SECOND LIFE BATTERIES FOR LIGHT ELECTRIC VEHICLES (LEVS)

FACULTY OF ENGINEERING – UNIVERSITY OF THE REPUBLIC (UDELAR) – URUGUAY

ANII AGENCIA NACIONAL DE INVESTIGACIÓN E INNOVACIÓN

Green Star EFFICIENT MOBILITY

FACULTAD DE INGENIERIA

UNIVERSIDAD DE LA REPÚBLICA URUGUAY

Framework:

- Research Project conducted in the Faculty of Engineering of the University of the Republic (UDELAR), Montevideo, Uruguay.
- Financing institutions: National Agency for Research and Innovation (ANII) + the participation of the Uruguayan SME *GreenStar Electric Vehicles*.

Motivation:

- Given the projected EVs rise in the coming years, it is needed to find a second use for EV batteries in order to reduce their environmental impact and add value to such "waste".

Objectives:

- To develop a test method to identify the reusable cells of a battery pack.
- To study the feasibility of EV batteries reuse & second life.
- To build a second life battery pack (SLBP), from used EV cells.

Original Battery Pack:

- Origin: light electric vehicle
- Technology: $LiFePO_4$ (LFP)
- Original number of cells: 24
- Cell capacity: 50 Ah
- Nominal cell voltage: 3.2 V
- Manufacturer: similar to HHE (China)
- Battery pack delivered without metal casing
- Battery pack delivered without BMS
- Original interconnection: welded terminals
- Discard reason: overvoltage fault during charging

Lab. Equipment (Faculty of Engineering):

Battery cycler.

- Brand & model: Chroma 17020 (US)
- Main function: Programable waveform battery charge and discharge curve (i.e. WLTP driving cycle discharge curve)

Ex-proof chamber.

- Brand & model: Dongguan Xinbao Instrument Co. XB-OTS-665
- Volume: 1m3
- Maximum battery size: 9 kWh

Tests performed on each cell

Were based in the IEC 62660-1:2018 standard "*Secondary lithium-ion cells for the propulsion of electric road vehicles - Part 1: Performance testing*", and the USABC Electric Vehicle Battery Test Manual.

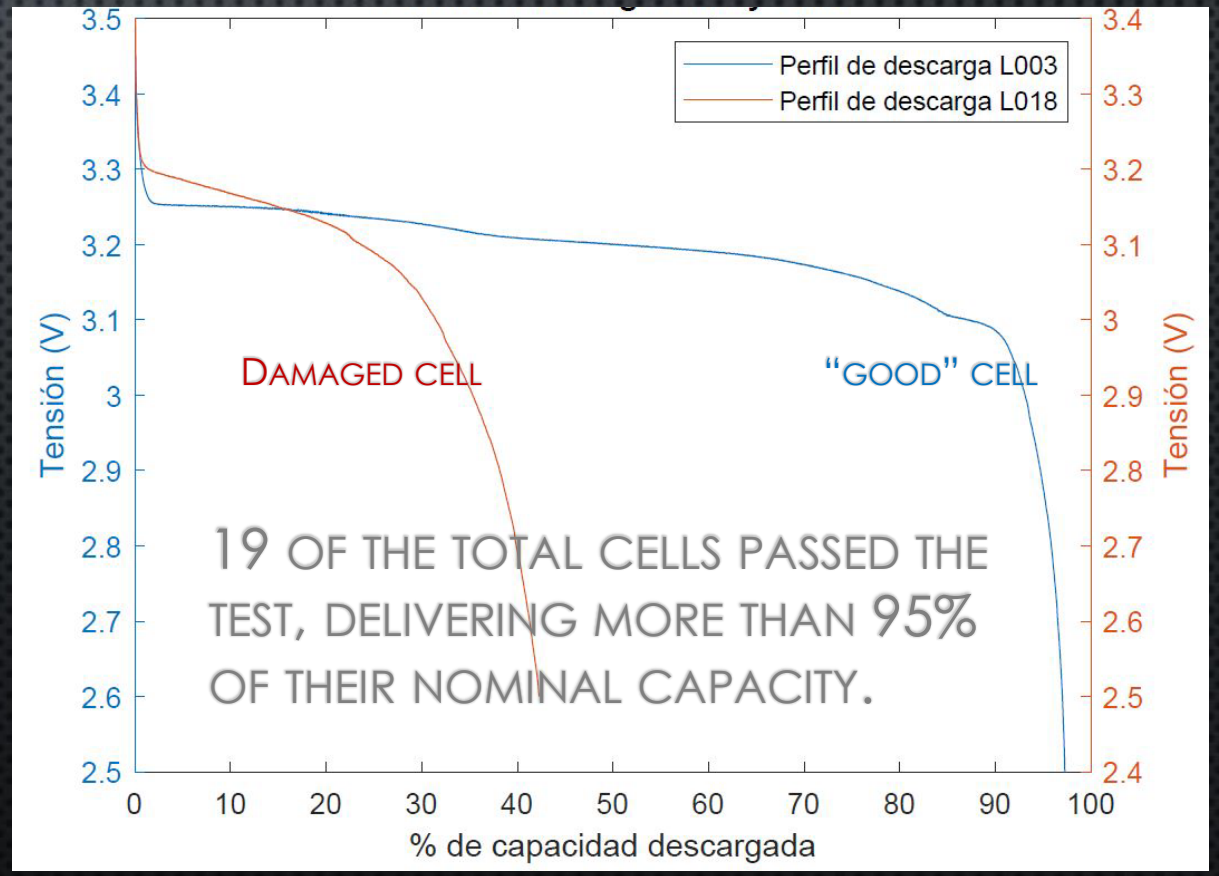
1st. Static capacity test:

