



cooler • lighter • safer

Challenges for Thermal Runaway Mitigation and Prevention of Cell-to-Cell Propagation

Energy Storage Systems Safety and Reliability Forum (ESSSRF) 2022

William Q. Walker, PhD.
Director of Engineering

With contributions and collaborations from,

Peter J. Hughes
KULR Technology, Lead Technical
Marketing Engineer

Michael Mo
KULR Technology, Chief Executive Officer

OVER 150 YEARS OF COMBINED SUCCESS IN INNOVATION AND GROWTH OF TECHNOLOGY PRODUCTS

THERMAL RUNAWAY CHALLENGES

- INHERENT POSSIBILITY
 - There is inherent risk associated with utilization of lithium-ion (Li-ion) cells and batteries due to the possibility of thermal runaway.
 - These events can be brought on by several failure modes including thermal induced failure, structural or mechanical failure, electrochemical abuse, and short circuiting.
 - For battery packs, the energy released from a single cell can cause neighboring cells to undergo thermal runaway in a chain reaction like event referred to as cell-to-cell propagation.
- MOST THERMAL RUNAWAY CAUSES CAN BE PREVENTED WITH THOUGHTFUL DESIGN
 - Robust thermal management system ensures that thermal failure will not occur.
 - Appropriate design decisions can ensure that structural failure of the cell casing will not be allowed.
 - Multiple fault tolerant battery management systems can ensure that overcharge and over discharge do not occur.
 - Although thoughtful design measures can also ensure that external short circuit does not occur, internal short circuits are still possible.

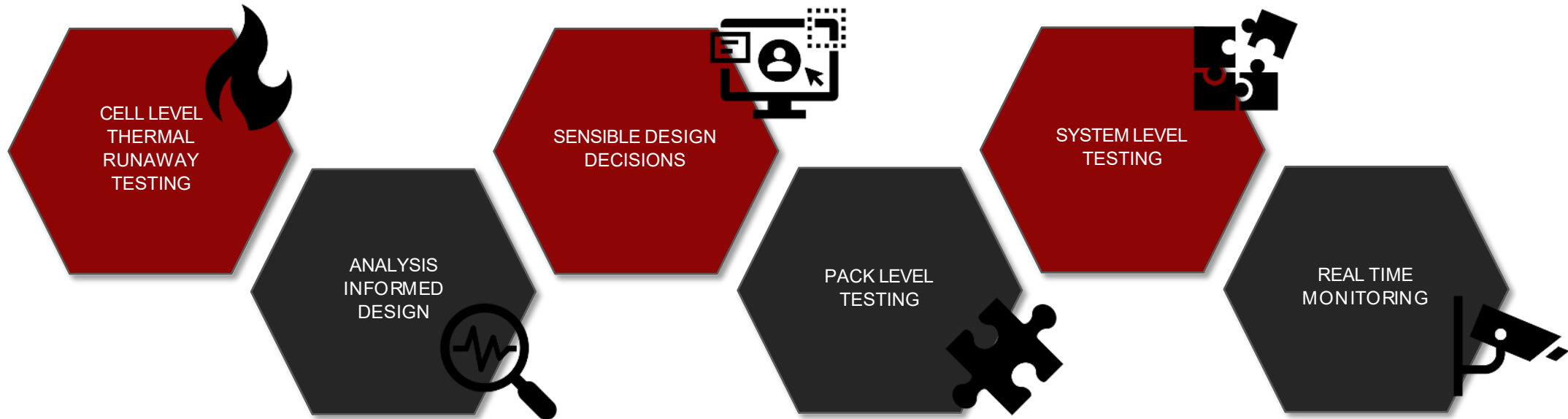


NASA high voltage battery pack design using 18650 format Li-ion cells.



Photos taken of cells following a thermal runaway experiment.

