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Document Name: ABYC E-09: Direct Current (DC) Electrical Systems on Boats

CFR Section(s): 46 CFR 183.340(b)(4)

Standards Body: American Boat and Yacht Council

APPROVED

Official Incorporator:

THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

E-9 DIRECT CURRENT (DC) ELECTRICAL SYSTEMS ON BOATS

Based on ABYC's assessment of the state of existing technology and the problems associated with achieving the requirements of this standard, ABYC recommends compliance with this standard by August 1, 1991.

E-9.1. PURPOSE

These recommended practices and engineering standards establish the requirements for the design and installation of direct current (DC) electrical systems on boats.

E-9.2. SCOPE

These recommended practices and engineering standards apply to direct current (DC) electrical systems on boats which operate at potentials of 50 volts or less.

EXCEPTION: Any wire permanently attached to an outboard engine and extending not more than 72 inches from the outboard engine.

E-9.3. DEFINITIONS

a. *Battery Cold Cranking Rating* - The discharge load in amperes which a battery at 0° F(-17.8° C) can deliver for 30 seconds and maintain a voltage of 1.2 volts per cell or higher.

b. *Battery Reserve Capacity* - The number of minutes a new fully charged battery at 80° F(26.7° C) can be discharged at 25 amperes and maintain a voltage of 1.75 volts or higher per cell (10.5 volts for a 12 volt battery or 5.25 volts for a 6 volt battery).

c. *DC Grounded Conductor* - A current-carrying conductor connected to the side of the source which is intentionally maintained at boat ground potential.

d. *DC Grounding Conductor* - A normally non-current-carrying conductor used to connect metallic non-current-carrying parts of direct current devices to the Engine Negative Terminal or its bus for the purpose of minimizing stray current corrosion.

e. *Double Insulation System* - An insulation system comprised of basic insulation and supplementary insulation, with the two insulations physically separated and so arranged that they are not simultaneously subjected to the same deteriorating influences (temperature, contaminants, and the like) to the same degree.

f. *Engine Negative Terminal* - The point on the engine at which the negative battery cable is connected.

g. *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.

h. *Ignition Protection* - The design and construction of a device such that under design operating conditions:

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(E-9.3.h.)

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

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

NOTES:

1. *It is not the intention to require such devices to be "explosionproof" as that term is defined in the National Electrical Code of the NFPA pertaining to shore systems, or 46 CFR 111.105-9, "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.*

3. *It is not the intention to require such devices to be "intrinsically safe" per Article 504 of the National Electrical Code of the NFPA or 46 CFR 111.80-5(a)(3) "Subchapter J-Electrical Engineering".*

4. *Devices that are "intrinsically safe" are considered to be ignition protected.*

5. *Test standards to determine ignition protection include SAE J1171 "External Ignition Protection of Marine Electrical Devices" and UL 1500 "Ignition Protection Test for Marine Products".*

i. *Overcurrent Protection Device* - A device, such as a fuse or circuit breaker, designed to interrupt the circuit when the current flow exceeds a predetermined value.

j. *Panelboard* - An assembly of devices for the purpose of controlling and/or distributing power on a boat. It may include devices such as circuit breakers, fuses, switches, instruments and indicators. Panelboards are intended to be installed in enclosures and shall be accessible from the front or the rear.

k. *Pigtails* - External conductors that originate within an electrical component or appliance installed by their manufacturer.

l. *Polarized System* - A system in which the grounded (negative) and ungrounded (positive) conductors are connected in the same relation to terminals or leads on devices in the circuit.

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(E-9.3.)

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

n. *Switchboard* - An assembly of devices for the purpose of controlling and/or distributing power on a boat. It may include devices such as circuit breakers, fuses, switches, instruments and indicators. They are generally accessible from the rear as well as from the front and are not intended to be installed in cabinets.

o. *Trip-Free Circuit Breaker* - A thermal and/or magnetically operated overcurrent protection device, designed so that the resetting means cannot be manually held in to over-ride the current-interrupting mechanism.

p. *Weatherproof* - Constructed or protected so that exposure to the weather will not interfere with successful operation.

NOTE: *For the purpose of this standard as applied to marine use, weatherproof implies resistance to rain, spray and splash.*

q. *Watertight* - So constructed that water will not enter the enclosure under test conditions specified in NEMA standard 250.

E-9.4. REQUIREMENTS - IN GENERAL

a. *Two-Wire System* - All direct current electrical distribution systems shall be of the two-wire type. (See Figures 1 and 2 and ABYC E-9.16.a.)

EXCEPTION: Engine mounted equipment.

b. *Bonding and DC Grounding Systems* - A metallic hull or the bonding and DC grounding systems shall not be used as a return conductor. (See Figures 1 and 2 and ABYC E-9.20.)

c. *Grounded Systems* - If one side of a two-wire direct current system is connected to ground, it shall be the negative side and polarized as defined in ABYC E-9.3.l.

d. *Multiple Engine Installation* - If a boat has more than one engine with a grounded cranking motor,(includes auxiliary generator engine), the engines shall be connected to each other by a common conductor that can carry the cranking motor current of each of the grounded cranking motor circuits. Outboard engines shall be connected at the battery negatives.

e. *Crossover (Parallel) Cranking Motor Circuits* - In multiple inboard engine installations (includes auxiliary generator) with cross-over (parallel) cranking motor systems, the engines shall be connected together with a cable large enough to carry the cranking motor current. This cable and its terminations shall be in addition to and independent of any other electrical connections to the engines including those required in ABYC E-9.4.d.

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(E-9.4)

EXCEPTIONS: 1. Installations using ungrounded DC Electrical Systems.

2. Outboard Engines.

f. A paralleling switch may be either of the maintained contact or momentary contact type. The paralleling switch shall be capable of carrying the largest cranking motor current.

g. *Power Distribution System Negative Connections* -

(1) The negative terminal of the battery and the negative side of the electrical power distribution system shall be connected to the engine negative terminal or its bus. On boats with outboard motors, the load return lines shall be connected to the battery negative terminal or its bus, unless specific provision is made by the outboard motor manufacturer for connection to the engine negative terminal.

(2) If an accessory negative bus, with provision for additional circuits, is used for the connection of accessories, the ampacity of this bus and the conductor connected to the engine negative terminal or the DC main negative bus shall be at least equal to the ampacity of the feeder(s) to the panelboard(s) supplying the connected accessories. (See Figures 1 and 2.)

(3) If the electrical power distribution system is to be connected to ground, the connection shall be made only from the engine negative terminal, or its bus, to the DC grounding bus. This connection shall be used only as a means of maintaining the negative side of the circuit at ground potential and is not to carry current under normal operating conditions.

h. *Continuously Energized Parts* - Except for circuits provided with overcurrent protection in accordance with ABYC E-9.11. continuously energized parts, such as positive battery terminals and both ends of all wires connected thereto, shall be protected to prevent accidental short circuits.

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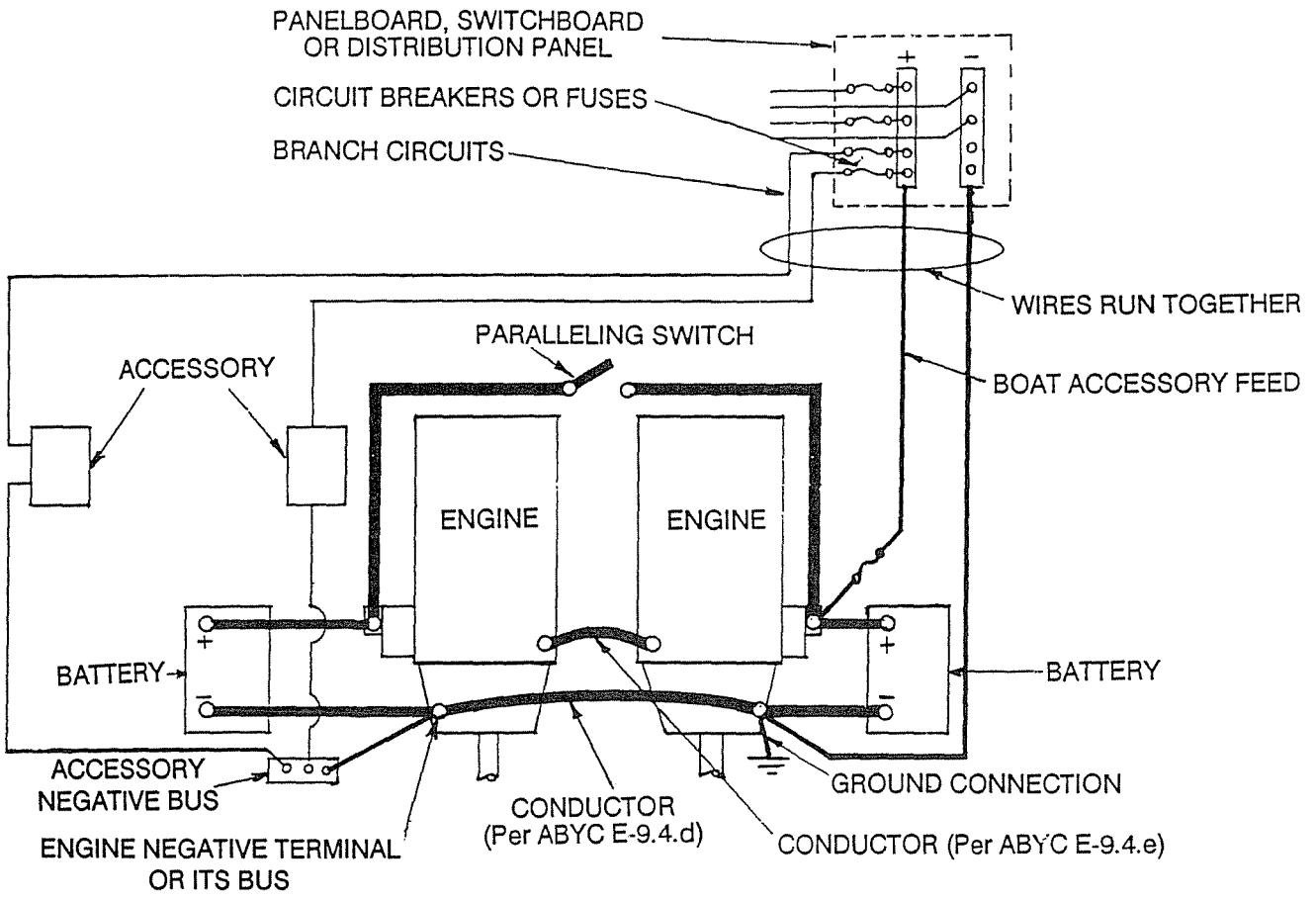
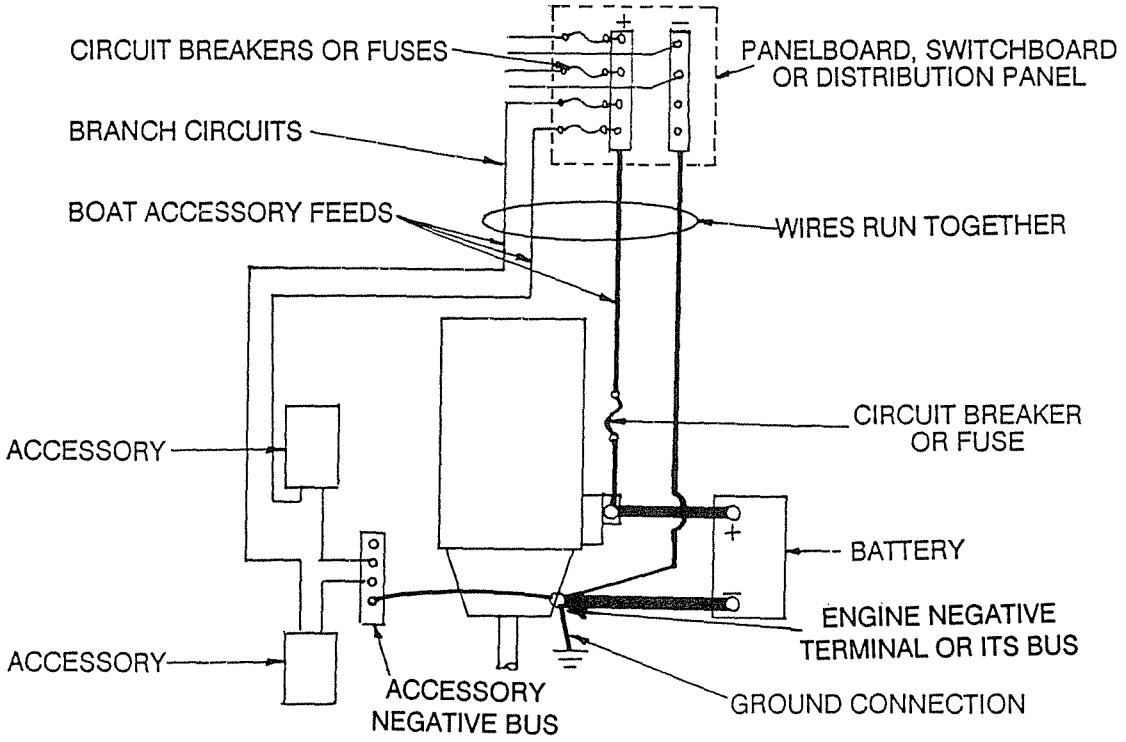
FIGURE 1 - TYPICAL INBOARD DC SYSTEMS





