CREATING YOUR BATTERY RISK MITIGATION PLAN WITH UPDATED SAFETY CODES AND STANDARDS

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Abstract
Battery room safety requirements are a combination of Federal, State, and Local requirements. These model codes are subject to change every 3 years and standards are updated as the market dictates based on technology, selection, and application. Changes in Federal, State, and Local requirements are essential to note because local authorities, insurance companies, and other entities specify safety requirements for a site and will often require a risk mitigation program to address any safety risk presented in a battery application. As these standards and requirements cross organizations and jurisdictions, this paper guides end users in understanding the updated requirements, where to find information, best practice standards, and adopted codes to create your risk mitigation plan.

Introduction
The National Electric Code (NEC), and NFPA 70 historical fire codes have addressed battery safety prior to 1994. Uniform Fire Code (UFC) was later created in 1994 and revised in 1997 to address specific safety requirements for stationary batteries. However, qualifications to follow the UFC were based on chemistry and the volume of electrolyte and primarily covered only normal battery operating conditions in stationary battery systems.

The three primary building codes created in 2000 were the Building Officials and code Administrators International, International Conference of Building officials, and Southern Building code Congress International which later merged into the International Code Counsel (ICC) as the International Building Code (IBC). This also changed the classification of batteries from being high hazard use classification to incidental use area classification providing the batteries did not exceed the maximum threshold of electrolyte volume of 50 gallons. This helped the industry by not classifying these systems as high hazard, it reduced the requirements facilities had to meet by the volume of electrolyte present.

The 2000 International Fire Code was created and addressed also abnormal conditions such as thermal runaway and overcharging. Section 608 was created to cover lead acid battery topics in 2000 and later in 2003 Section 608 was revised to include Vented Lead Acid (VLA) batteries. Section 609 was a later addition to address Valve-Regulated Battery Systems (VRLA). The 2000 version of NFPA-1 did not contain any language that addressed stationary batteries until 2003 where similar language from the IFC was added and it remained the same until 2009. The 2006 revision of the IFC added new chemistries including nickel-cadmium (Ni-Cad) and Lithium-ion (Li) batteries. Likewise, NFPA-1 added language to include Li and Ni-Cad batteries in addition to key differences on lithium ion and lithium metal polymer batteries.

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	Model Code / Association	Last Update
Building Codes	Uniform Building Code (UBC) by the International Conference of Building Officials (ICBO)	1997
	Standard Building Code (SBC) by the Southern Building Code Congress International (SBCCI)	1999
	Building Officials and Code Administrators / National Building Code (BOCA/NBC)	1999
	NFPA 5000 Building Construction and Safety Code	2021
	International Building Code (IBC)	2021
Fire & Codes	Uniform Fire Code (UFC) • Article 64, Section 80.304 & 80.314	1997
	International Fire Code • Article 608 • Chapter 12	2018 2021
	National Fire Protection Association • NFPA 855	2023

Fig 1

With the increase of energy storage batteries, the Energy Storage Systems Working Group was born out of the ICC in 2018 to create the IFC Chapter 12, Energy Systems. This led to specific requirements based on technology and application and gave the AHJ some discretion to approve modifications based on risk mitigation plans and testing results. The first NFPA 855 First Draft was a culmination of language from the International Fire Code, International Building Code and the International Residential Code which provided additional language for outdoor and remote locations. Changes to the 2021 IFC and the 2023 NFPA 855 provided more industry participation (such as IEEE PES Energy Storage and Stationary Battery Committee) to prepare an improved document.

Risk & Hazard Analysis

Risk mitigation plans are an important part of any company's operations, as they help protect both assets and employees from potential harm. These plans are designed to identify, assess, and reduce the likelihood and impact of risks that could affect the company's operations and safety of employees. The use of risk assessments and hazardous mitigation analysis (HMA) are in the most recent versions of building and fire codes to address various hazards created by battery technologies specific to application and configuration. As we evolve into new and emerging stationary power storage technologies, AHJs may need to be educated on the hazards, failure modes, and other safety considerations. Proper risk analysis and education can provide a balance between the technology, how it applies to site safety, and code compliance. Below are examples of Hazard Mitigation analysis requirements mentioned in the code documents for design, installation, and operations. A good example of a standard document that is used in hazard mitigation analysis is the IEEE 1635/ASHRE 21 published by IEEE PES Energy Storage and Stationary Battery Committee (ESSB). The document assists in the evaluation of hydrogen evolution in batteries and how to calculate ventilation requirements to meet code and industry best practice.

