





Jean CHEVALIER
Battery Event 2023



Summary



- Introduction to Immersion cooling
-  &  **E-MERSIV** expertise
- Case studies : battery abuse test results
- Conclusion

Unlock potential with Immersion Cooling



Unrivalled Safety
No thermal runaway propagation



Ultra-fast Charging
10 min (20% – 80% SOC)



Longer Lifetime
+ ~20 – 30%

EXOES E-MERSIV



IMMERSION COOLING BY EXOES

EXOES = Advanced thermal management systems

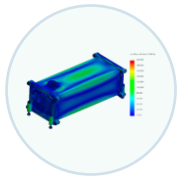
From proof of concepts concept to industrializable designs of immersion cooling batteries

Advanced engineering

Manufacturing



Design & Simulation



Design of correlated simulations

*Proprietary design process
Top of the line software*

Prototyping



Design and manufacturing of prototypes

Material sourcing from longstanding partners and suppliers

Advanced testing



Creation of customized test benches

*Material compatibility
Fluid endurance
Performance test
Aging test
Abuse test*

Vehicle integration



Integration into a demonstration vehicle

Real life simulation & test capabilities



Test rooms



Manufacture and distribution of customized containerized battery test chambers

Battery packs



Manufacture of complete immersion battery packs by 2024

Coverage of all form factors & architectures

Containerized battery test chambers



EXOES turnkey solution

- > Fully equipped and customized standard maritime container
- > Easy & secured shipping and transportation
- > Fast implementation
- > Flexible layout



All technical information provided in this document are EXOES standard proposal.

This product can be adapted to customer



Main features

- > Battery module test bench
- Immersion cooling and/or cold plate
- Performance test
- Abuse test : nail penetration and external heater

- > DUT Energy : up to 10 kWh

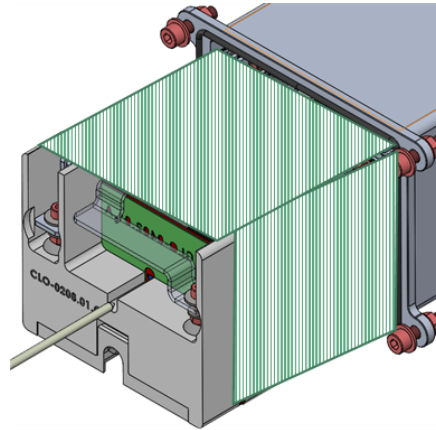
- > Gas filtration unit

- > Fire suppression system

- > EUCAR rating : 7

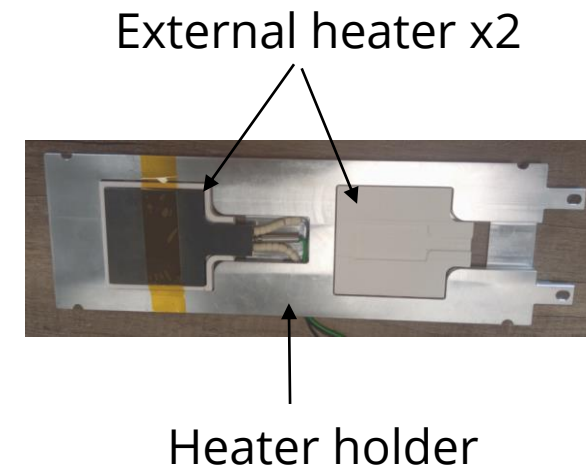
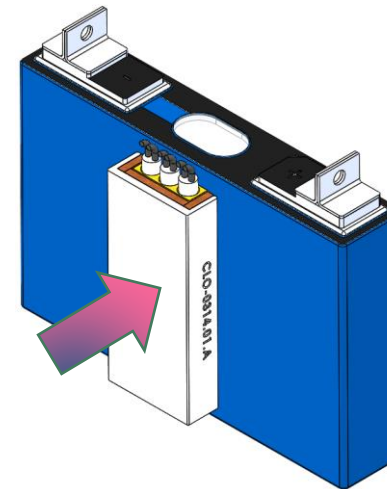
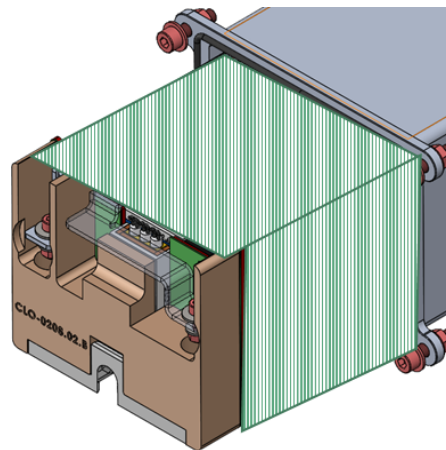
Nail penetration

