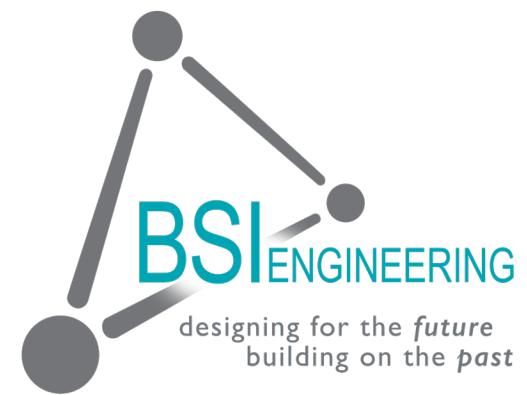


Corrosion

An Ounce of Prevention



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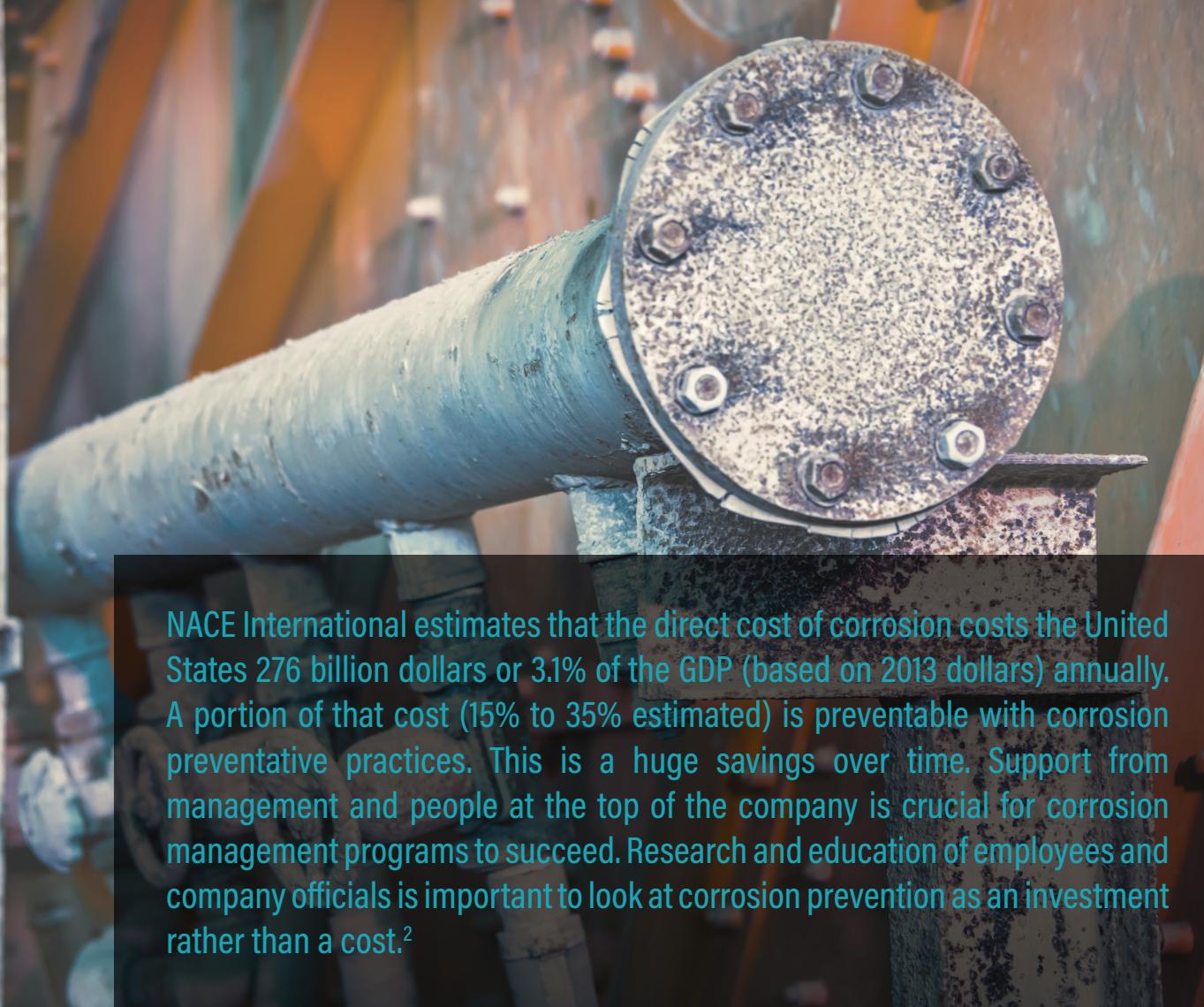
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ABSTRACT



