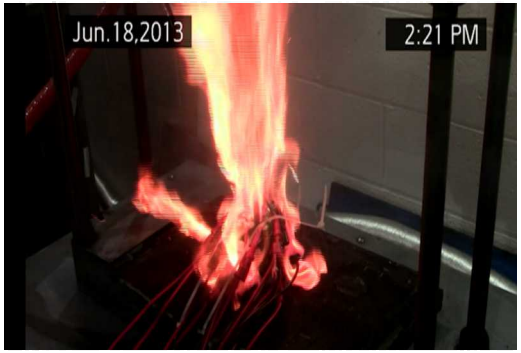
SAND2016-9433C

Exceptional service in the national interest

Sandia National Laboratories



Thermal Runaway Propagation Suppression in Lithium-Ion Battery Systems

David Rosewater, Summer Ferreira, Josh Lamb, John Hewson, Leigh Anna Steele, Sandia National Laboratories

Tuesday September 22nd 2016, DOE OE Energy Storage Peer Review

U.S. DEPARTMENT OF ENERGY

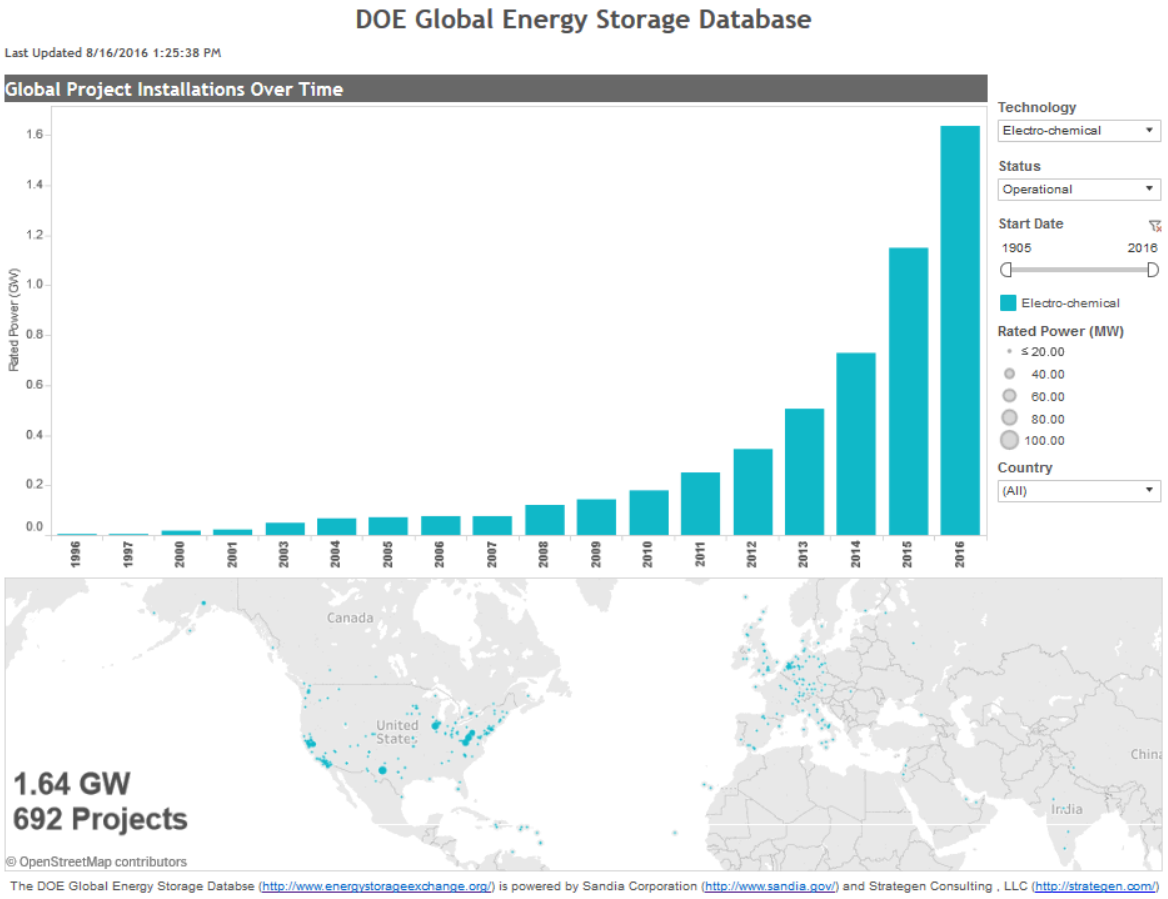
NNSA National Nuclear Security Administration

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Introduction

As an increasing number of energy storage systems are deployed, the risk of safety incidents increases.

