UL Battery Safety Science Symposium

August 11, 2021

SAE G-27 Committee, AS6413 Lithium Battery Packaging Performance Standard

United Nations Dangerous Goods Working Group on Classification of Lithium Batteries

George A. Kerchner*
PRBA – The Rechargeable Battery Association
1776 K Street, NW
Washington, DC
gkerchner@wiley.law
202.719.4109

With contributions from Dr. Claude Chanson with RECHARGE, The Advanced Rechargeable and Lithium Batteries Association, and Dr. Arnaud Bordes with Ineris

PRBA – The Rechargeable Battery Association

- Established in 1991, members include:
  - Primary and secondary cell/battery manufacturers, and battery recyclers
  - Manufacturers of electronic equipment, medical devices, power tools, automobiles
  - Retailers, testing labs
  - Airlines, dangerous goods consultants, packaging manufacturers
- Focus on regulatory, legislative, and policy issues at state, national and international level
  - Safety, state and federal battery recycling legislation, transportation, fire codes
- International transportation forums
  - UN Sub-Committee of Experts
  - ICAO Dangerous Goods Panel
  - IMO Sub-Committee on Carriage of Cargoes and Containers

SAE G-27 Committee

- SAE (Society of Aerospace Engineers) established G-27 Committee in 2016 after International Civil Aviation Organization implemented prohibition on transporting lithium ion batteries as cargo on passenger aircraft
- Prohibition viewed as temporary measure until additional controls established to improve on safe transport of lithium ion batteries by air (e.g., development of lithium battery performance-based packaging standard)
- Other measures were adopted in 2016 include 30% state of charge limit on lithium ion batteries, restrictions on Section II “excepted” lithium ion battery shipments, and cargo segregation requirements

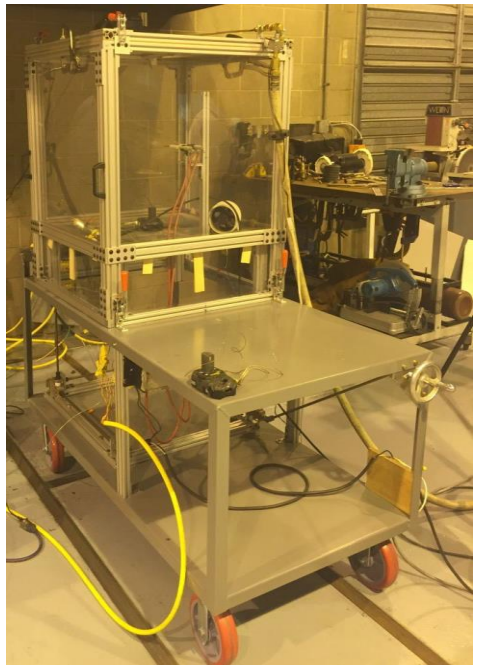
G-27 Committee Members

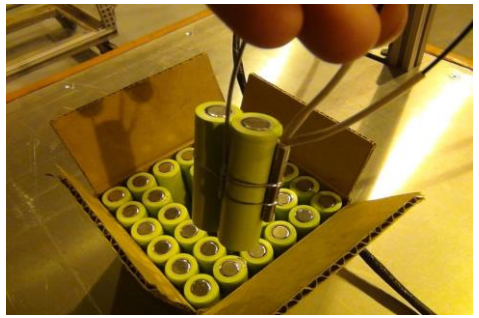
- Approximately 280 individuals listed members
- Writing subcommittee consisted of 20 individuals from different industries/government agencies
- Approximately 50 voting members on Committee
- First meeting was held in February 2016

AS6413 Standard in its Most Basic Form

- Establish test methods for packages that can contain/limit hazards associated with transporting Lithium metal batteries (UN3090) and Lithium ion batteries (UN3480) by air
  - Would not apply to batteries packed with or contained in equipment (UN3481 and UN3091)
- Controlling hazards (e.g., single cell failure leading to propagation) within package that could compromise fire suppression systems in cargo hold
- Test: Abuse single cell and force into thermal runaway that could result in propagation between cells, larger event

Baseline Test Method





- Place package in transparent box with a 0.3 m^3 free volume to contain gases generated from thermal runaway
- Spark ignition source within box capable of igniting vapors reaching flammable concentration
- Use heat source (e.g., tape, cartridge) to create temperature rise at 5 to 20 °C per minute until thermal runaway
- Videos and test data on FAA's website: https://www.fire.tc.faa.gov/systems/Lithium-Batteries

Pass/Fail Criteria

- Verification of “non-hazardous flame” and “non-hazardous particle”
- No ignition of vapor collected within test chamber
- Cheese cloth placed no more than 25 mm away from package shall not ignite
- Surface of package shall not be sufficient to ignite adjacent materials
- Average increase in temperature of each thermocouple on each face of package shall not be greater than 100 °C

Remaining Issues for G-27 Committee to Address

- Testing large format battery in modified chamber (e.g., pipe connecting battery/package to test chamber)
- Testing sub-system (e.g., module) of large format battery
- Generic packaging: How can a single package design be used to accommodate different cell and battery designs?