NACE International estimates that the direct cost of corrosion costs the United States 276 billion dollars or 3.1% of the GDP (based on 2013 dollars) annually. A portion of that cost (15% to 35% estimated) is preventable with corrosion preventative practices. This is a huge savings over time. Support from management and people at the top of the company is crucial for corrosion management programs to succeed. Research and education of employees and company officials is important to look at corrosion prevention as an investment rather than a cost.²

Corrosion is a natural process that can cause substantial costs to industry and endanger the safety of people. Corrosion can be seen in many common areas of industry. Corrosion is a risk for storage tanks, outdoor equipment, heat exchangers, piping, handrails and stairs, reactors, pumps, and structural supports.

To make metal that can be manufactured and used, raw metal ore undergoes reduction. When corrosion occurs, the metal experiences oxidation which removes the electrons that were gained in reduction.

This puts the metal in a state that is more chemically stable.³

In industrial plants, corrosion can be potentially dangerous problem if it occurs on equipment that sees hazardous materials. Down time to repair corrosion damaged equipment is costly, especially if it was not planned. Corrosion mitigation and prevention is important to protect vulnerable equipment from being damaged, minimize unplanned shutdowns and releases, and protect human lives.¹

CORROSION

Corrosion is the gradual destruction of a material, usually a metal, into a more chemically stable form. When metal ore is turned into a usable metal a reduction reaction occurs which requires energy input to the metal. The metal is at a heightened energy state that is chemically unfavorable. When corrosion or oxidation occurs, energy is released which brings the energy level of the metal back to a chemically stable level. Corrosion happens because it is chemically favorable.^{(1) (3)}

To accurately evaluate corrosion, both the material and the environment need to be defined. This is crucial to determine the best corrosion resistant technologies for the application. There are two general categories that corrosion falls in to, uniform and localized corrosion. Uniform corrosion is when corrosion is spread across the material evenly. Localized corrosion is when it is restricted to one area. There are additional subcategories within localized corrosion that will be discussed in the next section.⁽¹⁾



EIGHT COMMON TYPES OF CORROSION

UNIFORM CORROSION

Uniform corrosion takes place at the surface of a metal usually across the entirety of it or a large section. The corrosion attack is even across the surface. The metal over time becomes thinner and will eventually fail. This type of corrosion is easy to monitor the integrity of the equipment. This is the most common type of corrosion and can be prevented by using the proper material of construction, using inhibitors, or cathodic protection.^{(4), (8)}



PITTING CORROSION

Pitting is a type of localized corrosion that can be hard to detect and predict. A small anodic or cathodic cell develops on the material and develops a hole, usually downwards, into the material. There are different types of pitting corrosion as seen below. This type of corrosion is especially dangerous because the signs of pitting can be hidden, and a small amount of metal loss can cause catastrophic failure. This type of corrosion may be prevented by using a material that when tested shows resistance to pitting corrosion.^{(4), (8)}

TYPES OF PITTING CORROSION:

