DGP/28-IP/9
22/11/21

DANGEROUS GOODS PANEL (DGP)

TWENTY-EIGHTH MEETING

Virtual, 15 to 19 November 2021

Agenda Item 4: Managing safety risks posed by the carriage of lithium batteries by air ***(Ref: Job Card DGP.003.03)***

BATTERY PACKAGING CONFIGURATION TESTS

(Presented by the Secretary)

SUMMARY

This information paper includes the presentation given to DGP/28 on battery packaging configuration tests

— — — — — — — —

Battery Packaging Configuration SAE-G27 Tests

Tapesh Joshi, PhD

Judy Jeevarajan, PhD

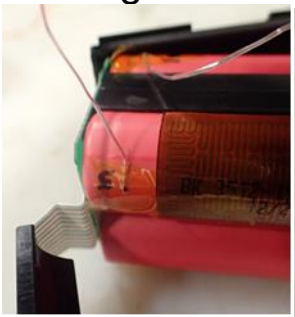
Electrochemical Safety Research Institute

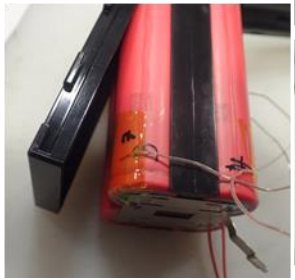
November 2021

Empowering Trust®

SAE- G27 Thermal Runaway Propagation - Battery Test Packaging Configuration

Battery Capacity: 4900 mAh
4 18650 cells; 2P2S
Heating rate: 10 °C/min





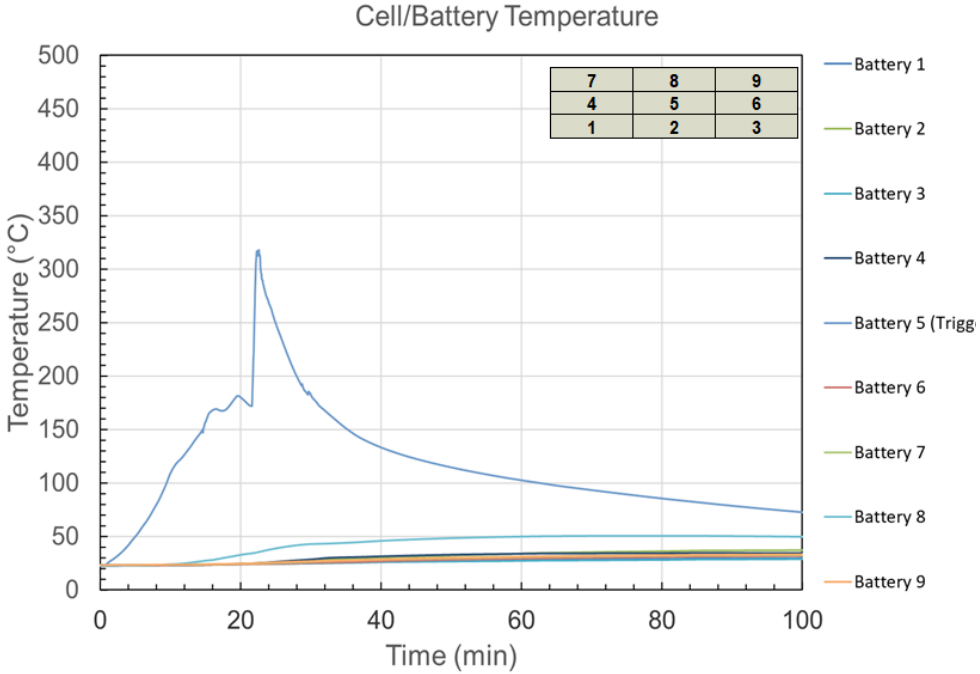
As received battery in shipping configuration

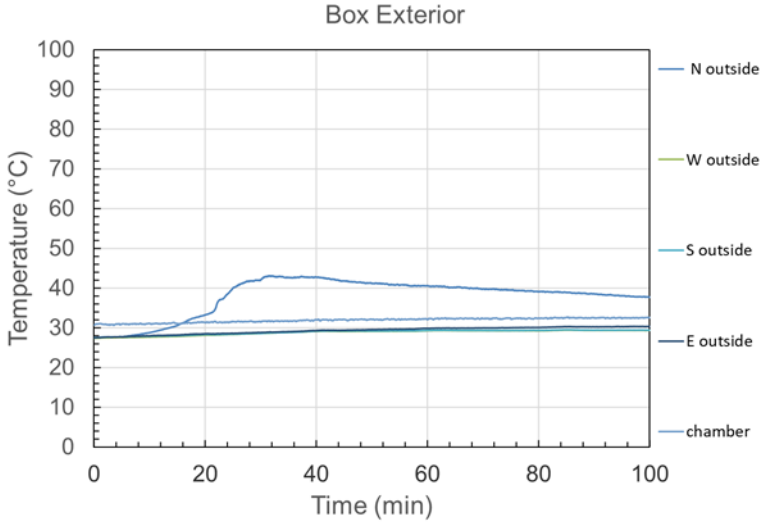
3x3 batteries with trigger battery in the center

