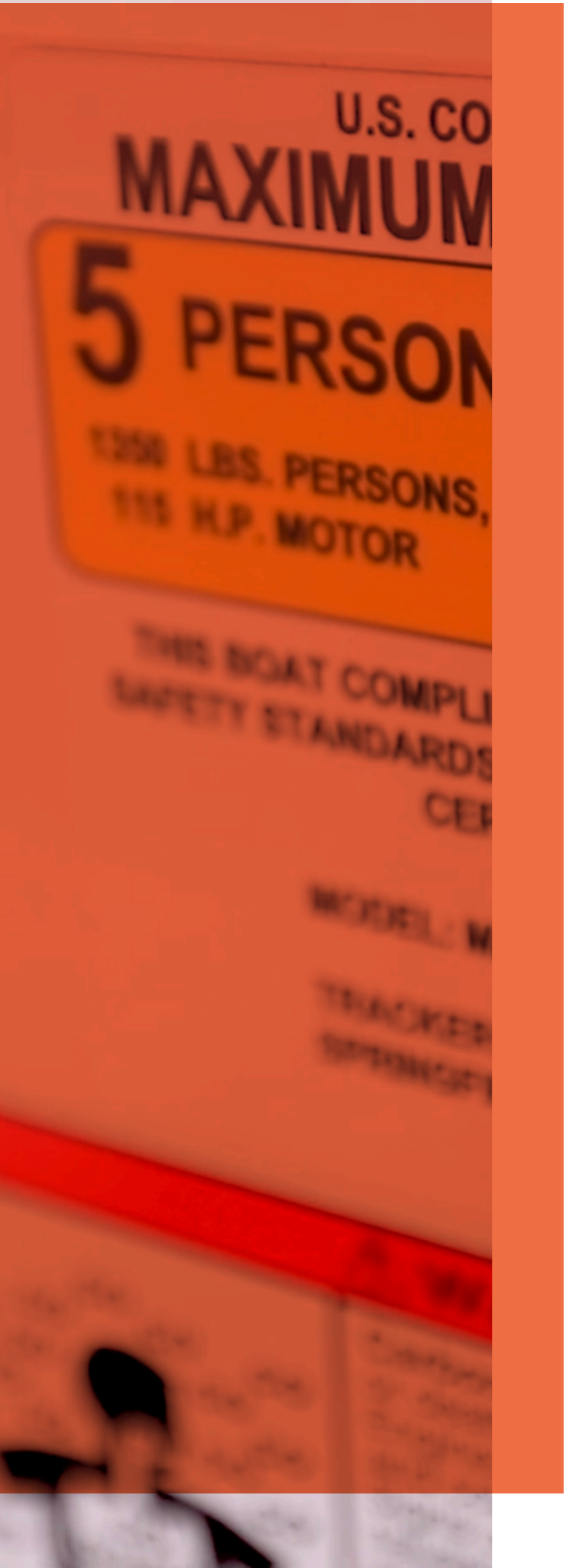


BOAT BUILDER'S HANDBOOK

2021 Edition

ELECTRICAL SYSTEMS

33 CFR 183 SUBPART I

Produced under a grant from the Sport Fish Restoration and Boating Trust Fund Administered by the U.S. Coast Guard.

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INTRODUCTION

Electrical systems for many types of boats are complex. U. S. Federal regulations address critical areas pertaining to electrical systems from the standpoint of safety and stipulate requirements to assure good practice in these areas. Some requirements may be specifically applied but many requirements interact with others such as determination of wire size and overcurrent protection. The large number of requirements and the possible interpretations tend to be confusing for those using the regulations.

Regulations are typically written in concise terms, the words and arrangement chosen to be enforceable and in some cases to be legally interpreted. This format prohibits including explanations, recommendations and easily detected alternate solutions. A regulation provides an outline about which a great deal of further information, interpretation, explanation, clarification and helpful hints are needed in order to provide good understanding and compliance with its intent.

This electrical system guideline attempts to assist the average boat builder in achieving compliance with these regulations. It explains, diagrams, makes some recommendations and, in general, complements the regulations to improve the boat builder's understanding.

> **TAKE HEED:** Boat builder compliance means fully meeting all applicable regulations.. The Boatbuilder's Handbook provides a basic introduction and summary of the regulations.. Builders need to refer to the actual regulations for the complete text of the regulation to ensure full compliance.. It is the boat manufacturer's responsibility to review, understand, and comply with all applicable regulations.

FORMAT

The format of this guideline has been chosen to follow the sequence in the electrical system regulation. This format provides a consistent sequence of information, thereby reducing confusion for the boat builders and component manufacturers who use it.

First, a section of the regulations will be stated in plain language – then the topic will be discussed in detail. Often a figure will be added to supplement the discussion. The section will identify the CFR cite; the full text of the regulation is readily available in Appendix 1.

Typical electrical systems of various types of boats are annotated to show the applicable section of the regulation. The systems shown are examples and are not intended to be limiting in any way. Both simpler and more complex systems may be installed on any of the depicted boats. Appendix 2 lists references and resources.

ENGINE CUT-OFF SWITCH

A new (electrical system related) requirement regarding engine cut-off switches has been included in guideline section 13.0. The requirement is not yet included in the CFR.

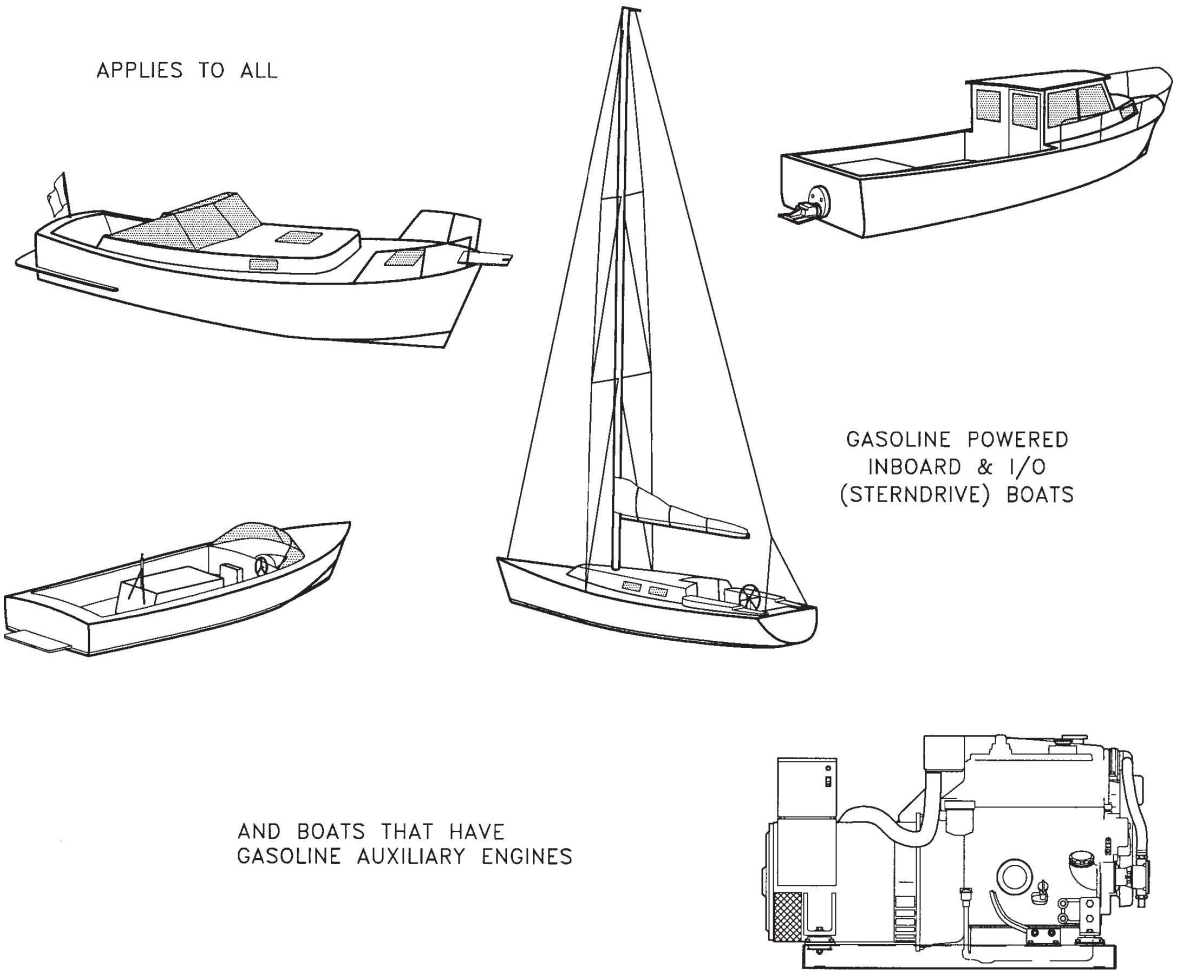
1.0 APPLICABILITY

> Per 183.401 the electrical systems regulation applies to all boats that have gasoline engines (except outboard engines) for electrical generation, mechanical power, or propulsion.

A boat with (only) an outboard engine is not subject to this regulation. An outboard powered boat that also has a gasoline engine generator installed is subject to this regulation. An 'installed' generator will require tools for removal. Such a boat with (only) a 'portable' generator strapped to the deck, or simply held by hand tightened wing nuts, is not subject to this regulation.

Each electrical component on boats subject to this regulation must be compliant. It is the boat builder who must certify full compliance of all components – and of the complete boat. Boat builders may cite supplier documentation and or national standards organizations for component compliance.

FIGURE 1 Applicability



Per 183.405: Each component of the electrical system (on applicable type boats) must be compliant.

The boat manufacturer, not the manufacturer of each component, is required to certify each boat as complying with this regulation. Component parts of outboard engines and portable equipment, such as a self-contained gasoline engine generator unit, are not covered by these regulations.

The Equipment Standards of this regulation appear to impose requirements, and consequently certification responsibilities, on component manufacturers including inboard engine manufacturers. This is not the case. The boat manufacturer is responsible under these regulations and must certify compliance. Purchase orders can stipulate that component manufacturers provide affidavits of compliance that a boat manufacturer may choose to recognize as supporting evidence in certifying the entire electrical system.

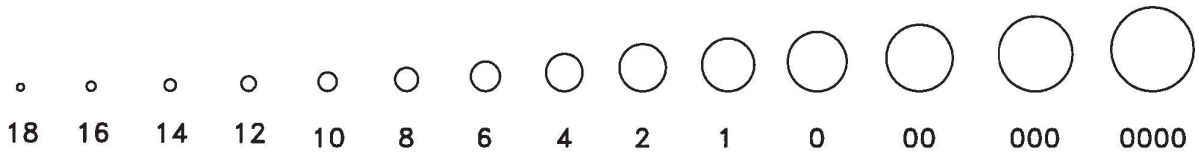
2.0 DEFINITIONS

Per 183.402: electrical system terms are defined.

2.1 AWG. AWG MEANS AMERICAN WIRE GAUGE.

The gauge of a wire is its size. The American Wire Gauge is a nationally accepted convention for designating wire sizes. The higher the number, the smaller the diameter of the wire. For example, 16 gauge wire has a smaller diameter than 12 gauge wire. For large sizes of wire, 0, 00, 000 and 0000 are used. The more zeros, the larger the wire.

FIGURE 2 Conductor Gauge (insulation not included)



(APPROXIMATE SIZES – FOR COMPARISON ONLY)

Conductors may be labeled with their size. If not, and the size is to be determined, then measure the diameter of an individual strand using a micrometer. Square the diameter of the strand (in mils) and multiply by the number of strands in the conductor. This will provide the total circular-mil area of the conductor. Refer to Table 1 to find the gauge.

TABLE I Conductors

Conductor Size	MINIMUM ACCEPTABLE CM AREA SAE (See Note 2)	MINIMUM ACCEPTABLE CM AREA AWG (See Note 3)	APPROXIMATE DIAMETER OF WIRE—INCHES (Insulation not included)
18	1,537	1,620	.050
16	2,336	2,580	.060
14	3,702	4,110	.075
12	5,833	6,530	.090
10	9,343	10,380	.115
8	14,810	16,510	.160
6	24,538	26,240	.210
4	37,360	41,740	.275
2	62,450	66,360	.335
1	77,790	83,690	.375
0	98,980	105,600	.420
00	125,100	133,100	.475
000	158,600	167,800	.535
0000	205,500	211,600	.595

Formula: CM = d2 x N

Where: d = diameter of one strand in mils (one mil = .001 inch) N = number of strands in the conductor

1. *If the conductor contains strands of various sizes, measure the diameter of each strand, square the diameter, and add the individual circular mil area for the conductor.*
2. *Below 50 volts, SAE wire size may be used.*
3. *50 Volts and above, AWG wire size MUST be used.*

2.1 ELECTRICAL COMPONENT. Electrical component means electrical equipment such as but not limited to conductors, solenoids, motors, generators, alternators, distributors, resistors, appliances, and electrical control devices.

In general, any item related to the electrical system is an electrical component. A panel box is NOT itself an electrical component, but it contains a number of electrical components. Batteries and fuel tank sending units are NOT electrical components. Audio speakers and lights (in the engine space but with a switch outside the space) are NOT electrical components. Support clamps and straps and their fastenings are NOT electrical components.

It must be noted that the regulation's requirements apply to the installation of electrical components, and their external connection into the electrical circuit. The regulation does not apply to internal wiring or terminations within a component. For example, the windings of a motor, generator or alternator are not regulated; however, the external wiring used to connect them to a boat's electrical system is required to comply with the regulation. The construction details of electrical components are only regulated insofar as whether the electrical component is or is not ignition protected.

2.3 PIGTAILS. Pigtails means external power conductors or wires that are part of electrical components and appliances, such as bilge pumps, blowers, lamps, switches, solenoids, and fuses.

Pigtails are the wires that are provided by a device manufacturer to connect the device into the electrical circuit. Pigtails are usually electrically connected internally and led through a protective covering to be connected to electrical service connectors. Examples of electrical devices that are commonly equipped with pigtails are cabin lighting fixtures, navigation light fixtures, blowers, bilge pumps, horns, searchlights, indicator lights, in-line fuses, switches and solenoids.

The regulation exempts pigtails that are less than 7 inches in length, only from:

183.425 — Conductors: General

183.430 — Conductors in Circuits of Less Than 50 Volts

183.435 — Conductors in Circuits of 50 Volts or More

183.455 — Overcurrent Protection: General

To determine the length of pigtails, measure the length of conductors that are visible outside the device, i.e. from the point on an electrical component where the conductors pass through a shell or housing to their end. This length must be less than 7 inches if the pigtails are to be excepted from these requirements. The portions of the conductors inside the component are not part of this pigtail length. In bilge installations, the pigtail connections must not be below the level of normal bilge water accumulation.

2.4 SHEATH. Sheath means a material used as a continuous protective covering, such as electrical tape, molded rubber, molded plastic, or flexible tubing around one or more insulated conductors.

A "sheath" is a flexible continuous covering, as distinguished from a "conduit" or "duct" which are rigid continuous coverings. As the regulation states, a "sheath" may be a continuous wrapping of electrical tape, molded or extruded rubber or plastic, or flexible tubing (sometimes referred to as "spaghetti").

A "sheath" may be used around one or a number of conductors, which may or may not be different gauges. Each of the conductors must be insulated, that is, the sheath is NOT to take the place of a conductor's insulation.

A "sheath" does not have to hold the conductors tightly bonded together. Individual conductors are allowed to move in relation to each other within a sheath. A "sheath" is generally used as a means of

3.0 IGNITION PROTECTION

An electrical component that is "ignition protected" is capable of operating in an explosive environment

> Per 183.410: Each electrical component must not ignite a gas mixture – unless it is isolated from gasoline sources.

without igniting that environment. "Ignition protection" of electrical devices is accomplished by the use of seals, flame arrestors and potting (sealing), or a combination of such means.

An "ignition protected" component:

- will not ignite a flammable hydrocarbon mixture surrounding the device when an ignition source causes an internal explosion, or;
- is incapable of releasing sufficient electrical or thermal energy to ignite a hydrocarbon mixture; or
- has the source of ignition hermetically sealed.

A flammable hydrocarbon mixture is a mixture of gasoline and air, or propane and air, between the lower explosive limit (LEL) and the upper explosive limit (UEL).

In general, the tests are conducted in an explosion chamber containing an explosive atmosphere, defined by this regulation as a 4.25 (LEL) to 5.25 (UEL) percent mixture by volume of propane gas and air. The mixture is introduced into the component where internal sparking occurs, or is induced, so that an explosion is evident within the component. An internal explosion must not ignite the explosive

atmosphere surrounding the device in order for the component to pass the test. To assure

compliance of a component, this sequence is repeated 50 times. Propane, not gasoline, is used for ignition protection tests because it is much easier to get repeatable results using this mixture rather than gasoline vapor.

1. *It is not the intention to require such devices to be "explosion proof" as that term is defined in the National Electrical Code of the National Fire Protection Association pertaining to shore systems, or within the meaning of 46 CFR 110.15-65.(e), Subchapter J, "Electrical Engineering". It is intended that the protection provided be generally equivalent to that of wiring permitted by this standard wherein a definite short or break would be necessary to produce an open spark.*

2. *Devices that are "explosion proof " are considered to be "ignition protected" when installed with the appropriate fittings to maintain their "explosion proof' integrity.*

To determine if a component is "ignition protected", there are a number of test procedures available that are acceptable to the U.S. Coast Guard. For details of these test procedures, refer to the following:

- SAE J1171 "External Ignition Protection of Marine Electrical Devices" UL 1500 "Standard Test Procedure for Ignition Protection"
- USCG "USCG Compliance Test Procedure — Electrical System Standard" Published January, 1973.

3.1 ISOLATION FROM FUEL SOURCES

The regulation also provides an alternative where electrical components need not be ignition protected. If the electrical component is installed in a boat and is isolated from gasoline engines and gasoline fuel system components, except for uninterrupted runs of fuel lines, then the electrical component does not need to be ignition protected. Isolation of electrical components is discussed in 183.410 (b)(2), later in this guideline.

Isolation of an electrical component may be accomplished in a number of ways:

- Bulkheads.
- Deck or special enclosures.
- Installing the component in an open space with 2 feet minimum distance from the source of fuel.

Bulkheads

A bulkhead is a vertical wall-like structure that may run transversely (across) or longitudinally (fore to aft) in a boat. Bulkheads are used both for strength and to separate a boat into different use areas, such as engine room, fuel tank compartment, living space, storage compartment, etc. By taking advantage of the location of bulkheads and installing electrical components accordingly, it may be possible to use non-ignition protected electrical components in many installations. Figures 3, 4, 5 and 6 depict some typical boats and the use of bulkheads for isolation.

A bulkhead and deck may be combined to accomplish isolation, such as where a boat has a cabin bulkhead in front of the engine compartment and a deck over the engine compartment.

Specific details of the construction of a bulkhead including water tightness, opening, penetrations and structural extent are covered in 183.410.(c), later in this guideline.

Decks

Isolation that separates an electrical component from a gasoline fuel source may be accomplished by a deck between the two or by means of an enclosure. Either the electrical component or the gasoline fuel source may be enclosed to accomplish isolation.

The electrical component may be installed lower or higher than the gasoline fuel source.

If the electrical component is installed lower than the gasoline fuel source, then the deck or enclosure used to create the isolation must prevent liquid fuel and fuel vapors from coming in contact with the electrical component. This requires the compartment to be liquid (water) tight and vapor tight.

If the electrical component is installed higher than the gasoline fuel source, then there must be a deck or enclosure to create the isolation, but it is not necessary that it be liquid or vapor tight. Fuel vapors are heavier than air and would tend to collect below the isolation deck or enclosure. Should it be obvious in a specific installation that fuel vapors could surround an electrical component, then good practice would be to make the deck or enclosure an isolation barrier or to select ignition protected electrical components.

Figures 3, 4, 5, 6, and 7 depict typical boats and the use of decks and enclosures for isolation.

Open Space

Ignition protection is not required for electrical components that are in a space that is open to the atmosphere and is located at least two feet from a gasoline fuel source. The term "open to the atmosphere" is defined as a space or a compartment having at least 15 square inches of unobstructed area opening into the compartment for every square foot of compartment volume. Open boats, such as runabouts, with the engine aft and the fuel tank located far enough forward to meet the two foot provision will be able to use non-ignition protected components in their instrument panel. Figure 8 depicts a typical open boat, whose bow compartment is open to the atmosphere, with a two-foot distance maintained between electrical components and the gasoline fuel source. Figure 4 shows a saddle tank installation with a two-foot distance between electrical components and the gasoline fuel source.

