NFPA 855: WHERE DO WE GO FROM HERE?

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Abstract
NFPA 855 has become recognized as the bellwether North American standard for qualifying a stationary energy storage system. However, ensuring its timely acceptance and implementation face certain noteworthy challenges. This paper will highlight the history of its inception, the important changes that occurred with the updated 2023 edition and explain the hurdles that exist to ensuring its wholesale adoption and enactment. These include competing codes/standards, regulatory fences, and a fluid ascendancy of technologies.

Introduction
Few will argue with the fact that safety codes and standards have become an important topic within the rank and file of the stationary battery community. There are actually a number of safety code categories that address the various aspects of concern. These include fire protection and safety, occupational risk and hazards safety, transportation safety – especially as it relates to transporting hazardous materials from point A to point B, whether from factory to warehouse or from warehouse to user – and the safety of the actual materials, whether used in buildings and external containers, or of the devices or equipment itself.

However, within the energy storage body of suppliers, developers, first responders and ultimate users which include electric utilities, industrial complexes, consumers or fire and fire safety personnel, the issue of safety has risen to the top of the pyramid of concerns. While all of the categories just mentioned are important in the overall scheme of energy storage, this paper will concentrate on the reasons behind the introduction of NFPA 855 and its evolutionary progression.

First, let's define the difference between a safety code and a safety standard. The terms tend to be used interchangeably, but technically there is a difference. According to NFPA - Reporter's Guide: About codes and standards:

- A code is a model, a set of rules that knowledgeable people recommend for others to follow. It is not a law but can be adopted into law.
- A standard tends be a more detailed elaboration, i.e., the nuts and bolts of meeting a code.

Another way of putting it is codes are where safety guidelines are to be applied and what kind of guidelines are required, while standards direct how the codes are to be applied, i.e. codes define the where and what while standards direct the how.

On February 8, 2023 a major news story appeared on NBC News, both during its morning NBC Today show news segment and its Nightly News report. It addressed the issue of a growing number of lithium-ion fires, especially in New York City as well as the somewhat recent fire and explosion that occurred in Surprise AZ.

To be clear, the purpose of this paper is not to disparage any particular technology nor to ascribe the advantages or disadvantages of any of the technologies being introduced in this new world of decentralized energy storage. There are plenty of papers and presentations that can handle those aspects accordingly. The purpose of this paper is to focus on why fire and explosion issues are a concern that demand a measured spotlight on fire and explosion safety standards with the result of assuring adequate protection to all the stakeholders involved in implementing energy storage and the subsequent use of batteries in these energy storage equations.

It is not only interesting but important to note that from its inception, just like electricity, fire has been a significant part of our human experience and survival. We have centuries of knowledge with incidents, tragedies, the development of safety standards and educating all participants in the user community. This has helped to develop a safer means to handle, control, prevent, contain, and assure safe conditions with fire and explosions. That is not to say that as the energy storage world continues to progress, and especially now with new technologies and patterns leading us in these new directions of grid transformation, the work of providing safety standards is done.

The History of Safety Codes Development

Let us quickly walk down the road of fire protection and standards development beginning with the great fire of Rome in 64 AD. This led to the first documented start of recording "standards" which led to changes that would provide a safer means of preventing the catastrophe of a fire burning down a large urban environment. This resulted in wider streets, restrictions on the height of houses, and a mandate that common walls of buildings were to be constructed with fire resistant material such as stone instead of wooden pillars.[1]

However, the Great Fire of London that destroyed 80% of the city in 1666 and the great Chicago fires of 1871 followed by a second major one in 1903 that destroyed 1/3 of the buildings in Chicago and killed 600 patrons trapped in a theater proved that fire codes needed serious development.[2]

The *History of Fire and Fire Codes* catalogs the casualties and the resulting destruction of a number of deadly fires that destroyed much of several cities including Boston, Baltimore, and San Francisco.

The first automatic sprinkler system was patented by Philip W. Pratt in 1872 and the first automatic sprinkler head was invented and installed on Pratt's sprinkler system two years later.[3] You may ask, what does this have to do with NFPA 855? It provides the foundational background for some of the dilemma we have with the enforcement of standards today. There were a myriad of designs and problems causing confusion that led to the creation of the NFPA® in 1872 and the release of what is now known as NFPA 13, *Standard for the Installation of Sprinkler Systems*. Without belaboring the entire history of the NFPA®, it is important to note that this was the first standard published by the nascent NFPA®. The other major standard to come out of the early beginnings of the NFPA® was NFPA 70 which is known universally as the National Electrical Code (NEC), not to be confused with IEEE C2, the National Electrical Safety Code (NESC) which guides the internal workings of electrical safety for the United States electric utility industry.

Figure 2-Early Fire Suppression Sprinkler and Head, *History of Fire and Fire Codes, December 2021*

All that said, there is one more important piece to this history lesson that should be explained before we delve into NFPA 855.

It is important to understand the creation of the International Code Council (ICC) as well. This body created the International Fire Code (IFC®), the International Building Code (IBC®) and the International Residential Code (IRC®). These three codes along with a few others are commonly known as the ICC I-Codes.[4] At the same time that the NFPA® was being created as a result of insurance concerns in New York City, there were a number of other groups trying to create some meaning to standards development, specifically with fire and fire protection. NFPA initially was interested in water and electrical safety issues, while the pre-ICC was dealing with fire and fire protection.

Prior to the development of the IFC®, there were four separate standards for fire protection: [1] The National Fire Prevention Code, [2] the Standard Fire Prevention Code, [3] the Uniform Fire Code, and [4] the NFPA 1-Fire Prevention Code[5]. While the intentions were noble, cities and states began adopting different sets of standards. This naturally led to difficulty understanding the regulations as they became more complex and confusing. In 1994 the first three codes listed above merged into the International Code Council to create the IFC®.