- **Objective:** To measure the cell capacity (Ah) under a constant current discharge.
- **Procedure:**

I. Charge the cell according to the manufacturer information (CC-CV).

II. Discharge the cell with a C/3 DC (direct current) up to the cut-off voltage.

III. Calculate the capacity according to the IEC 62660-1:2018 standard.



2ND: POWER TEST

BASED ON THE HPPC (HYBRID PULSE POWER CHARACTERIZATION) AND PEAK POWER TEST FROM THE USABC HANDBOOK.

OBJECTIVE:

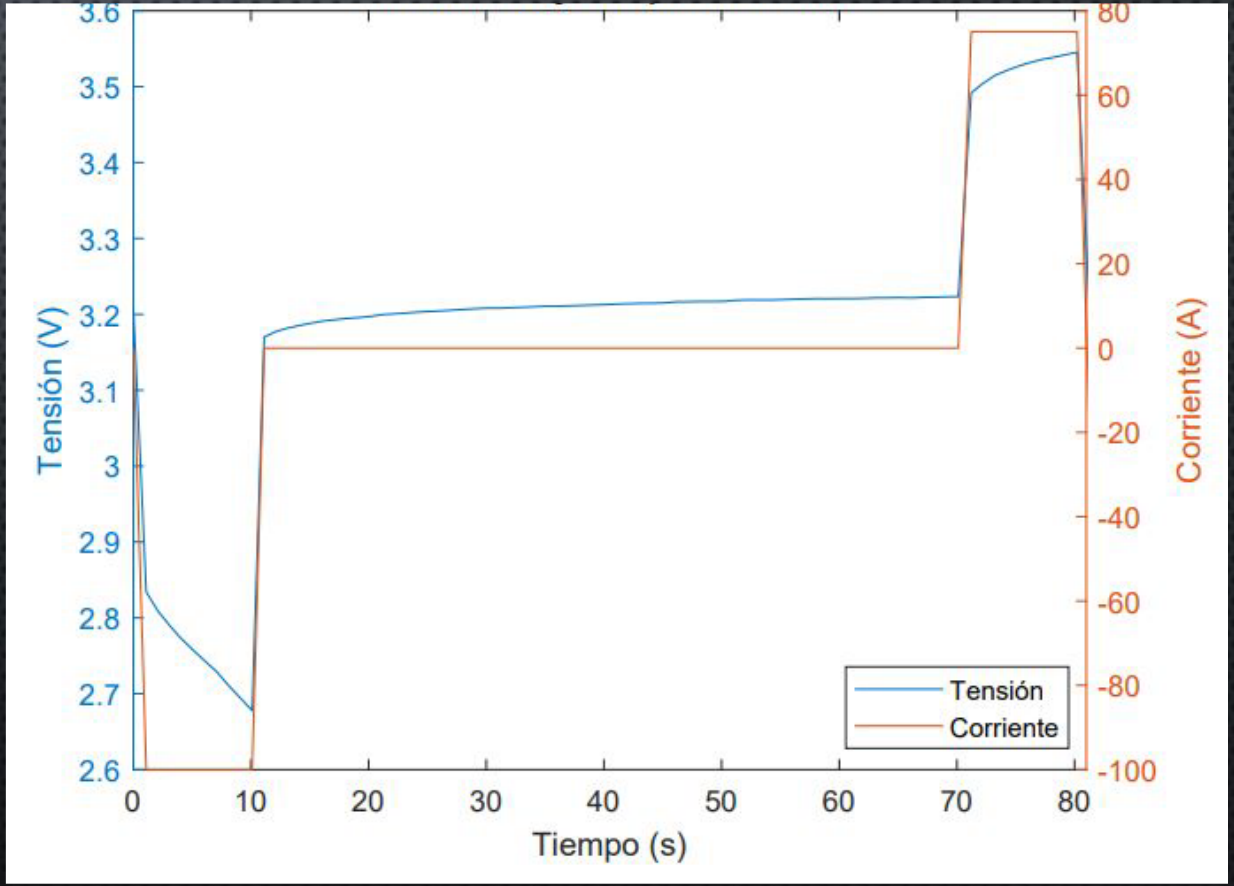
TO DETERMINE THE DISCHARGE POWER AND REGENERATION CHARACTERISTICS OF THE CELL, THROUGH A HYBRID PROFILE CONTAINING A CHARGE PULSE AND A DISCHARGE PULSE.

