



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

Missouri-Kansas Chapter of SFPE
Overland Park, KS

November 2019

NFPA.ORG | © National Fire Protection Association. All rights reserved.

Bob Sullivan

- National Fire Protection Association (NFPA)
Southwest Regional Director
- 8 states (CO, UT, NV, AZ, NM, TX, OK, KS)
- 31 years in the Fire Service
- 17 of those years as Senior Fire Protection
Engineer/Deputy Fire Marshal

NFPA.ORG | © National Fire Protection Association. All rights reserved.

2

Contact Information

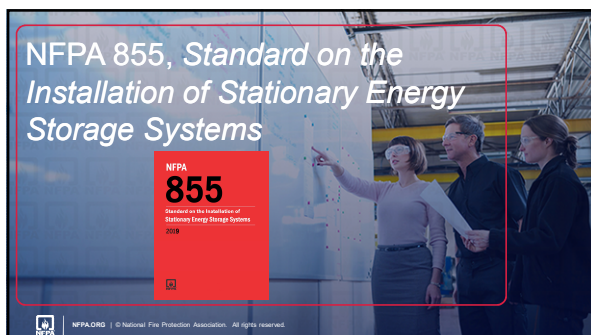
Bob Sullivan, CFPS
Southwest Regional Director | NFPA
(Based in Broomfield, CO)

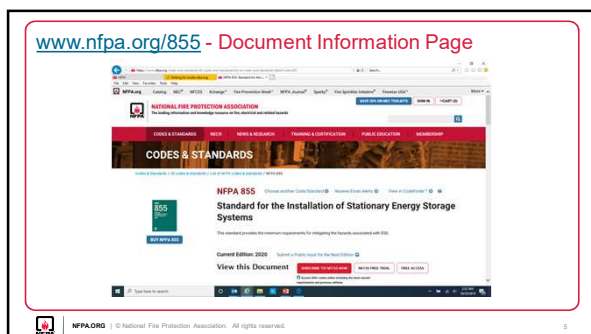
bsullivan@nfpa.org

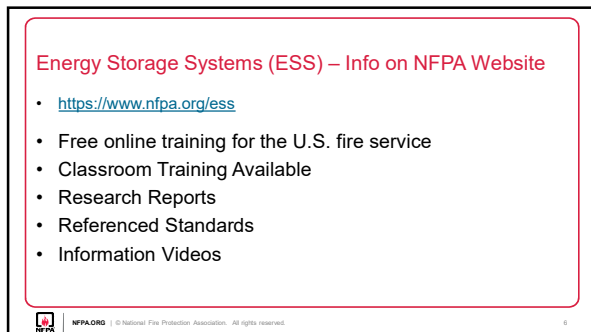
720 237-1752

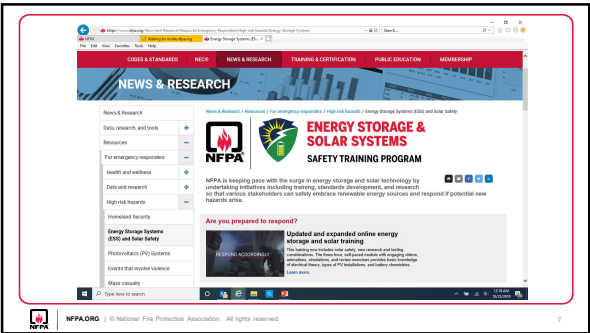
www.nfpa.org

NFPA.ORG | © National Fire Protection Association. All rights reserved.









NFPA Energy Storage Systems (ESS) Research

2014 - DOE Published a Strategic Plan for Energy Storage Safety.

- Identified gaps in codes, standards and regulations (CSR) and first responder training.

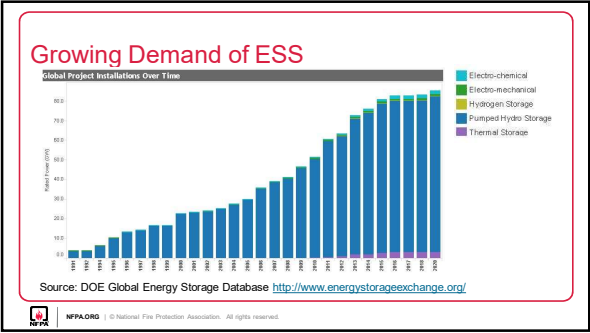
2016 – NFPA released Fire Service ESS Online & Classroom Training.