AS6413/1 and AS6413/2 “Slash Sheets”

- Includes additional test criteria to supplement standard that address fire risks external to packages of batteries (e.g., fire in cargo hold)
  - Oven Test
  - Direct Flame Test
- External Fire Working Group has been meeting monthly and recently completed work
- Slash sheets are independent of AS46413 thermal runaway testing requirements
- Slash sheet criteria may be applied to package, unit load device (ULD), fire containment cover (FCC), or other form of mitigation

Balloting of AS6413 Standard and Slash Sheets, Adoption by ICAO

- Likely to see extensive balloting and comments filed on standard and slash sheets in 2021/2022
- After SAE completes work (in 2022/2023?), several ICAO Panels must determine how or if standard/slash sheets could be implemented in accordance with ICAO Technical Instructions on the Safe Transport of Dangerous Goods by Air
  - *AS6413 and slash sheets include technically complex and expensive testing requirements*
- Could standard only apply to shipping lithium batteries on passenger aircraft?
- Could airlines choose to require AS6413 packaging through "operator variations"?

United Nations (UN) Working Group on Lithium Battery Classification (as Dangerous Goods)

- Purpose of Working Group: Establish a new, hazard-based classification system for shipping lithium batteries as dangerous goods
- Current lithium battery dangerous goods regulations based on UN38.3 tests, Watt-hours, lithium metal content
  - Authorizes lithium batteries to be classified and shipped as Class 9 dangerous goods

United Nations (UN) Working Group on Lithium Battery Classification (as Dangerous Goods)

- Address new lithium battery technologies entering market
- Example: UN Sub-Committee in 2005 – 2006 considered RECHARGE and PRBA proposals for regulating rechargeable lithium metal polymer batteries
- Provide greater "granularity" to classify different lithium battery chemistries based on hazards
- Reward "safer" lithium battery chemistries?
- *New classification system will result in more complex regulatory scheme for testing and shipping lithium batteries*

UN Lithium Battery Working Group Participants

- Lithium cell, battery, equipment, and automobile manufacturers from Korea, China, Japan, U.S., and Europe
- Dangerous goods transport authorities
- Test labs
- Aircraft manufacturers
- Pilots
- Airlines
- Packaging manufacturers
- First meeting held November, 2017. Last in-person meeting October, 2019 in Texas
- Web-based meetings are being held to continue work, testing

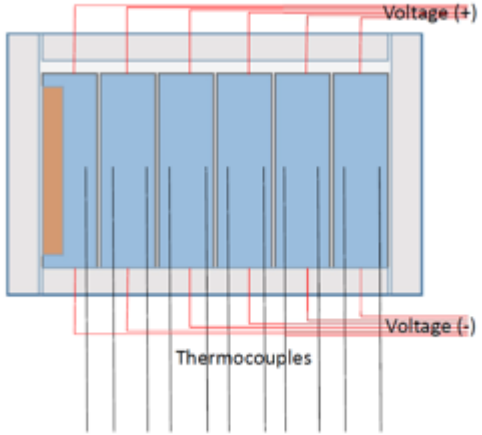
How Will New Classification be Assessed and Determined?

- Classification of lithium batteries expected to be based on new testing scheme and resulting:
  - Cell initiation
  - Propagation between cells
  - Fire, temperature, and gas hazards
  - Thermal energy released

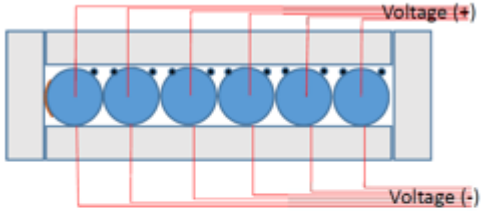
Testing Lithium ion Cells – Phase 1

- Cells with same capacity, from same manufacturers, and same cell lots were tested
- Goal: Repeatability of propagation tests
- Seven labs conducted propagation tests on six cells at 100% state of charge
  - Three times on cylindrical (18650) cells
  - Three times on pouch cells

Side view



Top View



All test data available on RECHARGE's website:
https://rechargebatteries.org/sustainable-batteries/unsctdg/

