

## Galvanic Corrosion

Understanding galvanic corrosion can help reduce the risks of corrosion on steel structures.

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Few designers of steel structures would claim ignorance of galvanic corrosion. Yet, based on the bitter experience of field service, it remains a common and poorly understood phenomenon that can greatly reduce the service life of a structure.

Galvanic corrosion, often termed bimetallic or dissimilar metal corrosion, is the phenomenon whereby direct contact between two metals can accelerate the corrosion of one of them. Painted steel structures in particular can be vulnerable to such corrosion in moist and immersed service.

Galvanic corrosion occurs because of an electro potential difference between the metals in contact. The electro potential difference causes a current to flow between the metals when covered by an electrolyte (a chemical solution in water). This electrolyte may be quite dilute; in fact, potable water usually contains enough dissolved salts to cause a problem under the right conditions. Thus, one metal (the cathode) is protected at the expense of the other (the anode), which corrodes at an accelerated rate.

### Causes of Galvanic Corrosion

The four causes discussed below are also important in determining the rate of galvanic corrosion.

#### Electro potential

When placed in the same electrolyte, different metals have a different electro potential. This means that when two metals are electrically coupled in the same solution, current will flow between them, causing corrosion of the more active metal at a rate proportional to the current. Thus, the more inert or passive metal, termed the cathode, will result in corrosion of the more corrodible or active metal, termed the anode.

The greater the potential difference between the metals, the greater the tendency for corrosion. Metals can be conveniently arranged according to increasing degrees of reactivity, as shown in the electrochemical series.

#### The Environment

The nature of the environment has a crucial influence on the rate of galvanic corrosion; in a dry area such as within buildings or on a well-drained structure such as a roof, galvanic couples can be used successfully, while the same combination in sea or fresh water immersion might be catastrophic.

For example stainless steel strapping on galvanized fixings in seawater immersion would cause serious local corrosion of the galvanizing. In contrast, in a benign atmospheric environment, stainless steel not only has a negligible impact on the life of the galvanizing but also can be used to advantage. Had the strapping on the bus stop sign been made from galvanized steel, even of the same zinc thickness, the service life would be considerable.

#### Proximity of Anode and Cathode

The most severe galvanic corrosion occurs closest to the anode/cathode junction. Because galvanic corrosion is an electrochemical process, the length of the resistance path through the electrolyte governs current flow. Thus, the further the current has to travel, the greater the resistance path, resulting in less corrosion to the junction.

Corrosion will be more widespread where the electrical conductivity of the electrolyte is higher. It can expect that corrosion will be more localized for identical anode/cathode junctions, on the junction immersed in fresh water than on the one immersed in seawater. Seawater has much higher conductivity than fresh water. Corrosion will also be more localized on wet, rather than fully immersed surfaces.

#### Cathode to Anode Ratio

The ratio of the area of the cathodic metal to the anodic metal is a critical factor in galvanic corrosion. For example, the sump on a cooling tower in South Australia, lined with a coal tar epoxy showed pitting corrosion in less than 18 months. Large, uncoated copper pipes (cathode), immersed and in direct electrical contact with the steel (anode), caused the accelerated corrosion: Ironically, had no protective coating been applied to the steel, corrosion would have been more general. Perforation of the steel would have been delayed, because the corrosion would have been widespread, not localized. This phenomenon would have resulted because the copper pipes were unpainted and the steel coated. The anode was the steel at the small, inevitable pinholes in the coating. (Hence, the anodes were very small compared with the cathodic copper.) Had the steel been uncoated, the anode would have been very large and the attack more even (as in the example below).

## **Solutions**

There are a number of ways to reduce or eliminate galvanic corrosion; however, the most appropriate depend on the problem. Some suggested solutions appear below.

### **Selection of Metals**

Metals close together in the electrochemical series will have little difference in electro potential, and, therefore, little effect on each other. For example, mild steel and cast iron are the most common construction materials and can be successfully used together. However, in wet environments, the attachment of small areas of other metals can be a problem. The use of small, more active metal fixings (e.g., zinc, magnesium, and their alloys), can result in rapid corrosion of these components. In contrast, small fixings of stainless steel or copper alloys can be appropriate because of these metals are (cathodically) protected by the large mass of mild steel or cast iron. This feature can be used to advantage, especially on critical items (e.g., fasteners on metal roof and wall claddings, specialized fittings on boats, transmission towers, and valve seats, etc., in water pumps).

### **Coat the Cathode**

One of the ironies of coating the cathode, or passive metal, is that the material may have been originally selected because of its inherent corrosion resistance. It is the large, bare area of the cathode that presents the problem; reduction of this area can minimize its corrosive influence. While insulating the cathode is ideal, it may not always be practicable. Coating is often a viable operation; however, it is necessary to maintain the coating throughout its service life.

### **Cathodic Protection**

Since it may not be possible to coat or insulate all items, cathodic protection may be an effective option. Cathodic protection is based on the principles of galvanic corrosion. In this instance, the metal is protected using a more anodic metal (such as zinc or magnesium) than the corroding material. The metals are electrically connected to the structure, and immersed in the same electrolyte in close proximity to the metal causing the galvanic corrosion. Cathodic protection was a supplementary procedure used to retard corrosion in the cooling tower and the water tank examples described above. The technique is only practical in fully immersed or tidal situations.

Cathodic protection can also be implemented by applying external, direct current power (impressed current cathodic protection) rather than using more corrodible “anodes” (sacrificial cathodic protection).

### **Modify the Environment**

If the corrosivity of the environment is reduced, galvanic corrosion will be lessened as well. Corrosion can be reduced if the junction of the two different metals can be made in a less corrosive location (e.g., atmospheric rather than immersion service). In the case of immersed metals, coating the junction and treating the water with corrosion-inhibiting chemicals are other supplementary procedures.

A related problem common in the building industry is the washing of water over copper and copper alloys. The corrosive products deposit on more anodic metals, notably aluminum or galvanized steel. A particular example is the use of copper-finned heat exchangers on galvanized roofs.

In tropical Australia, severe corrosion of the galvanized roofs occurred in about four years. In contrast, dry conditions in central Australia have had little effect on similar roofs.

The solution given above are not mutually exclusive, and one or more approaches might be used on any given structure.

### **The Benefits**

Galvanic corrosion can be used to advantage in the cathodic protection of structures. The use of more cathodic metals is crucial where any significant corrosion would be unacceptable. For example, the mating faces of valves or a fine wire strainer in a water supply system is usually constructed of stainless steel or a copper alloy, with the remaining assembly constructed of steel or cast iron. There will be some accelerated corrosion of the iron or mild steel immediately adjacent to the cathodic metal. As long as the area is small relative to the area of the iron or steel, or the water is of low conductivity, the galvanic effect can usually be accommodated.

### **Summary**

The phenomenon of galvanic corrosion can be used to protect structures. Various metal fasteners and fixings attest to the benefits of using corrosion-resistant metals in conjunction with more corrodible metals. However, many designers presume that these corrosion-resistant metals (notably stainless steel, copper, and copper alloys) can be used without discrimination with the same beneficial result. When large areas and amounts of these metals are, by design, in contact with less corrosion-resistant metals, particularly in corrosive locals, the effect on the more anodic metals can be catastrophic. Galvanic corrosion remains, therefore, widespread. It can only be avoided by designers and fabricators who are aware of the important principles of, and procedures for, reducing or protecting against galvanic corrosion.