Figure 3 Isolation of Electrical Components

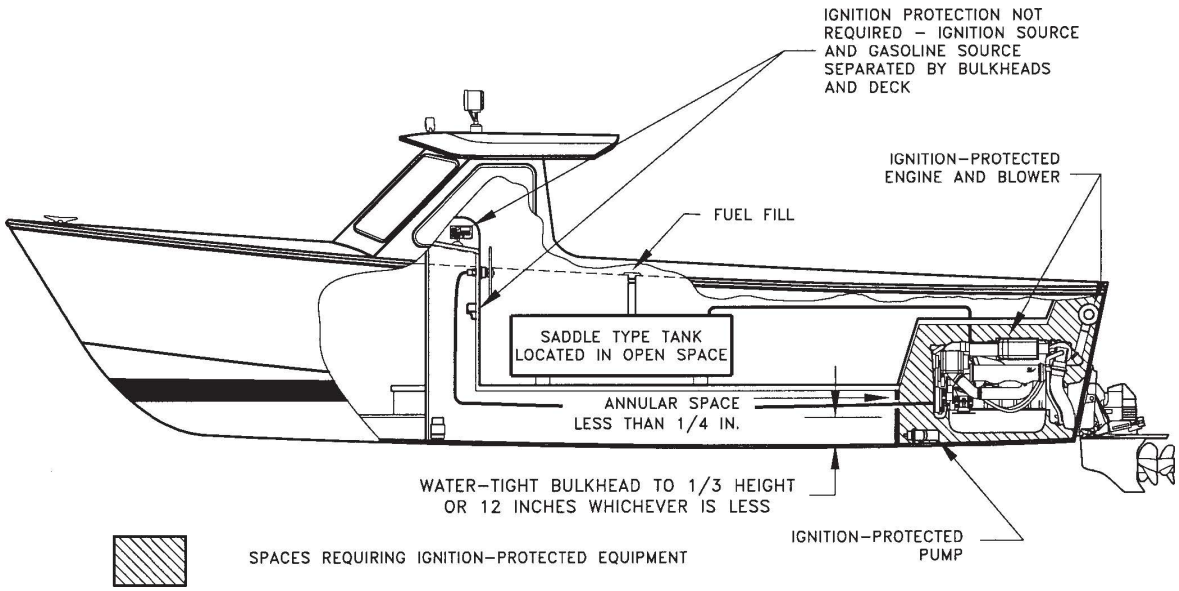


Figure 4 Isolation of Electrical Components

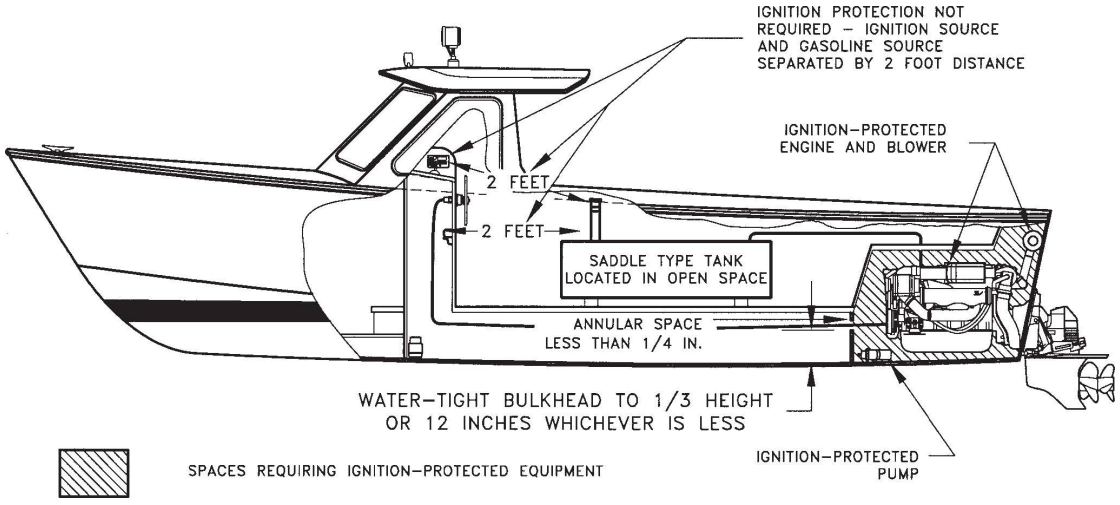


Figure 5 Isolation of Electrical Components

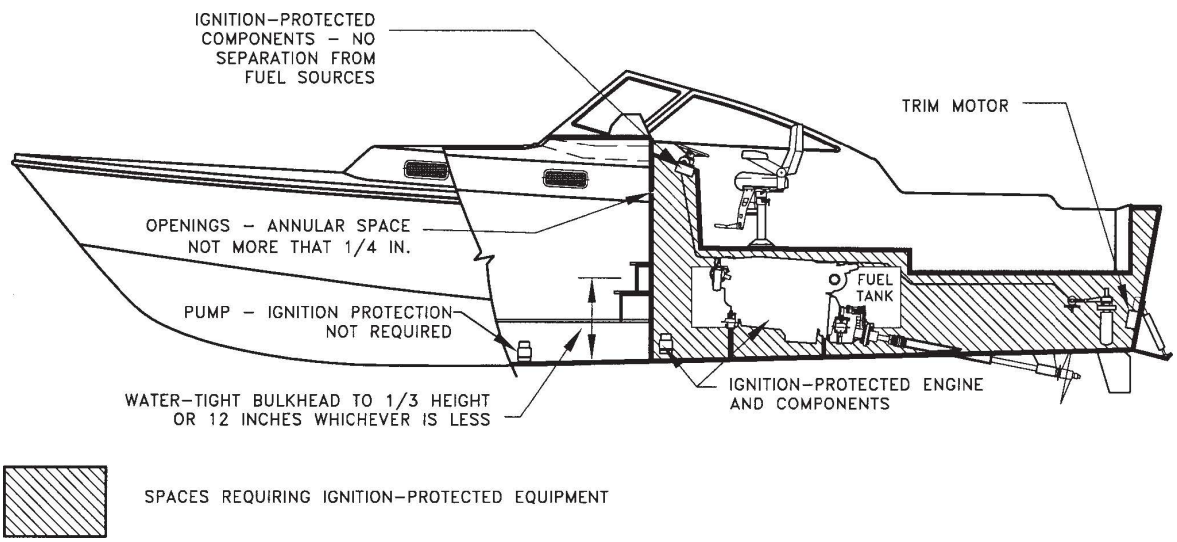


Figure 6 Isolation of Electrical Components

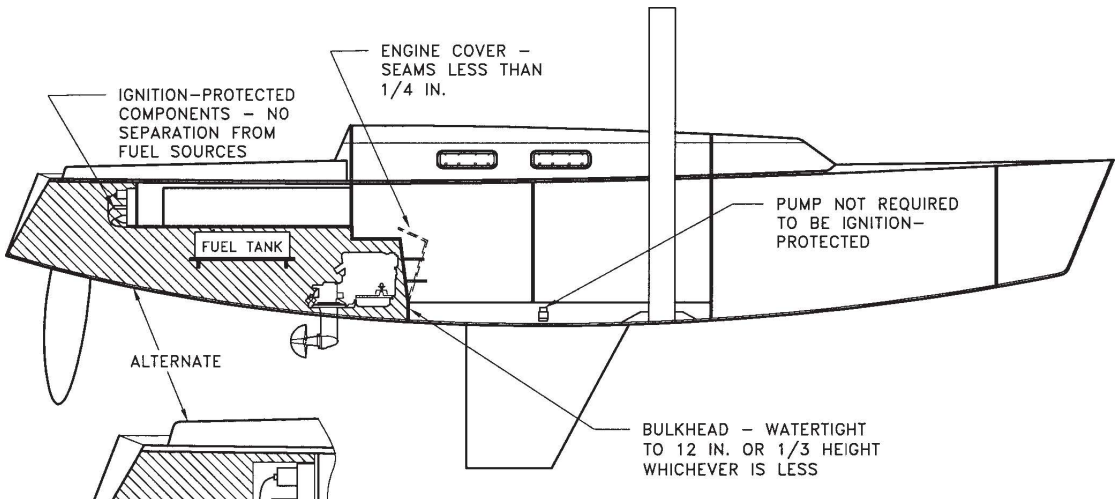
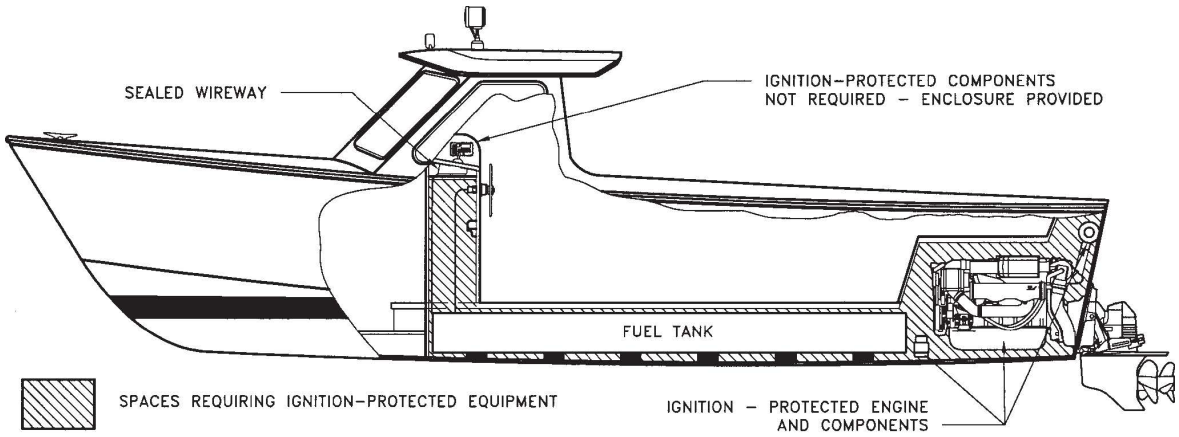
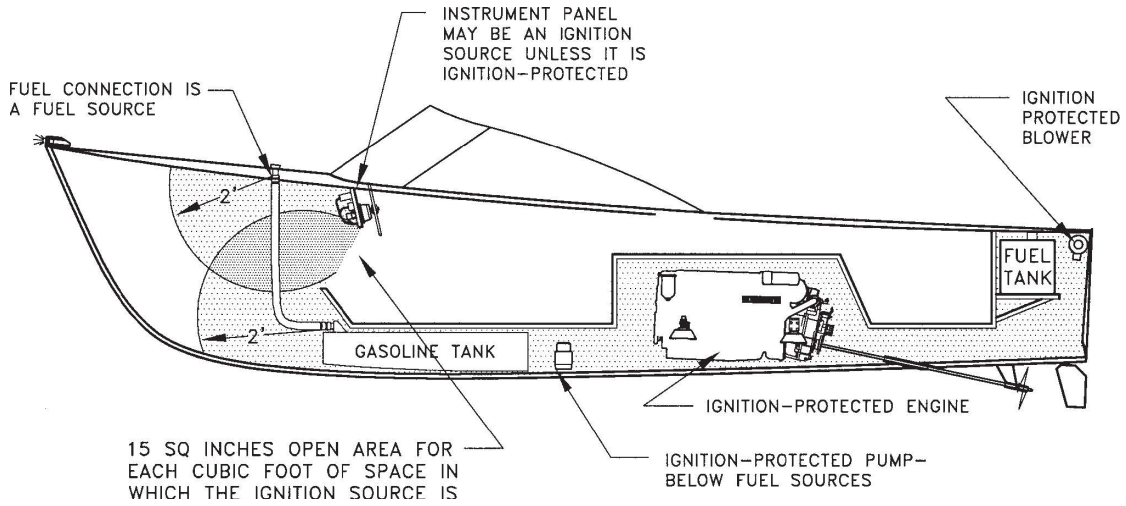


Figure 7 Isolation of Electrical Components



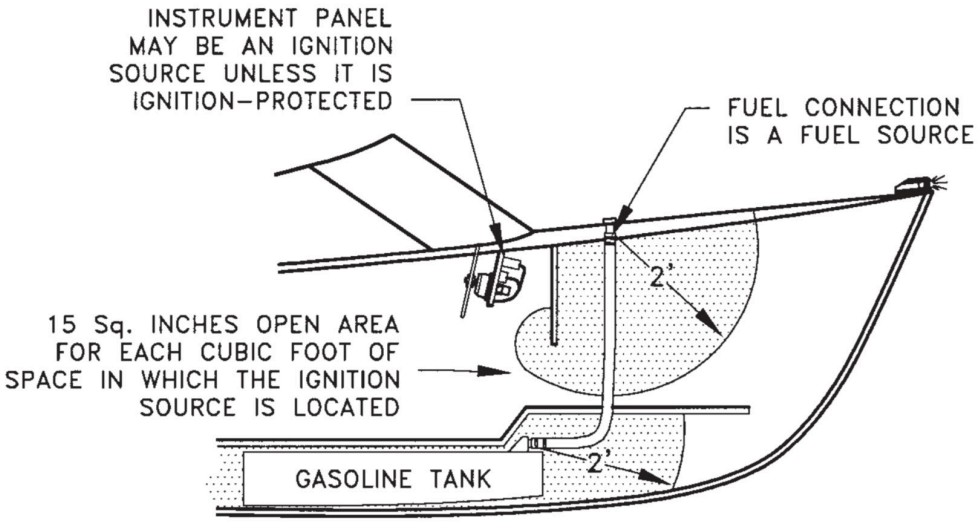
Partial Bulkhead — Foot board, Toe board — In figure 8a,b,c, we see how boat structures such as a partial bulkhead may be fitted to increase the distance between the source of fuel and the source of ignition.

Figure 8a Isolation of Electrical Components



In figure 8a, the switches in the dashboard are within 2′ of the fuel deck fitting, and also within 2′ of the fitting at the fuel tank. Each of these fittings is a potential source of fuel leak. In this installation, all switches would have to be ignition protected.

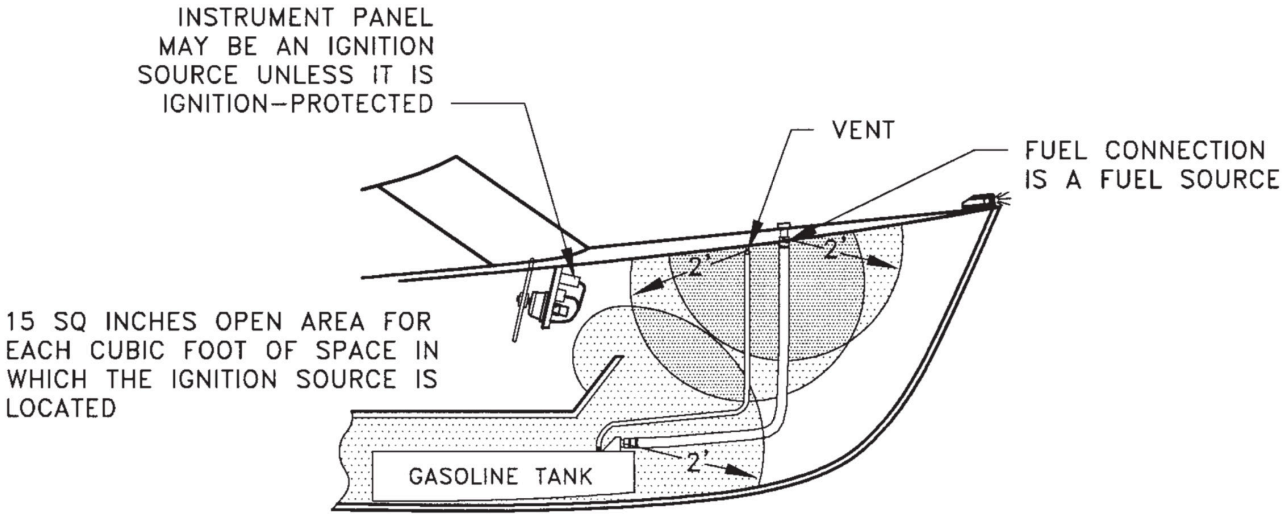
FIGURE 8b Isolation of Electrical Componenets



PARTIAL BULKHEAD USED TO CREATE ISOLATION OF FUEL SOURCE FROM IGNITION SOURCE

Here the builder has fitted a partial bulkhead across the boat, behind the dash to increase the distance between the fuel deck fitting and the backside of the dash. The builder has also decked over the front of the tank so that the tank fitting is also more than 2′ from the back of the dash.

FIGURE 8c Isolation of Electrical Componenets



TOE BOARD USED TO CREATE ISOLATION OF FUEL SOURCE FROM IGNITION SOURCE

Here there are three potential sources of fuel: The vent fitting in the side of the hull, the fuel deck fitting, and the connections at the tank. The vent and fill fittings are more than 2′ from the dashboard. The tank fittings were too close to the dashboard. Here the boat builder has installed a foot board to increase the separation from the dashboard.

Bulkhead Criteria

To effectively separate a gasoline fuel source and an electrical component by a bulkhead, the regulation has established certain criteria covering the following:

- the extent of the bulkhead both horizontally and vertically.
- the water-resistant height of the bulkhead and permitted rate of seepage.
- openings through the bulkhead below the water-resistant height.
- openings through the bulkhead above the water-resistant height.

Figures 9 and 10 depict a typical bulkhead installation with a number of the regulated items noted.

Bulkhead Extent — A bulkhead intended to isolate an electrical component from a gasoline fuel source must effectively close off one space from another. The bulkhead must be fitted closely to the sides, bottom and top of the space or compartment. There should be no vent holes, corners snipped off, limber holes or hand holds in this bulkhead. It should reach the full width and the full height of the space being closed off.

Water-Resistant Height — The water-resistant height to be used for a particular bulkhead is based on the maximum height of the bulkhead. The water-resistant height is the lesser of 12 inches or one-third the maximum height of the bulkhead. For example, if the total height from the lowest point of the bulkhead to the uppermost point of the bulkhead is 33 inches, then the water-resistant height is 11 inches. If the total height is 42 inches, then the water-resistant height is 12 inches (less than one-third of 42 inches). Any openings for piping, wiring, ducting, controls, etc. must have a sealed fitting used to prevent seepage around the item going through the bulkhead. The total maximum seepage permitted for the entire area of the bulkhead below the water-resistant height is one-quarter ounce (approximately one-half tablespoon) of fresh water per hour.

Openings Below the Water-Resistant Height — Bulkheads used for isolation may have openings for: wiring, piping, ducts, controls, doors, hatches, access panels, drains, and other such purposes, but each opening located below the water-resistant height of the bulkhead must be sealed or have a fitting to minimize seepage. Doors and hatches or portions thereof must also be fitted or sealed to minimize seepage. The maximum seepage permitted for all openings and edges of the bulkhead may not exceed a total of one-quarter ounce (approximately one-half tablespoon) of fresh water per hour.

Openings Above the Water-Resistant Height — Openings above the water-resistant height are permitted for: wiring, piping, ducts, controls, doors, hatches, access panels, drains, and other such purposes, but each opening must not have more than a one-quarter inch wide space around whatever passes through the bulkhead, such as piping, wiring, ducts, controls, etc. Hatches, doors, access panels, etc. must be fitted so there is no more than one-quarter inch clearance around them when they are closed, except if they extend below the water-resistant height (see above), where they must be sealed.

Openings for wiring, piping, etc. in the bulkheads surrounding the engine and exhaust components may also allow carbon monoxide to enter the accommodation spaces of the boat. Extra attention is recommended to seal those openings to reduce the passage of carbon monoxide gas.

SPECIAL NOTE

The U.S. Coast Guard has developed the following compliance policy concerning drain holes in isolation bulkheads:

> *"Any hole installed for drainage in an isolation bulkhead must be fitted with a plug or sealing device that is intended to be in place when the boat is being used. The plug or sealing device must be attached to the drain fitting or the bulkhead near the drain hole so it will not be lost. It must be understood that when this drain hole is open, the isolation integrity of the bulkhead has been breached causing a potentially hazardous condition. It is the responsibility of the boat manufacturer to make this intent known to the consumer via means such as labeling, information in a boat owners manual, etc."*

FIGURE 9 Isolation Bulkhead Requirements

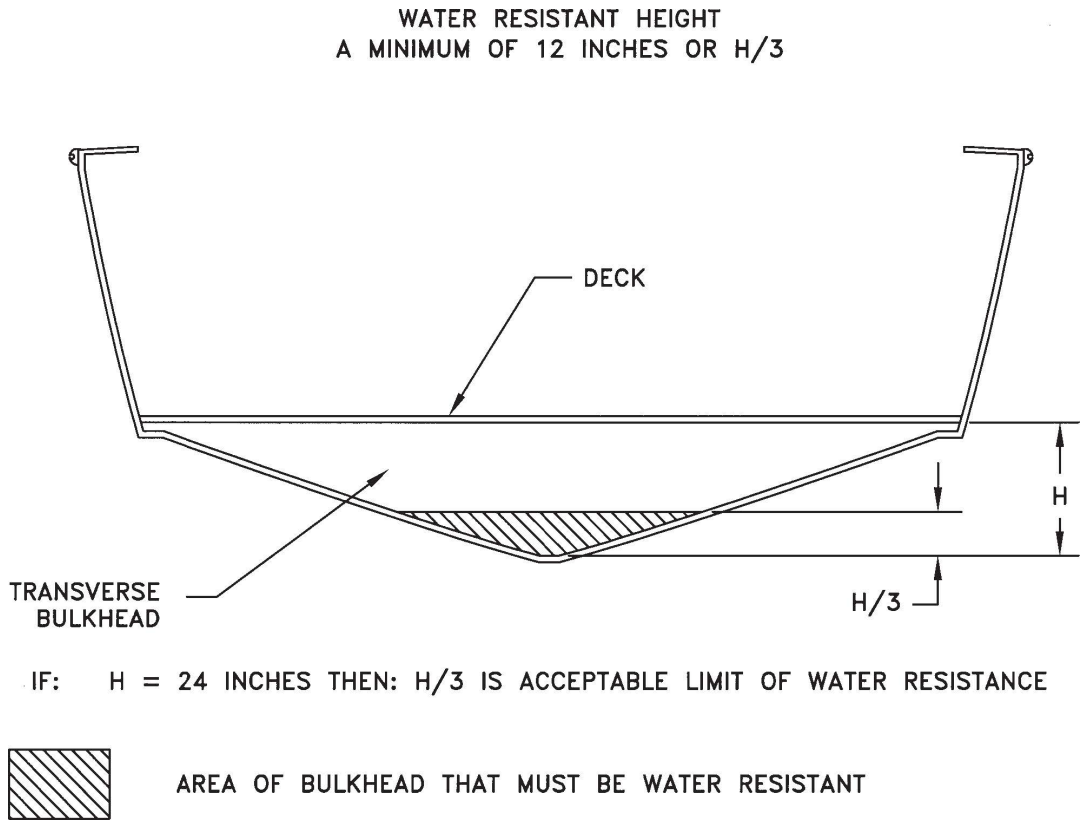
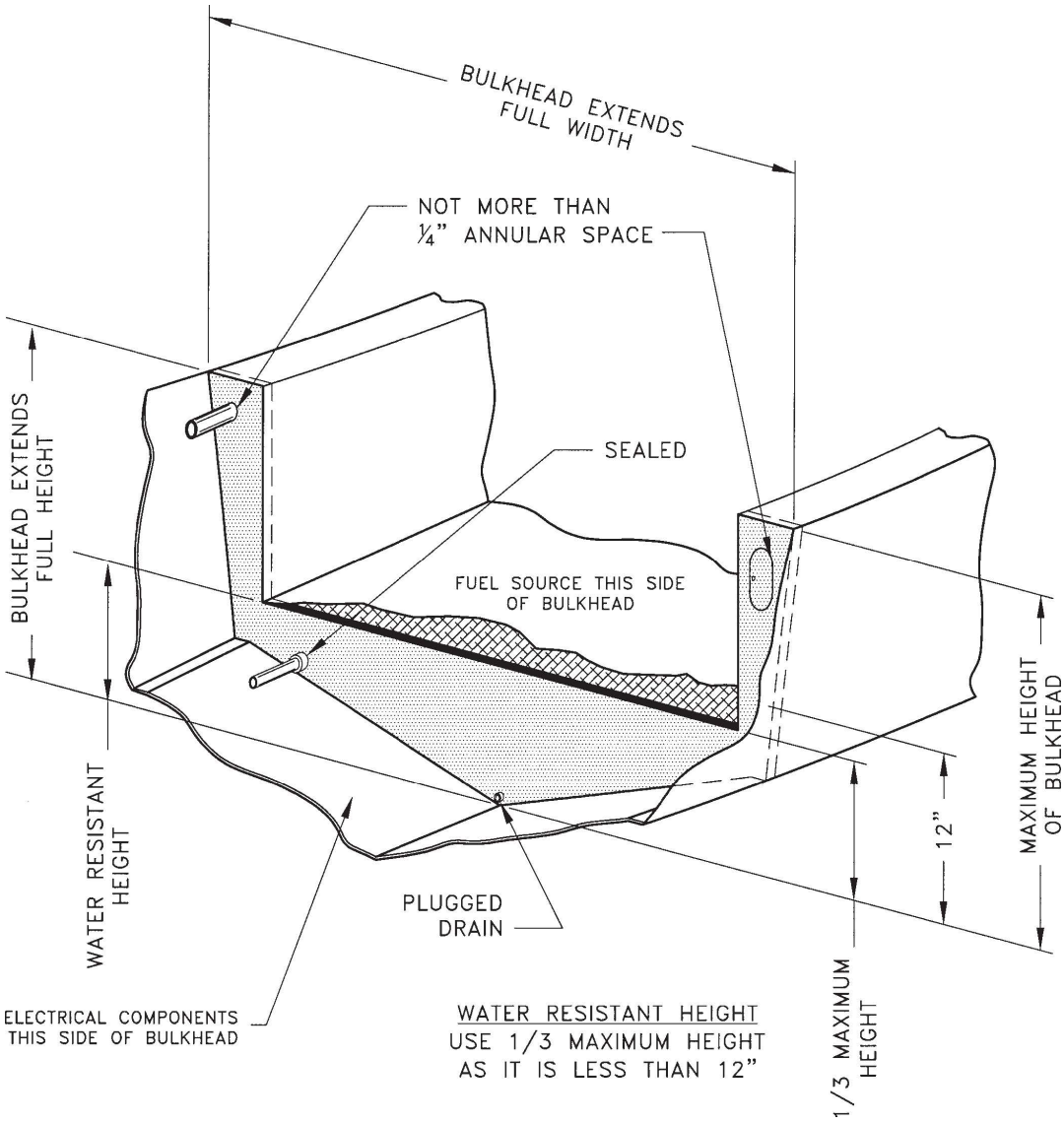


FIGURE 10 Isolation Bulkhead Requirements



NOTES TO FIGURE 10

1. *Seepage of not more than one-quarter fluid ounce per hour permitted below the water-resistant height. This includes bulkhead fastenings and around any openings.*
2. *Openings above the water-resistant height may not have more than 1/4 inch annular space around the opening.*

4.0 GROUNDING

> Per 183.415: If a boat has more than one gasoline engine, grounded cranking motor circuits must be connected to each other by a common conductor circuit that can carry the starting current of each of the grounded cranking motor circuits.

