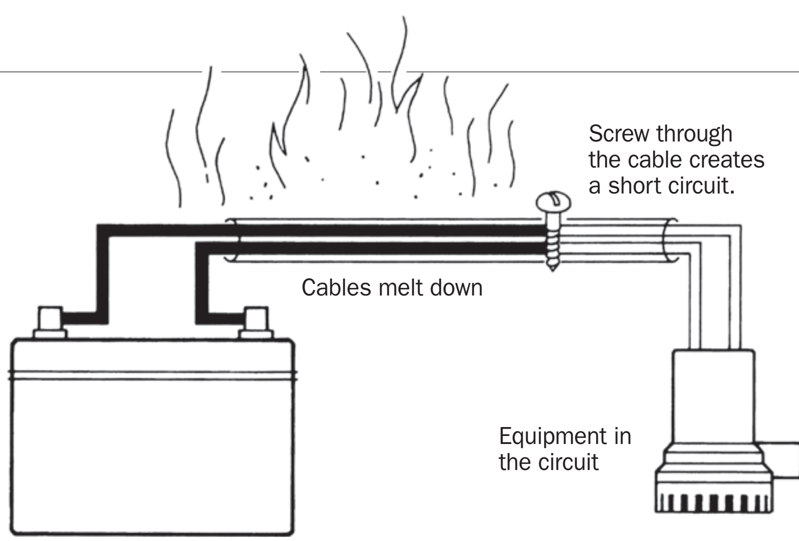
# The ABCs of OCP

## Keeping wiring safe as complex onboard systems proliferate.

**Text and photographs by [redacted]**




***Above—****When a screw creates a dead short across a circuit, the cables on the positive and negative sides melt down along their entire length, from the source of power (the battery, in this case) to the short.* ***Top right—****The author created a real-life example of the illustration above: the results of a dead short across a 12-gauge circuit.*

I have, on occasion, demonstrated what happens when I use a length of 12-gauge (AWG 12/4mm²) cable to put a dead short across a 12V battery. The moment I throw the switch on the circuit, the cable vaporizes, filling the entire room with a cloud of noxious smoke and forcing everyone to hastily evacuate.

I am not suggesting that anyone try this experiment, but I frequntly see what is, in effect, a similar test apparatus on boats I inspect. It is done by wiring one or more pieces of equipment directly to the boat's batteries without installing a fuse or circuit breaker for overcurrent protection (OCP) at the battery's positive connection, thus

setting the stage for a cable meltdown. All it takes to set things in motion is a short to ground, such as may occur if the insulation is damaged or a terminal comes adrift and contacts a grounded object, or someone installing new cabinetry puts a screw through the wiring.

Unfortunately, the plethora of electric circuits on modern boats, as compared to boats of even a few years ago, has greatly increased the likelihood of unprotected circuits. Worse yet are older boats upgraded by tacking on additional circuits, rather than by rewiring the boat. And, generally, worst of all are boats on which the owners themselves have done the wiring. A common culprit is the small-gauge voltage-sensing wires for systems-monitoring devices: wherever these connect to the positive side of a system, they need the correct fuse (typically 1 or 2 amps).

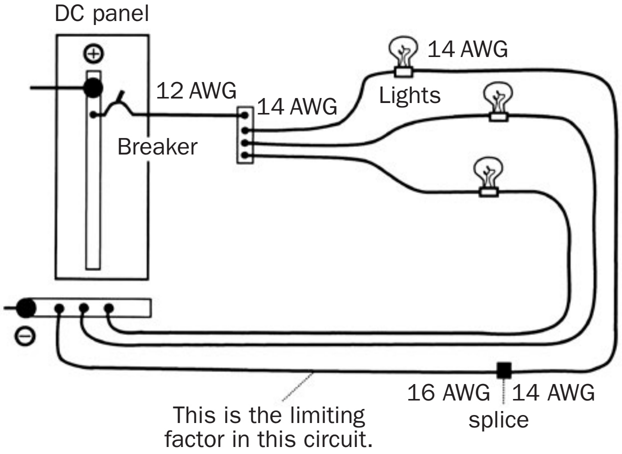
Insurance statistics from Boat U.S. show that 55% of boat fires are electrical in origin, of which more than half are caused by short circuits, most of them in the DC circuits. By comparison, engine overheating causes 22% of fires, and fuel leaks (almost all on gasoline-engine boats) cause another 8%. So be warned: If you, or anyone else, adds any circuits to a boat, make sure they are properly protected. Better yet, make a complete wiring diagram for the boat and ensure that all existing circuits are properly protected.

It also amazes me how many boats with one or more unprotected or inadequately protected circuits come from boatbuilders. (Note that circuits used solely for data transfer between electronic devices, and wiring to temperature sensors, are the only ones that do not require OCP.)