TRough PITS

Narrow, deep



Shallow, wide



Elliptical



Vertical grain attack



SIDEWAY PITS

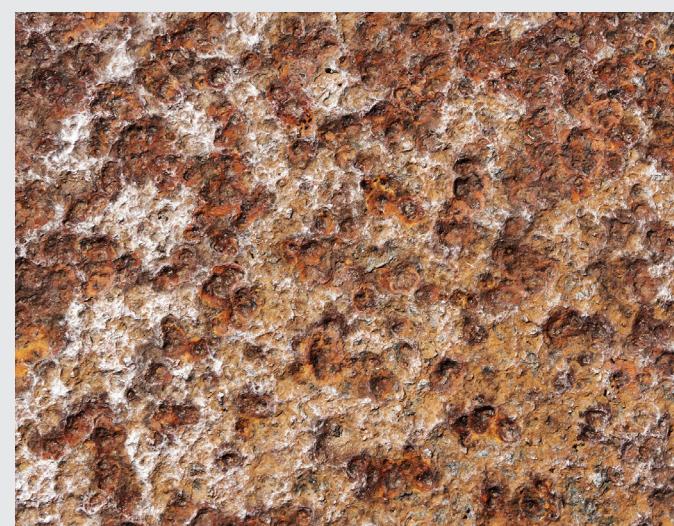
Subsurface



Undercutting



Horizontal grain attack



CREVICE CORROSION

Occurs in a gap or crevice. This is a localized corrosion attack usually at or close to the adjacent surfaces. This is caused by a concentration differential that sets up an electrochemical concentration cell. Once the crevice has been formed the method is the same as pitting corrosion. This type of corrosion can be developed under insulation, gaskets, washers, lap joints, clamps, and fastener heads. The main reason for crevice corrosion is oxygen depletion in the moisture films which causes an oxygen differential cell. The concentration of dissolved oxygen in the crevice is lower than on the main surface. The moisture film with lower oxygen concentration creates an anode and the moisture film exposed to air is the cathode, this cell results in corrosion. Measures of prevention include, using welded butt joints instead of riveted or bolted joints, using nonabsorbent gaskets made of Teflon, cathodic protection, and using higher alloys that resist crevice corrosion. ^{(6), (15)}

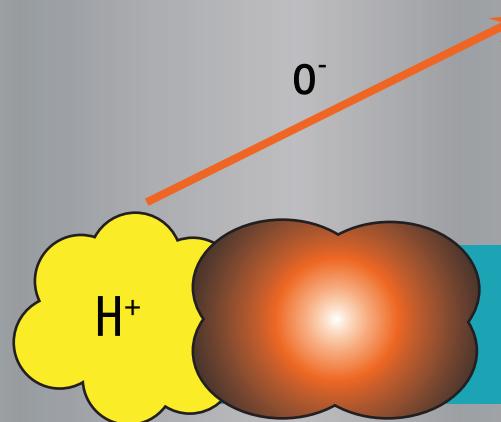


Metal

Crevice

Water →

Metal



Corrosion of this type occurs along the grain boundaries of the metal. Grain boundaries can have a higher percentage of impurities and have enrichment or depletion of certain elements, which can lead to intergranular corrosion. Stainless steel under high temperatures can cause carbide precipitation. This sensitizes the stainless steel and makes it susceptible to corrosion within the grain boundaries. With higher carbon concentrations (0.02% or higher) the chromium precipitates out of solid solution as a carbide precipitate. The carbide precipitate is not attacked, but the surrounding chromium deficient areas are consumed causing intergranular corrosion. At least 10% chromium is needed to make stainless steel. When the depleted chromium areas are below the 10%, due to the carbide precipitation, poor corrosion resistance of regular carbon steel is present.

