



MARINE AC AND DC
ELECTRICAL SYSTEMS

SEMINAR

BY

DENNIS KRUG and JOHN CHADWICK

Topics

- Electrical Basics
- Wire Sizing and Connections
- Circuit Protection
- Batteries
- Battery Charging Systems
 - Battery Chargers
 - Alternators
 - Solar and Wind

Topics

- Battery Monitors
- Inverters
- AC Systems
- Grounding Systems

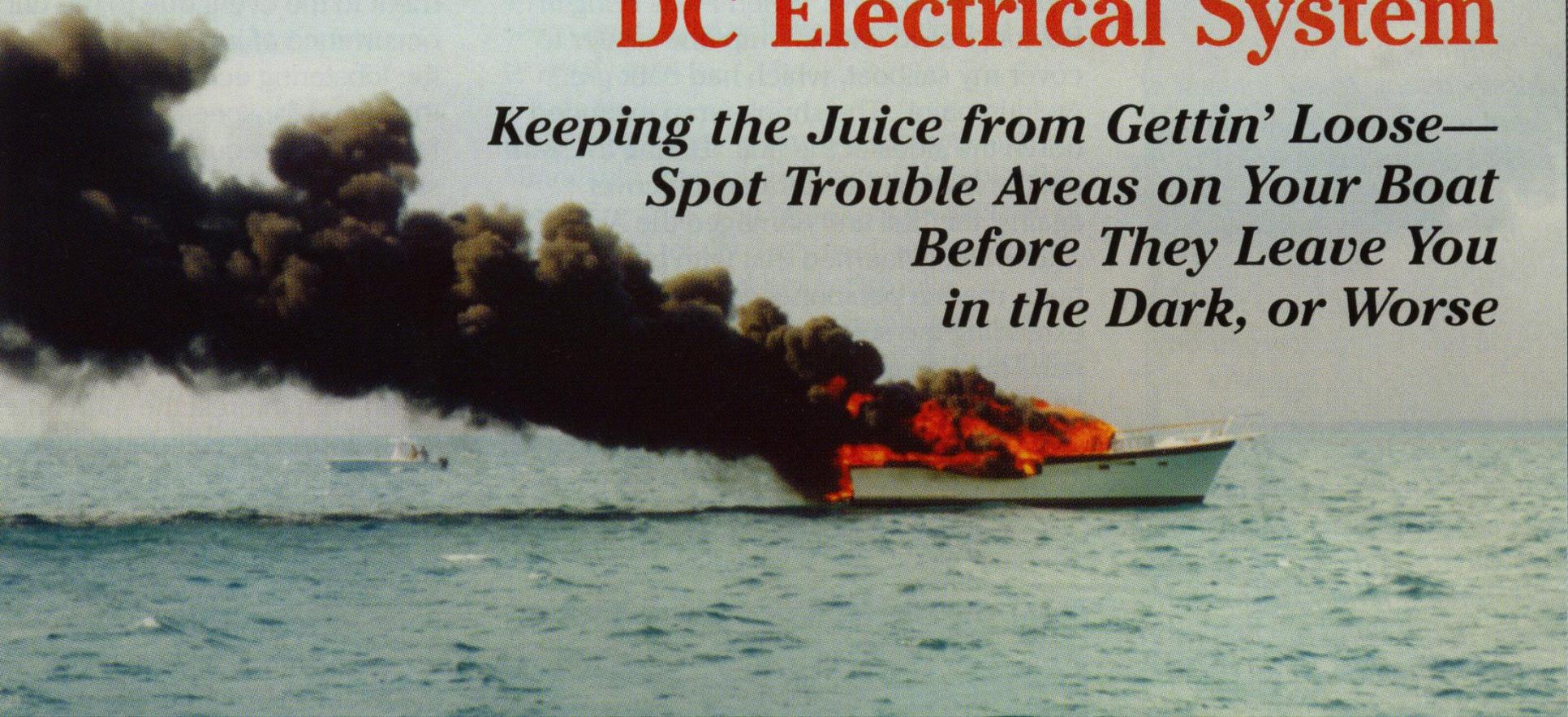


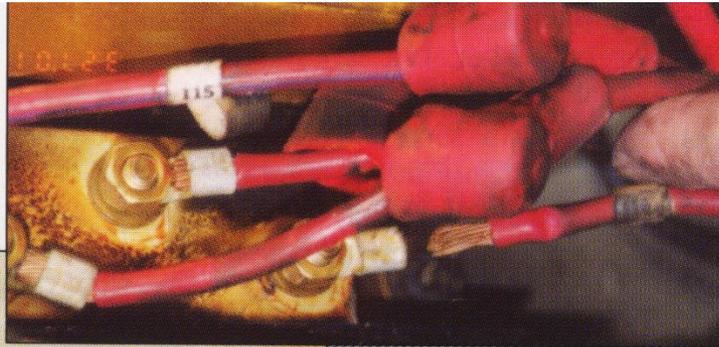
- American Boat & Yacht Council, Inc. (ABYC) develops the consensus safety standards for the design, construction, equipage, maintenance, and repair of small craft. The development of uniform standards is the basis for industry-wide comparisons of products and performance.
- ABYC standards are minimum requirements for a safe design, construction and repair. Boaters should insist that builders, repairers and installers use these ABYC standards as a minimum. Their boating experience will be enhanced and the image of the marine industry justifiably improved..

- Q:What is the most common problem on a boat?
- A:The most common problem on a boat is the failure of it's electrical system.
- Q:What causes most boat fires?
- A:Most boat fires are directly related to a faulty electrical system

A Quick Trip Through Your Boat's DC Electrical System

*Keeping the Juice from Gettin' Loose—
Spot Trouble Areas on Your Boat
Before They Leave You
in the Dark, or Worse*





Check for loose connections aboard periodically—an occasional tug can head off major problems.



Starter cables carry a lot of electricity. This cable wasn't supported with cable clamps in the engine room and abraded against a spinning shaft. The subsequent fire began destroying the engine control cables and after the member shut down the engine, it restarted. The kill switch wiring was damaged and the engine had to be stopped by choking the air supply (Claim # 9605729).



When one wire overheats, others in the same bundle can ignite. Not having proper fusing during a battery charger malfunction caused most of this boat's wiring to be damaged—a daunting repair (claim #0100202).



Adding a larger circuit breaker to a distribution panel without also upgrading the wiring can cause the wire to overheat inside the panel and ignite.

Electrical Basics

- Ohms law

- Ohms Law is a mathematical equation that shows the relationship between Voltage, Current and Resistance in an electrical circuit. It is stated as:

$$V = I \times R$$

$$R = V / I$$

$$I = V / R$$

- Where
 - **V = Voltage**
 - **I = Current**
 - **R = Resistance**

A SUMMARY OF WHAT THE MATH MEANS

(Which assumes the Unmentioned Value stays Constant)

- If voltage increases, there will be an increase in current flow (amps)
- If resistance (OHMS) increases Amperage will decrease
- In all circuits, voltage is lost as it travels through the circuit. This is referred to as VOLTAGE DROP.
 - *Things Which Add Resistance To A Circuit:*
 - **Long wire runs to a load and back to the power source**
 - **Inadequate wire diameter (AWG Size)**
 - **Wire Type, (Material, # of Strands)**
 - **Loose or Corroded Connections**
- **Remember, the primary by-product of excessive resistance is heat!**

Wattage

Amps (current flow)

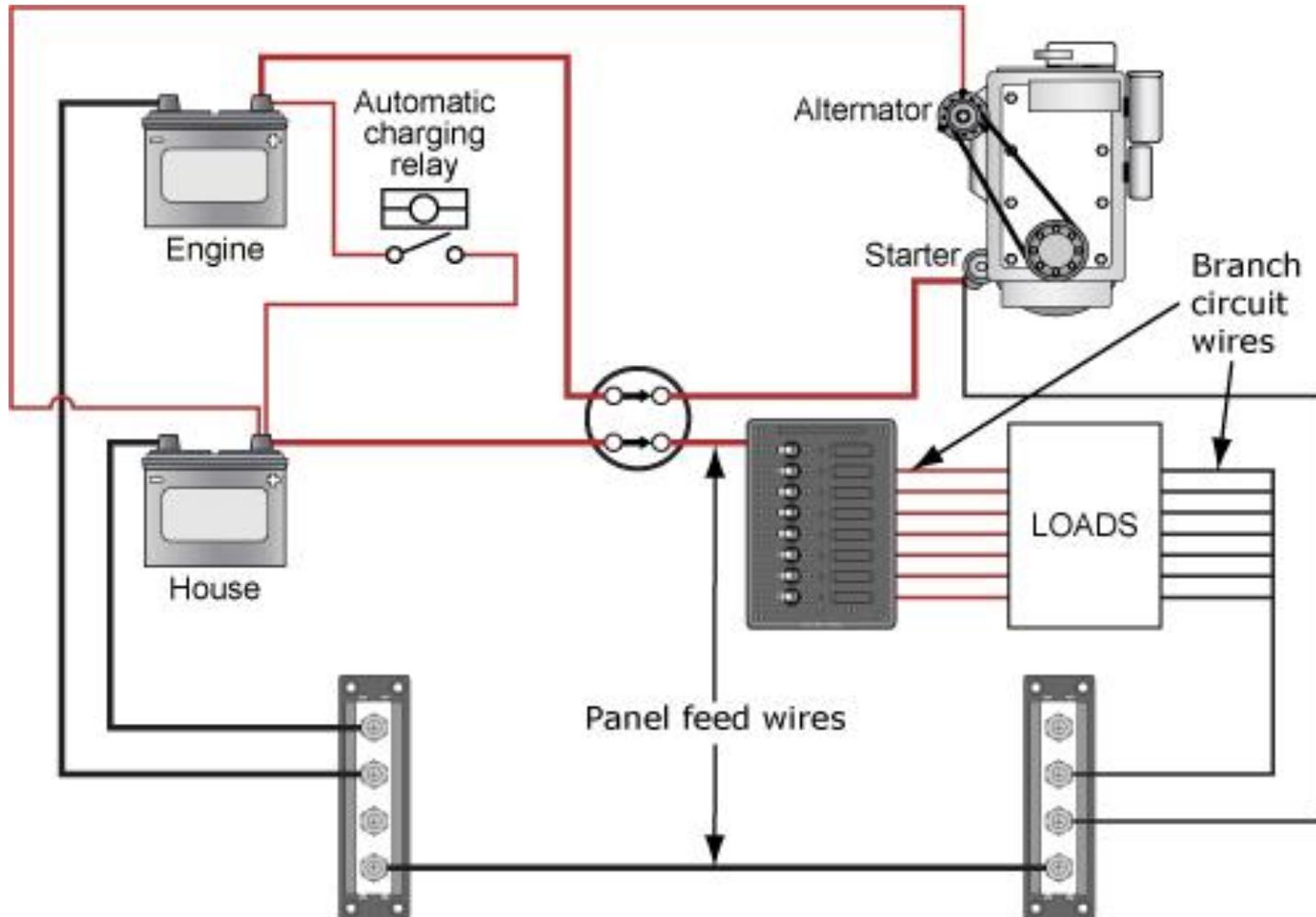
x

Volts (system voltage)

=

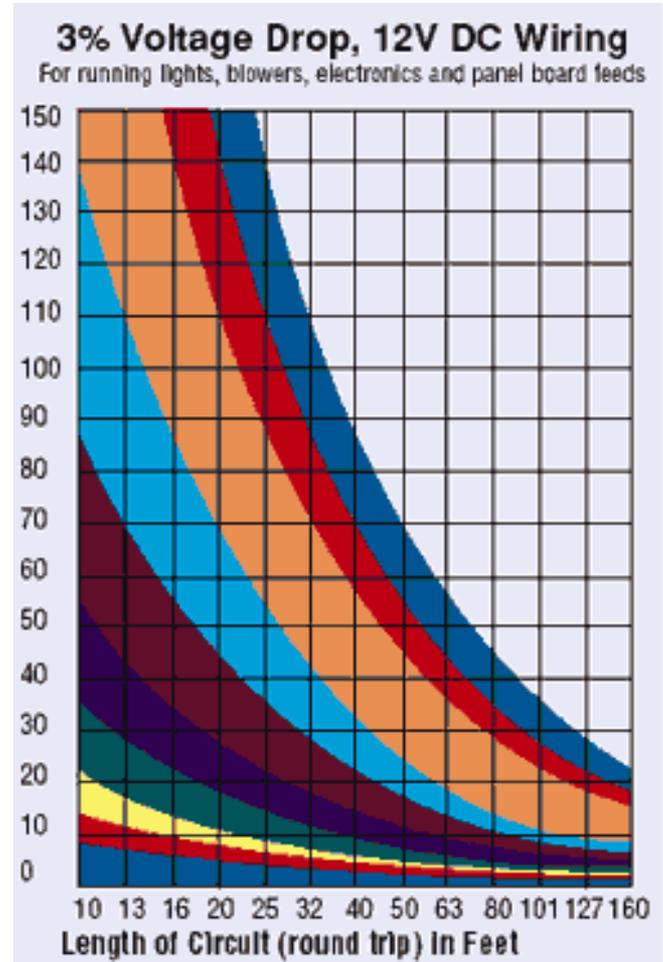
Watts (power, either production or consumption)

What size wire do I need?



