THE END OF RANGE ANXIETY IN BEV THANKS TO FAST CHARGING AND IMMERSION COOLING

Stéphane WATTS (Chief engineer)
Rémi DACCORD (CTO and Co-Founder)

Torino – June 21st 2022

EXOES

E-MERSIV
Submerged battery packs

ANFIA Associazione Nazionale Filiera Industria Automobilistica

ATA ASSOCIAZIONE TECNICA DELL'AUTOMOBILE

SAE TORINO
An SAE International Section

C2 reduction for Transportation Systems Conference

A unique expert in immersion cooled batteries

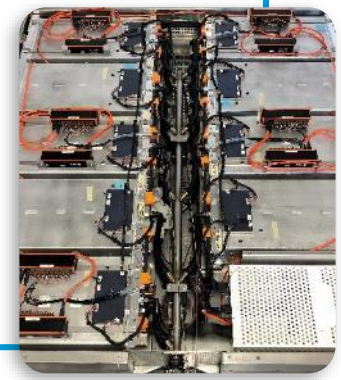
- An expert in **advanced thermal systems**
- Worldwide customer database (35% in France)
- Awarded by **11 customers**: **OEMs, fluid makers and cell makers** for advanced engineering on batteries and heat pumps

- Engineering on:
  - Component simulation & design
  - Prototyping
  - Tests & model calibration

E-MERSIV
Submerged battery packs

- Sells & manufactures immersion-cooled battery packs

- Markets:
  - Racing
  - Premium cars
  - Mass market (licensing)



TRL3 TRL4 TRL5 TRL6 TRL7 TRL8 TRL9 Industrialization

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How To Increase EV Customer Adoption Rate?

Mass Market

> 300 km	< 10 min	> 8 years	30 min
Highway range	Charging time	Lifetime	To reach a fast charger on the highway

Narrowing the user experience gap between fossil fuel vehicles and BEVs is key

Improved battery cooling is one of the keys

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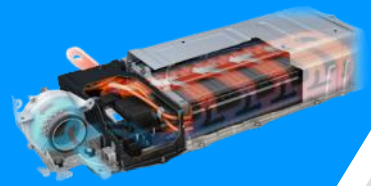
Existing cooling solutions for batteries

Air-cooled

- Simple and easy to implement
- Low heat transfer
- Low compactness



Water/Glycol

- Most common nowadays
- More compact and better efficiency than air
- Simplified vehicle thermal system with one-fluid-for-all

Refrigerant

- High heat-transfer and cooler
- Difficult to apply to large batteries
- No preheating mode

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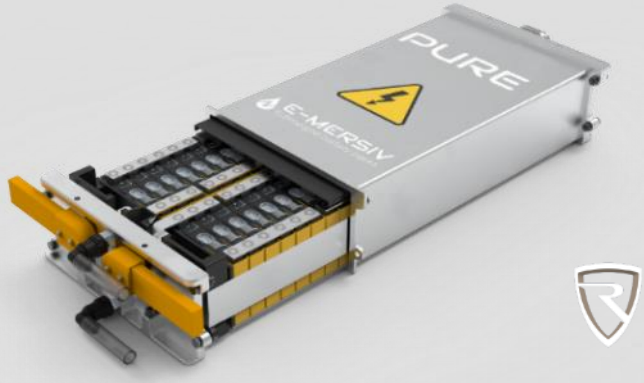
Immersion cooling technology

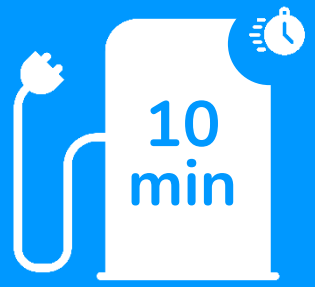
- Direct cooling of cells & busbars
- No fire propagation
- Fast charging enabled for BEVs
- High C-Rates for HEVs
- Already in use on motorsport and high performance supercars



RIMAC AUTOMOBILI

McLaren

Koenigsegg



SAFER
For end customer

Charging Time | Power to Energy ratio | Safety

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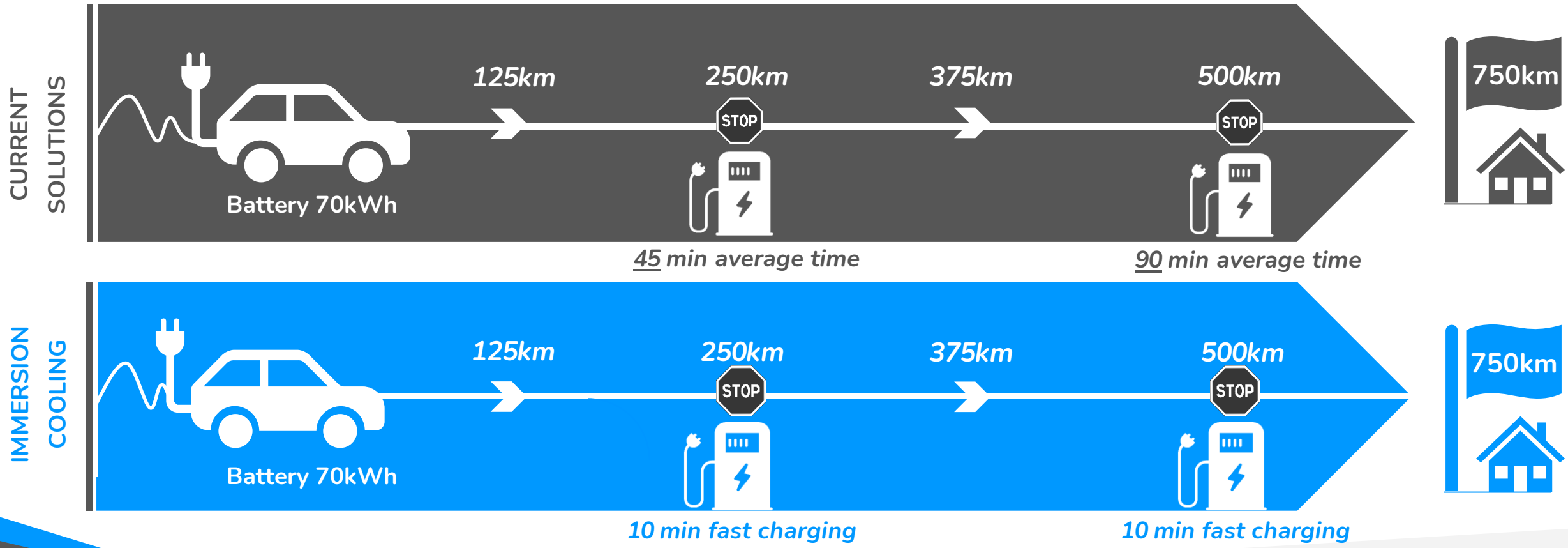
No more range anxiety on highways with immersion



10 minutes break every 2 hours of driving

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How does the technology work ?

