Galvanic corrosion. Why it happens and how to avoid it

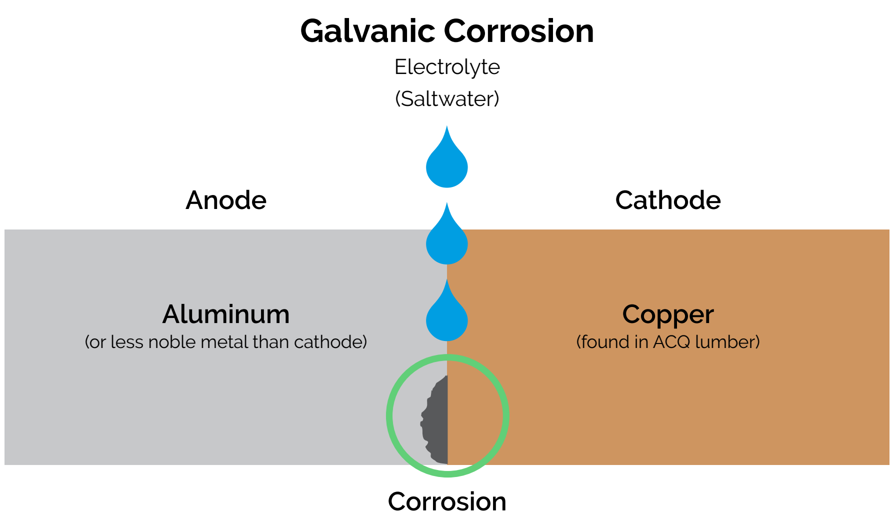
We touched briefly on galvanic corrosion in Chapter 4 however this chapter gives you a deeper look into what it is, why it happens, and what you can do to avoid it.

3 things are required for galvanic corrosion to occur: two electrochemically dissimilar metals, an electrolyte solution, and electrical contact between the metals. A common scenario is marine equipment in a saltwater environment. When salt dissolves in water, it releases electrolytes which are attracted to the electrons of the nearby metals. An electrical contact or flow occurs when the electrolytes attach to both metals, creating the conditions for galvanic corrosion.

Damage from galvanic corrosion

The damage from galvanic corrosion can be extensive and even result in failure of a structure or a joint. A classical example is the Statue of Liberty which has a copper surface on a cast iron frame. The two metals were originally separated by an insulating material which eventually failed resulting in significant galvanic corrosion. Repairs and improvements done in the 1980's took two years and while originally estimated at $103 million, was actually much more.

The most severe corrosion occurs where the metals are in contact – like a joint or around fasteners. This site gives an example of a mild steel and aluminum joint with significant corrosion and perforations in the aluminum after 2 years. You can also see an example of brass and steel in contact.



PROTECTING FASTENERS

Fasteners are a common source of galvanic corrosion. The fastener typically has a smaller surface area than the material it is fastening, so if the fastener is the anode, corrosion can be very rapid. To avoid issues, consider the following when planning a project or assembly:

- Whenever possible, use the same material for the fastener and the piece it is fastening
- If using different materials, choose a fastener material that will be the cathode
- Only use zinc coated fasteners on steel coated with aluminum, zinc, or galvalume
- Do not use zinc or aluminum coated fasteners for copper or stainless steel

This table can help with the selection of fasteners for a sheet metal fabrication project.

Base Metal	Fastener Metal					
	Zinc, galvanized steel	Aluminum and aluminum alloys	Steel and cast iron	Brasses, copper, bronzes, monel	Stainless steel type 410	Stainless steel type 302/304, 303, 305
Zinc, 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
Teme (lead tin) plated steel	ADE	AE	AE	C	C	B
Brasses, copper, bronzes, monel	ADE	AE	AE	A	A	B
Stainless steel type 430	ADE	AE	AE	A	A	A
Stainless steel type 302/304	ADE	AE	AE	AE	A	A

Key:
A: Corrosion of the base metal is not increased by the fastener
B: Corrosion of the base metal is marginally increased by the fastener
C: Corrosion of the base metal may be marginally increased by the fastener material
D: Plating on the fasteners is rapidly consumed, leaving the bare fastener metal
E: Corrosion of the fastener is increased by the base metal
Source: http://www.preservationscience.com/materials/metals/PGC.html

Sacrificial anodes

Electrolytes are preferentially attracted to highly chemically active metals – called anodes. When a current flow is created between a highly active and a less active metal, the electrolytes move the electrons from the anode towards the less active metal, causing the anode to corrode more quickly and the cathode corrode more slowly. This process is used to slow galvanic corrosion by intentionally introducing a highly active metal to act as a sacrificial anode.