All of which leaves us with three questions:

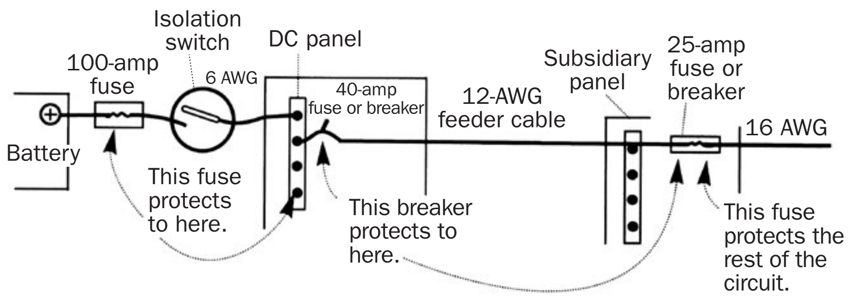
- What size fuse or circuit breaker should be used on a given circuit?
- What is the best practical method for ensuring that all circuits are properly protected?
- Where in a circuit should OCP be located?

**Fuse Principles 1**

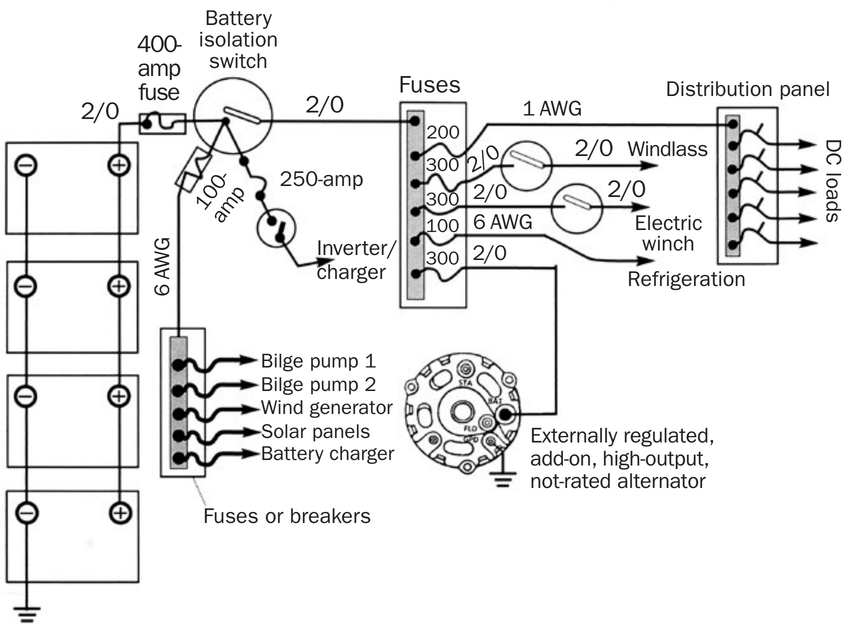



| Cable size | Ampacity outside engine spaces |
|---|---|
| 12 AWG | 45 |
| 14 AWG | 35 |
| 16 AWG | 25 |

**Fuse Principles 2**




**Fuse Principles 3**




## Fuse or Circuit Breaker Size

A popular misconception is that fuses and circuit breakers should be sized according to the current rating (amperage) of the equipment on a circuit. This betrays a misunderstanding of the purpose of the overcurrent device: to prevent the wiring in the circuit from melting down in the event of a short circuit. Since the most heat in any circuit will be developed by the section of wiring with the *highest* resistance (i.e., the smallest wire), an overcurrent device is sized to protect the *smallest* wire in the circuit. This includes the wiring on the negative and the positive sides of the circuit.

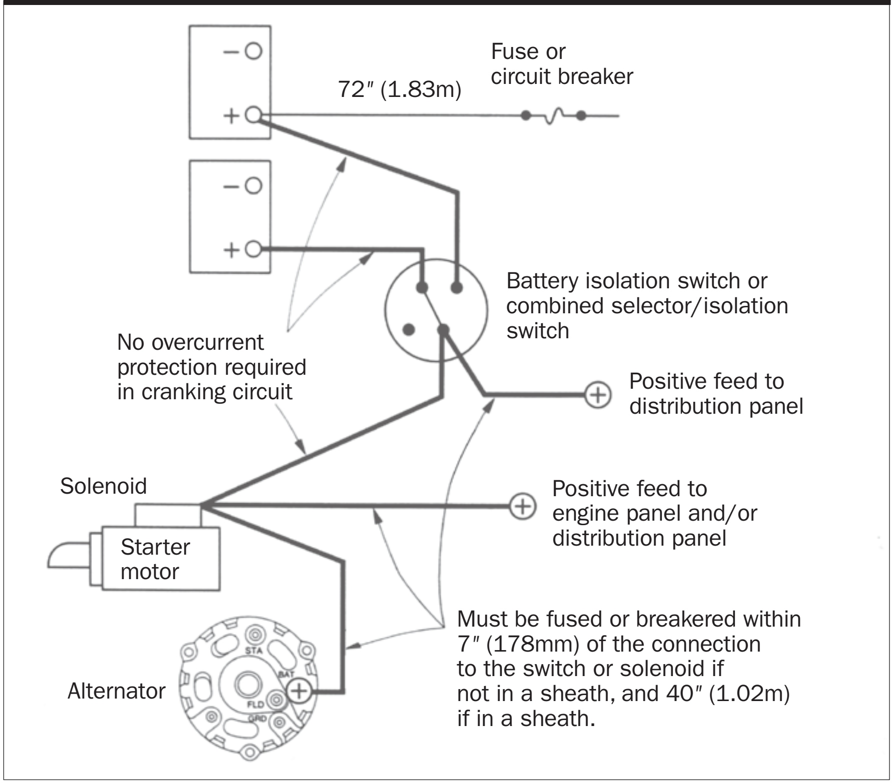
For example, if a GPS, which draws minimal current, is hooked into a circuit wired with 12-gauge (4mm²) cable, the overcurrent device should be rated to protect the wire, not the