- Mechanically invasive
- Specific casing (hole for the nail)
- Protocol adapted from GB38031 standard



Heating pad

- Best repetability
- Specific module design
- Protocol adapted from ISO6469 standard





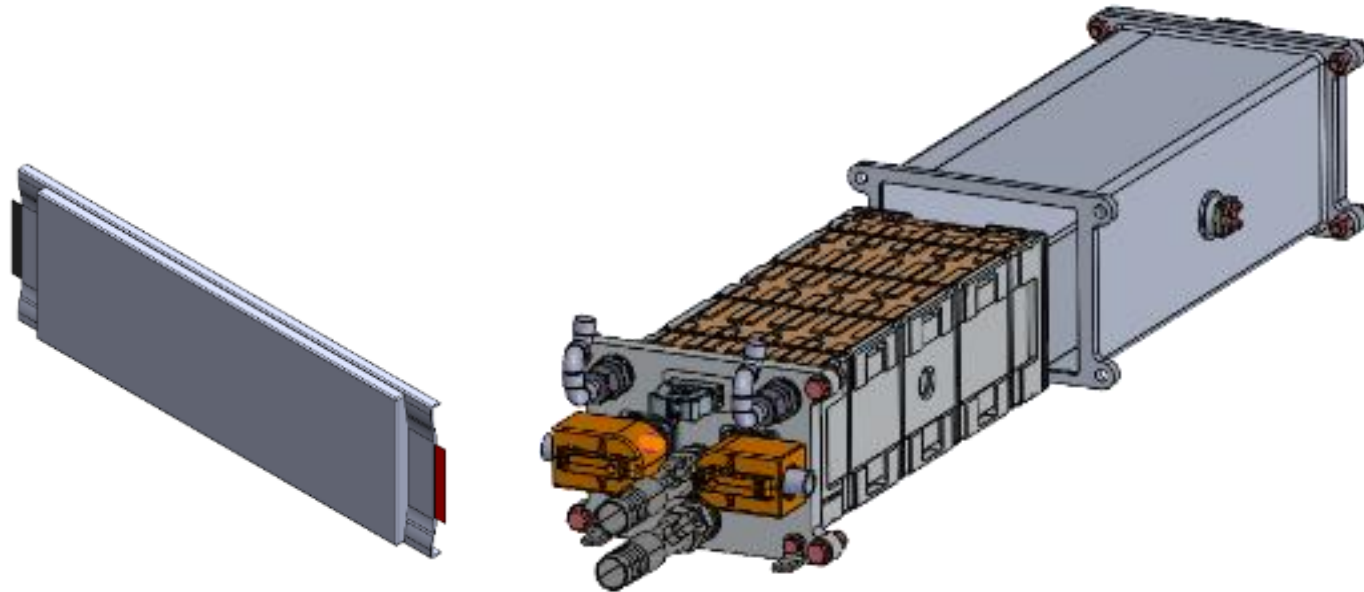
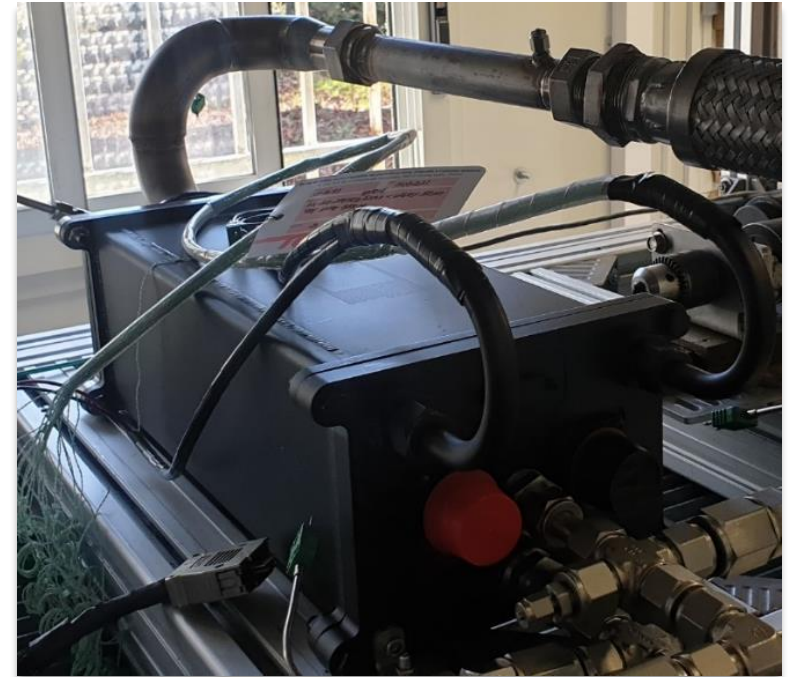
Case Studies - Safe Battery Development: **Abuse testing on pouch cells module**





