Best Practices – Corrosion

This is a document assembled for J Boats owners as a guide through the often-confusing subject of corrosion onboard boats. The goal is to protect onboard metals from corrosion as much as possible – especially those underwater.

It has been assembled based on information in ABYC's Corrosion Certification Program, and with input from David Rifkin, of Quality Marine Services - who teaches the program for ABYC, and performs corrosion surveys. His contact information is listed at the end of this document.

The three main forms of corrosion discussed here are:

Single-metal corrosion
Galvanic corrosion
Stray Current (Electrolytic) corrosion

In most ways, preventative measures are the same regardless of the J Boats model you own, but we've tried to cover important differences between models as well.

Preventing Single-Metal Corrosion Onboard

Choosing Materials

Single-metal corrosion is the natural corrosion of a metal on its own in the marine environment. The first way to reduce corroding metals onboard is to use fewer metal components. J Boats models use Forespar Marelon (fiber-reinforced plastic) through-hulls and seacocks where possible. This reduces the number of freely-corroding metal components underwater, and also the number of fittings attached to the "bonding system." (See below.)

Silicon Bronze

Another approach is to use corrosion resistant metals. Silicon Bronze is used below the waterline for propellers, prop struts, and the J/95 centerboard. Bronze has a relatively high resistance to corrosion, and will last many years on its own underwater.

Stainless Steel

Various stainless steel alloys are also used below the waterline for prop shafts (and keel bolts), and above the waterline in lifelines, stanchions, chainplates, etc. Wherever stainless steel is used, it is important to ensure that salt water is not held motionless against it. Oxygen-starved water held against stainless steel will cause crevice corrosion. The most minor form of this appears when metal parts "bleed" rust stains on a boat, but taken to an extreme, crevice corrosion can cause chainplates to fail if water has penetrated the deck where they pass through and has been held against them for many years. Water can also get under the cover of vinyl coated lifelines and cause crevice corrosion there. This is why ISAF offshore regulations specify that wire used for lifelines be uncoated.

Aluminum
Aluminum is used above the waterline for spars and hardware, and below the waterline for saildrive legs. Below the waterline, one needs to be especially careful of protecting aluminum – more on this in the Galvanic Corrosion section below.

One form of aluminum corrosion that affects fuel tanks on older boats is "poultice corrosion." This is the tendency for aluminum to corrode wherever water is held against it. Leaks in aluminum fuel tanks are often the result of poultice corrosion that occurs at the spots where a tank rests on its supports. Dampness at those spots can, after several years, cause enough corrosion to create a pinhole leak in the tank.

Coatings and Treatments
Finally, we rely on coatings to isolate metals from the water. Saildrive legs and keels depend on barrier coats to protect them. Aluminum spars are painted, or treated by anodizing. Stainless steel is electropolished or passivated, and sprays such as Corrosion X ™ can be used on metals exposed to the salt air. In all cases, the coatings are more than just decorative and need to be maintained.

Preventing Galvanic Corrosion

Galvanic Corrosion occurs when two different metals are electrically connected (for instance, with a bonding wire inside the boat) and immersed in the same "electrolyte." An electrolyte is a solution, such as salt water, that contains ions and thus is electrically conductive. Fresh water, without many ions dissolved in it, is not as good a conductor. In galvanic corrosion, the more "noble" metal (on the Galvanic Table) becomes the "cathode" and is protected – at the expense of the other metal, which becomes the "anode," and corrodes. The rate of corrosion depends on the relative size of the metal pieces, the electrolyte they're in, and their relative positions on the Galvanic Table – more to come on that.

The first question you might ask is, "So . . . why connect the different metals exposed to the same water under the boat with bonding wires? Isn't that just asking for galvanic corrosion?"