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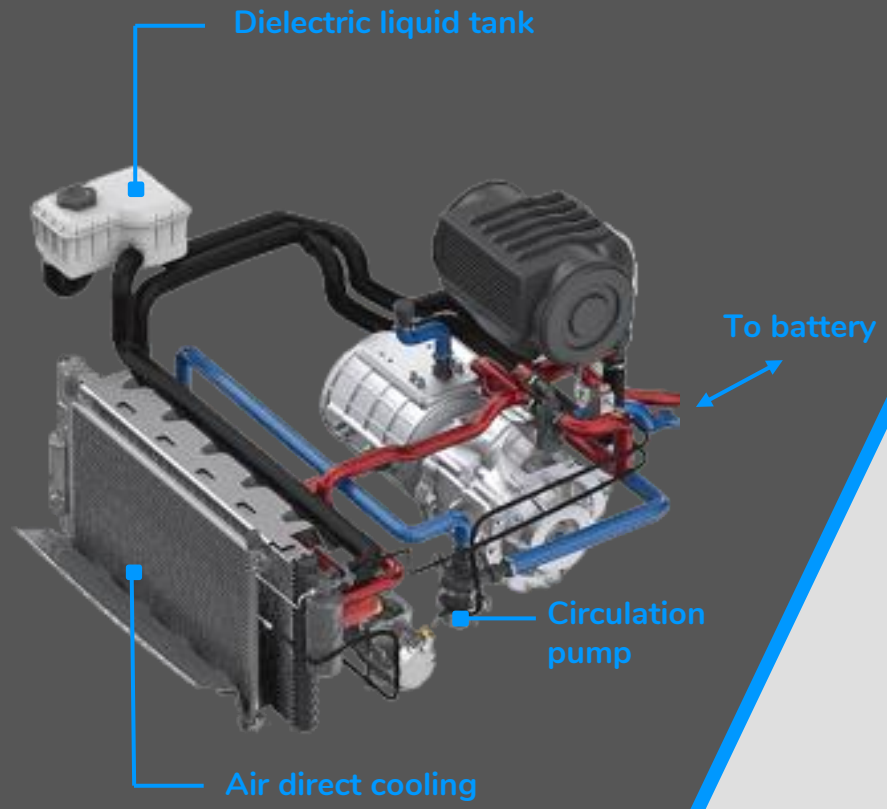
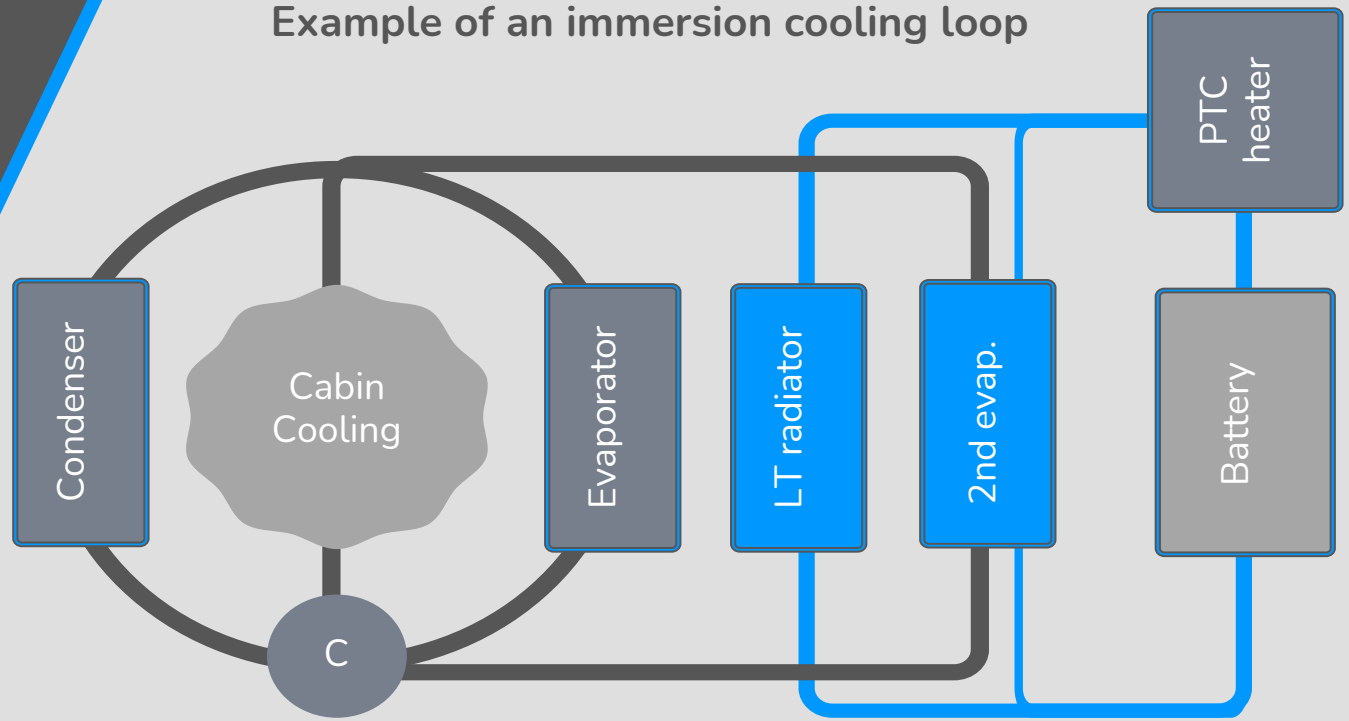
How Does Immersion Cooling Work?

