# YOUR BOAT'S ELECTRICAL SYSTEM

REGENT POINT YACHT CLUB

NOVEMBER 2, 2024

# TODAY'S AGENDA

- Electricity 101
- Circuits & circuit diagrams
- How electricity flows into and around a boat (batteries, wires, distribution panels, etc.)
- Sources of AC & DC power on a boat
- Boat electrical survey
- Additional sources of electricity including generator, solar, wind, & water power
- Galvanic corrosion/Stray current corrosion
- Recommended tools/Resources
- ABYC

# ELECTRICITY 101

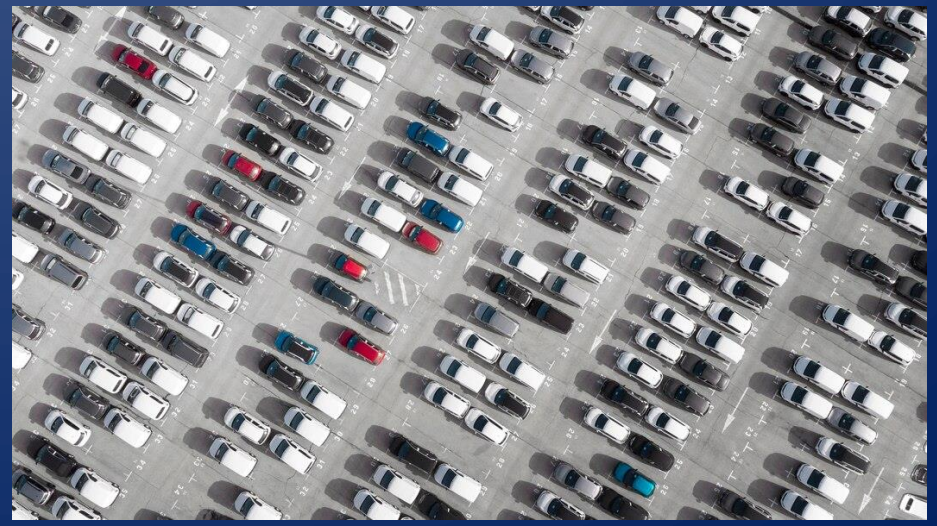
- Electricity is a form of energy that can be carried by wires and is used for heating, lighting, and to provide power for machines.

# ELECTRICITY 101

- Amp - The unit of electricity used to measure electrical current (The number of electrons that pass a given point on a wire over a given period of time). Represented by the symbol (I).

# ELECTRICITY 101

- Volt – The unit of electricity used to measure potential in electrical force. (The number of amps that could flow over that wire). Represented by the symbol (V).

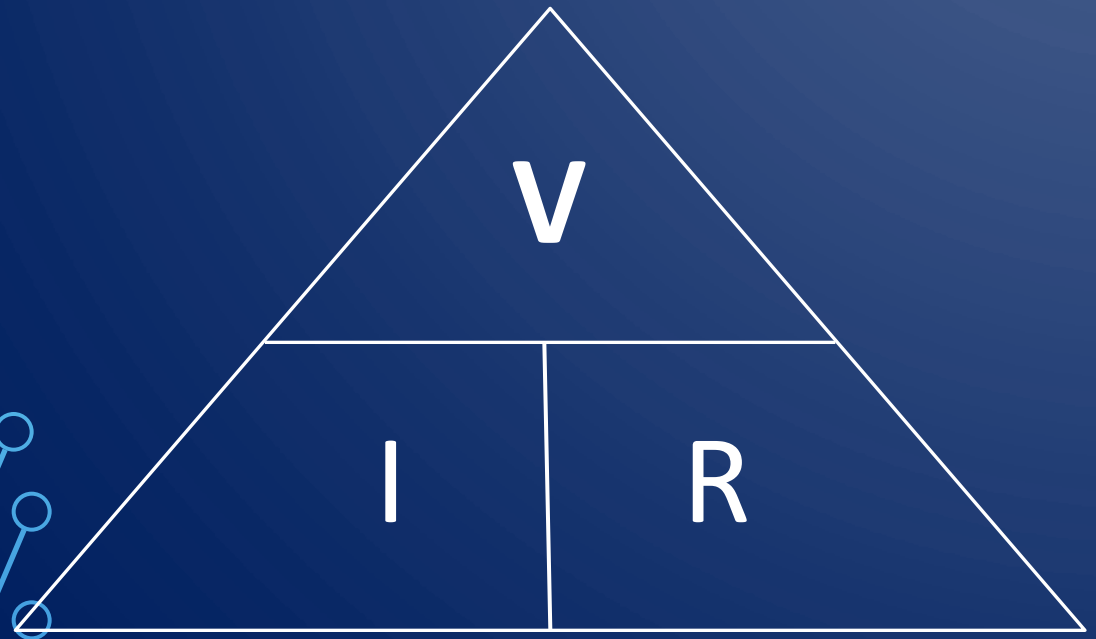



# ELECTRICITY 101

- Ohm – The unit of electricity used to measure resistance. (The effects of size, length, type/condition of conductor & equipment on electricity flow). Represented by the symbol (R).

# ELECTRICITY 101

- Ohm's Law: Amps (I) = Volts (V)/Resistance (R)




$$I = V / R$$

$$R = V / I$$

$$V = I \times R$$

# ELECTRICITY 101


What is the resistance in this circuit?

Resistance (R) = Volts (V) / Amps (I)

Resistance = 12 Volts / 4.0 Amps

Resistance = 3.0 Ohms – (Ω)

# ELECTRICITY 101

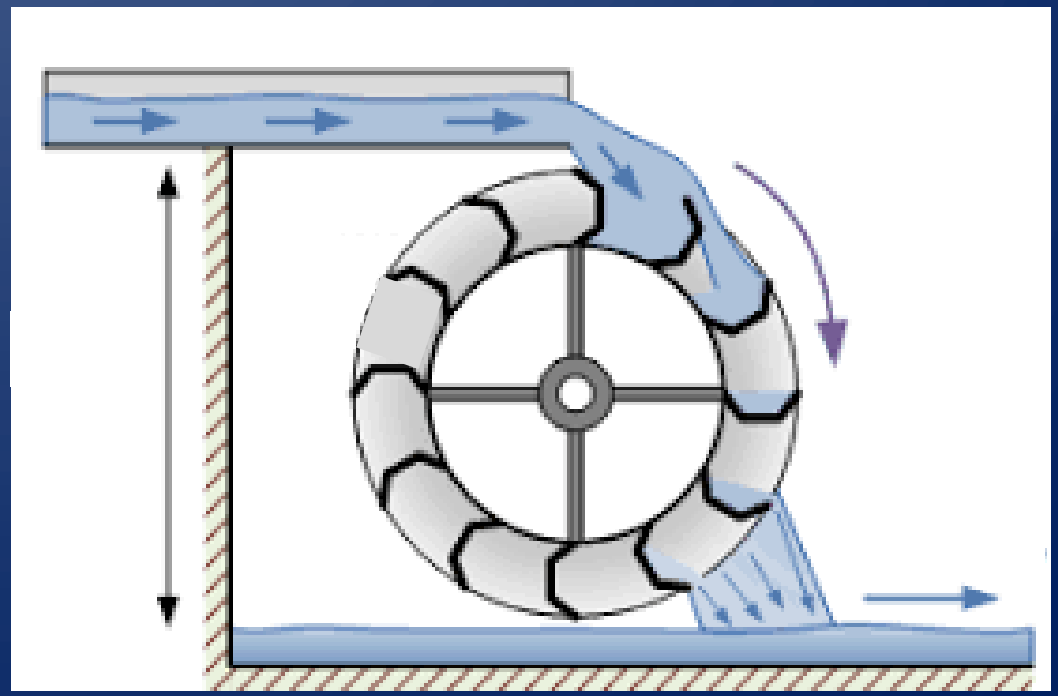
- Watt - The unit used to measure the useful work done by electricity.  Represented by the symbol (P)

Water pressure = Volts

Water flow = Amps

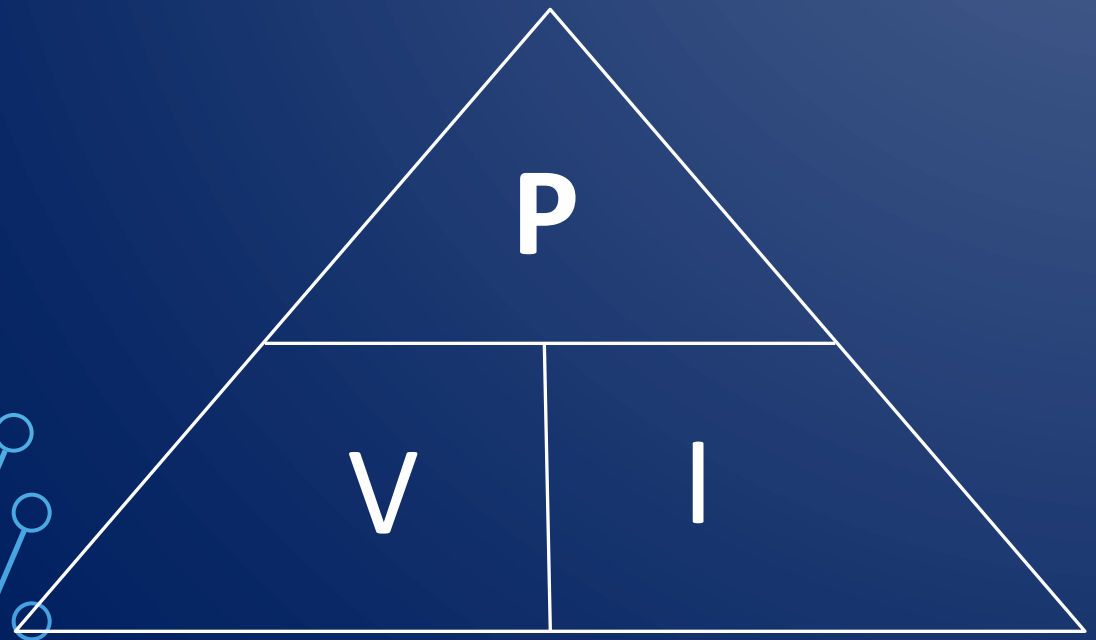
Pipe size = Resistance

Energy created = Watts



# ELECTRICITY 101

- Watts (P), Volts (V), Amps (I)




$P = V \times I$

$V = P / I$

$I = P / V$

# ELECTRICITY 101


- What is amp draw of this pump?
- Amps (I) = Watts (P)/Volts (V)
- Amps = 70 Watts/12 Volts
- Amps = 5.83*

*Amp draw per hour

# ELECTRICITY 101


- Direct current (DC)(12 volts) - Electric current flows in one constant direction. (Navigation lights, electronics, etc.)

- Alternating current (AC) (120 volts 60 Hz) - Electric current periodically cycles and inverts its direction. (Microwave, TV, hair dryer, etc.)

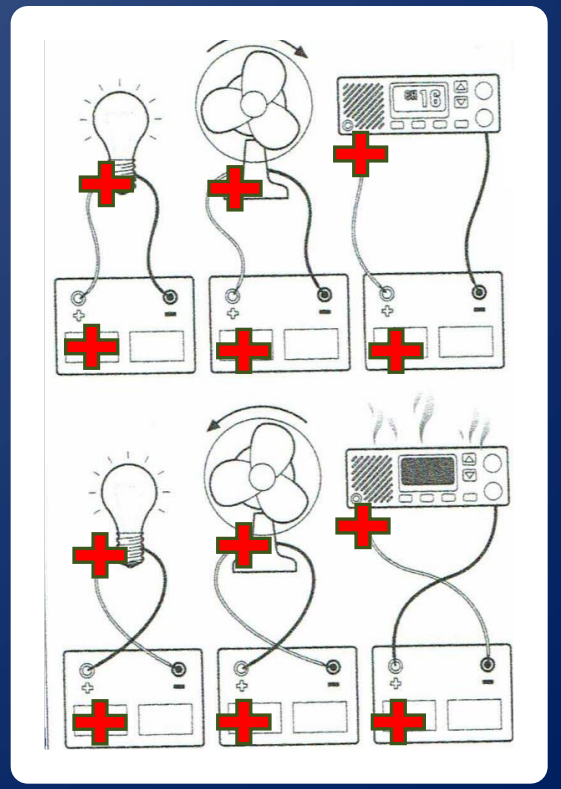
*Europe = 220-240 volts 50 Hz

# ELECTRICITY 101

- Polarity – Direction of current flow in an electrical circuit

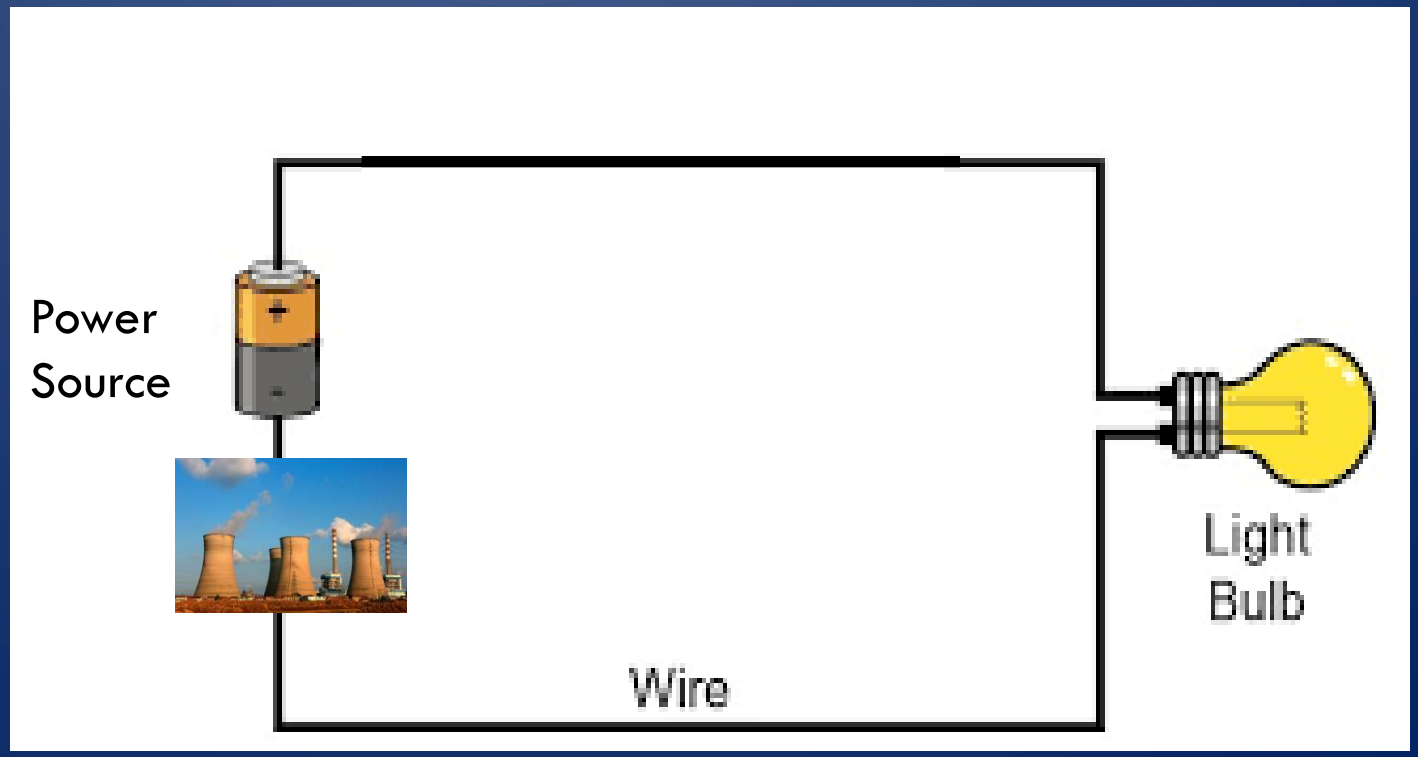
- 12 volt components work properly when connected to positive side of circuit

