Corrosion Control Basics

SSPC
The Society For Protective Coatings

The key to a profitable service life for critical metal assets depends on protecting them from corrosion.

Corrosion is so common a concern that it can sometimes fall on deaf ears.

But hear this: A NACE study released in 2016 estimated that corrosion costs the world $2.5 trillion a year. The study estimated that as much as $875 billion a year could be saved if existing corrosion control measures were implemented.

Clearly, the key to a profitable service life for critical metal assets depends on protecting them from corrosion. That begins with a deeper understanding of the many forms it takes and the ways it can be controlled or prevented.

What is Corrosion?

Corrosion is a loss of mass caused by a metal's natural reaction to the atmosphere around it. That loss of mass makes metal assets or structures less able to handle the stresses they were designed to sustain. Left unchecked, corroded assets are bound to fail.

The metals common in industrial applications today are highly processed so they can support structures or carry loads. But those processes work against nature.

For example, steel is widely used across industries around the world. But the iron in steel always wants to return to its most natural and stable state—iron atoms bonded to oxygen in the form of iron ore. It gets there via corrosion.

Four components must be in place for corrosion to occur:

- **Anode –** Metal parts with positive charges are anodes. They attract electrons or anions and are electron acceptors in an electrochemical reaction.
- **Cathode –** Metal parts with negative charges are cathodes. They attract cations or positive charges and act as electron donors in an electrochemical relationship. (Learn more about anodes and cathodes **here**.)
- **Metallic path –** The route that electrons take from anodes to cathodes during electrochemical reactions is the metallic path. That route is inherent in metal parts but is interrupted if anodes and cathodes are separated by insulating materials like plastic or rubber.
- **Electrolyte –** Electrolytes are liquids containing charged particles (ions). All salts form charged particles when dissolved in water, which is why ocean water poses such a serious threat to metal assets at or near sea.

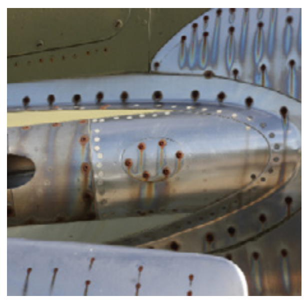
Corrosion will not occur unless all four components are present.

Types of Corrosion

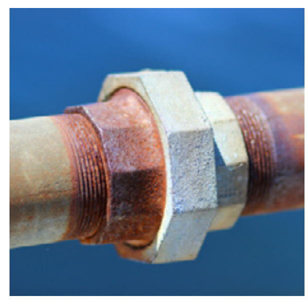
Many forms of corrosion exist. The way an asset corrodes depends on how it was designed, how its parts were treated after manufacturing, whether protective coatings were applied, what wear and tear occurs during the asset's service and the ambient environment in which it is used or stored.

Uniform Corrosion

Pitting Corrosion

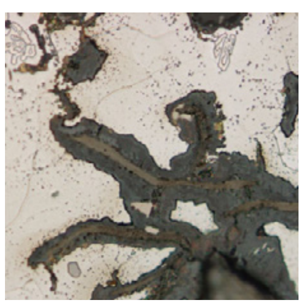


Dissimilar Metal Corrosion



Crevice Corrosion

Stray Current Corrosion



Dealloying*

Erosion Corrosion

Exfoliation

* Picture courtesy of Eisenbeisser, https://commons.wikimedia.org/wiki/File:Spongiose500.jpg#file

Uniform Corrosion

Uniform corrosion occurs when whole surfaces are attacked at about the same rate. Uniform corrosion is simple in that it's the natural result when metal surfaces are exposed in atmospheres like water, soil or air. It's also easy to spot because it attacks whole surfaces. Other forms of corrosion are more localized and have more complex causes.

Pitting Corrosion

Pitting corrosion gets its name from the small cavities —or pits— that form on a metal surface during an attack. The pits can form in a variety of ways, including:

Following any impact on a surface that damages the protective oxide film that naturally forms after it's manufactured.

When metal surfaces aren't properly cleaned before protective coatings are applied. Protective coatings designed for metal substrates may not adhere to areas where foreign objects are present. Corrosion is likely to follow in the area where a protective coating has failed. If appropriate protective coatings are not applied as specified, or if protective coatings not designed for use on metal substrates are applied to metal. Pitting corrosion is more dangerous than it plainly appears because the attacks bore inward from the surface. The extent of the damage it can cause goes largely unseen

Dissimilar Metal Corrosion

When metals of differing electrical potentials are joined in a corrosive environment, the more unstable metal (one with more electrical potential) in a reaction becomes the anode and the more stable metal (one with less electrical potential) becomes the cathode.

