



Methods for Thermal Runaway Validation of Aviation Batteries

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Methods for Thermal Runaway Validation of Aviation Batteries

Outline

- ◇ Introduction- DO 311A Standard
- ◇ Thermal Runaway Analysis Methodology
- ◇ Samsung 30Q Results
 - ◇ Cell
 - ◇ Module
- ◇ Eagle Picher: Standard Flammability Electrolyte versus Reduced Flammability Electrolyte
 - ◇ Cell
 - ◇ Module
- ◇ Summary



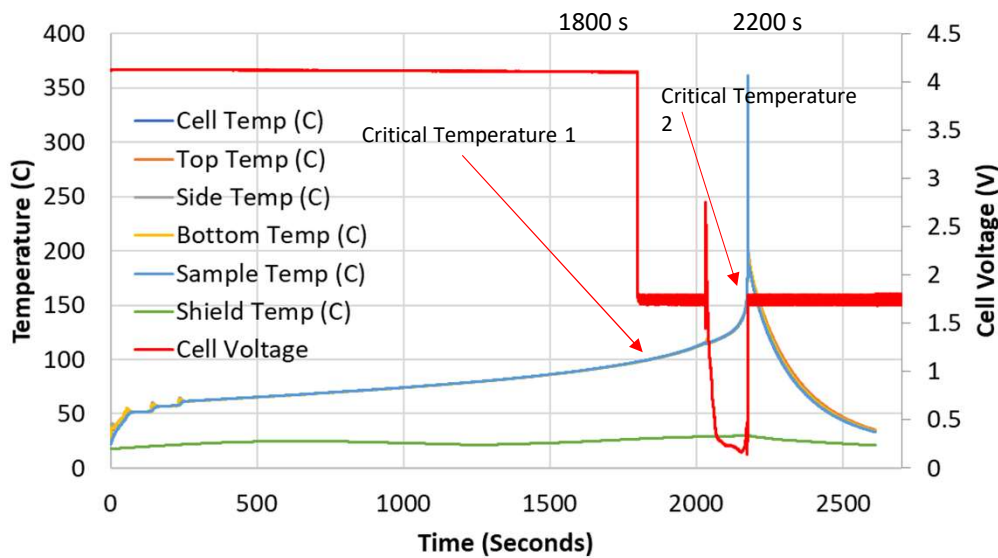
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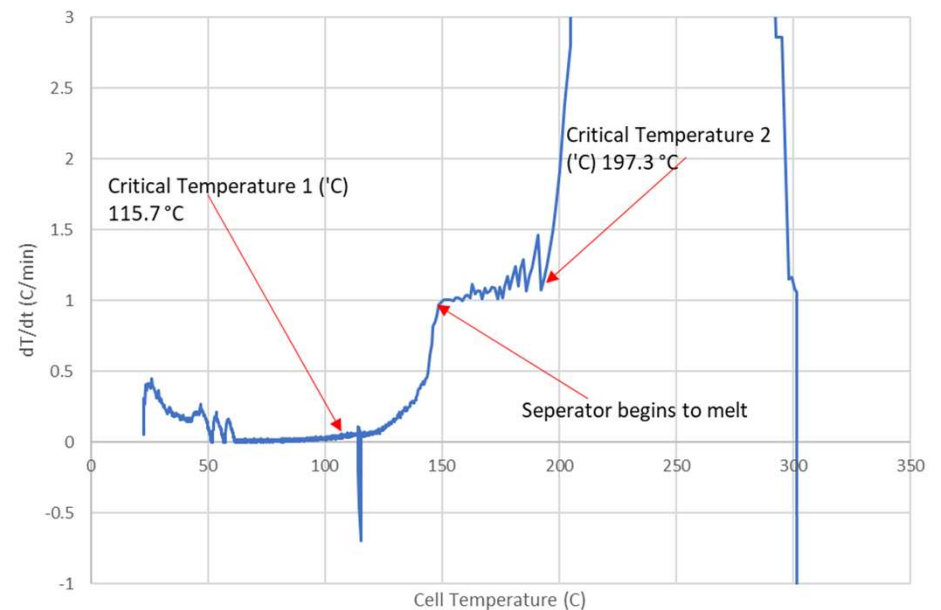
- Aviation rechargeable lithium-ion battery safety is governed by RTCA DO-311A for
FAA certification
- Thermal runaway testing (DO-311A) was developed to assure passenger safety through battery containment
- To facilitate certification, the testing and design aspects proceed as follows:
 - Cell level
 - Module level
 - System level