PROFILE USED:

I. DISCHARGE PULSE @ 2C / 10 SEC.

II. REST TIME: 1 MINUTE (1 HOUR IN HPPC)

III. REGENERATION PULSE @ 1.5C / 10 S



Power test

Procedure:

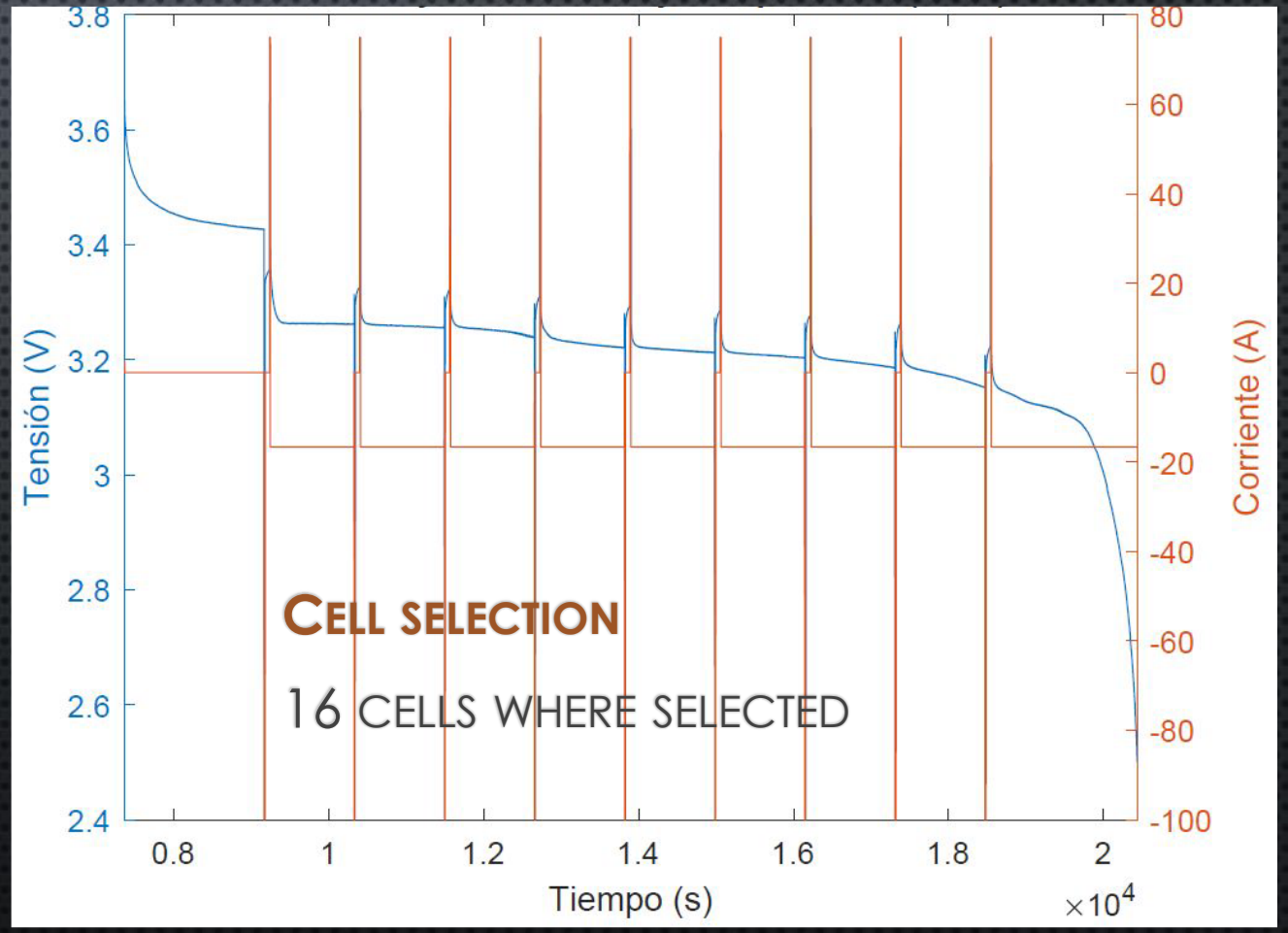
i. Fully charge the cell according to the manufacturer information.

