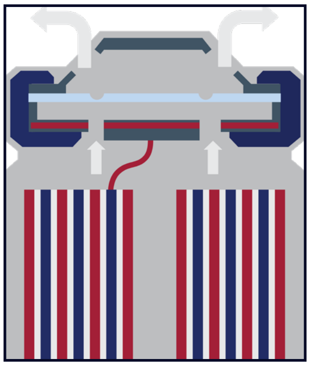
XTS™ DESIGN CONSIDERATIONS FOR THERMAL RUNAWAY PREVENTION

INFORMATION SHEET | DATE: 09/13/2022 | VERSION: 1

UNDERSTANDING THERMAL RUNAWAY AND THERMAL RUNAWAY PROPAGATION

Thermal runaway occurs in Li-Ion cells when the anode, cathode, and electrolyte irreversibly react, releasing the energy stored within the cell near-instantaneously. This energy manifests in the form of intense heat, accompanied by a violent expulsion of flamable gases.



A cell experiencing thermal runaway will rapidly increase in temperature, typically achieving surface temperatures of 400-800°C within seconds of the triggering event. Additionally, gas pressure building within the compromised cell will result in rupture of the cell-wall or, in the case of cylindrical cells, escape through the safety vents located at the positive terminal.   Both modes of this venting behavior pose thermal and mechanical dangers to nearby components.

The typical triggers for thermal runaway events include:

- Crushing
- Puncture
- Overcharging
- Overheating (commonly beginning above 130°C)*

RUPTURED CELL WALL

* Li-Ion cell overheating thresholds may vary by model and manufacturer

In the case of multi-cell battery packs the threat of a single-cell thermal runaway event cascading to other nearby cells, known as thermal runaway propagation, is a major safety concern. Unconstrained thermal runaway propagation typically results in catastrophic damage to both the electrical device in which the battery pack is housed and to the surrounding environment, sparking fires and emitting toxic gases.

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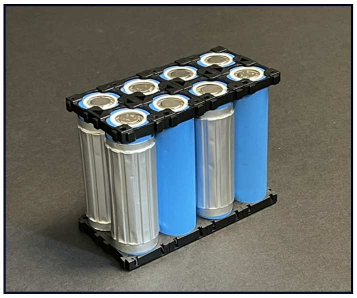
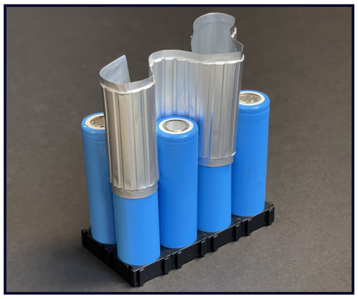
LHS XTS PRODUCTS OVERVIEW

LHS offers three varieties of XTS products for the prevention and mitigation of thermal runaway events, which additionally provide passive thermal management benefits during normal battery pack operations.

CONFORMABLE POUCHES

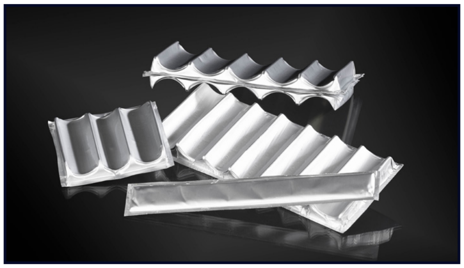
- Standardized design compatible with multiple battery pack configurations
- Supplied in ribbons or rolls
- Available in varied lengths, widths, and thicknesses





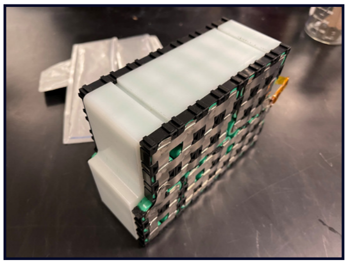
CUSTOMIZED POUCHES

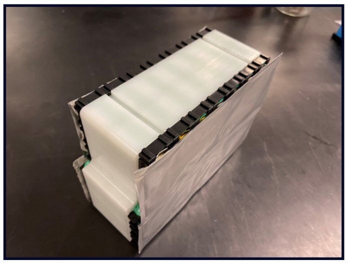
- Customizable to diverse cell geometries and pack designs
- Larger potential fill volumes than Conformable Pouches provide improved thermal management



STRUCTURAL COMPOSITES

- Provide structural support to prevent cell collapse and minimize side rupture events
- Synergistic with pouches (not a standalone thermal runaway solution)





