Technical Brief - DC Circuit Protection

Electrical shorts are the number one cause of fires on boats. In fact, more than half of boat fires are electrical in origin. More than half of those are caused by short circuits, most in the DC circuits. If you add any circuits to your boat, make sure they are protected.

Important factors to consider when adding circuit protection to your boat's DC electrical system include:
- Ampere Interrupt Capacity (AIC)
- Mounting location
    - Overcurrent protection (7/40/72 Rule)
    - Ignition protection

If more current flows in a wire than the wire is rated to handle, the wire can heat up, its protective insulation can melt, and the heated wire can start a fire. This overcurrent condition can occur, for example, when a short circuit occurs. Fuses and circuit breakers are used to limit the amount of current that flows through circuit wires. Except for those wires that are intended to carry starting currents, every positive wire in the DC main power distribution system must be protected by a fuse or circuit breaker.

The American Boat & Yacht Council (ABYC) develops safety standards for boat building and repair. These standards are useful guidelines when planning and installing boat electrics (see Application Brief: DC Main Power Distribution). ABYC publishes standards for AIC, overcurrent protection, and ignition protection.

This Technical Brief addresses issues related only to circuit breakers. For information on fuses, refer to Blue Sea Systems 2006 catalog, pages 27-29.

AIC (Ampere Interrupt Capacity)
In certain circumstances, main DC circuit breakers may have to break very high amperages. In such situations, the points inside the breaker may arc over, and may fuse together. The ability of a circuit breaker to safely handle such a situation is its Ampere Interrupt Capacity (AIC) rating.

According to ABYC standards, circuit breakers shall have:
- A DC voltage rating of not less than the nominal system voltage
- Be capable of an interrupting capacity according to the values in the table below
- Remain operable after the fault

The potential short-circuit current on a DC circuit is related to the size of the battery bank. Therefore, AIC is a function of a battery's Cold Cranking Amperes (AIC) capacity as shown in the table.

DC Voltage Rating	CCA of all connected batteries	Ampere Interrupt Capacity (AIC)	
		Main CB (Amperes)	Branch CB (Amperes)
12 Volt and 24 Volt	650 or less	1500	750
	651-1100	3000	1500
	over 1100	5000	2500
32 Volts	1250 or less	3000	1500
	over 1250	5000	2500

For example, a boat with a group 24 or 27 battery may have as much as 650 CCA. The DC main circuit breaker for this circuit must have an AIC rating of 1500 Amperes. Then, if very high amperage occurs in the circuit, the circuit breaker will break the circuit without arcing over or fusing together. And it will remain operational after the fault.

Overcurrent Protection Placement
The ABYC also publishes standards for the placement of circuit protection in the DC main circuit. The goal of overcurrent protection is to provide protection at the source of power for each circuit. With DC circuits, the overcurrent protection is always placed in the positive side. Circuit protection should be connected as close as possible to the source of power.

Sometimes there are physical limitations to how close a circuit protection 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 gasses. The question then arises, how close is close enough?

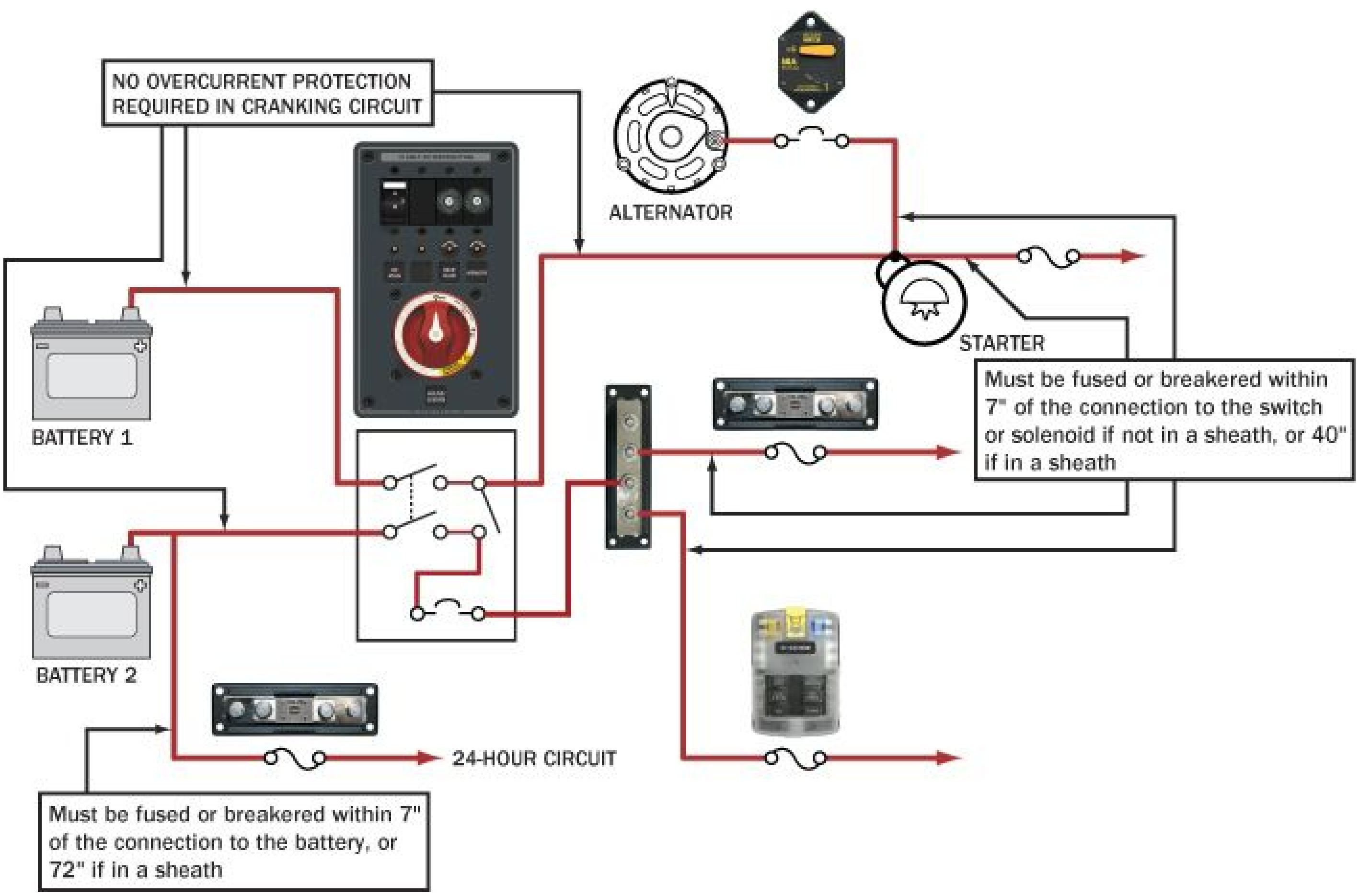
ABYC E-11 recommends that each ungrounded conductor connected to a battery, battery charger, alternator, or other charging source, shall be provided with overcurrent protection within a distance of seven inches (175mm) of the point of connection to the DC electrical system or to the battery. There are exceptions to this seven-inch rule.

