SAND2019-5865C

Scaling Accelerating Rate Calorimetry Results

PRESENTED BY

Joshua Lamb, Loraine Torres-Castro, June Stanley, Mohan Karulkar, Chris Grosso, Lucas Gray and Randy Poirier

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

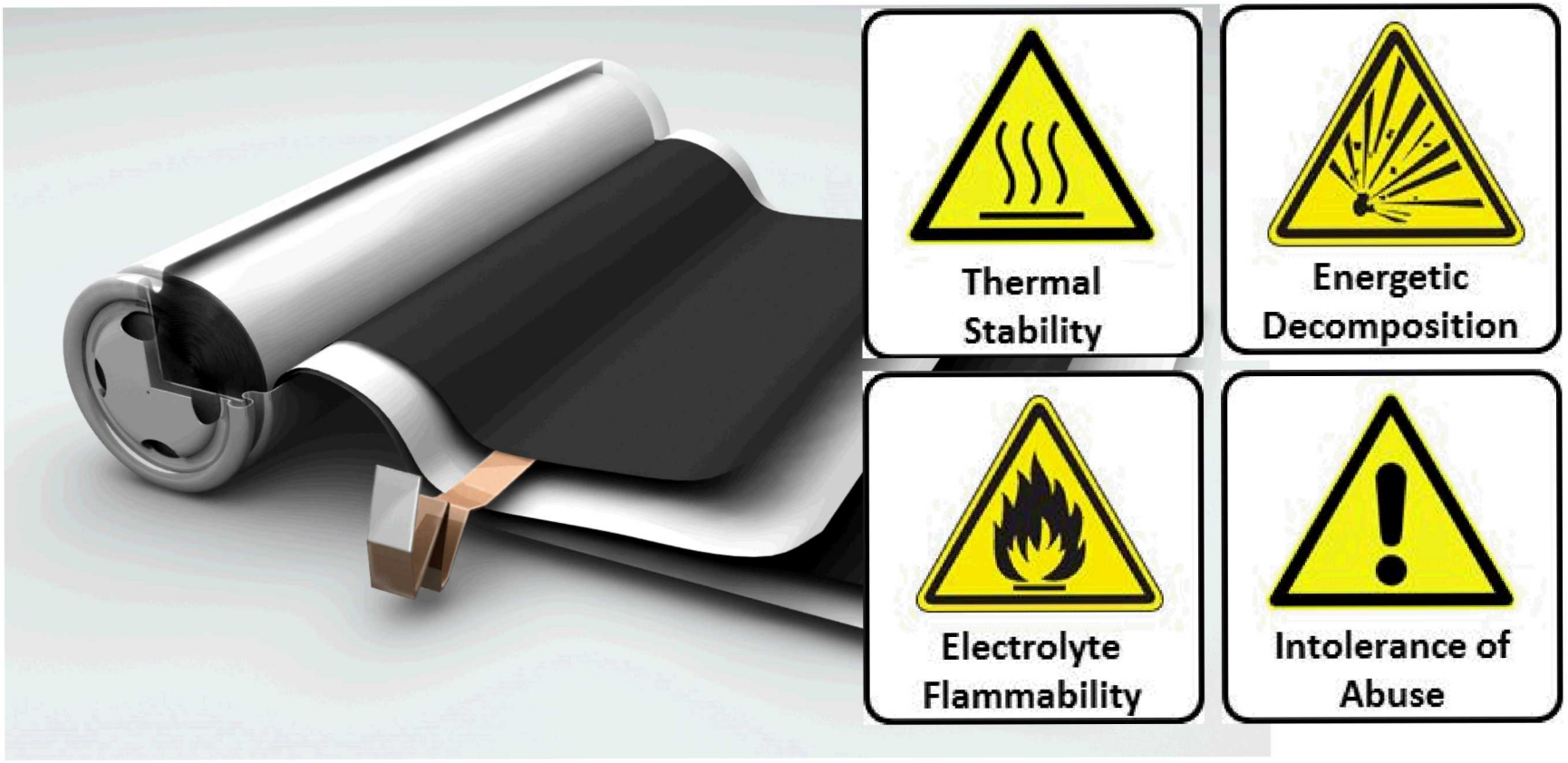
Approach and Capabilities

Cell and Module Testing
Battery Abuse Testing Laboratory (BATLab)

