Ultra-fast charging thanks to immersive cooling

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How to keep batteries cooler with less efforts ?

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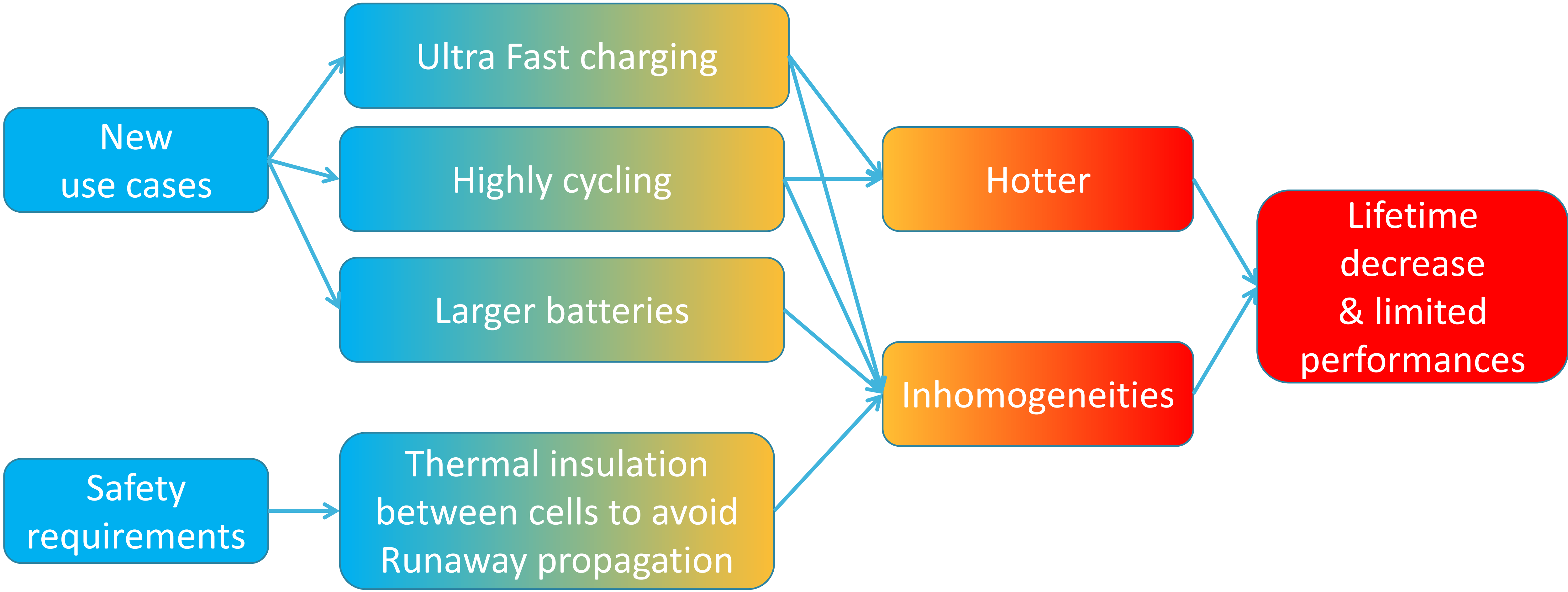
BATTERY EXPERTS FORUM
10.-12. April 2019 – FRANKFURT (DE)

Fast charging>4C

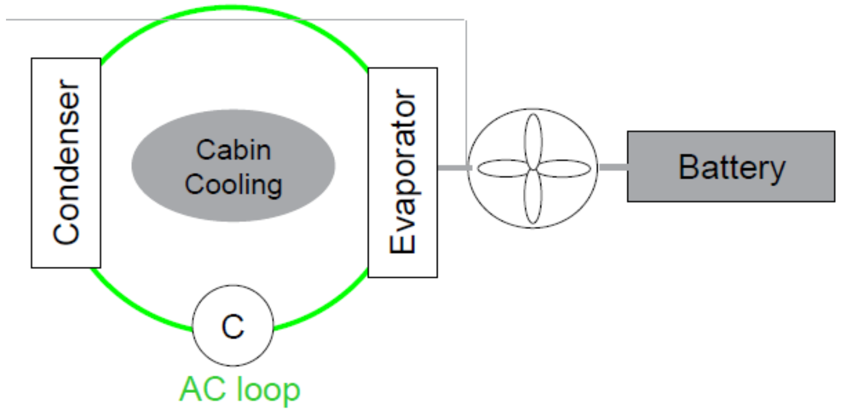
New customers for premium EVs want <15 min charge time



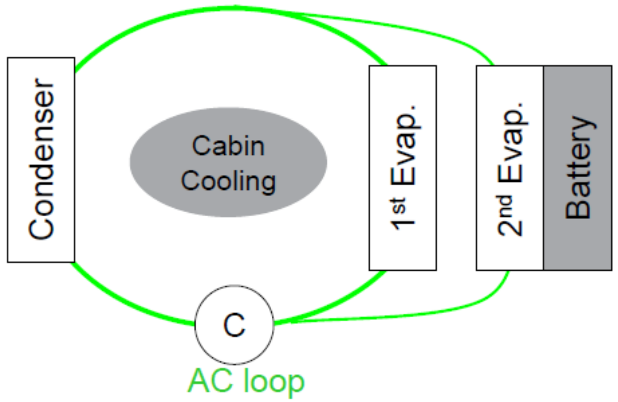
Unless you work hard on the thermal management system, it won’t work !

