Ti-15Mo-3Nb-3Al-.2Si

TIMETAL® 21S

HIGH STRENGTH, OXIDATION RESISTANT STRIP ALLOY

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. *TIMETAL* 21S is useful for applications from 550°F (228°C) to 1100°F (593°C). The alloy's resistance to aircraft hydraulic fluids, such as Skydrol, is excellent at all temperatures. *TIMETAL* 21S 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 1500°F (816°C). Strip is available in gauges from 0.016 in (0.4mm) to 0.090 in (2.3mm).

TABLE 1

CHEMICAL COMPOSITION

ELEMENT	WEIGHT % Min.	Max.
Molybdenum	14.0	16.0
Niobium (Columbium)	2.4	3.2
Aluminum	2.5	3.5
Silicon	0.15	0.25
Iron	—	0.40
Oxygen	0.11	0.17
Carbon	—	0.05
Nitrogen	—	0.05
Hydrogen	—	0.015
Residual Elements, each	—	0.10
Residual Elements, total	—	0.40
Titanium	Remainder	

TABLE 2

PHYSICAL PROPERTIES

AGED AT 1000°F (538°C) FOR 8 HRS

Property	*T (°F)*	*T (°C)*	*Value*	*Value SI*
Density	72	22	0.178 lb in^{-3}	4.93 g cm^{-3}
Beta Transus	1485	807		
Thermal Conductivity	91	33	4.4 Btu hr^{-1} ft^{-1} °F^{-1}	7.6 W m^{-1} K^{-1}
	498	259	6.8	11.8
	1024	551	9.8	16.9
	1520	827	12.0	20.8
Specific Heat Capacity	75	24	.117 Btu lb^{-1} °F^{-1}	.117 J kg^{-1} K^{-1}
	500	260	.128	.128
	1000	538	.142	.142
	1500	816	.155	.155
Electrical Resistivity	75	24	53 μΩ•in	1.35 μΩ•m
	500	260	56	1.42
	1000	538	58	1.48
	1500	816	58	1.48
Mean Coefficient of Thermal Expansion	100	38	3.93 x 10^{-6} in in^{-1} °F^{-1}	7.07 x 10^{-6} m m^{-1} °C^{-1}
	200	93	4.41	7.9
	400	204	4.75	8.6
	600	316	4.95	8.9
	800	427	5.11	9.2
	1000	538	5.28	9.5
	1500	816	5.73	10.3
Modulus of Elasticity				
Solution Treated	75	24	10.5-12 Msi	72-85 GPa
Aged 1000°F (538°C)/8hrs	75	24	15-16 Msi	103-110 GPa
Overaged	75	24	14-15 Msi	96-103 GPa

TABLE 3

HEAT TREATMENT

Solution Temperature	1500°-1550°F air cool equivalent	816°-843°C air cool equivalent
Solution Time	3 - 30 min	3 - 30 min
Age Temperature	950°-1275°F	510°-679°C
Age Time	8 - 16 hrs	8 - 16 hrs

TIMET®

TABLE 4

TYPICAL ROOM TEMPERATURE TENSILE PROPERTIES STRIP AND SHEET TO 0.1875 IN THICK

1550°F (843°C)-1650°F (900°C) SOLUTION HEAT TREATMENT, AIR COOL

Age	UTS ksi (MPa)	TYS ksi (MPa)	Elongation %
None	135 (931)	128 (883)	12
1000°F, 8hrs	207 (1427)	194 (1338)	6
1100°F, 8hrs	174 (1200)	161 (1110)	10
1275°F, 8hrs + 1200°F, 8hrs	149 (1027)	138 (952)	13

TABLE 5

TENSILE PROPERTIES STRIP AND SHEET TO 0.1875 IN THICK

1550°F (843°C) SOLUTION HEAT TREATMENT, AIR COOL

Aging Temp °F (°C) Duration	Ultimate Tensile Strength ksi (MPa)	0.2% Yield Strength ksi (MPa)	Elongation %
—	115-140 (793-965)	110-135 (759-931)	12 min
1000 (538), 8 hrs	170 (1172) min	160 (1103) min	4 min
1100 (593), 8 hrs	150 (1034) min	140 (965) min	6 min
1275 (691), 8 hrs	125 (862) min	115 (793) min	10 min
plus 1200 (645), 8 hrs			

TABLE 6

COLD ROLLED BAR TENSILE PROPERTIES

AGED 900°F (482°C) FOR 20 HRS

% Cold Work	UTS ksi (MPa)	0.2% YS ksi (MPa)	Elongation %
40	227 (1565)	202 (1393)	6.5
40	227 (1565)	210 (1448)	6.3
60	222 (1531)	201 (1386)	6.0
60	220 (1517)	205 (1413)	7.0
80	250 (1724)	211 (1455)	4.8
80	252 (1738)	206 (1420)	5.0