NOTE: *For location of overcurrent protection devices, see ABYC E-9.10 & 11.*

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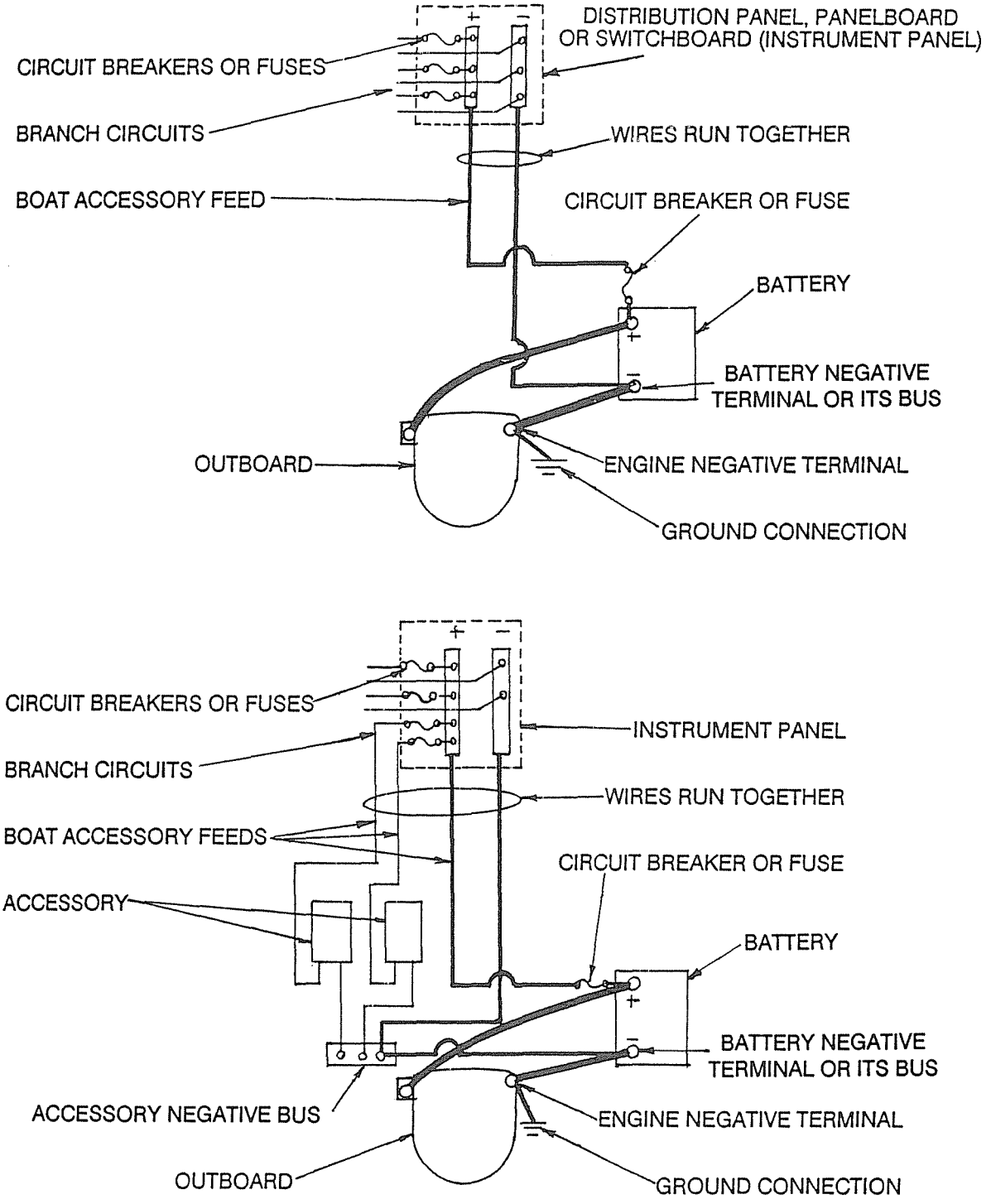
FIGURE 2 - TYPICAL OUTBOARD DC SYSTEMS



NOTE: *For location of overcurrent protection devices, see ABYC E-9.10 & 11.*

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E-9.5. MARKING

a. *Marking* - Switches and electrical controls shall be marked to indicate their usage.

EXCEPTION: A switch or electrical control whose purpose is obvious and whose mistaken operation will not cause a hazardous condition.

b. *Marking of Equipment* - Electrical equipment, except a part of an identified assembly, such as an engine, shall be marked or identified to indicate:

(1) Manufacturer.

(2) Product identification.

(3) DC electrical rating in volts. Rated amperage or wattage of electrical equipment shall be available and may be marked on the device.

(4) The terminal polarity or identification, if necessary to operation.

(5) Ignition-protected if applicable. This is to be identified by a marking such as "SAE J1171-Marine", "UL Marine-Ignition Protected", or "Ignition Protected".

E-9.6. AMBIENT TEMPERATURE

Maximum ambient temperature of machinery spaces is considered to be 50°C (122°F) and of all other spaces is considered to be 30°C (86°F).

E-9.7. IGNITION SOURCE

a. Potential sources of ignition located in gasoline machinery spaces, and in gasoline fuel tank spaces or spaces containing joints, fittings or other connections between components of the gasoline fuel system shall be ignition protected, unless the electrical component is isolated from a gasoline fuel source as described in ABYC E-9.7.c. (See Figures 3 through 10.)

EXCEPTION: Boats using diesel fuel as the only fuel source.

b. If LPG or CNG is provided on the boat, unattended potential sources of ignition below the main deck shall be ignition protected.

EXCEPTION: The ignition protection requirements will not be extended beyond those in ABYC E-9.7.a. if the following conditions are met:

1. Only one gas appliance is provided on the boat.

2. The LPG or CNG tank connections and regulators are outside the confines of the hull or located in an enclosure that is vaportight to the hull interior and is vented overboard. Additionally all other aspects of the installation shall comply with ABYC A-1, "LPG Gas Systems" or ABYC A-22, "CNG Gas Systems".

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(E-9.7.b.)

3. The gas supply at the tank can be shut off by means of an automatic or manually operated control that is an integral part of, or is located in the vicinity of, the gas appliance. Manual controls shall have a warning light or warning device to indicate when the gas supply valve is open.

c. An electrical component is isolated from a gasoline fuel source if:

(1) A bulkhead that meets the requirements of ABYC E-9.7.d. (see Figures 9 and 10) is between the electrical component and the gasoline fuel source, or

(2) The electrical component is:

(a) Lower than the gasoline fuel source and a means is provided to prevent gasoline fuel and gasoline fuel vapors, that may leak from the gasoline fuel sources, from becoming exposed to the electrical component, or

(b) Higher than the gasoline fuel source and a deck or other enclosure is between it and the gasoline fuel source, or

(3) The distance between the electrical component and the fuel source is at least two feet and the space is open to the atmosphere. (See Figure 8.)

d. Each bulkhead required by ABYC E-9.7.c.(1) (see Figures 9 and 10) shall:

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

(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 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 distance around each item or door, hatch or access panel shall not be more than one-quarter inch.

NOTE: For additional information on the sealing of bulkheads see ABYC T-22 "Educational Information About Carbon Monoxide".

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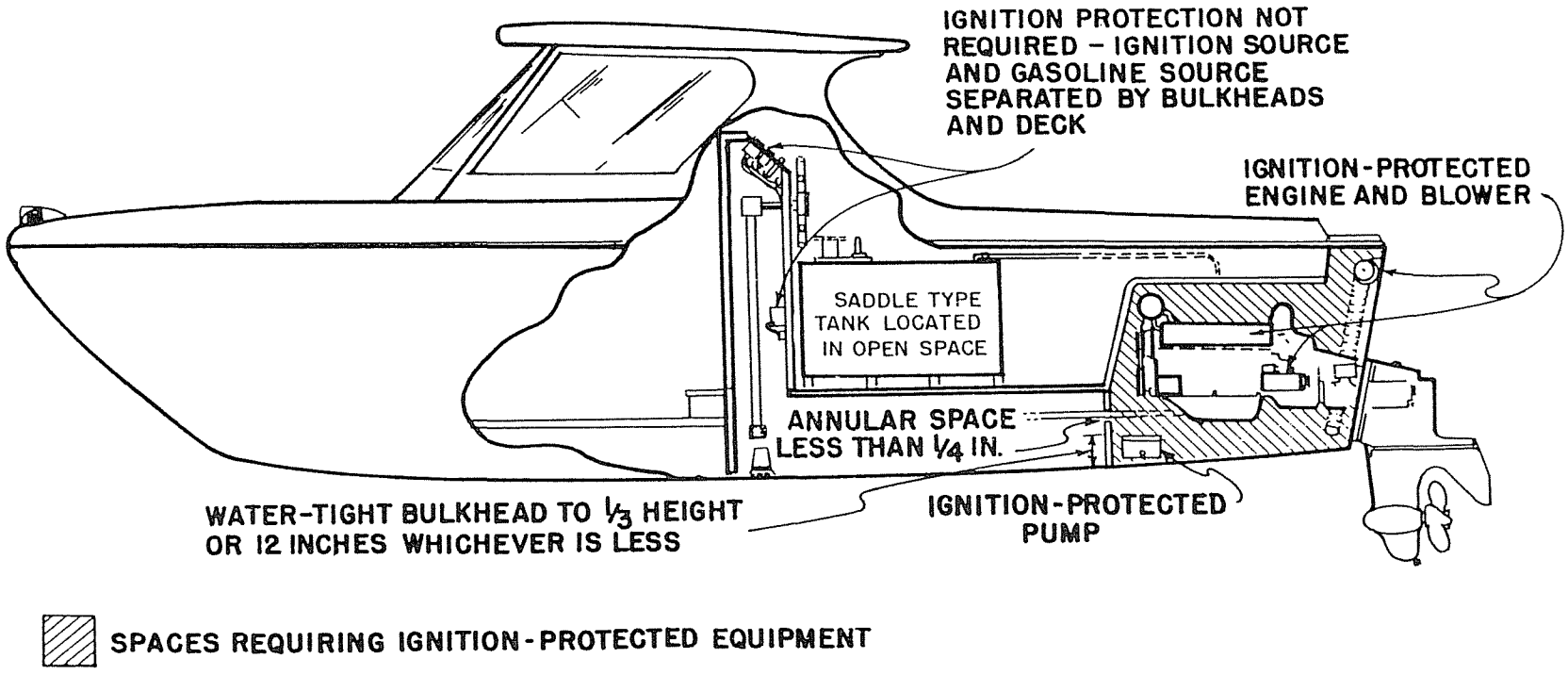
FIGURE 3 - ISOLATION OF ELECTRICAL COMPONENTS



NOTE : This Figure is taken from the USCG Electrical System Compliance Guideline.

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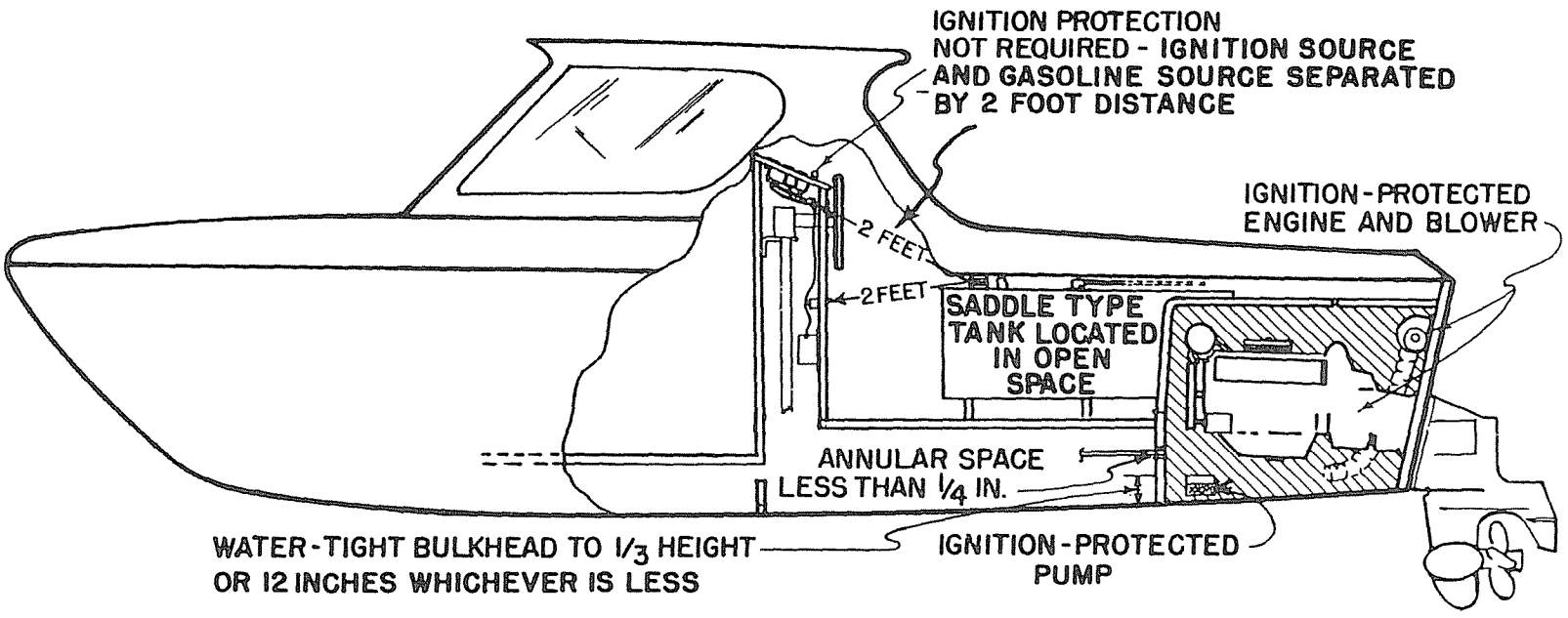
FIGURE 4 - ISOLATION OF ELECTRICAL COMPONENTS



NOTE : This Figure is taken from the USCG Electrical System Compliance Guideline.