- AC appliances may work properly but **Reverse** Polarity = DANGER



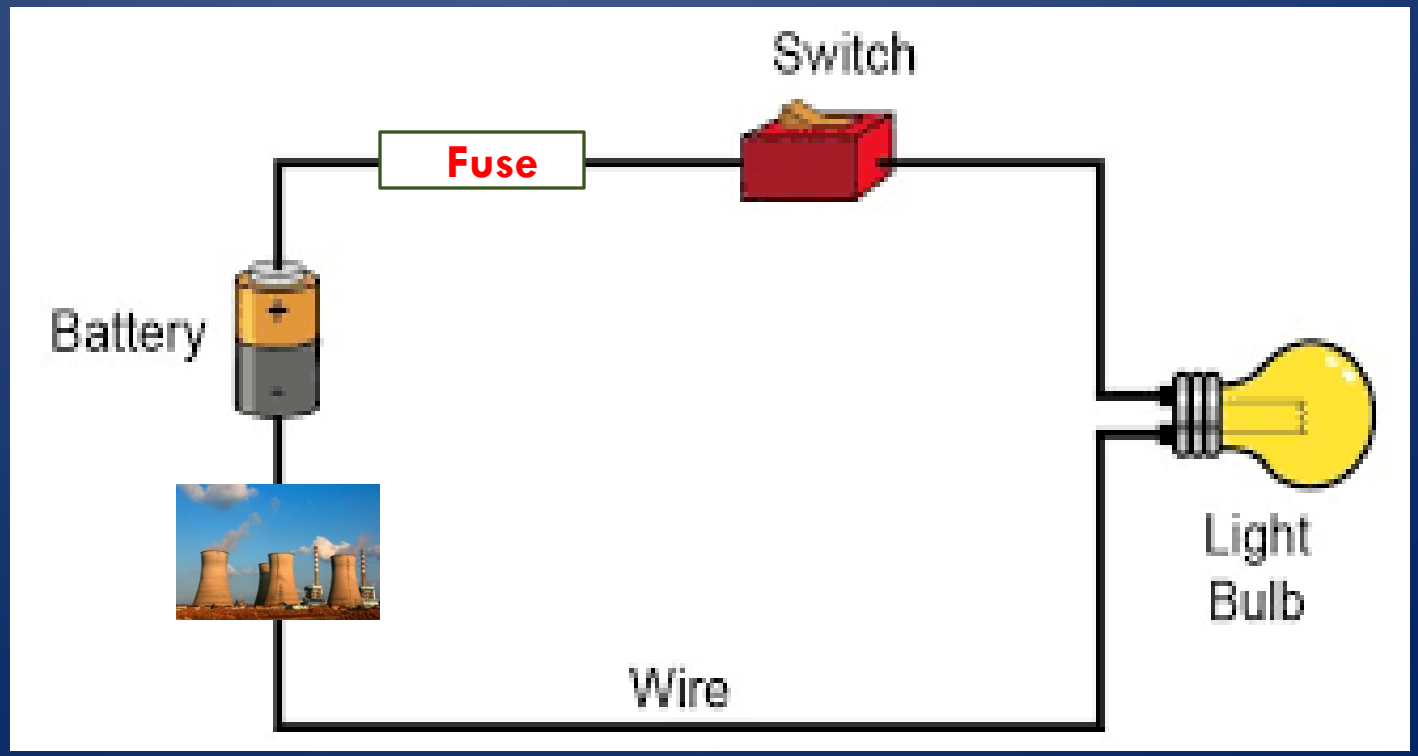
# CIRCUITS

- Basic AC/DC circuit



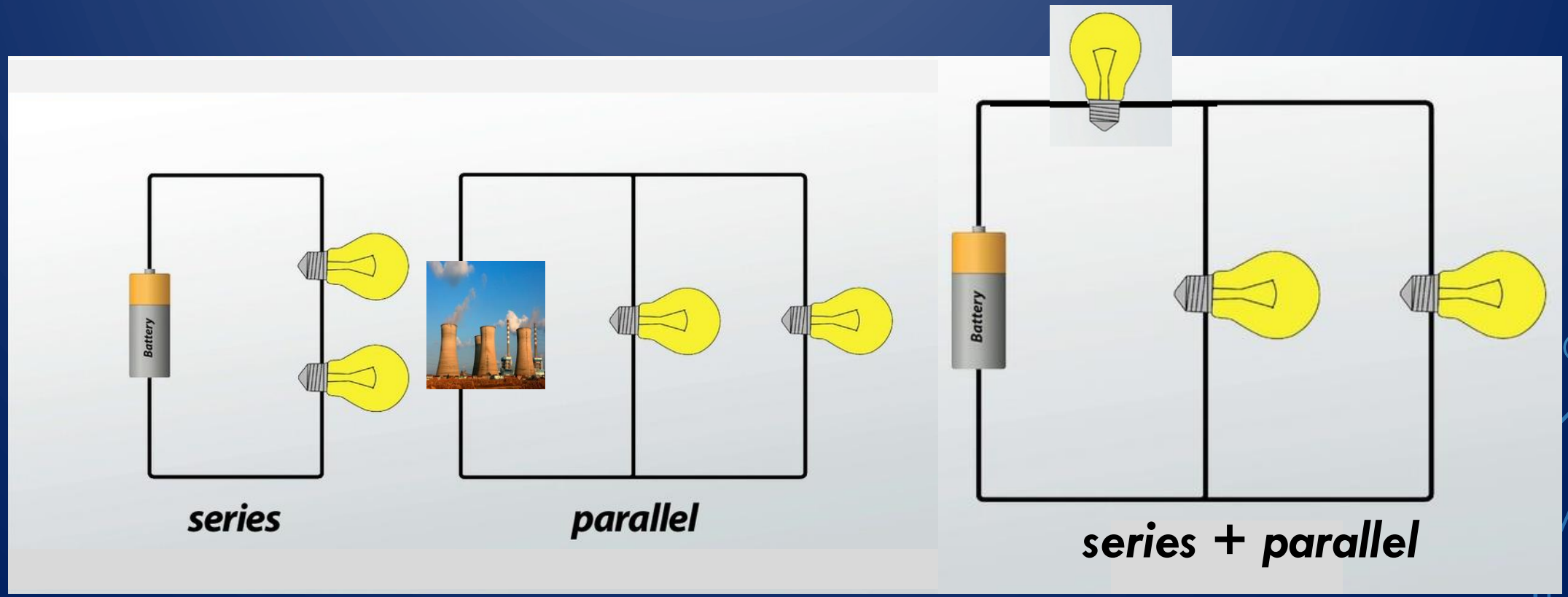
# CIRCUITS

- More common AC/DC circuit on boat



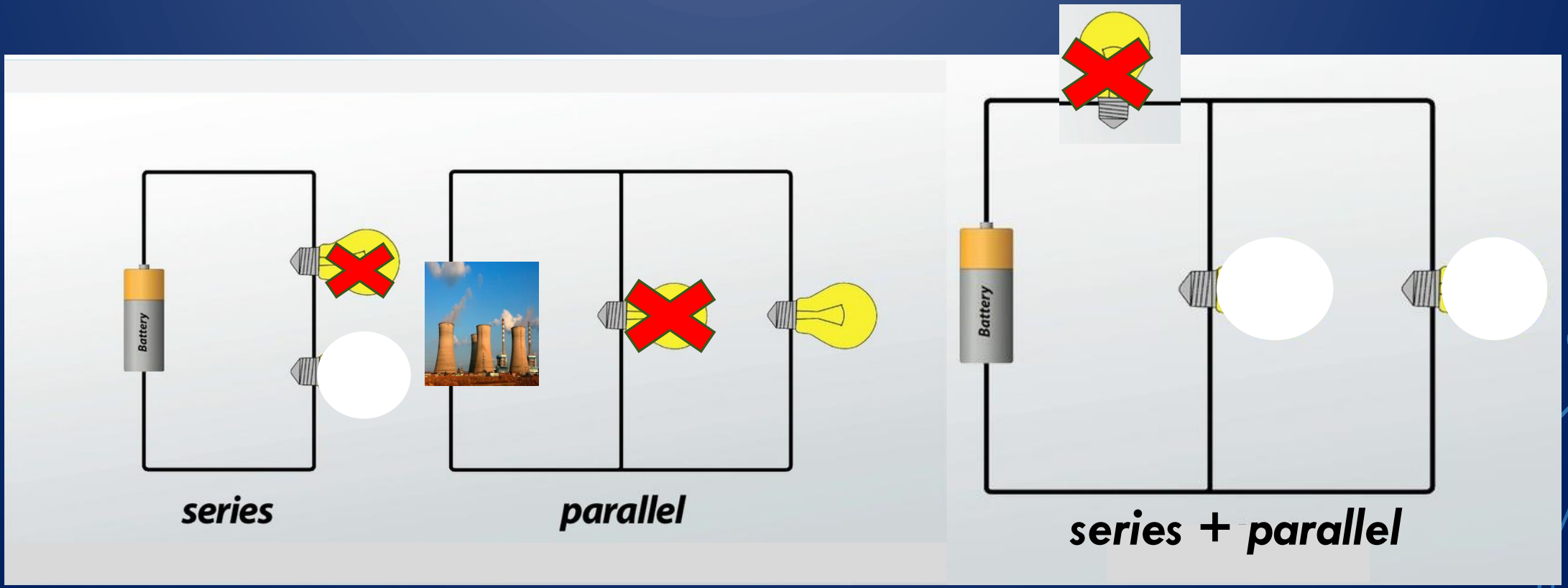
# CIRCUITS

- Series/Parallel/Series plus Parallel Circuits



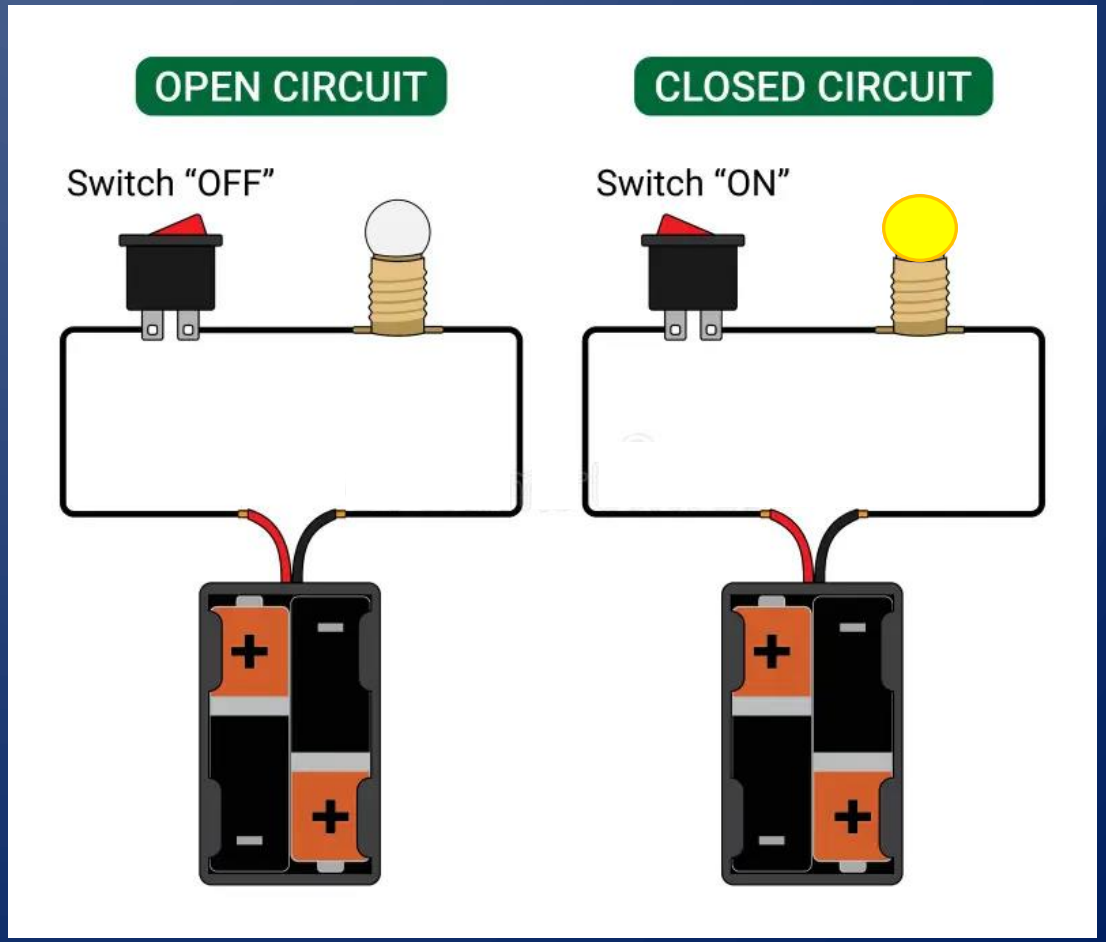
# CIRCUITS

- Series/Parallel/Series plus Parallel Circuits – Pros & Cons



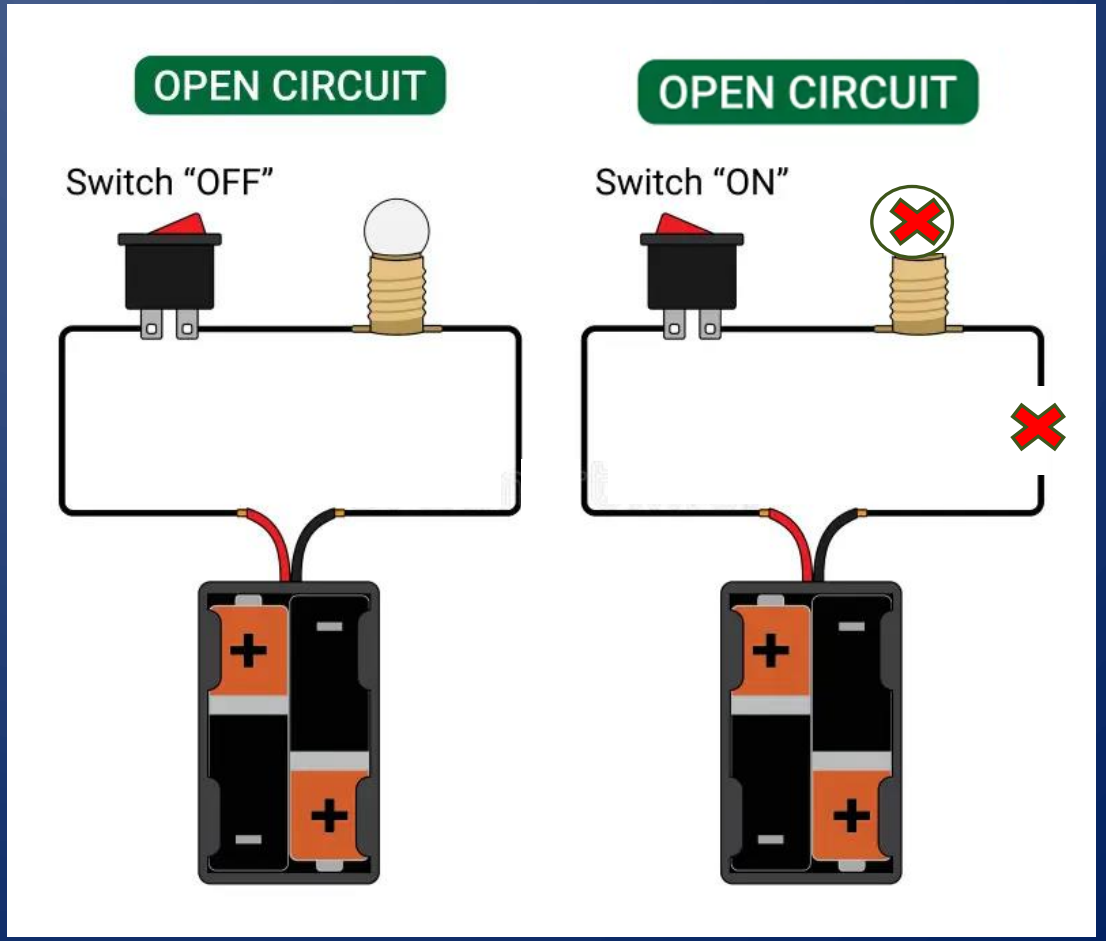
# CIRCUITS

- Open/Closed Circuit



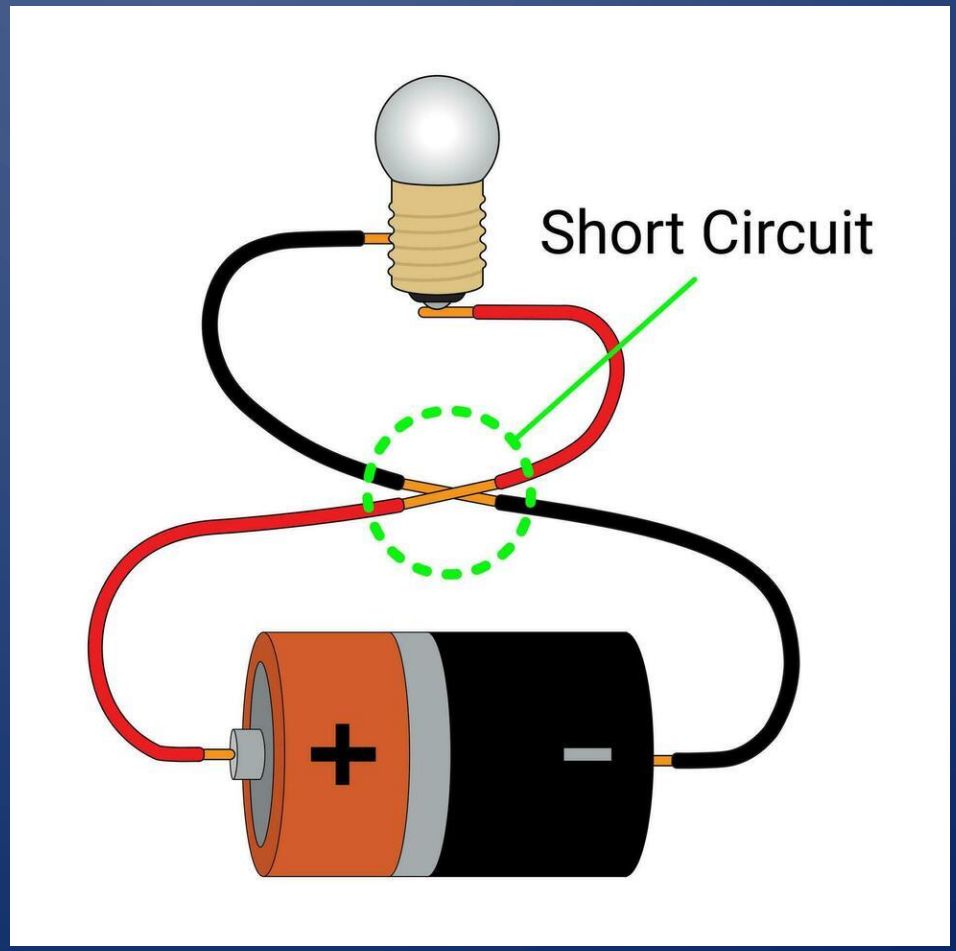
# CIRCUITS

- Open Circuit



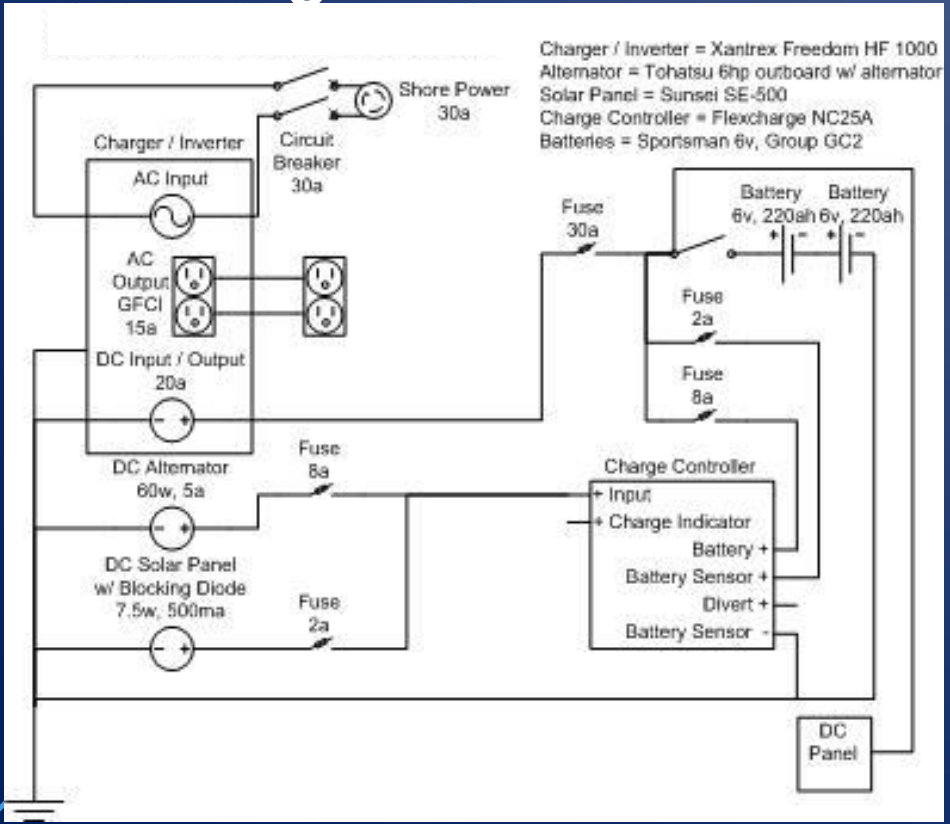
# CIRCUITS

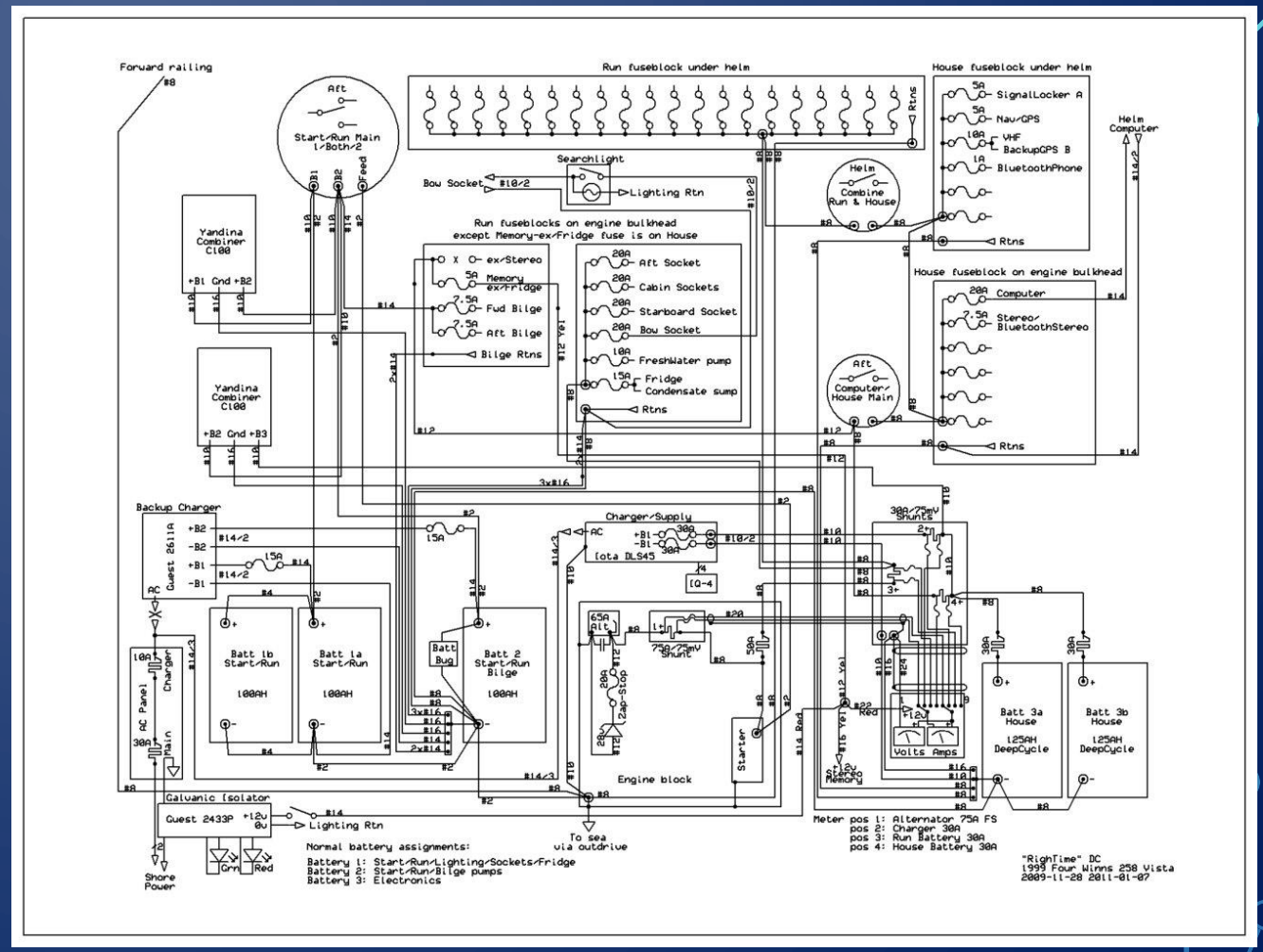
- Short Circuit



# CIRCUITS

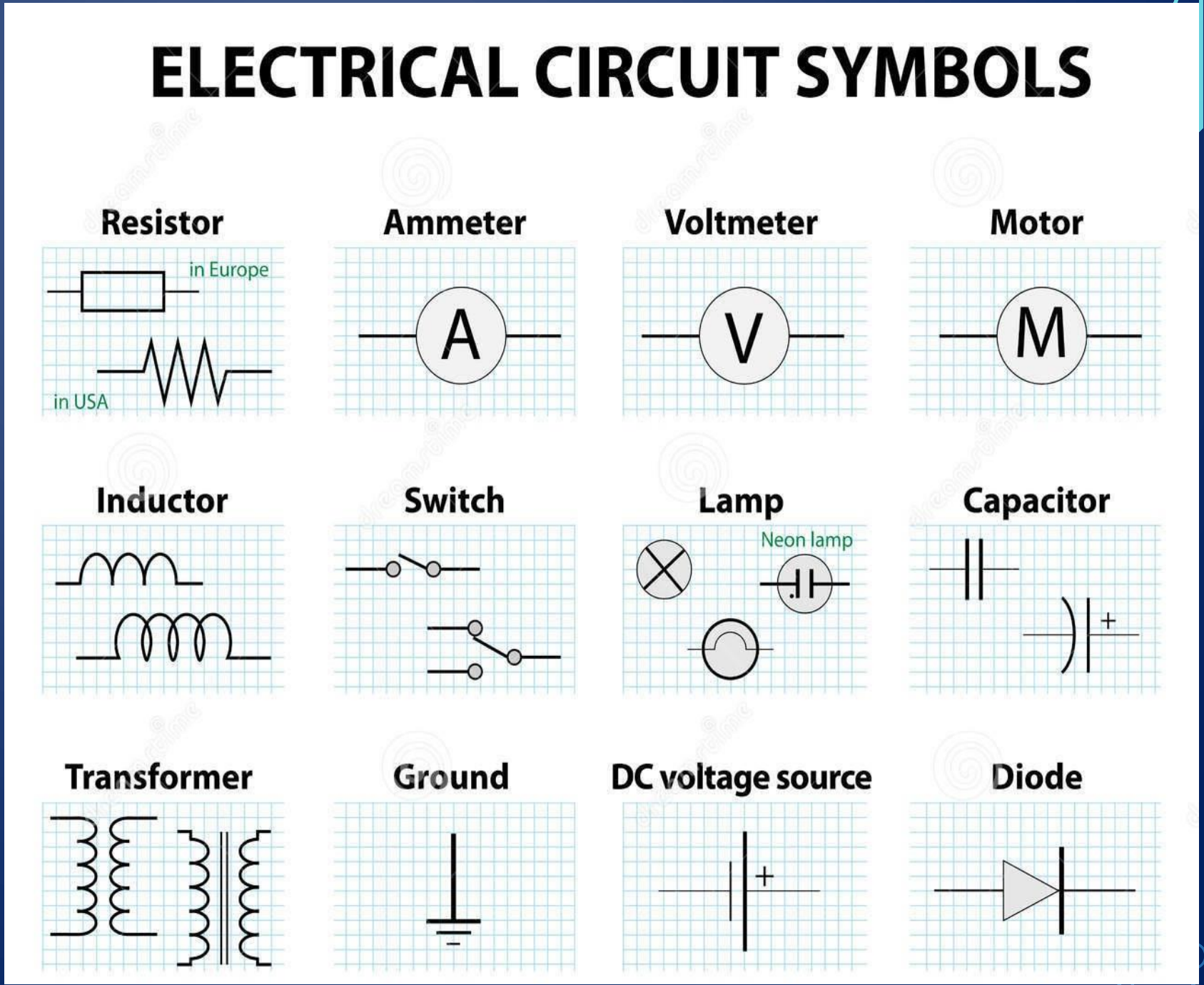
- Basic electrical circuit diagrams



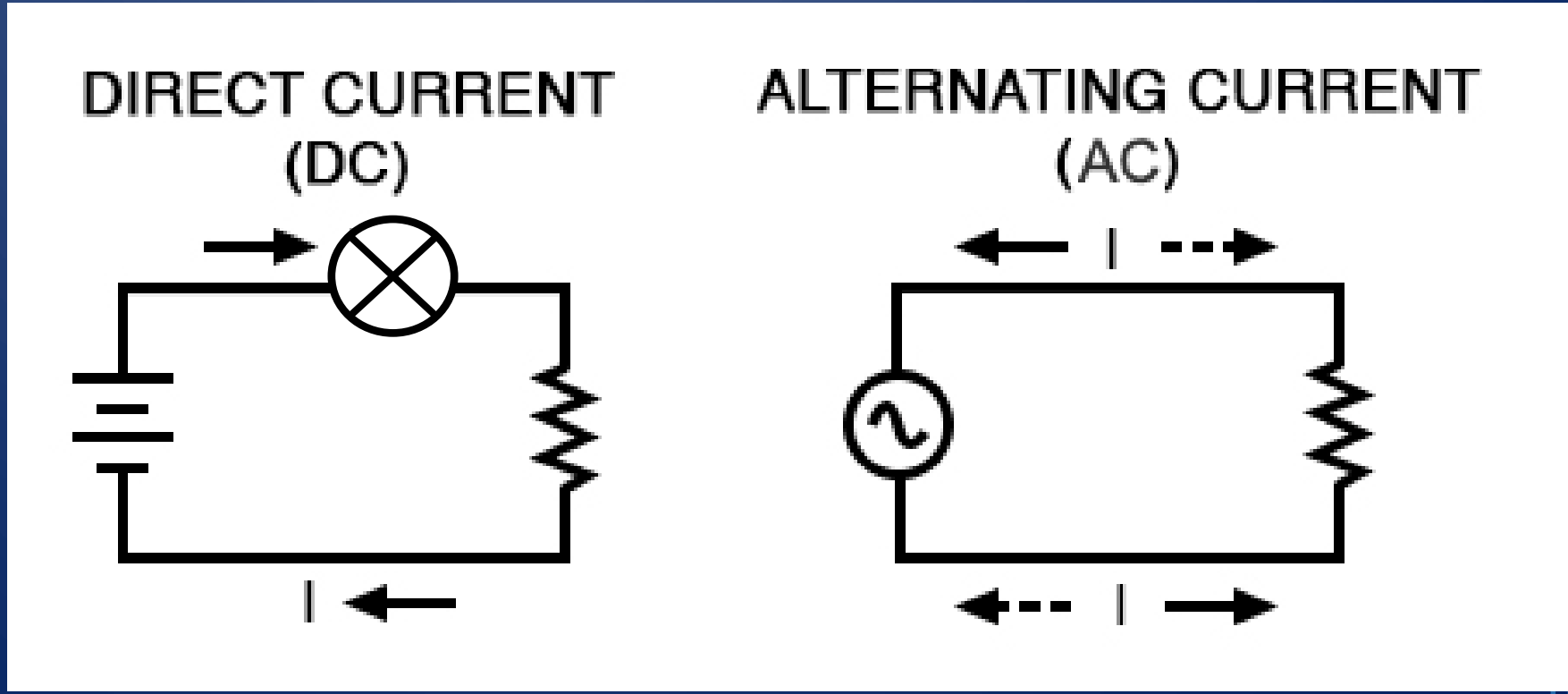
# CIRCUITS

- Electrical circuit diagram symbols



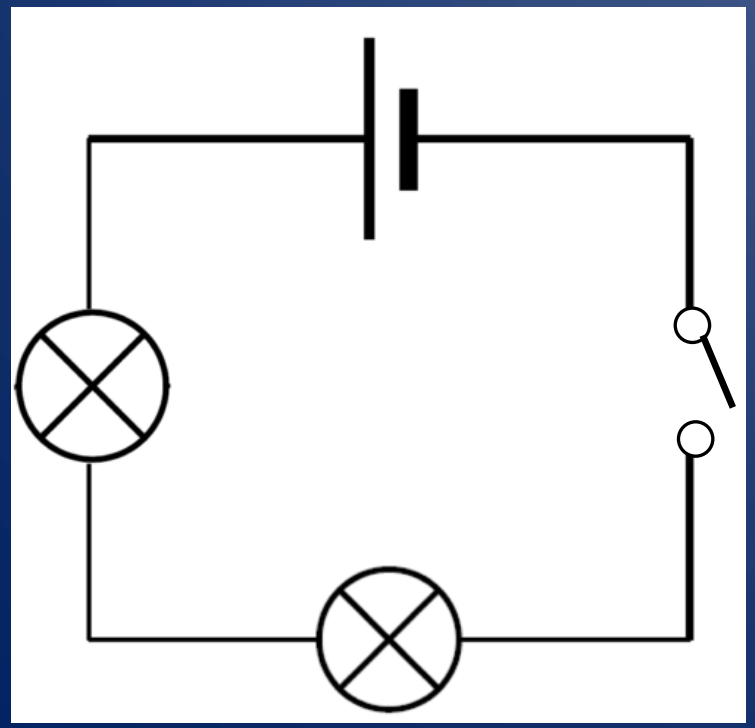
# CIRCUITS

Basic AC/DC circuit diagram

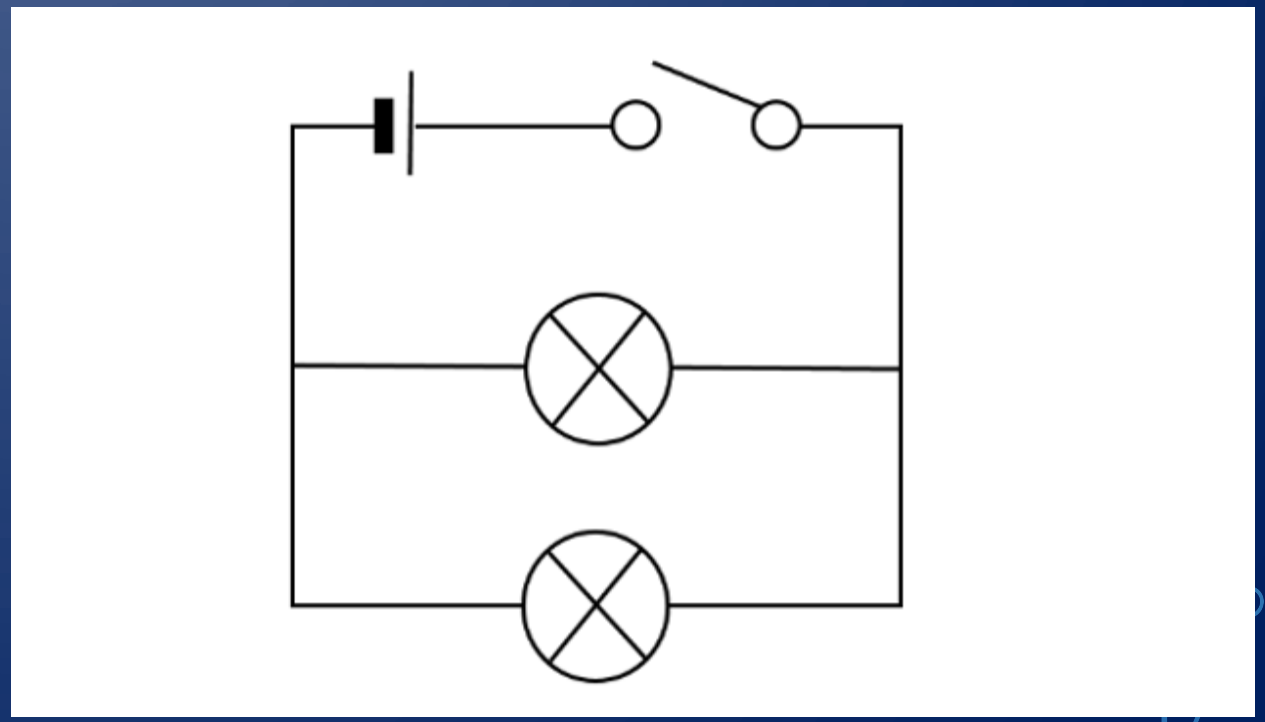


