Part 1. Faraday Lithium-ion Battery Rebuild

1. Parts List and Tools

Item	Where to Buy	Quantity	Price	Total Price	Comments
Sanyo NCR18650GA 3500mAh 10A Li-ion cells	https://www.18650batterystore.com	24	@$6.00 for 10+	$144	You need 24 cells for the Faraday battery, but it will handy if you have more since you'll probably mess a few along the way
kWeld – Complete Kit	https://gridrewired.com/	1	$238	$238	You will need a spot welder to attach the nickel strips to the battery. After having tried several cheaper ones, I settled on this. It just works on 0.2mm thick nickel strips
TURNIGY GRAPHENE PANTHER 5000MAH 3S 75C BATTERY PACK	Hobbyking.com	1	$65.97	$65.97	This the battery you need to use the kWeld.
LiPo Charger for Lipo Battery	Amazon.com	1	$56	$56	Charger for the LiPo battery for kWeld
Li-ion cell charger/tester	SkyRC MC3000 or Megacell Charger and Software	1	$99 or $245	$99 or $245	It's a good practice to charge or condition your cells prior to assembling them. I've give you 2 options that I think are very good. I bought the SkyRC MC3000 but that's because I didn't know of the Megacell option.
60W soldering Iron	Amazon.com	1	$10	$10	Any one will do but this one is the model I purchased
Sheet metal cutter	Amazon.com	1	$16	$16	Any generic sheet cutter will do. Even a pair of kitchen scissors may suffice but you might have to chuck them since you'll pretty much destroy the cutting edges
Barley Paper Battery Insulator Rings	Amazon.com	1	$8.88	$8.88	Optional but I ended up using them it's a good way to avoid shorts
Soldering Lead (0.8mm)	Amazon.com	1	$8.98	$8.98	
Battery Welding Holders	Amazon.com	1	$10.49	$10.49	Optional but helpful to keep the cells steady as you weld the nickel strips
100% pure Nickel strips 0.1mm x 6mm 100% pure Nickel strips 0.15mm x 8mm	Amazon.com	1 of each @$21	$42	$42	
Nickel tabs	Amazon.com	1	$6.99	$6.99	Optional. You could just fashion these tabs yourself but having these for Part B makes it easier
Thermal Glue	Amazon.com	1	$9.99	$9.99	
Heat resistant tape ½"	Amazon.com	1	$11.99	$11.99	You'll need this to insulate a set of connectors for Part B of the Battery
Heat shrink tubing 70mm x 2m	Amazon.com	1	$5.39	$5.39	As a final step, you'll slide your battery into this tubing and use a strong hair dryer to shrink wrap and protect it.
			Total	$625 + $99/$245 plus shipping	

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Part 2. Faraday Li-ion Battery Disassembly

In this section, we're going to disassemble your ebike's Li-ion battery. And before you can attempt this, you must remove the battery from within the bicycle.

Here's a link to video by Faraday bikes that shows you how to do this.
https://www.faradaybikes.com/support-articles/component-installation-guides/battery-replacement/

Before proceeding, we should take a moment to briefly discuss the overall procedure of rebuilding the battery. The best way of thinking about the next few steps is that you are going to be replacing the cells housed within the battery, much as you might in your TV remote. The only difference is that your TV remote battery compartment is designed for user serviceability, whereas an modern Li-ion battery is more complex and not designed for anyone except experts to service. Another thing to bear in mind is that a Faraday battery was constructed with severe physical constraints in terms of dimensions, size and ruggedness. A bicycle receives lots of shocks and you wouldn't want your bike to go up in flames when you hit the kerb really hard! As you go about disassembling the battery in this stage and rebuilding it, one really has to take the approach that you're literally doing the exact same thing as with changing your TV remote batteries. All the battery cells, connectors, wires, placement etc will be replaced as you found it. Don't make the mistake that I made with my first battery where I thought that I could get away with some sloppiness, thicker wire here or there should be fine, right? No, you cannot as space is at a premium and the Faraday engineers built the battery with the most optimal placement of everything.

If all that isn't daunting enough, remember that you cannot have any things jutting out or an extra bit of solder poking out. Li-ion batteries are incredibly energy dense and regular insulators are just not sufficient at times. Most of these flaws will manifest as you try to squeeze the cells back into the tube. The good news is that once you've rebuilt your Faraday battery, you can pretty much rebuild any Li-ion battery out there!

I recommend that you spend lots of time just observing how the original battery was constructed as you attempt to replicate that exactly. Bear in mind, you have to insert the battery back into the original tube and it won't fit if you're not careful. Follow the steps below and hopefully you should be able to have a usable battery that works just like the original one.

Coming back to disassembling the battery, it isn't particularly hard, but as with attempting anything the first time, it appears to be a bit more complex than it is. But once you've retrieved your battery it should look like this. It's a long cylinder with wires dangling off one end, as shown in the picture below.

Battery End **A** – the end-cap with the battery power and management cables

Battery End **B** – the end-cap

Figure 1. A Faraday e-Bike Lithium Ion battery.

Use a fine-toothed hacksaw to create a groove around the end caps, and then use a flat-head screwdriver to gently pry it apart. There is some silicone adhesive you are trying to overcome, but also the crimping on the end (those little divets) that secure into a circumferential groove on the end-caps. Using a narrow width flat-head screwdriver helps. Be patient as its quite easy to "tear" the aluminium as you pry with a screwdriver. You want to preserve the shape as much as possible and not introduce any sharp edges. Remember, you must slip the reassembled battery back into this tube and seal the ends as they originally were, take your time and just be careful.

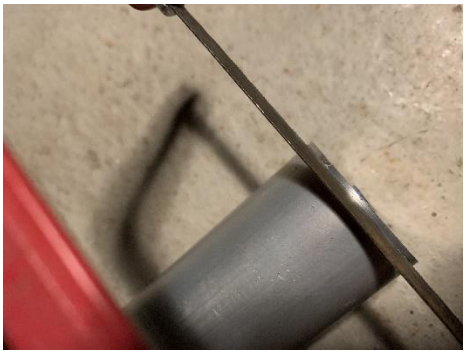

Figure 3. This picture shows where you place the hacksaw blade to create an edge.

Figure 2. Use a fine toothed hacksaw to create a ridge along the battery cylindrical body, and the flat end cap.