Cédric Rouaud, Ricardo, Taking a Pugh matrix approach to selecting the cooling medium, The Battery Show and Electric & Hybrid Vehicle Technology Conference Europe, 15-17 May 2018

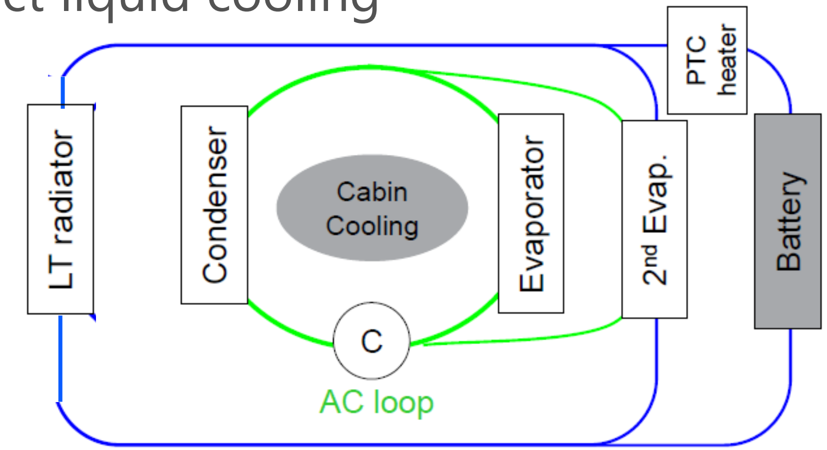
Forced air cooling



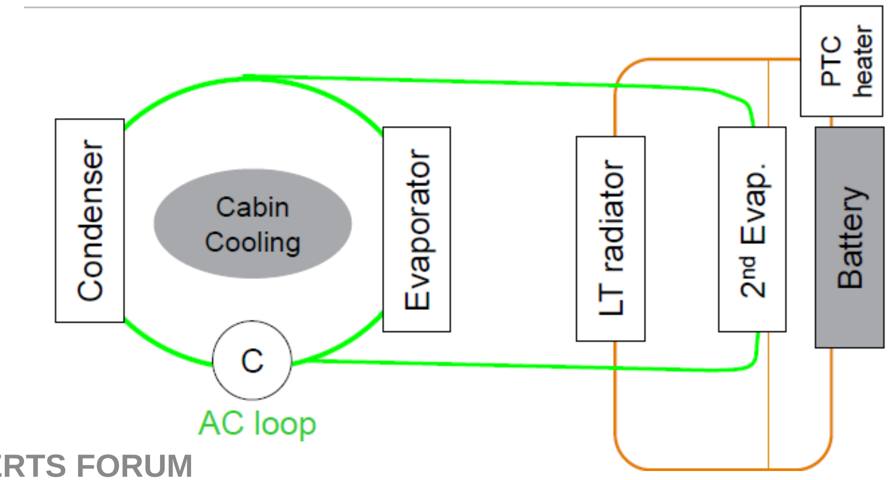
Indirect evaporative cooling



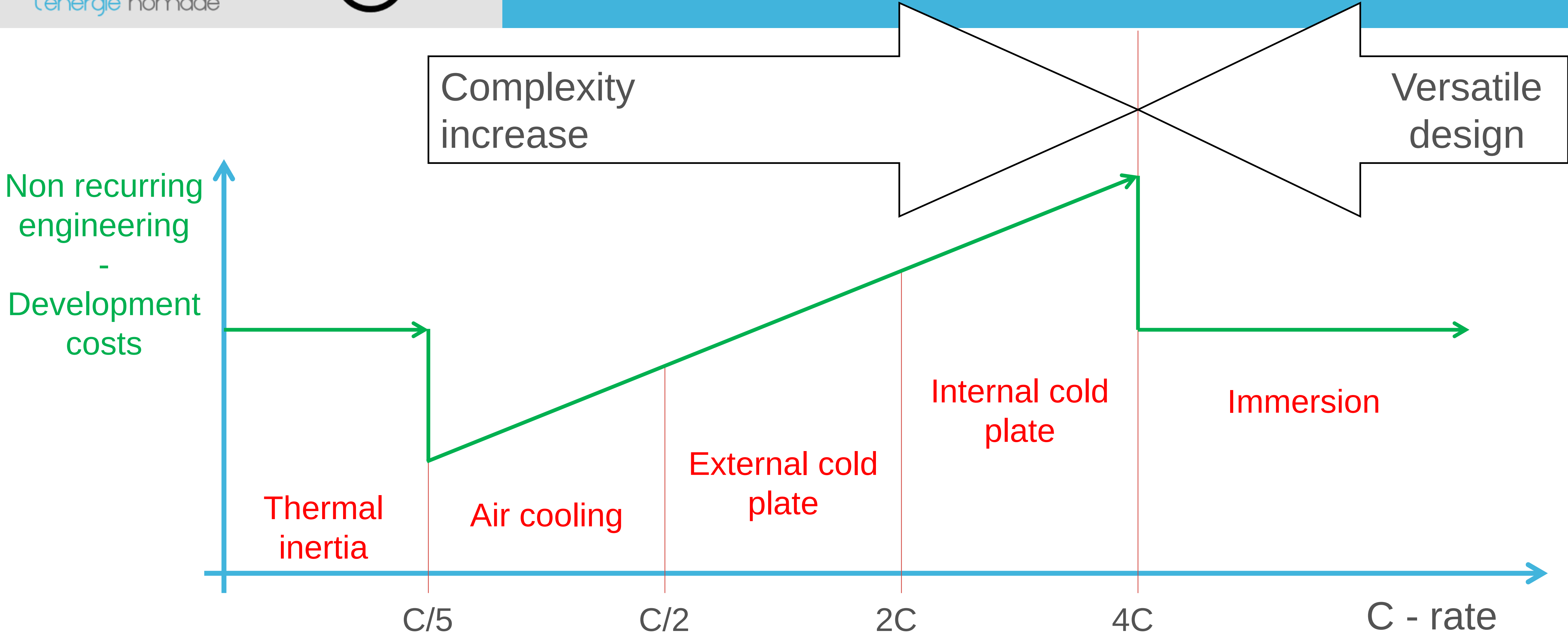
Indirect liquid cooling



Immersion cooling



The 4C limit



Above 4C, Immersion cooling answers the needs for a safe battery simple to design and to use