2019 – NFPA 855, Installation of Stationary Energy Storage Systems published.



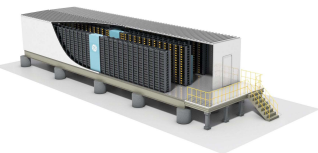


NFPA.ORG | © National Fire Protection Association. All rights reserved. 8



What are Energy Storage Systems (ESS)?

- A device capable of storing energy for use as electrical energy at a future time.



NFPA.ORG | © National Fire Protection Association. All rights reserved.

Types of ESS

- Pumped Hydro
 - Represents 95% of ESS in use

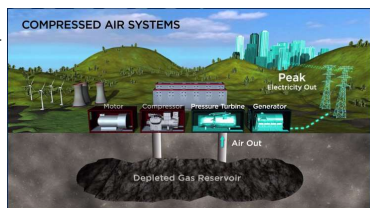


NFPA.ORG | © National Fire Protection Association. All rights reserved.

11

Types of ESS

- Mechanical
 - Compressed Air
 - Least common

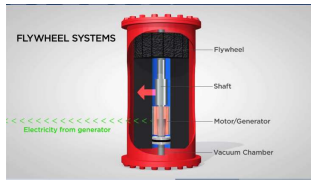
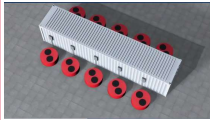


NFPA.ORG | © National Fire Protection Association. All rights reserved.

12

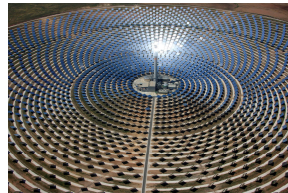
Types of ESS

- Mechanical
 - Flywheel



Types of ESS

- Thermal
 - Molten Salts
 - 99% Heat Retention
 - Used in in Concentrated Solar Power



Types of ESS

- Electro-Chemical (Battery)



- Typical as a car battery
- Is more mature of a technology than others
- Sulfuric and water mixture as an electrolyte

Types of ESS



- Normal operating temperature is over 500°F
- Used in large scale ESS such as utility substations
- Highly reactive to water



NFPA.ORG | © National Fire Protection Association. All rights reserved.

16

Types of ESS



- Utilize 2 different liquid electrolytes
- Ion exchange over membrane
- Electrolytes are typically non-flammable



NFPA.ORG | © National Fire Protection Association. All rights reserved.

17

Types of ESS



- Common in:
 - Consumer electronics
 - Electric and hybrid vehicles
- Lithium found in Li-Ion Batteries is not pure
- Lithium salts are flammable and release toxic gasses





NFPA.ORG | © National Fire Protection Association. All rights reserved.

18

ESS Applications

- Supplement Renewable Energy

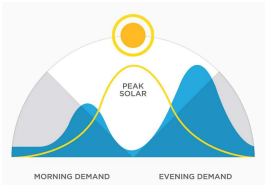




NFPA.ORG | © National Fire Protection Association. All rights reserved.

19

ESS Applications

- Peak Shaving

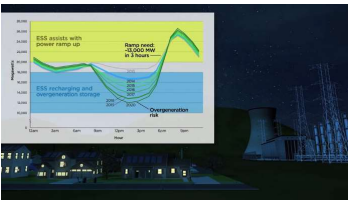



NFPA.ORG | © National Fire Protection Association. All rights reserved.

20

ESS Applications

- Load Leveling



NFPA.ORG | © National Fire Protection Association. All rights reserved.

21

ESS Applications

- Uninterruptible Power Supply
 - A power supply used to provide alternating current power to a load for some period of time in the event of a power failure.



NFPA.ORG | © National Fire Protection Association. All rights reserved.

