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

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- NFPA 855 – Technical Member
- NFPA 800 – Technical Member
- UL 9540/A – Technical Member
- UL 1487 – Technical Member
- UL 1973 – Technical Member
- CSA C801 – Technical Member

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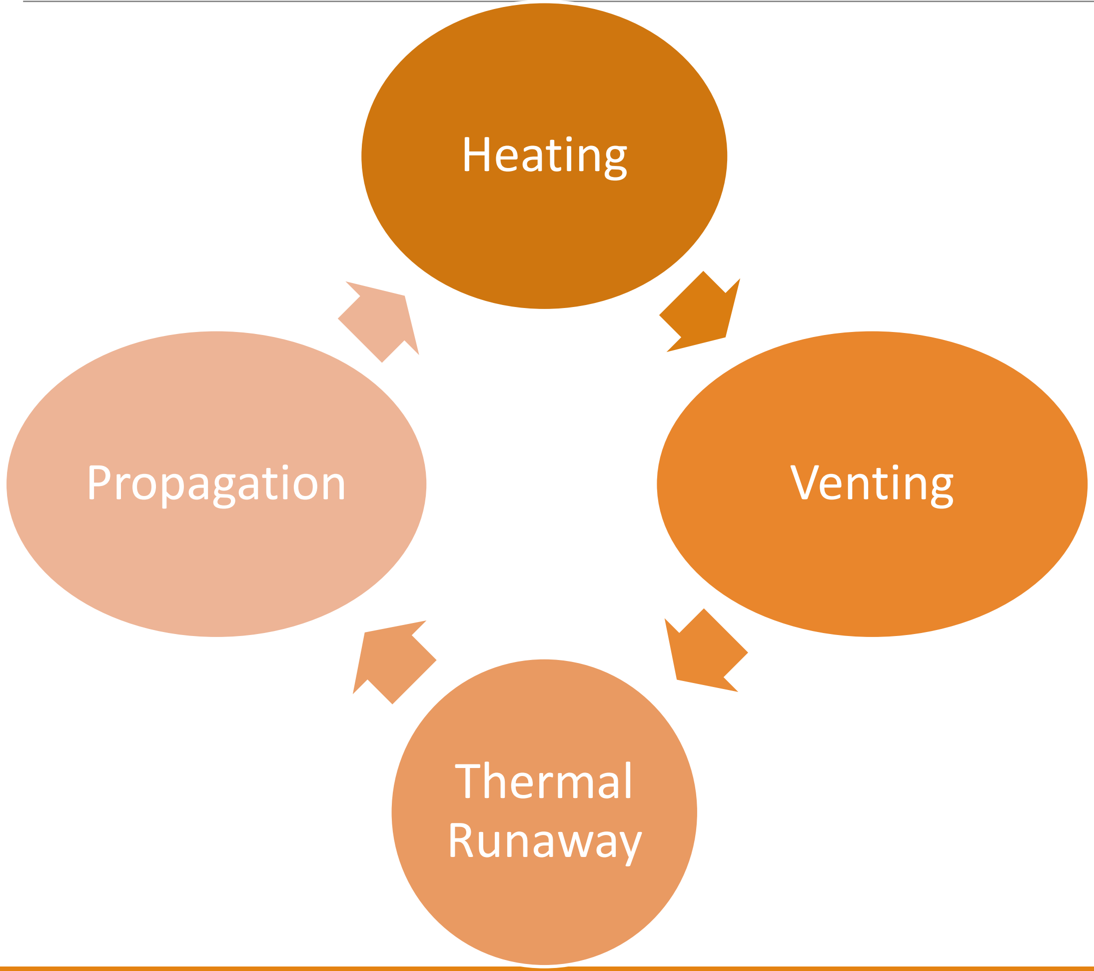
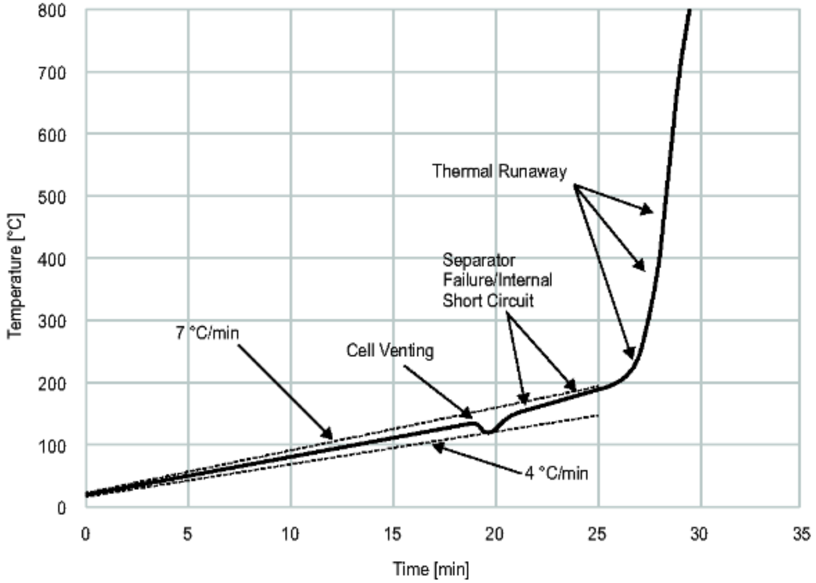
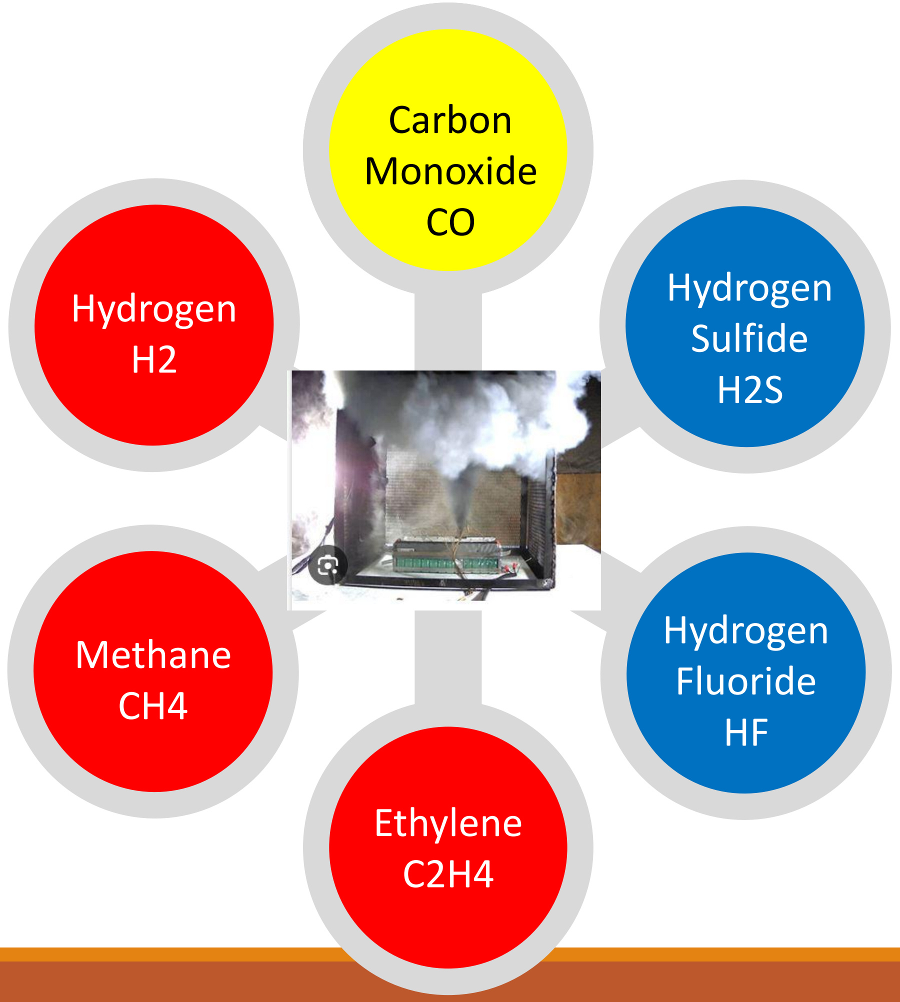
# Thermal Runaway




