Fixed Fire Suppression Systems for Electric Vehicles

O. Willstrand[1], R. Bisschop, and M. Rosengren
RISE Research Institutes of Sweden, Borås, Sweden

Fixed fire suppression systems are common in heavy vehicles and are widely considered to be an effective way to mitigate fires. In Sweden, 94% of public transport buses are equipped with these on-board installations [1]. Here they protect engine compartments and spaces with auxiliary heaters, mostly in conventionally powered vehicles. The ongoing shift to electromobility however has identified new risk areas, specifically those related to the on-board lithium-ion battery (LIB). Abuse due to unexpected mechanical or thermal loading or internal failures can turn the LIB into a fire hazard. It is therefore of importance to investigate whether fixed fire suppression systems can act as a control measure. [2]

The electrolyte in lithium-ion cells are flammable. Given heat from a short circuit or other source, exothermic reactions may occur and release oxygen such that the LIB can provide all that is necessary to produce and sustain a fire [3]. Uncertainty prevails about the type of extinguishing agent or system that is most appropriate for LIB fires, although there does seem to be a growing consensus that suppression agents having the ability to remove heat from the cells/module and thus inhibit the propagation of thermal runaway have the best and most reliable performance. Water-based fire suppression systems pose a good candidate for testing as they offer great cooling potential [4].

Research and fire testing of cells, modules and battery packs have resulted in many different ideas about the best way to extinguish a fire in a LIB [5] [6] [7] [8] [9] [10] [11]. Much testing has been conducted on individual cells, but the most severe challenge lies in extinguishing fires inside the battery packs. The suppression agent needs access to the seat of the fire, i.e. the cells inside the modules. Access can however prove challenging when conventional fire suppression attempts are considered. This is due to high levels of ingress protection as well as the location in which LIBs are placed. Strategic integration of fixed fire suppression systems into LIBs may help to circumvent this issue. It is however also important to find a balance between suppression and the possibility that there could be a build-up of flammable gas that leads to an explosion in case of delayed ignition [12].

There are many challenges associated with fighting LIB fires. As such, this work considers experimental testing to evaluate the performance and applicability of fixed fire suppression systems for an automotive LIB pack [13]. A test series of seven tests were performed using a LIB pack that contained both live battery modules, with 12 prismatic cells each, as well as dummy modules. Heat transfer and thermal runaway propagation were evaluated both in case of internal fire suppression within the battery pack and external from outside.

The test results [13] showed that internal activation of a water-based fire suppression system inside a battery pack has good potential to have a lasting cooling effect on the battery and to increase the chance of mitigating and preventing thermal runaway propagation. External activation had, in this case, no cooling effect or impact on the thermal runaway propagation. Flames on the outside of the battery pack were put out mitigating fire spread from the battery to the surroundings, however, bear in mind that without cooling of the battery and without flames there is a risk that large quantities of flammable gas are released. If these gases could accumulate in enclosed spaces, e.g. the battery compartment, there is a risk of explosion in case of available ignition sources, e.g. sparks from the battery or hot surfaces on the vehicle.

[1] Ola.willstrand@ri.se, +46 10 516 54 50, Box 857 SE-501 15 Borås

Due to very limited free space inside a battery pack the results indicate that it is more optimal to have a low flow rate and longer release time of the suppression agent. The test results did not show the minimum amount of agent needed, but 12-13 l resulted in a good effect in this case for a battery pack of about 12 kWh. It was observed that a large quantity of agent was thrown out from the battery pack due to the limited free space inside, indicating that similar results could have been achieved for significantly less amount of agent.

The test results are valid for this type of battery cells, modules and pack, and this type of scenario, but give an indication of the potential of using fire suppression systems for other types of battery packs and scenarios. To ensure good effect and good design of a fire suppression system intended for cooling and mitigation of thermal runaway propagation it is recommended that tests are performed for each unique battery installation.

Acknowledgements

This work is financed by the Swedish Energy Agency and the Swedish automotive industry through the FFI programme (Strategic Vehicle Research and Innovation).

References

[1] ”Statistik om bussbranschen,” Sveriges Bussföretag, 2017.

[2] R. Bisschop, O. Willstrand, F. Amon och M. Rosengren, ”Fire Safety of Lithium-Ion Batteries in Road Vehicles,” RISE Research Institutes of Sweden, RISE Report 2019:50, 2019.

[3] Ruiz, V. och Pfrang, A., ”JRC exploratory research: Safer Li-ion batteries by preventing thermal propagation - Workshop report: summary & outcomes,” Publications Office of the European Union, Luxembourg, 2018.

[4] F. Larsson and B.-E. Mellander, “Lithium-ion Batteries used in Electrified Vehicles – General Risk Assessment and Construction Guidelines from a Fire and Gas Release Perspective,” RISE Research Institutes of Sweden, SP Rapport 2017:41, 2017.

[5] DNV GL, “Considerations for ESS Fire Safety - Final Report,” Report No.: OAPUS301WIKO(PP151894), Rev. 3, New York, USA, 2017.

[6] C. Grant, “Responding to Electric Vehicle Battery Fires,” in *Proceedings from 3rd International Conference on Fires in Vehicles - FIVE2014*, Berlin, Germany, 2014.

[7] P. Andersson, M. Arvidson, F. Evegren, M. Jandali, F. Larsson and M. Rosengren, “Lion Fire: Extinguishment and mitigation of fires in Li-ion batteries at sea,” RISE Report 2018:77, Borås, 2018.

[8] W. T. Luo, S. B. Zhu, J. H. Gong och Z. Zhu, ”Research and Development of Fire Extinguishing Technology for Power Lithium Batteries,” *Procedia Engineering,* vol. 211, pp. 531-537, 2018.

[9] P. Russo, C. Di Barib, M. Mazzaroc, A. De Rosac och I. Morriellod, ”Effective Fire Extinguishing Systems for Lithium-ion Battery,” *Chemical Engineering Transactions,* vol. 67, pp. 727-732, 2018.

[10] M. Egelhaaf, D. Kress, D. Wolpert och T. Lange, ”Fire Fighting of Li-ion Traction Batteries,” *SAE International Journal of Alternative Power,* vol. 2, nr 1, pp. 37-48, 2013.

[11] DEKRA, “Lithium-ion Batterien stellen in Brandversuchen Sicherheit unter Beweis,” [Online]. Available: http://www.dekra.com/de/pressemitteilung?p_p_lifecycle=0&p_p_id=ArticleDisplay_WAR_ArticleDisplay&_ArticleDisplay_WAR_ArticleDisplay_articleID=24844066.

[12] P. Andersson, J. Wikman, M. Arvidson, F. Larsson och O. Willstrand, ”Safe introduction of battery propulsion at sea,” RISE Research Institutes of Sweden, 2017.

[13] O. Willstrand, ”Fire Suppression Tests for Vehicle Battery Pack,” RISE Research Institutes of Sweden, Test Report 8P03983-03, 2019.