Energy Storage Systems (ESS)

UL 9540 ESS Standard

UL 9540A Testing Standard

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Why Energy Storage?

Expanding the energy storage infrastructure.

The benefits of energy storage are driven by several dynamic factors.

Energy Storage Systems (ESS)

Expanding energy storage infrastructure

- Electric utility grid balancing and resiliency
- Eliminates renewable energy intermittency
- UPS for data centers
- Residential

Davidson Code Concepts

Location Specific Considerations

Mixed Occupancy Building

Outdoor Cabinets

Dedicated ESS Building

Outdoors Near Building

Rooftop Installations

Outdoors Remote

Modern Battery Technologies

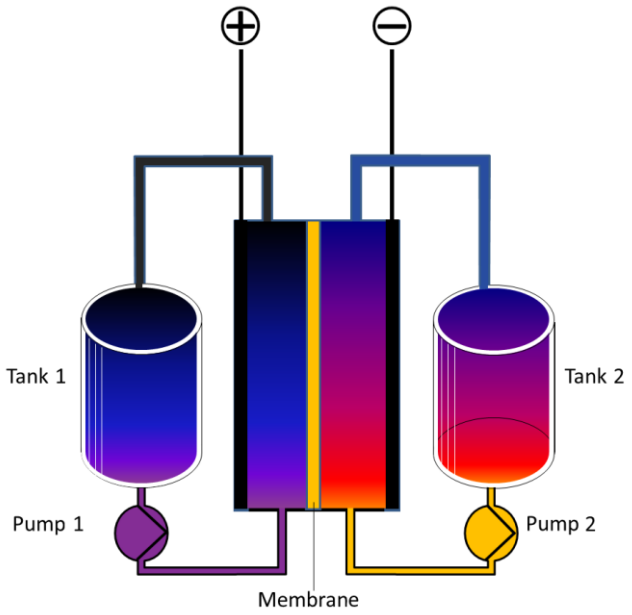
Stationary battery technologies include

- Flow batteries
- Sodium-sulfur batteries
- Lithium-ion batteries

Energy density and cost drive new battery technologies

Flow Batteries

- Two tanks of liquids, pumped past a membrane between electrodes
- Electric current produced while both liquids circulate in their own respective space
- System includes pumps, sensors, control units, secondary containment



Lithium-ion Batteries

- Excellent energy density
- The current battery of choice
- Batteries and systems are readily available

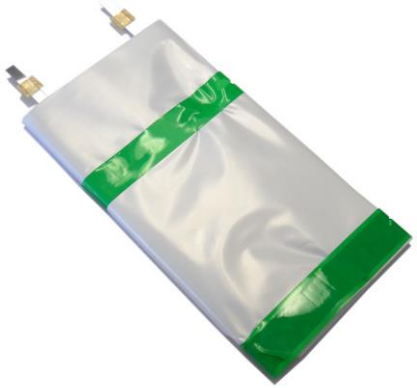
Lithium-ion Batteries

- Lithium technologies differ and are continually evolving
- Lithium NMC – Higher energy density, operating temperatures
- Lithium LFP – Lower energy density, cost, operating temperatures

Risks and potential fire hazards vary between technologies

Li-ion Battery Cell Failure Modes

- Overheating and cell rupture is possible from:
  - Overcharging
  - Short circuits
  - Manufacturing defects
- Overheated cell can vent flammable gas
- Ignition source creates fire/explosion
- Lithium-ion batteries burn at 1500˚C



Thermal runaway in one cell can readily spread to adjacent cells

FIRE SAFETY APPROACH

Installation Codes

NEC: National Electric Code (NFPA 70)

NFPA 855: Standard for the Installation of Stationary Energy Storage Systems

ICC: The International Fire Code, International Residential Code

Battery Safety Certification

UL 1642: Lithium Batteries

UL 1973: Batteries for Use in Stationary, Vehicle Auxiliary Power and Light Electric Rail (LER) Applications