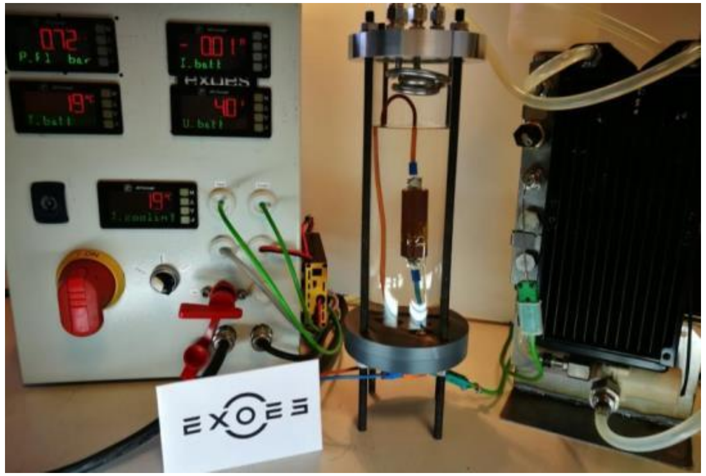
Immersion cooling

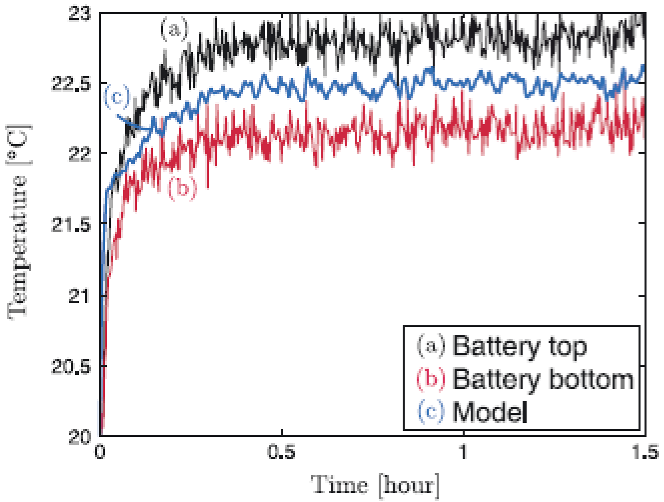
- A sealed battery module is flooded with a dielectric fluid – the fluid directly comes into contact with the cells
- The liquid prevents thermal runaway propagation giving a passive safety feature
- Cooling of all auxiliairies: electronics, bus-bars, electrodes,… at the same time: Higher balancing currents and thinner wires are possible
- No need for gap fillers

Pack performance = Cell performance

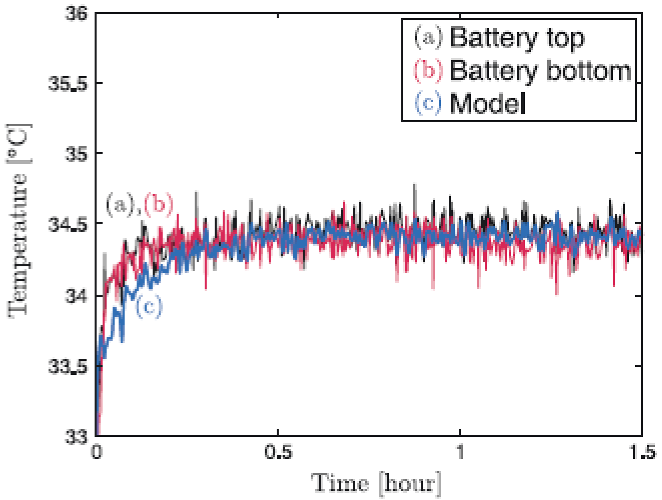
Our methodology and progress in immersion cooling

- Experiment from Eindhoven University* gives for a 18650 cell @ 5C:
  - Single phase liquid: heat transfer coefficients ~350W/K/m2
  - Two-phase: ~750W/K/m2





