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Multifunctional Battery Housings and their Application at a small, full electric Truck

Dr. Jobst Kerspe, TEB Dr. Kerspe, D-69256 Mauer, Schubertstr. 23, kerspe@vakuum-isolierung.de
Michael Fischer; König Metall, 76571 Gaggenau, Josef-König-Str. 1; m.fischer@koenigmetall.com

Summary

To optimize lifetime and capacity of batteries, the temperature conditions have to be kept in a well-defined sector. All interactions regarding thermodynamics are summarized under “thermal management”.

To our point of view, “thermal management” should be embedded in the battery housing, just to save space and weight and to separate cooling devices from cell chemistry. This also means, the housing should provide the right thermal conditions for the battery.

More over the housing should keep the battery safe under all operating conditions, such like vibrations caused by the driving car as well as crash conditions.

Keywords: 3.1 Batteries/ 3.6 auxiliary units/ 3.9 Heating and cooling ; 1.2 Freight transport / 1.5 special vehicle technologies; 7.1 Urban mobility concepts

0. Introduction

Increasing safety and lifetime requirements for traction batteries also increase functional and quality demands for battery housings. Multifunctional Battery housings – offered under the trademark B:House® - are based on the GVI®-technology, which is a highly efficient, vacuum based thermal insulation technology; additionally GVI® has excellent mechanical properties like a honeycomb sandwich structure. The functional diagram is shown in figure 1.

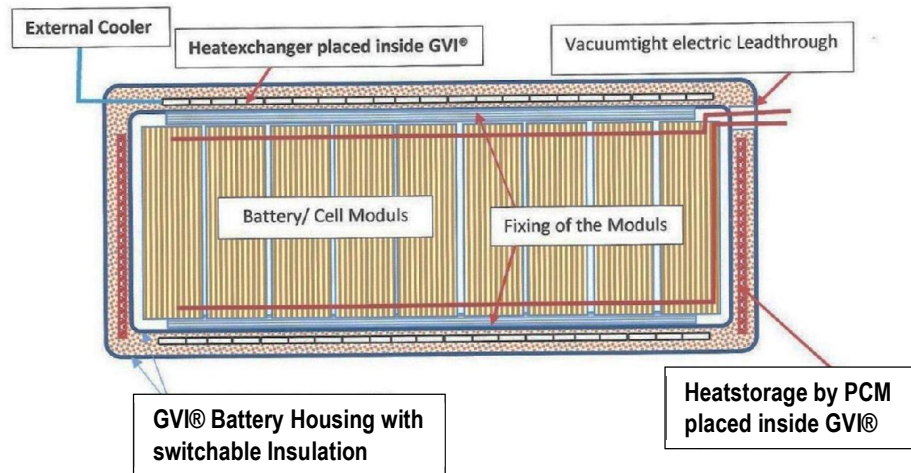


Figure 1: Functional Diagram of the Multifunctional Battery Housing

Inside a car these battery housings are acting on several levels – as shown in the next slide.