Why Have a Bonding System?
It's true that leaving individual metal components isolated would eliminate the chance of galvanic corrosion affecting them (in fact, this is a common approach in Europe, and on boats build by J Composites in France). The trade-off is that the various underwater metals would need to be individually protected from Single-Metal Corrosion. The bonding system allows one "sacrificial anode" to protect multiple metal components (cathodes), which is far more convenient that needing to attach an anode to every different metal component in the water.). Furthermore, the bonding system provides multiple exit routes if lightning strikes the boat, and grounds everything so that electrical fault currents have a way to get to ground, and can trip a breaker – rather than leaving an isolated component charged (until a person touches it). Finally, there are increased

chances of Stray Current Corrosion without a bonding system (see below). If configured correctly, a bonding system is a great asset to the boat.

Choosing Sacrificial Anodes

There are three common materials used for sacrificial anodes – Zinc, Magnesium, and special Aluminum alloys (with Zinc and Indium added). When commissioning any boat, it's important to consider the type of water where the boat will be used (fresh, brackish, or salt). Zinc anodes should only be used in salt water; in fresh water, they can become coated with Zinc Hydroxide – a white crust that insulates them and stops them from working as anodes. Magnesium can be used in clean fresh water, but is too "active" for polluted fresh water or brackish/salt water, and can actually overprotect and damage a saildrive leg in those conditions. Aluminum anodes can be used for all types of water, and are becoming increasingly common. All three types of anodes are available for prop shafts or saildrives. Dealers and/or their commissioning yards should already be aware of the best anodes for their sailing area, and be sure all boats are commissioned accordingly.

After choosing the correct anode, it's important to ensure that it has enough surface area to do the job. The "job" depends on the type and surface area of the metals it's protecting, which is why it's important to seal lead keels and aluminum saildrive legs so that the anode isn't struggling (and failing) to protect large, exposed metal surfaces. (At the same time, make sure nobody paints the anodes on your boat – sealing them off from the water!)

Check Your Anodes Regularly!

A key thing to check during the season is the rate of corrosion of the anode on your boat. If the anode is rapidly depleting (called "wasting"), it may be trying to protect too much, (or there could be a small stray current issue onboard). Conversely, if the anode isn't corroding much at all, (especially if you have a zinc anode that has turned white in fresh water), you may have the wrong type of anode or a break in your bonding system – which could be leaving other metals unprotected.

Determining if your Sacrificial Anodes are Sufficient

Another good check (which sounds more difficult than it is), is to measure the "hull potential" - the voltage between the bonding system and a "reference electrode" hung off the side of the boat in the water. This tells you whether the size/type of the sacrificial anode is sufficient. For a boat with a saildrive, the hull potential should be -950 to -1100 millivolts, and for a boat with a conventional shaft and propeller, the reading should be between -750 and -1100 millivolts.

While this check is usually done by a corrosion surveyor or marine electrician as part of a specific corrosion survey, anyone can learn to do it using only a multimeter and the reference electrode. Reference electrodes, and a guide to this process are available through BoatZincs.com. http://www.boatzincs.com/

A more permanent approach is to install a corrosion monitor to check the hull potential continuously. Electro-Guard is one source for monitors, and others can be found online. A link to Electro-Guard is: http://www.boatcorrosion.com/index.html

And if you're plugged-in . . .

For boats plugged-in to shore power at marinas, there is another possible cause of rapidly depleting sacrificial anodes. The green grounding wire in your shore power cord is connected to your bonding system, and connects to the marina's grounding system as soon as you plug in. The same is true for other boats that are plugged in, so your boat actually becomes connected with all of the other boats through the grounding system. If the other boats' sacrificial anodes are insufficient to protect their onboard metals, your anode may start corroding to protect the metals on their boats as well as yours. Now imagine what can happen if there are 50 boats plugged in . . .

(This can even happen if you do not have a shore power system installed, but are using a portable battery charger plugged-in to a dock receptacle to charge your batteries. This is not recommended for many reasons, but you also run the risk of forming a connection to the marina's ground system – and to other boats.)