Battery Pack/System Testing
Thermal Test Complex (TTC) and Burnsite

Battery Calorimetry

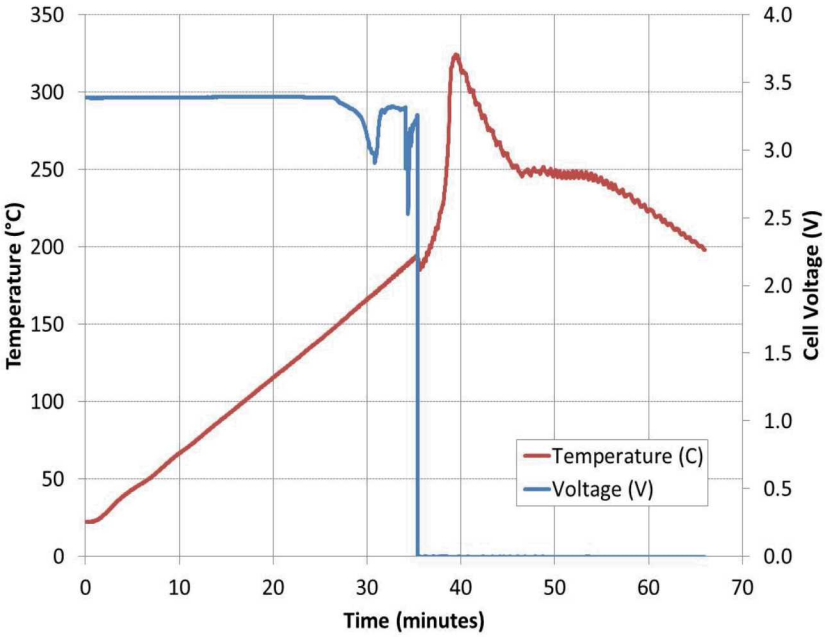
Lithium-ion Safety Issues



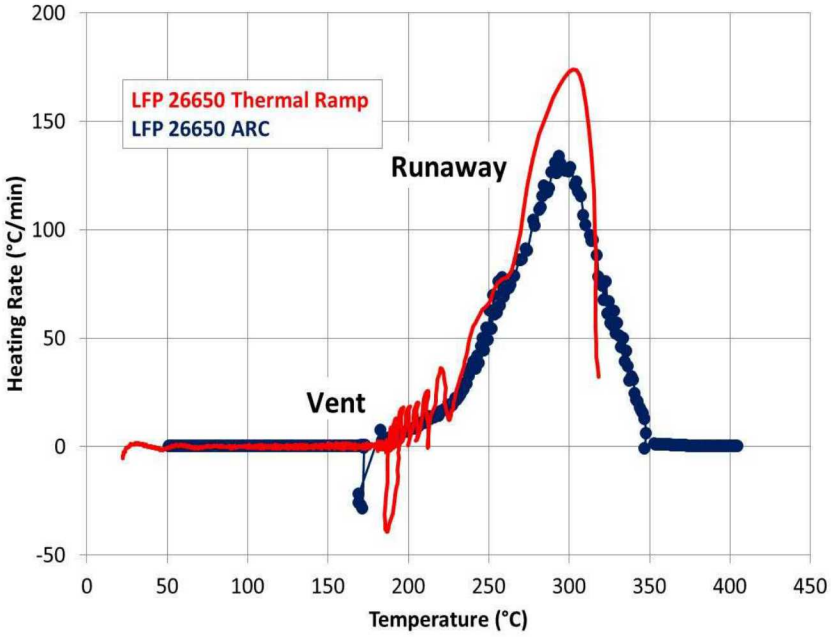
Testing program aimed at understanding and improving abuse tolerance of energy storage systems

