Corrosion and corrosion protection for flange connections in pipelines

In addition to choosing the right materials, protective products like insulating sets will help to reduce corrosion. Important is that the gaskets and washers will not break or absorb any water. Corrosion can also be avoided by correct installation.

By Dick Pronk

We see the consequences of corrosion in our environment daily. Brown, rusted metal parts that have not been treated well or well enough. It is even worse particularly in areas with wet or at least high humidity.
Corrosion is defined as the unwanted degradation of a material due to a chemical or electrochemical reaction with components from the environment. It immediately follows from the definition that corrosion control is aimed at prevention or at least limiting the attack as much as possible. All measures taken to combat corrosion, or its consequences entail additional costs.
A lot of money is spent to prevent corrosion. But also, significant resources are spent to repair or slow down corrosion. These are direct costs but many of the costs are indirect. Think of overdesign of metal thickness or a result of cessation of production or reduction of capacity due to repair caused by corrosion.
Finally, an important aspect is the loss of raw materials and energy due to corrosion. Good corrosion control contributes to the more effective use of the available natural sources.

Redox reaction

Zooming in on the corrosion process, it is the deterioration of a substance (usually a metal) and/or its properties because of a reaction with the environment. The cause of corrosion is an imbalance of energy that equalizes during the corrosion process. This 'balancing' process is called an electrochemical reaction. Several types of corrosion can occur, in which different (electro)chemical reactions play a role.
The most important corrosion reaction is where oxygen from the atmosphere, in combination with water or moisture, reacts with iron or other metal resulting in an oxidized state (Figure 1). This electrochemical reaction is called a Redox reaction, combining oxidation together with a reduction reaction. Both reactions are essential

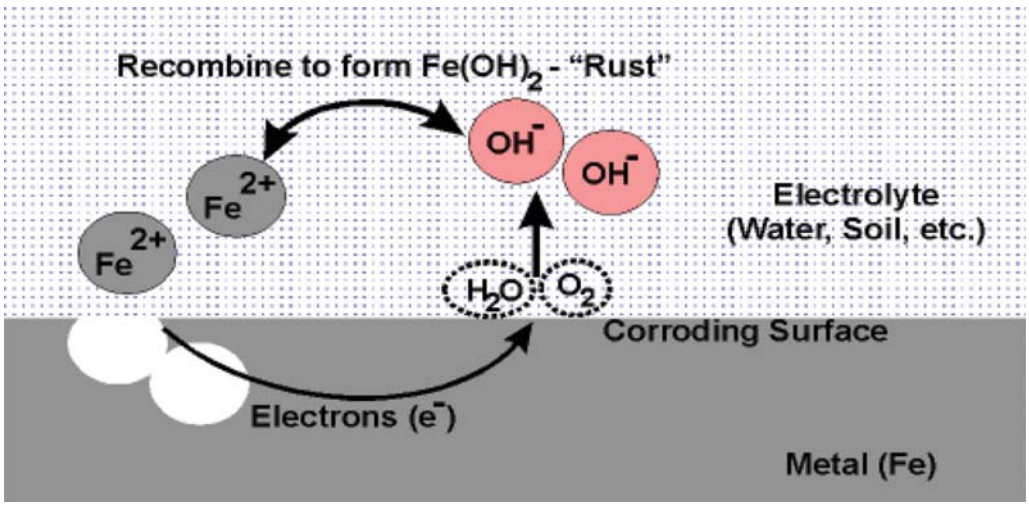

Fig. 1: Corrosion process.

About the author

Dick Pronk is the Region Product Manager Flange Gaskets Europe for Eriks and ESA Flange Gaskets Division member. He is a mechanical engineer with over 35 years' experience in flange gaskets.

for corrosion to occur. The transformation of an element into positive ions with the withdrawal of electrons is called oxidation. Oxidation occurs when electrons are 'lost' as a result of a chemical reaction. The positive Ions pass from Anode into solution. The electrons can remain in the metal and move freely within the metal. It occurs at the ANODE.