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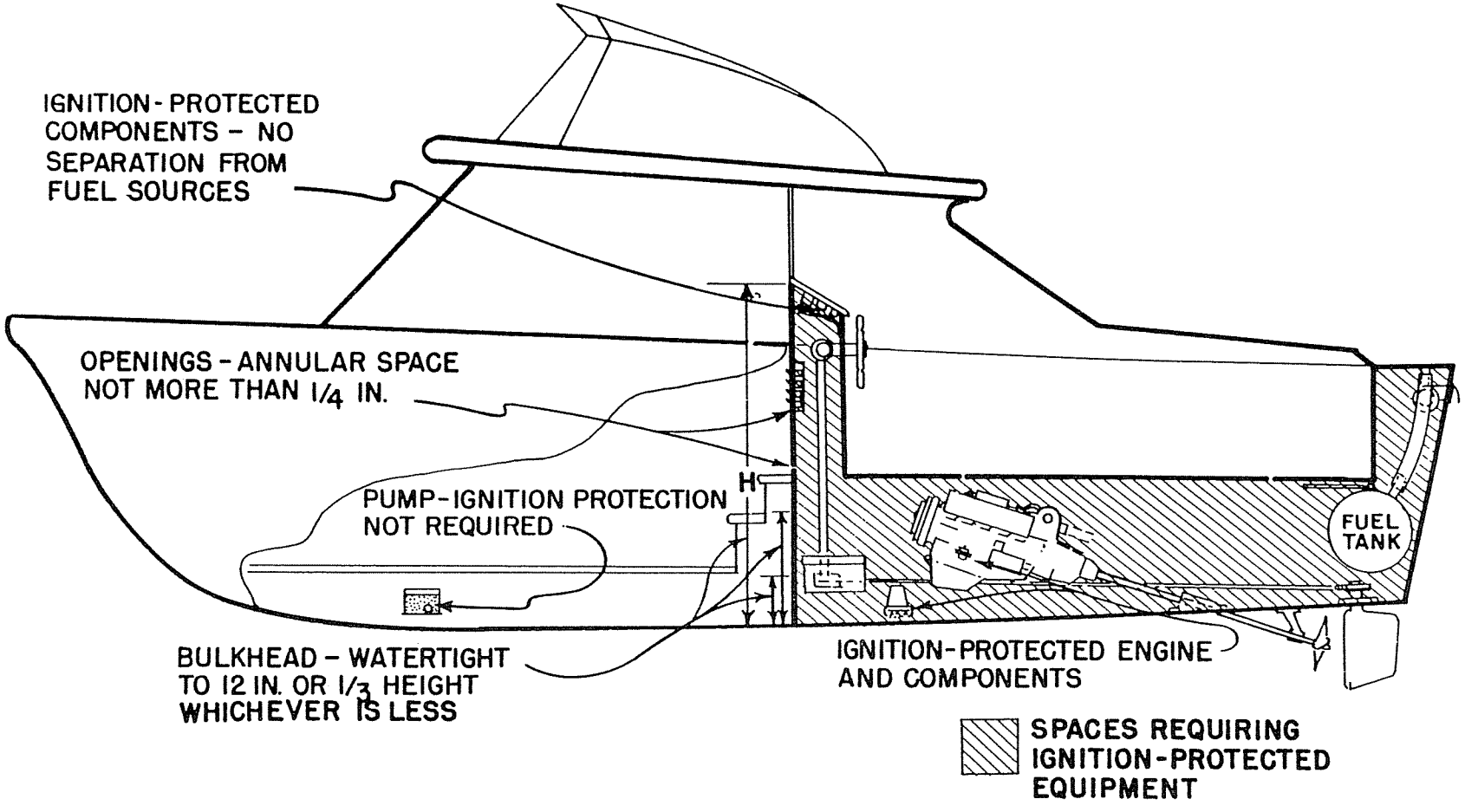
FIGURE 5 - ISOLATION OF ELECTRICAL COMPONENTS



NOTE : This Figure is taken from the USCG Electrical System Compliance Guideline.

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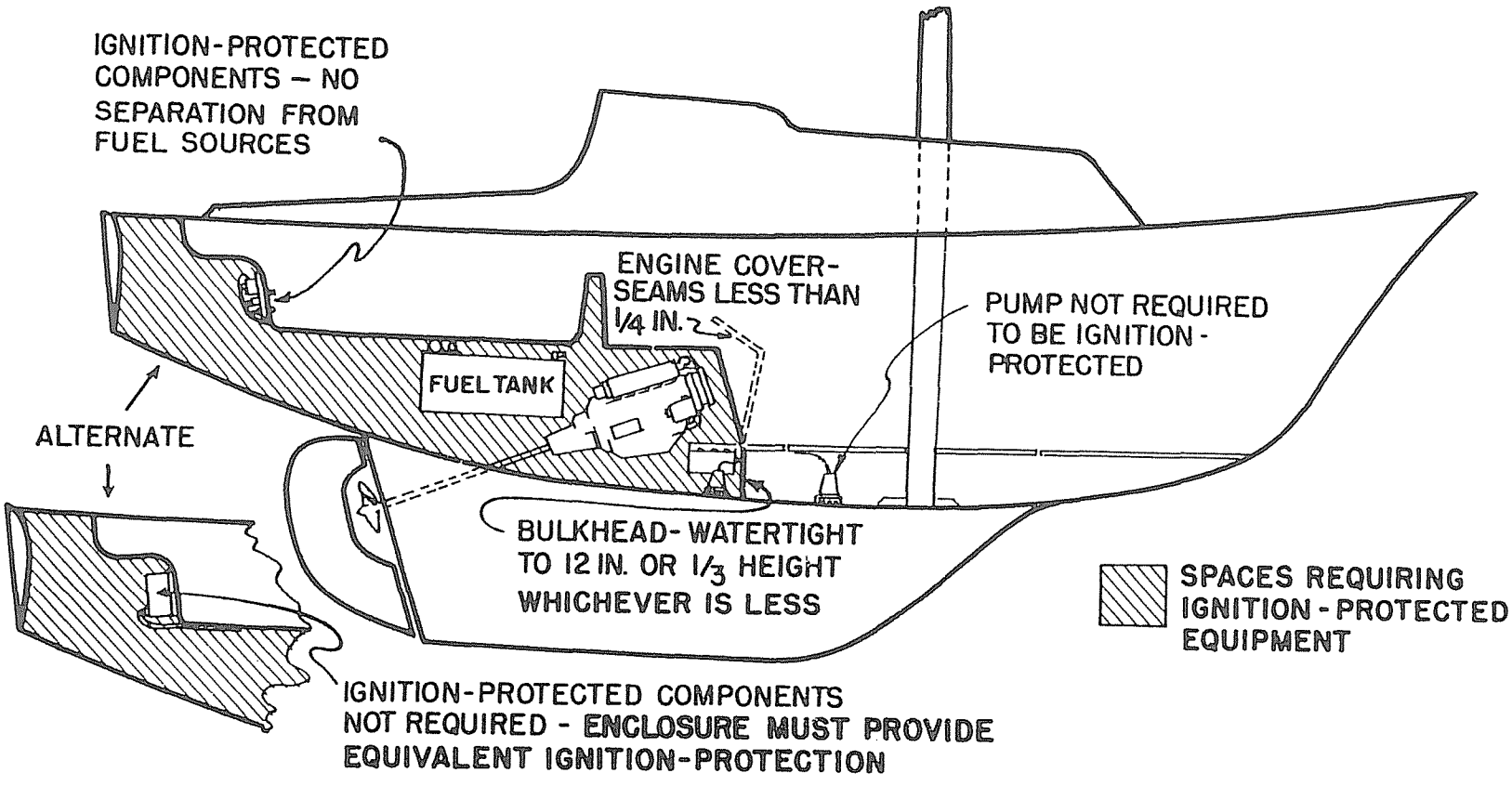
FIGURE 6 - ISOLATION OF ELECTRICAL COMPONENTS



NOTE : This Figure is taken from the USCG Electrical System Compliance Guideline.

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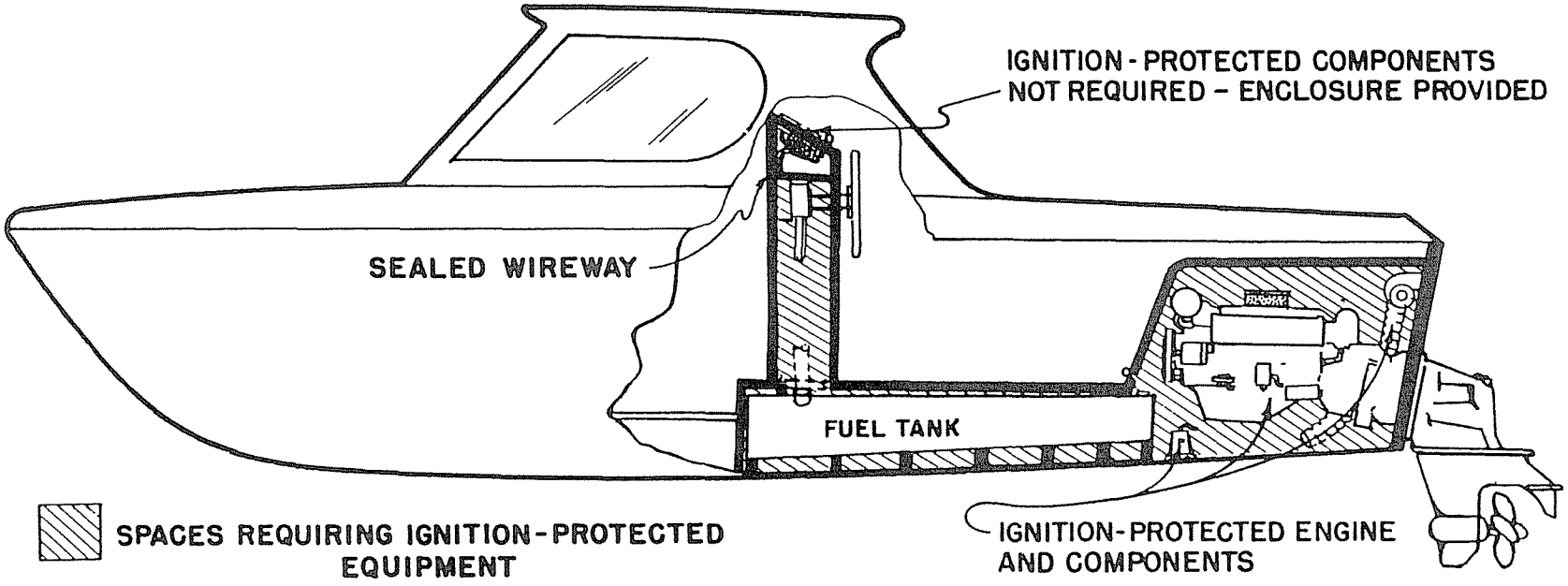
FIGURE 7 - ISOLATION OF ELECTRICAL COMPONENTS



NOTE: This Figure is taken from the USCG Electrical System Compliance Guideline.

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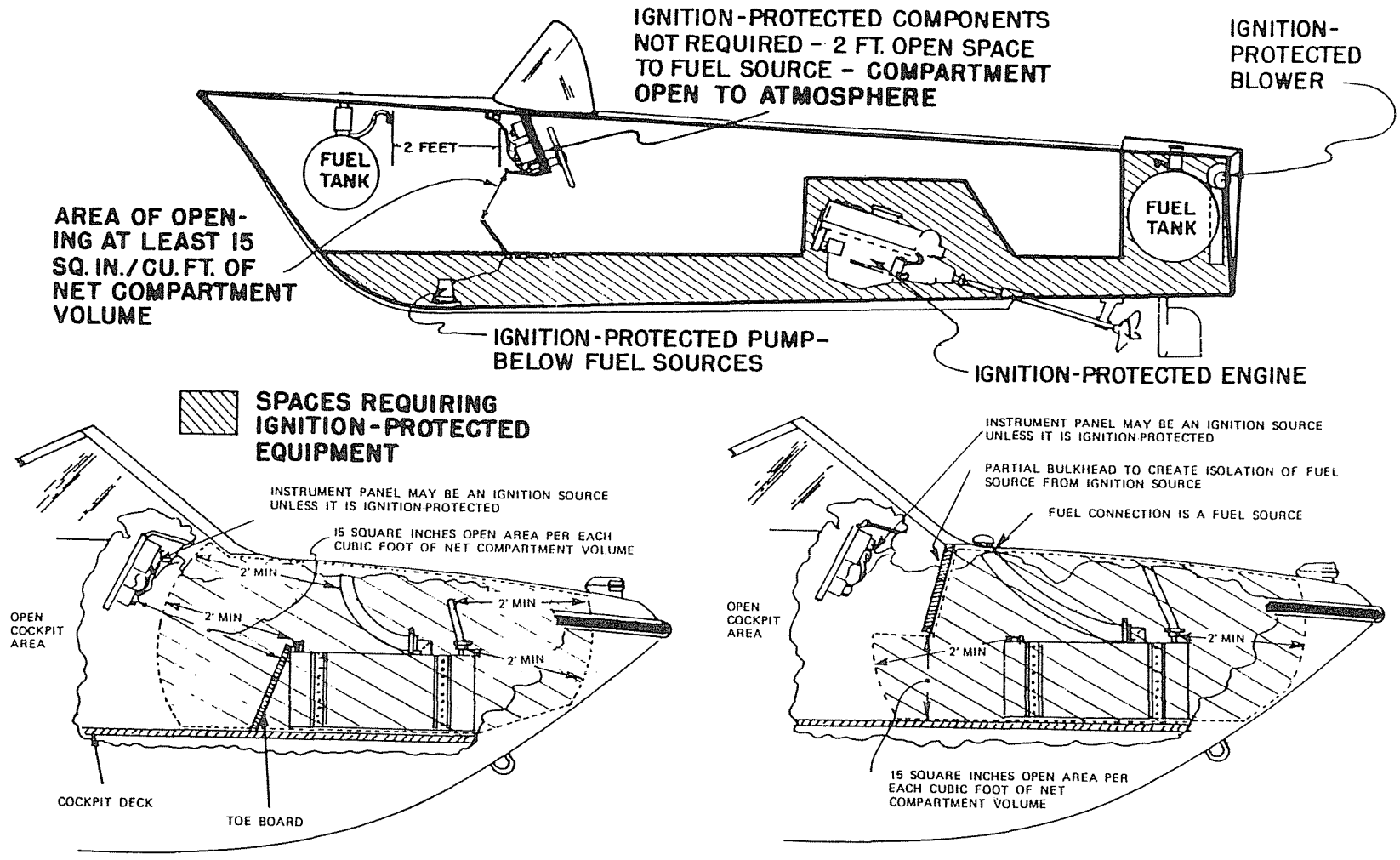
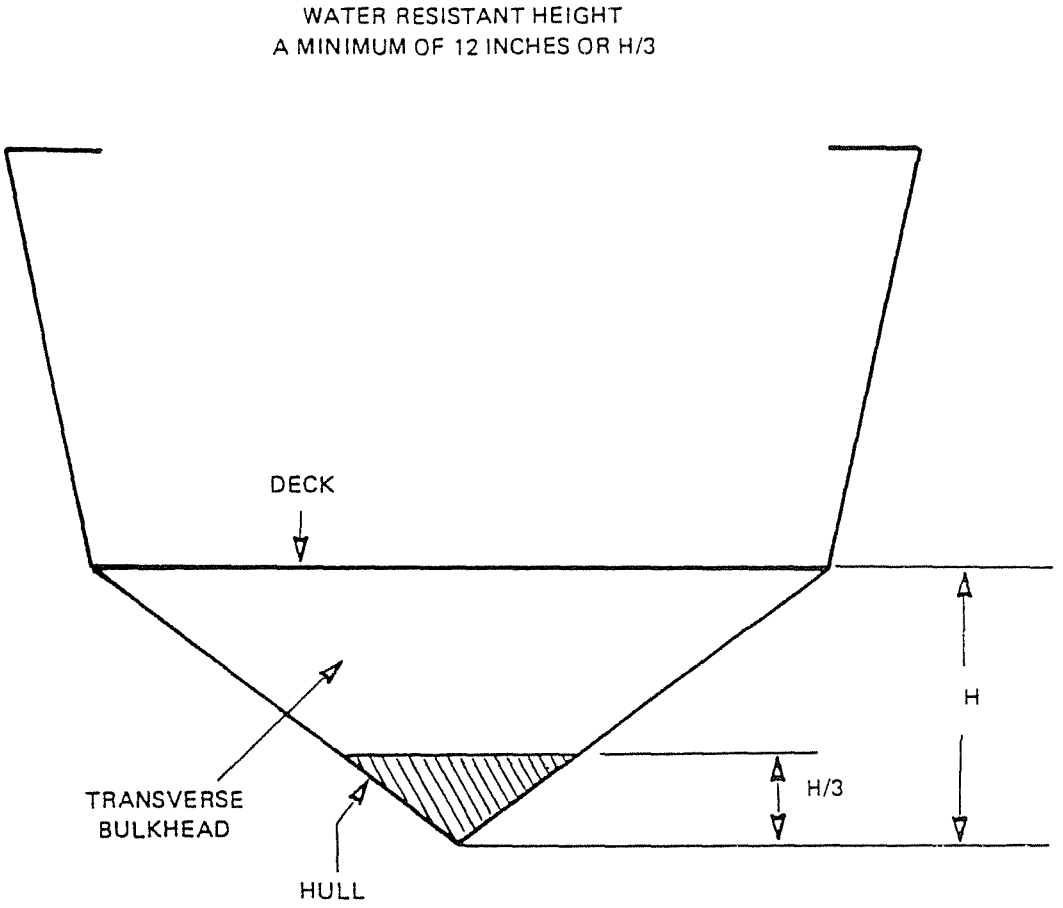
FIGURE 8 - ISOLATION OF ELECTRICAL COMPONENTS