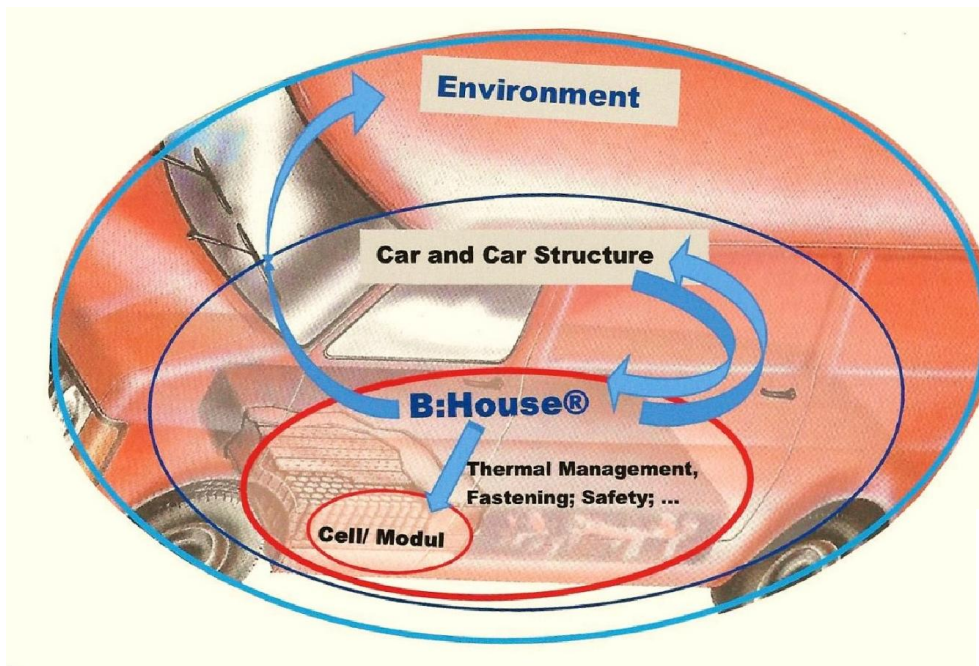


Figure 2: Functional and Safety Levels in an EV

1. Thermal Management and Safety demands for Li-ion Batteries

To optimize lifetime and capacity of traction batteries for e-mobility, the temperature conditions of the cells have to be kept in a well-defined sector (for Li-ion: 15° to 35°C)! Below 15°C the capacity and the recuperation are decreasing drastically with decreasing temperatures – this means: the battery should be kept warm by an effective insulation. On the other hand, with increasing temperatures above 35°/ 40°C lifetime will decrease and possibly “thermal run away” may be caused. Two reasons for increasing temperatures can be detected: 1. Exothermal reaction of the cell - cooling may be necessary; 2. External heat flow in summer (e.g. temperature of the street above 80°C will cause severe radiation) - again an effective insulation of the battery is necessary and will help to lower the input for cooling. All these interactions may be summarized under “balancing of the external temperature influence” as well as the so called “thermal management”.

2. The Multifunctional Battery Housing

To our point of view, the necessary actions for the thermal management should be implemented and embedded in the battery housing, just to save space and weight and to separate cooling devices from cell chemistry for security reasons. This means, to keep the battery under correct thermal conditions is task of the housing!

More over the housing should keep the battery safe under all operating conditions, such like vibrations caused by the driving car as well as crash conditions. The optimum will be, that the housing encapsulates the cells and avoids environmental pollution of chemical reaction-products of destructed cells.

All these functions are embraced by the term “multifunctional battery housing”. The basic technology is a so-called “supported vacuum insulation” - GVI® - with an excellent insulation characteristic (Figure 3), high mechanical strength and lightweight potential. Furthermore, the efficiency of GVI® for thermal management is not only given by its excellent insulation characteristic but also by the “switch-ability” of the insulation (Figure 4): this means, that the heat-flow via the insulation can be drastically increased, when exothermal energy has to be shifted away from the cells. The specific heat-flow can be regulated in a range between 0.002 and 0.2 W/m·K – relating to the big surface area of the housing, much energy can be shifted along this path.

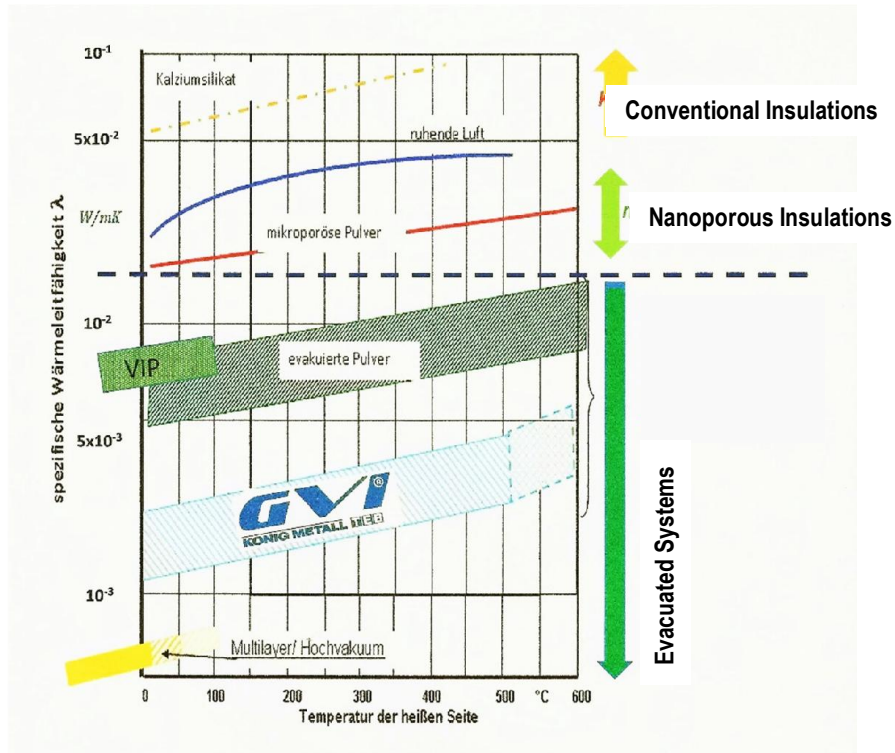


Figure 3: Comparison of the Insulation Characteristics of Different Insulation Systems [11]

