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QUEEN'S UNIVERSITY IONIC LIQUID LABORATORIES

QUILL

Department for the Economy

Runaway Propagation Prevention for Lithium-ion Batteries

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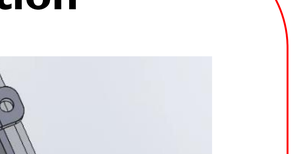
Motivation

Legislation and running costs are accelerating adoption of electric vehicles, while safety concerns continue to hinder it. Safety is an increasing priority across all six countries surveyed by Deloitte.

Technology review

Commercial

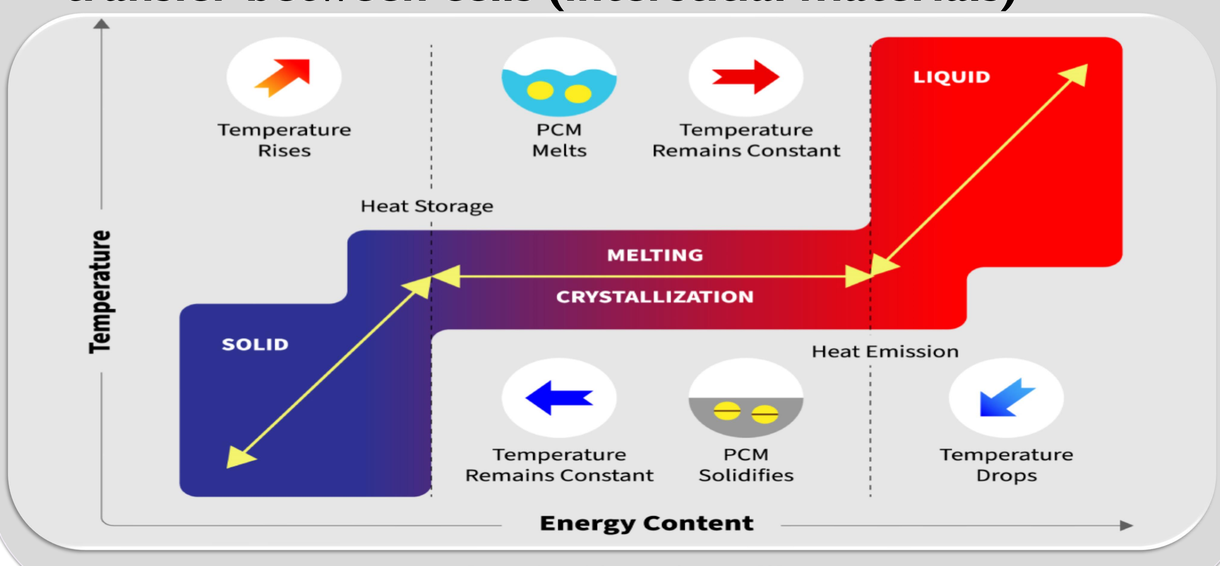


- Tesla model 3 - BMS – Indirect liquid cooling- intumescent foam [2]
- Nissan leaf - BMS -Air cooled battery pack [3]
- BMW i3 - BMS -AC cooling system (refrigerant)[4]

Academic Research

- Phase change materials – Paraffin [5]
- Dedicated suppressants – CO_2, water mist [6]
- Cell material modification –Electrolyte, separator, etc,[6]
- Early detection –Vent gas, cell swelling, temperature [7]

Phase change materials (PCMs) used to slow heat transfer between cells (interstitial materials)

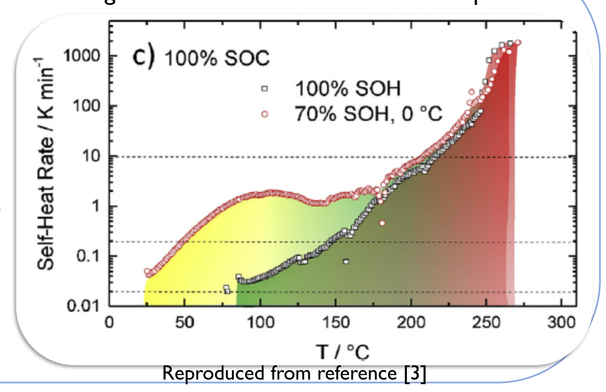


Reproduced from reference [9]

Thermal runaway

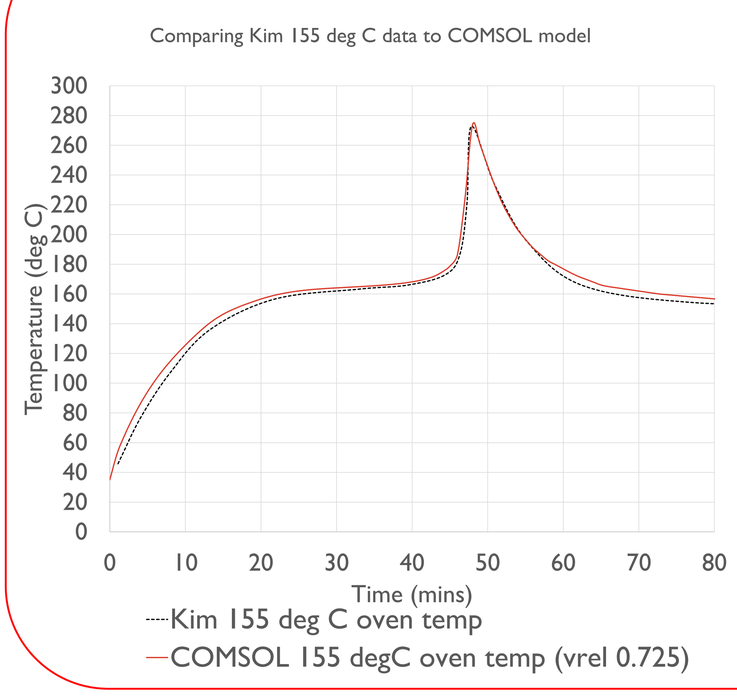
Large amounts of heat are generated, the heat from one cell can propagate to the neighbouring cells causing a runaway reaction culminating in the destruction of the pack and vehicle.

