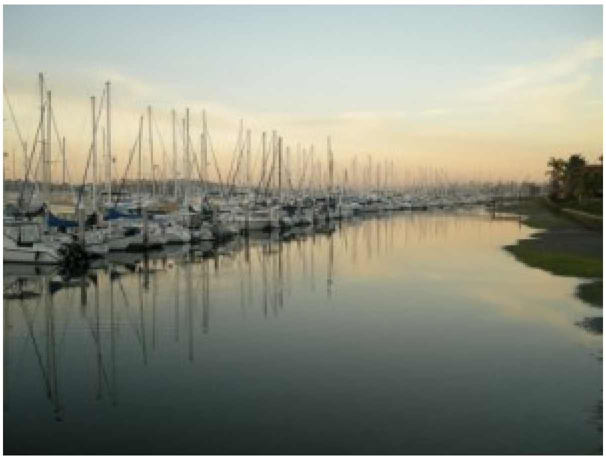
Safe Shore Power and Electrocution Prevention

Safe Shore Power and Electrocution Prevention

By Steve D'Antonio
Photos by Steve D'Antonio



The serene water and inviting shore may look like an inviting location for a refreshing swim, but with all those boats and docks plugged into AC shore power, the risk of fault is simply too great to chance it.

Readers may have heard about five cases of electrocution that occurred over the Independence Day holiday. Tragically, they resulted in the deaths of four children, siblings Brayden and Alexandra Anderson – 8 and 13 respectively, Noah Winstead – 10, and Nathan Lynam – 11, and one adult – 26-year-old Jennifer Lankford. All of the events occurred on lakes, one in Tennessee and the two in Missouri.

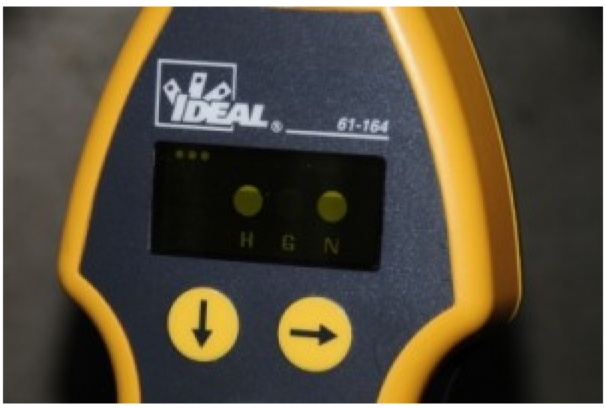
Each year electrocution events such as these occur and each year a hue and cry goes out within the marine industry to educate boat owners, marina managers, marine electricians and swimmers about the dangers associated with swimming around boats that are plugged into shore power, or other shore power devices such as electric boat lifts or docks that are equipped with electricity. Sadly, for these children and young woman and their families, it’s too late; however, it’s not too late for you to learn about these potentially disastrous scenarios and how to avoid them. The following column on the subject of shore power systems and electrocution is adapted from my marine systems book; it will be released next year. I hope you find it useful.

Beneath the rubber boot, this 50-amp shore power cord is severely corroded, probably as a result of it falling into the water. The insulation of one of the hot or energized wires is almost entirely melted away and is nearly touching the green grounding wire.

The Safe Shore Power System

Once you agree to bring AC power aboard, you, your boat’s builder, and the yard that carries out your electrical work if you don’t do it yourself, must accept the responsibility for ensuring that it is safely wired. This means following the standards set forth by The American Boat and Yacht Council's "Standards and Technical Information Reports for Small Craft" chapters E-2, E-4, and E-11, "Cathodic Bonding", "Lightning Bonding", "AC and DC Electrical Systems " respectively. Together, these guidelines weave an intricate mosaic, which endeavors to make the mixture of seawater (for the purposes of this discussion, this includes any water that your boat may be floating upon, salt, fresh or brackish) and electricity, an inherently unsafe combination, as safe as possible.