ii. Keep the cell in open circuit for 30 min.

iii. Run the power test discharging the 10% of the cell capacity (Ah) at C/3 DC.

iv. Repeat steps II and III 9 times until at least 90% of the nominal capacity has been discharged.

v. Finalize the test by discharging the cell to its cut-off voltage at C/3 DC.

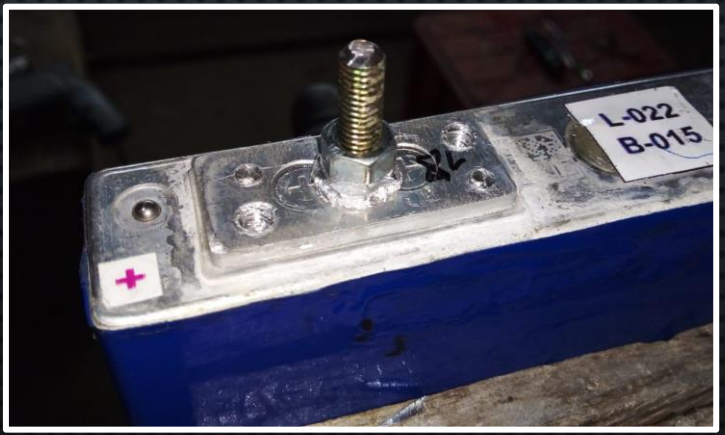


Battery pack construction (16 cells in series)

The battery voltage has to be 48 V (compatible with Valeo powertrain & GreenStar vehicle). Due to the series connection, the battery pack capacity is 50 Ah (that means 2,4 kWh).

Cell connection:

It was implemented a screwed connection.