# CIRCUITS

## DC circuit diagrams



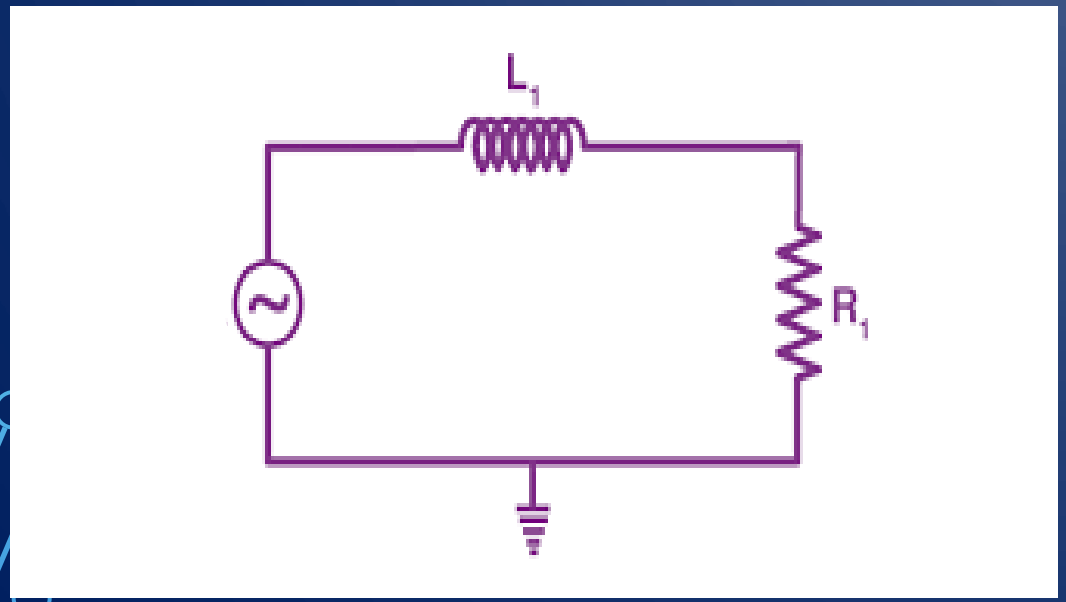
Series



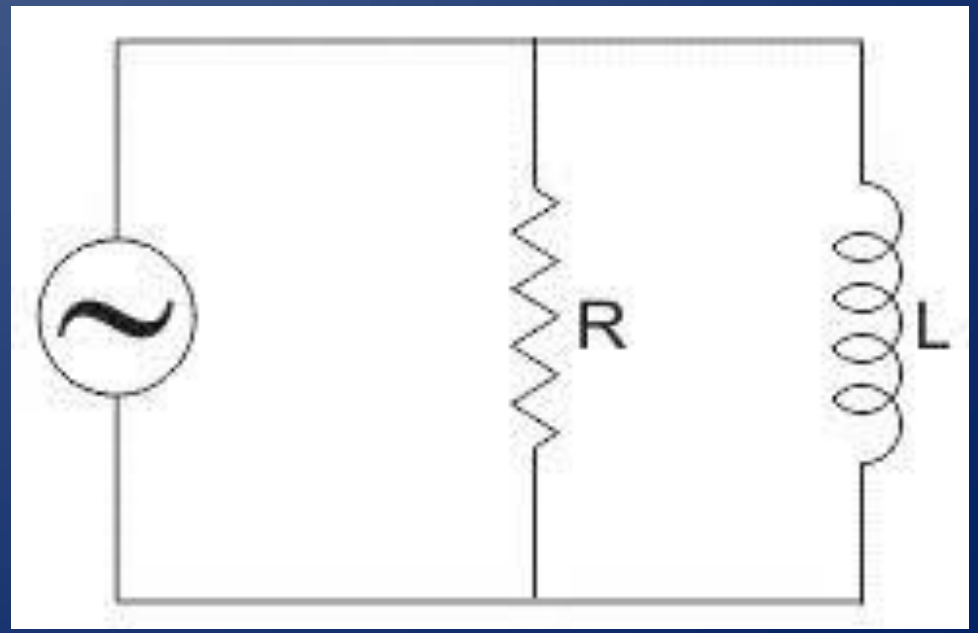
Parallel

# CIRCUITS

## AC circuit diagrams

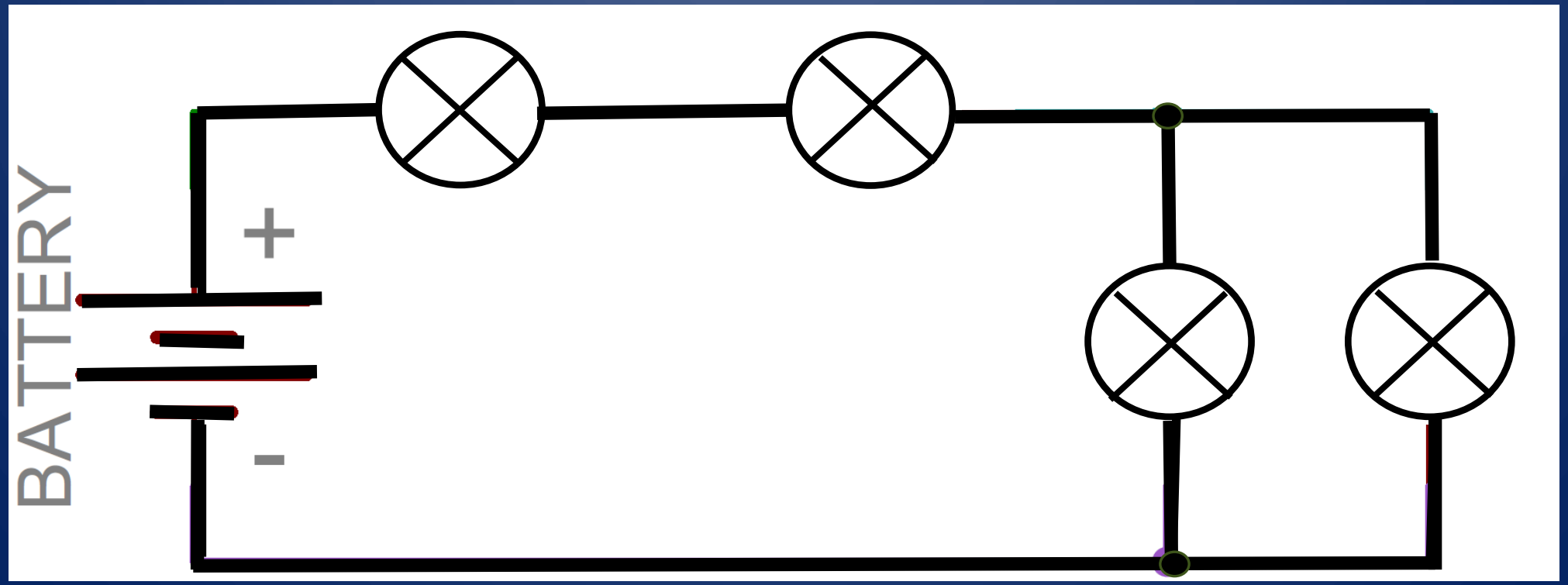



Series




Parallel

# CIRCUITS




Series + Parallel

# BATTERIES


Flooded Lead Acid

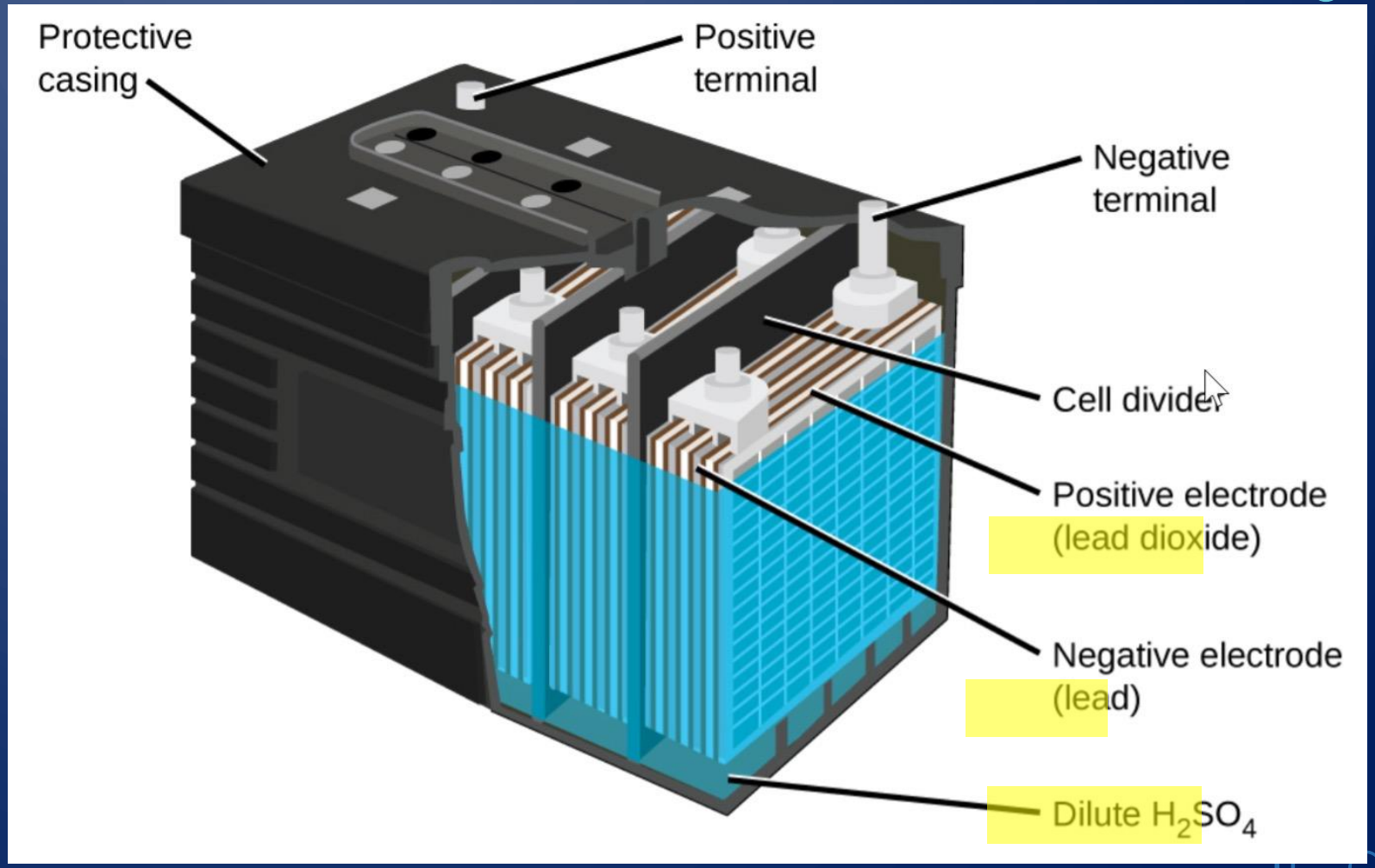

Gel


AGM (Absorbent Glass Mat)


Lithium Iron Phosphate (LFP or LiFePO4)

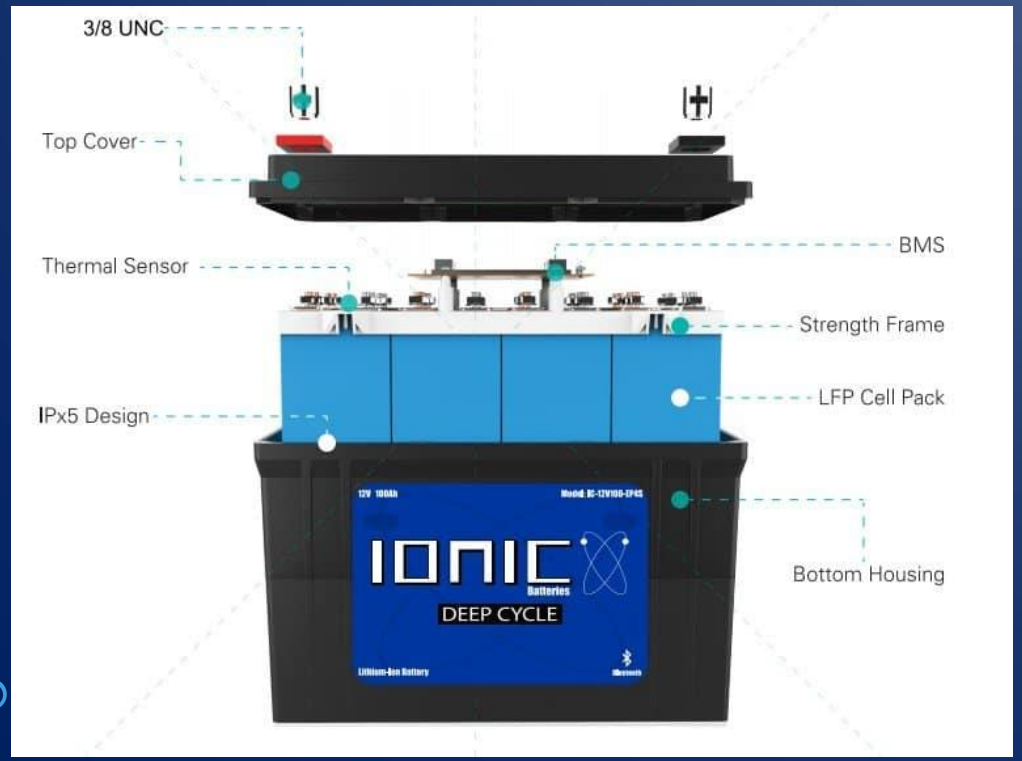
# BATTERIES

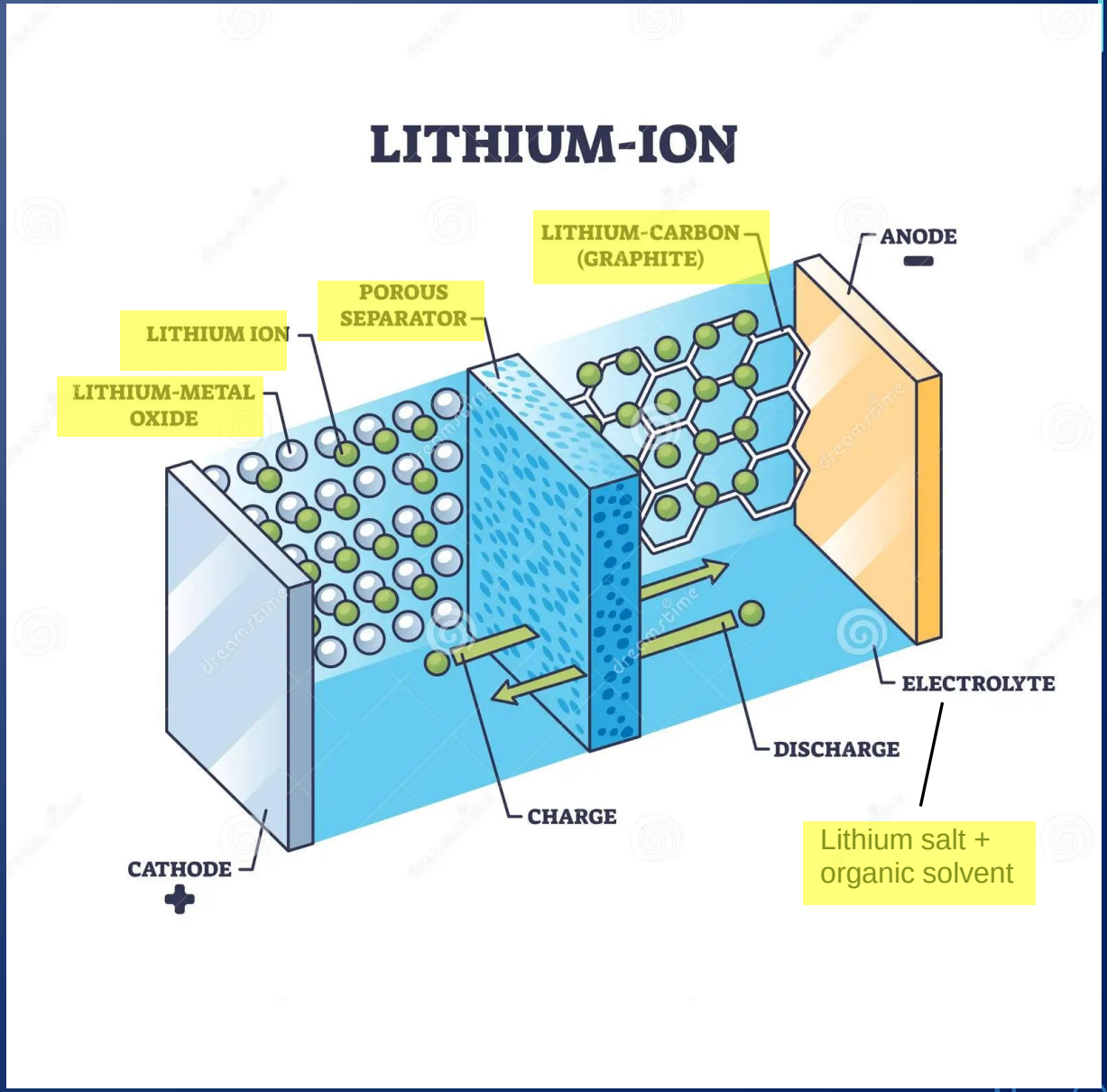
- Flooded Lead Acid, Gel & AGM



# BATTERIES

- Lithium-Ion



# BATTERIES

- Sizes and weights

| BCI Group # | Length (in) | Width (in) | Height (in) |
|---|---|---|---|
| 24 | 10.25 | 6.81 | 8.88 |
| 24F | 10.75 | 6.81 | 9.00 |
| 24H | 10.25 | 6.81 | 9.38 |
| 24R | 10.25 | 6.81 | 9.00 |
| 24T | 10.25 | 6.81 | 9.75 |
| 27 | 12.06 | 6.81 | 8.88 |
| 27F | 12.50 | 6.81 | 8.94 |
| 27H | 11.75 | 6.81 | 9.25 |
| 31 | 13.00 | 6.72 | 9.44 |
| 8D | 20.75 | 11.13 | 9.88 |