The purpose of this requirement is to prevent accidental passage of the battery supply current through fuel systems and smaller electrical conductors that may be common to engines. If one of the grounded cranking motor circuits accidentally opens (breaks) due to corrosion, vibration, etc., the accidental passage of starter motor current could melt fuel lines or burn up smaller conductors such as instrument wiring. Both of these hazards could lead to fire and explosion accidents. The common conductor circuit referred to in the regulation is a circuit made up of jumper conductors and may include a common bus bar.

Definitions:

Ground — ground applies to the potential of the earth's surface. The boat's ground is established by a conducting connection (intentional or accidental) with the earth, including any conductive part of the wetted surface of a hull.

Grounded Conductor — a current-carrying conductor connected to the side of a source that is intentionally maintained at boat ground potential.

In a two-engine installation, a jumper conductor will satisfy compliance if connected between the negative sides of the grounded cranking motor circuit.

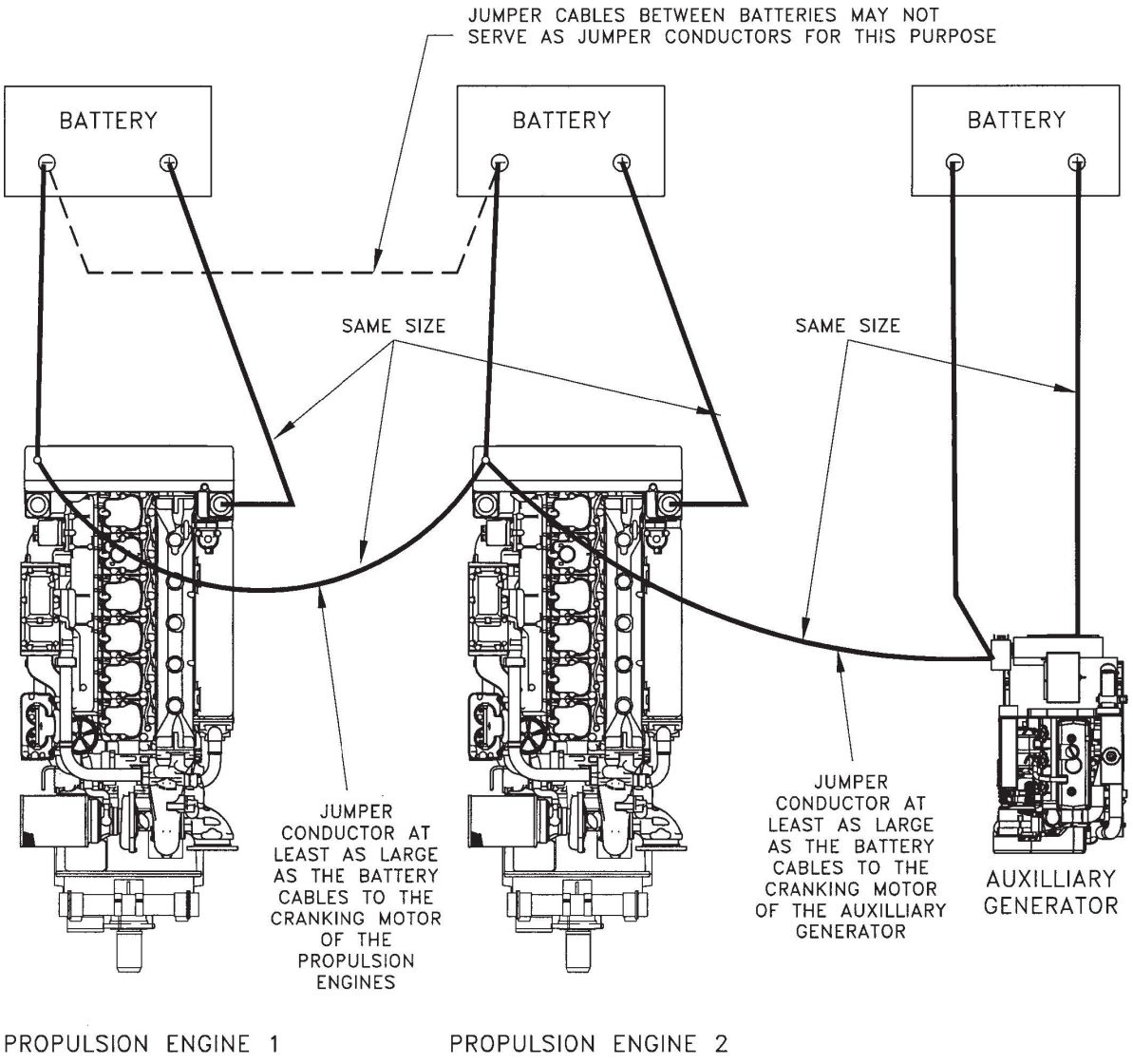
In installations of three or more grounded cranking motor circuits, the common conductor circuit can be of several different configurations. Installing a common bus bar to which a conductor from each circuit is attached is one approach.

Common and convenient points of attachment to the negative side of the grounded cranking motor circuits are the engine negative terminal, any point on the engine block, and in direct contact with the negative side of the cranking motor.

In all cases, proper sizing of the conductor leading from each grounded cranking motor circuit is imperative. A rule of thumb to use when selecting the conductor is to use one as large as the conductor used to supply power from the battery to the cranking motor (the battery cable). Table 5 of the regulation can also be used as a guide when selecting the conductor.

If there are two or more starting battery installations and the negative terminals are connected by a common conductor, that common conductor does not satisfy this grounding requirement. Additional conductor(s) are necessary. Figure 11 diagrams typical circuits.

FIGURE 11 Cranking Motor Circuits



5.0 BATTERIES

Batteries must meet criteria for the restriction of movement, protection from sparking, location with respect to other fuel system components, venting, and cable connection.

5.1 BATTERY MOVEMENT

> Per 183.420 (a): Batteries must not move more than 1 inch in any direction when subjected to a specified force for a specified time.

If a battery was allowed to reposition itself indiscriminately at the will of the forces that occur when a vessel (especially smaller boats with quicker motion) is operated in waves, or while being trans- ported over land with its battery installed, the battery could become damaged. If the battery casing ruptures, the electrolyte may run out. If a battery terminal loosens, poor contact or sparking could occur. The electrolyte is usually sulfuric acid that can severely attack many metals and other materials. Such attack on fuel system components has the potential of causing fuel lines and fittings to fail and leak fuel. Movement of a battery could cause the battery terminal to come in contact with grounded items, resulting in sparking.

Therefore, the regulation calls for restraint of the battery in the horizontal and vertical directions. A battery as installed by a manufacturer may not move more than one inch when subjected to a test force for a one minute duration in each of three directions: vertical, horizontal — fore and aft, and horizontal — port and starboard. The test force selected is 90 pounds, which is approximately twice the weight of the popular size of marine battery used in small boats, which may be subject to high accelerations. For this reason, 90 pounds was selected as the maximum that needed to be applied. For batteries weighing less than 45 pounds, a force of twice the battery weight is specified. This test force is to be applied through the center of gravity of the battery. (See Figure 12).

The commercially available plastic battery boxes may be used to install a battery; however, it may be necessary to provide means within the battery box to prevent excess movement of the battery. The materials used for restraining battery movement within a battery box should be selected with regard to potential deterioration by the electrolyte. The battery box must be fastened in such a manner that the battery installation will comply with this section of the regulation.
It is recommended that the use of materials to wedge the battery in a battery box be described in the boat's owners manual to affirm its intended use. (See Figure 13).

FIGURE 12 Battery Pull Test

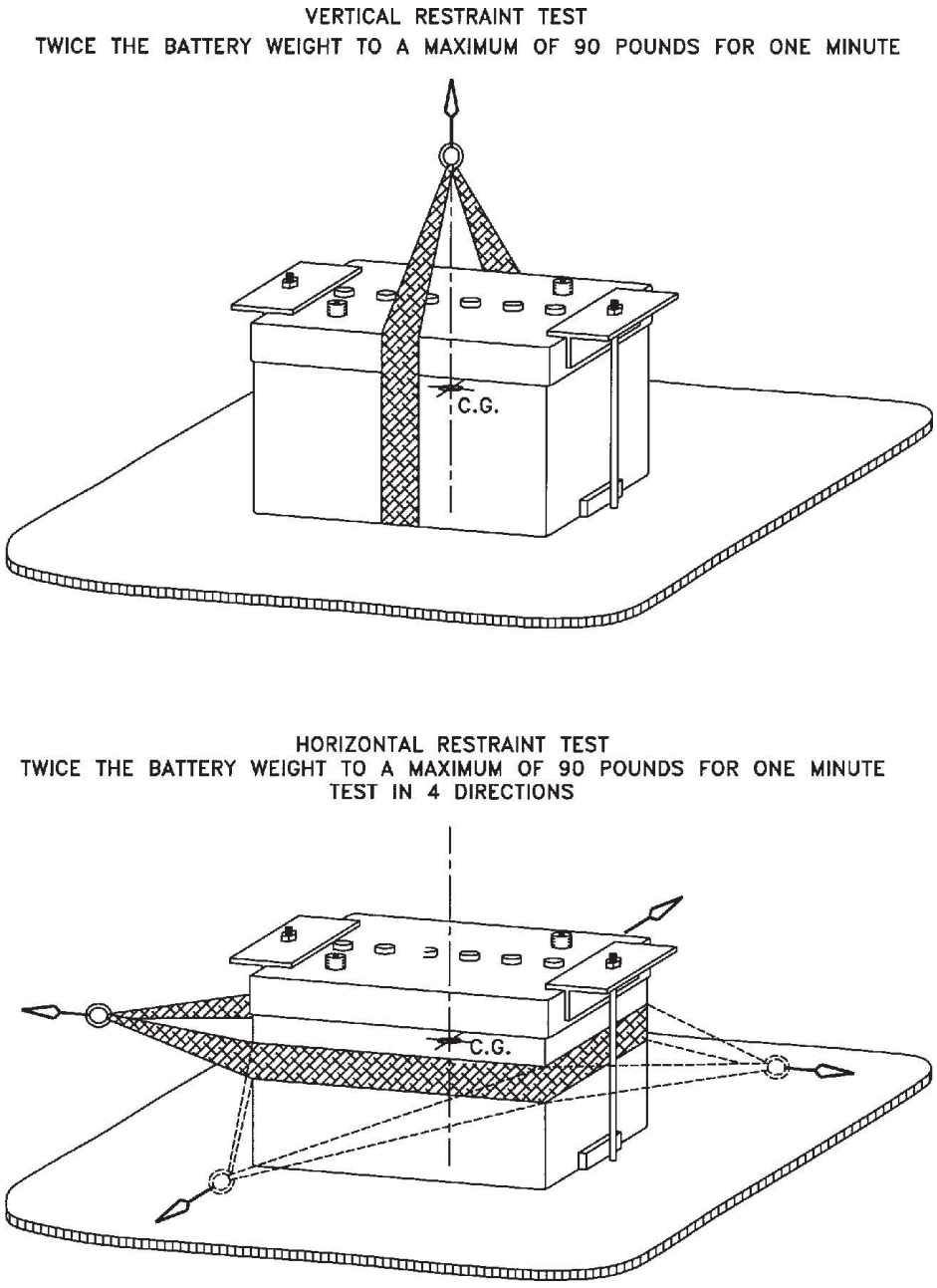
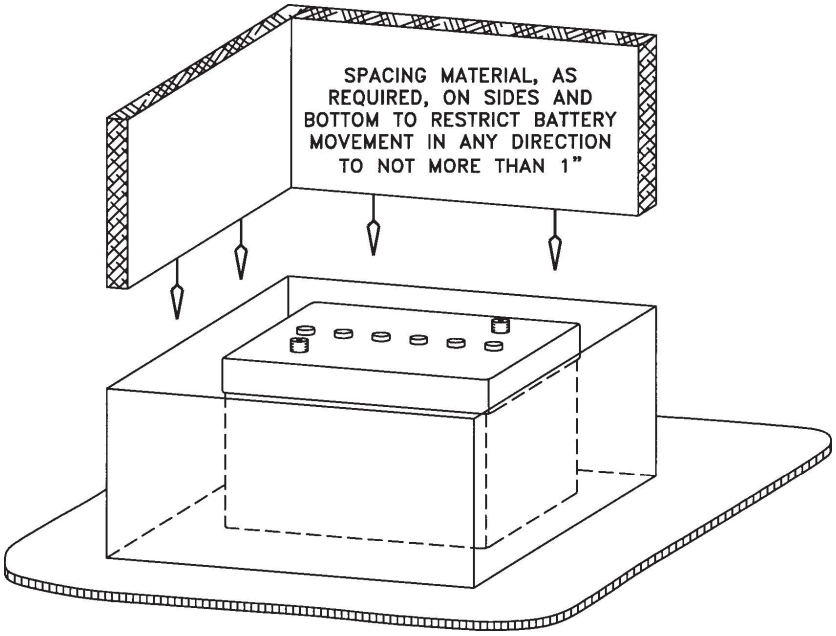


FIGURE 13 Installation in a Battery Box



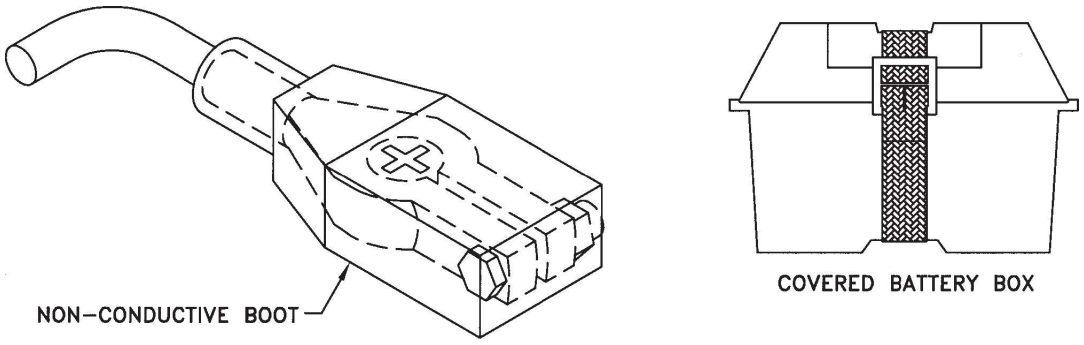
5.2 BATTERY PROTECTION

> Per 183.420 (b): Ungrounded battery terminals must be installed to prevent contact with metallic objects.
>
> Per 183.420 (c): Metallic fuel line components near the battery must be shielded.

If an ungrounded battery terminal is left exposed, it is possible that an accidental connection to ground could occur. The use of or dropping of tools nearby could make such a connection during routine engine servicing. This connection could result in a spark of sufficient energy to ignite any explosive vapors that might be present or to start an electrical fire.

To prevent accidental contact with the ungrounded battery terminal, it may be covered with a boot or non-conductive shield. The battery could be installed in a covered battery box or special, fitted compartment. (See Figure 14).

FIGURE 14 Ungrounded Battery Terminal Connection

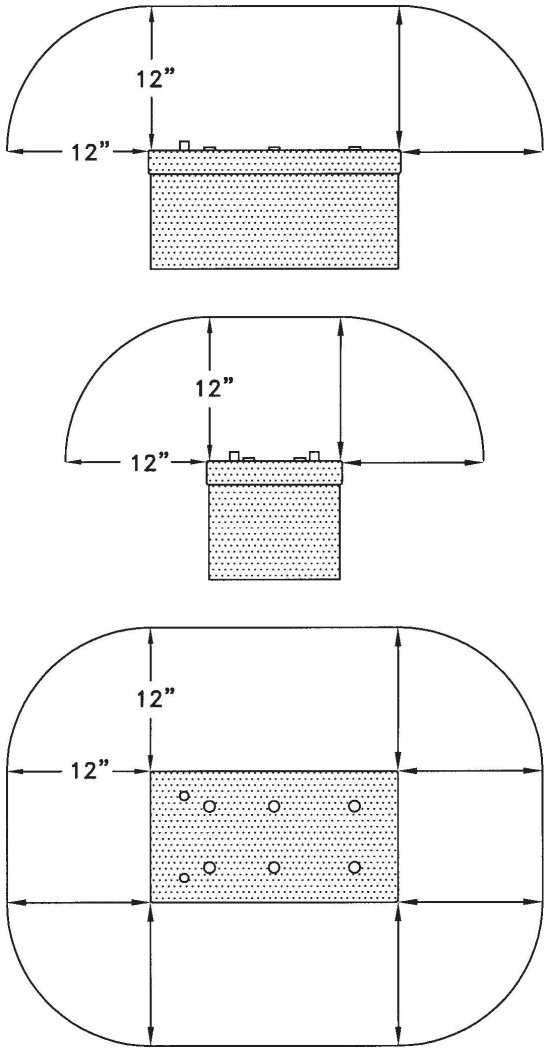


Metallic fuel lines and fuel system components are usually electrically grounded, either intentionally or because they are connected to an engine or a fuel tank. If, while servicing, installing or removing the battery, a tool should contact the ungrounded (positive) terminal and the fuel line or component, a spark could occur. This could cause the battery to explode, or a hole could be burned in the fuel line, creating a fire or fuel explosion hazard. Also, installing or removing a battery with exposed terminals could result in both terminals contacting a fuel line or component, which could result in a similar hazard.

The regulation calls for shielding of fuel lines and components within 12 inches of the top surface of the battery. Twelve inches was chosen as a practical distance to provide for installation or removal of a battery. Terminal insulation or battery covers are not considered adequate since these protective devices are usually removed during installation or removal of a battery.

Figure 15 shows the envelope within which any fuel line or fuel system component must be shielded, using a dielectric material. Any non-conductive material may be used for shielding as long as it is durable enough to withstand accidental contact by a tool or the battery terminals during servicing, installation or removal. Some materials that appear suitable include electrical tape (continuous wrapping), plastic pipe or tubing, dielectric sheathing, fiberglass, wood, etc.

FIGURE 15 Dielectric Shielding Envelope



5.3 BATTERY LOCATION

> Per 183.420 (d) : The battery must not be directly above or below a fuel tank, fuel filter, or fitting in a fuel line.

Certain components of the fuel system have been identified as prime sources of potential leakage. These items are the fuel tanks, fuel filters, and fuel line fittings. Many fuel filters are equipped with drain plugs for servicing.

If a battery is installed directly below these fuel components, there is a potential for gasoline to leak on the battery, possibly attacking the battery case material.

If a battery is installed directly above the fuel items, leaking electrolyte may attack fuel system components, creating fuel leakage. (See Figure 16).

Also of concern is the servicing of fuel system components if a battery is installed directly above or below them. Accidental short-circuiting may occur while servicing, installing or removing a battery. This does not prohibit a battery from being installed directly above or below an uninterrupted fuel line; however, if a metal fuel line is within the 12-inch envelope of the top surface of the battery, it must be shielded dielectrically as required in 183.420(c)

> Per 183.420 (e): Batteries must be ventilated to avoid the accumulation of hydrogen.

5.4 BATTERY VENTILATION

Hydrogen gas is explosive. Boat design and battery installations that permit the accumulation of hydrogen gas must be avoided since batteries emit hydrogen gas. Even "sealed" batteries have venting provisions and therefore must be considered vented batteries.

Hydrogen gas will disperse rapidly and will seek to exit through any opening, particularly through overhead openings, since the gas is lighter than air. Pockets above the battery that could trap and hold the hydrogen gas must be vented. Likewise, a battery box whose cover forms a pocket over the battery must be vented.

Particular attention must be paid to battery installations in special, isolated compartments that are not part of ventilated compartments. These areas may require special ventilation considerations to accommodate battery installations.

If in doubt about gas accumulation in the boat, a test may be conducted by charging the battery in the boat. The boat should be equipped as it would be in normal service, particularly in terms of normally supplied means of ventilation. A gas analyzer may be used to check areas above the battery where hydrogen gas accumulation is possible. If there are no dangerous quantities of gas found, then the installation should be acceptable.

The best practice is to install batteries in well-ventilated locations.

FIGURE 16 Battery Location vs. Fuel System

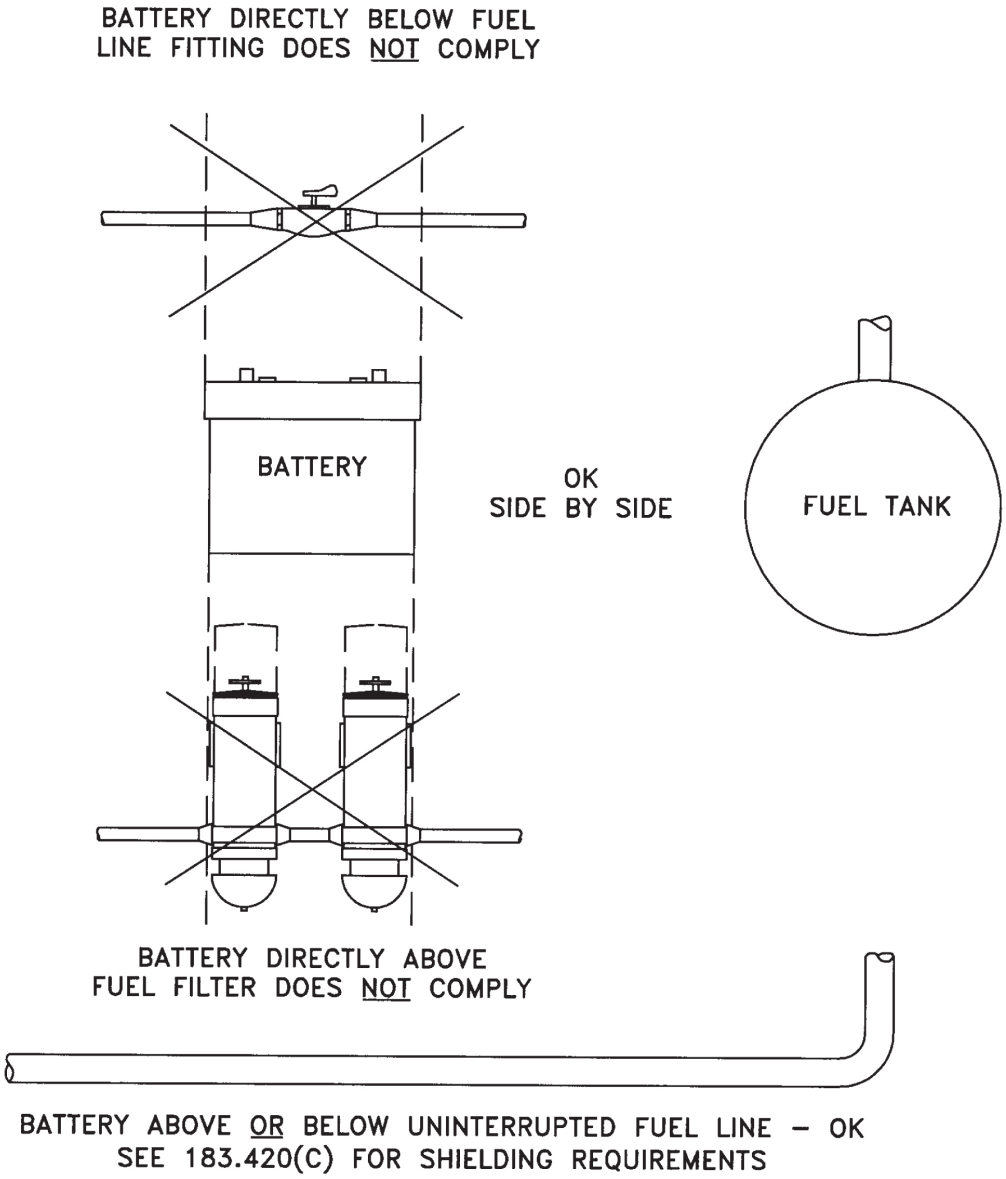
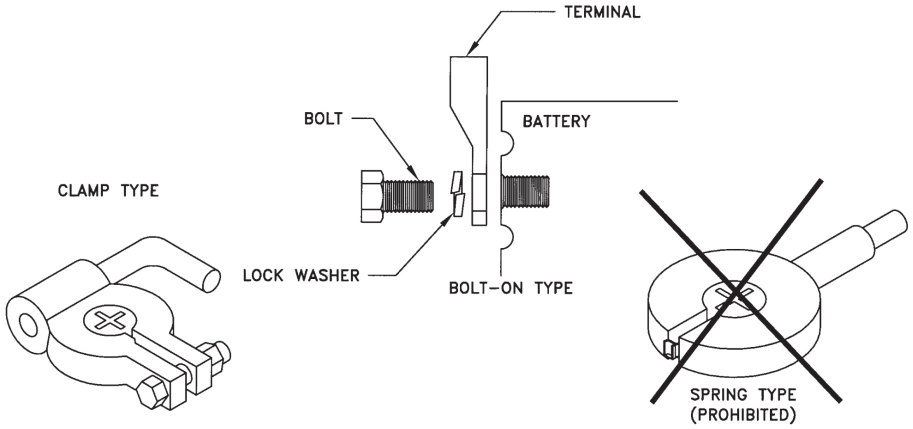


FIGURE 17 Battery Terminal Connections



6.0 CONDUCTORS

Section 183.425 covers the general requirements for conductors with respect to size & type, current rating, usage in engine spaces. The next sections 183.430 and 183.435 covers specific requirements for conductors in DC circuits (less than 50 volts) and AC circuits (50 volts or more) respectively.

