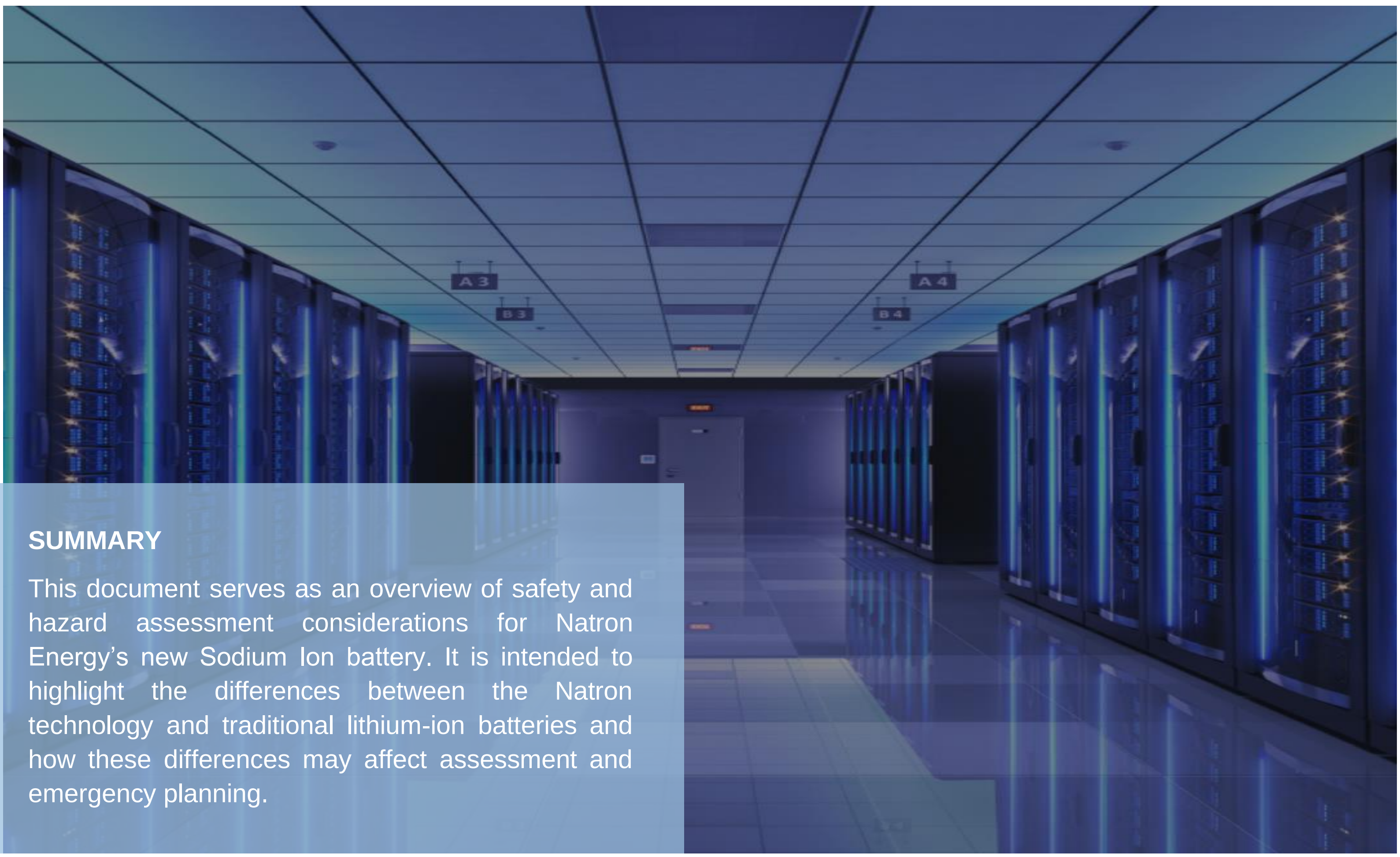
Natron Energy

# Natron Battery Technology and US Safety Codes and Standards

June 17, 2022 | Rev. 0




**SUMMARY**

This document serves as an overview of safety and hazard assessment considerations for Natron Energy's new Sodium Ion battery. It is intended to highlight the differences between the Natron technology and traditional lithium-ion batteries and how these differences may affect assessment and emergency planning.

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# PROJECT DESCRIPTION

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# 1 INTRODUCTION

Natron Energy is providing a new, safer battery technology in the commercial marketplace and became the world's first Sodium Ion battery to achieve UL 1973 listing for their battery product. This battery technology and associated battery energy storage systems (BESS) offers significant advantages to end users with improved energy density, efficiency, and safety.

## Document Purpose and Scope

This document provides a review and discussion of safety codes and standards for Natron battery technology in Data Processing Facility (DPF) applications. This includes a general overview of the United States regulatory process, a specific discussion with respect to the key application standards NFPA 855 and NFPA 75, and a discussion of the development of Hazard Mitigation Assessment (HMA) and Risk Assessment as outlined in these NFPA standards. Specific additional detail is provided on the implementation of batteries and BESS for the occupancy of Data Processing Facilities.

## Regulatory Overview

Codes and standards for the built environment are the regulatory documents that are implemented to keep people safe. In the common lexicon of codes and standards, a code is typically written to be directly adopted as a law or regulation that sets forth minimum requirements where something must be done. A standard typically spells out the methods for achieving the desired result; that is, "how" something must be done. However, the distinction is not precise, and it is not always easy to differentiate between a code and a standard.

As the commercial applications of Natron's technology are developed, it is important to understand the regulatory oversight of the safety infrastructure for these applications. In essence, both the process for obtaining safety approval and the authority granting the approval need to be considered at its earliest stage. (See Appendix C for discussion of Authority Having Jurisdiction (AHJ) and Appendix D for further explanation of Codes and Standards.)

## Safety and Response

Life safety of facility personnel, emergency responders, and the general public is a primary concern for all energy storage systems. Installation personnel need to be able to safely evacuate in fire and emergency conditions. Battery Energy Storage Systems are designed to react and respond to emergencies by providing early detection, alarm, notification, power isolation, and suppression system activation, as outlined in codes and standards. NFPA 855 is the leading codes and standards safety document that is being used throughout the United States and internationally, to address safe installation of Battery Energy Storage Systems. It has provisions for both a prescriptive and a performance-based approach to ensuring safety. The performance-based assessment is done, when required, through a Hazard Mitigation Assessment (HMA), coupled with Large Scale Testing, depending upon the circumstance (see Appendix E).

The process of completing an HMA necessitates the consideration of possible release scenarios – i.e., what can go wrong – while identifying the most critical and relevant hazards. Four failure modes are specifically called out for consideration, with the consequences of these failure modes set as critical pieces of the assessment. This approach allows the AHJ latitude in approving installations that exceed the standard thresholds and limits. The AHJ is also allowed to require other failure modes as deemed appropriate. The process of identifying these potential critical failure points is a necessary component of designing the fire protection system, writing an Emergency Response Plan (ERP), and securing the requisite permits for installation. The following section will consider some of these failure modes.

# 2 Natron Battery Test Results as Compared to Lithium-Ion

Lithium-ion batteries have many advantages, including a high-energy density, low maintenance, and high voltage. However, lithium-ion batteries have multiple pathways to experiencing an exothermic self-sustaining reaction that is called thermal runaway which will result in off gassing and often fire and/or explosion. Thermal runaway in a single cell may extend (propagate) to neighboring cells, which may result in a loss of a module (group of cells), a rack (group of modules), or possibly the loss of the entire enclosure.