UL 9540: Energy Storage Systems and Equipment

Testing for Performance

UL 9540A: Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems

26 Major ESS Fires in South Korea 2017 - 2019

ESS System Explosion in AZ

Thermal Runaway - 25 Lithium-Ion Cells

Thermal Runaway - 25 Lithium-ion Cells

Let's do the math…

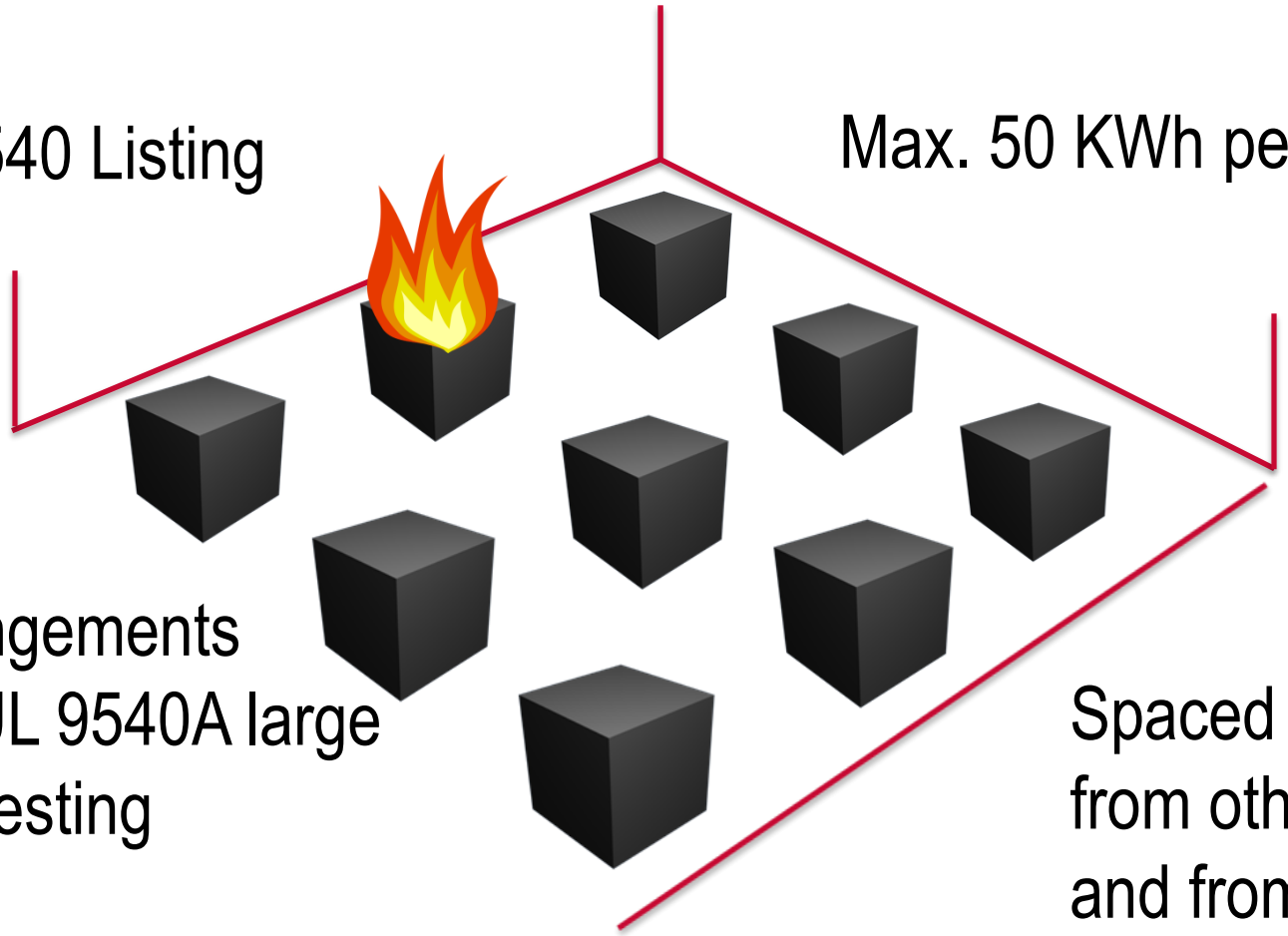
- A single 18650 Li-Ion cell is ~ 10 WH
- 25 cells is ~ 250 WH
- A typical ESS module has 3,100 WH
- A typical rack has 10 modules for 31,000 WH
- This typical rack has over 120 times more energy than the 25 cell example in the video

IFC 2021 / NFPA 855

Listing, Size, Separation, MAQ

UL 9540 Listing

Max. 50 KWh per unit



Other arrangements based on UL 9540A large scale fire testing

Spaced min. 3 ft. from other arrays and from walls

Max. 600 KWh aggregate/fire area

What You Need to Know About UL 9540A Fire Testing

2018 IFC Large Scale Fire Testing

The fire code official can approve the following installations based on large-scale fire testing:

- Increased array (unit) size
- Reduced spacing to adjacent units and/or walls
- Increased MAQ in a fire area

Testing to be conducted by an approved test lab and show:

- A fire in one unit will not propagate to an adjacent unit
- A fire in one unit will be contained within the test room
- UL 9540A was developed to conduct these fire propagation tests

