AC Electrical Safety

From Pacific Fishing, June 2001
By Terry Johnson, University of Alaska Sea Grant, Marine Advisory Program
4014 Lake Street, Suite 201B, Homer, AK 99603, (907) 235-5643, email: rftlj@uaf.edu

We all live safely with alternating current (AC) electricity in the home. But with the same voltage, the marine AC system is potentially more dangerous because the boat and the people who work on it are surrounded by water. A person who becomes part of the pathway between a hot wire and the sea can experience severe shock.

Forget the blinding flash and the smoking flesh. It doesn't take a lot of juice to kill a person. Remember, what makes the heart tick is a faint electrical impulse generated within the muscle itself. It takes only a very small amount of current through the chest to disrupt the heart rhythm, causing fatal fluttering of the heart muscle called fibrillation.

A critical factor is where the current passes through the body. Touching hot and neutral leads with one hand can give you a jolt and maybe even a burn, but won't kill you. But grabbing a hot lead with one hand and a neutral with the other, or the lead with one hand while standing in water, can send the current through the chest. One effect that electrical current has on the body is to make muscles contract, so a person getting a shock may be unable to release the item that's carrying the current.

The body isn't a perfect conductor of electricity, but passing through the chest it takes only 0.05 amp to kill. That's barely enough to light a small bulb, and an amount which easily can pass through a human body that becomes a conduit between a hot AC wire and ground.

No one intentionally grabs a hot wire, but things happen. Two-prong plugs get put into sockets backwards (a condition known as reverse polarity). Circuitry chafes or cracks, exposing bare wire. Wiring inside a power tool breaks and contacts the metal case. Pick up with one hand an electric drill that has a loose wire inside, while bracing against the engine block with the other hand, and you could be the next industrial fatality.

Grounded and Grounding

AC current must alternate between two points making a circuit. Coming from the power source is the "hot" wire, which normally has black insulation, and returning is the neutral or "grounded" conductor, which is white. "Neutral" carries the same current as the hot wire. As long as the current remains in this closed circuit there is no danger, but if it should escape (a "fault" or "short circuit"), it will attempt to go directly to ground.

Most modern AC circuits have a green third wire, which is a "grounding" wire. It is connected to the third prong of the common three-prong plugs; it parallels the white wire and it connects to neutral at the power source. It's supposed to ground the circuit when a short occurs. In a household system the third wire works well as long as three-prong plugs are used and the grounding wire is intact. (Note: it won't protect you if you touch the hot and neutral wires at the same time.)

Household electrical systems are grounded through a metal rod driven into the earth under or next to the building. Between that rod and the people in the house are many layers of wood, concrete and other electrically insulating materials.

In a boatyard, where workers may be standing or crawling on wet ground, there is a potential for electrocution. When a boat is floating, the water is the ground and any metal that has an electrical path to it, including the hull of a metal boat or the engine of a glass or wood boat via the shaft, becomes a path to the ground. Touching any of these items and a hot wire at the same time can send current through the body.

Onboard Circuits

When the boat is afloat, inverters and gensets are grounded to the water via the engine and shaft, which act like the metal rod driven into the ground under your house. The risk aboard a boat comes from a short that bypasses the grounding system and finds an alternative route to the sea. Standing in bilge water or touching a metal object like rudder stock or engine block, while contacting a hot wire, could make you the conductor if there is no functional grounding wire.

Shore power presents a different set of potential problems. The shore power circuit is grounded at the dock junction box through the shore power cord and receptacle. Faulty installation, reversed polarity, defective or damaged cord or boat receptacle can create a situation that could be hazardous to persons or contribute to stray current corrosion damage to the boat.

Ground Fault Circuit Interrupters

A GFCI is an inexpensive ($20 each), switch-like device that continuously monitors current in the hot and neutral conductors. When it detects an imbalance between the two, as would occur if there were a short to ground, it instantly trips the circuit. A single GFCI can protect persons throughout the boat if it is located on the main AC feed, but because boats usually have various small current leaks, the unit may trip frequently with no indication of the source of the fault. It may be more practical to install one GFCI on each of the circuits to wet locations, such as head, galley, engine room, and weather deck.

GFCIs are extremely sensitive and can be tripped by "steam" or dense moisture in the air such as from cooking or showering, so they should be mounted in dry locations. On gas-powered boats, GFCIs must be ignition protected, or located in areas where fumes cannot collect. GFCIs should be checked at least monthly.

Shore Power

Stick to approved marine shore power cords with female twist-lock fittings that match male sealed receptacles on the boat, and male fittings for the female receptacles on the dock. Several plug patterns are in use for specific purposes, and it is essential that the correct plug be used in the receptacle. The specially made cords are sealed from moisture and rated for the correct voltage and amperage. It's better to use factory-made adapters, if plugs don't fit receptacles, than to try to cobble something together that's not made for the purpose. Extension cords modified to fit the receptacles can cause shock or fire. The shore power system is grounded at the dock junction box, but the breaker protects only the dock wiring, not the circuits inside the boat.