Venting ~ 120 - 160 ° C
TR Usually ~160-200 °C[1]

# Hazards – Fire/Explosion




## Example Gas Composition (UL 9540A)

| Cell | Chem | H2 | CO | CH4 | C2H4 | CO2 | LFL |
|---|---|---|---|---|---|---|---|
| 1 | NMC | 24.7 | 28.3 | 6.1 | 7.4 | 30.2 | **9.21** |
| 2 | NCA | 32.7 | 40.9 | 15.4 | 0.5 | 9.2 | **9.04** |
| 3 | LFP | 48.7 | 9.9 | 4.6 | 4.8 | 28.7 | **6.1** |
| 4 | LFP | 47.4 | 11 | 6.2 | 3.7 | 29.2 | **7.15** |
| 5 | LFP | 48.1 | 10.4 | 19.3 | | 22.1 | **5.3** |

# Known Causes of Incidents

- Megapack Australia – Coolant Leak

*"The incident was most likely initiated by a Megapack coolant leak."*

- McMicken, AZ – External Heat Source

***Exponent indicates this failure is condensation due to HVAC programming issue!!***

*"data collected and analyzed point to initiation of cell thermal runaway through intense heating of the incident cells by an external heat sources such as an external electric arcing…"*

- Moss Landing Fire 2021 – Water Spray

*"A small number of couplings on the flexible hoses and pipes that were part of the battery heat suppression system experience failures that resulted in water spraying on the battery racks…this resulted in short circuiting and arcing.."*

- Moss Landing Fire 2022 – Rainwater

*"Cause was significant water ingress, which allowed electrical shorts to initiate the thermal runaway of the battery cells. Rainwater intrusion was the result of displaced umbrella valves…."*

- Warwick NY Fire 2023 – Water

*"water seepage into the battery containers as the primary cause"*

**South Korea – 23 incidents in 2017-2018: Lack of BMS & protective features (overvoltage, overcurrent); condensation; dust [ref IEEE 1635 – dust].**