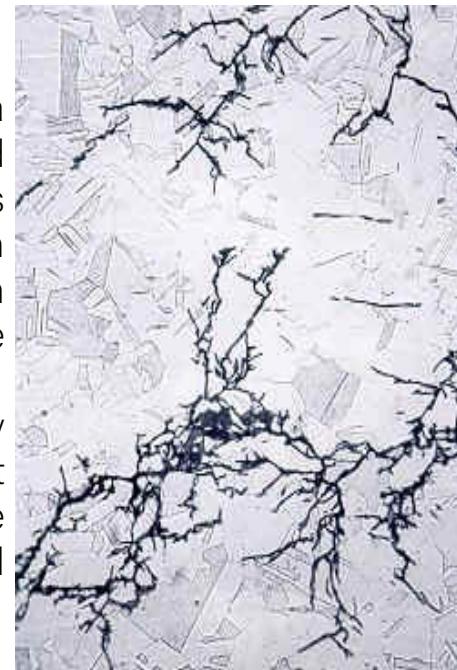
The carbides form a protective layer around the grains that leaves the grains unaffected by the corrosion occurring within the grain boundaries. Intergranular corrosion can weaken the grains to the point where they fall out.

Austenitic stainless steels are particularly susceptible to intergranular corrosion due to higher concentrations of carbon (0.06% to 0.08%). This excess carbon at elevated temperatures provides the chromium extra carbon to precipitate out with. When welding or hot work is done on equipment of this material, intergranular corrosion is possible. This concern is reduced by using "L" grade (e.g. 326L) with lower carbon content when components are welded.^{(6), (7), (8)}

STRESS CORROSION CRACKING

Stress and a corrosive environment are simultaneously present for a stress corrosion cracking (SCC) classification. Both intergranular and transgranular corrosion are observed. A common example of SCC is austenitic stainless steel in the presence of chlorides, tensile stress, high temperature, and oxygen. This is an intergranular attack when chromium carbide precipitates leave anodic metal areas open to corrosion in the grain boundaries.⁹

SCC is not easily detected, and catastrophic failure can occur with very little metal depletion. Prevention methods include using the correct material of construction, reduction of stresses, removal of corrosive environmental species, a corrosion resistant coating, or avoid dead space where chlorides and hydroxide may become concentrated.^{(8), (9)}



GALVANIC CORROSION

This type of corrosion is due to two dissimilar metals when they are subject to a corrosive environment. There is an electrical potential difference between the two metals. When they are connected, they induce an electron flow between themselves. One metal is more corrosion resistant than the other. The least corrosion resistant metal becomes the anode and corrosion attack is increased, while the more corrosion resistant metal is the cathode and corrosion attack decreases. Some prevention methods for this type of corrosion are by choosing metals that are similar in potential to each other, insulate the two metals, avoid the effect of areas with small anodes and a large cathode, make anodes readily replaceable and/or thicker.^{(8), (10)}

