ALBATROSS

Advanced Light-weight BATteRy systems Optimized for fast charging, Safety, and Second-life applications

NEWSLETTER

NOVEMBER

Contents

- Thermal Management System

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This project received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 963580- ALBATROSS

WP4 - Battery Management System, Thermal Management and Sensing

This newsletter aims to provide an in-depth look into the developments of the activities carried out for the different tasks of Work Package (WP) 4. We hope that you enjoy to read and know about them, as much as we have enjoyed working on them!

▪ Thermal Management System

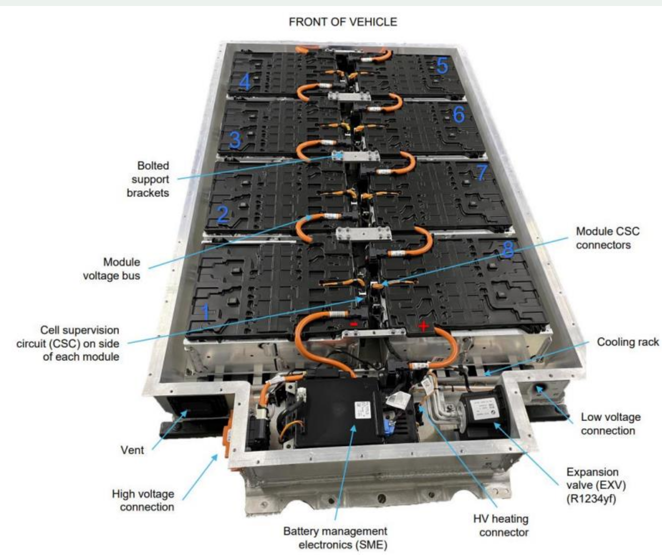
The current thermal management system of the benchmarked BMW i3 utilized in ALBATROSS, makes use of direct expansion (using air-conditioning refrigerant fluid). The system is integrated in the vehicle HVAC system allowing a common coolant for thermal management of the cabin and the battery system, and a common pump, reservoir, and heat exchanger to manage the coolant fluid.

In the automotive market, there is not still a common consensus on the optimal thermal management system for battery systems with different manufacturers following different approaches to meet their needs (which is reasonable due to the rapid development of automotive BEV batteries).

Regarding the vehicle thermal management system, the battery is linked in one circuit of the refrigerant loop (where the fluid utilizes direct expansion) to reduce and manage temperatures during operation, so that to ensure optimal thermal conditions, important to battery life and performance.

The BMW i3 direct expansion lines rest in the bottom of the battery box and the system has eight channels for the refrigerant fluid to flow through (four downwards from the fluid entry towards the rear of the box and four channels in the returning direction).

Figure 1. BMW i3 battery architecture.



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A schematic of the direct expansion infrastructure of the BMW i3 is presented in Figure 2.

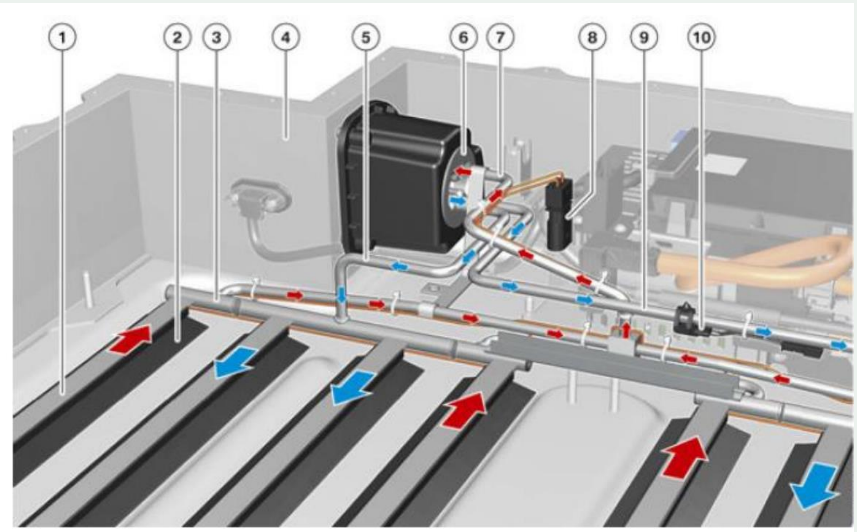

Figure 2. BMW i3 schematic direct expansion infrastructure.

Nº	Component
1	Cooling grid
2	Spring strip
3	Connecting pipe
4	Battery housing box
5	Refrigerant supply
6	Expansion and shutoff valve
7	Refrigerant return
8	Electric heating connection
9	Refrigerant supply
10	Temperature sensor (fluid line)

Different concepts were considered for upgrading the BMW i3 thermal management system:

- Single-phase immersion cooling
- Two-phase immersion cooling (using partial boiling)
- Improved direct expansion system (with the potential for offboard cooling during re-charging)
- Cold plate cooling
- Indirect evaporative cooling

An initial evaluation was conducted comparing a wide variety of potential cooling systems with different potential thermal management systems, being considered relatively to each other and numerically scored (enabling the concept generation to focus on the system with the optimal characteristics before more advanced evaluation was undertaken).