# BATTERIES

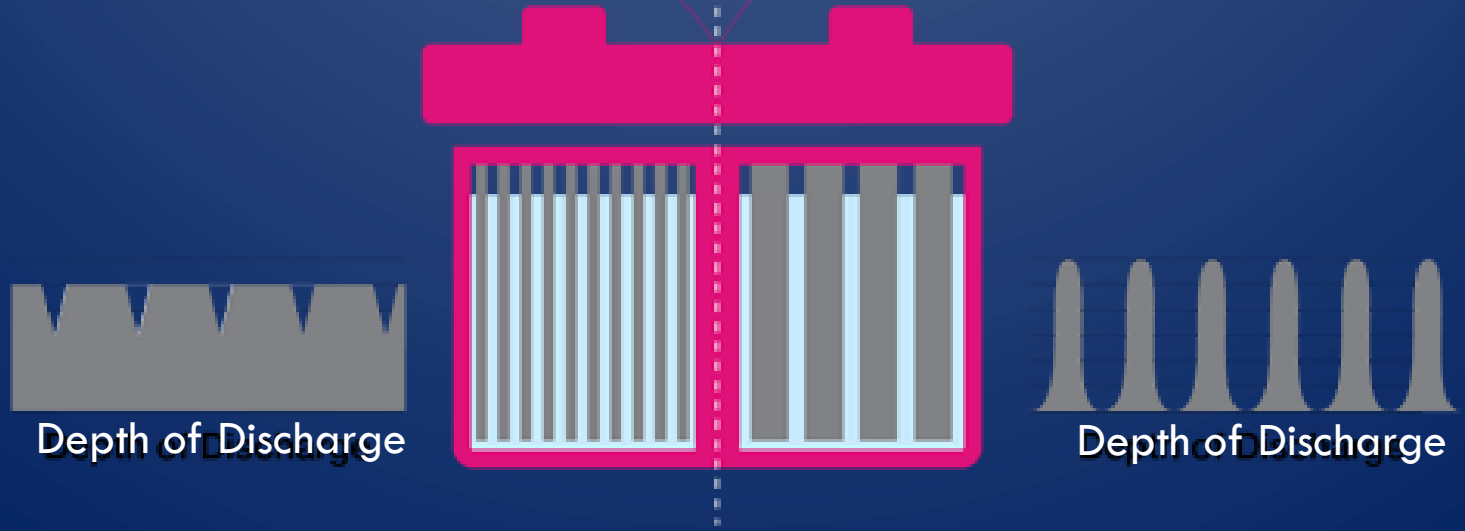

- Starting vs. Deep Cycle


**STARTER BATTERY**

*Engine Starting*

**DEEP CYCLE BATTERY**

*Continuous Power*




# BATTERIES


- Starting Battery Terminology

- Cold Cranking Amps - # of amps a battery can deliver for 30 seconds at 0° F, while maintaining voltage of 7.2 volts. (400, 500, 650 CCA etc.)

- Marine Cranking Amps - # of amps a battery can deliver for 30 seconds at 32° F, while maintaining voltage of 7.2 volts (Usually higher because batteries work better when it is warmer)

# BATTERIES


- Deep Cycle Battery Terminology
- Amp – hours (Ah) - Total amount of energy a battery can deliver for 20 hours at a constant rate of discharge before voltage drops to 10.5 volts. (100 amp-hour battery can run a 5A load for 20 hours)* (60Ah, 80Ah, 100Ah etc.)
- Reserve Minutes- The number of minutes a battery can run a 25A load until dropping to 10.5 volts. (Battery with a 180 reserve rating, will run a 25A load for three hours.

# BATTERIES

- Deep Cycle -Number of Amp-Hours (Ah)

| BCI Group # | Voltage | Type | Part # | Amp Hours | Continuous (A) | Peak (A) |
|---|---|---|---|---|---|---|
| 24 | 12V | Deep Cycle | RB60 | 60 | 60 | 140 |
| 24 | 12V | Deep Cycle | RB75 | 75 | 75 | 150 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 27 | 12V | Deep Cycle | RB80 | 80 | 80 | 160 |
| 31 | 12V | Deep Cycle | RB100 | 100 | 100 | 200 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 31 | 12V | Dual Purpose | RB100-**HP** | 100 | 100 | **800** |
| 8D | 12V | Deep Cycle | RB200 | 200 | 100 | 200 |
| 8D | 12V | Deep Cycle | RB300 | 300 | 100 | 200 |
| 8D | 12V | Dual Purpose | RB300-**HP** | 300 | 100 | **800** |

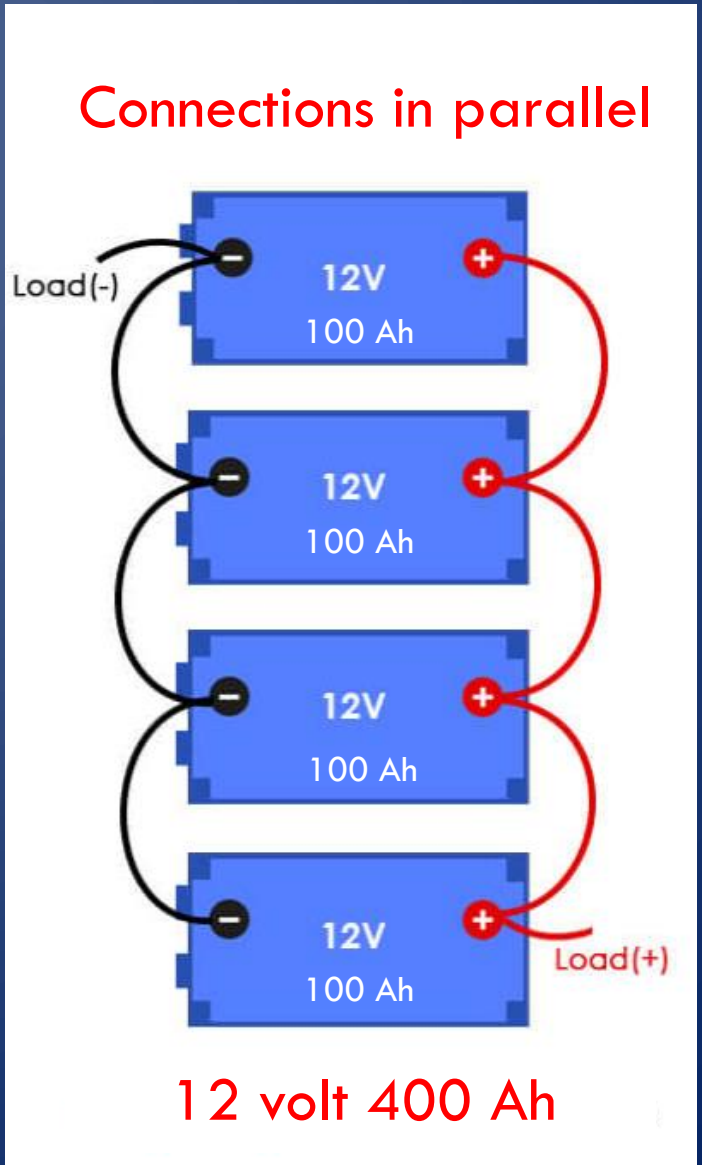
*Max 50% Discharge

# BATTERIES

- 6 volt vs. 12 volt

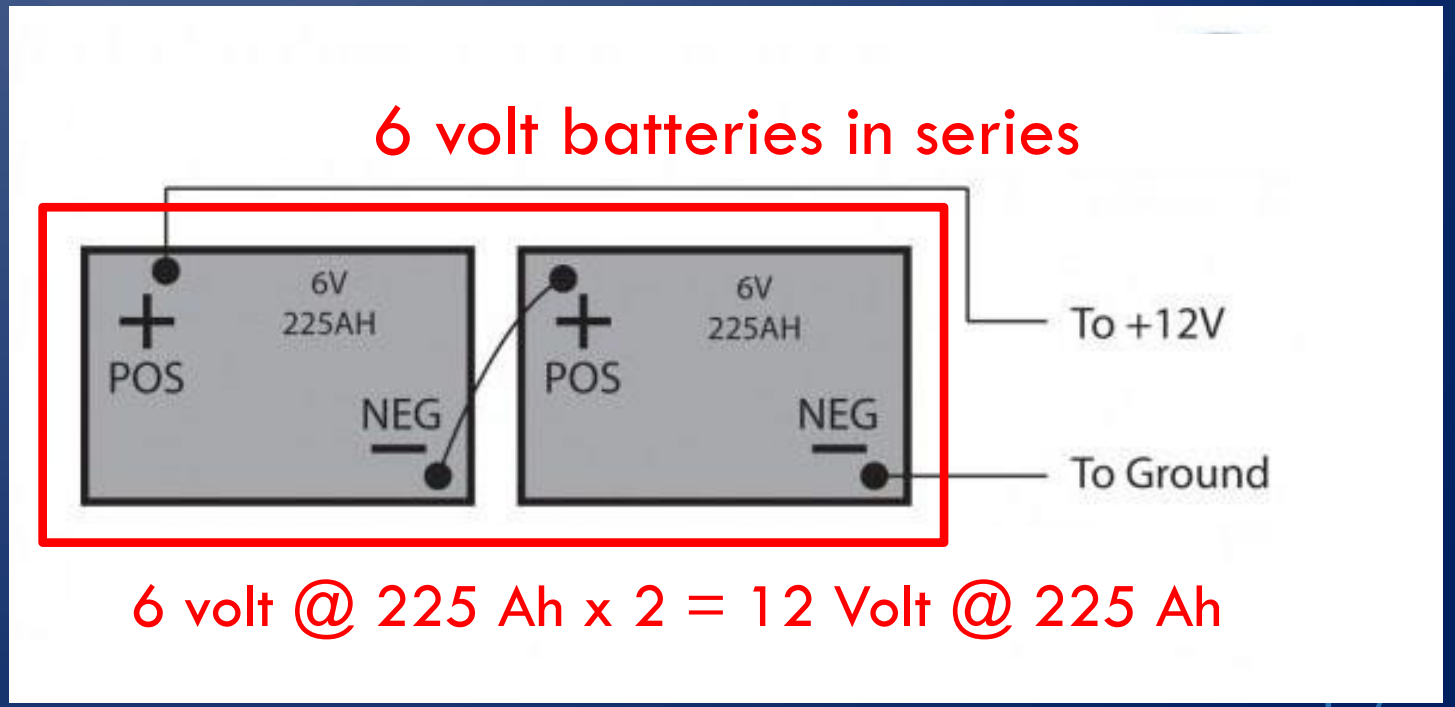

# BATTERIES

- 12 volt bank

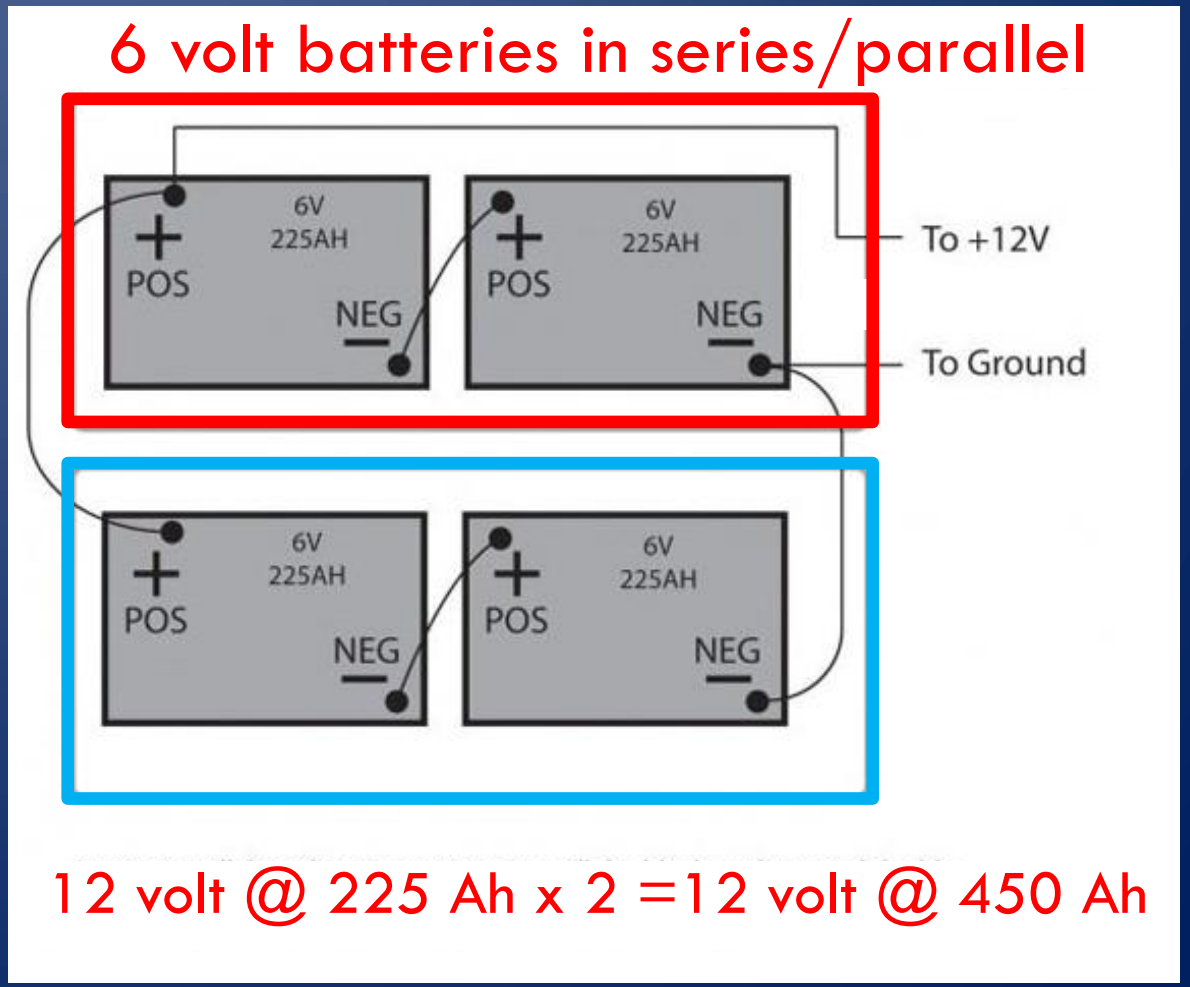
# BATTERIES

- 6 volt bank

# BATTERIES

- 6 volt bank

# BATTERIES

- Relative Benefits/Downsides*


Flooded Lead Acid

- Tolerates overcharging
- Requires maintenance
- High self-discharge rate
- Hates vibration
- Heavy
- $

# BATTERIES

- Relative Benefits/Downsides*


Gel

- Sensitive to overcharging
- Maintenance free, spill & leak proof
- Low self-discharge rate
- Handles extreme temps
- Long life span
- Heavy
- $$

# BATTERIES

- Relative Benefits/Downsides*


AGM
(Absorbent Glass Mat)

- Sensitive to overcharging
- Maintenance free, spill & leak proof
- Low self-discharge rate
- Handles extreme temps
- Long life-span
- Heavy
- $$

# BATTERIES

- Relative Benefits/Downsides*


Lithium Ion
(LFP or LiFePO4)

- Sensitive to overcharging
- Maintenance free & spill and leak-proof
- Low self-discharge rate
- Higher discharge capacity - *80% vs. 50%
- Longer life-span
- Lighter than others
- Can overheat & cause fires
- $$$

# BATTERIES

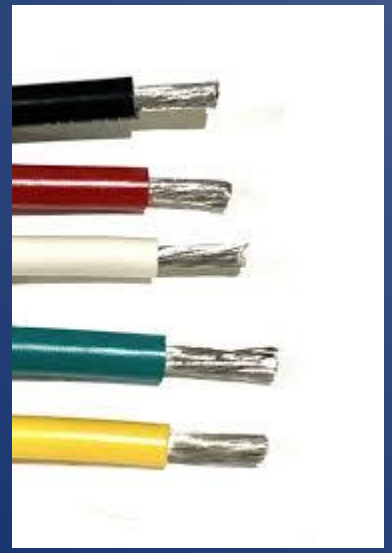
- Do's and Don'ts
- Don't mix types – AGM with Flooded Lead Acid, etc.
- Don't mix old and new
- Keep batteries clean and dry – remove corrosion – use dialectic grease on connections
- Check cables and terminal connections frequently to insure they haven't come loose

# BATTERIES

- Add distilled water as needed for flooded lead acid batteries
- Use smart charge controller (multi-stage charging (Bulk, Absorption & Float) and use controller to disulfate battery cells - (Do not overcharge)
- Orient batteries per manufacturer's recommendation
- Use proper wiring
- Install appropriate fuses/circuit breakers

# WIRE

- Color & Type



*Tinned & stranded

## "ABYC" CABLE & WIRE COLOR CODES FOR MARINE/BOAT WIRING

| WIRE / CABLE COLOR CODE | COLOR NAME | ITEM USED FOR | USAGE / APPLICATIONS |
|---|---|---|---|
| | RED | DC +Ve Conductor "L+" | Positive Mains "+" |
| | BLACK or YELLOW | DC -Ve Conductor "L-" | Negative Mains "-" |
| | YELLOW w/Red Stripe | Starting Circuit | Starting Switch to Solenoid |
| | BROWN | Generator Armature, Pumps, Alternator Charge Light | Generator Armature to Regulator, Fuse or Switch to Pumps or Lights, Generator - Terminal - Alternator or Light to Regulator |
| | BROWN w/ Yellow Stripe | Bilge Blowers | Fuse or Switch to Blower |
| | DARK BLUE | Cabin & Instrument Lights | Fuse or Switch to Lights |
| | LIGHT BLUE | Oil Pressure | Oil Pressure Sender to Gauge |
| | TAN | Water Temperature | Water Temperature Sender to Gauge |
| | ORANGE | Common Feed & Accessory Feed | Distribution Panel to Accessory Switch, Ammeter to Alternator or Generator Output & Accessory Fuses or Switches. |
| | PURPLE | Ignition & Instrument Feed | Ignition Switch to Coil & Electrical Instruments, Distribution Panel to Electrical Instruments |
| | PINK | Fuel Gauge | Fuel Gauge Sender to Gauge. |
| | GRAY | Tachometer & Navigation Lights | Tachometer Sender to Gauge, Fuse or Switches to Lights or Bonding Wires (if insulated) |
| | GREEN or GREEN w/ Yellow Stripe | Protective Ground "PG" DC Grounding Conductor | Bonding System, Bonding Wiries if Insulated |

# WIRE

- Size – AWG - (American Wire Gauge)