(a) Walls fixed at 20 °C



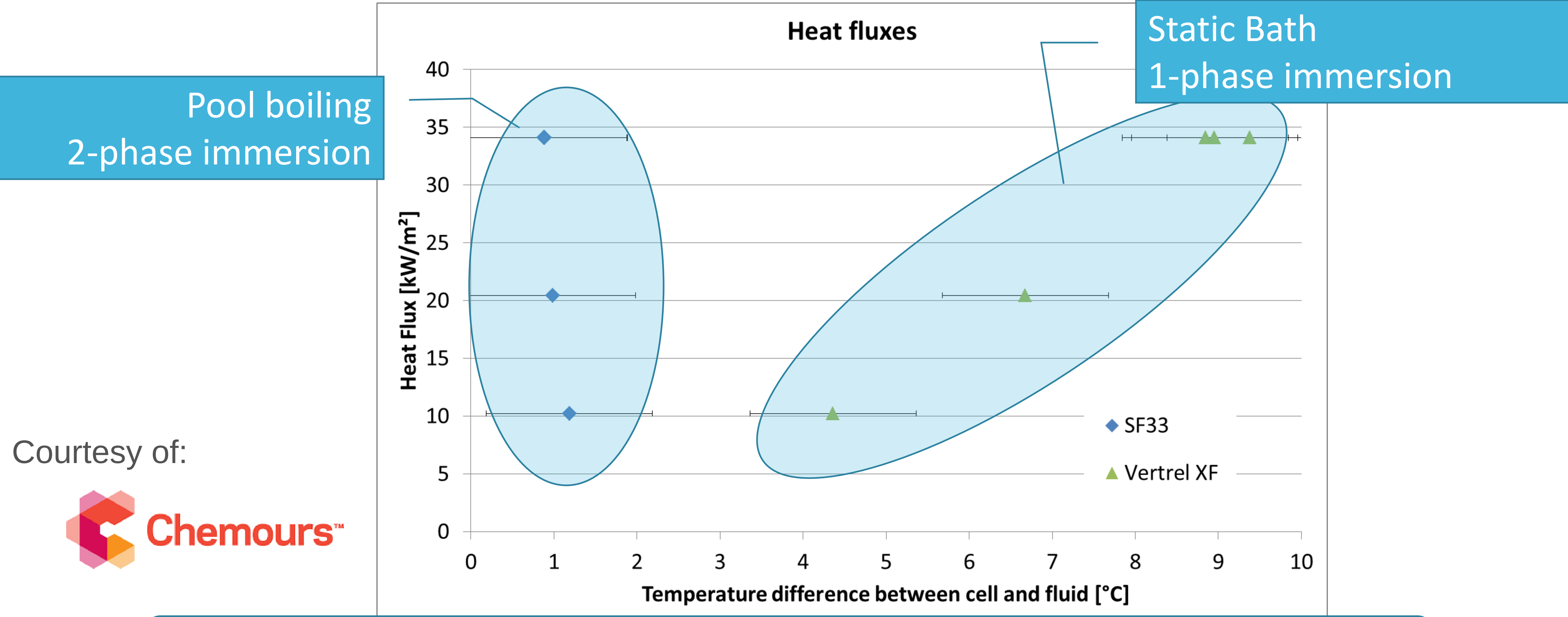
(b) Walls fixed at 33 °C

Single phase: <+3°C

Two-phase: <0.5°C

*: van Gils, Rob & Danilov, Dmitry & Notten, Peter & Speetjens, Michel & Nijmeijer, Henk. (2014). *Battery thermal management by boiling heat-transfer.* Energy Conversion and Management. 79. 9–17. 10.1016/j.enconman.2013.12.006.

Heat fluxes – initial results



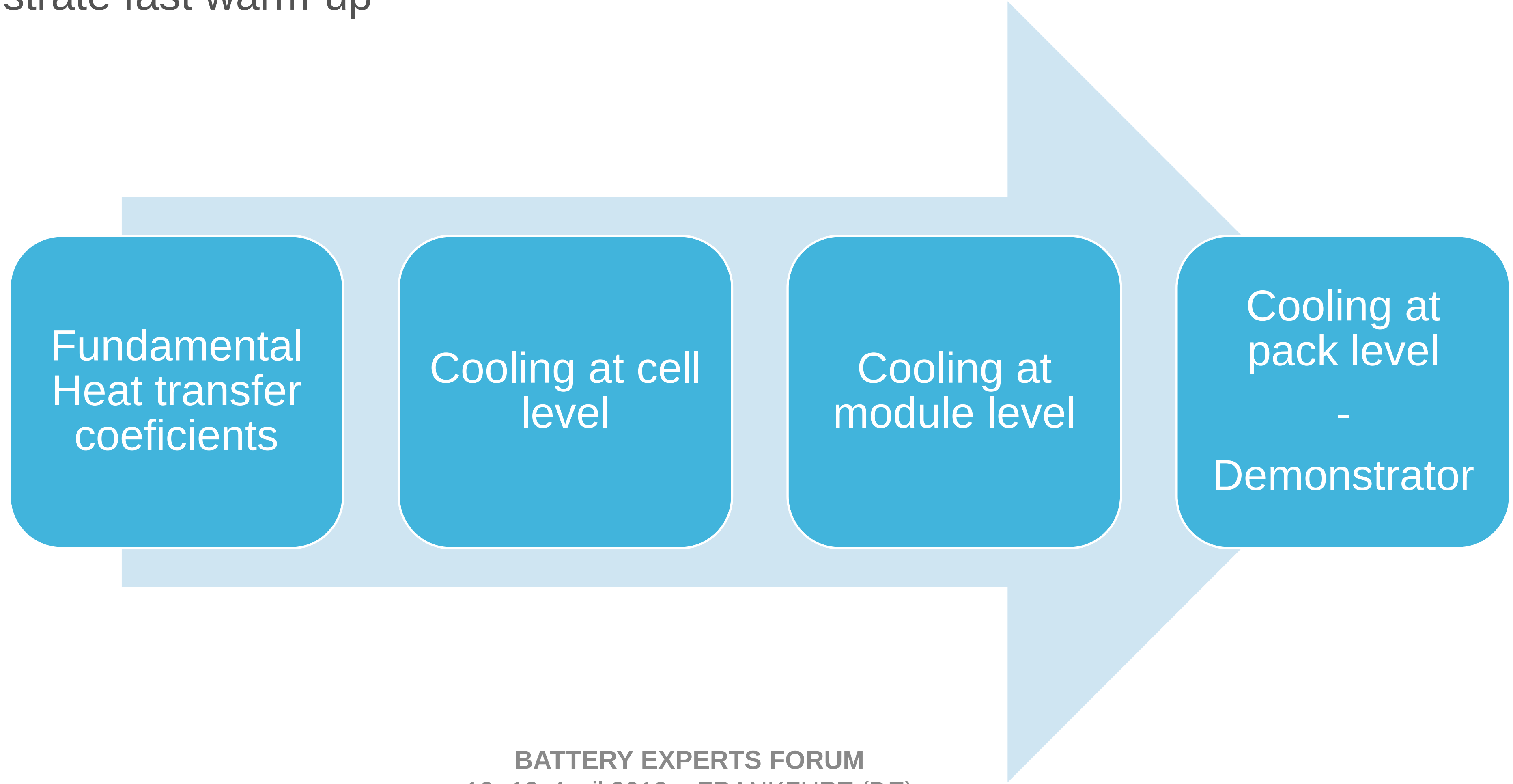
Courtesy of:

Reducing the temperature gap between fluid and cell
= reducing the difficulty to cool

Target 1: demonstrate battery pack temperature control at +1°C above coolant temperature