DC WIRE SIZING

Allowable amperage of conductors under 50 Volts with 105 °C insulation						
AWG Wire Size	Metric (Sq mm)	AWG CM Area	SAE CM Area	Ohms /1000ft	Ampacity Engine Space	
					Outside	Inside
18	0.8	1,600	1,537	6.385	20	17
16	1	2,600	2,336	4.016	25	21.3
14	2	4,100	3,702	2.525	35	29.8
12	3	6,500	5,833	1.588	45	38.3
10	5	10,500	9,343	0.9989	60	51
8	8	16,800	14,810	0.6282	80	68
6	13	26,600	24,538	0.3951	120	102
4	19	42,000	37,360	0.2485	160	136
2	32	66,500	62,450	0.1563	210	178.5
1	40	83,690	77,790	0.1239	245	208
0	50	105,600	98,980	0.09827	285	242.3
2/0	62	133,100	125,100	0.07793	330	280.5
3/0	81	167,800	158,600	0.06180	385	327.3
4/0	103	211,600	205,500	0.04901	445	378.3



Blue Sea Circuit Wizard

MARINE GRADE WIRE

- **Marine Tinned Primary Wire**
- Constructed to American Wire Gauge standards, AWG wire is up to twelve percent larger than the equivalent SAE wire sizes. AWG wire provides a greater current capacity when compared to SAE gauge wire.
- Marine Tinned Wire and Cables are manufactured from tin coated copper strands for maximum protection against corrosion, electrolysis and resists fatigue due to vibration and flexing.
- Rated at 600 volts and 105 degrees C, the heavy duty insulation is resistant to heat and abrasion. Exceeds all UL1426, US Coast Guard Charterboat (CFR title 46) and ABYC standards.



MARINE GRADE TERMINALS AND TOOLS

Marine Grade Heat Shrink



Marine Grade Crimp Terminals



JUNK DO NOT USE ON A BOAT



ABYC E-11

- All conductors shall be supported and/or clamped at least every 18 inches to relieve strain on connections.

Like this



Not This



Circuit Protection

What is circuit protection?

- Circuit protection is the intentional installation of a "weak link" in an electrical circuit. This is a fuse or circuit breaker, referred to here as a circuit protection device.



Circuit Protection

What is the Circuit protection against?

- Prevention of wire conductor overheating and resulting burning of the wire insulation is the primary reason to install a fuse or circuit breaker. In some cases they are also installed to protect electrical or electronic equipment from damage.

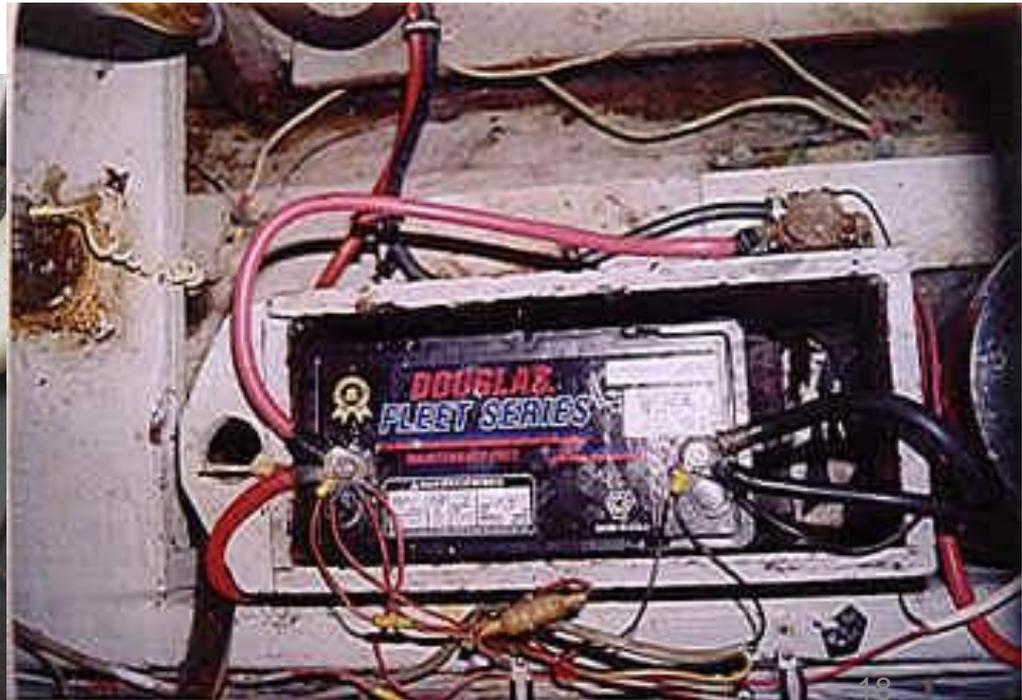
How does fire start in an electrical circuit?

- Fire results when too much amperage travels through a wire. Amperage is electron flow through a conductor. If too much amperage flows through a wire, enough heat can be generated to melt and burn the wire insulation or surrounding materials.

No Circuit Protection

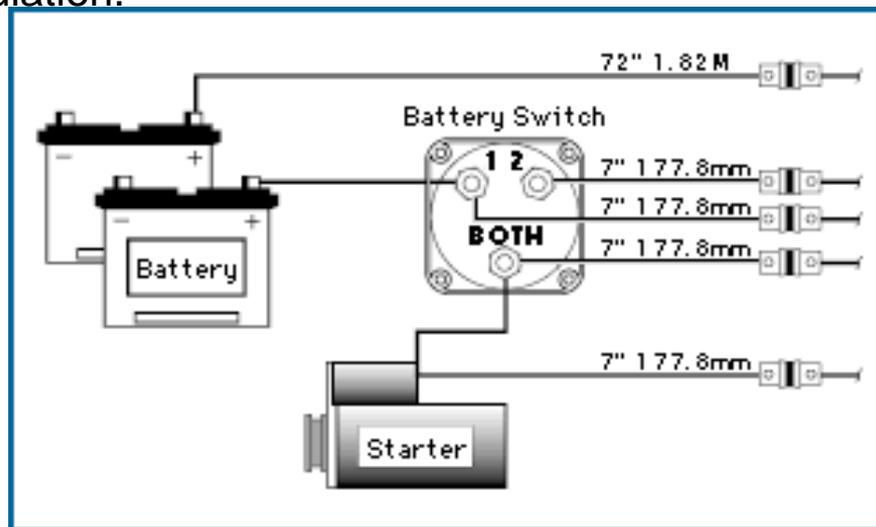
If you have electrical problems and your system looks something like this, then you needn't look much farther for the source of the problem.

Unfortunately this is seen to often

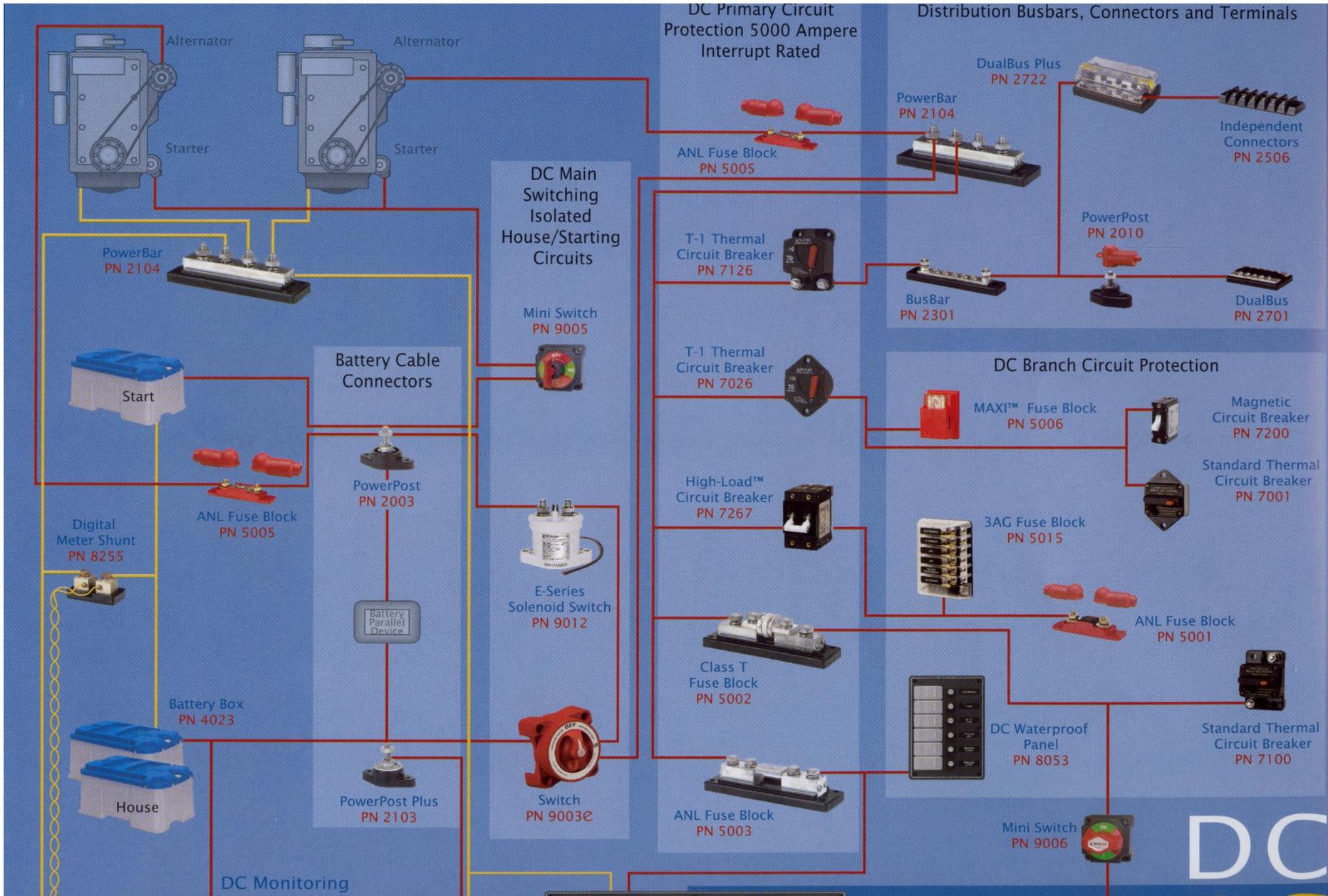


Circuit Protection

- **What wires need to have Circuit Protection installed?**
- The ideal answer is that every wire in the boat needs to be protected by a fuse or a circuit breaker. The Circuit Protection Device must be correctly sized to the wire it protects. As wires branch away from the batteries or other power source and become progressively lighter, smaller CPDs must be installed at the beginning of each wiring run.
- **ABYC Standards exempt wiring between the batteries, the main battery switch and the starter motor.** It is not that these wires do not require CPDs, but that it is often not practical to provide such protection. The diagram below shows where ABYC standards for CPD placement. Measurements are maximum lengths between the point of connection and the CPD. All 7" dimensions may be increased to 40" if the conductor is enclosed in a sheath or enclosure in addition to the wire insulation.



