Putting Corrosion to the Test

We’ve talked about galvanic corrosion in previous issues of Seaworthy, mostly regarding its detection, cure and prevention. There is, or can be, a larger issue regarding corrosion, and a series of simple tests, combined with some basic recordkeeping, will enable you to determine your boat’s exposure to or propensity for corrosion damage. The purpose is to prevent corrosion before it happens.

First, a few principles: There are two basic kinds of electrically-induced corrosion on boats. The first is galvanic, caused by nothing more than immersing two electrically connected dissimilar metals in an electrolytic solution, in this case, saltwater. The second is stray current, which can result from improper grounding in your boat’s electrical system, the marina, a nearby boat in the marina, or a system fault such as a bilge pump failure from hot to ground. Stray current corrosion is 12 VDC current leaking from inside your boat.

The analysis of your boat’s electrical stability should be an ongoing process, beginning with a series of tests designed to reveal the electrical potential between various parts of your boat and the surrounding seawater. Keeping a record of the resulting tests is vital. The first series of tests will establish a baseline on your boat, and should be done well away from other boats. Anchor in a quiet cove and then plan on spending a few hours going over your boat.

What You’ll Need

First, you’ll need a digital multimeter that will read millivolts. Nearly any digital voltmeter will do this. An analog-type meter, however, must be of the high-impedance variety or it won’t give you sufficiently accurate readings. Alternatively, you could buy a corrosion test meter, which is little more than an analog millivolt meter that is calibrated to read in the range of zero to 1,200 mV (1.2 volts) and has color-coded sections reading “freely corroding,” “protected,” and “overprotected.” There are typically three scales, one for bronze, one for steel and one for aluminum. If you are using a digital multimeter, set the range to read in millivolts DC. The better digital meters have a self-ranging feature, so there will be no need to set it.

The other item needed to begin testing your boat is a silver/silver-chloride half-cell or reference cell, available from several sources easily found with a quick online search. It looks like a small cylinder, about the size of a Chapstick, with an insulated wire and a plug to connect to the positive socket on your multimeter. Purchase it from a chandlery and it will probably come complete with a length of wire and a jack to fit your multimeter. You will also need a length of fairly heavy copper wire—10- or 12-gauge, to eliminate any voltage drop— with an alligator clip at one end. The other end should fit into the socket on your multimeter. The combined length will need to be long enough to reach any part of the boat. In practice, the wire connected to the reference cell should be longer so you will be able to touch metal fittings through the hull and be close enough to the meter to write down the voltage readings. Having a helper makes this much easier.

Getting Started

With the reference cell connected to the red (positive) plug of the meter, you will get voltage readings expressed in negative volts. This is the customary value, although if you reverse the plugs, you will get the same reading, but expressed positively.

Make a simple drawing or write up a complete list of the metal underwater fittings. Include through-hulls, prop shafts, and anything that is part of the boat’s electrical bonding circuit. Include the stern drives, trim tabs and any other metal part that is normally in the water.

Drop the silver reference cell over the side and wait a few minutes for the seawater to soak into the porous housing. Then attach the black lead, the one with the alligator clip, to the metal fitting nearest to a sacrificial anode (for example, a through-hull fitting or the propeller shaft), take a reading and begin to work your away from the anode, following the bonding circuit to the next fitting. If your boat’s metal through-hull fittings are not bonded, you will need to touch each fitting; even with a properly grounded system, you should do this to detect any breaks in the bonding system.

Among the things that may be revealed is a ground that has been interrupted, as you should get exactly the same reading from each fitting. Note that if you have installed a new sacrificial anode, it will require up to 24 hours of immersion before you get an accurate reading.

With your drawing of the boat and each fitting in hand, record the reading you get. The following is a list of the range of mV readings you should find, next to the type of metal concerned:

- Bronze: -500 mV to -700 mV
- Steel: -750 mV to -850 mV
- Aluminum: -800 mV to -1,050 mV

Note that the numbers, or range of numbers, varies according to who you talk to, but all the sources agree within about
50 mV. If you get a number that is less—for example a bronze seacock gives you a reading of ~400 mV—then the item being tested is eroding. The smaller the number, the more the erosion that has taken place. You can have too much of a good thing; overprotected fittings, revealing themselves with a larger number, will result in decreased effectiveness of your antifouling paint as it will bubble off the boat, and painted metal fittings will lose paint. This could happen, for example, if the anode is made of magnesium, perhaps because it was fitted for freshwater use but the boat is now in saltwater. Impressed-current corrosion prevention devices can also cause this if the voltage setting is wrong. Wooden hulls can also be damaged, and the barrier coatings on steel or aluminum hulls could be lost as well.