Characterizing Thermal Runaway

Thermal Ramp

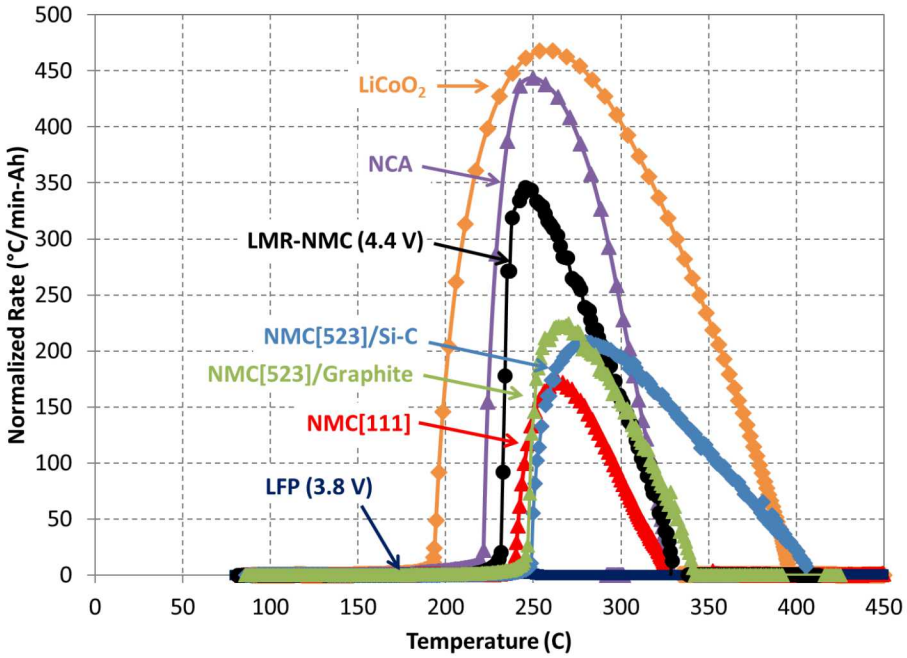


Thermal Ramp + ARC



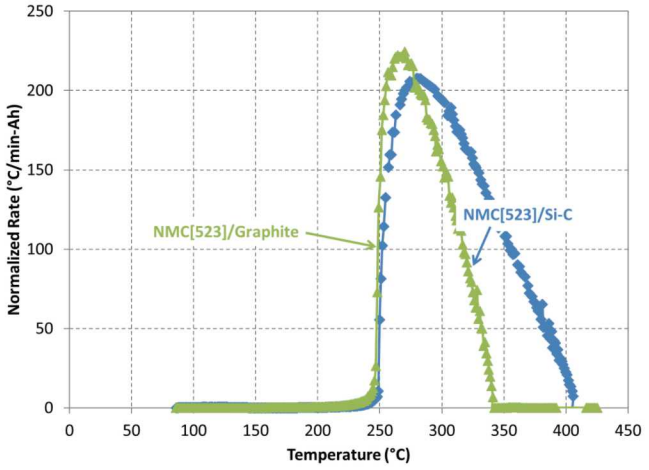
- Consistent cell behavior between thermal abuse and calorimetry experiments.
- Greater total temperature rise observed for the ARC experiment because it is an adiabatic environment.
- May be able to use these data to compare results obtained between the two types of experiments.

Characterizing new materials

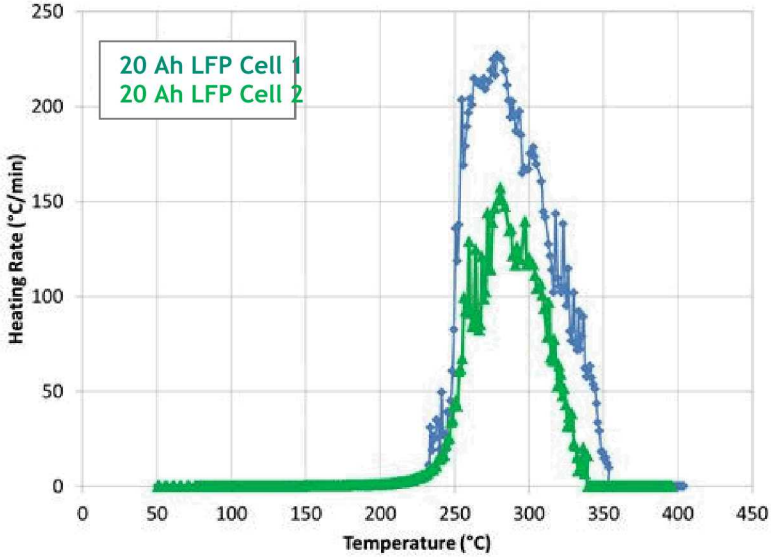


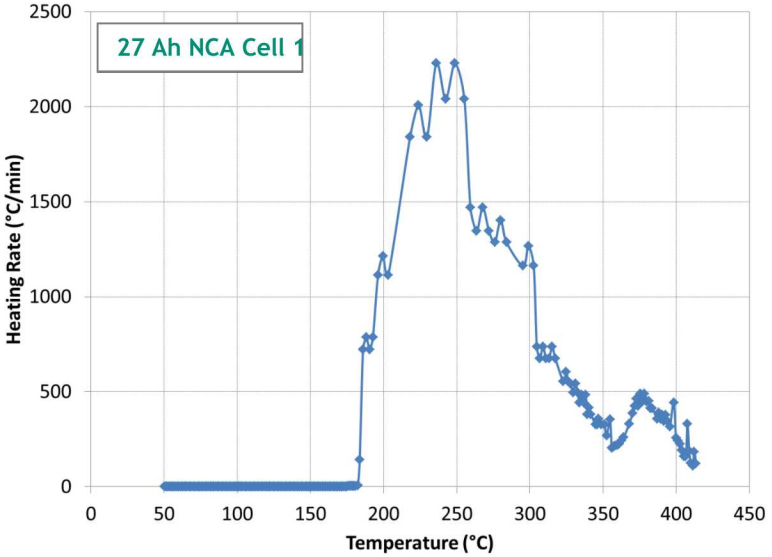
- Accelerating rate calorimetry shows the behavior of various chemistries.
- This gives information about peak heating rates and total energy of the thermal runaway.
- Newer materials such as LFP provide significantly reduced thermal runaway intensities, but have limited energy density.

