An Ode to Zinc and Aluminum

BY JACK TAR

When placing an order for haul out and bottom paint with his local boatyard, Billy Boater said, "Oh, yeah. While it's out, let's replace the zincs."

Billy's reference to a sacrificial anode as a "zinc" is based on generations of experience in combating galvanic corrosion. Absent any other instruction, it's likely that the boatyard will indeed replace Billy's existing but partially spent anodes with a zinc alloy.

Traditionally, Billy Boater was taking an important step to preserve critical underwater metal components such as props, shafts, rudders, and through hull fittings.

When any metal is immersed in a conductive medium (like water) it will generate an electrical voltage. When different metals are immersed in the same medium, they produce different electrical voltages. By virtue of the laws of physics, and to the constant frustration of mariners everywhere, electrical current will flow between any two materials with different voltages, or "electrical potential." Electrons flow from the anode (the least noble metal with the most electrical potential) to the cathode (the more noble metal). The transfer of electrons introduces galvanic corrosion, and the least noble metal will virtually seem to dissolve as it degrades and disappears.

Without protection, critical components will weaken, break or fail. For example, a bronze propeller on a stainless steel shaft would corrode very quickly unless an even more electrically active, or less noble, metal is supplied. The sacrificial anode, traditionally zinc, becomes the terminal point of the electrical current, sacrificing electrons to leave the bronze prop unscathed. If all the metals used in a boat were the same, there wouldn't be any reason to worry about galvanic corrosion, but the best metal for a prop is seldom the best choice for a shaft, and dissimilar metals are frequently placed in contact in marine applications.

Should Billy Boater still be using zinc for his sacrificial anodes? Perhaps not. Even though we have relied on zinc for most boats in most aquatic environments, there have been some changes. New materials, new environmental concerns, and more extensive research into controlling galvanic corrosion are increasingly indicating that other materials may do the job better, and at a lower cost. Some of the variables depend on a vessel's construction, and the type of water in which a vessel is operated is a critical factor as well.

Two metals available for use as sacrificial anodes are more electrically active (i.e. less noble) than zinc. When immersed in seawater, zinc generates a negative voltage of 1.05. Aluminum alloy generates a negative 1.1 volts, while magnesium generates 1.6 negative volts.

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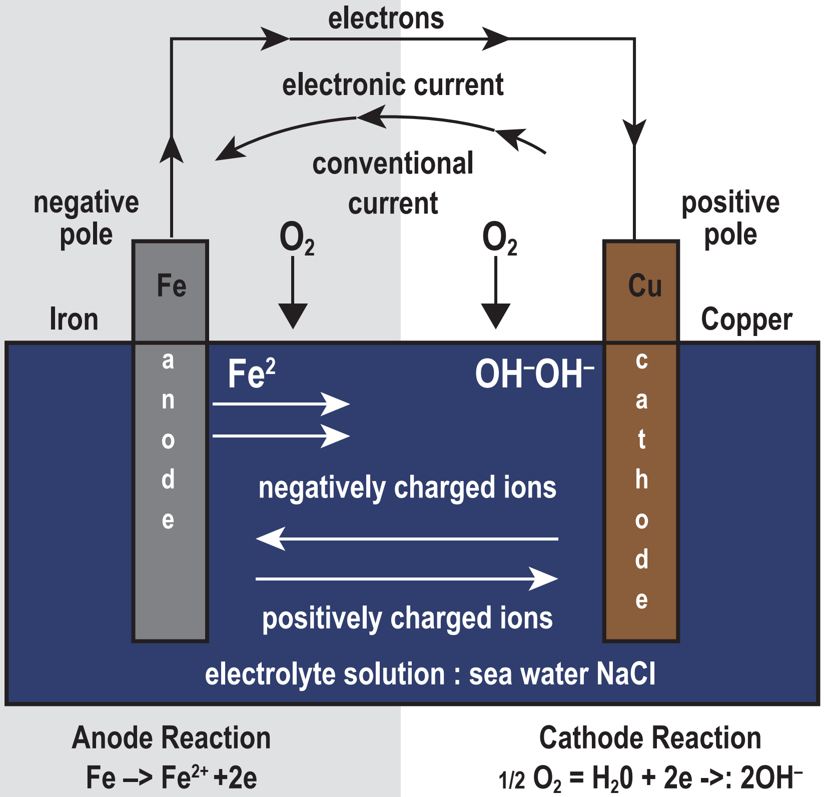
Above: Aluminum prop nut for Mercury outboard. Below: Effects of galvanic corrosion on a prop shaft.