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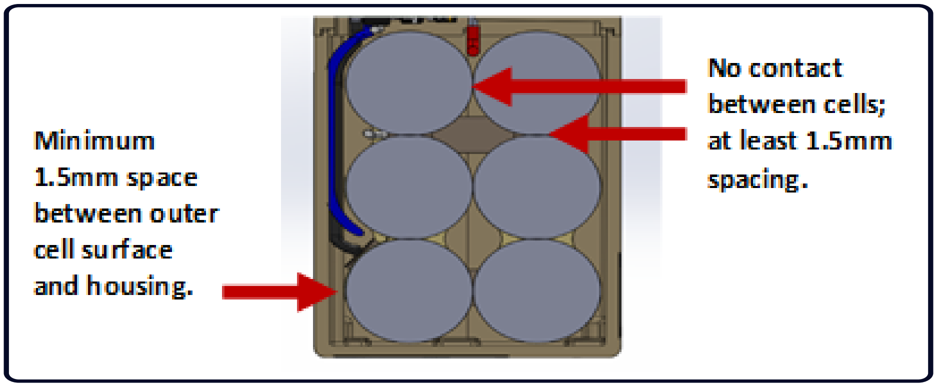
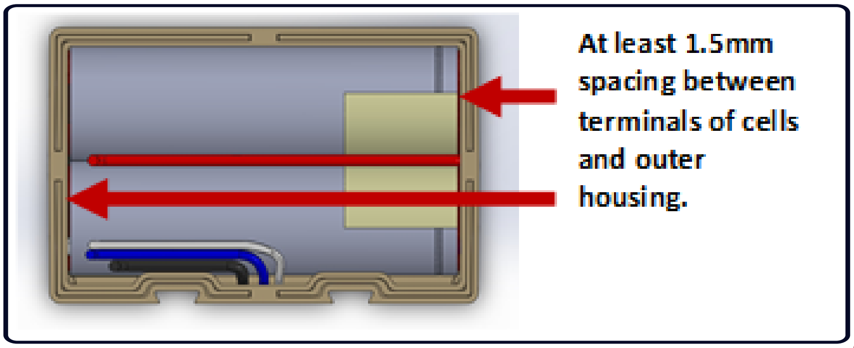
DESIGN CONSIDERATIONS FOR THE PREVENTION OF THERMAL RUNAWAY PROPAGATION

The prevention of thermal runaway propagation hinges on two criteria. Firstly, thermal and mechanical isolation of individual cells within a battery pack should be optimized. And secondly, heat energy generated by any initial thermal runaway events must be captured and transfered rapidly out of the system. Without any method to dispose of the heat no amount of cell-to-cell insulation will be sufficient to prevent thermal runaway propagation indefinitely. Therefore, LHS commonly recommends the following battery pack design criteria be observed:

- Minimum 1.5mm cell-to-cell and cell-to-housing spacing. This allows for sufficient thermal and mechanical isolation of individual cells and for the inclusion of sufficient XTS materials to capture and dispose of heat energy from an initial thermal runaway event.
    - Barrier materials between cells prevent mechanical damage by venting gases and other ejecta.
    - XTS Conformable Pouches and XTS SC-1 Composites offer advantages over traditional barrier materials in total weight and cost, as well as in specific heat capacity and thermal conductivity for tailored cooling behaviors during normal battery pack operations.

- The inclusion of sufficient XTS material, either in contact with the cell walls or the positive cell terminals. This facilitates the capture and disposal of thermal energy from the initial thermal runaway event and quenches any flames ignited within the battery pack housing.
    - Minimum XTS product mass of 2.5g per cell is the general guideline to ensure sufficient thermal energy absorptive capacity.
    - Lower XTS masses may be effective, but case-specific testing is necessary to determine the optimal mass for specific pack designs and temperature thresholds.





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XTS PRODUCT IMPLEMENTATION STRATEGIES

The combination of the XTS Pouch's laminate and fill materials work together to rapidly capture and dispose of thermal energy associated with thermal runaway events. Additionally, they quench flames and serve as a reflective barrier between battery pack components.

The XTS SC-1 and SC-1 FR Composites provide similar but lesser thermal management properties in exchange for superior mechanical damage protection as well as structural support for cell walls, preventing side-rupture events.

Latent Heat Solutions' XTS Pouch and Composite products can be applied to battery packs in a variety of ways based on customers' requirements for their pack assembly process, weight restrictions, and safety/performance needs.

	XTS Conformable Pouches	XTS Conformable Pouches & Terminal Pouches	XTS Custom Pouches	XTS Custom Pouches & Terminal Pouches	XTS SC1 and SC1-FR Composites	XTS SC1 and SC1-FR Composites & Terminal Pouches
Minimum Cell Spacing	1.5mm	1.5mm	1.5mm	1.5mm	1.5mm	1.5mm
Possible Cell Configurations	Aligned or Staggered	Aligned or Staggered	Aligned	Aligned	Aligned or Staggered	Aligned or Staggered
Estimated Mass of XTS	2-3g / cell	3-4g / cell	4-13g / cell	5-14g / cell	6-9g / cell	7-10g / cell
Cell Coverage	70-100%	70-100%	70-100%	70-100%	100%	100%
Side Rupture Protection	No	No	No	No	Yes	Yes
Ejecta Management	No	Yes	No	Yes	No	Yes
Cost	$	$	$$	$$	$$$	$$$
Propagation Protection	Medium	High	Medium	High	Low	High
Thermal Management	Medium	Medium	High	High	Low	Medium

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