Safety is Critical for the Wide Scale Deployment of Energy Storage Technologies

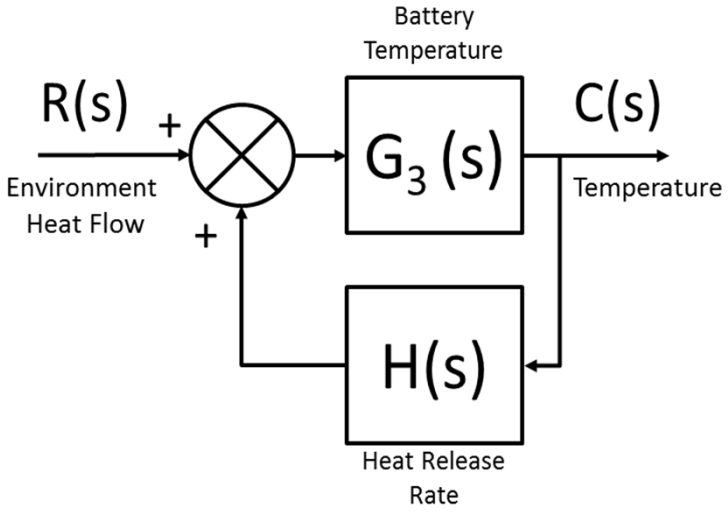


Electrochemical Storage Projects, world wide over time

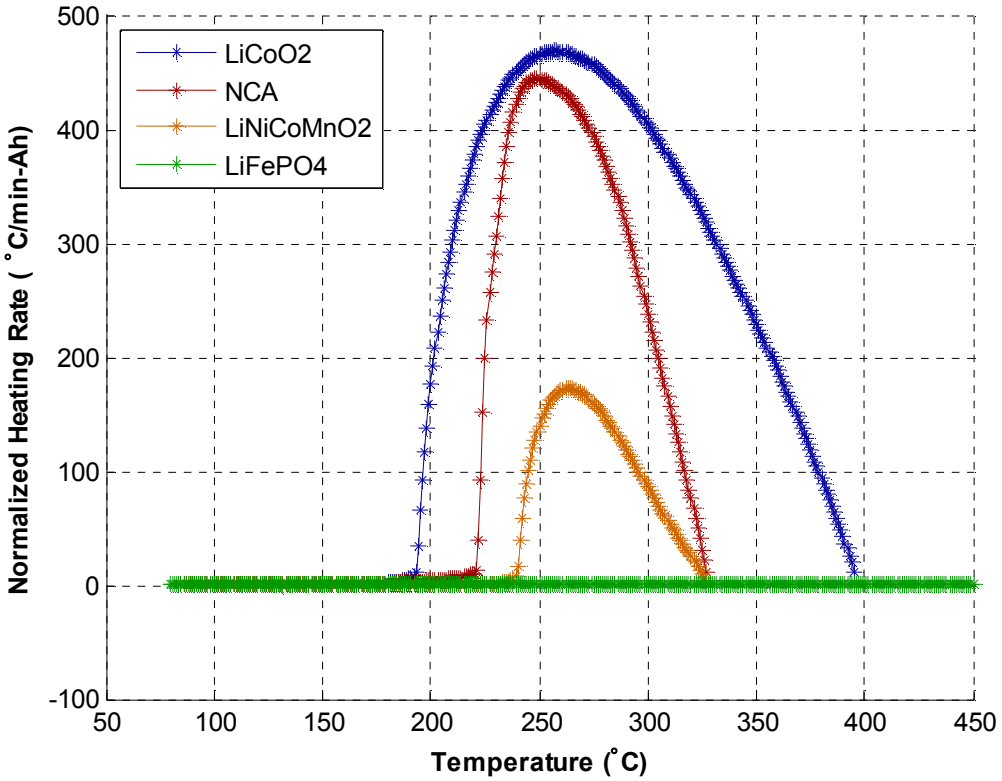
Source: DOE Energy Storage Global Database, Visualization by Tableau