Immersion cooled pouch cells module

- A module made of 8x NMC63Ah pouch cells (2p4s)
- Abuse test performed with **active flow rate upon thermal runaway detection according to ISO 6469**
- Thermal runaway triggered by **heating pad**



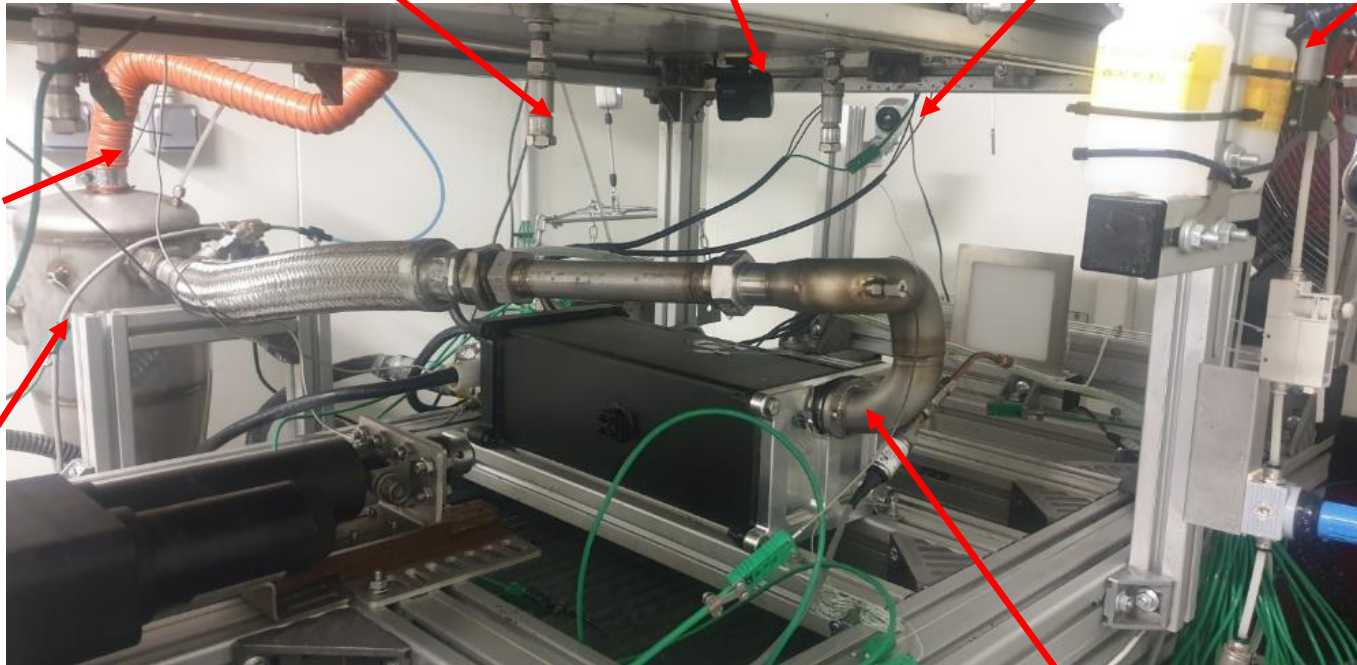
- Thermal runaway triggered by thermal pad heated up to 400°C within 10s

