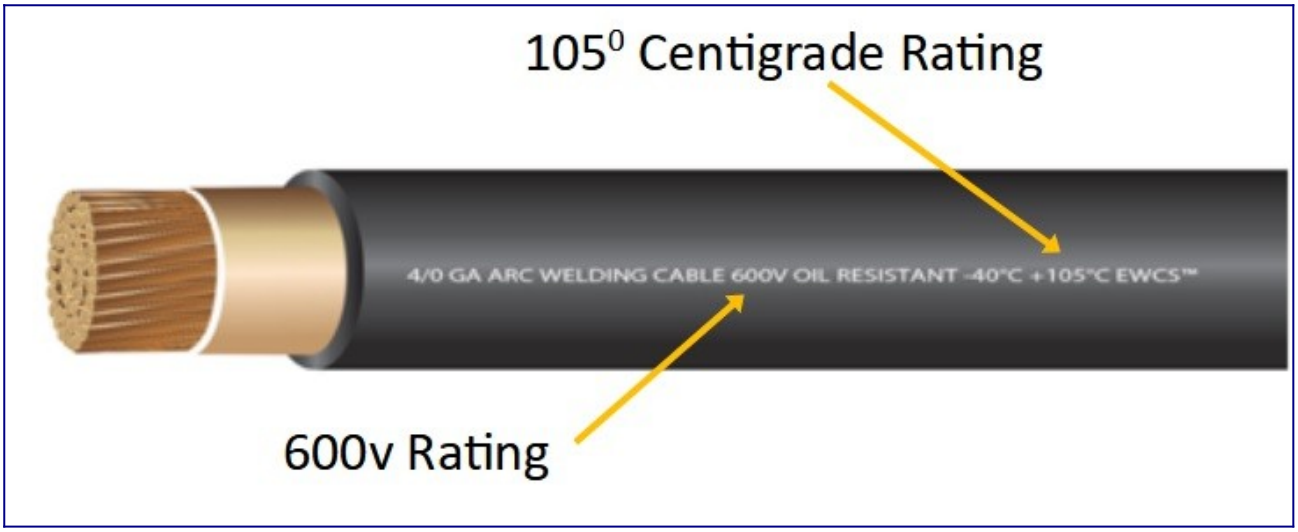
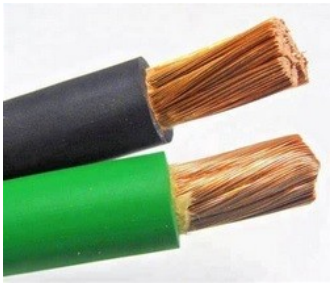
Chapter 5 - DC Wire & Fuse Basics

One of the things that can get confusing, but is extremely important, is knowing what size of wire to use when working with DC circuits. And once you get the wire size figured out...then trying to figure out what size fuse should you use can be just as daunting.

So I've included a wire sizing chart in this chapter for you to download. And I will provide a couple of tips as well. Finally, I will provide a link to a great little sizing and fusing calculator that I think makes everything much easier when trying to calculate all of this. But first, some good information to know…



Also, it is important to note that when dealing with DC currents in solar power systems (SPS) you need a high-quality wire with a good insulation rating; 105 degrees centigrade is commonly referred to as the standard. Voltage rating should be at least "600V".



Also, stranded wire is best when using wire in the DC side of SPSs...the more strands the better. But, a good measure would be as follows, with each strand being 30AWG wire...

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6AWG - 260 strands
4AWG - 364 strands
2AWG - 624 strands
1AWG - 767 strands
1/0 - 975 strands
2/0 - 1196 strands
3/0 - 1547 strands
4/0 - 1950 strands

Most wire wire/cable will come with rubber or rubber-based insulation. Silicone-based wire insulation is generally considered superior to rubber-based wire insulation for a number of reasons, one being a higher heat rating, up to 200 degrees centigrade...almost double standard rubber-based insulation.

Silicone is the most fire-resistant of common insulation material, it is also highly resistant to extreme environments. Then we also see silicone as being more flexible and more compression resistant. And yes, silicone is more suitable for outdoor applications, but when running wire outdoors it's always best to place wire inside a protective conduit.