One of the primary tenets of these standards is the prerequisite for bonding, which is simply another name for electrically connecting selected onboard metal objects. This includes, but is not limited to, the engine, metal equipment cases, metal fuel and water tanks, steering gear, below-the-waterline metallic hardware, spars, shrouds, stays, davits, arches etc. Suffice it to say, there's no shortage of controversy where this practice is concerned. However, I, along with many boat builders and industry professionals, do subscribe to it for several reasons, but one in particular stands out: a properly bonded boat is less likely to electrocute one of its crew or a swimmer.



There are several useful tools you or a qualified marine electrician can use to diagnose faults within the AC system aboard your boat. This Ideal circuit tester shows an AC receptacle with a missing ground connection.

Aboard a properly wired vessel, if an energized, often referred to as “hot” AC wire (in the US it will typically be black or red, but can be brown, orange or blue) comes into contact with one of these bonded masses, a tank or rudder post for instance, the electricity is safely discharged to ground and will, ideally, trip the circuit breaker as well, stemming the flow of electricity. On a vessel that does not follow these guidelines; the hot conductor will energize the metal mass, until an unsuspecting crew member comes along and touches this object with one hand, and touches another mass, which is grounded, such as the engine block or propeller shaft, with the other hand. The resultant electrical shock across the chest will be a frightening, and potentially fatal, experience. Detractors of the “bonded boat” will argue that this arrangement is much more likely to incur the ravages of galvanic corrosion, sometimes incorrectly referred to as electrolysis. They are partially correct.

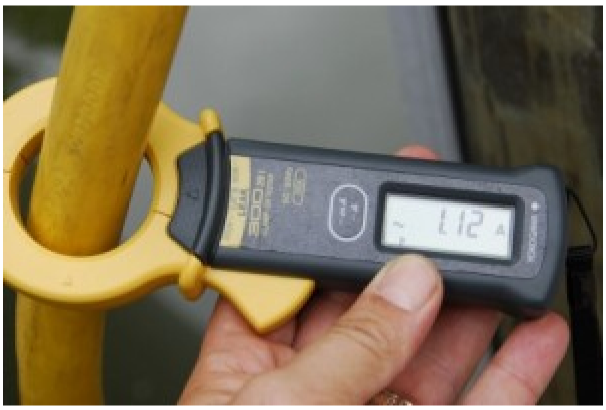
Corrosion, galvanic and stray current, as well as other forms, can be confusing topics. A brief explanation of the process will assist the reader in understanding what follows. Galvanic or dissimilar metal corrosion occurs when two dissimilar metals, aluminum and bronze for instance, remain in contact either directly or through a wire while they are immersed in an electrolyte – seawater in this case. The rate and severity of corrosion is dependent on many factors, the types of metals involved, the salinity and temperature of the water, the presence of anodes to name a few. Typically, galvanic corrosion is a relatively slow process causing cumulative damage over the course of months, if not years. Even if no solution to this dilemma existed, and it does, read on, the choice should be clear: suffer galvanic corrosion damage vs. electrocute yourself or one of your crew or a swimmer. The decision is, or should be, an easy one indeed.

This stainless steel prop shaft suffered extreme corrosion and was clearly condemned. This is very likely a case of stray current corrosion, which is nearly always associated with DC rather than AC or shore power current.

Common AC Mistakes

In addition to the failure-to-bond problem, many vessels are also plagued with other AC electrical land mines. The most notorious of which is the coupled AC neutral conductor (white wire) and the safety grounding (green wire). Unlike a house or other land-based structure, these two conductors should have nothing to do with each other aboard the boat. Rather, they must only be connected ashore. The reason for this idiosyncrasy is the potential for transmission of current through seawater (again, salt or fresh, it doesn’t’t matter. In fact, studies and anecdotal evidence indicates that the lethality of AC current is greater in fresh rather than salt water, although it’s a dangerous fault regardless). The reason for this is the directness of the path which current takes when it travels through fresh as opposed to salt water.

