HOW SAFETY STANDARDS ADDRESS THE HAZARD OF FIRE PROPAGATION IN BATTERY SYSTEMS

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Agenda

1. Intro - Incidents involving lithium ion over the course of its commercial use
2. Reasons for those incidents
3. What is propagation and how can it be prevented?
4. Background on test methods to determine resistance to propagation
5. UL 1973 Propagation Task Group
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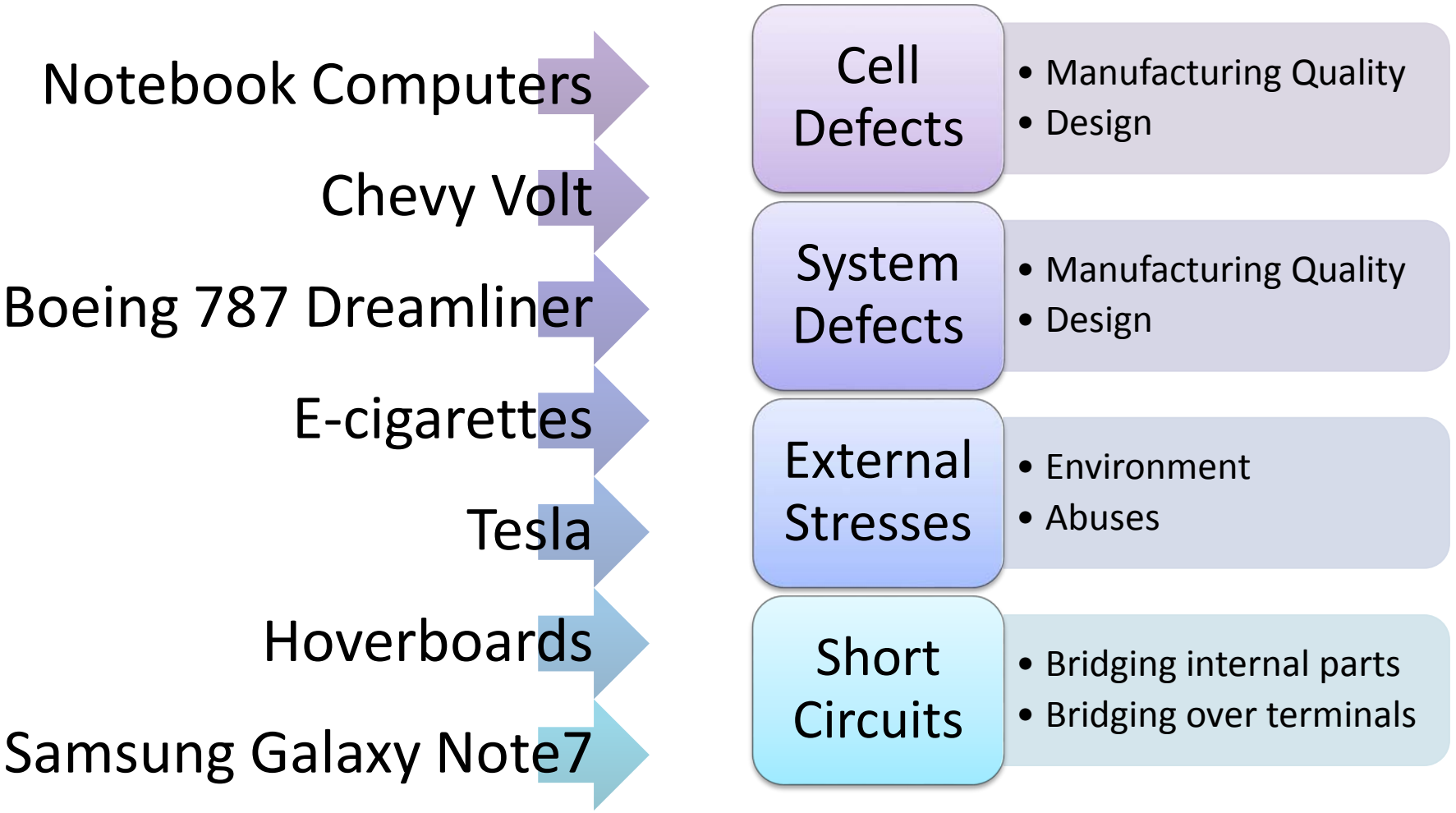
Intro - Incidents involving lithium ion over the course of its commercial use

Since the widespread commercialization of lithium ion batteries, there have been well publicized incidents that have occurred.