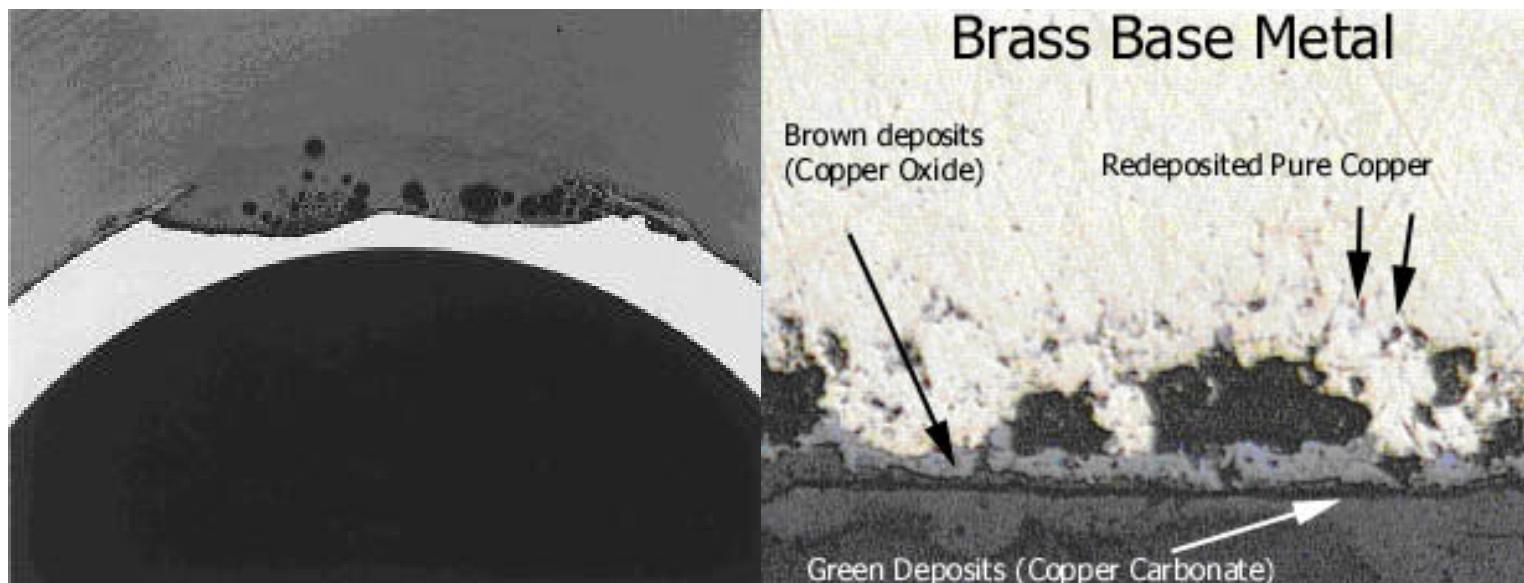


EROSION CORROSION

Erosion corrosion is because of the movement of a corrosive fluid and a metal surface. The protective layer of a metal is stripped with mechanical fluid movement. Protective layer such as passivation treats the top of the metal to reduce the chemical reactivity at the surface. Once the protective layer is removed the exposed metal is easily corroded. This can happen in a short amount of time and can cause sudden unexpected failure. Usually, the failure comes as a surprise because corrosion tests were done in static conditions where erosion was not considered. Corrosive fluids that cause erosion can be liquid, slurries, or gas. The effect of erosion corrosion may be small until a critical velocity is present. To help prevent erosion corrosion, materials with erosion resistance qualities should be used, consider the design of the system, reduce the corrosiveness of the environment, adding coatings (e.g. passivating or re-passivating), and cathodic protection.^{(8), (11), (14)}

SELECTIVE LEACHING / DEALLOYING

This type of corrosion is the preferential extraction of one element from an alloy. A common example is the removal of zinc from brass alloys, called dezincification. The commonly accepted mechanism is that the brass dissolves with the zinc and copper replates out of the solid solution, which leaves a weakened copper structure behind. There can be uniform or localized dezincification. Another common type is graphitic corrosion of cast iron. The iron is dissolved and leaves behind a porous graphite network. This can be hard to detect because the cast iron retains its shape and appearance, however, structurally the cast iron is much weaker. A knife can be used to test the area to see if there is any crumbling. A way to prevent this type of corrosion is to minimize the aggressiveness of the environment.^{(8), (13)}



SUMMARY

In conclusion, there are eight main types of corrosion. From uniform noticeable corrosion to localized hard to detect corrosion. All these types have the possibility to cause unexpected catastrophic failure. Corrosion is a natural process and, in some cases, unavoidable. However, being aware of the types of corrosion that may be present in a process and the ways to prevent and identify these types of corrosion can improve personnel safety and the reliability of the process.

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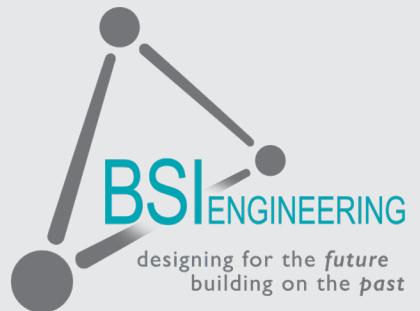
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