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Cell Temperature & Voltage vs Time



Temperature vs dT/dt



Critical Temp 1: Solid Electrolyte Interface Decomposition

Critical Temp 2: Full Thermal Runaway Event

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Results from 10- TR test on Samsung 30Q cells

	Maximum Temperature (°C)	Initiation Temperature (°C)	Energy Released (kJ)	Mass Lost (gm)	Jellyroll Ejection
Cell 1	377.3	200.9	14.0	31.8	No
Cell 2	358.0	188.9	13.2	26.4	No
Cell 3	400.5	194.8	30.0	37.0	Yes
Cell 4	302.7	197.3	22.1	37.1	Yes
Cell 5	428.4	194.1	32.2	36.6	Yes
Cell 6	462.7	187.7	34.3	32.4	No
Cell 7	410.1	195.8	30.8	36.8	Yes
Cell 8	325.8	201.4	23.9	33.7	No
Cell 9	325.3	190.3	23.8	25.9	No
Cell 10	355.1	201.9	26.2	33.2	No
Average	374.6	195.3	25.1	33.1	
Standard Dev.	50.8	5.2	7.2	4.2	

High variability in:

- Max Temperature, Energy Released, and Mass Lost

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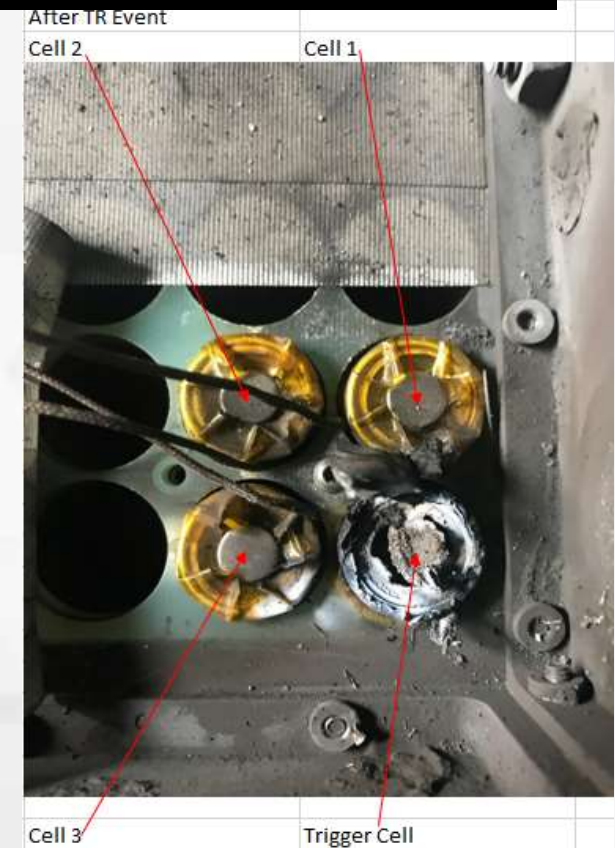
- Cell results guide module level design decisions and test plan
- The module design used for these tests is similar to that used for the NASA X-57 program - (Passed Containment tests)
- Three module TR configurations were evaluated: corner, side, and center
 - Samsung Cell
 - Eagle Picher Cells
 - Standard Flammability
 - Reduced Flammability Electrolyte

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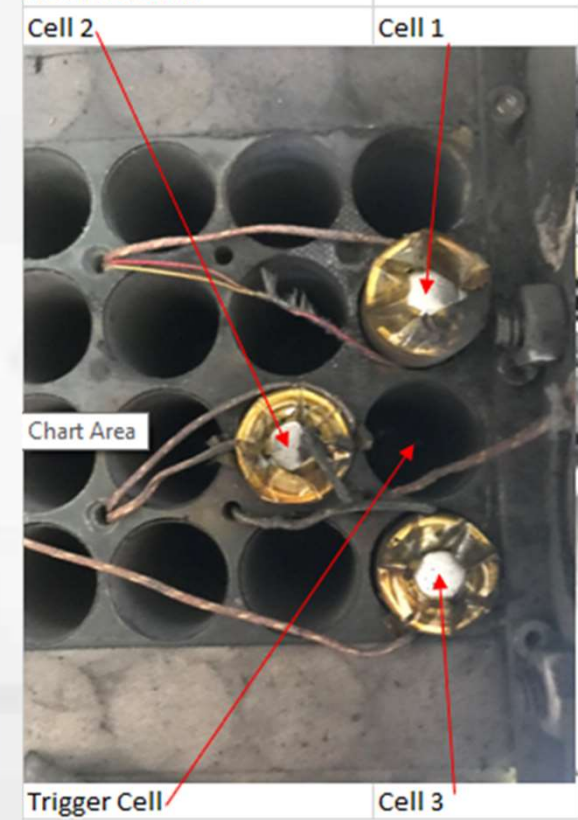
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- Corner
- No cell-to-cell Propagation Occurred