***1**—When checking for overcurrent protection (OCP), start at the circuit farthest from the batteries and with the smallest gauge wiring, and work back toward the batteries on the positive side of the circuit until you find an OCP device, which must be sized to protect the smallest gauge wire, on both sides of the circuit, downstream of this point. In this illustration, that's a 16-gauge cable, rated at 105°C/221°F, spliced into the circuit on the negative side. In the ampacity table on page 34, we find that outside engine spaces it can carry up to 25 amps, the maximum OCP that can be used.*

***2**—Working back toward the batteries on the positive side, there's an OCP sized to protect the cables downstream from here to the first OCP.*

***3**—Each high-current device (windlass, electric winch, etc.) fed by a high-current bus bar requires cabling with OCP where it connects to the bus bar. Finally, the circuits we want to keep connected to the batteries when the battery-isolation switch is turned off are wired to another fuse or circuit breaker panel, which is wired back to the battery side of the isolation switch. The feeder cable to this panel is protected by its own OCP at the point of connection to the isolation switch. Working back to the battery, the last fuse in the system protects the feeder cable between the battery and the next OCP downstream.*

**ABYC Distance Rules**




ABYC

*Working from the battery, the first fuse must be "as close as practicable" but no more than 72" (1.83m) from the battery, and the cabling between the battery and fuse needs additional protection (sheathing, a conduit, etc.). Once we get to a switch, bus bar, or any other connection point, if cable sizes reduce, additional OCP is required within 7" (178mm) of the point of connection. Certain exceptions permit the OCP to be up to 40" (1.02m) away, so long as it is "as close as practicable" and is protected by sheathing or conduit.*

GPS, from melting down. Something on the order of a 20-amp fuse or breaker will do fine. Separate protection (generally a fuse, probably as low as 1 amp) will be needed for the GPS or any other equipment on the circuit.

If, however, a circuit breaker in a distribution panel protects a circuit to a single load, and the protection required by the load is less than that required by the cables, the breaker can always be sized to protect the load, down to about 5 amps, typically the smallest breaker available. If, on the other hand, the same approach is used for a breaker that protects several circuits, the sizing is more complex. Two factors must be considered: (1) the total load of all the electrical equipment to be served by the breaker, and (2) the current-carrying capability (ampacity) of the smallest wire being protected. The breaker must be sized according to the lower of the total load or current-carrying capability of the smallest conductor.

If a breaker feeds another subsidiary panel or fuse block, and if all the conductors from the second panel or fuse block to individual appliances are protected by their own breakers or fuses, the only conductor the first breaker has to protect is the feeder cable to the subsidiary panel. In this case, the breaker will be rated according to the lower of the total load on the subsidiary panel, or the current-carrying capability of the conductor to the feeder panel. The same design approach governs the sizing of fuses for battery cables. The fuse generally protects the circuit up to the main breaker in the panel, in which case it is sized to protect the smallest cable up to the panel.

