aerospace
climate control
electromechanical
filtration
fluid & gas handling
hydraulics
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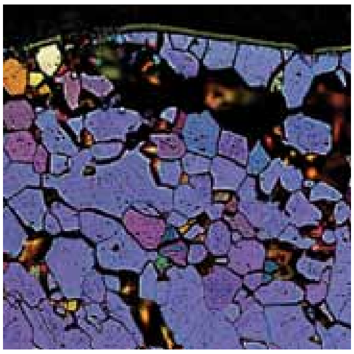
process control
sealing & shielding



Smarter Materials Selection for Corrosion Control

ENGINEERING YOUR SUCCESS.

The Problem

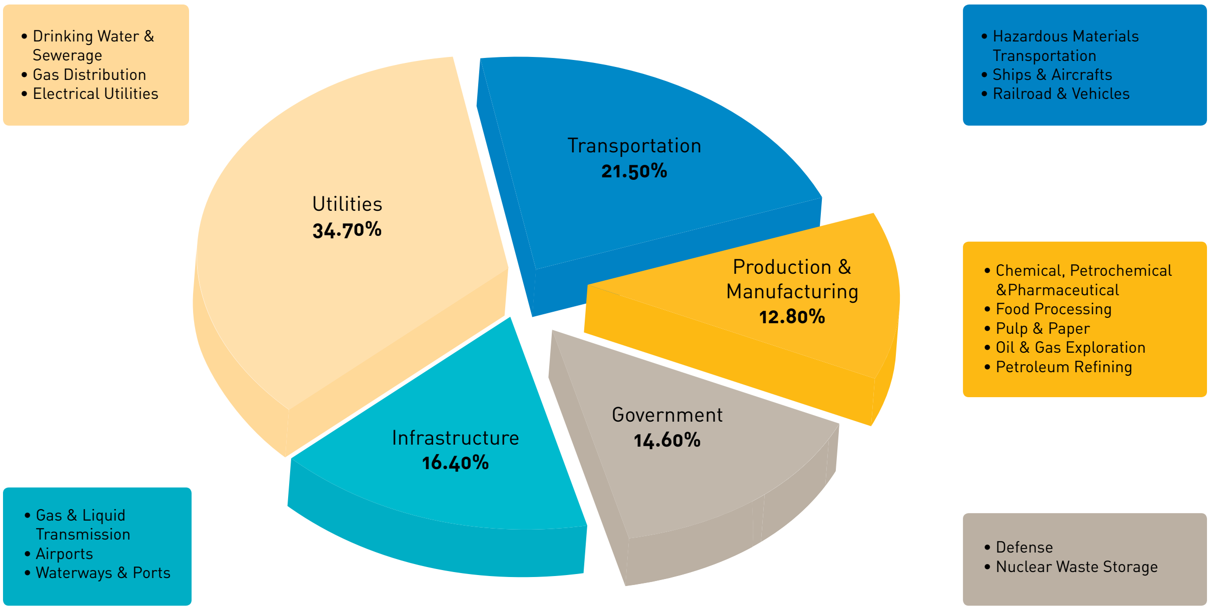
For the customers & markets that we serve, Corrosion represents the difference between trouble-free operation and costly downtime.

What is Corrosion?
According to NACE, Corrosion is the deterioration of a substance, usually a metal, or its properties because of a reaction with its environment.

The Problem of Corrosion
Direct and indirect economic losses derived from corrosion include the following:

- Replacement of damaged equipment
- Overdesign to allow for corrosion
- Preventive maintenance
- Shutdown due to corrosion failure
- Loss or contamination of the product being produced (i.e. food industry)
- Efficiency decrease. For example, corrosion products lower the heat transfer rate in heat exchangers
- Failure of adjacent equipment
- Health and safety. Loss of natural resources, pollution or even human lives.