- Less chemically active metals are called cathodes and include platinum, titanium, stainless steel, and silver.
- The more chemically active metals (anodes) include zinc, magnesium, and aluminum alloys.

Preventing galvanic corrosion

Galvanic corrosion can often be prevented through good design and planning. Start by choosing compatible metals to potentially avoid the problem altogether. If that's not possible, coatings and non-conductive barriers are an option.

CHOOSE COMPATIBLE METALS

If possible, choose metals that are compatible and less likely to create conditions favorable to galvanic corrosion. There are two things to consider: their distance on a galvanic table, and their difference in anodic index.

- Choose similar, compatible metals whenever possible
- Use metals close to each other on the anodic index (conditions dependant)
- If you have to use dissimilar metals, try to make the surface area of the anode larger than the cathode to slow corrosion

A galvanic table ranks metals based on their tendency to interact galvanically, with galvanic corrosion more likely when the metals are further apart on this table. The galvanic table is meant as a guide as it doesn't take into consideration other factors that might impact the corrosive potential of the metals.

The table lists the most active anode metals first and the least active cathodes last and different versions of the table are available for different environments or electrolyte solutions. Included below is the table for low oxygen seawater.

Galvanic series table for stagnant (low oxygen) seawater

1. Graphite
2. Palladium
3. Platinum
4. Gold
5. Silver
6. Titanium
7. Stainless steel 316 (passive)
8. Stainless steel 304 (passive)
9. Silicon bronze
10. Stainless steel 316 (active)
11. Monel 400
12. Phosphor bronze
13. Admiralty brass
14. Cupronickel
15. Molybdenum
16. Red brass
17. Brass plating
18. Yellow brass
19. Naval brass 464
20. Uranium 8% Mo
21. Niobium 1% Zr
22. Tungsten
23. Tin
24. Lead
25. Stainless steel 304 (active)
26. Tantalum
27. Chromium plating
28. Nickel (passive)
29. Copper
30. Nickel (active)
31. Cast iron
32. Steel
33. Indium
34. Aluminum
35. Uranium (pure)
36. Cadmium
37. Beryllium
38. Zinc plating
39. Magnesium

The **anodic index** shows the electro-chemical voltage between a metal and gold.

- In harsh environments with high humidity or saltwater there should be no more than 0.15V different between the metals
- In less harsh environments without temperature or humidity controls there should be no more than 0.25V different between the metals
- In temperature and humidity-controlled environments, a difference of 0.50V is possible

Metal	Index (V)
Gold, solid and plated; gold-platinum alloy	−0.00
Rhodium-plated on silver-plated copper	−0.05
Silver, solid or plated; monel metal; high nickel-copper alloys	−0.15
Nickel, solid or plated; titanium and its alloys; monel	−0.30
Copper, solid or plated; low brasses or bronzes; silver solder; German silvery high copper-nickel alloys; nickel-chromium alloys	−0.35
Brass and bronzes	−0.40
High brasses and bronzes	−0.45
18%-chromium-type corrosion-resistant steels	−0.50
Chromium plated; tin plated; 12%-chromium-type corrosion-resistant steels	−0.60
Tin-plate; tin-lead solder	−0.65
Lead, solid or plated; high lead alloys	−0.70
2000 series wrought aluminum	−0.75
Iron, wrought, gray, or malleable; low alloy and plain carbon steels	−0.85
Aluminum, wrought alloys other than 2000 series aluminum, cast alloys of the silicon type	−0.90
Aluminum, cast alloys (other than silicon type); cadmium, plated and chromate	−0.95
Hot-dip-zinc plate; galvanized steel	−1.20
Zinc, wrought; zinc-base die-casting alloys; zinc plated	−1.25
Magnesium and magnesium-base alloys, cast or wrought	−1.75
Beryllium	−1.85

COATINGS AND NON-CONDUCTIVE BARRIERS

Coating either or both metals can protect it from electrolytes and therefore galvanic corrosion. This can work in 2 different ways:

1. A metallic coating becomes the sacrificial anode to protect the metal it is coating – which is a common use for zinc coatings.
2. A non-conductive material separates the two metals, removing the electric connection between them.

- Common coatings to prevent galvanic corrosion include:
  - Zinc plating
  - Galvanized dipped metals
  - Ecoating
  - Powder coating
  - Dacromet
  - Anodizing
- If only one metal can be coated it should be the cathode
- The thickness of a coating is important if it is intended to act as a sacrificial anode
- Common non-conductive insulators include polymer or elastomer-based bushings, washers, gaskets, or coatings.
- A non-conductive barrier must remain intact. Damage or degradation will lead to corrosion.
- A non-conductive barrier must break all contact between the metals in order to be effective.