Heater and T/C placement on cell in initiation battery; cell facing the circuit board is trigger cell

Battery model chosen based on extensive experience with this particular model.

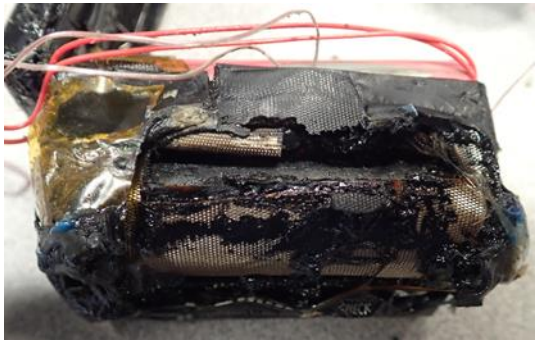
Battery Configuration 3X3 - 33 % SOC





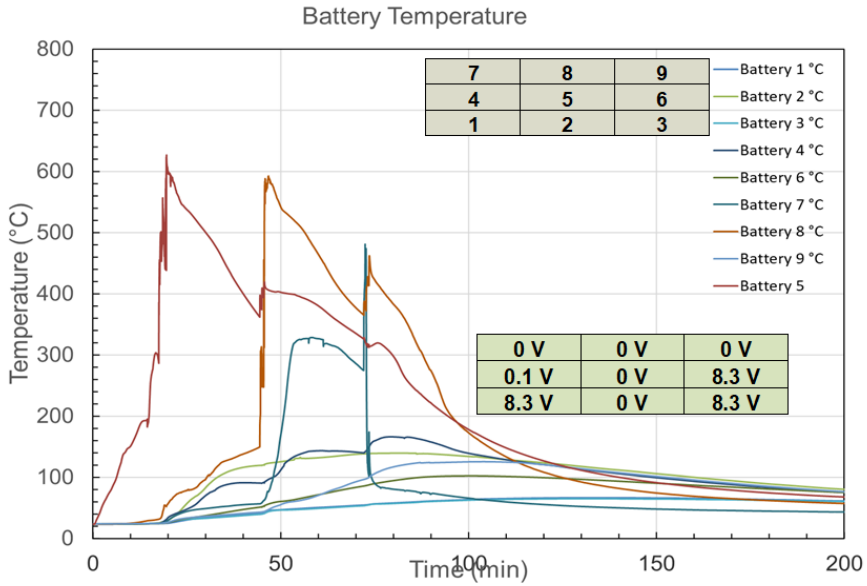
- No propagation of thermal runaway from trigger battery
- Box remained intact with exterior temperature below 45 °C

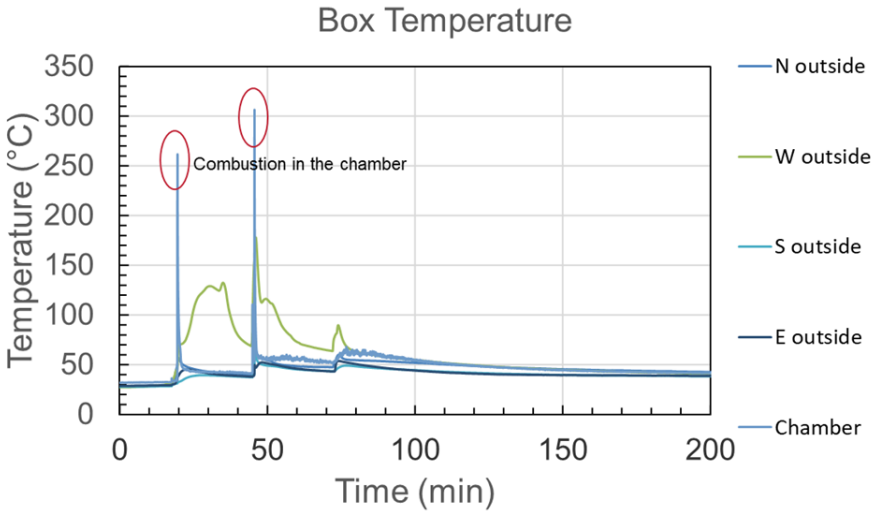
Battery Configuration 3X3 - 33 % SOC



- Box and batteries remained in place with no signs of visible damage
- All batteries besides the trigger battery maintained pre-test voltage
- Trigger battery showed melting of the casing and packaging plastic

