The TRIDENT Company

Nickel & Titanium Alloy Designation

Nickel Alloys	
Commercially Pure Nickel Alloys	These alloys contain not less, than 99% of nickel. Three digit numbers (2xx, 3xx) are used as trade names of commercial nickel. The alloys are characterized by very good corrosion resistance and high ductility. *Alloy 200:* Exhibits good corrosion resistance and is ferromagnetic and has relatively low electrical resistivity.
Nickel-Copper Alloys	These alloys contain about 30% of copper, which form solid solution with nickel. This alloy when it contains aluminum and titanium as additional alloying elements (Alloy K-500), is heat-treatable and may be strengthened by precipitation hardening. *Alloy 400:* The alloy is characterized by moderate strength, good weldability, good general corrosion resistance and toughness. *Alloy R405:* This alloy is a free-machining version of Alloy 400. This grade contains sulfur to enhance machinability. *Alloy K500:* Combines the excellent corrosion resistance characteristic of Alloy 400 with the added advantages of greater strength and hardness.
Nickel-Chromium-Iron Alloys **(Non-heat-treatable)**	The major alloying elements of these alloys (15-22% of chromium and up to 46% of iron) form solid solution with nickel and may be hardened by cold work. *Alloy 600:* Is a nonmagnetic, high temperature alloy possessing an excellent combination of high strength, hot and cold workability, and resistance to ordinary form of corrosion. This alloy also displays good heat resistance and freedom from aging or stress corrosion throughout the annealed to heavily cold worked condition range. *Alloy 601:* An alloy with an addition of aluminum for outstanding resistance to oxidation and other forms of high temperature corrosion. It also has high mechanical properties at elevated temperatures. *Alloy 625:* The alloy has excellent fatigue strength and stress-corrosion cracking resistance to chloride ions. *Alloy 718:* A precipitation hardenable alloy designed to display exceptionally high yield, tensile and creep rupture properties at temperatures up to 1300°F. The sluggish age hardening response of this alloy permits annealing and welding without spontaneous hardening during heating and cooling. This alloy has excellent weldability. *Alloy 800:* Moderate strength and good resistance to oxidation and carburization at elevated temperatures. Excellent resistance to chloride stress corrosion cracking. *Alloy 825:* Good corrosion resistance to sulfuric and phosphoric acids and sea water. It is similar to alloy 800 but with improved resistance to aqueous corrosion, good resistance in neutral chloride media. *Alloy 925:* This is an age-hardenable alloy. The additions of titanium and aluminum enable it to be age hardened while molybdenum and copper contents enhance resistance to corrosive media. *Alloy C-276:* Excellent general corrosion resistance and good fabricability. The alloy has resisted both general and localized corrosion, including pitting, crevice corrosion, and stress corrosion cracking
Nickel-Chromium-Iron Alloys **(Heat-treatable)**	These alloys may be strengthened by precipitation hardening due to presence of additional alloying elements: aluminum, titanium, silicon. *Alloy X750:* A precipitation-hardenable alloy, the alloy is highly resistant to chemical corrosion and oxidation and has high stress rupture strength and low creep rates under high stresses at temperatures up to 1500°F (816°C) after suitable heat treatment.
Nickel-Cobalt Alloys	These alloys contain about 17% cobalt. The accepted trade name is Kovar. *Kovar:* An iron-nickel-cobalt alloy with a coefficient of thermal expansion similar to that of hard (borosilicate) glass. This makes it especially suitable for uses which require a matched expansion seal between metal and glass parts
Nickel-iron-molybdenum Alloy	*HyMu 80:* Is 80% nickel-iron-molybdenum alloy which offers extremely high initial permeability as well as maximum permeability with minimum hysteresis loss.

Maching Classification of Nickel Alloys	
<u>Group A</u> **Alloy 200**	These alloys are characterized by moderate mechanical strength and a high degree of toughness. These can be hardened only by cold work. The alloys are quite gummy in the annealed or hot worked condition, and cold drawn material is recommended for best machinability and smoothest finish.
<u>Group B</u> **Alloy 400**	These alloys have higher strength and slightly lower toughness then those in group A. They can be hardened only by cold work. Cold drawn or cold drawn, stress-relieved material is recommenced for best machinability and smoothest finish.
<u>Group C</u> **Alloy K500-unaged** **Alloy 600** **Alloy 800** **Alloy 825**	These alloys are quite similar to the austenitic stainless steels. They can be hardened only by cold work and are machined most easily in the cold drawn or cold drawn, stress relieved condition.
<u>Group D</u>	These alloys are characterized by high strength and harness, particularly when aged. Material which has been solution annealed and quenched or rapidly air cooled is in the softest condition and does machine easily. Because of softness, the unaged condition is necessary for ease in drilling, tapping and all threading operations.
Alloy K500-aged	Heavy machining of the age hardenable alloys is best accomplished when they are in one of the following conditions.
Alloy 718	1. Solution annealed.
Alloy X750	2. Hot worked and quenched or rapidly air cooled.
	Although fully age hardened material is usually too hard for tools with weak cutting edges, such as small drills and taps, and also for rough machining, material in this condition can be finish machined to fine finishes and close tolerances. The best way to machine the alloys in this group is to machine slightly oversize in the unaged condition, age harden, then finish to size. Because the age hardening treatment will relieve machining stresses, allowance must be made for possible warpage. Aged material has good dimensional stability.
<u>Group E</u> **Alloy R405**	This alloy was specifically developed for good machinability. It is recommended for use with automatic screw machines. Other alloys in groups A, B, C, and D, may be machined on automatics, but the lower speeds required are generally not possible with this type of equipment. Alloy R450 combines the toughness, strength, and corrosion resistance of alloy 400 with excellent machinability.