Circuit Protection



BATTERIES

Ampere Hour Rating (Reference Rating)

- This is the number of amps which a battery can deliver for a 20-hour period. This test is also referred to as the 20-hour rate. The larger the ampere hour rating, the more power the battery can deliver over time.

Marine Cranking Amps (MCA)

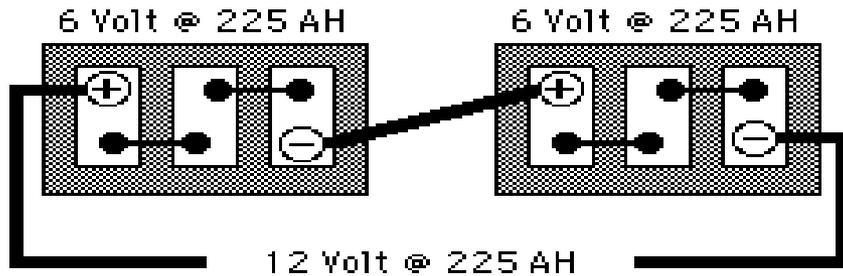
- This is the number of amps a battery can deliver at 32 degrees fahrenheit for 30 seconds, and maintain at least a voltage of 1.2 volts per cell. This differs from cold cranking amps which are measured at 0 degrees fahrenheit.

Reserve Capacity (RC)

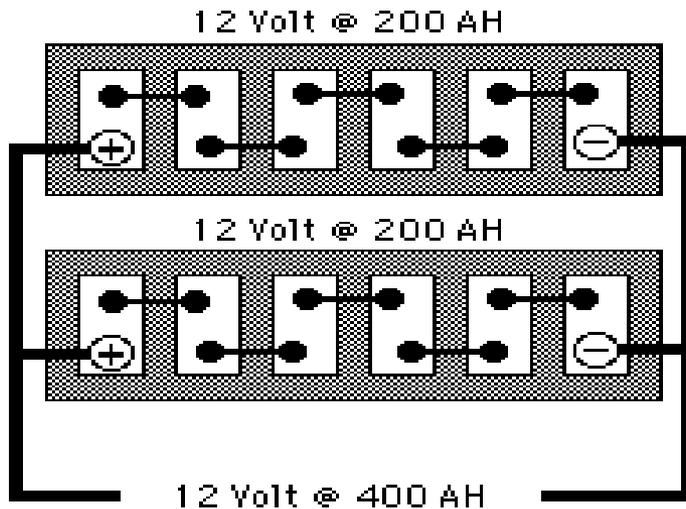
- This is the time, in minutes, for which a battery will deliver 25 amperes at 80 degrees fahrenheit. This represents the time which the battery will continue to operate essential accessories in the event of alternator or generator failure or while the key is off.

Batteries

Series Connection

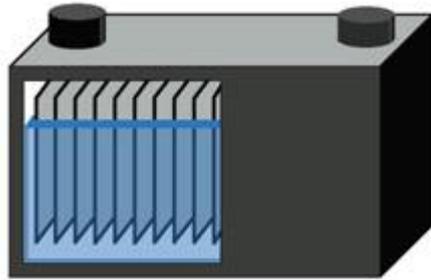


Parallel Connection



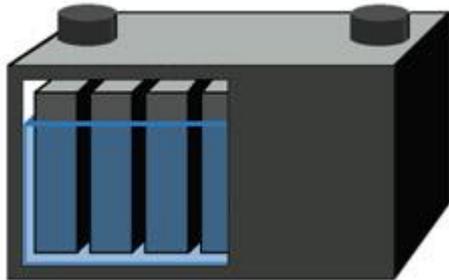
- **What happens to volts and amps?**
- Combining batteries in series multiplies voltage, capacity (Amp Hours) is unchanged (equivalent to the rating for one of the batteries in the series)
- Combining batteries in parallel multiplies the amperage
- Only combine batteries of like kind and vintage

Lead Batteries



Starter battery

The starter battery has many thin plates in parallel to achieve low resistance with high surface area. The starter battery does not allow deep cycling.



Deep-cycle battery

The deep-cycle battery has thick plates for improved cycling abilities. The deep-cycle battery generally allows about 300 cycles.

Lead Batteries

Depth of Discharge	Starter Battery	Deep-cycle Battery
100%	12–15 cycles	150–200 cycles
50%	100–120 cycles	400–500 cycles
30%	130–150 cycles	1,000 and more cycles

Advantages

Inexpensive and simple to manufacture; low cost per watt-hour
Low self-discharge; lowest among rechargeable batteries
High specific power, capable of high discharge currents
Good low and high temperature performance

Limitations

Low specific energy; poor weight-to-energy ratio
Slow charge; fully saturated charge takes 14-16 hours
Must be stored in charged condition to prevent sulfation
Limited cycle life; repeated deep-cycling reduces battery life
Flooded version requires watering
Transportation restrictions on the flooded type
Not environmentally friendly

AGM Batteries

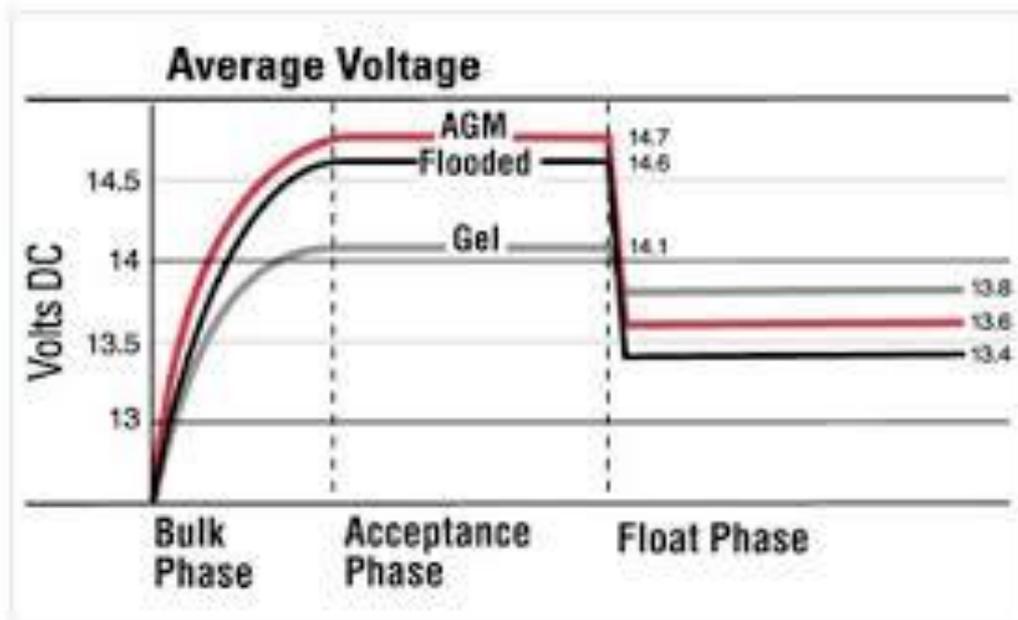
Advantages

Spill-proof through acid encapsulation in matting technology
High specific power, low internal resistance, responsive to load
Up to 5 times faster charge than with flooded technology
Better cycle life than with flooded systems
Water retention (oxygen and hydrogen combine to produce water)
Vibration resistance due to sandwich construction
Stands up well to cold temperature

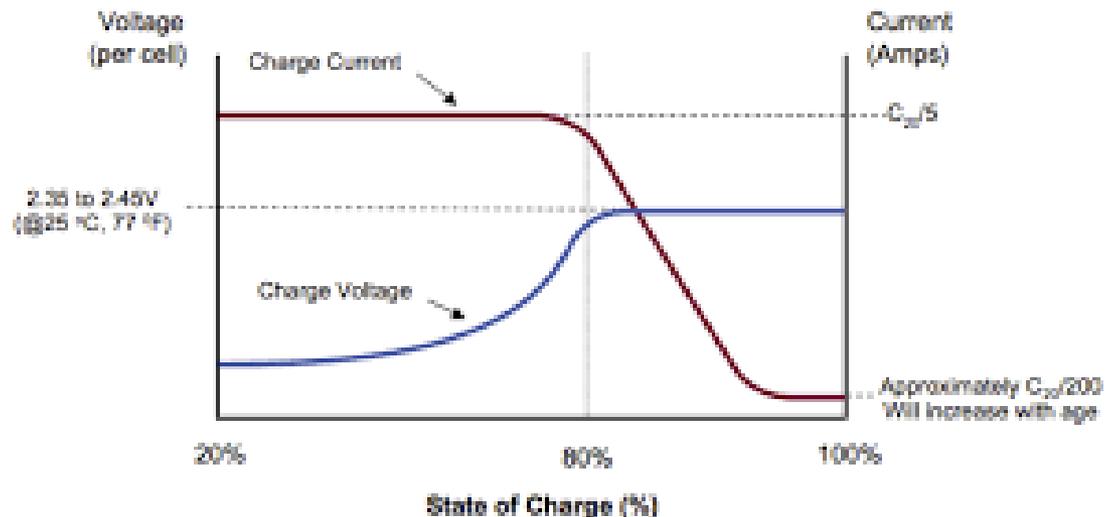
Limitations

Higher manufacturing cost than flooded (but cheaper than gel)
Sensitive to overcharging (gel has tighter tolerances than AGM)
Capacity has gradual decline (gel has a performance dome)
Low specific energy
Must be stored in charged condition (less critical than flooded)
Not environmentally friendly (has less electrolyte, lead than flooded)

Charging Characteristics



Recommended Trojan AGM Charging Profile



How long will they last ?

