Galvanic or two-metal corrosion

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When two different metals are used in the same environment they often obtain different potentials. If they are in contact or otherwise electrically connected a sufficient potential difference might produce a flow of electrons between them. The more noble material becomes cathodic and the less corrosion resistant anodic. This often results in increased corrosion of the anodic material and a decreased attack of the cathodic. This phenomenon is used for cathodic protection, where a so called sacrificial anode is connected to the material to be protected. When coupling different stainless steel grades potential differences are generally too small to cause galvanic corrosion problems.
The ranking of materials with regard to potential can be found in galvanic or EMF-series (electromotive force). Low EMF values are found for magnesium and zinc, among others, whereas copper, platinum and gold have high values. Standard EMF values have been calculated for standard conditions but the order between metals often differs depending on the environment. For metals such as titanium or aluminium, which form very protective oxide layers even at room temperature in air, the low standard values of potentials can seldom be reproduced. For a more realistic ranking of metals galvanic series have been determined empirically for special environments, such as sea water (see table 1).
Table 1. Approximate EMF-values in sea water Material Free corrosion potential / volts SCE*

Magnesium -1.6

Zinc -1.0

Aluminium alloys -1.0 to -0.75

Mild steel, cast iron -0.65

Copper -0.34

Admiralty brass -0.30

Ferritic stainless steel, 430 -0.24

Nickel 200 -0.2 to -0.1

304-type stainless steel** -0.08

316-type stainless steel** -0.10 to 0

Titanium -0.05 to +0.05

Platinum +0.2

* Saturated Calomel Electrode

** For passivated material values well above +0.1 can be obtained.

When evaluating the risk of galvanic corrosion it is of great importance that the correct potential values are used, determined for the right solution and temperature. In the same way, when sacrificial anodes are used, and thus galvanic corrosion is desired, the material which functions as an anode can become cathodic to the material to be protected in certain environments. This is the case when zinc is used for the protection of steel, if the concentrations of carbonates become too high.
Galvanic corrosion of stainless steels in the passivated state is unusual. When in connection to other metals, such as copper or carbon steel, stainless steels will generally be cathodic.
The relative area of the anode compared to the cathode greatly influences the corrosion rate. The larger the cathode area is compared to the anode area the faster the corrosion will be.
As an example of this steel bolts in a more noble copper sheet corrode more quickly than steel sheet with copper bolts, in the same environment. When the metals are in contact with one another the rate of anodic corrosion often decreases with increasing distance from the cathode, i.e. the material loss is greatest close to the cathode. This is especially pronounced when the surrounding electrolyte has low conductivity. There also exists a related corrosion type sometimes called indirect galvanic corrosion. In this case the metals need not be in direct contact. Instead the more noble metal corrodes by uniform corrosion and its metal ions are transported, e.g. in solution, to the surface of the anodic metal. They are there reduced and at the same time enhanced oxidation of the anodic metal occurs. The corrosion of the anodic metal can accelerate even further if the noble metal atoms on its surface can act as sites for more efficient reduction of other species, e.g. from the electrolyte.

Galvanic corrosion

Galvanic corroion can occur when two metals or alloys come into contact with each other in an electrolyte. The less noble material will corrode.
Galvanic corrosion very seldom occurs between two stainless steels. When stainless steel is joined with carbon steel, e.g. stainless tubes and carbon-steel tube plates in a heat exchanger, the carbon steel may suffer from galvanic attack.
When stainless steel is combined with graphite, the attack will be on the steel. Graphite gaskets should therefore be avoided.

A document from the Sandvik Materials Technology web-site.