A white motorboat is shown on a trailer in a marina. The boat has a cabin with windows and a steering wheel. It is surrounded by other boats and a cloudy sky. The text is overlaid on the right side of the image.

This month Nikkulas looks at the warning signs to prevent your boat falling victim to corrosion.

How to beat ALLOY CORROSION

Aluminum is the favoured material for most small trailable boats for reasons such as lightweight, low maintenance and strength. What more could you ask for? Yes it sounds like a perfect combination. There is one serious potential problem you will have to manage correctly if you wish to enjoy your alloy boating experience and that is corrosion.

Yes it's true in the marine environment your aluminum boat can be attacked by this devastating and debilitating disease. This corrosion comes in two forms electronic and galvanic which if not detected can

become very hard to beat.

Most of us that have some knowledge of boat corrosion with electrolysis the most common on alloy boats, but in reality galvanic corrosion is more common on trailable aluminum boats. The symptoms of both types of corrosion are virtually identical. In each case a chemical reaction will occur and parts of your vessel will start disintegrating.

Electronic corrosion or electrolysis can only occur when a stray or external current is flowing between two metals via a conductive solution such as saltwater. The metals don't have to be in physical contact but the solution

such as saltwater transfers the current causing a reaction.

Galvanic corrosion occurs when two dissimilar metals are in contact with one another and then exposed to saltwater. In the past it was thought the two differing metals had to be immersed but recent studies suggest that even irregular exposure will result in galvanic corrosion.

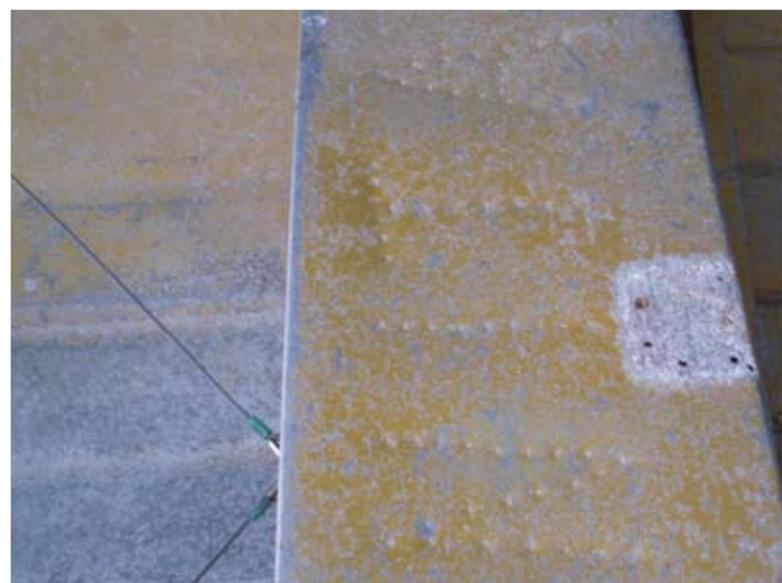
Ok enough of the typical stuff; both forms of corrosion are bad news for your aluminum boat. But why? In both cases the chemical reaction taking place results in the weaker metal on the 'Galvanic Scale' to react. The 'Activity Scale' is a list of metals ranked



OPPOSITE: Good condition, but notice the anchor corrosion starting.

THIS PICTURE: An example of the beginning of corrosion.

BELOW: Seat with pinholes caused by galvanic corrosion from a metal plate.



in order of their ability to resist corrosion .The higher up on the list the better, as they are able to resist corrosion. On the boating version of this ranked list Aluminum sits near the bottom of the list above magnesium and zinc. So if you have either form of corrosion on your aluminum boat the aluminum is going to start being eaten away first before brass, copper lead etc.

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The metals don't have to be in physical contact but the solution such as saltwater transfers the current causing a reaction.

It's not uncommon to find on aluminum boats differing metals in contact with one another. Structurally the brass base of an aerial fitted to the deck of an aluminum boat gets covered in spray and this saltwater solution is enough to start galvanic corrosion. The brass is the more resistant metal and metal in contact with the base starts to be eaten away.

A dropped sinker or a small brass swivel left trapped under the carpet or in the hull hidden by the supports of your tinny will also set off galvanic corrosion. I often think of this in boat designs that have many places these types of objects can be trapped and if undetected can cause all sorts of problems.

At the start of galvanic corrosion, the two metals appear to be welding or fusing together and can often be impossible to part. Then in the later stages the most alarming pinprick holes start to appear in the keel and

other areas under the water line.

I remember many times forcing surfboard wax into these tiny but annoying holes of my alloy dingy. After a while it reminded me of a sieve as the boat sat on the trailer draining out. Once this type of corrosion sets in it can become expensive to repair. In the extreme case the whole section should be cut out. Pin holes can be welded up but you still have to stop the cause of the problem.