22

Lithium Ion Battery Uses

- Portable
 - Cell Phones/Tablets
 - Power Tools
- Automotive
 - Electric Vehicles
- Stationary
 - Energy Storage

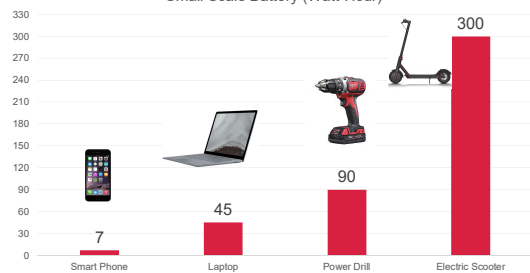


NFPA.ORG | © National Fire Protection Association. All rights reserved.

Video ^

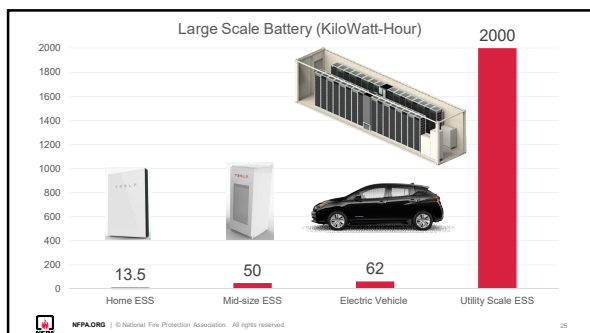
23

Small Scale Battery (Watt-Hour)



NFPA.ORG | © National Fire Protection Association. All rights reserved.

24



Failure Modes

- Thermal Abuse – Exposure to external heat sources
- Mechanical Abuse – Battery is physically compromised
 - Dropped, Crushed, Penetrated

NFPA.ORG | © National Fire Protection Association. All rights reserved.

Failure Modes

- Electrical Abuse – Overcharged, Charges too rapidly or at high voltage, Discharged too rapidly
- Internal Faults – poor design, deficiencies in manufacturing
- Environmental Impacts – seismic activity, rodent damage to wiring, extreme heat, floods

NFPA.ORG | © National Fire Protection Association. All rights reserved.

Disposing of Li-Ion Batteries

- In 2017, 65 percent of fires in California waste facilities started with lithium-ion batteries.
- Need to be Recycled



NFPA.ORG | © National Fire Protection Association. All rights reserved.

28

Lithium Ion vs Lithium Metal

- Lithium Metal
 - Highly reactive metal (Class D)
 - Disposable (Primary)
- Lithium-Ion
 - Lithium Salts
 - Flammable
 - Produce flammable/toxic gasses in thermal runaway
 - Rechargeable



NFPA.ORG | © National Fire Protection Association. All rights reserved.

29

Problems with ESS

- Lack of Knowledge
- Thermal Runaway
- Ability to reignite
- Toxicity
- Off-Gassing
- Stranded Energy
- Growing Demand
- Explosion Potential




NFPA.ORG | © National Fire Protection Association. All rights reserved.



30

Incidents

Kahuku, Hawaii: August 2011



- 12,000 lead acid batteries
- Fire burned for several days
- Initial extinguishment was attempted with dry chemical with limited success
- Building not designed for hazard level

**ENERGY STORAGE
SYSTEMS**

SAFETY TRAINING PROGRAM

31

Flagstaff, Arizona 11/26/2012

- 1.5MW Containerized System
- Let the Batteries Burn







NFPA.ORG | © National Fire Protection Association. All rights reserved.

32

Port Angeles, Washington July 2013

- 50kW battery bank
- The Landing Mall
- Two fires in one week
- Used dry chemical extinguisher






NFPA.ORG | © National Fire Protection Association. All rights reserved.



33

Incidents

Franklin, Wisconsin: August, 2016



- Fire in a battery energy storage system under construction in shipping container
- Facility staff advised against using water due to Lithium
- 20+ departments responded, fire confined to container

34

ENGIE ESS Fire, Belgium

November 11th, 2017

- 6MW project
- 1MW container fire, total loss
- Concerns about toxicity in the air
- Fire Suppression System failed to control the fire









© National Fire Protection Association. All rights reserved.

