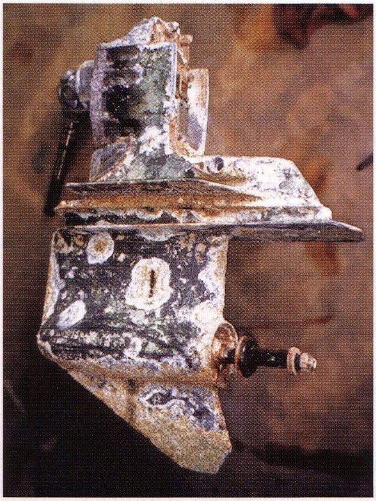
The Current Scoop on Galvanic Corrosion

Pitting on the outdrive's lower unit was first noticed by the boat's owner in the spring of 2002. The following year, "some degree of corrosion was evident" on the same outdrive, so the owner slapped on a fresh coat of paint and hoped for the best. He was making a big mistake.

By the next spring, the price of ignoring an obvious warning sign became painfully evident: the outdrive was so badly corroded it would no longer go into gear.

The reason was simple: the lack of an anode, which should have been sacrificed to protect the aluminum outdrive from galvanic corrosion. The last anode, it seems, had been placed on the outdrive in 2001, which is an eternity when two dissimilar metals are immersed in saltwater.

Connecting dissimilar metals in an electrolyte creates a direct current (DC) "battery" and the scientific explanation as to why galvanic corrosion occurs has to do with things like migrating electrons and electrical potential. As a practical matter, a boat owner need only be aware that dissimilar metals, especially dissimilar metals left unprotected below the waterline, can cause horrendous corrosion problems to the least noble or "anodic" metal. As a general rule, the more dissimilar the metals (see chart), the more current will be created and the more likely galvanic corrosion will occur.



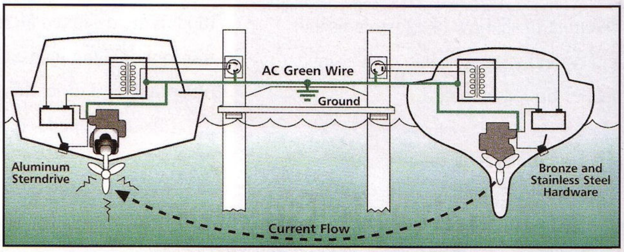
If you want to see what would happen to an anodic fitting if it wasn't protected, look at a wasted anode. In this case, the anode (zinc) is long gone, so that the aluminum outdrive, or what's left of it, looks like a wasted anode. Note that corrosion is not covered by insurance.

Saltwater is a more effective electrolyte than freshwater, which means that galvanic corrosion takes place more quickly in saltwater. Galvanic corrosion can even occur when dissimilar metals are joined above the waterline, since spray and moist salt air will act as an electrolyte. A sport fisherman in Florida, to use one dramatic example, had a Zamac (chrome-plated zinc) fuel fill mated with a galvanized steel nipple below the deck. Saltwater washing over the fittings eventually corroded the Zamac, which then allowed gasoline to pour into the bilge. The boat exploded when the engine was started but fortunately nobody was hurt.

There are two things to remember about fittings above the waterline. First, don't install Zamac fittings whenever a boat is going to be used in saltwater. Avoid conjoining dissimilar metals, especially two metals that are far apart on the galvanic scale. When dissimilar metals must be used together, one can usually be insulated from the other. A stainless steel halyard winch, for example, can be insulated from an aluminum mast with zinc chromate, polysulfide, a wood pad, or an inert insulating material like nylon or Tufnol.

But below the waterline, when you have a stainless steel shaft and a bronze prop, which can't be isolated, you'll need an anode — either zinc, magnesium or aluminum — that will be sacrificed to save the fitting. Zinc can be used in saltwater; magnesium can be used in freshwater (never in salt or brackish water); but the most widely affective anodes these days are being made of aluminum, which can last up to 50% longer, and remain active anywhere — in fresh, brackish and saltwater. How, you may ask, does an aluminum anode protect an aluminum outdrive? The answer is that an anode is made with an aluminum alloy that is significantly different (more anodic) than the alloy used on an outdrive.

A word of warning: Don't mix anodes! If you decide to use aluminum anodes, then use only aluminum anodes throughout the boat. When two different anodes are used, one (the least noble) will protect the other, which then won't do it's job.



When two or more boats are connected to shore power, one side of the necessary circuit required to form a galvanic couple is provided by the AC green grounding wire, which is also connected to the boat ground system, engine, and underwater hardware. The seawater electrolyte provides the other side of the circuit. Galvanic current flowing around the circuit will corrode the least noble metal between the two (or more) boats, in this case an aluminum sterndrive.

Likely candidates for an anode include shafts, rudders, outdrives, engines, and trim tabs. Replacing anodes is typically done annually, sometimes semi-annually, especially on outdrives. (The exception may be on boats kept in uncrowded, northern harbors where the water is colder and anodes typically last longer.) Anodes that are more than half-dissolved should be replaced.

It's a common misconception that as long as some of the anode remains, it will still be doing its job. It may not be. An anode that is crumbling isn't as effective and may no longer be preventing corrosion.

You may be able to get longer-lasting protection by using two anodes, for example on a shaft, but they should be inspected midway though the season. Conversely, an anode that doesn't appear to be worn at the end of the season is suspect and may contain impurities that kept it from doing its job. Before changing suppliers, make sure the anode is snug against the metal it is supposed to be protecting; an anode that is even slightly loose won't be doing its job. An anode should never be painted.

