Transporting Batteries: Considerations for SOC, Cell Types, and Test Methods

Tapesh Joshi, Ph.D., Judith Jeevarajan, Ph.D.
Underwriters Laboratories, Inc.

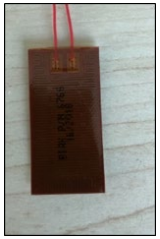
Empowering Trust®

Heating Test

- 40W Kapton heater was used to initiate thermal runaway
  1” x 2” – 20W/in^2 **or** 2” x 2” – 10W/in^2
- Heating rate was maintained at 10 ºF/min
- Cells were subjected to thermal runaway test at 6 different states-of-charge
  -100%, 50%, 40%, 30%, 15%, and 0%

Manufacturer	Cell Design	Cathode Chemistry	Rated Capacity (mAh)	Measured Capacity (mAh)	Internal Resistance (mΩ)
A	18650	NCA	3200	3230	45
B	18650	NCA	3200	1810	35
C	26650	NMC	5000	5030	19
D	Pouch 526495	NMC	3300	3180	18
E	26650	LFP	2500	2520	6
F	Pouch 8790160	LFP	10000	10400	8
G (Single cell Smart phone battery)	Single pouch cell with BMS	Unknown	2915	2770	57
H (2P2S Camcorder battery)	18650	Unknown	4900	4950	111

2” x 2” Kapton Tape Heater



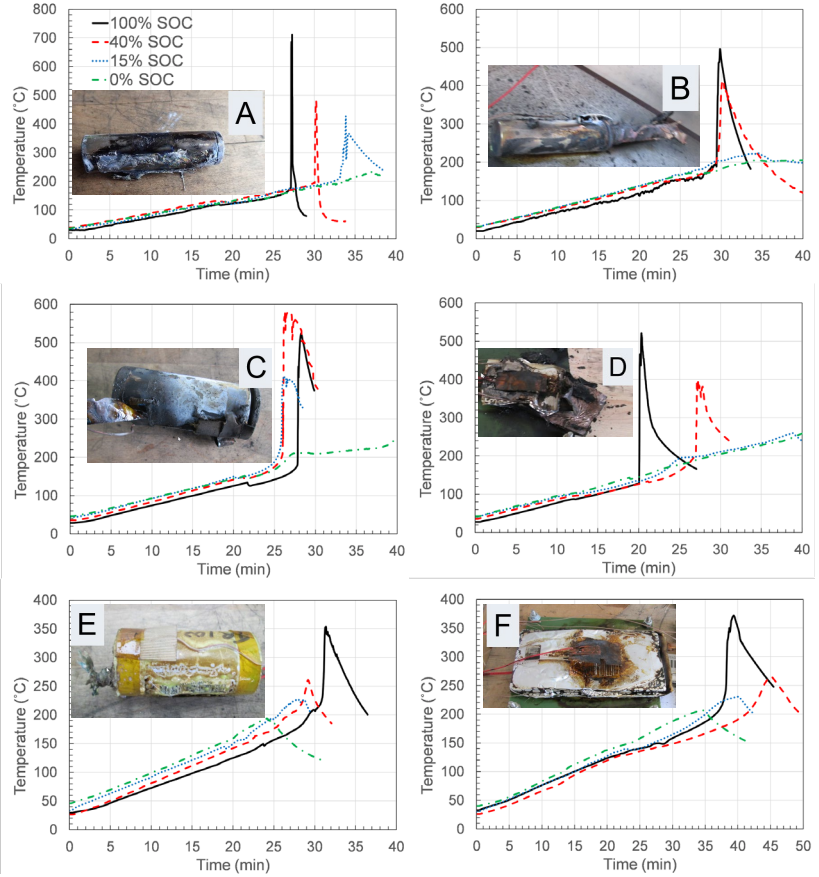
1” x 2” Kapton Tape Heater

https://doi.org/10.1149/1945-7111/abc8c4

Heating Test

- **Venting temperature**
  - Most of the cells followed similar trends, where temperature at which venting occurs increases (↑) as SOC goes down (↓)
  - Except for Manufacturer D, E, and F (LFP & Pouch) – venting temperature is around the same value
- **Thermal runaway onset temperature**
  - Onset temperature increases (↑) as SOC goes down (↓) except for manufacturer B (low-cost cells)
- Electrolyte leakage observed for all Manufacturers at all SOCs, except for Manufacturer B (no correlation) , and D (only low SOCs)

