Tesla electric vehicles batteries

for students

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The aim of the lesson:
To gain knowledge about the constitution and function of electric vehicles batteries cells.

APPENDIX 2

Tesla Electric Vehicles Batteries

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Tesla Electric Vehicles Batteries

Modules

Tesla 18 650 cells of Lithium-Ion are inserted in the battery pack. Modules themselves are from different sizes, as their configuration in parallel changes for different capacity battery packs which are available.

Tesla first generation battery packs, as those we find in 85 and 90 kwh batteries had 15 modules. Second generation packs introduced with Model S facelift have 16 modules.

Then, what is a battery module and what it is used for? Why are not cells directly placed in a battery pack?

One of the main reasons is the manufacturability. In a Tesla 100kwh battery pack, there are more than 8.000 cells, which means there are approximately 16.000 electric cells connections, which are divided in approximately 1.000 per module, which is finally a more manageable task.

Another key reason to use modules is safety while manufacturing them. The 85kwh module of Tesla pack has a configuration of 6s 74P, which means it has 6 groups connected in series and 74 cells connected in parallel per module. On the whole, that would be 444 cells per module. This produces a voltage of approximately 23,4V.

According to IEC 60038 rule, any device under 120 volts continuous stream (from now on DC) will be considered to cause a low risk electric shock through the dry skin of a person.

An additional reason for the use of modules is that they work as firewalls. In case one of the cells have a fault or in case of a car crash, if only one cell gets on fire, the number of cells exposed to the fire is lower and as a consequence, the seriousness of fire is reduced.

Moreover, from a service capability perspective, if there is an error for any reason in one cell, it is better to replace a module instead of a complete battery pack.

Nowadays there are three Tesla battery modules in the market.

1- The most extended and known model which is assembled in *Model S* and *Model X.* This has been updated and developed along the years.

2- The module Tesla assembles in its Power Packs (Batteries for industrial energy supply) which was the beginning of the transition between 18 650 cells and 21 700 cells. In addition, this uses a cooling system in the base of each module instead of cooling using pipes between cells, which reduces cost and complexity.

3- The Tesla Model 3 module. There is not much information about this module, we just know that it is longer than those modules used in *Model S* and *Model X*. It uses 21 700 cells the same as Power Packs. It has a refined thermal management system and they join the positive terminal and the negative terminal on the same side of the cell instead of using opposite sides.

Hereafter we will focus on the Model S and Model X modules.

Image Source (15 November 2019):
http://skie.net/skynet/projects/tesla/view_post/20_Pics+and+Info%3A+Inside+the+Tesla+100kWh+Battery+Pack

This image represents the top view and bottom view of a 100kwh battery pack module belonging to a Model S 100D.

In the top view, we can appreciate that it is divided in four segments. Meanwhile in the bottom view we can only observe the division into three segments.

Each segment of the module connects 86 terminals from positive cells in parallel with 86 terminals of negative cells also in parallel. It included a connection in series between both of them, with the exception of the segments connecting orange terminals that can be observed at the top of the image.

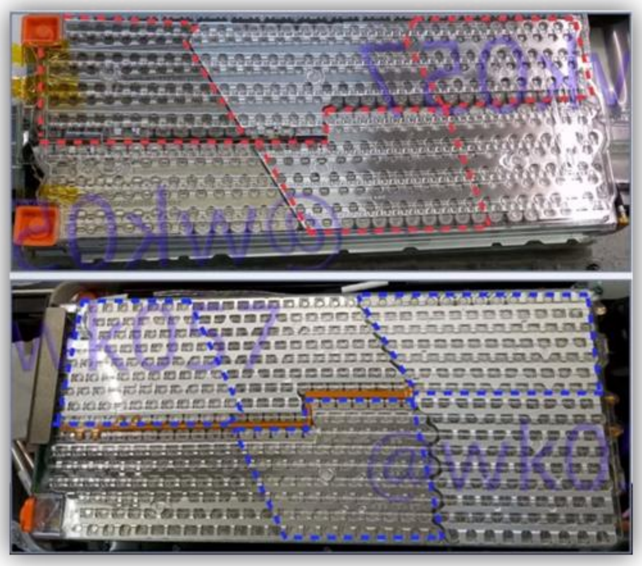


Image Source (15 November 2019):
http://skie.net/skynet/projects/tesla/view_post/20_Pics+and+Info%3A+Inside+the+Tesla+100kWh+Battery+Pack