6.1 CONDUCTOR TYPE

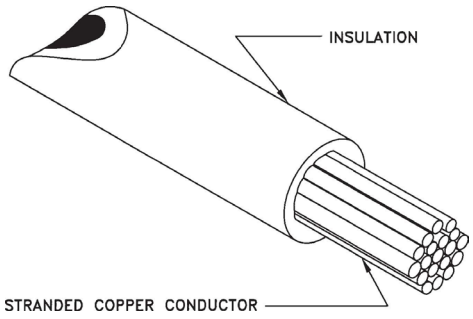
> Per 183.425 (a) Each conductor must be insulated, stranded copper.

Each conductor must be insulated with an insulation compound meeting:

- Sec. 183.430, if less than 50 volts, or
- Sec. 183.435, if 50 volts or more.

The conductor must be stranded to resist failure due to vibration and flexing. Copper is specified for the best combination of conductivity and corrosion resistance.

FIGURE 18 Insulated Stranded Copper Conductor



6.2 CONDUCTOR CURRENT CAPACITY

> Per 183.425 (b): Conductor must carry current (per Table 5) based on gauge and temperature rating.
>
> Per 183.425 (c): Conductor capacity must be corrected (per Table 5) for use in engine spaces.

The current values referred to in Table 5 are constant or steady values as compared with the intermittent higher currents which may occur momentarily in circuits, such as those associated with stern-drive trimming devices or electrical motor starting situations. To select a conductor size use the maximum steady state load.

Due to engine heat, the ambient temperature in engine spaces is usually higher than in other spaces of the boat. Wiring in and passing through engine spaces must be able to operate at these higher ambient temperatures. The ampacity values in Table 5 are based on an ambient temperature of 30° C (86° F), which is considered reasonable for use on boats except in engine spaces. The correction factors of Note 1 in Table 5 convert the ampacities of Table 5 to acceptable values in an ambient temperature of 50° C (122° F). This higher temperature has been selected as satisfactory for engine spaces.

Tables 5A through 5E are supplied to eliminate the need for calculating the corrections to Table 5 (see Notes 1 and 2 under Table 5). The values are already corrected. Sample calculations appear under the discussion of section 183.435 (a) later in this guideline.

3 CONDUCTORS ARE BUNDLED

TEMPERATURE RATING OF CONDUCTOR INSULATION

CONDUCTOR SIZE (AWG)	Temperature rating of conductor insulation						
	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)
18	10	10	15	20	20	25	25
16	15	15	20	25	25	30	35
14	20	20	25	30	35	40	45
12	25	25	35	40	45	50	55
10	40	40	50	55	60	70	70
8	55	65	70	70	80	90	100
6	80	95	100	100	120	125	135
4	105	125	130	135	160	170	180
3	120	145	150	155	180	195	210
2	140	170	175	180	210	225	240
1	165	195	210	210	245	265	280
0	195	230	245	245	285	305	325
00	225	265	285	285	330	355	370
000	260	310	330	330	385	410	430
0000	300	360	385	385	445	475	510

1. See the following table:	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)
Temperature rating of conductor	0.58	0.75	0.78	0.82	0.85	0.89	1.00

2. See the following table:	
Number of current carrying conductors:	Correction Factor
3	0.70
4 to 6	0.60
7 to 24	0.50
25 and above	0.40

TABLE 5A Allowable Amperage of Conductors of 50 Volts or More When No More Than 2 Conductors are Bundled

NO MORE THAN 2 CONDUCTORS ARE BUNDLED FOR 50 VOLTS AND OVER

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	10	5.8	10	7.5	15	11.7	20	16.4	20	17.0	25	22.3	25
16	15	8.7	15	11.3	20	15.6	25	20.5	25	21.3	30	26.7	35
14	20	11.6	20	15.0	25	19.5	30	24.6	35	29.8	40	35.6	45
12	25	14.5	25	18.8	35	27.3	40	32.8	45	38.3	50	44.5	55
10	40	23.2	40	30.0	50	39.0	55	45.1	60	51.0	70	62.3	70
8	55	31.9	65	48.8	70	54.6	70	57.4	80	68.0	90	80.1	100
6	80	46.4	95	71.3	100	78.0	100	82.0	120	102.0	125	111.3	135
4	105	60.9	125	93.8	130	101.4	135	110.7	160	136.0	170	151.3	180
3	120	69.6	145	108.8	150	117.0	155	127.1	180	153.0	195	173.6	210
2	140	81.2	170	127.5	175	136.5	180	147.6	210	178.5	225	200.3	240
1	165	95.7	195	146.3	210	163.8	210	172.2	245	208.3	265	235.9	280
0	195	113.1	230	172.5	245	191.1	245	200.9	285	242.3	305	271.5	325
00	225	130.5	265	198.8	285	222.3	285	233.7	330	280.5	355	316.0	370
000	260	150.8	310	232.5	330	257.4	330	270.6	385	327.3	410	364.9	430
0000	300	174.0	360	270.0	385	300.3	385	315.7	445	378.3	475	422.8	510

TABLE 5B Allowable Amperage of Conductors of 50 Volts or More When 3 Conductors are Bundled

3 CONDUCTORS ARE BUNDLED

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	7.0	4.1	7.0	5.3	10.5	8.2	14.0	11.5	14.0	11.9	17.5	15.6	17.5
16	10.5	6.1	10.5	7.9	14.0	10.9	17.5	14.4	17.5	14.9	21.0	18.7	24.5
14	14.0	8.1	14.0	10.5	17.5	13.7	21.0	17.2	24.5	20.8	28.0	24.9	31.5
12	17.5	10.2	17.5	13.1	24.5	19.1	28.0	23.0	31.5	26.8	35.0	31.2	38.5
10	28.0	16.2	28.0	21.0	35.0	27.3	38.5	31.6	42.0	35.7	49.0	43.6	49.0
8	38.5	22.3	45.5	34.1	49.0	38.2	49.0	40.2	56.0	47.6	63.0	56.1	70.0
6	56.0	32.5	66.5	49.9	70.0	54.6	70.0	57.4	84.0	71.4	87.5	77.9	94.5
4	73.5	42.6	87.5	65.6	91.0	71.0	94.5	77.5	112.0	95.2	119.0	105.9	126.0
3	84.0	48.7	101.5	76.1	105.0	81.9	108.5	89.0	126.0	107.1	136.5	121.5	147.0
2	98.0	56.8	119.0	89.3	122.5	95.6	126.0	103.3	147.0	125.0	157.5	140.2	168.0
1	115.5	67.0	136.5	102.4	147.0	114.7	147.0	120.5	171.5	145.8	185.5	165.1	196.0
0	136.5	79.2	161.0	120.8	171.5	133.8	171.5	140.6	199.5	169.6	213.5	190.0	227.5
00	157.5	91.4	185.5	139.1	199.5	155.6	199.5	163.6	231.0	196.4	248.5	221.2	259.0
000	182.0	105.6	217.0	162.8	231.0	180.2	231.0	189.4	269.5	229.1	287.0	255.4	301.0
0000	210.0	121.8	252.0	189.0	269.5	210.2	269.5	221.0	311.5	264.8	332.5	295.9	357.0

TABLE 5C Allowable Amperage of Conductors of 50 Volts or More When 4 to 6 Conductors are Bundled

4 to 6 CONDUCTORS ARE BUNDLED

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	6.0	3.5	6.0	4.5	9.0	7.0	12.0	9.8	12.0	10.2	15.0	13.4	15.0
16	9.0	5.2	9.0	6.8	12.0	9.4	15.0	12.3	15.0	12.8	18.0	16.0	21.0
14	12.0	7.0	12.0	9.0	15.0	11.7	18.0	14.8	21.0	17.9	24.0	21.4	27.0
12	15.0	8.7	15.0	11.3	21.0	16.4	24.0	19.7	27.0	23.0	30.0	26.7	33.0
10	24.0	13.9	24.0	18.0	30.0	23.4	33.0	27.1	36.0	30.6	42.0	37.4	42.0
8	33.0	19.1	39.0	29.3	42.0	32.8	42.0	34.4	48.0	40.8	54.0	48.1	60.0
6	48.0	27.8	57.0	42.8	60.0	46.8	60.0	49.2	72.0	61.2	75.0	66.8	81.0
4	63.0	36.5	75.0	56.3	78.0	60.8	81.0	66.4	96.0	81.6	102.0	90.8	108.0
3	72.0	41.8	87.0	65.3	90.0	70.2	93.0	76.3	108.0	91.8	117.0	104.1	126.0
2	84.0	48.7	102.0	76.5	105.0	81.9	108.0	88.6	126.0	107.1	135.0	120.2	144.0
1	99.0	57.4	117.0	87.8	126.0	98.3	126.0	103.3	147.0	125.0	159.0	141.5	168.0
0	117.0	67.9	138.0	103.5	147.0	114.7	147.0	120.5	171.0	145.4	183.0	162.9	195.0
00	135.0	78.3	159.0	119.3	171.0	133.4	171.0	140.2	198.0	168.3	213.0	189.6	222.0
000	156.0	90.5	186.0	139.5	198.0	154.4	198.0	162.4	231.0	196.4	246.0	218.9	258.0
0000	180.0	104.4	216.0	162.0	231.0	180.2	231.0	189.4	267.0	227.0	285.0	253.7	306.0

TABLE 5D Allowable Amperage of Conductors of 50 Volts or More When 7 to 24 Conductors are Bundled

7 to 24 CONDUCTORS ARE BUNDLED

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	5.0	2.9	5.0	3.8	7.5	5.9	10.0	8.2	10.0	8.5	12.5	11.1	12.5
16	7.5	4.4	7.5	5.6	10.0	7.8	12.5	10.3	12.5	10.6	15.0	13.4	17.5
14	10.0	5.8	10.0	7.5	12.5	9.8	15.0	12.3	17.5	14.9	20.0	17.8	22.5
12	12.5	7.3	12.5	9.4	17.5	13.7	20.0	16.4	22.5	19.1	25.0	22.3	27.5
10	20.0	11.6	20.0	15.0	25.0	19.5	27.5	22.6	30.0	25.5	35.0	31.2	35.0
8	27.5	16.0	32.5	24.4	35.0	27.3	35.0	28.7	40.0	34.0	45.0	40.1	50.0
6	40.0	23.2	47.5	35.6	50.0	39.0	50.0	41.0	60.0	51.0	62.5	55.6	67.5
4	52.5	30.5	62.5	46.9	65.0	50.7	67.5	55.4	80.0	68.0	85.0	75.7	90.0
3	60.0	34.8	72.5	54.4	75.0	58.5	77.5	63.6	90.0	76.5	97.5	86.8	105.0
2	70.0	40.6	85.0	63.8	87.5	68.3	90.0	73.8	105.0	89.3	112.5	100.1	120.0
1	82.5	47.9	97.5	73.1	105.0	81.9	105.0	86.1	122.5	104.1	132.5	117.9	140.0
0	97.5	56.6	115.0	86.3	122.5	95.6	122.5	100.5	142.5	121.1	152.5	135.7	162.5
00	112.5	65.3	132.5	99.4	142.5	111.2	142.5	116.9	165.0	140.3	177.5	158.0	185.0
000	130.0	75.4	155.0	116.3	165.0	128.7	165.0	135.3	192.5	163.6	205.0	182.5	215.0
0000	150.0	87.0	180.0	135.0	192.5	150.2	192.5	157.9	222.5	189.1	237.5	211.4	255.0

TABLE 5E Allowable Amperage of Conductors of 50 Volts or More When 25 or More Conductors are Bundled

25 or MORE CONDUCTORS ARE BUNDLED

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	4.0	2.3	4.0	3.0	6.0	4.7	8.0	6.6	8.0	6.8	10.0	8.9	10.0
16	6.0	3.5	6.0	4.5	8.0	6.2	10.0	8.2	10.0	8.5	12.0	10.7	14.0
14	8.0	4.6	8.0	6.0	10.0	7.8	12.0	9.8	14.0	11.9	16.0	14.2	18.0
12	10.0	5.8	10.0	7.5	14.0	10.9	16.0	13.1	18.0	15.3	20.0	17.8	22.0
10	16.0	9.3	16.0	12.0	20.0	15.6	22.0	18.0	24.0	20.4	28.0	24.9	28.0
8	22.0	12.8	26.0	19.5	28.0	21.8	28.0	23.0	32.0	27.2	36.0	32.0	40.0
6	32.0	18.6	38.0	28.5	40.0	31.2	40.0	32.8	48.0	40.8	50.0	44.5	54.0
4	42.0	24.4	50.0	37.5	52.0	40.6	54.0	44.3	64.0	54.4	68.0	60.5	72.0
3	48.0	27.8	58.0	43.5	60.0	46.8	62.0	50.8	72.0	61.2	78.0	69.4	84.0
2	56.0	32.5	68.0	51.0	70.0	54.6	72.0	59.0	84.0	71.4	90.0	80.1	96.0
1	66.0	38.3	78.0	58.5	84.0	65.5	84.0	68.9	98.0	83.3	106.0	94.3	112.0
0	78.0	45.2	92.0	69.0	98.0	76.4	98.0	80.4	114.0	96.9	122.0	108.6	130.0
00	90.0	52.2	106.0	79.5	114.0	88.9	114.0	93.5	132.0	112.2	142.0	126.4	148.0
000	104.0	60.3	124.0	93.0	132.0	103.0	132.0	108.2	154.0	130.9	164.0	146.0	172.0
0000	120.0	69.6	144.0	108.0	154.0	120.1	154.0	126.3	178.0	151.3	190.0	169.1	204.0

6.3 CONDUCTOR SIZE

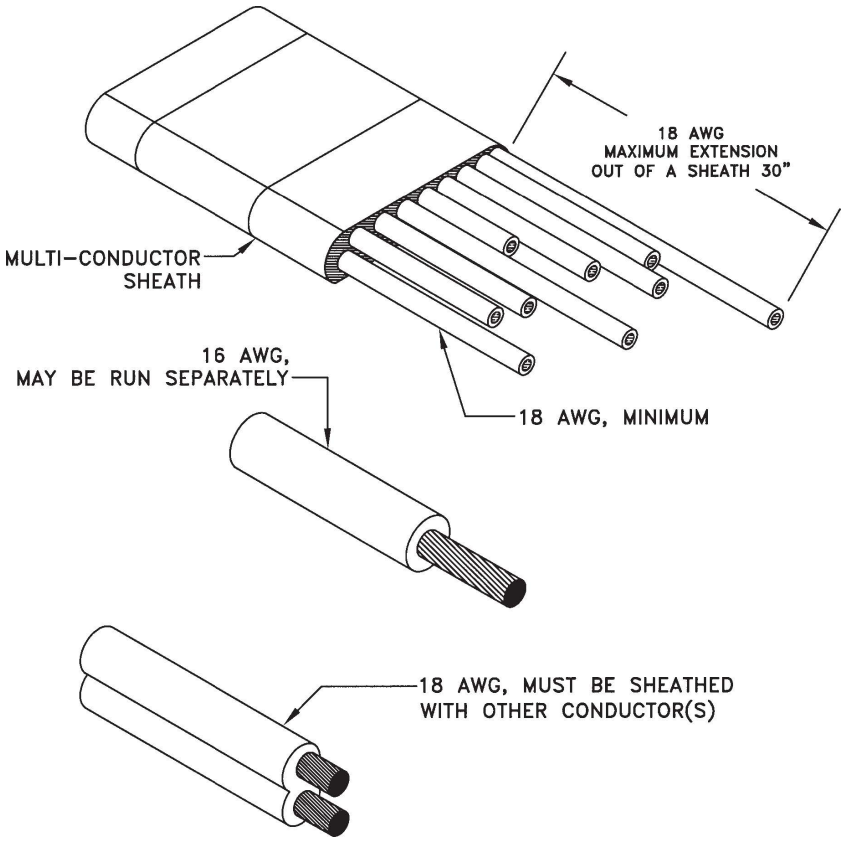
Per 183.425 (d) & (e): A single conductor must be at least 16 AWG. Each combined conductor in a sheath must be at least 18 AMG.

A conductor smaller than 16 AWG may not be used by itself. An 18 AWG is the smallest conductor permitted, except for the regulatory exceptions, and it must be in a multiconductor (2 or more conductors) sheath.

An 18 AWG conductor is limited to a 30 inch length from the end of a sheath. (See Figure 19).

Note: This section does not apply to communication systems; electronic navigation equipment; electronic circuits having current flow of less than one ampere; conductors which are totally inside an equipment housing; resistance conductors that control circuit amperage; high voltage secondary conductors and terminations that are in ignition systems; pigtails of less than seven inches of exposed length; and cranking motor conductors.

FIGURE 19 Permitted Conductor Size



7.0 CONDUCTORS IN CIRCUITS OF LESS THAN 50 VOLTS

Per 183.430: Conductors in circuits of less than 50 volts must meet the requirements of 183.435 or current SAE standards.

This section allows alternate choices of conductor requirements for circuits less than 50 volts. Conductors for circuits less than 50 volts may be used if they:

- meet the requirements of SAE J1127 "Battery Cable" or SAE J1128 "Low Tension Primary Cable" and the insulating material temperature rating requirements of SAE J378 "Marine Engine Wiring" such as those designated:
- GPT, HDT, SGT, STS, HTS, and SXL, or
- are classified as moisture resistant and flame retardant in Article 310 of the National Electrical Code, such as those designated:
- THW, TW, THWN, XHHW, MTS, or
- are flexible cords type SO, STO ST, SJO, SJT, SJTO, SE, SEO, SJ, SJEO, SJTOO, or STOO listed in Article 400 of the National Electrical Code (see Table 6), or
- are conductors that meet the IEEE Standard 45, such as those designated:
- R, B, T, V, AV, TA, M, S, or
- are conductors that meet the requirements of UL Standard 1426.

Conductors, as purchased, often do not indicate whether or not they conform with the above requirements and standards. If the conductors or their packaging are not so marked, then an alternate means of assurance of compliance should be obtained. Certification of compliance by the wire vendor is one acceptable means.

Note: This section does not apply to communication systems; electronic navigation equipment, resistance conductors that control circuit amperage; and pigtails of less than seven inches of exposed length

8.0 CONDUCTORS IN CIRCUITS OF 50 VOLTS OR MORE

Per 183.435: Conductors in circuits of 50 volts or more must meet electric code, NFPA, IEEE, and UL standards.

This section applies only to wiring in circuits of 50 volts or more. However, conductors meeting any one of these alternate requirements will also qualify for circuits of less than 50 volts. The alternating current (AC) systems of 120 and 240 volts are the systems normally in use on boats to which these requirements apply.

Paragraphs (a)(1), (a)(3) and (a)(4) apply to conductors in general, while (a)(2) applies specifically to various types of flexible cords.

Types

Conductors for circuits of 50 volts or more may be used if they:

- are classified as "moisture resistant" and "flame retardant" in Article 310 of the National Electrical Code, such as those designated:
- THW, TW, THWN, XHHW, MTW or;
- are flexible cords type SO, STO ST, SJO, SJT, or SJTO, listed in Article 400 of the National Electrical Code, (see Table 6);
- are conductors that meet the IEEE Standard 45, such as those designated:
- R, B, T, V, AV, TA, M, S; or
- are conductors that meet the requirements of UL Standard 1426.

There may be other cords or wires on the market, such as S, SE, SEO, SJE, SJEO, SJOO, SJTOO, and SOO, which have been accepted by the U.S. Coast Guard. If you are considering a cord or wire other than one listed above, check with the supplier for a copy of the Coast Guard's letter of acceptance.

Conductors, as purchased, often do not indicate whether or not they conform to the above requirements and standards. If the conductors or their packaging are not so marked, then an alternative means of assurance of compliance should be obtained. Certification of compliance by the cable vendor is one acceptable means.

Per 183.435 (b): Conductors in circuits of 50 volts or more are also sized in accordance with Table 5.

Sizing

Table 5 is used to select the size of conductors. Correction factors are provided for conductors used in engine spaces (Note 1) and also for bundling of conductors used in circuits of 50 volts or more (Note 2).

Tables 5A through 5E have been developed for this guideline, and include corrected values, so it is not necessary to perform the calculations required if using Table 5. Select the proper table according to the number of 50 volts or more current carrying conductors in a bundle and then read the wire gauge needed according to the temperature rating, location of the conductor and the circuit lead. Refer to "How to Select a Conductor" which follows, for further information.

Conductors, as purchased, often do not display the temperature ratings of conductor insulation. If the conductors or their packaging are not so marked, then an alternate means of assurance of compliance should be obtained. Certification of compliance by a vendor is one acceptable means.

How to Select a Conductor

FACTORS

To select a conductor in accordance with the regulation, there are a number of factors to consider:

- Temperature rating of conductor insulation.
- Current rating required for the circuit.
- Is the conductor in an engine space?
- Is the system voltage less than 50 volts, or is it 50 volts or more?
- How many conductors will run in a bundle?
- What type of conductor is permitted; i.e. SAE, NEC, IEEE, UL or other?

PROCEDURE

1. Determine the circuit load — add up the rated loads of the electrical devices in the circuit.
   The boat manufacturer will have to determine the circuit loads in the boat in order to properly size conductors and the related overcurrent protection. If a conductor is supplying a single load, sizing the conductor and its overcurrent protection is simple. If, however, a single conductor is supplying multiple or cumulative loads, such as a distribution panel, the boat manufacturer does not have to size the conductor to carry the summation of all the loads connected to the panel, but only a percentage of these loads, due to loading factors. The regulation does not require that a conductor be sized to carry the full load of a distribution panel, but does require that proper overcurrent protection be provided for the size of the conductor chosen.
   The boat manufacturer has a choice between the extremes of providing a conductor that can carry the full load, and using a smaller conductor that is adequate because of load factors, but still large enough to avoid nuisance tripping of its overcurrent protection.

Of course, whichever size conductor is used, it must be protected with the proper size overcurrent protection. It must also be noted that 183.425(b) restricts the maximum load a conductor may carry to that specified in Table 5, except for intermittent higher currents. (See 183.455 and 183.460 for Overcurrent Protection Requirements).

2. Decide what temperature rating of conductor will be used.

3. If in an engine space, apply the correction factor to the amperage values in Table 5 for the temperature rating selected. Tables 5A through 5E provide a column of corrected amperages for use in engine spaces.