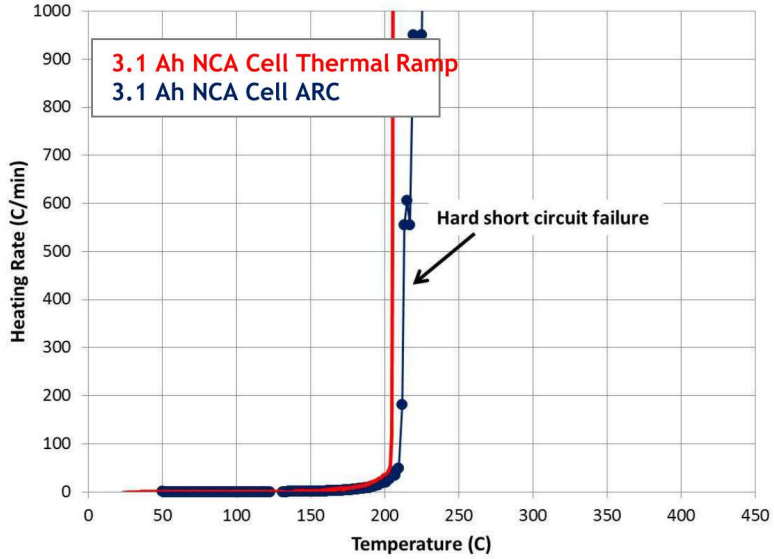
- ARC has been a powerful tool in performing these evaluations of new materials
- However, all work is generally performed on 18650 cells, how results change as we scale cell size?