Cost of Corrosion
According to a nationwide report conducted in the USA, the cost of corrosion accounted for a total of $276 billion per year. The specific industrial sectors and associated cost were broken down as follows:



The Problem

Using the right materials and processes can help to beat corrosion problems throughout industry.

Uniform Corrosion
Uniform or general corrosion is the most classical form of corrosion, but is not always the most important in terms of cost or safety.

The consequences of uniform corrosion are a decrease in metal thickness per unit time or a more or less uniform deposit of these corrosion products in the surface of the metal.

Uniform corrosion can be limited or prevented by an appropriate choice of material or modification of the medium among other solutions.

Galvanic Corrosion
Galvanic corrosion can be defined simply as being the effect resulting from the contact between two different materials in a conducting corrosive environment.

In many cases, galvanic corrosion may result in quick deterioration of the least corrosion resistant material, and can lead to fatal failure.

Common methods of minimising and preventing galvanic corrosion are choosing material combinations in which the constituents are all made from the same material or different materials as close as possible in the corresponding galvanic series, avoiding an unfavourable surface area ratio, using protective coatings, or controlling the aggressiveness of the environment.

↑ **LESSON:** Do not mix tube and fitting or valve alloys wherever possible.

Galvanic reaction created by mixing different body & nut materials.

The Problem

Crevice Corrosion

Crevice corrosion is an electrochemical oxidation-reduction process, which occurs within localized volumes of stagnant solution trapped in pockets, corners or beneath a shield (seal, deposit of sand, gasket or fastener, for instance).

Crevice corrosion is highly accelerated if chlorine, sulphide or bromide ions are present in the electrolyte solution. Once a crevice is initiated, even the most benign atmospheric environments can become extremely aggressive. Crevice corrosion is considered much more dangerous than uniform corrosion as the corrosion rate can be up to 100 times higher.

Crevice corrosion is encountered particularly in alloys which owe their resistance to the stability of a passive film. A classic example is stainless steel in the presence of moderate to high concentrations of chlorine ions.

Crevice corrosion can be limited or prevented by using welds rather than bolted or riveted joints, designing installations with a proper draining system and avoiding stagnant areas, using solid and high quality seals or controlling the severity of the electrolyte.

Crevice corrosion between the tube/tube trap interface.

Pitting Corrosion

Pitting is characterised by the localised attack in the form of deep and narrow holes that can penetrate inwards extremely rapidly, while the rest of the surface remains intact. A component can be perforated in a few days with no appreciable loss in weight on the structure as a whole.

Pitting corrosion is most aggressive in solutions containing chloride, bromide or hypochlorite ions. The presence of sulphides and H2S is also detrimental to this type of attack. The stainless steels are particularly sensitive to pitting corrosion in seawater environments.

Pitting corrosion can be reduced or prevented by choosing the most appropriate material for the service conditions, avoiding stagnant zones and deposits, reducing the aggressiveness of the medium or using cathodic protection.

↑ **LESSON:** Every batch of Parker 6Mo steel is tested for Pitting Corrosion as per the ASTM G48 standard.

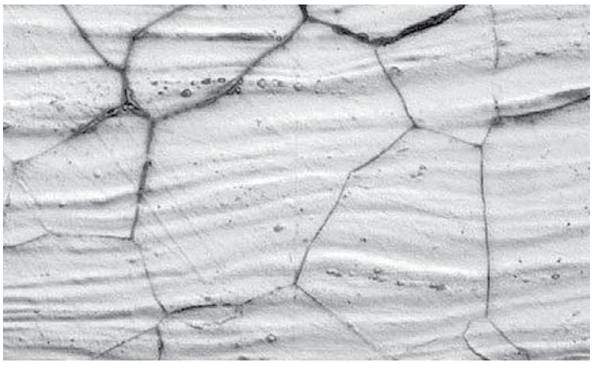
Intergranular Corrosion

Intergranular corrosion is a form of attack that progresses preferentially along the grain boundaries paths and can cause the catastrophic failure of the equipment, especially in the presence of tensile stress. Under certain conditions, the grain boundaries can undergo marked localized attack while the rest of the material remains unaffected. The alloy disintegrates and loses its mechanical properties. This type of corrosion is due either to the presence of impurities in the boundaries, or to local enrichment or depletion of one or more alloying elements.