Aluminum wire should not be used...period.

Copper wire is the standard for DC applications due to its high electrical conductivity. However, there is even better wire than standard copper wire, tin-plated stranded copper wire. Tin-plated copper wire is noted for its longevity because of its anti-corrosion properties. And, studies show that this variety of copper wiring is able to withstand adverse weather conditions and end up lasting far longer than the standard copper wires. It's also preferred in applications where the wire will be exposed to a high degree of humidity. And lastly, tin-plated copper wire has more electrical conductivity as compared to other varieties of copper wires. And yes, it is more expensive.

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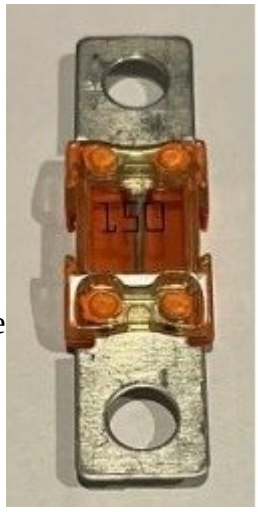
Here is a little tip for you when it comes to correctly sizing wire...up-size wire recommendations one size. Yup, look up the recommended wire size...then go with one size larger. This gives you a measure of safety when deciding on your wiring. Better to have a wire/cable one size too large than one size too small. One size too small can result in more resistance and potentially melting the wire itself. And obviously, if you melt wire it is a bad thing, a very band thing...which could result in a fire.

And that brings me to another tidbit of information that should be, will be, important to you...protecting your wire from over-current. The reason you protect your wire from over-current is to prevent melting the wire/cable and the possibility of fire is plain and obvious. So you put a fuse in the circuit.



Quality equipment manufacturers (Tier 1 companies) will provide fusing and/or circuit breakers internally to the equipment to protect that equipment. It is the installer's responsibility to protect the wire connecting the equipment with fuses and/or circuit breakers.

Looking at a fuse and its job is pretty simple...the job of the fuse is to melt its wire or plate element at a lower current (amperage) than the wire can handle. That breaks the circuit and stops the flow of electricity. If the fuse is rated for a higher current than the wire, then the wire becomes the fuse by failing before the fuse blows.

Here's an example: 1AWG wire is rated to handle 150amps at a total circuit of under 15'. Now, if you wanted to protect that wire from failure and put a 200amp fuse in the circuit...the wire would theoretically fail at 150amps before the fuse "blew" (a.k.a. opened) at 200amps.

To avoid this problem in our example you would use a fuse of less than 200amps...say 125 - 150amps. That way the fuse would do its job before the wire failed and caused a potentially serious problem.

And here is another thing to consider when deciding on the correct fuse to use...its different ratings. So take a 125amp/58v BF-2 fuse from Littelfuse. It is rated at 125amps, yes? But does that mean it will blow as soon as the current hits 126amps? No. If you review the chart that accompanies the fuse you will see it will maintain integrity for different lengths of time at different currents (amps).

At 100% of rating, in this case 125amps, the fuse will maintain integrity for 4 hours. If the current rises to 135% of its rating (169amps) the fuse will still be good for approximately 2 minuets before it opens/blows. At 200% of its rating (250amps) it will open/blow at about the 1 second mark. And at 750amps it will open/blow at about 1/10th of a second. So before you decide on the right fuse looks closely at its ratings.

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125amp Fuse Category

Time-Current Characteristics

% of Rating	Opening Time Min / Max (s)	
	100A - 250A	300A
75	– / –	– / –
100	4 h / –	4 h / –
135	120 s / 1,800 s	– / –
200	1 s / 15 s	1 s / 15 s
350	0.300 s / 5 s	0.500 s / 5 s
600	0.100 s / 1 s	0.100 s / 1 s

@100% (125a) good for 4 hours

@135% (169a) good for 2 mins

@200% (250a) good for 1 second

@600% (750a) good for 1/10th second

In our 1AWG, 200amp wire circuit at a full 200amps of current, the 125amp fuse would blow in 2 - 3 seconds. Also, notice the fuse description in the example, "125amp/58v", that means it is rated for 125amps only up to 58volts. Meaning, if you try to employ it in a circuit above 58 volts it will not function correctly...as in it will *fail* to do its job and put your wire at risk.

