Hazard Focused Discussion on Lithium-ion Batteries

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From Hazard to Protection

- Protection guidance framework
  - Define the application.
  - Define the hazard.
  - Determine the available means of prevention / protection.
  - Establish the acceptable loss.
What is a “Battery”

Cell
(multiple cells)

Module
(System)
(multiple modules)

Small format  Large Format
What is the Application?

ESS (single rack)

Grid System (multiple racks)

Utility Scale (multiple racks)

Small Application  Large Application
Warehouse Storage
Define the Hazard

- Unique hazards for Li-ion technology
  - Fire can initiate within the battery
- Failure mode dependent on battery type
  - Venting mechanism
  - Chemistry
  - State-of-charge
- Packaging or system components
  - Other contributions to fire development
Thermal Runaway

- Rapid self-heating of a battery
- Converts electrical energy to heat
  - More energy = more heat
- May (or not) cause combustion of chemical energy
  - i.e., flammable electrolyte
- Battery-to-battery propagation
Available Means of Protection

- Passive protection, e.g.,
  - Battery design, module design, etc.
  - Segregation or separation from other combustibles
  - Fire scenarios can override passive protection

- Active protection, e.g.,
  - Sprinklers, water mist, gaseous agents, etc.
  - Fire service intervention
Establish the Acceptable Loss

- What is the goal of the protection system?
- Limit the fire spread to:
  - Battery, module, rack, container, etc.
- Associated damaged
  - Hazard gas release, water contamination, building damage
  - Loss of product
  - Equipment down time
Goal: Determine sprinkler system design guidance for warehouse storage

Approach: Bench-scale through large-scale fire testing

Application: As many battery types as possible

Difficulties: Cost and logistics of acquiring and disposing of large quantities of batteries
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Scale
Warehouse Storage Fires

30 s

60 s

90 s

120 s
Hazard Comparison

Conveective HRR (kW)

Time (s)

- CUP Commodity
- Class 2 Commodity

[Public]
Hazard Comparison

Convective HRR (kW)

Time (s)

- CUP Commodity
- Class 2 Commodity
- Cylindrical, 2.6 Ah
- Prismatic Pouch, 2.6 Ah

[ Public ]
Hazard Comparison

- CUP Commodity
- Prismatic Pouch, 20 Ah
- Battery Pack, 2.6 Ah (x 10)
- Class 2 Commodity
- Cylindrical, 2.6 Ah
- Prismatic Pouch, 2.6 Ah

Convective HRR (kW)

Time (s)
Comparison of Battery Hazard

- Sprinkler Response
  - Fire hazard similar at sprinkler operation
  - i.e., fire growth rate and size

- Time of significant battery involvement
  - Large-format: 90 - 180 s
  - Small-format: 300 s

- The large-format cells represented a higher hazard than small-format cells
Warehouse Storage

- **Protection**
  - K22.4 gpm/psi^{1/2}
  - QR, 165°F
  - 1.3 gpm/ft^{2} (35 psi)

- **Application**
  - Up to 15 ft storage
  - Up to 40 ft ceilings
Warehouse Storage

- **Protection**
  - K320 lpm/bar\(^{1/2}\)
  - QR, 74°C
  - 53 mm/min (2.4 bar)

- **Application**
  - Up to 4.6 m storage
  - Up to 12.2 m ceilings
Warehouse Storage – Success!

One sprinkler provided effective protection
Potential Application of Results

- Sprinkler protection option established
  - May apply to cells with a hazard ≤ to cell used in sprinklered test
  - Cell hazard evaluated in reduced-commodity test
Application of Warehouse Storage Test

- Sprinkler protection guidance may be applicable to additional batteries, e.g.

- Methodology in place to limit large-scale testing

- Overall protection guidance needs to consider additional hazards, such as battery projectiles
Summary

- No one-size fits all methodology!
- Experimental evaluation needs to occur at the proper scale to capture the hazard scenario

- All data included in this presentation are preliminary and may change pending issuance of the test report.
Questions


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