# NFPA 855: What is it NOT?

Certification

Vehicular/Transport

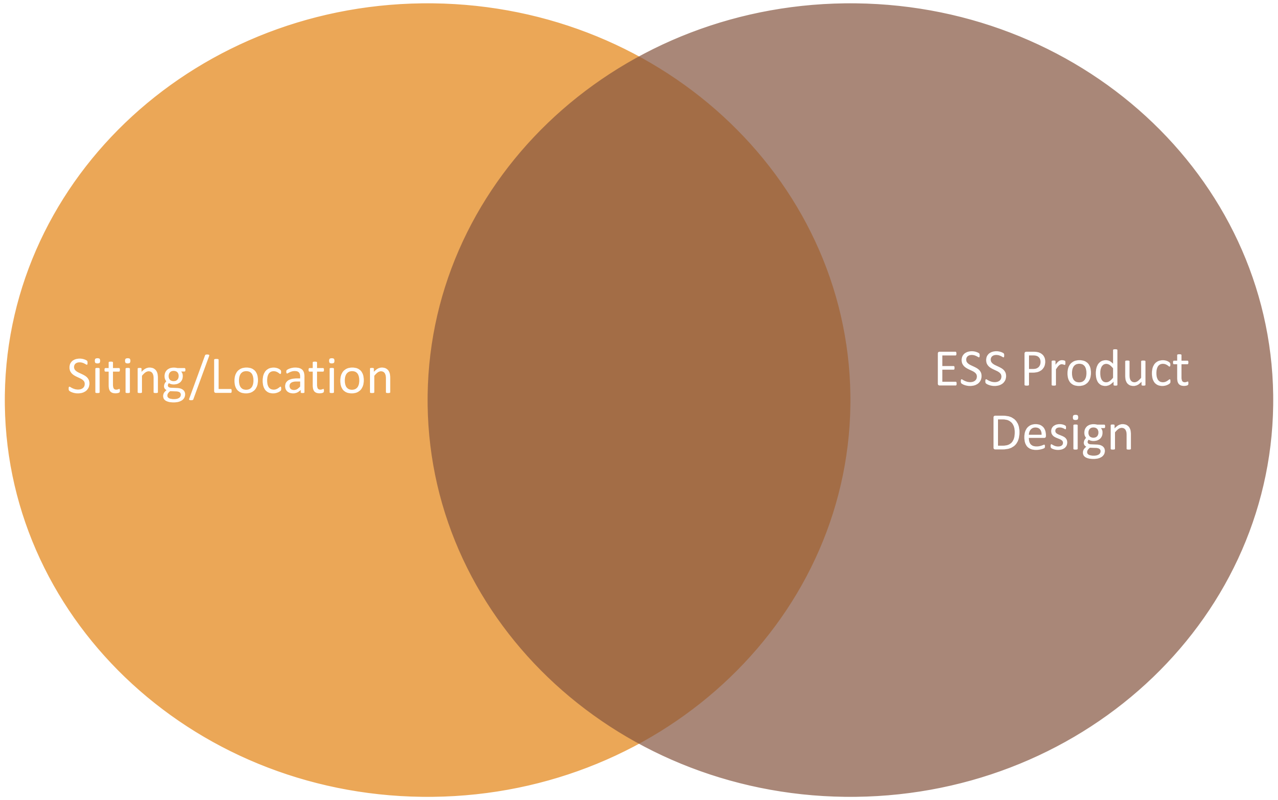

Implementation

E-Mobility

Cyber Security

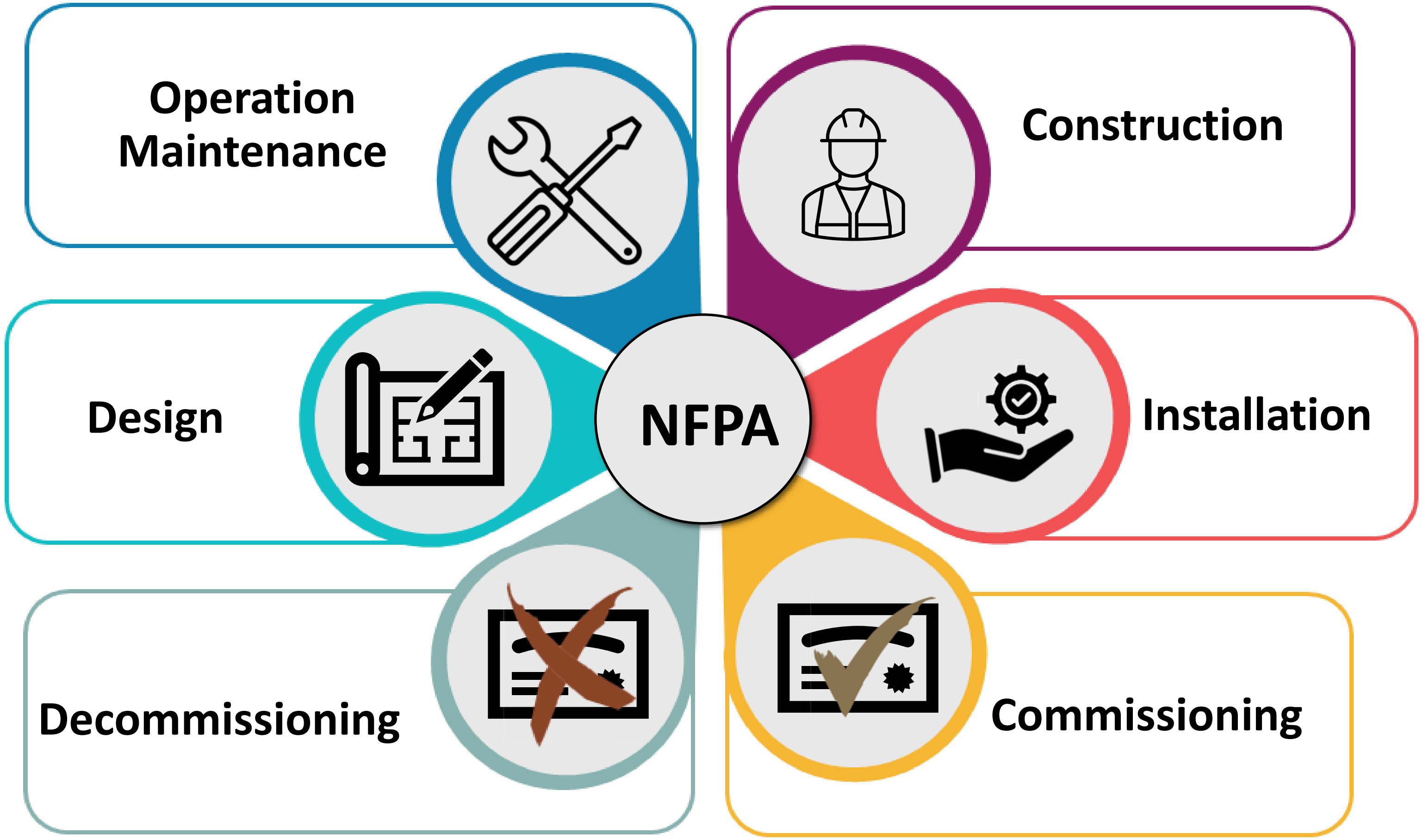
City Planning Guide

# NFPA 855 –Location vs Design



# 1.1/1.2 Scope & Purpose

Minimum requirements for mitigating hazards associated with ESS and the storage of lithium metal or lithium-ion batteries.



# 1.3 Application

**MOST IMPORTANT TABLE IN NFPA 855!**

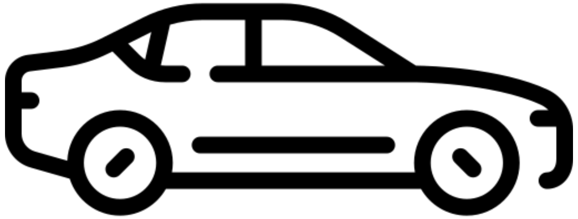
**Many new chemistries for 2026**

# Relative Size (kWh)

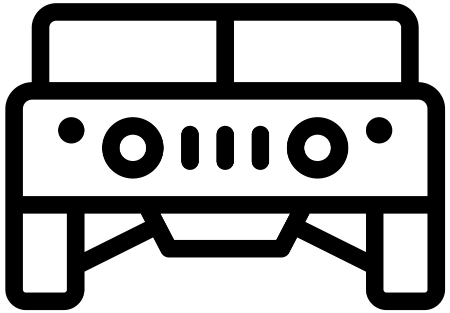
60-100 Wh

150-750 Wh


5-20 kWh

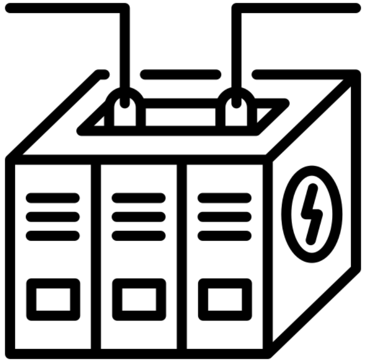


40-80 kWh

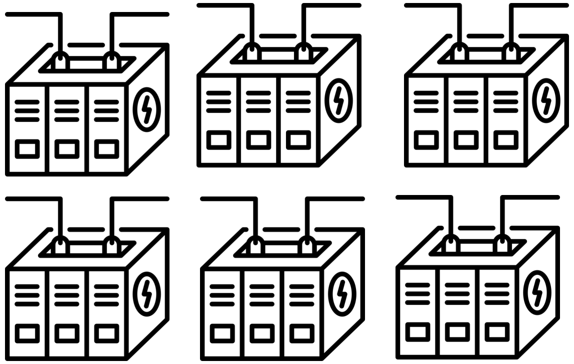


212 kWh

700-900 kWh



80 kWh – 5 MWh+



1200 MWh+
Moss Landing

# 4.3 Emergency Planning and Training

4.3.1: General

- Required for ESS>20 kWh
- Provided by owner
- EOP vs ERP

Mitigation

Preparedness

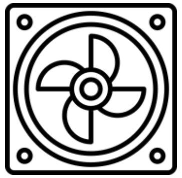
Response

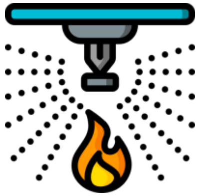