2021 IFC specifies UL 9540A for this testing

UL 9540A Test Method

Scope

- Evaluate fire characteristics of a battery ESS that undergoes thermal runaway.
- Artificially forces cells into thermal runaway (if possible)
- Evaluates/documents the resulting fire/explosion characteristics
- Test results used to determine fire and explosion protection required for an installation

UL 9540A Testing Methodology

Cell Level Test

- Whether cell can exhibit thermal runaway
- Thermal runaway characteristics
- Gas composition (flammability)

Module Level Test

- Propensity for propagation of thermal runaway
- Heat and gas release rates (severity/duration)
- Flaming/deflagration hazards

Unit Level Test

- Evaluation of fire spread
- Heat and gas release rates (severity/duration)
- Deflagration hazards
- Re-ignition hazards

Installation Level Test

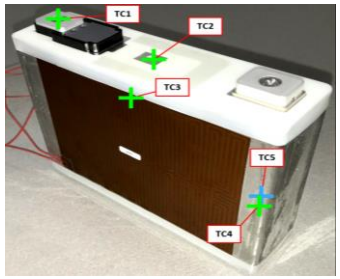
- Effectiveness of fire protection system(s)
- Heat and gas release rates (severity/duration)
- Deflagration hazards
- Re-ignition hazards

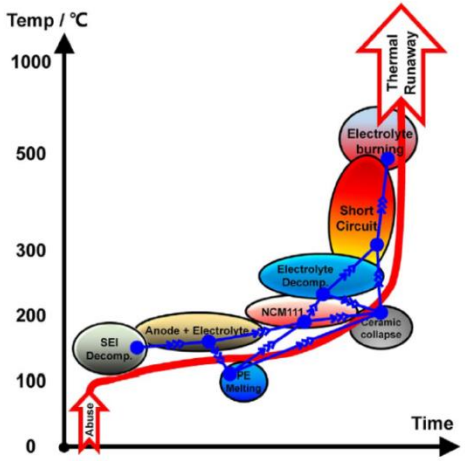
Challenge – AHJ needs to evaluate the test results

UL 9540A Cell Level Testing

Purpose:

- Determine if thermal runaway can be induced,
- If so, document thermal runaway methodology, instrumentation,
- Determine cell surface temp at venting and thermal runaway,
- Measure gas generation and composition.

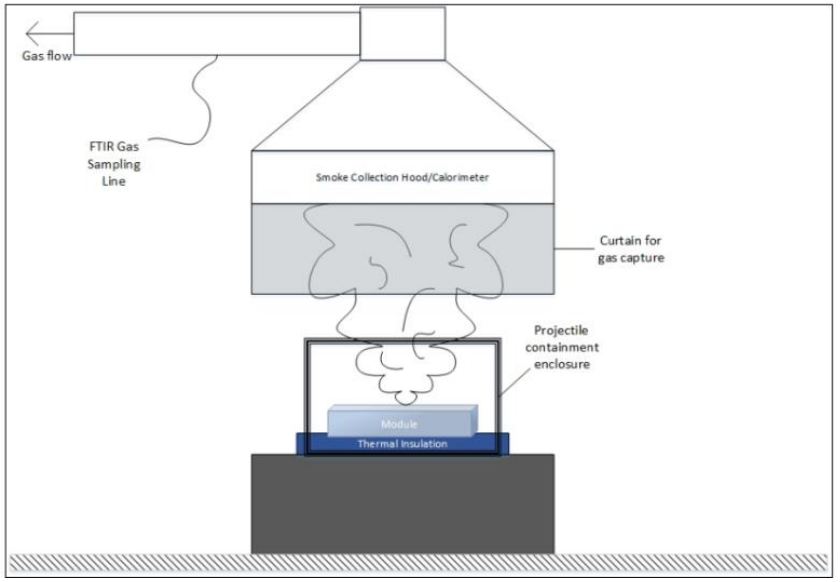




UL 9540A Module Level Testing

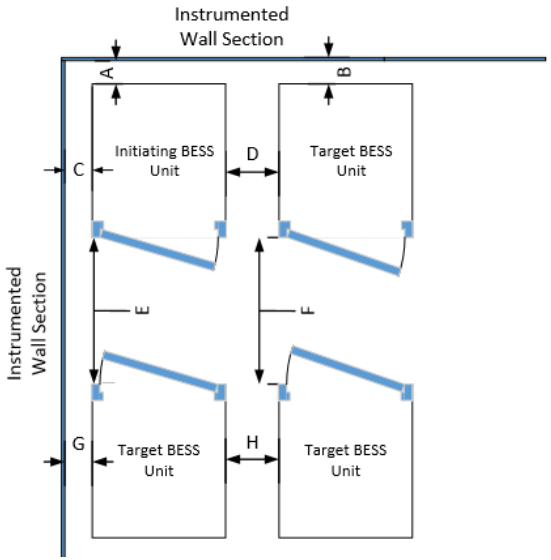
Purpose:

- Evaluate thermal runaway propagation within a module,
- Develop data on heat release rate and vent gas generation rate and composition,
- Document fire and deflagration hazards.