Instability of Thermal Runaway

- Accelerating Rate Calorimetry (ARC)



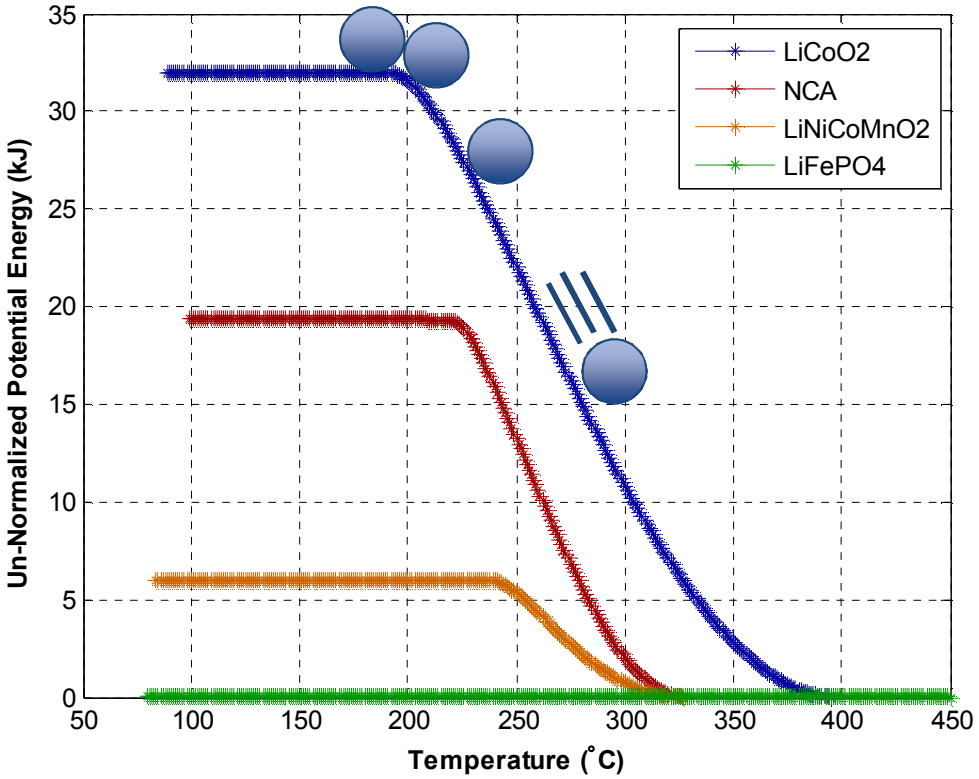
Positive Feedback Process



ARC Data collected by the Sandia BATLab

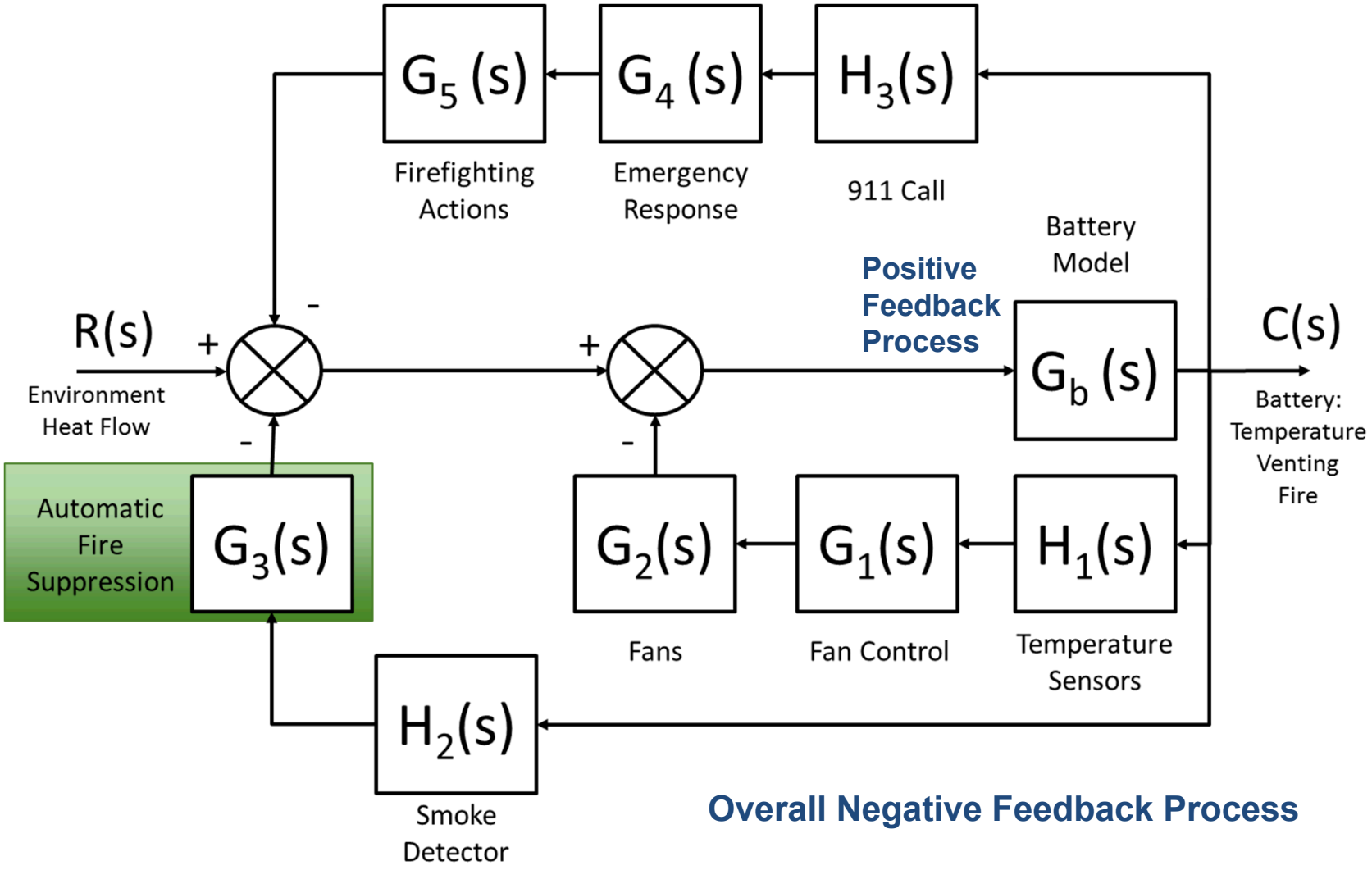
Heating Rate Analysis

- Below the critical temperature the reaction is non-spontaneous
