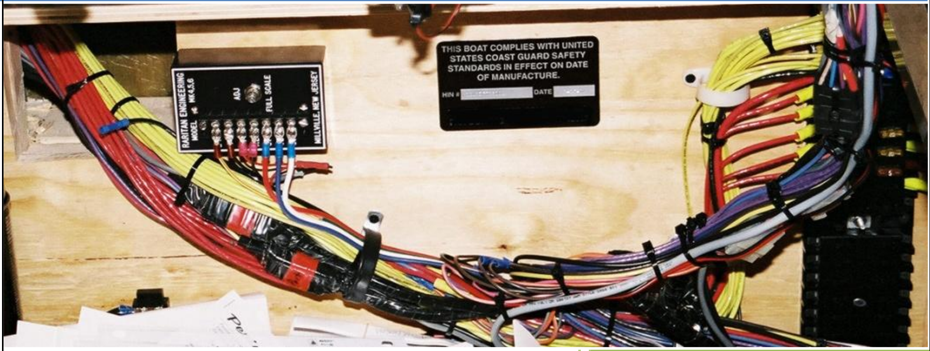
2016

ELECTRICAL SYSTEMS



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BASIC ELECTRICITY: Part 1

Electricity: I am going to try to keep this a simple as possible, not because I think you can't understand it. I assume that to master the art of boat building you have to be smart. Mainly, I don't want to end up writing a book on electricity. I want to this to be simple, but complete enough to give you a basic understanding of how this electrical stuff works. When I was much younger I worked on radars and computers on Coast Guard ships and when people asked us "how does it work?" we would say magically, mystically, wonderfully, electronically. But it's actually a lot simpler than that. However, to some it still seems like magic.

So what is electricity? As we all learned in grade school the world is made up of atoms. Atoms are made up of electrons, protons and neutrons. What we are interested in is the **electrons**, surrounding the nucleus of the atom. Electrons can be dislodged from their atom and attached to another one giving it an excess of electrons. Excess electrons give an atom a negative charge. Atoms with not enough electrons have a positive charge. Through a chemical reaction or other force, electrons can be made to flow though a conductor from the negative to the positive and used as electricity. So electricity is really just a stream of electrons flowing through a conductor from point A to point B and back to where they came from (a complete circuit). This is called **current.**

All of us have experienced this either by getting a static discharge off of a door knob or other metal object, or by seeing nature's ultimate display of electricity, lightning. This is simple exchange of electrons from one point to another. We use this every day in our homes, our cars, our cell phones and every other electric or electronic device we use, but we give little thought to what is actually happening.

In grade school most of us had a science teacher show us an experiment where a strip of lead with a wire attached and a strip of zinc with a wire attached, were put into a glass jar filled with acid. This is what is called a **voltaic cell, or battery.** The other ends of the wire were connected to a light, and lo and behold it lit up!

Battery History
http://en.wikipedia.org/wiki/History_of_the_battery

That is about as basic a battery as there is. What is happening here is not magic, just simple chemistry. The acid is an **electrolyte.** An electrolyte is a fluid that allows electrons to flow through it from one pole to another. Salt water is a pretty good electrolyte. Fresh water is not but will still conduct current and is actually more dangerous if current gets into the water.

When you put two dissimilar metals near each other in an electrolyte, one of the metals gives up electrons to the other metal. But this only happens if there is a complete circuit, which is the wire and the light. So the electrons flow from one plate to the other through the wire and the light and back to the plates. This doesn't go on forever though. One plate will gradually disappear and soon there will be no more electron flow. Then the light goes out. Where does it go? It gets plated onto the other plate. Remember this, because this is crucial to how batteries work, and how galvanic corrosion works. In fact this is called the **Galvanic Process.**

If we didn't have a light in the circuit, just a wire, electrons would still flow, but it would happen so fast that our primitive battery would be dead in no time at all, or the wire would get too hot and melt. This is called a short circuit. The positive side is connected directly to the negative side. The light we put in is called a **load.** It provides some **resistance** to the flow of electrons and slows down the process. Also the filament in the light gives off some of the energy of the electrons in the form of light and heat. Otherwise no work would get done by the electrons. So for electricity to do work there needs to be a load in the circuit. This can be lights, appliances, electronic equipment, or motors, all of which put the electrons to work.

The wire getting hot and melting is the basic principle behind a **fuse.** If too many electrons are flowing through the wire, the fuse is designed to get hot and melt at a predetermined amount of current flow. This breaks the circuit, or what is called an **open circuit**, and stops the current flow, the same way throwing a switch does.

So now we know what current is. It is electron flow. The amount of current is measured in **Amperes**, or milliamperes. The symbol for Amperes is A, or for milliamperes, mA.

What drives this current is called voltage. **Voltage** is a measure of potential energy contained in the battery and is measured in volts. The symbol for volts is V.

