

Interacting Influences

This brief look at the rusting of steel points up the interacting influences which initiate, and control, the mechanism of electrochemical corrosion.

First, there must be the possibility for any electrical current to flow. This means either the contacting of dissimilar metals with different electropotentials, or some measure of heterogeneity in the same base metal. The greater the differential, the stronger the current flow and the faster and more severe the corrosive action. Corrosion of the same metal, for example; the rusting of steel, normally results in a uniform corroding of the entire exposed surface. When dissimilar metals contact, the attack is usually more localized.

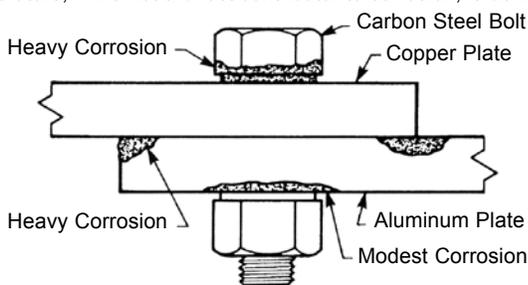
Second, there must be an electrolyte a medium through which the electrical current flows. Electrolytes occur naturally in our everyday environments - humidity, fog, dew, condensation, rain - and with a broad variation in their occurrence and intensity. For example, the corrosion survival expectancy of steel is shortened considerably when exposed in the high humidity Southern states as opposed to the ultra-dry desert climates of Nevada and Arizona. Similarly, structures and equipment survive longer in rural Midwestern states than in either ocean bordering states or in heavily industrialized areas with their high impurity atmospheres. Even in the home, storing articles in the dryness of an attic is more protective than in the dampness of a basement.

Distilled water is a poor conductor; tap water with its modest chemical content is better; industrial exposures with their pollutants and contaminants are even better; and salt water is exceptionally good. Whenever the electrolyte is agitated, such as flowing water, its conductivity is significantly magnified. The "dirtier" the electrolyte, the better its conductivity, and the faster the rate of corrosion.

Third, there must be oxygen. As most products of corrosion are oxides formed by the chemical reaction, the presence of oxygen is mandatory. Without oxygen, most forms of corrosion would be stalemated. However, its complete elimination is an engineering impracticality. Oxygen is the principal element of the air we breathe, and it is present, although to a lesser degree, underground and underwater.

The importance of oxygen can be illustrated by considering an oceangoing steel-hulled ship. Without suitable protection of its exposed surfaces, the entire hull would corrode, but at three different rates. The plates at the water line would go first because of the concentrated aggressiveness of the sea water coupled with unlimited oxygen. The upper structure and decks would corrode more slowly because the electrolyte is now a spray which has lost some of its intensity although the oxygen supply is undiminished. The fully submerged bottom of the hull would survive the longest simply because of the meagerness of the oxygen supply.

Temperature, while not a direct contributor to corrosion, is definitely a



Effects of Galvanic Corrosion

factor in the rate at which it occurs. Generally, heat accelerates chemical reactions. All other conditions being equal, corrosion happens quicker and more markedly in southern climates than in those of the north. It also

occurs more quickly in industrial plants where heat is inherent in the process as opposed to industries which conduct their operations at ambient temperatures or in the luxury of an air conditioned atmosphere.

Galvanic Corrosion

Similar metals are compatible; dissimilar metals are not. When dissimilar metals contact in the presence of an electrolyte, a galvanic action occurs which causes one of the metals to corrode at a much faster than normal rate, while the other corrodes more slowly, if at all. The rate, location and extent of the corrosion depends on three factors:

- The difference in electrical potentials
- The conductivity strength of the corroding medium, and
- The relative sizes of the contacting areas.

All metals have electrical potentials. Through research, the potentials of different base metals and their alloys, when exposed to sea water, were measured and then ranked into a series. In an electrical couple, the metal of higher electrical potential is the cathode (-), that of the lower the anode (+). Current flows from the cathode to the anode, from the anode through the electrolyte (corroding medium), and back to the cathode. Corrosion occurs at the point the current leaves the anode to enter the electrolyte. When dissimilar metals contact, the anode corrodes, the cathode survives.

Galvanic Series

Table 1 presents the Galvanic Series of Metals and Alloys. The various metals are grouped. Those within the same group are reasonably compatible when used together; those from different groups cause a corrosion problem. Some metals, basically those with significant contents of nickel and chromium, are included in the Series both in their active and passive conditions. Passivation (surface cleaning and sealing) lowers the metal's electrical potential and improves its corrosion behavior.

Study of the Galvanic Series suggests that steel and aluminum are reasonably compatible; but, if titanium and aluminum contact, the aluminum, as the anode, will corrode. Fig. 2 illustrates another example. A copper plate is joined to an aluminum plate using a carbon steel bolt. If none of the contacting surfaces are protected, corrosion will occur. The bolt, where it touches the copper, will corrode severely. However, the bolt, where it contacts the aluminum, will not corrode, because it is now the cathode. The aluminum plate in contact with the bolt may corrode, but only slightly because of the minor difference in their electropotentials and the large anode-to-cathode area ratio. The aluminum plate will corrode where its exposed exterior surfaces contact the copper plate. The aluminum plate may also corrode on its interior surface, but not to the same degree, because the corroding medium and oxygen supply are largely sealed out due to the bolt's clamping action.

GALVANIC SERIES OF METALS AND ALLOYS

+Corroded End (anodic, or least noble)

- Magnesium, Magnesium alloys, Zinc
- Aluminum 1100, Cadmium, Aluminum 2024-T4, Steel or Iron, Cast Iron, Chromium-iron (active), Ni-Resist cast iron
- Type 304 Stainless (active), Type 316 Stainless (active)
- Lead tin solders, Lead, Tin
- Nickel (active), Inconel nickel-chromium alloy (active), Hastelloy Alloy c (active)
- Brasses, Copper, Bronzes, Copper-nickel alloys, Monel nickel-copper alloy
- Silver solder, Nickel (passive), Inconel nickel-chromium alloy (passive)
- Chromium-iron (passive), Type 304 Stainless (passive), Type 316 Stainless (passive), Hastelloy Alloy C (passive)
- Silver, Titanium, Graphite, Gold, Platinum

- Protected End (cathodic, or most noble)

Taken from IFI Fastener Standards