Reduction

The reverse process is reduction and occurs when electrons are 'gained'. Reduction is the absorption of electrons because of a chemical reaction. Negative ions pass from cathode into solution. This occurs at the CATHODE.

The environment is one major factor which influences corrosion resistance. A metal may be corrosion resistant in some environments but not others. Factors which affect the speed of corrosion include temperature, oxygen - and chloride concentration and pH-value. But also, conductivity of the electrolyte, distance between parts (anode, cathode) and relative size of anode versus cathode.

In salt water, all corrosion processes are accelerated although oxygen remains the oxidizer. However, because of the presence of the sodium and chloride ions, the conductivity in salt water is much higher than in pure water and the short-circuit current of the corrosion cell in also much higher.

Galvanic corrosion

There are several types of corrosion, including galvanic, pitting and crevice corrosion.

Galvanic corrosion is the most common type in pipelines. This occurs when there are two diverse types of metal and both flanges are in 'contact'. Galvanic corrosion arises when there is a potential difference between the metals (see Figure 2).

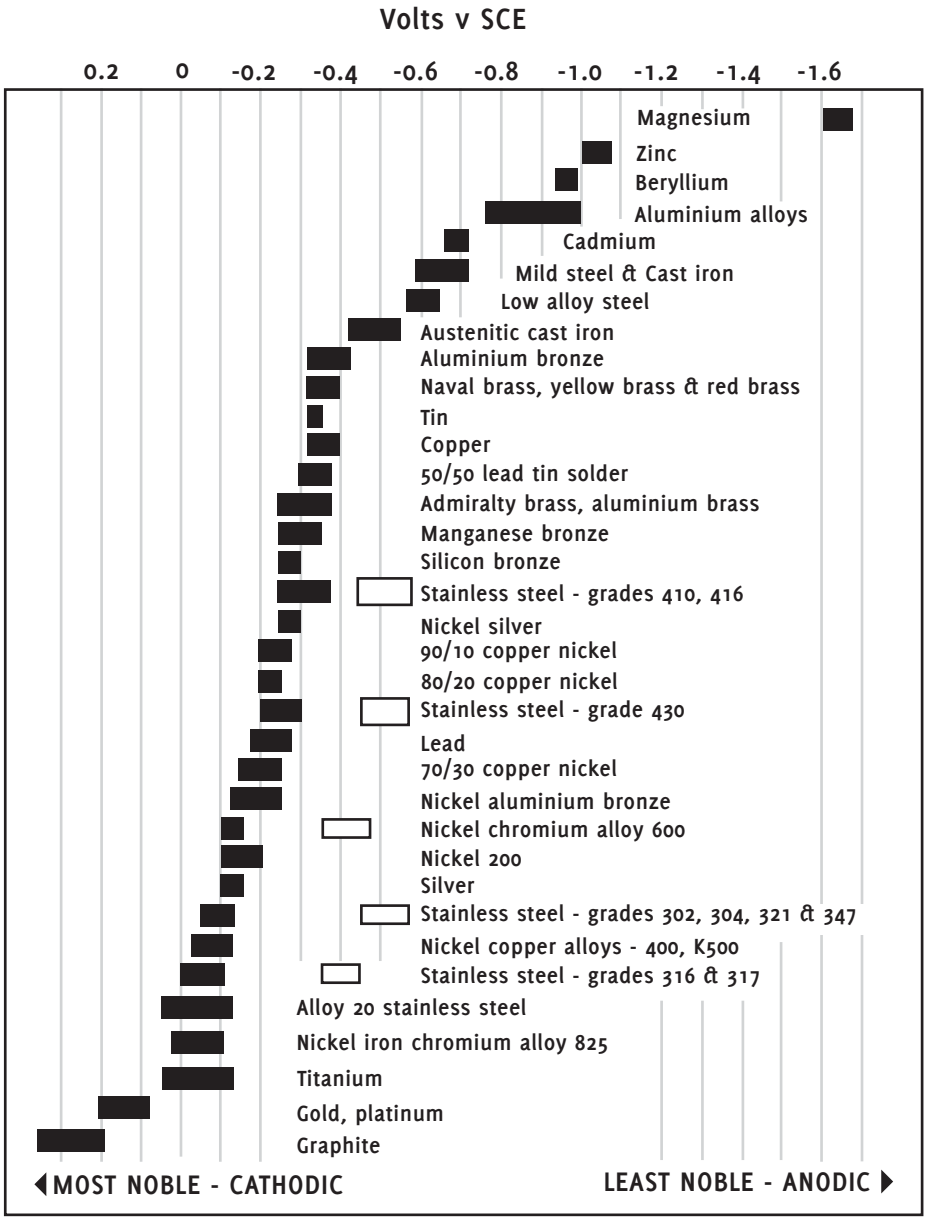

Fig. 2: Potential difference between metals

Every metal has a standard electrode potential with respect to a reference electrode which is set to 0,00 Volt in a galvanic cell to measure this electrode potential. One metal flange will function as the anode and the other metal flange will act as the cathode. The presence of a conductor (electrolyte), such as moisture and other electrical conductors including acid or base solutions, accelerates this process. This electrolite can be on the outside of the flange as well when water, humidity and condensation due to temperature changes can create a corrosion environment.

Four elements

For galvanic corrosion in flange connections the following four elements must be present:

- Anode: this flange will corrode
- Cathode: flange where electrons are produced
- Electrolyte: provides reactants for the reaction and allows the flow of ions
- Conductive metallic path: metal-to-metal contact by gasket and/or bolts and nuts

There will be no galvanic corrosion when there is:

1. No electric conduction (contact) between metals.
   The two flanges must be electrically separated from each other.
2. No or extremely low potential difference between metals.
   Probably not possible in the design.
3. No connection by electrolyte.
   It is possible to add barrier coatings on outside and/or inside of flanges and pipes to create a longer path between anode and cathode.

Pitting and crevice corrosion