Recovery

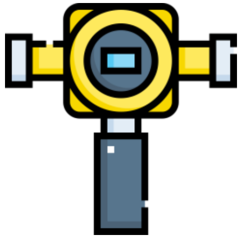
Staff Training Required Annually! 4.3.2.2

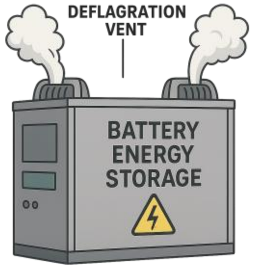
Site Tours are required!

# 4.4 Hazard Mitigation Analysis









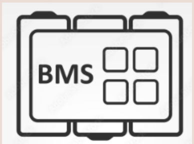

4.4.1 Required > 20 kWh

4.4.2: Failure Modes

**Single Failures Only**

## Failure Modes

Thermal runaway/Mechanical Failure




Failure of ESMS or other Protective System

Failure of required system (HVAC, liquid cooling, BMS, communications, etc)


Per AHJ

# 4.4 HMA Key Concepts

- **Barriers to Thermal Runaway**
  - module design
  - insulation monitoring
  - battery analytics
  - **h**eating/**v**entilation/**a**ir **c**onditioning (**HVAC**)
  - IP Ratings
  - chemistry
  - fuses
  - **b**attery **m**anagement **s**ystem (BMS)
- **Consequence Mitigation Measures**
  - **t**hermal **r**unaway **p**ropagation **p**rotection (**TRPP**)
  - fire alarm
  - emergency planning
  - vegetation
  - size & separation
  - suppression
  - explosion control