If the conductor is connected to a source of power other than a battery terminal and is contained throughout its entire distance in a sheath or enclosure such as a conduit, junction box, control box, or enclosed panel, the overcurrent protection shall be placed as close as practicable to the point of connection to the source of power, but not to exceed 40 inches (1.02m).

If the conductor is connected directly to a battery and is contained throughout its entire distance in a sheath or enclosure such as a conduit, junction box, control box, or enclosed panel, the overcurrent protection shall be placed as close as practicable to the battery, but not to exceed 72 inches (1.83m).

Overcurrent protection is not required in conductors from self-limiting alternators with integral regulators if the conductor is less than 40 inches long (1.02m), is connected to a source of power other than the battery, and is contained throughout its entire distance in a sheath or enclosure.

This diagram shows the required placement of main circuit protection devices.



Notice that wires intended to carry engine-starting currents between the batteries, the switch, and the starter, are not required to have main-circuit-protection devices installed.

This exception is based on the notion that the starting battery would have just enough power to handle starting the engine, and the wiring would be appropriately sized such that the full capacity of the battery would be unlikely to overstress the wire. It was also assumed that the batteries would be very close to the engine.

Some modern installations violate some or all of these assumptions with very large house banks that may include an emergency cross connection switch, making them part of the starting system. The house banks may be some distance away from the engine in different compartments. Some experts believe that all circuits on a boat should be protected - including the start circuits. However, at this time, this is not an ABYC recommendation.

Choosing an Amperage Rating
Generally, circuit protection devices are installed to protect the wiring from overheating during overloads or faults. The simplest approach for selecting a circuit protection device rating is to choose an amperage rating that is equal to or less than the current rating, ampacity of the wire. If the wire ampacity is significantly greater than the load current, as might be with small loads or with wiring of increased size to reduce voltage drop, then a range of circuit protection values between the load requirement and the wire ampacity may be acceptable. Larger ampacity values reduce the probability of nuisance failures and reduce fuse heating; smaller ampacity values provide more conservative protection for the wiring.

In some cases, a product manufacturer may recommend that a specific fuse or circuit breaker size should be used with the product. If that is the case, the wire to the product should be selected so that the wire ampacity exceeds the recommended rating, which will protect both the product and the wiring.

Ignition Protection
When installing electrical components in your boat, you must consider the risk of igniting volatile fumes. If devices are installed in locations where they can ignite fumes, they must be ignition protected. ABYC E-11.5.1.3 and US Coast Guard regulations require that electrical sources of ignition located in spaces containing gasoline-powered machinery, gasoline fuel tanks, and locations where fumes from gasoline or LP gas fumes can accumulate, comply with standards for ignition protection. To be ignition protected, these devices must have spark-producing mechanisms sealed, and have low enough surface temperatures that they will not ignite gas fumes. Even diesel-powered vessels have suffered major fires and explosions as a result of fumes from dinghy fuel or stored painting supplies. Switches, circuit breakers, and fuses are all considered to be potential sources of ignition.