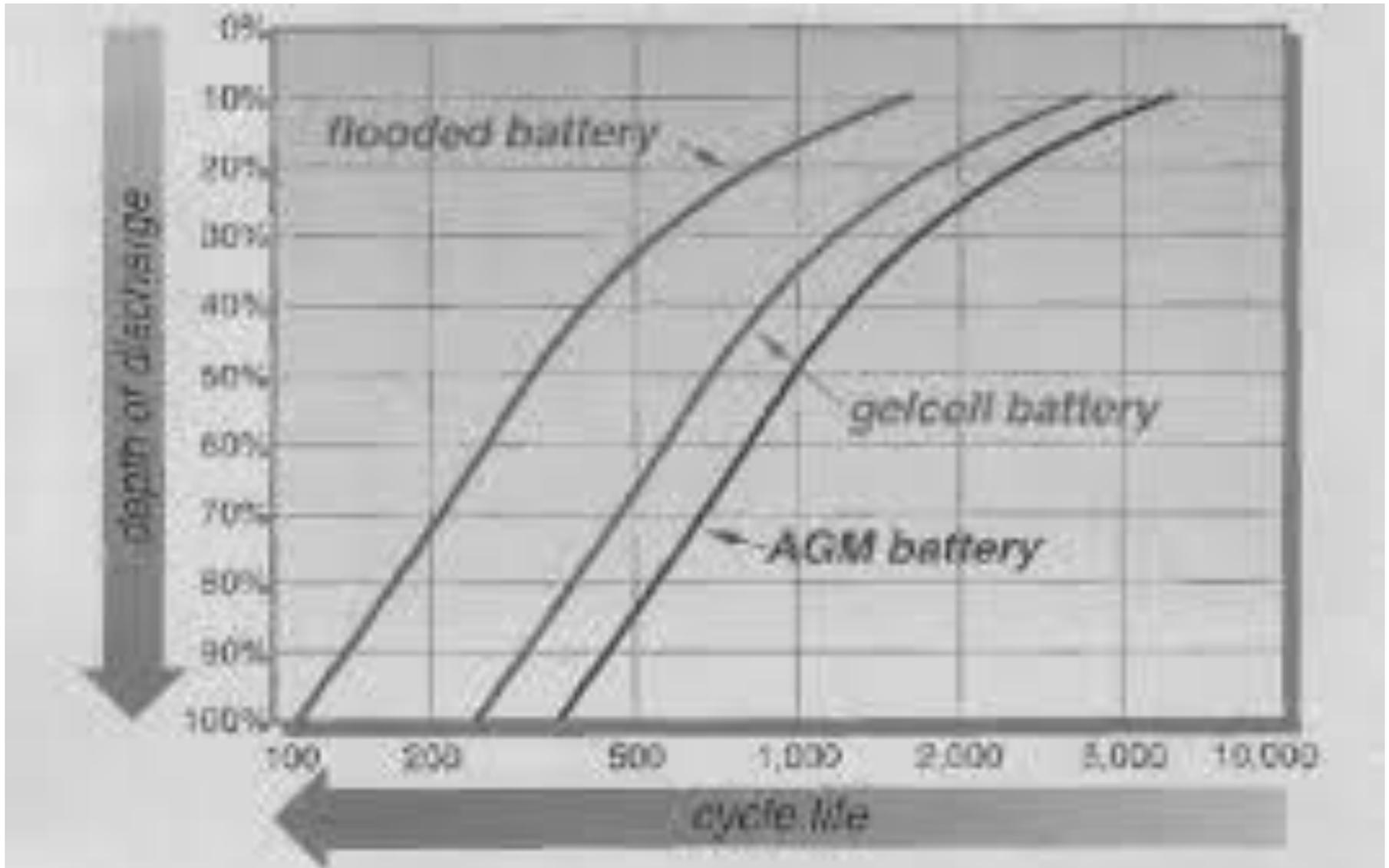


Figure 2: Cycle life compared to depth of discharge for flooded, gelcell, and AGM batteries

Sizing Your House Battery Bank

Item	Item Amperage	Hours of Expected Use	Daily Amp Usage
Autopilot	4	20	80
Marine VHF	0.2	24	4.8
Stereo	2	12	24
Nav Computer	0.5	24	12
LED Nav Lights	0.3	12	3.6
LED Cabin Lights	0.3	4	1.2
Camera/Phone Chargers	0.5	3	1.5
		Total Daily Amp Draw:	127.1

Sizing Your House Battery Bank

Group Size	Typical Ah Rating	Nominal Voltage
U1	34 - 40Ah	12 Volts
Group 24	70 - 85Ah	12 Volts
Group 27	85 - 105Ah	12 Volts
Group 31	95 - 125Ah	12 Volts
4-D	180 - 215Ah	12 Volts
8-D	225 - 255Ah	12 Volts
Golf Cart	180 - 225Ah	6 Volts
L-16	340 - 415Ah	6 Volts

Battery Chargers



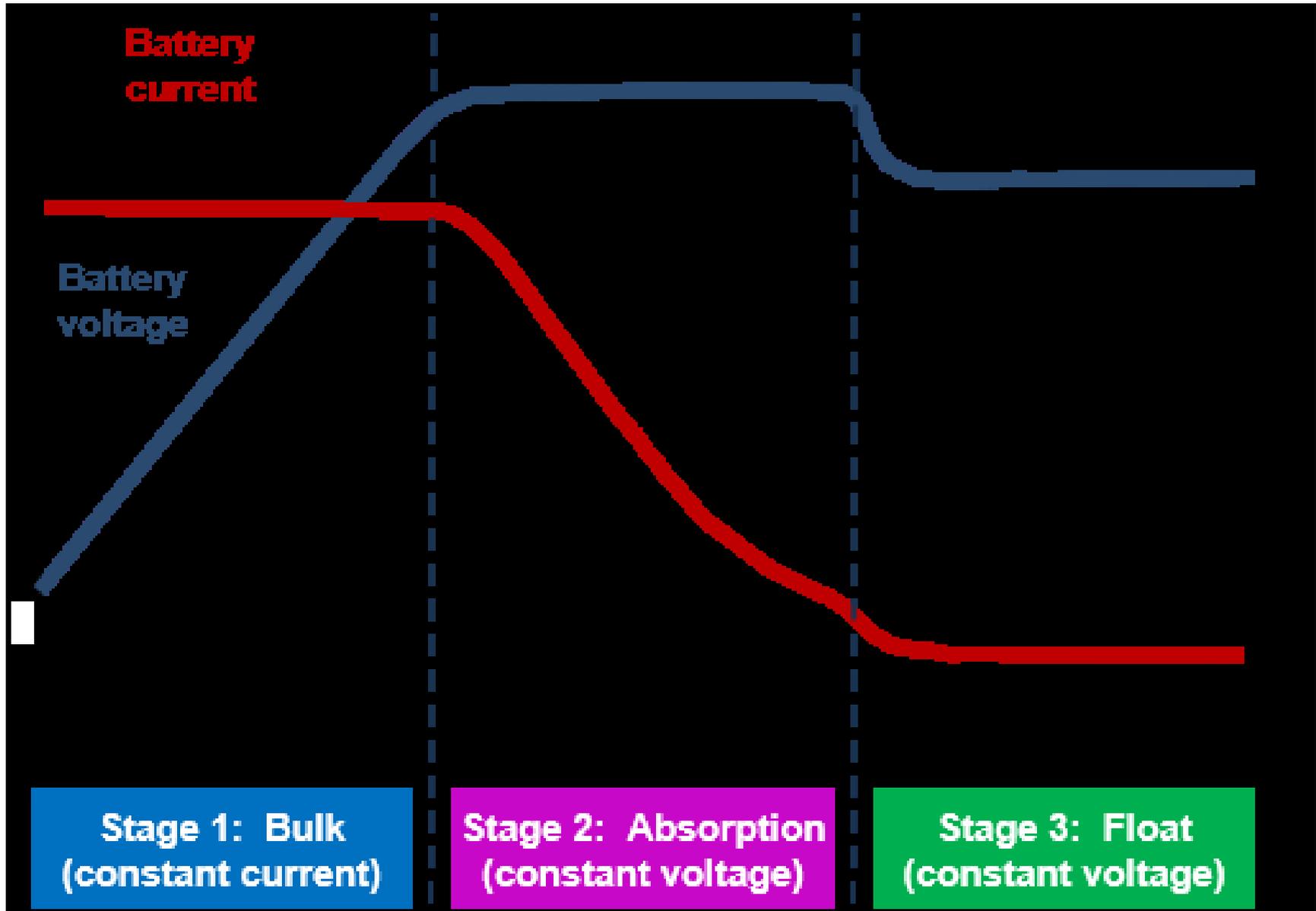
Ferroresonant Chargers

- The better chargers work ok on wet cell batteries
- Do not do a good job on AGM and Gel batteries
- May cause premature battery failure because of constant overcharging

If you have one, replace it



Three Stage Battery Charger



Battery Charger Wiring

MOUNTING

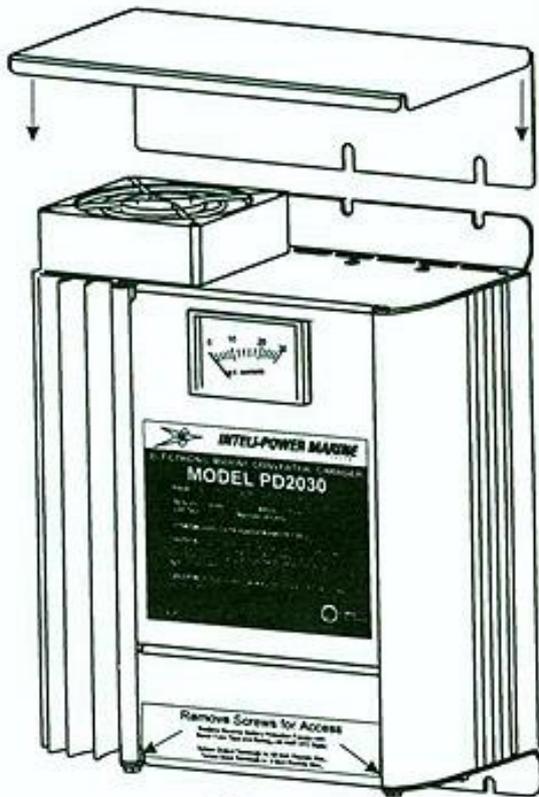


Figure 1

WIRING DIAGRAM

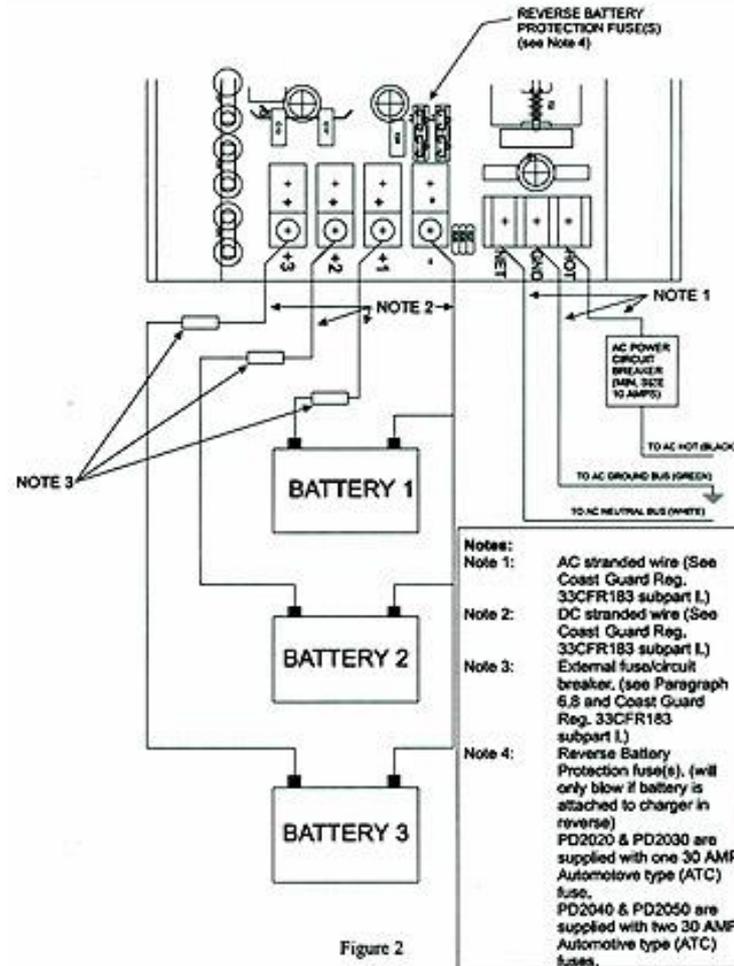


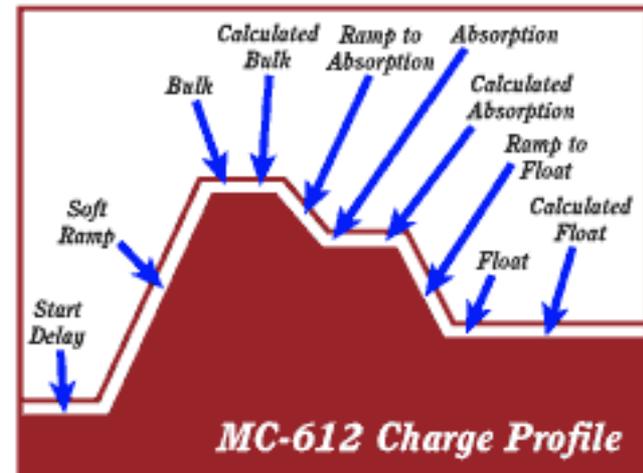
Figure 2

Alternators



- **Internal or external regulators**
- In automotive type alternators, current for the alternator is supplied by an internal regulator, which drives the alternator to a specific voltage value (usually about 14.1 volts), which works great for a starting battery, just like the one in your car.
- Deep cycle and sealed gel and AGM marine batteries require a more complex program of charging voltages to achieve their optimal charge. Multi-stage external voltage regulators, like the Balmar Max Charge and ARS-5 enable the alternator to vary charging voltages, based on the battery's temperature, chemistry (flooded, gel or AGM types) and level of discharge, to ensure that batteries are recharged quickly and safely.