NFPA 855 section 3.3.14 NFPA 855 section 4.2.1.3 NFPA 855 section 4.4	Hazard Mitigation Analysis (HMA) HMA – Plans and Specifications HMA – Failure Modes, Safety of ESS Installation, Operation, Construction Equipment & Systems
IFC section 1201.3 IFC section 1207.1.4	Hazard Mitigation Analysis: Failure Modes Hazardous Mitigation Analysis: Fault Detection

Fig 2

Typical Battery Room Requirements

Common topics found in code documents are Exhaust/Ventilation, Explosion Control, Safety Caps, Spill Control & Neutralization, Thermal Runaway, and others. However, the battery type and application are considered within code requirements as not all batteries are aqueous, have the same deflagration potential, or contain a free-flowing electrolyte. It is also noteworthy that even though model codes are mostly adopted at the state level, local governments may enact a Local Modified Code that includes all the requirements of the state codes plus items that are important to the local government. An example of a local modified code is discussed later in this paper.

Threshold Quantities & Exclusions

Batteries with capacity exceeding the stated energy capacity values must comply with code (fig 3). However, there are some exclusions which are discussed later in the paper. Note: The change to 70 kWh rating for aqueous batteries is not a big change from the 55 gallons as described in NFPA 855 section 9.6.5.2 to Fig 3 below as 70 kWh generally equal to 50 gallons of electrolyte in VLA batteries.

Battery Technology	IFC Chapter 12 – Min to Comply
Flow Batteries	20 kWh
Lead-Acid Batteries	70 kWh
Lithium-Ion Batteries	20 kWh
Nickel Metal Hydride Batteries	70 kWh
Nickel- Cadmium Batteries	70 kWh
Other Battery Technologies	10 kWh
Other Electrochemical Energy Storage Systems	3 kWh

Battery Technology	NFPA 855 – Min to Comply
Lead Acid Batteries	70 kWh
Ni-Cad/Ni-MH, Ni-Zn	70 kWh
Lithium-Ion Batteries	20 kWh
Sodium Nickel Chloride	20 kWh or 70 kWh if tested to UL 1973
Flow Batteries	20 kWh
Other Battery Technologies	10 kWh
Batteries in one-and-two family dwellings/townhouses	1 kWh

Fig 3

A Closer Look at the Common Requirements

Based on the safety areas discussed above, there have been changes and enhancements to the language with the new model code documents. Keep in mind that states must adopt the model codes to become law, therefore it's a good practice to check the adopted code and the year of adoption to understand requirements at the state and local level. Let's look at the topics and how they pertain to the model codes:

Explosion Control (IFC section 1207.6.3, NFPA 855 section 9.6.5.6)

Sites with batteries that have high deflagration rates are required to provide deflagration prevention systems such as barriers and deflagration venting unless UL 9540A testing proves that flammable gasses are not released. IFC chapter 12 section 1207.6 states that explosion protection is not required for lead-acid and Ni-Cad batteries in communications facilities that comply with NFPA 76 that operate less than 50 VAC and 60 VDC.

Safety Caps (IFC section 1207.6.4, NFPA 855 section 9.6.5.4)

Flame arrestor caps are required on Lead acid, Ni-Cad, Ni-MH and other aqueous batteries to prevent flame from entering the battery.

Exhaust /Ventilation (IFC section 1207 6.1, NFPA 855 section 4.9, 9.6.5.1, IEEE 1635/ASHRE 21)
Exhaust/Ventilation are requirements for aqueous battery types that could gas. This includes lead-acid, Ni-Cad, and flow batteries. The ventilation system should be designed to keep the maximum concentration of gas to 25% of the lower flammability limit or 1% of total room volume in worst case scenarios. The IEEE 1635/ASHRE 21 standard will assist with calculations to determine the hydrogen evolution of the battery and ventilation required. Fans may either be continuous or activated by a gas detection system. According to code, the detection system should be designed with 2-hour backup power, should announce an audible alarm or alarm to a monitoring system. Facility alarm systems include Supervisory Control & Data Acquisition Systems (SCADA), Data Center Infrastructure Monitoring Systems (DCIM), Building Management Systems (BMS) and Battery Monitoring Systems. NFPA 855 states that the hydrogen detection system should send a trouble signal upon failure of the gas detection system and send an alarm if the flammable gas concentration exceeds 10% of the LFL.

Spill Control & Neutralization (IFC section 1207.6.2, NFPA 855 sections 9.6.5.2, 9.6.5.3, IEEE 1578)
Spill control prevents free-flowing electrolyte and other hazardous materials from contaminating other areas making an unsafe condition. The containment system needs to capture the electrolyte from the largest jar/container/vessel and neutralize it to a pH of 5.0 – 9.0. NFPA 855 states that batteries with free-flowing electrolyte over 55 gallons require spill control. Spill control systems also need to capture fire protection discharge for a period of 10 minutes. It also states that VRLA batteries and other batteries with immobilized electrolyte do not need spill control or neutralization. FM Global, the largest commercial insurer in the world, also has a requirement regarding the flammability of pillow fabrics according to FM4955 "Flammability of Absorbent battery Acid Spill Containment Pillows." Local AHJs may have their own requirement with neutralization requirements and should be consulted pertaining to local regulations.