Many alloys can suffer from intergranular attack, but the most common example is the intergranular corrosion of austenitic stainless steels, related to chromium carbide depletion in the vicinity of the boundaries, during a "sensitising" heat treatment or thermal cycle.

Intergranular corrosion can be prevented by selecting the right material, avoiding low cost equipment where the material is likely to have impurities and poor heat treatment, using low carbon or stabilised grades if welding or applying post-weld heat treatments correctly.

↑ **LESSON:** Our stainless steel is capable of passing the intergranular corrosion test as per the ASTM A262 Practice.



Intergranular Corrosion – HAZ Area – Stainless Steel Weld in Seawater Environment

Stress Corrosion Cracking Stainless Steel in Seawater Environment

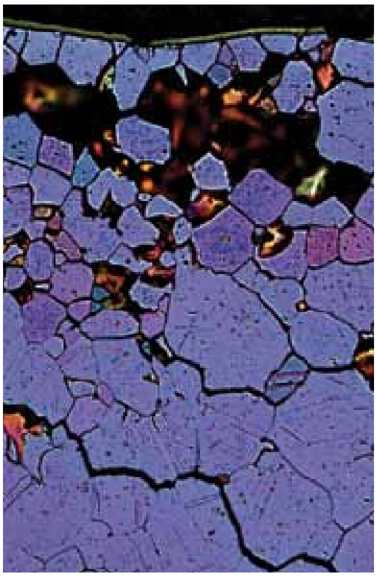
Stress Corrosion Cracking

Stress corrosion cracking (SCC) is a process involving the initiation of cracks and their propagation, possibly up to complete failure of a component, due to the combined action of tensile mechanical loading and a corrosive medium. The time necessary for a part to fail by SCC can vary from a few minutes to several years.

This kind of attack normally occurs in media that are little or non-aggressive towards the metal or alloy concerned in the absence of tensile loading.

This form of corrosion is of a paramount importance and represents a permanent risk in numerous industrial installations, in terms of both the safety and economic consequences involved. No commercial alloy is fully immune to SCC.

Stress corrosion can be avoided by selecting materials that are not susceptible in the specific corrosion environment and minimised by stress relieving or annealing after fabrication and welding, avoiding surface machining stresses and controlling the corrosive environment.



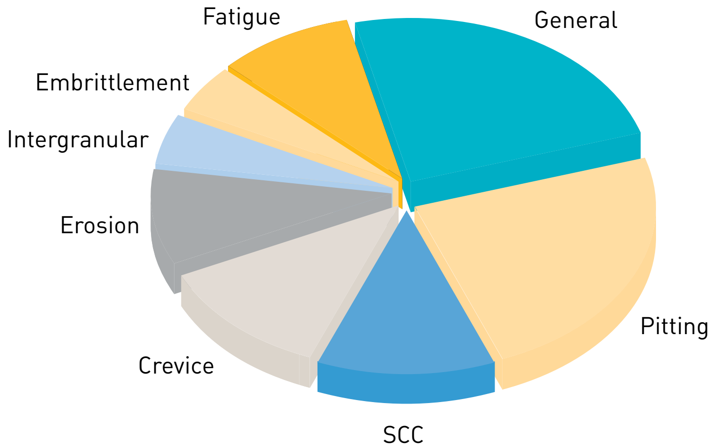
↑ **LESSON:** Do not take shortcuts. Select the best material for a safer & more cost effective application.