MAINTENANCE

Aluminum corrosion can be prevented. After each outing hose down the entire boat with freshwater. Here's a tip, if you use a car wash you won't be breaking any council laws and the high pressure foam jets are perfect for removing built up salts. Top to bottom is the go but make sure you have the jockey well extended and fully up to allow the water to flow out of the transom drain hole.

When you attach your new hardware to your alloy boat such as rod holders, brackets etc make sure not to mix your metals. For example when attaching a transom mount transducer to an alloy boat, a plywood or Teflon pad is a good buffer between the hull and the transducer. Marine grade stainless is still the best for all screws nuts and bolts, etc used for these fittings.

Regarding the stray current, if you don't have a battery isolator switch then disconnecting both leads is an option when the boat isn't in use. This is of great concern to boats on moorings as the automatic bilge system should be still connected but the isolator switch is off. Don't take your battery leads off in this situation but get your electrical system checked out when you get an isolator switch fitted.

TO PAINT OR NOT PAINT.

To paint or not to paint Aluminum is a good question. I have been told



ABOVE: New alloy with painted sides and bare underside.

OPPOSITE: Another victim of galvanic corrosion.

that by painting alloy it does offer some protection but when it gets scratched or chips the small edge can provide a place for salt to build up. So once again if you paint it must be done correctly and any scratches chips repaired ASAP. However flecking paint may just be the result of poor undercoating or finishing coat.

There have been some boats on to the

market recently that have the natural alloy look. They generally have been sealed offering protection and a good cosmetic look therefore paint is not needed.

SPOTTING THE PROBLEM

The best way you could tell if there are any potential corrosion problems would be to lift up the floor and have a good look around. If there are hooks, sinkers, etc lying around then there's a good chance that the corrosion has already started. You may see the pinholes straight away but if you were to partially

fill the transom end of deck with water then (unless they have been plugged up with my old surf board wax trick) if the holes are present you will see the sieve effect. This is a great way to check for leaks when the boat is on the trailer but not practical for larger boats. Thankfully it is not as frequent on pressed alloy boats and even rarer in plate alloy.

If you take care keeping different metals apart and retrieve lead sinkers dropped under the floor then this is a good start to avoid aluminum corrosion.

WHAT'S THE TRUTH ABOUT ALUMINUM SACRIFICIAL ANODES?

A NEW SACRIFICIAL ANODE MATERIAL IS APPEARING ON THE SCENE – AN ALLOY OF ALUMINUM, ZINC AND INDIUM. IS IT AN IMPROVEMENT ON THE OLD TRIED AND TESTED ZINC?

First, what do sacrificial anodes do?

Sacrificial anodes “sacrifice” themselves by wasting away instead of the propeller, the propeller shaft, rudder, engine or other metal parts in or connected to the water being “eaten” away or wasting away due to the electrochemical process of corrosion.

Sacrificial anodes are relatively cheap pieces of metal. They are designed specifically to corrode instead of the more expensive metal parts of your boat corroding. Sacrificial Anodes, which are known as “active” metals, are chosen for this task.

Traditionally sacrificial anodes were usually made of Zinc, hence the name “zincs” but they can also be made from magnesium or a special alloy of aluminum. Anodes are very important, indeed essential, even when you trailer your boat, and will help to prevent very expensive damage to the metal parts of your boat that are underwater.

Sacrificial anodes come in all shapes and sizes but they all perform the same task. They have to be connected “electrically” - usually metal to metal - to the valuable metal parts on your boat that need protecting. Thus you will see these gray pieces of metal attached to rudders, outboard motors, propeller shafts etc.

The sacrificial anode forms the negative terminal of a battery and is connected electrically to the metal to be protected. Because the metal of the sacrificial anode is more active electrically, i.e. it wastes away; it forms the negative terminal (anode) of the battery in the electrolyte which is, for example, sea water. The anode is the terminal that will always corrode with its metal literally dissolving into the water. The positive terminal of this “battery” is of course the metal (cathode) that is being protected, e.g. the propeller shaft, propeller, engine etc. This whole process is known as galvanic corrosion. The saltier or more polluted the water, the more it will conduct electricity and the faster the sacrificial anode will be corroded.

You may hear the term “electrolysis”, which is often used to describe “galvanic corrosion” or “stray current” corrosion. This is an inappropriate use of the term, and has no relevance in the marine industry.

What metals are used in sacrificial anodes?

The three most active materials used in sacrificial anodes are zinc, aluminum and magnesium. They have different properties and uses.