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There are two end-caps, one on either end of the battery, that are mostly identical except that one end-cap (A) serves as a conduit for the 2 cables that exit the battery. The thicker cable supplies the power from the battery to the bike. The thinner cable is used by the Faraday controller to monitor the battery vitals, and make sure that the battery is in proper working order and that it's not too discharged to ride the bike. Li-ion batteries are incredible finicky and its only using lots of modern controller technology that make the batteries practical. When creating the ridges, make sure that you don't cut it too deeply. At most you need something like 1mm. You don't need to go in any deeper, and you should be especially careful on the end-cap A where you need to keep the cables intact and avoid making any cuts into them.

Figure 4. A broom end serves well the push the contents of the battery out. Insert the broom handle into the end that does not have the cables coming out.

Once both end-caps are out, you next task is to gently but firmly push the battery cells out from end B to A. A wooden broom end that's narrower than the battery helps but any suitable non-metal cylindrical object of the right length and slightly narrower than the battery tube will work. Unfortunately, this isn't an easy process as the battery as such was not meant to be disassembled and contains silicon adhesives. But with some firm pressure you should be able to wiggle the contents out. Don't tap the end using a mallet as you're pushing against the battery controller heatsink plate and you don't want to damage it. Just apply constant pressure and once you the contents come out of the other end, you can rotate it around to break away of the internal adhesives.

And once you've done that, you'll have come to the end of the first (of many difficult) challenges in your Faraday battery rebuild. It should look something like the blue shrink-wrapped object in Figure 5.

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Figure 5. The battery innards with the outer aluminium tube removed.

At this stage, you can carefully peel away the blue sheathing to reveal the cells inside, which should look like Figure 7 and Figure 6

Figure 7. Another view of the naked battery

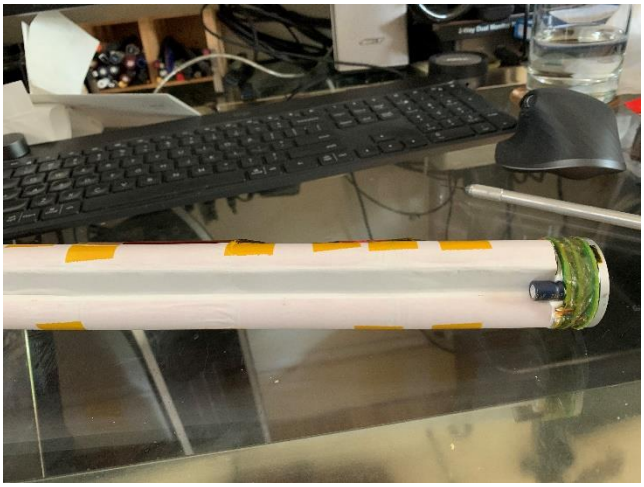

Figure 6. Faraday battery with blue shrink wrap removed.

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At this point, you should take as many pictures of the battery as possible. How the cables are placed and routed, how the cells are laid out, how they are taped together etc. This is crucial you remember this as the next few steps will be to de-solder the wires. DO NOT CUT any of the wires. All the wires are of the precise length, and it makes things harder if you must extend a wire that you cut. But at this stage, you should just take a break and just admire the battery that you will now attempt to recreate.

Part 3. Understanding the Construction of the Faraday battery

Before we go any further, let's take a moment to understand the battery construction. In many respects there is nothing particularly special about a Faraday Li-ion battery that would differentiate it from a regular Li-ion battery. So what you are about to learn will also serve to help you disassemble other Li-ion batteries if you so choose, but I digress.

Roughly speaking, a Faraday battery has 5 parts

1. Outer aluminium shell or casing (the part that you just removed in order the expose the cells inside)
2. Insulation and various types of tape. The white paper tape serves as a structural component and provides some rigidity that helps maintain the shape of the battery. The Orange plastic tape is a special type of tape known as "Klapton" tape and is used widely in electronics where you need some electrical insulation as well as some thermal protection. It's insulation isn't as good as regular electrical tape, but regular electrical tape is much thicker so avoid using it here.
3. The wires or "Harness" – this refers to the bundle of electrical wires you see all over the battery. We will need to carefully remove the harness with a soldering iron. I'll go over the entire process in the next section. The harness has a few different functions a) Supply current to bicycle motor b) Charge the battery, and c) Monitor the batter function and ensure that its not overheating or depleting any of the cells beyond a "safe" limit. Notice that the wires occupy the "ridges" and this is critical to adhere to as you rebuild.
4. The Battery Controller, or Battery Monitoring System (BMS). That's the clever part of the battery that does all the monitoring of the battery cells, voltages, currents, temperatures etc. Usually this is bulky, but the Faraday engineers managed to create a very compact unit and that's what you see in Figure 8 on the right side. The 3-layered circuit-board sandwich is a very smartly designed controller that neatly fits together with the Li-ion cells. The aluminium disc a the very far right serves as a thermal "heat sink" i.e. absorbs heat from the power electronics and dissipates it so the temperatures remain within the working range for the devices.

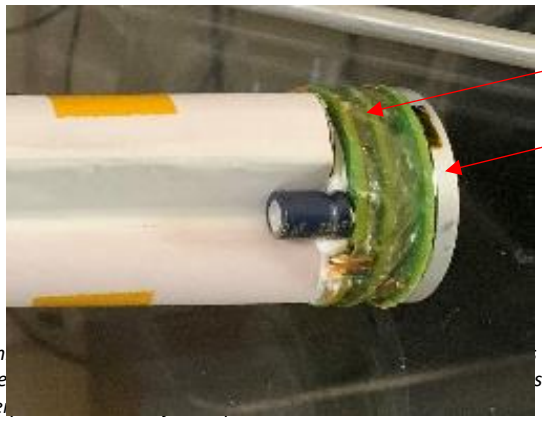

Figure 8. The Battery Controller or BMS is visible on the right end of this picture

Warn they can sever electrical and thermal burns if they are improperly handled. These se observe all safety precautions including having a fire extinguisher. A Li-ion batte

5. The Li-ion cells that stack up to create the battery. The Faraday batter consists of 12 cells connected in series, but due to the lack in space in the bicycle, the battery engineers had to come up with an ingenious way to do this. Although visually the battery looks like a stack of 8, with each stack comprised of 3 cells, that is not how the cells are electrically connected.

A simplified electrical view of the Faraday battery is shown below – 2 cells connected in parallel and stacked 12 times.