Water spray nozzle for safety

HD camera

Thermal camera

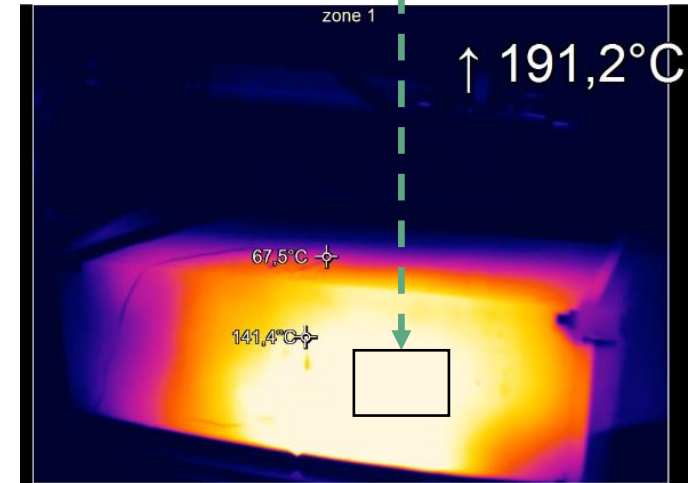
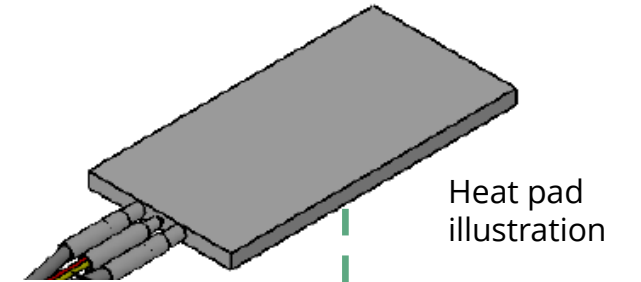
Gas sampling



Gas vent line

Oil separator

Burst disc

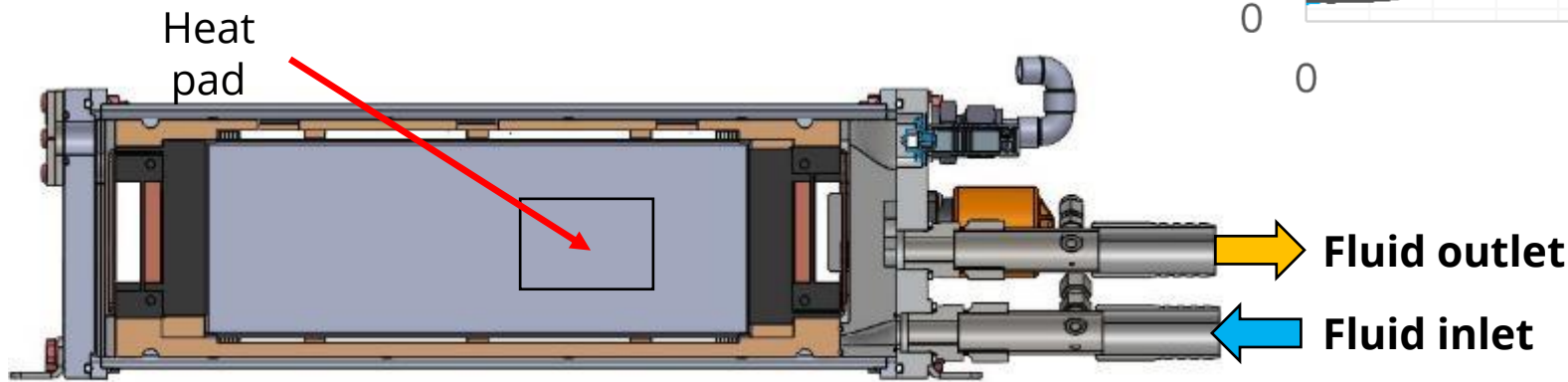
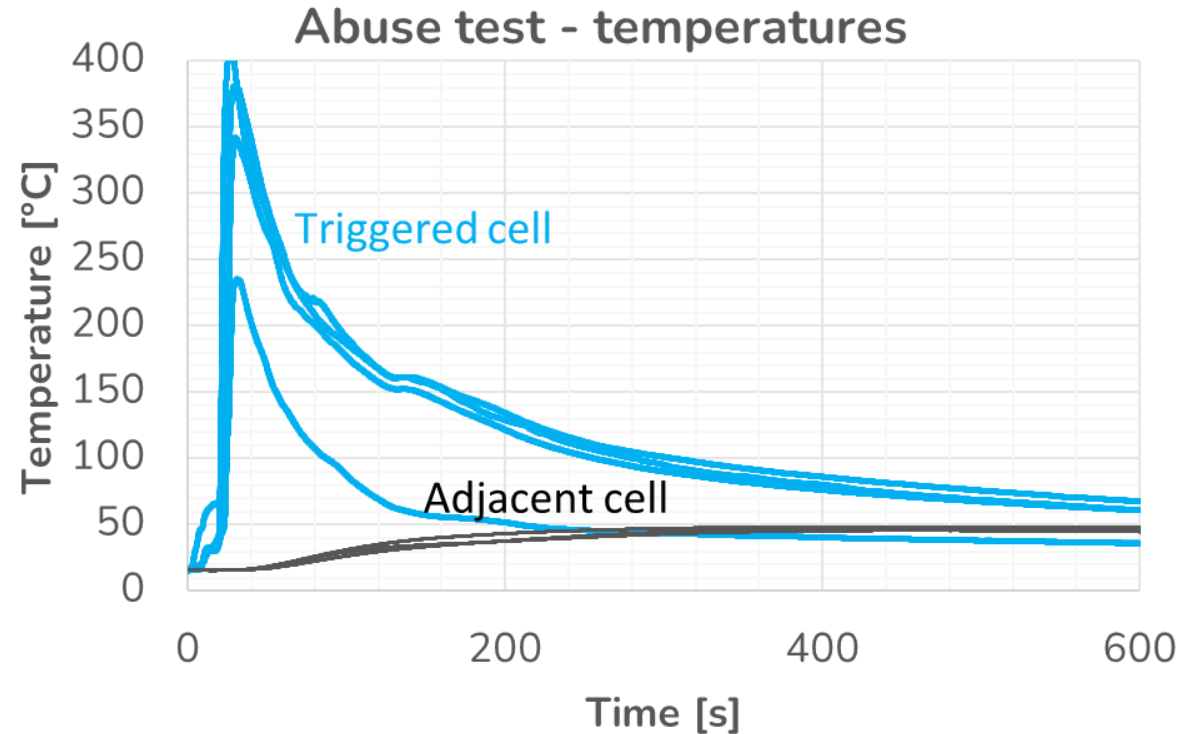