More Amps/Distance


Wire in engine room

# WIRE

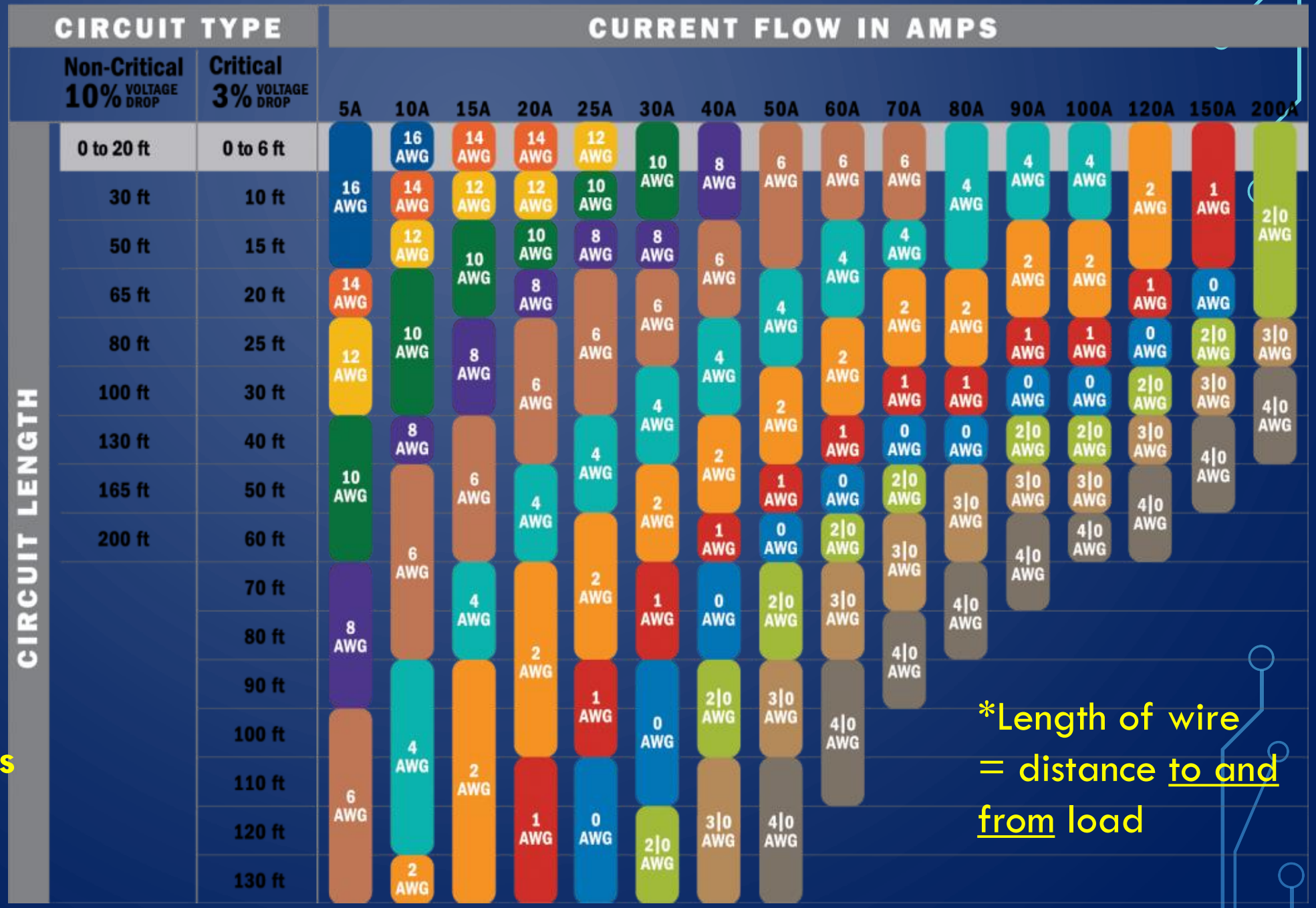
- Size

***Critical Circuits**

Bilge pumps
Bilge blowers
Electronics
Navigation lights

***Non-Critical Circuits**

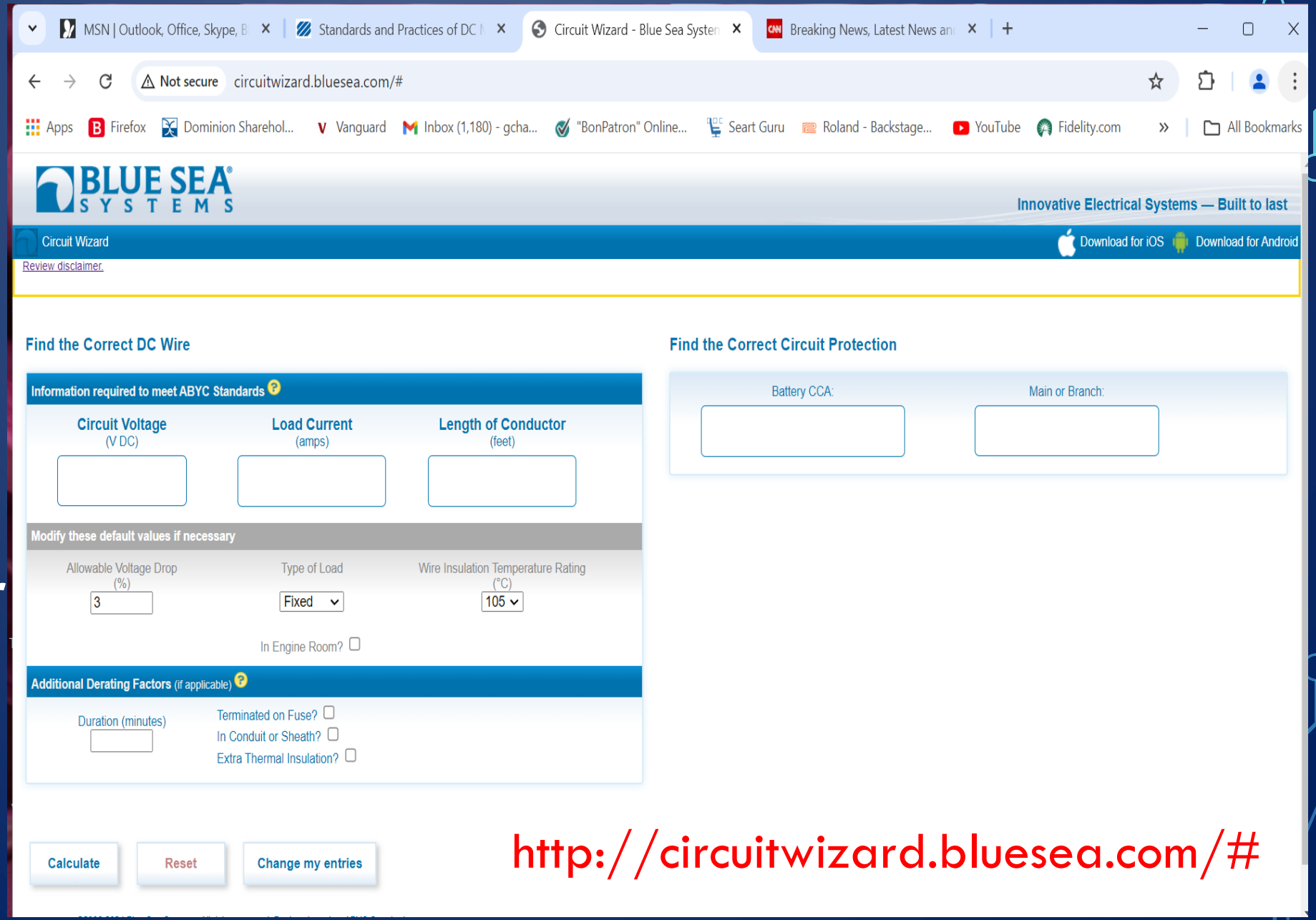
Everything else




*Length of wire = distance to and from load

# WIRE

- Size & Type Calculator

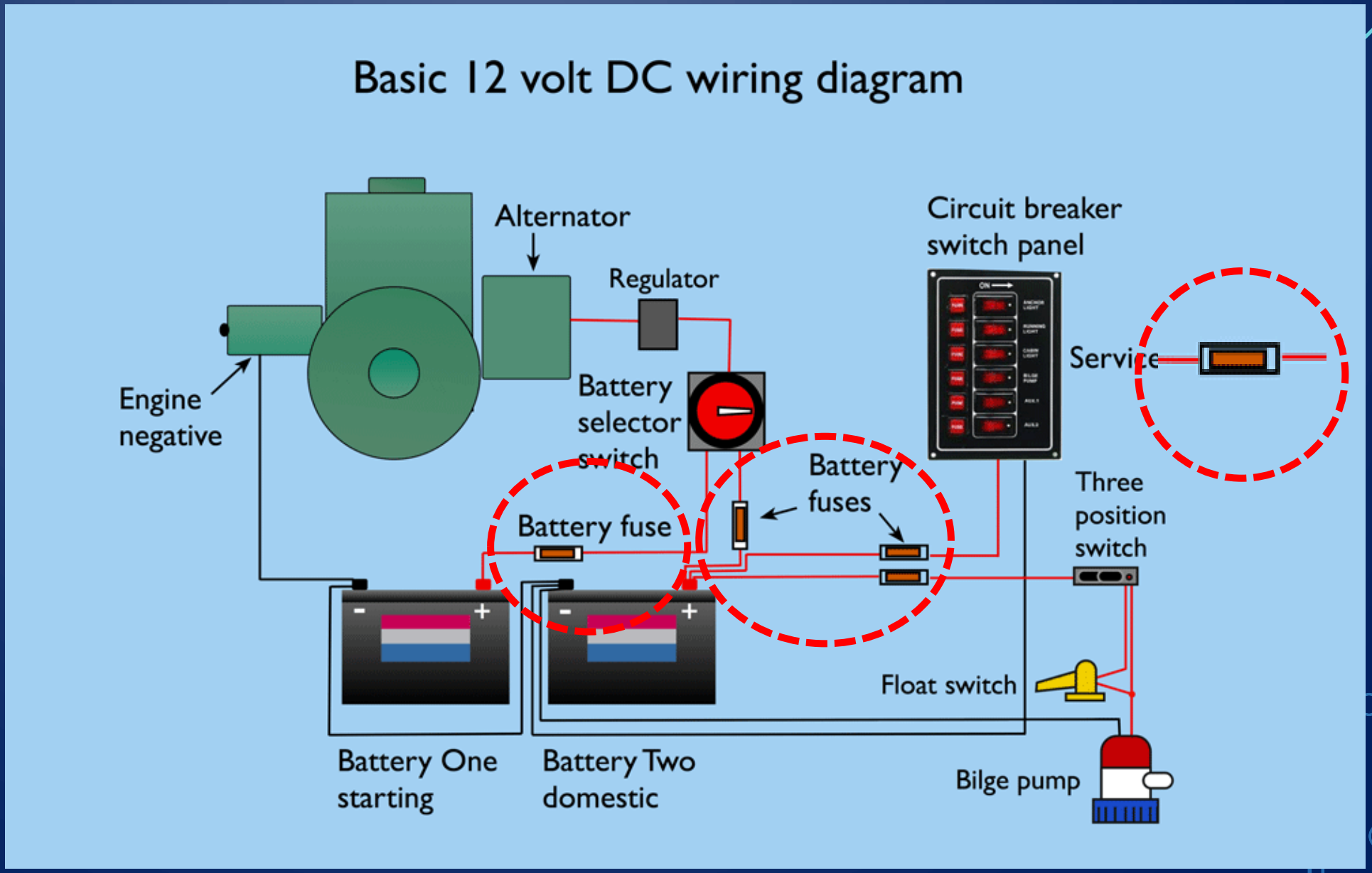



http://circuitwizard.bluesea.com/#

# FUSES

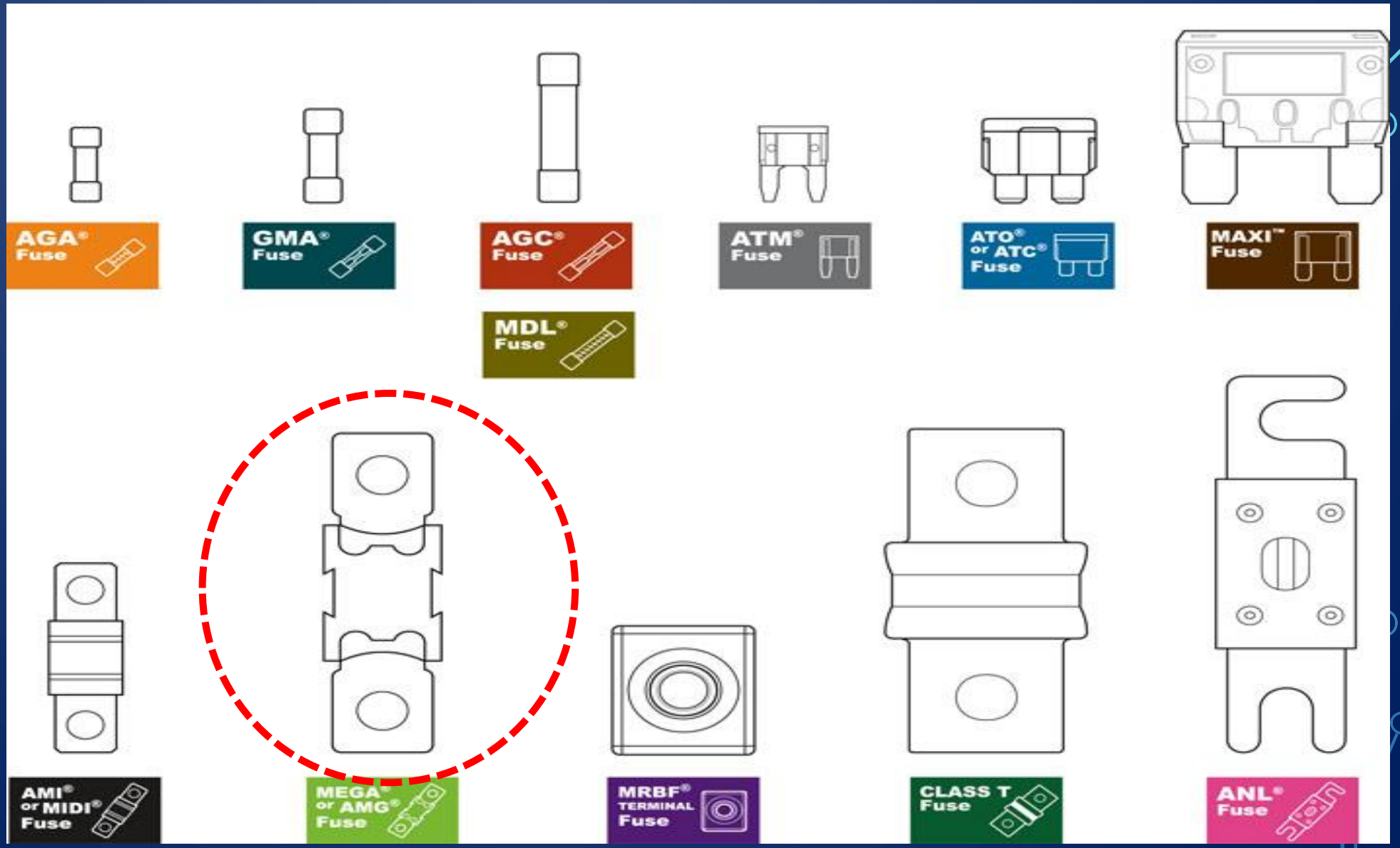
Uses

*Protect wire and appliance



# FUSES

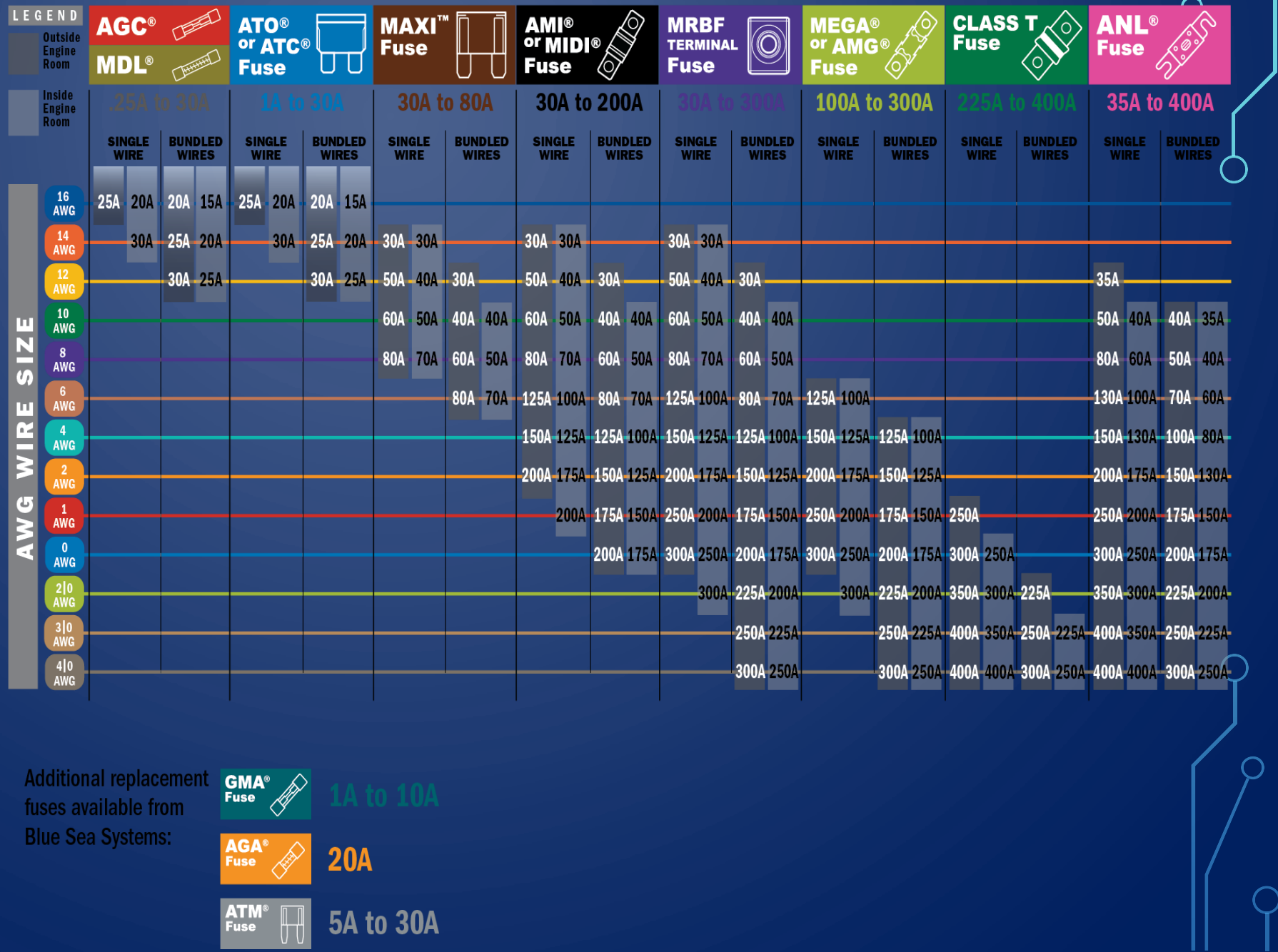
## Types


AGA® Fuse
GMA® Fuse
AGC® Fuse
MDL® Fuse
ATM® Fuse
ATO® or ATC® Fuse
MAXI™ Fuse
AMI® or MIDI® Fuse
MEGA® or AMG® Fuse
MRBF® TERMINAL Fuse
CLASS T Fuse
ANL® Fuse

# FUSES

## Sizes & Types

*Size of smallest wire in circuit and amps is important



# FUSE HOLDERS

- Types

## FUSE HOLDER SELECTION CHART

### MDL® AGC®

**Crimpable In-Line Fuse Holder**

5060

**Waterproof In-Line Fuse Holders**

5061 ●

5062 ●

**Heavy Duty In-Line Fuse Holder**

5063

**ST Glass Fuse Blocks**

5015
5018

### ATO® or ATC® Fuse

**ATO® or ATC® In-Line Fuse Holders**

5064

5065

**ST Blade Fuse Blocks**

**Battery Terminal Mount**

5023 ●

**Compact Fuse Block**

5045 ●
5046 ●

**Split Bus**

5032

**Common Sourced**

5025
5026
5028
5029

**Independent Sourced**

5035

**SafetyHub Fuse Block**

7748 ● ●

7725 ● ●

### MAXI® Fuse

**MAXI® In-Line Fuse Holder**

5068

**MAXI® Fuse Block**

5006100 ●

### AMI® or MIDI® Fuse

**AMI® or MIDI® Safety Fuse Block**

7720 ● ●

**SafetyHub Fuse Block**

7748 ● ●

7725 ● ●

### MRBF TERMINAL Fuse

**Terminal MRBF Fuse Blocks**

5191* ●

2151* ●

5194* ●

5196* ●

*Ignition Protected when using Blue Sea Systems MRBF Fuses.

### MEGA® or AMG® Fuse

**MEGA® or AMG® Fuse Block**

5001

**MEGA® or AMG® Safety Fuse Block**

7721 ● ●

### CLASS T Fuse

**CLASS T Fuse Block**

5502

5007100 ●
110A–200A

5502100 ●
225A–400A

### ANL® Fuse

**ANL® Fuse Blocks**

5005

5503

**LEGEND**

● Ingress protection
● Ignition protection

*Although this process uses information from ABYC E-11 to recommend wire size and circuit protection, it may not cover all of the unique characteristics that may exist on a boat. If you have specific questions about your installation please consult an ABYC certified installer.*

