Experimental Studies on Lithium-Ion Pouch Cells

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Lithium-ion batteries (LIB) are present in a wide range of terrestrial and space mission applications due to their high specific energy, stability under charging and rapid discharging operations, and long cycle life. However, LIB have shortcomings in particular with regards to the hazards from utilizing flammable electrolyte solvents. Li-ion batteries can experience a thermal runaway (TR) event as a result from a mechanical, electrical, or thermal abuse. This effort intentionally drives single LIB pouch cells into TR using an external heater to emulate thermal abuse. The tests were conducted inside a 1.5 m^3 enclosure with the capability to evacuate the smoke and heat generated during the TR. The heating rate, state-of-charge (SOC), and test article orientation were varied for these tests. Results indicated that the state-of-charge has a significant impact on the TR characteristics, heat release rate, and the emission from gaseous and solid particulates. Gases such as CO, CO_2, and O_2 were measured and used as inputs for estimating the peak heat release rate (HRR) with oxygen consumption calorimetry. The highly dense and potentially irritant smoke generated from battery failures was captured with video cameras and radiometers. Experimental testing with single pouch cell tests will provide quantitative insight into the risks associated with battery modules that contain multiple pouch cells, such as those present in tablets, which are widely used inside the International Space Station.

At a 30% SOC, typical surface cell temperatures remained below 380℃, indicating that the internal temperatures did not exceed autoignition temperatures (445℃) for the dimethyl carbonate, and as a result, only cathode/anode reactions with electrolyte occurred. At low SOC, cells smoldered for long durations prior to observing TR. Lower smoke concentrations were observed at these conditions. The long durations from electrolyte venting could provide sufficient warning time to mitigate the cascading of TR events. Typically, at low SOC and at a horizontal orientation, electrolyte vapor condenses on the cooler support structure surface and solidifies, which could potentially corrode material, become an ignition source, or an irritant on contact. Cell failures at 30% SOC and slow heating, indicated a 30% increase in humidity during TR, which may affect clean-up and the overall dynamics in aerosols inside an enclosed environment.

The failure from 100% SOC cells have the highest risks and a major influence in the magnitude of HRR (above 2-9 kW). Surface cell temperatures exceed 600 ℃ and a large concentration of electrolyte vapor and gases from decomposed material is aggressively expelled. Sparks and fire were apparent with surrounding temperatures increasing significantly. High obscuration from the large quantity of gases and aerosols were observed inside the enclosure. Future work will be conducted with highly energetic battery packs (45 Wh) to characterize the energy release, gaseous, and solid particulate emissions from battery fires.