Cell Type	% SOC						Trends
	100	50	40	30	15	0	SOC ↓
A – 18650 **NCA**	TR, Fire, Smoke	TR, Fire, Smoke	TR, Fire, Smoke	TR, Fire, Smoke	Mild TR, Smoke	-	Venting T (↑) Onset T (↑) Max T (↓)
B- 18650 **NCA**	TR, Fire, Smoke	TR, Smoke	TR, Smoke	TR, Smoke	-	-	Venting (same) Onset T (no correlation) Max T (↓)
C – 26650 **NMC**	TR, Fire, Smoke	TR, Fire, Smoke	TR, Smoke	TR, Smoke	TR, Smoke		Venting T (↑) Onset T (↑) Max T (↓)
D – Pouch **NMC**	TR, Fire, Smoke	TR, Smoke	TR, Smoke	-	-	-	Venting T(same) Onset T (↑) Max T (↓)
E – 26650 **LFP**	TR, Smoke	TR, Smoke	TR, Smoke	-	-	-	Venting T(same) Onset T (↑) Max T (↓)
F – Pouch **LFP**	TR, Smoke	-	-	-	-	-	Venting T(same) Onset T (↑) Max T (↓)

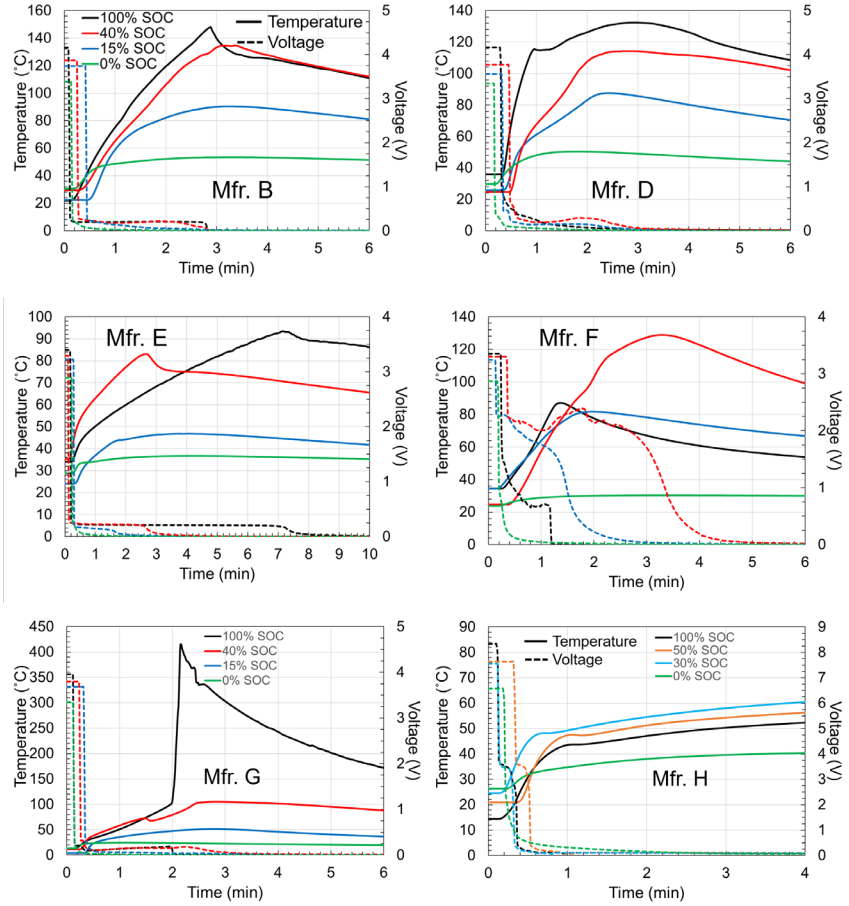


https://doi.org/10.1149/1945-7111/abc8c4

External Short Test

- External short was carried out on cells that do not contain the internal PTC device. This includes low quality cells, pouch format, and LFP cells.
- The load was held for 3 hours, or until thermal runaway.
- Load used for the short was 8-10 mohms.

- Thermal runaway observed in 100% SOC for manufacturers B and G.
- Melting tab prevented hazards in some cases (fail-safe conditions).
- BMS provided protection against external short for batteries and were removed for tests.
- Protection against external shorts was provided through BMS in batteries and PTC in cells for manufacturer H.



https://doi.org/10.1149/1945-7111/abc8c4

Tapesh Joshi, Ph.D.
tapesh.joshi@ul.org