NOTE : This Figure is taken from the USCG Electrical System Compliance Guideline.

FIGURE 9 - ISOLATION BULKHEAD REQUIREMENTS



IF: H = 24 INCHES THEN: H/3 IS ACCEPTABLE LIMIT OF WATER RESISTANCE.

AREA OF BULKHEAD THAT MUST BE WATER RESISTANT.

NOTE : This Figure is taken from the USCG Electrical System Compliance Guideline.

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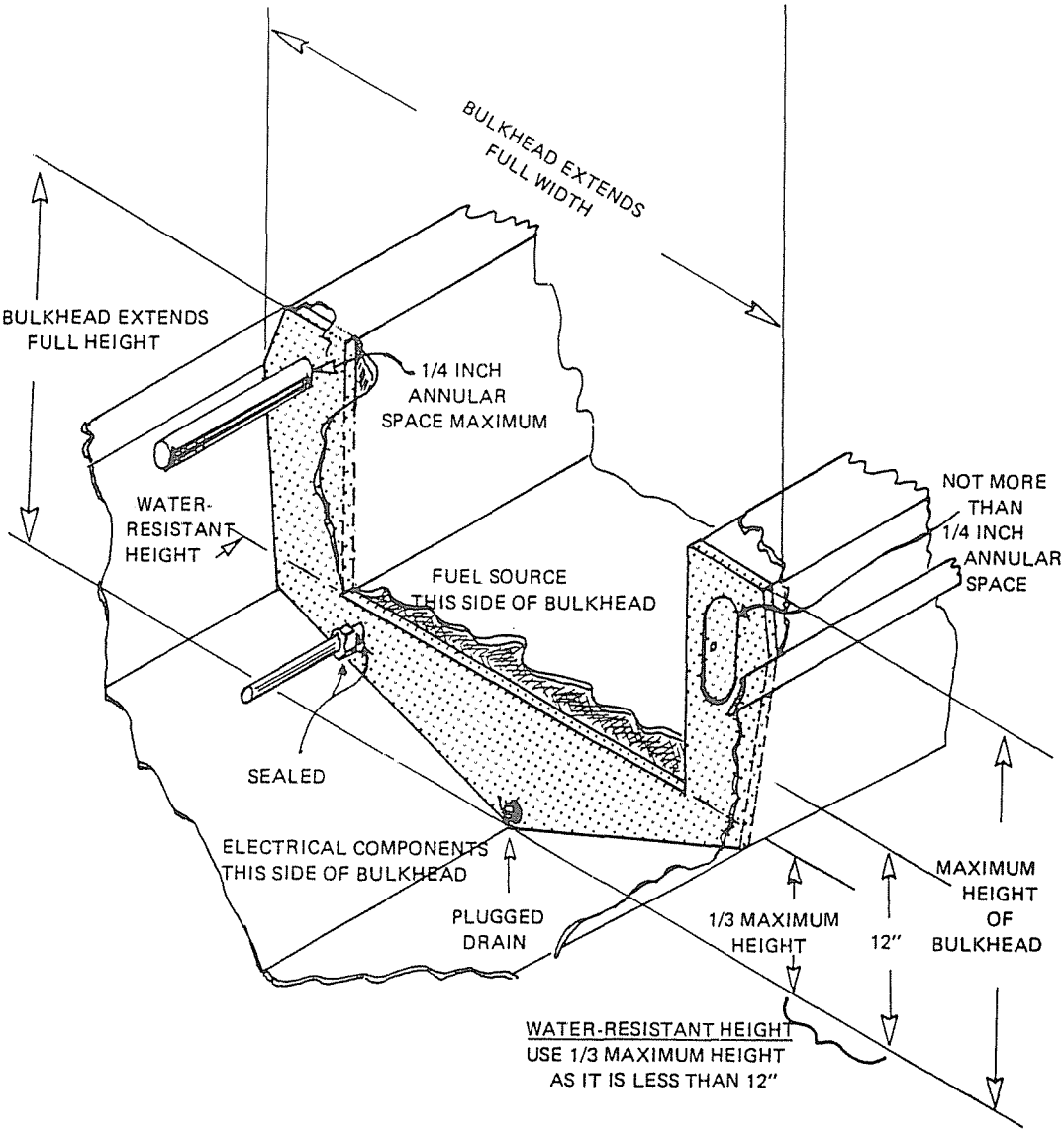
FIGURE 10 - BULKHEADS



NOTE: (1) Seepage of not more than one-quarter fluid ounce per hour permitted below the water-resistant height. This includes bulkhead fastenings and space around hatches, doors, access panels etc. and items passing through the bulkhead.

(2) Openings above the water-resistant height may not have more than 1/4 inch annular space around items passing through the openings.

(3) This Figure is taken from the USCG Electrical System Compliance Guideline.

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E-9.8. LOAD CALCULATIONS

The following method shall be used for calculating the total electrical load requirements for determining the minimum size of each panelboard, switchboard and their main conductors. Additionally this information may be used to size the alternator or other charging means, and the battery. (See ABYC E-9.9. and ABYC E-10, "Storage Batteries".)

a. List in Column A the loads that must be available for use on a continuous duty basis for normal operations.

b. List in Column B the remaining loads which are intermittent and will be calculated based on a diversity factor of 10% or the current draw of the largest item, whichever is larger.

NOTE: Calculations are based on the actual operating amperage for each load and not on the rating of the circuit breaker or fuse protecting that branch circuit.

A	AMPERES	B	AMPERES
Navigation Lights	_____	Cigarette Lighter	_____
Bilge Blower(s)	_____	Cabin Lighting	_____
Bilge Pump(s)	_____	Horn	_____
Wiper(s)	_____	Additional Electronic Equipment	_____
Largest Radio (Transmit mode)	_____	Trim Tabs	_____
Depth Sounder	_____	Power Trim	_____
Radar	_____	Toilets	_____
Searchlight	_____	Anchor Windlass	_____
Instrument(s)	_____	Winches	_____
Alarm System(standby mode)	_____	Fresh Water Pump(s)	_____
Refrigerator	_____	_____	_____
_____	_____	_____	_____
Total Column A	_____	Total Column B	_____
		10% Column B	_____
		Largest Item in Column B	_____

Total Load Required

Total Column A ____

Total Column B ____ The larger of 10% of Column B or the largest item.

Total Load ____

E-9.9. BATTERY CAPACITY

The battery (or battery bank) shall have at least the cold cranking amperage required by the engine manufacturer. Additionally the battery (or battery bank) shall have a rated reserve capacity in minutes such that:

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(E-9.9.)

- for boats with one battery charging source the battery shall be capable of supplying the total load of Column A for a minimum of 1 1/2 hours, or

- for boats with multiple simultaneous battery charging sources, the capacity of all charging sources except the largest charging source shall be subtracted from the total load of Column A. The battery shall be capable of supplying the resulting differences for a minimum of 1 1/2 hours.

NOTE: *In order to calculate the required reserve capacity use the following formula:*

Required Reserve Capacity (min.) =

$$\frac{\text{Load from Column A(Amps) x 1 1/2 (hr.) x 60 (min.per hr.)}}{\text{25 (Amperes)}}$$

E-9.10. DC POWER SOURCES

a. *Overcurrent Protection Device Location* - Ungrounded conductors other than cranking motor conductors shall be provided with overcurrent protection within a distance of 7" of the point at which the conductor is connected to the source of power measured along the conductor. (See Figure 11.)

EXCEPTIONS: *1. If the conductor is connected directly to the battery terminal the 7 inch distance may be increased up to 72 inches.*

2. If the conductor is between the source of power, other than the battery terminal, and the required overcurrent protection device, and is contained throughout its entire distance in a sheath or enclosure such as a conduit, junction box, control box or enclosed panel, the 7 inch distance may be increased up to 40 inches.

b. *Battery Charging Sources*

(1) Each ungrounded conductor to a battery charger, alternator or other charging source shall be provided with overcurrent protection within a distance of 7" of the point of connection to the DC electrical system or to the battery.

EXCEPTIONS: *1. Overcurrent protection is not required if the charging source is within 72 inches of the battery measured along the conductor.*

2. Overcurrent protection is not required if the charging source is within 40 inches of a point of connection other than to the battery and is contained throughout its entire distance in a sheath or enclosure such as a conduit, junction box, control box or enclosed panel.

(2) In addition to the provisions of ABYC E-9.10.b.(1) the ungrounded conductor shall be provided with overcurrent protection within the charging source based on the maximum output of the charger.

EXCEPTION: *Self-limiting devices do not require overcurrent protection within the charging source.*

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(E-9.10.)

c. *Battery Switch* - A battery switch shall be installed in all inboard and I/O cranking motor supply circuits and shall be mounted in a readily accessible location as close as practicable to the battery.

EXCEPTION: Boats less than 26 feet in length.

d. *Battery Switch Ratings* - The intermittent rating of a battery switch shall not be less than the maximum cranking current of the largest engine cranking motor which it serves. The continuous ratings of a battery switch shall not be less than the total of the ampacities of the main overcurrent protection devices connected to the battery switch.