The solution to this problem is to install a Galvanic Isolator (GI) in your boat's shore power system. A GI blocks low-level DC current caused by galvanic action, while still allowing any significant AC (shore power) current to flow if an electrical fault occurs. New J/111's and J/95's with shore power systems are equipped with GI's from Dairyland Electrical Industries. http://www.deimarine.com/

Checking for Problems when You're Plugged In

The reference electrode mentioned above can also tell you if your zinc is protecting other boats in the marina, or if your GI is working. When you plug in, if your hull potential jumps in the positive direction (less negative), your anode is corroding to protect the other boats. If you have a GI, there should be no change in your hull potential when you plug in, unless the GI has either failed or been bypassed by another connection to the marina's ground system. In that case, it's time to get an ABYC-Certified marine electrician involved.

How the Galvanic Isolator can be Bypassed

Any other connection to the marina's grounding system can create a way for galvanic current to bypass the Galvanic Isolator. Cable TV or telephone hookups can create a separate path, and any connection between the AC neutral and AC ground wire onboard the boat could do the same thing. There is typically a ground/neutral connection at sources of power, so when plugged into shore power, AC generators and inverters onboard must be isolated from the shore power system. While finding the bypass might be difficult, detecting it is easy using a reference cell - as mentioned above. If your hull potential changes when you plug in, you've got a problem.

Galvanic Corrosion Inside Engines

Remember that sacrificial anodes only protect other metals immersed in the same electrolyte. The salt water flowing through the enclosed spaces of an engine or saildrive is effectively a separate "ocean" from the one outside the boat. Many engines or saildrive housings are equipped with "pencil zincs" which are threaded into the engine block and immersed in the cooling water. These need to be checked regularly, and need to have an electrical connection to the engine block – they should not be installed with Teflon tape or sealant that may isolate them.

And Above the Waterline . . .

Of course, galvanic corrosion occurs out of the water as well – wherever two different metals are joined and subjected to salt spray. Stainless steel fasteners tapped into aluminum spars are perfect examples. In that case, if you can isolate the metals from each other electrically, you can prevent the corrosion. Using Duralac, or Tef-Gel on stainless fasteners in aluminum can help to prevent corrosion there.

Preventing Stray Current Corrosion

On your own boat . . .

Stray current corrosion can happen when a frayed DC positive conductor or loose connection comes in contact with an underwater metal fitting, or with the bilge water around a fitting. It can be <u>very</u> damaging – causing drastic, rapid corrosion. However, this will only damage the fitting if it can become charged differently than the other underwater metal components on the boat and a circuit develops using the boat's wiring and the water under the boat.

Here's where the bonding system comes to the rescue. The green wires connecting all underwater metals prevent any one metal component from becoming charged differently than any other – so there can be no stray current corrosion of those fittings. Furthermore, they provide a path for the DC stray current to get back to the battery (where it wants to go), and it's likely that this will trip a breaker in the process. If the level of current is very small, for instance from a bilge pump leaking a small amount of current into the bilge, the breaker will not trip, but you'll notice your batteries running down – an annoying electrical problem, but not a damaging corrosion issue thanks to the bonding system.

So, to guard against stray current corrosion, make sure the bonding system is intact, and be careful about sources of stray DC current. One way to check for stray current is to check for any current running to/from the batteries when breakers are on, but the components they are powering are not operating. Some components may interfere with this test by drawing small amounts of current (say, for keeping memories intact), but others should not be drawing any power. For a bilge pump wired directly to the battery, just check when the pump isn't running. If you have a reference electrode mentioned above, you can also check for changes in the hull potential when various DC electrical components are actually running. If in doubt, ask a marine electrician or corrosion surveyor to check the system for you.

From Other Boats . . .

There are two ways that another boat can cause DC stray current damage on your boat. The first (more common) scenario is if you are both plugged-in to the same shore power system. However, it's also possible to have a stray current problem if you are unconnected, but sitting near the other boat in a current field in the water created by that boat.