Four main conditions that may lead to a thermal runaway event for lithium-ion batteries include electrical abuse, thermal abuse, mechanical abuse, and internal short circuit.

Mechanical abuse, usually caused by some external application of force such as a car or forklift impact can result in electrical shorting producing localized heating.

Electrical abuse (over-charging/discharging) entails over-charging or discharging to voltages beyond the manufacturers specified charge window.

Thermal abuse (over-temperature) may cause decomposition of electrolyte, among other components.

Internal short circuit (ISC) due to the failure of the separator, allowing contact between the cathode and anode via the electrolyte. This can happen due to any of the above abuse conditions, or as a result of a manufacturing fault.

In order to test for battery cell resilience to the aforementioned abuses, Underwriter Laboratories developed a standardized test method – UL 9540A – that incorporates various means for driving batteries into thermal runaway according to these pathways.

Natron's batteries have been tested according to the UL 9540A standard and by contrast were unable to be induced into thermal runaway by all cell failure test methods. The following is a summary of Natron's test results:

**Mechanical:** UL 9540A testing utilized a nail penetration test, which typically results in a pressurized release of gases for lithium-ion batteries followed by fire (see Appendix F photos). Natron's batteries were tested and found not to sustain either off gassing or fire. Further, testing at an independent lab showed that Natron's battery was not affected by crushing, cutting, or high-speed projectiles (bullets). All of these stimuli cause severe reactions in lithium-ion batteries.

**Thermal:** UL 9540A testing utilizing an external heater (alone) did not put the cell into thermal runaway. While high heat may cause some internal degradation or electrical shorting, it is not anticipated to produce the same level of gas evolvement that is typically experienced by lithium-ion batteries that undergo thermal runaway. With direct flame impingement, the plastic casing of Natron's battery is anticipated to catch on fire, but again, no thermal runaway is expected.

**Electrical:** UL 9540A testing for overcharging/discharging and short circuit did not result in thermal runaway amongst the five samples, though one of the samples produced gas that is determined to be flammable in accordance with ASTM E918 with the failure mode of overcharge and external heater[1].

Short circuit testing according to UL 1973 and UN 38.3 results of less than 2.5 milli-Ohm, an order of magnitude less than that typically witnessed by lithium-ion batteries that range from 20 to 100 milli-Ohm.

Since Natron's batteries operate under 60v for a whole module, arcing is not considered a significant risk for causing fire.

**Battery Off Gases:** Lithium-ion batteries when subjected to thermal, mechanical, or electrical insult may experience off gassing and thermal runaway and have been found to produce a mixture of flammable and toxic gases.

Among the more toxic gases, exhibited in varying degrees depending upon the exact type of battery chemistry, are hydrogen fluoride (HF), hydrogen chloride (HCL), hydrogen cyanide (HCN), and carbon monoxide (CO)[2]. Natron's battery under certain conditions, such as being exposed to heat or fire, may off-gas hydrogen cyanide.

Testing has shown that Natron batteries do not experience thermal runaway as lithium-ion batteries do and thus the likelihood of a single cell (or even multiple cells simultaneously) starting a fire is low and not considered a realistic scenario. Though the Natron batteries most likely would

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[1]The flammable gas generated from the condition of overcharge and heating of the cell can pose an explosion hazard and this type of hazard needs to be addressed through Hazard Mitigation Analysis (HMA) in accordance with the relevant codes and standards.

[2]https://www.nyserda.ny.gov/-/media/Files/Publications/Research/Energy-Storage/20170118-ConEd-NYSERDA-Battery-Testing-Report.pdf Accessed January 8, 2022.

not be a concern for initiating a fire, they may still release gases when externally exposed to fire from equipment or room contents. To better understand this risk, Natron battery cells were tested by an independent consultant (Fire and Risk Alliance) and the gases evolved collected and analyzed[3]. Based on the internal chemistry of the batteries, hydrogen cyanide was deemed the primary gas of concern given its potential toxicity and the chemical makeup of the batteries. The test was performed in an 82-liter vessel. The highest of the three cell tests evolved 10 ppm of HCN in an oxygen depleted condition in the vessel. Within the pressure vessel this level is below IDLH (50 ppm) and at the ERPG-2 threshold, which allows occupants an hour to escape from an area without suffering irreversible health effects. However, the quantity of gas released by a single cell in the testing chamber would be greatly diluted when released in a larger volume such as a standard sized data center. Thus a significantly greater number of cells may be allowed to fail in an oxygen depleted environment to produce a similarly measurable, but still mild, safety concern. This type of event would require tremendous amounts of heat to fail multiple cells or modules simultaneously, such as could occur in a fire, and would also require an oxygen depleted environment. At a high level, the type of event which may cause such a large number of cell failures, for example a rapidly burning fire being suppressed by a clean agent system, would likely have staff evacuating away from the event and any fire service response would necessitate utilizing self-contained breathing apparatus (SCBA), which ESRG strongly recommends.

While this assessment is not intended to thoroughly consider all the circumstances and variabilities associated with data center design and ventilation, one recommendation may be to leave HVAC systems on, or convert to an exhaust mode (that is, pulling 100% fresh makeup air into the space while exhausting the existing air to atmosphere) for sufficient time for occupants to evacuate from the data center, as well as following an event, to ensure any gas production, regardless of composition or quantity is evacuated.

In the case of utilization of clean agent suppression systems, where ventilation is intentionally shut off, a recommendation would be to ensure staff are evacuated away from the area when exhaust is off and that the space is thoroughly ventilated prior to the return of any staff not in appropriate PPE. If the fire department is required at the scene, it is recommended they use four gas meters, common to all fire departments, to monitor HCN levels before allowing staff to re-enter the building.

Consideration of all possible scenarios involving data center fires or other site-specific risks from other equipment that may initiate an event are beyond the scope of this report. Such would be part of a site-specific Hazard Mitigation Assessment (HMA) as is often required by NFPA 855 and/or a performance-based risk assessment as outlined in NFPA 75. (See Appendix A). Ultimately, ESRG believes, based on the test data provided, the relative hazard posed by Natron batteries, due to gases evolved when heated, appears to be no greater than standard lithium-ion

[3]Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems with HCN Analysis, Cell Level Test Report, Natron V6.1, Project Number 536-002, Revision 00, Prepared by Fire & Risk Alliance, LLC., February 21, 2022.

batteries as documented in a DNV-GL study[4].

# 3 NFPA 855 HMA Considerations

Personnel in occupied work centers need to be able to safely evacuate in fire conditions. Assumptions on evacuation distance and time to leave from various point should be assessed. Toxic and highly toxic gases released during fires and other fault conditions need to remain below IDLH for the amount of time required to evacuate the area.

NFPA 855 refers one to develop an HMA in many circumstances and evaluate the consequences of the four failure modes and others deemed necessary by the AHJ**.** Large-scale fire testing is also required at times. (Note that NFPA 75 refers to this as "large scale fire and fault testing.") The HMA, along with risk assessments, begin by identifying possible release scenarios – i.e., what can go wrong. The method of accomplishing this for Natron's purposes is tied to looking at the most critical hazard; the potential evolution of HCN gas. While other scenarios should be reviewed, for the sake of this discussion, it is assumed that the evolution of HCN gas is the primary event of concern.