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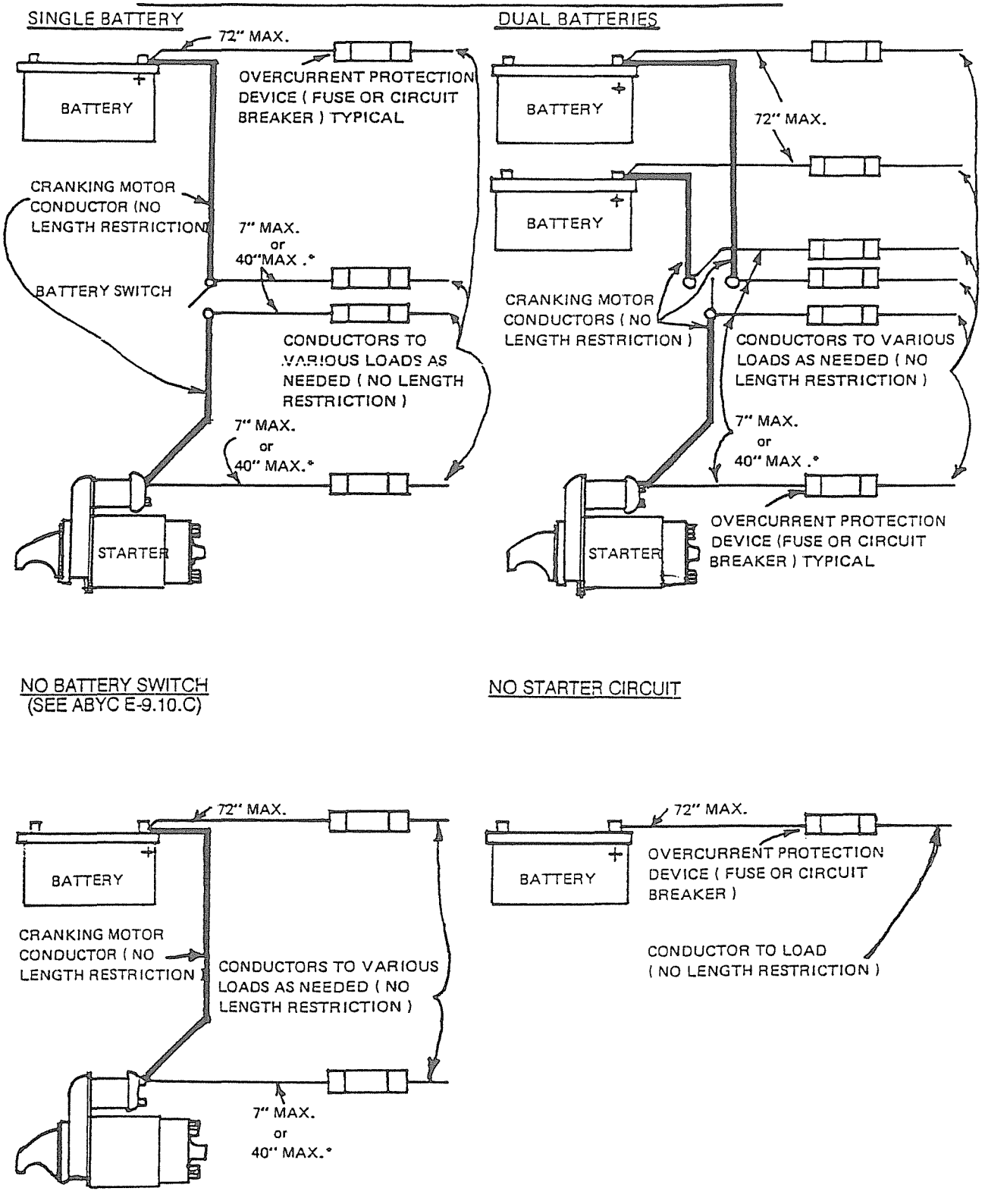
FIGURE 11 – BATTERY SUPPLY CIRCUITS – LOCATION OF OVERCURRENT DEVICES



** NOTE : 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.*

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E-9.11. OVERCURRENT PROTECTION

a. *Motors or Motor Operated Equipment* - Motors and motor operated equipment except for engine cranking motors shall be protected internally, at the equipment, or by branch circuit overprotection devices suitable for motor current. The protection provided shall preclude a fire hazard if the circuit, as installed, is energized for seven hours under any conditions of overload, including locked rotor. This may require the use of thermally responsive protection devices on the equipment or system if the motor is not capable of operating continuously at maximum possible loading.

NOTE: *It may be necessary to test as installed in order to assure compliance with the locked rotor requirement. Voltage drop due to wire size and delay characteristics of the overcurrent protection device may have to be adjusted to protect the motor.*

b. *Non-motor Loads* - The rating of overcurrent protection devices used to protect a load other than a DC motor shall not exceed 150% of the current carrying capacity of its supply conductor. (See Table I.)

c. *Branch Circuits* - Each ungrounded conductor of a branch circuit shall be provided with overcurrent protection at the point of connection to the main switchboard unless the main circuit breaker or fuse provides such protection. Each fuse or trip-free circuit breaker shall be rated in accordance with ABYC E-9.11.a. and b. and also shall not exceed 150% of the conductor ampacity in Table I. (See Figure 12.)

d. *Panelboards and Switchboards* - A trip-free circuit breaker or a fuse shall be installed at the source of power for panelboards and switchboards and shall not exceed 100% of the load capacity of that panel, or 100% of the current carrying capacity of the feeders.

EXCEPTION: *The trip free circuit breaker or fuse at the source of power may be rated at up to 150% of the conductor ampacity if there is a sub-main circuit breaker or fuse in the panelboard or switchboard which is rated at no more than 100% of the load capacity or the feeder ampacity whichever is less. (See Figure 13)*

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FIGURE 12 - MAIN AND BRANCH CIRCUIT PROTECTION

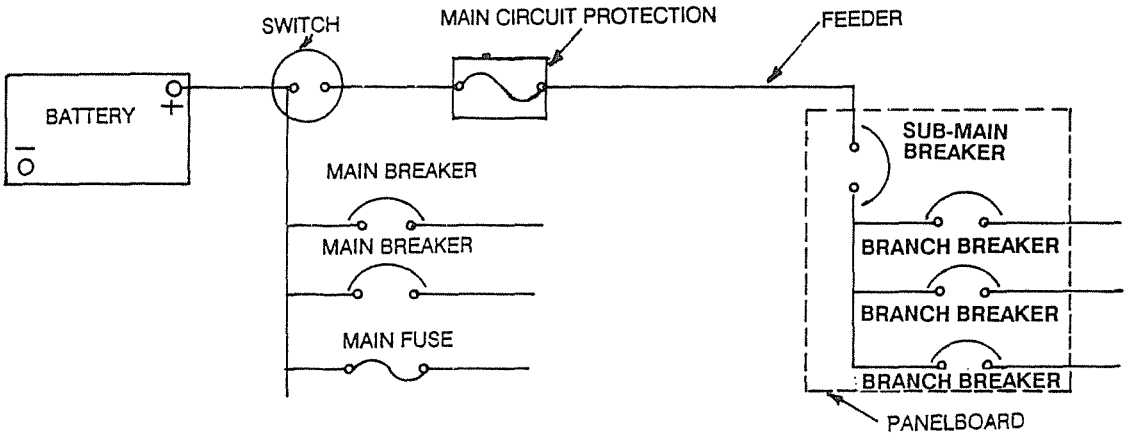

FIGURE 13 - PANELBOARDS AND SWITCHBOARDS

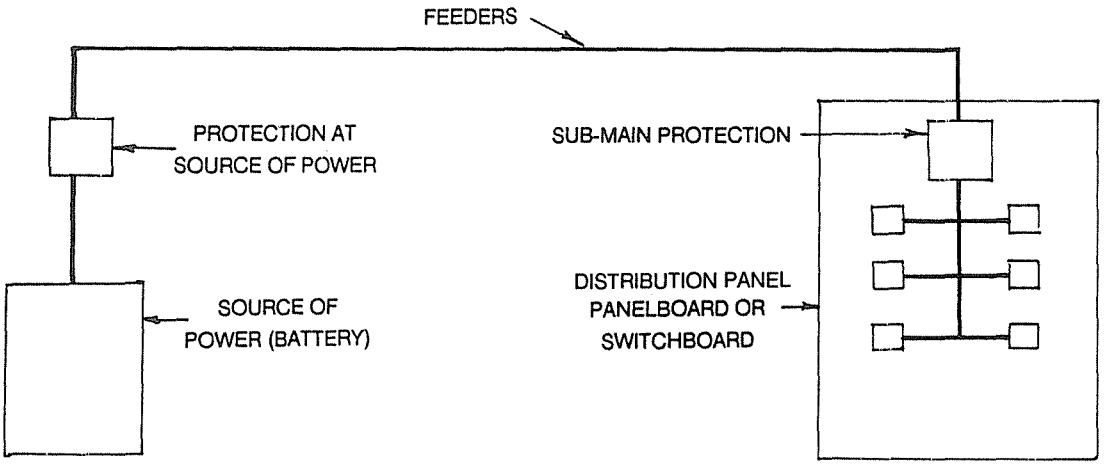

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TABLE I
ALLOWABLE AMPERAGE OF CONDUCTORS FOR UNDER 50 VOLTS

CONDUCTOR SIZE ENGLISH(METRIC) SEE TABLE IV	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)
	OUTSIDE ENGINE SPACES	INSIDE ENGINE SPACES	OUTSIDE ENGINE SPACES	INSIDE ENGINE SPACES	OUTSIDE ENGINE SPACES	INSIDE ENGINE SPACES	OUTSIDE ENGINE SPACES	INSIDE ENGINE SPACES	OUTSIDE ENGINE SPACES	INSIDE ENGINE SPACES	OUTSIDE ENGINE SPACES	INSIDE ENGINE SPACES	OUTSIDE OR INSIDE ENGINE SPACES
18 (0.8)	10	5.8	10	7.5	15	11.7	20	16.4	20	17.0	25	22.3	25
16 (1)	15	8.7	15	11.3	20	15.6	25	20.5	25	21.3	30	26.7	35
14 (2)	20	11.6	20	15.0	25	19.5	30	24.6	35	29.8	40	35.6	45
12 (3)	25	14.5	25	18.8	35	27.3	40	32.8	45	38.3	50	44.5	55
10 (5)	40	23.2	40	30.0	50	39.0	55	45.1	60	51.0	70	62.3	70
8 (8)	55	31.9	65	48.8	70	54.6	70	57.4	80	68.0	90	80.1	100
6 (13)	80	46.4	95	71.3	100	78.0	100	82.0	120	102.0	125	111.3	135
4 (19)	105	60.9	125	93.8	130	101.4	135	110.7	160	136.0	170	151.3	180
2 (32)	140	81.2	170	127.5	175	136.5	180	147.6	210	178.5	225	200.3	240
1 (40)	165	95.7	195	146.3	210	163.8	210	172.2	245	208.3	265	235.9	280
0 (50)	195	113.1	230	172.5	245	191.1	245	200.9	285	242.3	305	271.5	325
00 (62)	225	130.5	265	198.8	285	222.3	285	233.7	330	280.5	355	316.0	370
000 (81)	260	150.8	310	232.5	330	257.4	330	270.6	385	327.3	410	364.9	430
0000 (103)	300	174.0	360	270.0	385	300.3	385	315.7	445	378.3	475	422.8	510

(E-9.11.)

TABLE II
CIRCUIT BREAKER MINIMUM AMPERE INTERRUPTING CAPACITY

Total Connected Battery (Cold Cranking Amperes)	Ampere Interrupting Capacity (A.I.C.) (Amperage available at Circuit Breaker Terminals) Main Circuit Breaker (Amperes) - See Note	Branch Circuit Breaker (Amperes) - See Note
12 Volts and 24 Volts		
650 or less	1500	750
651 - 1100	3000	1500
over 1100	5000	2500
32 Volts		
1250 or less	3000	1500
over 1250	5000	2500

NOTE: *The "Main Circuit Breaker" shall be considered to be the first breaker(s) in a circuit connected in series with the battery. All subsequent breakers, including sub-main breakers, connected in series with a Main Circuit Breaker shall be considered to be "Branch Circuit Breakers". See Figure 12.*

e. *Circuit Breakers* - Circuit breakers shall:

(1) Have a DC voltage rating of not less than the nominal system voltage;

(2) Be of the trip-free type;

(3) Be capable of an interrupting capacity according to Table II and remain operable after the fault. (Integral overcurrent protection in electrical devices may have a lower interrupting capacity.);

NOTE: *A fuse in series with, and ahead of, a circuit breaker may be required by the circuit breaker manufacturer to achieve the interrupting capacity in Table II.*

(4) Be of the manual reset type except as provided in ABYC E-9.11.g.; and

(5) Be tested at four times their current rating when being tested for ignition protection.

EXCEPTION: *"Sealed devices" tested in accordance with; SAE J1171 "External Ignition Protection of Marine Electrical Devices" or UL 1500 "Ignition Protection Test for Marine Products".*

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(E-9.11.)

f. *Fuses*

Fuses shall have a voltage rating of not less than the nominal system voltage and be tested at four times their current rating when being tested for ignition protection.

EXCEPTION: "Sealed devices" tested in accordance with; SAE J1171 "External Ignition Protection of Marine Electrical Devices" or UL 1500 "Ignition Protection Test for Marine Products".

g. *Integral Overcurrent Protection Devices* - Integral overcurrent protection devices without a manual reset may be used as an integral part of an electrical device provided the rest of the circuit is protected by a trip-free circuit protection device(s) or a fuse(s).

h. *Pigtails* - Pigtails less than 7 inches in length are exempt from overcurrent protection requirements.

E-9.12. SWITCHES

a. If single pole switches are used in branch circuits they shall be installed in the positive conductor of the circuit.

EXCEPTIONS: 1. Engine mounted pressure, vacuum and temperature operated switches.

2. Switches such as used for control of alarm systems.

b. Switches shall have voltage ratings not less than the system voltage, current ratings not less than the connected load and shall be rated for the type of load (inductive or resistive).

E-9.13. APPLIANCES AND EQUIPMENT

a. Appliances and fixed DC electrical equipment shall be designed so that the current carrying parts of the device are insulated from all exposed electrically conductive parts.

EXCEPTIONS: 1. 12 volt equipment not located in machinery spaces, not in contact with bilge water and not in contact with a fuel line.

2. Communications and audio equipment.

3. Electric navigation equipment.

4. Instruments and instrument clusters.

5. Liquid level gauge transmitters (For installation of fuel tank transmitters on conductive surfaces see ABYC E-9.13.d.)

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(E-9.13.a.)

6. *Navigation lights operating at nominal 12 volts. (See ABYC A-16.)*

7. *Auxiliary generator sets.*

8. *Engine mounted equipment. (See ABYC E-9.4.a.)*

b. Devices subject to exceptions 1 through 8 in ABYC E-9.13.a. shall be installed with the case negative and the positive connection shall be identified.

c. All exposed electrically conductive non-current carrying parts of fixed DC electrical equipment and appliances that may normally be in contact with bilge water or seawater shall be connected to the DC grounding system.

EXCEPTIONS: 1. *Boats not equipped with a DC grounding system.*

2. *Equipment with an effective double insulation system.*

3. *Metal parts isolated in nonconductive material.*

4. *Electric trolling motors.*

d. *Grounded Liquid Level Gauge Transmitters (senders)* - Grounded liquid level gauge transmitters mounted on fuel tanks or tank plates shall have the transmitter negative return conductor connected directly to the DC Main Negative Bus, the Engine Negative Terminal, or for outboard boats the battery negative terminal or its bus. No other device shall be connected to this conductor. This conductor shall also serve as the static ground and/or the bonding conductor for the tank and fill. If a fuel tank is included in the lightning protection system the conductor between the fuel tank and the DC Main Negative Bus shall be at least 8 AWG. (See ABYC E-4, "Lightning Protection" for additional requirements.)

