GENERAL MOTORS

GALEN RESSLER

IMPROVING THE SAFETY OF LITHIUM-ION BATTERY SYSTEMS

-- A SYSTEMS APPROACH --

TOPICS

- Why is lithium ion battery safety a topic?
- Why do incidents happen?
- How can they be managed?

WHY IS LITHIUM ION BATTERY SAFETY A TOPIC?

- Ubiquity
  - When many exist, potential for safety critical events increases
  - High volume manufacturing & economic opportunity – increased risk of quality issues

- Fundamental technology
  - Reactive materials (e.g., electrolyte, cathode)
  - Significant electrical energy

- Societal perception of risk
  - Social media visibility and virality
  - Long term image retention

WHY IS LITHIUM ION BATTERY SAFETY A TOPIC?

- There have been incidents
  - Over 261 air/airport incidents involving lithium batteries (cargo or baggage) since January 1, 2006. (FAA[1])
  - Laptops (>3,000 incidents), cell phones (>2,000), power supplies (>400), drones (>200), e-cigarettes, hover boards. (CPSC[2])
  - Approximately 63 incidents involving lithium ion batteries in automobiles (2010-2018, North America and Europe) (ACEA[3] , Automotive Alliance[4])
    - *Reference: Approximately 171,500 vehicle fires occur annually in US (USFA [5])*

WHY IS LITHIUM ION BATTERY SAFETY A TOPIC?

- Virality Example

Have you ever seen this picture?

What's the difference?

Google search:

- Top 60 images for "car fire"
- Top 10 for "electric car fire"
- Top 5 (multiple in top 10) for "Tesla car fire"

Incident occurred in October 2013

How about this one?

[See Sources slide for image sources.]

WHY IS LITHIUM ION BATTERY SAFETY A TOPIC?

- Long term image retention
  - Misrepresentation of event for visual impact

Picture of vehicle associated with headline, right?

- The fire started after the 19-year-old driver crashed into a motorway barrier
- 35 crew members battled the blaze while wearing special breathing equipment
- Electric car fires are especially hard to put out because the often relight
- The battery must be cooled enough to cut the power supply

By SHIVALI BEST FOR MAILONLINE
PUBLISHED: 11:17 EST, 19 October 2017 | **UPDATED:** 12:08 EST, 19 October 2017

Actual event:

- Different continent
- > 1 year earlier
- Different cause

[See Sources slide for image sources.]

WHY DO INCIDENTS HAPPEN?

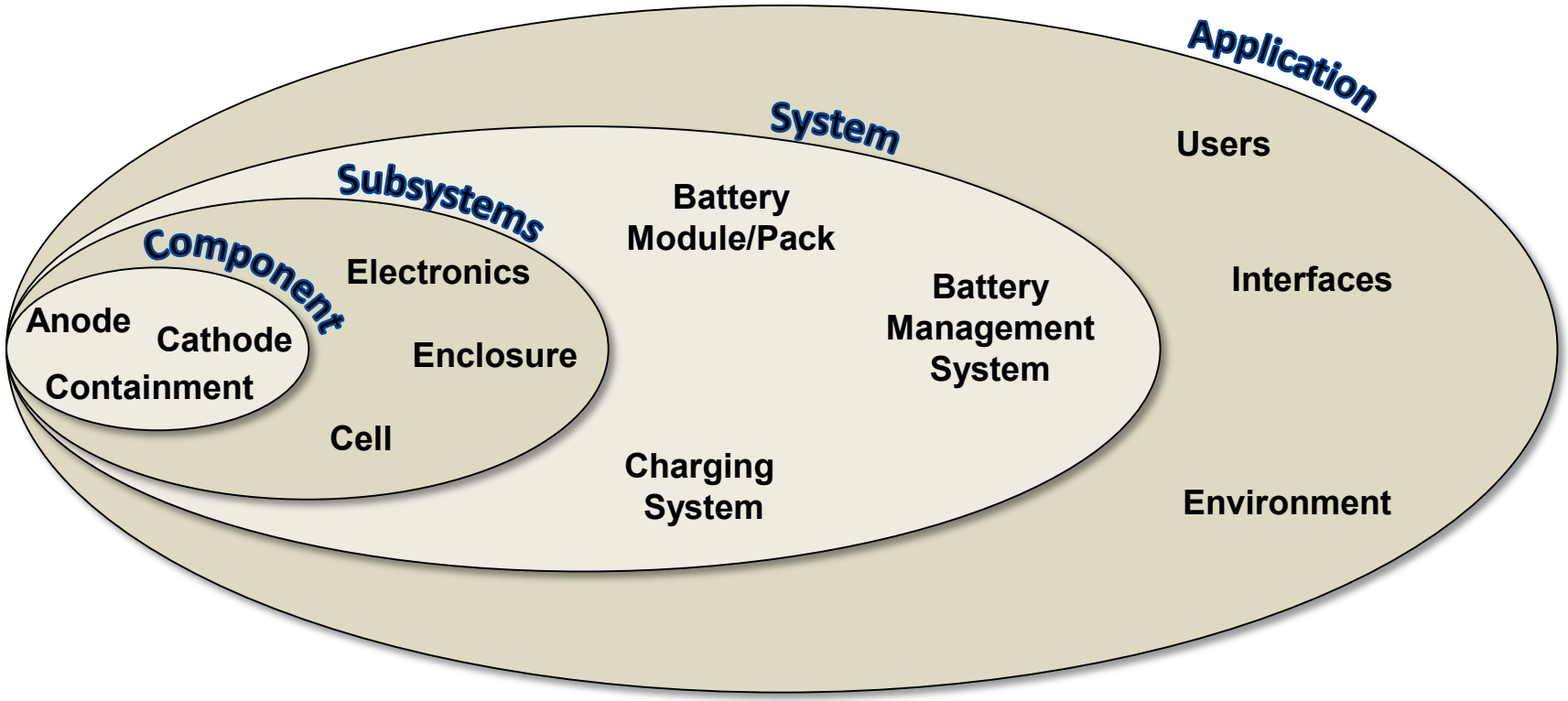
- Usage compatibility
  - Energy, power, load compatibility
  - Aging
- Integration
  - Wiring
  - Location
  - Consideration for usage environment
- Inadequate battery management system
  - Charging
  - Monitoring (voltage, temperature) with appropriate system response
- Manufacture
  - Cells not manufactured to standards and best practices
  - Inadequate quality in assembly of packs and systems
- Physical damage
  - Impact/Drop
  - Crash/Crush
  - Flexure
  - Water exposure