SMART REGULATORS



Preset Battery Programs:

1. Universal Factory
2. Deep Cycle Acid
3. Gel
4. AGM
5. Standard Lead Acid
6. Optima
7. Halogen/Voltage Sensitive

Advanced Programming:

1. Delay Time
2. Compensation Limit
3. Minimum Field Value
4. Bulk Voltage
5. Bulk Time
6. Absorption Voltage
5. Absorption Time
6. Float Voltage
7. Float Time
8. Amp Manager
9. Equalize Voltage
10. Equalize Time

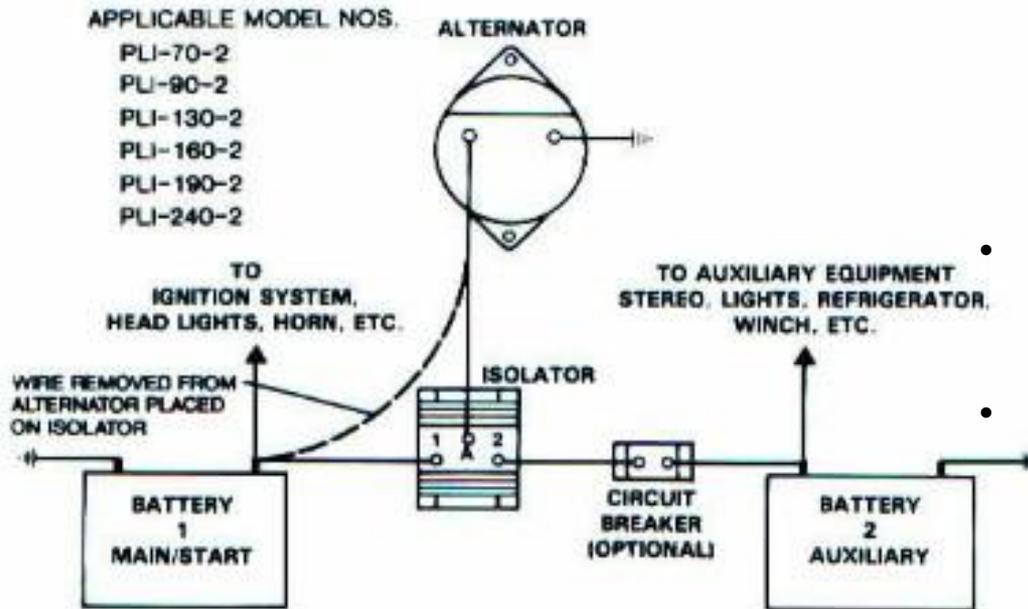
Alternators

- The Rule of thumb is that the alternator output in amps should not be less than 25% of the battery capacity in amp hours for lead batteries and 40% for AGM.
- You can figure 1 hp draw per 25 amps (12 volt) at maximum output.

Belt Type	Belt Width	Max. HP Load	Highest Recommended Output
Single Vee	3/8	3.5	80A @ 12V, 30A @ 24V
Single Vee	1/2	4.5	110A @ 12V, 45A @ 24V
Dual Vee	1/2	12	310A @ 12V, 220A @ 24V

Charging Multiple Battery Banks

The Battery Isolator



APPLICATION: 1 ALTERNATOR - 2 BATTERY

- IT'S IMPORTANT TO REMEMBER THAT IF A BATTERY ISOLATOR IS INSTALLED, VOLTAGE SENSING FOR THE ALTERNATOR MUST BE DONE AT THE BATTERIES, OR AT LEAST ON THE BATTERY SIDE OF THE ISOLATOR.
- THIS IS DUE TO THE INHERENT 0.7 V LOSS THROUGH THE ISOLATOR DIODES.
- ALSO, ISOLATORS MUST BE RATED FOR THE MAXIMUM ALTERNATOR AMPERAGE OUTPUT
- Battery Isolators are made with two or more silicon diodes that act like check valves. The diodes will pass current from the charging source to the batteries, but will not pass current backward from one battery to the other or back to the charging source.

A Better Way

BATTERY COMBINERS

- Automatically combines battery banks during the charging cycle and isolates under discharge
- Ignition protected - safe for installation aboard gasoline-powered boats
- Activates from any charging source - alternators, battery chargers, or solar panels
- Requires circuit protection device at batteries



- 60 Amperes
- Current Limiting
- 12 Volt
- Dual or single sensing



- 120 Amperes
- Waterproof rated IP67
- 12/24 Volt
- Dual sensing

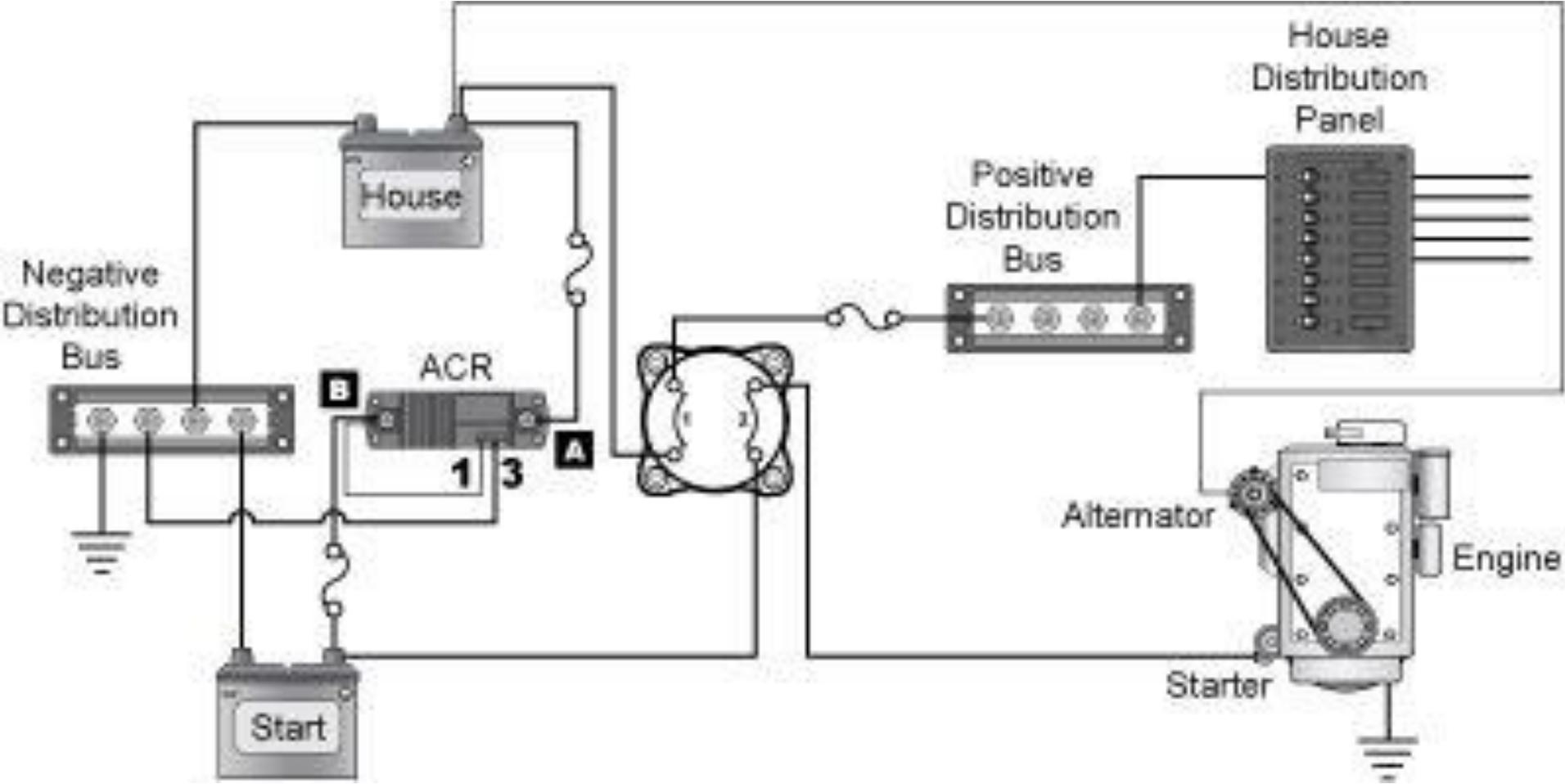


- 400 Amperes
- Low power consumption
- 12/24 Volt
- Dual or single sensing



- The ACR has two parts:
- A relay – a switch that is activated by an electrically powered magnetic coil.
- An electronic circuit that senses the voltage level of the boat's batteries and signals the relay switch:
- Closed when voltage is high (the ACR's COMBINE voltage)
- Open when voltage is lower (the ACR's UNDERVOLTAGE voltage)

Battery Combiner Diagram

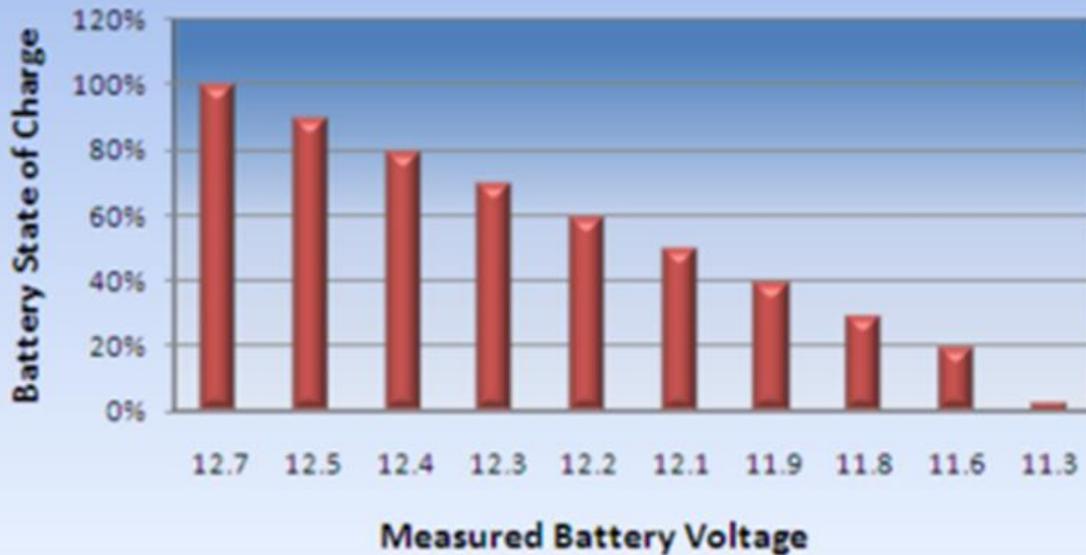


Effect of Solar and Wind Energy on Marine Battery Charging



How do you know if your batteries are properly charged?

