Combat Corrosion by Design

By John L. Campbell

Careless construction carries rain water off a flat roof onto steel pipe that supplies natural gas to a restaurant.

John Campbell uncovers several examples of poor design methods that induce or speed up the corrosive process.

The National Association of Corrosion Engineers estimates that the economic losses due to corrosion in the U.S. amount to $300 billion a year.A big chunk of those losses, estimated at 92 percent, is due to careless neglect and poor design.Once a fewillustrations grab your attention, you'll see daily evidence of corrosion that could be prevented. While vacationing in Florida, I noticed the aluminum frames around exterior sliding doors at our condo turning white, a powder residue, and an oxide of aluminum chemically similar to bauxite. At an indoor swimming pool, aluminum doors have to be replaced every few years when the aluminum corrodes above the swivel plates that are chromium plated bronze.Getting out of my car at a restaurant parking lot, I observed water pouring out of a downspout impinging on steel pipe that carried natural gas to the building in front.In my daughter's backyard, her brass bell shows pits due to dezincification,the zinc bailing out of the brass alloy, leaving early pits i its place.Nothing seems immune from corrosion. Even stainless steels corrodes under certain circumstances.

FYI IN THIS ARTICLE . . .

SUBJECT: Senior *Fabricator* writer John Campbell reveals how members of our industry can use their design skills to fight corrosion.

FOR MORE INFO: See *The Handbook of Corrosion Engineering* by Dr. Pierre R. Roberge (also listed on NOMMA's web site under *Literature Guide*, visit: www.nomma.org).

WEB SITES:

www.corrosion-doctors.org

www.nautarch.tamu.edu

www.nace.org

(NACE stands for the National Association of Corrosion Engineers)

Authorities on the subject cite five methods to control corrosion:

- Change the material of construction.
- Change the location of a structure.
- Apply the best protective coatings for the material.
- Employ either cathodic or anodic protection.
- Design to obtain the best ventilation and drainage possible.

The steel support frame on a commercial trailer is corroding the aluminum skin, an example of coupling dissimilar metals and the resultant galvanic corrosion.

In all cases, time of wetness and atmospheric pollution are key factors in corrosion of alloys and the deterioration of wood and cement. Tom Johnson, an outstanding metallurgist who has numerous patents to his name for corrosion-resistant alloys, once observed, “The energy released by corrosion is directly proportional to the input of energy to produce and shape metal for structural applications.” Design engineers in the metals industry are like prison wardens, trying to make sure their products serve their time before warranties expire and the alloys escape back to their natural state. We can’t stop corrosion any more than we can prevent aging; but in the design stages we can do more to deter the process.

Galvanic Series of Metals

One of the most obvious design violations is fabricating with dissimilar metals, metals and alloys having a large difference in electrical potential. Coupling them is courting trouble. So much has been written about galvanic corrosion that you have to ask why engineers and designers continue to overlook this well documented phenomenon.

Almost every year for a science project some student demonstrates how a primitive wet cell battery can be made by inserting dissimilar metals like thin copper and zinc plates into a lemon. The acid in the lemon acts as the electrolyte and two metals at the extreme ends of the galvanic scale exchange weak electrically charged ions. Wire a dozen such cells together and enough electrical current develops to dimly light a small flashlight bulb. That’s putting galvanic action to productive use, sacrificing the zinc, which is the anodic corroding part of the cell, going into solution in the process of giving up electrons.

Crevice corrosion occurs where moisture accumulates to become the electrolyte between overlapping metal surfaces. A difference in electrical potential builds up between the oxygen deprived crevice (anodic area) and the surrounding surface (cathodic) exposed to the air.

In the early 1950s one of our automobile manufacturers tried to cut costs by substituting drawn steel top tanks in place of copper on their cars' radiators. They lined the steel tank with a plastic intended to prevent the galvanic action between the steel and the copper cooling core. However, the plastic peeled off in numerous radiators. The electron exchange between steel and copper produced enough hydrogen under the plastic that the thin coating separated and was sucked down onto the water passages, causing the vehicles' engines to overheat.

"Why do engineers and designers continue to overlook the well documented phenomenon of galvanic corrosion?"

Initially, the car manufacturer blamed a major anti-freeze producer for the blockage, claiming their brand of ethylene glycol with its oily corrosion inhibitor plugged their radiators. The anti-freeze people, compelled to defend their product, identified the problem, and not long after, the car manufacturer acknowledged their responsibility for radiator replacements.

This steel fence, which is set back from a main thoroughfare about 20 feet, illustrates the corrosive effects of road salt used in northern communities to melt ice and snow.

If you’re looking for more current examples of galvanic corrosion, the coupling of two metals with different electrical potentials, you don’t have to travel far to find one.

• A nonprofit organization collects clothing and discarded items in the parking lot of a nearby supermarket. Their trailers are old, probably donated equipment, not meant for long hauls. Nevertheless, the aluminum skins on the trailers show evidence of their steel frames underneath. The aluminum, being anodic to the steel, is eaten away leaving traces of the steel frames showing through the trailers’ exterior skin.
• In your basement you’ll probably find a brass valve or fitting threaded directly to steel or iron pipe without an insulator coupling. In my garage I see inexpensive gardening equipment using steel rivets to join aluminum plates. Even worse would be aluminum rivets to attach steel plates.

It’s recommended that insulation materials like gaskets be used to separate dissimilar metals in fabrication. However, don’t use an insulating material that absorbs moisture. When the insulating barrier gets damp, it becomes the carrier and not the barrier of electrons. That’s what caused the Statue of Liberty to require a $200 million dollar face lift.