The Facts

Some of the most popular factors that can have a significant influence in terms of corrosion are listed below:

- **Materials Selection:**
  - Environment
  - Mechanical Properties
  - Availability of Design &
  - Test Data
  - Cost
  - Availability
  - Maintainability
  - Compatibility with other components
  - Reliability
  - Appearance
- **Process Parameters:**
  - Media Chemistry
  - Temperature
  - Velocity
  - Pressure
- **Construction Parameters:**
  - Drainage, Welding, etc.
- **Dissimilar Metals**
- **Crevices**
- **Corrosion Allowance**
- **Operating Lifetime**
- **Maintenance & Inspection Requirements**

Some Figures About Corrosion
The industrial importance of localized corrosion problems has been revealed in many reports. The following pie chart summarizes the findings of 363 corrosion failure cases investigated in a major chemical processing company. The importance of pitting comes second, just after general corrosion and before stress corrosion cracking which is often also initiated by pitting.



Sour Gas Service and NACE MR0175

Hydrogen sulphide (H2S) is a colourless, flammable, and extremely hazardous gas.
It occurs naturally in crude petroleum, natural gas, and hot springs. In addition, hydrogen sulphide is produced by bacterial breakdown of organic materials and human and animal wastes (for instance, sewage systems). Industrial activities that can produce the gas include petroleum/natural gas drilling and refining, wastewater treatment, coke ovens, tanneries, and paper mills. Hydrogen sulphide can also exist as a liquid compressed gas.

When dissolved in water, H2S forms a weak acid which is extremely corrosive, especially in the case of steel where the corrosion products of iron, sulphide and atomic hydrogen can penetrate the steel and embrittle it. Under the influence of applied stresses, cracking can develop in a very short time and result in failure of the equipment and potential human and environmental loss. This type of failure is known as sulphide stress corrosion cracking (SSCC) and there are many cases in history that account for this type of failure.

NACE MR 0175/ISO 15156 is a Materials Standard issued by the National Association of Corrosion Engineers. It aims to assess the suitability of materials for oilfield equipment where sulphide stress corrosion cracking may be a risk in hydrogen sulphide (sour) environments. This 3-part document gives requirements and recommendations for the selection and qualification of carbon and low-alloy steels, corrosion-resistant alloys, and other alloys for service in equipment used in oil and natural gas production and natural gas treatment plants in H2S-containing environments, whose failure could pose a risk to the health and safety of the public and personnel or to the environment. It can be applied to help to avoid costly corrosion damage to the equipment itself.

Parker Instrumentation can offer all the range of materials compliant to the metallurgical requirements of NACE MR0175 in selected ranges. For more information, please contact us.

The Solution

Corrosion control does not just happen. It must be planned. We can help you find the best solution for your application.

As the worldwide search for oil and gas, power generation or chemical production is turning to more challenging applications an increasing number of situations are being encountered where corrosive production environments and products are present. Many of these cases often involve significant amounts of hydrogen sulphide, carbon dioxide, brine or hazardous chemicals among others, where their high corrosivity along with the wrong decisions made during the design stage have often lead to fatal failure and invaluable human, environmental and economic loss. In most cases, these situations could have been avoided by properly analysing the specific operating parameters and designing the most suitable equipment.

In addition, other factors such high pressures and temperatures or severe environments are on demand. Requirements for higher production rates or more complex processes along with climate change and new environmental regulations can complicate the material selection process and ultimately the performance and integrity of the application. Under these circumstances materials can offer a valid and cost effective alternative to conventional methods of corrosion control.

The material selection process can sometimes become complex, usually involving multiple factors like high strength requirements, operating temperature, high corrosion resistance, availability and cost.

Our Materials Statement

Our primary philosophy is to build reliable, efficient, cost-effective equipment for the intended service. We always strive for the best quality in the designs we produce, the materials we select and manufacturing processes we apply. All our materials come from the most prestigious mills in Europe and North America, and are fully traceable to the source of origin and mercury and radioactive free. We want to add value to every component we create and make all the applications we serve **smarter, faster, cleaner** and **safer.**

Due to their versatility, reliability and excellent corrosion resistance, the set of alloys and equipment that we offer usually meet all the demands in markets, including the oil and gas, chemical and petrochemical processing, pollution control, marine engineering, power generation, or pulp and paper among others.