4. If the electrical system is 50 volts or more, determine the number of current carrying conductors (grounding conductors are not normally current carrying) that will be bundled together. If more than two, select the appropriate correction factor and apply it to the amperage values in Table 5 or as corrected for use in engine spaces. Tables 5B through 5E provide corrected amperages for various numbers of conductors in bundles and also provide a column for conductors used in engine spaces.

5. In Table 5 or Tables 5A through 5E under the column for the selected temperature rating of the conductor, find the amperage that, when the necessary correction factors are applied (not needed when using Tables 5A through 5E) equals or exceeds the circuit load.

6. Read the gauge of the conductor to be used.

7. Select a conductor of STRANDED COPPER construction with insulation properties permitted in accordance with the system voltage, as follows:
   - less than 50 volts — SAE conductors are permitted in addition to those for 50 volts and over. (See 183.430).
   - 50 volts or more — NEC, IEEE and UL conductors are permitted. (See 183.435).

EXAMPLES

1. A circuit in a boat consists only of a 12-volt bilge pump, rated at 12 amps. The bilge pump and its wiring are in the engine compartment and the conductors will run in a bundle of 8 conductors except where they break out of the bundle to go to the pump, a distance of 40 inches from the bundle.

FACTS	
Circuit Load	12 amps
Location	Engine Space
Bundling	8 conductors
Voltage	Less than 50 volts

CONDUCTOR

The boat builder decides to use 75° C temperature rated conductors for the bilge pump.

ENGINE SPACE CORRECTION

The factor for 75° C conductors is 0.75.

CALCULATION

In Table 5, under 75° C, a 16 AWG conductor will carry 15 amps; however, when corrected for use in an engine space, it may only carry:

0.75 x 15 = 11.25 amps therefore 16 AWG conductors are too small.

Try 14 AWG:

0. 75 x 20 = 15 amps 14 AWG, 75° C conductors may be used.

Tables 5A through 5E may be used in lieu of these calculations.

Bundling corrections DO NOT apply to conductors used in circuits less than 50 volts.

2. A lighting and receptacle circuit is planned for the 120 volt AC system on a boat. The maximum permanent lighting load is known to be 5 amps. The receptacle load is unknown but the receptacles are rated at 15 amps. The conductors go through the engine space in a bundle of 8 conductors, 3 of which are DC and 5 of which are current carrying AC conductors.

FACTS

Circuit Load	Unknown
Location	Conductors run through engine space
Bundling	8 conductors; 3 DC, 5 AC
Voltage	50 volts or more (actually 120 volts AC).

CONDUCTOR

The boat builder decides to use 75° C temperature rated conductors for this lighting and receptacle circuit.

ENGINE SPACE CORRECTION

The factor for 75° C conductors is 0.75. The correction factor applies to the length of the conductors used in the engine space. The lengths outside the engine space need no correction. If a conductor runs inside and outside an engine space, it must be sized for the engine space.

CIRCUIT LOAD

Since the circuit load is unknown, the size of the circuit protection device will determine the anticipated load. In this case, a 20 amp was selected.

CALCULATION
In Table 5, under 75° C, a 12 AWG conductor will carry 25 amps. Corrected for engine spaces it may only carry:

0.75 x 25 = 18.75 amps 12 AWG, 75° C conductors are too small.

Try 10 AWG

0. 75 x 40 = 30 amps

Bundling Correction — Even though there are 8 conductors in the bundle, only 5 are current carrying in circuits of 50 volts or more. Therefore, the correction factor from Note 2 used is for bundles of 4 to 6 conductors, or 0.60.

Try 10 AWG, corrected for engine spaces:

0.60 x 30 = 18 amps 10 AWG 75° C conductors are too small.

Try 8 AWG

Correct for engine spaces: 0.75 x 65 = 48.75
Correct for bundling: 0.60 x 48.75 = 29.25

8 AWG, 75° C conductors may be used in the engine spaces. Please note that outside the engine spaces, 10 AWG conductors may be used, as the following bundling calculation shows:

0.60 x 40 = 24 amps

Conductors with a higher insulation temperature rating could be used to reduce the size of the conductor.

(Table 5C may be used in lieu of these calculations).

3. For the same example used in (c)(2) above, there is another method for determining proper conductor size. Again, use a 20 ampere load and a 75° C rated conductor. This method avoids the iterative process used in examples (1) and (2). Simply divide the load, 20 amperes, by the correction factor for engine space:

CALCULATION

$$\frac{20}{0.75} = 26.67 \text{ amps}$$

Then divide the result (26.67 amperes) by the correction factor for bundling:

$$\frac{26.67}{0.60} = 44.44 \text{ amps}$$

Enter the 75° C column of Table 5 and select the first conductor size whose allowable amperage exceeds 44.44 amperes. In this case, a 10 AWG conductor is allowed to carry 40 amperes, which is not enough. An 8 AWG conductor can carry 65 amperes. The selection will have to be an 8 AWG conductor or larger. If an 80° C rating is used, then a 10 AWG conductor would be adequate.

(Table 5C may be used in lieu of these calculations.)

TABLE 6 Flexible Cords and Cables (from Article 400, NEC)

TRADE NAME	TYPE LETTER	SIZE AWG	NUMBER OF CONDUCTORS	INSULATION	NOMINAL *INSULATION THICKNESS		BRAND ON EACH CONDUCTOR	OUTER COVERING	USE		
					AWG	MILS					
HARD SERVICE CORD	SO SEE NOTE 5	18-2	2 OR MORE	THERMOSET	18-16	30		OIL-RESISTANT THERMOSET	PENDANT OR PORTABLE	DAMP LOCATIONS	EXTRA HARD USAGE
	SOO SEE NOTE 5			OIL-RESISTANT THERMOSET	14-10	45		OIL-RESISTANT THERMOSET			
					8-2	60					
HARD SERVICE CORD	ST SEE NOTE 5	18-2	2 OR MORE	THERMO-PLASTIC OR THERMOSET	18-16	30	NONE	THERMO-PLASTIC	PENDANT OR PORTABLE	DAMP LOCATIONS	EXTRA HARD USAGE
	STO SEE NOTE 5				14-10	45		OIL-RESISTANT THERMO-PLASTIC			
	STOO SEE NOTE 5			OIL-RESISTANT THERMO-PLASTIC OR THERMOSET	8-2	60					
HARD SERVICE CORD	S SEE NOTE 5	18-12	2 OR MORE	THERMOSET	18-16	30	NONE	THERMOSET	PENDANT OR PORTABLE	DAMP LOCATIONS	EXTRA HARD USAGE
	SE SEE NOTE 5			THERMO-PLASTIC ELASTOMETER	14-10	45		THERMO-PLASTIC ELASTOMETER			
	SEO SEE NOTE 5				8-2	60		OIL-RESISTANT THERMO-PLASTIC ELASTOMETER			
JUNIOR HARD SERVICE CORD	SJ	18-10	2, 3, 4 OR 5	THERMOSET	18-12	30	NONE	THERMOSET	PENDANT OR PORTABLE		HARD USAGE
	SJE			THERMO-PLASTIC ELASTOMETER				THERMO-PLASTIC ELASTOMETER			
	SJEO							OIL-RESISTANT THERMO-PLASTIC ELASTOMETER			
	SJO			THERMOSET				OIL-RESISTANT THERMOSET			
	SJOO			OIL-RESISTANT THERMOSET				OIL-RESISTANT THERMOSET			
	SJT			THERMO-PLASTIC OR THERMOSET	10	45		THERMO-PLASTIC			
	SJTO			THERMOSET OR THERMO-PLASTIC				OIL-RESISTANT THERMO-PLASTIC			
	SJTOO			OIL-RESISTANT THERMO-PLASTIC OR THERMOSET				OIL-RESISTANT THERMO-PLASTIC			

To select the right bundling correction factor, count only the current carrying conductors that are in circuits of 50 volts or more. Other conductors in the same bundle do not have to be counted, such as grounding conductors, conductors from senders to gauges, and conductors in low voltage circuits less than 50 volts. For example, if a bundle contains a total of ten conductors:

3 — 12 volt system

1 — oil pressure gauge

2 — grounding conductors

4 — 120 volt AC system

then the bundling factor is based only on the 4 current carrying conductors in the 120 volt AC system.

Tables 5B through 5E contain tabulated values for allowable amperage in 50 volts and over circuitry in which 3 or more current carrying conductors are bundled. See the correct table for the bundling being selected: 5B = 3; 5C = 4 to 6; 5D = 7 to 24; and, 5E = 25 or more. These tables incorporate all necessary correction factors as noted in both 183.425 and 183.435.

Note: This section does not apply to communication systems; electronic navigation equipment; resistance conductors that control circuit amperage; conductors in secondary circuits of ignition systems; and pigtails of less than seven inches of expose length.

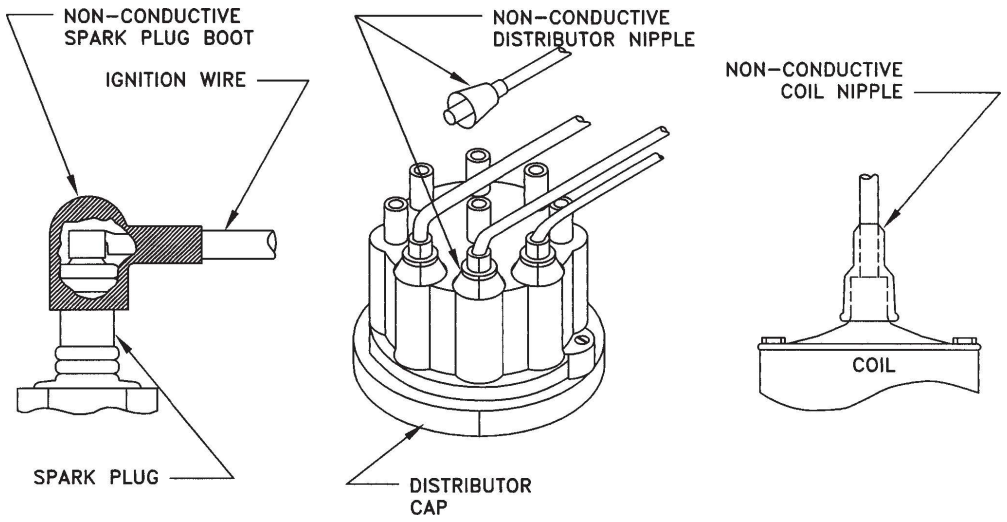
9.0 SECONDARY CIRCUITS OF IGNITION SYSTEMS

Per 183.440: Spark plug wires must meet the current SAE standard – and the connection must be protected.

Conductors in secondary circuits of ignition systems consist of the conductor from the center tap on the ignition coil to the center or rotor terminal on the distributor cap and the spark plug wires.

These conductors must meet the specialized requirements of SAE J557 “High Tension Ignition Cable”. Both ends of these conductors must be connected in such a manner as to be protected by a tight fitting cap, boot or nipple. Caps, boots and nipples that meet test requirements incorporated in SAE J1191, “High Tension Ignition Cable Assemblies”, are acceptable.

FIGURE 20 Ignition Conductor Connections



10.0 CONDUCTORS: PROTECTION

Section 183.445 covers the protection of conductors both in terms of passage through rigid surfaces – and protection of the terminal ends from short-circuiting.

> Per 183.445 (a) Conductors must be protected where the run goes through a bulkhead, or deck, or similar structure.

A conductor or bundle of conductors must have abrasion protection, in addition to its own insulation, where it goes through a hole. This applies to holes in any rigid surface such as a bulkhead, junction box, electric panel, etc. Any means such as clamping, grommets, caulking, hose, bushings, taping, special devices or others may be used. Note the requirements for isolation bulkhead openings in section 183.410(c), if applicable.

> Per 183.445 (b) The ungrounded terminals of continuously energized conductors must be protected to prevent accidental short-circuiting.

Any continuously energized terminal or stud that is not protected by a fuse or circuit breaker, as required by section 183.455, must be protected from accidental short-circuiting. Continuously energized means directly connected to a power source without any switches or solenoids between the source and the

terminal. Protection against accidental short-circuiting must be by means of an insulated boot, nipple, or cap or by a cover or shield. The test to determine if the protection is effective is whether or not the terminal or stud can be touched by a 3/4 inch diameter ball. If it cannot be touched, then the protection is adequate.

FIGURE 21 - Abrasion Protection

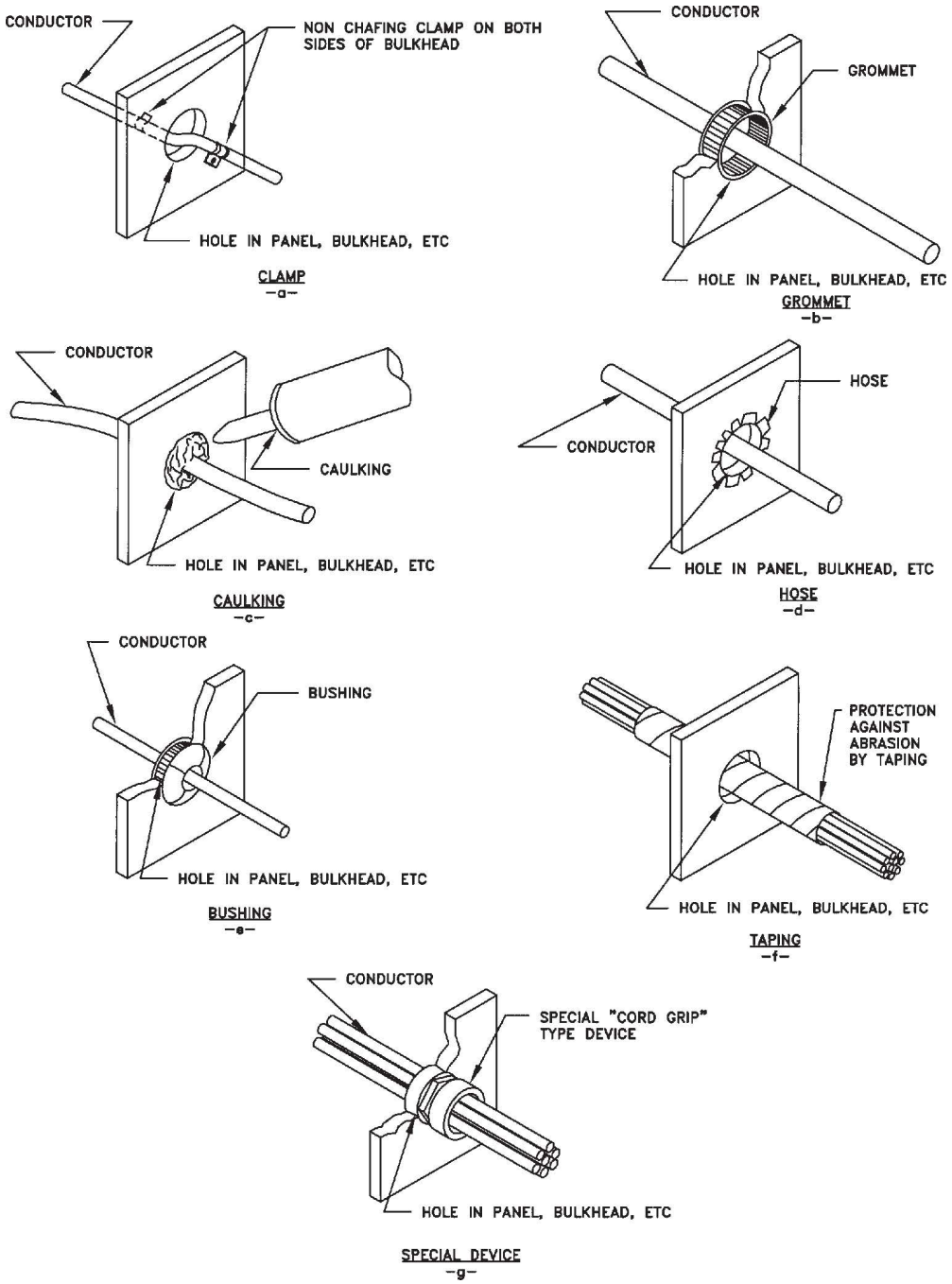
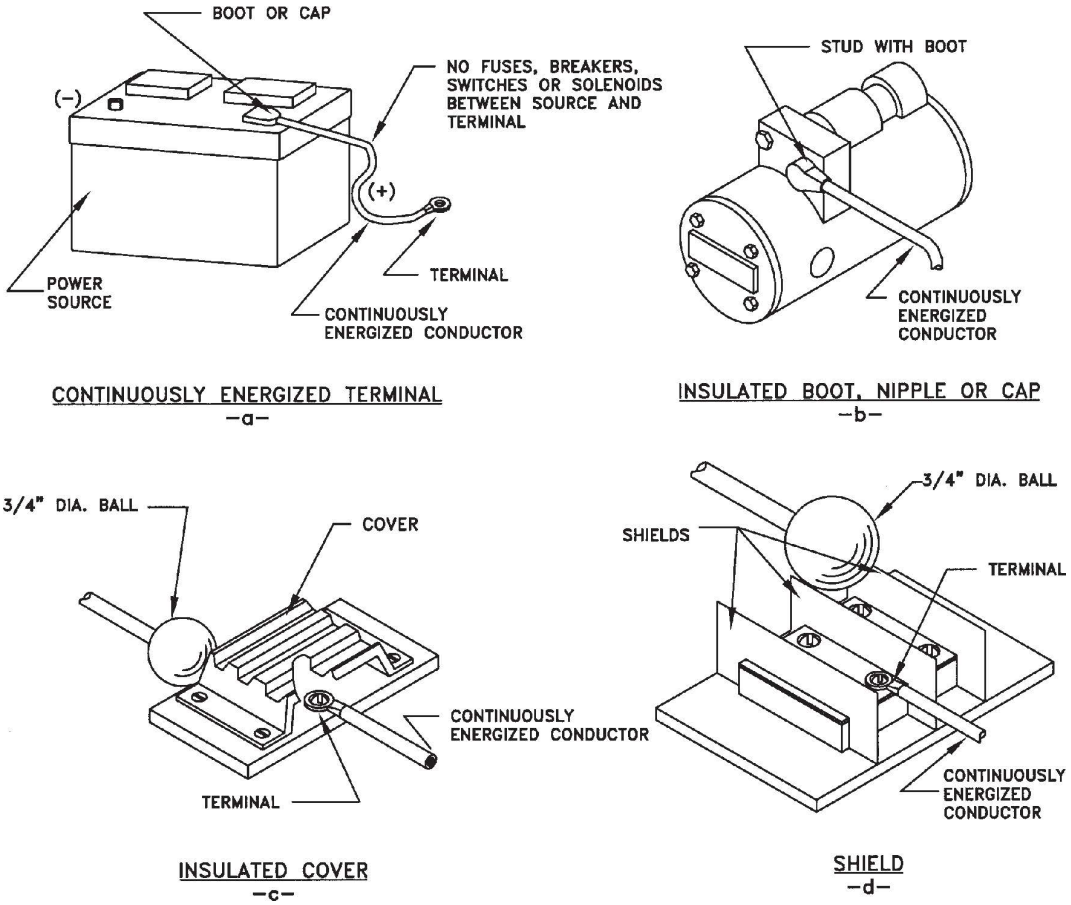


FIGURE 22 - Terminal Protection



11.0 OVERCURRENT PROTECTION

Sections 183.455 and 183.460 cover both the general requirements for overcurrent protection and two special applications.

Per 183.455 (a): Ungrounded current carrying conductors must be protected by a manually reset, trip free circuit breaker or fuse.

Per 183.455 (b): That circuit breaker or fuse must be placed at the source of power.

Per 183.455 (c): That circuit breaker of fuse must meet the current rating.

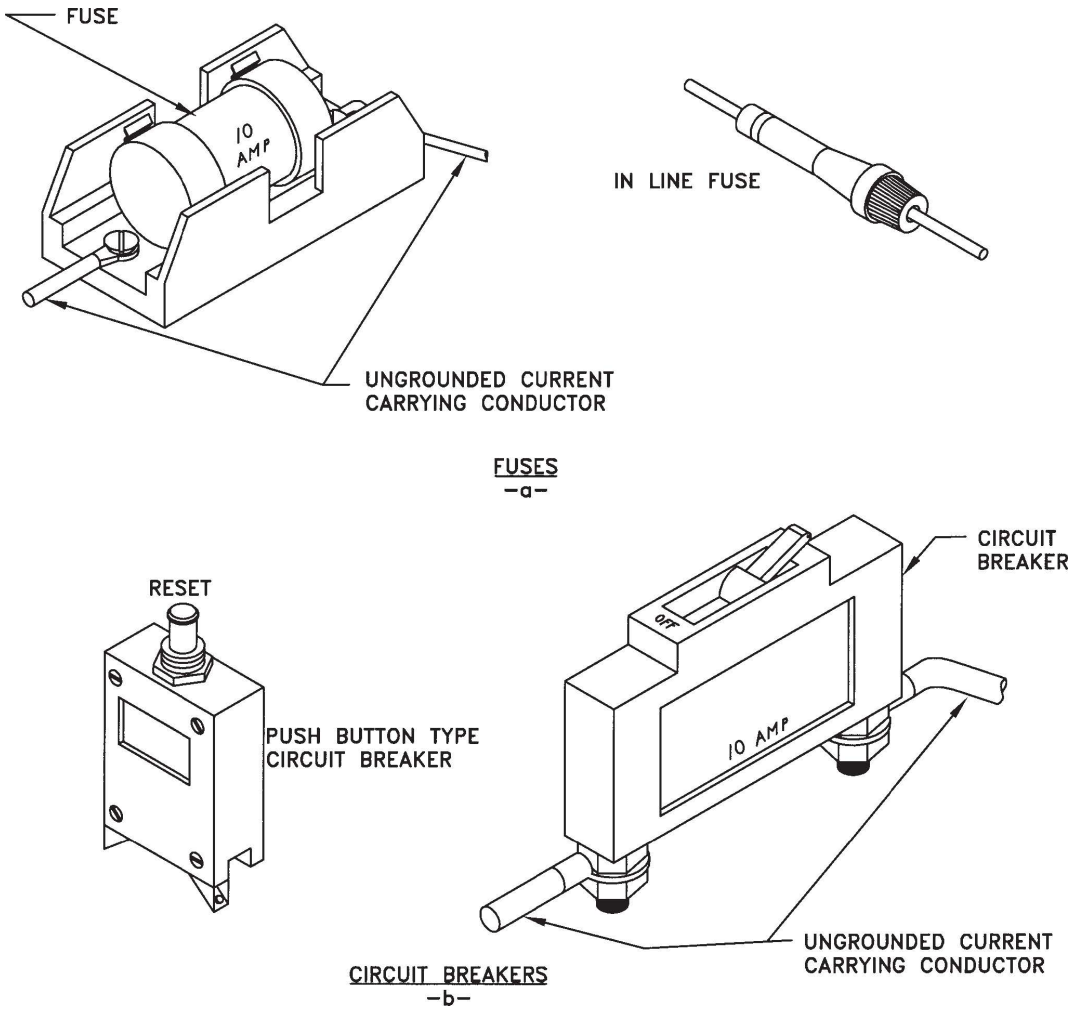
Per 183.455 (d): That circuit breaker of fuse must meet the voltage rating.