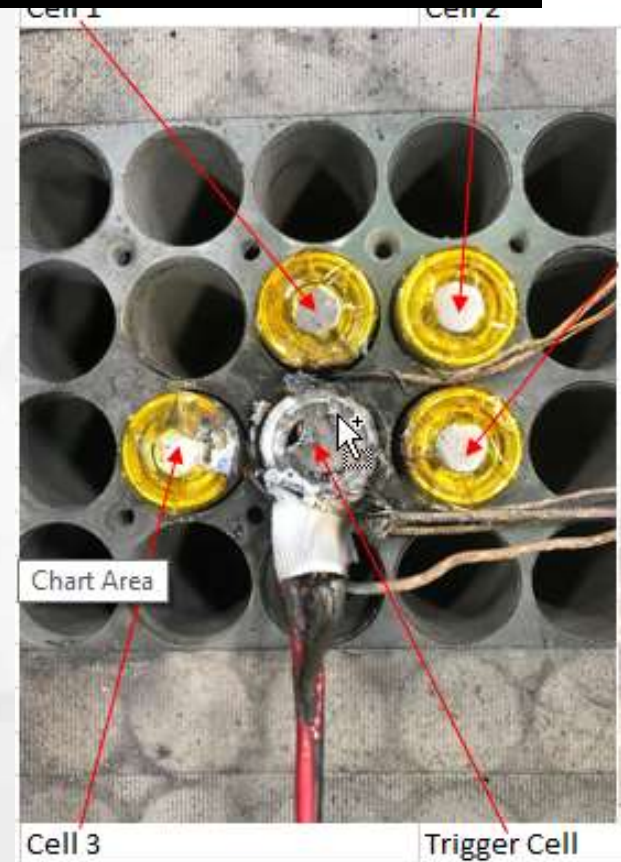
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- Side
- No cell-to-cell Propagation Occurred
- Cell was ejected



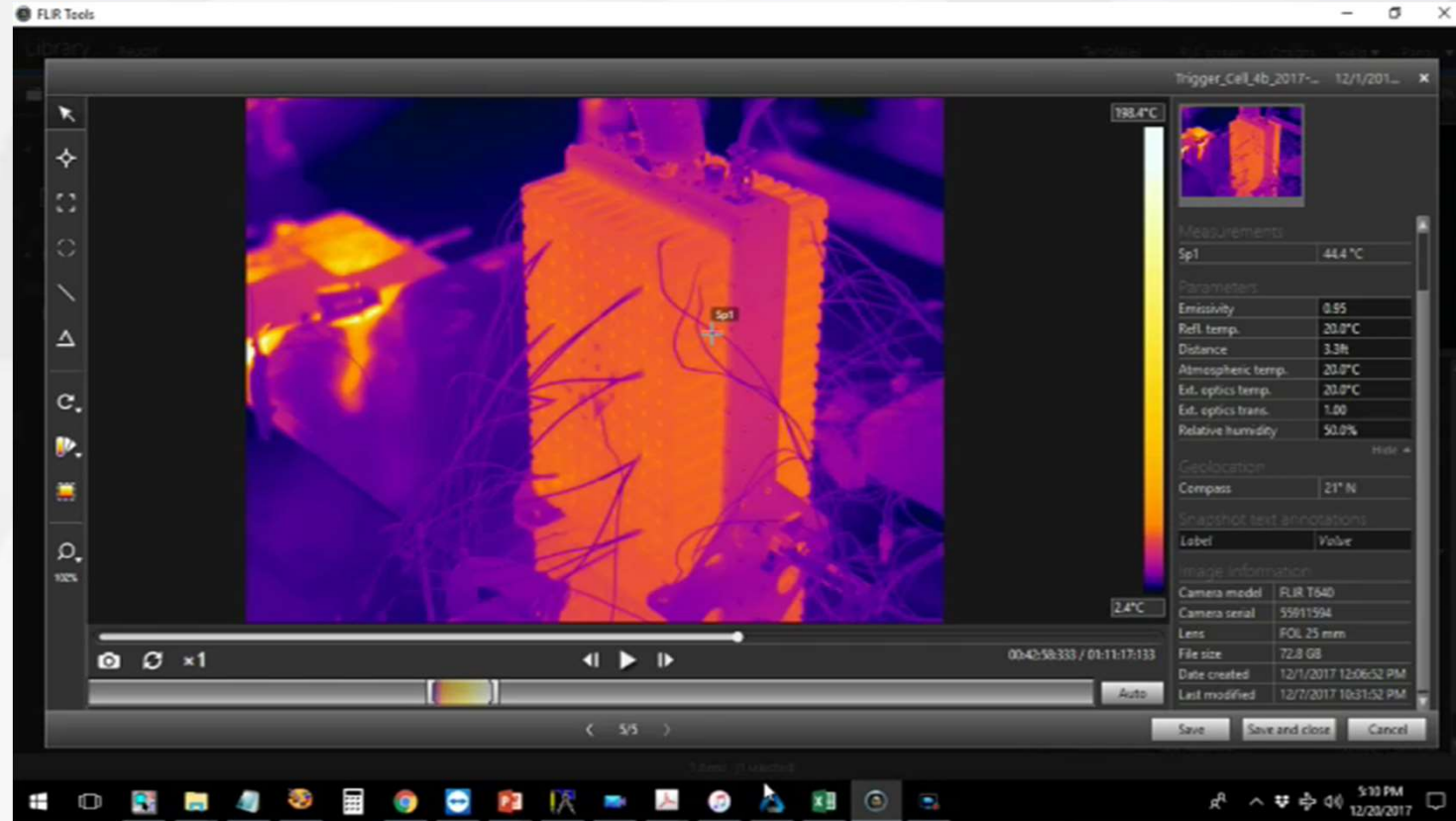
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- Center
- No cell-to-cell Propagation Occurred