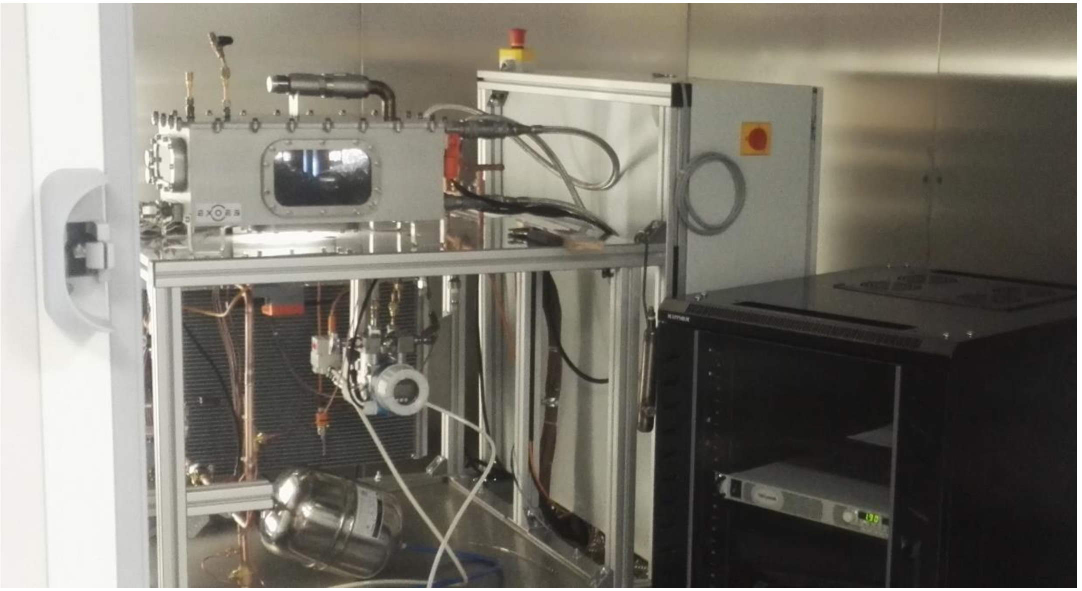
Target 2: demonstrate temperature homogeneity within +/- 1°C at any location