# 4.6 Listings

## 4.6.1: Listings

JOINT CANADA-UNITED STATES NATIONAL STANDARD

**ANSI/CAN/UL 9540:2025**

**STANDARD FOR SAFETY**

Energy Storage Systems and Equipment

JOINT CANADA-UNITED STATES NATIONAL STANDARD

**ANSI/CAN/UL 1973:2022**

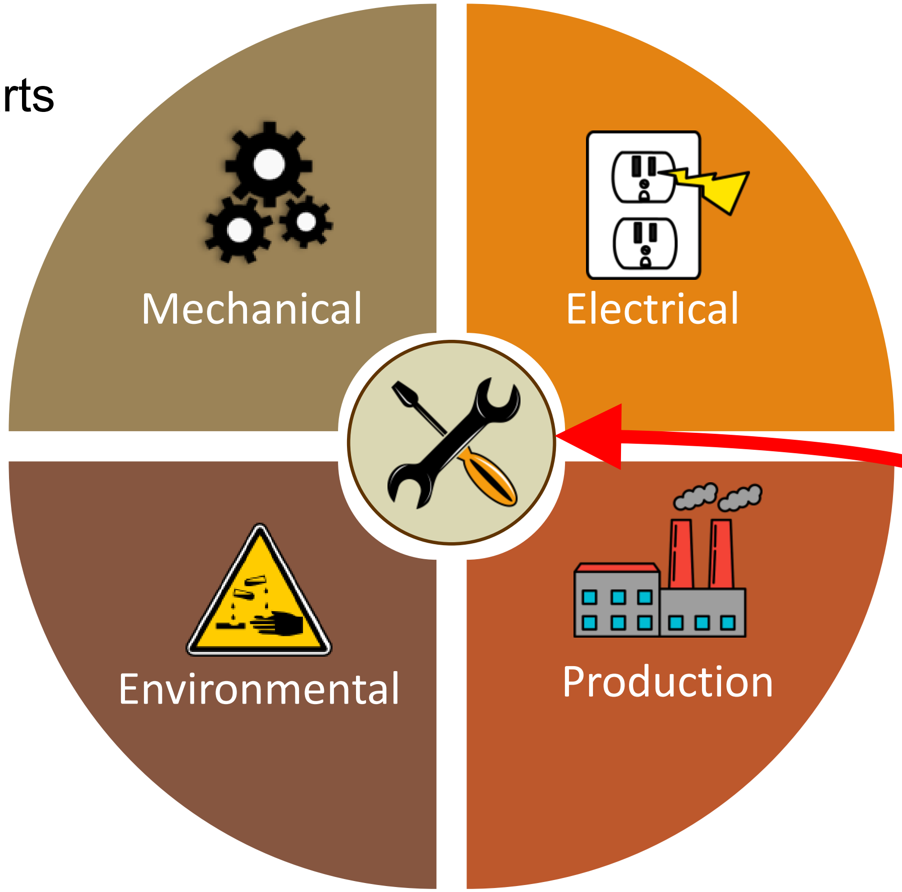
**STANDARD FOR SAFETY**

Batteries for Use in Stationary and Motive Auxiliary Power Applications

# UL 9540 At a Glance

Containment of Moving Parts
Leakage Tests
Strength Tests
Wall Mount Fixture Test

Normal Operations Test
Dielectric Voltage
Impulse Test
Grounding/Bonding
Insulation Resistance
Electromagnetic Immunity



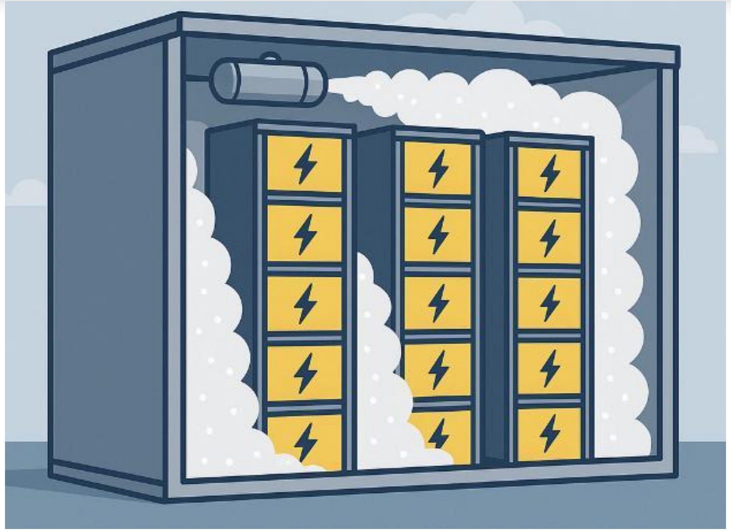

Construction
19 Items!

Moisture Exposure
Marine Environments
Seismic

Electrical Production
Mechanical Production
Production Quality Control

# 4.9 Fire Control and Suppression

Only required *indoors*, or for outdoor walk-in units!
Not required for spaces that cannot be occupied!



# Fire Suppression – A Word of Caution

- McMicken Incident Investigation
  - LG Chem/Exponent Report

*"LG Chem agrees there is industry consensus that NOVEC 1230 clean agent cannot stop module to module propagation during a thermal runaway event"*

- McMicken Incident Investigation
  - UL FSRI Report

*"It is unlikely the concentration of NOVEC 1230 remaining in the ESS at the time the door was opened provided meaningful protection against the ignition of flammable gases and vapors that had accumulated in the ESS"*
*"The clean agent suppression system prevented flaming during the early phase of the incident, but was not designed for and did not provide explosion protection"*

- FM 5-33 (Electrical Energy Storage Systems)

*Section 3.3.A "As of 2019, there is no evidence that gaseous protection is effective in extinguishing or controlling a fire involving energy storage systems…the hold time is generally 10 minutes, not long enough to fully extinguish a LIB-ESS fire or prevent thermal runaway from propagating…"*

# UL 9540A Testing – Multi Level

9540A is for <u>Information Only!</u>

Force thermal runaway ➔ 1 Cell!

