Safety of Lithium Nickel Cobalt Aluminum Oxide Battery Packs in Transit Bus Applications

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Cell surface temperatures surpass 700 degrees Celsius seconds after the start of a thermal event and can remain above 200 degrees Celsius for more than 20 minutes.

The future of mass transportation is clearly moving toward the increased efficiency and greenhouse gas reduction of hybrid and electric vehicles. With the introduction of high-power/high-energy storage devices such as lithium ion battery systems serving as a key element in the system, valid safety and security concerns have emerged. This is especially true when the attractive high-specific-energy and power-chemistry lithium nickel cobalt aluminum oxide (NCA) is used. This chemistry provides great performance but presents a safety and security risk when used in large quantities, such as for a large passenger bus. If triggered, an NCA cell can completely fuel its own fire, and this triggering event occurs more easily than one may think.

This research project provides bus manufacturers and transit authorities with validated design guidelines to address crash safety of high-energy-density, high-voltage NCA battery systems. The study focused on producing a better understand of how high-energy cells of this chemistry fail and which materials can be used to manage these failures in a way that increases passenger survivability.

Study Methods

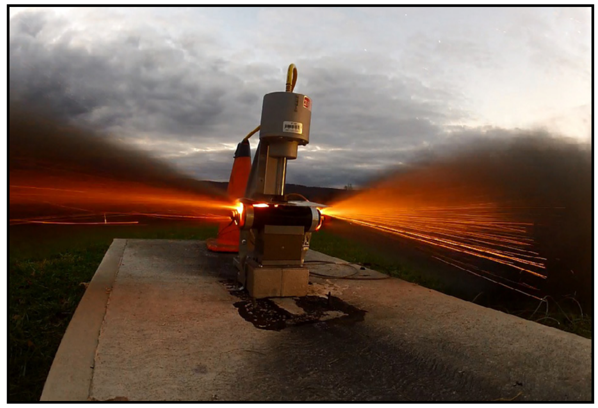
To assist engineers and technicians in this transfer from the use of primarily fossil fuels to battery energy storage on passenger buses, the researchers studied the safety concerns of NCA battery chemistry. The research team ran numerous experiments on cells and modules, using various packaging materials, studying rarely considered thermal runaway events and venting events. Special considerations were made to gather supporting information to help better understand what happens, and most importantly how to best mitigate these events and/or manage them when they occur on a passenger bus.

Using large-format, 45-Ampere-hour cells, tests were performed ranging from single cell to 20-cell modules, including nail puncture, overcharge, short-circuit, and a full-scale crash test. Venting gases were also captured and analyzed following the venting event caused by a nail puncture test.

Findings

The research team found that the greatest safety concern when using such a high-energy chemistry is ensuring passenger safety when a cell's electrolyte boils and causes the ventilation of high-temperature toxic material. A cell-venting event can be triggered by a variety of scenarios with differing levels of likelihood. Also, though the duration of a venting event is relatively short, the temperature of the venting material and cell is extremely high and the cells that have vented remain at high temperature for tens of minutes after the event. This is likely to cause secondary fires if not properly packaged and/or cooled after an event. Cell surface temperatures surpass 700 degrees Celsius seconds after the start of a thermal event and can remain above 200 degrees Celsius for more than 20 minutes.

Through material testing and module design the team was able to achieve a successful test in which cell electrolyte and hot gases were directed away from neighboring modules. The image below shows this over-charge test in which all 20 cells vented in a chain reaction.



Nail Puncture Test of a Large Format Lithium Nickel Cobalt Aluminum Oxide Cell

Policy Recommendations

The authors recommend:

- A properly functioning and intelligent battery management system with voltage and temperature measurement to avoid loading cells beyond their limits.
  - Redundant pack voltage measurement is necessary to validate individual measurements by comparison.
  - Internal cell temperature estimation and rate increase detection are necessary, as cells are able to vent within usable temperature limits when only absolute temperature is measured. If temperature is analyzed over a reasonable duration of time, much larger than a few seconds, thermal runaway can be avoided.
- Carefully choosing packaging materials for both cell/modules as well as the battery system enclosure. Likewise one must be aware of the venting gas and cell temperatures when designing a battery system.
- Avoiding the use of aluminum or even plastic enclosures on passenger buses. This is not acceptable and such materials cannot withstand the temperatures of venting or sustained battery fires.
- Modularize battery systems by separating them with high temperature materials to avoid thermal propagation.

About the Authors

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To Learn More

For more details about the study, download the full report at ***transweb.sjsu.edu/project/1247.html***

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