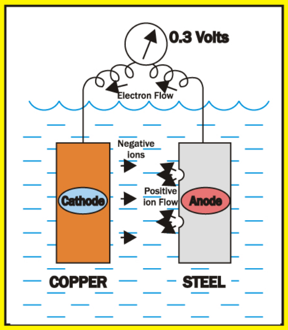
# Basics of Corrosion

## Galvanic Corrosion

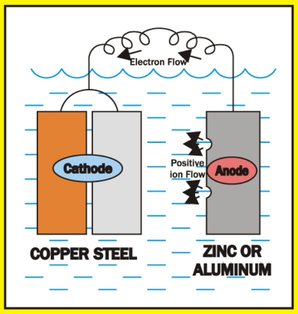
When two different metals (copper and steel in the example) are in contact, electrons will flow from the more negatively charged metal (anode) to the more positively charged metal (cathode). The voltage generated between copper and steel would be 0.3 volts. The circuit is completed by the loss of positively charged ions from the anode into the electrolyte and the negatively charged ions at the cathode.




This release of small particles (ions) into the water is much more rapid than with one metal alone, and is limited to the corrosion of the steel. The cathode material (copper) is protected.

## Sacrificial Anode

If you want to protect both types of metal you must add a third more active metal. The most common metal is zinc although magnesium and aluminum are also used. This active metal becomes the anode for both metals. The zinc or aluminum sacrifices itself to protect the other two metals, hence the term "sacrificial anode."




## Zinc Anodes

Zinc is the most common material used. Zinc anodes are not very effective in freshwater and can stop working after only a few months if not made to U. S. Military specifications. It is a good policy to change them regularly, even if they look OK. Remember, if an anode doesn't wear away it is not working!

## Navalloy®(Aluminum) Anodes

The aluminum alloy used in anodes is very different from normal aluminum. It includes about 5% zinc and a trace of Indium, which prevents the build up of an oxide layer.
Aluminum anode alloy provides more protection and lasts longer than zinc (see chart on page 2). It will continue to work in freshwater and is safe for use in salt water. Aluminum is the only anode that is safe for all applications.

## Magnesium Anodes

Magnesium is the most active metal on the Galvanic scale. It can be used in freshwater, but care must exercised. Magnesium can over-protect aluminum hulls or outdrives in salt or brackish water or even polluted freshwater, causing paint to be lifted with resulting corrosion. Even a few hours immersion can cause severe damage.

## Anode Do's and Don'ts

**DO:**

Change your anodes when they are 50% corroded. A "Wear Indicator" anode will help tell you when to change.

Make sure they make good electrical contact with the metal to be protected - remove paint and clean the mounting surface.

Protect trim tabs individually (do not bond). Although they are usually made from stainless steel they can still corrode and need sacrificial anodes.

On sterndrives be sure to use new fasteners (usually supplied with anode) - even stainless bolts fail as a result of corrosion.

Keep a sterndrive immersed in the water so that the anodes can work.

**DON'T:**

Do not paint anodes. They will not work!

Do not mix anode types - aluminum anodes will try to protect zinc anodes on the same bonding circuit.

Do not use zinc anodes on aluminum outdrives - they will not provide the correct protection.

Do not use magnesium anodes on outdrives in salt or brackish water as they will "overprotect" the aluminum.

## Why Do Some Metals Corrode More than Others?

All metals tend to be oxidized (corrode), some more easily than others. The relative rate can be plotted on the GALVANIC SERIES.

