



**TITANIUM – PROPERTIES, ADVANTAGES AND APPLICATIONS  
SOLVING THE CORROSION PROBLEMS IN MARINE SERVICE**

**John A. Mountford, Jr.  
Director of Marketing**

**TICO TITANIUM, INC.  
52900 Grand River Avenue  
New Hudson, MI 48165**

**“RUST 2001”**

**U.S. Navy & Industry  
Corrosion Technology Information Exchange**

**July 17, 2001**



## CHEMISTRY - WGT. %

	O <sub>2</sub> max.	Fe max.	H <sub>2</sub> max.	C max.	N <sub>2</sub> max.	Al	V	Other (each)	Other (total)	Ti
<b>Grade 2</b>	0.25	0.30	0.015	0.08	0.03			0.10	0.40	Bal.
<b>Grade 9 ( 3Al - 2.5V )</b>	0.15	0.25	0.015	0.08	0.03	2.5 - 3.5	2.0 - 3.0	0.10	0.40	Bal.
<b>Grade 5 (6Al - 4V)</b>	0.20	0.40	0.015	0.08	0.05	2.5 - 3.5	2.0 - 3.0	0.10	0.40	Bal.
<b>Grade 23 ( 6Al - 4V ELI )</b>	0.13	0.25	0.0125	0.08	0.03	5.5 - 6.5	3.5 - 4.5	0.10	0.40	Bal.

**ELI = Extra Low Interstitials**



## MECHANICAL & PHYSICAL PROPERTIES

PROPERTY	Titanium Grade 2		90-10 Cu-Ni		70-30m Cu-Ni		316 Stainless	
	KSI	MPa	KSI	MPa	KSI	MPa	KSI	MPa
Tensile Strength (min)	50	345	40	275	52	360	75	515
Yield Strength (min)	40	275	15	105	18	125	35	240
Yield Strength (max)	65	450	--		--		--	
Elongation (min)	20%		30%		15%		30%	
Elastic Modulus ( $10^6$ psi)	16		18		22		28	
Thermal Expansion Coeff. ( Micro in/in $^{\circ}$ F )	4.8		9.5		9.0		8.9	
Thermal Conductivity ( BTU/hr-ft $^2$ $^{\circ}$ F/in )	150		348		204		95	
Density ( lbs/in $^3$ )	0.163		0.323		0.323		0.286	

Thermal Expansion Coefficient for HY 80 Steel = approx. 6.0 Micro in/in  $^{\circ}$ F



## **ISSUES & BENEFITS**

- **DENSITY / WEIGHT SAVINGS**
- **CORROSION RESISTANCE  
[SEAWATER IMMUNITIES]**
- **EROSION RESISTANCE**
- **PROPERTY ADVANTAGES**
- **FABRICATION & WELDING**
- **MAINTENANCE REDUCTION**
- **FREQUENTLY ASKED QUESTIONS**



## WEIGHT COMPARISON - TITANIUM VS. COPPER - NICKEL

BASIS : SAME PIPE SIZE [SCH 10] -- Ti & Cu-Ni

OD Nominal [in.]	OD Actual [in.]	WALL Nominal [in.]	WEIGHT Gr. 2 Ti [lbs./100ft.]	WEIGHT Cu-Ni [lbs./100ft.]	WEIGHT REDUCTION [lbs./100ft.]
2	2.375	0.109	152	301	149
3	3.500	0.120	249	493	244
4	4.500	0.120	323	640	317
6	6.625	0.134	534	1,058	524
8	8.625	0.148	771	1,528	757
10	10.750	0.165	1,073	2,125	1,052
12	12.750	0.180	1,390	2,753	1,363

49.50%



## WEIGHT COMPARISON - TITANIUM VS. COPPER - NICKEL

**BASIS : TITANIUM [SCH 10] vs . CLASS 200 CU-NI**

		Ti	Cu-Ni				
OD Nominal [in.]	OD Actual [in.]	WALL Nominal [in.]	WALL Nominal [in.]	WEIGHT Gr. 2 Ti [lbs ./100ft.]	WEIGHT Cu-Ni [lbs./100ft.]	WEIGHT REDUCTION	
						[lbs ./100ft.]	%
2	2.375	0.109	0.083	152	229	77	<b>34</b>
3	3.500	0.120	0.095	249	391	142	<b>36</b>
4	4.500	0.120	0.109	323	583	260	<b>45</b>
6	6.625	0.134	0.134	534	1,058	524	<b>50</b>
8	8.625	0.148	0.148	771	1,528	757	<b>50</b>
10	10.750	0.165	0.187	1,073	2,405	1,332	<b>55</b>
12	12.750	0.180	0.250	1,390	3,805	2,415	<b>63</b>