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(E-9.13.d.)

TABLE III
SAE CONDUCTORS

TYPE	DESCRIPTION	AVAILABLE INSULATION TEMPERATURE RATING PER SAE J378b
GPT	Thermoplastic Insulation, Braidless	60°C (140°F), 90°C (194°F), 105°C(221°F)
HDT	Thermoplastic Insulation, Braidless	60°C (140°F), 90°C (194°F), 105°C (221°F)
SGT	Thermoplastic Insulation, Braidless	60°C (140°F), 90°C (194°F), 105°C (221°F)
STS	Thermosetting Synthetic Rubber Insulation, Braidless	85°C (185°F), 90°C (194°F)
HTS	Thermosetting Synthetic Rubber Insulation, Braidless	85°C (185°F), 90°C (194°F)
SXL	Thermosetting Cross Linked Polyethylene Insulation, Braidless	125°C (257°F)

TABLE IV
FLEXIBLE CORDS

TYPE	DESCRIPTION	AVAILABLE INSULATION TEMPERATURE RATING
SO	Hard Service Cord, Oil Resistant Compound	60°C (140°F), 75°C (167°F) & higher
ST	Hard Service Cord, Thermoplastic	60°C (140°F), 75°C (167°F) & higher
STO,SEO	Hard Service Cord, Oil Resistant Thermoplastic	60°C (140°F), 75°C (167°F) & higher
SJO	Junior Hard Service Cord, Oil Resistant Compound	60°C (140°F), 75°C (167°F) & higher
SJT	Junior Hard Service Cord, Thermoplastic	60°C (140°F), 75°C (167°F) & higher
SJTO	Junior Hard Service Cord, Oil Resistant Thermoplastic	60°C (140°F), 75°C (167°F) & higher

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(E-9.13.d.)

TABLE V
CONDUCTORS

TYPES (SEE NOTE)	DESCRIPTION	AVAILABLE INSULATION TEMPERATURE RATING
THW	Moisture and Heat-Resistant, Thermoplastic	75°C (167°F)
TW	Moisture-Resistant, Thermoplastic	60°C (140°F)
HWN	Moisture and Heat-Resistant,Thermoplastic	75°C (167°F)
XHHW	Moisture and Heat-Resistant, Cross Linked Synthetic Polymer	90°C (194°F)
MTW	Moisture, Heat and Oil Resistant, Thermoplastic	90°C (194°F)
AWM Style Nos. 1230, 1231-1232, 1275 1344-1346	Moisture, Heat and Oil Resistant, Thermoplastic, Thermosetting	105°C (221°F)
UL 1426	Boat Cable	(See UL 1426)

NOTE: Some of the listed types are not commonly available in stranded construction for sizes smaller than 8 AWG.

E-9.14 SYSTEM WIRING

a. Conductors and flexible cords shall have a minimum rating of 300 volts.

b. The construction of insulated cables and conductors shall conform with the requirements of SAE J378, J1127, J1128 or UL1426 "Boat Cable".

c. Conductors may be selected from the types listed in Tables III, IV and V. The temperature ratings shown contemplates the routing of wires above bilge water in locations protected from dripping exposure to weather, spray and oil.

d. Flexible cords shall conform with the National Electrical Code and shall be selected from the types listed in Table IV.

e. Conductors and flexible cords shall be stranded copper according to Table VI and sized according to Table I subject to the following:

(1) Conductors used for panelboard or switchboard main feeders shall have ampacities as determined in ABYC E-9.8. These conductors shall be sized for a voltage drop not to exceed 3% (see Table VII).

(2) Conductors used for branch circuits or in electrical systems that do not use a panelboard or switchboard shall have ampacities as determined by their loads. (See Table I) Conductors, if used for bilge blowers, electronic equipment, navigation lights and other circuits where voltage drop must be kept to a minimum, shall be sized for a voltage drop not to exceed 3% (see Table VII). Conductors used for lighting (other than navigation lights) and other circuits where voltage drop is not critical shall be sized for a voltage drop not to exceed 10% (see Table VIII).

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(E-9.14.e.)

(3) To use Table VII and VIII:

(a) Measure the length of the conductor from the positive power source connection to the electrical device and back to the negative power source connection. Note that the power source connection may be either the battery or a panelboard or switchboard if used.

(b) Using the ampacities as determined in ABYC E-9.14.e.(1) and (2) select the conductor size from the proper voltage drop Table.

(c) In the event of a conflict between the voltage drop Tables and the ampacity Tables use the larger size conductor.

(4) Conductor sizes not covered in Tables VII and VIII may be calculated by means of the following formula based on 3% and 10% voltage drop. If the circular mil area is found to be less than the value in Table VI, the next larger size conductor is to be used.

$$CM = \frac{K \times I \times L}{E}$$

LEGEND

CM = Circular mil area of conductor.

K = 10.75 (constant representing the mil-foot resistance of copper).

I = Load current in amperes.

L = Length of conductor from the positive power source connection to the electrical device and back to the negative power source connection, measured in feet.

E = Voltage drop at load in volts.

(5) Reference is made to Table VI for conversion of circular mil areas to wire gauges.

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(E-9.14.e.(5).)

TABLE VI
CONDUCTOR CIRCULAR MIL (CM) AREA AND STRANDING

CONDUCTOR GAUGE	MINIMUM ACCEPTABLE CM AREA	MINIMUM NUMBER OF STRANDS		
		TYPE 1 *	TYPE 2 **	TYPE 3 ***
18	1537	-	16	-
16	2336	-	19	26
14	3702	-	19	41
12	5833	-	19	65
10	9343	-	19	105
8	14810	-	19	168
6	25910	-	37	266
4	37360	-	49	420
2	62450	-	127	665
1	77790	-	127	836
0	98980	-	127	1064
00	125100	-	127	1323
000	158600	-	259	1666
0000	205500	-	418	2107

* Type 1 - Solid conductor and stranding less than that indicated under Type 2 shall not be used.

** Type 2 - Conductors with at least Type 2 stranding shall be used for general purpose boat wiring.

*** Type 3 - Conductors with Type 3 stranding shall be used for any wiring where frequent flexing is involved in normal use.

NOTE: *Metric wire sizes may be used if of equivalent circular mil area. If the circular mil area of the metric conductor is less than that listed, the wire ampacity shall be corrected based on the ratio of the circular mil areas.*

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(E-9.14.e.(5).)

TABLE VII
CONDUCTOR SIZES FOR 3% DROP IN VOLTAGE

Length of Conductor from Source of Current to Device and Back to Source – Feet

TOTAL CURRENT ON CIRCUIT IN AMPS.	10	15	20	25	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170
	12 Volts – 3% Drop Wire Sizes (gage) – Based on Minimum CM Area																		
5	18	16	14	12	12	10	10	10	8	8	8	6	6	6	6	6	6	6	6
10	14	12	10	10	10	8	6	6	6	6	4	4	4	4	2	2	2	2	2
15	12	10	10	8	8	6	6	6	4	4	2	2	2	2	2	1	1	1	1
20	10	10	8	6	6	6	4	4	2	2	2	2	1	1	1	0	0	0	2/0
25	10	8	6	6	6	4	4	2	2	2	1	1	0	0	0	2/0	2/0	2/0	3/0
30	10	8	6	6	4	4	2	2	1	1	0	0	0	2/0	2/0	3/0	3/0	3/0	3/0
40	8	6	6	4	4	2	2	1	0	0	2/0	2/0	3/0	3/0	3/0	4/0	4/0	4/0	4/0
50	6	6	4	4	2	2	1	0	2/0	2/0	3/0	3/0	4/0	4/0	4/0				
60	6	4	4	2	2	1	0	2/0	3/0	3/0	4/0	4/0	4/0						
70	6	4	2	2	1	0	2/0	3/0	3/0	4/0	4/0								
80	6	4	2	2	1	0	3/0	3/0	4/0	4/0									
90	4	2	2	1	0	2/0	3/0	4/0	4/0										
100	4	2	2	1	0	2/0	3/0	4/0											
	24 Volts – 3% Drop Wire Sizes (gage) – Based on Minimum CM Area																		
5	18	18	18	16	16	14	12	12	12	10	10	10	10	10	8	8	8	8	8
10	18	16	14	12	12	10	10	10	8	8	8	6	6	6	6	6	6	6	6
15	16	14	12	12	10	10	8	8	6	6	6	6	6	4	4	4	4	4	2
20	14	12	10	10	10	8	6	6	6	6	4	4	4	4	2	2	2	2	2
25	12	12	10	10	8	6	6	6	4	4	4	4	2	2	2	2	2	2	1
30	12	10	10	8	8	6	6	4	4	4	2	2	2	2	2	1	1	1	1
40	10	10	8	6	6	6	4	4	2	2	2	2	1	1	1	0	0	0	2/0
50	10	8	6	6	6	4	4	2	2	2	1	1	0	0	0	2/0	2/0	2/0	3/0
60	10	8	6	6	4	4	2	2	1	1	0	0	0	2/0	2/0	3/0	3/0	3/0	3/0
70	8	6	6	4	4	2	2	1	1	0	0	2/0	2/0	3/0	3/0	3/0	3/0	4/0	4/0
80	8	6	6	4	4	2	2	1	0	0	2/0	2/0	3/0	3/0	3/0	4/0	4/0	4/0	4/0
90	8	6	4	4	2	2	1	0	0	2/0	2/0	3/0	3/0	4/0	4/0	4/0	4/0	4/0	
100	6	6	4	4	2	2	1	0	2/0	2/0	3/0	3/0	4/0	4/0	4/0				
	32 Volts – 3% Drop Wire Sizes (gage) – Based on Minimum CM Area																		
5	18	18	18	18	16	16	14	14	12	12	12	12	10	10	10	10	10	10	8
10	18	16	16	14	14	12	12	10	10	10	8	8	8	8	8	6	6	6	6
15	16	14	14	12	12	10	10	8	8	8	6	6	6	6	6	6	6	4	4
20	16	14	12	12	10	10	8	8	6	6	6	6	6	4	4	4	4	4	2
25	14	12	12	10	10	8	8	6	6	6	6	4	4	4	4	2	2	2	2
30	14	12	10	10	8	8	6	6	6	4	4	4	4	2	2	2	1	1	1
40	12	10	10	8	8	6	6	4	4	4	2	2	2	2	2	1	1	1	1
50	12	10	8	8	6	6	4	4	2	2	2	2	2	1	1	0	0	0	0
60	10	8	8	6	6	4	4	2	2	2	2	1	1	0	0	0	2/0	2/0	2/0
70	10	8	6	6	6	4	2	2	2	1	1	0	0	0	2/0	2/0	2/0	3/0	3/0
80	10	8	6	6	4	4	2	2	1	1	0	0	0	2/0	2/0	3/0	3/0	3/0	3/0
90	8	6	6	6	4	2	2	2	1	0	0	2/0	2/0	2/0	3/0	3/0	3/0	4/0	4/0
100	8	6	6	4	4	2	2	1	0	0	2/0	2/0	2/0	3/0	3/0	3/0	4/0	4/0	4/0

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TABLE VIII
CONDUCTOR SIZES FOR 10% DROP IN VOLTAGE

TOTAL CURRENT ON CIRCUIT IN AMPS.	Length of Conductor from Source of Current to Device and Back to Source — Feet																		
	10	15	20	25	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170
	12 Volts — 10% Drop Wire Sizes (gage) — Based on Minimum CM Area																		
5	18	18	18	18	18	16	16	14	14	14	12	12	12	12	12	10	10	10	10
10	18	18	16	16	14	14	12	12	10	10	10	10	8	8	8	8	8	8	6
15	18	16	14	14	12	12	10	10	8	8	8	8	8	6	6	6	6	6	6
20	16	14	14	12	12	10	10	8	8	8	6	6	6	6	6	6	4	4	4
25	16	14	12	12	10	10	8	8	6	6	6	6	6	4	4	4	4	4	2
30	14	12	12	10	10	8	8	6	6	6	6	4	4	4	4	2	2	2	2
40	14	12	10	10	8	8	6	6	6	4	4	4	2	2	2	2	2	2	2
50	12	10	10	8	8	6	6	4	4	4	2	2	2	2	2	1	1	1	1
60	12	10	8	8	6	6	4	4	2	2	2	2	2	1	1	1	0	0	0
70	10	8	8	6	6	6	4	2	2	2	2	1	1	1	0	0	0	2/0	2/0
80	10	8	8	6	6	4	4	2	2	2	1	1	0	0	0	2/0	2/0	2/0	2/0
90	10	8	6	6	6	4	2	2	2	1	1	0	0	0	2/0	2/0	2/0	3/0	3/0
100	10	8	6	6	4	4	2	2	1	1	0	0	0	2/0	2/0	2/0	3/0	3/0	3/0
	24 Volts — 10% Drop Wire Sizes (gage) — Based on Minimum CM Area																		
5	18	18	18	18	18	18	18	18	16	16	16	16	14	14	14	14	14	14	12
10	18	18	18	18	18	16	16	14	14	14	12	12	12	12	12	10	10	10	10
15	18	18	18	16	16	14	14	12	12	12	10	10	10	10	10	8	8	8	8
20	18	18	16	16	14	14	12	12	10	10	10	10	8	8	8	8	8	8	6
25	18	16	16	14	14	12	12	10	10	10	8	8	8	8	8	6	6	6	6
30	18	16	14	14	12	12	10	10	8	8	8	8	8	6	6	6	6	6	6
40	16	14	14	12	12	10	10	8	8	8	6	6	6	6	6	6	4	4	4
50	16	14	12	12	10	10	8	8	6	6	6	6	6	4	4	4	4	4	2
60	14	12	12	10	10	8	8	6	6	6	6	4	4	4	4	2	2	2	2
70	14	12	10	10	8	8	6	6	6	6	4	4	4	2	2	2	2	2	2
80	14	12	10	10	8	8	6	6	6	4	4	4	2	2	2	2	2	2	2
90	12	10	10	8	8	6	6	6	4	4	4	2	2	2	2	2	2	1	1
100	12	10	10	8	8	6	6	4	4	4	2	2	2	2	2	1	1	1	1
	32 Volts — 10% Drop Wire Sizes (gage) — Based on Minimum CM Area																		
5	18	18	18	18	18	18	18	18	18	18	18	16	16	16	16	14	14	14	14
10	18	18	18	18	18	18	16	16	14	14	14	14	14	12	12	12	12	12	12
15	18	18	18	18	18	16	14	14	14	12	12	12	12	10	10	10	10	10	10
20	18	18	18	16	16	14	14	12	12	12	10	10	10	10	10	8	8	8	8
25	18	18	16	16	14	14	12	12	10	10	10	10	10	8	8	8	8	8	8
30	18	18	16	14	14	12	12	10	10	10	10	8	8	8	8	8	6	6	6
40	18	16	14	14	12	12	10	10	8	8	8	8	8	6	6	6	6	6	6
50	16	14	14	12	12	10	10	8	8	8	6	6	6	6	6	6	6	4	4
60	16	14	12	12	10	10	8	8	8	6	6	6	6	6	6	4	4	4	4
70	14	14	12	10	10	8	8	8	6	6	6	6	6	4	4	4	4	2	2
80	14	12	12	10	10	8	8	6	6	6	6	4	4	4	4	2	2	2	2
90	14	12	10	10	10	8	6	6	6	6	4	4	4	4	2	2	2	2	2
100	14	12	10	10	8	8	6	6	6	4	4	4	4	2	2	2	2	2	2

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E-9.15 WIRING IDENTIFICATION

a. Each electrical conductor that is part of the boat's electrical system shall have a means to identify its function in the system.