- Above the critical temperature the reaction is spontaneous
- “Gibbs Free Energy” diagrams provide a useful visualization of thermal runaway phenomena



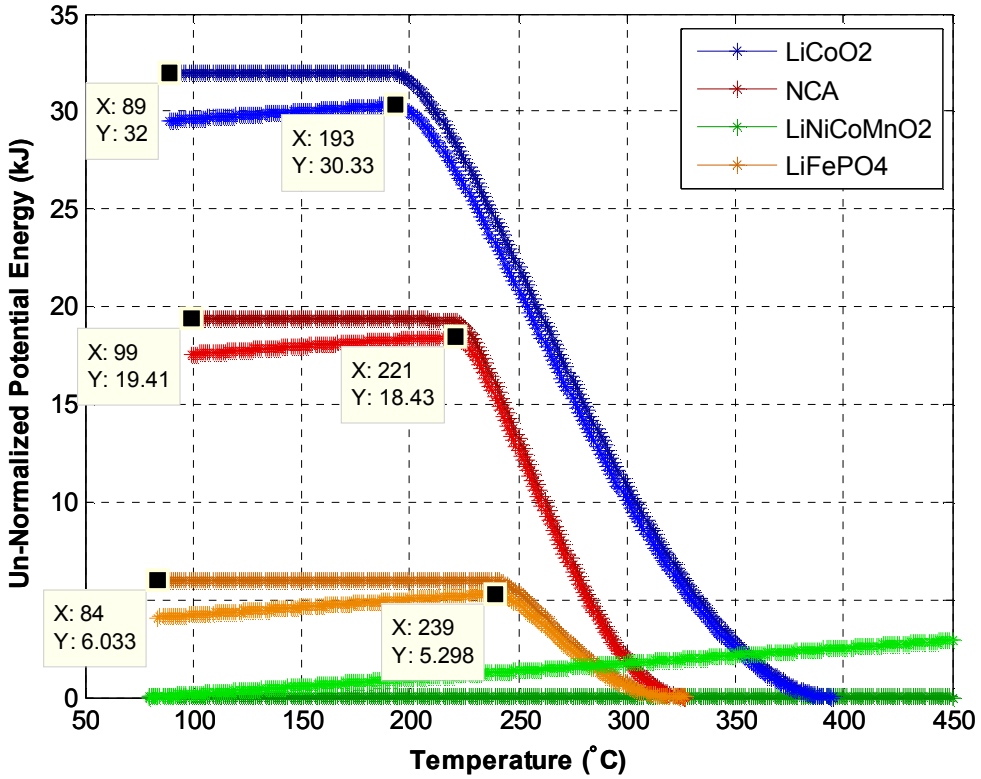
Integral of ARC Data collected by the Sandia BATLab