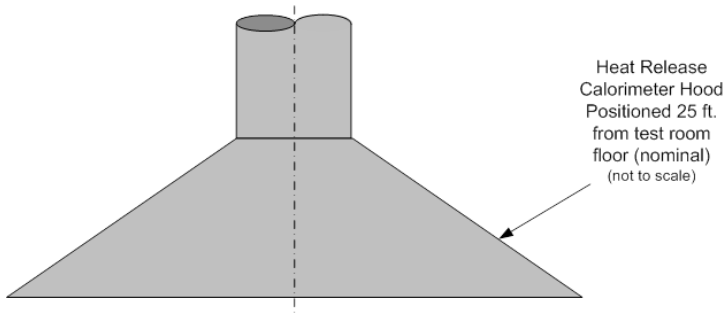


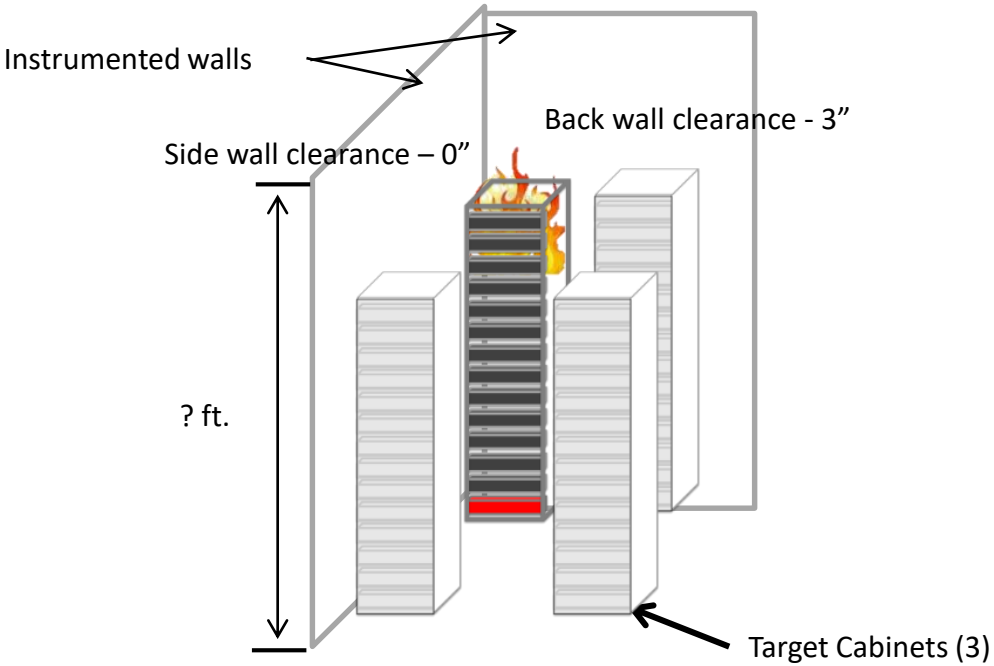
UL 9540A Unit Level Testing

- Document thermal runaway progression within the unit,
- Document if flaming occurs outside the unit,
- Measure heat and gas generation rates,
- Measure surface temperatures and heat fluxes in target units,
- Measure surface temperatures and heat fluxes on walls.



UL 9540A Unit Level Testing





UL 9540A Unit Level Performance

Acceptable results:

- No flaming outside the unit under test *
- No explosion hazard observed
- Maximum temperatures on target units ≤ the vent temperature in the cell level test, and
- Maximum surface wall temperature rise ≤ 97 °C (175 °F).

* If flaming is observed, the test will be conducted with a manufacturer recommended automatic sprinkler system or other fire protection system present.

UL 9540A Installation Level Testing (If Required)

Assesses the effectiveness of the fire mitigation methods:

Fire mitigation methods can include:

- Ceiling mounted automatic sprinklers,
- Alternate extinguishing system,
- Designed fire protection plan (a combination of fire detection, suppression, containment methods).

Questions/Discussion on UL 9540A Large Scale Fire Testing

Questions?

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