Bonding your boat’s underwater metal fittings together is critical; any fitting that isn’t connected to the sacrificial anode will be left to its own electrolytic devices, so to speak, and could corrode. Note that the engine, even though the block is connected to the bonding system, requires its own sacrificial anode in the cooling system. The silver cell dropped over the side is not sitting in the same body of water as that contained in the engine block and therefore the anode cannot be tested in the same way. Remove and check the condition of the engine’s anode. It is usually a thin pencil of zinc with a threaded fitting that is screwed into a passage of the coolant jacket. When in doubt, put in a new one; it should be replaced annually anyway.

The testing of your boat’s bonding system and the effectiveness of your anodes can also reveal problems with stray AC or DC current, either from the shore connection or the boat’s wiring. Even though AC current is generally not considered to contribute to corrosion, the presence of, or changes in, voltage will indicate a problem. Stray DC current will induce galvanic corrosion that is functionally the same as that caused by unprotected, dissimilar metals, but its effects can be even more rapid.

Testing Fittings

Assuming the boat is properly bonded, your next step will be to check the voltage potentials of each fitting. Begin by switching the main shore power switch on and off with the shore power cable disconnected. The voltage should remain constant. If not, there may be problems with the AC ground. This can be very serious, even life-threatening, and while the troubleshooting and correction of problems with the AC circuit are beyond the scope of this article, a quick check of the polarity of the AC circuit can be safely made using a plug-in polarity indicator. This is an inexpensive device about the size of a three-prong adaptor that is readily available at any hardware store.

To check for DC problems, switch on each DC breaker in turn (including the master battery switch) while monitoring the voltage on the fitting. Again, there should be no changes in the voltage reading. Changes in voltage can indicate either a broken bonding wire or stray current. If you suspect a problem with the battery switch, you will need to physically disconnect the batteries from the boat’s circuit in order to perform this test.

Next, plug in the shore power cord, and with the AC switches in the OFF position, check for any changes. Repeat, this time after turning the main shore power switch to ON. If you observe a change in voltage (other than a brief blip), you have a problem with the grounding wire or the circuit between the dockside shore connection and the master switch. Grounding-wire shorts, improper wiring, or broken insulation can produce the reading changes. Any fault traced to the marina’s grounding circuit is potentially dangerous. Voltage that changes when shore power is connected can also be a sign of another source of corrosion. The green (ground) wire of the shore power cable will connect your boat to the ground of every other boat in the marina that shares the same shore power circuit. This connection will allow potentially damaging corrosion, either through stray current or from other boats using your sacrificial anodes to protect their hulls. This can occur whether you have adequate anodes or not. The cure, apart from not being plugged in to shore power, is to install either a galvanic isolator or an isolation transformer on your boat. These devices “isolate” your boat from the marina’s ground, albeit in a different manner (you can download a brochure on galvanic isolators at www.BoatUS.com/Seaworthy/galvanic). Note also, that West Marine carries both products.

Concluding the Test

Continue working your way along the boat’s electrical circuit. With the master switch now on, and shore power turned off at the boat master switch or disconnected entirely, go to the next section “downstream” of the switch. Turn the switch on and off. If there is a voltage change, the problem lies between the previous switch and the one you’re testing.

A full test will include going over every circuit, from every branch in the wiring. Note that a full check takes considerable time, and ideally would only need to be done once in order to establish baseline numbers. To keep tabs on the state of your boat’s anodes or to monitor any new conditions relating to your boat’s galvanic corrosion rate at a new marina, test any fitting and compare it to the numbers you previously logged.

If you discover a problem, finding the cause can be difficult. A section of wire with broken insulation may only leak electricity when it is flexed, giving an intermittent indication of the problem. With the exception of bilge pump wiring, wires in the bilge should be well clear of any standing water. Bilge pumps are on the list of usual suspects, as by their very nature the wires are submerged at least part of the time.

Careful record-keeping and consistent monitoring will do much to reduce, if not eliminate, problems with stray currents and galvanic corrosion. At the very least, you will be informed of potential problems before they occur. For those interested, permanently installed “hull potential meters” that display real-time corrosion potential 24/7 are available. For more information, see ABYC E-2 Cathodic Protection. The ABYC standards are available on a three-day trial basis by going to www.abycinc.org and clicking on “ABYC Standards Free Demo.”

Attach the negative end of the corrosion meter (or your digital multimeter) to the metal item being checked, and the other end to the silver chloride cell hanging over the side in the water.