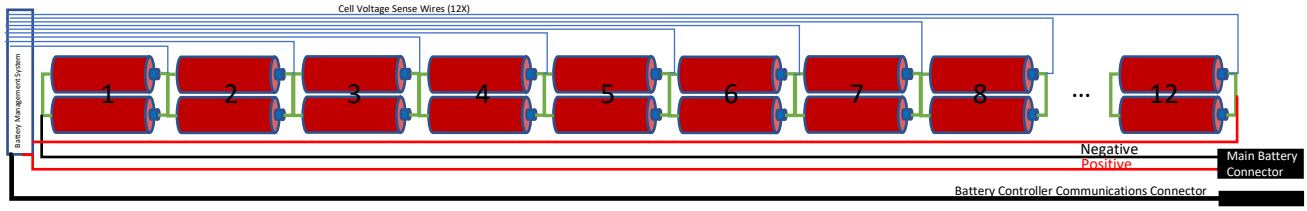

Figure 9. Simplified view of a Faraday Li-ion battery.

Even though stacking 12 high would simplify the battery construction, unfortunately the length could just be too long. Instead, the Faraday battery is constructed into 2 sections as shown in Figure 10 : Section 1 is 2 cells in parallel stacked 8 times, and Section 2: Two cells in parallel but laid out facing each other, stacked 4 times. Hence, we arrive at the electrically equivalent but with a modified battery geometry that allows us to get create a shorter battery with more girth.

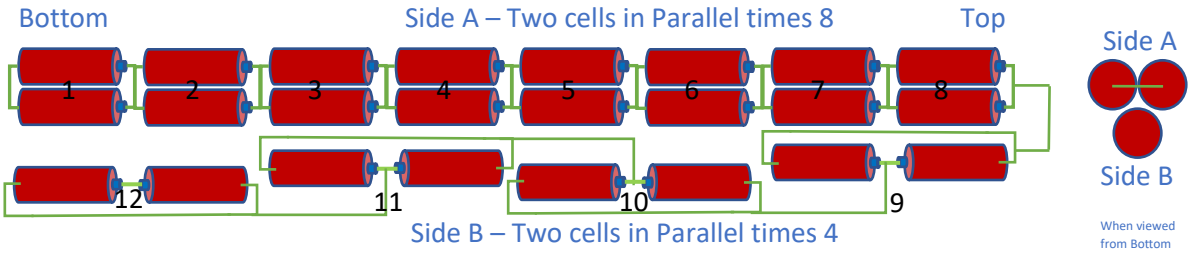

Figure 10. Physical layout of Faraday Li-ion battery cells

The next step is removing the wire harness and the battery controller from the cells, and this includes the Voltage Sense Wires (12), Positive Wire (1), and Negative Wire (1). We will tackle that in more detail in the next section, but as we go about doing this, you need to bear a few things in mind.

- Do not cut ANY wires. The wires are at the exact length we need them to be at and extending any wire adds insulation etc. there just isn't any room for anything that's not in the original battery.

- The battery controller is the brains of the battery, so be very careful in handling it. But more so, make sure you don't do anything that can cause an inadvertent electrical short circuit. The battery controller is delicate and if you fry it for whatever reason, you can kiss the rebuild project goodbye. You will have to redo all steps with a different Faraday battery. This becomes critical in the last step of the build where you're trying to fit everything back into that aluminium tube that encased the battery.

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- Unless you are an inveterate Li-ion battery expert, at no point make the mistake that you can do something different or better. I'm a fairly competent electronics engineer and I made this mistake which cost me a battery. You're trying to re-make the battery as is, and as long as you think along those lines, you'll be fine.

Part 4. Disassembling the old battery – Disconnecting the Wire Harness

Tools Needed: 45W or 60W Soldering iron.

Disassembly is probably an overstatement as most of the physical battery disassembly would have already been performed if you've removed the aluminium tubing. This stage is where you separate the battery controller, along with the voltage sense wires from the battery itself.

Just as reminder again, you are not going to cut any of the wires. Why? Because they are already at the exact length, and you merely want to de-solder them from their existing connections.

To be precise, you should exactly 14 wires to de-solder as follows.

- 14 voltage sense wires (shown with red circles in the images below)
    - 7 on side A connected via narrow tabs

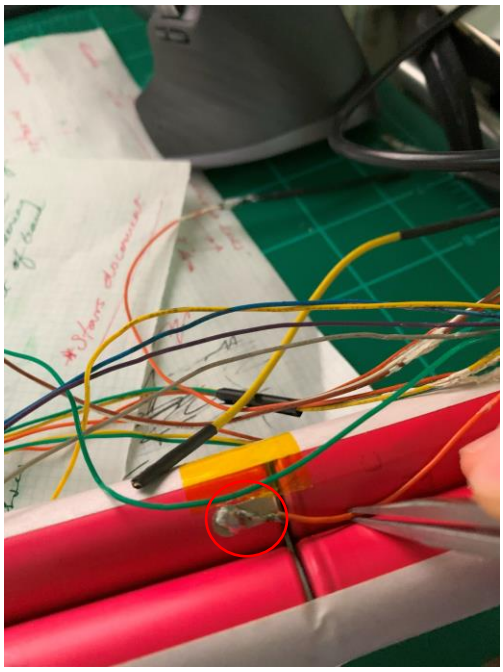

Figure 11. Voltage sense wires on Side A are connected to narrow tabs with very narrow wires. A soldering iron will help you disconnect the wires easily.

    - 5 on side B connected via broad tabs

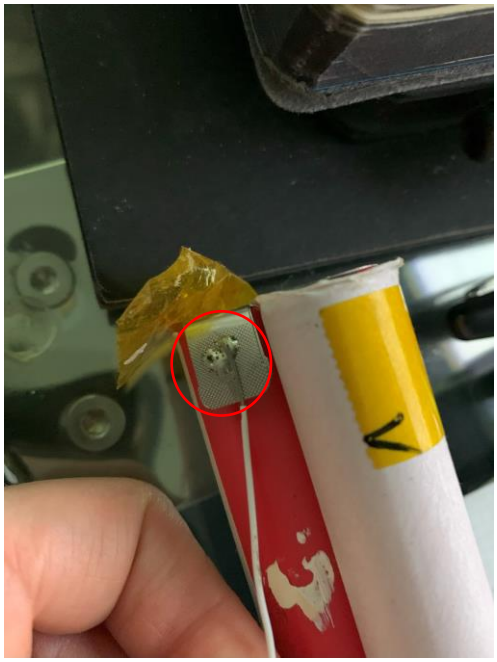

Figure 12. Side B Voltage tabs use broader tabs.