TABLE 7

SIC: *TIMETAL* 21S METAL MATRIX COMPOSITES TYPICAL LAMINATE TENSILE MECHANICAL PROPERTIES

4-PLY UNIDIRECTIONAL LAMINATE; SCS-6 FIBERS

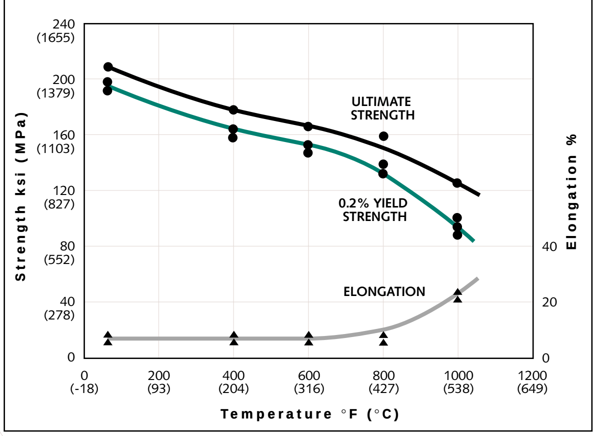
Temp. °F (°C)	Density lb in^{-3} (g cm^{-3})	Strength ksi (MPa)	Modulus Msi (GPa)
70 (21)	.153 (4.24)	250 (1724)	27 (186)
1000 (538)	—	165 (1138)	—
1500 (816)	—	75 (517)	—

Reference:
J. Sorensen. "Titanium Matrix Composites — NASP Materials and Structures Augmentation Program," AIAA — 90 — 5207, 10/90.

FIGURE 1

TENSILE MECHANICAL PROPERTIES vs. TEMPERATURE

1500°F (816°C) SOLUTION TREATMENT, AGED 1000°F (538°C) FOR 8 HRS



FORMING NOTES FOR *TIMETAL* 21S

TIMETAL 21S is formed in the solution heat treated (as supplied) condition, then aged to the desired strength level. The forming characteristics of *TIMETAL* 21S are similar to those of *TIMETAL*® 15-3.

Typical minimum bend radii are 1.0 - 1.5 times the thickness.

Cold reductions greater than 80% are possible in compressive operations, including rolling, spinning and swaging.

Because of relatively low work hardenability, maximum tensile deformations are achieved when strains are uniform, such as in hydroforming and bulge-forming.

The alloy is strain rate sensitive; therefore forming should be performed as slowly as practical.

Spring back is relatively severe, but can be compensated for by over-forming or by forming at higher temperatures.

Elevated temperatures [400°-1400°F (204°-760°C)] increase deformation capability and reduce spring back.

Intermediate anneals can be used between forming operations to restore workability. However, it is essential to choose a combination of cold work and solution heat treatment that produces a high degree of recrystallization with minimal grain growth, such as suggested in *Table 8.* Surface contamination (alpha case) must always be removed prior to further forming operations.

Excess flanges on hemispheres, cups, and other hydroformed or drawn parts should be left on until after aging to minimize distortion due to spring back.

Machining should only be performed after aging to avoid a brittle surface that can result from the enhanced aging response of the machining-induced severely cold worked layer.

Hot forming and hot sizing are best done at the aging temperatures (they are then counted as part of the total aging cycle). Exposure of solution heat treated material to temperatures of 500°-800°F (260°-427°C) should be kept to less than one hour to avoid embrittlement. If forming temperatures exceed the beta transus [about 1485°F (807°C)], time at temperature should be minimized to avoid excessive grain growth.

Surface contamination (alpha case), when present, must always be removed prior to forming.

FIGURE 2

CHEMICAL MILLING

HYDROGEN PICKUP FOR SOLUTION HEAT TREATED (AS SUPPLIED) CONDITION (0.060 IN GAUGE)

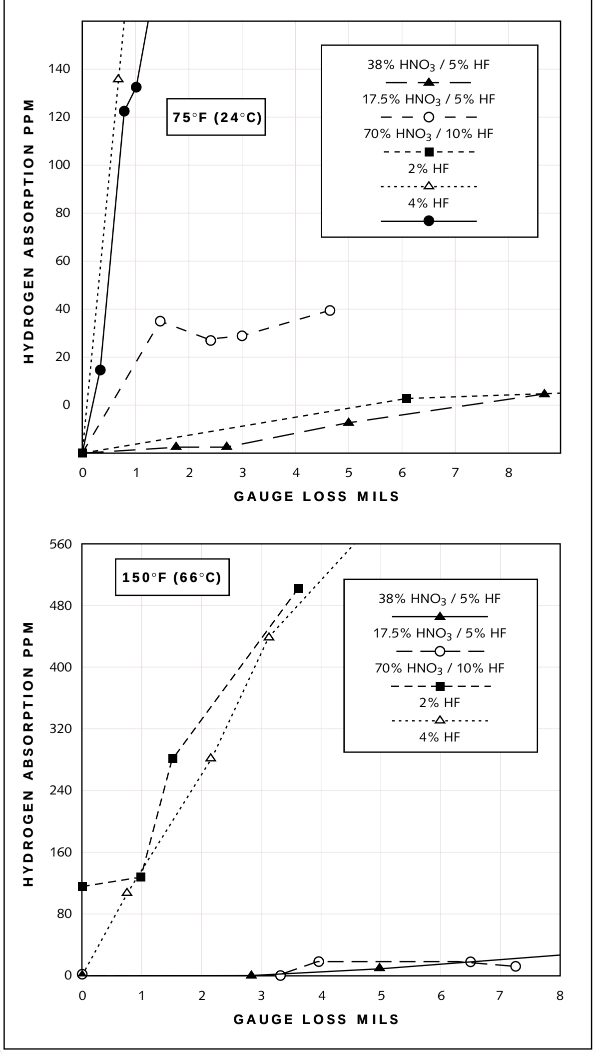


TABLE 8

RECRYSTALLIZATION ANNEALING (RE-SOLUTION HEAT TREATMENT)

