Cost-Benefit Analysis of Various Alloys

BSI ENGINEERING
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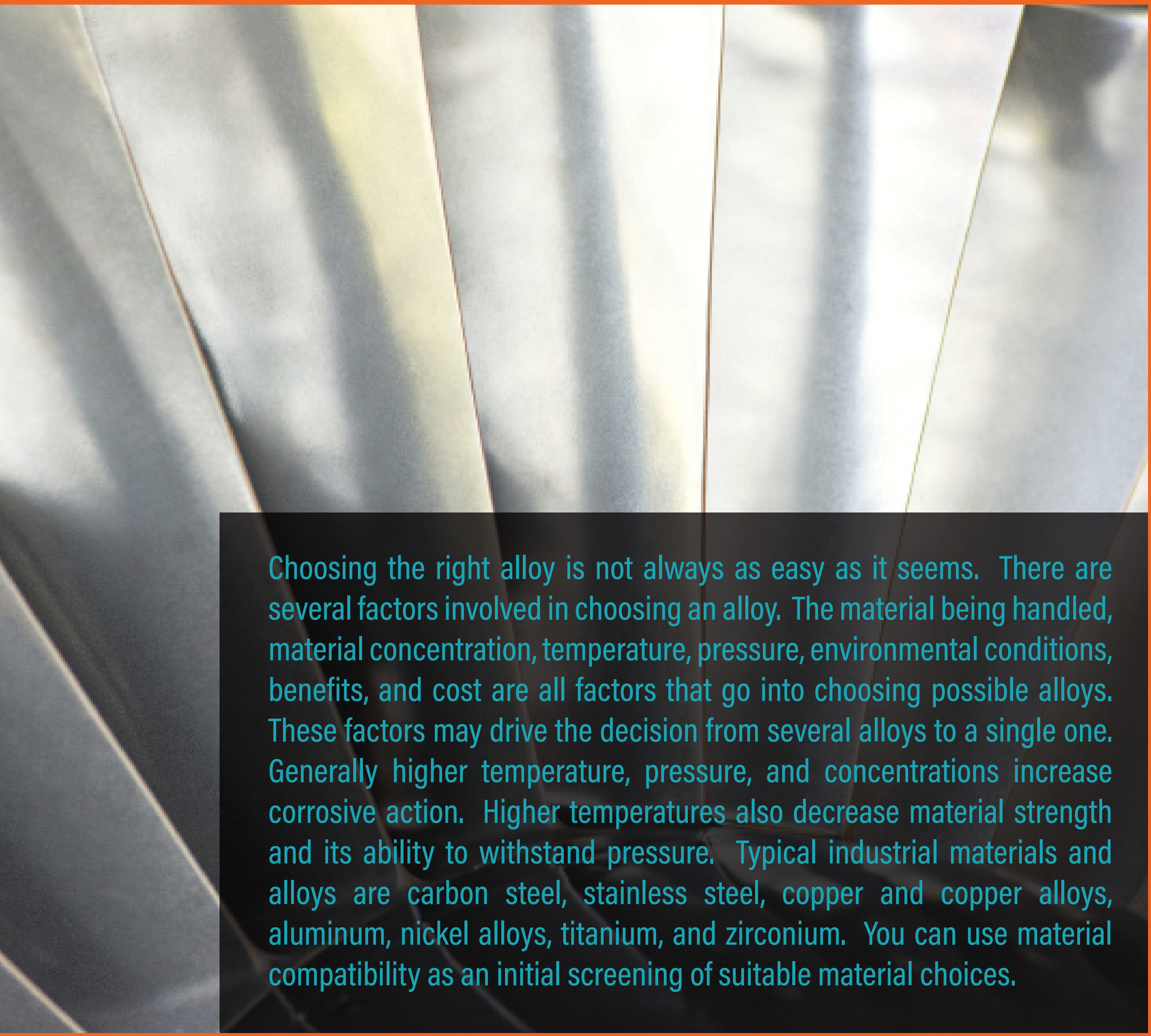
ABSTRACT



Choosing the right alloy is not always as easy as it seems. There are several factors involved in choosing an alloy. The material being handled, material concentration, temperature, pressure, environmental conditions, benefits, and cost are all factors that go into choosing possible alloys. These factors may drive the decision from several alloys to a single one. Generally higher temperature, pressure, and concentrations increase corrosive action. Higher temperatures also decrease material strength and its ability to withstand pressure. Typical industrial materials and alloys are carbon steel, stainless steel, copper and copper alloys, aluminum, nickel alloys, titanium, and zirconium. You can use material compatibility as an initial screening of suitable material choices.