# CONNECTORS

- Sizes & Types

*Tinned

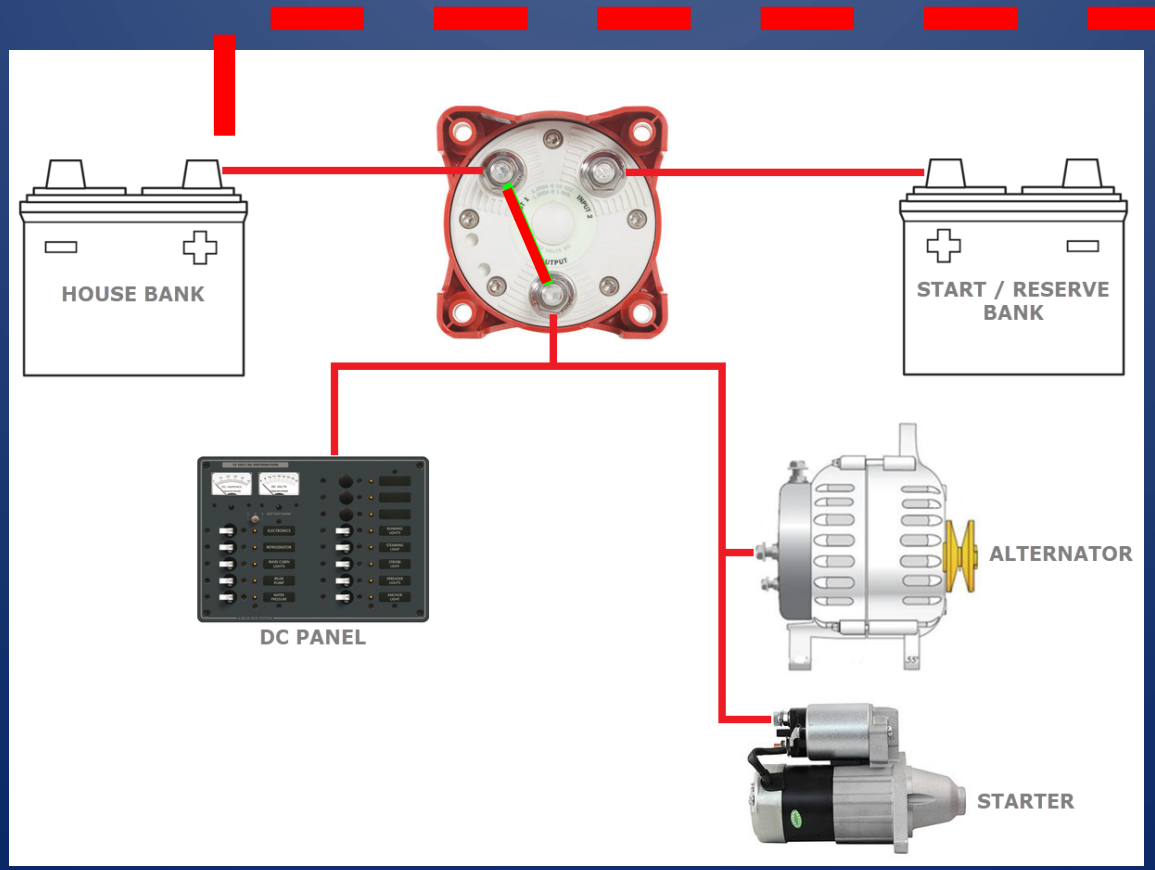
# BATTERY SELECTOR SWITCHES

- On, Off vs. 1, 2, 1+2, Off



# BATTERY SELECTOR SWITCH(ES)

- Determines route of electricity to and from battery

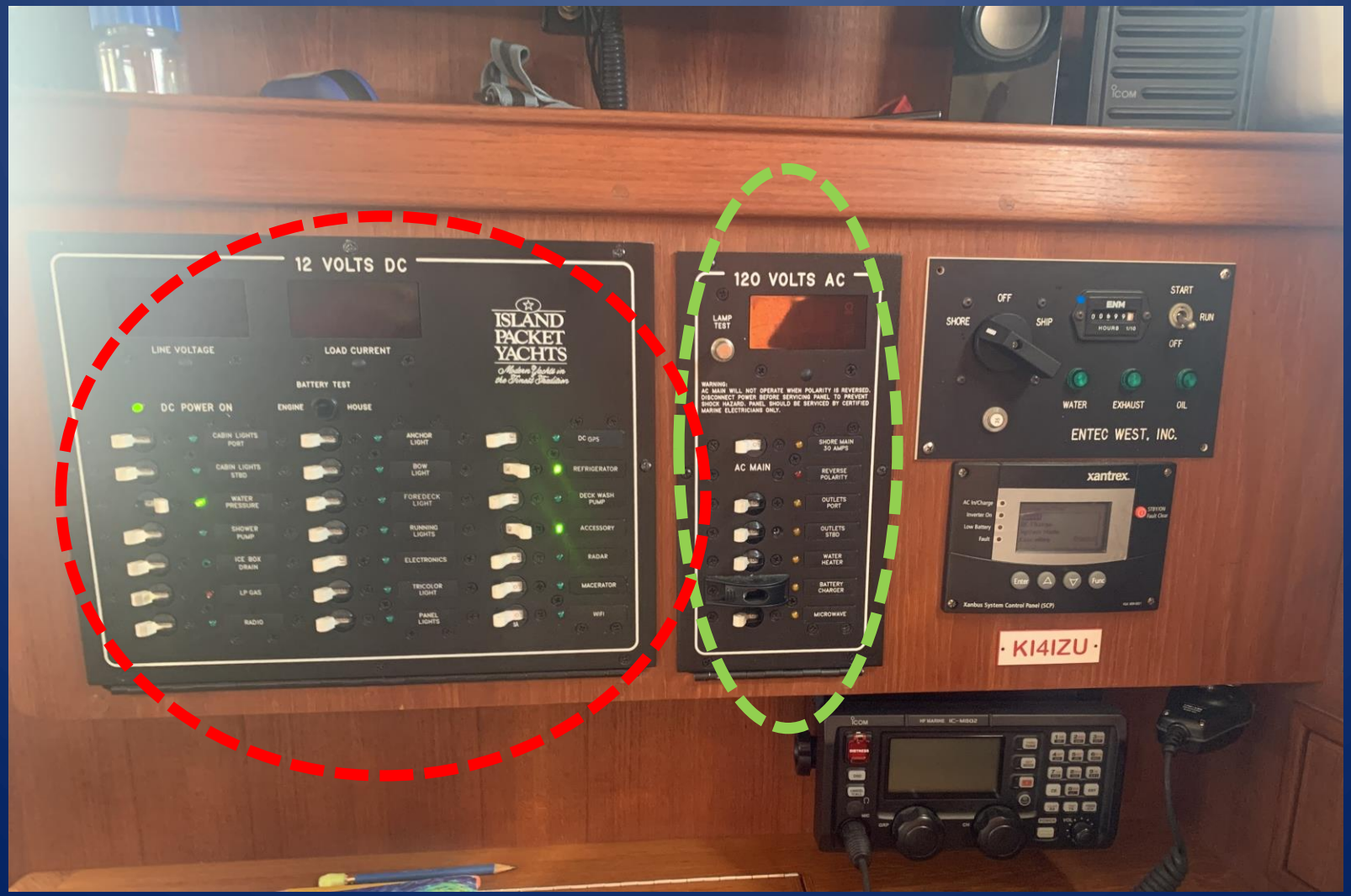



# BATTERY SELECTOR SWITCHES

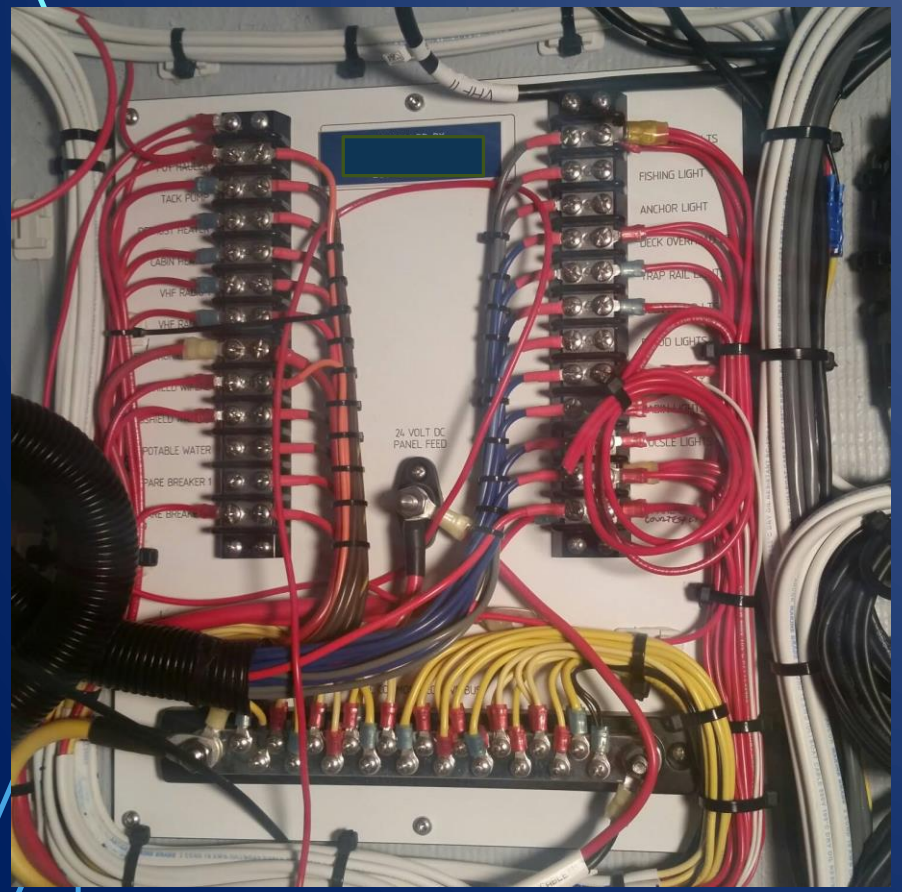

NO

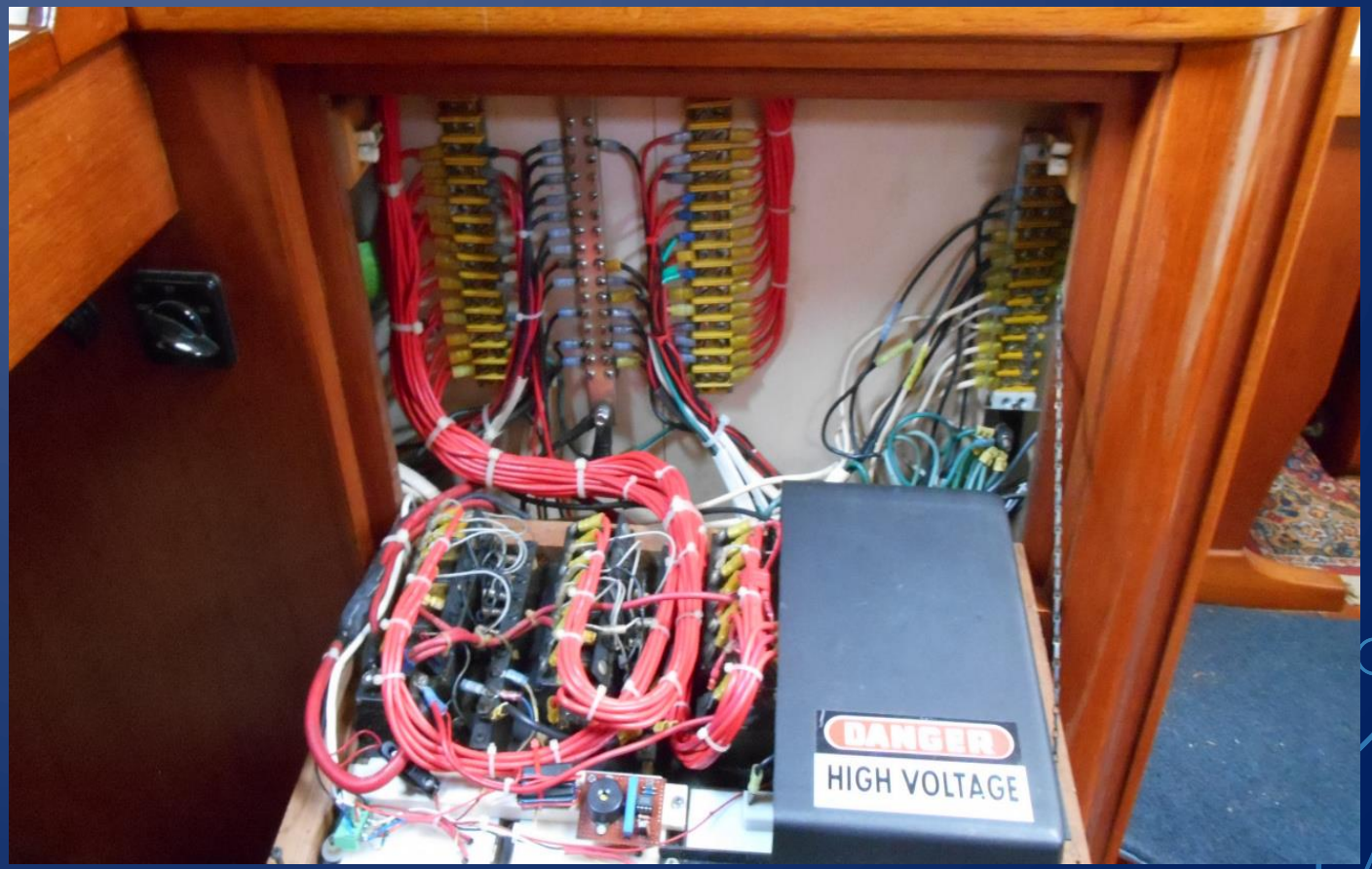

YES

# DISTRIBUTION PANEL(S)



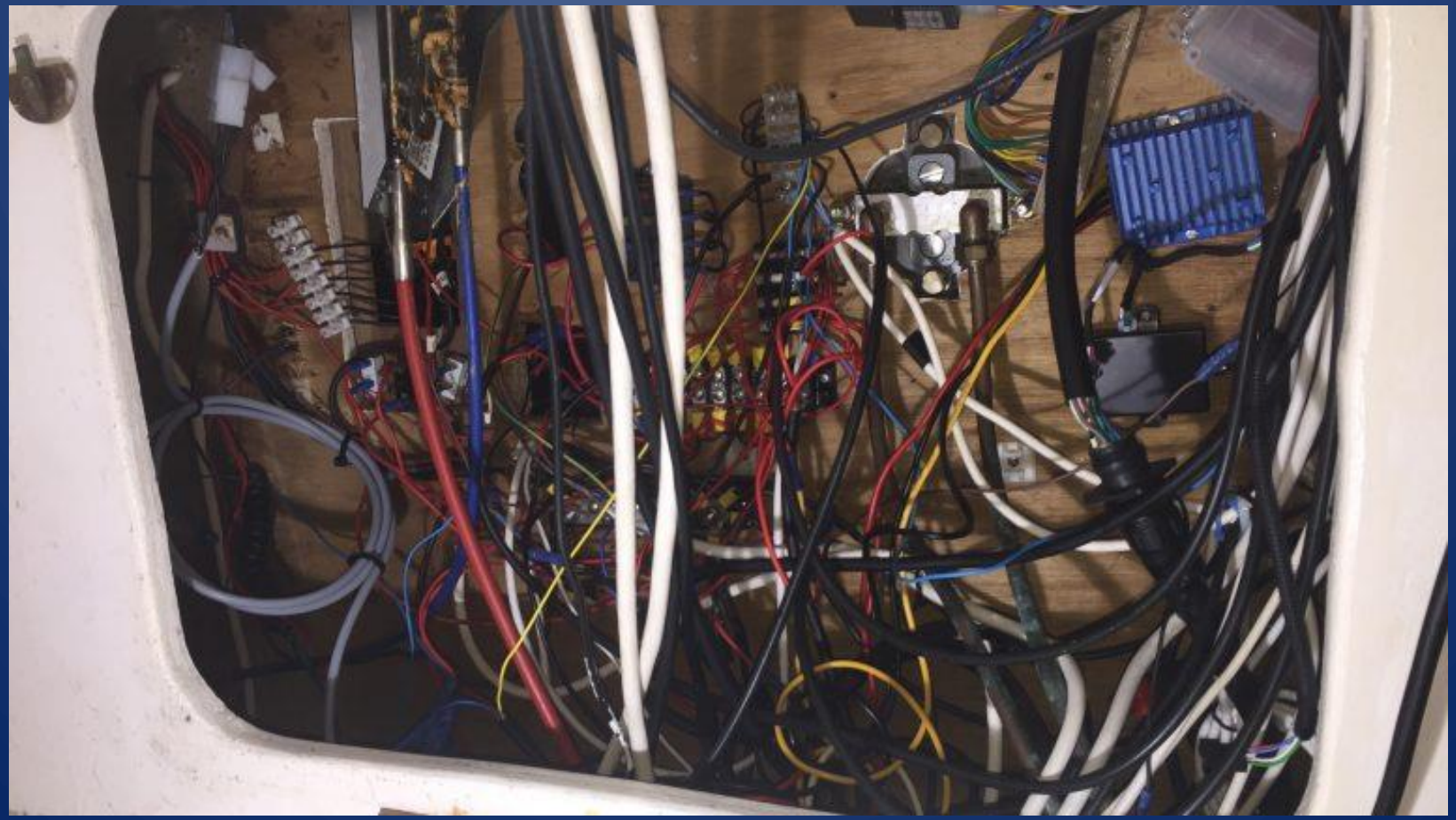
# DISTRIBUTION PANELS




"Good"

# DISTRIBUTION PANELS

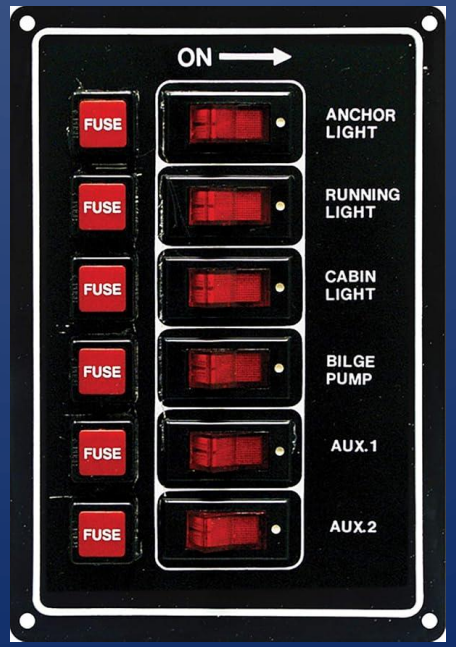


"Bad"

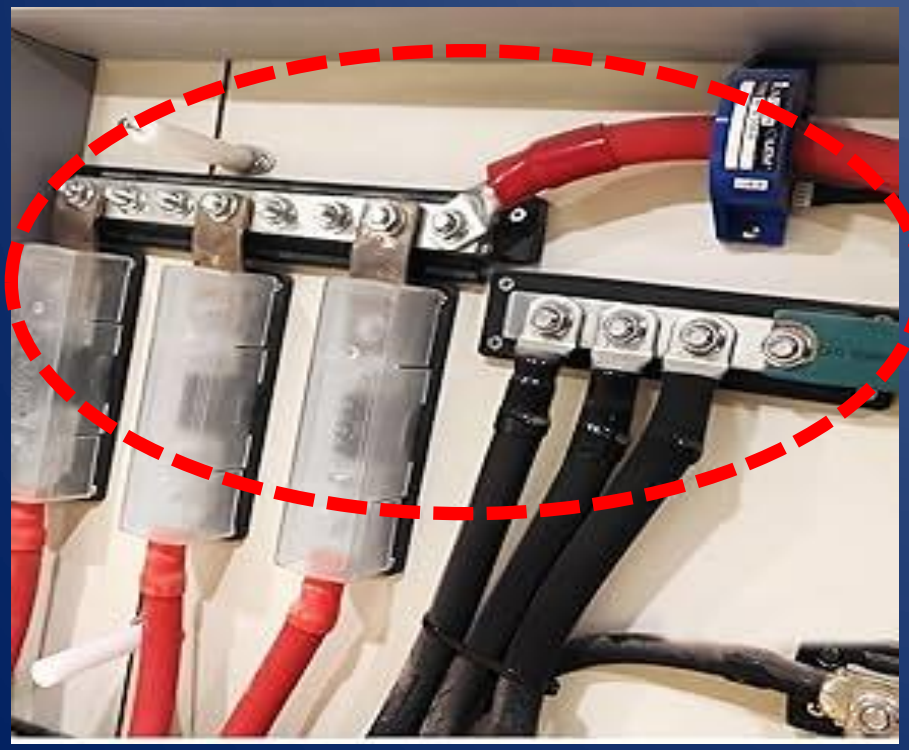
# CIRCUIT BREAKERS

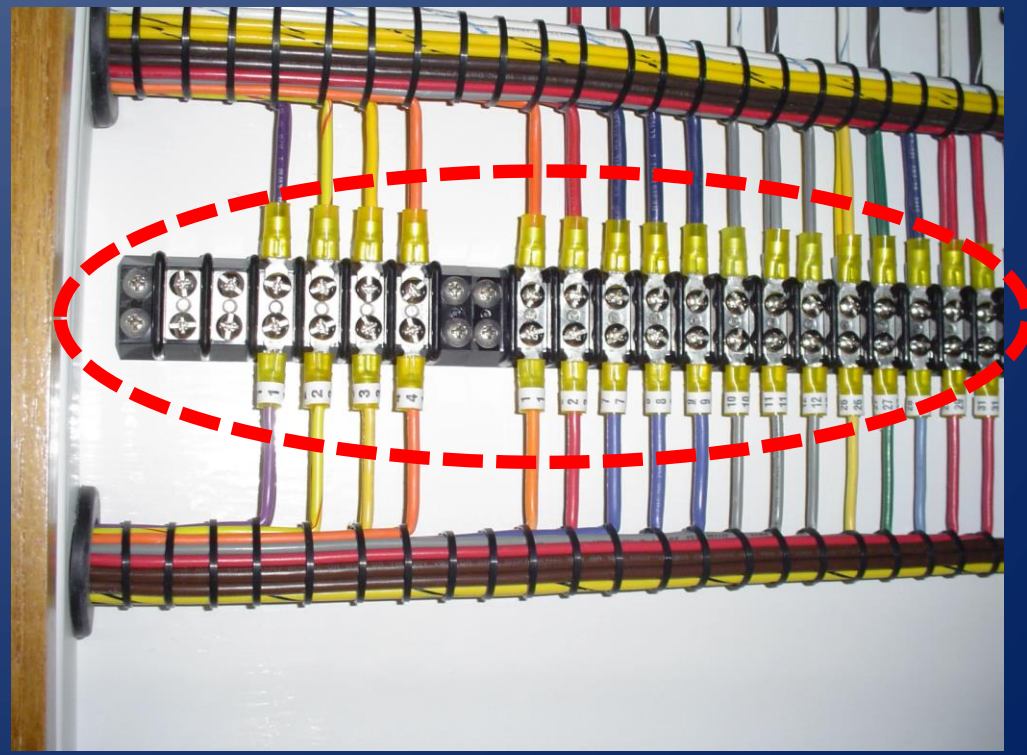
- Types




# BUS BARS AND TERMINAL BLOCKS





# SOURCES OF AC ELECTRICITY ON BOAT (DOCKSIDE)

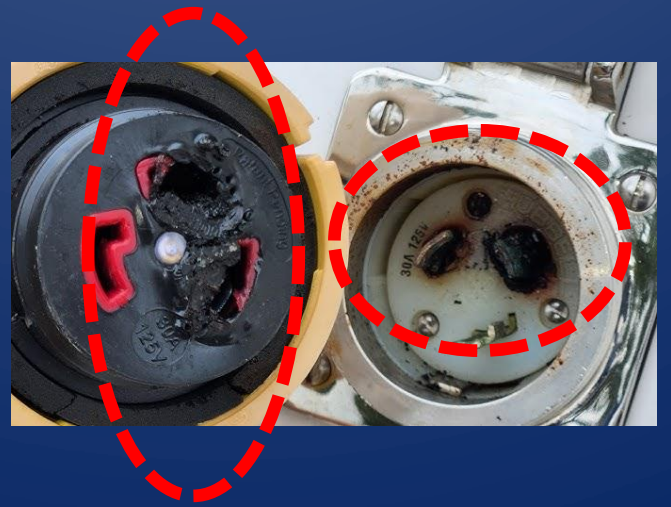


# SOURCES OF AC POWER ON BOAT (DOCKSIDE)

| Amperage/Voltage | Female Connector | Male Plug |
|---|---|---|
| 15A or 20A 125V Straight Blade |  |  |
| 20A 125V Locking |  |  |
| 30A 125V Locking |  |  |
| 50A 125V Locking |  |  |
| 50A 125/250V Locking |  |  |

# SOURCES OF AC ELECTRICITY ON BOAT (DOCKSIDE)

- Care of power cables - What to look for:
  - Burning/blackening/melted cable plug/connector
  - Corrosion on blades on the connector/plug
  - Exposed wires



# SOURCES OF AC ELECTRICITY ON BOAT (DOCKSIDE)

Smart Plug

# SOURCES OF AC ELECTRICITY ON BOAT (AT ANCHOR)



*Energy conversion penalty


# SOURCES OF AC ELECTRICITY ON BOAT (AT ANCHOR)

*Cost/ output/ noise/smell & fuel


# SOURCES OF AC ELECTRICITY ON BOAT (AT ANCHOR)



How many amps can these generators produce?