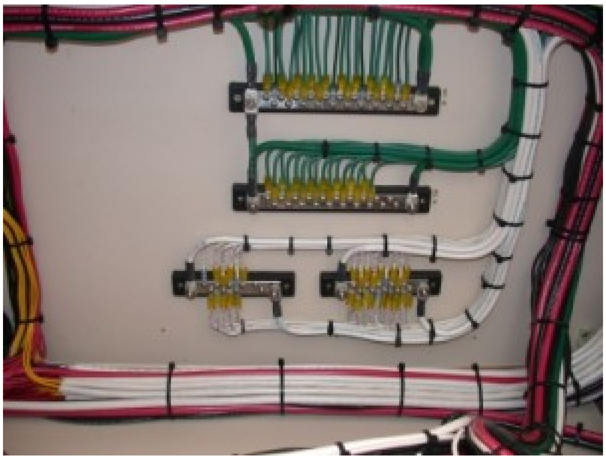
A more direct path equates to a higher current density in the water and thus greater likelihood of injury to a swimmer. All AC power coming aboard on the "hot" or energized conductors (on a vessel equipped with 240-volt service there will be two hot conductors) must ultimately find its way back to its source. In an improperly wired vessel or one with an electrical fault, the return paths may be threefold, through the grounded neutral conductor (this is white), which is correct and where all return current should flow, through the green safety grounding conductor, this is indicative of a fault on board, however, it's the path fault current should take, and finally through the boat's bonding system and underwater hardware, and thence to the seawater. The latter path is incorrect and presents an injury risk to crew and swimmers alike. If high resistance should develop in the neutral and/or ground conductors, for instance a loose shore power plug or corroded connection, the sole return path for shore power current could become the seawater (however, any amount of current returning to the source of power though the water represents a serious risk). A swimmer transiting this electrical path could be killed, even if the quantity of current is not great enough to be considered lethal ashore. Sadly, this has been documented on a number of occasions, and it's likely it will turn out to be the case with the recent, aforementioned deaths.



By utilizing a sensitive amp clamp-style meter, it is possible

to find current that is not flowing back through the shore power cord as it should be. This reading should be zero; the 1.12 amps of AC current shown is finding another route back to ground – through the water.

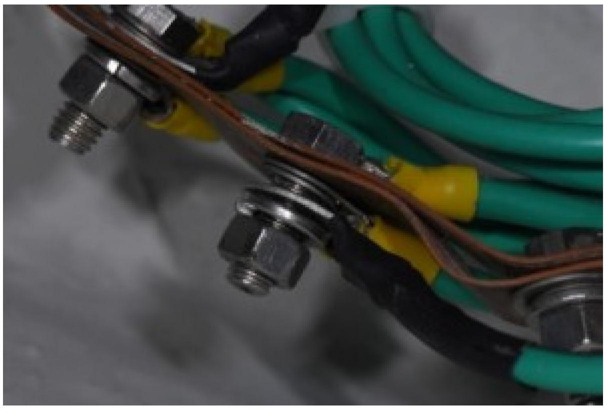
In a case that occurred in 1999, a nine year old boy was electrocuted as he swam adjacent to a marina dock located on fresh water. He was wearing a life jacket and his face never touched the water. His mother jumped in to save him and as she did so, her limbs and extremities went numb. In spite of this, she was able to pull her son to the dock, where others helped pull them from the water (the scenarios in Missouri and Tennessee were very similar, with adults entering the water to assist the children). The ensuing investigation determined that this unfortunate tragedy occurred because of an electrical fault in a nearby un-bonded boat. A melted wire allowed AC shore power current to leak into the water around the boat and the nearby dock where the boy was swimming. Because this was fresh water, the current made its way to its source, although with some difficulty, until the boy entered its path. Because of the salinity of the human body, it is a much better conductor than fresh water. The boy's mother was able to transit the path of the current without being electrocuted herself because of her increased body weight and skin surface area. The current was great enough, however, to be lethal to the boy's smaller, lighter body. Had the vessel with the offending electrical fault been properly bonded, it's likely this tragedy would never have occurred. The fault current would have passed safely ashore over the green safety grounding wire, where it would most likely have tripped the dockside circuit breaker. If no other lesson is learned from this sad tale, let it be this, never swim in a marina or adjacent to docks where shore power is present.