Feedback Control to Prevent Propagation



Heating Rate Analysis (w/ Fire Suppression)

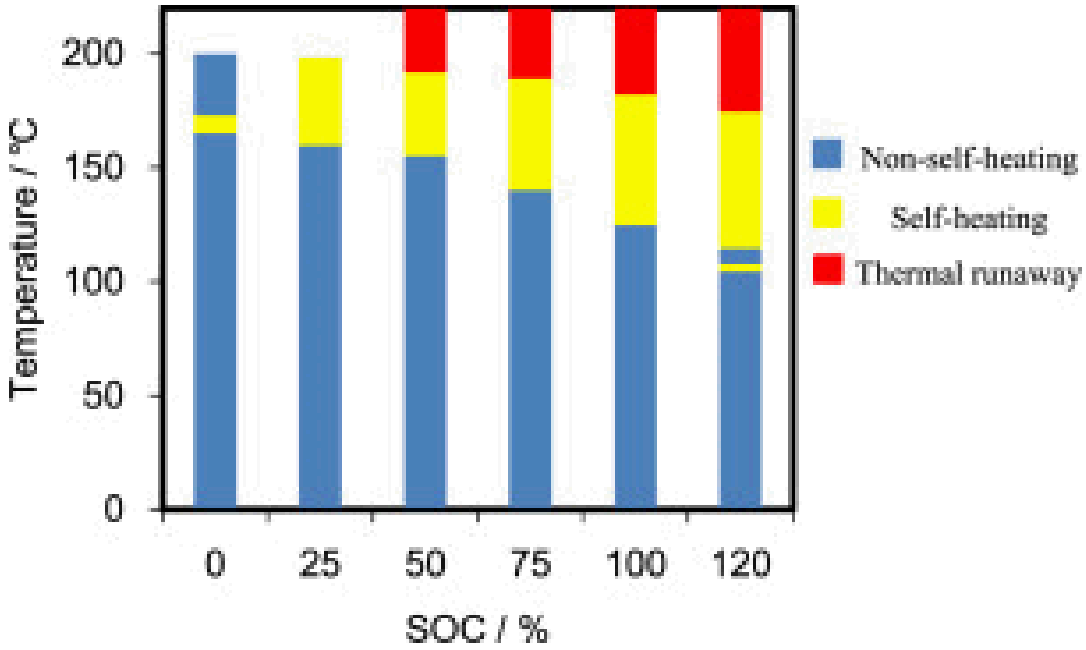
- Direct cooling raises the thermal runaway critical temperature
- Early action could (potentially) dissipate potential thermal energy before a fire
- Runaway reactions can temporarily exceed the ability of water to cool them