35

Smoke color is very important

- White smoke coming from Energy Storage Systems is very toxic smoke!
- = Flammable Cocktail
- The white smoke is very flammable and can ignite



© National Fire Protection Association. All rights reserved.

36

Flammable or Toxic Cocktail

- Hydrogen
- Hydrogen Cyanide
- Hydrogen Chloride
- Hydrogen Fluoride
- Nitrogen Oxides
- Oxygen
- Runoff concerns from firefighting water



NFPA.ORG | © National Fire Protection Association. All rights reserved.

South Korea

Throughout 2018



- 23 Battery ESS fires
- Government
- Fires attributed to poor management of batteries



NFPA.ORG | © National Fire Protection Association. All rights reserved.

38

Surprise, Arizona

April 19, 2019

- Explosion Occurred
- 8 Firefighters Injured
- Still Under Investigation



NFPA.ORG | © National Fire Protection Association. All rights reserved.

39

About NFPA

Global non-profit devoted to eliminating death, injury, property and economic loss due to fire, electrical and related hazards.

- Support for development, adoption, and enforcement of codes and standards
- Research and data analysis
- Technical training and certification
- Public education
- Outreach and advocacy

FAST FACTS

- Founded in 1896
- More than 60,000 members
- 6,000 volunteers
- 275+ technical code development committees
- 300 codes and standards
- 300 employees



NFPA.ORG | © National Fire Protection Association. All rights reserved.

40

NFPA Standards Development Process

Uniquely Open Process

1. Public Input Stage
2. Public Comment Stage
3. Tech Session
4. Appeals and Issuance of Standard



NFPA.ORG | © National Fire Protection Association. All rights reserved.

41


NFPA Standards That Address ESS



NFPA.ORG | © National Fire Protection Association. All rights reserved.

42


NFPA 1 – Fire Code (2015 Edition)



- **Chapter 52, Stationary Storage Battery Systems**
 - Venting
 - Thermal Runaway
 - Location & Separation
 - Spill Control
 - Neutralization
 - Signs
 - Seismic Protection
 - Smoke Detection

NFPA ENERGY STORAGE SYSTEMS SAFETY TRAINING PROGRAM 43

NFPA 1 – Fire Code (2018 Edition)



- **Chapter 52, Energy Storage Systems**
 - Separates out more mature battery technologies
 - Lead-Acid
 - Nickel-Cadmium
 - Prescriptive or Alternative with Testing

NFPA ENERGY STORAGE SYSTEMS SAFETY TRAINING PROGRAM 44

NFPA 1, 2018 Edition

- Lead Acid and Nickel-Cadmium Batteries
 - Sprinklered Building: >100gal Electrolyte
 - Unsprinklered Building >50gal of Electrolyte
- Additional Battery Technologies

- Lithium Ion	20KWh
- Sodium	20KWh
- Flow Batteries	20KWh
- Capacitors	70KWh
- Other	10KWh

NFPA.NFPA.ORG © National Fire Protection Association. All rights reserved. 45

NFPA 1, 2018 Edition

- Location
 - No more than 75ft above fire department vehicle access
 - No more than 30ft below lowest exit discharge
- Separation
 - 1 or 2 hour fire rated barrier, depending on occupancy
 - 3ft from container walls



NFPA.ORG | © National Fire Protection Association. All rights reserved.

46

NFPA 1, 2018 Edition

- Maximum Allowable Quantities
 - Lithium Ion 600KWh
 - Sodium 600KWh
 - Flow Batteries 600KWh
 - Other 200KWh

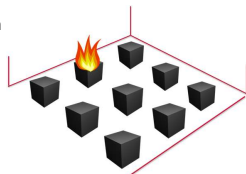


NFPA.ORG | © National Fire Protection Association. All rights reserved.

47

NFPA 1, 2018 Edition

- Battery Arrays
 - Segments not exceeding 50KWh
 - 3ft Separation from walls and other arrays
 - Max 250 KWh for Listed Systems
 - Other arrangements as approved by AHJ based on large scale fire and fault condition testing



NFPA.ORG | © National Fire Protection Association. All rights reserved.