**ABYC Table**

**Temperature Rating of Conductor Insulation**

| Conductor Size AWG | 60°C (140°F) | | 75°C (167°F) | | 80°C (176°F) | | 90°C (194°F) | | 105°C (221°F) | | 125°C (257°F) | | 200°C (392°F) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Outside Engine Spaces | Inside Engine Spaces | Outside Engine Spaces | Inside Engine Spaces | Outside Engine Spaces | Inside Engine Spaces | Outside Engine Spaces | Inside Engine Spaces | Outside Engine Spaces | Inside Engine Spaces | Outside Engine Spaces | Inside Engine Spaces | Outside or Inside Engine Spaces |
| 18 (0.8) | 10 | 5.8 | 10 | 7.5 | 15 | 11.7 | 20 | 16.4 | 20 | 17 | 25 | 22.3 | 25 |
| 16 (1) | 15 | 8.7 | 15 | 11.3 | 20 | 15.6 | 25 | 20.5 | 25 | 21.3 | 30 | 26.7 | 35 |
| 14 (2) | 20 | 11.6 | 20 | 15 | 25 | 19.5 | 30 | 24.6 | 35 | 29.8 | 40 | 35.6 | 45 |
| 12 (3) | 25 | 14.5 | 25 | 18.8 | 35 | 27.3 | 40 | 32.8 | 45 | 38.3 | 50 | 44.5 | 55 |
| 10 (5) | 40 | 23.2 | 40 | 30 | 50 | 39 | 55 | 45.1 | 60 | 51 | 70 | 62.3 | 70 |
| 8 (8) | 55 | 31.9 | 65 | 48.8 | 70 | 54.6 | 70 | 57.4 | 80 | 68 | 90 | 80.1 | 100 |
| 6 (13) | 80 | 46.4 | 95 | 71.3 | 100 | 78 | 100 | 82 | 120 | 102 | 125 | 111.3 | 135 |
| 4 (19) | 105 | 60.9 | 125 | 93.8 | 130 | 101.4 | 135 | 110.7 | 160 | 136 | 170 | 151.3 | 180 |
| 2 (32) | 140 | 81.2 | 170 | 127.5 | 175 | 138.5 | 180 | 147.6 | 210 | 178.5 | 225 | 200.3 | 240 |
| 1 (40) | 165 | 95.7 | 195 | 146.3 | 210 | 163.8 | 210 | 172.2 | 245 | 208.3 | 265 | 235.9 | 280 |
| 0 (50) | 195 | 113.1 | 230 | 172.5 | 245 | 191.1 | 245 | 200.9 | 285 | 242.3 | 305 | 271.5 | 325 |
| 00 (62) | 225 | 130.5 | 265 | 198.8 | 285 | 222.3 | 285 | 233.7 | 330 | 280.5 | 355 | 316.0 | 370 |
| 000 (81) | 260 | 150.8 | 310 | 232.5 | 330 | 257.4 | 330 | 270.6 | 385 | 327.3 | 410 | 364.9 | 430 |
| 0000 (103) | 300 | 174 | 360 | 270 | 385 | 300.3 | 385 | 315.7 | 445 | 378.3 | 475 | 422.8 | 510 |

**Maximum Allowable Amperage**

ABYC

## Defining Limits

The current-carrying capability of cables is given in various tables. These are used to determine the maximum circuit breaker or fuse rating (you can always go lower). In the American Boat & Yacht Council (ABYC) table, for a given wire size (e.g., AWG 12/4mm²) there are various columns with different temperature ratings (e.g., 90°C/194°F; 105°C/221°F), with each temperature rating column divided in two ("Inside Engine Spaces" and "Outside Engine Spaces"). The wire size (e.g., AWG 12/4mm²) defines the diameter of the copper core in the cable. When current (amperage) is run through this copper, its internal resistance causes some heating. The higher the melting point of the insulation wrapped around the copper, the more amps it can carry, hence the various columns with insulation temperature ratings. The higher the insulation temperature rating, the more amps we can safely put through a given piece of copper.

For cabling in an engineroom, it is assumed that engine operation will raise the ambient temperature (to 50°C/122°F in the case of the ABYC standard in the U.S., and 60°C/140°F

### Cable Sizing: ISO versus ABYC, and AWG versus SAE

U.S. cable sizes are counterintuitive—the bigger the cable, the smaller the number. Eventually, the system gets down to 0 and runs out of numbers, at which point as cables get even bigger the zeros are stacked up (e.g., 00, commonly written as 2/0, or 000, written as 3/0, and so on). The European system simply measures the diameter, or cross-sectional area, of the copper in a cable and uses that.

Not only are U.S. cable sizes counterintuitive, but there are also two different cable-sizing formulas using the same numbering system. One is American Wire Gauge (AWG); the other has been developed by the Society of Automotive Engineers (SAE). For a given wire size (e.g., 16-gauge), SAE-rated cables have approximately 10% less copper than AWG-rated cables. SAE sizing is acceptable in DC circuits, but is not acceptable in AC circuits.

To avoid confusion, the best practice is to use AWG-sized cables in all applications.

for the ISO norm in Europe), in which case the cable is already warmed up before any amps are run through it. This preheating means the cable can carry fewer amps before the insulation reaches its temperature limit, and thus the "Inside" and "Outside" engine-room subcolumns for each insulation temperature rating.

A cable can also be preheated if it is installed in a bundle with other cables that are under load and have warmed up. To cope with this situation, the higher the number of cables in a bundle, the more the current-carrying capability (ampacity) of the individual cables is de-rated. This is done by applying a de-rating factor. Until recently the ABYC applied this de-rating of bundled cables only to circuits carrying more than 60V, which in practical boating applications means AC circuits, but the ABYC now also partially applies de-rating to DC circuits.

A coiled shore-power cord sitting in the sun is one instance not covered by bundling and other rules for which a cable should still be de-rated because of high temperature. The combined effects of the coiling (in effect, a form of bundling) and solar heating can effectively de-rate a shore-power cord by as much as 50%. Another example would be cables run against insulated surfaces, or inside a conduit surrounded by insulation. A cable should be de-rated any time there is any obstruction to dissipating the heat generated within it.