Magnesium anodes are very effective in fresh water, but become so "hot" in the more conductive medium of saltwater that it is inadvisable to use magnesium on any vessel used in salt or brackish water. Even for vessels used exclusively in fresh water, some cautions apply. Using too much magnesium on a boat with an aluminum or wooden hull can literally "overprotect" the boat. Among other effects, excessive protection voltage can literally peel the paint off a hull. It's much more difficult to "overprotect" a fiberglass hull, and magnesium may be an excellent choice for a fiberglass boat used exclusively in fresh water.

Zinc performs well in most saltwater environments, and is safe for use with fiberglass, wood, steel, or aluminum hulls. Other advantages include easy availability and possibly lower costs. Zinc has long been the default choice for sacrificial anodes, but we may be at one of those historic points where technology trumps tradition. There are some downsides to the use of zinc in freshwater; something that should be of concern to the thousands of Seattle area boats that spend most of the year moored in fresh water and venture out through the locks for several weeks, or less, most years.

Zinc anodes are notorious for acquiring a coating of "scum" in freshwater applications. The coating actually insulates the zinc and prevents it from doing its job. Boaters moored in fresh water have been heard bragging about the long service life of their sacrificial anodes, yet many of these boaters may not be aware that the zincs are lasting a long time because they literally are not working.



Another downside associated with traditional zinc is cadmium pollution. While a sacrificial anode may be labeled "zinc," it is customarily a zinc alloy that includes cadmium. Cadmium is a fairly nasty substance. Once this heavy metal enters the food chain, it just transfers from organism to organism. There are specific dangers to human health associated with cadmium. All the while a zinc sacrificial anode is galvanically corroding on a boat, small amounts of cadmium are being released into the water.

Cadmium pollution is one of those "collective" concerns we need to recognize when we boat. It's unlikely that enough cadmium would ever leach out of the zincs on our individual boats to make a difference in the local environment, if we had the only boat in that environment. The same is certainly true for copper in bottom paint, or other substances we release into the water. One boat? No real problem. Hundreds of boats in a concentrated area, such as a marina? People fishing from nearby piers? Potential problem. While it's easy to say, "Hey, my one boat isn't going to pollute the water so I don't recognize any personal responsibility," that doesn't really absolve us of our individual contributions to the collective problem.

Aluminum anodes are becoming increasingly popular, for several good reasons. Aluminum anodes work well in saltwater, and are less susceptible than zinc to "scumming over" in fresh water. Aluminum anodes can even protect aluminum components, such as sterndrives or aluminum props. Anode manufacturers formulate the aluminum to be just a bit more electrically active than the aluminum alloys used for props or stern drives. Aluminum anodes can be used for all types of hulls, including aluminum.

Aluminum anodes are considered more environmentally benign than traditional zincs.

Among factors discouraging the use of aluminum alloys is the initial cost of the anode itself. Boaters will appreciate that the cost of the anode will be small when compared with the cost of labor to install it, and the labor cost should be the same regardless of the anode material chosen. Surface area is a more critical factor than weight when considering the physics of a sacrificial anode. Metals are generally priced by weight, so while aluminum will be more per pound than zinc it is also 2 ½ times lighter than zinc and fewer pounds of aluminum will be required to achieve the same surface area.

A properly functioning aluminum anode can also be expected to last about 50% longer than a properly functioning zinc anode in most applications.

When should Billy Boater replace his zincs? When sacrificial anodes are reduced to about half of their original size it is time to replace them. Even if there may be "plenty of material left", proper anodic protection relies on a ratio of anode surface area to the surface area of the metal being protected.

Should Billy Boater replace his zincs with aluminum, or magnesium? He may do very well to consider his options. If Mr. Boater changes any of his current zinc anodes to another metal, he will want to change the rest of his sacrificial anodes to the same material simultaneously.

New anodes fitted to the transom and rudders.

Replacing the anodes would have been much cheaper than replacing this prop.