Corrosion-Resistant Titanium

Commercially Pure

INTRODUCTION

ATI offers corrosion-resistant commercially pure titanium produced as plate, sheet, and strip products. Titanium's low density and high strength-to-weight ratio make it the material of choice for many corrosive chemical environments, including oxidizing chloride solutions (including seawater) and chlorine-based bleaches.

PRODUCT GRADES, FORMS AND REQUIREMENTS*

	Nominal Composition	Forms		
		Coil	Sheet	Plate
CP Grade 1	Ti	X	X	X
CP Grade 2	Ti	X	X	X
CP Grade 3	Ti	X	X	X
CP Grade 4	Ti	X	X	X
CP Grade 7	Ti (Gr2) 0.2 Pd	X	X	X
CP Grade 11	Ti (Gr1) 0.2 Pd	X	X	**
CP Grade 16	Ti (Gr2) 0.05 Pd	X	X	**
CP Grade 17	Ti (Gr1) 0.05 Pd	X	X	**

* Produced to ASTM, AMS, ASME and MIL Specifications.
** Inquire with your sales representative.

SIZES, TOLERANCES*

Sheet	
Width** (in)	Thickness (in)
24" - 48"	Up to 0.1874"
Strip	
0.250" - 24"	0.001" - 0.1874"
Plate	
96"	0.1875" - 4.0" x 360" max

* Tolerances per relvant ASTM, AMS, ASME and MIL Requirements; available sizes are grade and gage dependent.

** Typically supplied with #3 EDGE on coil product.

Finish varies depending upon size. Consult your sales representative with your specific finish requirements.

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TYPICAL APPLICATIONS

Heat Transfer
A major industrial application for titanium is in heat transfer applications for which the cooling medium is seawater, brackish water or polluted water. Titanium condensers, shell and tube heat exchangers, and plate and frame heat exchangers are used extensively in power plants, refineries, air conditioning systems, chemical plants, offshore platforms, surface ships and submarines.

Millions of feet of welded titanium tubing are in power plant condenser service, and there have been no reported failures due to corrosion on the cooling water side.

DSA-Dimensional Stable Anodes
The unique electrochemical properties of the titanium DSA make it the most energy efficient unit for the production of chlorine, chlorate and hypochlorite.

Desalination
Its excellent resistance to corrosion, erosion, and high condensation efficiency make titanium the cost-effective and dependable material for critical segments of desalination plants. Increased usage of very thin walled welded tubing makes titanium competitive with copper-nickel.

Extraction and Electro-Winning of Metals
Hydrometallurgical extraction of metals from ores in titanium reactors is an environmentally friendly alternative to smelting processes. Extended lifespan, increased energy efficiency, and greater product purity are factors promoting the usage of titanium electrodes in electro-winning and electro-refining of metals like copper, gold, manganese and manganese dioxide.

Medical
Titanium is widely used for implants, surgical devices, pacemaker cases and centrifuges. Titanium is the most biocompatible of all metals due to its resistance to attack by body fluids, its high strength and its low modulus.

Hydrocarbon Processing
The need for longer equipment life, coupled with requirements for less downtime and maintenance, favor the use of titanium in heat exchangers, vessels, columns and piping systems in refineries, LNG plants and offshore platforms. Titanium is immune to general attack and stress corrosion cracking by hydrocarbons, hydrogen sulfide, brines and carbon dioxide.

Marine Applications
Because of high toughness, high strength and exceptional erosion/corrosion resistance, titanium is currently being used for submarine ball valves, fire pumps, heat exchangers, castings, hull material for deep sea submersibles, water jet propulsion systems, shipboard cooling and piping systems.

Chemical Processing
Titanium vessels, heat exchangers, tanks, agitators, coolers, and piping systems are utilized in the processing of aggressive compounds, like nitric acid, organic acids, chlorine dioxide, inhibited reducing acids and hydrogen sulfide.

Structural/Architectural Applications
Titanium's use as an architectural material is rapidly gaining worldwide acceptance. Its corrosion resistance, light weight, strength, durability, soft metallic appearance, and almost unlimited life span give titanium a cost-effective edge over other materials. Typical areas include roofs, ceilings, exterior wall panels, sculptures and monuments.

CORROSION RESISTANCE

General Corrosion
ATI titanium has excellent resistance to corrosion in a wide variety of environments including seawater, salt brines, inorganic salts, bleaches, wet chlorine, alkaline solutions, oxidizing acids, and organic acids. Titanium is incompatible with fluorides, strong reducing acids, very strong caustic solutions, and anhydrous chlorine. Due to its combustibility, titanium is

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not suitable for pure oxygen service. Titanium does not release any toxic ions into aqueous solutions, thus helping to prevent pollution.

Crevice Corrosion

ATI titanium has excellent resistance to crevice corrosion in salt solutions and generally outperforms stainless steels. Unalloyed CP titanium (grades 1, 2, 3, and 4) typically do not suffer crevice corrosion at temperatures below 80°C (175°F) at any pH.

Palladium alloyed CP titanium (grades 7, 11, 16 and 17) are more resistant and typically do not suffer crevice corrosion at temperatures below 250°C (480°F) at pH greater than 1.

Microbiologically Influenced Corrosion (MIC)

Titanium appears to be immune to MIC. They do suffer biofouling, but this can be controlled by chlorination (which does not impair titanium).