- 2005-2006 Notebook Computer Fires
- 2011 Chevy Volt test vehicle fire
- 2012 Boeing 787 Dream-liner battery fires
- 2013, Port Los Angeles, WA stationary battery fire
- 2013-2015 E-cigarette Fires
- 2013, 2014 Tesla vehicle accident fires
- 2015-2016 Hover-board Fires
- 2016 Sam-sung Galaxy Note 7 Cell Phone Fires

Reasons for the incidents



Lithium ion has proven to be safe but stuff happens!

Reasons for the incidents

All of these incidents ……

- Notebook Computers
- E-cigarettes
- Hoverboards
- Samsung Galaxy Note7
- Chevy Volt
- Tesla
- Boeing 787 Dreamliner

Led to propagation of fire

What is propagation and how can it be prevented?

"Cascading" can lead to propagation of fire external to the device under test. According to UL 1973:

CASCADING – The runaway failure or thermal propagation of a battery system or battery module when:

- One battery cell is triggered into catastrophic failure and this cell causes the failure of neighboring cells; and/or
- Continued thermal propagation of catastrophic cell failures until part of or the entire system is on fire or causing excessive hazardous gas generation or leakage of hazardous liquids.

What is propagation and how can it be prevented?

Battery modules/systems need to be designed to prevent a single cell failure from cascading/propagating to the outside of the enclosure through:

1. **Use of well designed, well manufactured cells** that are not susceptible to failure during anticipated worse case use scenarios

2. Design reliable control systems that **maintain all of the cells within their specified ratings**

3. Use fire resistant materials, and provide adequate spacings between cells and thermal controls to **prevent overheating and the spread of heat/fire should a cell fail**

What is propagation and how can it be prevented?

UL 1973 requires that non-metallic materials meet

- levels of flame resistance and
- have thermal properties sufficient for normal use exposures

UL 1973 requires that cells comply with cell safety requirements

- UL 1973 requires that controls maintain the cells within their specified operating regions

UL 1973 requires that safety critical electronics and software controls meet functional safety criteria

UL 1973 requires that batteries comply with tests representative under normal use and abuse conditions

UL 1973 includes a propagation test called the “internal fire test”

UL 9540 requires batteries to comply with UL 1973

Background on test methods to determine resistance to propagation

The UL Internal Fire Test

- UL 2580 and UL 1973
- Concept for UL test came from SAE J2464, RESS Abuse Manual's Passive Propagation Resistance Test

SAE J2464 Passive Propagation Resistance Test

- evaluates the ability of a DUT to withstand a single cell thermal runaway event so that a thermal runaway event does not propagate to adjacent cells.

Background on test methods to determine resistance to propagation

SAE J2464 Passive Propagation Resistance Test

- Any technology RESS
- 100% SOC, test at module or pack
- The DUT is heated until the cells are 55 °C or the maximum operating temperature
- One cell within the DUT is heated in-situ to 400 °C (or until TR) in less than 5 min
- After initiation of TR, the heater is turned off and DUT is observed for 1 h
- Other methods of failing the cell besides heating to 400°C can be used
- Observations are made but no pass/fail criteria

UL 1973 Internal Fire Test

- Secondary lithium and sodium sulfur
- 100% SOC, test at module or pack
- One cell (in center) is subjected to failure (heating, nail, etc.) with failure to occur in 20 min
- After initiation of TR, mechanism is turned off or removed
- 24 h observation period
- Can repeat if necessary on cell in different location
- Pass/fail: No fire propagate to the outside of the DUT enclosure or explosion

Background on test methods to determine resistance to propagation

IEC 62619 also has a type of propagation test

- Lithium ion only
- Option to do FISC test, which is done on a single cell
- Single cell failure using one of multiple mechanisms
- No fire outside of DUT or rupture of enclosure of DUT

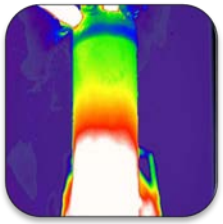
UL 1973 internal fire is essentially the same test but:

- Does not have option to do FISC test instead of internal fire test
- Required for secondary lithium and sodium sulfur

UL 1973 Propagation Task Group

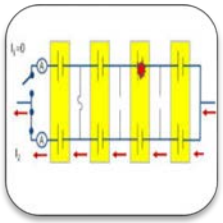
Issues with Internal Fire Test

Lot of questions on the correct way to do the test????????