Thermal image from testing



Immersion cooling prevented thermal runaway and fire propagation

- Pump actuated upon thermal runaway detection at 0.5L/min/cell
- Triggered cell temperature increased up to 400°C in 27s after the vent ruptured
- Adjacent cell temperature increased up to 50°C within 350s → **no propagation**



Data courtesy of Shell

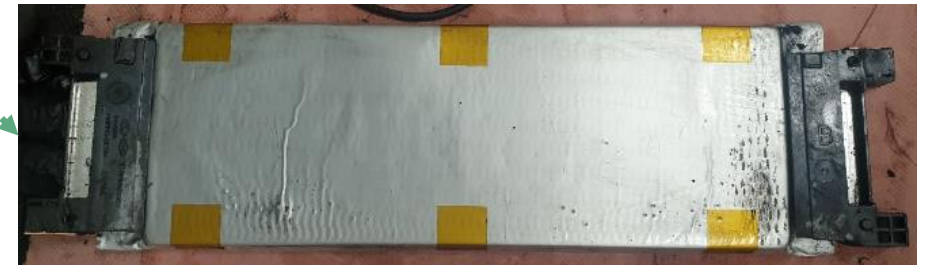
The adjacent cell remained intact

Cell#	Burnt cell	Weight [g]	Swelling [mm]
1	Yes	768	5.5
2	No	945	0.3
3		945	0.9
4		946	0.3
5		945	0.0
6		945	0.4
7		946	0.1
8		944	0.6

- Measurements showed near 20% mass reduction for triggered cell
- No damage observed nor measured on neighbouring cells
- Triggered cell fully ruptured along foil weld



Module corepack seen from top with visible ashes



Adjacent cell



Triggered cell seen from top (small face)