Power cords don't last forever and should be inspected periodically. Look for chafes and cracks. If plugs are corroded they may arc, and if they are burned, they have overheated in the past and could cause shock or fire, so they should be replaced. If a shore power cord in use feels more than slightly warm, there is resistance somewhere and the cord should be repaired or replaced.

Boat harbors have a lot of problems due to owners using incorrect cords, incorrect plugs, plugs that are burned or corroded, plugs that are forced in or not inserted correctly and locked, and with pedestal boxes that have been altered by boat owners. All of these situations can be dangerous. Any time you plug in to an unfamiliar dock box, check it first with a pocket polarity tester and with a voltmeter, then ascertain that the plug fits snugly and securely into the receptacle.

Marinas and Boat Harbors

Working inside a boat up on blocks is essentially the same as one in the water if it is grounded through its three-wire power cord. If the vessel is not grounded and a fault develops in the hot lead, workers outside the boat on wet ground or contacting metal ladders or stands are in danger. Extension cords, especially the household two-prong type, increase the risk; wearing rubber boots and rubber gloves can reduce the risk somewhat.

Using an AC on the exterior of a floating boat is courting disaster. If a power drill or sander gets splashed or falls overboard, seawater will conduct current from the hot wire to the case, making the tool hot. If the grounding wire is not effective, any path to the sea via wet decks or a metal conductor makes the worker part of the circuit.

Divers and swimmers in the water are susceptible to electrical shock, especially if there is a direct short such as would occur if a live power cord drops into the water. Even a relatively low-voltage fault can establish an electrical field around the boat, which could cause a current flow through a swimmer's body causing fibrillation. Current leakage into the water can also paralyze muscles and cause drowning with no visible evidence of electrocution.

Minimizing the Risk of Shock

Minimize electrocution risk from an onboard AC electrical system by ensuring that the vessel is properly wired by a professional marine electrician, and inspecting it periodically for damage or deterioration. If your electrician isn't familiar with ABYC (American Boat and Yacht Council) standards, find one who is.

Use only copper multi-strand wire (preferably tinned "boat cable"), of correct size for the load, with marine color coding.

Ensure that all connections are inside a panel box so that it's impossible to touch them accidentally. Better yet, make them accessible only with the use of tools. There should be no bare wires anywhere on the boat. All connectors must be properly sized "captive" (ring-type) terminals match the size of the screws, with insulated shanks, and should be made of corrosion resistant materials. Tension relief and drip loops should be incorporated.

All AC outlets on board must be three-prong type. Appliances should plug directly into three-prong wall sockets, not extension cords, and multiple socket plugs shouldn't be used on board. Maintain correct polarity by using only approved plugs and if anything in the system has been modified or repaired, check it with a polarity tester.

When making up plugs, ensure that the black wire goes to the brass or black screw, the white wire to the silver screw, and the green wire to the green screw.

Service outlets on the exterior of the boat are a potential problem and to be avoided.

Never interconnect the AC and DC systems. The green wire must connect to the boat's bonding system or metal underwater hardware, but the AC white wire must not. Don't confuse the black insulation on an AC power lead with the negative on a DC system. When you switch between a generator, inverter or shore power, the grounding connection must switch too.

(If the boat is on shore power the green wire connects to the underwater metal hardware of other boats on the same shore power system. This creates a galvanic cell that promotes stray current and galvanic corrosion. A galvanic isolator on the green wire allows passage of AC but not DC, thereby isolating the boat from the others. A more sophisticated device for the same purpose is called an isolation transformer.)

Here are a few more tips for minimizing risk when working around an AC system:

- Turn off the breaker at the shore power box before disconnecting the cord, and disconnect from the dock end first. Connect at the boat end first and switch on the dock breaker last.
- Use only tools and appliances with three-prong plugs, and if you must use extension cords temporarily with power tools, use only cords with three-prong sockets.
- Shut off generator, inverter, and main AC panel switch before working on the AC system
- If you must work on live AC, do like professional electricians and work with one hand behind your back to avoid touching hot and neutral or ground at once.
- Remove jewelry, wrist bands, or other conductive items.
- Protective clothing, including rubber boots, rubber kneepads, and rubber gloves offer some protection from shock. Rubber or plastic insulated handles on tools like pliers and screwdrivers also help.
- When working on the end of a cord with multiple wires, tape off all but the one wire you're working on.
- Unless you're trained in marine AC systems, leave it to a professional.

Two good guides for the do-it-yourselfers are *Boatowner's Illustrated Handbook of Wiring* by Charlie Wing, published by International Marine, and *Boatowner's Mechanical and Electrical Manual* by Nigel Calder, also published by International Marine.

Also check David Pascoe's Web site www.yachtsurvey.com/Electrical Systems.htm and Robb Zuk's at www.islandnet.com/~robb/marine.html. ✦