- Heating strip, nail, short circuit.

Cell


Module

Unit


Installation/
LSFT

# Cell Level - Gas Collection

Volume of vent gas (Liters)

Vent gas composition

Gas mixture lower flammability limit (LFL)

Burning velocity ($S_u$)

Deflagration pressure ($P_{max}$)

Used for Explosion Control Design!

Sample Gas Data

| Cell | Chem | H2 | CO | CH4 | C2H4 | CO2 | LFL |
|---|---|---|---|---|---|---|---|
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# UL 9540A Module Level Testing

Propensity for TR propagation

Heat release rate (kW) and smoke release rates

Flaming/deflagration hazards

Weight Loss

| Module Level Performance Criteria |
|---|
| 1) Thermal runaway contained by module design |
| 2) Cell vent gas nonflammable per cell level test |

# Large Scale Fire Test

9.2.1.3

Mandatory!

-Evaluates unit-unit propagation

-Assess impact to nearby combustibles

-FULL BURN – ‘DEVELOPED FIRE CONDITION’

-Involve batteries, non-batteries, plastics, etc.

-ESS is a ‘fuel package’

-Quantitative data (temperatures, heat flux)



Kolotv.com

# Example – Open Door Test


CREDIT: HITHIUM

# Examples – Vents Open



NOTE: VIDEO POSTED PUBLICY ON LINKEDIN; ALL PHOTOS PUBLIC DOMAIN

# 9.4 Location Classification

## Indoor

1. Dedicated Use
2. Non-Dedicated Use

## Outdoor

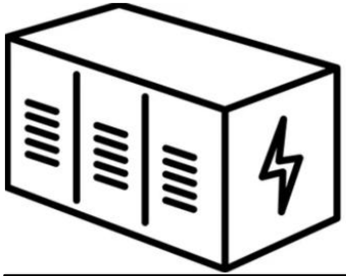
1. Remote
2. Near Exposures
3. Specific
   a) Rooftop
   b) Open Parking Garage
   c) Mobile ESS


INDOOR
9.4.1.3

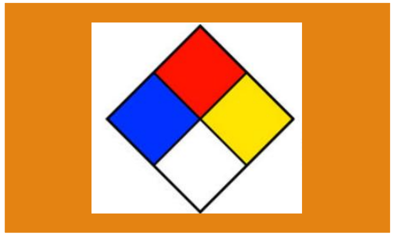
# 9.4 Location Classification 

## 9.4.2: Outdoor Installation

REMOTE



100’ (30 m)



Other Exposures (N/A Electrical Grid Infrastructure)

What do you get for being ‘Remote’?
Size/Separation
Water Supply*
Fire Suppression*
Clearances To Exposures (only apply to ‘near’)

# 9.4 Location Classification - Examples

https://www.environmentenergyleader.com/2021/01/worlds-largest-utility-scale-battery-energy-storage-system-now-online/

https://www.ess-news.com/2025/01/14/greece-launches-ci-battery-storage-subsidy-program/

# 9.4 Location Classification - Examples

Ormat Technologies

# 9.7.6 Thermal Runaway Propagation Protection (TRPP)

## Active Systems

Uses **electronic** and **mechanical** components

Novec 'Direct Injection'

JAD Module Level Aerosol

Fike Blue

## Passive Systems

Rely on **passive material choices** and **design features** to delay or prevent heat transfer and propagation.