There is no connection between the green grounding and white or neutral AC wiring at these bus bars. Care must be taken at installation and through all future service that, except for a few isolated cases, the two circuits remain separate aboard the vessel.

The Causes of Swimmer Electrocution

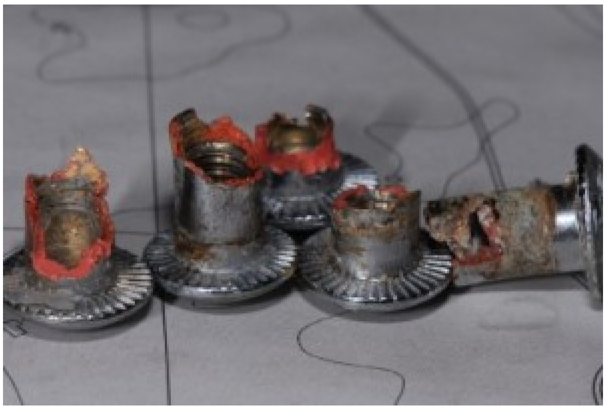
Small amounts of AC current (as low as 5 milliamps can cause muscle seizure) are sufficient to immobilize voluntary muscle reflexes, such as those used to swim and stay afloat. Higher current (50 milliamps for 2 seconds or 500 milliamps for just 0.2 seconds) may cause ventricular fibrillation and ultimately death (this is probably what happened to the boy mentioned above). Essentially, the swimmer could drown, or suffer heart stoppage, even in water that's not over his or her head. Once again, the green safety grounding and white neutral conductors must, for the above-mentioned reasons, never be connected aboard the boat, only ashore, typically at a transformer supplying the marina or individual dock. This includes the internal wiring of appliances such as some domestic microwave ovens, coffee pots, electric ranges, washers and dryers etc. In many instances, boat builders, repair yards or owners will obtain these common domestic appliances for installation aboard a vessel. In this case, the appliance must be tested and possibly modified in order to ensure safe shipboard use.



Ideally, this bonding "bus" should utilize a purpose made bus bar rather than copper strap material. The loose center log represents potential high resistance, which could prevent this component from functioning properly and safely.

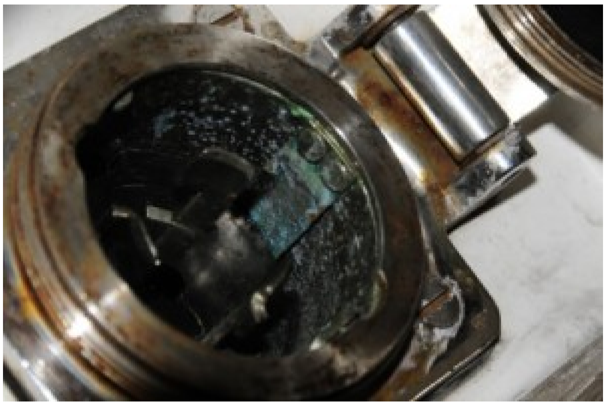
Another common AC faux pas is severing, or failing to maintain the integrity of, the connection between the boat's bonding system and the AC safety ground. These are both green wires, often of different gauges; one wired to most or all AC appliances and going ashore in the shore power cable and, as previously mentioned, a series of other wires aboard that connect various pieces of hardware. These two circuits must be connected and remain at the same electrical potential at all times.