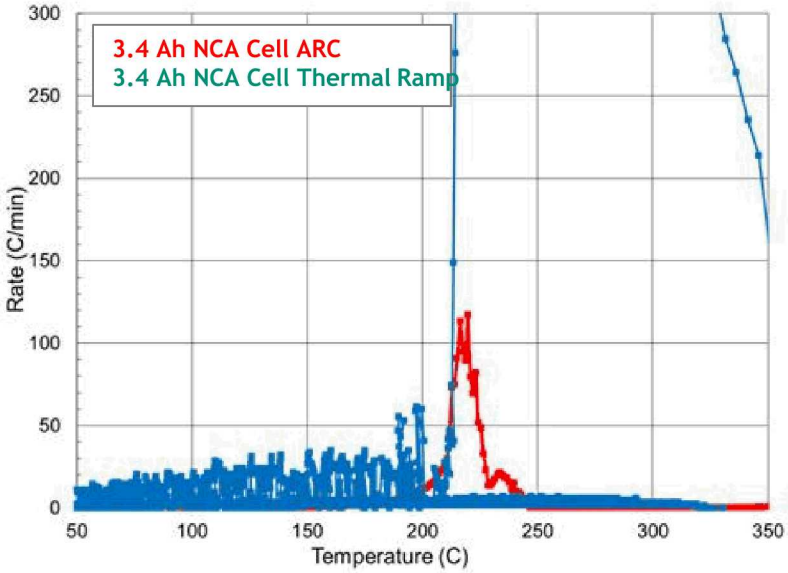


Selected NCA and LFP Results

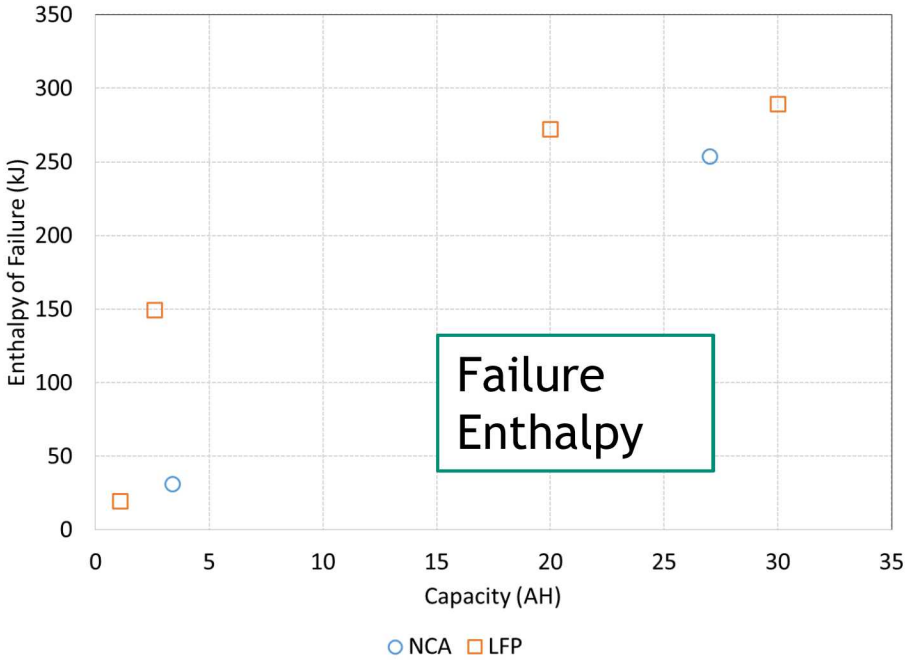


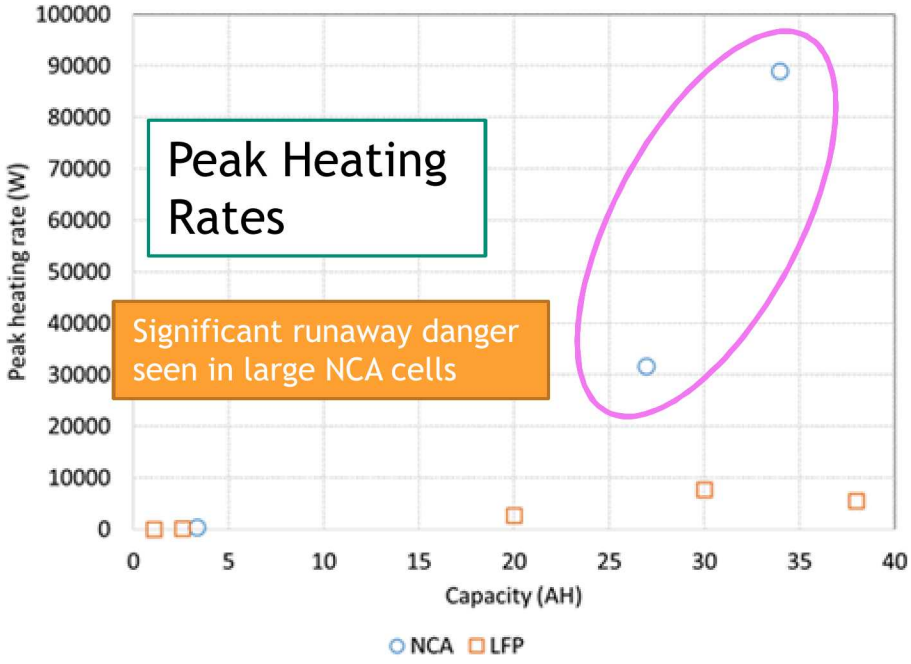






Cell Size and Thermal Runaway

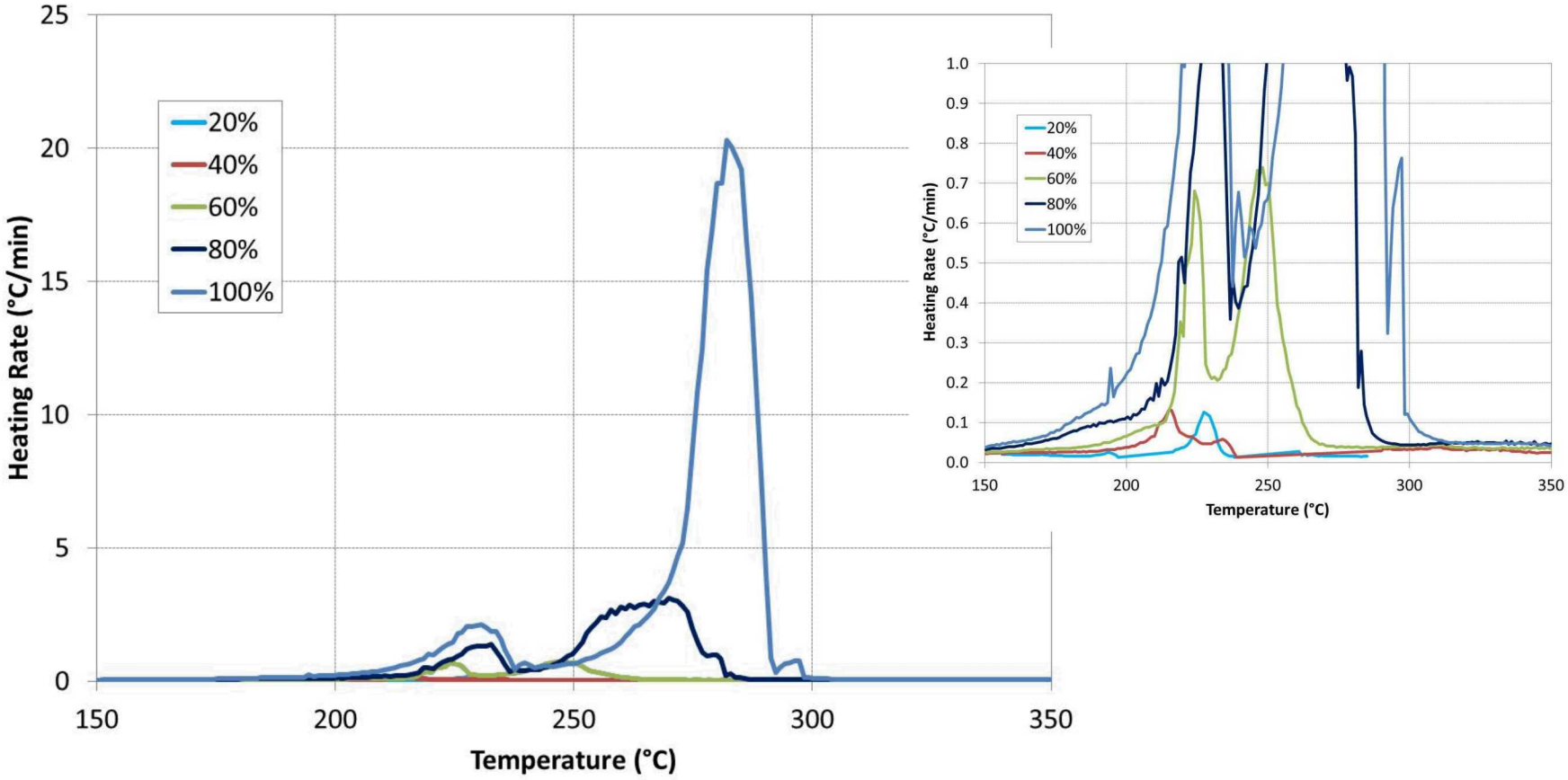




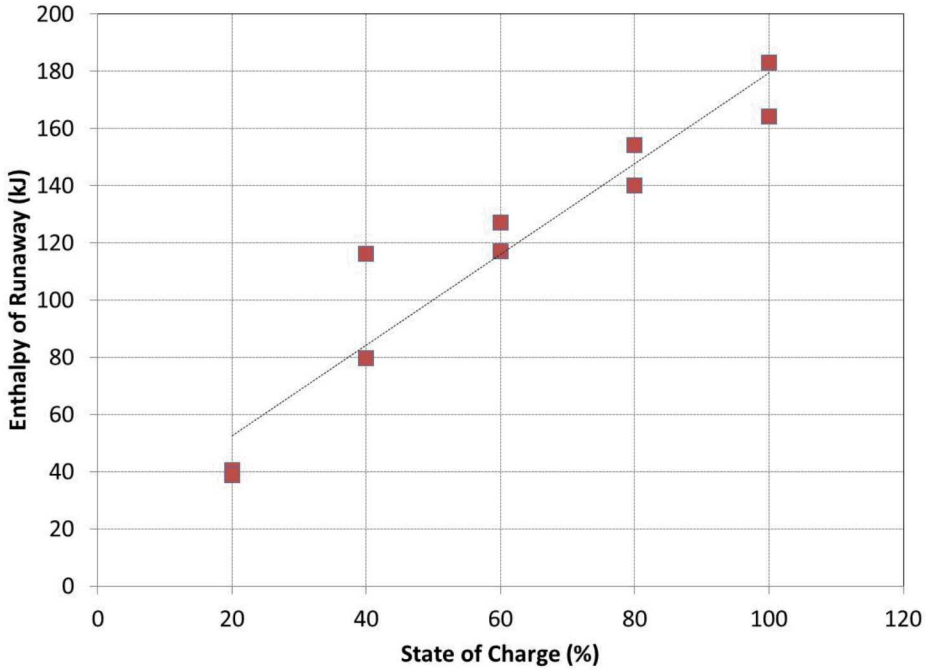
- **Enthalpy scales generally linearly with size, and is similar for both chemistries – This early data suggests that failure enthalpy is largely tied to the available stored energy**