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Past module performance shows containment of TR



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- In addition to the Samsung 30Q cells, additional cells from Eagle Picher were also tested for Thermal Runaway response.
 - Standard Flammability Electrolyte
 - Reduced Flammability Electrolyte
- These cells followed the same cell and module level testing as the Samsung 30Q cells.

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All cells included KULR technology, intended to initial TR at >60°C. Some didn't work as planned.

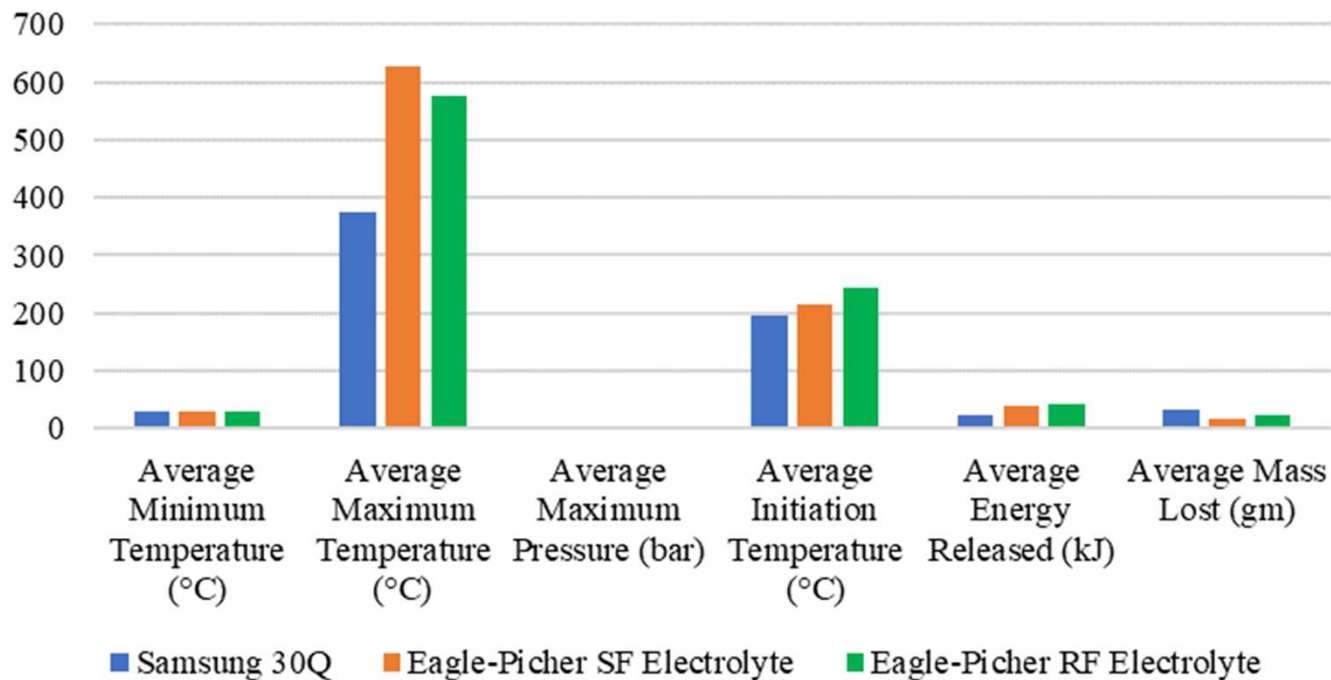
Test	Maximum Temperature (°C)	Initiation Temperature (°C)	Cell Enthalpy (kJ)	Canister Enthalpy (kJ)	Total Enthalpy (kJ)	Mass Lost (gm)
SF Cell 01a	673.2	143	21.7	28.8	50.5	15.5
SF Cell 02a	683.8	68.4	25.1		29.7	13.7
SF Cell 03a	523.6	214.6	12.5	24.9	37.4	18.1
Average	626.9	142.0	19.8	19.4	39.2	15.8
RF Cell 01a	538.1	64.6	19	21.4	40.4	25.5
RF Cell 02b	562	68	19.8	22.1	41.9	13.2
RF Cell 03a	627.5	243.8	15.5	30.5	46.1	18.4
Average	575.9	125.5	18.1	24.7	42.8	19.0