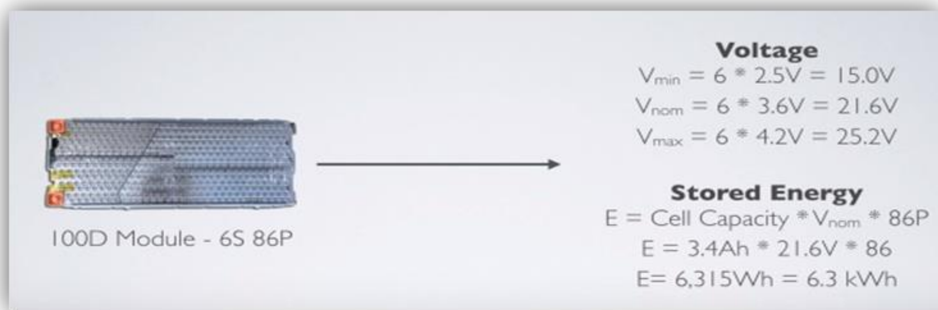
In the top view, the red segments show where the connections with the positive terminal are made. We can see the placement of the negative terminals in blue in the bottom view. The adjacent segments have opposite polarity.

Cells Electrical connection to Bus Bar.

Tesla used wire connections to connect electrically cells to the Bus Bar. Although this method increases resistance, which reduces the operative efficiency and increases heat, it has a number of advantages. During the connection process no significant heat is generated in the cell, the connection using a wire also works as a fuse, and if the connection has a fault for any reason, it is not very likely that the cell is damaged, which reduces the number of cells wasted while being manufactured.

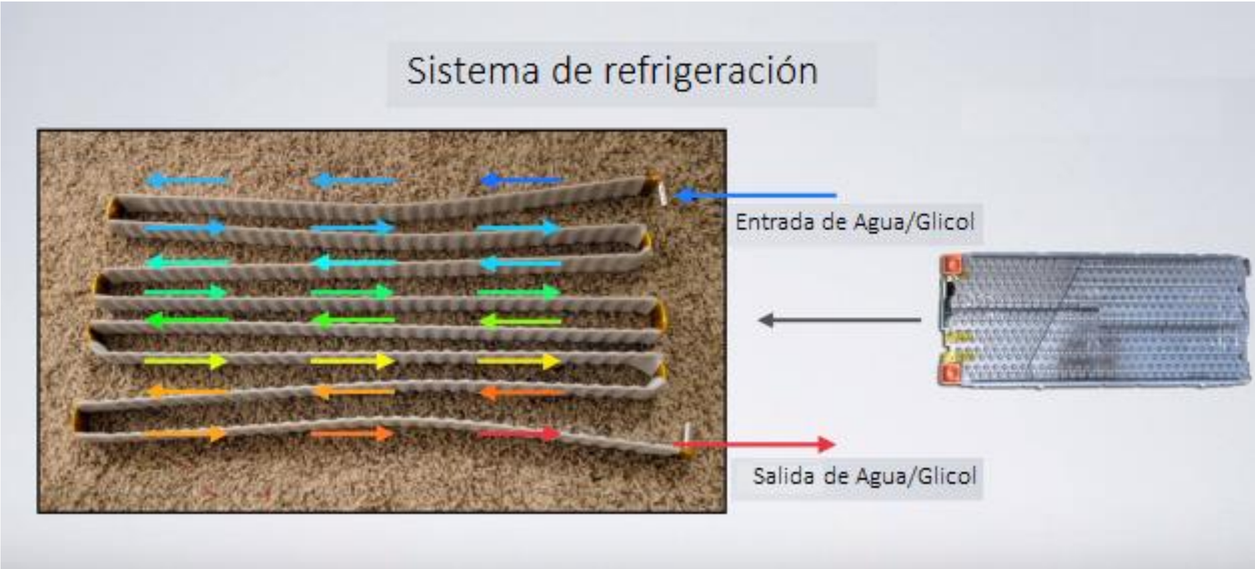
A 100 kWh module has 516 cells so it requires 1.032 wire connections. If this process was 99,9% effective, an error per module would be possible, which means the manufacturing capacity is the key.