Effects of Fire Suppression on Thermal Stability

Thermal Runaway and SOC

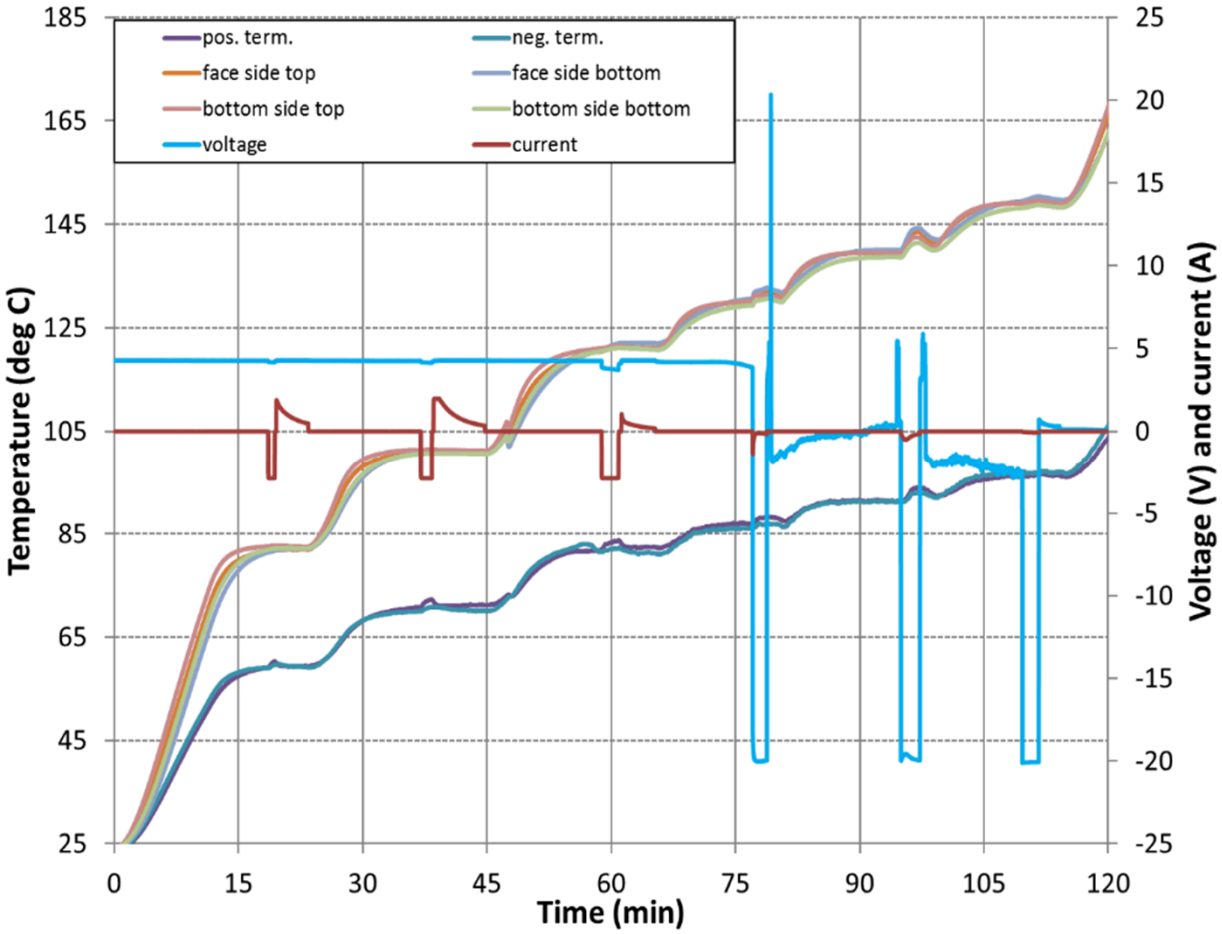
If SOC can be reduced, thermal runaway, may be avoided or abated.



Thermal mapping of LCO-Graphite cell as a function of SOC. Non-self-heating (blue), self-heating (yellow) and thermal runaway (red) regions are identified.