In an attempt to reduce the occurrence of corrosion, an unwitting skipper may follow the advice of a dockside or on-line "expert" and disconnect this all too important connection. His or her reasoning is that if the underwater metal is not connected to the dock through the bonding circuit and AC safety ground, then the vessel will no longer be plagued by galvanic corrosion induced by neighboring boats.



These fasteners are suffering from galvanic corrosion and specifically dezincification. They are chrome-plated brass, which has a high zinc content, and they are unsuitable for marine applications.

In fact, this is indeed true. Severing this connection may reduce the likelihood of galvanic (caused by the connection of dissimilar metals immersed in an electrolyte such as seawater) or stray current corrosion that travels over the shore power green grounding wire. The latter is aggressive and fast-acting; it's capable of causing significant damage in a very short time period and is "powered" in the respect that it's caused by leaking DC battery current. It's frequently caused by electrical "leaks" into the bilge water or the water surrounding the boat, often from a defective bilge pump, or an exposed, submerged, or non-waterproof electrical connection in the bilge. As an aside, many boat owners and some marine professionals incorrectly assume that because this corrosion often appears to occur or is exacerbated when a vessel is plugged into shore power, that the culprit must be the AC power (or the marina’s wiring) itself. In fact, this is typically not the case. Galvanic and stray current corrosion is most often a DC phenomenon. In rare cases, stray AC current may cause corrosion, however, the victim, because of its galvanic ignobility is usually aluminum hardware such as stern-drives, outboard lower units, props or the hulls of aluminum vessels. But even in these cases it’s rare – stray DC or galvanic corrosion is nearly always the culprit. Stray current from one boat may still enter and damage another boat’s bonded underwater fittings. Although this does occur, it’s not as common as galvanic corrosion. Nothing can prevent this phenomenon except elimination of the bonding system (or the fault) and for reasons discussed earlier, that’s not a safe option.



The green tab inside this 50-amp shore power connection should be bright metal. The tab is the ship’s connection to shore ground and when it is corroded that connection is compromised, jeopardizing the safety of the crew.

Once this connection between AC ground and the bonding system has been (improperly) disconnected, the scenarios of the previously mentioned electrocuted crew member and swimmer pays another visit. The following set of circumstances once happened to me. An onboard microwave oven developed a short between the hot conductor and the metal enclosure (the casing was sharp and as the microwave was pushed into its cabinet, it compressed and eventually cut the wire) and the ground contact on the shore power plug was heavily corroded (the entire plug was corroded, as if it had been dropped overboard). The stage was now set; there was no low resistance return path to ground for the energized enclosure, so it remained energized rather than shorting and tripping the circuit breaker. The boat was afloat and I was working on some galley plumbing. It was a summer day and I was sweating, making my skin and clothing somewhat conductive. Each time I brushed the microwave with my shirt-sleeved arm while I was touching a bonded piece of hardware, I felt a slight tingle. I was unwittingly attempting to become the return path for the fault current residing on the appliance's case. Had my sleeves had been rolled up, I might have succeeded and you may not be reading this today. The moral of this story is; a low resistance path through the shore power cable and to shore ground must exist and the AC safety ground circuit and the bonding system must always be connected and in sound, good working order and they must remain at the same electrical potential.

While anode wastage is a regular maintenance issue, it is part

of a comprehensive system designed to prevent electrocution aboard your boat. All parts of this bonding/AC system must be properly installed and in perfect working order.

The Problem

Now that it's been established that your vessel should be properly wired for AC safety ground and selected onboard hardware bonded, you might ask why anyone would not do this. The problem is, undeniably, when all of the above mentioned safety precautions are taken, the side effect is the increased potential for galvanic corrosion, particularly when plugged into shore power. When you bond underwater metals and dutifully connect them to the AC shore power safety ground, you may have unwittingly invited aboard an unwanted guest, corrosion. The circumstances are simple; you conscientiously bond your boat and inspect the anodes regularly, changing them whenever they are more than 50% depleted.