For the first case, the situation is similar to the marina scenario described above, because the green grounding wires on your boat and the other boat are connected through the marina's shore power system. A stray current problem on their boat could use the water to travel to your boat, and use your bonding system to get back through your grounding wire and their grounding wire to their battery.

The second stray current case is tougher to defend against, and less common. It's also one case where your bonding system could work against you. Even if you are not connected to shore power, if your boat is positioned close a boat that is plugged in, and that boat has a DC stray current problem, your boat may provide a low-resistance electrical path between an underwater fitting on the problem boat and the marina's ground stake. The current could exit the problem boat, travel through the water to a bonded metal fitting on your boat, take the low-resistance path through the bonding system to another metal fitting closer to the marina's ground stake, exit your boat, continue through the water to the ground stake, and back through the wires to their boat. This often is not detected until after it has caused a problem.

Help for Detecting Stray Current

Unfortunately, galvanic isolators only block DC current when the voltage is below about 1.4 Volts, so they will stop only a small percentage of stray current. One product now on the market that may help is the Marinco GalvanAlert. This is a "pigtail" that attaches between the shore power inlet and the cord. It has warning lights for reverse polarity and for DC current traveling through the green grounding wire in the shore cord. A yellow light illuminates when 25 milliamps of current is flowing – indicating a low-level situation that is not urgent. A red light illuminates when the current reaches 100 milliamps – indicating a situation that needs to be addressed immediately. Without a Galvanic Isolator installed in the boat, it might light up even when very low levels of galvanic current were travelling in the wire, but in combination with a GI, it could be effective for indicating if the GI were being bypassed, or if stray current were present above the level that the Galvanic Isolator would block – originating either from your boat or another one. Remember that current indicated by the GalvanAlert unit is not the marina's fault, or something they can control. Here's a link to the product on the Marinco site: http://www.marinco.com/product/galvanalert-shore-power-corrosion-detector

<u>An Important Note on AC Stray Current</u>

So far, the discussion has been on DC (direct current, battery, 12V or 24V current) stray current only. DC current is generally considered responsible for significant corrosion of underwater metals. AC (alternating current, shore power, 120V or 240V) stray current is not as damaging to metals, but is **DEADLY** to humans, especially in fresh water. Stray AC current has killed many swimmers in fresh water marinas. While salt water does a better job of dispersing the current, fresh water is not a very good conductor (electrolyte), and a person's body is a better conductor. Stray current uses a person's body in fresh water to get closer to the ground stake, and can paralyze them, causing "electroshock drowning." **Never go swimming in a fresh water marina, or even in a salt water marina.**

An effort is currently underway to prevent AC stray current from boats by installing devices called ELCI's. ELCI stands for "Equipment Leakage Circuit Interrupter," and is the equivalent of a GFCI (Ground Fault Circuit Interrupter) - but for your entire boat. GFCI's are the devices in household (and onboard) AC outlets that immediately cut off the power to the outlet if a ground fault occurs. ELCI's do the same thing if a fault occurs anywhere onboard. Ed Sherman has a good article on ELCI's on his website here: http://www.edsboattips.com/maintenance-a-diy/21-introducing-the-elci

All new J/95's and J/111's equipped with shore power also have ELCI's installed. If your boat has a shore power system, consider installing an ELCI. Here's a link to ELCI's on the Blue Sea Systems website: http://bluesea.com/category/81/3/productline/365

Special Considerations for Various J Boats Models

Considerations for J/95's

As described in the owner guide, the J/95 has a unique 2-part bonding system with a Galvanic Isolator separating the keel, rigging, and lifelines from the engine and electrical system. It is important to maintain this separation so that a galvanic cell is not created between the bronze centerboard and the saildrive. If there is a connection between these two that bypasses the GI, the saildrive anode will corrode to protect the bronze centerboard and will deplete quickly - which puts the aluminum saildrive leg at risk. **The most likely way to do this is by installing a VHF antenna bracket on the mast that creates a connection** between the antenna ground wire (which is on the engine/saildrive side of the bonding system), and the mast & rigging (which are on the keel/centerboard side of the bonding system). Even if steps are taken to isolate the bracket from the mast, such as using plastic washers, there is a chance the bracket may shift and create a connection. We strongly recommend using a plastic antenna bracket or creating a bracket from G10 (fiberglass/epoxy) angle stock. This will ensure that the antenna and the mast remain isolated from each other.