## **CORROSION RESISTANCE – SEAWATER IMMUNITIES**

- **Titanium is virtually IMMUNE to seawater (all waters)**
- **Complete resistance to General Corrosion and Crevice Corrosion in all waters at temperatures to 180<sup>0</sup> F (or somewhat above)**
- **No Corrosion in Polluted Waters (i.e. ports and harbors)**
- **No Effects from Microbiologically Influenced Corrosion (MIC) [microbes etc.]**
- **Titanium is Un-affected under Stagnant Water conditions**
- **Shock chlorine treatments can be used to prevent/clean fouling**
- **CP Grade 2 is Immune to Stress Corrosion Cracking (SCC) under sea service conditions**
- **Seawater cooled tubes have been in service for 40 years or more with zero corrosion**



# CORROSION RESISTANCE - COMPARISONS

<u>Corrosion</u>	<u>Cu-Ni</u>	<u>316 Stainless</u>	<u>Titanium CP, 5, 9, 23</u>
General	Resistant/Susceptible	Resistant	Resistant / Immune
Crevice	Susceptible	Susceptible	Resistant/Immune (<200 <sup>o</sup> F)
Pitting	Susceptible	Susceptible	Immune
SCC	Susceptible	Susceptible (>140 <sup>o</sup> F)	Immune (except Gr. 5)
Fatigue	Susceptible	Susceptible	Resistant
Galvanic	Susceptible	Susceptible	Immune
MIC	Susceptible	Susceptible	Immune
Erosion	Susceptible	Resistant	Resistant
Weld/HAZ	Susceptible	Susceptible	Resistant / Immune



## EROSION RESISTANCE

- **Titanium's "ceramic-like" outer protective oxide film (TiO<sub>2</sub>)**
- **Water velocities of 90 ft/sec (27 m/sec) and higher in the absence of suspended solids**
- **Flow rates to 15 ft/sec (4.6 m/sec) and higher under sand-laden conditions**
- **Mechanical Cleaning using Scrappers are not harmful to titanium**
- **Titanium's Surface instantly re-heals itself**



## PROPERTY ADVANTAGES

- **Density – Weight savings to 50% (and above)**
- **Low Thermal Expansion = Less Joint Stress**
- **Thermal Conductivity allows matching (or higher) Heat Transfer - ideal for Heat Exchanger applications**
- **Low Elastic Modulus = High Shock Tolerance**
- **High Yield Strength (min) = High Strength / Weight Ratio**
- **Excellent Ballistic properties = used for armor**
- **Non-Magnetic = No Electronic interference**



## FABRICATION & WELDING

- **Machining – Slow Speeds, Deep Cuts, High Cooling Fluid**
- **Cutting - Drill, Saw, Shear, Water-Jet, Oxy-Acetylene or Plasma Torch**
- **Bending – formable & forgiving [compensate for spring-back] (Pipe ends can be flared 90<sup>0</sup> to eliminate Flanges)**  
-----
- **Tungsten Inert Gas (TIG), Gas Tungsten Arc (GTA), Gas Metal Arc (GMA), Metal Inert Gas (MIG), Plasma, Resistance, Friction, Electron Beam, Laser and Orbital**
- **Training TIG welders – 2 weeks**
- **Fluid Welds (CP is single phase)**



## APPLICATIONS

### SHIPBOARD

Ship Service Turbine Generator  
Condenser (S/T)

Lube Oil Cooler

Aegis Radar Electronics Cooler  
(S/T) & (P/F)

De-Salination Units (S/T)

Firemain Systems

Service Water Piping

Air Conditioning Condenser (S/T)

HVAC - Air Ventilation Ducting

Distillation unit - Brine Heater  
and Brine Pre-Heater (P/F) and (S/T)

### OFFSHORE

Fire Sprinkler Heads, Deluge  
Nozzles and Deluge Valves

Lube Oil Cooler

Compressor Cooler

Ballast Systems and Valves

Firemain Systems

Service Water Piping

Central Exchanger (P/F)

Discharge Cooler

Direct Low Pressure Crude  
Oil Service Cooler (S/T)

(S/T) = Shell & Tube (Heat Exchanger)

(P/F) = Plate & Frame (Heat Exchanger)



## APPLICATIONS cont'd.

### SHIPBOARD

Engine Jacket Coolers for  
TAO oilers (P/F)

Low Pressure Air Compressor Cooler

Uptakes (Stack Liners) in DDG Destroyers

Light Boxes

Oil Waste System \*

Magazine Sprinkler Systems \*

Deck Drainage Systems \*

Bilges \*

Countermeasure Washdown Piping \*

Seawater Compensated Fuel Oil Systems

Missile Deluge Systems \*

Stanchions \*

### OFFSHORE

Engine Jacket Cooler

Quench Water Cooler (S/T)

Propane Condenser

Gas Dehydrator Cooler (S/T)

Natural Gas Cooler (S/T)

Glycol Cooler (S/T)

Flash Gas Compressor

Intercooler (S/T)

Interstage Oil Cooler (S/T)

\* = Applications for Consideration  
On Board Ship

(S/T) = Shell & Tube (H. E.)  
(P/F) = Plate & Frame (H. E.)