**Bundling of Cable**

| Number of conductors bundled | Multiply maximum amperage in the ampacity table by: |
|---|---|
| 4 to 6 | 0.7 |
| 7 to 24 | 0.6 |
| 25 or more | 0.5 |

Finally, note that most cabling used in U.S.-built boats has an insulation temperature rating of 105°C/221°F, as opposed to the 90°C/194°F or even 60°C/140°F cabling found in many European-built boats. The insulation temperature rating should be printed on the cable, and if it is not, the cable does not comply with ABYC standards. Most devices attached to this cabling are rated at 90°C/194°F or lower. If the cabling is run continuously at its maximum rated ampacity, heat generated in the cabling will be transmitted to attached devices, potentially exceeding their temperature ratings. In general, even with 105°C/221°F cabling, it is best to use the 90°C/194°F or lower insulation temperature rating columns for determining the maximum allowable ampacity and OCP rating for a given circuit.

## Determining Ampacity

When using the ABYC table, for any given cable size the maximum allowable OCP rating is found by looking up the cable size in the left-hand column and then tracing across the row to the appropriate insulation temperature rating column. As noted above, in some circumstances a lower cable insulation rating may be selected. If any part of the circuit being protected is inside an engineroom, the Inside Engine Spaces subcolumn is used to determine the maximum allowable OCP, but otherwise, the Outside Engine Spaces subcolumn is relevant. If the cable is in a bundle, apply the appropriate de-rating factor based on the number of cables in that bundle. The result is a maximum allowable OCP rating for this cable.

If there is no exact match between the resulting cable ampacity and available fuse or circuit breaker ratings, the ABYC standards permit the next highest rated fuse or breaker to be used on all but main distribution panel fuses and breakers (these cannot exceed 100% of the circuit rating), as long as the fuse or breaker's rating does not exceed 150% of the ampacity of the cable it is protecting. For example, if a cable is rated at 17 amps in a given environment, but the only fuses and breakers available are rated at 15 and 20 amps, the 20 amp breaker, at 117% of the cable rating, is acceptable.

Electric motors commonly have their own OCP. If this is not the case, the overcurrent protection on circuits with motors should be rated at 100% of the load, assuming the cable has at

*__Right__—This properly labeled cabling, as required by the ABYC, includes the cable size and temperature rating. __Far right__—The published ampacity rating of cables typically assumes installation in a dry environment. For cables installed in a wet environment, the temperature rating is substantially reduced, which in turn reduces the ampacity.*


**UL 1426 Boat Cable Temperature Ratings**

| Cable temperature rating, dry and wet | Temperature rating code |
|---|---|
| 60°C dry, 60°C wet | BC-1W1 |
| 75°C dry, 60°C wet | BC-2W1 |
| 75°C dry, 75°C wet | BC-2W2 |
| 80°C dry, 60°C wet | BC-3W1 |
| 80°C dry, 75°C wet | BC-3W2 |
| 90°C dry, 60°C wet | BC-4W1 |
| 90°C dry, 75°C wet | BC-4W2 |
| 105°C dry, 60°C wet | BC-5W1 |
| 105°C dry, 75°C wet | BC-5W2 |

## Ampere Interrupting Capacity

The primary rating for fuses and circuit breakers is the amperage at which they are designed to blow or trip. Buried in the small print is another amperage known as the Ampere Interrupting Capacity (AIC). This is typically thousands of amps, and tells us the maximum current the device can safely interrupt if it gets hit by an enormous spike, such as might occur with a dead short across a battery or in the event of a lightning strike. If the current goes above the AIC level, the device may arc across or form some other conductive path, and fail to do its job.

The ABYC requires AC and DC circuit breakers to have a minimum AIC rating of 3,000 amps in most circumstances, and 5,000 amps in some. The ABYC's E-11: AC and DC Electrical Systems on Boats has detailed prescriptions. The primary fuse on any relatively large battery bank needs to have an AIC rating of at least 5,000 amps and, in some cases, much more than this. (Lithium-ion batteries, for example, may be capable of creating short-circuit currents of tens of thousands of amps.) E-11 provides a table and procedure for determining the necessary AIC rating for that all-important first fuse in a DC system, and for the main breaker in an AC system. If a battery system requires a very high AIC rating, Class-T fuses will do the job. These are widely available and not that expensive.

least this ampacity. OCP devices for motor loads have to be designed to handle the start-up, or inrush, current, which may be up to six times the running load. This requires a fuse or circuit breaker with a slow response to overload conditions—generally a slow-blow fuse or a thermally rather than magnetically operated breaker.

One situation needs particular attention. If a motor gets into what is known as a locked-rotor state (meaning the motor is jammed—for example, a centrifugal bilge pump with a piece of trash in the impeller), its current draw can rise sharply, potentially overloading the circuit and/or melting down the pump housing. If the rise in current is high enough and the circuit or motor is properly breakered or fused, the breaker or fuse will trip or blow.