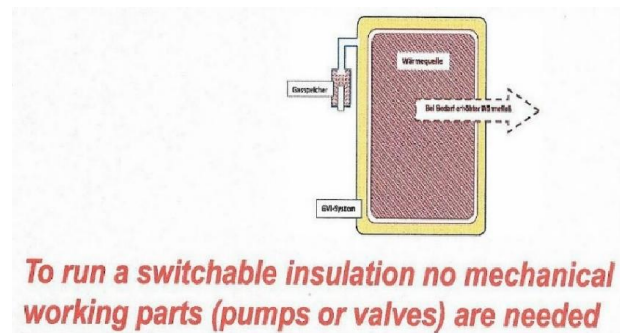
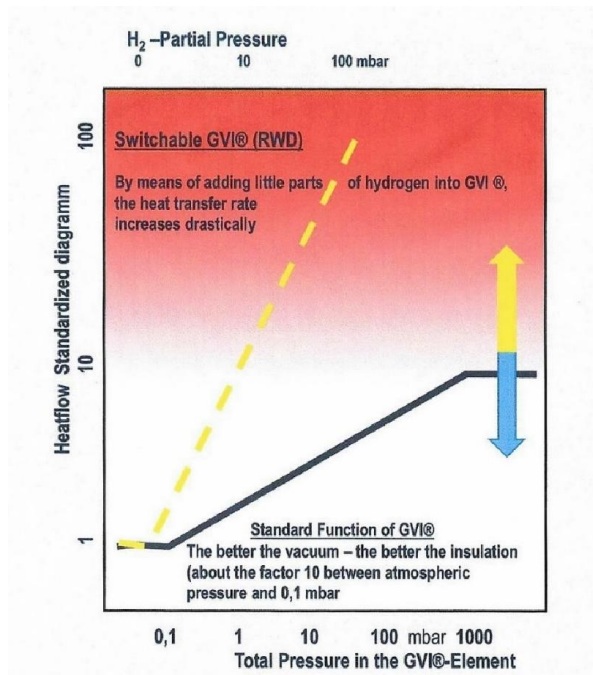


Figure 4: Switchable Insulation Systems [11]

Additional cooling devices can also be integrated into the double walled (vacuum-insulated) housing: storing elements on the basis of PCM as well as heat-exchangers (Figure 1)

Another outstanding property of the GVI®-Technology (this type of vacuum-insulation) is the high mechanical strength: the double-walled insulation acts like a honeycomb structure with very high stiffness. Thus lightweight design and high functionality can be combined in this multifunctional battery-housing, which is also patented under EP 2985804.

3. Results, that can be expected with an Multifunctional Battery Housing

Under extreme climate conditions EVs sometimes have problems to reach their lifetime, full capacity, mileage and /or ability for recuperation: with high temperatures above 45°C lifetime decreases and the risk of thermal runaway increases; with decreasing temperatures (below 15°C) the capacity and recharging decreases too. For each kind of heating and/ or cooling, additional energy is needed (and capacity runs down again).

The GVI®-Technology enables the battery housing to keep the temperature of the battery on a constant level – even under extreme conditions: with outside temperatures of -20°C and an insulation-thickness below 15 mm the battery temperature will remain in a range of +20°C for more than 12 h - without any demand for additional energy.