The galvanic series lists metals in order of their stability.

Galvanic Series:

Most Energy to Convert Anodic (Less Stable)

- Zinc
- Aluminum
- Cast Iron
- Carbon Steel
- Stainless Steel, Type 430, active
- Stainless Steel, Type 304, active
- Stainless Steel, Type 410, active
- Copper
- Brass
- Bronze
- Stainless Steel, Type 430, passive
- Nickel
- Stainless Steel, Type 410, passive
- Silver
- Titanium
- Stainless Steel, Type 304, passive
- Stainless Steel, Type 316, passive
- Zirconium
- Platonium
- Gold

Least Energy to Convert Cathodic (More Stable)

The rate of corrosion in these reactions is related to how far apart given metals are in the galvanic series. For example, nickel and bronze are relatively close to one another on the series. Dissimilar metal corrosion involving those metals would progress more slowly than if the metals at issue were platinum and carbon steel, which are far apart on the series.

Crevice Corrosion

Crevice corrosion occurs when moisture is trapped in crevices, angles or gaps in a part or structure. These areas support a more stagnant environment compared to areas where air and water can move freely—a recipe for corrosion problems.

Crevice corrosion most commonly noticed under bolt heads, at back-to-back angles or when there are skips in welding. It’s easy for moisture to seep into these spaces but hard to root it out. The resulting stagnation features lower pH and oxygen concentrations, conditions that promote speedier corrosion than would normally occur.

Stray Current Corrosion

Buried parts of metal structures can corrode in close proximity to electric railway or crane systems, when they're placed near grounded welding generators or when they're placed near cathodic protection systems. Measuring differences in voltage at different areas of a metal structure can verify whether stray current corrosion is ongoing.

It can be prevented by reducing currents flowing through nearby systems, modifying currents via electrical bonding or establishing counterbalancing cathodic protection on the affected structure.

Dealloying

Dealloying occurs over time as part of a metal asset's natural effort to return to its most stable state. As alloying elements leach out of parts, they lose mass and the critical added strength the alloying elements were designed to achieve

Erosion Corrosion

When abrasive materials impact a part or structure, they can slowly wear away protective coatings or a metal surface's protective oxide layer. This sets the stage for corrosion to occur. Examples include silt or slurry traveling through metal piping or wind- or water-borne sediments impacting a structure.

Exfoliation

Rolled metal products, and particularly rolled aluminum alloy plates, are at risk of exfoliation, which is described as an advanced form of intergranular corrosion where metal delaminates along grain boundaries.

Corrosion Control Measures

Just as there are numerous modes of corrosion, there are many ways to combat it. Asset owners should note that some control measures make more sense than others in given applications. In weighing the economic and practical impacts presented by the alternatives, owners usually end up developing a program made up of a combination of available corrosion control measures.

Protective Coatings

Protective coatings are widely used and considered an extremely effective corrosion control measure when they're applied appropriately. And it's not merely paint, as any continuous film forming a barrier between metal and the environment is considered a protective coating that slows the electrochemical reactions responsible for corrosion.

Liquid-applied coatings that dry to form solid films over metal surfaces are a popular choice. Often, these coatings feature chemical additives that inhibit corrosion or contain zinc (an unstable metal) to offer galvanic protection.

Another protective coating comes in the form of anodic or cathodic metal films added to parts via galvanizing, electroplating or thermal spraying.