Testing Lithium ion Cells – Phase 2

Table 1

	20% SoC	30% SoC	50% SoC	70% SoC	100% SoC
5 C/min					Priority #3
20 C/min	Priority #1	Priority #5	Priority #2	Priority #4	

- Same test set up as Phase 1 to examine effect of heating rate and SOC on propagation of cells
- Also analyzed gas hazards from cells based on SOC, heating rate

All test data available on RECHARGE's website:
https://rechargebatteries.org/sustainable-batteries/unsctdg/

Results of Phase 2 Testing

- Found variations within labs and between labs for measuring maximum cell temperatures
  - Repeatability (variation within labs) up to 50°C
  - Reproducibility (variations between labs) up to 100°C
- Measurement of gas volumes and composition very difficult for some labs and expected to be less reproducible

All test data available on RECHARGE's website:
https://rechargebatteries.org/sustainable-batteries/unsctdg/

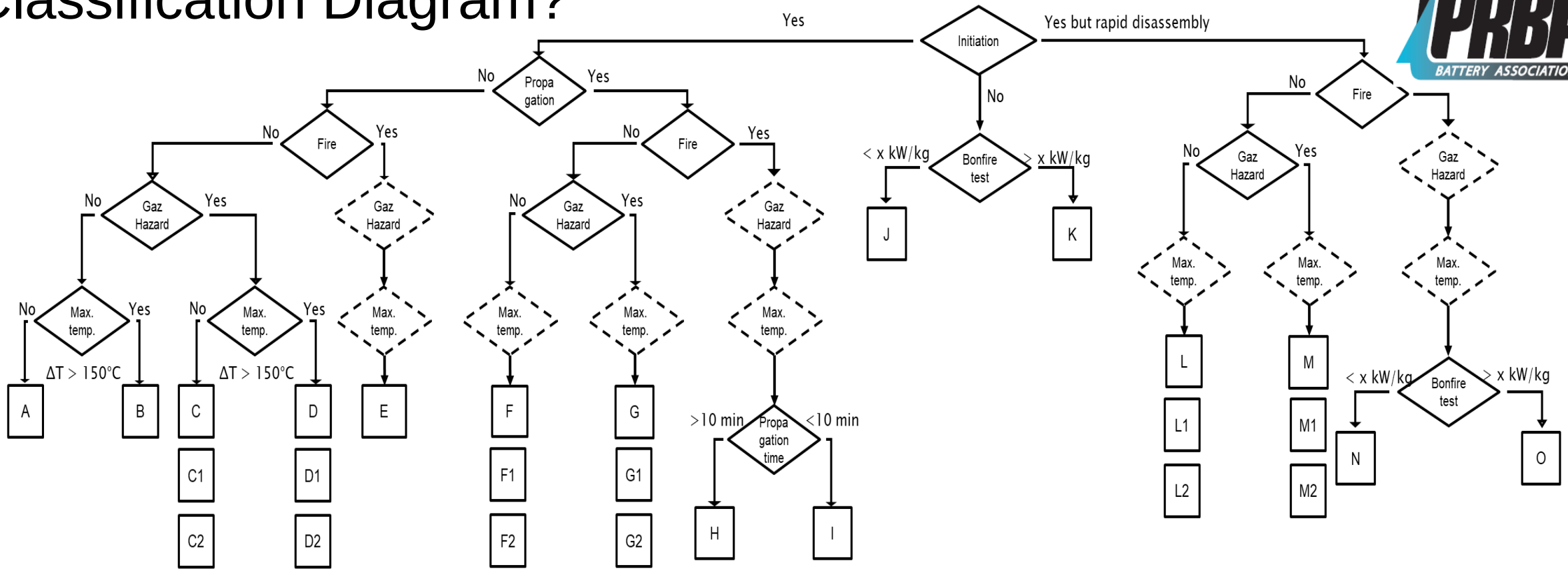
Initial Conclusions on Developing a Hazard-Based Classification System

- What influences cell hazards?
  - ✓ Form factors, heating rate, SOC
- Can a dangerous goods classification system for lithium cells and batteries based on their hazards be developed? Yes.
- Can new packaging requirements for transport be established to off-set hazards? Yes.

Initial Conclusions on Developing a Hazard-Based Classification System

- Next Steps: Harmonization on testing procedures for better reproducibility
- Analysis of gases generated has shown a lack of repeatability and reproducibility due to differences in analytical methods
  - Could a range of gas compositions be considered?
  - Do gases even need to be considered?
- Implementation of new classification system: 2027???

Classification Diagram?



1 — Indicates that emitted gas is non-toxic

2 — Indicates that emitted gas is non-flammable

Hazard — Dashed box correspond to hazard that are assumed and are represented only to help understanding how the diagram was built and what are the hazards considered in each category

Classification Diagram?