After a year in the water, this zinc anode has done its job of protecting the shaft and prop. However, it is time to replace it with a new one. Be sure to clean the shaft underneath the new zinc to assure the best electrical connection.

You also remain plugged into shore power to keep the batteries up, the reefer cold, and for the use of an air-conditioner, microwave, coffee maker or other appliances. Your slip neighbor however, hasn't been seen aboard his or her boat in months and this vacant vessel is plugged into shore power as well, to keep the fridge cold and the air conditioner running, if or when he does arrive. You've now inadvertently connected both of your boats together electrically through the AC shore power's safety ground. Galvanic current flows from one boat to the other via the bonded underwater metals. When his zinc anodes are depleted, yours take over, protecting both boats' underwater hardware. In this case, that's not for long. This could happen with any number of boats, potentially an entire marina.

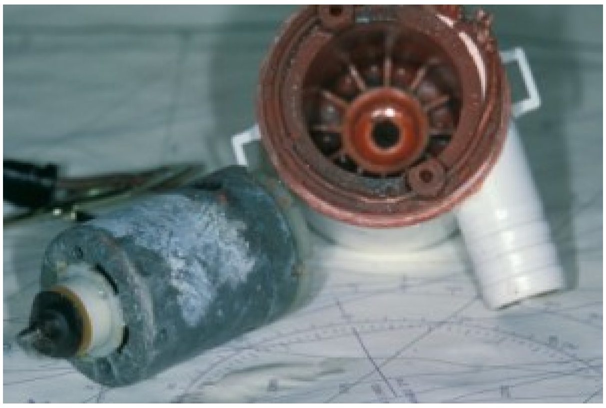
It's important enough to warrant reiteration, galvanic corrosion, sometimes incorrectly referred to as electrolysis, is DC (direct current) in nature. Stray current corrosion, which is different from galvanic corrosion but sometimes confused with it, requires the introduction of "leaked" voltage from, once again, most often a DC positive source, such as a wire immersed in bilge water whose insulation is damaged. I have encountered many folks who will argue strongly that corrosion can be caused by "hot marinas", referring to faulty dockside AC electrical systems. Their beliefs are usually fueled by a "corrosive" experience they've had while visiting a marina, which was, in all likelihood, caused by common DC galvanic or stray current corrosion. They, however, misidentified the source because it only occurred when the shore power cable was connected. While stray AC current has been shown to cause corrosion under some circumstances, it is typically isolated to aluminum and thus DC sources should first be ruled out before pointing the corrosion finger at AC current. It's important to remember that DC current may be superimposed on AC circuits and consequently cause corrosion. Faulty AC shore power wiring is, however, quite capable of injuring or killing people, as previously mentioned, whether swimming or not.

Finally, do not swim in marinas or around vessels that are plugged into shore power or around docks that are equipped with shore power. For more information on ELCI circuit breakers, devices that can prevent this sort of tragedy, visit the SDMC blog archives for the article entitled “Electrocution Prevention”.

For more on the subject of the neutral to ground connection, an article geared toward marine industry professionals is available at http://www.proboat.com/demystifying-the-neutral-to-ground-connection.html

In an upcoming blog, I’ll discuss the use of transformers and galvanic isolators and how they can reduce the likelihood of corrosion and, in the case of the former, can be safer for swimmers.

This propeller blade has been destroyed by stray DC current corrosion from a damaged bilge pump. While it may have occurred in a marina, it was not the direct result of AC or shore power current.



And this could have been the culprit, the failed bilge pump motor was leaking DC current directly into the bilge water which was in contact with an un-bonded through hull, and through the water and to the prop.

For more information on the services provided by Steve D'Antonio Marine Consulting, Inc. please e mail Steve at info@stevedmarineconsulting.com