58 volt rating

Bolt-down Fuses

Littelfuse
Expertise Applied | Answers Delivered

BF2 FUSE RATED 58V

RoHS

Description

This BF2 fuse is rated at 58V and offers a bolt-on fuse for high current wiring protection. Current rating 100A - 300A; with transparent housing for easy detection of blown fuses.

Specifications

Housing:	Out of thermoplastic (UL 94-V0, heat-resistant) Visible melting element
Terminal:	Copper alloy, gal. Sn 2 x M8 bolts, Distance 51 mm
Mounting Torque:	12.0 Nm +/- 1Nm
Breaking Capacity:	1000A, 58V DC
Complies with:	ISO 8820-5 UL 248 Special Purpose Fuses

Ordering Information

Part Number	Package Size
142.5395.xxx2	200

Time-Current Characteristics

% of Rating	Opening Time Min / Max (s)	
	100A - 250A	300A
75	– / –	– / –
100	4 h / –	4 h / –
135	120 s / 1,800 s	– / –
200	1 s / 15 s	1 s / 15 s
350	0.300 s / 5 s	0.500 s / 5 s
600	0.100 s / 1 s	0.100 s / 1 s

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What??? And why is it rated at 58v, sounds strange, eh? That fuse is designed for 48 volt solar power systems. So why the larger than 48 voltage rating? Remember that solar power system voltages can run as high as 56 - 58 volts +/- coming out of the MPPT charge controller.

Yup, that means no 24v or 32v rated fuse in a 48 volt system. And no 12v rated fuse in a 24 volt system.

Now, let's return to the wire insulation rating. Remember I mentioned that wire should have at least a rating of 105 degrees centigrade? That means 220 degrees Fahrenheit. That is above the boiling temperature of water before it fails. Silicone insulation can handle almost 400 degrees Fahrenheit before failure. So you can see one of the obvious benefits to silicone wire insulation.

Now, that being said...if you are building a circuit counting on silicone's ability to handle almost double the temps vs rubber-based insulation...you are building the circuit in dangerous country. Consider redesigning the circuit for more for safety.

And there is one really misunderstood aspect of deciding on wire/cable size...the distance or length of the actual wire run. Most folks will look at the circuit and say there is 5' between the pieces of equipment and then use that to choose the wire/cable size. WRONG!! You use the total distance of the wire run...round trip. The circuit is the wire *round trip* carrying the current. So 5' between equipment is a 10' distance/length.

OK, so here is the long awaited chart with one note before the displaying it...when looking at the "circuit type" use "Critical" and "3% voltage drop" and when looking at the distance, the distance is the maximum run. So when you see 15', that means ***up to*** *15'* round trip. Notice the "round trip"...that means the total distance of the wire going to AND from the two devices.

