PDHonline Course S118 (1 PDH)

Dissimilar Metal Corrosion

Instructor: D. Matthew Stuart, P.E., S.E., F.ASCE, F.SEI, SECB, MgtEng

2013

PDH Online | PDH Center

5272 Meadow Estates Drive
Fairfax, VA 22030-6658
Phone & Fax: 703-988-0088
www.PDHonline.org
www.PDHcenter.com

An Approved Continuing Education Provider

What is corrosion? Corrosion is the wearing away, or alteration of a metal by galvanic reaction, or by direct chemical attack.

Except for the "precious" metals, such as gold, metals in the refined form are inherently unstable. This instability is what drives the process of corrosion as a refined metal is continually trying to revert to its natural state (the mineral). Some metals do this faster than others.

Source: James B. Bushman

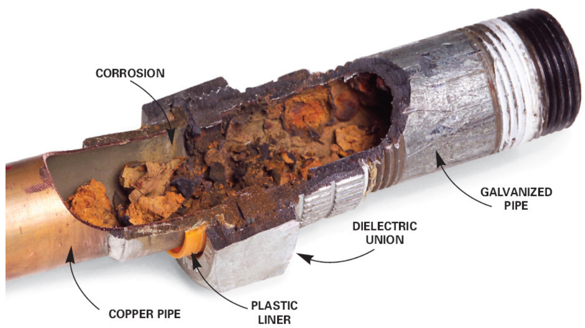
Direct Attack Corrosion:

Atmospheric corrosion is an example of direct chemical attack. The atmosphere contains oxygen, carbon dioxide, water vapor, sulfur, and chlorine compounds. The severity of the attack is directly related to the amount of water vapor, sulfur and chlorine compounds present.

Source: SVÚOM Ltd

Galvanic Corrosion:

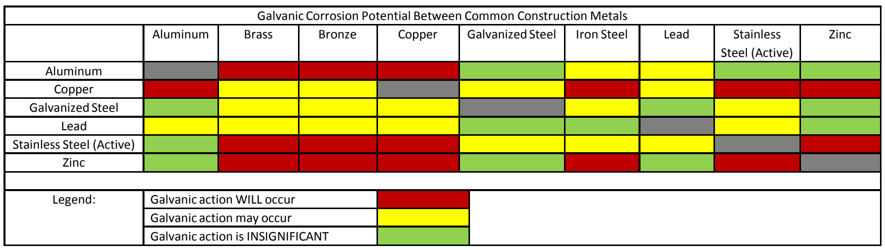
All metals have specific relative electrical potential. When metals of different electrical potential are in contact in the presence of moisture, a low energy electric current flows from the metal having the higher position in the galvanic series. This is called "galvanic action." Galvanic corrosion is a form of electrochemical corrosion that occurs when two dissimilar metals come together in the presence of an electrolyte to form an electrical couple, known as a galvanic couple. The more noble or cationic the metal, the less likely it will corrode relative to the other metal it is in contact with. It should be noted that mill scale is cathodic to steel and an electrical current can easily be produced between mill scale and the steel. Weld metal may also be anodic to the base metal, creating a corrosion cell when immersed. Additionally, a depletion of oxygen in crevices of a metal can cause the area to become anodic to the metal outside the crevice which is exposed to oxygen.



In building systems, the electrolyte is usually ordinary moisture, whether rainwater or high atmospheric humidity. When two metals form an electrical couple, an exchange of electrons takes place, its direction and intensity governed by each metal's ranking in the galvanic series. The farther apart the two metals are on the galvanic series, the greater the potential for corrosion. Galvanic corrosion potential is a measure of how dissimilar metals will corrode when placed against each other in an assembly. Metals close to one another on the chart generally do not have a strong effect on one another, but the farther apart any two metals are separated, the stronger the corroding effect on the one higher in the list. The list on this slide represents the potential available to promote a corrosive reaction, however, the actual corrosion in each application is difficult to predict. Typically, the presence of an electrolyte (i.e. water) is necessary to promote galvanic corrosion.