At vehicle level



Example of an immersion cooling loop



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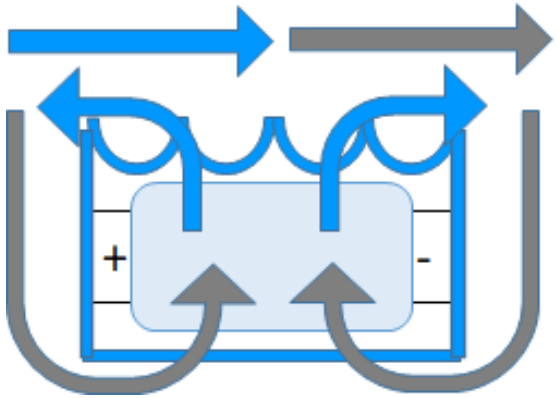
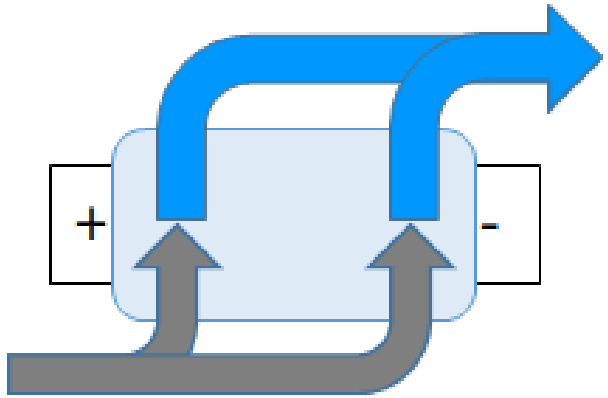
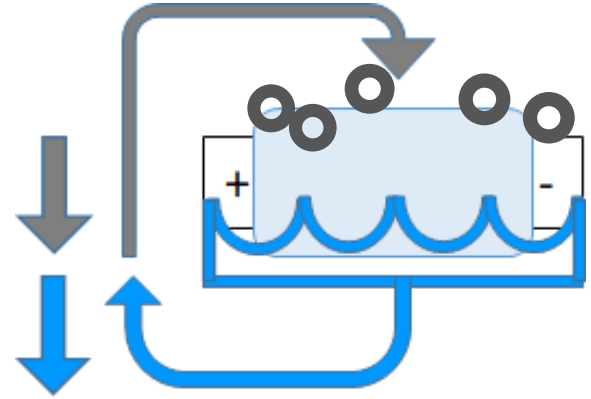
How Does Immersion Cooling Work?



Static bath



Full immersion



Spray / Jet cooling

Technology selection based on:

- Cost
- Weight
- Safety level
- System performances
- Cell to pack vs modular

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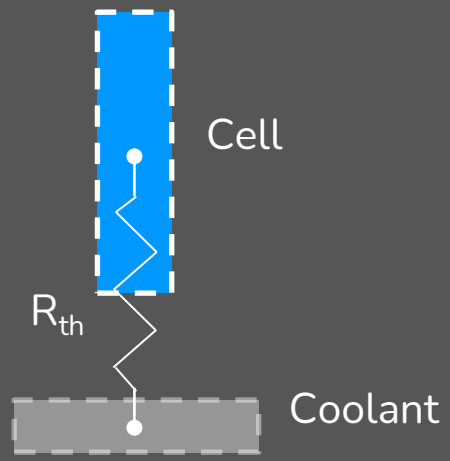
How Does Immersion Cooling Work?

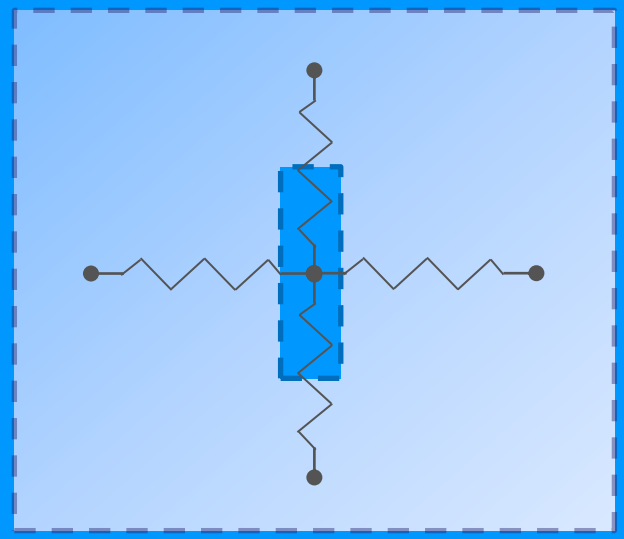
Immersion reduces the battery thermal resistance for better cooling:

Cold plate cooling



Thermal resistance typ. >0.8 K/W*
& busbar not cooled

Full immersion cooling



Thermal resistance typ. <0.2 K/W*
& hot spots cooling

Immersion cooling is 2 to 5x better than cold plates

*: *Calculated on prismatic cell – PHEV2 format*

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Our test results

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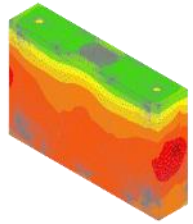
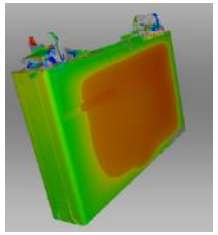
Design process