Battery State of Charge vs Voltage



Battery Monitors



- **Electrical Specifications**
- Voltage Measurement
- 0 - 35.0 VDC (+/-0.01 V resolution)
- Current Measurement
- -500 - 500 A
- Amp-Hour Measurement
- High range +/- 200 - 1,999 Ah (1 hour resolution)
- Battery Capacity Range
- 200 - 2000 Ah



- Read your battery bank like a fuel gauge
- Provides critical information about the status of your battery bank
- Displays voltage, current, consumed amhours and remaining battery capacity
- Secondary battery bank voltage monitoring

What they tell you



VOLTAGE



AMPS



AMPERE HOURS



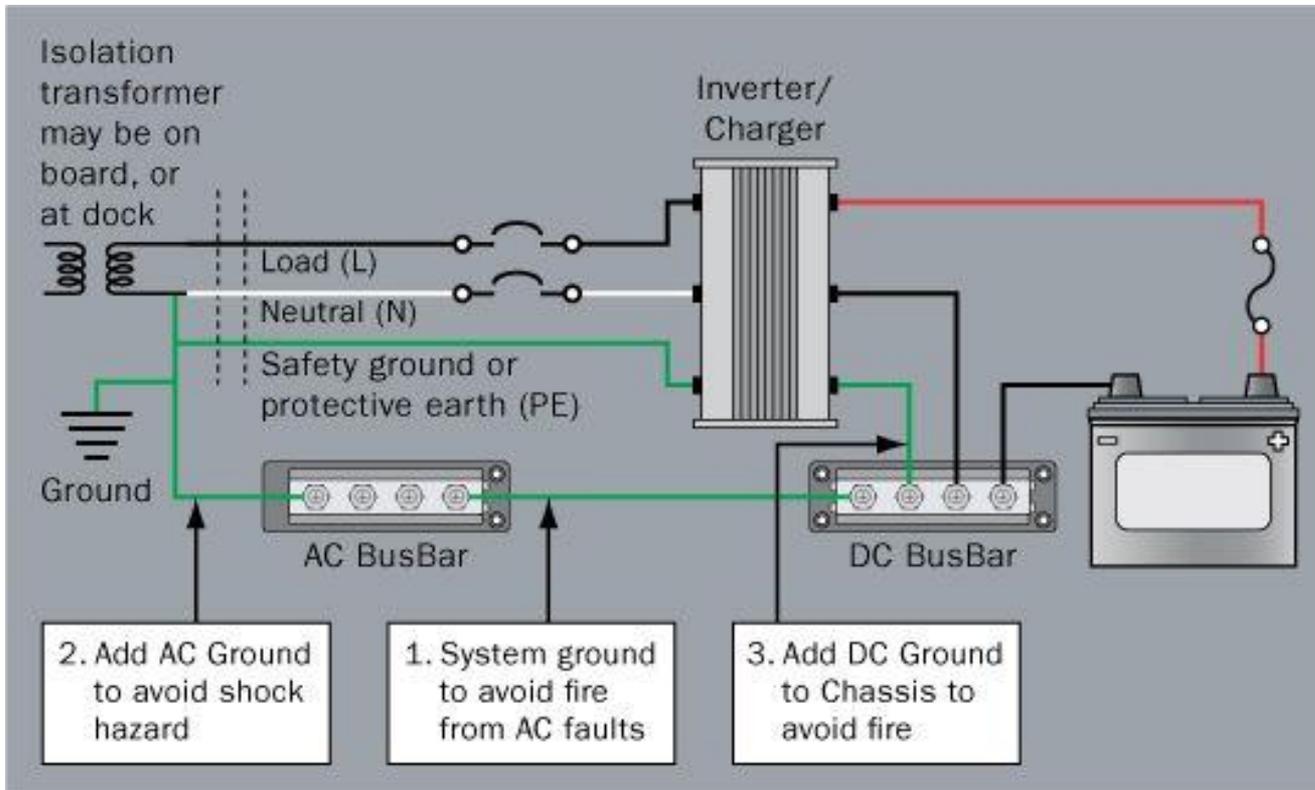
% REMAINING



TIME REMAINING

The ePRO Battery Monitor has been pre-programmed at the factory to suit the selected Lithium system and is software locked. There is no setup interaction required by the end user.

INVERTERS



- **A-25.5 REQUIREMENTS - IN GENERAL**

A-25.5.1 If the inverter also serves as a battery charger, it shall also meet the requirements of ABYC A-20, Battery Charging Devices.

NOTE: An inverter incorporating a battery charging circuit that meets UL 458, Power Converters/Inverters and Power Converter/Inverter Systems for Land Vehicles and Marine Crafts, and Supplement SA, Marine Power Converters/Inverters and Power Converter/Inverter Systems, need not meet UL 1236 as referenced in ABYC A-20, Battery Charging Devices.

A-25.5.2 Output voltage and frequency shall be in accordance with ABYC E-8, Alternating Current (AC) Electrical Systems On Boats.

EXCEPTION: Inverters dedicated to supply power to only a specific piece of equipment.

A-25.5.3 All marine power inverters shall meet the applicable requirements of UL 458, Power Converters/Inverters and Power Converter/Inverter Systems for Land Vehicles and Marine Crafts, and Supplement SA, Marine Power Converters/Inverters and Power Converter/Inverter Systems.

A-25.5.4 Power inverters shall be automatically controlled to provide frequency and voltage regulation compatible with section 27 of UL 1248, Engine-Generator Assemblies for Use in Recreational Vehicles.

A-25.5.5 Power inverters shall provide isolation of the AC output from the DC supply circuit.

A-25.5.6 Integral inverter receptacle shall be protected by an integral GFCI device in accordance with ABYC E-8, Alternating Current (AC) Electrical Systems On Boats. The receptacle is to be used only with cord connected loads.

A-25.5.7 A visible means (e.g., voltmeter or lamp) of determining that the inverter is "on line" and/or in "stand-by" mode shall be provided at the main electrical distribution panel.

A-25.5.8 A warning label shall be provided at the main electrical panel to indicate that the electrical system includes an inverter. See A-25.10.1.

A-25.5.9 Grommets, bushings, or other means shall be provided to prevent chafing of wires passing through the inverter case.

A-25.5.10 Safety signs and labels shall comply with ABYC T-5, Safety Signs and Labels, and shall contain at least the following informational elements:

A-25.5.10.1 The signal word for the hazard intensity level; and

A-25.5.10.2 the nature of the hazard; and

A-25.5.10.3 the consequences that can result if the instructions to avoid the hazard are not followed; and

A-25.5.10.4 instructions on how to avoid the hazard.

- **A-25.6 INSTALLATION AND LOCATION**

A-25.6.1 The installation and protection of electrical wiring associated with inverters shall comply with ABYC standards ABYC E-8, Alternating Current (AC) Electrical Systems on Boats, and ABYC E-9, Direct Current (DC) Electrical Systems On Boats.

A-25.6.2 Inverters shall be installed:

A-25.6.2.1 in a ventilated, dry, accessible location; and

A-25.6.2.2 where the ambient temperature will not exceed 122°F (50°C); and

A-25.6.2.3 away from heat sources, such as dry engine exhaust and other heat producing devices.

A-25.6.3 Inverters shall not be installed directly over batteries.

A-25.6.4 Inverter controls shall be readily accessible.

A-25.6.5 Inverters shall be located so that hinged covers and access plates can be opened.

A-25.6.6 Inverters shall be securely fastened to bulkheads or other vessel structural parts.

A-25.6.7 When mounted, the base of the inverter shall be at least two feet above normal bilge water, or protected so it is not subject to bilge splash.

A-25.6.8 The installer shall provide physical protection from falling objects or drippage unless such provision is integral to the inverter.

A-25.6.9 Overcurrent protection in the DC input circuit shall comply with the requirements of ABYC E-9. This protection is intended to protect the wiring in the DC circuit.

NOTE: See ABYC E-9 for battery switch requirements.

A-25.6.10 If ground fault circuit interruption is provided in the output of the inverter, the ground fault interrupter shall not be located in a compartment requiring ignition protection, unless it is ignition protected as provided in SAE J-1171 or UL 1500.

A-25.6.11 An inverter that does not have an integral ground fault protection device and is installed so that GFCI protection is required by ABYC E-8, shall have the required GFCI device(s) specified by the inverter manufacturer as to GFCI manufacturer and model number.

NOTE: Harmonic distortion of the AC output waveform from some inverters may affect the operation of some GFCI devices.

A-25.6.12 Power inverters installed in spaces requiring ignition protection shall meet the ignition protection requirements of SAE J1171 or UL 1500. See A-25.10.2 for labeling requirements.

NOTE: For information on spaces requiring ignition protected equipment see 33 CFR 183.410; ABYC A-1, Marine Liquefied Petroleum Gas (LPG) Systems; ABYC A-22, Marine Compressed Natural Gas (CNG) Systems; ABYC E-8, Alternating Current (AC) Electrical Systems On Boats; ABYC E-9, Direct Current (DC) Electrical Systems On Boats; and ABYC H-24, Gasoline Fuel Systems.

A-25.6.13 A means to achieve strain relief shall be installed within six inches of the case unless a strain relief method is integral with the case for wiring passing through.

- **A-25.7 AC WIRING CONNECTIONS**

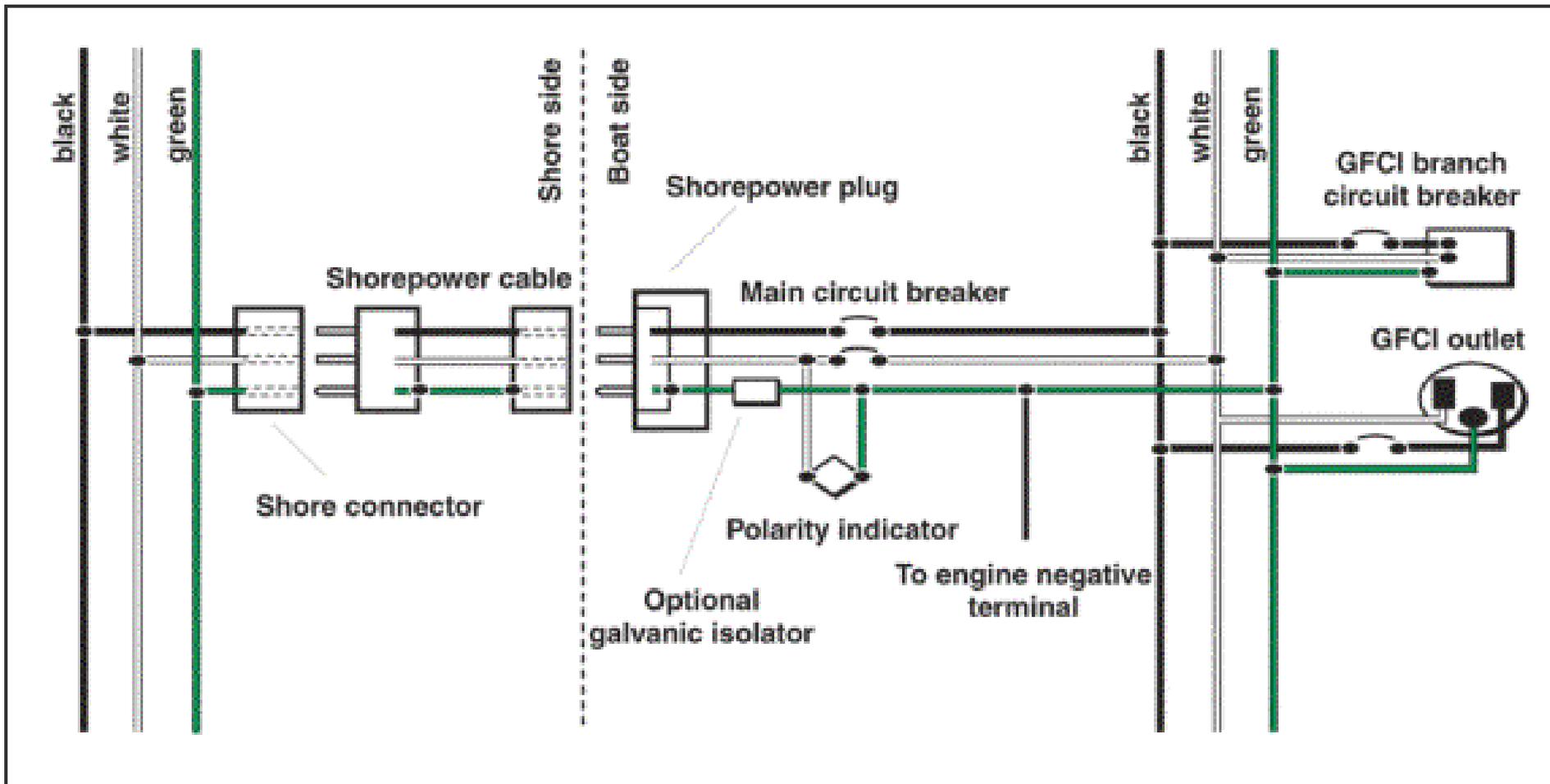
A-25.7.1 ABYC E-8, Alternating Current (AC) Electrical Systems On Boats, requires a grounded neutral system. The neutral for AC power sources shall be grounded only at the following points:

A-25.7.1.1 The shore power neutral is grounded through the shore power cable and shall not be grounded on board the boat.

