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# PRIMER

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# Galvanic Corrosion

At the detail design stage, careful consideration must be given to the compatibility of building materials or systems used in structural and architectural applications.

**A phenomenon known as galvanic corrosion occurs when dissimilar metals, subjected to the same environment, comprised of a conducting solution, are in direct electrical contact.**

One potential consequence of incompatibility is accelerated corrosion of metals, which can occur if dissimilar metals are combined in certain environments. This is galvanic corrosion. Evaluations of compatibility are increasing in importance, as the array of potential building materials is ever-expanding. Fortunately, durability issues related to galvanic corrosion can be minimized or prevented with proper design.

### Galvanic Corrosion Defined

In general, corrosion in metals is an electrochemcial reaction with the surrounding environment consisting of two partial reactions: an oxidation reaction and a reduction reaction. When different metals, or metal alloys, are placed in a corrosive environment, each metal develops a potential for corrosion that is unique to both the metal and to the environment. Corrosion will occur at different rates when different metals are placed in the same corrosive environment, and likewise, the same metal will corrode at different rates when placed in different corrosive environments. When different metals develop potentials for corrosion that are significantly different, these metals are termed 'dissimilar.' A phenomenon known as galvanic corrosion occurs when dissimilar metals, subjected to the same environment, comprised of a conducting solution (usually a water-based solution in which an electrolyte, such as sodium, potassium, chloride, calcium, or phosphate, is dissolved), are in direct (electrical) contact. When the requirements for galvanic corrosion are met, one dissimilar metal will corrode preferentially to the other (termed 'galvanic action'). The more 'active' metal will support the oxidation reaction and corrode (becoming the anode, where metal will be consumed), while the more 'noble' metal will support the reduction reaction (becoming the cathode, where metal will not be consumed).

### The Galvanic Series

Compatibility of different metals can be assessed, relative to the potential for galvanic corrosion, with the use of charts depicting the galvanic (or electromotive force) series in different environments. The galvanic series indicates which dissimilar metal will tend to corrode (anode) and which dissimilar metal will tend to support the reduction reaction (cathode), when the requirements for galvanic corrosion are met. All other things being equal, a greater separation between the metals in the galvanic series will result in greater galvanic action. A chart depicting the galvanic series for some common metals in a frequently encountered conducting solution, seawater, is included in Figure 1. Though the order of metals in a galvanic series remains the same in most conducting solutions, some electrolytes can affect this order. While galvanic series are most commonly presented for seawater, seawater is a severely corrosive environment and does not necessarily represent the service environment or localized conditions to which metals will be subjected. The potential for galvanic corrosion is greater in other highly corrosive environments (urban or industrial), and lower in less corrosive environments (rural); metals that are relatively compatible

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## Galvanic Corrosion (CONTINUED)

in one environment are not necessarily compatible in other environments.

### Most Common Occurrences of Galvanic Corrosion

Examples of common areas for occurrence of galvanic corrosion in buildings and other structures include the following:

- Where a fastener metal is dissimilar from the metal of the connected elements (such as structural connections, fasteners for metal roofing and facade elements, fasteners for metal roof edge terminations and copings, strap and clip anchors for metal gutters/downspouts/piping, etc.):
  - — Stainless steel screws and aluminum window components
  - — Carbon steel clip anchors with copper downspouts (see Figure 2)
  - — Galvanized steel fasteners and aluminum kerf anchors (see Figures 3 and 4)
  - — Galvanized steel hurricane clip roof tile fasteners and copper eave flashing
  - — Stainless or galvanized steel fasteners and aluminum termination bar or aluminum flashing
- Where structural systems interface with architectural systems or different structural systems (such as facade and curtainwall connections to structural framing):
  - — Wrought iron framing and copper cladding (Statue of Liberty)
  - — Galvanized steel railings set in stainless steel sleeves
  - — Stainless steel access ladders connected to structural weathering steel
  - — Aluminum and stainless steel space frame components

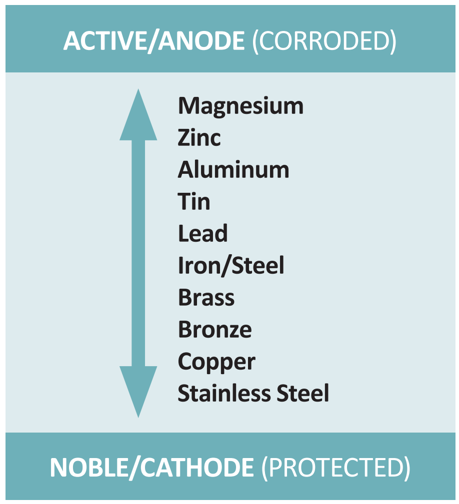


*FIGURE 1*
*Galvanic Series in Seawater.*

*FIGURE 2*
*Galvanic corrosion of carbon steel clip angle connecting copper downspout to substrate (Photo by James Chiropolos of WJE).*