Battery Configuration 3X3 - 100 % SOC





- Propagation of thermal runaway to two batteries on top row
- Each thermal runaway event was followed by gas release and subsequent combustion
  - There were three combustion events at 19:44, 45:09, and 45:49
  - Pressure relief panel did not open up. Setting for pressure relief panel is 0.25 psi
- Only 3 batteries maintained pre-test voltage after the test completion

Battery Configuration 3X3 - 100 % SOC

Flap opened during test
Multiple cells with contents ejected

Post-test battery voltage:

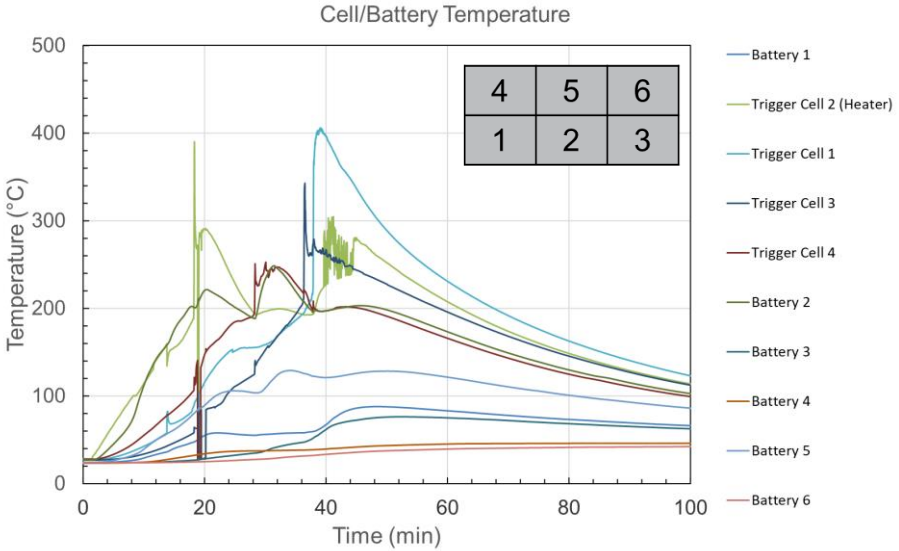
0 V	0 V	0 V
0.1 V	0 V	8.3 V
8.3 V	0 V	8.3 V

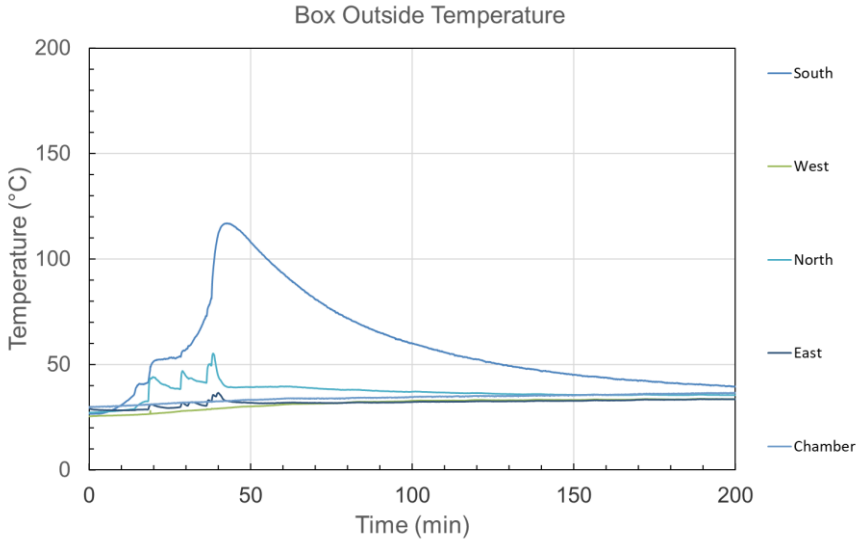
.08 V	1.17 V
2.88 V	.07 V

.58 V	0.79 V
0.3 V	.02 V

Battery package and casing burned/melted
Cell shrink-wrap (label) melted

Batteries - 3X2 Configuration–33 % SOC





- Propagation to all cells within trigger battery
- No propagation of thermal runaway from trigger battery
- Box remained intact with maximum exterior temperature below 120 °C