Is the chosen cell failure method adequate?

What are the steps to the cell failure?

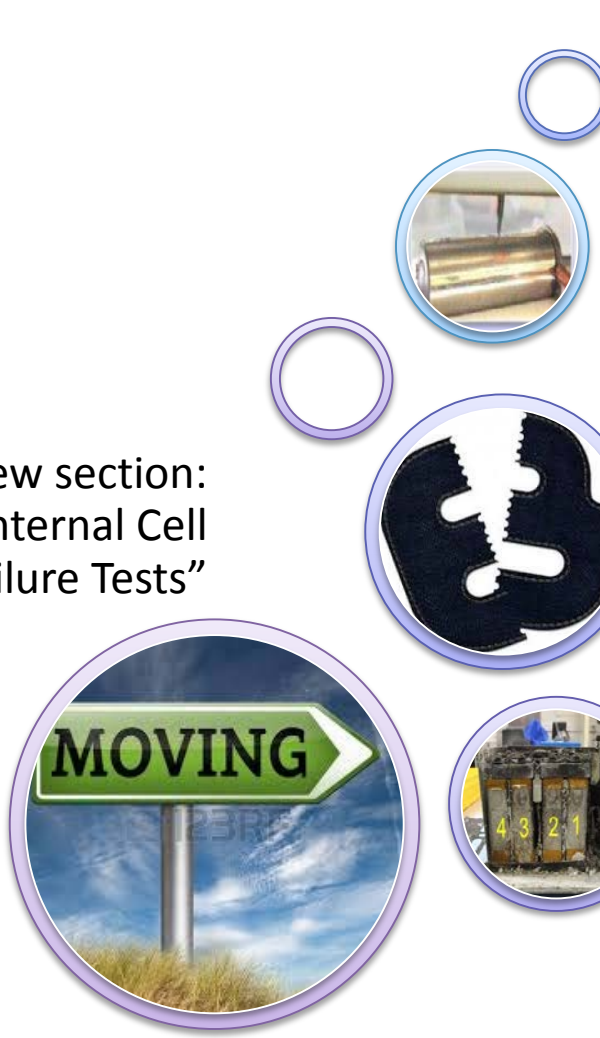


What cell should be failed?

In the summer of 2016, a UL 1973 Internal Fire Task Group was set up

- Clarify intent of test
- Improve internal fire test method
  - Clarify intent
  - Ensure consistent approach
- Proposal was completed end of 2016
- Currently being processed out for preliminary review by the UL 1973 STP

UL 1973 Propagation Task Group



Include an appendix with more details on cell failure methods

Separate test into two parts: 1) lithium ion and 2) other technologies

Change name of test to “Single Cell Failure Design Tolerance”

Put test in new section: “Tolerance To Internal Cell Failure Tests”

UL 1973 Propagation Task Group

Single Cell Failure Design Tolerance

A lithium ion battery system shall :

- be designed to mitigate a single cell failure leading to a thermal runaway of that cell

The cell failure mechanism used shall:

- reflect what is known or anticipated to occur in the field for a given technology or
- be a close simulation through the use of an external stress

The testing agency is responsible for selecting and demonstrating an appropriate method

an analysis to determine the cell location with greatest potential to lead to a significant external hazard shall be conducted

UL 1973 Propagation Task Group

Single Cell Failure Design Tolerance

Other technologies such as lithium metal, sodium sulfur, sodium nickel chloride, and lead acid are to be tested