REMOVES COLD WORK AND RESTORES FORMABILITY

Cold Work, %	Annealing Temperature °F (°C)	Annealing Time Minutes
20 – 40	1550 (843)	20
40 – 60	1525 (829)	20
60+	1500 (816)	20

TABLE 9

THERMAL STABILITY

RESIDUAL ROOM TEMPERATURE TENSILE PROPERTIES FOR 0.052 IN STRIP AGED AT 1275°F (641°C) FOR 8 HRS PLUS 1200°F (691°C) FOR 8 HRS PRIOR TO EXPOSURE IN AIR

Exposure Temp. °F (°C)	*Exposure Time hrs.*	*Surface Removed (1)*	*Ultimate Tensile Strength ksi (MPa)*	*0.2% Yield Strength ksi (MPa)*	*Elong. %*
None	None	—	133 (917)	123 (848)	19
950 (510)	500	No	145 (1000)	132 (910)	15
		Yes	145 (1000)	133 (917)	15
	1000	No	147 (1014)	137 (945)	13
		Yes	147 (1014)	134 (924)	14
	3000	No	147 (1014)	137 (945)	13
		Yes	147 (1014)	134 (924)	14
1050 (566)	500	No	139 (958)	130 (896)	11
		Yes	137 (945)	127 (876)	13
	1000	No	137 (945)	130 (896)	10
		Yes	138 (952)	127 (876)	17
	3000	No	135 (931)	130 (896)	6
	5000	No	135 (931)	129 (876)	6
1140 (616)	500	No	133 (917)	128 (883)	5
		Yes	138 (952)	127 (876)	13
	1000	No	132 (910)	127 (827)	3
		Yes	137 (945)	122 (841)	15
	3000	No	Broke Before Yield		
	5000	No	Broke Before Yield		

(1) Descaled and pickled to remove 0.004 in (0.010cm)

TABLE 10

STRESS STABILITY

STRESS STABILITY AT 1000°F (538°C) — 30 KSI (207 MPa) AGED AT 1100°F (593°C) FOR 8 HRS BEFORE EXPOSURE

Exposure	*RT Tensile After Exposure*		
Time hrs	*UTS ksi (MPa)*	*YS ksi (MPa)*	*% Elong.*
None	176 (1214)	163 (1124)	10
500	182 (1255)	169 (1165)	11
1000	179 (1234)	167 (1151)	12.5

TABLE 11

OXIDATION RESISTANCE

1200°F (650°C) EXPOSURE

	Wt. Gain (mg/cm²)			
	24 hrs	*48 hrs*	*72 hrs*	*96 hrs*
TIMETAL 15-3	1.26	1.81	2.29	3.18
Commercially Pure Ti	0.18	0.27	0.34	0.53
TIMETAL 21S	0.06	0.07	0.10	0.11

TABLE 12

SKYDROL RESISTANCE

SPECIMENS PARTIALLY SUBMERGED FOR 48 HRS; SKYDROL REPLENISHED TWICE

Test Temp. °F (°C)	*TIMETAL Alloy*	*Hydrogen Absorbed (ppm)*	*Comments*
350 (177)	6-4	0	0.0004 in (0.01mm) of Thinning
350 (177)	21S	12	No attack
450 (232)	6-4	>1000	Thinned to knife-edge
450 (232)	21S	97	Scattered pits = 0.0002 in (0.005mm) deep
550 (288)	6-4	>1000	0.028 in (0.71mm) of Thinning
550 (288)	21S	138	Scattered pits = 0.0014 in (0.038mm) deep; 0.0018 in (0.046mm) of Thinning
650 (343)	6-4	>1000	0.028 in (0.71mm) of Thinning
650 (343)	21S	83	Scattered pits = 0.0014 in (0.038mm) deep; 0.0018 in (0.046mm) of Thinning

Reference: R. Boyer, Boeing, 1993

TYPICAL APPLICATIONS

Warm Airframe of Engine Structure	*Honeycomb*
Metal Matrix Composites	*Fasteners*
Welded and SeamFree™ Tube	*Castings*

The data and other information contained herein are derived from a variety of sources which TIMET believes are reliable. Because it is not possible to anticipate specific uses and operating conditions, TIMET urges you to consult with our technical service personnel on your particular applications.

For more information, please contact the TIMET Sales Office/Service Center nearest you, TIMET's Technical Laboratories or TIMET's Website @ www.timet.com

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TITANIUM MEMBER

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