CARBON STEEL

Although many alternatives have better corrosion resistance than steel, the cost aspects favor this material. In some cases, a certain level of corrosion is known to occur when this material is used along with an expected periodic replacement of equipment. This material is not resistant to dilute acids, but it can be used with many strong acids at high concentrations and anhydrous ammonia. Steel can be used for caustic soda and potash (NaOH and KOH) where contamination is not a concern, and also for dry hydrogen chloride and dry chlorine gases.

STAINLESS STEELS

There are a large variety of stainless steel alloys that have excellent corrosion resistance to many process fluids. The workhorses in process industries are 304, 304L, 316, and 347 stainless steel. These and other stainless steels contain ~18% chromium and ~8% nickel leading being called 18-8 stainless steel.

Stainless steel corrosion resistance comes from the formation of a surface oxidation layer through a passivation process using weak nitric acid. Localized corrosion can occur in process fluids that can scratch or wear the surface layer.

Stainless steel is susceptible to stress corrosion cracking when in contact with small concentrations of halides.

Stainless steel alloys also have greater strength as compared to steel for high temperature and pressure applications.

COPPER & COPPER ALLOYS

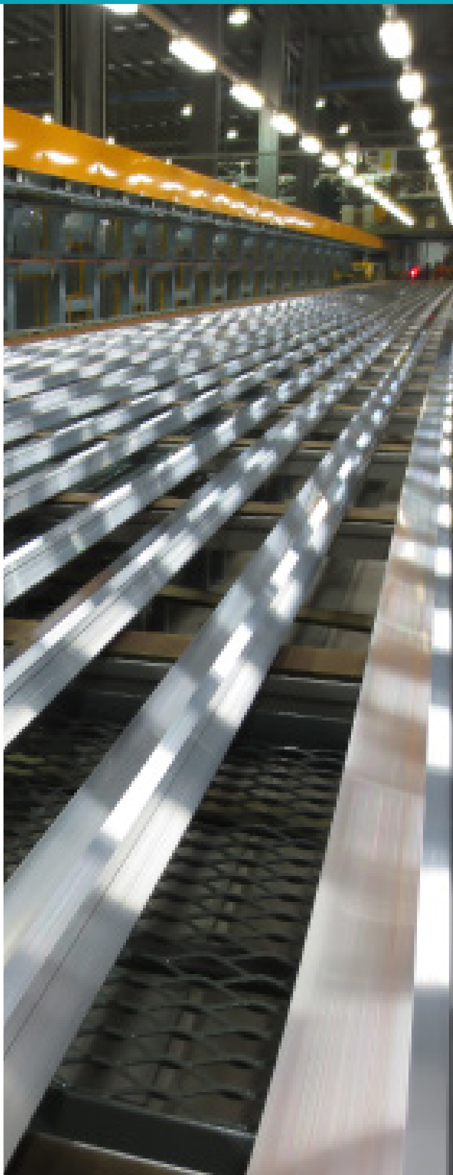
Copper can be a relatively inexpensive alternative. It has good corrosion resistance to strong alkalies (except ammonium hydroxide), room temperature sodium hydroxide and potassium hydroxide solutions, most organic solvents, and aqueous organic acids. Copper combines corrosion resistance with high electrical and thermal conductivity.

Copper alloys such as admiralty brass, brass, and bronze improve corrosion resistance and mechanical properties over pure copper. High zinc copper alloys should not be used with acids or alkalies. Most low zinc copper alloys are resistant to hot dilute alkalies.

ALUMINUM

Aluminum's light weight and ease of fabrication are the main reasons favoring its use. Aluminum is resistant to most process atmospheres, ammonium hydroxide solutions, Urea-ammonium nitrate fertilizer solutions containing excess ammonia, fatty acids, >80% nitric acid, and distilled water. Aluminum is not good for many strong acids except under certain conditions, alkalies, and chlorinated solvents.

Because of the relative higher cost for aluminum, it tends to be used in relatively few industrial process applications.