Battery Configuration 3X2 - 33 % SOC

Trigger Battery

Battery 5 (above trigger)

- Box and batteries remained in place with no signs of visible damage from the outside
- All batteries besides the trigger battery maintained pre-test voltage
- Trigger battery showed melting of the battery casing and bubble wrap

Charge Retention test on Li-ion Pouch Cells – Current Study

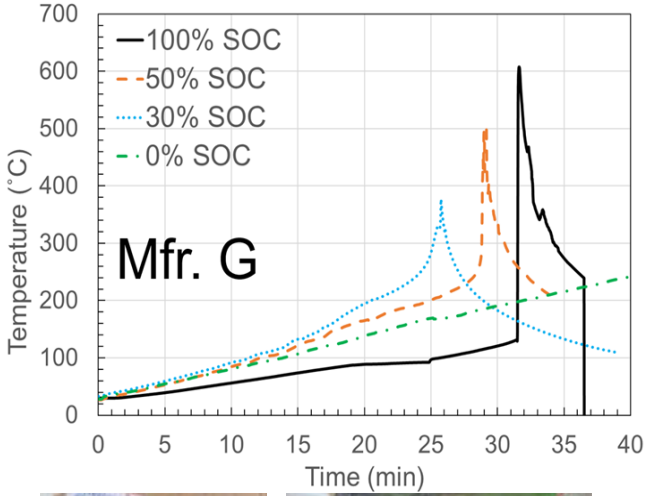
Day		0 SOC	10 SOC	30 SOC	50 SOC	75 SOC	100 SOC
1	Wed	3.2744	3.4883	3.7621	3.7877	3.9389	4.1686
2	Thur	3.2741	3.487	3.7622	3.7876	3.9382	4.1664
3	Fri	3.2741	3.487	3.7626	3.7876	3.9374	4.1638
6	Mon	3.2738	3.487	3.7625	3.7876	3.9366	4.1607
7	Tue	3.2736	3.487	3.7626	3.7876	3.9362	4.1597
8	Wed	3.273	3.4869	3.7621	3.7875	3.9361	4.1582
9	Thur	3.2729	3.4869	3.7621	3.7873	3.9351	4.1558
10	Fri	3.273	3.4867	3.7621	3.7873	3.9351	4.1545
13	Mon	3.2724	3.4865	3.7618	3.7871	3.9343	4.1524
14	Tue	3.2721	3.4865	3.7614	3.787	3.9336	4.1506
Change %		0.070242	0.051601	0.031893	0.018481	0.134555	0.4318
	Max	3.2744	3.4883	3.7626	3.7877	3.9389	4.1686

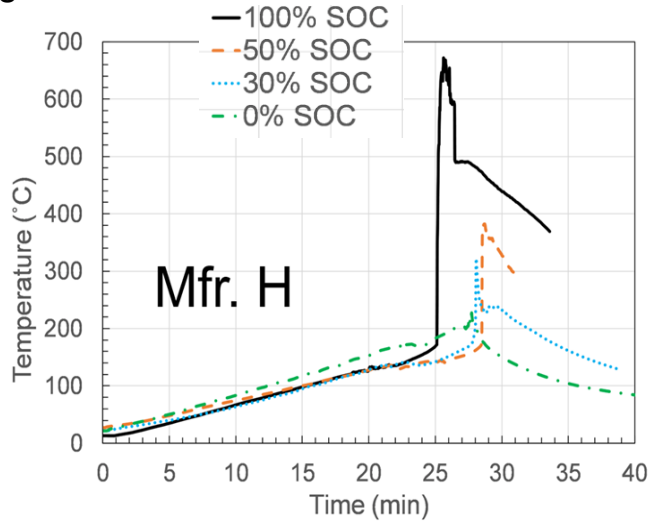
Study is part of a larger project on internal short simulation and characterization with Purdue Univ. Charge retention test will continue for 6 months.

