Abuse testing of E-vehicle battery cells and packs

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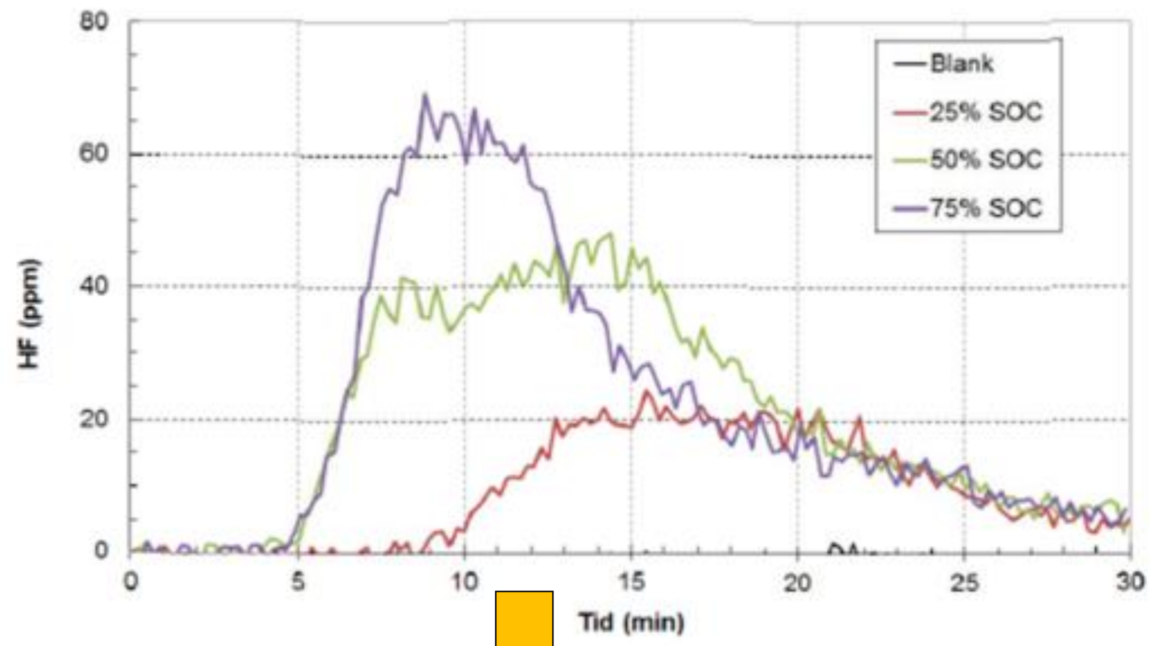
Background

There is considerable uncertainty among first responders concerning priorities and prefer-able actions when responding to accidents involving e-vehicles. A research project, *E-Vehicle Safe Rescue,* was initiated in 2012 by The Swedish Civil Contingencies Agency (MSB) together with academic and industry partners. The purpose was to investigate the effects of abuse on lithium ion (Li ion) battery systems in vehicles with electric drive.

Li ion batteries contain high electric energy and power density and comprise combustible mate-rials and fluorine-based salts [1-3]. Risk analysis identifies thermal abuse as a key failure pathway [4]. Gases emitted during a thermal event contain a variety of species including flammable constituents like hydrogen and hydrocarbons (*e.g.* methane and ethane), vaporized electrolyte (alkyl carbonate) as well as varying concentrations of highly toxic CO and HF.

External fire exposure and water immersion are the focus of this study, as water is the recommended firefighting medium for Li ion battery fires. In addition, flooding has been reported to initiate thermal event s in e-vehicles.



$LiFePO_4$ [7Ah]	HF total (g)	HF per cell (g)	NMC [14Ah]	HF total (g)	HF per cell (g)
25 % SOC	5,6	1,1	25 % SOC	1,55	0,31
50 % SOC	11,7	2,3	50 % SOC	NA	NA
75 % SOC	12,0	2,4	75 % SOC	2,19	0,44

