/cm ³
Beta transus, ± 15 °C	915 °C
Thermal expansion, 20 - 100 °C	8.6 *10 ⁻⁶ K ⁻¹
Thermal expansion, 0 - 300 °C	9.2 *10 ⁻⁶ K ⁻¹
Thermal conductivity, room temperature	20.8 W/mK
Thermal conductivity, 400 °C	16 W/mK
Specific heat, room temperature	0.52 J/gK
Specific heat, 400 °C	0.6 J/gK
Electrical resistivity, room temperature	56 μW*cm
Poisson's ratio	

Heat treating			
		Temperature	Time
Annealing	air-cooled	650-760 °C	6 min - 2 hours
Stress relieving	air-cooled	480-595 °C	15 min - 4 hours

Weldability – excellent

Grade 26 has very good weldability. Being substantially single phase material, the microstructure of the alpha phase is not affected greatly by thermal treatments or welding temperatures. Therefore, the mechanical properties of a correctly welded joint are equal to, or exceed those of the parent metal and show good ductility.

Available mill products

Bar, billet, ingot, extrusions, plate, sheet, strip, tubing, wire, pipe, forging, casting

Typical Applications

Good corrosion resistance for chemical processing industry applications in which the liquid medium is mildly reducing or varies between oxidizing and reducing.

Palladium improves resistance to crevice corrosion. Grade 26 has good formability.

Industry specifications ASTM Grade26

Sheet and plate	ASTM B265
Bars and billets	ASTM B348
Forging	ASTM B381
Casting	ASTM B367
Tube	ASTM B337 , ASTM B338

TITANIUM Grade 27

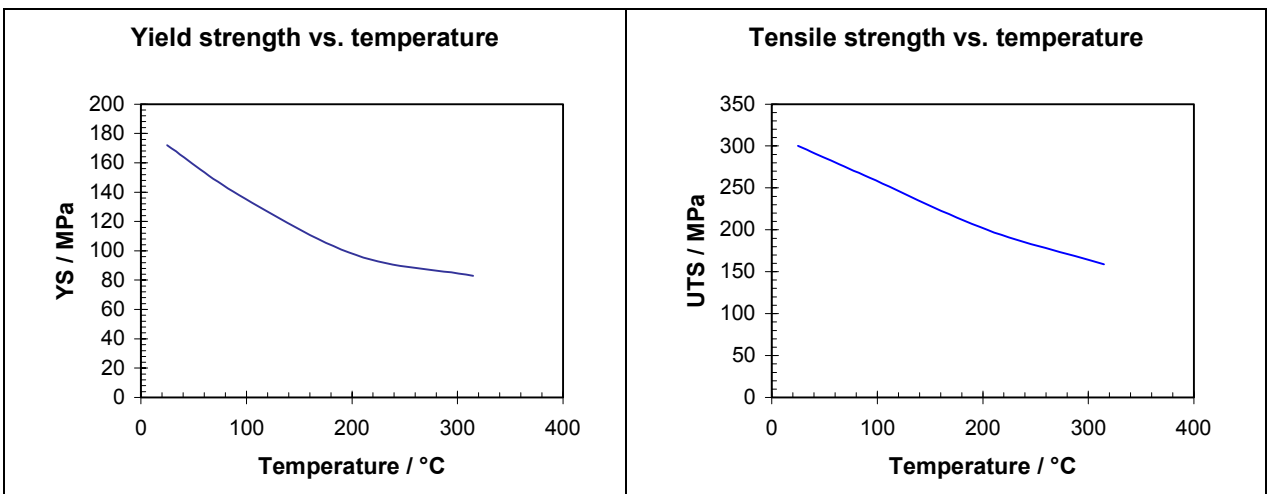
Commercial pure titanium with 0.1%Ru (Grade 1 with Ru)

The data given is for information not for design

Chemical composition (weight %) (Maximum values unless range is shown)										
O	N	C	H	Fe	Al	V	Ni	Mo	Ru	Residuals
0.18	0.03	0.08	0.015	0.2					0.08-0.14	0.4

This alloy is the same as Grade 1, but with Ruthenium for better corrosion resistance. Grade 27 has optimum ductility and cold formability with useful strength, high-impact toughness, and excellent weldability. Very resistant to crevice corrosion.

Mechanical properties at room temperature		
	Minimum values	Typical values
Yield Strength	170 MPa	220 MPa
Ultimate Strength	240 MPa	345 MPa
Elongation in 50 mm, A5	25 %	37 %
Reduction in Area	30 %	%
Hardness		115 HV
Modulus of elasticity		103 GPa
Charpy V-Notch Impact		95-162 J



Fatigue properties at room temperature (Stress to cause failure in 10^7 Cycles)		
Rotating bend		
Smooth	$K_t=1$	193 MPa
Notch	$K_t=3$	123 MPa