The conditions for buildup of HCN have been seen in testing to only occur during fire conditions where a certain range of heat is applied to the Natron battery. Too little heat and no gas is evolved. With excessive heat, HCN that is released may be consumed, such as if a fire from a building directly impinges upon the casing of a natron battery. A set of event scenarios that might be constructed should be tied to the design of the specific data center being considered. HVAC operation, fire suppression, and related components would be considered with this assessment. A limited set of event scenarios might include:

Fire involving energized electrical equipment (servers) in a neighboring rack that grows slowly and releases large amounts of smoke; continuing until power is shut down.

Fire underneath a raised floor involving wiring.

Fire overhead in a drop ceiling.

Mixed battery-use cases: lithium-ion batteries that go into thermal runaway in the occupancy.

The failure of a required smoke, fire, or gas detection or suppression system and the failure of a required ventilation system are among the HMA failure modes that are required by the AHJ. (See Appendix E - NFPA 855 Section 4.1.4.3 (3) and (5).) (Each failure mode is considered individually.) Any other conditions or situations that might delay the detection and alarm notification should be assessed with respect to the accumulation of gas along an evacuation route.

[4]Considerations for ESS Fire Safety - NYSERDA ... Considerations for ESS Fire Safety DNV GL – OAPUS301WIKO(PP151894), Rev. 4 iii February 9th, 2017

# 4 Summary

The development of a set of fire scenarios should be carefully assessed while constructing an HMA. Building design, room ventilation, fire detection, and fire suppression are interrelated components for ensuring the safety for occupants and firefighters. The overall fire protection design should consider the results from a site specific HMA to guide the sequence of operations involving ventilation, in conjunction with any suppression activities, taking into account the need for a safe evacuation of building staff. Firefighters should also be guided by standard operating procedures ensuring proper respiratory protection and monitoring for levels of gases prior to reoccupying the space.

# 5 NFPA 855 Code Considerations and Discussion

NFPA 855 provides prescriptive standards for battery installations based upon certain key features such as minimum safe standoff distances and the maximum stored energy. In order to deviate from the stated requirements, large scale testing, an HMA, and/or mitigations are required. Below are indicated some of the key metrics in NFPA 855 (2020 edition):

**Threshold Quantity from Table 1.3**

From NFPA 855, Section 1.3 Application: Natron falls under "other battery technologies" and the threshold quantity for this category is indicated as 10 kWh.

**Size and Separation – Section 4.6**

Section 4.6.2 requires groups to have a maximum stored energy of 50 kWh each. Section 4.6.3 also requires each group to be spaced a minimum 3 ft from other groups and from walls in the storage room or area. Of note, Section 4.6.4 states that the AHJ shall be permitted to approve groups with larger energy capacities or smaller group spacing based on large-scale fire testing complying with 4.1.5.

**Maximum Stored Energy - Section 4.8**

The Maximum Stored Energy allowed for Natron is 200 kWh. As a basis for increasing this stored amount, Section 4.8.1 requires that approval is obtained from the AHJ, based upon an HMA in accordance with 4.1.4 and large-scale fire testing complying with 4.1.5.

**Mixed Battery Technologies – Section 4.8.3**

In addition, Section 4.8.3 addresses situations where more than one ESS technology is present within a fire area, stating that the fire protection systems shall be designed to protect against the greatest hazard.

**Other Conditions that Require an HMA – Section 4.1.4**

In addition to increasing total stored energy capacity, increasing battery group capacity, or decreasing distances separating groupings of batteries, an HMA will be required under three conditions as per NFPA 855 Section 4.1.4:

(1) When technologies not specifically addressed in Table 1.3 are provided.

(2) More than one ESS technology is provided in a room or indoor area where adverse interaction between the technologies is possible.

(3) When allowed as a basis for increasing maximum stored energy as specified in 4.8.1 and 4.8.2.

Natron should be required under the first condition because it is not specifically addressed in Table 1.3. It may also be required should it be added to an area that already has a significant number of lithium-Ion batteries. Lastly, for increasing the maximum storage capacity above 200 kWh, an HMA will be required.

Further, the analysis shall evaluate the consequences of the following failure modes and others deemed necessary by the AHJ, as per Section 4.1.4.2:

(1) Thermal runaway condition in a single module, array, or unit

(2) Failure of an energy storage management system

(3) Failure of a required ventilation or exhaust system

(4) Failure of a required smoke detection, fire detection, fire suppression, or gas detection system

Note that only single failure modes shall be considered for these four modes, and others that would be deemed necessary by the AHJ.

The AHJ shall be permitted to approve the HMA, as documentation of the safety of the ESS installation as per Section 4.1.4.3, provided six criteria are met. Natron's HMA should focus on two of these criteria in particular:

(3) ESS cabinets in occupied work centers allow occupants to safely evacuate in fire conditions.

(5) Toxic and highly toxic gases released during fires and other fault conditions will not reach concentrations in excess of immediately dangerous to life or health (IDLH) level in the building or adjacent means of egress routes during the time deemed necessary to evacuate from that area.

# 6 NFPA 75 Considerations and Discussion

NFPA 75 provides the minimum requirements for the protection of ITE equipment and ITE areas from damage by fire or its associated effects —namely, smoke, corrosion, heat, and water. A fire protection approach, as per Section 4.1.1, is required to be established considering the threat to facility occupants, the general public, emergency responders, and exposed property from a fire occurring at the facility; either adjacent to or within ITE systems, rooms, and areas, based upon an evaluation of fire risks and hazards associated with the site and services provided.

The Fire Risk Analysis is a means of characterizing the risk associated with fire that addresses the fire scenario or fire scenarios of concern, their probability, and their potential consequences. (Section 3.3.11) NFPA 551 can be used as a reference guide for conducting and evaluating Fire Risk Assessments. Note: This report for Natron provides a Risk Assessment overview in Appendix A.

The fire protection approach will result in the use of one or both of the following strategies within ITE areas: a prescriptive-based approach (according to this standard) or a fire risk-based approach.

The prescriptive requirements of this standard are intended to provide a minimum level of fire protection for ITE systems and facilities. Although technology is anticipated to change, Appendix A 1.2 points out that the Fire Risk Assessment is intended to reveal any causes that justify modification of the prescriptive requirements of this standard for a specific installation.

Chapter 5 covers the performance-based design approach which provides equivalent performance to the prescriptive requirements of this standard. An approved performance-based approach is permitted to be applied selectively to specifically identified areas, hazards, or equipment or to specific fire protection requirements for an entire ITE area.

Finally, it should be noted that NFPA 75 Figure A.1.3 provides a decision tree for applying NFPA 75 when evaluating data center installations and helps to determine the prescriptive vs. performance-based approach to be taken. It states that other applicable codes and standard should be followed as warranted.

# 7 NFPA 855 and NFPA 75 – Summary

As technology rapidly evolves, the codes and standards bodies attempt to maintain pace. Within NFPA circles there has been some discussion about NFPA 855 incorporating key requirements of NFPA 75 due to the overlap in jurisdictional scope for these two committees. Some of the critical points of concern are left to the AHJ for interpretation.