Another likely way the galvanic isolator can be bypassed is if a frayed wire at the bow or stern rails touches the rail or the stainless running light bracket and forms a connection. Fortunately, it's easy to check for any connection that may be bypassing the galvanic isolator without climbing the mast or taking apart running lights. The galvanic isolator is mounted just behind the engine, and the two sides of the bonding system are attached to the terminals on either side of the isolator. Here's how to check for a connection:

If the boat is in the water:

A digital multi-meter should be used to test the galvanic isolator. With the boat in the water, the voltage measured across the isolator terminals should be between 0.3 - 0.6 VDC, or slightly higher.

If the boat is out of the water:
First, short the isolator terminals momentarily to remove any residual charge. Then set the multi-meter to its diode checking function and connect the leads to the isolator terminals. The meter should show a voltage reading that very slowly increases from zero to the 0.8 - 0.9 VDC range. This may take up to 10 minutes. If the voltage jumps to 0.8 - 0.9 VDC immediately or does not reach at least 0.8 VDC, replace the isolator. Once the test is complete, short the terminals again, and repeat it in the opposite direction – with the multimeter leads reversed on the galvanic isolator. If the voltage reading in either of the previous tests stays near zero, either the GI is bypassed, or has failed (which could happen due to a lightning storm).

To determine which is the case, simply disconnect the bonding wires from one side of the GI and test between the GI terminals again. If the voltage does not increase this time, the GI has failed. If the voltage increases, showing normal GI function, then the GI must have been bypassed in the previous test, and there is a connection between the two sides of the bonding system.

The simplest check of all is simply to monitor the anode on the saildrive when cleaning the bottom of the boat. If it appears to be wasting away quickly, there could be a problem with the bonding system, and the anode could be trying to protect the centerboard.

For additional protection, we recommend clipping an additional "fish" or "Guppy" anode to the boat when it is at rest. It is important to use the same type of anode as is used on the saildrive, but do not use additional magnesium anodes as this could over-protect the system, as mentioned above. It's best to clip the additional anode to a spot on the engine/saildrive side of the bonding system. A convenient way to do this would be to attach an additional wire where the green bonding wires connect to the back side of the fuel fill fitting, or to the top of the fuel gauge sender on the fuel tank. Then lead this wire to an easily accessible spot in the port cockpit locker, where the additional anode could clip to it. Another approach could be to mount a small padeye next to the fuel fill fitting, and connect it with a wire under the deck to the fuel fill. This would act as an on-deck attachment point for the anode.

J/111's and other J Boats with Yanmar Saildrives
The J/111 and other J Boats with Yanmar Saildrives have more conventional bonding systems that join all underwater metals. The epoxy barrier coat on the keel serves to isolate the keel's metals from the water - so the saildrive anode is not forced to protect them. However, it's possible for the barrier coat to be compromised – either at a spot where metal is exposed during fairing, or a spot where minor damage removes the coating on the keel. Two things result if the metal is exposed. First, the saildrive anode is forced to protect the exposed metal on the keel and depletes more quickly. In an extreme

case, that could put the saildrive leg at risk of corrosion. Second, if the antifouling paint contains copper, “halos” can form in the paint around this point due to a reaction with copper ions released by the paint.