EXCEPTION: Pigtails less than 7 inches in length.

b. Insulated grounding conductors shall be identified by the color green or green with yellow stripe(s).

c. The color code shown in Table IX identifies colors for DC conductors used for general wiring purposes on boats.

TABLE IX
WIRING COLOR CODE

Color	Use
Green, or green w/yellow stripe(s)	DC Grounding Conductors
Black, or Yellow	DC Negative Conductors
Red	DC Positive Conductors

d. The color code shown in Table X identifies one selection of colors for use as an engine accessory wiring color code. Other means of identification may be used providing a wiring diagram of the system indicating the method of identification is provided with each boat.

(1) Color coding may be accomplished by colored sleeving or color application to wiring at termination points.

(2) If tape is used to mark a wire, the tape shall be at least 3/16 inch in width and shall have a sufficient length to make at least two complete turns around the conductor to be marked. The tape shall be applied to be visible near each terminal.

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(E-9.15.d.)

TABLE X
ENGINE AND ACCESSORY WIRING COLOR CODE

COLOR	ITEM	USE
Yellow w/Red Stripe (YR)	Starting Circuit	Starting Switch to Solenoid
Brown/Yellow Stripe (BY) or Yellow (Y) - see note	Bilge Blowers	Fuse or Switch to Blowers
Dark Gray (Gy)	Navigation Lights Tachometer	Fuse or Switch to Lights Tachometer Sender to Gauge
Brown (Br)	Generator Armature	Generator Armature to Regulator
	Alternator Charge Light	Generator Terminal/Alternator Auxiliary Terminal to Light to Regulator
	Pumps	Fuse or Switch to Pumps
Orange (O)	Accessory Feed	Ammeter to Alternator or Generator Output and Accessory Fuses or Switches
	Accessory Feeds	Distribution Panel to Accessory Switch
Purple (Pu)	Ignition	Ignition Switch to Coil and Electrical Instruments
	Instrument Feed	Distribution Panel to Electric Instruments
Dark Blue	Cabin and Instrument Lights	Fuse or Switch to Lights
Light Blue (Lt Bl)	Oil Pressure	Oil Pressure Sender to Gauge
Tan	Water Temperature	Water Temperature Sender to Gauge
Pink (Pk)	Fuel Gauge	Fuel Gauge Sender to Gauge
Green/Stripe (G/x) (Except G/Y)	Tilt down and/or Trim in	Tilt and/or Trim Circuits
Blue/Stripe (Bl/x)	Tilt up and/or Trim out	Tilt and/or Trim Circuits

NOTE: If yellow is used for DC negative, blower must be brown with a yellow stripe

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E-9.16 INSTALLATION

a. Wiring shall be installed in a manner that will avoid magnetic loops in the area of the compass and magnetically sensitive devices. Direct-current wires in this area, which may create magnetic fields, shall run in twisted pairs.

b. Junction boxes, cabinets and other enclosures in which electrical connections are made shall be weatherproof or installed in a protected location to minimize the entrance or accumulation of moisture or water within the boxes, cabinets or enclosures. In wet locations, metallic boxes, cabinets or enclosures shall be mounted to minimize the entrapment of moisture between the box, cabinet or enclosure and the adjacent structure. If air spacing is used to accomplish this, the minimum shall be 1/4 inch (6.25mm).

c. Current-carrying conductors shall be routed as high as practicable above the bilge water level and other areas where water may accumulate. If conductors must be routed in the bilge or other areas where water may accumulate, the wiring and connections shall be watertight.

d. Conductors shall be routed as far away as practicable from exhaust pipes and other heat sources. Unless an equivalent thermal barrier is provided, a clearance of at least 2 inches between conductors and water cooled exhaust components and a clearance of at least 9 inches between conductors and dry exhaust components shall be maintained. Conductors shall not be routed directly above a dry exhaust.

EXCEPTIONS: 1. Wiring on engines.

2. Exhaust temperature sensor wiring.

e. Battery cables without overcurrent protection shall comply with the following:

(1) Battery cables shall be routed above normal bilge water levels throughout their length.

(2) Battery cables shall be routed to avoid contact with metallic fuel system components.

(3) The ungrounded battery cable shall be routed to avoid contact with any part of the engine or drive train.

f. Conductors which may be exposed to physical damage shall be protected by self-draining: loom, conduit, tape, raceways or other equivalent protection. Conductors passing through bulkheads or structural members shall be protected to minimize insulation damage such as chafing. Conductors shall also be routed clear of sources of chafing such as steering cable and linkages, engine shafts and throttle connections.

g. When AC and DC conductors are run together, the AC conductor shall be sheathed, bundled, or otherwise kept separate from the DC conductors.

h. Conductors shall be at least 16 gauge.

EXCEPTION: 18 gauge conductors may be used if included with other conductors in a sheath and do not extend more than 30 inches outside the sheath.

i. Conductors shall be supported throughout their length or, alternatively shall be secured at least every 18 inches by one of the following methods:

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(E-9.16.i.)

EXCEPTIONS: 1. Battery cables within 36" of a battery terminal.

2. Cables attached to outboard motors.

(1) Non-metallic clamps of a size to hold the conductors firmly in place. Non-metallic straps or clamps shall not be used over engine(s), moving shafts, other machinery or passageways if failure would result in a hazardous condition. The material shall be resistant to oil, gasoline, and water and shall not break or crack within a temperature range of -34° C (- 30° F) to 121° C (250° F).

(2) Metal straps or clamps with smooth, rounded edges to hold the conductors firmly in place without damage to the conductors or insulation. That section of the conductor or cable directly under the strap or clamp shall be protected by means of loom, tape or other suitable wrapping to prevent injury to the conductor.

(3) Metal clamps lined with an insulating material resistant to the effects of oil, gasoline and water.

j. All electrical appliances and equipment designed for permanent installation shall be securely mounted to the boat's structure.

k. *Wiring connections*

(1) All connections shall be in locations protected from the weather or in weatherproof enclosures or shall be watertight. If connections are exposed to immersion they shall be watertight.

(2) Wiring connections shall be designed and installed to make mechanical and electrical joints without damage to the conductors.

(3) Metals used for the terminal studs, nuts and washers shall be corrosion resistant and galvanically compatible with the conductor and terminal lug. Aluminum and unplated steel shall not be used for studs, nuts and washers.

(4) Each conductor splice joining conductor to conductor, conductor to connectors, and conductor to terminals shall be able to withstand a tensile force equal to at least the value shown in Table XI for the smallest conductor size used in the splice for a one minute duration and not break.

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(E-9.16.k.(4).)

TABLE XI
TENSILE TEST VALUES FOR CONNECTIONS

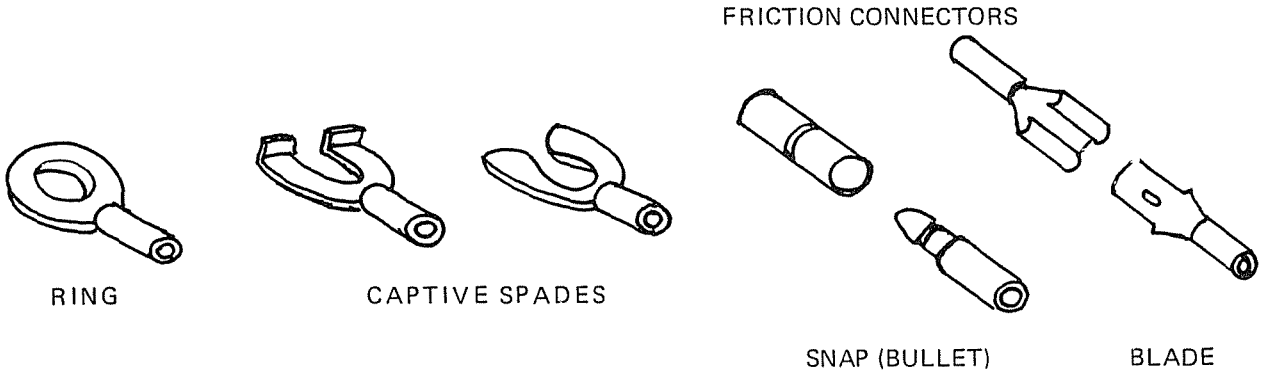
CONDUCTOR SIZE GAUGE	TENSILE FORCE POUNDS	TENSILE FORCE NEWTONS	CONDUCTOR SIZE GAUGE	TENSILE FORCE POUNDS	TENSILE FORCE NEWTONS
18	10	44	4	70	311
16	15	66	3	80	355
14	30	133	2	90	400
12	35	155	1	100	444
10	40	177	0	125	556
8	45	200	00	150	667
6	50	222	000	175	778
5	60	266	0000	225	1000

(5) Terminal connectors shall be the ring or captive spade types. (See Figure 14.)

EXCEPTION: Friction type connectors may be used if:

- *The voltage drop from terminal to terminal does not exceed 50 millivolts for a 20 amp current flow, and*
- *The connection does not separate if subjected to a six pound tensile force along the axial direction of the connector for one minute.*

FIGURE 14 - TYPES OF TERMINALS



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(E-9.16.k.)

(6) Connections may be made using a set screw pressure-type conductor connector providing a means is used to prevent the set screw from bearing directly on the conductor strands.

(7) Twist-on connectors (wire nuts) shall not be used.

(8) Solder shall not be the sole means of mechanical connection in any circuit.

EXCEPTION: Battery lugs with a solder contact length of not less than 1.5 times the diameter of the conductor.

(9) Solderless crimp-on connectors shall be attached with the type of crimping tools designed for the connector used and which will produce a connection meeting the requirements of ABYC E-9.16.k.(4).

(10) No more than four conductors shall be secured to any one terminal stud. If additional connections are necessary, two or more terminal studs shall be connected together by means of jumpers or copper straps.

(11) Ring and captive spade type terminal connectors shall be the same nominal size as the stud.

(12) Conductors terminating at switchboards, in junction boxes or fixtures shall be arranged to provide a length of conductor to relieve tension, to allow for repairs and to permit multiple conductors to be fanned at terminal studs.

(13) The shanks of terminals shall be protected against accidental shorting by the use of insulation barriers or sleeves, except for those used in grounding systems.

E-9.17 RECEPTACLES

a. Receptacles installed in locations subject to rain, spray or splash shall be weatherproof when not in use such as is provided by a spring-loaded, self-closing or snap-type cover.

b. Receptacles installed in areas subject to flooding or momentary submersion shall be of a watertight design, the integrity of which is not affected when the receptacle is in use.

c. Receptacles and matching plugs used on DC systems shall not be interchangeable with receptacles and matching plugs used elsewhere on the boat for AC systems.

E-9.18 PLUG CONNECTIONS

Multi-wire plugs and receptacles used in conjunction with harness type wiring systems shall comply with the following:

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(E-9.18.)

a. The plugs and receptacles shall incorporate means for supporting all wires to limit flexing at the connection, such as cable clamps, molded connectors, insulation grips, extended terminal barrels.

b. Plugs and receptacles exposed to weather shall be weatherproof or if subject to immersion shall be watertight.

c. Each terminal in a multi-wire plug and receptacle shall be protected from accidental short- circuiting to adjacent terminals.

d. Plug connectors shall have a minimum disengagement force of 6 pounds along the axial direction of the connector for one minute.

e. Plug connector's capacity shall be selected to meet or exceed the ampacity and temperature rating of the connecting conductors in addition to its wire size capability.

E-9.19 MAIN SWITCHBOARD OR PANELBOARD

A main switchboard or panelboard shall be installed in a readily accessible location, shall be weatherproof or protected from the weather and splash.

a. Switchboards and panelboards used on boats with more than one system voltage shall have a permanent marking showing the system voltage and its type (DC).

b. Switchboards and panelboards shall be designed so that there are no exposed live parts accessible to the operator in the normal operating position.

E-9.20 DC GROUNDING AND BONDING

a. *DC Grounding* - If a DC grounding system is installed, the DC grounding conductor shall be used to connect metallic non-current-carrying parts of those direct current devices identified in ABYC E-9.13.c. to the engine negative terminal or its bus for the purpose of minimizing stray current corrosion.