- 1 on side B connected at the bottom via a narrow tab (electrically connected to battery -ive terminal)

Figure 13. The voltage sense wire is on the left-hand side in the picture above soldered to a narrow tab.

- 1 on side B connected with the +ive connection

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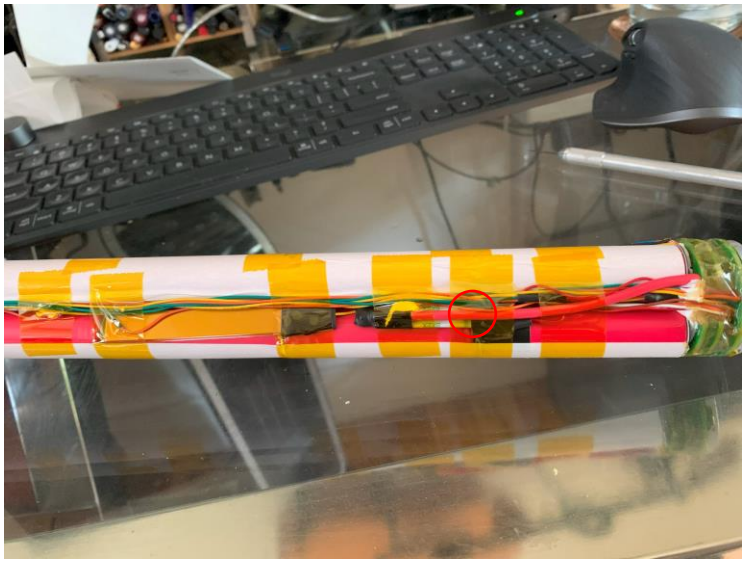

Figure 14. The +ive wire (thick) red, is connected to the battery +ive through a metal strip

- Battery -ive (Side A bottom)

Figure 15. The -ive wire (thick) black is connected to the battery -ive through a wide tab.

- Battery +ive (Side B) – Desolder the fat red wire and metal strip from the battery tab as shown in Figure 16 with the red circle. Do not desolder the metal strip from the thick red wire.

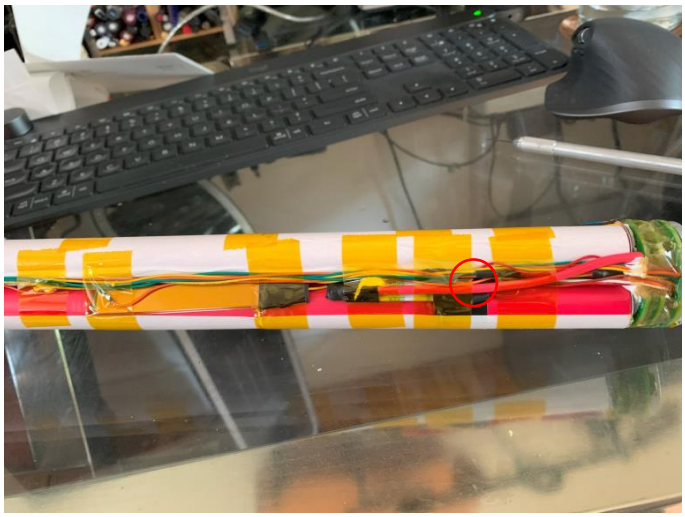

Figure 16. The +ive wire is soldered onto a metal strip. The metal strip is then soldered onto a tab on the battery. You want to keep the metal strip connected and desolder it from the battery tab. It's somewhat hidden in the picture above but you should be able to identify it. I'm not quite sure what purpose the metal strip serves.

In addition, you will notice that there a few wires on side B that are glued on. These are temperature sensors (also known as thermistors) and there are 4 of these.

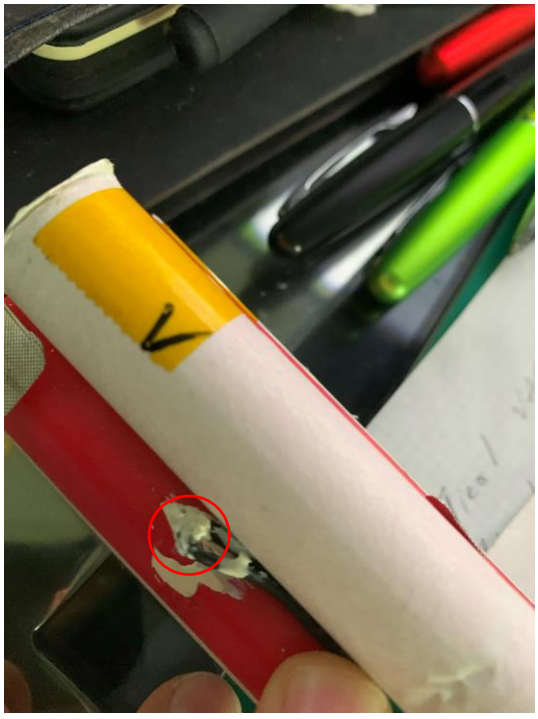

Figure 17. Notice the temperature sensor. It is held in position with thermal glue (white) that you can easily pry off.

You can gently pry them out. Don't pull on the wires as those will break easily and my guess is that the battery controller will refuse to work if it doesn't detect them. So again, be very careful.

But before you start separating the battery controller, pay close attention to its orientation with regards to Side A & B. On reassembly, you will need to make sure that its oriented exactly the same way. The capacitor below serves as a great reference point in Figure 18

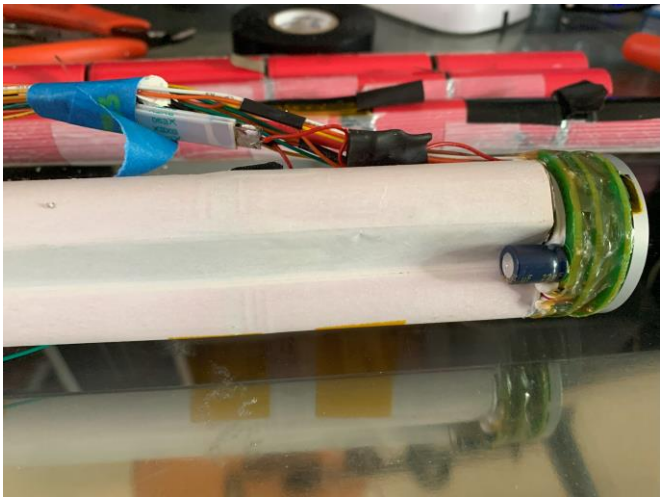

Figure 18. You'll want to keep orientation of the battery controller in mind when reattaching the battery controller.