The Galvanic Series Chart	
Magnesium & Magnesium Alloys	POSITIVE CHARGE: Anode (+) least noble
Zinc	
Aluminum 1100	
Cadmium	
Aluminum 2024-T4	
Steel or Iron Cast Iron	LESSENING POSITIVE CHARGE
Type 304 & 316 Stainless (active)	
Lead, Tin	
Nickel (active)	(ELECTRIC CURRENT FLOWS FROM POSITIVE TO NEGATIVE)
Brasses, Copper, Bronzes & Copper-Nickel Alloys	
Nickel (passive)	INCREASING NEGATIVE CHARGE
Chromium-iron (passive)	
Type 304 & 316 Stainless (passive)	
Silver	
Titanium	
Graphite, Gold Platinum	NEGATIVE CHARGE: Cathode (-) most noble

This slide includes a chart of galvanic corrosion potential between common construction metals. When dissimilar metals are used together in the presence of an electrolyte, separate them with a dielectric material such as insulation, paint or similar surface coating.



This slide includes a chart of guidelines for the selection of fasteners based on the potential for galvanic action.

Guidelines for Selection of Fasteners Based on Potential Galvanic Action

	Fastener Metal					
Base Metal	Zinc and Galvanized Steel	Aluminum and Aluminum Alloys	Steel and Cast Iron	Brasses, Copper, Bronzes, Monel	Ferritic Stainless Steel (Type 410)	Austenitic Stainless Steel (Type 300)
Zinc and Galvanized Steel	A	B	B	C	C	C
Aluminum and Aluminum Alloys	A	A	B	C	**NOT RECOMMENDED**	B
Steel and Cast Iron	AD	A	A	C	C	B
Terne (Lead-Tin) Plated Steel Sheets	ADE	AE	AE	C	C	B
Brasses, Copper, Bronzes, Monel	ADE	AE	AE	A	A	B
Ferritic Stainless Steel (Type 410)	ADE	AE	AE	A	A	A
Austenitic Stainless Steel (Type 300)	ADE	AE	AE	AE	A	A

Source: American Iron and Steel Institute Committee of Stainless Steel Producers April 1977

Key:

A. The corrosion of the **base metal** is **NOT** increased by the fastener.
B. The corrosion of the **base metal** is marginally increased by the fastener.
C. The corrosion of the **base metal MAY BE** markedly **INCREASED** by the fastener material.
D. The plating on the **fastener** is **RAPIDLY CONSUMED**, leaving the bare fastener metal.
E. The corrosion of the **fastener** is **INCREASED** by the base metal.

Note: Surface treatment and environment can change activity.

Galvanizing means simply overlaying steel with zinc, either by plating or by dipping the steel in molten zinc. An undamaged piece of galvanized steel will corrode at the same rate as a similar piece of zinc. Once the zinc coating is perforated (by mechanical damage, for example), the zinc forms a galvanic couple with the steel, the zinc corroding to protect the steel. The zinc will continue to protect the steel until most of the zinc is gone. When the zinc is gone, you may begin to see a lot of thin patches of rust. What this means depends on whether the zinc was applied by plating or dipping. On an electroplated surface, such as a galvanized-metal roof, the rust indicates that corrosion of the underlying metal has begun. On a hot-dipped galvanized surface, however, the zinc actually diffuses partway into the steel. The initial patches of rust mean that the pure zinc overlay has corroded away. Thus a piece of hot-dipped galvanized steel will give you some warning before the steel begins to corrode.

Hot Dip Galvanizing
Source: Galvanizers, Inc.

Corrosion of reinforcing embedded in concrete can also occur as a result of galvanic corrosion even though no dissimilar metals such as aluminum conduits may be in contact with the carbon steel bars. It should be noted, however, that Aluminum reacts with the alkalis found in Portland cement concrete. When these two chemicals are combined, the reaction produces hydrogen gas. This is why, when the reaction occurs in wet concrete, you'll notice tiny bubbles coming to the surface of a slab.

As noted above, concrete is a highly alkaline material, an attribute that protects embedded steel from corrosion. However, with the introduction of chlorides (in the form of de-icing salts) and in the presence of moisture and oxygen, an electrochemical process develops which will allow corrosion of the steel. This corrosion process results in an increase of metal volume at the reinforcing steel surface as iron is oxidized and precipitated on the metal. As this layer of rust builds, forces generated by the expansion cause the surrounding concrete to crack, delaminate from the reinforcing steel and spall. This deterioration of the concrete has the effect of accelerating the corrosion process because it allows greater exposure of the reinforcing to the salts, moisture and oxygen.