1 Heat generation



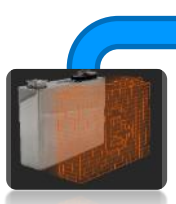
2 Swelling and internal stress



3

Dedicated module design

4 Physical model of anode potential



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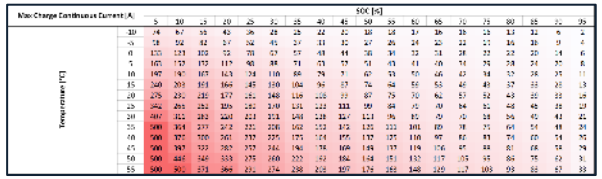
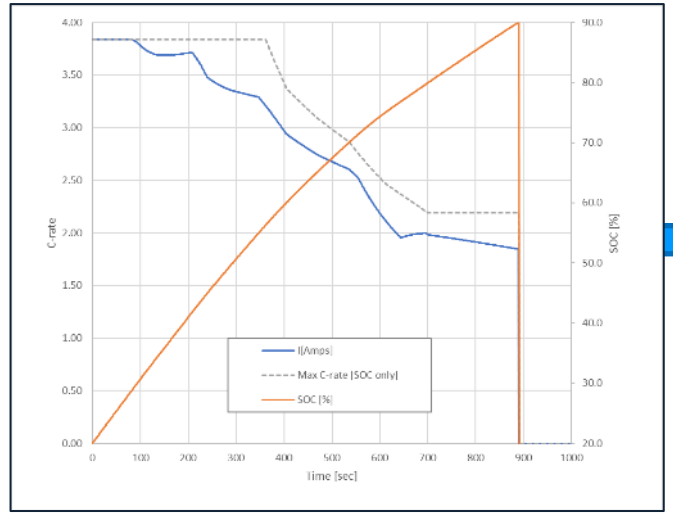
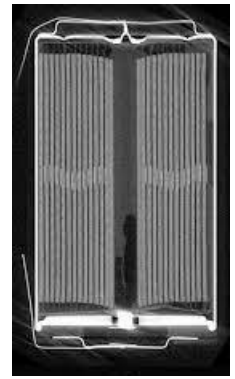


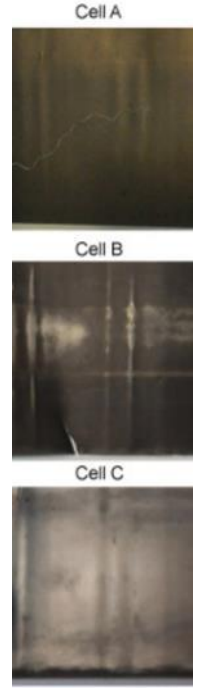
BMS integration

6 Actual tests
Performance / Aging / Abuse / Vibration



7 Validation w/ Swelling/Plating analysis after X fast-charging cycles





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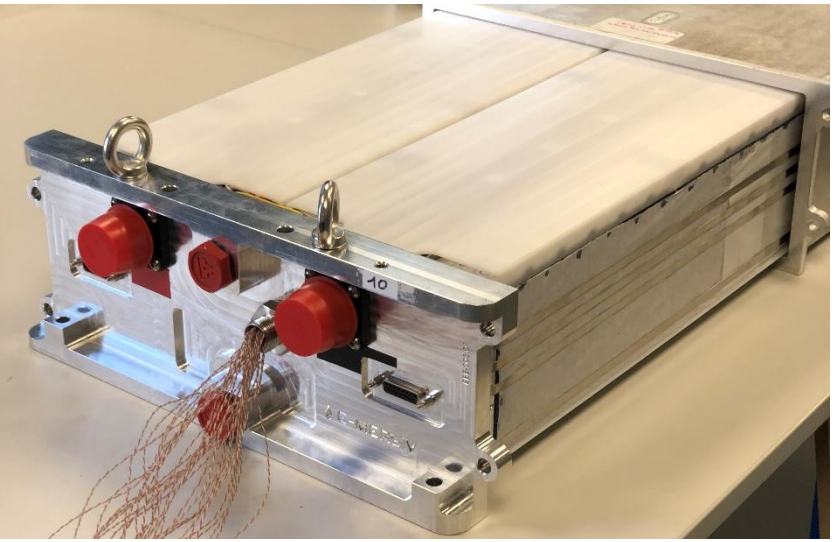
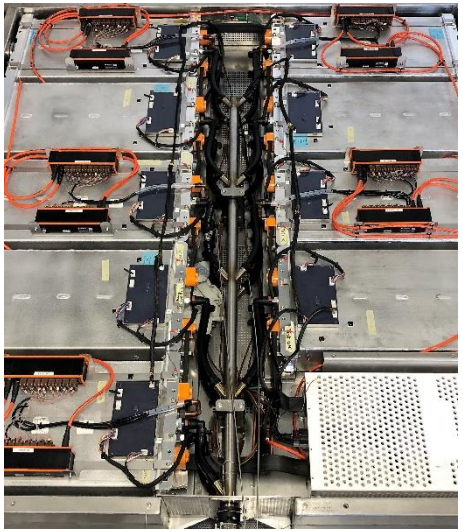
Our last battery design

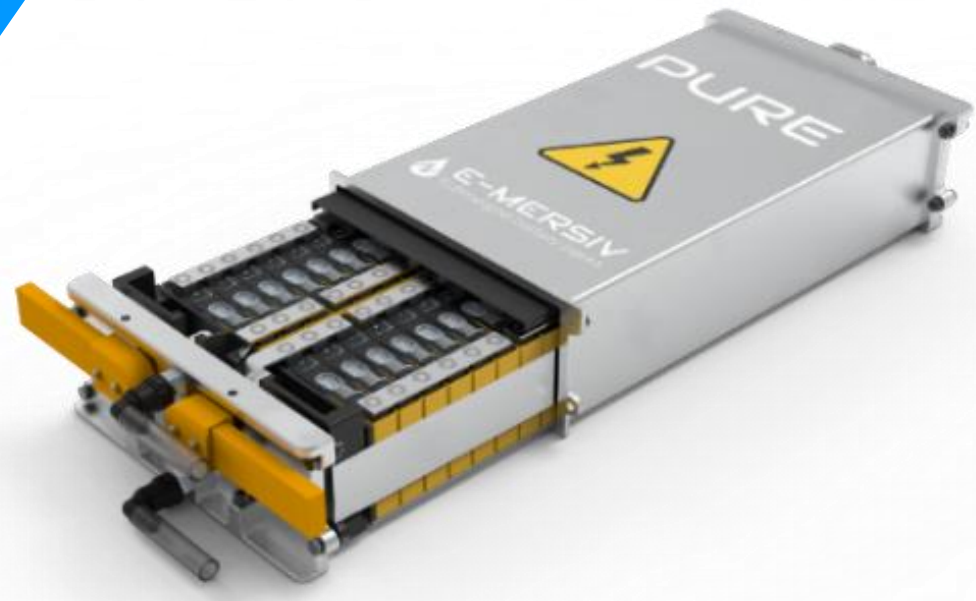


a module made of 36x NMC prismatic cells (3p12s)