Thermal Runaway (IFC section 1207.6.5, NFPA 855 section 9.6.5.5
According to the IFC, thermal runaway protection is required for lead-acid, Ni-Cad, Ni-MH, Lithium-ion, and other technology types that could go into thermal runaway. NFPA 855 makes an exception for vented lead-acid and Ni-Cad batteries.

Seismic Codes
The Uniform Building Code was in place for decades and provided a zone map to choose the seismic rating needed for a rack or cabinet. However, the last update was in 1997 and has since been largely replaced by the International Building Code with the exception of a few cities and government buildings that use NFPA 5000. Based on this change, zones have been replaced by SDS levels calculated by site specific factors such as importance factor, soil density, elevation (location in building), exact location (coordinates/address), and USGS short term acceleration factor. Importance factors 1-3 may use Finite Element Analysis (FEA) software to certify their designs. Importance factor 4 for essential facilities requires a shake test per ASCE-7 requirements. One online tool available used to calculate site specific SDS level is: https://www.seismicmaps.org/ . Other seismic certifications such as IEEE 693 seismic for Utility applications, NEBS GR-63 Core for Telecom applications and OSHPD may require shake test experience data.

Other Safety Requirements
Other requirements inside the battery room such as battery hazard signage, shrouds & shields, emergency contact signs may be required by state code and local modified codes as listed in Fig 4.

Fig 4

Topic	**Standard/Regulation**
PPE	OSHA 1926.441(a)(5) NFPA 70E article 320
Eyewash/Shower	OSHA1926.441(a)(6) ANSI 358.1
Shrouds & Shields	OSHA 29 CFR 1910.308 (a)(7)(IV) OSHA 29 CFR 1910.333(a) OSHA 29 CFR 1910.333(c)(5) OSHA 29 CFR 1910.335 NFPA 70E
Signage	OSHA 29CFR 1910 IFC section 1207.4.8 NFPA-1 section 52.1.18.1 NFPA 855 section G.1.4.2 NFPA 70e section 310.5 (B) ANSI Z535 ANSI 358.1

Local Modified Codes

Home Rule, in most state constitutions or legislation, gives local governments the authority to create and enforce their own laws provided they meet state minimum guidelines. A great example of a local modified code is New York City's FDNY B-28 "Supervision of Stationary Energy Storage Systems." B-28 (formerly B-29) now has been modified to include language from the IFC and NFPA 855. In addition, companies must have certificate holders on-site if the size of the battery system meets the minimum kWh to comply. Certificate holders must study and be tested on battery theory, maintenance procedures, and understand how their systems were installed. Understanding risks and hazards along with the appropriate emergency response procedure is another part of the certificate holder's responsibilities. A local government and the AHJ may be able to enforce more than the state code based on local laws, so it's important to know the state and local laws pertaining to a specific site to ensure your Hazardous Management Plan addresses all local requirements for reporting and risk mitigation.

Summary

In conclusion, model codes have been evolving for decades to improve safety. As technology changes, so do the design, installation, and operational requirements. In the last several years, we have seen many changes based on the introduction of different battery and energy storage chemistries. Due to the complexities with many different energy storage technologies and applications, the International Code Council's *Energy Storage Working Group* was formed to write the new chapter 12 version of the International Fire Code. Likewise, the NFPA created the 855 document to address a wide range of commercial and residential energy storage systems.

Differences in technologies including energy storage chemistry and site application are the main drivers that affect the Hazardous Mitigation Analysis. As it relates to battery racks and cabinets, the adoption of the International Building Code has made the use of seismic zones obsolete. Seismic zones have been replaced with the use of site-specific factors that are summarized into what is known as an SDS level.

Local modified codes have become more prevalent with the emergence of various energy storage technologies causing increased safety incidents. This has resulted in consulting engineers, installers, and site managers to create risk mitigation programs that include items for local AHJ requirements that in some cases may be more stringent than state adopted codes.

Citations

1. CHAPTER 16 STRUCTURAL DESIGN SECTION 1604.5 2009, Edition IBC Interpretation 11-11
2. ICC-ES AC156 Seismic Certification by Shake-Table Testing of Nonstructural Components - Approved October 2010, editorially revised December 2020
3. International Building Code 2021
4. International Fire Code 2021 section 1207
5. National Fire Protection Association, NFPA 855 2023
6. National Fire Protection Association, NFPA 855 2023 Annex F "Fire and Building Codes – A Short History on Stationary Storage Battery Systems"
7. ANSI Z358.1-2014
8. American Society of Civil Engineers (ASCE) Minimum Design Loads for Buildings and Other Structures ASCE 7-10
9. NFPA 70E, Standard for Electrical Safety in the Workplace, 2021
10. 1635-2018 IEEE/ASHRAE Guide for the Ventilation and Thermal Management of Batteries for Stationary Applications
11. NEBS GR-63-CORE Issue 4