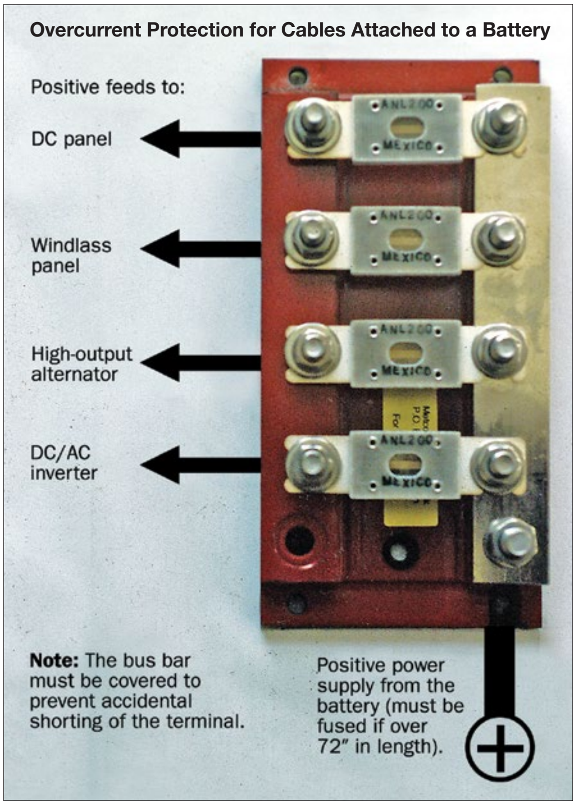
But sometimes, particularly with bilge pumps, there is a long run of marginally sized wiring to the motor. If a locked-rotor condition develops, the total resistance in the circuit may be sufficient to limit the current flow to a level that will not trip the breaker or blow the fuse but which nevertheless is high enough over time to start a fire at the pump. Using a lower-rated fuse or breaker is not the answer, because it may lead to nuisance blowing/tripping with normal inrush currents. The wire size must be increased so that the voltage drop on the circuit is lowered to a level at which sufficient current to trip the breaker or blow the fuse can flow. In any event, the ABYC requires that all motors and motor circuits be designed and protected so that they can withstand a locked-rotor condition for seven hours without creating a fire hazard. (Typically, if the motor might melt down, it is given an internal heat-sensitive trip device; some of these reset themselves once the motor has cooled off, while others require manual resetting.)

### High-Current Circuits

Historically, high-current DC circuits (100 amps and higher) have been the hardest to protect simply because of the lack of affordable OCP devices. Relatively cheap and compact breakers rated at up to 150 amps are now widely available, together with cheap, compact fuses up to 800 amps. There is simply no excuse for not protecting all high-current circuits, including cranking circuits.

Those have large, awkward-to-handle cables. The neatest way to deal with them, and provide the necessary protection, is to run a single heavy cable, normally 2/0 gauge ($70mm^2$), from the positive post on the house batteries to a battery-isolation switch. This cable must be properly fused as close to the battery as possible. If the cable is bolted (as opposed to clamped) to the battery post, there are purpose-built fuses that can be added at the battery post itself.

Another cable (the same size as the first) is run from the isolation switch to a high-current bus bar, which is nothing more than a heavy copper plate (preferably tin-plated for corrosion resistance) drilled and tapped to take a series of bolts. The cable from the isolation switch is bolted to the bus bar. The bus bar is mounted on a phenolic or plastic base plate, with another series of bolts set up parallel to the bolts in the bus bar. Fuses are bolted in place between the bus bar and the second set of electrically isolated bolts. With this installation you can attach




***Above***—*This example of a high-current bus bar is mounted on a nonconductive base plate with appropriately rated ANL fuses for various high-current circuits.*
***Top right***—*These fuses are booted to protect against accidental short circuits. Note that there are still exposed conducting surfaces between the fuses.*
***Bottom right***—*These hand-tightened knurled knobs are convenient for rapid fuse changes without tools but do not create adequate pressure for high-current circuits. Bolted connections are needed.*

the boat's various high-current circuits, such as a windlass, bow thruster, high-output alternator, the DC panel, etc., to the isolated bolts. The various fuses are sized according to the current-carrying capability of the cables bolted to them. For example, a windlass may need an AWG 2/0 (70mm$^2$) cable with a 300-amp or lesser fuse, while a distribution panel will normally have cables on the order of AWG 4-gauge (25mm$^2$), protected with a fuse of around 150 amps or less.

## Circuits Bypassing the Isolation Switch

Some circuits will still need to bypass the isolation switch so that they may be left on when the rest of the boat is shut down. These circuits typically include a bilge pump and any charging devices (including solar panels, maybe a wind generator, and the inverter if it also doubles as a battery charger). Other examples are a carbon monoxide or propane alarm, DC-systems-monitoring devices, power supplies to electronics with a memory function, impressed current cathodic protection systems, and sometimes a refrigerator and freezer, although these last two are not currently permitted under ABYC standards.

All but the inverter are wired to a separate auxiliary bus bar fed by a fused cable that is tied into the battery side of the isolation switch. Each circuit is, in turn, fused at the bus bar. Because of the heavy cable that likely leads to the inverter, wire the inverter directly to the terminal on the switch, and provide it with its own fuse as close to the switch as possible.

The net result of such an approach is that every single circuit on the boat will be fully overcurrent protected at its source. However, if the boat is wired as suggested, the circuits that bypass the battery switch will be fused but not switched; in other words, they can never be turned off. I prefer this method, because it prevents the bilge pump and other key circuits from being accidentally turned off, but others prefer a switch or circuit breaker in this circuit.