In taking NFPA 855's prescriptive approach, one is required to develop an HMA for the AHJ review according to the previously mentioned criteria. Essentially this allows a form of performance-based assessment for technologies that fall outside of the ones specified or exceeds the quantities they list.

NFPA 75 provides a set of criteria to assist one in determining whether a prescriptive approach is adequate or whether a fire risk-based approach is the preferred approach. For battery storage technology, both documents highlight the need for considering scenarios based upon the hazard for the creation of risk assessments that consider the frequency and consequence in order to provide the overall hazard to be expected from a technology or process.

Based upon the testing conducted to date, as highlighted in Appendix F, Natron batteries should present a significantly reduced risk to data centers when compared by the same metrics to lithium-ion batteries.  In particular, the potential for initiation of a fire is greatly reduced, as Natron batteries have shown increased resistance to mechanical, thermal, and most electrical abuse.  As a result, the risk to a data center from a fire would be reduced when utilizing Natron's batteries as compared to lithium-ion. Should the Natron batteries be involved in a fire, whether the cause or not, they may respond more positively to fire suppression, be less apt to propagate or exacerbate the event, and generally pose a lower overall risk relative to lithium-ion batteries.

# Appendix A: Qualitative Risk Assessment

The Fire Risk Analysis is a means of characterizing the risk associated with fire that addresses the fire scenario or fire scenarios of concern, their probability, and their potential consequences. NFPA 551 can be used as a reference guide for conducting and evaluating fire risk assessments.

A fire protection approach considers the threat to facility occupants, the general public, emergency responders, and exposed property from a fire occurring at the facility; either adjacent to or within the installation, based upon an evaluation of fire risks and hazards associated with the site and services provided.

The fire protection approach will result in the use of one or both of the following strategies: a prescriptive based approach (according to this standard) or a fire risk-based approach.

The prescriptive requirements are intended to provide a minimum level of fire protection for the facility. The fire risk assessment is intended to reveal any causes that justify modification of the prescriptive requirements of this standard for a specific installation.

The performance-based design approach provides equivalent performance to the prescriptive requirements of a standard. In taking NFPA 855's prescriptive approach, one is required to develop an HMA for the AHJ review according to the previously mentioned criteria. Essentially this allows a form of performance-based assessment for technologies that fall outside of the ones specified or exceeds the quantities they list. For battery storage technology, an HMA requirement highlights the need for considering scenarios based upon the hazard. These scenarios form the basis for conducting a Hazard Mitigation Analysis. Appendix E will outline requirements for an HMA.

**A-1 Overview**. This appendix provides a general discussion on a qualitative risk assessment. This addresses a simplified qualitative approach where there is limited data, versus a more rigorous quantitative approach which can be used when statistically valid data is available. The risk assessment methodology used here is primarily based on the following:

- NFPA 551, Guide for the Evaluation of Fire Risk Assessments" National Fire Protection Association, 2019 edition
- "SFPE Engineering Guide to Application of Risk Assessment in Fire Protection Design", Society of fire Protection Engineers, 1st edition

**A-2 Risk Assessment Procedure.** The process used for risk assessment is illustrated in Figure A-1: Risk Assessment Procedure. This process is followed in the subsequent sections and preceded by a review of the available data.

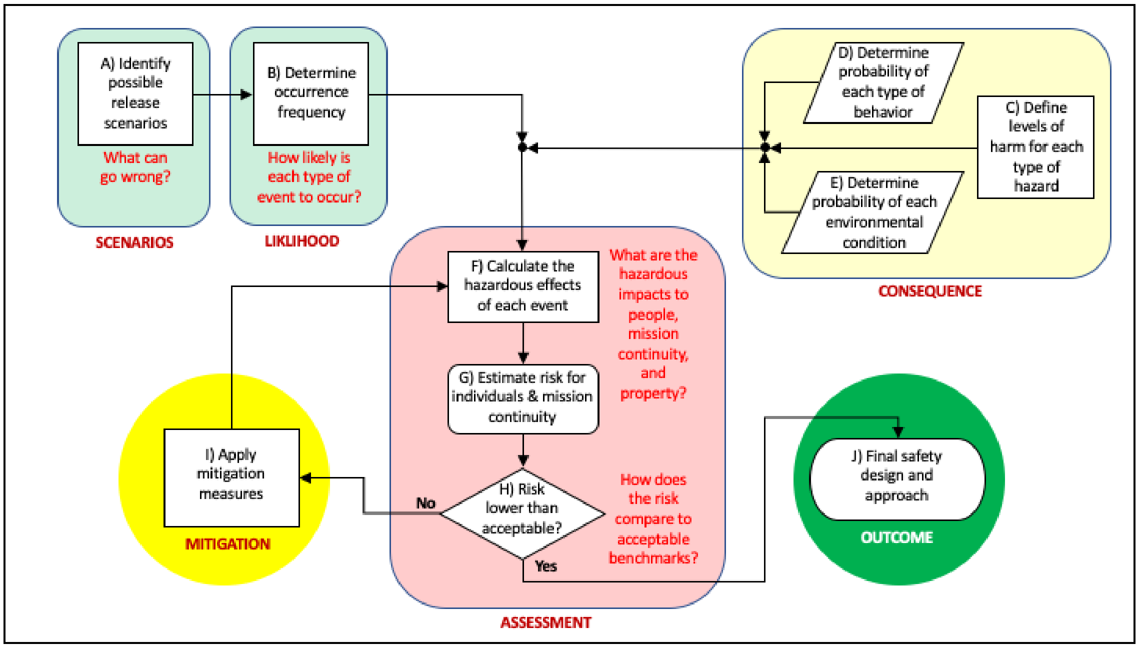


Figure A-1: Risk Assessment Procedure

(Adapted from approach used by Raj, P.K. & Lemoff, T., "*Risk Analysis Based LNG Facility Siting Standard in NFPA 59A*", Journal of Loss Prevention in the Process Industries, 22, 2009, pp 820-829)

**A-2.1 Risk Metrics**. The primary risk metrics for this evaluation consider both individual and societal risk and include the classical objectives of fire protection. The following are the risk metrics considered for this risk assessment review:

**A-2.1.1 Life Safety**. This includes injuries and fatalities to:

a) Fire fighters and other emergency responders
b) Workplace employees,
c) Public

**A-2.1.2 Continuity of Operations**. Repairs and return to service may take considerable time.

**A-2.1.3 Property Protection**. The direct and indirect costs of replacing lost or damaged property.

**A-2.1.4 Environmental Protection**. The direct and indirect cost of damage to the environment, including remediation, fines, and other costs.

**A-2.2 Risk Thresholds**. Threshold criteria can vary based on multiple factors that are still unknown or are estimates (like cost of equipment involved in lost property). The following are examples of the thresholds considered herein for unacceptable risk of the risk metrics:

**A-2.2.1 Life Safety**. Fatalities and serious injuries are considered unacceptable, with serious injury resulting in missing normal employment for one week or more.

**A-2.2.2 Continuity of Operations**. Repairs and return to service may take considerable time.

**A-2.2.3 Property Protection**. The direct cost of lost or damaged equipment in excess of $100,000 USD is considered unacceptable.

**A-2.2.4 Environmental Protection**. The direct cost of remediation, fines and other damage in excess of $100,000 USD is considered unacceptable.