Safire

aspen aerogels

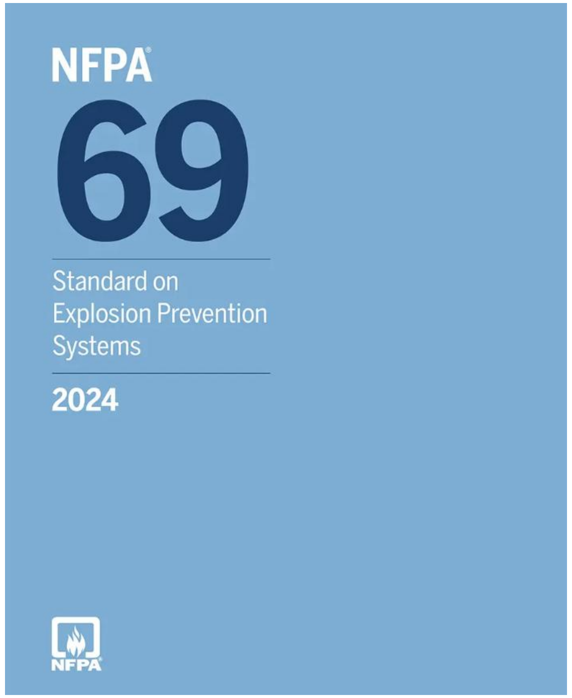
ETICAG

Hanwha Aerospace

SK enmove

# Explosion Control

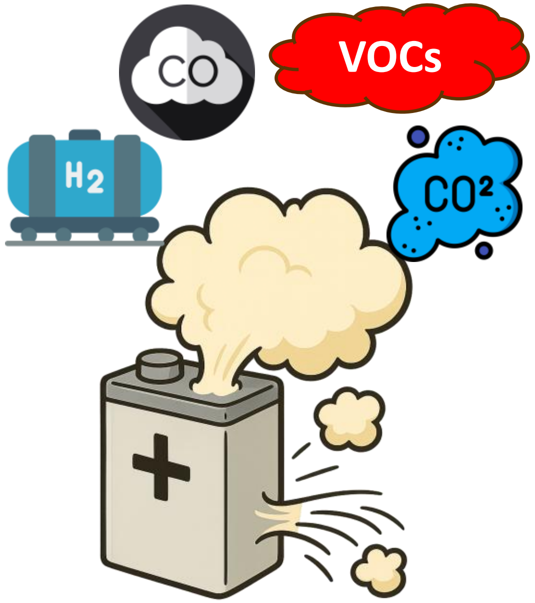
9.7.6.7.3 – NFPA 69
9.7.6.7.3.1 PVD per NFPA 68
9.7.6.7.3.2 – 9540A




NEW

+ PVD


Using



# Explosion Control - Example

Carnegie Road Incident – September 15, 2020

-Debris blown 6-23 meters (20-75 ft)

-Fire occurred, NOVEC system activated

Photos: EPRI White Paper. Carnegie Road Energy Storage System Failure Response, Recovery, and Rebuild Lessons Learned – April 2023

# Explosion control –NFPA 69

9.7.6.7.4

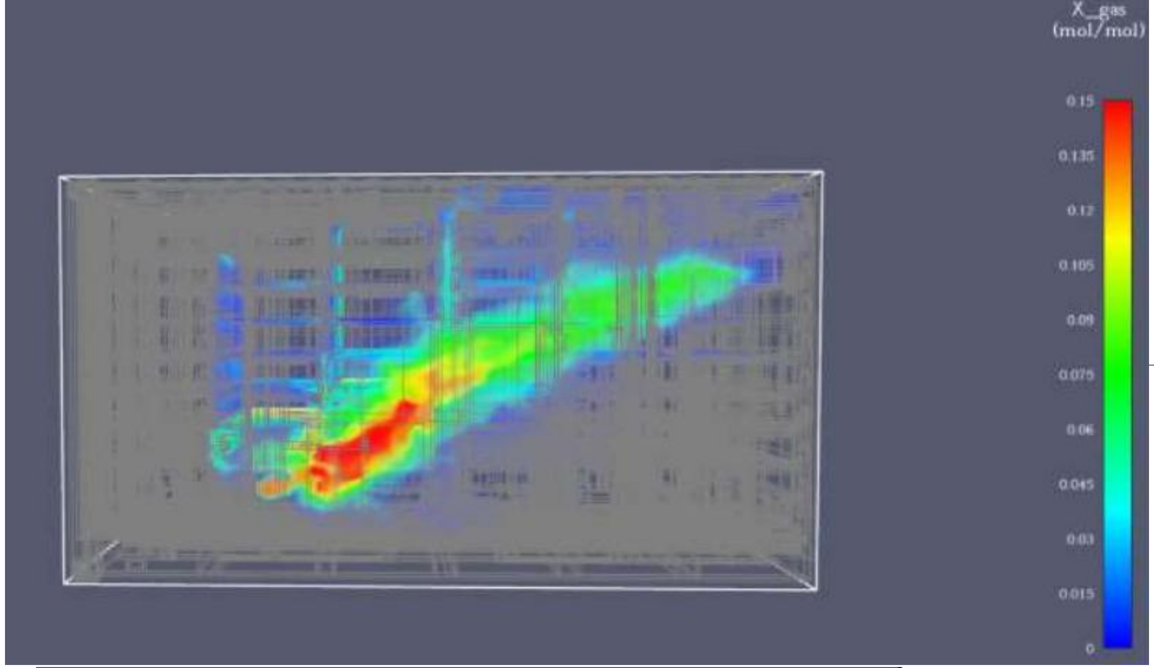
Suitable for thermal runaway temperatures -<u>UP UNTIL FIRE OCCURS</u>