## What Factors Affect Corrosion?

Note: some of these factors can vary microscopically at the surface of the metal.
Conductivity of electrolyte - seawater is a good conductor and freshwater a bad conductor, so corrosion is worse in seawater.
Amount of oxygen - Generally, corrosion rates increase in proportion to the amount of oxygen in the water. However, cracks and crevices, which are areas starved of oxygen, become anodic and corrode also.
Presence of pollutants - increases corrosion.
Flow Rate - Will increase corrosion rates. Pitting in stainless steel is reduced however.
Temperature - Higher temperature increases corrosion rates - approximately doubling for every 10°C (18°F).
Stress - Metal under tensile stress (stretched) in combination with corrosion can suffer sudden failure due to stress cracking.
Presence of bio-organisms - There are various types of microorganisms that can contribute to corrosion, either by removing protection or causing a corrosive environment.

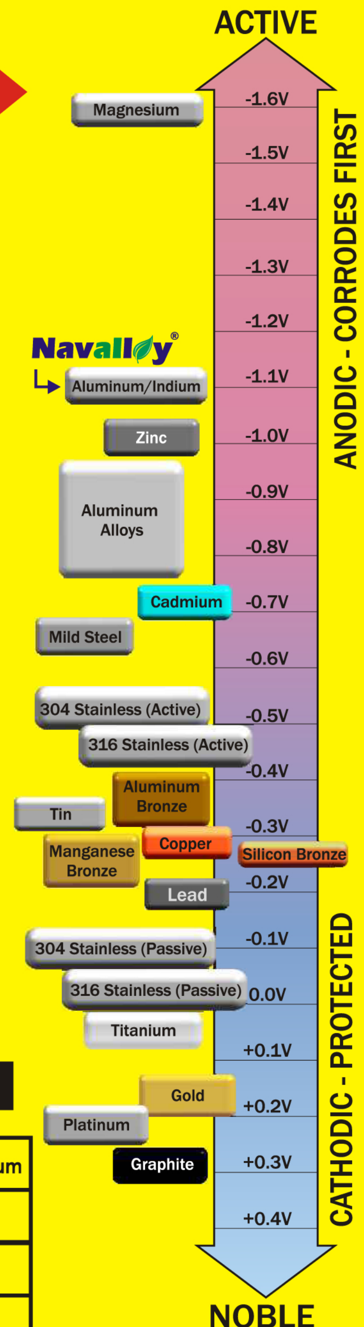
## Area and Weight of Anodes

The surface area of the sacrificial anodes determines how much protection (amperage) you get. The weight determines how long they will last. Different anodes have different capacities measured in Amp Hours per Pound.

## Cathode to Anode Ratio

The ratio of the area of the cathodic (protected) surface to the anodic (corroding) surface is critical in galvanic corrosion. The smaller the area where the anode is giving up material, the faster it will take place. Ideally the anodic area should be much bigger than the cathodic area. This ratio can be improved by painting the cathodic surface.

## Which Metal Corrodes First?
## Galvanic Series




## Sacrificial Anode Materials

| | Zinc | Navalloy® Aluminum | Magnesium |
|---|---|---|---|
| Voltage (in seawater) | -1.03V | -1.1V | -1.6V |
| Relative Life (Zinc = 100 Same Size) | 100 | 150 | 30 |
| Relative Density (Zinc = 100) | 100 | 42 | 27 |
| Mil.Spec. | MIL-A-18001 | MIL-A-24779 | MIL-A-21412 |

Navalloy® anodes provide better protection than zinc, have the longest life and are much lighter.

## Which Anode Material?

| | Inboard | | | | Outdrive |
|---|---|---|---|---|---|
| Hull | Wood | Fiberglass | Aluminum | Steel | All |
| Freshwater (Pure) | Alum | Alum/Mag | Alum | Alum/Mag | Alum/Mag |
| Freshwater (Polluted) | Alum | Alum | Alum | Alum | Alum |
| Brackish | Alum/Zinc | Alum/Zinc | Alum/Zinc | Alum/Zinc | Alum |
| Salt | Alum/Zinc | Alum/Zinc | Alum/Zinc | Alum/Zinc | Alum |

Navalloy® aluminum anodes are safe in any type of water. Magnesium must not be used on aluminum outdrives or hulls in saltwater.