The load is resistance to current flow and is measured in something called **ohms**, named after the guy who discovered it. The symbol for this is either R or the Greek letter Omega. I will just use R because the Omega symbol is too hard to find on my computer.

Types of Electricity: AC and DC

Yes, electricity comes in different flavors, AC and DC. No, that is not a rock group. **AC** stands for alternating current, which is what we all have in our houses, and most appliances run on AC, and is usually 110 volts, or 220 volts for some large appliances such as clothes dryers. **DC** stands for Direct Current and is usually low voltage such as 6 volts or 12 volts. Many of the small electronic devices we commonly use, such as cell phones, calculators, and IPods all run on DC. Your car also uses DC and most small boats use only DC. However, as the boats get bigger they use both AC and DC, until you get into the ship sized yachts that use only AC. First though, I will deal with DC because it is simpler to explain and what most small boats use.

Direct current comes primarily from batteries. You can get it by converting AC to DC but for now I will stick with batteries. The simplest batteries are a single cells such as the D cells used in flashlights, or AA and AAA cells used in most small electronic devices. A long time ago, someone discovered that any single cell battery, no matter how big, puts out about 1.2 volts. Over the centuries that has been upped to about 2 volts. The larger you make this cell, the longer it will last, and the more current you will get out of it (amperes) but you still won't get any more than about 2 volts.

So how do we get typical 12 V and 6 V batteries? These are lead-acid type batteries and have about 2.0 volts per cell, compared to the 1.5 volts of most flashlight-type cells. If you tie a lot of these cells together in series (I'll explain series in a minute) they add up. So three cells is six volts, and 6 cells is 12 volts. So actually that 12 V battery in our car or boat is really six cells (count the vent caps) wired together to make twelve volts.

Series means battery cells that are connected together thus; The positive pole on the first cell is wired to the negative on the second, and the negative on the first is wired to the positive on the second, and so on until you have the voltage you need.

Parallel means just the opposite. All the positive poles are connected to each other and all the negative poles are connected to each other. This still only gives you 1.5 volts but it increases the amount of current. This is commonly done in boats and recreational vehicles to make a large battery bank to power all the DC equipment on board. Two or more twelve volt batteries will be connected in parallel to increase the current, to run more equipment, or to run your equipment for a longer time. However, if you have something that runs on 24 volts or 48 volts, you can connect 12 volt batteries in series to get the desired volts. In series you add the voltages. In parallel you add up the amperages.

See the Figure below, and the photo of two deep cycle batteries in parallel. The battery on the right is the starting battery and not connected to the two deep cycle house batteries. However, in this instance there is a switch which allows the house batteries to be used to start the engine.

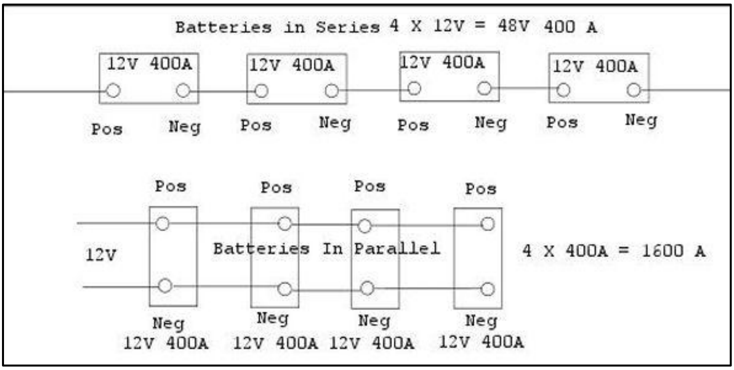

Fig. 1 Batteries in Series and Parallel

Fig. 2: Deep Cycle Batteries on the left, starting battery on the right.

So why use DC? DC has certain advantages. It comes in convenient sized packages; for example, your typical automotive batteries. Also, DC does not present the big shock hazard that AC does (until you get over 50 volts). Plus that, most equipment used on small boats is designed specifically to run on DC. You don't need a large generator to produce DC, and you can easily recharge the batteries from an alternator on your engine, or with a charger from shore power.

Why is it called direct current? **DC current flows in only one direction**, as opposed to AC, which flows both directions. For low power devices, DC is more than adequate to supply your power needs. See Wikipedia on Direct Current https://en.wikipedia.org/wiki/Direct_current

So what about AC? It's called **Alternating Current because the current flow switches direction every 1/120th second**, meaning it takes 1/60 of a second to go through a complete cycle, or 60 cycles per second, now called Hertz after the inventor, and shown as Hz. See Wikipedia on Alternating current. https://en.wikipedia.org/wiki/Alternating_current

Alternating current's biggest advantage is that it can be easily transformed to higher or lower voltages with a transformer. To send lots of power a long distance, a high voltage up to hundreds of thousands of volts is used ("High Tension" lines). The current is much less, so the voltage drop is much less. Some of the newest long-distance lines now use DC, as new methods of converting DC up and down in voltage have been developed.