a 60kWh battery made of 9x modules

A ruggedized product
to supply the specialty vehicle markets



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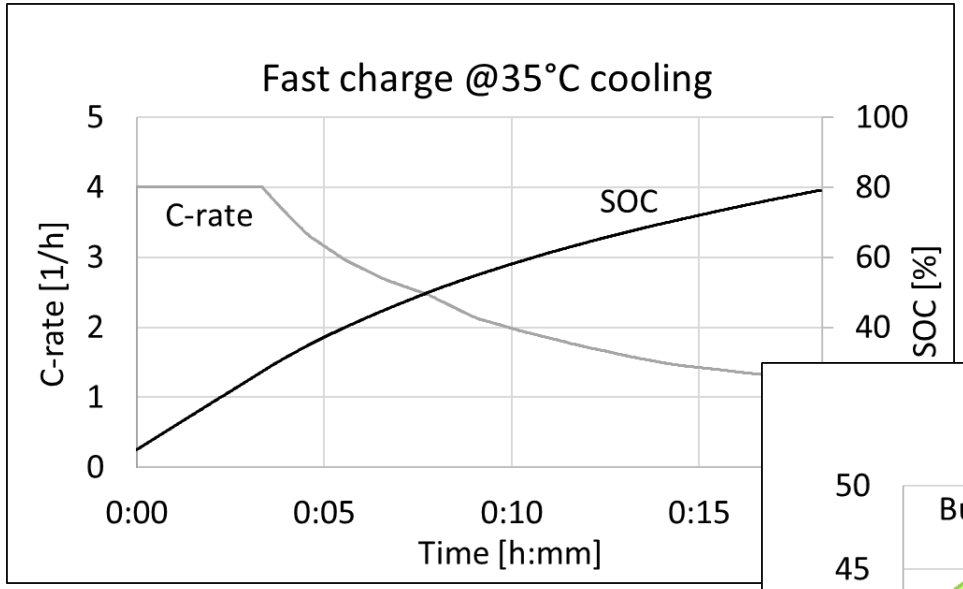
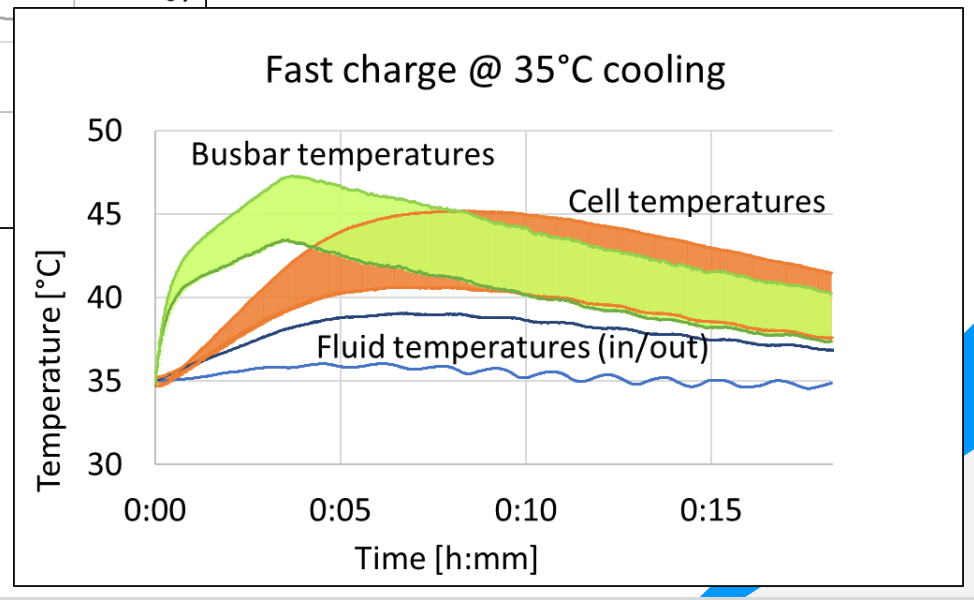
Feasibility of fast charges

Data courtesy of MOTUL

Test Conditions

- Charge 5 to 80%
- Initial temperature 35°C
- Cooling at 0.3L/min/cell
- Cooling at 35°C





Results

- Max cell temp. <45°C *(max cell limit is 55°C)*
- Max ΔT on cells <5K
- Average C-rate = 2.5C
- Peak C-rate = 4C

»» 4C peak charge accessible:
»» From 5 to 80%SOC in 18min30sec (Average 2.5C)