Data courtesy of Shell



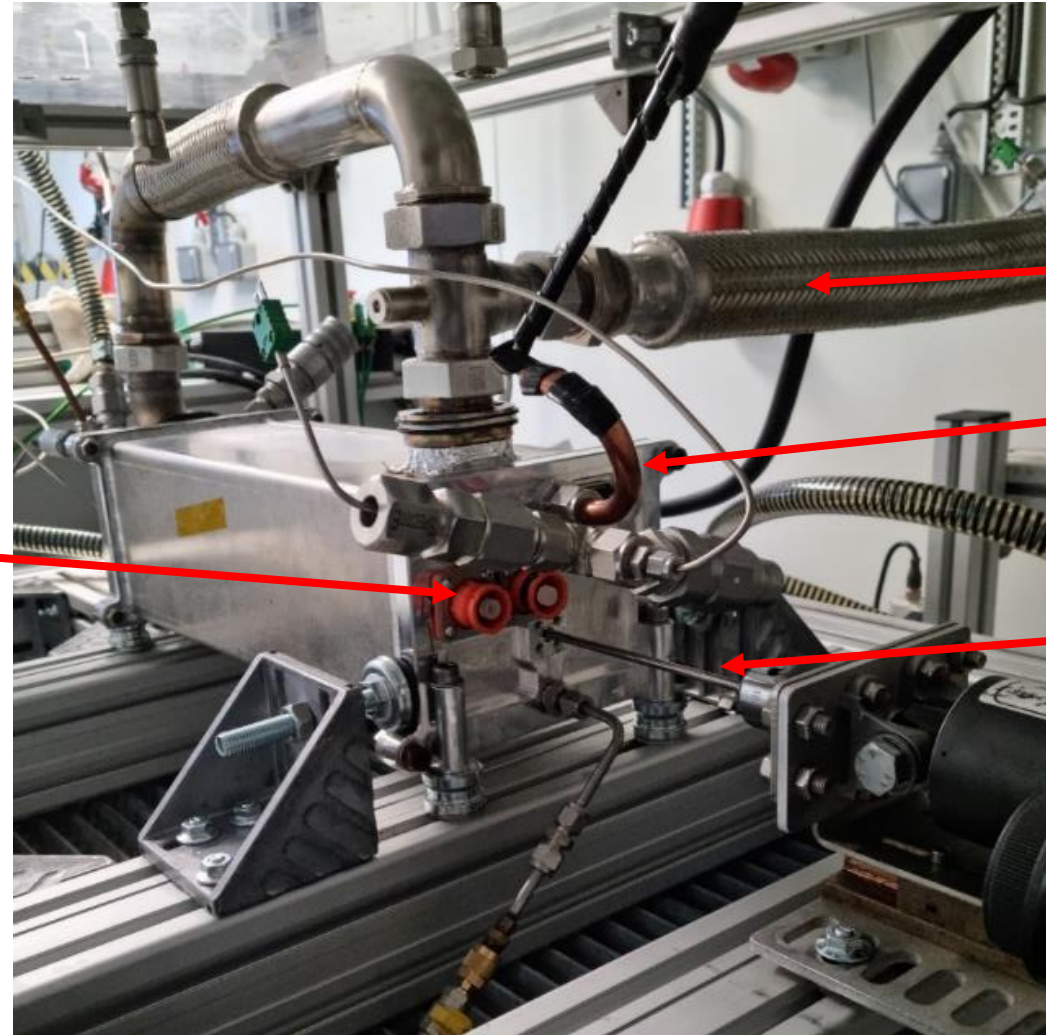
Case Studies - Safe Battery Development: **Abuse testing on prismatic cells module**



- A module made of 12x NMC prismatic cells
- Abuse test performed with **nail penetration**
- **No active cooling**