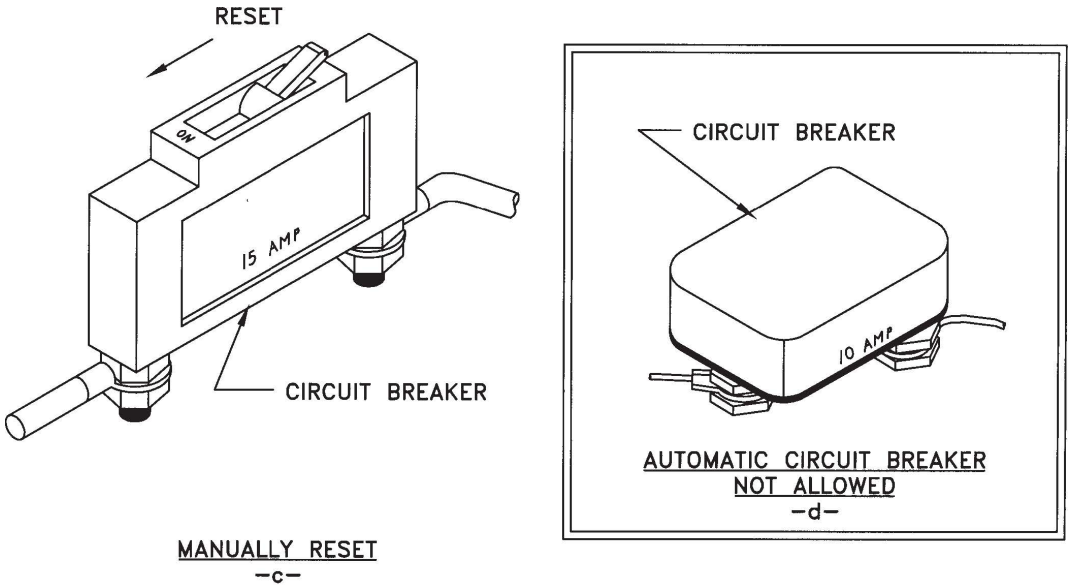
Each ungrounded conductor used to carry current must be protected by a fuse or a circuit breaker. If used, a circuit breaker must be of the manually reset type rather than the automatic reset type.

Additionally, the circuit breaker must be of the trip free type, which means that the breaker will open the circuit even if the handle is held in the "on" position.

For the 'source of power', refer to Figure 25 for the location of overcurrent protection. The minimum distances from the source are shown from a battery, battery switch, starter, and distribution buss.

FIGURE 23 OVERCURRENT PROTECTION




RESET
ON
15 AMP
CIRCUIT BREAKER
MANUALLY RESET
-c-
CIRCUIT BREAKER
10 AMP
AUTOMATIC CIRCUIT BREAKER
NOT ALLOWED
-d-

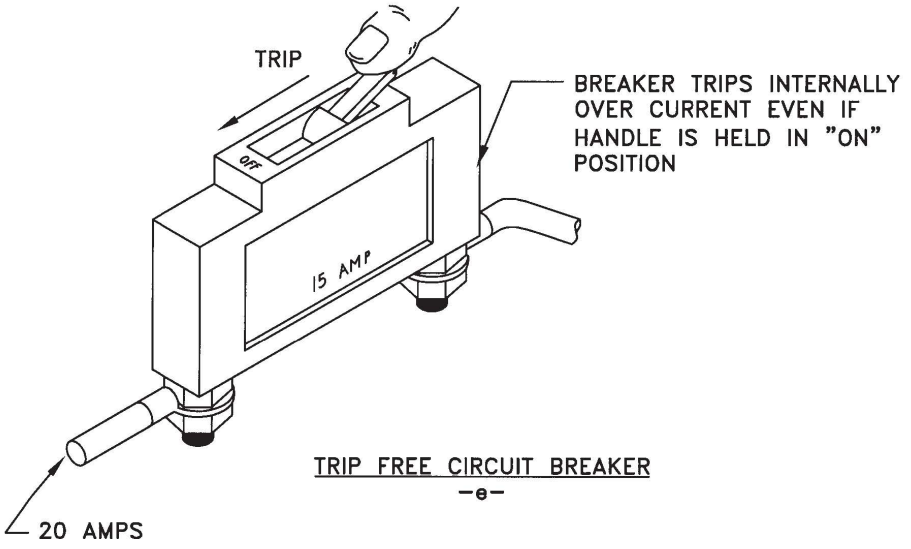
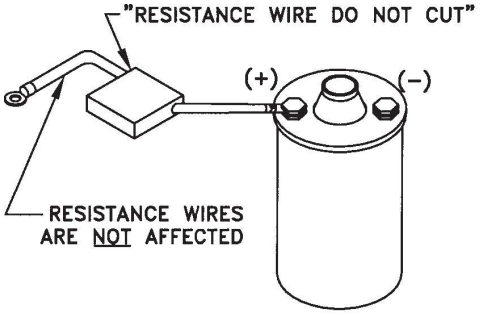
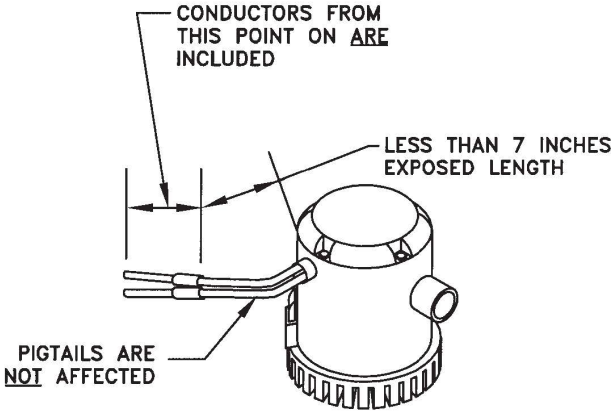

TRIP
OFF
15 AMP
BREAKER TRIPS INTERNALLY
OVER CURRENT EVEN IF
HANDLE IS HELD IN "ON"
POSITION
TRIP FREE CIRCUIT BREAKER
-e-
20 AMPS

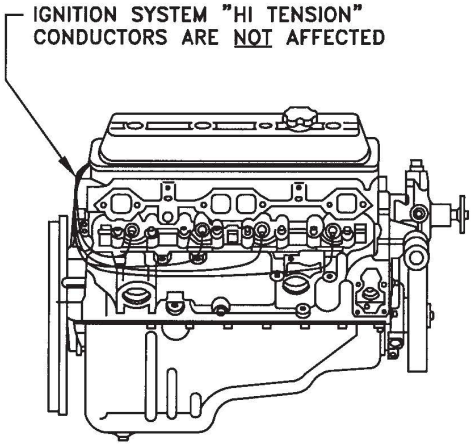
FIGURE 24 OVERCURRENT PROTECTION EXCEPTIONS



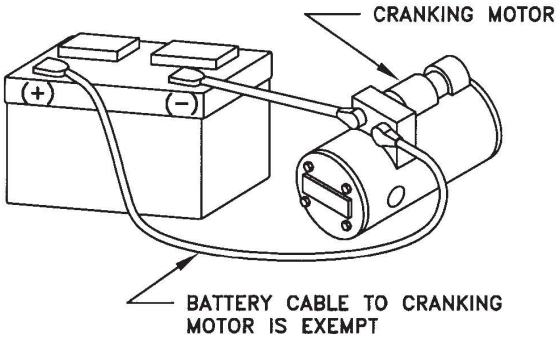
RESISTANCE CONDUCTOR
–a–



PIGTAILS OF LESS THAN 7 INCHES
–b–



IGNITION SYSTEM SECONDARIES
–c–



CRANKING MOTOR POWER SUPPLY CONDUCTORS
–d–

LOCATION

The circuit breaker or fuse required must be located in one of three places:

1. at the point where a conductor receives its power (see Figure 25a)
2. at the point where a smaller conductor is connected to a larger conductor (see Figure 25b); or
3. at the point where a circuit initially receives its power if the breaker or fuse is sized to protect the smallest conductor in the circuit. (See Figures 25c and 25d.)

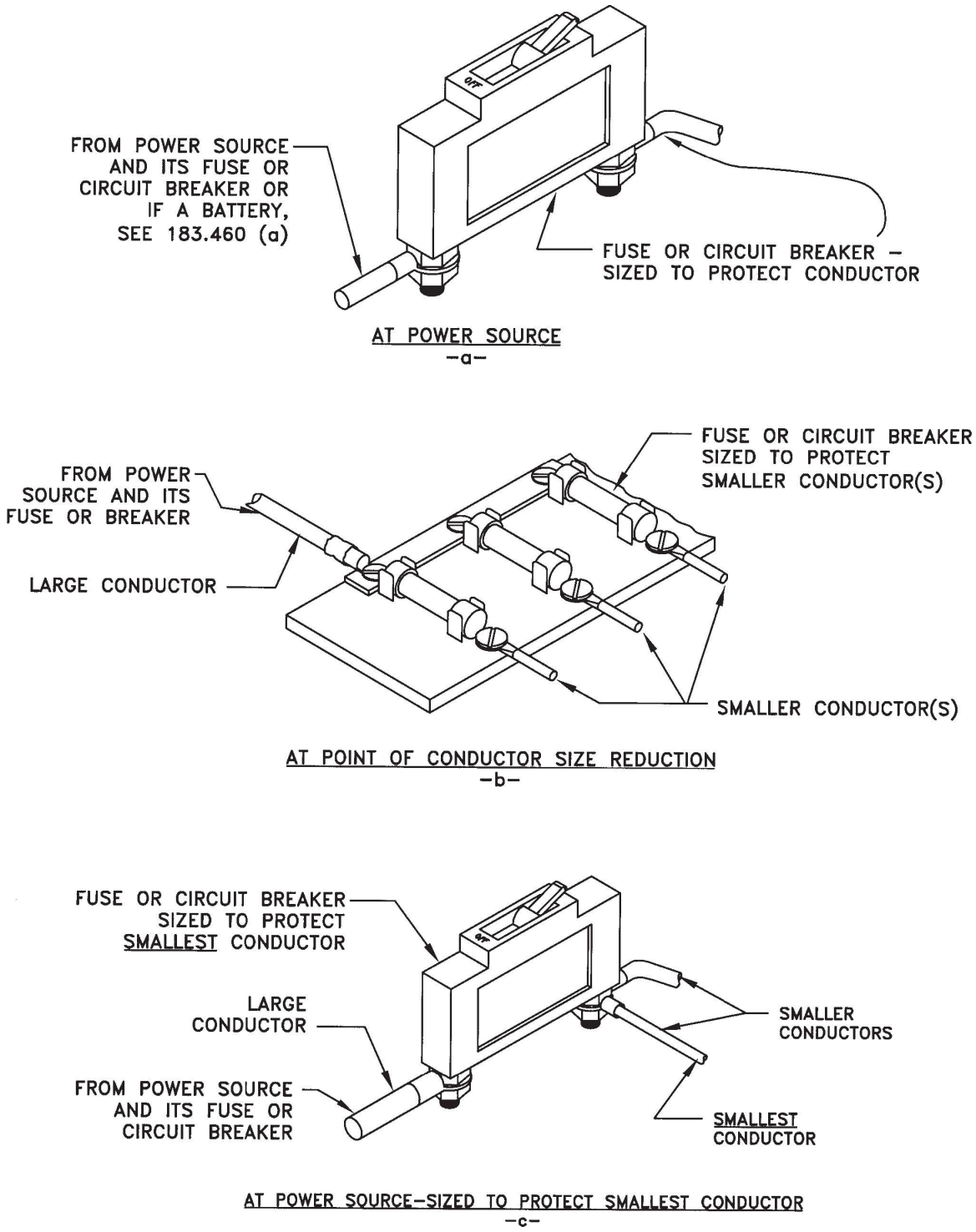
The schematic in Figure 25e shows these three methods of overcurrent protection.

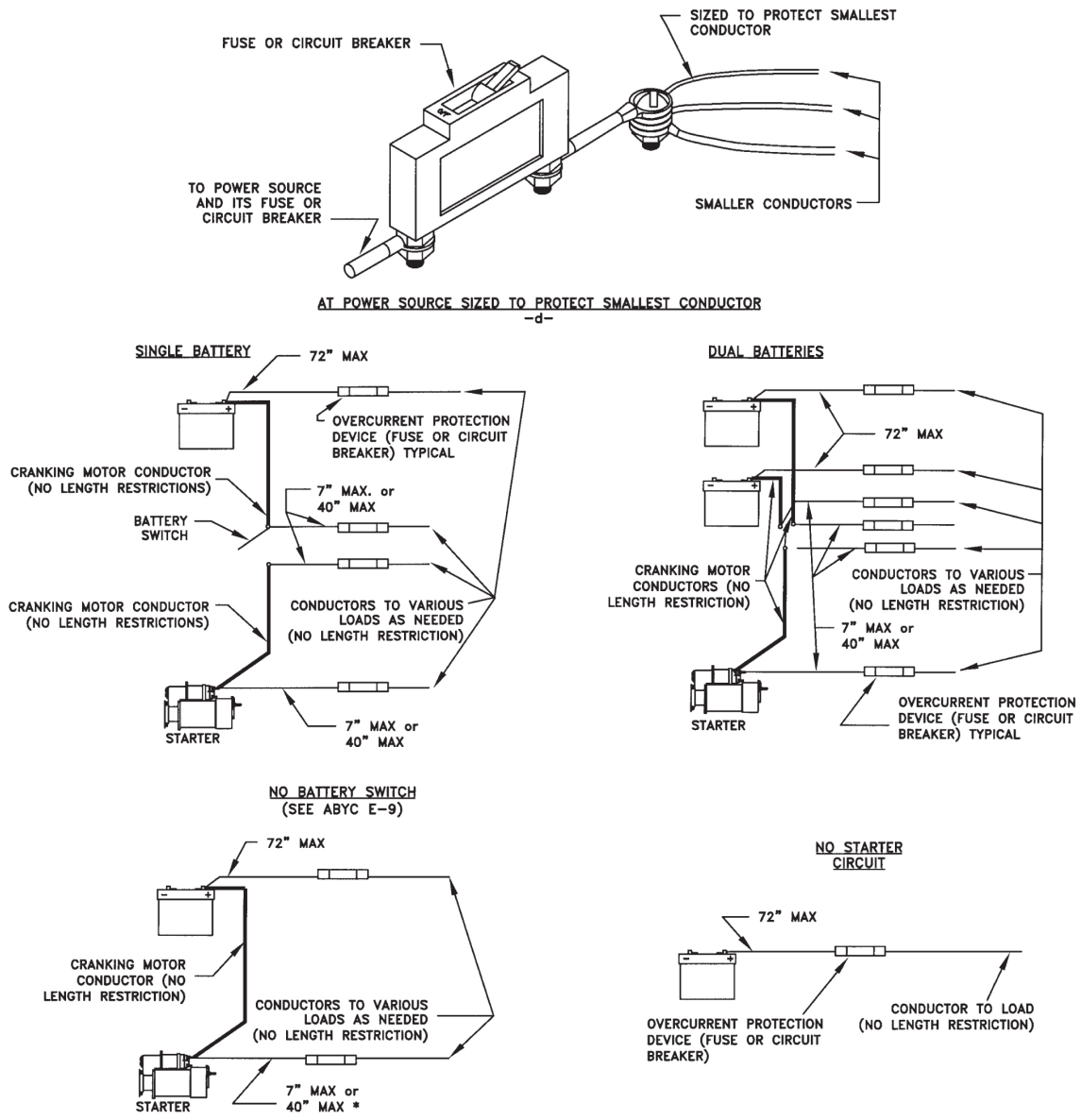
Locations 1 and 2 actually describe a single location. The point in a circuit where a smaller conductor is connected to a larger conductor becomes the source of power for the smaller conductor. Basically, each conductor, noting the permitted exceptions, must be provided with overcurrent protection. This overcurrent protection may be located at a conductor's power source or at the point where the circuit receives its power, as long as the current rating of the overcurrent protection device protects the smallest conductor. Circuits in which there is no reduction in conductor size must be protected at the circuit's source of power, again noting the permitted exceptions.

For shore power installations, the source of power is the dockside or shore located receptacle. The shore power cable and the main power feeders from the shore power inlet on the boat to the main distribution panel are protected by overcurrent protections at the dockside or shore locate connection.

Circuits using conductors of different insulation temperature ratings resulting in the use of a smaller gauge conductor to carry the same or larger rated current must have overcurrent protection sized to protect the conductor with the lowest amperage rating. For example, if a 10 AWG supply conductor (60° C) is connected to a 14 AWG (125° C), the conductor amperage capacity is 40 amps in both cases and therefore one circuit breaker at the source end of the 10 AWG conductor is all that is needed.

FIGURE 25 LOCATION OF OVERCURRENT PROTECTION





Up to 40" is allowed if the conductor, throughout this distance, is contained in a sheath or enclosure such as a junction box, control box, or enclosed panel.

CURRENT RATING

A circuit breaker or fuse must be sized so as not to exceed the permitted percentages of the current (ampere) rating of the conductor it is to protect as permitted in this section of the regulation. The current rating of the conductors must be taken from Table 5, including correction factors as applicable, as referred to in 183.425 and 183.435. The voltage of the circuit must be known in order to properly size the overcurrent protection.

FOR LESS THAN 50 VOLTS

The breaker or fuse rating cannot exceed the Table 5 value by more than 150% (i.e. 1.5 times the table value). See Example A below.

FOR 50 VOLTS OR MORE

The breaker or fuse should correspond exactly to the Table 5 value (See Example B). If, however, a standard rating of breaker or fuse does not correspond to the Table 5 value, then the next larger size breaker or fuse may be used, provided it does not exceed 150% (1.5 times) the Table 5 value (see Example C).

EXAMPLE A Less Than 50 Volts

For a No. 10 AWG 90° C conductor in an engine room, Table 5 gives a value of 45.1 amperes (55 X .82 correction factor). 150% of this value is 67.65 (45.1 X 1.5). The MAXIMUM breaker current rating would be 67.65 amperes. In practical terms, a 60 or 65 ampere device would be chosen.

EXAMPLE B 50 Volts or More

For a No. 6 AWG 105° C conductor in an engine room, Table 5 gives a value of 102 amperes (120 X .85 correction factor). If a standard size breaker or fuse is available in this rating, it should be used.

EXAMPLE C 50 Volts or More

For a No. 6 AWG 80° C conductor run with two other current carrying conductors, in circuits of 50 volts or more, in an engine room, Table 5 gives a value of 54.6 amperes (100 X .70 correction factor X .78 correction factor). As the next larger standard breaker or fuse rating is 60 amperes, this value may be used provided it does not exceed 150% of the table value. The 150% value would be 81.9 amperes (54.6 X 1.5) and, as 60 amperes is LESS than this, then a 60 ampere breaker or fuse is the maximum that may be used. Of course, a lower rated circuit breaker or fuse may be used, as could a larger conductor.The boat manufacturer will have to determine the circuit loads in the boat in order to properly size conductors and the related overcurrent protection. If a conductor is supplying a single load, sizing the conductor and its overcurrent protection is simple. If, however, a single conductor is supplying multiple or cumulative loads, such as a distribution panel, the boat manufacturer does not have to size the conductor to carry the summation of all the loads connected

to the panel, but only a percentage of these loads, due to loading factors. The regulation does not require that a conductor be sized to carry the full load of a distribution panel, but does require that proper overcurrent protection be provided for the size of conductor chosen.

The boat manufacturer has a choice between the extremes of providing a conductor that can carry the full load, or, using a smaller conductor that is adequate because of load factors, but still large enough to avoid nuisance tripping of its overcurrent protection.

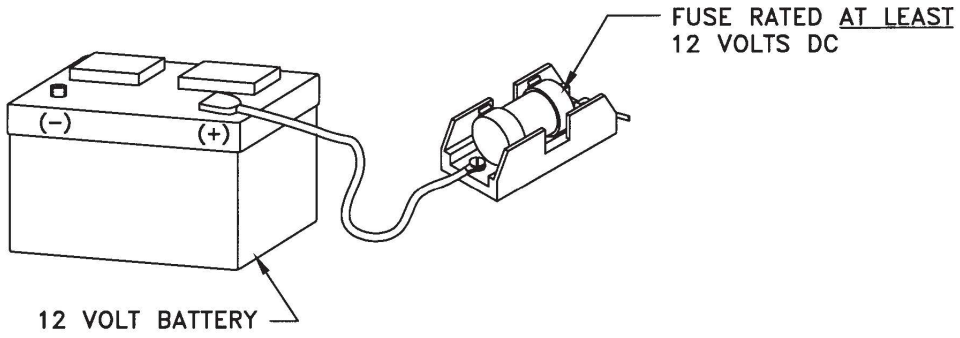
Of course, whichever size conductor is used, it must be protected with the proper size overcurrent protection. It must also be noted that 183.425(b) restricts the maximum load a conductor may carry to that specified in Table 5, except for intermittent higher currents as discussed under 183.425(b).

VOLTAGE RATING

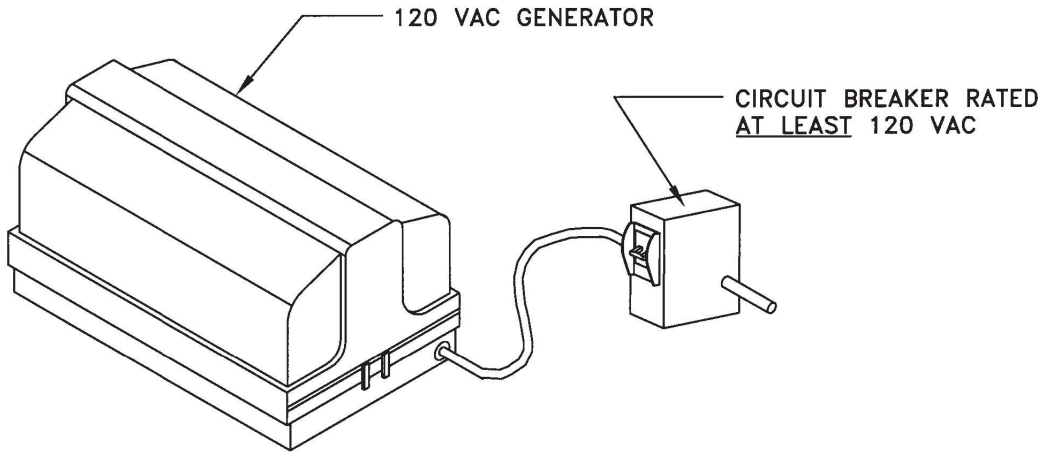
In addition to a current (ampere) rating, a circuit breaker or fuse also has a voltage rating. A circuit breaker or fuse must have a voltage rating equal to, or preferably greater than, the nominal voltage of the circuit it is protecting. This is to ensure that the device will operate properly when an overcurrent (too many amperes) situation occurs. See Figure 26.

Nominal circuit voltage means the named voltage — i.e. a 12 volt DC system may charge at about 13.8 volts, but the nominal circuit voltage is 12 volts DC.

FIGURE 26 VOLTAGE RATING OF OVERCURRENT PROTECTION



NOMINAL 12 VOLT DC CIRCUIT
−a−



NOMINAL 120 VOLT AC CIRCUIT
−b−

Per 183.460 'Special Applications' regarding overcurrent protection apply to the engine cranking conductor – and self-limiting alternators or generators

CRANKING MOTOR CONDUCTORS

Ungrounded conductors connected to a storage battery, other than cranking motor conductors, must have overcurrent protection in accordance with 183.455(a). This section of the regulation provides an exception to 183.455(b) which allows the overcurrent protection location for the battery cable, as described, to be a distance from the connection at the battery (Section 182.455(b) requires the overcurrent protection to be at the power source). The distance from the battery connection depends on whether or not the overcurrent protection device is equipped with a switch.

Overcurrent protection without a switch must be located within 72 inches of the battery connection. See Figure 25.

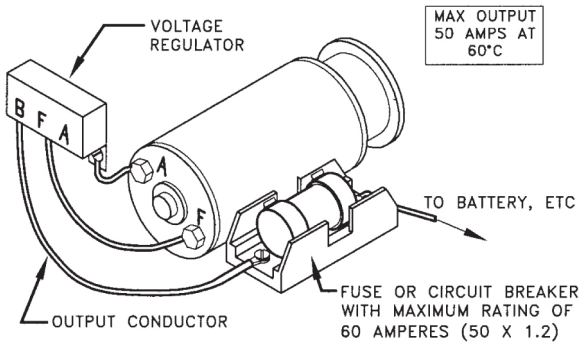
The only exception to the overcurrent protection requirement for conductors is for cranking motor power conductors, as excepted in 183.455(e). Schematics of typical main supply circuits are shown in Figure 25.