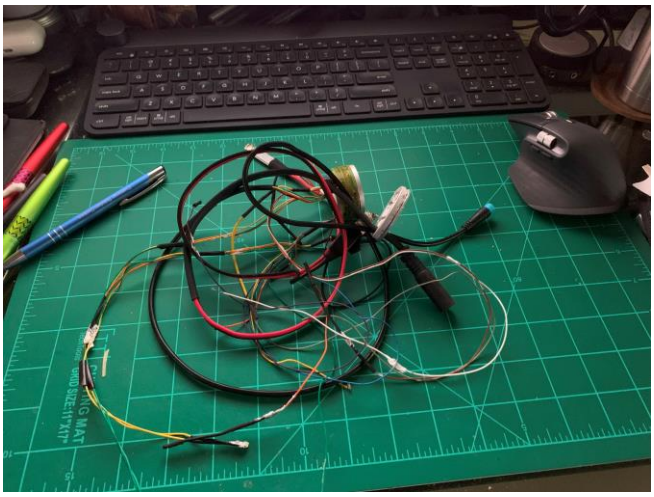

Figure 19. The separated wire harness and battery controller

At this point, you should be able to separate the wire harness from the li-ion cells as shown in Figure 19. You are going to reuse the harness so store it carefully.

Also keep the (spent) li-ion battery handy as a building reference, not only as a visual guide on where the various tabs need to be placed, but also from a dimension perspective. You want to make sure that your battery adheres to the dimensions (both length and girth) exactly.

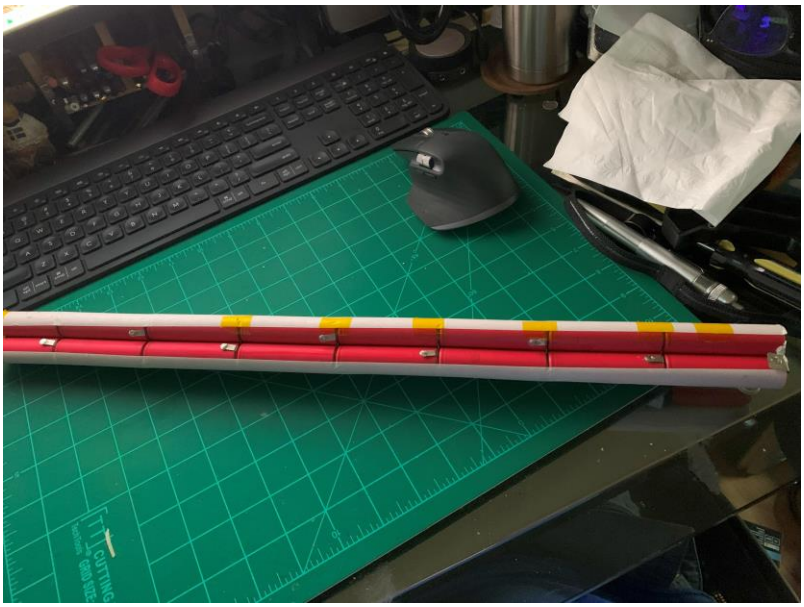

Figure 20. Keep this handy as you'll want to refer to this as you build your new battery

Part 5. Building a new battery

Before you start assembly, please make sure you take a good look at the old one. The tab placement is crucial, but also how sides A and B are placed together.

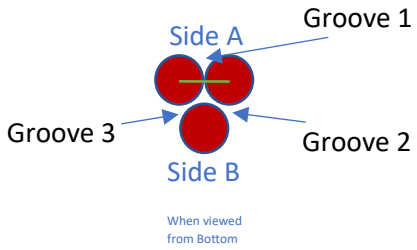

Figure 21. Identifying the various grooves on the battery

Of the 3, Grooves 1 and 3 are the most important because they serve as a channel for the various wires as shown in Figure 22, Figure 23 and Figure 24.

Figure 22. Groove 1 on Side A – Notice this contains the voltage sense wires, as well as the wires (thick) that lead to the external connectors.

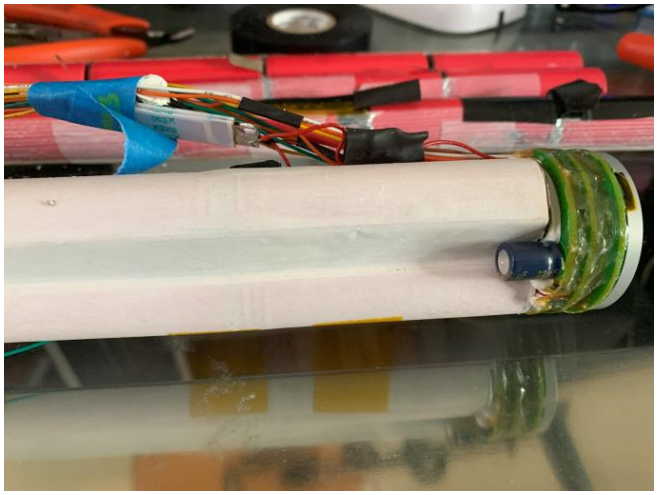

Figure 23. Groove 2 - Notice the placement of the capacitor in the battery controller

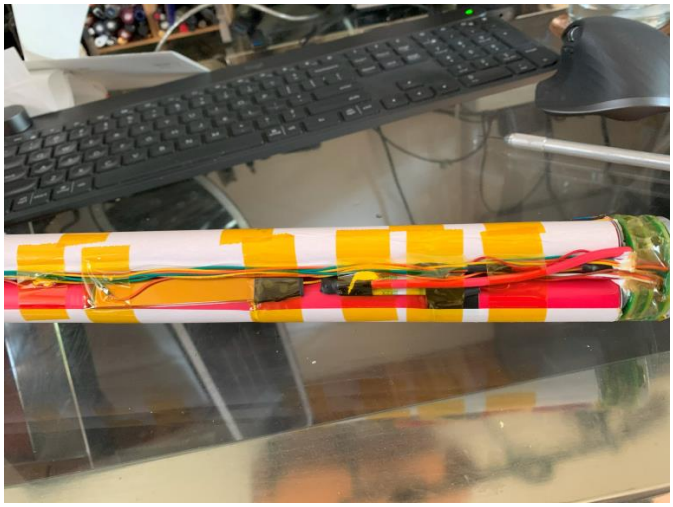

Figure 24. Groove 3 - Notice how the voltage sense, temperature sense, and the thick red +ive wire are all housed in the groove

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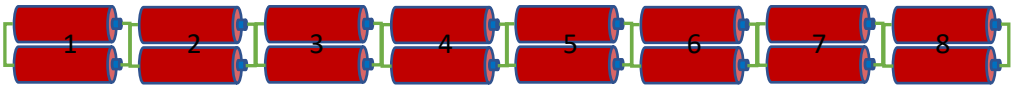
We are going to build the battery in two parts namely, Side A & Side B. As a reminder, Side A is comprised of the two cells in parallel stacked 8 high as shown in Figure 10, and Side 2 is comprised of slightly different layout where the 2 parallel cells are laid out linearly, and then stacked 4 high.

