Li-ion Pouch Cell Thermal Abuse Test and Cylindrical Cell Mechanical Abuse Test

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Project Overview

- **Project Goal:** To identify the thermal runaway severity of Li-ion batteries through abuse tests.
- **Current Practice:** Thermal runaway (TR) is often triggered by complex electrochemical-thermal interactions. Current thermal abuse tests using accelerating rate calorimetry (ARC), or mechanical abuse tests with nail penetration on cell can provoke the TR on Li-ion batteries (LIBs) but has difficulties to compare their TR results.
- **Why:** Oak Ridge and Sandia National Labs have introduced a single-side indentation protocol to induce internal short circuits in Li-ion pouch cells. This method analyzes voltage and temperature to calculate a Calculated Hazard Severity (CHS) score and categorize a cell's TR severity. ORNL is also developing a new thermal abuse test protocol to categorize the TR severity for small capacity pouch cells.
- **Innovation:** The thermal abuse and mechanical abuse tests at our lab can slow down the TR chain reactions in a controllable and consistent way by reducing the loading speed and the special indenter design, monitoring the temperature and voltage changes in real-time, and quantifying the test measurements of comparable TR severities for different cells. Additionally, acoustic emission (AE) monitoring is used to monitor short-lived, stress-induced acoustic signals or vibrations emitted by materials, offering insights into battery phenomena typically difficult to observe with the naked eye [1].
- **Impact:** TR is one of the major safety concerns of using Li-ion battery energy storage systems (ESS) [2]. It is crucial to better assess TR risk from single cell to reduce potential hazards in large scale deployment [3]. The thermal abuse tests introduced in the project will develop standard test protocols to evaluate LIBs thermal runaway severity and grade them for different applications. The test results will construct a knowledge base for that purpose. Analysis of the AE signals may help find an engineering way to prevent the TR before reaching the critical moment.
- **Alignment:** This effort aligns with DOE OE's mission to advance energy storage and maintain a reliable electricity delivery infrastructure.

Safety concerns of ESS:

- Energy Storage Systems (ESS) present several safety concerns primarily related to battery technology. The thermal runaway of the battery poses the fundamental risk, which can lead to fire, explosions, and the release of toxic gases and potential environmental impacts.

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https://www.nbcnews.com/news/us-news/hundreds-ordered-evacuate-fire-erupts-huge-california-battery-storage-rcna188101

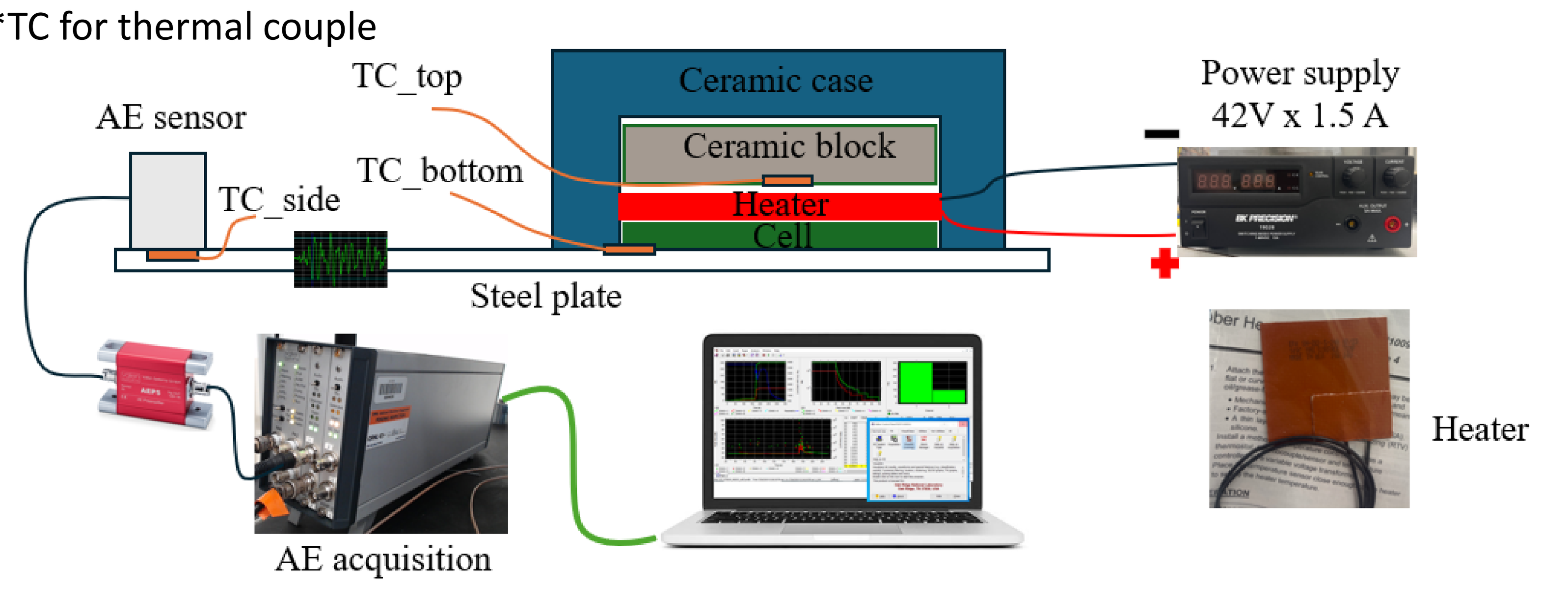
Mitigation Strategies:

- **Regular Safety Testing**: Stress tests and failure simulations are crucial for identifying and addressing potential weaknesses from single cells. The thermal abuse test simulates the cell behavior under heat propagation circumstances, while the mechanical abuse test puts the cell under a certain stress. Both tests can provide fundamental information for a cell's safety evaluation.
- **Choosing Appropriate Batteries for ESS**: Li-ion batteries are cheaper and larger in size, but not all of them satisfy ESS safety requirements. The abuse tests at ORNL and Sandia are building a cell thermal runaway database (https://doi.org/10.1016/j.dib.2024.110609), which can grade the thermal runaway severity for various battery types. The standard test methods and database can help an ESS builder to make correct and safe decisions.
- **Safety Instrumented Systems**: The AE instrument can monitor the cell internal changes in real-time, providing potential opportunity to identify critical events to prevent the thermal runaway in advance.

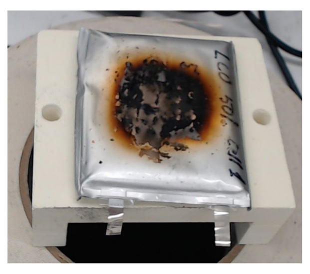
Methods

Thermal abuse test setup

*TC for thermal couple

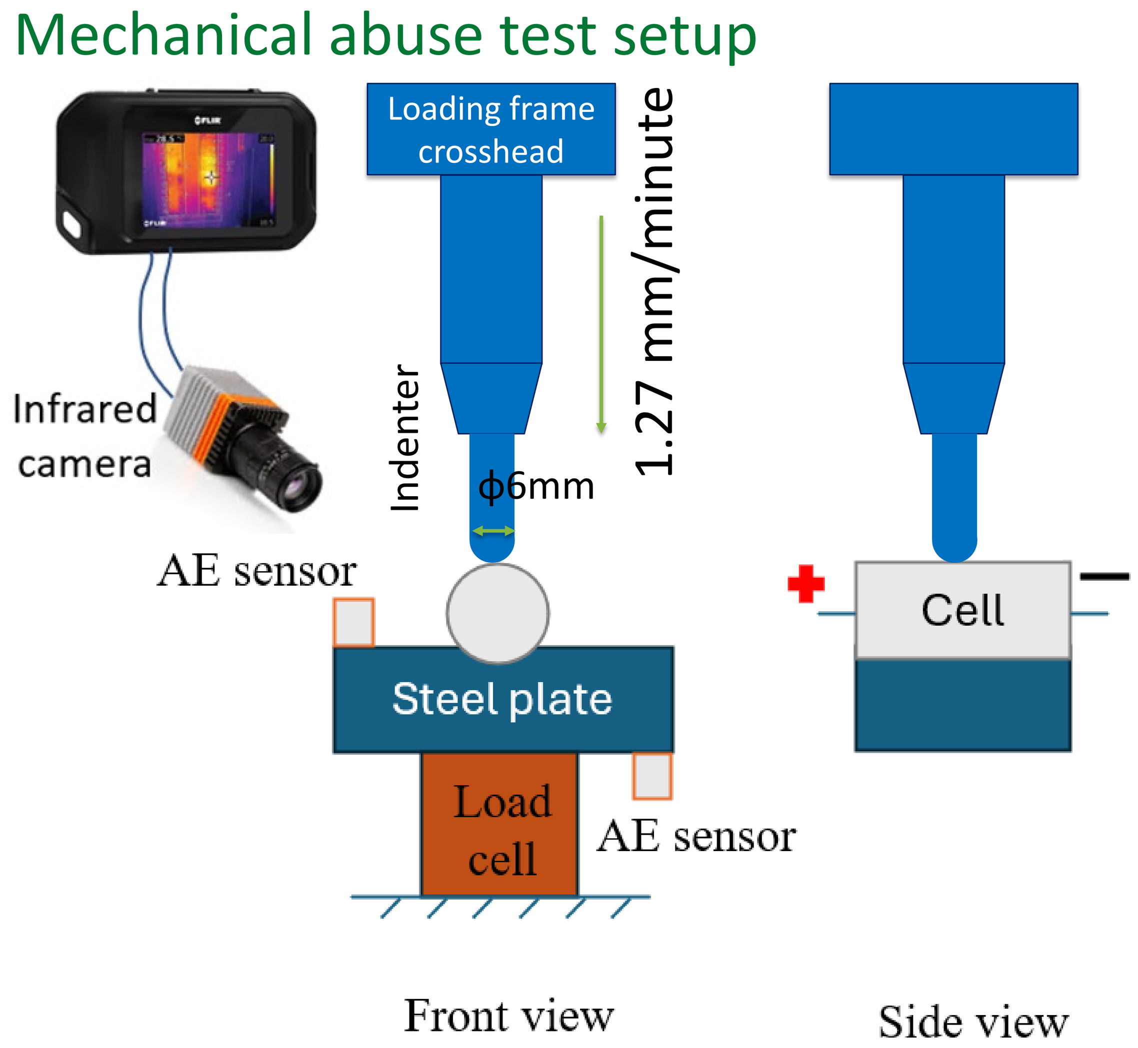


Test configuration in a venting chamber



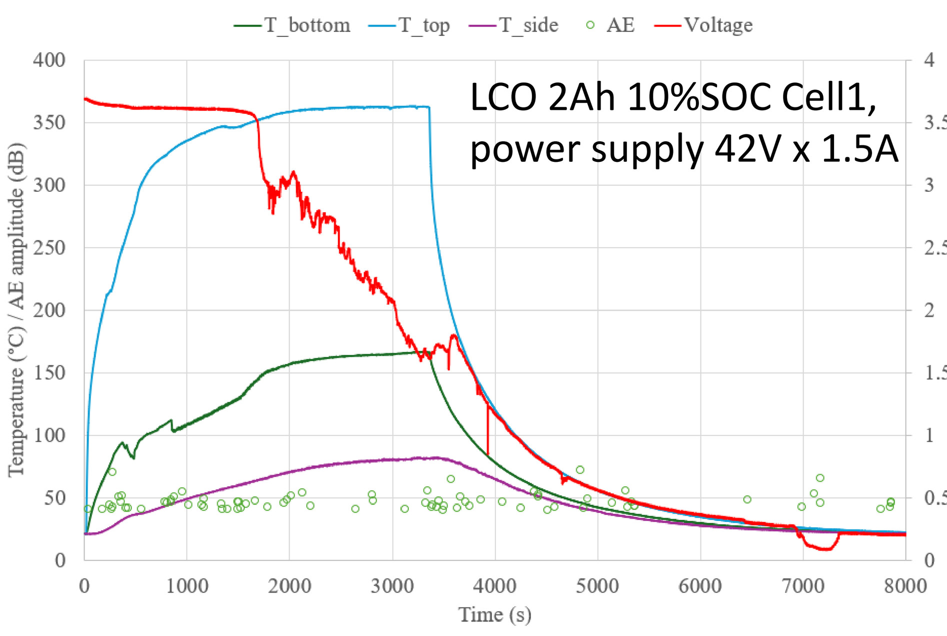
Cell after test

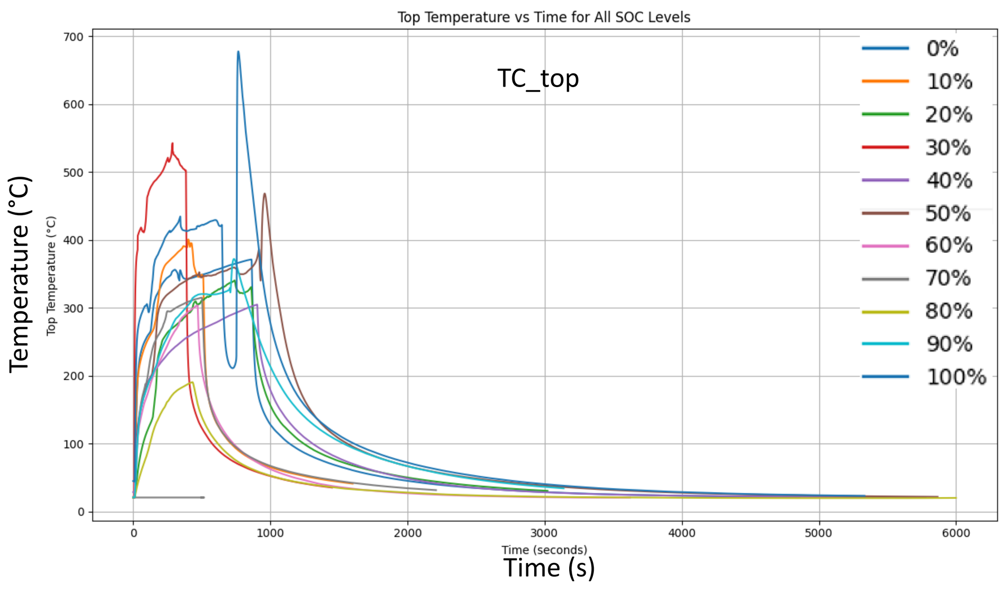
Mechanical abuse test setup



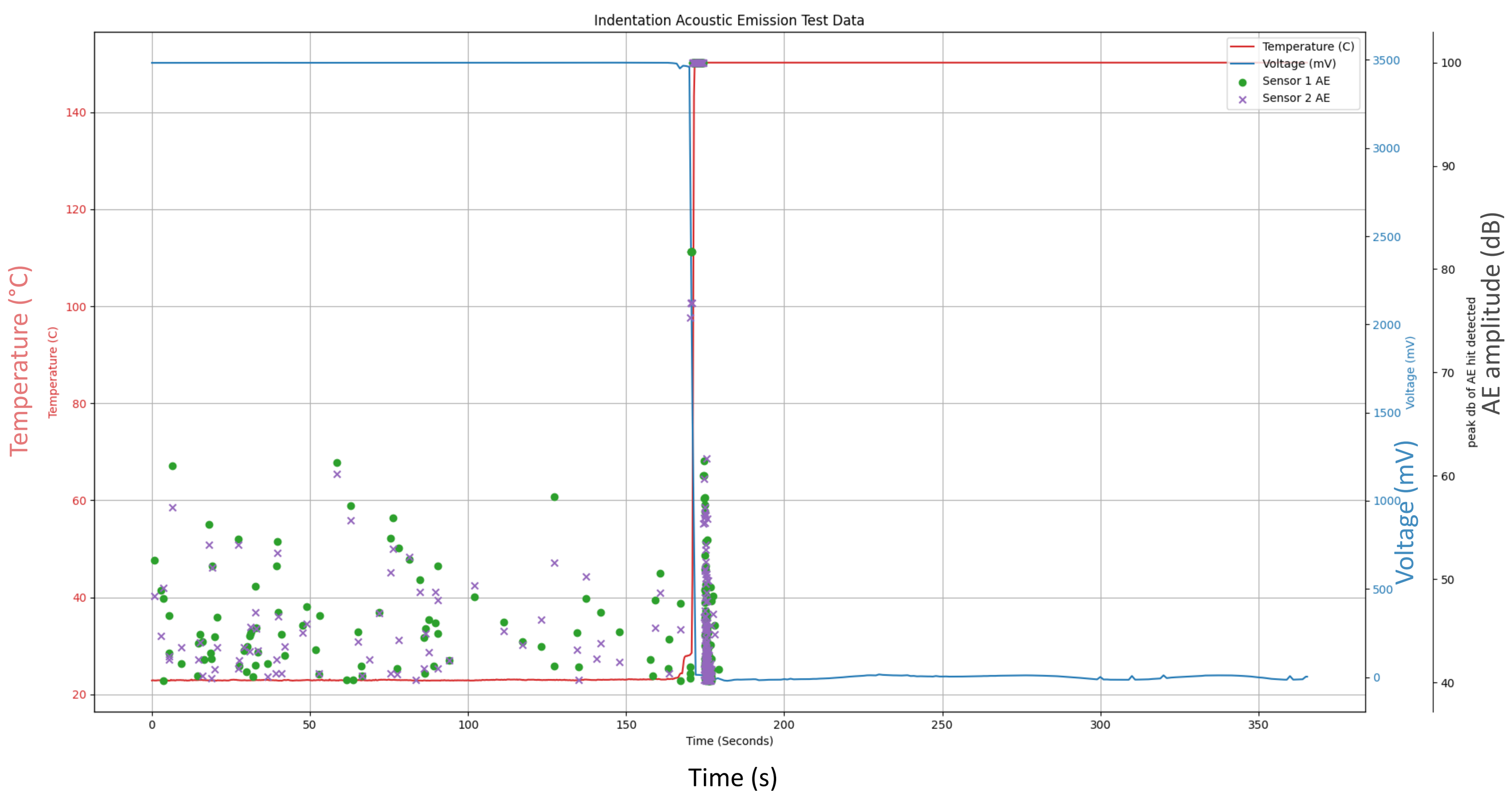
21700 cell under compression

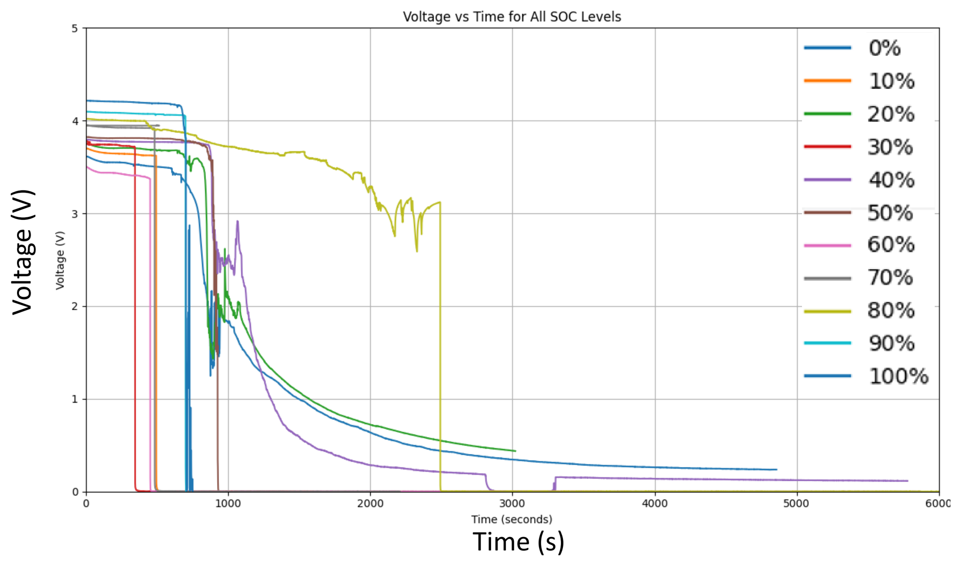
Results