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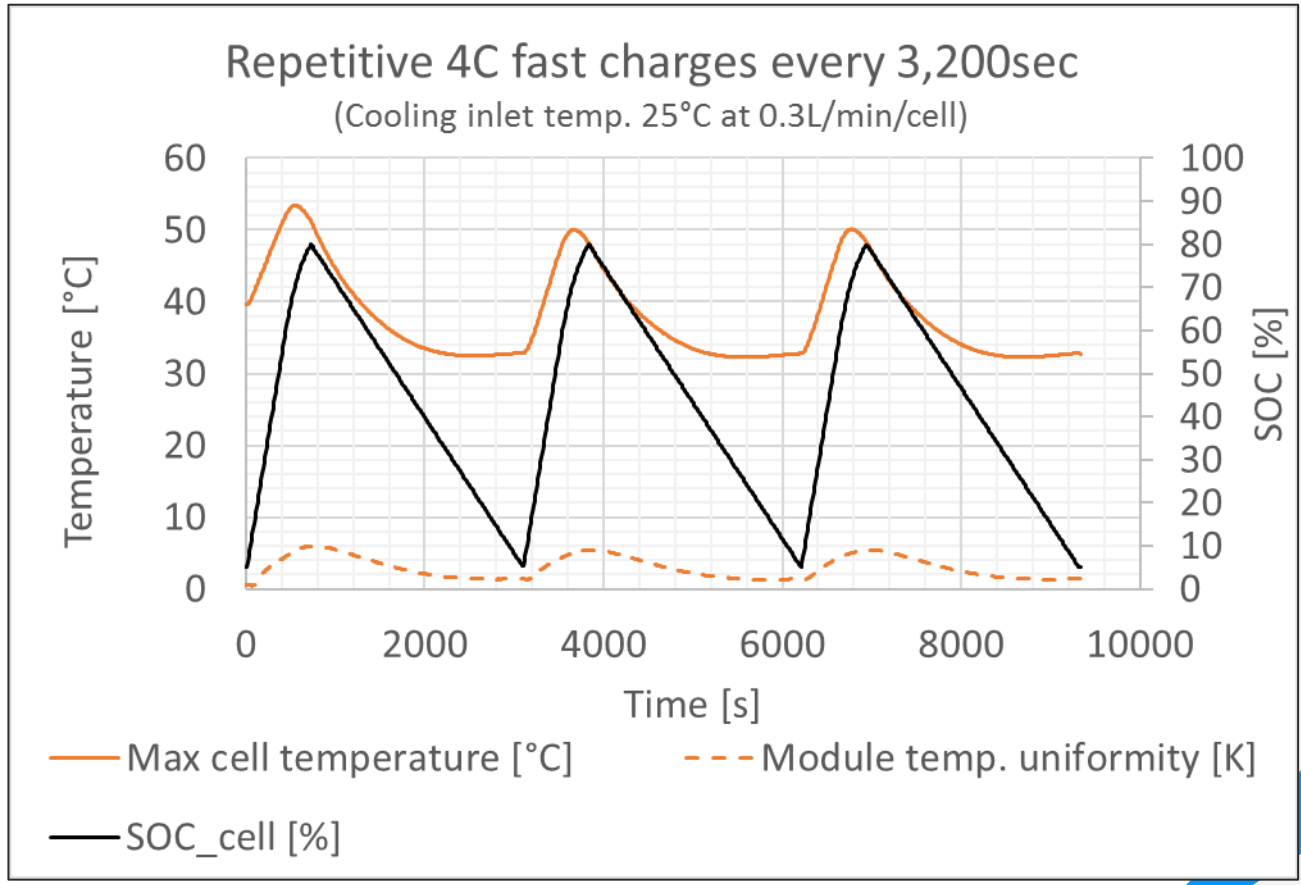
Repeatibility of fast charges

Test Conditions

- 4C charge 5 to 80%
- Followed by 1C discharge
- Cooling at 0.3L/min/cell
- Cooling at 25°C

Results

- Max cell temp. <55°C *(max cell limit is 55°C)*
- Max ΔT on cells <6K
- No derating !



Data courtesy of Lubrizol

»» Repetition of 4C charges accessible
»» Back to initial state in less than 30min

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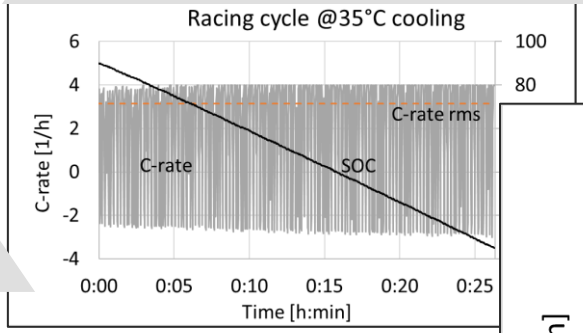
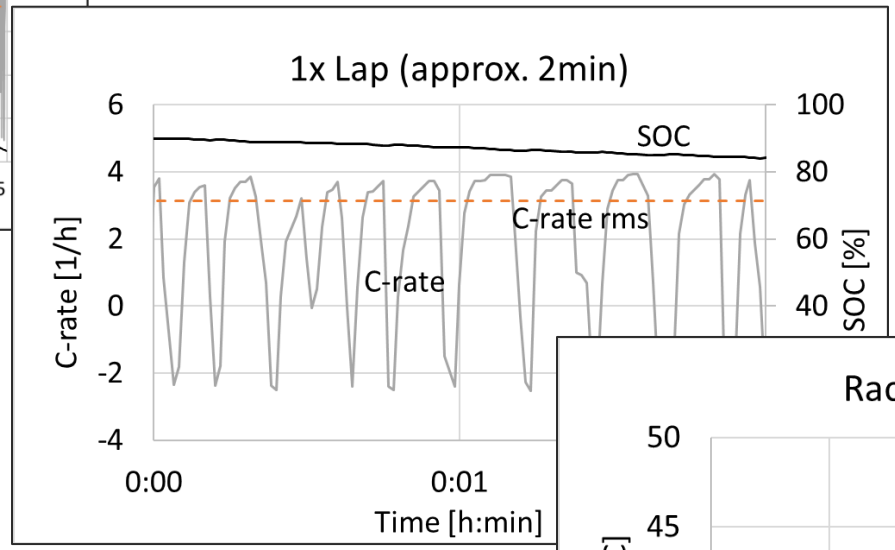
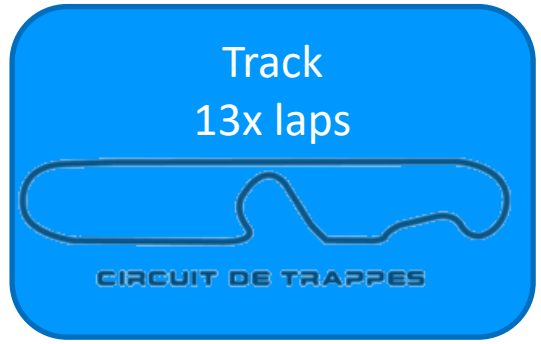
Feasibility of racing cycle