SELF-LIMITING ALTERNATORS OR GENERATORS

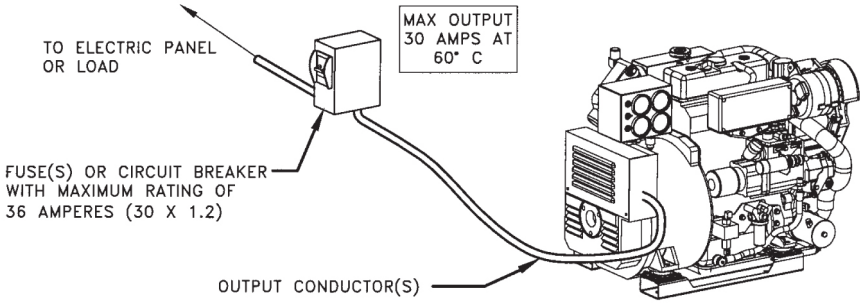
The output of alternators or generators (AC or DC) must have overcurrent protection as described in 183.455. This must be by means of a circuit breaker or fuse rated at no more than 120% (1.2 times) of the maximum rated output current of the alternator or generator. As this output rating may be temperature sensitive, a 60° C (140° F) temperature is used as a standard (see Figure 27). The only exception to the breaker or fuse requirement is for "self limiting" alternators or generators. These are devices that are designed and manufactured to provide only a certain maximum output no matter how much load is applied (i.e. they cannot be overloaded). This information must be obtained from the alternator or generator manufacturer, or may be available on the nameplate.

The "self limiting" concept can also be applied to certain battery chargers, magneto grounding circuits, and other similar components that provide electrical output for specific functions. This electrical output is limited by the construction of the electrical components no matter what the load, and when its output circuit is grounded, the voltage drops to zero.

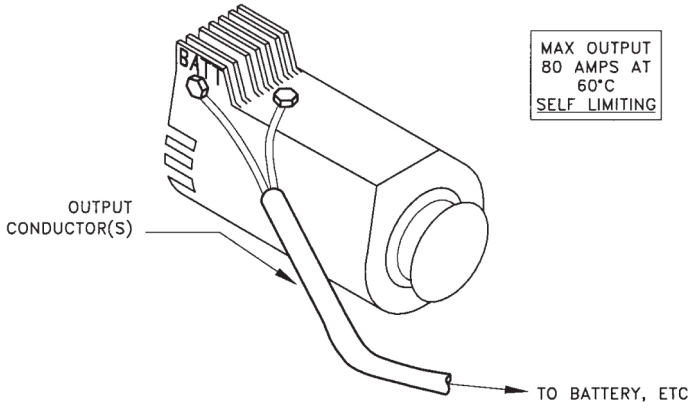
The overcurrent protection requirements of section 183.455 apply to ungrounded conductors. For the purpose of these requirements, the conductors used with sender units such as fuel gauges, oil temperature switches, thermostats, etc., are considered to be grounded conductors and do not require overcurrent protection. The supply conductors in a gauge or other measuring systems are protected by overcurrent protection, and this indirectly protects the grounded conductors discussed above.



DC GENERATOR – NOT SELF LIMITING
–a–

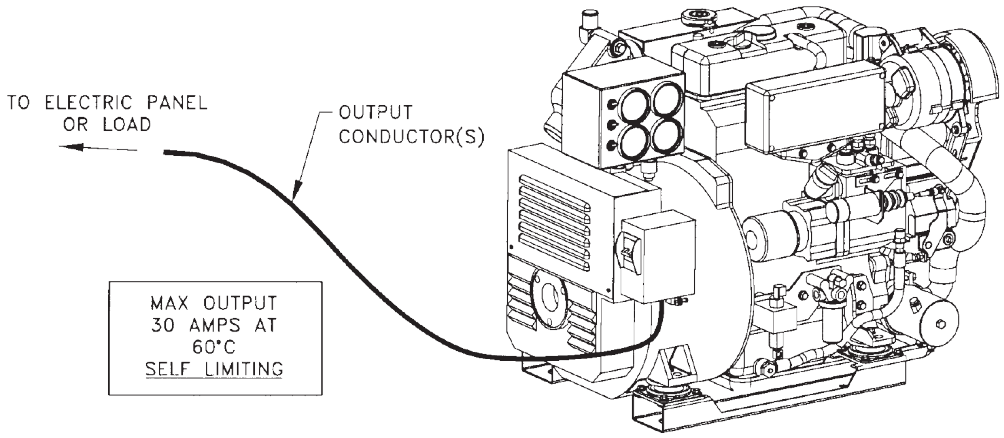


AC GENERATOR – NOT SELF LIMITING
–b–



DC ALTERNATOR – SELF LIMITING
NO PROTECTION REQUIRED
–c–

FIGURE 27 ALTERNATORS AND GENERATORS (CONTINUED)



AC GENERATOR – SELF LIMITING
NO PROTECTION REQUIRED
–d–

12.0 TYPICAL WIRING DIAGRAMS

- Diagram 1 Auxiliary Sailboat
- Diagram 2 Inboard and Sterndrive Runabout
- Diagram 3 Instrument Wiring
- Diagram 4 Harness
- Diagram 5 Cruiser — Wiring — Less Than 50 Volts
- Diagram 6 Cruiser — Wiring — 50 Volts or More

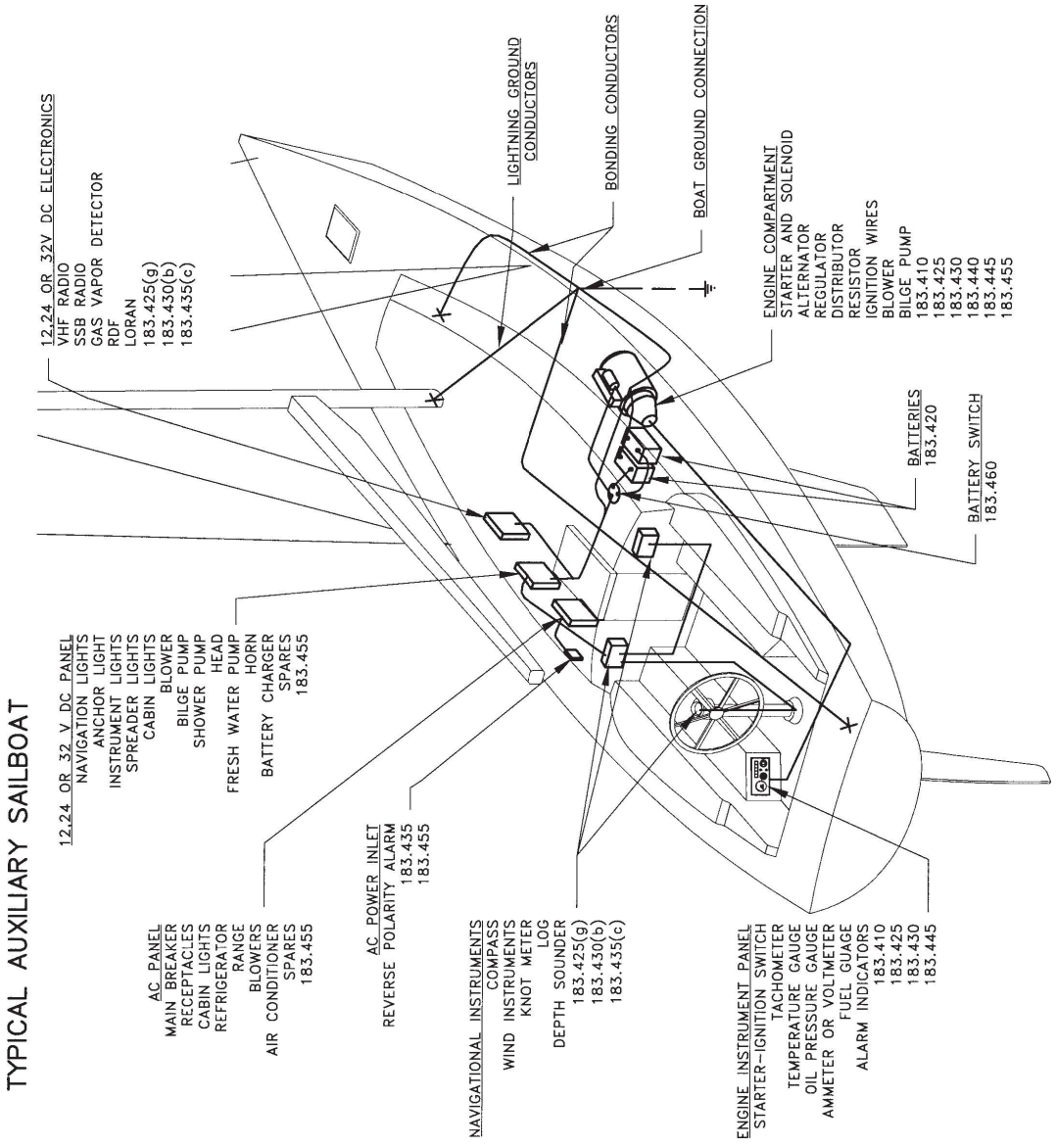
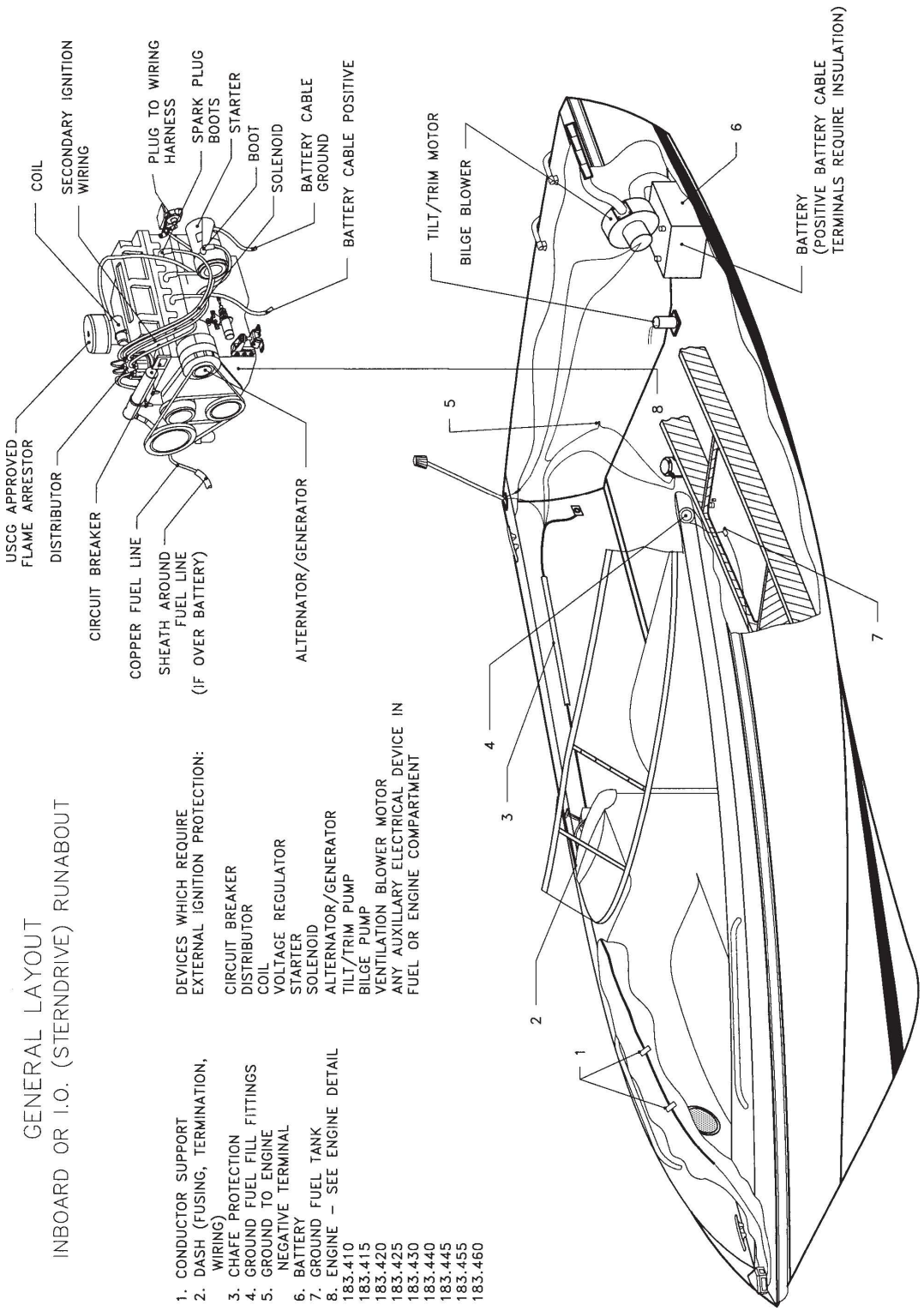
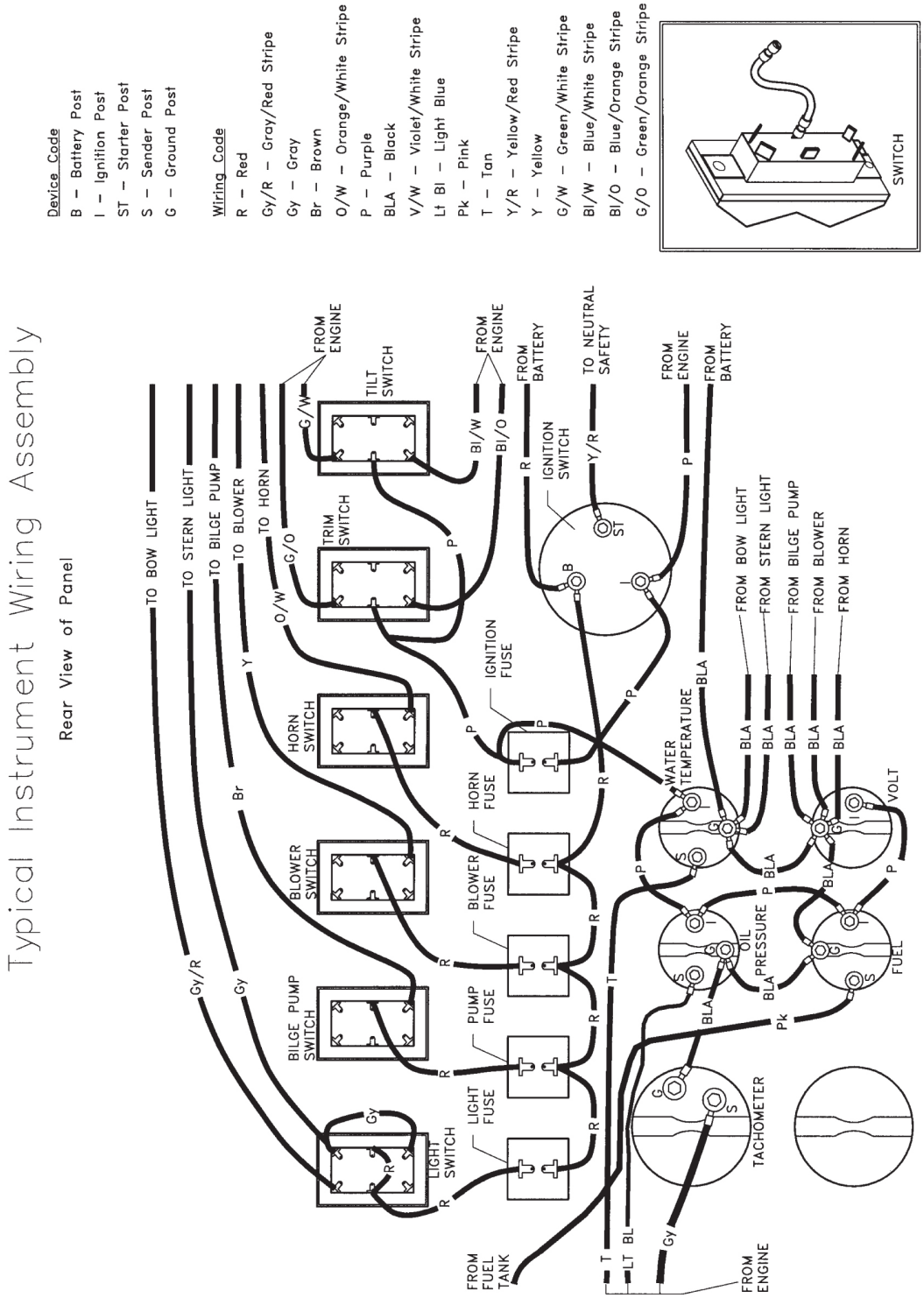
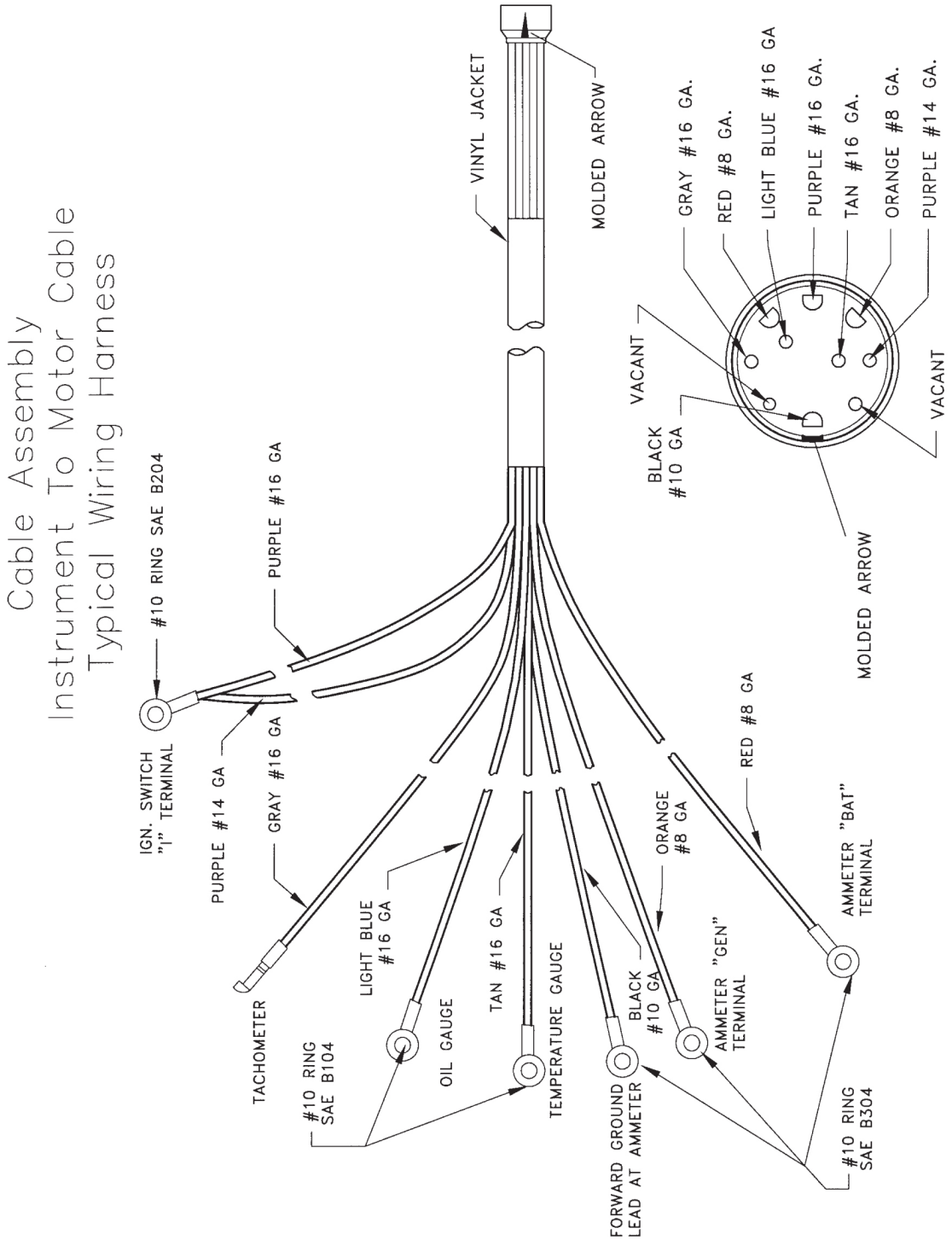
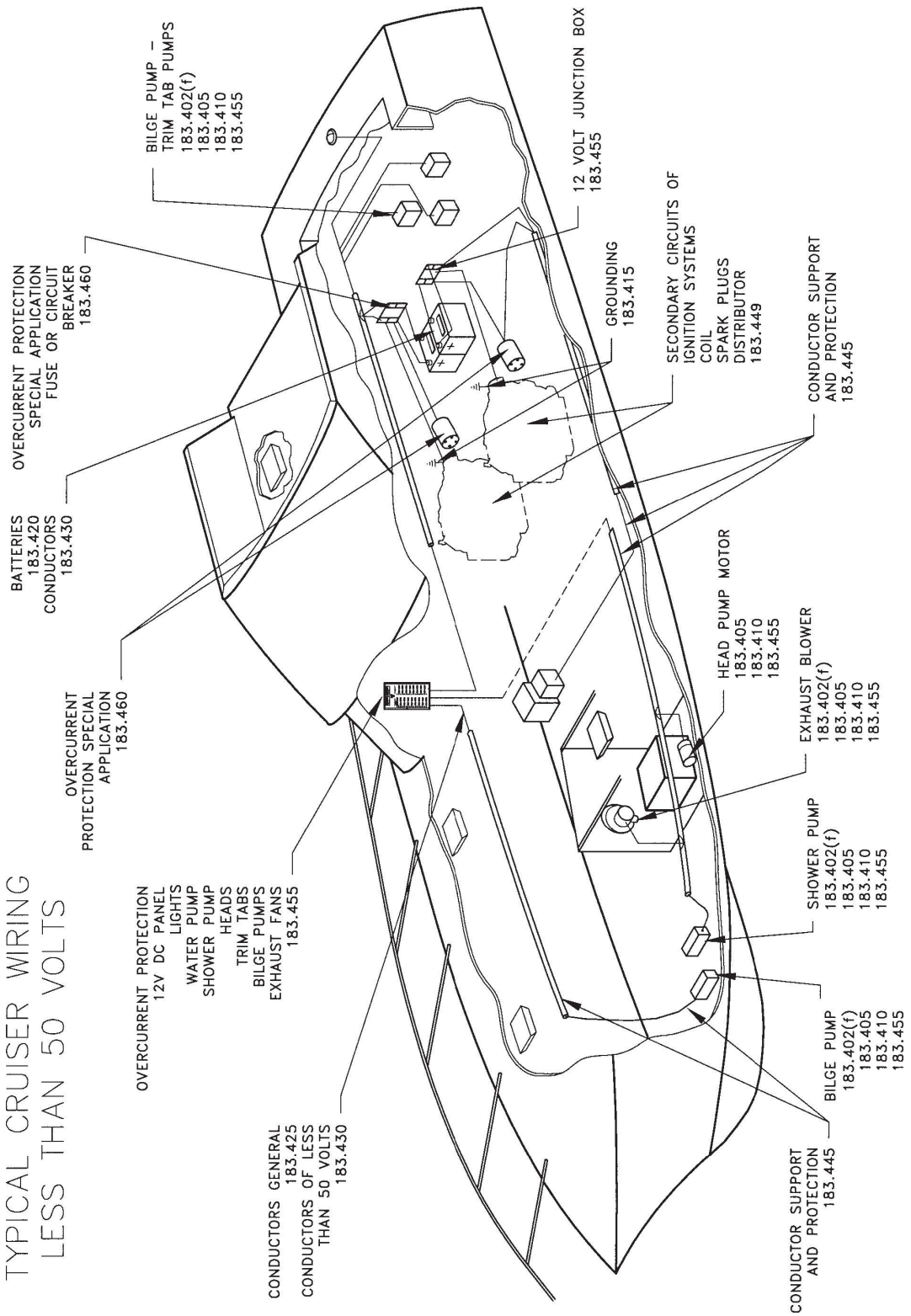