48

NFPA 1, 2018 Edition

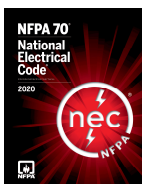
- Smoke detection
- Ventilation
- Fire Suppression



NFPA.ORG | © National Fire Protection Association. All rights reserved.

49

NFPA 70 – National Electrical Code



Benchmark for Safe electrical design, installation, and inspection to protect people and property from electrical hazards

- Adopted in all 50 states
- Article 706 is new with the 2017 edition
- Electrochemical Energy Storage Systems
- Flow Battery Energy Storage Systems
- Applies ESS above 1kWh
- No PDF 2020 edition



ENERGY STORAGE SYSTEMS
SAFETY TRAINING PROGRAM

50

NFPA 70, National Electrical Code, Article 706



- Disconnecting Means
- Installation requirements
- Circuit Requirements
- Flow Battery ESS
- Other ESS Technologies



NFPA.ORG | © National Fire Protection Association. All rights reserved.

51



NFPA
855
Standard for
the Installation of Stationary
Energy Storage Systems
2020

**ENERGY STORAGE
SYSTEMS**
SAFETY TRAINING PROGRAM

NFPA 855 – Standard on the Installation of Stationary Energy Storage Systems

Standard will address

- Design
- Construction
- Installation
- Fire Protection
- Fire Prevention
- Commissioning
- Operation
- Maintenance
- Decommissioning


**ENERGY STORAGE
SYSTEMS**
SAFETY TRAINING PROGRAM

NFPA 855 Content

Scope

Table 1.3 Threshold Quantities


ESS Technology	Aggregate Capacity ^a	
	kWh	MJ
Battery ESS		
Lead-acid, all types	70	252
Nickel including Ni-Cad, Ni-MH, and Ni-Zn ^b	70	252
Lithium-ion, all types	20	72
Sodiumnickel chloride	20	72
Flow batteries ^c	20	72
Other battery technologies	10	36
Batteries in one- and two-family dwellings and townhouse units	1	3.6
Capacitor ESS		
Electrochemical double layer capacitors ^d	3	10.8
Other ESS		
All other ESS	70	252

**NFPA.ORG** | © National Fire Protection Association. All rights reserved.

1.1

NFPA 855 – Emergency Planning

- Emergency Operations Plan
 - Safe shutdown
 - Emergency procedures
 - Response considerations (SDS)
 - Removal of damaged ESS
 - Annual staff training
- Hazard Mitigation Analysis (HMA)
- Fire Mitigation Personnel



4.1.3
4.1.4
4.16

NFPA 855 – Equipment

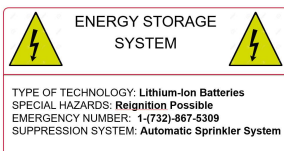
- System listed to UL 9540
- Charge Controllers
- Inverters & Converters
- Energy Storage Management System
- Reused and Repurposed Equipment



4.2

NFPA 855 - Electrical Installations

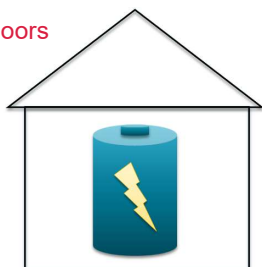
- NFPA 70 or IEEE C2
- ESS Signage
- Separation (2hr Fire Rating)
- Impact Protection
- Security
- Elevation
- Open Rack



4.3

NFPA 855 – Location: Indoors

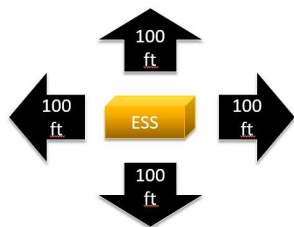
- Dedicated Use Buildings
- Non-dedicated Use Buildings
- Dwelling and Sleeping Units