HOW CAN THEY BE MANAGED?

- Codes, Standards, and Regulations (CSR) [2,6]
  - Generally “follow” technology advancements
    - New technology introduced → voluntary, industry standards revised/created → voluntary standards adopted as regulation
    - Need continuous update as technology evolves
  - Designer focus on identifying applicable standard and meeting its requirements
  - Effectiveness dependent on compatibility of system and CSR assumptions

- Systems approach[e.g., 7]
  - Applicable for new and existing technologies
  - Intended to achieve acceptable risk throughout all phases of the system life-cycle
  - Effectiveness dependent on consistency of “acceptable risk” definition between decision maker and system user

SYSTEMS APPROACH



Safety strategies at each level build from lower level designs

DIVERSITY OF PERSPECTIVES IS KEY!

- Diversity of design perspectives
  - Cell
  - Electronics
  - Pack
  - Application

- Diversity of experience perspectives
  - Test
  - Manufacture/assembly
  - Field
  - Application environment

SOURCES

Technical References

1. Federal Aviation Administration. "Events with Smoke, Fire, Extreme Heat or Explosion Involving Lithium Batteries." 1 December 2019. Lithium Battery Safety Resources. Report. 18 December 2019. <https://www.faa.gov/hazmat/resources/lithium_batteries/media/Battery_incident_chart.pdf>.
2. Consumer Product Safety Commission Staff. "Lithium-Ion Battery Safety Standards for Consumer Product Import into the United States." 16 May 2017. U.S. Consumer Products Safety Commission. Presentation. 18 December 2019. <https://www.cpsc.gov/s3fs-public/3LeeCPSC.En_.pdf?QMvz78vcq0web.KaXE_TJD.dpk7DbADF>.
3. Börger, Alexander and Annika Ahlberg Tidblad. "European Incident EV Field Data (EVS17-E1TP-0200)." January 2019. UNECE Electric Vehicle Safety Informal Working Group 17th Session. <https://wiki.unece.org/download/attachments/72024290/EVS17-E1TP-0200%20%5BOICA%5DACEA%20study%20European%20field%20data.pdf?api=v2>.
4. Schmidt, Scott. "United States EV Fire Incident Field Data Review (EVS17-E1TP-0100)." January 2019. UNECE Electric Vehicle Safety Informal Working Group 17th Session. <https://wiki.unece.org/download/attachments/72024290/EVS17-E1TP-0100%20%5BOICA%5DUnited%20States%20EV%20Fire%20Incident%20Field%20Data%20Review.pdf?api=v2>.
5. U.S Fire Administration. "Highway Vehicle Fires (2014-2016)." Topical Fire Report Series 19.2 (2018). <https://www.usfa.fema.gov/downloads/pdf/statistics/v19i2.pdf>.
6. Cole, P C and D R Conover. "Energy Storage System Guide for Compliance with Safety Codes and Standards." U.S. Department of Energy, Contract DE-AC05-76RL01830, 2016.
7. Department of Defense. "Department of Defense Standard Practice - System Safety. MIL-STD-882E." United States Department of Defense, 11 May 2012.

Photo Credits

Slide 5:

Tesla car fire. Digital image. *Automotive News*. 3 October 2013, https://www.autonews.com/article/20131003/OEM11/131009936/tesla-grapples-with-pr-nightmare-after-battery-fire-in-u-s.
SUV vehicle fire. Digital image. *WXFR-TV Local News*. 8 January 2020, https://www.wfxrtv.com/news/local-news/suv-burns-wednesday-morning-in-bedford/.

Slide 6:

Tesla says someone fired a bullet into battery pack of a Model S that caught on fire. Digital impact. *Electrek*. 16 December 2018, https://electrek.co/2018/12/16/tesla-fire-bullet-battery/.
Firefighters battling a fire after a Tesla Model S crashed in Austria. Digital image. *DailyMail.com*. 19 October 2017, https://www.dailymail.co.uk/sciencetech/article-4997486/35-firefighters-tackle-enormous-Tesla-Model-S-fire.html.