- **Peak heating rates significantly higher for large NCA cells**
- **High peak heating rates are generally thought to carry a higher thermal runaway risk, but what is the impact when significant energy is available in numerous smaller cells?**

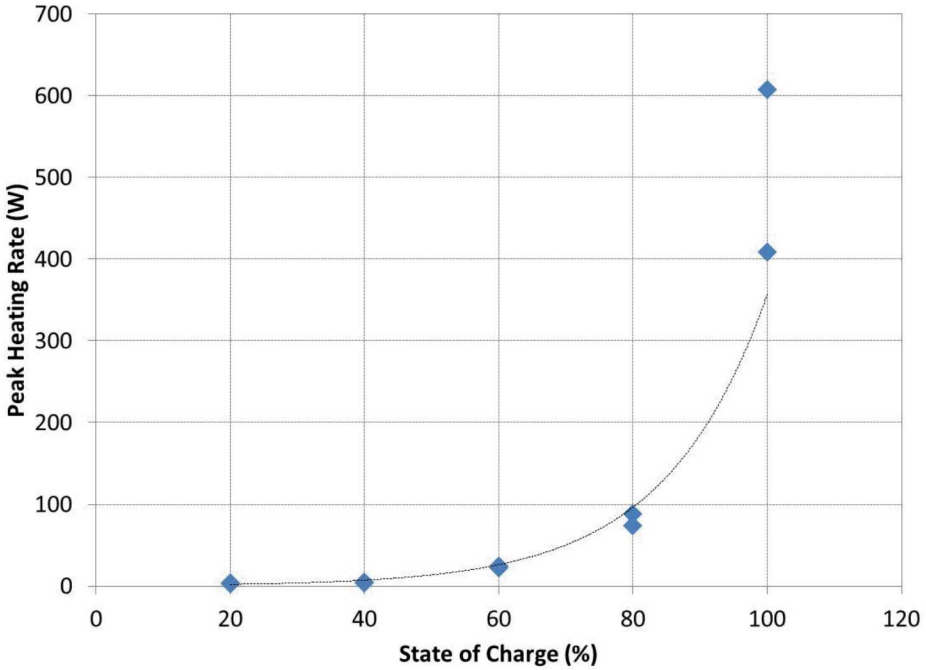
SOC and Thermal Runaway

- 16 Ah automotive (PHEV) pouch cells (mixed $LiMn_2O_4$ spinel)
- Significant impact can be easily observed above 60% SOC, very low rate self heating below that