4.4.2

NFPA 855 – Location: Outdoors

- Remote
- Near Exposures
- Rooftop & Open Parking
- Garage



4.4.3

NFPA 855 - Mobile ESS Equipment and Operations

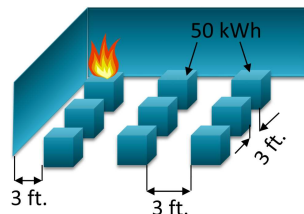
- Charging and Storage
- Deployed



4.5

NFPA 855 - Size and Separation

- 50kWh groups
- Spaced 3ft from groups & walls
- Other arrangements based on large scale fire test
- Exempt: Remote Locations



4.6

NFPA 855 - Maximum Stored Energy

Table 4.8 Maximum Stored Energy

ESS Type	Maximum Stored Energy* (kWh)
Lead-acid batteries, all types	Unlimited
Nickel batteries ^b	Unlimited
Lithium-ion batteries, all types	600
Sodium nickel chloride batteries	600
Flow batteries ^d	600
Other battery technologies	200
Storage capacitors	20

Exempt: Dedicated use buildings and remote locations

4.8

NFPA 855 - Ventilation and Detection

- Exhaust Ventilation
 - 1ft³/min/ft²
 - Designed to keep flammable gasses under 25% of LFL
 - Exhaust away from openings
- Smoke and Fire Detection
 - Gas detection activates ventilation
 - Smoke detection per NFPA 72



4.9

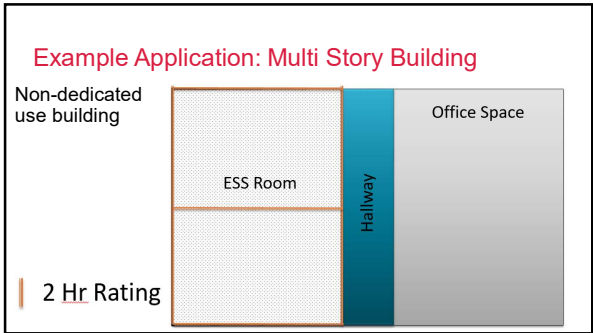
4.10

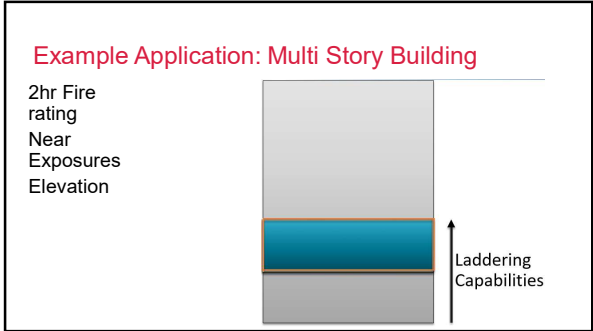
Fire Control & Suppression

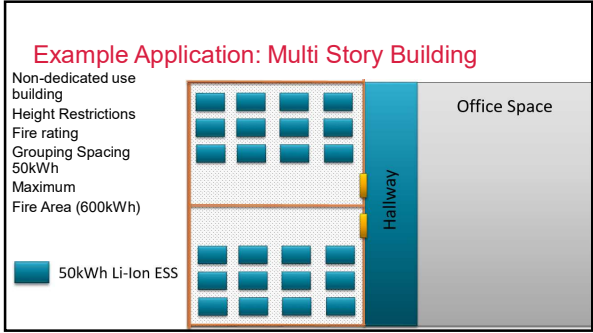
- Sprinkler System 0.3gpm/ft² over 2,500 ft²
- Other Fire Protection Systems
 - Large Scale Fire Test
 - UL 9540A
- Explosion Control
 - ESS exceeds 25% LFL



4.11 & 4.12





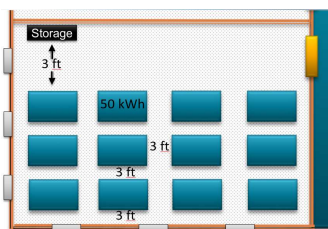


Example Application: Multi Story Building

- Size and Separation
- Explosion Venting
- Storage

Storage ESS Related
Combustible
Storage

Explosion Vent

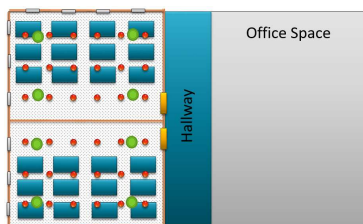


Example Application: Multi Story Building

- Suppression
- Detection

• Sprinkler

• Detector



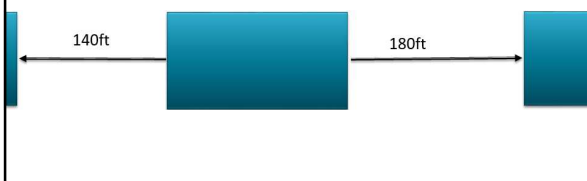
Example Application: Multi Story Building