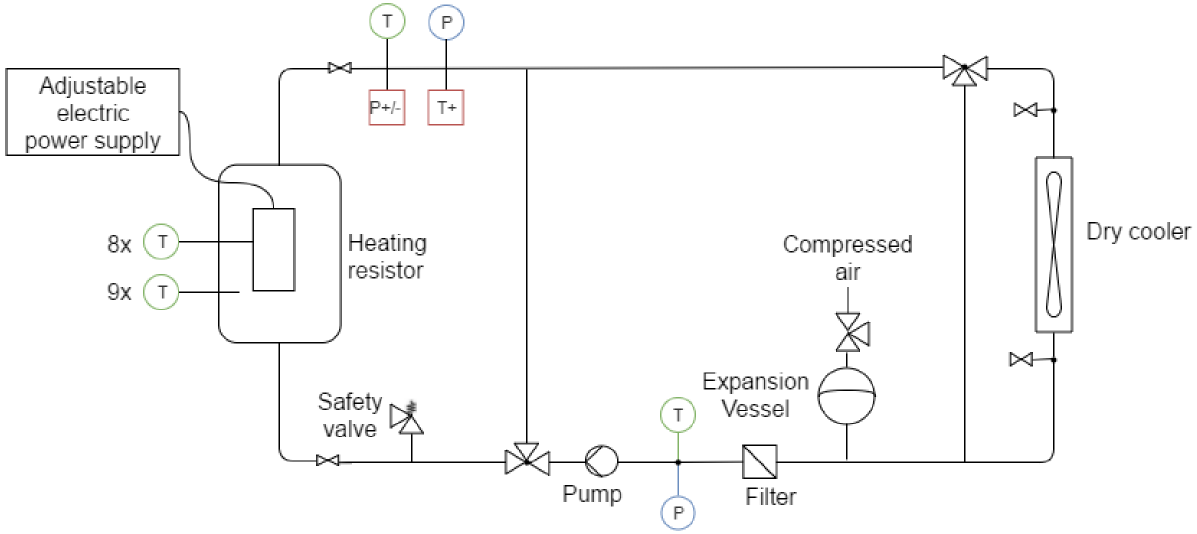
Target 3: demonstrate fast warm-up



Test rig details

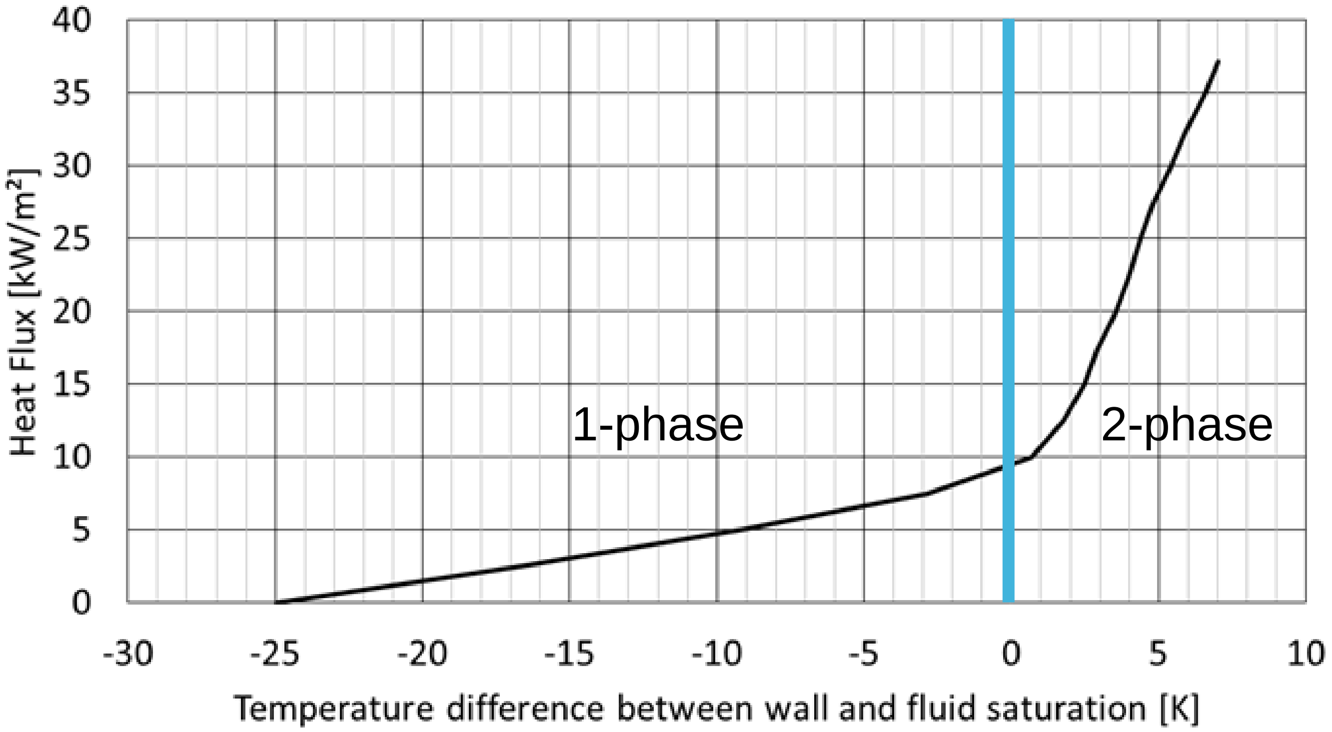
	values
Fluids	HFO, HFE, TSH, PAO oil, etc.
Flowrate	~3 L/min
Pressure	0 – 2.5 barA
Temperature	cooled by ambiant air Placed in a walk-in thermic chamber -40°C ; +60°C
Power	Test rig: 3 kWth @ΔT=5°C
Acquisition & control	Real time Labview control T-type calibrated thermocouples x18 Flowmeter, pressure sensors, … Power supply: <60Vdc – <100A

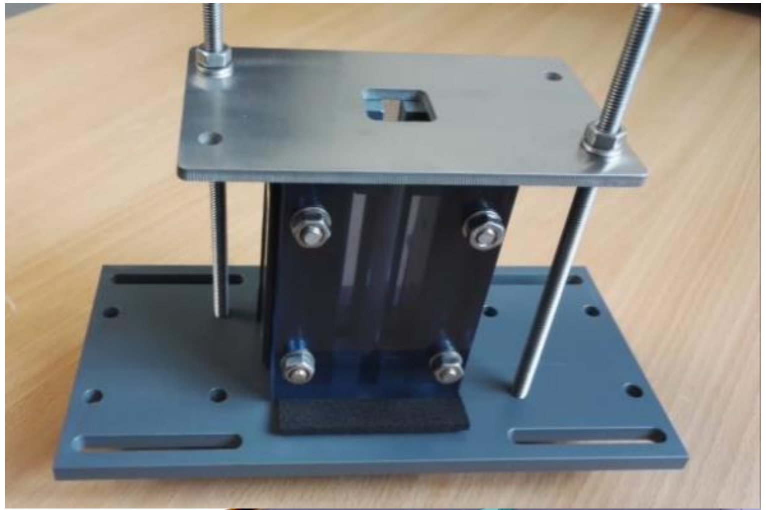


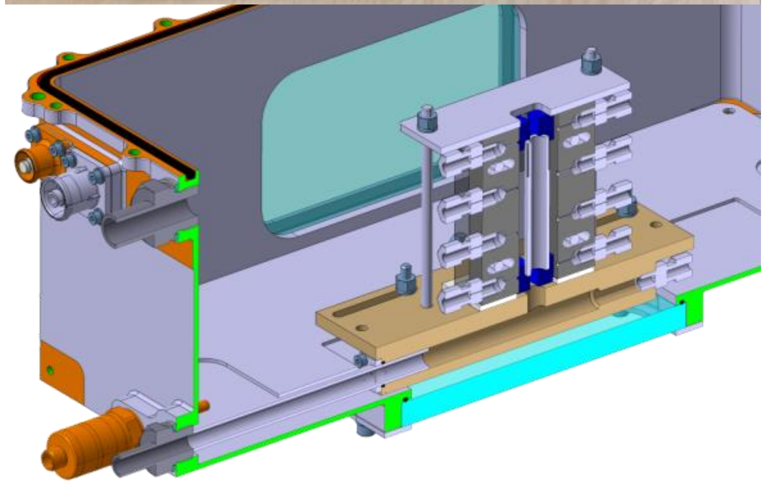


Heat transfer measurement setup

- Cylindrical shape heat resistor, up to 250 kW/m²
- Immersion in fluid with controled fluid gap thickness, temperature and speed
- 12x fluids being tested