However, the unique requirements of some of the projects often demand special approaches. Parker Instrumentation understand those needs and has the technical knowledge and experience to help our customers to find the better solutions for their applications and meet even the most challenging demands.

Together, we can create innovative solutions that ensure your success

Materials Range for Corrosion Control

Our experienced credentials in materials selection are the results of years of expertise in successful applications worldwide.

Materials Range

Parker offers the most extensive range of alloys in the market. The range varies from conventional steels to high nickel alloys and titanium for the most demanding applications. The table below depicts the standard range of materials per product family. Other alloys might be offered on request.

	A-LOK® Fittings	Phastite® Fittings	Valves	Manifolds	Flanged Products
Brass	Yes	No	Yes	No	No
Carbon Steel	No	No	Yes	No	Yes
Stainless Steel 316/316L	Yes	Yes	Yes	Yes	Yes
Duplex Steel	No	Yes	Yes	Yes	Yes
Superduplex Steel	No	Yes	No	Yes	Yes
Super austenitic 6Mo	Yes	Yes	Yes	Yes	Yes
Monel 400	Yes	Yes	Yes	Yes	Yes
Alloy 825	Yes	Yes	Yes	Yes	Yes
Alloy 625	Yes	Yes	Yes	Yes	Yes
Alloy C-276	Yes	Yes	Yes	Yes	Yes
Titanium	Yes	No	Yes	Yes	Yes

Parameters To Be Considered in the Materials Selection Process

The main parameters to be considered when selecting any equipment are:

- Operating conditions, including temperature, pressure and media contained
- Environment
- Legislation and Internal Regulations
- Cost
- Availability
- Lead time
- Expected life time of the equipment
- Safety

In terms of materials, the selection criteria normally translate into some of the following parameters:

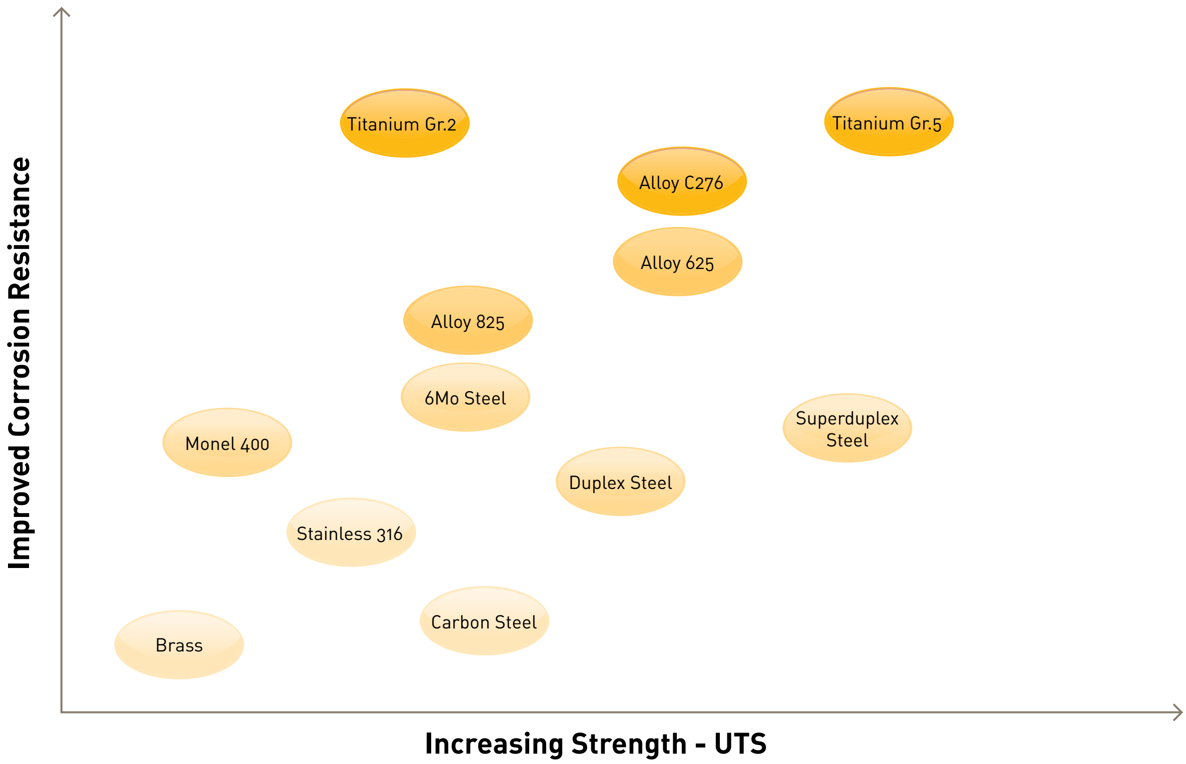
- Mechanical properties
- Corrosion resistance to media and environment
- Temperature operating range
- Cost
- Availability on request