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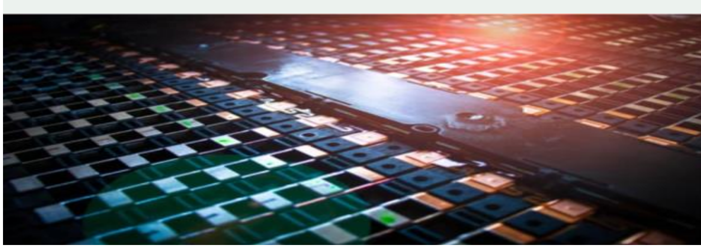
The thermal management systems considered were baseplate with aluminium fins, indirect fin cooling (with active coolant in the fins), heat pipe cooled fins, immersion cooling (with dielectric coolant), two-phase cold plate and looped heat pipe cold plate. The results from the evaluation have shown that immersion cooling with dielectric fluid has the optimal characteristics.

After this first analysis, another conceptual analysis was conducted focused on the immersion system architecture. To evaluate the thermal management concepts, the core criteria used were the same as those used previously (cell and pack temperature variation, packaging, mass, system maturity, cost, energy consumption and global warming potential).

From the conceptual evaluation, the two-phase direct immersion cooling had the highest score. Considering broader criteria such as manufacturability, BMS integration, heating integration and challenges due to the low manufacturing readiness level of two-phase direct immersion, both immersion techniques which are direct single and two-phase were selected for the future battery pack.

The developed concept builds from the selection of direct single and two-phase cooling as well as the use of cylindrical cells.

To maximize the battery cell thermal performance, a computational fluid dynamics (CFD) analysis was conducted, providing an understanding of the pressure drop across the pack and temperature rise in the coolant fluid at different flow rates and heat loads.



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The simulations consisted of steady-state heat transfer analyses where both solid and fluid domains are solved simultaneously, allowing to observe their interaction. Due to the large number of cells and small gaps between them, just a fraction of the entire battery pack was modelled. All the cells were assumed to have the same heat generation rate and a uniform flow distribution is achieved throughout the pack.

Both side and tab cooling of the battery cells were initially considered in the modelling, but it then became clear from the results that double-tab cooling was the optimal solution.

Due to the large size of the pack and number of cells, for modelling purposes a representative domain of the pack was considered. The studies were completed at power loads of 5kW and 15kW, with an initial mass flow rate of 5 kg/s and 8 kg/s.

Targeting both cell tabs for cooling is shown to be more advantageous then singularly targeting a cell tab or restricting side cooling to the side wall. The benefits of tab cooling over the side cooling are noticeable at 5 kW and 15 kW.

For simplicity, the fluid was assumed to be in a single-phase steady state, with cooling occurring only on the side walls of the cell and with appropriate thermal assumptions assigned to the cells to account for the anisotropic behaviour. Thermal conductivity values of 0.99 W/m*K and 25.8 W/m*K, as per the datasheet were assigned along the radial and axial directions, respectively.

	Max Cells ∆T	
Pack Power (kW)	5	15
Side Cooling (°C)	3.5	12
Single Tab Cooling (°C)	3	-
Double Tab Cooling (°C)	1	3.5

Table 1. Results from the CFD analysis for the side and tab cooling concepts.

The developed thermal management utilizes an optimized double tab cooling system, which accommodates cylindrical battery cells with raised and staggered connection pins that are improving the heat transfer coefficient between the cell and the coolant fluid (see Figure 3).

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The core system includes:

- Cylindrical cells
- Tab cooling housing - each housing encases 1/3 of the cell, sealed with fluid inlet, outlet and fixings.
- Integrated busbars - busbar connections are integrated into the tab cooling housing.
- Optimized battery case - expanded volume is maximizing the energy storage and thermal management capacity.
- Dielectric cooling fluid - pressurized heat transfer via coolant fluid with single phase or two-phase capability.
- Continuous film printed sensors

The current thermal management system can support a significantly improved onboard battery system.

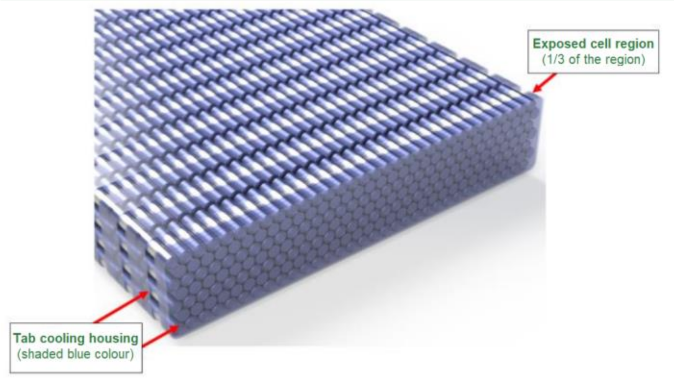

Figure 3. Representation of the tab cooling developed concept.

While the current BMW i3 direct expansion system rests underneath the battery modules (42.2kWh battery using 8 modules with 96 prismatic cells), the upgraded system benefits from direct cell to fluid cooling by using dielectric fluid and a housing that supports the cells, fluid and the busbars (it is predicted to support more than 70kWh with 4032 cylindrical cells).

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