**A-2.3 Risk Benchmark**. The primary benchmark for evaluating the risk assessment of specific hazards and events are the scenarios to be developed for the HMA.

## Appendix B: Other Supporting Standards and Documents

The aforementioned codes and standards further reference many other standards and standards-related documents. For example, a typical active fire protection system (e.g., smoke detection) includes a multitude of electrical components, all of which are designed and manufactured to specific standardized specifications to assure they will function reliably over their life span.

The following is a highlight of the more noteworthy secondary codes and standards that have some degree of applicability to a facility:

ANSI Z535.2, *American National Standard for Environmental and Facility Safety Signs*, 2011 edition.

IEEE C2, *National Electrical Safety Code*, 2017 edition.

IEEE 1635/ASHRAE 21, *Guide for the Ventilation and Thermal Management of Batteries for Stationary Applications*, 2018 edition.

NECA 416, *Recommended Practice for Installing Energy Storage Systems (ESS)*, 2017 edition.

NFPA 1, *Fire Code*, 2018 edition

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 2022 edition

NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*, 2020 edition

NFPA 68, *Standard on Explosion Protection by Deflagration Venting*, 2018 edition.

NFPA 70®, *National Electrical Code®*, 2017 edition

NFPA 70E®, *Standard for Electrical Safety in the Workplace®*, 2021 edition

NFPA 72®, *National Fire Alarm and Signaling Code®*, 2019 edition

NFPA 101®, *Life Safety Code®*, 2021 edition

NFPA 484, *Standard for Combustible Metals*, 2022 edition

NFPA 1300, *Standard on Community Risk Assessment and Community Risk Reduction Plan Development,* 2020 edition

UL 1564, *Standard for Industrial Battery Chargers*, 2013 edition.

UL 1741, *Standard for Inverters, Converters, Controllers and Inter- connection System Equipment for Use with Distributed Energy Resources,* 2016 edition.

UL 1778, *Uninterruptible Power Systems*, 2014, revised 2017 edition.

UL 1973, *Standard for Batteries for Use in Light Electric Rail (LER) Applications and Stationary Applications*, 2016 edition.

UL 1974, *Evaluation for Repurposing Batteries*, 2018 edition.

UL 2743, *Standard for Portable Power Packs*, 2016 edition.

UL 9540, *Safety of Energy Storage Systems and Equipment*, 2016 edition.

UL 9540A, *Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems*, 2018 edition.

## Appendix C: Defining the Authority Having Jurisdiction

Codes and standards provide an important regulatory framework, but to be effective they need to be applied and enforced. Traditionally, safety codes and standards are enforced by an independent, unbiased third-party enforcing agent, usually a governmental representative and often a local government official for a particular jurisdiction.

This enforcing agent is normally part of the permitting process for that jurisdiction. They are commonly referred to as the "Authority Having Jurisdiction", or its acronym "AHJ". Specifically, the AHJ is defined as the "organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure." [*NFPA Regulations Governing Committee Projects", NFPA Annual Directory, Sect. 3.3.6.1, National Fire Protection Association, Quincy MA, 2009 edition, pg. 17*] A common approach used by AHJs is to require a permitting and approval process that controls the bureaucratic administration of all new construction and existing buildings.

In the built environment the AHJ may be a federal, state, local, or other regional department representative. Examples include a building official, fire chief; fire marshal, fire inspector; electrical inspector, plumbing inspector, health inspector, labor department representative, or others having statutory authority. Sometimes these roles are combined, and for any particular application multiple individuals or entities may be involved in the permitting and approval process.

The legislated scope and powers of any particular AHJ in any particular jurisdiction can vary widely. Although the AHJ is most commonly recognized as a government enforcer, it is also applicable to others who indirectly require safety despite not having statutory authority.

A common example are insurers and their associated rating bureaus, who use the economic leverage of higher insurance rates if the protected assets are deemed high risk and not conforming to minimum codes and standards. Another example is a municipal fire department or private corporation that has best practices, which enforce their own high standards consistent with the model safety codes and standards, for reasons such as to provide safe operations for their employees, avoid litigation, and maintain a positive image in the court of public opinion. Figure B-1 provides an overview of the various statutory and non-statutory entities that function as AHJs.

Normally, any application will require permits, letters of approval, or similar documentation proving that regulatory requirements have been met. The permitting effort may involve a range of other agencies or groups, some with very narrow or specific focus. Examples include a hazardous material review committee, planning/zoning board, conservation commission, environmental protection agency, public utility committee, historic preservation foundation, and similar review groups.

In many jurisdictions there is a distinction between new construction and existing buildings, facilities and processes. New construction is generally channeled through the building inspectors with some fire inspector coordination and involvement. This includes renovations of existing facilities. But re-inspection after all construction is completed generally falls to the local fire officials, especially with buildings that are occupied by the public or appreciable numbers of people.

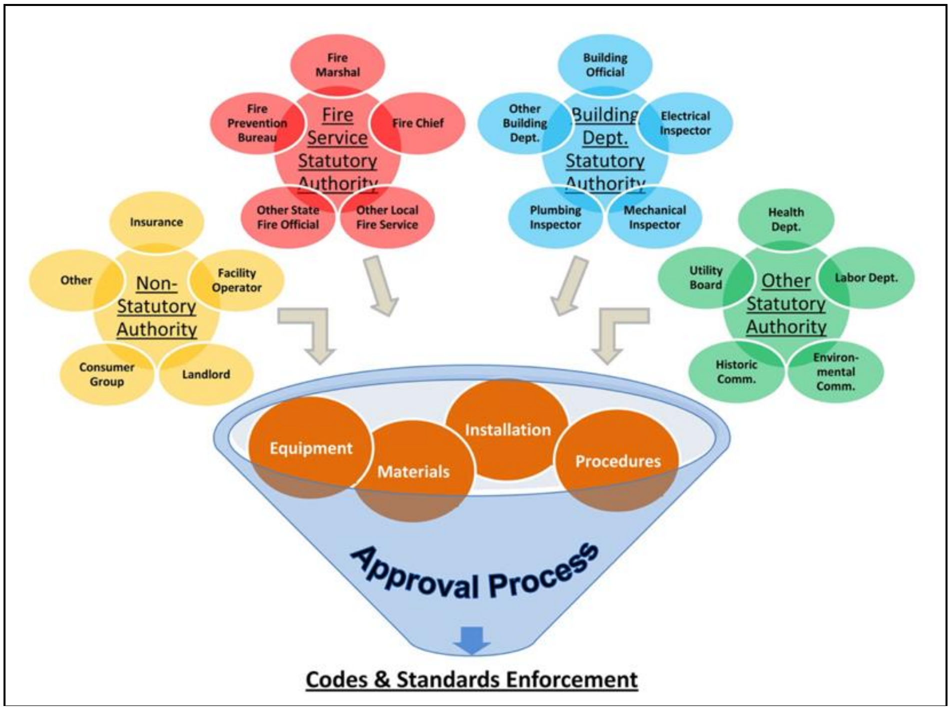


Figure B-1: AHJs that Support Codes and Standards Enforcement.