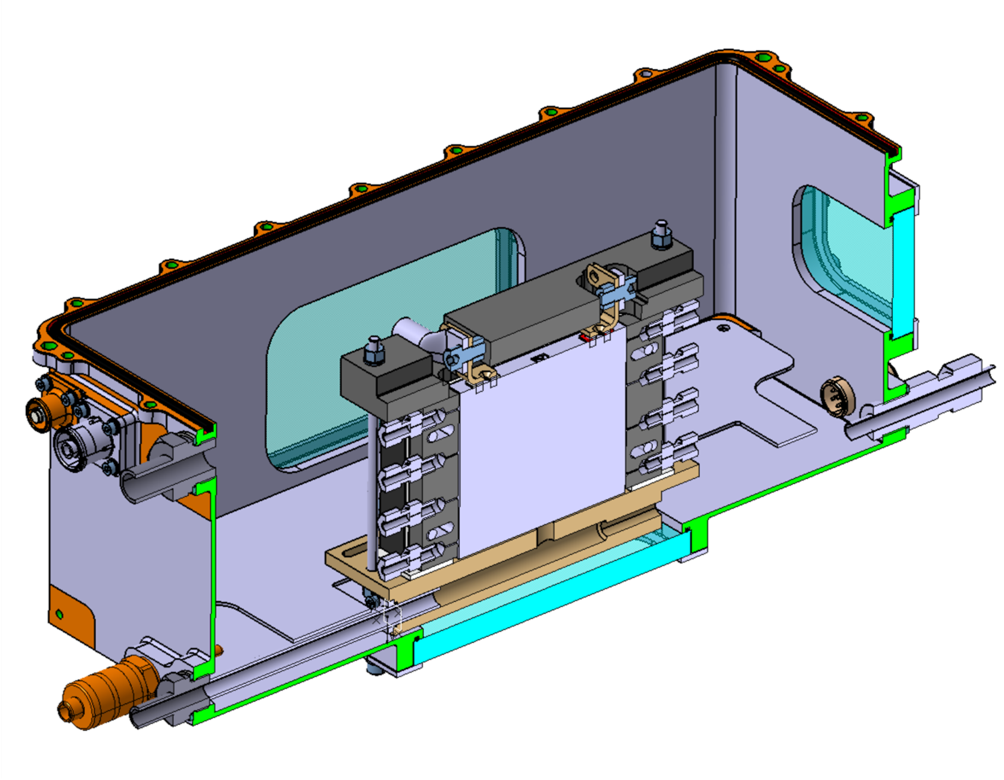


Courtesy of: Chemours™

Cell-level performance assessment

Test Module description	
Cells	Prismatic (based on Toshiba LTO cans) Size : H103 x W115 xT22 mm (w/o terminal)
Heating	Real cell or Heat resistors 48V ~60W/cell inserted in cans
Heat flux	<35 kW/m²

Empty Toshiba can equiped with heat resistors inside (black painting for IR temperature measurement in air)



Results to come in May → *Come to our dialogue presentation at EVs32*

Module-level performance assessment

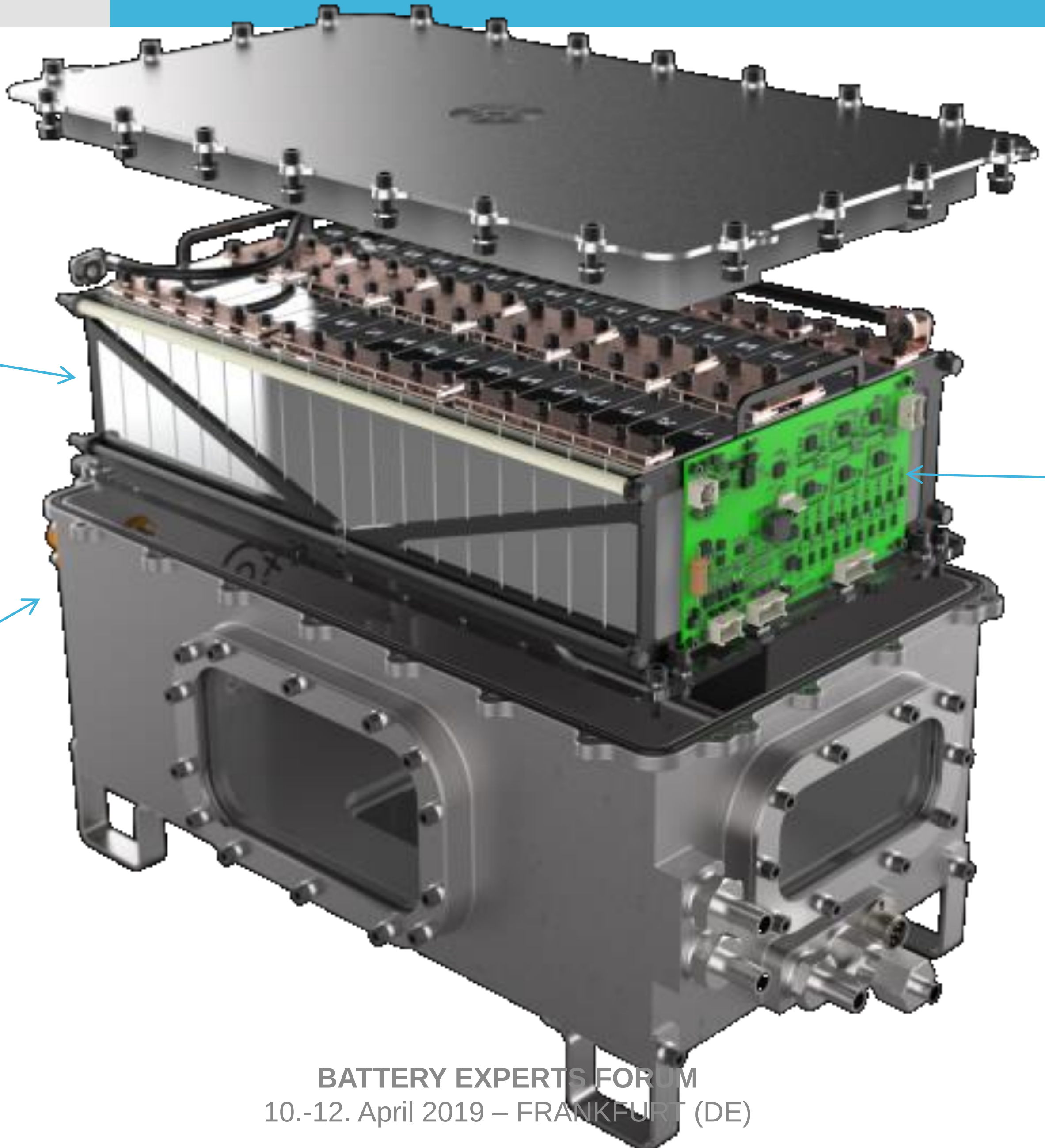
Test Module description	
Cells	36x Prismatic (Toshiba LTO 23Ah)
Heating	Up to 2.7 kW
Size [mm]	470 x 270 x 181
Cooling system compatibility	Compatible of the following immersive cooling systems: Pumped single phase Pumped two phase Pooling booling Static bath single phase
Electric Test	Representative electric insulation testing