Module terminals



Gas exhaust line

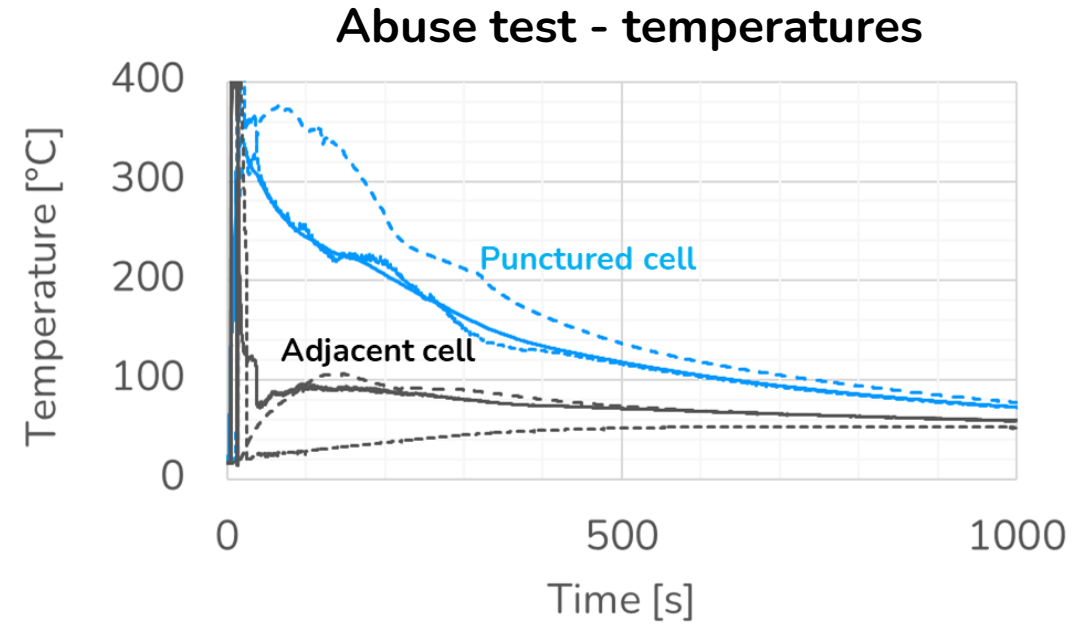
Pass-through for thermocouples

Nail

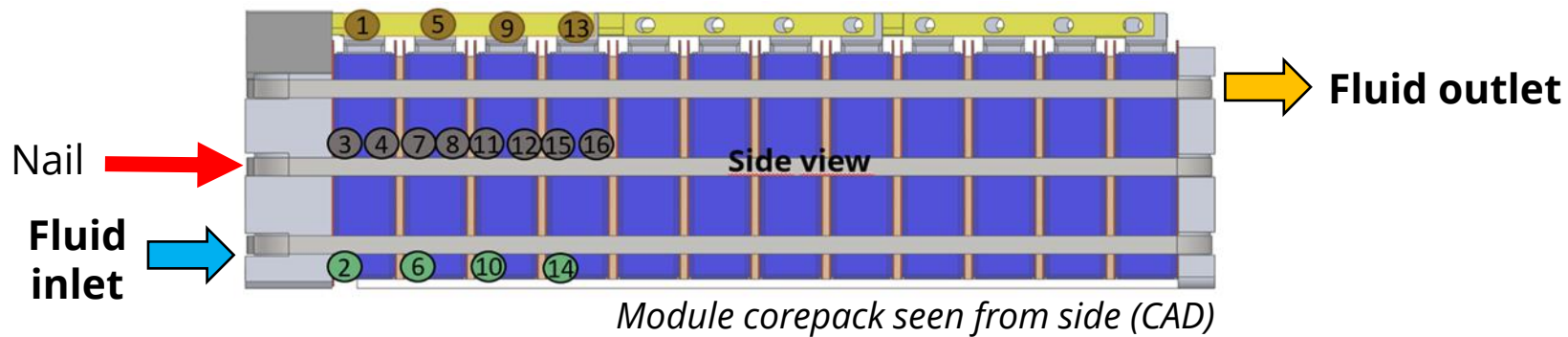


Immersion cooling prevented thermal runaway and fire propagation

- No Active flow rate by pumping action
- Flow of 0.025 L/min/cell induced by gravity
- Punctured cell temperature increased up to 350°C in 20s after the vent ruptured
- Adjacent cell temperature increased up to 105°C within 100s → **no propagation**



Data courtesy of





The adjacent cell is intact

Cell#	Weight [g]	Swelling [mm]
1	731	+3
2	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	

- Measurements showed 15% mass reduction for triggered cell
- No damage observed nor measured on neighbouring cells

Adjacent cell



Module corepack seen from top with visible ashes



Data courtesy of



Conclusion

- Addressing battery safety is a priority across the industry
- Immersion cooling is a promising technology to **dramatically enhance battery packs safety**
- We have demonstrated that immersion cooling combined with the right design allows:
 - | All form factors to be addressed for safety
 - | Prevention of Thermal Runaway propagation even in the absence of active pumping to circulate the fluid
- **Immersion cooling** has the DNA to become **mainstream and mass market**

EXOS