*[Grant, C, "Reaching the U.S. Fire Service with Hydrogen Safety Information: A Roadmap", Part 1: Fire Service Primer, Fire Protection Research Foundation, Quincy, MA, Sept 2009, page 54.]*

# Appendix D: Overview of Codes and Standards

Codes and standards for the built environment are the regulatory documents that are implemented to keep people safe. In the common lexicon of codes and standards, a code is typically written to be directly adopted as a law or regulation that sets forth minimum requirements where something must be done. A standard typically spells out the methods for achieving the desired result; that is, "*how*" something must be done. However, the distinction is not precise, and it is not always easy to differentiate between a code and a standard.

## Safety Codes and Standards Overview

Safety codes and standards address the will of society on complex technical topics. This is based on balancing acceptable risk with our measures to control that risk. Risk, quite simply, is an estimated (i.e., qualitative) value or calculated (i.e., quantitative) value based on how often an adverse event may occur (i.e., frequency) and how bad it could be (i.e., consequence).[1]

Safety is the inverse or opposite of risk. Thus, greater safety means the reduction or elimination of some risk to people or property or some other vulnerable entity of concern. Risk can never be entirely eliminated, and so safety is never absolute.

We can never have a perfectly safe world; despite how much we seek it. So how safe is safe enough? Even short of absolute safety, any relative increase in safety will not have unlimited value. Individual, organizational, or societal decision makers must decide whether a particular increase in safety (i.e., reduction in risk) is worth more to them than what they must provide in terms of resources (i.e., pay) in order to achieve that safety increase.

Because financial resources are the most obvious sacrifice required to decrease risk, the trade-off involved is often called "willingness to pay." The lower the risk becomes, the more it typically costs to achieve each additional constant or incremental increase in safety. In addition, part of the cost of risk elimination can be the reduction of some freedoms. Many aspects of safety systems or materials standards have this effect, as they come to bear on the establishment of an "acceptable level" of risk.[2] In addition, the standard of care provided by the code may either eliminate certain materials or processes or set demanding performance criteria for such elements.

Assessments of levels of risk are also needed with respect to cost of use of the codes and standards themselves, including complex calculations or other costs of information. If tolerance limits are exceeded, codes and standards will be modified in practice or ignored. Also, the more onerous and costly compliance becomes, the more carefully critics will examine the "degree of contribution to a safe environment" that the code or standard will bring about. In other words, attempts at applying cost–benefit models may be used as a part of the justification for an increased level of performance or, conversely, to show why the suggested performance is impractical from an economic standpoint.

The many effects of codes and standards on what people value bring various complex factors into play—social, economic, political, legal, business-competitive, and others—that affect how much people value safety and how much they value what may be sacrificed for safety. A pure economic, engineering, or public health approach cannot do justice to all these factors, many of them unavoidably or even intrinsically subjective, in establishing a cost–benefit analysis.

### Understanding the Built Environment

A *code* is a law or regulation that sets forth minimum requirements. In particular, a *building code* is a law or regulation that sets forth minimum requirements for the design and construction of buildings and structures. These minimum requirements, established to protect the health, well-being, and safety of society, attempt to represent society's compromise between optimum safety and economic feasibility. [3]

Although builders and building owners often establish their own requirements, the minimum code requirements of a jurisdiction must be met. Features covered include, for example, structural design, fire protection, means of egress, light, sanitation, and interior finish. Because of the complexities of modern building code development, several organizations develop model building codes for use by jurisdictions, which can then adopt the model codes into law either in total or with amendments deemed to be necessary for that jurisdiction.

### Products versus Processes and Systems

There are two broad categories of voluntary codes and standards: (1) safety codes and standards and (2) product standards. Just as their names imply, safety documents uphold levels of safety, and product documents address products.

Pure safety codes and standards are often adopted with the power of law and, thus, require more extensive technical advisory support and enforcement. Thus they tend to be more complex and extensive than product standards. Pure product documents are more focused on marketplace conformity and consistency for the consumer (e.g., bolt threads and corresponding nut threads). Sometimes in the safety arena, there is reference to the hybrid 'safety-product' standards, which refer to safety standards that address the details of products and uphold safety for the end-user

These documents are not solely a matter of science, especially safety codes and standards.[4] Codes and standards for buildings and structures embody value judgments as well as facts and sometimes must use empirical evidence on judgment to compensate for gaps or limits in the relevant science (also see the *SFPE Handbook of Fire Protection Engineering [5]*). Although building codes provide much focus, a variety of other related codes also readily serve the built environment. Specifically, these codes address distinct interrelated topics that are essential components in structures of all kinds. These are often process or system oriented, like the service utilities within a building.

Topics that are typically addressed include electrical, plumbing, mechanical, fuel gas, energy, and fire prevention. Yet this is not an all-inclusive list, and any particular subject that lends itself to specific and detailed criteria is eligible and, thus, “electrical codes,” “plumbing codes,” “mechanical codes,” and so on have also evolved. Often the reference to “building codes” is intended to include, in a general sense, a reference to all of these related codes for the built environment.

Of these different related topics, fire prevention codes are somewhat unique (e.g., construction versus ongoing operation and maintenance). It is sometime difficult to differentiate between items that should go into a fire prevention code and those best included in a building or other related code, or in some cases, identical requirements that need to appear in two or more codes. Generally, those requirements that deal specifically with construction of a building are part of a building or similar code administered by the building department. A fire prevention code, on the other hand, includes information on fire hazards in a building and is usually regulated by the fire official.

Requirements for exits and fire-extinguishing equipment are generally found in building codes, whereas the maintenance of such items is covered in fire prevention codes. More simply stated, building and other related codes address the original design or major renovation of a building, whereas a fire prevention code usually addresses the building during its useful life after the initial construction or renovation is complete.

### The US Codes and Standards Infrastructure

Most countries in the world administratively process their codes and standards in a top-down manner, that is more-or-less controlled, updated and implemented through their respective national government channels. But the approach in the United States is different from most countries. It is a bottom-up system composed of numerous private Standards Development Organizations (SDOs) that generate thousands of model documents.

These model documents work their way into direct and indirect adoption by legislative authorities, sometimes with the power of law, generally at the State level. There are other drivers in the United States that make it unique among other nations. For example, one is the historical laissez faire culture of US citizens being less concerned with preventative measures in the so-called ‘land-of-plenty’. Another arguably unique driver is the judicial system in the US, among the more litigious in the world. Civil lawsuits provide intense motivation for the use of recognized ‘best practices’ that set the baseline for expected duty of care.

The voluntary standards development system in the United States is efficient, cost-effective, and highly productive and results in the promulgation of thousands of quality standards each year. A diverse, decentralized network of private-sector entities develops the U.S. voluntary standards.

With the exception of the independent operations of some of the largest cities, the business of code development for the built community in the United States is primarily in the hands of the model code organizations. The primary objectives of these model code organizations are to provide standardization of construction regulations and/or support of the enforcement of these regulations.

In the United States, prominent organizations that currently have code sets for the built environment include ICC (International Code Council, established in 1995) and NFPA (National Fire Protection Association, established in 1896). These code-set developers have a notable difference in their development and maintenance processes. NFPA utilizes a full consensus approach that is accredited per ANSI requirements (described in the next section), and no single interest group is able to unfairly dominate the process. ICC utilizes a limited consensus development process without ANSI accreditation, where the building officials dominate the proceedings and have majority control over acceptance of all proposed changes.