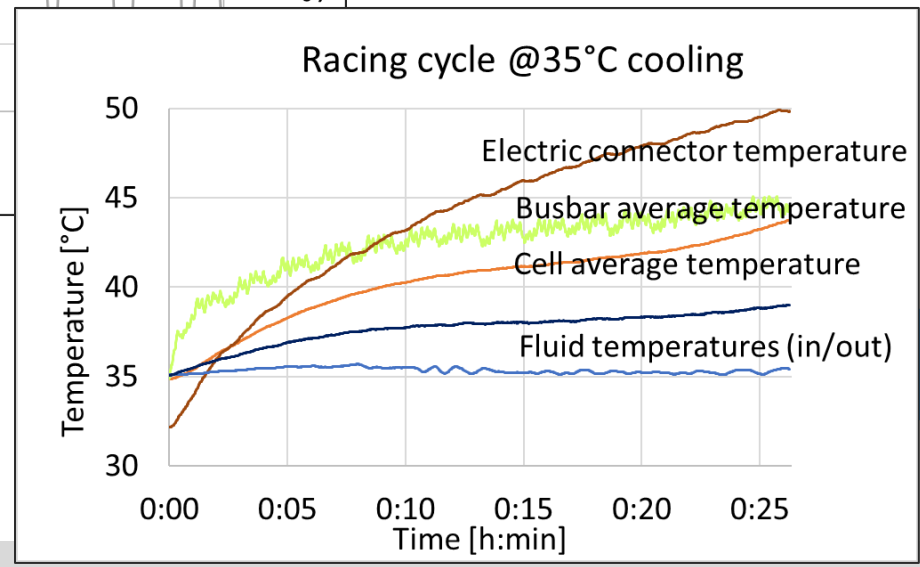
Test Conditions

- Racing cycle from 90% to 5%SOC
- Vehicle 950kg / 240kW / 60kWh
- Initial temperature 35°C
- Cooling at 0.3L/min/cell
- Cooling at 35°C









Data courtesy of MOTUL

Results

- Max cell temp. <45°C *(max cell limit is 55°C)*
- Max ΔT on cells <5.5K
- Average C-rate = 3.1C
- Peak C-rate = 4C

»» 4C peak discharge and charge possible
»» Average 3.1Crms from 90 to 5% SOC

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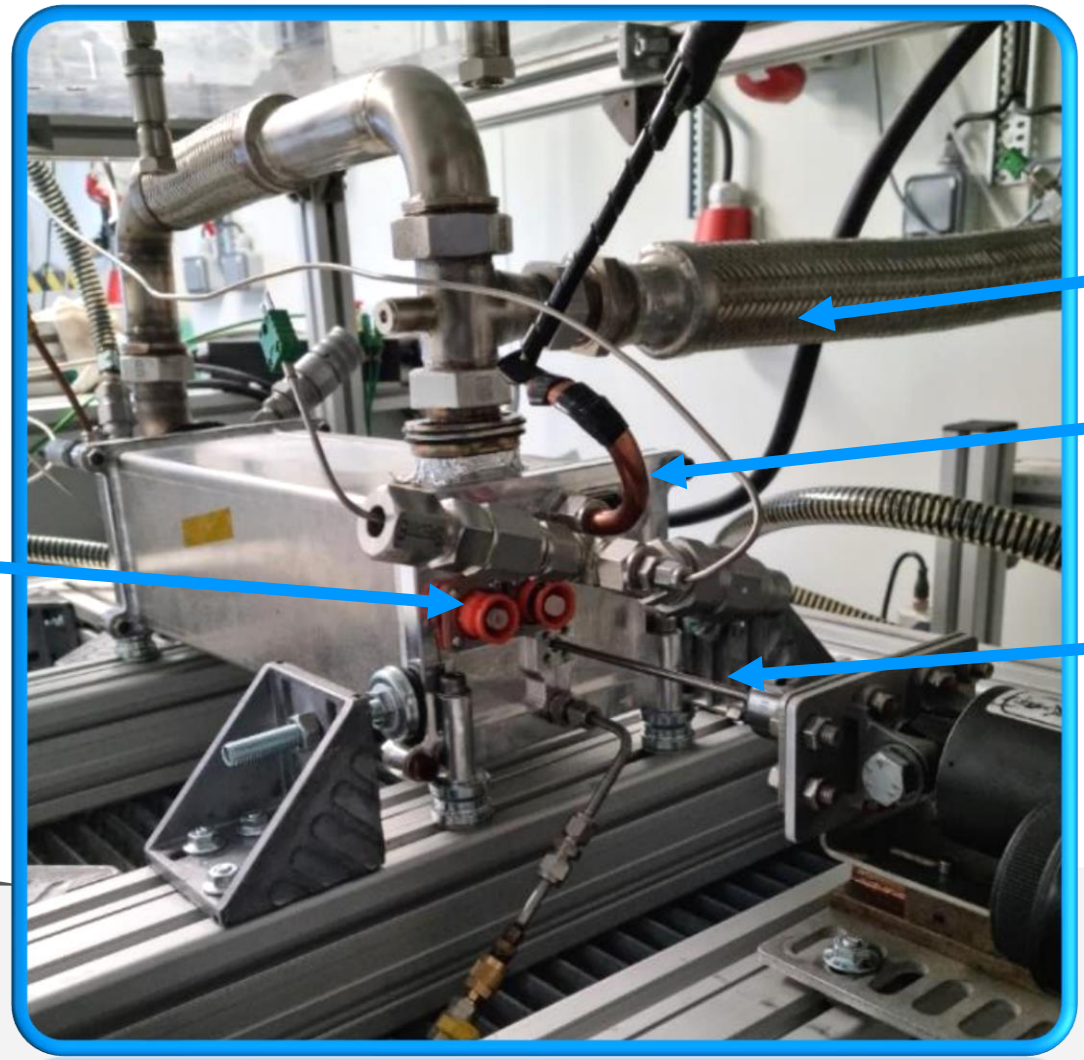
Nail Penetration Test (NPT)