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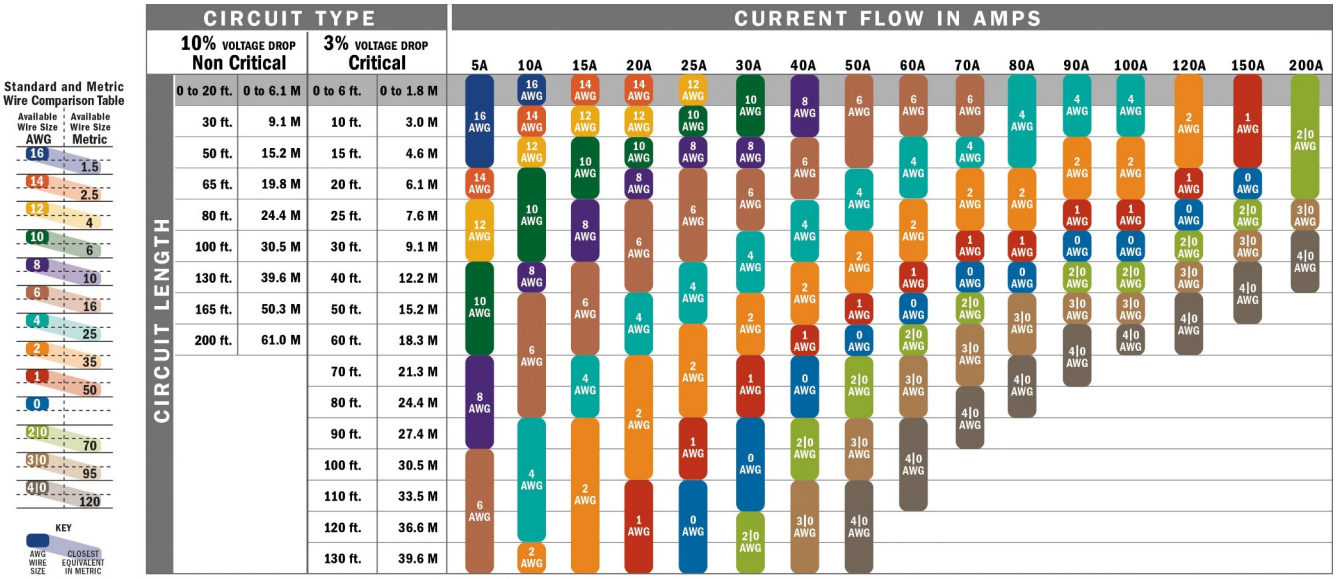
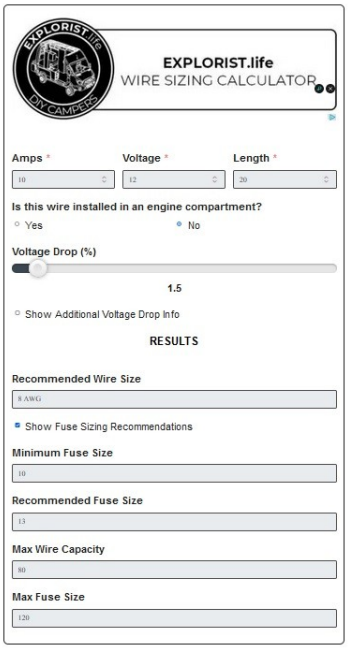


Although this process uses information from ABYC E-11 to recommend wire size and circuit protection, it may not cover all of the unique characteristics that may exist on a boat. If you have specific questions about your installation please consult an ABYC certified installer.

[< click here to download the DC Wire Selection Chart in PDF file format >]

"Voltage drop"...don't worry about it...just use "3%" when using the chart. But if you really want to know...*voltage drop* is the amount of voltage will be lost through "resistance" in the wire. Meaning the lower the quality of the wire, the more resistance, the more voltage drop, resulting in less energy being moved from one device to another. Yes, that is a bad thing, it's a waste of energy. That is the reason to correctly size wire...to efficiently move current/power through the wire.



Now, let's talk about the wire sizing and fusing calculator that is found on the "explorist.life" website. I like it...I like it a lot! You input the "amps", the "voltage", and the round trip “length” between the devices...then it shows you the recommended size of wire/cable to safely and efficiently carry that current. I like to reduce the "voltage drop" to 1.5% when using the calculator. That gives me an extra margin of safety and efficiency.

There is also an option "Show Fuse Sizing Recommendations " it gives you a great bunch of fuse information; 1) Minimum Fuse Size, 2) Recommended Fuse Size, 3) Max Wire Capacity, 4) Max Fuse Size. That is great, and critical, information to help guide you through making those design decisions. But again, I like to up-size the wire/cable one size just to be safe...and it allows for a little system expansion should the need arise.

The calculator link is https://www.explorist.life/wire-sizing-calculator/

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And yes, https://www.explorist.life, run by Nate Yarbrough, has a lot of great information for you if you care to look around, including some very good videos.

Chapter TakeAways -

- Use high quality, well insulated, stranded wire in DC circuits.
- Up-size the wire by one size.
- Use the right chart and/or calculator to determine the correct fuse size.
- Ensure that the fuse rating(s) always are lower than the wire rating.
- If you don't understand all of this...then you shouldn't be doing it yourself.