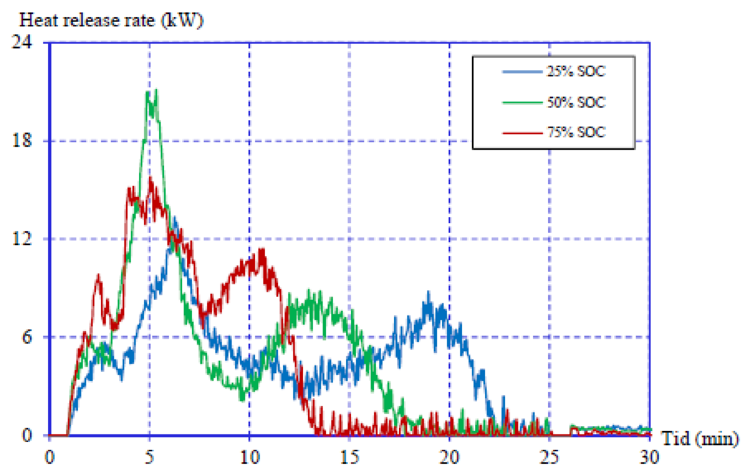
Fire testing

Experimental

Fire test have been conducted on 2 types of Li ion pouch cells designed for E-vehicles. The electric capacity differs between the cells due to different cathode materials: 7 Ah LFP ($LiFePO_4$) and 14 Ah NMC ($Li(Ni_{1/3}Mn_{1/3}Co_{1/3})O_2$). Complete combustion of single cells, multiple cell bundles and a complete electric vehicle battery pack over an open flame have been studied. Measurements include temperature monitoring and chemical analysis of the emitted fumes. The effect of the state of charge (SOC) on the energy release and the composition of the gas emissions, particularly the concentration of the highly toxic hydrogen fluoride (HF), was evaluated.

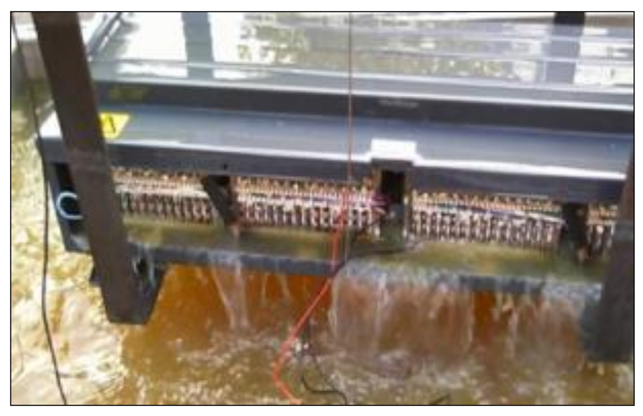
Conclusions

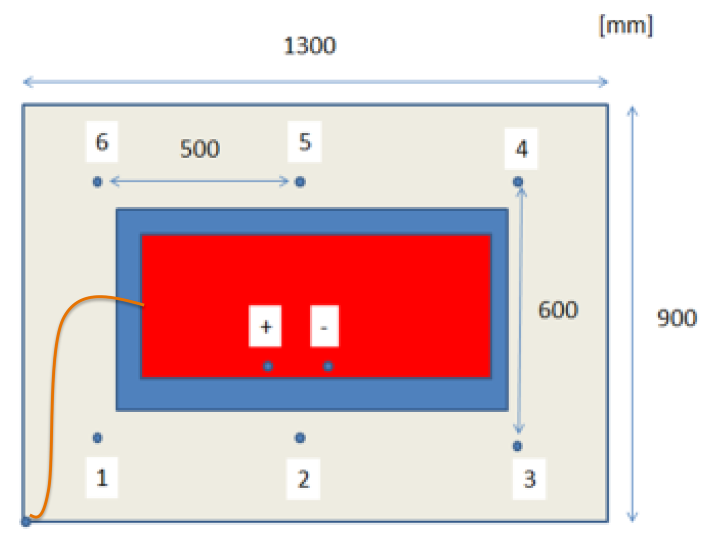
More HF is generated per cell as the number of cells increases. The NMC cells tested generate significantly less HF gas than the LFP cells. However, only one cell type from a single supplier was tested so it is impossible to conclude if this is a general characteristic of NMC cells. Higher SOC levels resulted in more HF released although the relationship is not linear. The total amount of electric energy stored in the cells did not significantly affect the total amount of heat energy released. This indicates that the chemical energy per unit weight of Li ion cells is higher than the electric energy. However, the heat release rate (HRR) was higher for cells at medium and high SOC than at low SOC. The peak HRR of the NMC cells was much higher than for the LFP cells, indicating a higher reactivity in the NMC cells.



Exposure to external fire

Water immersion





		REESS #1 $LiFePO_4$	REESS #2 NMC
Fresh water	Test time	7:10 min	30 min
	Δ Volt	-Δ 4V	-Δ 2V
3% salt water	Test time	7:25 min	15 min
	Δ Volt	-Δ 300V	Inoperative

Water immersion

Experimental

Testing was performed on a prototype LFP hybrid battery pack, 396V/2.4kWh, and a NMC hybrid battery pack, 375V/11.2kWh. The batteries were fully immersed in fresh water and in salt water (3% NaCl saline solution).

Conclusions

Fresh water has negligible effect on the battery voltage and the pack can retain its electrical energy for several months after immersion. Salt water discharges the battery violently, completely draining the electric energy in less than 15 minutes, forming chlorine gas. Significant heating of the water surrounding the battery is observed. The heat evolved from the NMC pack raised the temperature of 400 liters of water with approximately 20ºC in 15 min.

The resulting electric field strength formed in the water is harmless to humans (<0,5 V/m at a distance of 100 mm from the battery pack).

References

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