To make the construction easier, we will build each side independently, and then combine them together.

You will notice that the factory battery has pre-cut nickel tabs that they weld onto the battery. Unfortunately for us, we can't access those pre-cut tabs and instead we will have to fashion our own from strips of nickel.

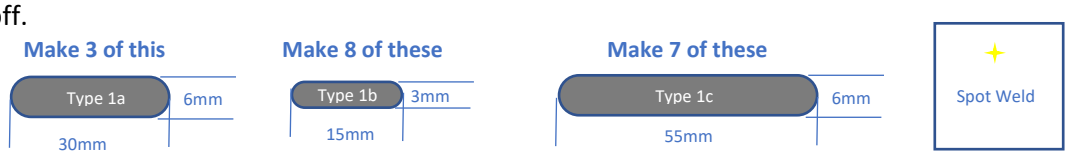
Building Side A



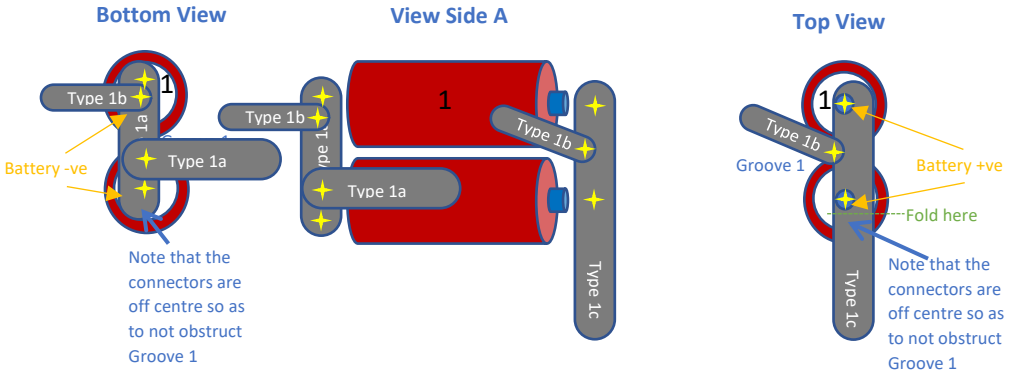
This part is simple and straightforward – not it can get a bit unwieldy especially when you have all 8 cells in place. I approached this by constructing 4 sets with 2-banks of cells in each.

Step 1.

Make the following connecting surfaces from 0.1mm x 6mm pure nickel. Please make sure all edges are rounded off.



Follow the diagrams below to spot weld the various nickel tabs onto the li-ion cells as follows



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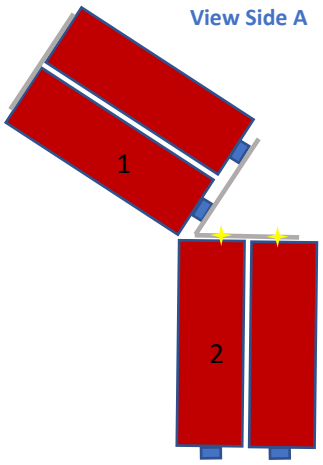
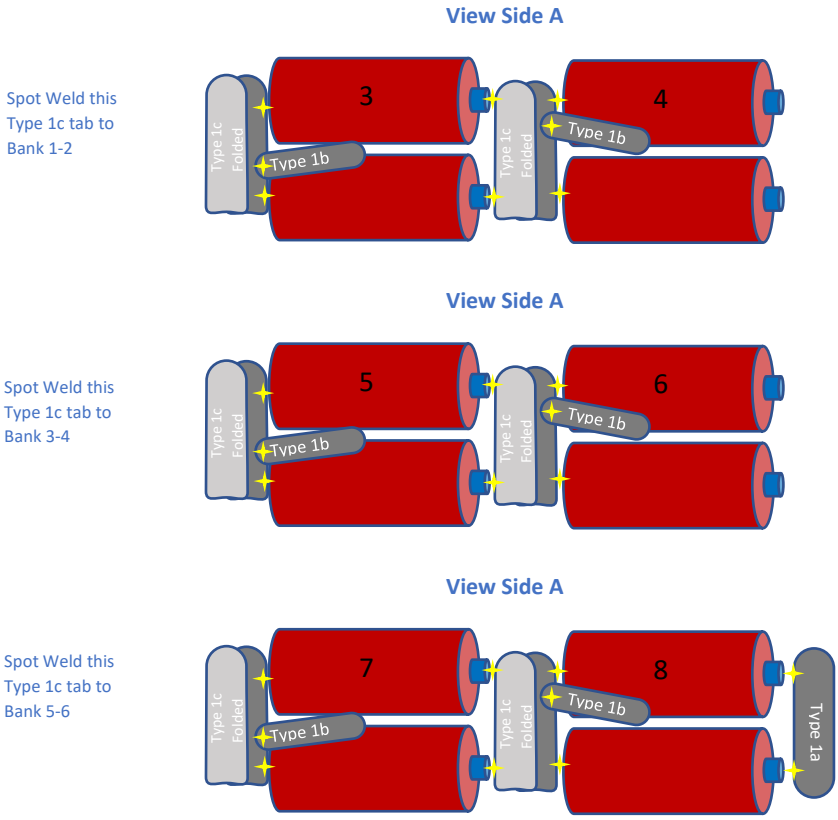
Step 2. Fold the Type 1c connector and spot weld to cell bank 2 as shown below. It's a bit tricky since you must keep the bank 1 at an angle. A second set of hands will be helpful here.



Step 3. Connect the remaining cell banks in a similar in groups of two. Note the Type 1b tabs (battery voltage sense tabs have an alternating offset pattern. Banks 3-4, 5-6 are identical. Bank 7-8 is also very nearly identical except for the Type 1a tab at the end.



