CHEMICAL ENGINEERING
FACTS AT YOUR FINGERTIPS
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Specialty Metals

One of the most important factors to consider when evaluating a specialty metal for use in valves, fittings and instrumentation is its corrosion resistance or corrosion rate of the metal in the target media. Each material discussed here has its own niche, and depending on the processing environment and the needs of the application, the metal's strengths and weaknesses may or may not be suitable. In either H_2SO_4 or HCl solutions, the corrosion resistance of tantalum is second to none, followed by zirconium, nickel alloys and titanium. Thermal expansion coefficient and melting point data for each metal are given in the table.

Metal	UNS Number	Coefficient of Thermal Expansion (10^{-6} mm/(mm°C)	Temperature range, °C	Melting temperature, °C
Nickel alloy 200	N02200	13.3	20–90	1,440–1,450
Titanium	R50250	8.6	0–100	1,705
Zirconium	R60702	5.2	0–100	1,860
Tantalum	R05200	6.5	0–200	2,996

TANTALUM

The physical properties of tantalum are similar to those of mild steel, although tantalum has a higher melting point. Tantalum is the most corrosion-resistant metal that is in common use, due to its tenacious oxide layer. Its superb corrosion resistance is comparable to glass and is practically inert to most oxidizing and reducing acids, except fuming sulfuric acid, hot alkalis and HF. While tantalum is an ideal choice from a corrosion-resistance point of view, it is typically cost prohibitive, even when cladded. Only in process conditions where no other material will perform adequately is tantalum a material of choice, at least in its traditional forms. This limits tantalum's use to heating coils, bayonet heaters, coolers and condensers operating under severe conditions. When economically justified, larger items of equipment, such as reactors or tanks, may be fabricated with tantalum liners. Since tantalum linings are usually very thin, very careful attention to design and fabrication details is required.

Tantalum can typically be found in applications that deal with hot concentrated acids. Due to its negligible corrosion rate, it is ideal for use in the pharmaceutical and food manufacturing industries [*2*].

Recently, tantalum has been processed to create a surface alloy on valves and other fittings, instrumentation and equipment. This relatively new option exhibits all the chemical properties of tantalum, allowing excellent corrosion resistance without the high costs. However, this option is not suitable for slurries or solutions that contain abrasive particles that could lead to mechanical erosion and abrasion of the surface.

ZIRCONIUM ALLOYS

Zirconium alloys exhibit excellent resistance to corrosive attack and work well in many organic and inorganic acids, salt solutions, strong alkalies, and some molten salts. It owes its corrosion resistance to the natural formation of a dense, stable, self-healing oxide film on its surface. Unalloyed zirconium has excellent resistance to H_2SO_4 up to 60% concentration at the boiling point, and has excellent corrosion resistance in HCl. Zirconium is also highly resistant to most alkali solutions up to their boiling point.

Zirconium's corrosion resistance could be compared with titanium in many ways, but it is much more robust than titanium in withstanding organic acids, such as acetic, citric, and formic at various concentrations and elevated temperatures. However, zirconium can still be corrosively attacked by fluoride ions, wet chlorine, aqua regia, concentrated sulfuric acid (above 80%), and ferric or cupric chlorides [*3*]. Zironium has excellent resistance to reducing environments, but oxidizing agents frequently cause accelerated attack. Commercial-grade zirconium, which contains up to 2.5% hafnium, is often used in hydrogen peroxide production, rayon manufacture, and the handling of phosphoric acid, sulfuric acid and ethyl benzene.

TITANIUM

Titanium is an established metal when dealing with corrosive applications. Titanium is available in a range of different alloys with the most-corrosion-resistant grades being titanium 7, 11 (containing 0.15% Pd), and 12 (containing 0.3% Mo and 0.8% Ni). Titanium and its alloys offer good corrosion resistance that is due to a strong oxide film. The oxide film formed on titanium is more protective than on stainless steel, and it often performs well in media such as seawater, wet chlorine and organic chlorides. While titanium offers good corrosion resistance to these solutions, it certainly is not immune to them, especially at elevated temperatures (for example, seawater at temperatures greater than 110°C) [*3*]. It has a number of disadvantages as well, as it is not easy to form, it has a high springback and tends to gall, and welding must be carried out in an inert atmosphere.

Titanium metal can be found in a variety of industries, including chemical processing, pulp and paper, and marine applications. It is also used extensively in the production of chlorine.

NICKEL ALLOYS

Nickel alloys are commonly used when typical steel materials don't offer the corrosion performance that is needed. To enhance the performance of nickel in aqueous-solution service, the most important alloying elements are Fe, Cu, Si, Cr and Mo. Cr and Mo play a major role in nickel's corrosion resistance. Varying the concentrations of these elements in the nickel alloys changes the corrosive environments in which nickel alloys can be successfully applied, but they are typically used in a range of acid, salt and alkali applications. The addition of Cr (15–30%) improves the corrosion resistance to oxidizing solutions, while the addition of Mo (up to 28%) improves the resistance to non-oxidizing acids.

The nickel alloys C-22, C-276, and B-2 all have good corrosion resistance in a variety of media. In the case of HCl, the corrosion resistance of these alloys depends greatly on the Mo content. The alloy with the highest concentration of Mo, B-2, exhibits the best corrosion resistance.

In solutions such as nitric acid (HNO_3), Cr is an essential alloying element for providing corrosion resistance. Nickel alloys' weaknesses revolve around their interaction with the media and their environment in the form of impurities. Under ideal testing conditions, these alloys (for example, B-2), work well in pure de-aerated H_2SO_4 and HCl, but deteriorate rapidly when oxidizing impurities, such as oxygen and ferric ions, are present. Another consideration is the presence of chlorides (Cl^-), which generally accelerate the corrosion attack at different degrees for various alloys.

Having a wide range of applicability in acids, salt solutions, and caustic environments, nickel alloys have found their way into a variety of industries, such as chemical, petrochemical, oil and gas, nuclear, conventional power generation and paper.

References

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4. "Perry's Chemical Engineers' Handbook," 8th ed. New York: McGraw Hill, 2008.