A-25.7.1.2 The inverter output neutral shall be grounded at the inverter.

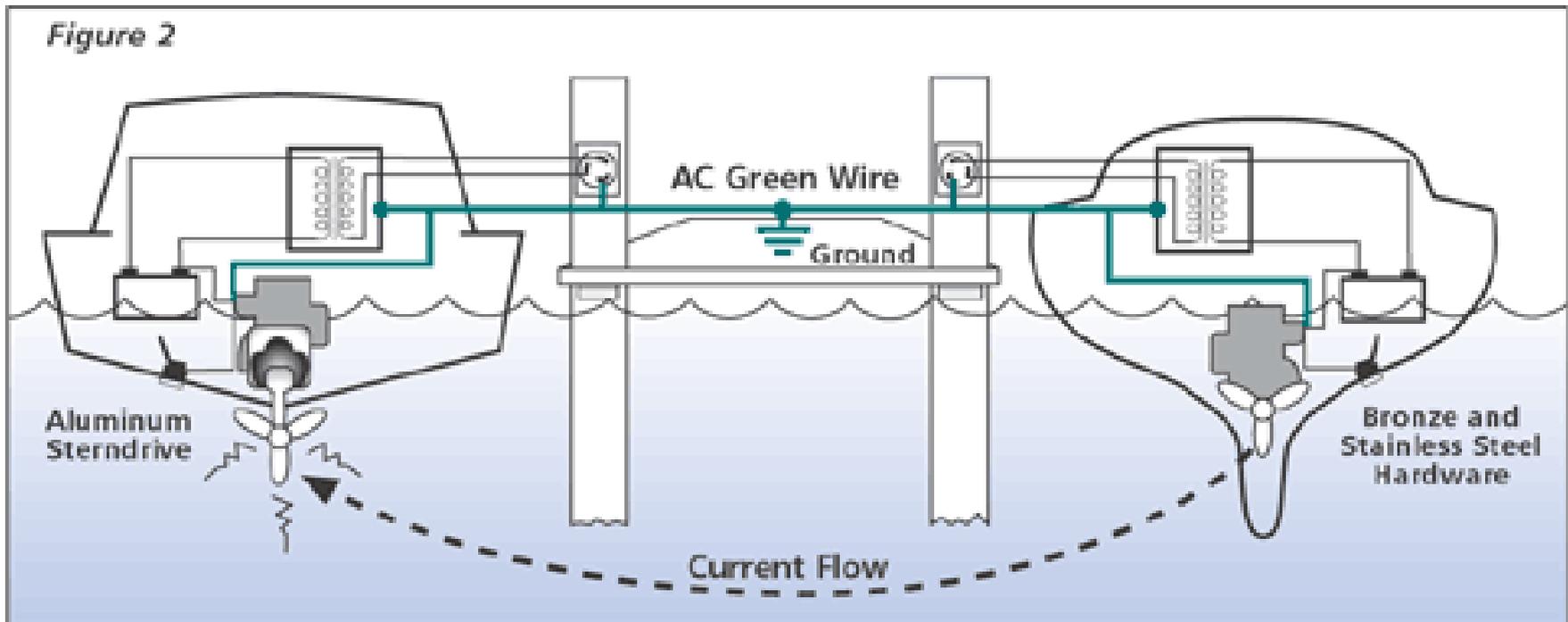
A-25.7.1.2.1 The inverter/charger output neutral shall be grounded at the inverter/charger.

AC Systems



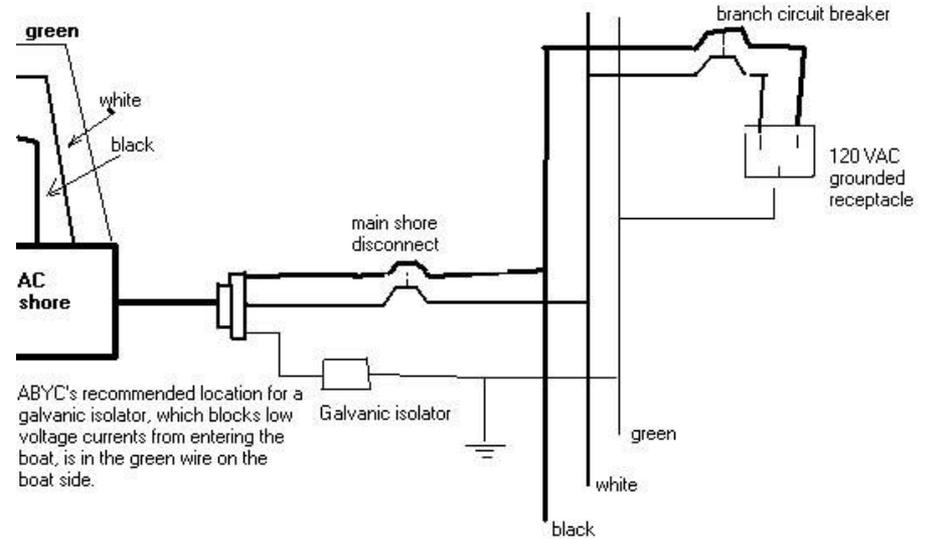
Galvanic Isolators

- **What is a galvanic isolator and why should my shore power system have one?**
- A galvanic isolator is a device used to block low voltage DC currents coming on board your boat on the shore power ground wire. These currents could cause corrosion to your underwater metals; through hulls, propeller, shaft etc.
- Boats in a marina plugged into shore power all act as a giant battery. They are all connected together by the green shore power ground wire, which is (or should be) connected to their DC grounds, engine block, and bonded underwater metals. (Required by ABYC If the boats are in salt water then that forms an electrolyte and the dissimilar metals connected together act as a battery, causing corrosion.



GALVANIC ISOLATOR

OLD STYLE ISOLATOR



- DUE TO THE INHERENT VOLTAGE DROP THAT OCCURS ACROSS A DIODE – TYPICALLY 0.6 V TO 0.7 V –
- GALVANIC ISOLATORS CAN BE USED TO EFFECTIVELY BLOCK GALVANIC CURRENTS UP OT ABOUT 1.4 V. BY PUTTING TWO DIODES IN SERIES

Fail Safe Galvanic Isolators



Fail-safe construction featuring Fail-Safe Plus™ and Fail-Safe Max™ technology

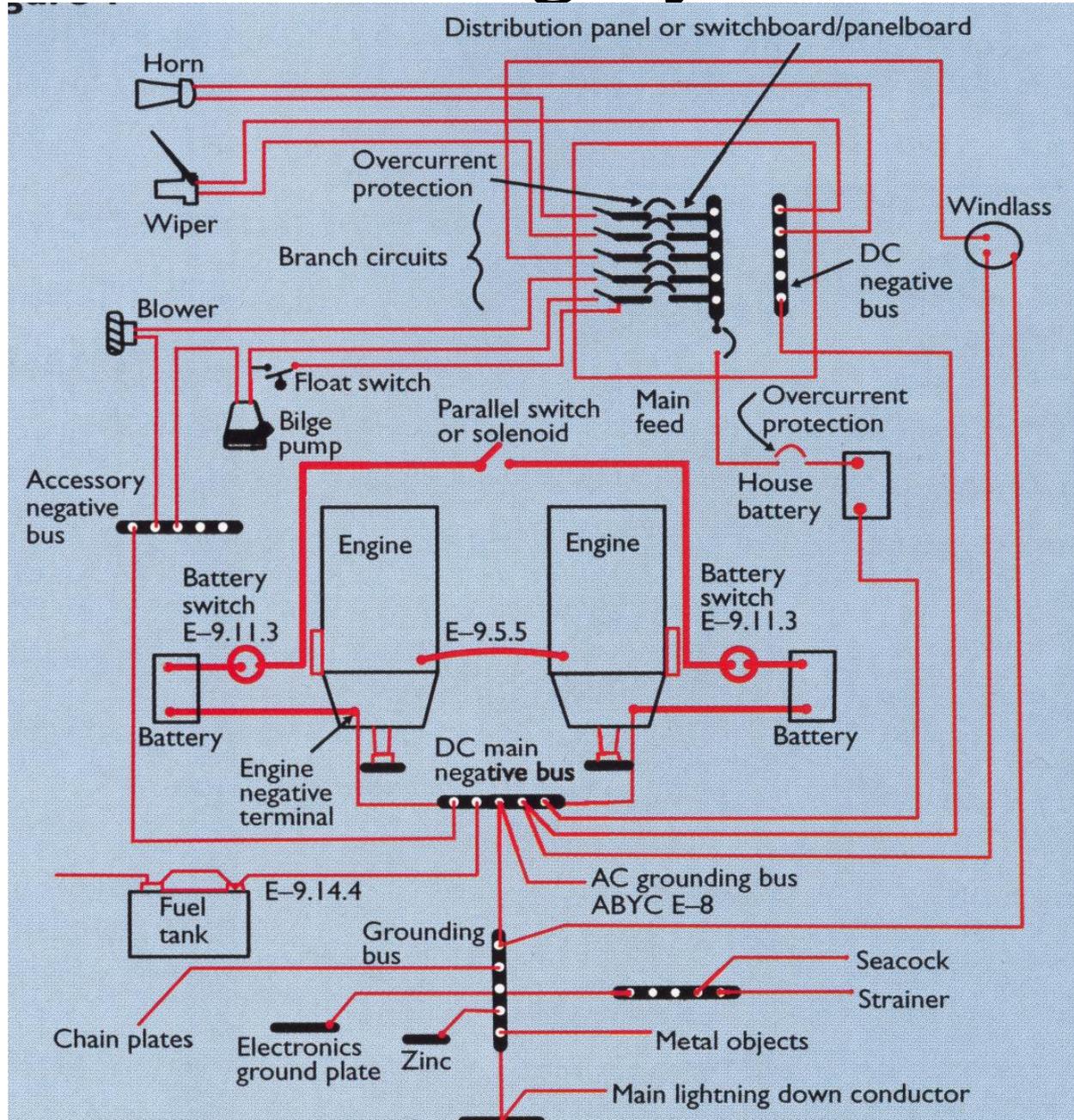
- Certified to ABYC A-28 July 2008 publication
- No monitoring system required
- Highest AC fault current ratings available
- Ignition protected
- Maintenance-free solid-state design
- Rated for high levels of lightning current
- Very low DC leakage current allowed