NOTE: This system is the DC grounding system formerly called BONDING. (see Fig. 15)

b. *DC Grounding Conductor* - A DC grounding conductor shall comply with ABYC E-9.16.h. and shall not be smaller than one size under that required for current carrying conductors supplying the device. (see Fig. 15)

c. *Routing* - The DC grounding conductor shall be routed from the device to the engine negative terminal or the DC main negative bus by one of the following means:

(1) The DC grounding conductor may be routed together with the current carrying conductors as a third wire.

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(E-9.20.c.)

(2) The DC grounding conductor may be routed as a separate conductor.

(3) The DC grounding conductor may be connected to a DC grounding bus in accordance with ABYC E-9.20.e.

d. *Connections* - DC grounding conductor connections shall be made in accordance with ABYC E-9.16.k.

e. *DC Grounding Bus* - The DC grounding bus serving more than one electrical device shall comply with ABYC E-9.20.b. for the largest device and shall be installed in accordance with the following:

(1) The DC grounding bus may be fabricated from copper or bronze strip with a minimum thickness of 1/32 inch and a width of not less than 1/2 inch. The copper or bronze strip may be drilled and tapped providing its thickness ensures no less than three full threads of engagement for the terminal screws. Copper pipe may be used providing its wall thickness is sufficient for the pipe to be drilled and tapped as required above. The strip or pipe may also be through-drilled and the connections made with machine screws and locknuts.

(2) Copper braid shall not be used.

(3) The DC Grounding Bus shall be connected directly to the Engine Negative Terminal or DC main negative bus.

f. *Combined DC Grounding and Bonding Systems* - The DC grounding conductors may be combined with the following bonding systems providing all the requirements with respect to conductor size are met for each system. (see Fig. 16).

(1) *Lightning Bonding* - See ABYC E-4, "Lightning Protection".

(2) *Cathodic Bonding* - see ABYC E-2, "Cathodic Protection".

(3) *Static Electricity Bonding* - see ABYC E-9.13.d.; H-24, "Fuel Systems - Gasoline"; and H-33, "Fuel Systems - Diesel".

g. *Radio Ground Plate* - If the radio ground plate is connected to the engine negative terminal, the connecting conductor shall be at least 8 AWG since a radio ground plate may also function as a lightning ground plate.

h. *Coaxial Cables and Conduit* - The metallic braid of coaxial cables and metal conduit used for radio interference or any form of radio shielding or armoring shall be connected to earth ground with an insulated stranded copper conductor.

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FIGURE 15 - DC NEGATIVE SYSTEM - DC GROUNDING SYSTEM
(Terminology and Alternative Connections)

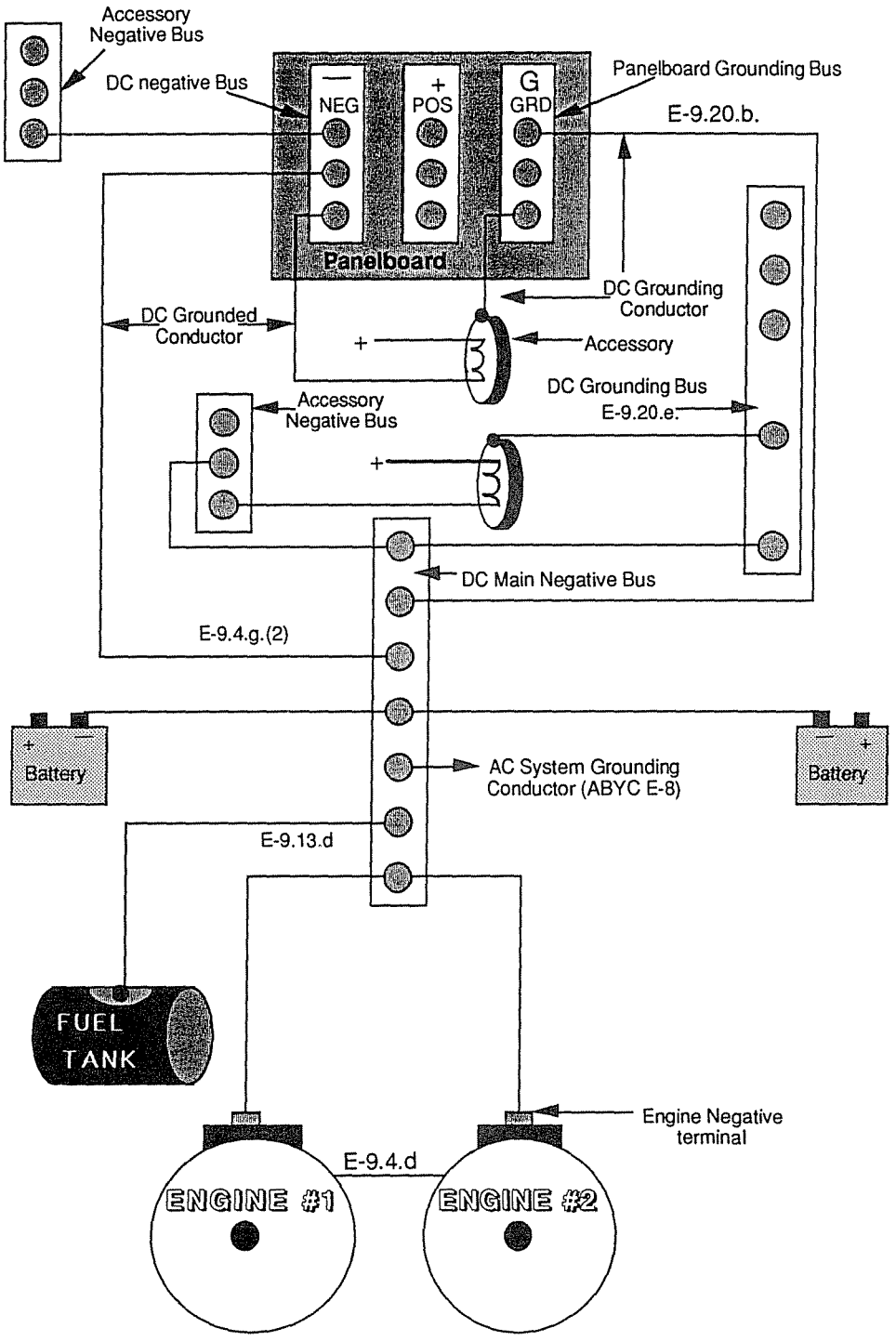

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FIGURE 15 - DC NEGATIVE SYSTEM - DC GROUNDING SYSTEM (cont'd)

Conductor Sizes

Routing	Capacity
Battery to DC Main Negative Bus	Cranking Current
DC Main Negative Bus to Engine	Cranking Current
Engine to Engine	Cranking Current
DC Main Negative Bus to Accessory Negative Bus	Load Current (E-9.4.g.(2)).
DC Panelboard Grounding Bus to DC Main Negative Bus	E-9.20.e.
DC Grounding Bus to DC Main Negative Bus	Panelboard load minus one size

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FIGURE 16 - DC COMMON GROUNDING SYSTEM

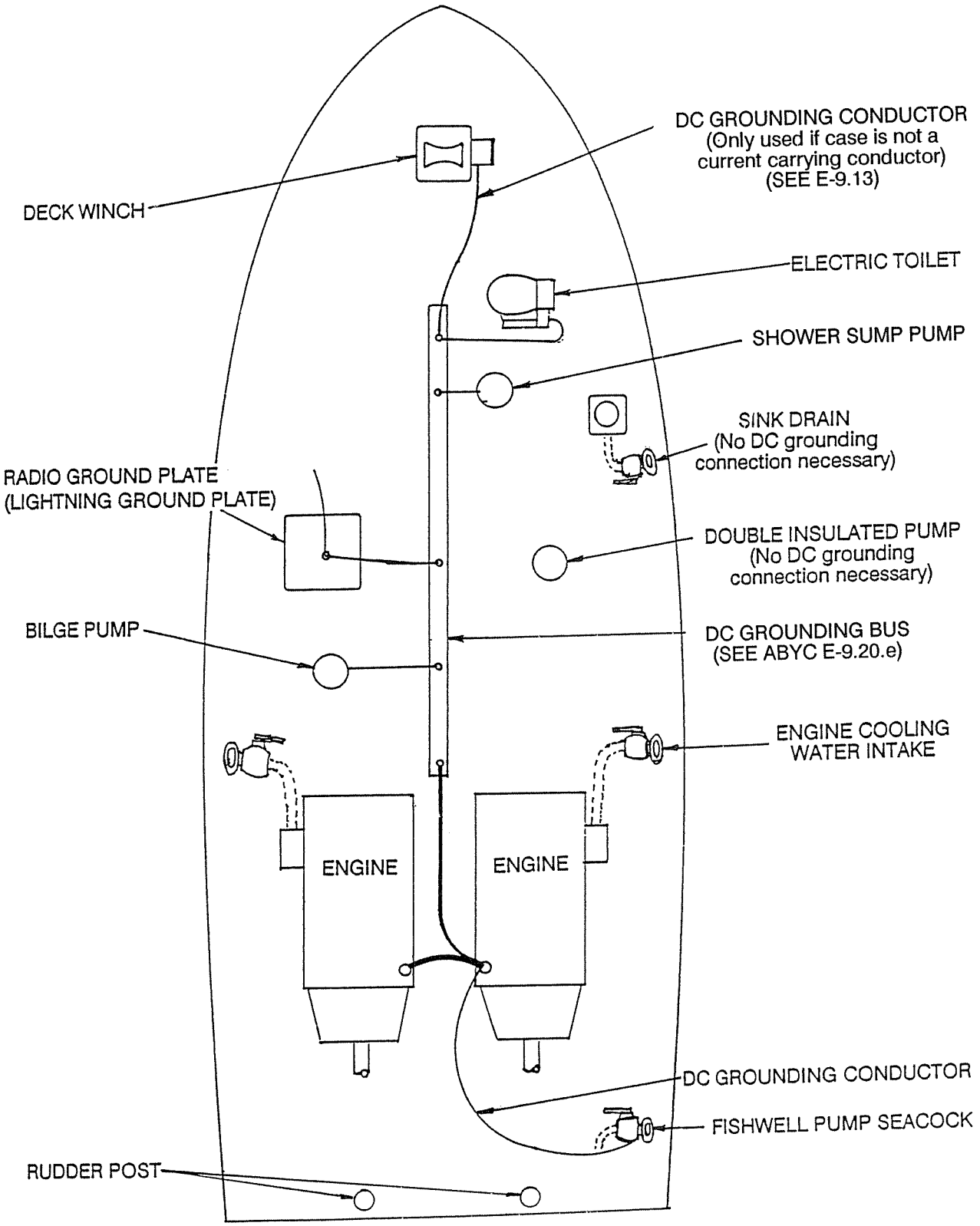

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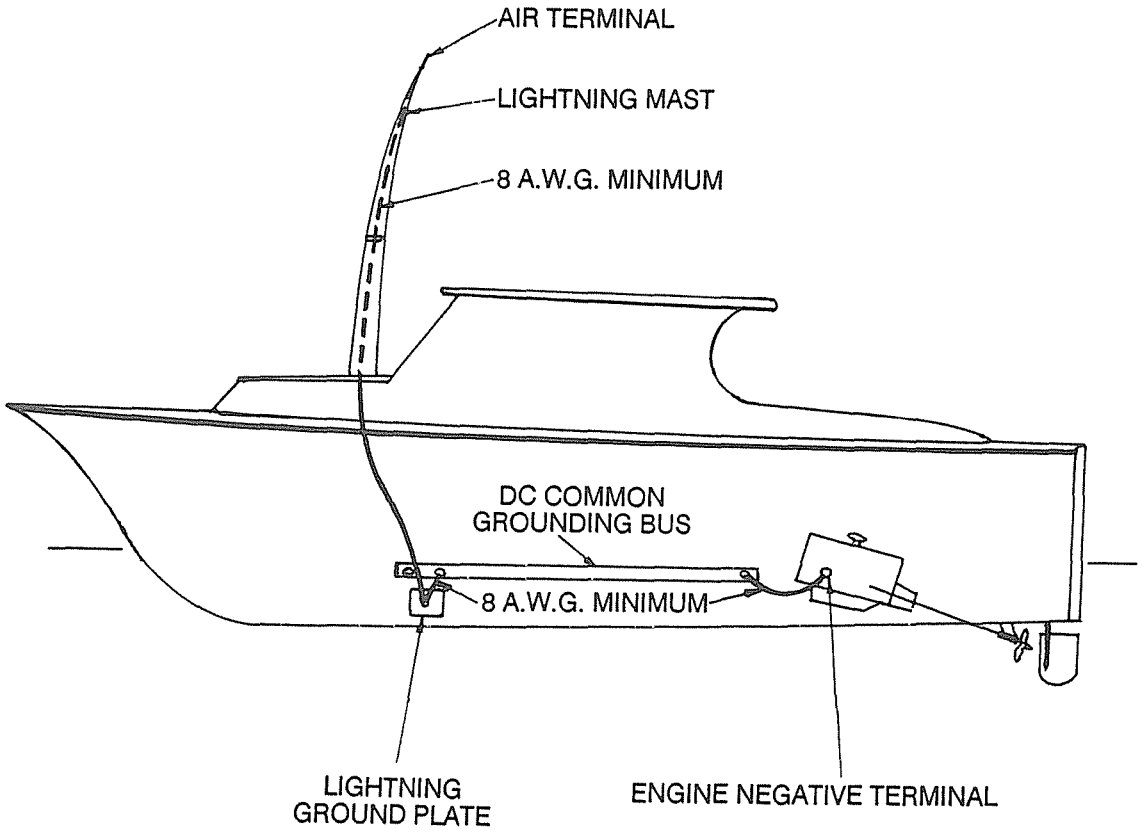
FIGURE 17 - COMBINED LIGHTNING/DC GROUNDING SYSTEM



NOTE: *Lightning protection requires conductivity to ground of not less than that of an 8 A.W.G. copper conductor (See ABYC E-4, "Lightning Protection").*

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