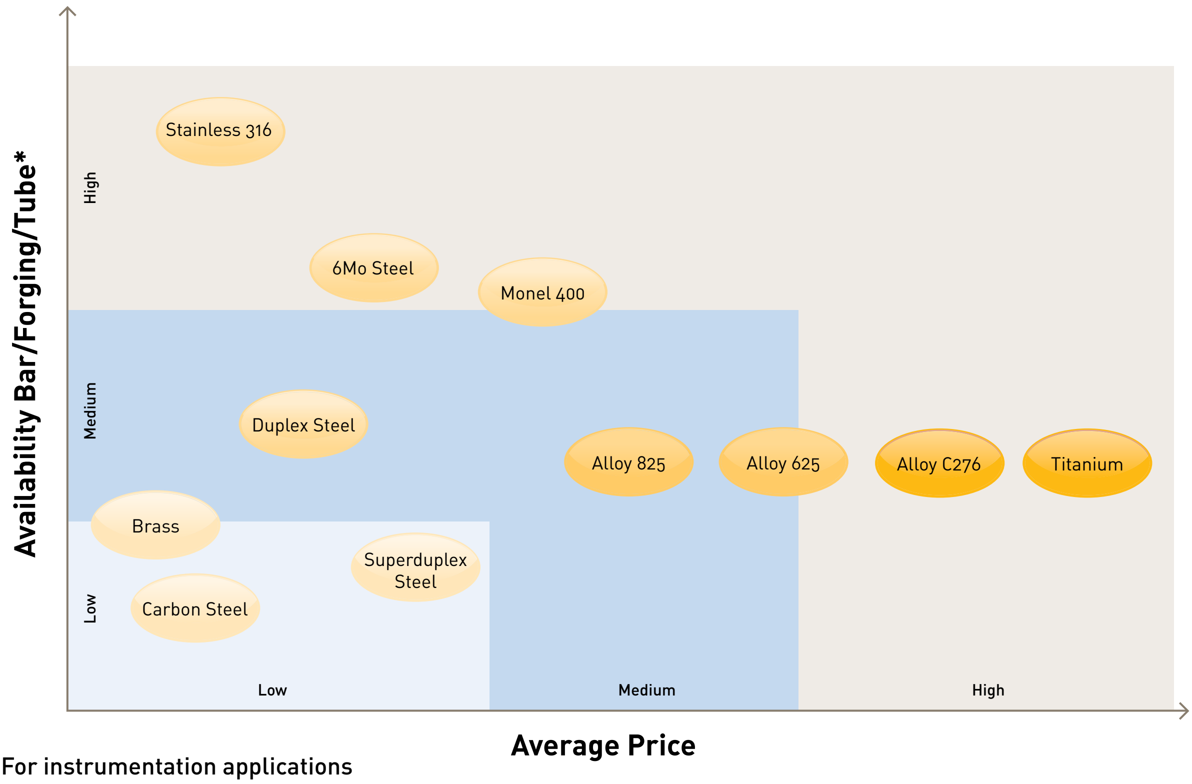
Although the mechanism of corrosion is highly complex the actual control of the majority of corrosion reactions can be effected by the application of relatively simple concepts. Indeed, the Committee on Corrosion and Protection concluded that 'better dissemination of existing knowledge' was the most important single factor that would be fundamental in decreasing the enormous cost of corrosion in the UK.*