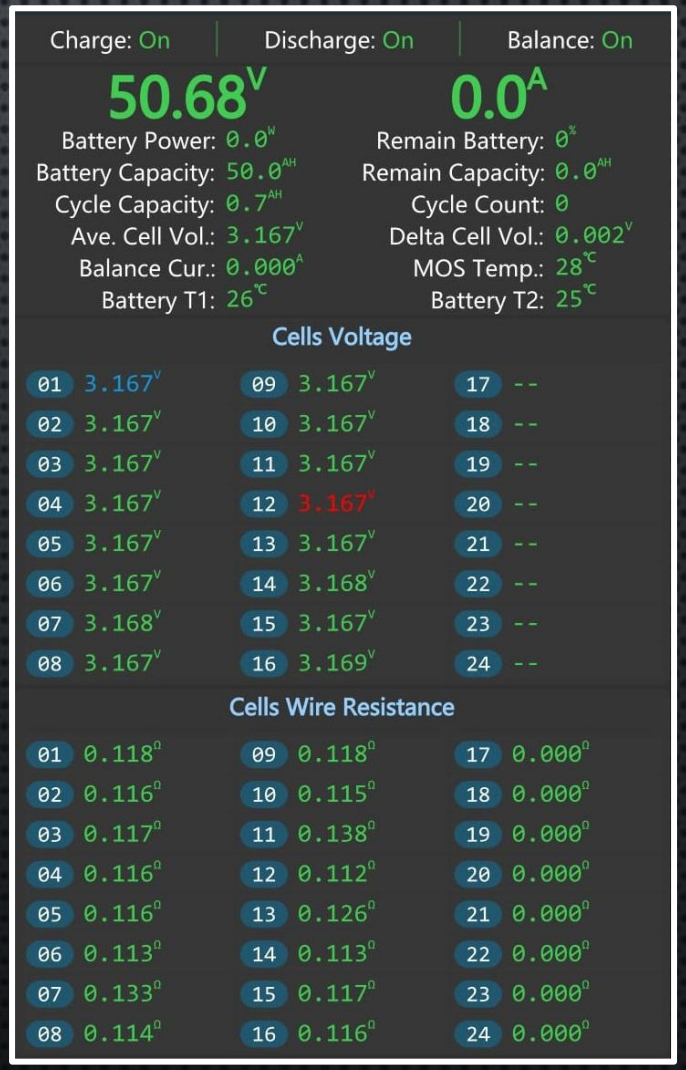
Container cabinet:

A metal cabinet was designed and manufactured to provide mechanical protection to the battery pack.

Battery pack construction

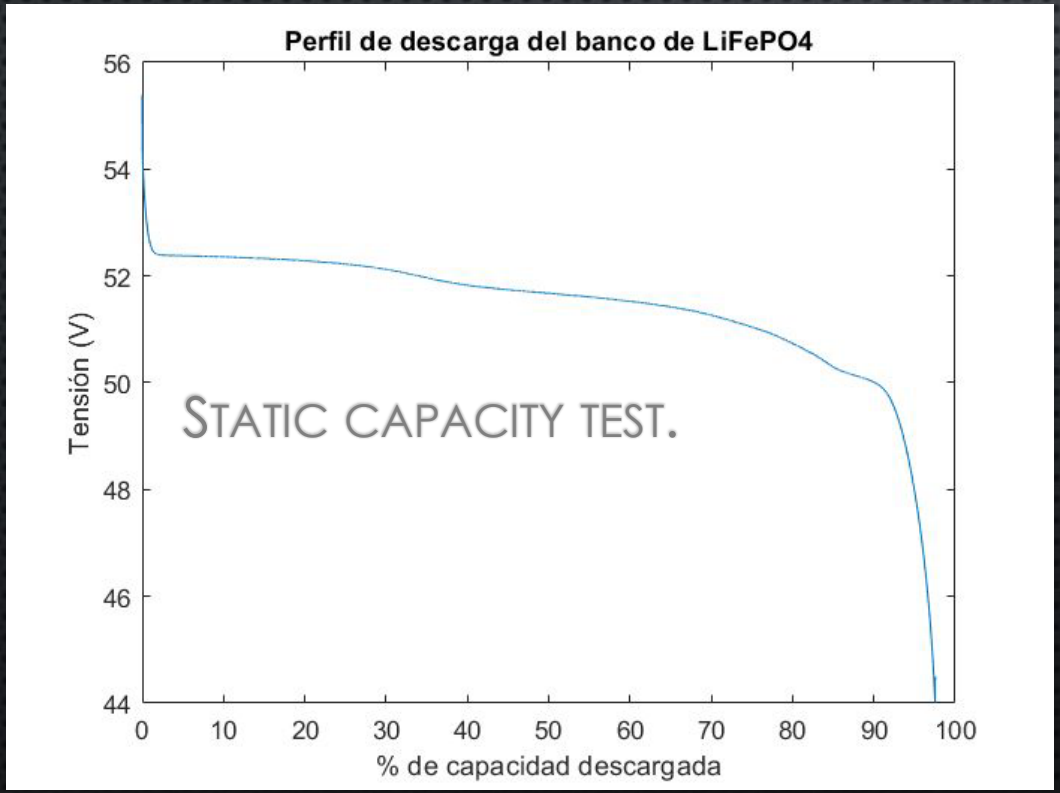
BMS (battery management system):