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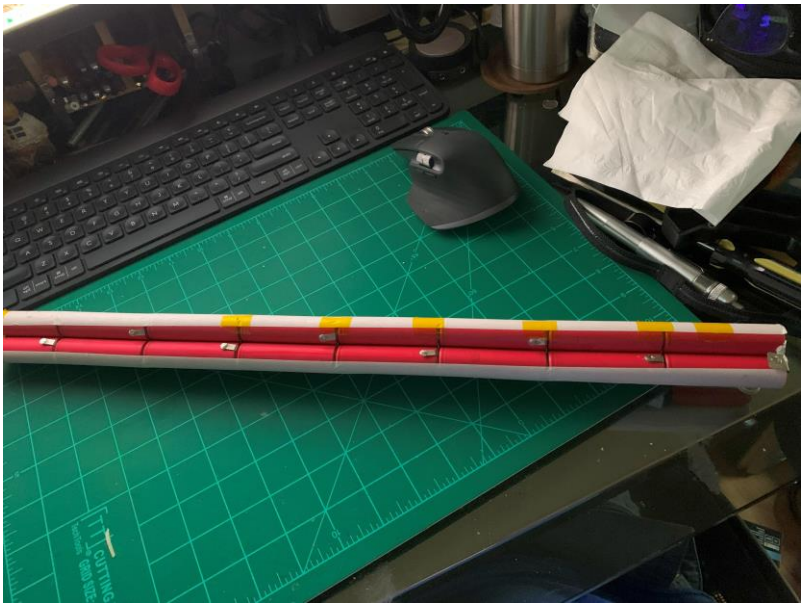
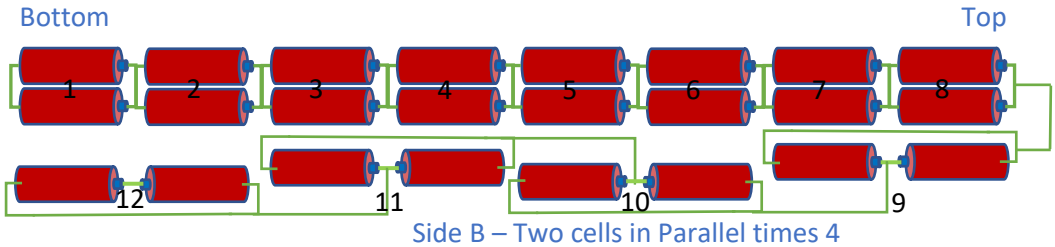
At the end of the following steps, you should have the following Side A battery in place, but with all the proper tabs in place etc. Again, always use the original battery to make sure you have ALL the tabs in their required places. Also pay attention to the direction of how the tabs are folded – it is done to ensure that you don't have accidental shorts. Again, you want your battery to look EXACLY like the original as much as possible. The nickel tabs themselves aren't very strong as I'm sure you've noticed as you build banks 1-8. You will have to use paper tape to give the banks some mechanical structure and stability. Again, don't be tempted to use duct tape as its too thick and you won't be able to slide the battery into the aluminium tube.



Building Side B



Side B – Two cells in Parallel times 4

Side B construction is a bit more tricky compared to Side A as you can see in the image above. The good news is that it uses a repeating pattern that we can use to make build a bit easier. The bad news is that spot welding can be a bit more challenging since you are working in tight spaces. We will be using 0.15x8mm pure nickel strips for making these connectors. There is a lot of potential for shorting in this stage so as always make sure the +ive terminals never come into contact with the -ive terminals. A good practice is to temporarily insulate an ends

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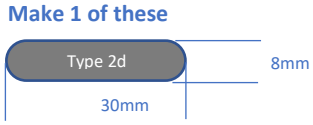
Make 3 of these

Make 1 of these

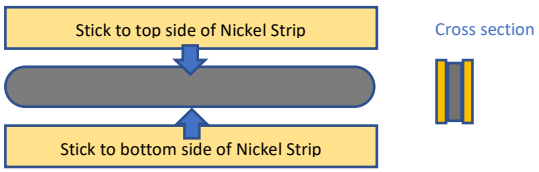
Make 3 of these

Make 1 of these



Make 1 of these

Step 1: Put a layer of the Kapton tape on both sides of the connectors. Here is a picture of the original battery which shows the Kapton tape sandwiching the connector. This is to insulate it. Ordinary electrical insulation tape won't do as its too thick. Leave a small portion of the end exposed so you can spot weld to the cell terminals.



Place 2 cells with the +ive facing each other. Use a Type 2b connector, and spot weld to the -ive terminals of each cell as shown below.

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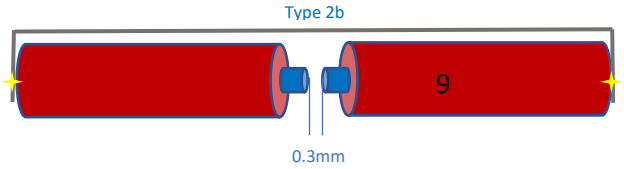
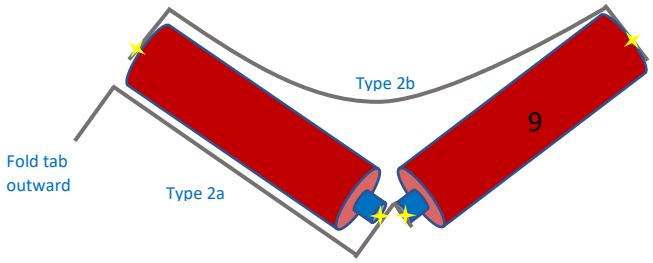
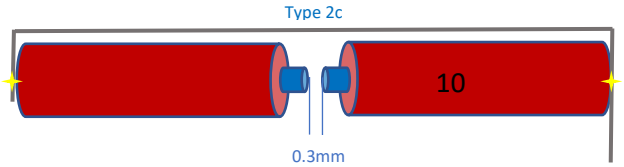
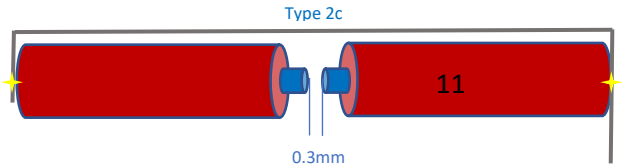


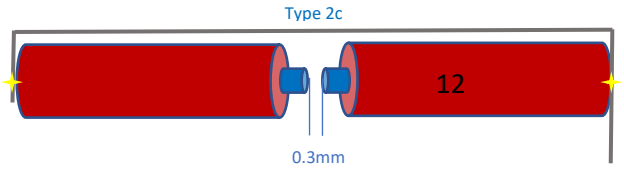
Step 2: Use type 2 connector, fold one end into a V and spot weld the battery +ive to each leg of the V



Step 3: Banks 10, 11 and 12 are fairly similar, except that you will use the Type 2c connector instead which are slightly longer and will give you bit of an overhang that you will need to connect with the other battery banks. Follow Step 2 to connect the Type 2a connectors for each of the battery banks 10 to 12 as shown below.