Galvanic Corrosion

Although it is a reactive metal, due to the extreme stability of the passive film which forms on its surface, titanium typically exhibits noble behavior. Thus it functions as the cathode when coupled with other metals. Titanium is not affected by galvanic corrosion, but can accelerate corrosion of other metals.

Stress Corrosion Cracking

ATI CP titanium has excellent resistance to stress corrosion cracking in hot chloride salt solutions.

Erosion Corrosion

CP Titanium exhibits excellent resistance to flow-induced and erosion corrosion at velocities to above 40 m/sec.

Hydrogen Embrittlement

Titanium is susceptible to hydrogen embrittlement under some circumstances. This is generally less of a problem for the low- strength grade 1 and grade 2 titanium alloys than for higher strength titanium alloys. Absorption of hydrogen by titanium normally occurs when the temperature is above 80°C (175°F), and the titanium is galvanically coupled to an active metal or an impressed current or the pH is less than 3 or greater than 12.

FABRICATION

Welding

ATI CP titanium is readily weldable using GTAW (gas tungsten arc welding) or TIG (tungsten inert gas) processes if adequate shielding is provided using pure inert gas (argon or helium). Use of a trailing shield is recommended. Titanium must be free of oil, grease or other contamination before welding. Preheat or post-heat are not required. Friction welding, laser welding, resistance welding, plasma arc welding, electron beam welding, and diffusion bonding can also be used.

Formability

ATI titanium is readily formed at room temperature, using techniques and equipment suitable for steel. When correct parameters have been established, tolerances similar to those attainable with stainless steel are possible with titanium and its alloys. Three factors make forming of titanium somewhat different from forming of other metals.

1. The room temperature ductility of titanium, as measured by uniform elongation, may be less than that of other common structural metals. This means that titanium may require more generous bend radii and has lower stretch formability.

2. The modulus of elasticity of titanium is about half that of steel. This causes significant spring back after forming titanium for which compensation must be made.

3. The galling tendency of titanium is greater than that of stainless steel. This necessitates close attention to lubrication in any forming operation in which titanium is in contact (particularly moving contact) with metal dies or other forming equipment.

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The various grades of ATI unalloyed titanium exhibit differences in formability. Grades 1, 11 and 17 titanium, which are the softest and most ductile grades, exhibit the greatest formability. The slightly greater strengths of Grades 2, 7 and 16 titanium are still quite formable, but less so than Grades 1, 11 or 17. The higher strength of Grade 4 titanium makes it the least formable of the CP titanium alloys.

Normally, titanium surfaces are acceptable for forming operations as received from the mill. Gouges and other surface marks introduced during handling should be removed by sanding. To prevent edge cracking, burred and sharp edges should be filed smooth before forming.

CHEMICAL COMPOSITION (WEIGHT %)

Grade	Carbon Max	Oxygen Max	Nitrogen Max	Iron Max	Aluminum	Vanadium	Palladium	Molybd-enum	Nickel	Hydrogen Max
Grade 1	0.08	0.18	0.03	0.20	...	...	...	...	...	0.015
Grade 2	0.08	0.25	0.03	0.30	...	...	...	...	...	0.015
Grade 3	0.08	0.35	0.05	0.30	...	...	...	...	...	0.015
Grade 4	0.08	0.40	0.05	0.50	...	...	...	...	...	0.015
Grade 5	0.08	0.20	0.05	0.40	5.5-6.75	3.5-4.5	...	...	...	0.015
Grade 7	0.08	0.25	0.03	0.30	...	...	0.12-0.25	...	...	0.015
Grade 9	0.08	0.12	0.03	0.25	2.5-3.5	2.0-3.0	...	...	...	0.015
Grade 11	0.08	0.18	0.03	0.20	...	...	0.12-0.25	...	...	0.015
Grade 12	0.08	0.25	0.03	0.30	...	...	...	0.2-0.4	0.6-0.9	0.015
Grade 16	0.08	0.25	0.03	0.30	...	...	0.04-0.08	...	...	0.015
Grade 17	0.08	0.18	0.03	0.20	...	...	0.04-0.08	...	...	0.015
Grade 18	0.08	0.15	0.03	0.25	2.5-3.5	2.0-3.0	0.04-0.08	...	...	0.015

MECHANICAL PROPERTIES*

Grade	Tensile Str. ksi min	Tensile Str. MPa min	Yield Strength ksi min/max	Yield Strength MPa min/max	Elongation in 2", % min
CP Grade 1	35	240	20/45	138/310	24
CP Grade 2	50	345	40/65	275/450	20
CP Grade 3	65	450	55/80	380/550	18
CP Grade 4	80	550	70/95	483/655	15
CP Grade 7	50	345	40/65	275/450	20
CP Grade 11	35	240	20/45	138/310	24
CP Grade 16	50	345	40/65	275/450	20
CP Grade 17	35	240	20/45	138/310	24

*Mill Annealed Condition **Minimum

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TYPICAL PHYSICAL PROPERTIES

	Grade 1, 2, 3, 4, 7, 11, 12, 16, 17
Density	0.163 lb/in^3
Modulus	15 x 10^6 psi
Beta Transus (± 25°F)	1635°F - 1735°F
Thermal Conductivity	13-10 Btu/ft·h·°F
Thermal Expansion (32-600°F)	5.1 x 10^{-6}/°F
Melt Temperature	~3000°F

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