Impact of SOC on Runaway

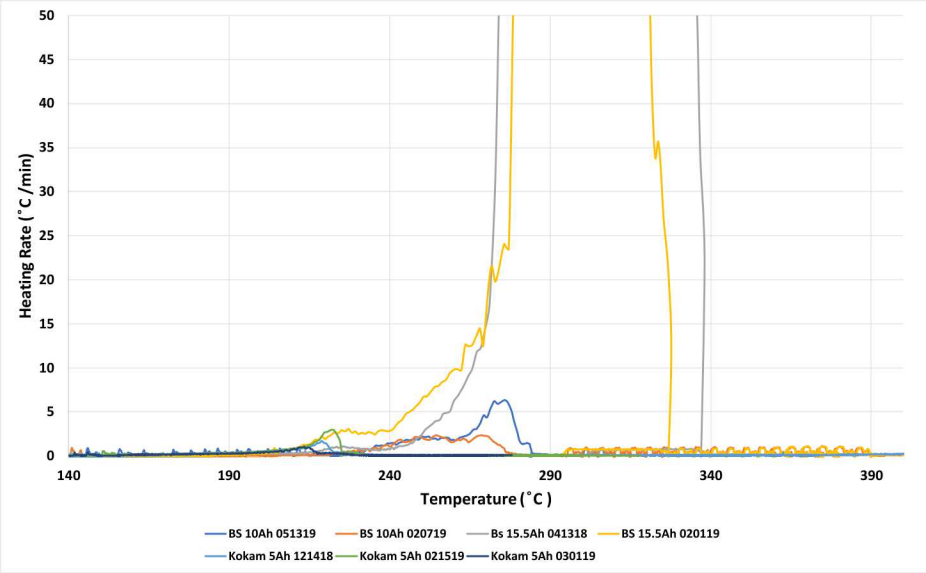




- **Results show a nearly linear relationship between total heat release (kJ) and cell SOC – similar to data for cell size this suggests that failure enthalpy is based largely on the stored energy available**
- **Heat release rates (e.g. runaway reaction kinetics) follow an almost exponential relationship with cell SOC – again this is traditionally thought to cause a greater risk of thermal runaway**
- **Could a runaway still occur with large numbers of low SOC cells or cells in well insulated conditions?**