Step 4: For battery bank 12, spot weld the Type 2e connector. This is where the Battery Controller +ive wire will eventually connect to.

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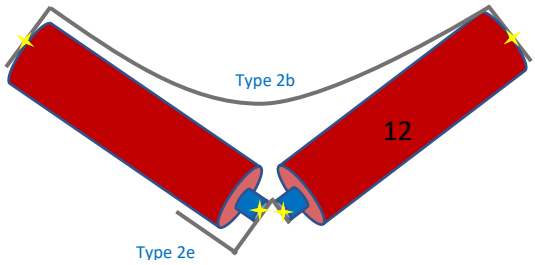
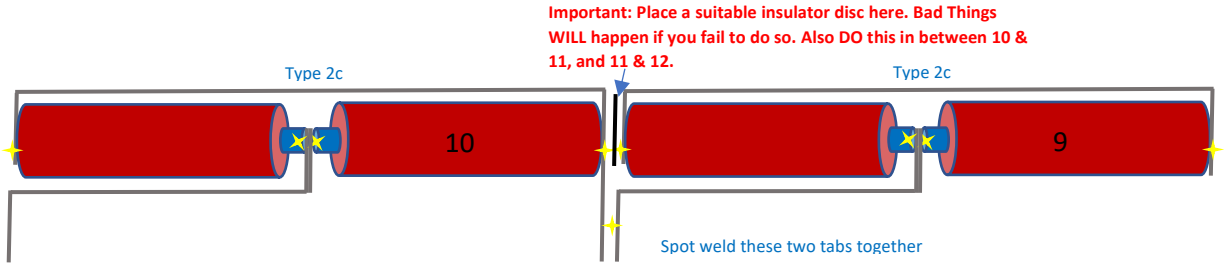


Step 5: At this point, you should have 4 separate battery banks 9-12. In this step, we're going to connect those banks together. The batteries can be a bit unwieldy, so use paper tape as a temporary aid to give it some structural stability. First connect banks 9 and 10 together as shown below.

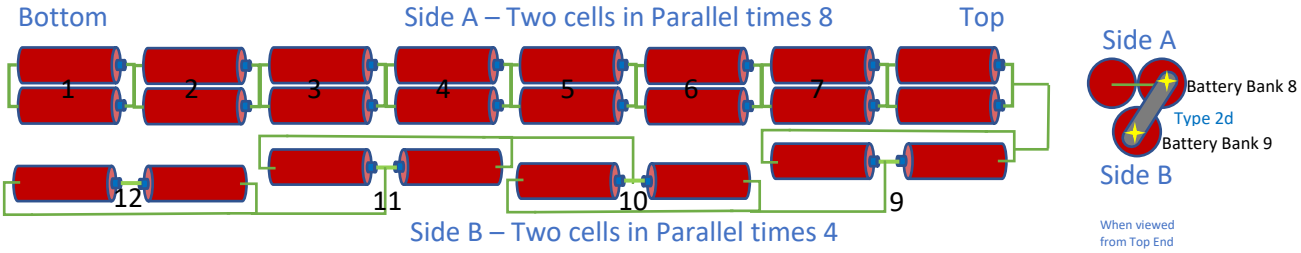
Warning: Don't forget to place an insulator disc in between the battery banks as shown by the BLACK line below. You have to do this between battery banks 9 & 10, 10 & 11, and 11 & 12.

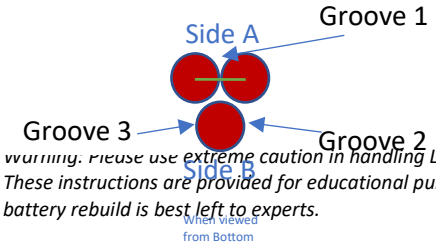


Follow step 5 for connecting bank 11, and then bank 12.

Step 6: At this point you should have the completed the 2 parts of the battery i.e. Side A and Side B, however they are electrically disjointed. We connect them together in the final spot weld using a Type 2d connector.

First, place Side A and B so that Side A banks 1 & 2 align with Side B bank 12. Side B nestles into the groove of Side A to form a triangle. You can use paper tape in Groove 2 to attach Side A and B together. You can then spot weld the Type 2d connector to Banks 8 and 9 as shown below.





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Part 6. Putting it all back together

If you've made it thus far without burning your house down, then hearty congratulations are in order! The last few steps are walk in the park compared to everything you've been through so far.

Step 1: Reattach the wire harness. This is essentially the opposite of Part 4, so you have to follow the same steps in reverse order. Remember to align the capacitor on the battery controller to Groove 2 at the bottom of Battery Bank 1. Re-solder back voltage sense wires.

Step 2: Reattach the +ive and -ive wires to battery bank 12 and 1 respectively.

Step 3: Place the temperature sensors at Battery banks 9-12 and use thermal paste to stick them in place.

Step 4: Place the wires so that they fit neatly in the respective Grooves 1 and 3. Make sure all the insulation matches the original battery. Also make sure that at no point is the battery and wires wider than the width of the aluminium tubing. Making a cardboard cutout of the aluminium tube with the same diameter and slide it over the length of the battery. If anything is jutting out and tuck it in as neatly as you can.

Step 5: Insert the battery into a heat shrink tubing and use to heat gun to shrink the film and hold everything in place.

Step 6: Check the dimensions of the shrink-wrapped battery to ensure that it's smaller than the diameter of the aluminium tubing.

Step 7: Remove any sharp edges in the aluminium tubing. You might want to slightly flare out one of the ends to make it easier to slide the battery inside.

Step 8: Carefully slide the battery inside the tubing. Do not force it excessively at any point, since too much force will likely tear any insulation inside and the battery could short and start smoking. At this point having a fire extinguisher is a necessary safety precaution.

Step 9: Replace metal end-caps.

Congratulations, at this point if all is well, you should be able to slide your new battery into your Faraday bike, connect it and all should work as usual.

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