(I) Amps = (P) Watts/(V) Volts
I = 1800Watts/Voltage at 120 AC
I = 15 Amps per hour

(I) Amps = (P) Watts/ (V) Volts
I = (5kw) = 5,000 Watts/Voltage at 120 AC
I = 41 Amps per hour

# SOURCES OF AC ELECTRICITY ON BOAT (AT ANCHOR)





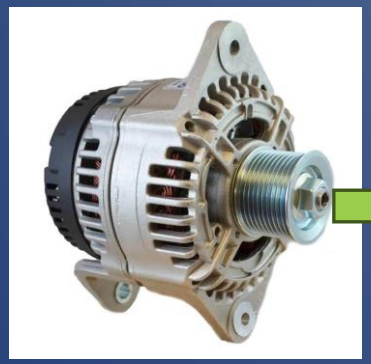
# SOURCES OF DC ELECTRICITY ON BOAT (AT ANCHOR)


House


Start




# SOURCES OF DC ELECTRICITY ON BOAT (AT ANCHOR)







House

Start

*Output/noise/smell/fuel/wear and tear



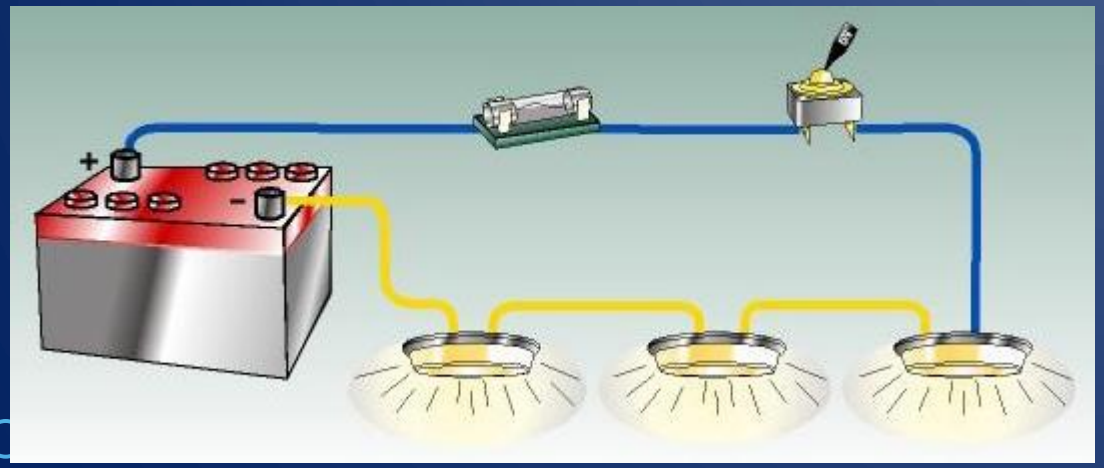
# DO I NEED MORE ELECTRICITY, IF SO HOW MUCH?

Boat electrical survey

*Don't ignore inputs from engine, generator, solar, wind, etc.

| | Energy Budget | | |
|---|---|---|---|
| **Budget 1** | **Passage Making** | | |
| **Item** | **Amps** | **Hours** | **AH/day** |
| Living areas | | | |
| Refrigeration | | | 0 |
| Potable water pump | 5 | 0.1 | 0.5 |
| Sump pump | | 0 | 0 |
| cabin lights | 5 | 5 | 25 |
| Water maker | | 0 | 0 |
| CD/radio | 4 | 0.5 | 2 |
| TV/DVD | 2 | 3.5 | 7 |
| Laptops/personal electronics | 1 | 5 | 5 |
| Gas solenoid | 1.2 | 24 | 28.8 |
| Heating | 1 | 0 | 0 |
| Other | 3 | 10 | 30 |
| Instruments | | | |
| VHF | 0.2 | 24 | 4.8 |
| GPS | 0.2 | 24 | 4.8 |
| Radar | | | 0 |
| Autopilot | 0.3 | 24 | 7.2 |
| **Running Systems** | | | |
| Windlass | 30 | 0 | 0 |
| Running lights | 3 | 10 | 30 |
| Anchor light | 1 | 0 | 0 |
| Engine Starting | 50 | 0.005 | 0.25 |
| Total | | | 145.35 |
| Charging | Amps | Hours | AH/day |
| Engine | 2 | 5 | |
| Solar (watts nameplate) | 220 | 5 | 92 |
| Wind | | | |
| Total | | | 92 |
| | **Number** | **AH** | **AH, usable** |
| Batteries | 3 | 140 | 147 |
| Days reserve if 20% generation | 1.2 | | |
| Days reserve if full generation | 2.7 | | |
| Days to rechage from 50% TO 85% battery capacity | 1.6 | | |

# DO I NEED MORE ELECTRICITY, IF SO HOW MUCH



15 Watts | 15 Watts | 15 Watts

- What is amp draw of these lights?
- Amps (I) = Watts (P)/Volts (V)
- Amps = 15 Watts + 15Watts +15Watts/ 12 Volts
- (I) = 3.75 Amps per hour

# DO I NEED MORE ELECTRICITY, IF SO HOW MUCH?



# ADDITIONAL SOURCES OF DC ELECTRICITY

*Cost/savings

2 - 4
Amps
per hour

.2 - .5
Amps per
hour

# ADDITIONAL SOURCES OF DC ELECTRICITY

*Cost/output/ engine compatibility

60 amp

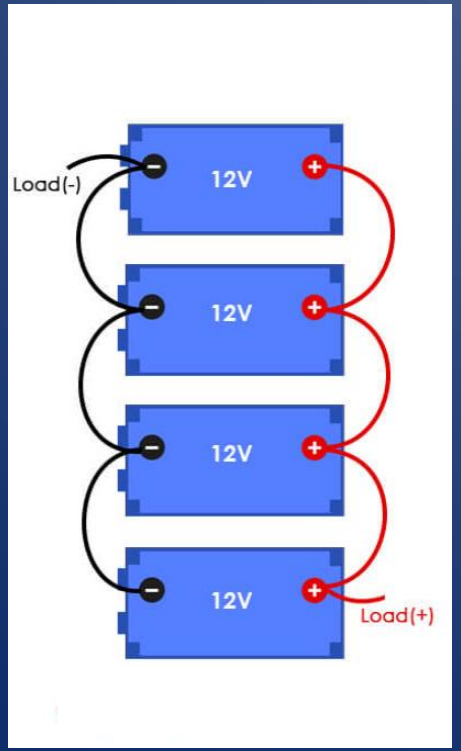
100 -150 amp

*Alternator ≥ 25% - 40% of battery bank.

# ADDITIONAL SOURCES OF DC ELECTRICITY

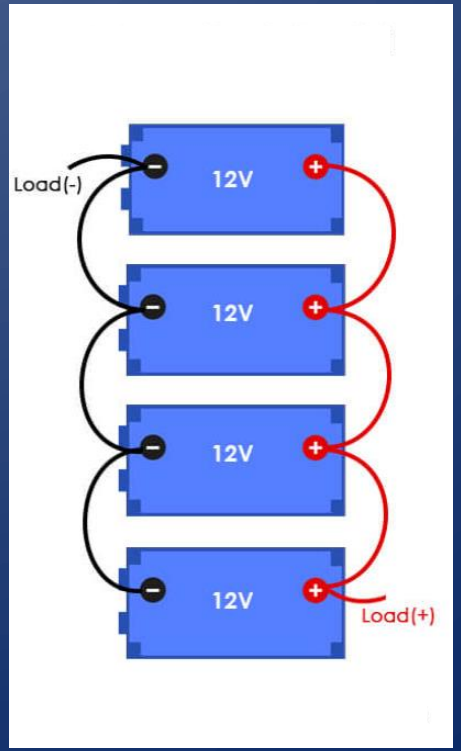
* Don't Mix & Match

*Cost/output/ room




200 Ah

+



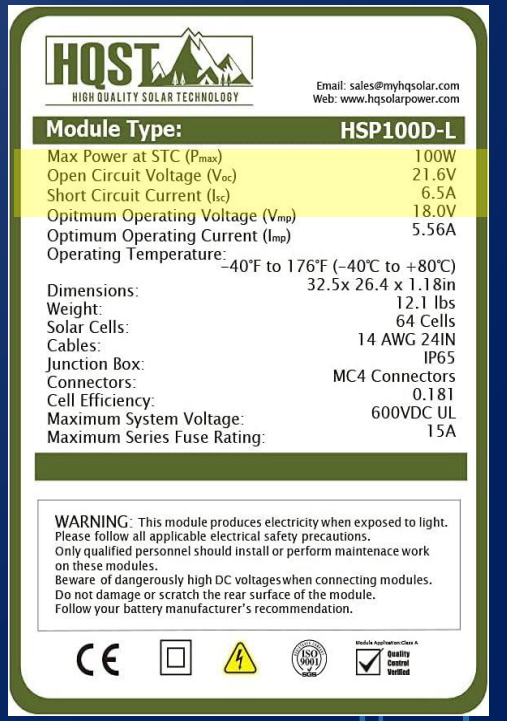

200 Ah

* Lithium Ion 50% vs. 80% discharge

# ADDITIONAL SOURCES OF DC ELECTRICITY

- **Monocrystalline**: High efficiency and durability.
- **Polycrystalline**: Balanced between cost and efficiency.
- **Thin-film**: Most flexible and lightweight, but less efficient.

*Cost/output/ location/ exposure



# ADDITIONAL SOURCES OF DC ELECTRICITY


How many amps can this solar panel produce?

Amps (I) = Watts (P) / Volts (V)

(I) = 200Watts/Voltage (at Pmax 18.6v)

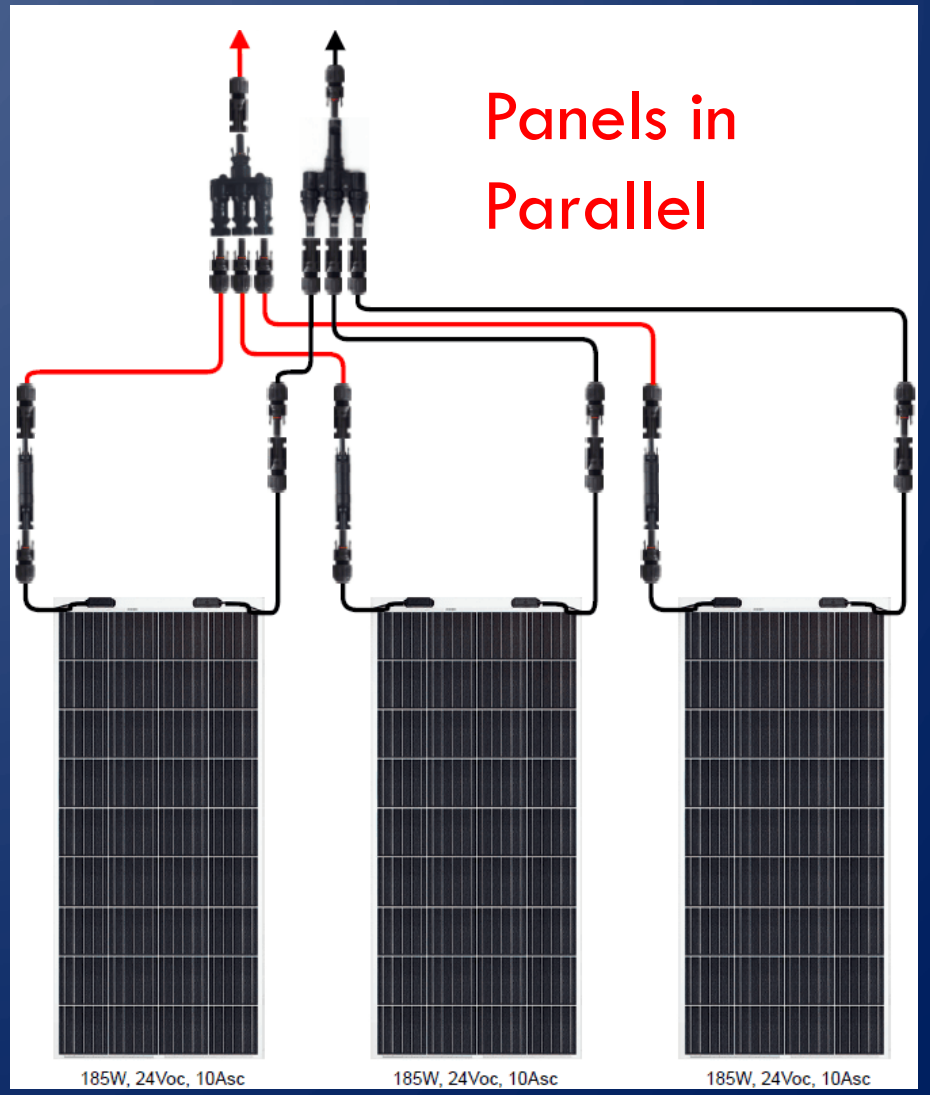
(I) = 10.75 Amps per hour*

*Not all the time

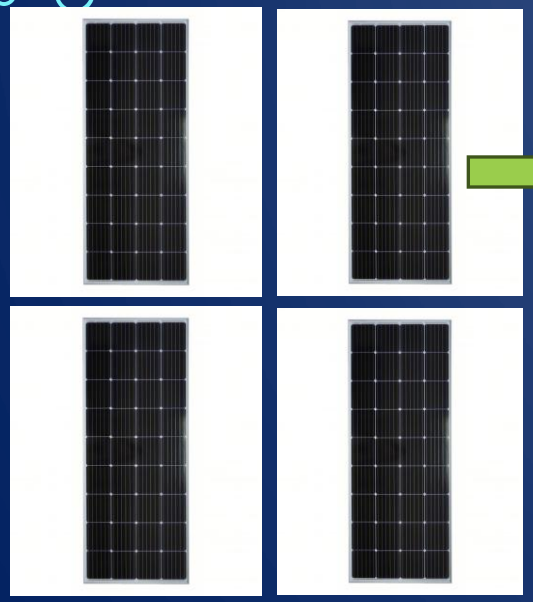
# ADDITIONAL SOURCES OF DC ELECTRICITY


10.75 Amps 10.75 Amps 10.75 Amps

= 32.25 Amps x 4-5hrs/day = 128 Amps – 162 Amps per day



# ADDITIONAL SOURCES OF DC ELECTRICITY





House

Start

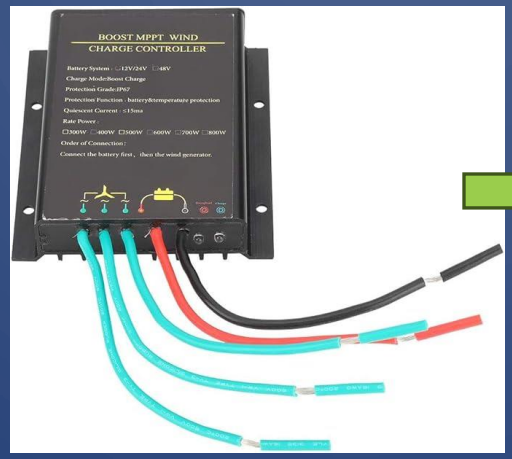
*MPPT vs. PWM



# ADDITIONAL SOURCES OF DC ELECTRICITY


*Cost/output/ min-max windspeed/ noise/location/ danger

# ADDITIONAL SOURCES OF DC ELECTRICITY



House

Start



# ADDITIONAL SOURCES OF DC ON BOAT

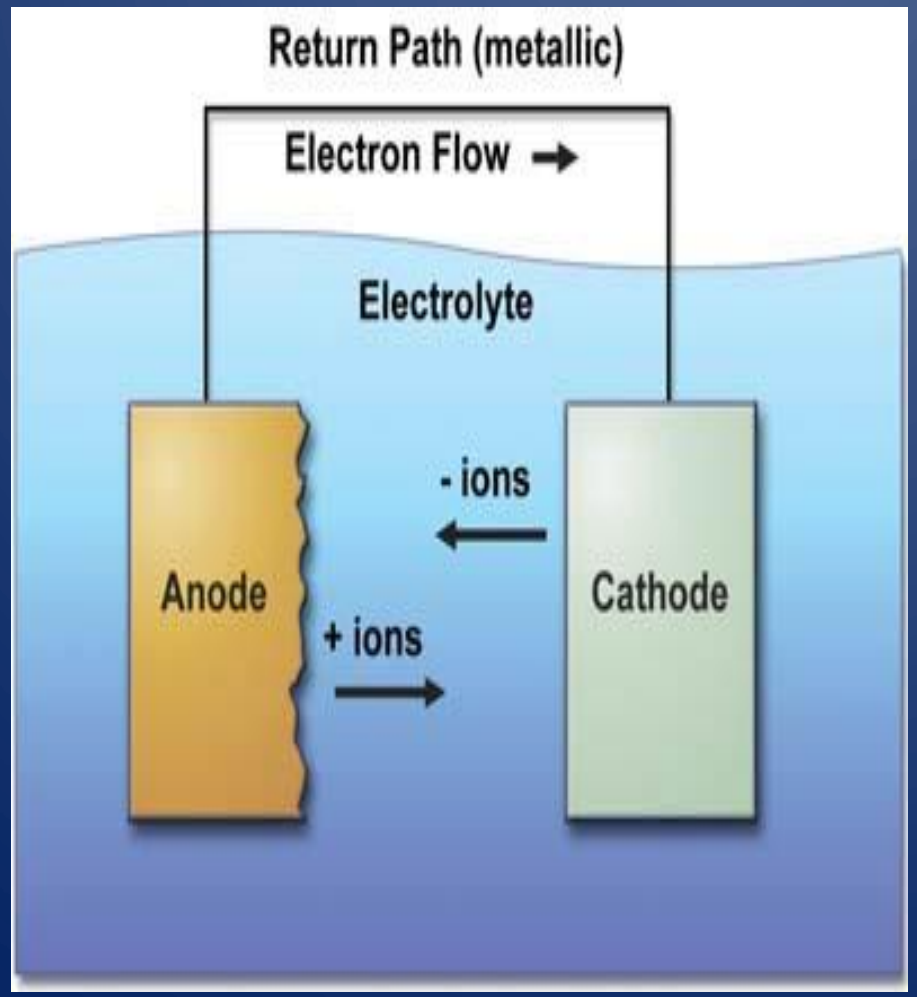
*Cost/output/ support/drag/fish strikes?

# ADDITIONAL SOURCES OF DC POWER ON BOAT

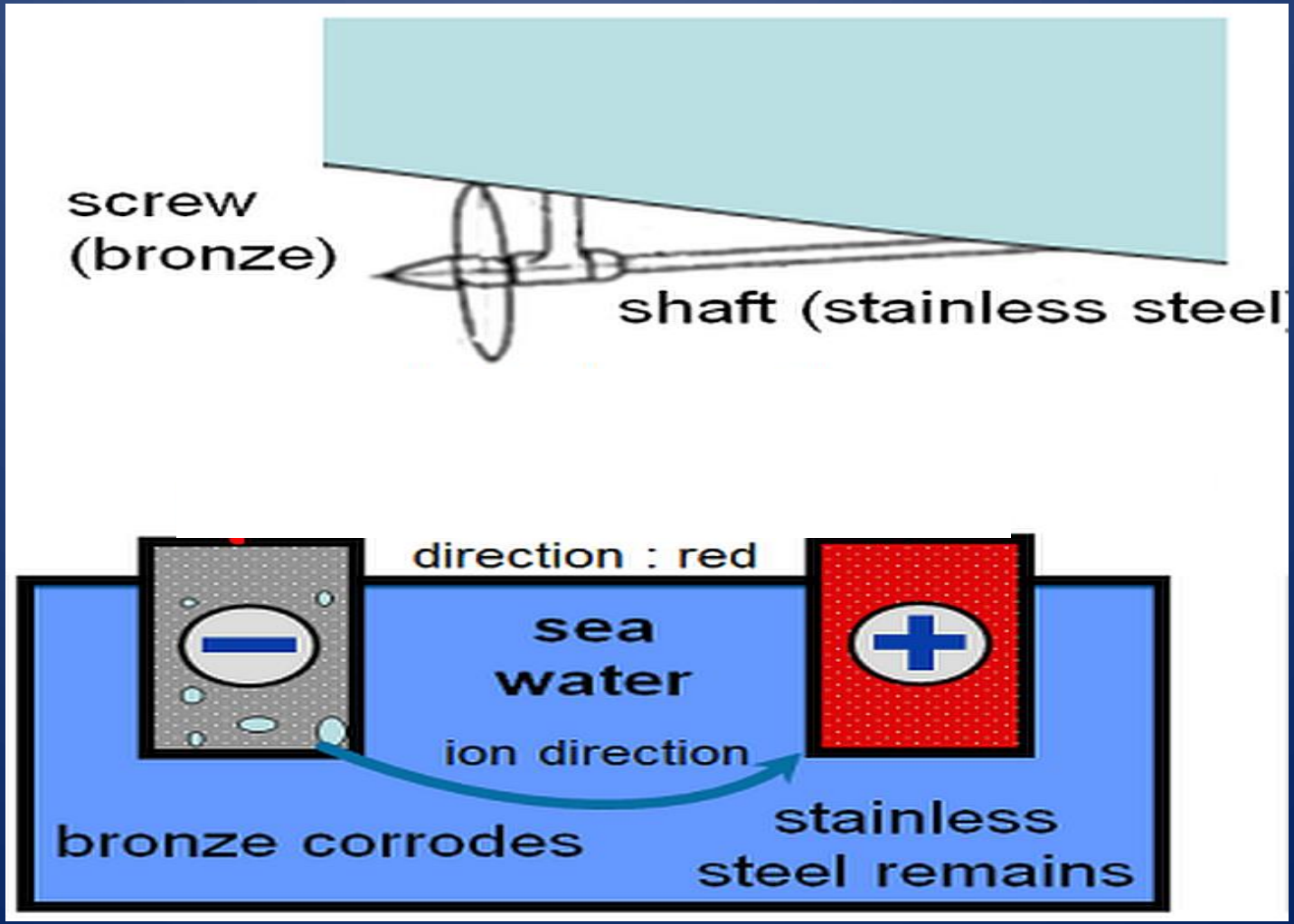

House



# GALVANIC CORROSION




# GALVANIC CORROSION



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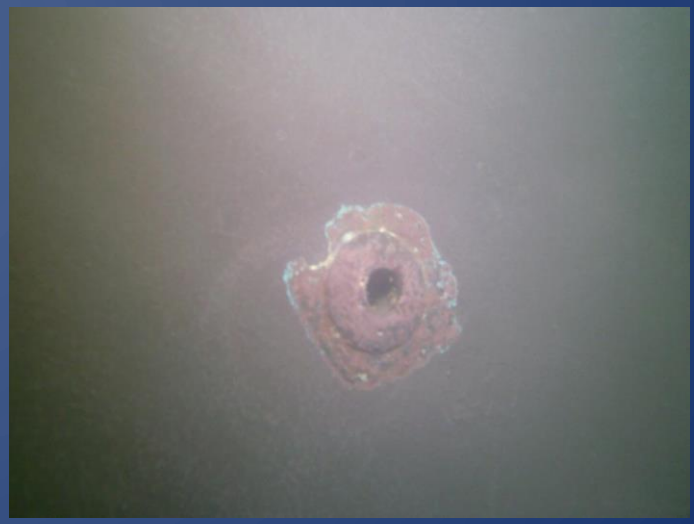