Studies carried out in 2019/2020
SOC vs Safety

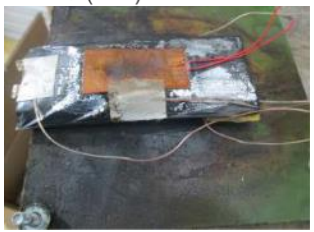
Battery Tests – SOC vs Safety – Heating Method

Single Batteries were tested; propagation in shipping containers was not studied

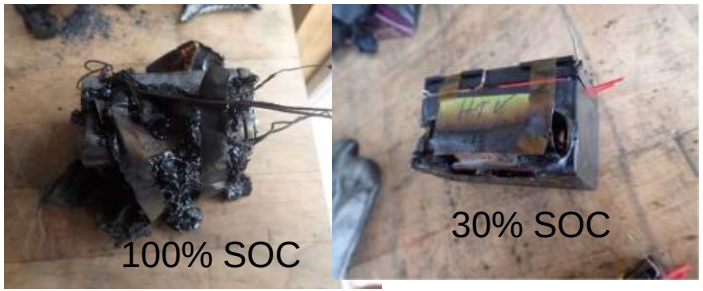




100% SOC



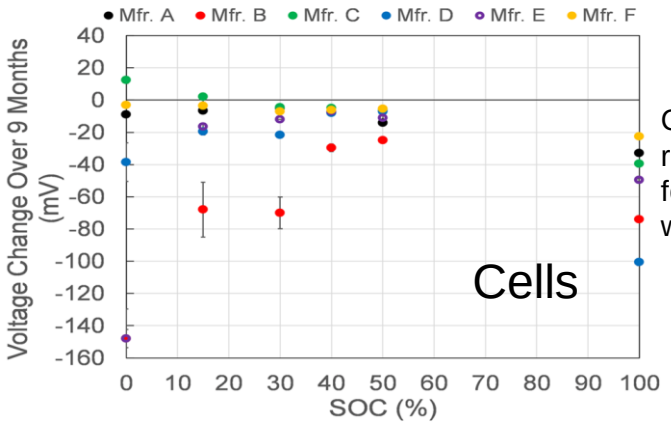
30% SOC



Joshi et al., *J. Electrochem. Soc*., 167, 140547 (2020)

Charge Retention at Different SOC for Cells and Batteries

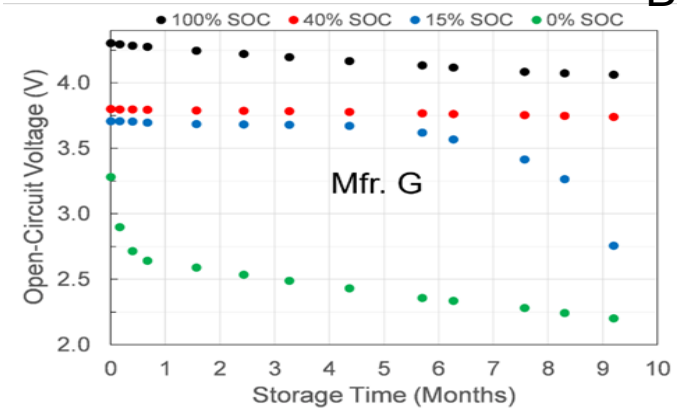
- Cells and batteries from all manufacturers were subjected to charge retention test to characterize self-discharge.
- Cells were stored in ambient temperature (controlled) at 6 different SOCs
  100%, 50%, 40%, 30%, 15%, and 0%
  2 samples are under test for each condition.
- OCV was recorded once every week for the first month and then once every month for up to 9 months.

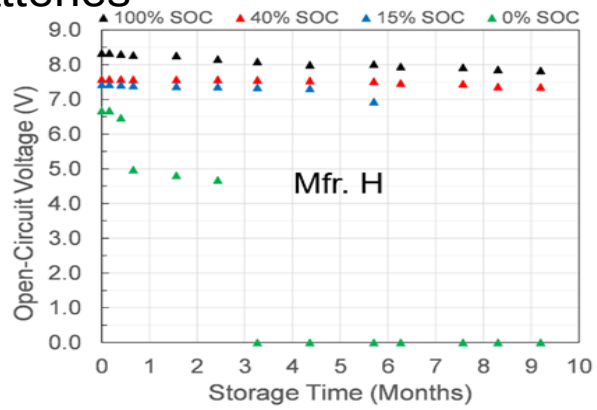


Changes were random only for Mfr.B which was low quality

Batteries

Battery voltage did not fall below 2 V in any of the SOC cases





Battery voltage unreadable after 2.5 months at lower SOC but resets itself when placed on charger at the end of 9 months of storage

Joshi et al., *J. Electrochem. Soc*., 167, 140547 (2020)

Electrochemical Safety Research Institute

Judy.Jeevarajan@ul.org
Tapesh.Joshi@ul.org