One of the strengths of the voluntary consensus codes and standards-development system (used in certain countries like the United States) is that the deliberative committee structure, which comprises a balanced representation of all affected interests, including users, consumers, manufacturers, suppliers, distributors, labor, testing laboratories, enforcers, and federal, state, and local government officials, can consider all of the diverse factors at hand and develop a consensus on an acceptable level of standardization. It has been observed that "this may be one of the greatest strengths of the private standards-writing system, insofar as it truly represents variety, and one of the greatest insufficiencies of a governmental system." [6]

Standards exist for virtually all industries and product sectors, and this continues to expand in the 'information era'. The oldest standards-developing organization in the United States is the U.S. Pharmacopeia, which published standards for 219 drugs in 1820. The number of standards in the United States is roughly estimated on the order of 100,000. This, however, is a gross estimation. This number is based on NIST Special Publication 806 conducted in 1996, which is obviously dated. Some fields and professions, such as for example computer science and data science, have been expanding rapidly. Countering this, there are some activities like the US Department of Defense that have had active programs to retire standards.[7]

The significant private-sector standards-development system in the United States is largely self-administered, with oversight and coordination provided by ANSI, a federation of U.S. codes and standards developers, company organizations, and government users of those standards.

Under ANSI procedures, all American National Standards must be reviewed and reaffirmed, modified, or withdrawn no less frequently than every five years—a requirement that ensures that voluntary standards in the United States keep pace with developing technology and innovations. Thus, the voluntary system produces quality standards that do not become outdated.

ANSI provides accreditation for the development of documents that meet its fundamental principles for full consensus. Organizations that meet these requirements typically have elaborate processes involving volunteer committees and utilizing extensive public input and decision-making authority. Although federal, state, and local governments usually participate, they do so as would any other participant. The resulting documents are referred to as “model documents,” and it is then up to any particular authority to subsequently implement the issued document as it sees fit (i.e., into law, as a specification, etc.).

### Tenth Amendment and Dillon's Rule

An important characteristic for U.S. codes and standards for the built environment is how they are applied and enforced. This is the setting beyond the public and private organizations that generate, administer and maintain the U.S. codes and standards. At the highest level, overarching model codes (e.g., building code or fire code) are normally directly adopted into law. They typically reference other applicable standards on specific technical details, and they are thus included by reference. These standards in turn reference other standards, addressing greater levels of detail where required.

In the United States, the State level governments are the primary administrators for the application of codes and standards in the built environment. This is guided the U.S. Constitution, and specifically the Tenth Amendment to the U.S. Constitution. The Tenth amendment delegates this fundamental power to the States, which allows and supports the restraint upon the personal freedom and property rights of an individual for the protection of the public health, safety, and welfare. The Tenth Amendment to the U.S. Constitution succinctly indicates: [8]

“The powers not delegated to the United States by the Constitution, nor prohibited by it to the States, are reserved for the States respectively, or to the people.” (U.S. Constitution, Tenth Amendment)

This important delegation of police power and enforcement is given to the State governments. Importantly, this is not automatically conveyed to local governments and municipalities within a particular State. An important and oft-referenced interpretation of the Tenth Amendment is “Dillon’s Rule”. This was a landmark State Supreme Court ruling named after Iowa Supreme Court Judge John Forrest Dillon based on legal case in the late 1800’s and upheld by the U.S Supreme Court in 1903 and again in 1923. It has been extended to other States and still widely referenced today. Dillon’s Rule is as succinct as the Tenth Amendment, and indicates: [9]

“Local jurisdictions only have powers expressly conferred to them from State constitutions, State statutes, or home rule charters.” (Dillon’s Rule)

Dillon's Rule clarifies that the power resides at the State level. If there is a reasonable doubt whether a power has been conferred to a local government, then the power has not been conferred. [10]

## Home Rule and Mini/Maxi

In the United States the power and responsibility of building and fire codes is clearly established at the State level. On this basis, most States have their own unique state building and fire codes. These are almost always based on available national model codes, which are updated and revised regularly through State legislative adoptions that often include specific amendments.

The implementation is not uniform, with variations from State to State. Some States adopt a State-wide code and allow the local jurisdiction to modify it based on local needs, as long as it is not less restrictive than the State code. Other States allow each local jurisdiction to adopt its own fire and building codes in lieu of a state code, which ultimately leaves municipalities without any building or fire code where no state code exists.

Dillon's Rule provides mention of a "home rule charter". A home rule State is one that has delegated its authority to the local jurisdiction level, either through its state constitution, statute or charter. When a defined region or specific area within a particular State becomes incorporated (e.g., city, town, district, village, etc.), certain State powers will generally be transferred to the local municipalities. This, however, varies from State to State. [11]

Some States have every portion of their defined areas incorporated into smaller local municipalities, and this is not uncommon in smaller or older States. Larger land-area States (e.g., in the mid-west and west) will often include unincorporated areas in rural areas, and these are typically served directly by State government or County government representing the State. Home Rule can be understood as an indicator of the degree of local authority within a particular State. It allows greater self-governance by the local governments in a particular state. [12]

Some States preclude their local jurisdictions from adopting any regulations or amendments through a concept known as "mini/maxi". In other words, mini-maxi codes are prohibited from being less stringent or more stringent than the state code.[13]

These mini/maxi State codes provide uniform regulations at the State level that cannot be amended by local counties, cities, towns, or villages. This uniformity is generally favored by builders and developers for its convenience, but conversely is generally not favored by local governing bodies as unwelcome oversight into their local issues.[14]

## Summary

Codes and standards serve many purposes, but foremost is their contribution to the overall betterment of civilization. Their role is particularly important as we work toward the challenges of a safer and more cost-effective built environment. In today's complex world, codes and standards provide a point of measurement to simplify our lives. In this sense, codes and standards provide the practical foundation for a better tomorrow.

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# Appendix E: NFPA 855

## Regulatory Requirements for Battery Applications

In the United States, there are numerous safety codes and standards that address a complex technological installation. These will vary to some extent from jurisdiction to jurisdiction, and are illustrated for Batteries in Figure 2, Safety Codes & Standards Hierarchy. A wide spectrum of additional regulations address areas of concern other than fire safety, such as system performance, environmental protection, public health, etc.

Almost all jurisdictions enforce some version of a building code (e.g., International Building Code (IBC)) for new buildings and a fire code (e.g., International Fire Code (IFC)) for existing buildings. In the United States this responsibility resides at the State level, which States sometimes delegate to their regional or local jurisdictions (see Appendix D). These building and fire codes typically provide mandatory references to specific application standards that provide detailed technical safety requirements. For the topic area addressed herein, i.e., batteries, the application standard is: NFPA 855, *Standard for the Installation of Stationary Energy Storage Systems*, 2020 edition.

Multiple installation and product safety codes and standards are directly referenced and utilized by the two overarching documents (NFPA 855 and 75). Some of these provide significant detail on the design and installation of site equipment, such as the installation of all electrical equipment per NFPA 70®, *National Electrical Code*®, and all fire alarm equipment per NFPA 72®, *National Fire Alarm and Signaling Code*®.