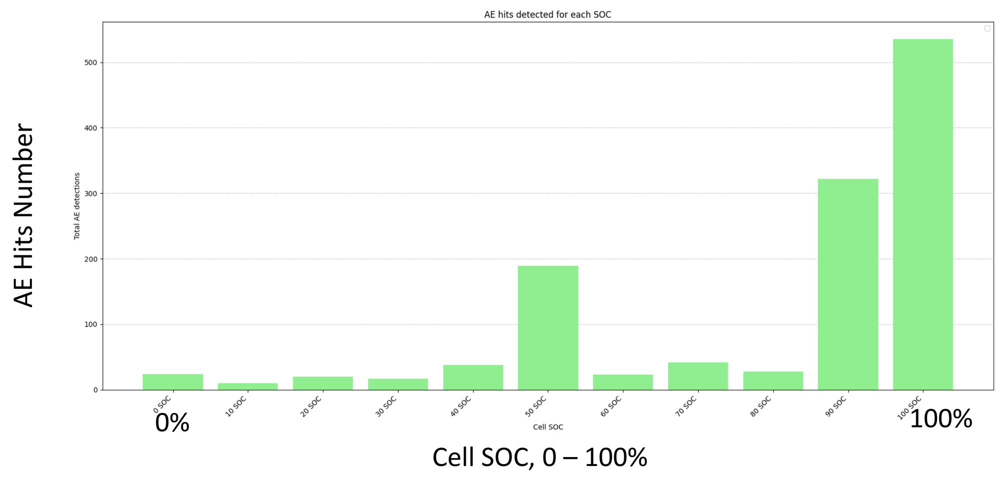


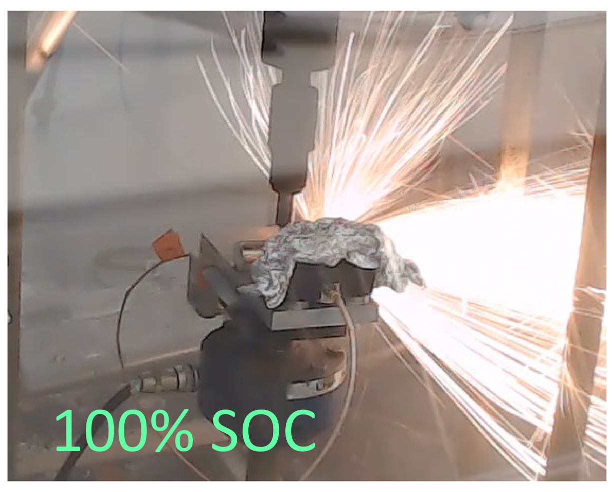


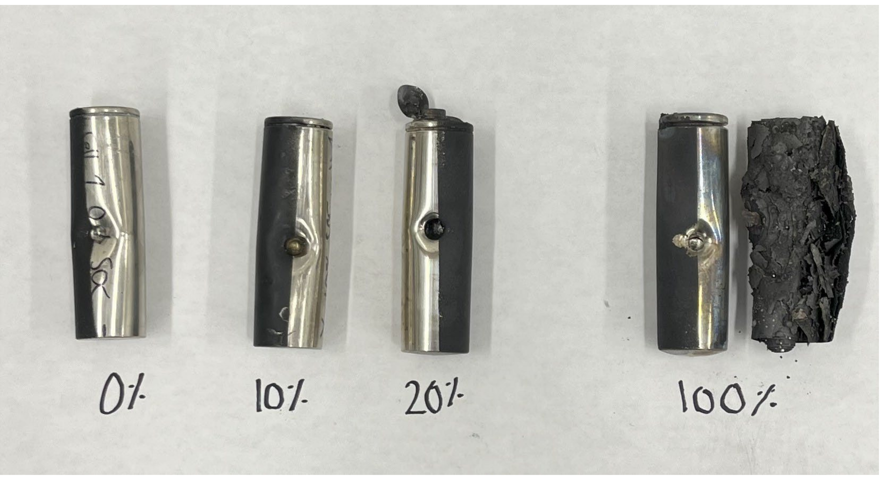
Tesla 21700 cell 20% SOC











Conclusions

- The thermal abuse test can simulate cell behaviors under heat propagation circumstances.
- Under the same heating conditions, cells with different SOCs respond differently at measured temperatures, voltages and AE signals. The high SOC cells (90% and 100%) experience full thermal runaway, and the lower SOCs exhibit mild failure (swelling and gas leaking). Much more AE signals were captured from high SOC cells during the test.
- The new design of the steel plate and the cell holder guarantee the mechanical indentation on cylindrical cells.
- Mechanical abuse tests show severe fire and explosion for the high SOC (100%) 21700 cell, but not for the lower SOC (0%, 10% and 20%) cells.
- More tests on the same cells are needed to further analyze their thermal runaway severity levels.

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