Fire and Suppression Tests with Lithium-Ion Traction Batteries

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INTRODUCTION

Climate change demands for a more sustainable usage of resources and energy. This effects many aspects, especially the field of mobility. In order to reduce the production of climate-wrecking gases like CO_2, new technologies based on alternative propulsion systems are developing. Those involve so-called new energy carriers (NEC) instead of internal combustion engines (ICE). NECs comprise gaseous fuels as CNG, LNG, LPG, and hydrogen as well as electric traction systems like fuel cells or Lithium-Ion (Li-Ion) batteries.

The burning characteristics of Li-Ion batteries differ from those of conventional hydrocarbon fuels in terms of ignition and fire behavior as well as the interaction with common firefighting systems and tactics. Further, battery fires may bear risks after being extinguished, as re-ignition even after several hours has to be considered.

Questions concerning the handling of Li-Ion batteries have been part of the German research project SUVEREN. The project is funded by the German Ministry of Education and Research and addresses the fire safety of NEC vehicles, including electric ones, in underground facilities. Up to now, only little knowledge about the burning behavior of Li-Ion batteries is publicly available. Therefore, these questions represented a major part of the experimental fire test program that was performed during the project. Two different fire test series have been executed. Both were aiming at a better understanding of the phenomena leading to and occurring during a fire of a Li-Ion battery and the possibilities for fire detection and suppression of such an event.

LI-ION BATTERY FIRES

The first fire test series was carried out at IFAB's (Institute for Applied Fire Safety Research) facilities in northern Germany in spring 2019. The major aim was to gain a deeper understanding of the burning behaviour of Li-Ion batteries in terms of heat release rate and combustion products. The batteries for all fire tests described were provided by a partner from the German automotive industry. They were fully charged and original vehicle components.

For these investigations, a specific calorimeter was developed, built and equipped with various measurement systems and conventional fire detection systems. The calorimeter covered a total volume of 32 m^3 (plus the roof), contained a ventilation system capable of extracting 2.0 m^3/s airflow and a water mist suppression system for safety reasons. Several thermocouples were placed all over the calorimeter, in the exhaust duct and on the surface of the tested battery. Different single gas sensors, including an oxygen sensor, were used and the exhaust flow was analyzed using a Fourier-transform Infrared (FTIR) Spectrometer to receive detailed data of the combustion products.

To understand the general behavior of Li-Ion traction batteries in the event of fire, the first test series was conducted using batteries of different types and sizes. The batteries tested contained prismatic or cylindrical cells and were ignited by mechanical penetration using a drilling machine.

The heat release rate of the battery fires was determined using different methods in order to compare their capability for battery fires. Moreover, the major combustion products have been quantified in terms of toxicity, including HF measurements. The first series showed large differences in fire behaviour depending on the battery cell type (cylindrical and prismatic) and the development of a reliable ignition method. Additionally, it was observed that the thermal runaway propagated to all cells and modules involved in the fire test if there was no suppression or any other interaction from the outside. Nevertheless, the propagation was interrupted by the installed water mist suppression system.

FIRE SUPPRESION TESTS

The second test series compared different firefighting agents regarding their performance and extinguishing abilities with battery fires. In order to guarantee comparability, the battery fire load was identical in all tests consisting of two modules with cylindrical cells and an overall energy content of 5 kWh. With this battery fire load, various firefighting agents and conventional detection systems including smoke and heat detectors have been investigated.

The following fire suppression agents and agents tested:

- Normal sprinkler
- High pressure water mist
- Low pressure water mist
- F-500
- Foam
- Nitrogen
- Carbon dioxide
- NOVEC
- Aerosol

The results and the extinguishing abilities will be evaluated in comparison to respective free-burn tests and among each other. Similar to the first fire test series, various measurement systems including e.g. measurements for gas concentrations and temperatures were used to collect data during the fire and suppression tests. Further findings include aspects like the time between the start of overcharging a battery cell and its bursting as well as criteria for activating the firefighting system.

CONCLUSIONS

As data processing is still ongoing, only preliminary conclusions can be drawn so far. Nevertheless, the authors are analysing the data as described above in terms of the repeatability of the batteries' thermal runaway and the influence of the different firefighting agents on the Li-Ion battery fires. The paper will give an overview and show results from both fire test series. This will include an analysis of the numerous data describing the behaviour of the batteries itself during the thermal runaway and the interaction and capabilities of different suppression systems during the battery fire tests.