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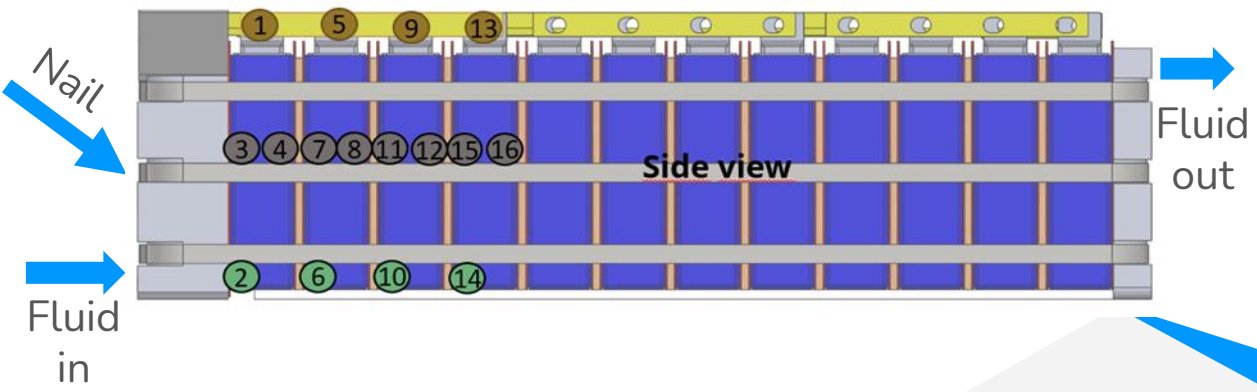
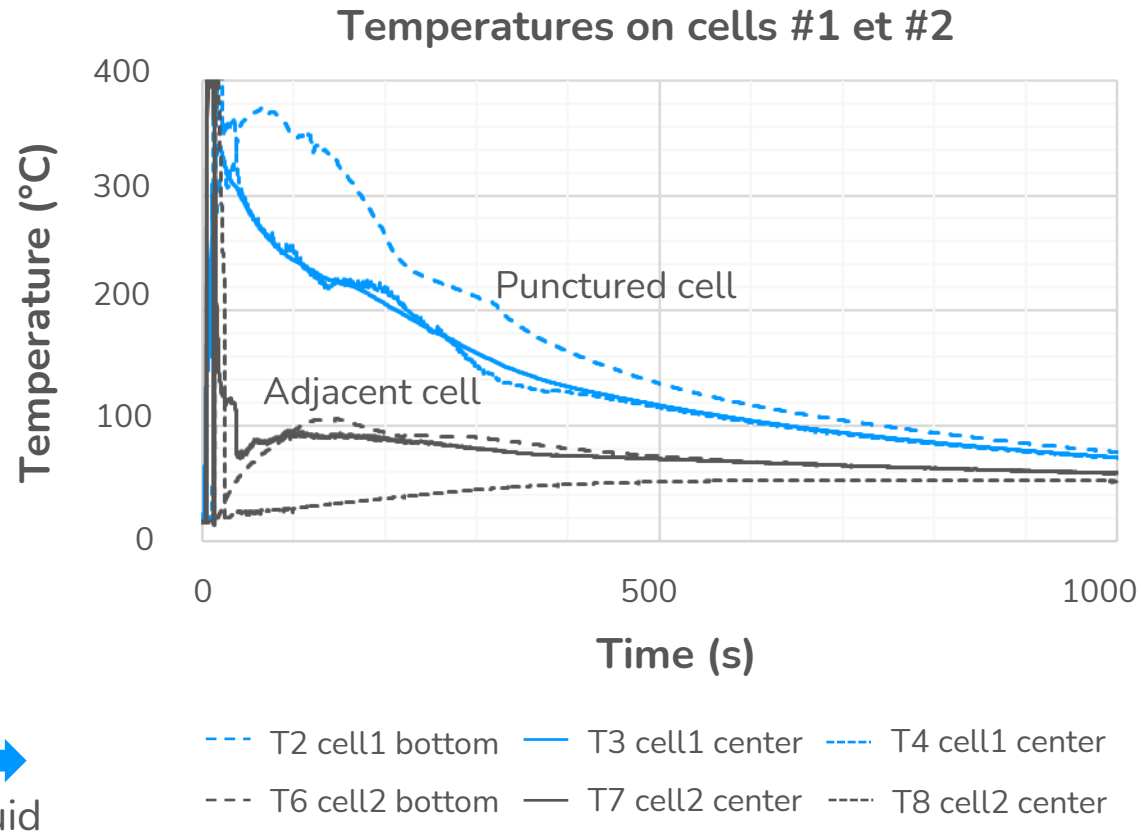
The cooling prevented the fire propagation

- No Active flow rate by pumping action.
  Flow of 0.025 L/min/cell induced by gravity
- Punctured cell temp. increased up to 350°C in 20s after the vent broke
- Adjacent cell temp. increased up to 105°C within 100s





Data courtesy of bp

No propagation to the adjacent cell

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The adjacent cell suffered but did not burn

Data courtesy of bp

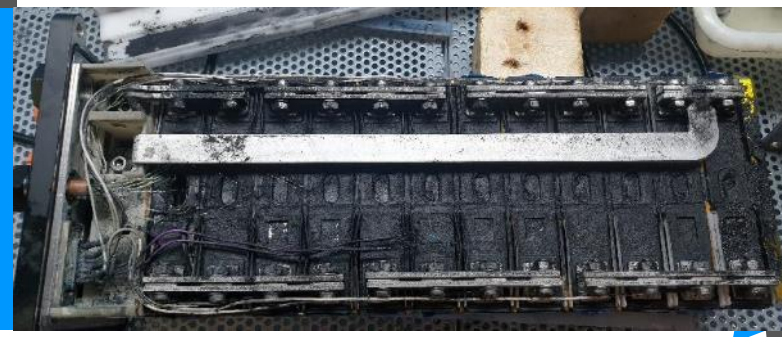
Battery design

has been improved

for greater robustness

Cell#	Fuse burnt	Internal short circuit	Weigth [g]	Swelling [mm]
1	**Yes**	**Yes**	**731**	**+3**
2	No	No	860	+1
3			860	+1
4			863	Not checked
5			858	
6			860	
7			859	
8			863	
9			861	
10			861	
11			861	
12			861	

Lots of ashes , but...



... the adjacent cell is intact !

** measured after a complete discharge process and a several days of relaxation*

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Conclusion

Immersion cooling is a promising technology to enable fast charging and democratize electric mobility

- We have demonstrated that immersion allows:
  - Increased thermal performances
  - Increased safety levels
  - No extra cost nor weight compared to current battery designs

- **The cooling fluid becomes a key component.** It has to be:
  - Good heat-transfer fluid
  - Robust dielectric properties
  - Easily pumped at all temperatures
  - Safe: not flammable
  - Environment friendly (low LCA)

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Submerged battery packs

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Thank you. Any question?

Stéphane WATTS (Chief Engineer) | Rémi DACCORD (CTO and Co-Founder)
stephane.watts@exoes.com

SAE International - Torino – June 21st 2022

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