Due to this possibility, it is very important to make sure that the barrier coat on the keel is intact (and exceeds the minimum thickness specified by the manufacturer) before applying bottom paint. Also, it is important to address any small nicks on the keel that may expose the stainless steel or lead.

To further protect against corrosive action, consider using antifouling paint with low copper content, or no copper at all. This will reduce or eliminate the halos that can appear if the barrier coat is nicked.

As with the J/95, it is important to monitor the anode on the Saildrive for signs of rapid depletion. This is a good way to detect that other metal may be exposed and the Saildrive anode is being forced to protect more than just the Saildrive.

For additional protection on any boat with a Saildrive, we recommend using an additional clip-on “fish” or “Guppy” anode when the boat is at rest. As mentioned above, it is important to use the same type of anode (zinc, aluminum) as is used on the saildrive, but do not use additional magnesium anodes as this could over-protect the system. Be sure to clip the additional anode to a point that is directly connected to the bonding system, such as a shroud chainplate, or other fitting with a green bonding wire attached.

> **A special note on J/111 keels:**
> The J/111 keel is built with certain sections left hollow in the stainless steel keel fin above the lead bulb. A drain plug is installed for the express purpose of routinely checking (upon seasonal haul out) for any condensation that might accumulate in the keel. As mentioned earlier in the section on Single Metal Corrosion, standing water against stainless steel can cause corrosion over time, so it is important to ensure that any water in the keel is drained. To drain most effectively, the boat should be at a slight bow-up angle, which is how it normally sits in a cradle or trailer.
>
> It is important not to fair over this plug in such a way that you cannot relocate it. If the drain plug has been hidden, it can be found on the port side of the keel 5.25” forward of the trailing edge, and approximately 36” down from the hull. It’s also important to coat over the plug with barrier coat once it is reinstalled – so that it does not become a point where metal is exposed.

J Boats with Volvo Saildrives
Volvo uses a different approach to protecting their saildrive anodes and saildrive legs. They isolate their saildrive units from their engines with gaskets/spacers that prevent

contact between the two. This isolation should be maintained and can be checked with a multimeter for any electrical continuity between the two.

With the saildrive isolated, its anode cannot protect any other metals – either on the boat where it is installed, or accidentally on a nearby boat.

J Boats with Conventional Shaft/Strut Drive Systems
All boats with conventional drive systems that have an exposed propeller shaft and shaft strut should have an anode attached to the shaft to protect the shaft and propeller. The shaft anode(s) may be able to protect other underwater metals on the boat through a bonding system, but this should be checked to ensure that there is continuity between the shaft and the engine – the bearings and grease in the marine gear (transmission) could isolate the shaft. If the continuity exists, exposed metals, such as lead on the keel, could cause the anodes to waste away more quickly than normal. Again, it's smart to check these anodes whenever the boat bottom is being cleaned.

If You Have a Corrosion Problem

First, don't wait to address it! If you find your sacrificial anode(s) depleting (wasting) faster than usual, remember that the next metal to corrode may be your saildrive leg or your propeller. The first step in solving any corrosion problem is to narrow-down the cause to either Single-Metal Corrosion, Galvanic Corrosion, or Stray Current Corrosion. Checking the hull potential with a reference electrode can help greatly in finding the cause, but for more help, we suggest calling your local J Boats dealer. They may be able to assist with the troubleshooting, or can help you find a local corrosion surveyor or marine electrician who can pinpoint the cause.

Additional Resources

Corrosion Guide with Galvanic Table
- From Performance Metals, Inc. – producer of Aluminum anodes:
http://www.performancemetals.com/images/pdfs/Corrosion%20Card%202010.pdf

Yanmar Saildrive Service Bulletin
- Reprinted on Boats.com
http://www.boats.com/boat-content/2010/05/yanmar-saildrive-service-bulletin/

Waterline Systems Keel Bolt Maintenance Bulletin
- From the Waterline Systems website
http://www.waterlinesystems.com/wp-content/uploads/2011/11/KeelBolts.pdf

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