Titanium Alloys

Titanium alloys are metallic materials which contain a mixture of titanium and other chemical elements. Such alloys have very high tensile strength and toughness (even at extreme temperatures), light weight, extraordinary corrosion resistance, and ability to withstand extreme temperatures.

Although "commercially pure" titanium has acceptable mechanical properties, titanium is alloyed with small amounts of aluminum and vanadium, typically 6% and 4% respectively, by weight. This mixture has a solid solubility which varies dramatically with temperature, allowing it to undergo precipitation strengthening. This heat treatment process is carried out after the alloy has been worked into its final shape, allowing much easier fabrication of a high strength product.

Some alloying elements raise the alpha-to-beta transition temperature (i.e. alpha stabilizers) while others lower the transition temperature (i.e. beta stabilizers). Aluminum, gallium, germanium, carbon, oxygen and nitrogen are alpha stabilizers. Molybdenum, vanadium, tantalum, niobium, manganese, iron, chromium, cobalt, nickel, copper and silicon are beta stabilizers. Titanium alloys are usually classified as alpha alloys, near alpha alloys, alpha + beta alloy or beta alloys depending on the type and amount of alloying elements.

Generally, alpha-phase Titanium is more ductile and beta-phase Titanium is stronger but more brittle. Alpha-beta-phase Titanium has a mechanical property which is in between both.

Titanium alloys are designated according to their compositions, referred to as grades:

Grade 1-4	Unalloyed and considered commercially pure or "CP". Generally the tensile and yield strength goes up with grade number for these "pure" grades. The difference in their physical properties is primarily due to the quantity of interstitial elements. They are used for corrosion resistance applications where cost and ease of fabrication and welding are important.
Grade 5	The most commonly used alloyed. It has a chemical composition of Ti6Al4V. This alloy contains 6% Aluminum and 4% Vanadium. It is also known as Ti-6AL-4V or simply Ti 6-4. Grade 5 is used extensively in Aerospace, Medical, Marine, and Chemical Processing.
Grade 6	Contains 5% Aluminum and 2.5% Tin. It is also know as Ti-5Al-2.5Sn. This alloy is used in airframes and jet engines due to its good weldability, stability and strength at elevated temperatures.
Grade 7	Contains 0.12 to 0.25% Palladium. This grade is similar to Grade 2. The small quantity of Palladium added gives it enhanced crevice corrosion resistance at low temperatures and high Ph.
Grade 7H	Contains 0.12 to 0.25% Palladium. This grade has enhanced corrosion resistance.
Grade 9	Contains 3.0% Aluminum and 2.5% Vanadium. This grade is a compromise between the ease of welding and manufacturing of the "pure" grades and the high strength of Grade 5. It is commonly used in aircraft tubing for hydraulics and in athletic equipment.
Grade 11	Contains 0.12 to 0.25% Palladium. This grade has enhanced corrosion resistance.
Grade 12	Contains 0.3% Molybdenum and 0.8% Nickel.
Grades 13, 14, and 15	All contain 0.5% Nickel and 0.05% Ruthenium.
Grade 16	Contains 0.04 to 0.08% Palladium. This grade has enhanced corrosion resistance.
Grade 16H	Contains 0.04 to 0.08% Palladium.
Grade 17	Contains 0.04 to 0.08% Palladium. This grade has enhanced corrosion resistance.
Grade 18	Contains 3% Aluminum, 2.5% Vanadium and 0.04 to 0.08% Palladium. This grade is identical to Grade 9 in terms of mechanical characteristics. The added Palladium gives it increased corrosion resistance.

Grade 19	Contains 3% Aluminum, 8% Vanadium, 6% Chromium, 4% Zirconium, and 4% Molybdenum.
Grade 20	Contains 3% Aluminum, 8% Vanadium, 6% Chromium, 4% Zirconium, 4% Molybdenum and 0.04% to 0.08% Palladium.
Grade 21	Contains 15% Molybdenum, 3% Aluminum, 2.7% Niobium, and 0.25% Silicon.
Grade 23	Contains 6% Aluminum, 4% Vanadium.
Grade 24	Contains 6% Aluminum, 4% Vanadium and 0.04% to 0.08% Palladium.
Grade 25	Contains 6% Aluminum, 4% Vanadium and 0.3% to 0.8% Nickel and 0.04% to 0.08% Palladium.
Grades 26, 26H, and 27	All contain 0.08 to 0.14% Ruthenium.
Grade 28	Contains 3% Aluminum, 2.5% Vanadium and 0.08 to 0.14% Ruthenium.
Grade 29	Contains 6% Aluminum, 4% Vanadium and 0.08 to 0.14% Ruthenium.
Grades 30 and 31	Contain 0.3% Cobalt and 0.05% Palladium.
Grade 32	Contains 5% Aluminum, 1% Tin, 1% Zirconium, 1% Vanadium, and 0.8% Molybdenum.
Grades 33 and 34	Contain 0.4% Nickel, 0.015% Palladium, 0.025% Ruthenium, and 0.15% Chromium.
Grade 35	Contains 4.5% Aluminum, 2% Molybdenum, 1.6% Vanadium, 0.5% Iron, and 0.3% Silicon.
Grade 36	Contains 45% Niobium.
Grade 37	Contains 1.5% Aluminum.
Grade 38	Contains 4% Aluminum, 2.5% Vanadium, and 1.5% Iron. This grade was developed in the '90 for use as an armor plating. The iron reduces the amount of Vanadium needed for corrosion resistance. It's mechanical properties are very similar to Grade 5.