## OCP Location

The goal is to provide protection at the source of power for each circuit. With DC circuits, the OCP is *always* placed in the positive side of DC circuits. (Apart from anything else, an unbroken connection to DC negative must be maintained at all times to protect against stray-current corrosion. Note that some European boatbuilders install fuses and battery switches in the DC negative side *and* on the positive side, but this is not recommended.)

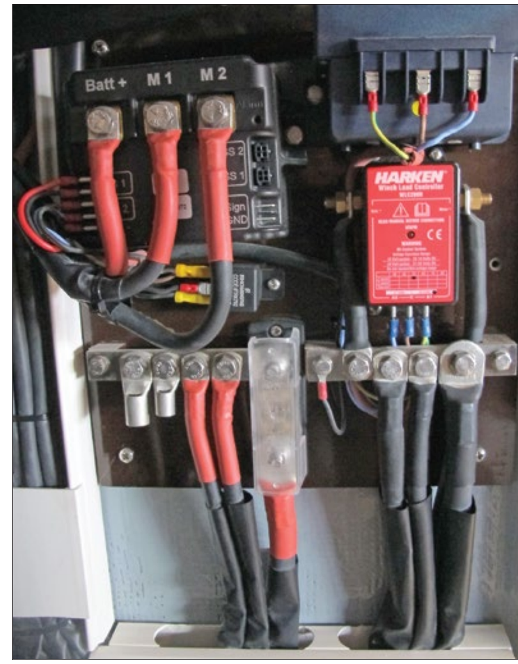
The ultimate source of power for any DC circuit is the battery, but the practical source of power is the connection point of the circuit to the DC system. This point may be at the battery, the battery switch, the distribution panel, a subsidiary panel, some distribution bus bar, or other connecting point.

If the cables in the new circuit are no smaller than the cable that feeds the new circuit's point of connection, then the OCP for the feeder cable will sufficiently protect the new circuit. The same will apply even if the feeder cable is larger than the cables in the new circuit, as long as the feeder cable's OCP has been downsized to the point at which it effectively protects the new circuit. But if the new circuit is not adequately served by overcurrent devices already in place, additional protection is required at its point of connection, i.e., at its source of power.

Sometimes space limits how close an OCP device can be placed to the source of power. (In any case, fuses, circuit breakers, and switches should not be installed in battery compartments, because of the risk of corrosion coupled with the potential presence of explosive gases. If they must be installed in battery compartments, they should be ignition protected.) The question then arises, how close is close enough? The generic answer, from the ABYC, is within 7″ (178mm).

The ABYC allows the following exceptions, which have been tightened up in recent years:

- A cable connected directly to a battery that is also "contained throughout its entire distance in a sheath or enclosure such as a conduit, junction box, control box or enclosed panel" must have its overcurrent protection "as close as practicable to the battery, but not to exceed 72 inches (1.83m)." Note the "as close as practicable" phrase. Gone is the blanket 72″ allowance that used to be there.
- A cable connected to a source of power other than the battery (i.e., the battery switch, the distribution panel, or some other point in the DC circuits) that is similarly contained in a sheath, etc., must have its overcurrent protection "as close as practicable to the point of connection to the source of power, but not to exceed 40 inches (1.02m)." Once again, the "as close as practicable" phrase has replaced the former blanket acceptance, 40 inches here.
- "Overcurrent protection is not required in conductors from self-limiting alternators with integral regulators if the conductor is less than 40 inches (1.02m) in length, is connected