- Not Covered Using Li-Ion:
 - Neutralization
 - Spill control
 - Exhaust Ventilation
 - Safety Caps

Example Application: Dedicated Use Building

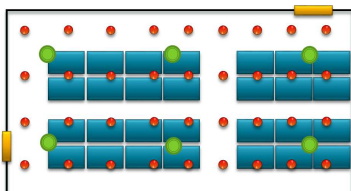


Example Application: Dedicated Use Building
100 ft from Exposures



Example Application: Dedicated Use Building

- No Max Stored Energy
- No Group Spacing



NFPA 855 – Annexes(Informational)

Annex B, Energy Storage System Hazards

Annex C, Firefighting Considerations (Operations)

Annex D, Overview of Energy Storage System Technologies

Annex E, Permits, Inspections, Approvals and Connections



NFPA.ORG | © National Fire Protection Association. All rights reserved.

73

NFPA 855 – Annex C – Firefighting Considerations

- Pre-Incident Planning Information
- Handover to Qualified Personnel – Procedures
- Suppression Systems – Water vs. Clean Agent
- Emergency Response with little information
- Overheated batteries with no fire – air & temp monitoring
- Fires – response procedures & suppression tactics; decisions about actively fighting the fire; water supply; potential for extended operations
- Suppression agents – water, dry chem, foam, clean agent
- Water runoff – containment? Water collection/added weight



NFPA.ORG | © National Fire Protection Association. All rights reserved.

74

About the Research Foundation

Plan, manage and communicate research in support of the NFPA mission

- Independent charitable organization
 - Formed by NFPA in 1982
 - Intended to provide data to support the needs of NFPA codes & standards
 - Research funds come primarily from:
 - Private and public sector consortia
 - Grants and government sources (e.g. DHS S&T, DOD, FEMA, AFG, NIOSH, NIST, NSF, etc)
 - Multiple other sources (including NFPA)



NFPA.ORG | © National Fire Protection Association. All rights reserved.

75

Fire Hazard Assessment of ESS

- Fire hazard assessment of lithium-ion battery ESS
- Literature review and gap analysis
- Full-scale fire testing
 - Manufacturer donated commercial systems



NFPA.ORG | © National Fire Protection Association. All rights reserved.

76

Fire Hazard Assessment of ESS

Full-scale Fire Tests: ESS Design

- Two 100 kWh units designed for commercial installation
- Modular – multiple units can be connected for increased capacity
- Outdoor installation – typically placed on concrete pad
- Location – can be remote from building of abutting



NFPA.ORG | © National Fire Protection Association. All rights reserved.

77

Fire Hazard Assessment of ESS

Fire Test Overview

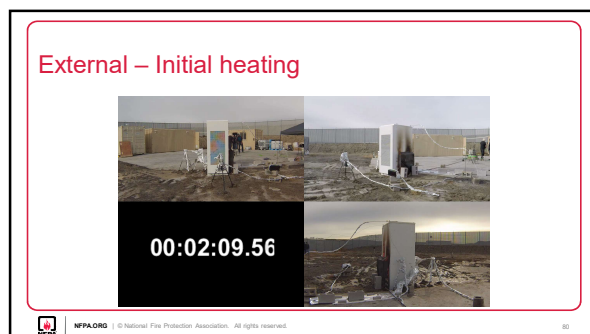
- Outdoors in open air
- Batteries at 100% State-of-Charge (SOC)
- Two ignitions scenarios
 - External ignition test; Internal ignition test
- Data Collection
- Free burn – no suppression



NFPA.ORG | © National Fire Protection Association. All rights reserved.