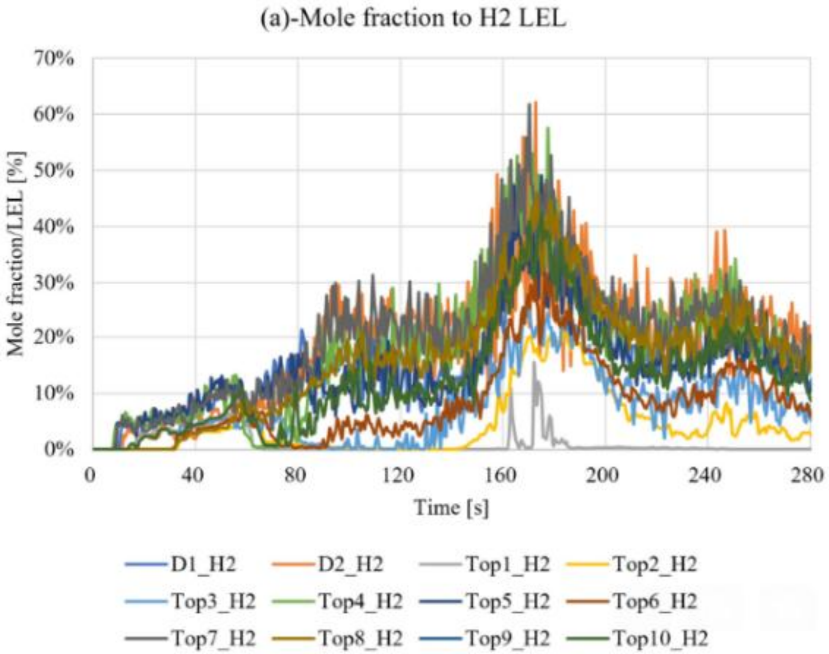
9.7.6.7.4.1

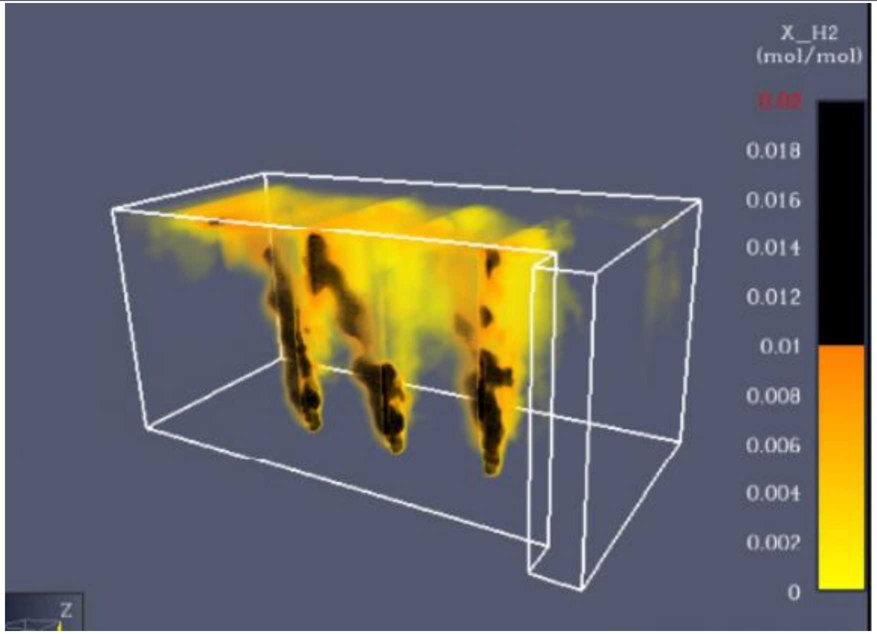
Where extinguishing systems are used, detection, logic solvers, and sequence of operations shall not impede CCR Performance. Provide analysis of no impact to AHJ

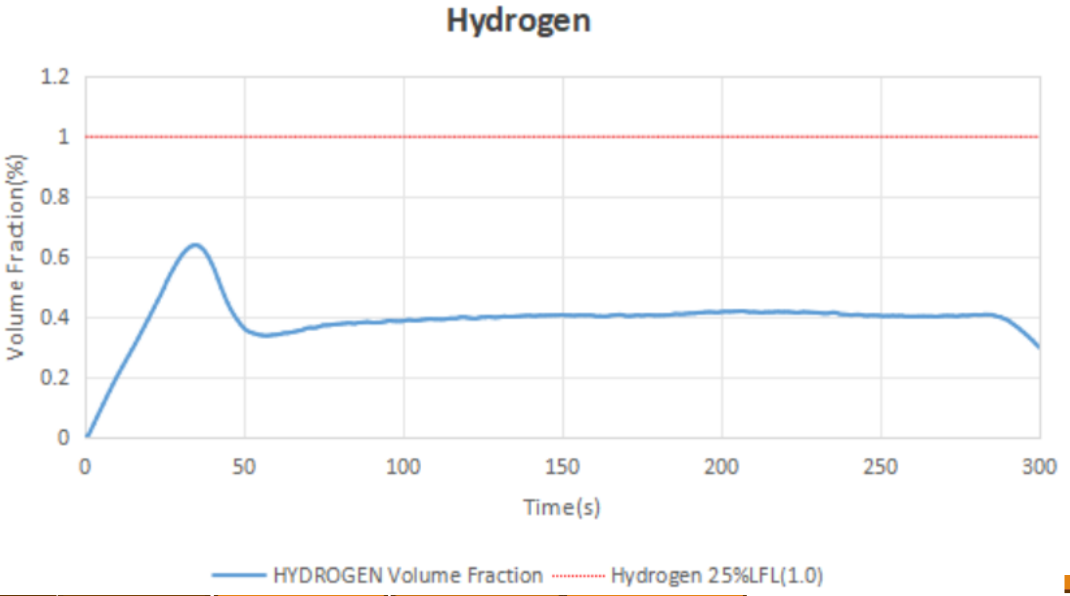
**<u>KEY TAKEAWAYS</u>**

**NFPA 69 SYSTEM SHALL LATCH! EXTINGUISHING SYSTEMS MAY NOT OVERRIDE NFPA 69 SYSTEM! NFPA 69 SYSTEM DOES NOT NEED TO SURVIVE FIRE**


X_gas
(mol/mol)
0.15
0.135
0.12
0.105
0.09
0.075
0.06
0.045
0.03
0.015
0


(a)-Mole fraction to H2 LEL
Mole fraction/LEL [%]
70%
60%
50%
40%
30%
20%
10%
0%
0
40
80
120
160
200
240
280
Time [s]
D1_H2
D2_H2
Top1_H2
Top2_H2
Top3_H2
Top4_H2
Top5_H2
Top6_H2
Top7_H2
Top8_H2
Top9_H2
Top10_H2


X_H2
(mol/mol)
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
Z


Hydrogen
Volume Fraction(%)
1.2
1
0.8
0.6
0.4
0.2
0
0
50
100
150
200
250
300
Time(s)
HYDROGEN Volume Fraction
Hydrogen 25%LFL(1.0)

# Thank You!

ATAR FIRE

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