Galvanic Series

Using the list below, you can get a fairly good idea how vulnerable a fitting might be to galvanic corrosion. A fitting made of a metal at the bottom of the scale will waste away in seawater if it is in contact with a fitting made of a metal at the top. Fittings will be damaged more quickly in saltwater than in freshwater, but it is also possible for galvanic corrosion to take place when dissimilar metals are out of the water. In general, the farther apart the two metals are on the scale, the more likely the anodic metal will be damaged.

Cathodic:	Graphite
	Monel
	Stainless Steel
	Bronze
	Brass
	Copper
	Tin
	Mild Steel
	Aluminum
	Zinc
Anodic:	Magnesium

Note: Galvanic series are frequently published that seem to disagree slightly. For example, some brasses may be listed ahead of bronze, or vice versa. This has to do with variations of the alloys, as well the electrolyte.

Corrosion and Galvanic Isolators

Let's say you dutifully put anodes on your outdrives in early spring, which, in years past, has always been sufficient to protect the outdrives from galvanic corrosion for an entire season. But midway through the season, the anodes are mysteriously gone; dangling screws are the only indication they were ever there. The outdrive is no longer being protected. What happened?

The likely answer has to do with shore power. Galvanic corrosion occurs whenever two dissimilar metals are immersed in electrolyte and the metals are connected by direct contact *or by an external wire*. In the case above, the external wire was the shore power cord.

The rules governing galvanic corrosion are exactly the same regardless of whether they're in direct contact or connected by the shore power ground wire. There won't be corrosion if all of the underwater fittings on all of the boats are made with the same metal — bronze, for example. If, however, there is an imbalance of metals among the boats, which is likely, then galvanic corrosion starts dissolving the least noble metal.

For example: several large cruisers are plugged into shore power on the same pier as an inboard center console with an aluminum outdrive. The cruisers all have bronze and stainless steel fittings under the water (rudder, shafts, props) and no anodes. If there is an anode on the center console's outdrive, the anode will begin to quickly waste away. As the anode is dissolved, the least noble metal on any of the connected boats — in this case, the center console's outdrive — will begin corroding.

Another possible situation: Several boats with aluminum outdrives are plugged into AC power on the same pier. Some are protected with anodes and some aren't. Initially, outdrives that aren't protected will be protected by the other boats' anodes. Conversely, the protected boats will find their anodes are dissolving quicker. All it takes is one boat that isn't protected to affect other boats that have less noble underwater fittings. As the anodes are worn down, all of the boats' outdrives will be vulnerable to galvanic corrosion.

The source of the corrosion isn't always apparent and there is no instant fix, short of constantly replacing your boat's anodes. If you unplug the shore power cord, you (and the boat) won't have the benefit of AC appliances like battery chargers and refrigeration. Another quick fix — interrupting the circuit by cutting the green grounding wire on your boat — means the AC electrical system will no longer be grounded and anyone in the water near your boat runs the considerable risk of being electrocuted by stray AC current. Even a few milliamps of AC electricity in the water can paralyze a swimmer's muscles, causing him or her to drown.

The most common way to reliably and safely interrupt the circuit is to install a galvanic isolator. Galvanic isolators attach to the green grounding wire to limit galvanic current flow (up to about 1.2 volts) between neighboring boats while also allowing dangerous AC current to safely pass through to the ground on shore. The most efficient galvanic isolators have a capacitor, which allow the isolator to continue to block galvanic DC current flow even if there is a small AC current leakage on the ground wire.

Protection can also be provided, typically on larger boats and aluminum boats, with an isolation transformer. The latter is much more expensive but will also protect the boat's AC system from shoreside power surges.

Isolators are rated in two sizes: 30-amp and 50-amp. A boat with a 30-amp cable needs a 30-amp isolator. A boat with a 50-amp cable needs a 50-amp isolator. If a boat has two shore power inputs, it needs separate 30-amp isolators for each input.

Just when all of this galvanic corrosion business starts to make sense, there may be instances involving corrosion that defy logic, such as when a more noble metal becomes severely corroded, leaving a less noble metal unharmed. This is likely the effect of stray current corrosion, which can drive normally cathodic metals to become anodic (see below).

— ***By Bob Adriance***

Stray Current Corrosion

Q: If placing two dissimilar metals in an electrolyte creates low-voltage DC current that can wreck unprotected metals in a matter of months, what would happen if all of the current from a boat's 12-volt batteries were to somehow come in contact with metal?

A: The metal fittings in contact with the bilge water would be in a lot of trouble — and are likely to be wrecked in a few days or even hours.

While less common than galvanic corrosion, stray current corrosion is typically swift and deadly. There have been boats that were sunk when someone carelessly left a battery cable dangling in bilge water. All of the underwater fittings (bronze) were pink and nearly crumbling in only a few days. In other cases, crimped wires in the bilge were "leaking" 12-volt current into the bilge water.

Stray current is one reason DC wires should always be well above bilge water levels. (AC wires must also be kept well away from the bilge! Although they don't cause corrosion, AC wires in water pose a dangerous shock hazard.)

If a DC wire must be left in the bilge (e.g., mast wires left short at the base), they should be enclosed in a weatherproof junction box to seal out moisture, or individually sealed in heat shrink tubing and secured as high as possible. Liquid electrical tape or corrosion inhibitor sprays can also help to seal terminals from dampness that may infiltrate enclosed junction boxes.