HOLLISTIC APPROACH TO PROTECTION AGAINST THERMAL RUNAWAY



VERTICAL DRIVEN STRATEGY



SAFE PRODUCT DESIGNS DURING ALL LIFECYCLE PHASES



VERTICAL 1 |
CERTIFIED BATTERIES



VERTICAL 3 | REAL TIME
DIAGNOSTICS



VERTICAL 4 | CELL
SCREENING CAPABILITIES



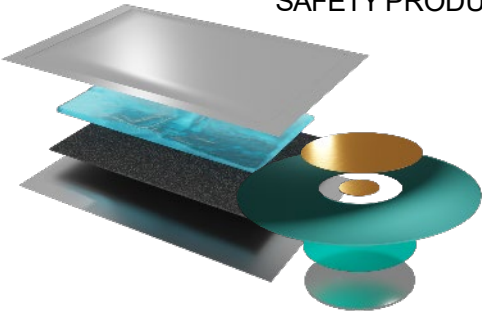
KULR'S PRODUCT
DRIVEN VERTICALS

VERTICAL 2 |
SAFEX PRODUCT LINE



KULR'S FOUNDATION FOR
BATTERY SAFETY

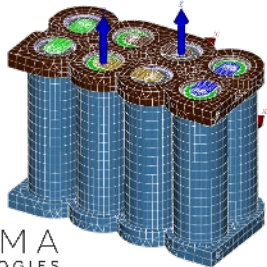
SAFETY PRODUCTS



CELL LEVEL THERMAL RUNAWAY
CHARACTERIZATION



COMPREHENSIVE
MULTI-PHYSICS ANALYSIS



NAVIGATING
REGULATIONS

SUCCESS STORY | PPR CUBESAT BATTERY



cooler • lighter • safer



JSC 20793-REV D COMPLIANT

All battery packs constructed to meet the same safety standards used by NASA for human spaceflight applications.

JSC WI-33/37 QUALIFIED CELLS AVAILABLE

Cells screened to the same extent as required for human spaceflight applications are available to be used in the construction of your battery pack.

OPTIMIZED DESIGN

Low mass 3-D printed materials, combined with KULR's state-of-the-art thermal management solutions, results in industry leading gravimetric and volumetric energy densities for our battery pack.

FLAME ARRESTING CAPABILITIES

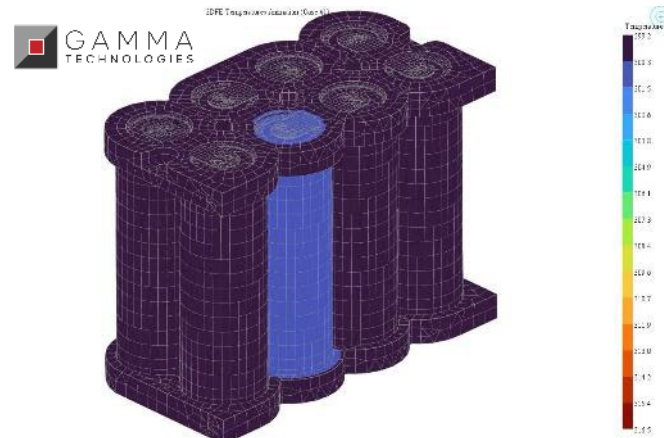
KULR's materials are strategically placed in the vent path to prevent expelled gases from igniting.

CELL-TO-CELL PROPAGATION RESISTANT

The design implements a combination of phenolic tubing and KULR proprietary Thermal Runaway Shield (TRS) materials to prevent cell-to-cell propagation stemming from a single cell thermal runaway event.

VALIDATED WITH TEST AND ANALYSIS

KULR's battery pack design and materials selections are supported with data collected from rigorous test and analysis campaigns.

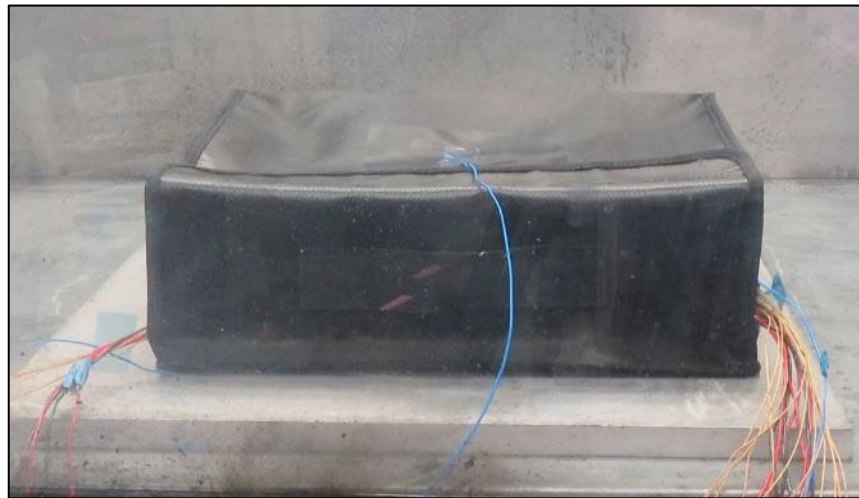


SUCCESS STORY | SAFECASE PRODUCT LINE



cooler • lighter • safer

- KULR'S PATENT PENDING SAFECASE IS A PASSIVE PROPAGATION RESISTANT (PPR) STORAGE AND TRANSPORTATION SYSTEM FOR BATTERIES
 - SafeCase is designed to mitigate thermal runaway, providing safe and sustainable storage and transportation for lithium-ion cells and battery packs.
 - DOT approved for transportation and rated up to 2.1 kWh per case.
 - Utilizes KULR's patented Thermal Runaway Shield (TRS) technology.
 - Foldable for compact storage and is constructed with safe nontoxic materials
- SIZES AND HOUSING MATERIAL CAN BE CUSTOMIZED UPON REQUEST





BACK-UP

OVER 150 YEARS OF COMBINED SUCCESS IN INNOVATION AND GROWTH OF TECHNOLOGY PRODUCTS