Someone discovered that electrical equipment such as AC motors run best at between 50 and 60 cycles. We in America chose to use 60, the rest of the world opted for 50. Also, most of the world outside the US uses 220 volts instead of the 115 we usually use. So if you go anywhere else, to run your US electrical equipment, you need an adapter that changes 220 volts to 115 volts. In most cases the difference between 50 and 60 Hz is not a problem. That's why when you go to Europe and take your laptop computer or a shaver, hair drier, or a curling-iron, you need appliances that have a switch for 110V to 220V, or a separate converter. Recently though many laptop chargers and small appliances will run from 110 or

220V and 50 or 60 Hz. Read the small print on the back of your charger!

AC can be changed easily to DC of various voltages as well, by power supply devices that change the voltage and rectify AC to DC.

Wikipedia Electrical Wiring (United States)
https://en.wikipedia.org/wiki/Electrical_wiring_in_North_America
Wikipedia Electrical Wiring (UK)
https://en.wikipedia.org/wiki/Electrical_wiring_in_the_United_Kingdom

Also **AC can be transformed**, that is changed easily to another voltage by use of a transformer, so you can have 110 volts AC, 220 or 440 AC, or whatever you need. It can be changed easily to DC as well, by a converter. Out on the power pole, the power in the lines coming into your neighborhood is around 10,000 volts AC. But the utility company mounts transformers on the poles to transform it to 110 volts AC 220 or 440 AC so you can use it in your house, or on your boat.

Why AC on a boat? As boats get bigger the owners want the convenience of appliances that run off of AC. Probably number one is air conditioning. There are 12 V air conditioners but AC ones are more available and more powerful. Also, house type appliances such as large screen TV's, VCR's, computers, refrigerators, etc., all run on AC. So AC has come aboard our boats and is here to stay. It is also appearing on smaller and smaller boats every year as the market gets more competitive.

Generating Electricity:

So **where does electricity come from**, or rather how do we make electricity? What are the sources?

The first and most obvious is the electrochemical process I described as a **battery**. Dissimilar metals in an electrolyte form a cell from which electrons will flow. But what about when the battery gets too low and we need to recharge it? Where does that electricity come from? And where do we get this Alternating Current?

That comes from a different process call **electromagnetic induction**. Many hundreds of years ago people discovered magnets. They also discovered that if you float a magnet in a liquid it points to the magnetic north pole. This led to the magnetic compass. But it wasn't until the last few hundred years' scientists determined why. Our earth has a magnetic field. This field radiates along lines of magnetic flux that flow north and south. Every magnet also has a magnetic field around it with these same lines of magnetic flux.
Wikipedia on Magnetic Flux.
https://en.wikipedia.org/wiki/Magnetic_flux

Then someone discovered that if you move a wire (a complete circuit, not just a short piece of wire) through a magnetic field it causes electrons to flow in the wire. You are creating electricity. As the wire moves through the lines of magnetic flux around the magnet, the electrons in the wire get all excited and start dashing about.

So after much experimentation it was discovered that if you rotate a magnet on a shaft (a rotor), inside a coil of wire (the armature), electricity is generated in the coil. This is a **DC generator**. If you are much over 40 you may remember that cars had generators, not alternators, up until the 1970's. For the most part, the devices that make electricity are still called generators, even though they are now mostly alternators. So what's the difference? A generator puts out DC, and an alternator puts out AC. Wikipedia on Electrical Generators
https://en.wikipedia.org/wiki/Electric_generator

As I said on the previous page, DC loses a lot of voltage when transmitted over long distances due to resistance in the lines, and a thing called voltage drop. Someone discovered that AC did not lose a lot of power this way. So until recently power plants have all put out AC from very large **Alternators.** In recent years methods have been discovered to transmit DC over long distances as well, but power plants are still mostly AC. In generators, if you wind half of the coil, (the armature) one direction, and the other half the opposite direction, as the rotor turns the electrons go one way in one half and the opposite way in the other half. That gives you alternating current. If you spin this rotor at 60 revolutions per second you get 60 cycle AC. War of Currents on Wikipedia
https://en.wikipedia.org/wiki/War_of_Currents

So, power plants put out AC. Car generators put out AC. Generators on your boat, whether on the engine, or a separate generator, all put out AC. This is then **"rectified"**, that is, converted to DC and used to charge your batteries and run equipment.

In the USA and around the world, there are thousands of plants generating electricity by using steam to turn the generators, water to turn the generators, wind turbines, tides, and even nuclear power. The plants are all connected to a power grid. In North America, the USA and Canada are both hooked up to the same power grid. This grid is divided up into many little grids and separate power sources, but by throwing switches the power you get in your home can come from almost anywhere in North America. This power can then be used by you to not only power all of your electric appliances, but also to charge your batteries. See Wikipedia on Electric Power Transmission.
https://en.wikipedia.org/wiki/Electric_power_transmission