Physical properties	
Melting point, ± 15 °C	1670 °C
Density	4.51 g/cm ³
Beta transus, ± 15 °C	890 °C
Thermal expansion, 20 - 100 °C	8.6 *10 ⁻⁶ K ⁻¹
Thermal expansion, 0 - 300 °C	9.2 *10 ⁻⁶ K ⁻¹
Thermal conductivity, room temperature	20.8 W/mK
Thermal conductivity, 400 °C	W/mK
Specific heat, room temperature	0.52 J/gK
Specific heat, 400 °C	0.60 J/gK
Electrical resistivity, room temperature	56 μW*cm
Poisson's ratio	0.34-0.40

Heat treating			
		Temperature	Time
Annealing	air-cooled	650-760 °C	6 min - 2 hours
Stress relieving	air-cooled	480-595 °C	15 min - 4 hours

Weldability – excellent

Grade 27 has very good weldability. Being substantially single-phase material, the microstructure of the alpha phase is not affected greatly by thermal treatments or welding temperatures. Therefore, the mechanical properties of a correctly welded joint are equal to, or exceed those of the parent metal and show good ductility.

Available mill products

Bar, billet, ingot, extrusions, plate, sheet, strip, tubing, wire, pipe, forging

Typical Applications

Very good corrosion resistance for chemical processing industry applications in which the liquid medium is mildly reducing or varies between oxidizing and reducing. Palladium improves resistance to crevice corrosion. Grade 11 has good formability.

Industry specifications ASTM Grade27

Sheet and plate	ASTM B265
Bars and billets	ASTM B348
Tube	ASTM B337, ASTM B338
Forging	ASTM B381

TITANIUM Grade 28

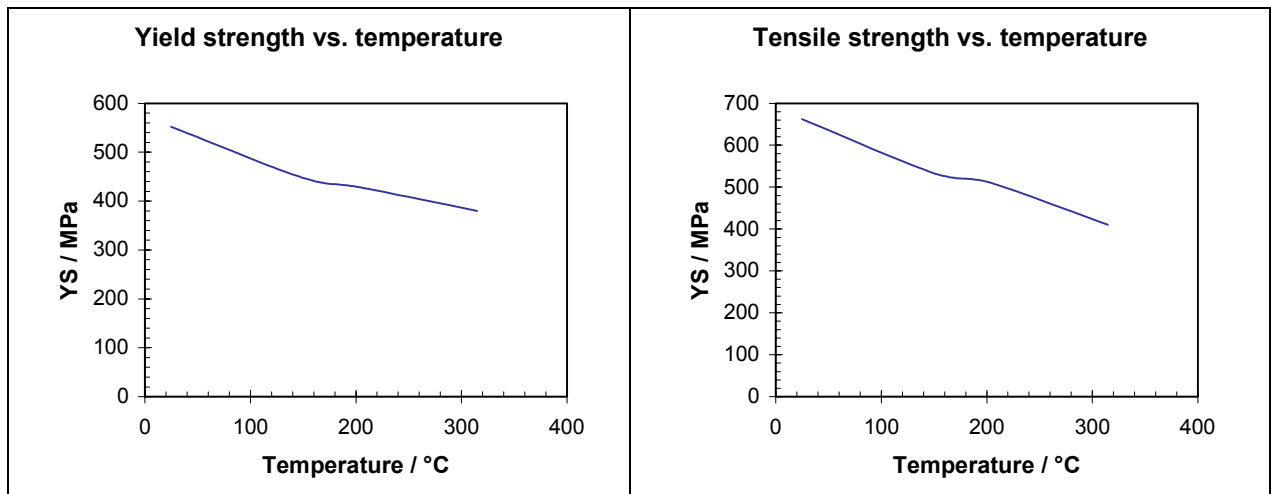
Ti - 3Al - 2.5V - 0.1 Ru (Grade 9 with Ru)

The data given is for information not for design

Chemical composition (weight %) (Maximum values unless range is shown)										
O	N	C	H	Fe	Al	V	Ni	Mo	Ru	Residuals
0.15	0.03	0.08	0.015	0.25	2.5-3.5	2.0-3.0			0.08-0.14	0.4

Grade 9 with Ruthenium for improved corrosion resistance.

Mechanical properties at room temperature		
	Minimum values	Typical values
Yield Strength	485 MPa	610 MPa
Ultimate Strength	620 MPa	740 MPa
Elongation in 50 mm, A5	15 %	17 %
Reduction in Area	25 %	%
Hardness		260-320 HV
Modulus of elasticity		107 GPa
Charpy V-Notch Impact		48-102 J



Fatigue properties at room temperature (Stress to cause failure in 10^7 Cycles)	
Rotating bend	
Smooth $K_t=1$	373 MPa

Physical properties	
Melting point, ± 15 °C	1700 °C
Density	4.48 g/cm ³
Beta transus, ± 15 °C	935 °C
Thermal expansion, 20 - 100 °C	9.5 *10 ⁻⁶ K ⁻¹
Thermal expansion, 0 - 300 °C	9.9 *10 ⁻⁶ K ⁻¹
Thermal conductivity, room temperature	7.9 W/mK
Thermal conductivity, 400 °C	7.6 W/mK
Specific heat, room temperature	0.55 J/gK
Specific heat, 400 °C	J/gK
Electrical resistivity, room temperature	126 μW*cm
Poisson's ratio	0.34

Heat treating			
		Temperature	Time
Annealing	air-cooled	595-760°C	1 - 3 hours
Stress relieving	air-cooled	315-650°C	0.5 - 3 hours
Solution treating	water quench	870-925°C	15 -20hours
Aging	air-cooled	480-510°C	2 - 8hours

Weldability – good

Same procedure as Grade 9, but special filler material is recommended.