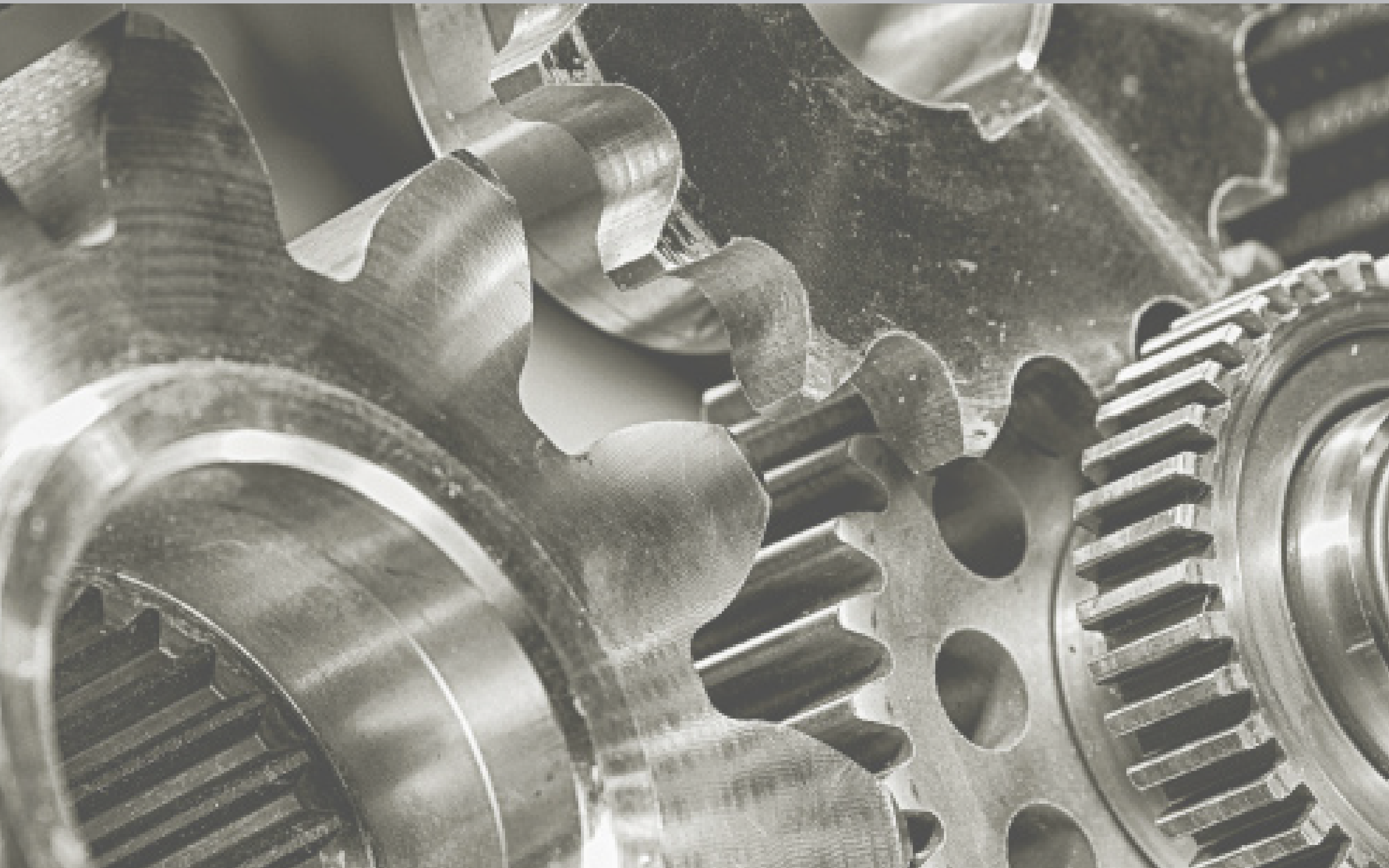
NICKEL & NICKEL ALLOYS

Nickel is resistant to many corrosive applications including caustics, and caustic solutions. It has good resistance to neutral and slightly acidic solutions as well. It is not resistant to strongly oxidizing solutions such as nitric acid and ammonia solutions.

Nickel alloys can handle other strong acids such as sulfuric, hydrofluoric, and hydrochloric acids. Nickel alloys also have greater strength as compared to steel for high temperature and pressure applications.

Hastelloy is used is used in special corrosion applications such as stress corrosion cracking in the presence of halides. Hastelloy is also used for improved corrosion resistance at higher temperatures. Hastelloy C is good for seawater applications.

Nickel and nickel alloys are widely used in process industries, but are a more expensive alternative. Because of high cost, nickel alloys are left to handle most of the more severe corrosive or higher temperature applications.