The voltage can be calculated multiplying the minimum voltage, each cell nominal and maximum by the number of cells connected in series. This module, of a 100kwh pack is 6s 86P with a minimum voltage of 2,5 V, nominal voltage 3,6 V and maximum voltage 4,2 V. Acknowledging this we know that this module has a nominal voltage of 21,6 V.



To calculate the stored energy in a module, we multiply the cell capacity by the nominal voltage of that module and by the number of cells connected in parallel. Tesla cells have a capacity of 3,4A, the nominal voltage for this module is 21,6 V and as it is 6s 86P we have 86 cells connected in parallel, so we can say that this module stores 6,3 kWh of energy.

In the image we can observe the cooling pipes inside the module. This thermal management system consists of a metal pipe, flat on the most of its surface and straight, it crosses the module following zig-zag patterns. This pipe is covered by grey colour heat insulating material which provides electrical insulation between the cooling system and the battery cells. At the same time it causes a certain level of heat transfer



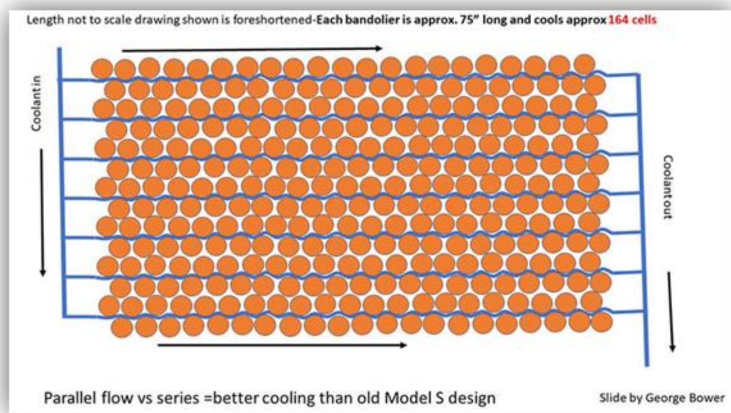
As we can see in the bending of the pipe, it is there where the connection between the cells and itself happens.

The orange tape we can observe in the image is the so-called Captain Tape in the US and provides additional electrical insulation.

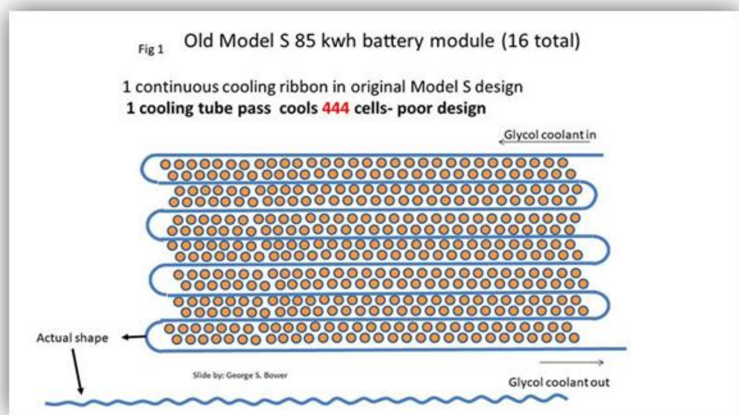
A water and glycol solution is introduced through the opening which goes across the cooling pipe to be discharged at the end of the module.

This is the cooling system used in Model S and in Model X, although Tesla made a major progress for Model 3.

Tesla managed to almost double the cooling capacity of the Thermal Management System (TMS) with a new pipe design which reduces the number of cells per each cooling pipe, adding more of these in parallel, and doubling the cooling fluid volume.



Tesla Model S and Model X TMS



Tesla Model 3.TMS

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