Grounding System

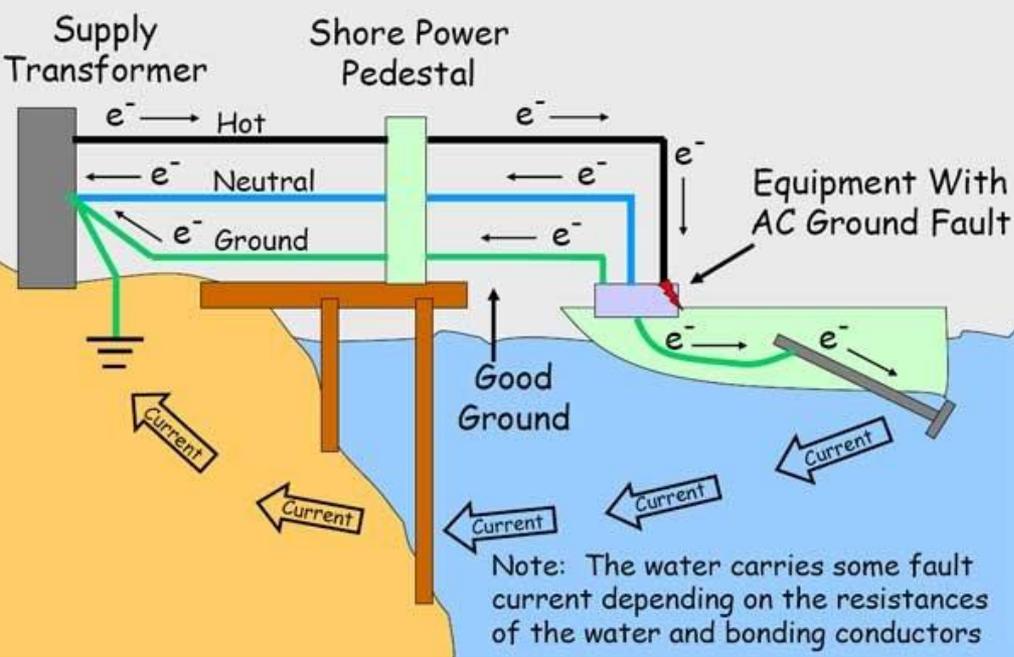
Multiple Roles of the Grounding System

- Prevent electrical shock hazard to people on board
 - In the event of an electrical fault in a AC appliance it is essential to provide a reliable path for this fault current back to the source of power, not through the person coming into contact with the device
- Prevent stray current corrosion
 - Equalize voltage potentials among dissimilar metal objects exposed to seawater.
Bonding systems – and cathodic protection (properly sized and placed anodes)
- Lightning Protection
- Radio Frequency Interference reduction
- Note : The AC Ground buss (green wire) is connected to the DC Negative Buss

Grounding System

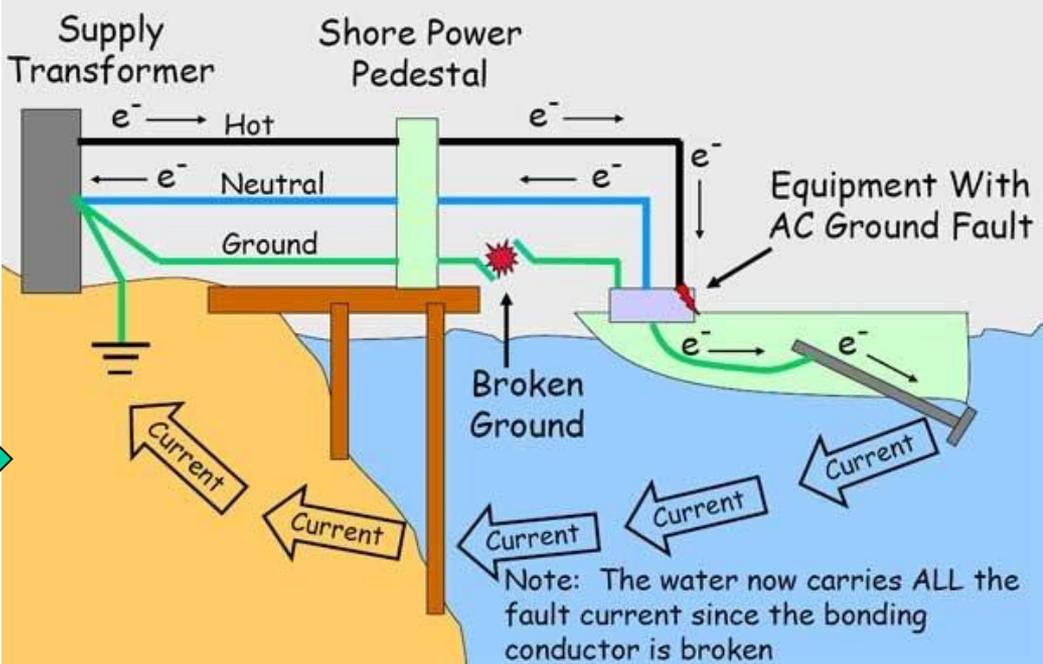


Electric Shock Drowning



Good Ground

Broken Ground



Note: The water now carries ALL the fault current since the bonding conductor is broken

Effects of a Lightning Strike

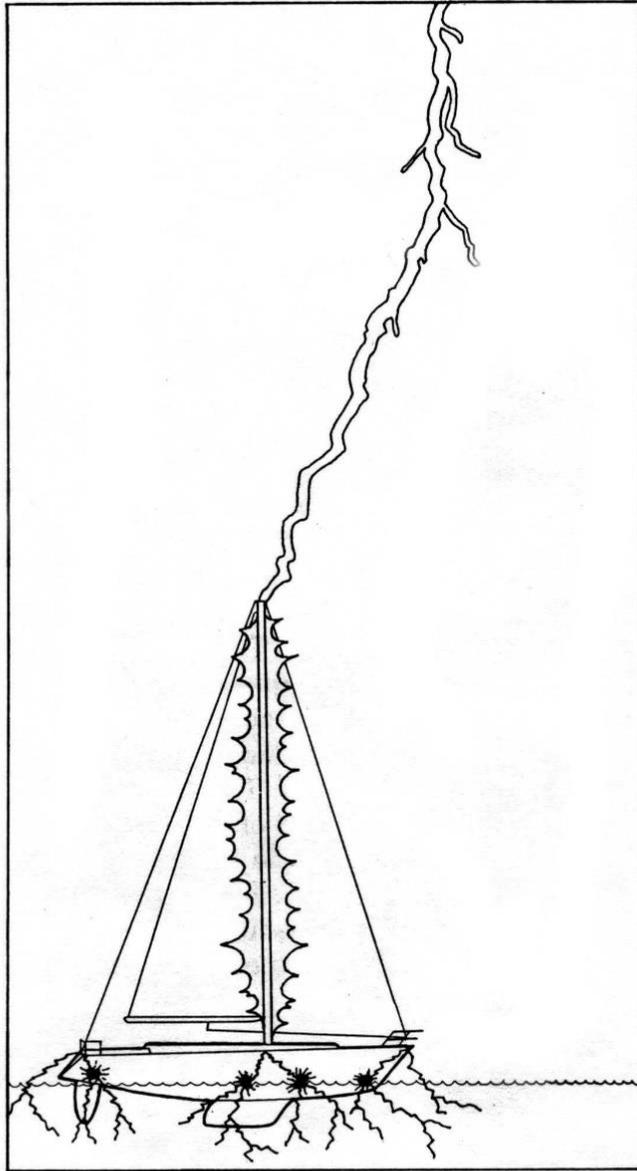


Figure 4. Possible effects of a lightning strike to an ungrounded boat.

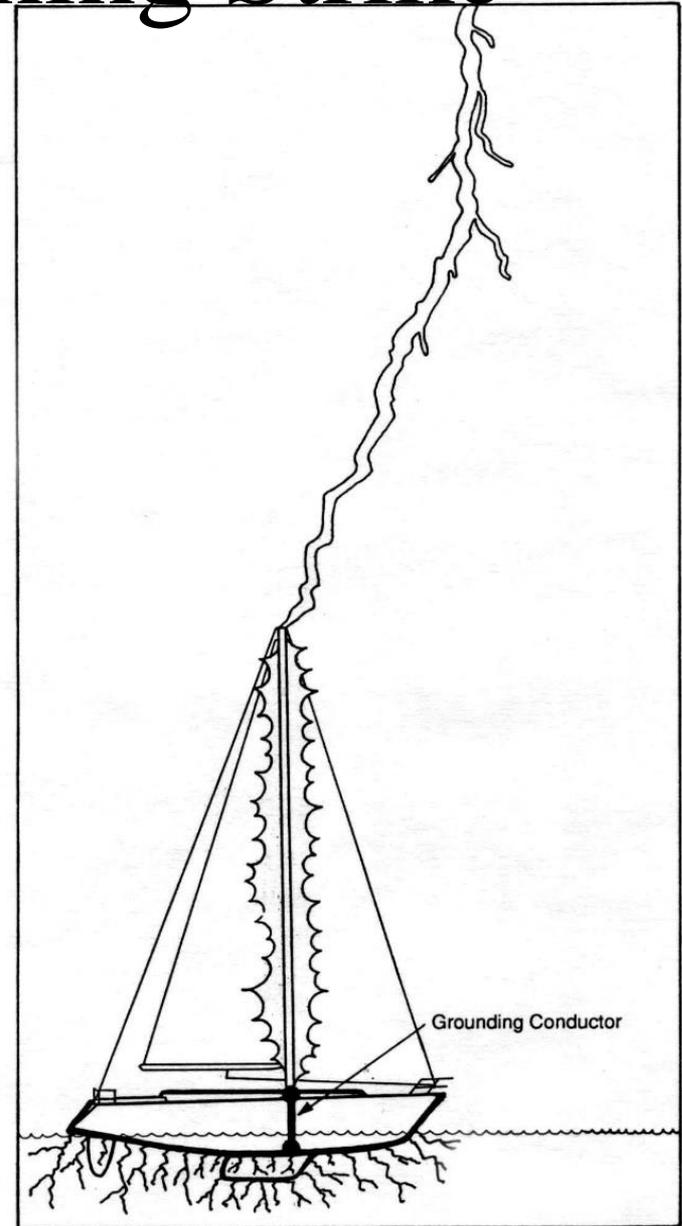


Figure 5. Effects of lightning strike to a grounded boat.

Lightning Grounding

- Connect a AWG 4 battery cable from the base of your aluminum mast to the nearest keel bolt from external ballast. If you have internal ballast, you should install a lightning ground plate. One square foot is recommended for use in salt water; fresh water requires much more. Do not rely on a thru-hull or a sintered bronze radio ground (e.g. Dynaplate) for use as a lightning ground.
- For additional comfort, also run a 6 AWG wire from your keel bolt or ground plate to the upper shroud chainplates, and to your headstay chainplate. Don't bother with the backstay if it is interrupted with antenna insulators. Have each of the cables that are used for lightning ground wires lead as directly as possible to the same keel bolt, with any necessary bends being smooth and gradual.
- Given that you have grounded your mast solidly to the ocean, your mast will be at exactly the same electric potential as the ocean. There is no chance that you can dissipate the charge between the ocean and the atmosphere, so don't bother with a static dissipater at the masthead. Wire "bottle brush" static dissipaters may be useful to dissipate seagulls.

Recommended Books



Boatowner's Mechanical and Electrical Manual, third edition

Nigel Calder

Maintain, repair, and improve a boat's essential systems. A comprehensive guide to electrical, mechanical, and propulsion systems.

Sailboat Electrical Systems: Improvement, Wiring and Repair

Don Casey

A basic treatment for recreational sailboats and powerboats. A good book for maintenance and repair.

Sailboat Electrics Simplified

Don Casey

How to install wiring, make good, safe connections, match your battery bank and alternator to your needs, troubleshoot problems quickly, and avoid shore power problems.

Recommended Books

- **Powerboater's Guide to Electrical Systems: Maintenance, Troubleshooting and Improvements, second edition**

Ed Sherman

Focused on power cruisers, the author is a recognized authority on electrical practice and is well respected by boat builders and marine electricians.

- **Advanced Marine Electrics and Electronics Troubleshooting**

Ed Sherman

Targeted at trade professionals. Boat builders, installers, electricians and boatyard owners will want this book for its insight into new tools and techniques for tracking down problems. The advanced boat owner will benefit as well.

- **Boatowner's Illustrated – Electrical Handbook, second edition**

Charlie Wing

Great for learning about a boat's electrical system.

Recommended Web Sites

- Blueseas.com
- ABYC

SUMMARY

- Each circuit must have its own properly rated circuit protection device.
- Only the starter motor circuit is exempt from having a circuit protection device
- Check connections for corrosion, loosening.
- Use marine grade “boat cable”
- Use marine grade connectors
- Support wiring every 18 inches
- Make sure all wire runs are routed above the bilge
- Ensure that the boat has a proper grounding system