Asbestos saddles that insulated her copper skin from an iron armature underneath gathered moisture. In the restoration the contractors used Teflon pads to insulate the stainless steel interior armature from the lady’s copper exterior. For fabrications exposed to the weather, keep them water-tight and allow drain holes for condensation. We wrote about the freeze-damage to hollow fences in the January-February 2002 issue of Fabricator (pg. 26), where either moisture or condensate either moisture or condensate accumulated and froze. Design to allow condensate and moisture run-off, weep holes if necessary. Avoid depressions where dirt can accumulate and retain moisture. Deprive a spot on a metal surface of oxygen and a concentration cell is formed, an anodic spot with a cathodic surface. When humidity reaches 60 percent to 65 percent, or the surface is wet, you’ve created a potential corrosion problem. The spot deprived of oxygen will pit and corrode.

Environmental factors should play a major role in materials selection and design

The first car I bought for my wife was a used station wagon. Under the lights at the car lot the paint job looked beautiful. Within a year I noticed a few rust blisters, one underneath each headlight. When I popped the bubble with my finger, a hole opened through with my finger, a hole opened through the steel.

Upon close examination I discovered pockets underneath each headlight where a mixture of road dirt, salt, and moisture had accumulated, probably thrown up by the front tires. Design modification could have prevented the accumulation and subsequent damage.

Sometimes atmospheric conditions speed up the corrosive process. Big offenders are sulfur dioxide and chlorides. Fabricators often use stainless steels as a blanket solution to corrosion problems, but alloys like AISI 304 and 316 are particularly susceptible to stress corrosion (SSC), cracking in chloride environments.

In 1985, a heavy concrete ceiling supported by stainless steel rebar (AISI 304) collapsed over an indoor swimming pool in Switzerland. The structure was only thirteen years old. Following the disaster, an investigation revealed that the rebar failed under the weight of the ceiling due to stress corrosion cracking. Chloride ions carried in the air from the pool chemicals were suspected as the cause. Stainless steels depend on exposure to oxygen for their continuous passivation. Most chloride environments are detrimental to stainless steels. The addition of molybdenum in AISI 316 and 317 stainless reduces the tendency for pitting that occurs in AISI 304 stainless. The seeds for intergranular corrosion can be induced into stainless fabrications by the extreme heat of welding. To avoid sensitization of stainless alloys in welding low carbon grades (.03 percent max.) and stabilized stainlessness like AISI 347 and 321 should be used.

In the 18 percent chromium and 8 percent nickel alloys like AISI 304 and 316, which have a specification of .08 percent maximum carbon, chromium is the element that gives these alloys their stainless characteristic. However, chromium has an affinity for carbon and when the heat of welding is applied the chromium latches onto carbon molecules forming chromium carbides in the heat affected zones.

The combination of high humidity in a chlorine atmosphere accelerates the galvanic action between an aluminum door and a chromium plated bronze swivel plate at an indoor pool.

This depletes the grains of metal adjacent to the welds of chromium and leaves the welded areas sensitized for a type of corrosion called intergranular, corrosion between grain boundaries.

A solution annealing heat treatment after welding will put the chromium back into solution, but that’s hardly practical with large fabrications and welding done on site. For that reason, it’s always advisable to use a low carbon grade like AISI 304L or 316L or one of the carbon stabilized grades like AISI 347 or 321 stainless steel, where the environment is extremely hostile. Niobium (columbium) in AISI 347 stainless and titanium in the 321 alloy will couple with carbon preferentially before it links with chromium. That's why they're called stabilized grades of stainless.

A deep nick or scratch on a metal surface will become anodic to the surrounding area and propagate itself. Likewise a difference in oxygen content causes a concentration cell where metal sheets overlap to form a crevice.

Crevice corrosion at the lap joints on aircraft skins are regular maintenance concerns. A 19-year-old Boeing 737 operated by Aloha Airlines lost a portion of its fuselage in 1988 at an altitude of 24,000 feet. The cause was determined to be a build-up of aluminum oxide trihydrate, a corrosive pillowing, between the overlap of the aluminum sheath. The buildup of corrosion products between the skin caused the rivets to stress and fracture.

A neighbor of mine installed a new aluminum pier at his lake home. He decorated it with two large ceramic planters. About four months later, when he pulled the pier up on shore, he noticed two round stains where the pots had sat. The stains didn't wash off. As a matter of fact, they made permanent circular depressions on the pier's surface. He was very upset.

*John Campbell is a senior writer for **Fabricator**. All photos courtesy of John Campbell.*

Five design tips to help combat corrosion:

1 Change the material of construction.
2 Change the location of a structure.
3 Apply the best protective coatings for the material.
4 Employ either cathodic or anodic protection.
5 Design to obtain the best ventilation and drainage possible.

The surface under the pots had less oxygen than the larger deck surface. Those areas became anodic to the surface exposed to air. A glob of mud or an object like a stone would have the same affect. Where one area is starved of oxygen it will become anodic to the adjacent surfaces exposed to air. Any design to combat corrosion is without relevance until the fabricator knows how and where the product is going to be used. After you've considered all possibilities, and taken all the precautions of good design, unforeseen circumstances can still arise. Strong winds carry the corrosive effects of sea water, which is why coastal areas are hot spots for accelerated corrosion; but the corrosive nature of street salt can be just as deadly. For instance, thousands of miles from either ocean, an iron picket fence rusted due to winter salt spray created by fast moving vehicles on a nearby thoroughfare.

A manufacturer of coin handling devices installed aluminum bases on their mass transit fare boxes. After one winter, the boxes had to be replaced on city buses in a major northern city because street salt carried on the shoes and boots of passengers corroded the aluminum.We concede that corrosion is a continuous problem; but by employing what we know about the causes, we can design to avoid duplicating the mistakes of others.