Results to come in September

Partnerships

NEOGY l'energie nomade

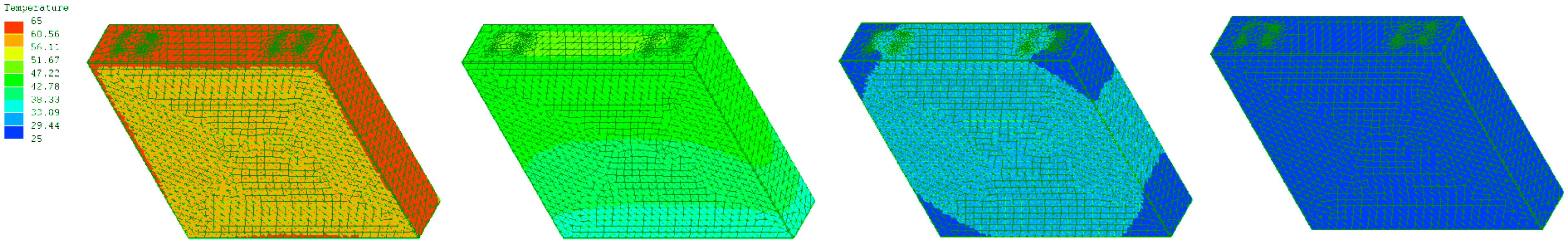
EXOES ENGINEERING



BMS PowerSafe THE BMS COMPANY

Initial simulation status

Application @ 10C rms on a Toshiba LTO 23AH – *simplified cell model*



	Air cooling 50 W/m²K	Bottom cold plate	Immersion (side surfaces only)	Immersion (optimized)
Average temperature	+ 40 K	+ 20 K	+ 10 K	+ 7 K
Skin gradient	5 K	12 K	6 K	2 K
Core gradient	9 K	14 K	9 K	7 K

Initial simulation status

<u>Focus on the 3rd configuration:</u>

- Basic pool boiling on small surfaces only

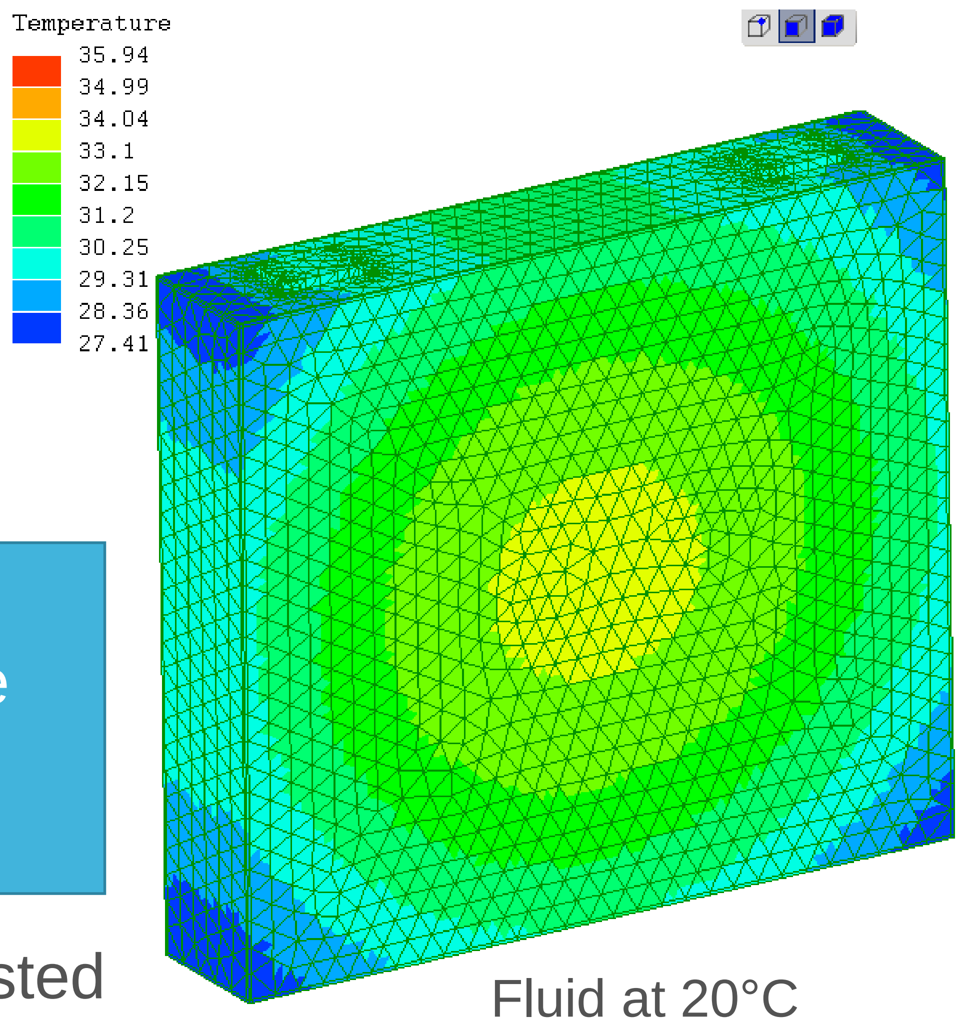
- Results:

  - Average temperature: +10K to fluid
  - Max skin temperature spread: 6K

New issues :

- High internal gradient 9K: cell core temperature remains high
- Some spots get too cold !

- From this status, design improvements will be tested



Fluid at 20°C

Conclusion

Neogy and Exoès are investigating a new high performing cooling system

To keep batteries cooler and within +/-1°C temperature range

Market introduction:

- Premium and sports passenger cars
- E-bus feeding station
- Grid stability
- Shuttles or AGV

Mass market:

- Passenger cars

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Thank you for your attention !

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