TYPICAL AUXILIARY SAILBOAT
12,24 OR 32V DC ELECTRONICS
VHF RADIO
SSB RADIO
GAS VAPOR DETECTOR
RDF
LORAN
183.425(g)
183.430(b)
183.435(c)
LIGHTNING GROUND CONDUCTORS
BONDING CONDUCTORS
BOAT GROUND CONNECTION
ENGINE COMPARTMENT
STARTER AND SOLENOID
ALTERNATOR
REGULATOR
DISTRIBUTOR
RESISTOR
IGNITION WIRES
BLOWER
BILGE PUMP
183.410
183.425
183.430
183.440
183.445
183.455
BATTERIES
183.420
BATTERY SWITCH
183.460
12,24 OR 32 V DC PANEL
NAVIGATION LIGHTS
ANCHOR LIGHT
INSTRUMENT LIGHTS
SPREADER LIGHTS
CABIN LIGHTS
BLOWER
BILGE PUMP
SHOWER PUMP
HEAD
FRESH WATER PUMP
HORN
BATTERY CHARGER
SPARES
183.455
AC PANEL
MAIN BREAKER
RECEPTACLES
CABIN LIGHTS
REFRIGERATOR
RANGE
BLOWERS
AIR CONDITIONER
SPARES
183.455
AC POWER INLET
REVERSE POLARITY ALARM
183.435
183.455
NAVIGATIONAL INSTRUMENTS
COMPASS
WIND INSTRUMENTS
KNOT METER
LOG
DEPTH SOUNDER
183.425(g)
183.430(b)
183.435(c)
ENGINE INSTRUMENT PANEL
STARTER-IGNITION SWITCH
TACHOMETER
TEMPERATURE GAUGE
OIL PRESSURE GAUGE
AMMETER OR VOLTMETER
FUEL GUAGE
ALARM INDICATORS
183.410
183.425
183.430
183.445

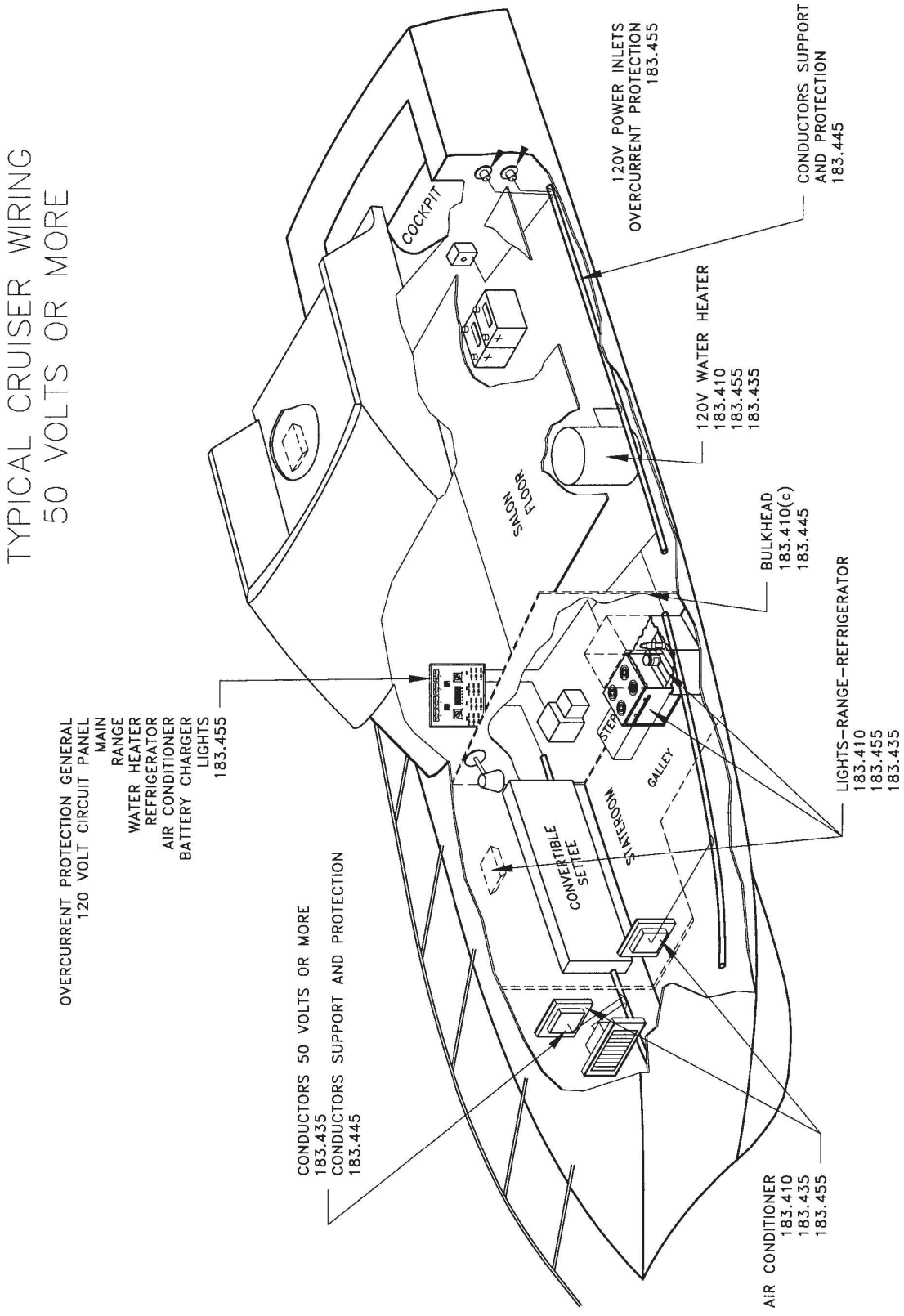
DIAGRAM 2 INBOARD AND STERNDRIVE RUNABOUT




Typical Instrument Wiring Assembly
Rear View of Panel
Device Code
B – Battery Post
I – Ignition Post
ST – Starter Post
S – Sender Post
G – Ground Post
Wiring Code
R – Red
Gy/R – Gray/Red Stripe
Gy – Gray
Br – Brown
O/W – Orange/White Stripe
P – Purple
BLA – Black
V/W – Violet/White Stripe
Lt Bl – Light Blue
Pk – Pink
T – Tan
Y/R – Yellow/Red Stripe
Y – Yellow
G/W – Green/White Stripe
Bl/W – Blue/White Stripe
Bl/O – Blue/Orange Stripe
G/O – Green/Orange Stripe
SWITCH
TO BOW LIGHT
TO STERN LIGHT
TO BILGE PUMP
TO BLOWER
TO HORN
FROM ENGINE
TILT SWITCH
TRIM SWITCH
HORN SWITCH
BLOWER SWITCH
BILGE PUMP SWITCH
LIGHT SWITCH
IGNITION FUSE
HORN FUSE
BLOWER FUSE
PUMP FUSE
LIGHT FUSE
FROM BATTERY
IGNITION SWITCH
TO NEUTRAL SAFETY
WATER TEMPERATURE
OIL PRESSURE
TACHOMETER
VOLT
FUEL
FROM FUEL TANK
FROM BOW LIGHT
FROM STERN LIGHT
FROM BILGE PUMP
FROM BLOWER
FROM HORN


Cable Assembly
Instrument To Motor Cable
Typical Wiring Harness
VINYL JACKET
MOLDED ARROW
GRAY #16 GA.
RED #8 GA.
LIGHT BLUE #16 GA
PURPLE #16 GA.
TAN #16 GA.
ORANGE #8 GA.
PURPLE #14 GA.
VACANT
BLACK #10 GA
VACANT
MOLDED ARROW
#10 RING SAE B204
PURPLE #16 GA
IGN. SWITCH "I" TERMINAL
PURPLE #14 GA
GRAY #16 GA
TACHOMETER
#10 RING SAE B104
LIGHT BLUE #16 GA
OIL GAUGE
TAN #16 GA
TEMPERATURE GAUGE
FORWARD GROUND LEAD AT AMMETER
BLACK #10 GA
ORANGE #8 GA
AMMETER "GEN" TERMINAL
RED #8 GA
AMMETER "BAT" TERMINAL
#10 RING SAE B304


TYPICAL CRUISER WIRING
LESS THAN 50 VOLTS
BILGE PUMP – TRIM TAB PUMPS 183.402(f) 183.405 183.410 183.455
12 VOLT JUNCTION BOX 183.455
OVERCURRENT PROTECTION SPECIAL APPLICATION FUSE OR CIRCUIT BREAKER 183.460
GROUNDING 183.415
SECONDARY CIRCUITS OF IGNITION SYSTEMS COIL SPARK PLUGS DISTRIBUTOR 183.449
CONDUCTOR SUPPORT AND PROTECTION 183.445
BATTERIES 183.420 CONDUCTORS 183.430
OVERCURRENT PROTECTION SPECIAL APPLICATION 183.460
HEAD PUMP MOTOR 183.405 183.410 183.455
EXHAUST BLOWER 183.402(f) 183.405 183.410 183.455
OVERCURRENT PROTECTION 12V DC PANEL LIGHTS WATER PUMP SHOWER PUMP HEADS TRIM TABS BILGE PUMPS EXHAUST FANS 183.455
SHOWER PUMP 183.402(f) 183.405 183.410 183.455
CONDUCTORS GENERAL 183.425
CONDUCTORS OF LESS THAN 50 VOLTS 183.430
BILGE PUMP 183.402(f) 183.405 183.410 183.455
CONDUCTOR SUPPORT AND PROTECTION 183.445


TYPICAL CRUISER WIRING
50 VOLTS OR MORE
OVERCURRENT PROTECTION GENERAL
120 VOLT CIRCUIT PANEL
MAIN
RANGE
WATER HEATER
REFRIGERATOR
AIR CONDITIONER
BATTERY CHARGER
LIGHTS
183.455
CONDUCTORS 50 VOLTS OR MORE
183.435
CONDUCTORS SUPPORT AND PROTECTION
183.445
AIR CONDITIONER
183.410
183.435
183.455
120V POWER INLETS
OVERCURRENT PROTECTION
183.455
CONDUCTORS SUPPORT
AND PROTECTION
183.445
120V WATER HEATER
183.410
183.455
183.435
BULKHEAD
183.410(c)
183.445
LIGHTS–RANGE–REFRIGERATOR
183.410
183.455
183.435
COCKPIT
SALON FLOOR
CONVERTIBLE SETTEE
STATEROOM
GALLEY
STEP

13.0 ENGINE CUT-OFF SWITCHES

The practice of installing engine cut-off switches has been a long-standing ABYC recommended standard. The installation of these switches on certain recreational boats is now a USCG requirement. The requirement is now law – but is not (yet) covered in the CFR.

> Per 46 USC 4312: As of December 4, 2019, new mechanically powered boats of less than 26 feet in length (and capable of static thrust of 115 pounds or more) are required to have an ABYC A-33 compliant engine cut-off switch installed.

"New" boats means those manufactured after the start date of December 4, 2019. That is taken to mean applicable boats with a hull identification number date of certification / model year of 'A020' and later.

"Mechanically powered" obviously means the usual inboard, sterndrive and outboard powered type boats – but, it also applies to diesel powered boats, auxiliary powered sailboats, and electric motor powered small boats.

"ABYC A-33 compliant" refers to ABYC standard "Emergency Engine/Propulsion Cut-Off Switches". A-33 does not include the boat length criterion; it just covers the system requirements for such a system 'if equipped'. The USCG applies this requirement to boats less than 26 feet in length. A-33 does not include a lower powering threshold; the USCG applies this requirement to a boat powering system with at least 115 pounds of static thrust. A typical electric trolling motor will not reach this limit, but new larger electric outboards will need to comply.

Typically, this system will consist of a lanyard attached to the operator and connected to a switch that will cut the engine in an emergency situation involving the ejection of the operator from the control station. Boats with multiple control stations require multiple cut-off switches.

The ABYC A-33 standard includes requirements for:

- Thermal conditioning, UV exposure, and mechanical testing prior to installation;
- Electrical connection at the engine;
- Watertight protection of components;
- Activation force;
- Means of rearming switch / restarting engine after emergency activation;
- Owner's manual requirements.

APPENDIX 1. ELECTRICAL SYSTEMS REFERENCES & RESOURCES

The following standards are referenced in the regulations:

IEEE 45	"Recommended Practice for Electrical Installations on Shipboard Design" - section 183.435.
NFPA 70	"National Electric Code" - section 183.435.
SAE J378	"Main Propulsion System Wiring" - section 183.430.
SAE J1127	"Low Voltage Battery Cable" - section 183.430.
SAE J1128	"Low Voltage Primary Cable" - section 183.430
UL 1426	"Standard for Electrical Cables for Boats" - section 183.430.
SAE J1191	"High Tension Ignition Cable Assemblies – Marine" - section 183.440.

The following standards are referenced in this compliance guideline:

SAE J1171	"External Ignition Protection of Marine Electrical Devices" - section 183.410.
SAE J1191	"High Tension Cable Assemblies – Marine" - section 183.440.
UL 1426	"Standard for Electrical Cables for Boats" - section 183.430.
UL 1500	"Standard for Ignition-Protection Test for Marine Products" - section 183.410.
NFPA 70	"National Electric Code" - sections 183.430 and 183.435.
ABYC A-33	"Emergency Engine/Propulsion Cut-Off Devices" – not covered in CFR

SAE standards are available from the Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096, ph724-776-4841, www.sae.org

UL standards are available from Underwriters Laboratories, P.O. Box 13995, Research Triangle Park, NC 27709-3995, ph919-549-1400, www.ul.com

IEEE standards are available from the Institute of Electrical Engineers, 445 Hoes Lane, Piscataway, NJ 08854-4141, ph 732-983-0060, www.ieee.org.

NAPA standards are available from the National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471, ph 800-344-3555, www.nfpa.org.

ABYC standards are available from The American Boat & Yacht Council, 613 Third St, Suite 10, Annapolis, MD 21403, (410)990-4460, abyc.org.

APPENDIX 2. 33 CFR 183 SUBPART I – ELECTRICAL SYSTEMS

§ 183.401 Purpose, applicability, and effective dates.

(a) This subpart applies to all boats that have gasoline engines, except outboard engines, for electrical generation, mechanical power, or propulsion.

§ 183.402 Definitions.

As used in this subpart –

AWG means American Wire Gauge.

Electrical component means electrical equipment such as, but not limited to, conductors, solenoids, motors, generators, alternators, distributors, resistors, appliances and electrical control devices.

Pigtails means external power conductors or wires that are part of electrical components and appliances, such as bilge pumps, blowers, lamps, switches, solenoids, and fuses.

Sheath means a material used as a continuous protective covering, such as electrical tape, molded rubber, molded plastic, or flexible tubing, around one or more insulated conductors.

§ 183.405 General.

Each electrical component on a boat to which this subpart applies must meet the requirements of this subpart unless the component is part of an outboard engine or part of portable equipment.

§ 183.410 Ignition protection.

(a) Each electrical component must not ignite a propane gas and air mixture that is 4.25 to 5.25 percent propane gas by volume surrounding the electrical component when it is operated at each of its manufacturer rated voltages and current loadings, unless it is isolated from gasoline fuel sources, such as engines, and valves, connections, or other fittings in vent lines, fill lines, distribution lines or on fuel tanks, in accordance with paragraph (b) of this section.

(b) An electrical component is isolated from a gasoline fuel source if:

- **(1)** A bulkhead that meets the requirements of paragraph (c) of this section is between the electrical component and the gasoline fuel source;
- **(2)** The electrical component is:
  - **(i)** Lower than the gasoline fuel source and a means is provided to prevent fuel and fuel vapors that may leak from the gasoline fuel source from becoming exposed to the electrical component; or
  - **(ii)** Higher than the gasoline fuel source and a deck or other enclosure is between it and the gasoline fuel source; or
- **(3)** The space between the electrical component and the gasoline fuel source is at least two feet and the space is open to the atmosphere.

(c) Each bulkhead required by paragraph (b)(1) of this section must:

(1) Separate the electrical component from the gasoline fuel source and extend both vertically and horizontally the distance of the open space between the fuel source and the ignition source;

(2) Resist a water level that is 12 inches high or one-third of the maximum height of the bulkhead, whichever is less, without seepage of more than one-quarter fluid ounce of fresh water per hour; and

(3) Have no opening located higher than 12 inches or one-third the maximum height of the bulkhead, whichever is less, unless the opening is used for the passage of conductors, piping, ventilation ducts, mechanical equipment, and similar items, or doors, hatches, and access panels, and the maximum annular space around each item or door, hatch or access panel must not be more than one-quarter inch.

§ 183.415 Grounding.

If a boat has more than one gasoline engine, grounded cranking motor circuits must be connected to each other by a common conductor circuit that can carry the starting current of each of the grounded cranking motor circuits.

§ 183.420 Batteries.

(a) Each installed battery must not move more than one inch in any direction when a pulling force of 90 pounds or twice the battery weight, whichever is less, is applied through the center of gravity of the battery as follows:

(1) Vertically for a duration of one minute.

(2) Horizontally and parallel to the boat's center line for a duration of one minute fore and one minute aft.

(3) Horizontally and perpendicular to the boat's center line for a duration of one minute to starboard and one minute to port.

(b) Each battery must be installed so that metallic objects cannot come in contact with the ungrounded battery terminals.

(c) Each metallic fuel line and fuel system component within 12 inches and above the horizontal plane of the battery top surface as installed must be shielded with dielectric material.

(d) Each battery must not be directly above or below a fuel tank, fuel filter, or fitting in a fuel line.

(e) A vent system or other means must be provided to permit the discharge from the boat of hydrogen gas released by the battery.

(f) [Reserved]

(g) Each battery terminal connector must not depend on spring tension for its mechanical connection to the terminal.

§ 183.425 Conductors: General.

(a) Each conductor must be insulated, stranded copper.

(b) Except for intermittent surges each conductor must not carry a current greater than that specified in Table 5 for the conductor's gauge and temperature rating.

(c) For conductors in engine spaces, amperages must be corrected by the appropriate correction factor in note 1 of Table 5.

(d) Each conductor in a multiconductor sheath must be at least a No. 18 AWG conductor.

(e) Each conductor installed separately must be at least a No. 16 AWG conductor.

(f) Each No. 18 AWG conductor in a multiconductor sheath may not extend out of the sheath more than 30 inches.

(g) This section does not apply to communications systems; electronic navigation equipment; electronic circuits having a current flow of less than one ampere; conductors which are totally inside an equipment housing; resistance conductors that control circuit amperage; high voltage secondary conductors and terminations that are in ignition systems; pigtails of less than seven inches of exposed length and cranking motor conductors.

TABLE 5 Allowable Amperage of Conductors

CONDUCTOR SIZE (AWG)	Temperature rating of conductor insulation						
	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)
18	10	10	15	20	20	25	25
16	15	15	20	25	25	30	35
14	20	20	25	30	35	40	45
12	25	25	35	40	45	50	55
10	40	40	50	55	60	70	70
8	55	65	70	70	80	90	100
6	80	95	100	100	120	125	135
4	105	125	130	135	160	170	180
3	120	145	150	155	180	195	210
2	140	170	175	180	210	225	240
1	165	195	210	210	245	265	280
0	195	230	245	245	285	305	325
00	225	265	285	285	330	355	370
000	260	310	330	330	385	410	430
0000	300	360	385	385	445	475	510

NOTES

1. See the following table:	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)
Temperature rating of conductor	0.58	0.75	0.78	0.82	0.85	0.89	1.00

2. See the following table:	
Number of current carrying conductors:	Correction Factor
3	0.70
4 to 6	0.60
7 to 24	0.50
25 and above	0.40

§ 183.430 Conductors in circuits of less than 50 volts.

(a) Each conductor in a circuit that has a nominal voltage of less than 50 volts must:

(1) Meet the requirements of § 183.435; or

(2) Meet:

(i) The insulating material temperature rating requirements of SAE Standard J378; and

(ii) SAE Standard J1127, or SAE Standard 1128.

(b) This section does not apply to communication systems; electronic navigation equipment; resistance conductors that control circuit amperage; and pigtails of less than seven inches of exposed length.

§ 183.435 Conductors in circuits of 50 volts or more.

(a) Each conductor in a circuit that has a nominal voltage of 50 volts or more must be:

(1) A conductor that has insulation listed and classified moisture resistant and flame retardant in Article 310, NFPA No. 70, National Electric Code;

(2) A flexible cord type SO, STO, ST, SJO, SJT, or SJTO listed in Article 400, NFPA No. 70, National Electric Code;

(3) A conductor that meets IEEE Standard 45.

(4) A conductor that meets UL Standard 1426.

(b) Where the nominal circuit voltage of each of three or more current carrying conductors in a duct, bundle, or cable is 50 volts or more, the amperages of each of those conductors must not exceed the value in table 5 multiplied by the correction factor in note 2 to Table 5 for the number of conductors that carry 50 volts or more.

(c) This section does not apply to communication systems; electronic navigation equipment; resistance conductors that control circuit amperage; conductors in secondary circuits of ignition systems; and pigtails of less than seven inches of exposed length.

§ 183.440 Secondary circuits of ignition systems.

(a) Each conductor in a secondary circuit of an ignition system must meet SAE Standard J557.

(b) The connection of each ignition conductor to a spark plug, coil, or distributor must have a tight fitting cap, boot, or nipple.

§ 183.445 Conductors: Protection.

(a) Each conductor or group of conductors that passes through a bulkhead, structural member, junction box, or other rigid surface must be protected from abrasion.

(b) Each ungrounded terminal or stud that is continuously energized must meet § 183.455 or must have a boot, nipple, cap, cover, or shield that prevents accidental short-circuiting at the terminals or studs.

§ 183.455 Overcurrent protection: General.

(a) Each ungrounded current-carrying conductor must be protected by a manually reset, tripfree circuit

breaker or fuse.

(b) A manually reset, trip-free circuit breaker or fuse must be placed at the source of power for each circuit or conductor except:

(1) If it is physically impractical to place the circuit breaker or fuse at the source of power, it may be placed within seven inches of the source of power for each circuit or conductor measured along the conductor.

(2) If it is physically impractical to place the circuit breaker or fuse at or within seven inches of the source of power, it may be placed within 40 inches of the source of power for each circuit or conductor, measured along the conductor, if the conductor is contained throughout its entire distance between the source of power and the required circuit breaker or fuse in a sheath or enclosure such as a junction box, control box, or enclosed panel.

(c) The current rating of each circuit breaker or fuse must not exceed:

(1) For circuits of less than 50 volts, 150% of the value of the amperage in Table 5 for the conductor size it is protecting; and

(2) For circuits of 50 volts or more, the value of the amperage in Table 5 for the conductor size it is protecting. If this value does not correspond to a standard size or rated circuit breaker or fuse the next larger size or rated circuit breaker or fuse may be used if it does not exceed 150% of the allowed current capacity of the conductor.

(d) The voltage rating of each circuit breaker or fuse must not be less than the nominal circuit voltage of the circuit it is protecting.

(e) This section does not apply to resistance conductors that control circuit amperage; conductors in secondary circuits of ignition systems; pigtails of less than seven inches of exposed length; and power supply conductors in cranking motor circuits.

§ 183.460 Overcurrent protection: Special applications.

(a) Each ungrounded output conductor from a storage battery must have a manually reset, trip-free circuit breaker or fuse, unless the output conductor is in the main power feed circuit from the battery to an engine cranking motor. The circuit breaker or fuse must be within 72 inches of the battery measured along the conductor, unless, for boats built prior to August 1, 1985, the circuit has a switch that disconnects the battery.

(b) Each ungrounded output conductor from an alternator or generator, except for self-limiting alternators or generators, must have a circuit breaker or fuse that has a current rating that does not exceed 120 percent of the maximum rated current of the alternator or generator at 60 °C.