*FIGURE 3*
*Galvanized steel fastener through aluminum kerf anchor (Photo by Fiona Aldous of WJE).*

*FIGURE 4*
*Fractured galvanized steel fasteners that were used with aluminum kerf anchors (Photo by Fiona Aldous of WJE).*

- Where dissimilar metal pipes are directly connected:
  - — Copper pipe and galvanized steel pipe

Metals that are very close together in a galvanic series can usually be used in direct contact without a problem, however consideration must be made for metals used in more corrosive environments and conditions as discussed previously. Metals that are further apart in a galvanic series, such as aluminum and stainless steel in the galvanic series example provided in Figure 1, are more commonly affected by galvanic corrosion.

## Galvanic Corrosion (CONTINUED)

### Factors Affecting Galvanic Corrosion

*Occurrence and Extent*

Aside from the separation between the metals or metal alloys in the galvanic series, the occurrence and extent of galvanic corrosion can be affected by a number of factors related to the conducting solution environment and its properties. These factors include the solution temperature, temperature gradients, humidity, volume, solution height above the metals (if submerged), flow rate across the surface of the metals, oxygen level, pH level, pollutant level, corrosivity, and conductivity.

Another factor that can possibly affect the occurrence and extent of galvanic corrosion is the method used to join the two dissimilar metals or metal alloys. This method could be direct contact between a fastener and the main component, a welded area creating a transition from one material to the other, or any number of other possible methods of joining the two metals or metal alloys.

*Rate of Attack*

The rate of galvanic attack will vary directly with the ratio of cathode area to anode area. In general, a high cathode to anode area ratio will result in rapid corrosion, while a high anode to cathode area ratio will result in slowed corrosion; this is commonly termed the 'area effect.' An example of the area effect is the rapid rate of corrosion in steel fasteners when used in copper members, and the negligible corrosion in the steel when copper fasteners are used in steel members. Even when metals are very close together in a galvanic series, the area effect can result in accelerated corrosion when the requirements for galvanic corrosion are met. Accelerated corrosion of the zinc coating and fracture of galvanized steel fasteners has been observed when the fasteners were used to attach facade panels through aluminum kerf anchors due to the large surface area of the aluminum kerf anchor (noble/cathode) to the zinc galvanizing coating on the steel fastener (active/anode).

### Prevention of Galvanic Corrosion

The simplest approach for prevention of galvanic corrosion is to use the same or compatible materials (for that environment) throughout the structure. However, using the same or compatible metals for all aspects of an assembly is not always possible or practical. Thus, tactics for reducing or preventing galvanic corrosion, including application of coatings at points of contact or the use of neoprene or other inert washers to isolate dissimilar metals, are often employed.

### Galvanic Action as Protection

The mechanism of galvanic action can be used to provide corrosion protection. A commonly recognizable example of this is the galvanization of steel for 'cathodic protection,' where a zinc coating is applied over the steel as a 'sacrificial anode'; thus, the zinc coating (anode) corrodes preferentially to the underlying steel (cathode) and limits steel corrosion. Cathodic protection of steel in water, soil, or concrete is often achieved in a similar fashion, with the use of sacrificial anodes made of zinc or magnesium. In many instances, when these sacrificial anodes are corroded away, they can be replaced and cathodic protection of the steel restored.

### Summary

The compatibility of metals in structural and architectural applications, especially at connections where dissimilar metals can come into direct contact, must always be considered to prevent accelerated corrosion of metals due to galvanic action. The occurrence and extent of galvanic corrosion will be affected by the relative separation, in the galvanic series, of the metals or metal alloys, the conducting solution environment, and the electrical connection between the dissimilar metals. Rapid galvanic corrosion will occur with a high cathode to anode area ratio. Galvanic corrosion can be reduced or prevented with the use of metals that are close together in the galvanic series or by electrically isolating the dissimilar metals. Fortunately, galvanic corrosion can often be avoided in the design phase. When designing or reviewing construction plans and details relative to the interaction of metal elements, the potential detriments of galvanic action should be considered.

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