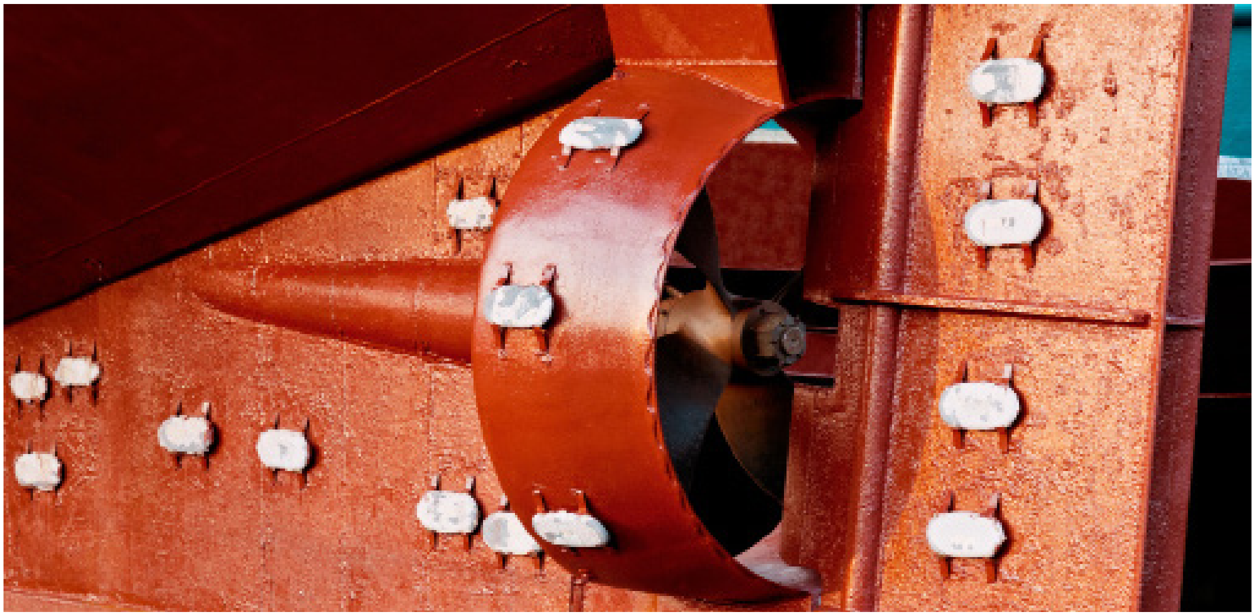
Design

Design considerations should include the way a part or structure is shaped as well as the metals used to make it. In terms of shape, assets resist corrosion much better when they do not include cavities or crevices that trap moisture. Eliminating those design features reduces the chance that the asset will support stagnant, corrosive environments. As an added bonus, it's easier to apply protective coatings to these structures or parts.

In terms of a metal asset's makeup, high-alloy steel is naturally more resistant to corrosion than low-alloy steel. High-alloy steel assets should still have protective coatings applied, but choosing a more corrosion-resistant steel could extend the lifespan of an asset even if its protective coating fails. The trade-off is that low-alloy steel is cheaper to buy and easier to machine while high-alloy steel is more expensive and harder to manipulate.

Cathodic Protection

Asset owners can also use the principles described in the section on dissimilar metal corrosion to their advantage. Commonly seen on marine structures but used across industrial applications, **sacrificial anodes** can be attached to parts of structures where corrosion is likely to occur. These unstable metal parts are attached with the intent that they will corrode, offering protection to the more stable —and more structurally important— portion of a structure.



Sacrificial anodes can be attached to parts of structures where corrosion is likely to occur.

Environment

The environment in which an asset or structure operates or is stored is a leading factor in whether —or how quickly— it will corrode. Some assets, such as maritime structures or anything that sits outdoors, will always be at risk of corrosion. Protecting assets exposed to harsh environments comes down to understanding how its design impacts corrosion risk and being diligent about regular re-coats and coating inspections.

In cases where assets or structures can be shielded from corrosive environments, it's wise to make every effort to do so. Store assets inside buildings or under shelters when they're not in use, and make sure they're thoroughly dried if they've gotten wet during use. If it's feasible, control the climate inside storage areas by using dehumidifiers. Reducing atmospheric moisture greatly reduces corrosion risk.

Well-rounded Corrosion Control

The best corrosion control programs include as many of the above measures as possible. A combination of the methods described above give an asset the best chance at a long service life with limited risk of corrosion.

In addition, it's critical that any protective coatings are applied and inspected by licensed technicians and inspectors.

SSPC's publication **Corrosion and Coatings** contains additional information about forms and mechanisms of corrosion as well as its control and prevention via coating systems. We also offer an in-depth look at the chemistry and composition of protective coatings **here**.

If you have more questions about corrosion, protective coatings, coating application or inspection, please **contact us**. We'll help direct you to the coating expert or publication that best answers your questions. You can also take advantage of discounted publications and training programs by **becoming an SSPC member**.

Phone: 412.281.2331
Toll-free: 877.281.7772

800 Trumbull Drive
Pittsburgh, PA
15205, USA