TITANIUM

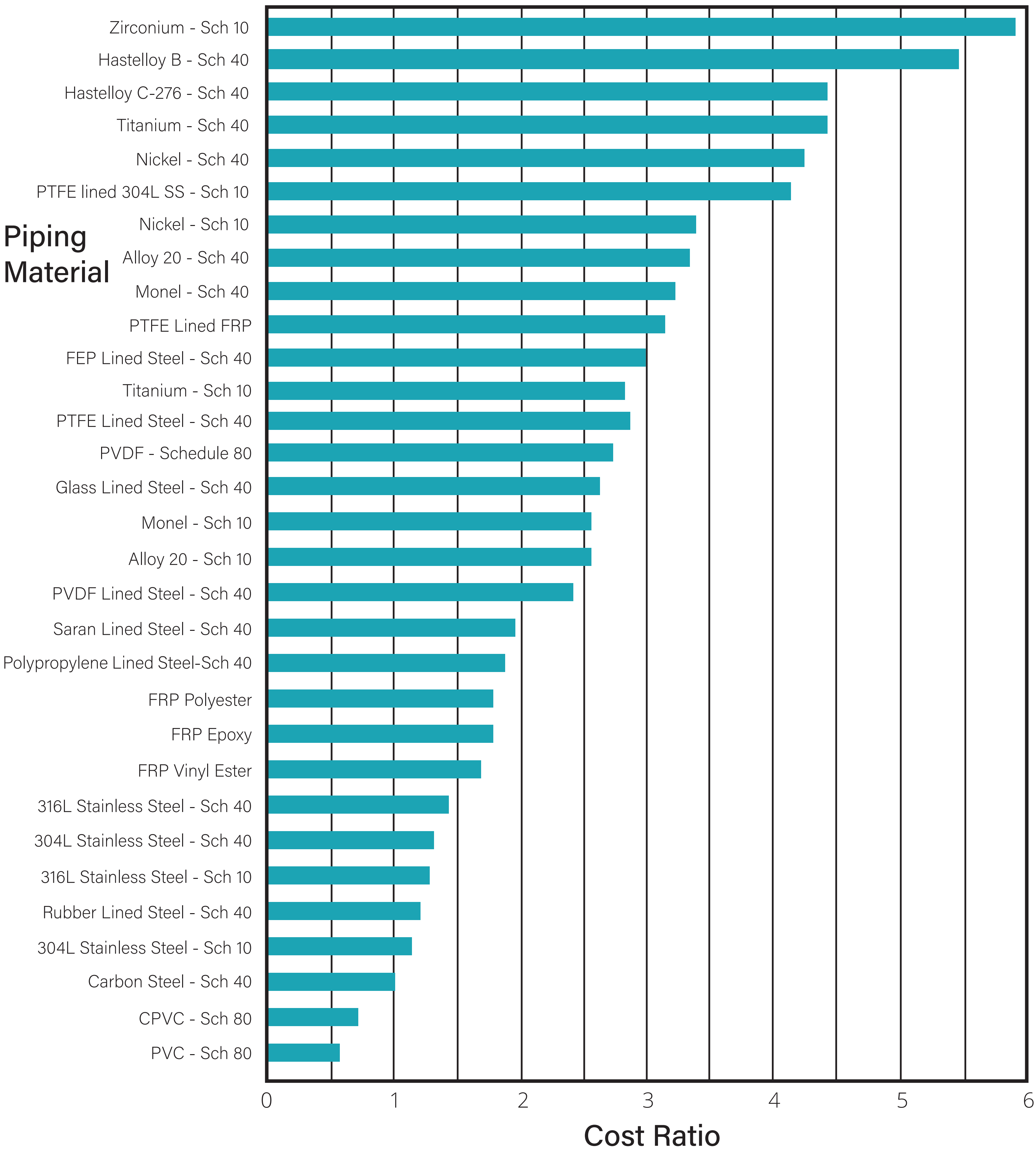
Titanium has a high melting point along with a high strength to weight ratio. It shows high resistance to chloride containing solutions (such as heavy metal chlorides, cupric chloride, and ferric chloride), seawater, hypochlorites and wet chlorine, and nitric acid. Titanium having a high relative cost, lends itself to specific applications and circumstances when less expensive materials are not suitable.

ZIRCONIUM

Zirconium use became prevalent in nuclear power applications because of its favorable neutron interactions but will work in process industries as well due to its chemical compatibility. Zirconium has good corrosion resistance to acids including nitric, hydroiodic, hydrobromic, and <70% sulfuric acids, but not good resistance to hydrofluoric and hot concentrated hydrochloric and sulfuric acids. Zirconium is also resistant to hot alkalies at all concentrations.

RELATIVE COST OF MATERIAL

The following chart shows installed cost of different piping materials relative to carbon steel.



Source: Engineering ToolBox, (2007). Piping Materials and Cost Ratios
https://www.engineeringtoolbox.com/piping-materials-cost-ratios-d_864.html

SUMMARY

Sometimes a more expensive material ends up costing less in manufactured equipment due to ease of fabrication or other factors for the manufacturer. You can use material compatibility as an initial screening of suitable material choices. Chemical resistance is often the most important characteristic when selecting a material followed by strength and mechanical properties. Periodic replacement and maintenance over the life of the equipment also become a factor. The final selection will need to be based on an economic analysis of possible materials.

THANK YOU

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