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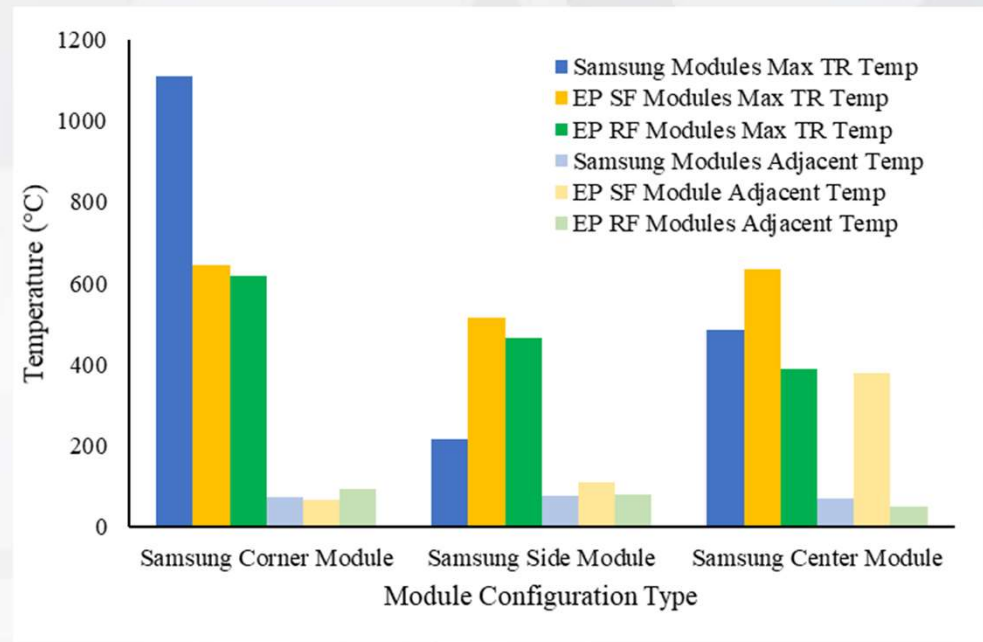
Samsung and Eagle-Picher Summmary



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Module Test Summary

Test Type	Maximum TR Temperature (°C)	Maximum Adjacent Cell Temperature (°C)	TR Propagation
Samsung Corner Module	1110	75.2	No
Samsung Side Module	216	78.6	No
Samsung Center Module	487	69.7	No
EP SF Corner Module	646	65.9	No
EP SF Side Module	515	111	Yes
EP SF Center Module	634	378	Yes
EP RF Corner Module	619	94.6	Yes
EP RF Side Module	466	80.1	No
EP RF Center Module	390	49.5	No



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- Cell Test results show differences at cell and module level
 - On average the RF cells showed ~50°C lower Max TR Temperature versus the SF cells.
 - At the module level the RF cells showed ~104°C lower Max TR temperature versus the SF cells.
- Results are only relevant to single cell TR results
- Module level testing is necessary to show cell TR impact on safety requirements.
- A system level test is necessary for DO-311A requirement

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- Acknowledgments
- FAA for the funding

Questions?

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APPENDIX

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