The first property to consider is their **electrical potential**. All metals generate a negative voltage (as compared to a reference electrode) when immersed in water. The lower – the more negative - the voltage, the more active the metal is considered to be, for example:

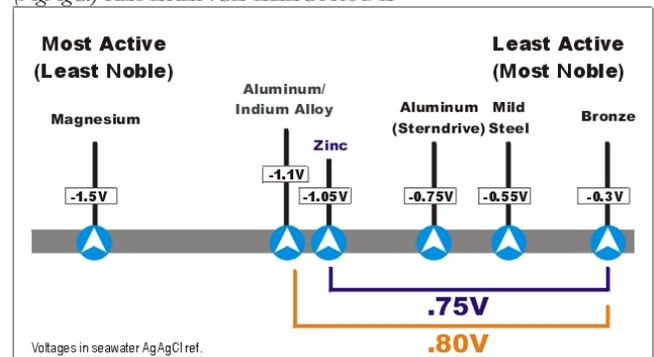
Magnesium generates -1.6 Volts, i.e. negative 1.6 volts.
Aluminum sacrificial anode alloy generates -1.1Volts
Zinc, -1.05 Volts

Now compare these voltages, by comparison, to metals commonly used in marine use:-

Bronze generates -0.3 Volts
Steel, -0.6 Volts
Aluminum, such as that used in hulls, sterndrives or outboard motors generates -0.75 Volts.

VOLTAGES IN SEAWATER OF MARINE-USE METALS

WITH REFERENCE TO A SILVER-SILVER-CHLORIDE (AgAgCl) REFERENCE ELECTRODE



In order to provide protection, the highest practicable voltage difference possible is required between the sacrificial anode and the metal to be protected.

For example, if zinc is used to protect a bronze propeller, a “driving or protecting voltage” of negative -0.75 volts will be available, i.e. zinc at -1.05 volts minus bronze at $-0.3 = -0.75$ volts.

If aluminum anodes are used this increases to -0.8 Volts.

Magnesium anodes increase this to -1.3 volts. The bigger the difference in voltage, the more protection you get. But, beware, some materials (aluminum) can be “overprotected” – more about that later.

The second property that is important is the **current capacity** of the anode material. The anode generates a voltage difference and this drives a current between the anode and the protected metal and through the water. It’s like having a bigger battery, the more capacity you have the longer it will keep protecting. Incidentally, for a particular anode, the rate of current flow is dependant on the surface area of the anode and the longevity depends on the mass. For the same size anode the relative capacities are:

Zinc: 100 (Taken as a datum e.g. this could be 100 days)
 Magnesium: 30
 Aluminum anode: 130 – 150 (Different manufacturers quote different ranges)

So if you used a magnesium anode in place of the “100 day” zinc anode it would only last 30 days.

The aluminum anode would last between 130 and 150 days.

The third property is **Quality of the Anode Alloy**

A word of caution about the metals used !!

Not just any zinc or any aluminum will work. Beware ! There are some imported anodes which are of questionable quality. It is important to ensure that the anodes you buy are made to the appropriate military or marine specification. Installing cheap or sub-standard anodes will undoubtedly cause increased and potentially very expensive corrosion problems. The most common material specifications are:

Zinc: MIL-A-18001K
 Aluminum: MIL-A-24779(SH)
 Magnesium: MIL-A-21412

The Winner so far?

It’s hard to pick a winner yet. Magnesium gives the highest voltage protection, but the aluminum lasts a lot longer (5 times as long as magnesium). The aluminum anode alloy is also a bit more active than the zinc.

So why is zinc is the most common material? Well, it was the simplest and cheapest material to use for many years, even centuries and it does do a good job in most salt water applications. Pure aluminum is useless as an anode material because it immediately forms an oxide layer that insulates and

protects it. Aluminum alloy was not developed until the middle of the 20th century after it was discovered that adding small quantities of zinc and indium (one method) to aluminum overcame the problem of aluminum forming an insulating oxide coating – which stopped the anode working effectively. It takes time for new ideas to catch on!

TABLE 1 – ANODE MATERIALS

	Zinc	Aluminum	Magnesium
Voltage (in seawater)	-1.05V	-1.10V	-1.6V
Relative Life (Zinc = 100)	100	130-150	30
Relative Density (Zinc = 100)	100	42	27
MIL SPEC.	MIL-A-18001K	MIL-A-24779(SH)	MIL-A-21412

What are you protecting?

The type of boat that you have will determine how careful you need to be. A fiberglass hull with an inboard engine will need much less protection than an aluminum hull or a boat with an aluminum Sterndrive for example. The surest way to determine whether your boat is fully protected is to measure its cathodic protection voltage or “hull potential”. This involves using a voltmeter, with one probe connected to the bonding system (red terminal) and the negative terminal connected to a reference electrode. You probably don’t have this equipment but don’t worry there are some simple guidelines.