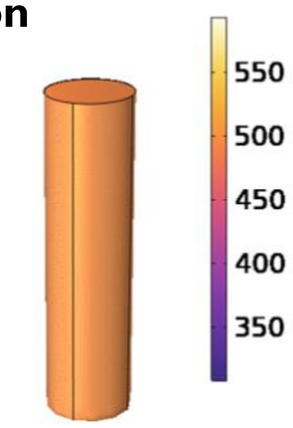
Self-heating rate of 18650 cells at elevated temperatures



Reproduced from reference [3]

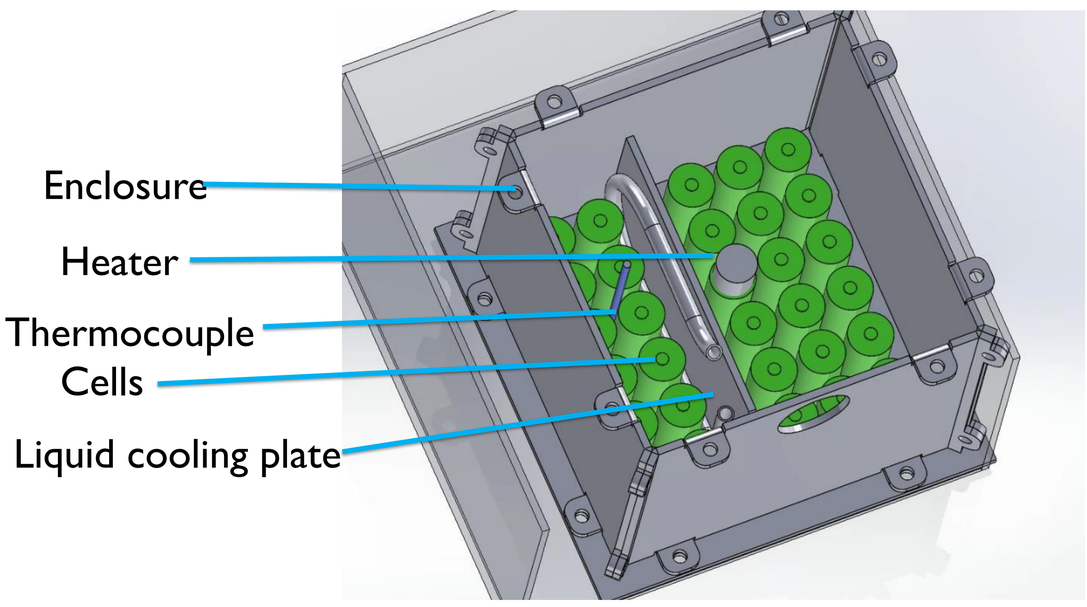
3D COMSOL Validation





Oven testing used to validate the correct function of the chemical kinetics and model set up. Comparison to literature shows strong agreement.

Low power rig for COMSOL Validation



A rig to conduct low power tests and validate the COMSOL model is under development. Designed to mimic an accumulator. This will ensure the conduction, convection and radiation mechanisms are functioning correctly and the rig can be used for final destructive testing.

Future work

- Consider additional thermal abuse initiation types.
- Consider alternative materials.
- Altering thermal conductivity of PCMs used as well as thermal contact.
- Further thermal management considerations.
- Sensitivity analysis - flow rate, initial temperature etc.
- Practical validation of simulation via rig test.

References
[1] Impact of cycling at low temperatures on the safety behaviour of 18650-type lithium ion cells: Combined study of mechanical and thermal abuse testing accompanied by post-mortem analysis **[2]** https://www.patentsencyclopedia.com/app/20100086844 **[3]** LaMonica M. MIT Technology Review [Internet]. 2012. Available from: https://www.technologyreview.com **[4]** https://leandesign.com/2020/02/14/tearing-down-tesla-segment-4-battery-cooling-system **[5]**Kshetrimayum KS, Yoon YG, Gye HR, Lee CJ. Preventing heat propagation and thermal runaway in electric vehicle battery modules using integrated PCM and micro-channel plate cooling system. Appl Therm Eng **[6]** Liu Y, Duan Q, Xu J, Li H, Sun J, Wang Q. Experimental study on a novel safety strategy of lithium-ion battery integrating fire suppression and rapid cooling. J Energy Storage [Internet]. 2020;28(December 2019):101185. **[7]** Koch S, Birke KP, Kuhn R. Fast thermal runaway detection for lithium-ion cells in large scale traction batteries. Batteries. **[8]** Lai X, Jin C, Yi W, Han X, Feng X, Zheng Y, et al. Mechanism, modeling, detection, and prevention of the internal short circuit in lithium-ion batteries: Recent advances and perspectives. Energy Storage Mater. 2021;35(October 2020):470–99. **[9]** Phase change material https://thermtest.com/phase-change-material-pcm