Pitting corrosion is a highly localized pitting attack that can arise in several ways. For example, when a material is partially wetted due to frequent drops on a steel plate. The infestation starts under these drops. It can also arize when there is insufficient ventilation in pipe systems or heat exchangers. Due to a locally increased oxygen concentration, the strongest damage will occur in places where air bubbles continue to form. Pitting corrosion can be prevented, among other things, by increasing the pH, cathodic protection and using stainless steel with molybdenum content.

Crevise corrosion occurs in narrow crevices. If an electrolyte (water) is present, the oxygen will be used up quickly and will not be refreshed. Over time the pH will drop and the concentration of aggressive ions will increase sharply. Just like with pitting corrosion, this will cause and accelerate the corrosion. To prevent crevice corrosion, it is important to design the construction in a way the electrolyte can be refreshed or at least cannot be 'trapped'.

Flange assembly protection

The question now is: how to slow down or to protect pipelines and/or flange assembly against/from corrosion? There are several methods available. Cathodic protection systems are widely used, as are isolation sets between flanges and monolithic joints in pipelines. Cathodic protection is a method of combating corrosion based on the principle of lowering the potential of the object (flange/pipe) to be protected. By sufficiently lowering the potential, the anode reaction of iron-to-iron ions is slowed down to such an extent that the effect is negligible. Isolation sets have the function of electrically separating both flanges. Therefore, you need a gasket which must also be an insulator. In addition, the bolts and the nuts must be separated for at least one flange, but ideally from both. This can be achieved using insulating washers. To prevent contact between bolt and flange, the bolt must be mounted within an insulating sleeve. A monolithic joint is a welded isolation joint that is used to electrically split up or separate pipelines. These techniques can all be used on their own or in combination.

Comments/conclusion

There are many types and forms of corrosion. Only a few have been highlighted in this article. Corrosion can always occur and therefor attention must always be paid to prevent it.
In addition to choosing the right materials, protective products like insulating sets will help to reduce corrosion. There is a wide variety of materials and designs. Important is that the gaskets and washers will not break or absorb any water.
Corrosion can also be avoided by correct installation. Design pipe systems and pipe supports in such a way that no water can remain in crevices or other spaces. Wherever trapped water remains, there is a high chance of corrosion, with all its consequences!