Inboard boats with mainly bronze and stainless metal parts can be protected using zinc or aluminum anodes. Don’t worry about overprotecting them. You are only overprotected when the weight of the anodes is so great that your boat sinks! The voltage generated by zinc or aluminum anodes will not cause any damage – no matter how much anode material is added, the maximum voltage that can be generated is the voltage of the anode itself. You could also use magnesium in freshwater locations on fiberglass-hulled boats. Be careful using magnesium on aluminum or wooden hulled boats since you can overprotect them. Steel hulls can also be overprotected to the point where excessive protection voltage rapidly lifts the paint off the hull.

Sterndrives and Outboard Motors require a little more care. The sacrificial anodes have a difficult task, since they have to protect what is already a very active aluminum assembly. Initially the anodes for these units were made of zinc, but in response to corrosion problems, Mercury and Johnson/Evinrude/OMC started selling the aluminum anodes in the early 1990’s. Other manufacturers are switching to aluminum too. The small increase in protective voltage helps ensure that the sterndrive is protected. If you use zinc anodes you may even invalidate your warranty! Again, be careful using magnesium anodes since you can overprotect your sterndrive or outboard.

Where do you do your boating?

Another point to consider in the choice is the *type of water* in which the boat will be used. This can range from salt to brackish to pure fresh water.

Zinc in Freshwater. In freshwater zinc can form a coating. This quickly insulates the anode and stops it from working. You may think your zinc anodes are lasting a long time when in fact they have simply stopped working - stopped protecting!

Magnesium in Salt or Brackish water. Magnesium is so active that in salt water it can disappear very quickly. If used on an aluminum Sterndrive or outboard motor it can be positively dangerous. Aluminum is “amphoteric”, which just means that you can “overprotect” it. If you take your boat down river to the ocean with magnesium anodes you will probably have a catastrophe on your hands. The overprotection causes hydrogen bubbles to form under the paint on the drive resulting in the paint being blown off! You also need to be careful about putting magnesium anodes on an aluminum-hulled boat since the same thing can happen. Your freshwater may not be so fresh either. Acid rain and general pollution can cause the water to be much more conductive resulting in the same problems.

Aluminum - The Final Winner!

In our opinion the best all-round anode material is aluminum. Consider these points!

- Aluminum anodes are more active than zinc and are accepted by the major Sterndrive manufacturers as the best material to use.
- Aluminum anodes are not so active that they are dangerous in salt or brackish water as are magnesium anodes.
- Aluminum anodes will last longer because of their increased current capacity.
- Aluminum is the only anode material that can be used safely in all types of water.
- Aluminum anodes are 2 ½ times lighter than zinc making them much easier to carry home from the store!
- Aluminum is a much better alternative than zinc as far as the environment is concerned, since it is not considered a pollutant.

TABLE 2 – WHICH ANODE IS RIGHT FOR YOUR BOAT?

Hull Material	Inboard				Sterndrive/ Outboard
	Wood	Fiber/ glass	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

Some Hints

Don't Mix Anode Types. If you install different anode materials like zinc and aluminum, the more active anode (aluminum) will spend part of its effort protecting the less active metal (zinc). This will reduce the overall protection that you are getting. A classic mistake is adding a zinc transom anode to a Sterndrive equipped with aluminum anodes. Transom anodes are connected through the bonding system so make sure you install aluminum replacements.

Keep an eye on your anodes. When they get to half their original size replace them. If you leave them any longer there may not be enough surface area on the anode to deliver the protective current you are looking for. Judging when to change your anodes can be difficult!

Performance Metals has made life simple for the boat owner and introduced the patented **Red Spot Wear Indicator** anode. Performance Metals' range of aluminum alloy anodes have a Red Spot plastic indicator that appears on the surface when it is time to change.

Don't forget - it's better to spend a little on replacing your anodes on a regular basis than the thousands you might incur buying new propeller shafts or a new Sterndrive lower unit!

THE AUTHORS

Martin Wigg is president of Performance Metals, Inc. He was educated in the U.K. where he received his Bachelor of Science degree in Mechanical Engineering at Lanchester Polytechnic, Coventry in 1969. He worked at Rolls-Royce (Aero Engine Division) as a research engineer and later at Guest Keen and Nettlefold where he finished as Director of Engineering and Development. He obtained his MBA at Coventry University in 1977 and has worked in a variety of engineering, sales and marketing positions in the U.K. and the U.S. Prior to joining SciCast International, a Pennsylvania based die-casting company, and founding Performance Metals he worked at WPP as an advertising executive.

Paul Fleury is an ex-U.S. Navy nuclear plant technician who founded Marine Services, a marine electrical engineering and corrosion consulting company. He is an acknowledged expert in marine corrosion and has been retained by many leading marine manufacturers. He is certified by ABYC (American Boat & Yacht Council) as an Electrical Technician, by NACE (National Association of Corrosion Engineers) as a Certified Corrosion Technologist, by NAFI (National Association of Fire Investigators) as a Certified Fire & Explosion Investigator, and by NASBLA (National Association of State Boating Law Administrators) as a Certified Boating Accident Investigator.