Dependent on the layout and outfit with different storage and cooling devices as shown in picture 1, thermal management with a “Multifunctional Battery Housing” may run in different stages:

- a) *Storage of additional heat/ energy in PCMs – homogenizing the temperature*
- b) *Heatflow directly via the GVI®-Structure - **switchable insulation***
- c) ***Active cooling** (heat exchangers with cooling liquids – mounted into the insulation space separate from the cells)*
- d) ***Predictive real-time control** - to improve the efficiency of the complete System.*

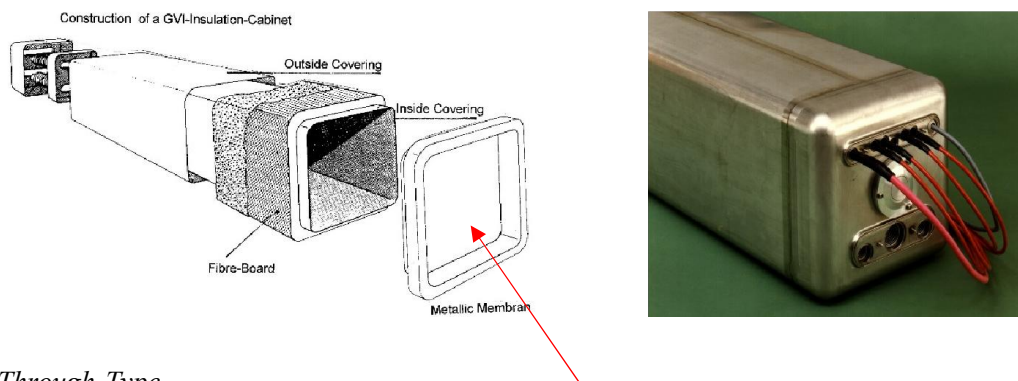
Envelopes for GVI®/ battery housings are made from thin (0,8 to 1 mm) stainless steel – however the housing reaches very high mechanical stress and strain resistance because of the filler material of GVI® as well as the effect of honeycomb structure. Even big and heavy batteries can be inclosed safe and secure inside such battery housings (Figure 5)



Figure 5: Modern Full Electric Truck with GVI® Battery Housing [10]

Different designs can be realized – depending on the requirements regarding mechanical strength, insulation characteristics, etc. Possible shapes are shown in Figure 6.

a) *Tube-Type* [1]

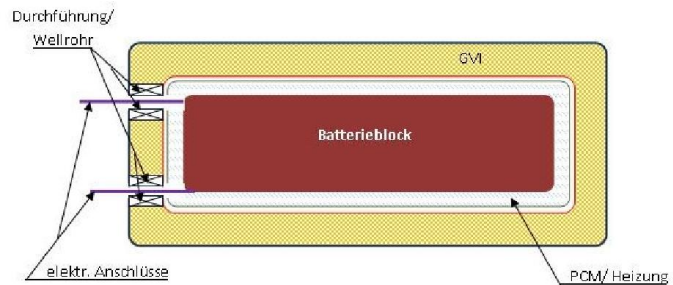
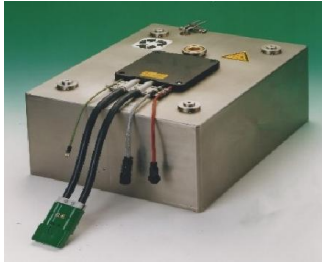


b) *Through-Type*



Figure 6: Different possible designs and shapes of Battery Housings

c) *Hermetic enclosure*



Cont. Figure 6: Different possible designs and shapes of Battery Housings

4. The Electro City Thermo Truck (ECTT)

The full functionality of GVI® and “Multifunctional Battery-Housing” can be shown by means of the ECTT, which is a new designed, full electric lightweight truck (up to 3.5 t) with cooling devices for urban supply and delivery (Figure 7).

Most of today's vehicles and trucks are redesigned and rebuilt from conventional cars, which causes heavy constructions and not really the optimum design.