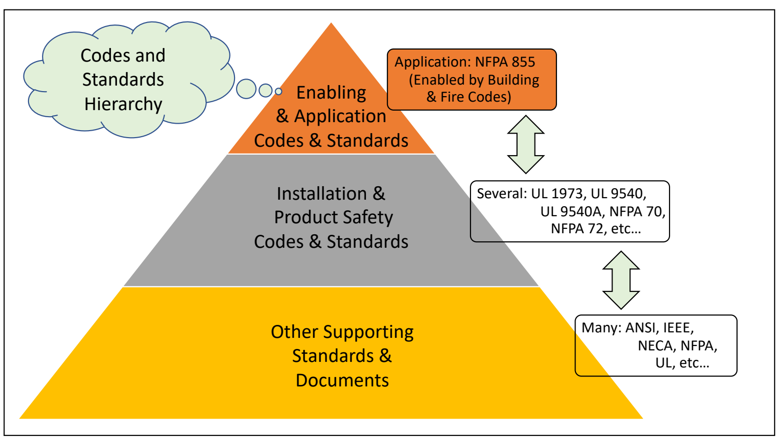



Figure 2: Safety Codes & Standards Hierarchy

Similarly, numerous devices and equipment are subjected to product safety testing to confirm their integrity for safe use, such as UL 1973, *Standard for Batteries for Use in Light Electric Rail (LER) Applications and Stationary Application*; UL 9540, *Safety of Energy Storage Systems and Equipment*; and UL 9540A, *Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems*. Additional codes and standards address similar technical issues to support and achieve fire protection objectives. (See Appendix B)

### Battery Technology Applications per NFPA 855

This discussion is structured around the key fire protection hazards for batteries as addressed in a BESS. There are 16 topic areas titled as "*Requirements*" in NFPA 855 (because they require specific focused attention). These are illustrated in Figure 3, Overview of Key Fire Protection Hazards. For convenience these are bundled into four basic groups of: (A) Inherent Design Features; (B) Alarm & Notification; (C) Active Fire Control Systems; and (D) Other.

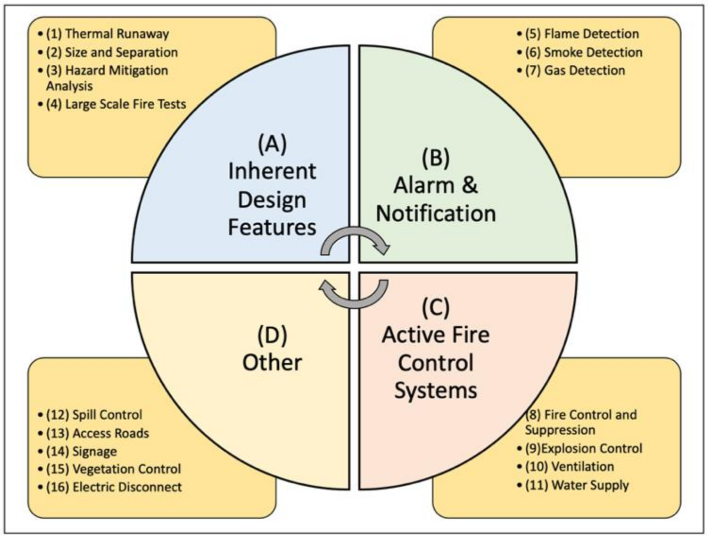



Figure 3: Overview of Key Fire Protection Hazards

NFPA 855 provides prescriptive standards for battery installations based upon certain key features such as the threshold quantity for applying the standard, size for each group of batteries and minimum safe distances, and the maximum amount of stored energy the battery will contain.

To deviate from the standard requirements, specific actions need to be taken, such as developing a Hazardous Mitigation Assessment (HMA), conducting approved testing, and/or taking steps to minimize or protect against the projected hazard.

### Hazardous Mitigation Analysis (HMA)

The section describes the conditions that require an HMA. In addition to increasing total stored energy capacity, increasing battery group capacity, or decreasing distances separating groupings of batteries, an HMA will be required under three conditions as per NFPA 855 Section 4.1.4:

*(1) When technologies not specifically addressed in Table 1.3 are provided.*

*(2) More than one ESS technology is provided in a room or indoor area where adverse interaction between the technologies is possible.*

*(3) When allowed as a basis for increasing maximum stored energy as specified in 4.8.1 and 4.8.2.*

Further, the analysis shall evaluate the consequences of the following failure modes and others deemed necessary by the AHJ, as per Section 4.1.4.2**:**

*(1) Thermal runaway condition in a single module, array, or unit*

*(2) Failure of an energy storage management system*

*(3) Failure of a required ventilation or exhaust system*

*(4) Failure of a required smoke detection, fire detection, fire suppression, or gas detection system*

Note that only single failure modes shall be considered for these four modes, and others that would be deemed necessary by the AHJ.

The AHJ shall be permitted to approve the hazardous mitigation analysis, as documentation of the safety of the ESS installation as per Section 4.1.4.3, provided six criteria are met.

*(1) Fires will be contained within unoccupied ESS rooms for the minimum duration of the fire resistance rating specified in 4.3.6.*

*(2) Suitable deflagration protection is provided where required.*

*(3) ESS cabinets in occupied work centers allow occupants to safely evacuate in fire conditions.*

*(4) Toxic and highly toxic gases released during normal charging, discharging, and operation will not exceed the PEL in the area where the ESS is contained.*

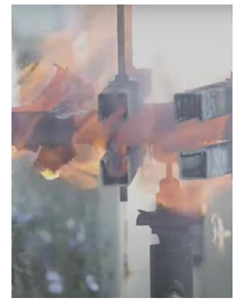
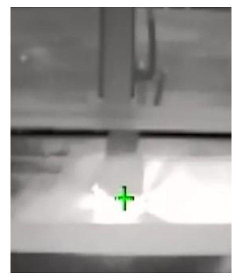
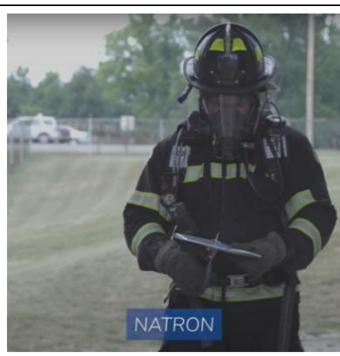
*(5) Toxic and highly toxic gases released during fires and other fault conditions will not reach concentrations in excess of immediately dangerous to life or health (IDLH) level in the building or adjacent means of egress routes during the time deemed necessary to evacuate from that area.*

*(6) Flammable gases released during charging, discharging, and normal operation will not exceed 25 percent of the LFL.*

NFPA 855 refers one to do an HMA and evaluate the consequences of the four failure modes AND others deemed necessary by the AHJ. It may be this catchall phrase that drives the further assessment through development of an HMA and conducting large-scale fire testing.

As part of the development of a set of scenarios, an event tree should be constructed that considers initiating event, time for fire development, time for evacuation, and anticipated temperature.

# Appendix F: Natron versus Lithium-Ion Battery Testing

| Natron vs. Lithium-Ion Battery Testing | | | | |
|---|---|---|---|---|
| | Natron | | Lithium Ion | |
| Nail Penetration Test |  |  |  |  |
| | Before | After | Before | After |
| Crush Test |  |  |  |  |
| | Before | After | Before | After |
| High Speed - Bullet |  |  |  |  |
| | Before | After (unaffected) | Before | After (explosion) |
| Cut Test |   | | **Cut Test for Lithium-Ion Battery was Not Conducted: (Explosion Hazard to Firefighter)** | |
| | Natron Test (No Fire or Explosion) | | LiON test not conducted due to hazard | |