Available mill products

Billet, ingot, plate, sheet, strip, tubing (welded), wire, pipe

Typical Applications

Seawater applications.

High crevice corrosion temperature.

Industry specifications ASTM Grade 28

ASTM B265, B337, B338, B381, B861, B862

TITANIUM Grade 29

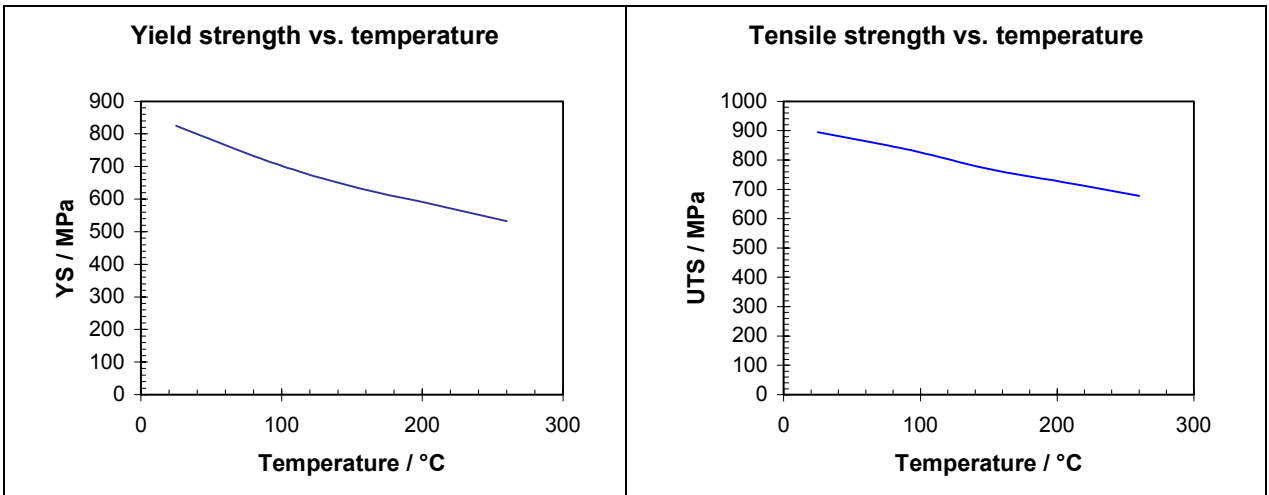
Ti - 6Al - 4V - 0.1Ru ELI (Extra low interstitials)

The data given is for information not for design

Chemical composition (weight %) (Maximum values unless range is shown)										
O	N	C	H	Fe	Al	V	Ni	Mo	Ru	Residuals
0.13	0.03	0.08	0.0125	0.25	5.5-6.5	3.5-4.5			0.08-0.14	0.4

Grade 23 with Ruthenium for improved corrosion resistance. High crevice corrosion temperature, improved stress corrosion resistance compared to Grade 5.

Mechanical properties at room temperature		
	Minimum values	Typical values
Yield Strength	790(760) MPa	825 MPa
Ultimate Strength	860(825) MPa	895 MPa
Elongation in 50 mm, A5	10 (7.5) %	15 %
Reduction in Area	25 (15) %	%
Hardness		350 HV
Modulus of elasticity		114 GPa
Charpy V-Notch Impact		24-40 J



Fatigue properties at room temperature	(Stress to cause failure in 10^7 Cycles)
300 MPa unnotched	
140 MPa notched with stress concentration factor $K_t=3.1$	

Physical properties	
Melting point, ± 15 °C	1650 °C
Density	4.43 g/cm ³
Beta transus, ± 15 °C	990 °C
Thermal expansion, 20 - 100 °C	9.2 *10 ⁻⁶ K ⁻¹
Thermal expansion, 0 - 300 °C	9.5 *10 ⁻⁶ K ⁻¹
Thermal conductivity, room temperature	7.3 W/mK
Thermal conductivity, 400 °C	W/mK
Specific heat, room temperature	0.57 J/gK
Specific heat, 400 °C	J/gK
Electrical resistivity, room temperature	165 μW*cm
Poisson's ratio	0.34

Heat treating			
		Temperature	Time
Solution treating temperature	water quench	900-950 °C	1 hour
Ageing temperature		480-590 °C	4hours 8hours
Full annealing	air-cooled	700-830 °C	15min - 2hours
Stress relieving	air-cooled	480-650 °C	60min - 4hours

Weldability – good

The same welding procedure as for Grade 5 can be used, but special filler metal required

Available mill products

Bar, billett, extrusions, plate, sheet, strip, wire

Typical Applications

Seawater and offshore applications

High crevice corrosion temperature, improved stress corrosion resistance compared to Grade 5.

Industry specifications

ASTM - B265, B348, B363, B381, B861, B862 and F136

AMS - 4907, 4930 and 4956