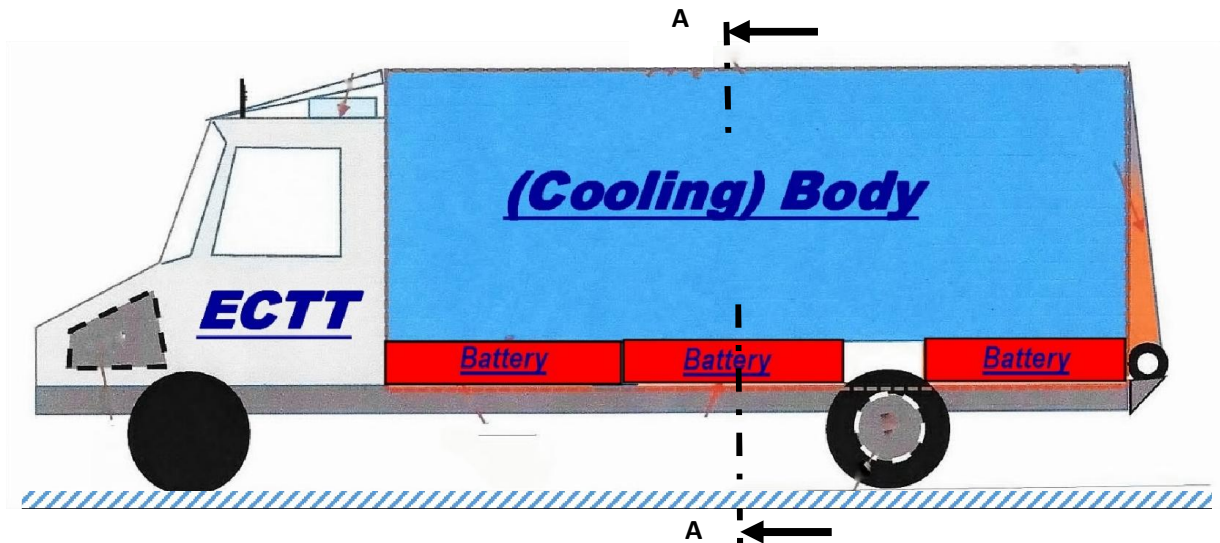


Figure 7: Basic design of the ECTT

With ECTT new solutions are found! Body and battery/ battery-housing are forming one unit, which means, that the battery housing supports the body (together with the lading). The complete unit can directly fixed to the frame of the car – or even be part of the car-structure/ frame. Thus much weight, material and space can be saved – much better than known from conventional solutions with batteries fixed to the side of the car frame. It might also be possible to design the battery housing that way, to be itself part of the car structure.

Another critical point is the performance of today's wall materials for the cooling body: sandwich panels with core material made from conventional foams are too heavy and the insulation is not good enough to run a full electric truck; well known lightweight panels have nearly no insulation performance!

For ECTT new lightweight wall materials with high mechanical strength and an insulation-performance, about 2 times better than conventional foam, are developed with good advancement.

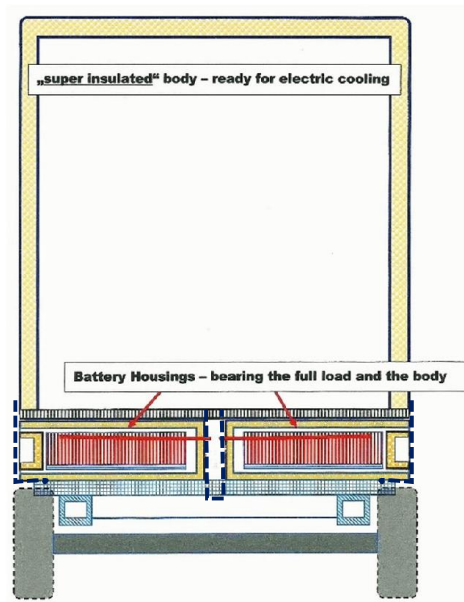


Figure 8: Cross Section (A A in Fig. 7) of the Battery/ Body-Unit

5. Future perspectives

Additional work is to be done in the investigation of new materials (envelope and filler material) for the use in GVI®/ “Multifunctional Battery Housings” to increase the performance as well as to decrease weight and costs.

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Jobst H. Kerspe

Since 2013 cooperation with König Metall Gaggenau

1985 – today Founding of TEB Dr. Kerspe (Technologie Entwicklung und Beratung – Technology Development and Consultancy); main works in the field vacuum insulations; different R+D projects together with customers

1983 Confer a doctorate on Doctor Engineer at the Technical university of Stuttgart

1981-85 Head of production at Brown, Boweri & Cie AG , project high-energy-battery (NaS); special task: development and build up of the complete manufacturing line for microporous vacuum-insulations.

1977 – 81 Scientific assistant at the Institute for Metal forming at the University of Stuttgart

1976 Engineer-Diploma in material sciences and metal forming; TU of Clausthal-Zellerfeld



Michael Fischer

2001 – Apprenticeship as tool-maker in König Metall Gaggenau

2006-2008 – Mechanical Engineering Technician at Carl-Benz-Schule Gaggenau

Since 2008 – Head of supply and Project-management in tooling-area

Since 2013 – Head of “GVI”-Division