* Report of the Committee on Corrosion and Protection, Department of Trade and Industry, H.M.S.O. (1971)

Materials Quick Selection Guide for General Industrial Applications

The following table classifies our materials range in terms of mechanical strength and general corrosion resistance, and aims to be a generic tool and guidance at an early stage of the design. The values given to the specific parameters are not absolute and should be used as a reference only. Each application needs to be evaluated carefully and individually as the rules below might not apply at all times.





* For instrumentation applications

Cost Considerations

Think of the equipment replacement cost, depreciation, re-qualification of the new systems, downtime or low production rates, fines or human and environmental loss. Avoid low cost equipment. Investing in a more expensive material today could be a cheaper and trouble-free solution in the medium and long term.

Parker Hannifin carried out Stress Corrosion Cracking Testing as per ASTM G48 conducted by an independent party and its aim was to determine the time to failure of the 6Mo super austenitic steel (UNS S31254) and the conventional 316/L stainless steel (UNS S31600/03) in exactly the same conditions. Results showed that the 6Mo grade took over 3 times more to fail than the 316 grade.

In service applications, those results translate into a life expectancy of 6Mo three times longer than that of 316 in the same given conditions, **reducing leakage and downtime and increasing safety by over 60%.**

Example of a typical installation and associated life cycle cost:

		Materials Selection A: Stainless Steel 316	Materials Selection B: Superaustenitic 6Mo
After 10 Years	8,000 meters of 1/2" x 0.065" tubing	$7/m	$23/m
	1,500 Fittings 1/2" x straight shapes	$15/unit	$40/unit
	Design Parameter	5 Years Life	15 Years Life
Initial Installation	Tubing & Fitting Replacement**	Tube: $7/m Fitting: $15/unit	$0
	MHR Labour Cost	40 MHR per 300 meters	$0
		$80 labour/hour	$0
After 5 Years	Tubing & Fitting Replacement**	Tube: $7/ft Fitting: $15/unit	$0
	MHR Labour Cost	40 MHR per 300 meters	$0
		$80 labour/hour	$0
TOTAL		$406,380	$244,000

** Figures exclude material cost increase

40% cheaper

Some of Our Experience

Here are some basic guidelines based on our extensive knowledge and experience in applications worldwide:

- Think about cost effectiveness, safety and reliability
- A cheap option today usually translates into high cost of ownership tomorrow
- Do not mix tube and fitting/ valve alloys whenever possible
- Use 6Mo for high pitting/ crevice corrosion performance
- Use Super Duplex for its tensile strength
- Do not use Twin Ferrule on Super Duplex rather use Phastite
- Use our range of exotic materials for demanding applications and NACE compliance

Let us help you select the best solution for your application. Start thinking **smarter, faster, cleaner** and **safer.**

For a successful and prolonged corrosion-free service, make sure the following parameters are checked during the design stage:

- ☐ Operating conditions, including temperature, pressure and media contained
- ☐ Environment
- ☐ Legislation and Internal Regulations
- ☐ Cost
- ☐ Availability
- ☐ Lead time
- ☐ Expected life time of the equipment
- ☐ Safety

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