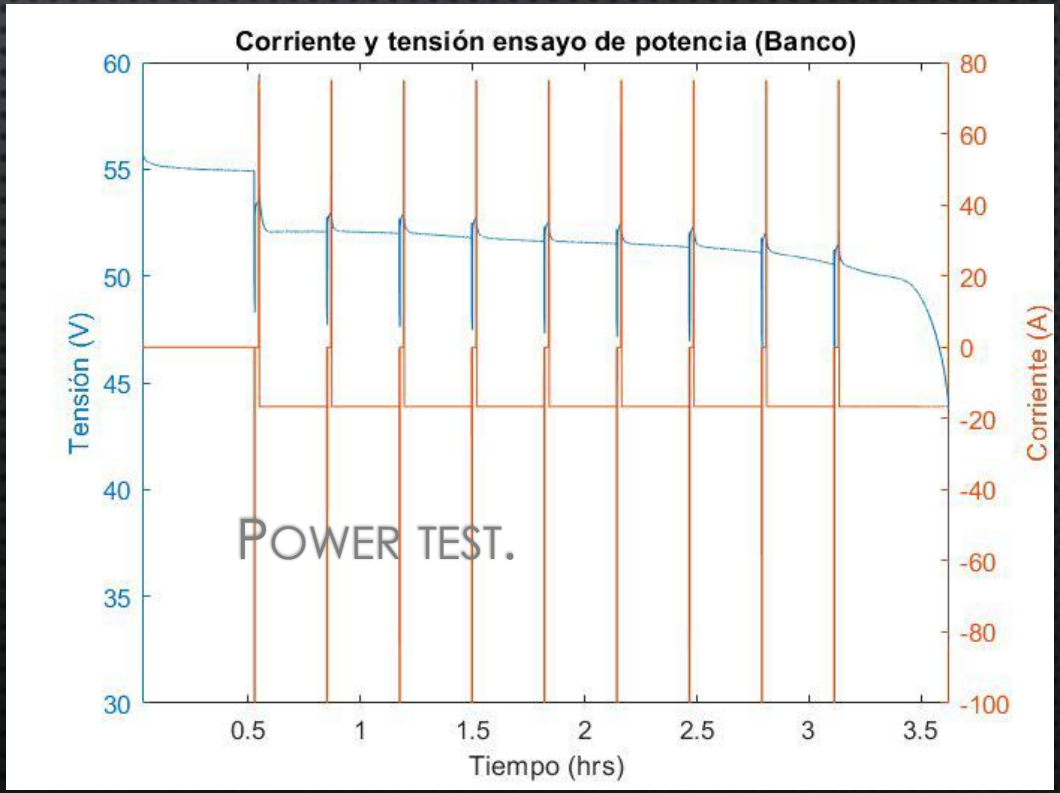
- BMS requirements comply with UN-R136, w/ protection against over-charge and over-discharge, short-circuit and over-temperature.
- Ability to manage up to 24 LiFePO4 cells / rated current of 150 A.
- Bluetooth connection w/App in English which permits to configure several parameters.
- Active cell balancing.



Conducted tests results:

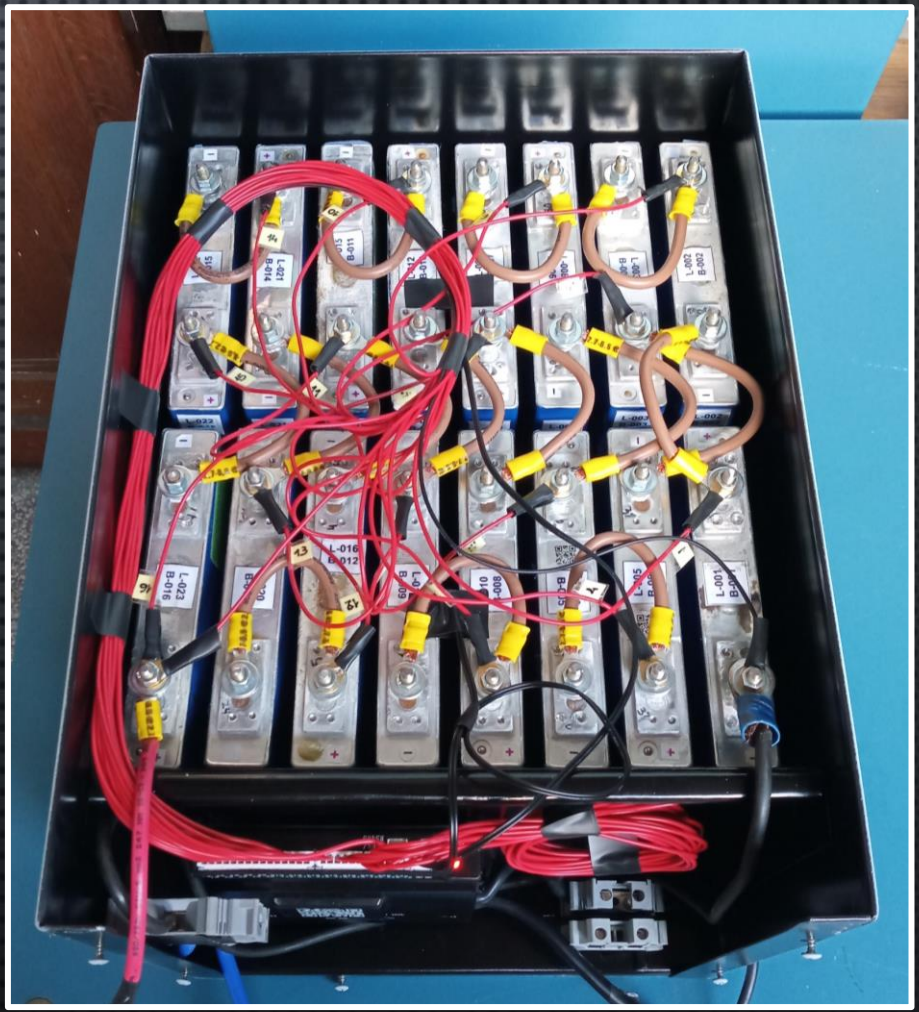
- **Static capacity test:** The built battery delivered 48.8 Ah.
- **Power test:** The built battery completed the power test without exceeding the voltage limits of each cell, delivering a total of 48.5 Ah.





Conclusions

- 79% of the original cells are still able to storage 95% of the original capacity and 16 cells were used for the SLBP manufacturing.
- Some difficulties arose when assembling the battery pack, due to the screwed cell terminals.
- SLBP SOC operation range is between 10% and 100%.
- 16 of 24 cells approved both tests (power & capacity tests) / 25 kg weight.
- SLBP discharge peak current is up to 2C and charge peak current is up to 1.5C during 10 seconds // SLBP is 48Ah capacity.

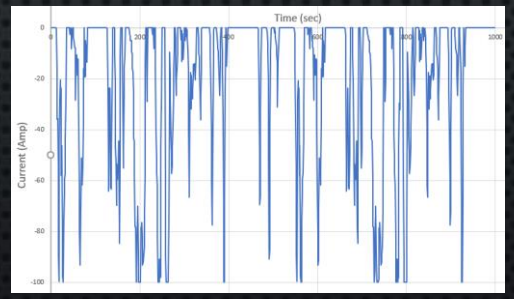


Vehicle simulations:

- Light electric vehicle (LEV) simulations where conducted finding that the SLBP would fit well to a LEV WLTP Class-3 driving cycle (vehicle parameters correspond to the local designed and manufactured LEV owned by the Uruguayan SME GreenStar) / 40 km range.

Next steps:

- Validation of the SLBP in the real vehicle.
- Cost evaluation and economic viability.
- Cell recycling for the discarded cells (ongoing at UDELAR University)



Thank you!

Juan Carriquiry

Faculty of Engineering – UDELAR

jpcarriquiry@fing.edu.uy

+59898707688