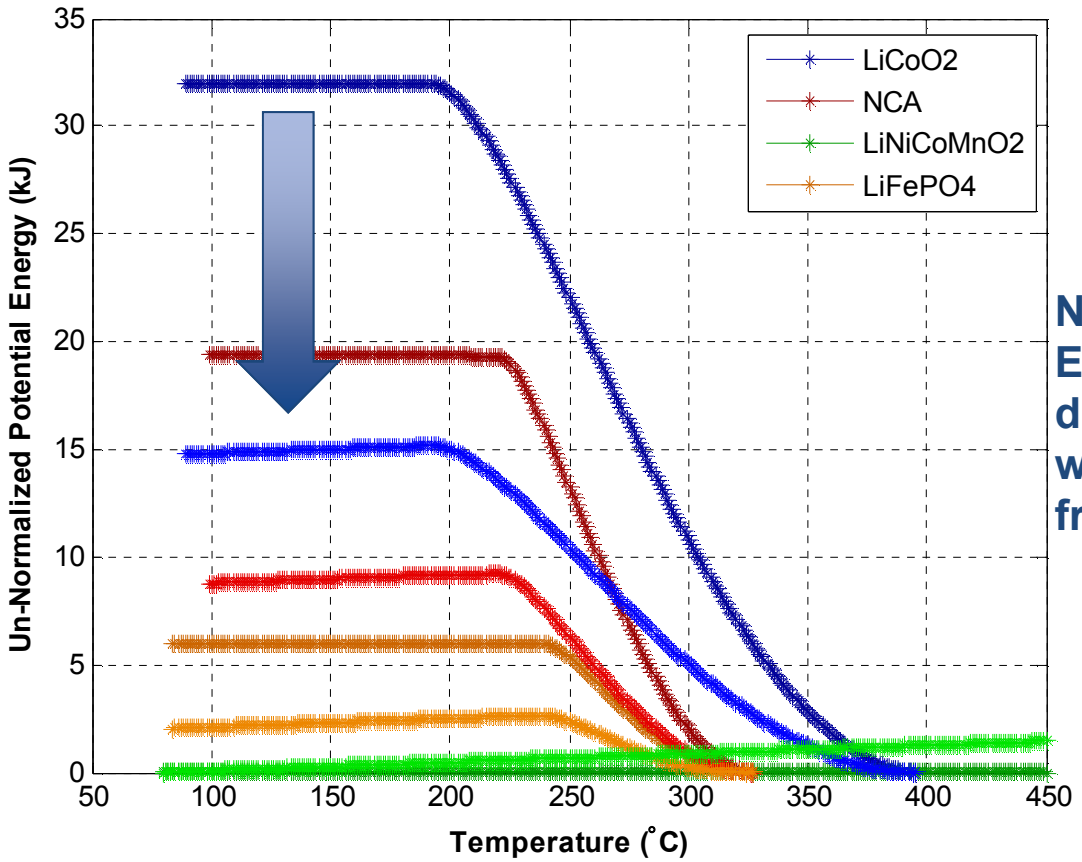
Graphic Source: Omar Samuel Mendoza-Hernandez, Hiroaki Ishikawa, Yuuki Nishikawa, Yuki Maruyama, Minoru Umeda, Cathode material comparison of thermal runaway behavior of Li-ion cells at different state of charges including over charge, Journal of Power Sources, Volume 280, 15 April 2015, Pages 499-504

Accessible Free Energy



Ability to sustain a discharge of a $LiCoO_2$ cell at abusive temperatures. The cell shows a reasonable ability to sustain discharge up to 120 °C but above that temperature the cell becomes increasingly resistive.

Heating Rate Analysis (w/ Discharge)



Notional Example of how discharge would effect the free energy

Discharging the cells can increase the margin to safely dissipate the free energy from surrounding cells and hence suppress thermal runaway propotation

Conclusions

- Sandia is conducting foundational research on energy storage safety
- Our experimental observations have implications for cell, module and system design
- This work could lead to a new class of safety systems for stationary batteries

Thank You to the DOE OE and especially Dr. Gyuk for his dedication and support of work to ensure the safe integration of energy storage to the electric grid

Questions?

David Rosewater
dmrose@sandia.gov
(505) 844-3722

References

[1] Nancy Leveson, 2012, Engineering a Safer World: System's Theory Applied to Safety, MIT Press, Cambridge, MA

[2] David Rosewater, Adam Williams "Analyzing system safety in lithium-ion grid energy storage" Power Sources, 300, p460-461, December, 2015

[3] Omar Samuel Mendoza-Hernandez, Hiroaki Ishikawa, Yuuki Nishikawa, Yuki Maruyama, Minoru Umeda, Cathode material comparison of thermal runaway behavior of Li-ion cells at different state of charges including over charge, Journal of Power Sources, Volume 280, 15 April 2015, Pages 499-504