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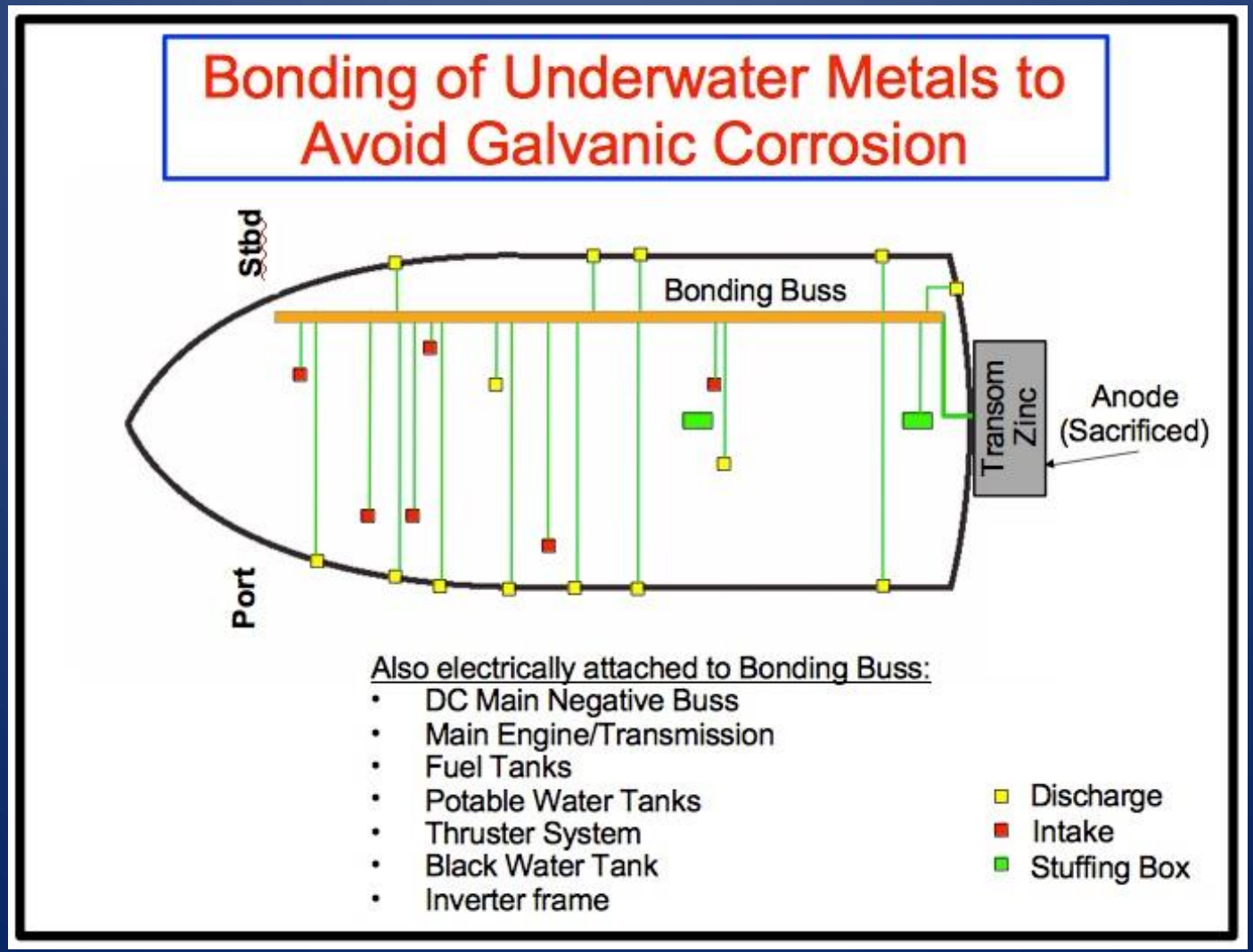

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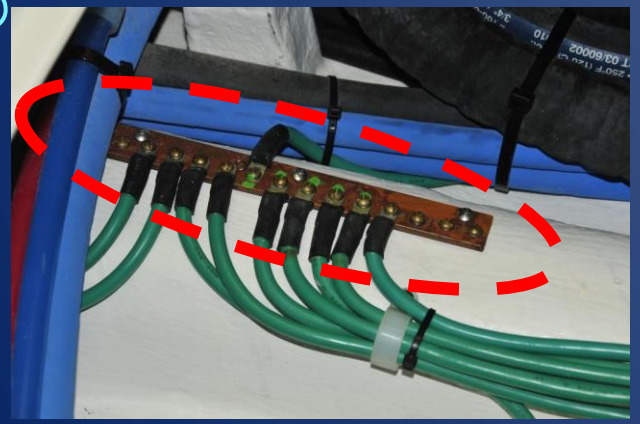

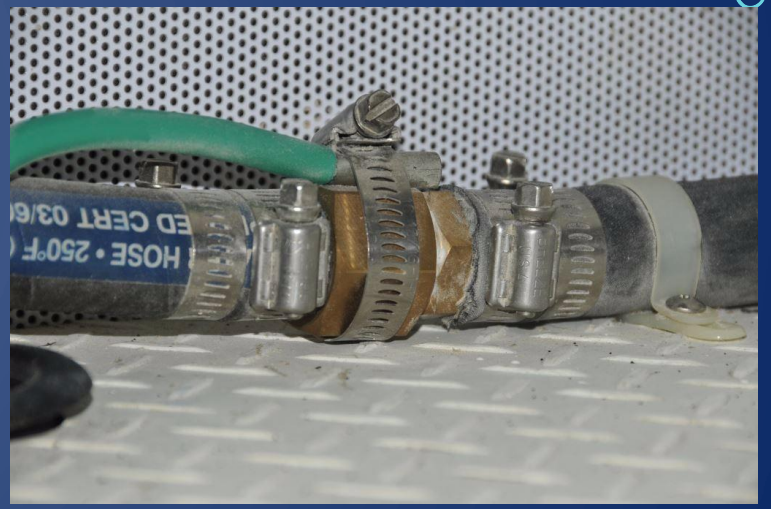

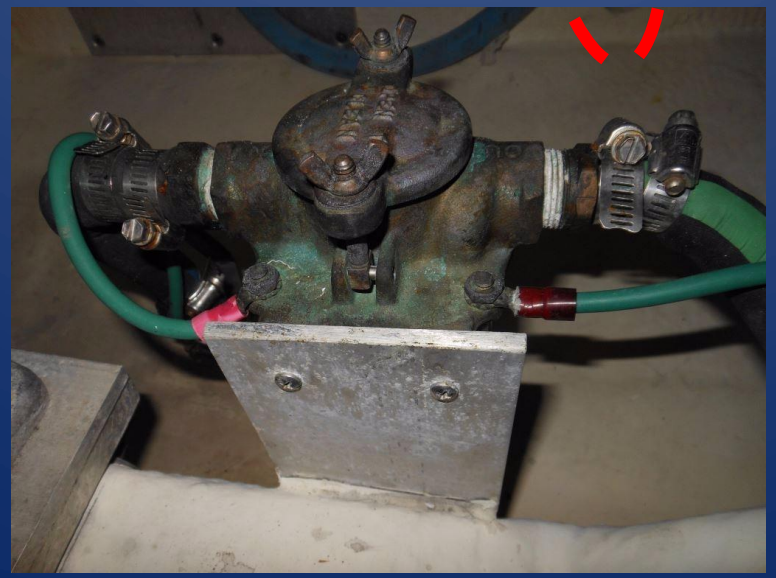

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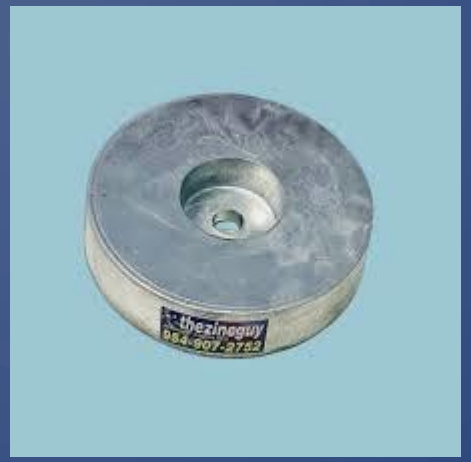
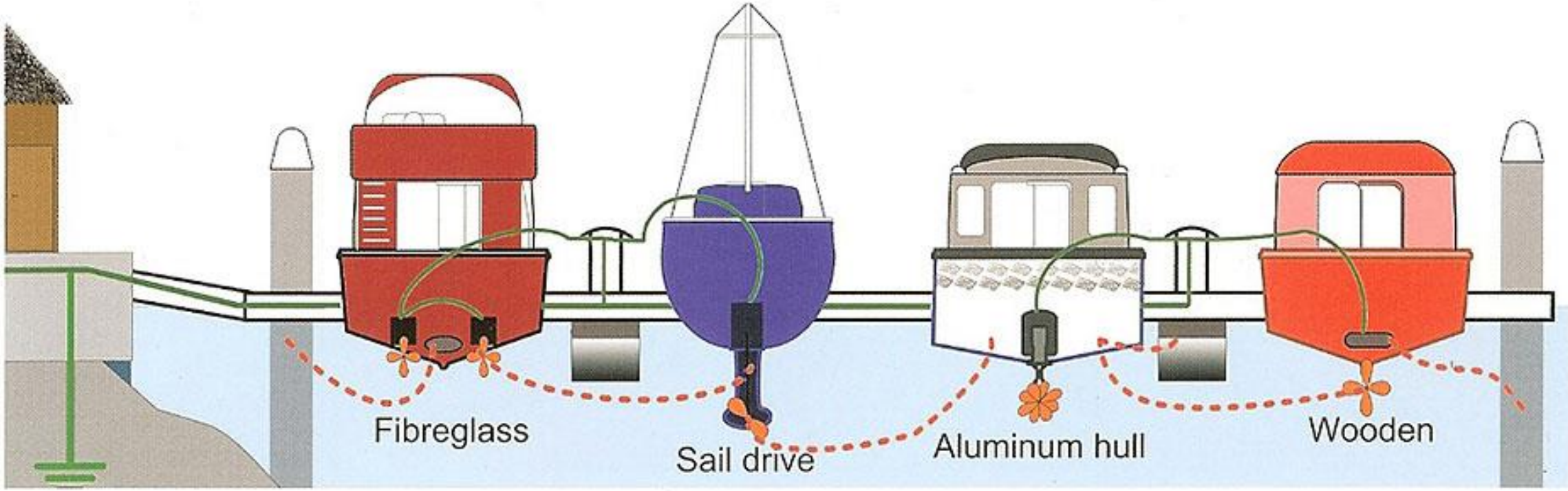



# GALVANIC CORROSION

# STRAY CURRENT CORROSION



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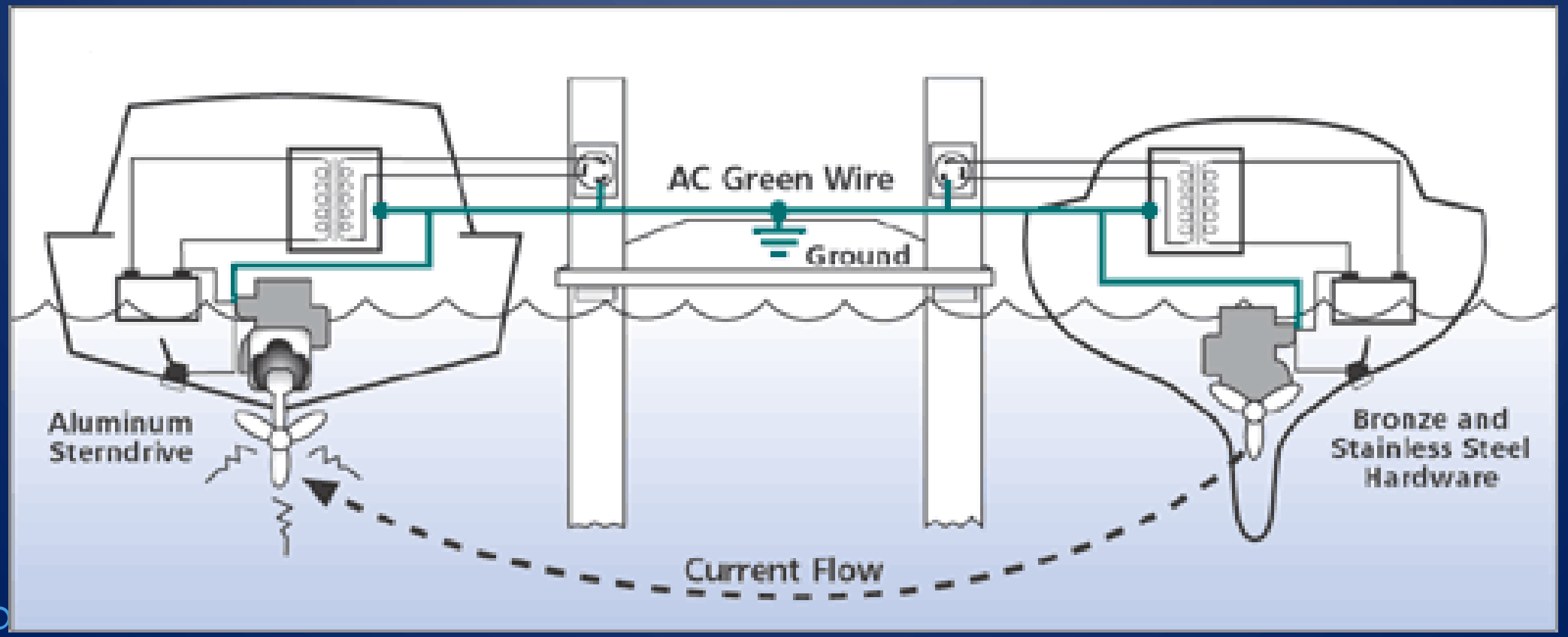

# STRAY CURRENT CORROSION


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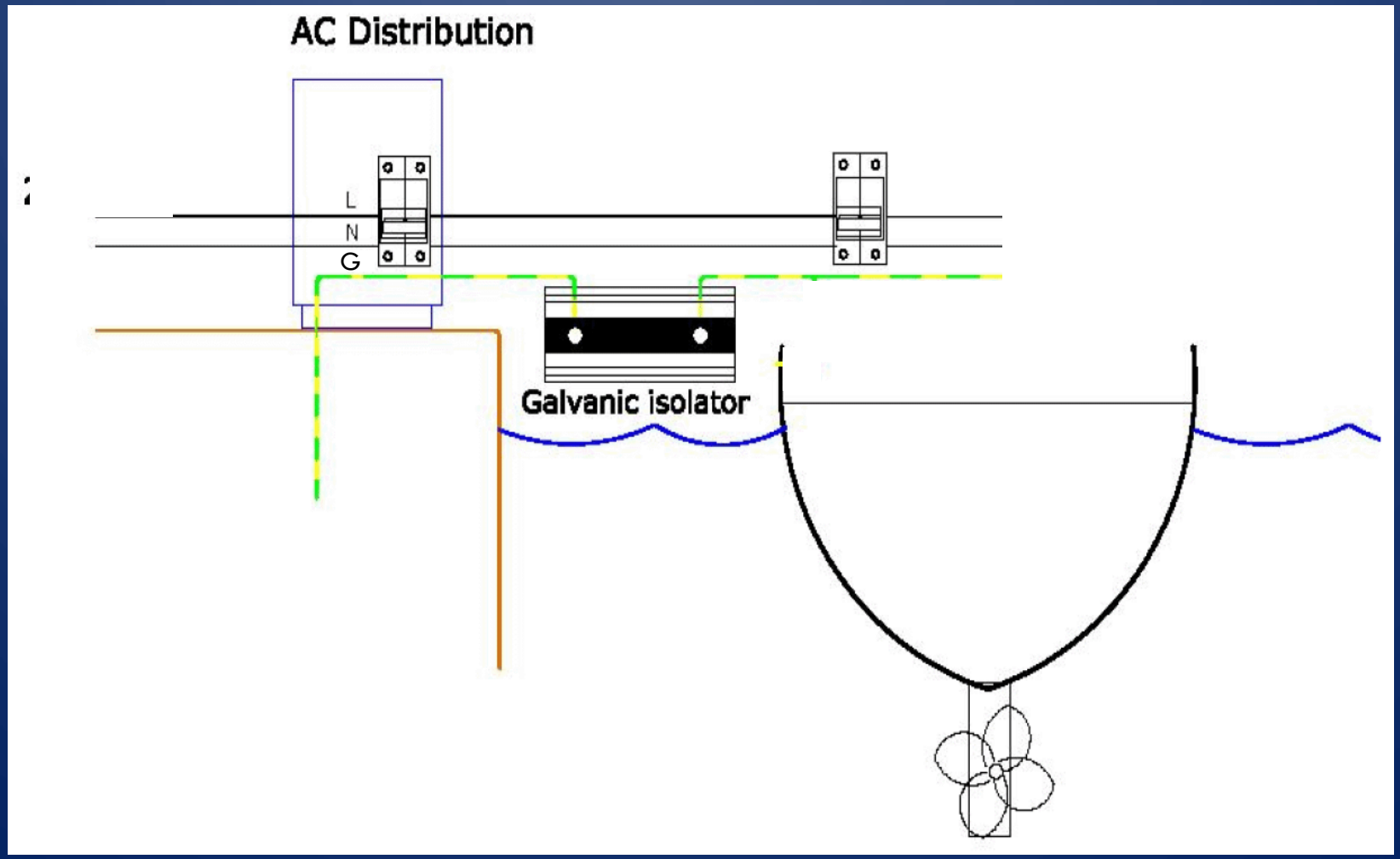


# RECOMMENDED TOOLS

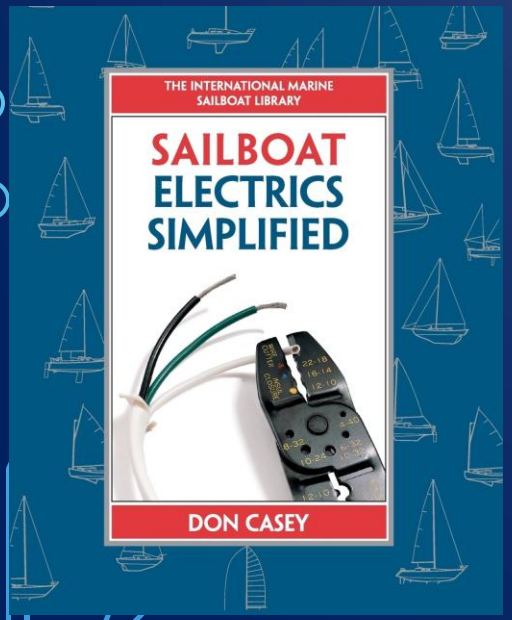


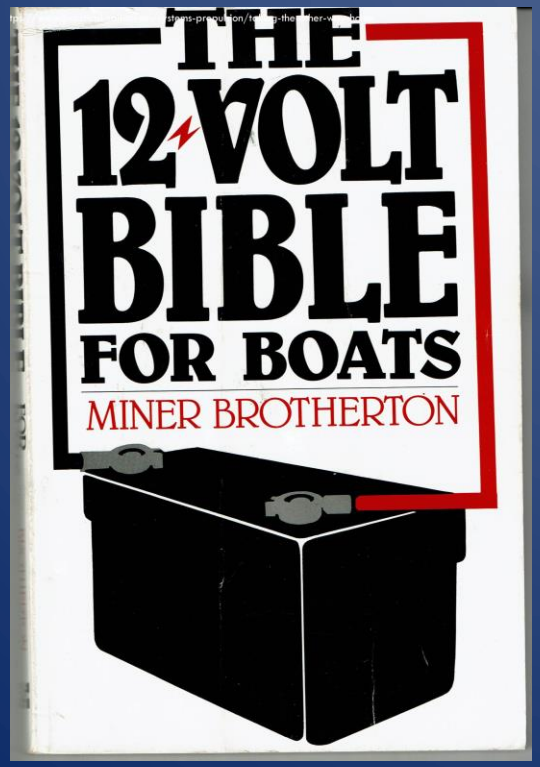


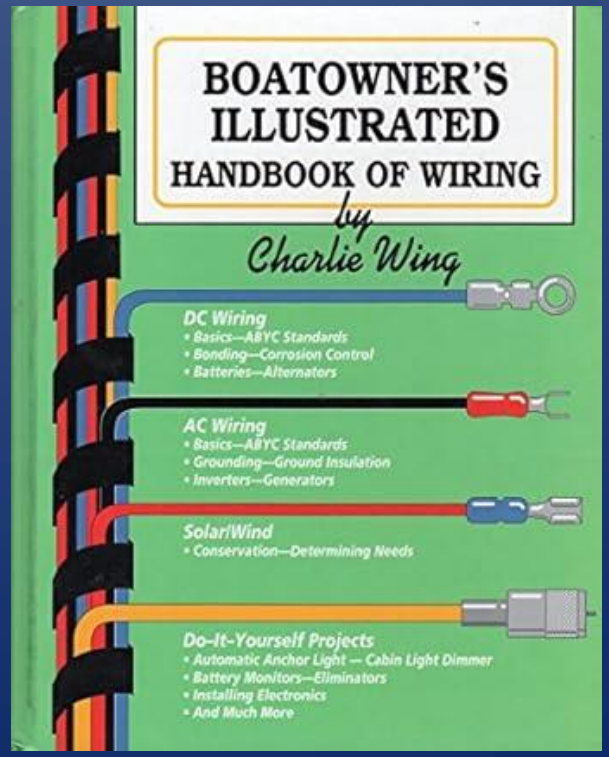


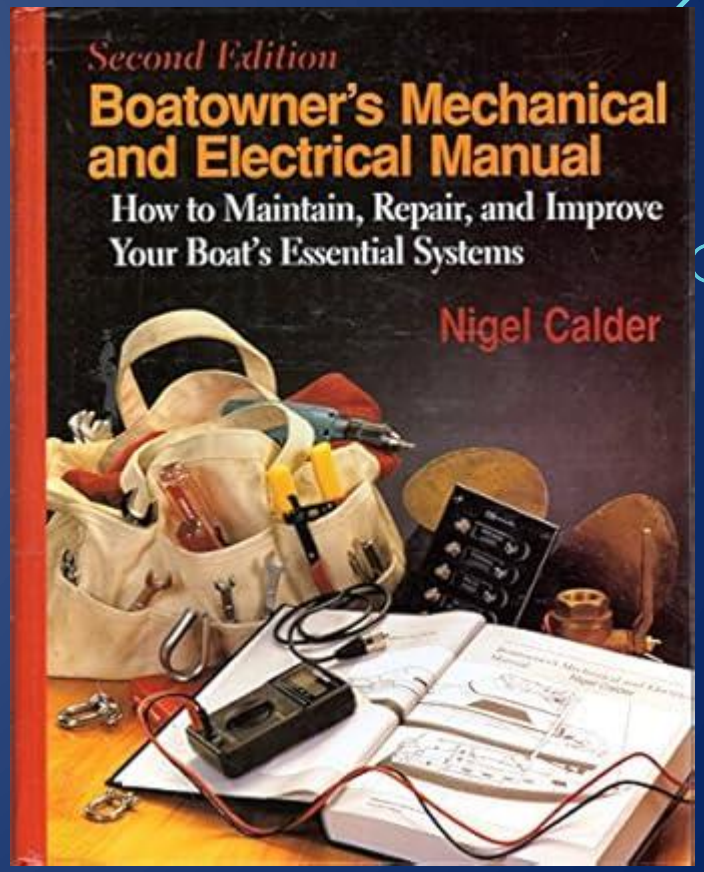


# RECOMMENDED BOOKS



# ABYC – AMERICAN BOAT & YACHT COUNCIL


- Sets voluntary standards for design, construction, maintenance and repair of recreational boats
- Mix of industry, surveyors and independent volunteers
- Concerned primarily with safety of systems

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