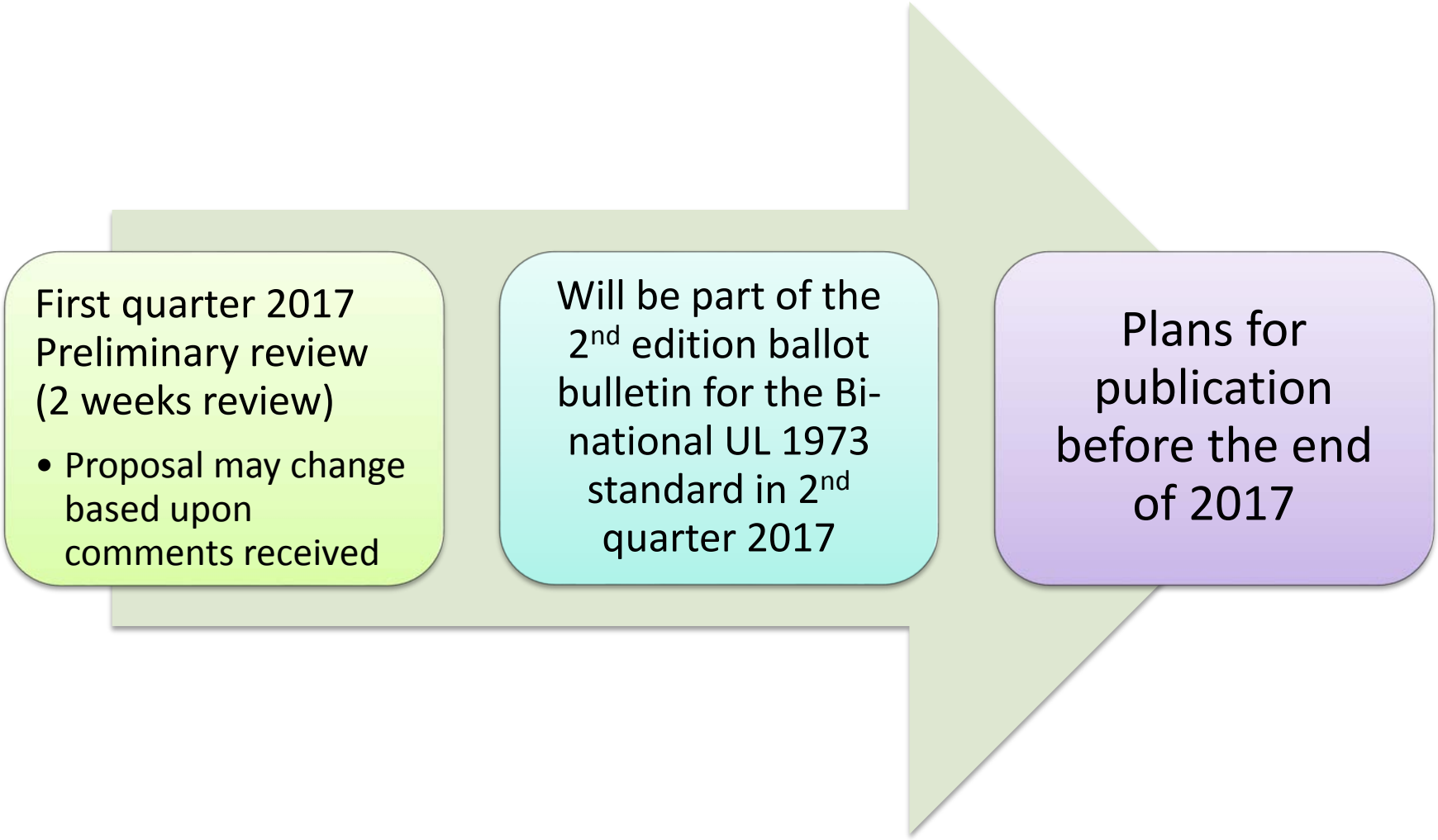
- There may not be enough field data regarding their tolerance to single cell failure events,
- Basically the same test method as lithium ion testing

Cell failure technique, it should be representative of what can occur in the field

- The failure mechanism may be different than lithium ion and thermal runaway may or may not result
  - Consider failures due to potential cell manufacturing defects for that technology and/or
  - Cell and battery design deficiencies that could lead to latent failures of the cell

The DUT shall be in a condition that reflects its operating parameters

Conclusion


First quarter 2017
Preliminary review
(2 weeks review)
• Proposal may change based upon comments received
Will be part of the 2nd edition ballot bulletin for the Bi-national UL 1973 standard in 2nd quarter 2017
Plans for publication before the end of 2017


Thank you!