78







External – Typical burn conditions



External – Compressor rupture



External – Peak reaction conditions



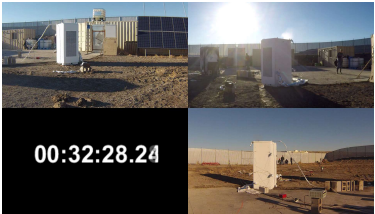
External – End of test conditions



Internal – Initial heating



Internal – Typical reaction conditions



Internal – Peak reaction conditions



Internal – End of test conditions



Fire Hazard Assessment of ESS

- Knowledge Gaps
 - No public fire test data demonstrating fire behavior of ESS
 - Limited public fire test data related to large format batteries
 - Limited incident data on large-scale (grid size) ESS
 - Thermal runaway protection
 - Post-fire incident response and recovery (i.e. overhaul) procedures

Fire Hazard Assessment of ESS

- Based on results of the two tests in this project
 - Significant (400 kW) external fire with long duration exposure (60 min) required to achieve self-sustaining thermal runaway
 - Multiple (6) internal heating elements on adjacent cells did not cause thermal runaway outside of initiator pod
 - Flames observed from exhaust vent and front door – separation distance from combustibles should be evaluated
 - HF detected at elevated levels
 - CO, HF, and CH₄ detected in significant quantities for internal thermal runaway – evaluate ventilation for indoor installation

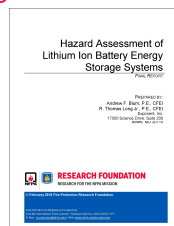


NFPA.ORG | © National Fire Protection Association. All rights reserved.

91

Fire Hazard Assessment of ESS

- Published February 2016
 - <http://www.nfpa.org/news-and-research/fire-statistics-and-reports/research-reports/other-research-topics/hazard-assessment-of-lithium-ion-battery-energy-storage-systems>

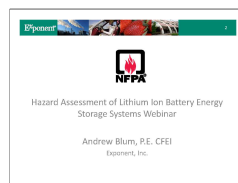


NFPA.ORG | © National Fire Protection Association. All rights reserved.

92

Fire Hazard Assessment of ESS

- Recording available for free on NFPA Xchange
 - <https://community.nfpa.org/community/xchange-exclusives/blog/2016/09/27/hazard-assessment-of-lithium-ion-battery-energy-storage-systems-webinar>



NFPA.ORG | © National Fire Protection Association. All rights reserved.

93

Sprinkler Guidance for Lithium-Ion Based ESS

- Fire Tests
 - Small Scale
 - Intermediate Scale
 - Large Scale
- Lithium Iron Phosphate (LFP)
- Nickel Manganese Cobalt Oxide (NMC)



Sprinkler Guidance for Lithium-Ion Based ESS

Recommended Separation			
Battery Technology	Object Combustibility	Sprinklered	Non-sprinklered
NMC	Combustible	9 ft.	13 ft.
	Noncombustible	6 ft.	8 ft.
LFP	Combustible	5 ft.	6 ft.
	Noncombustible	3 ft.	4 ft.

Fire Service Safety Training

- Instructor-led Classroom Course
- Online Training
- Interactive 3D Models
- Educational Videos
- Quick Reference Materials



The slide features a large, light blue rectangular area with a thin blue border. Inside this area, the NFPA logo is positioned on the left, consisting of a black square with a white flame icon and the letters 'NFPA' in white below it. To the right of the logo, the text 'IT'S A BIG WORLD.' is written in a large, bold, black sans-serif font. Below this, the phrase 'LET'S PROTECT IT TOGETHER.®' is written in a smaller, blue sans-serif font. At the bottom of the blue area, a white rectangular button with rounded corners contains the text 'Visit nfpa.org/855 to learn more.' in a blue sans-serif font. The overall background of the slide is white.


Contact Information

Bob Sullivan, CFPS
Southwest Regional Director | **NFPA**
(Based in Broomfield, CO)

bsullivan@nfpa.org

720 237-1752

www.nfpa.org

 **NFPA.ORG** | © National Fire Protection Association. All rights reserved.