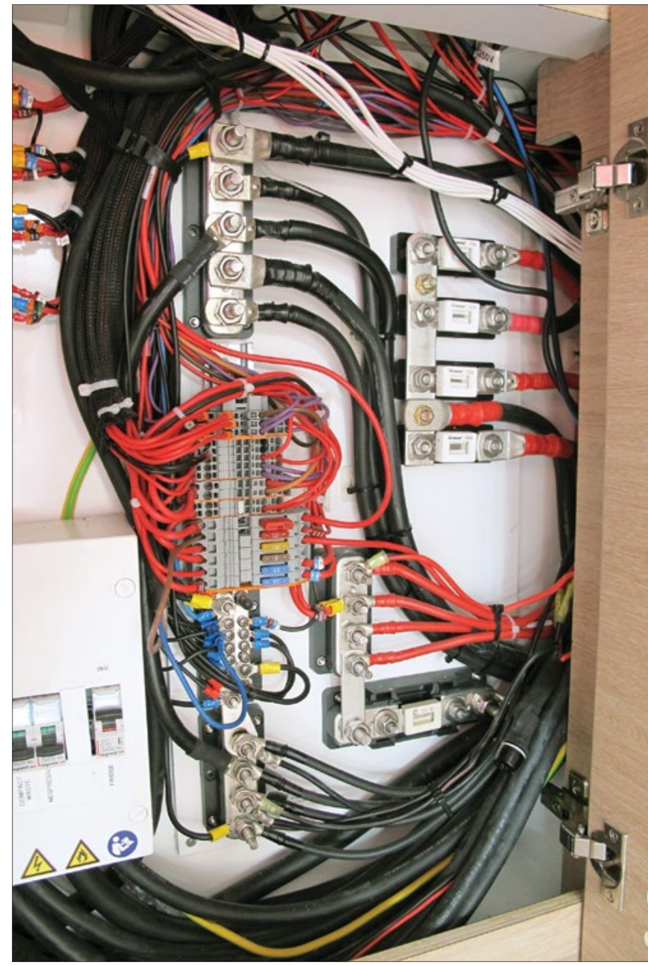




***Above*—Where is the OCP on the positive battery cables? It may be just out of sight, in which case the location complies with ABYC standards, but the cables need additional protection (sheath, conduit, etc.) up to the point of connection to the OCP. *Right*—These unbooted positive connections next to a negative bus bar are in a locker where other equipment is likely to be stored. If some conductive object creates a short circuit, there will likely be major arcing and potentially a fire on board.*

to a source of power other than the battery, and is contained throughout its entire distance in a sheath or enclosure." This exception covers the standard alternator that comes with a marine engine or generator and is wired to the starter motor solenoid, and the batteries, and which is almost never overcurrent protected.

• If the regular alternator is replaced by a high-output model with an external regulator, or an alternator with an internal regulator but which is wired back to the batteries, or if a second alternator is fitted with an external regulator or wired back to the batteries, the new alternator requires OCP at its point of connection to the source of power—i.e., wherever it ties into the DC system. Given that alternators themselves are a source of power, it has been debatable whether these added alternators required OCP at the alternator itself. This has been resolved in the latest version of the ABYC E-11 standard as follows: "Overcurrent protection is not required at an alternator if the ampacity of the conductor is equal to or greater than the rated output of the alternator."

• Cranking-motor circuits are not required to have overcurrent protection. This exception originates in the automotive field, where starter-motor cables are short and well secured. In the marine field, where cranking circuits may be long, this practice might create a hazard. If a car catches on fire, the occupants can pull over and jump out. If a boat catches fire, it is not so simple. It makes no sense to have any unprotected circuits on a boat. Protecting cranking circuits, however, is problematic. In cold weather, the inrush current on a 12V starter motor may be as high as 1,500 amps; the cranking current may be as much as 200 amps. Often, cranking cables are undersized even for the cranking current, let alone the inrush current. This situation does not pose a safety problem per se, because these currents are sustained for only a few seconds, so the cables do not have time to get hot enough to create a fire hazard. But if OCP is based on the ampacity of the cables (as required by ABYC standards for all other circuits), any fuse will blow whenever the engine is cranked. My solution is to oversize the fuse to avoid nuisance blowing, knowing that in the event of a dead short, the very high current flows will cause the fuse to blow. (For the typical auxiliary diesel with a 12V starter motor, I use a 300-amp slow-blow fuse. Given that the standards require no fusing in the cranking circuit, I am not concerned by the fact that this fuse does not comply with the general prescription for sizing overcurrent devices).



### Check All Boats

As the electrical load on boats increases, so too does the complexity of electrical circuits and the potential for short circuits and electrical fires. It is more important than ever to wire all circuits with proper OCP, and yet so often this protection is omitted—sometimes even by the original boatbuilder. It is important when performing electrical work on any boat to take a close look at all the cables attached to the battery positive posts. If any are unfused (other than wiring to temperature sensors), take immediate steps to correct the situation. Ideally, all the circuits on a boat will then be traced to their final circuits, ensuring that at each reduction in cable size there is appropriate OCP in place. The time and money will be well spent.

## Simplified Selection Procedure for Overcurrent Protection Devices

1. Determine whether a fuse or a circuit breaker is more suitable for the task.
2. Determine the ampacity of the smallest cable to be protected by the overcurrent device.
3. Determine the maximum continuous current that will flow on the circuit.
4. Check the ABYC AIC ratings tables to find the minimum acceptable AIC for the circuit.
5. Select a fuse or circuit breaker to meet the AIC rating and that has an amp rating no higher than the cable ampacity, and at least as high as the continuous load (as long as this load does not exceed the ampacity of the cable).
6. If this is a circuit to an electric motor, check that the fuse or circuit breaker will respond slowly enough to an overload condition to handle the start-up (inrush) current without nuisance blowing or tripping.

*(Adapted from a procedure courtesy Blue Sea Systems)*

*Left* **and** *above*—Two more examples of unbooted positive bus bars and connections adjacent to negative bus bars in lockers (I see this particularly on catamarans). Although technically ABYC compliant, if there is OCP upstream of the positive bus bars, the installations are all potential fire hazards if loose equipment causes a short circuit.

A fire at sea can be a terrifying experience. Smoke billowing out of the companionway hatch is not the way to find out that a boat has inadequate overcurrent protection.

### Resources

Relevant ABYC standard: E-11

Relevant ISO standards: ISO-10133 and ISO-13297

Wire-Sizing Tools

ABYC app (abycinc.org/page/wiresizer)

Dirty Dog app (dirtydogsoftware.com/dc-wire-sizer/)

Blue Sea Systems (circuitwizard.bluesea.com/#)