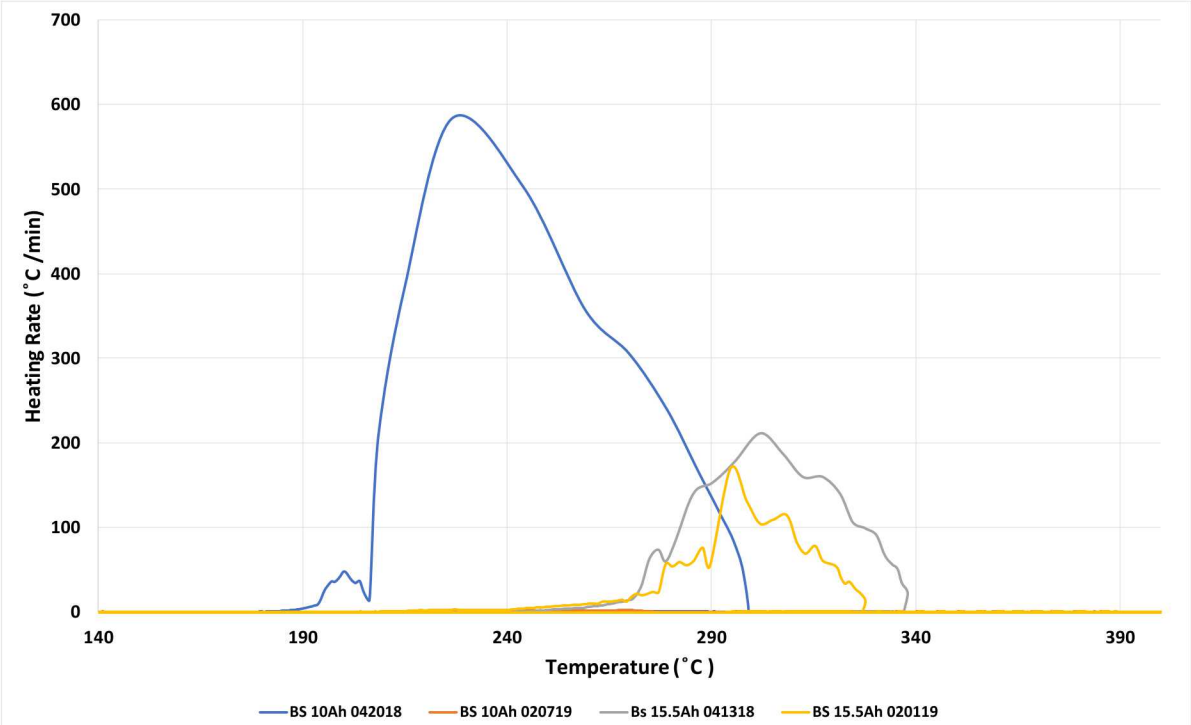
Scaling of NMC cells

Battery	Onset Temp (C)	Max Heating Rate (kW)	Total Enthalpy (kJ)
NMC 5 AH	170	0.22	225
NMC 5 AH	150	0.42	155
NMC 5 AH	170	0.22	225
NMC 10Ah	208	9	148
NMC 10Ah	215	0.34	165
NMC 10Ah	225	10	117
NMC 15.5Ah	243	3	189
NMC 15.5Ah	242	3	193



- NMC cells tested from two different cell suppliers
- 10 AH cells present a potential outlier

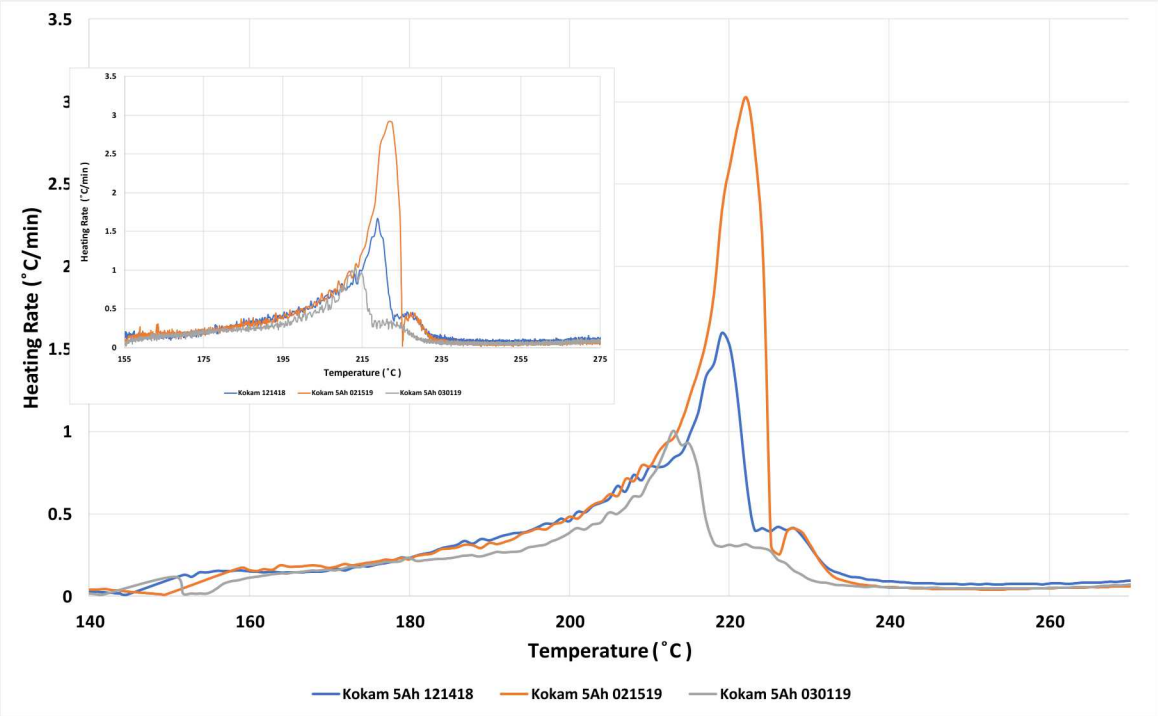
Scaling of NMC cells



- **Some signs of increased variance seen in 10 AH pouch cells.**
- **This indicates that some level of ARC response is being heavily impacted by cell construction variance**

Exploring Variance in Larger Scale ARC Tests

Test No	Onset Temp (˚C)	Max Heating Rate (kW)	Total Enthalpy (kJ)
1	170	0.22	225
2	150	0.42	155
3	155	0.14	128



- Further exploration of the variance within one manufacturer
- Generally low heating rates observed, but some variance in peak heating rates in particular

Summary

- Data collected so far suggests that while the intensity of a single cell failure is highly dependent on cell size, chemistry and state of charge, the total energy of a failure is largely only dependent on the stored energy
- This distinction is of greater consequence as more energy is made available, demonstrated here by adding multiple cells to a single system
- Future questions include how do equivalent energies but different numbers of cells compare (i.e. one 50 Ah cell vs. 5 10 Ah cells) and how large amounts of stored energy might impact a system even at low states of charge
- Pouch cells have exhibited more signs of variance than have been previously seen with COTS 18650 cells, potentially complicating analysis
- Production of pouch cells is highly non-standardized, leading to significant variance between manufacturers

Acknowledgements

DOE/VTO
- Dave Howell
- Samm Gillard
- Brian Cunningham

DOT/NHTSA
- Phil Gorney
- Steve Summers