The two main fire codes in use today are the IFC®, which is accepted as the foundation for regulation in 42 states, the District of Columbia, Puerto Rico, and Guam, and NFPA 1 which governs the few other states as shown in Figure 3. The U.S. government, especially the Department of Defense, follow NFPA 1. The IFC® established the minimum requirements necessary to protect people and property from fire and explosion hazard in their associated dangers in buildings, structures, and premises.[6] The IFC, IBC, and IRC are often referred to as the "model codes." The reason is that the requirements these codes contain are not legally binding, but they carry the force of law when adopted into state and municipal code.

Figure 3 - The adoption Map of IFC and NFPA 1.

The model codes must first be adopted through the state, county, city, or some other jurisdictional process to become legally enforceable. Adding to the challenge is the fact that [1] not very many regulatory authorities update their requirements together in sync with the most current edition releases of these two standards[7]; and [2] some states (or cities) use these codes merely as a foundational basis for regulation but may add or delete requirements from the actual regulations contained in the two "model codes." A few examples are New York City[8], California[9], Oregon[10], and Hawaii[11] among others.

This provides the necessary backdrop for the focus of this paper in describing how NFPA 855 fits into this matrix, what challenges exist in allowing NFPA 855's actual implementation, and where we need to go from here.

Current Reasons for Recent Focus on Safety Codes for ESS

Generally, there is common agreement that there are three pressing reasons for the recent focus on safety codes for energy storage devices and systems:

1. A growing realization that battery technologies are not always safe against fire and explosions due to the relatively recent rash of incidents in many parts of the world. This is especially true of lithium based and sodium sulfur batteries.
2. The growth of distributed energy resources (DER), including grid interactive microgrids, electric vehicles (EV) and the new emphasis on electrification.
3. The need for first responder safety and the ancillary requirements associated with it.

Now, quite frankly, there are a plethora of codes and standards that address various aspects of energy storage. IEEE, ANSI, ASME, EPRI, and the SunSpec Alliance, to name just a few of the standards development organizations, have certain codes or standards that are published.

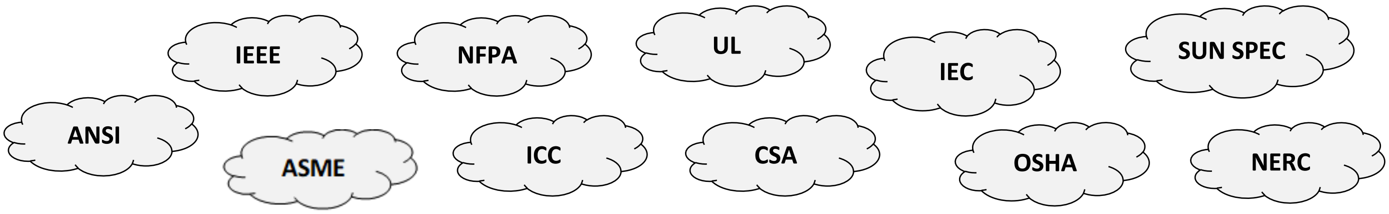

Figure 4 – Various SDO's with codes, standards, and safety related documents related to energy storage devices or systems floating in the ES atmosphere.

In fact, the U.S. Department of Energy (DOE) through a collaborative effort of three national laboratories publish an energy storage safety codes and standards report that currently track 57 different codes/standards spread across the ESS domain including: [1] the ESS built environment, [2] ESS systems, [3] ESS installations and [4] ESS components categories. [12] However NFPA 855 with its correlation to NFPA 1, IFC and certain UL standards is the most significant standard addressing the current safety needs of stationary energy storage at this time.

The Initial Release of NFPA 855

Again, speaking briefly of history, the conception of NFPA 855 began as a project taken on by the U.S. DOE and the NFPA Fire Protection Research Foundation. This resulted from a request by the California Energy Storage Alliance (CESA). Most everyone in the stationary battery community was familiar with lead-acid batteries and had worked through the fire and safety concerns associated with the new at the time valve regulated (VRLA) lead-acid batteries. The VRLA cell was introduced in 1957 (modern gelled electrolyte) or 1972 (the more commonly used absorbed glass mat plates). However, CESA was concerned with the advent of the increasing use of lithium batteries in particular, but also the initial use of NaS cells and the promising development of flow batteries, zinc and other potential BESS technologies. There was a need for addressing the safety concerns of these new technologies invading the stationary application space.

The creation of the first edition of NFPA 855 was somewhat contentious. A serious argument developed when the IEEE Stationary Battery Committee learned that a requirement specifying that lead-acid cells would need to be UL listed if they were to be used in stationary battery applications. US telecommunications carriers, electric utility providers and UPS manufacturers also were alarmed since they had hundreds of thousands of these batteries installed with ongoing service and replacement needs and believed that fire and fire safety issues affecting lead-acid batteries had been addressed quite successfully in recent decades. Unfortunately in 2019 a distinction wasn't made by those outside the lead-acid battery industry between standby uses where the batteries remain at a full state of charge, waiting to power loads when a power outage occurred, and the newer applications that involved cycling and partial charging/discharging demands in what are now called energy storage applications. Further, lead-acid batteries have technically always been considered energy storage devices.

As a result, the first edition of NFPA 855 was approved by the NFPA Standards Council on August 5, 2019, without a scope. It was then recognized as an American National Standard on August 25, 2019[13]. It was released to the public effective August 25, 2019, without a scope, which was the first time an NFPA standard was issued without a scope. The reason this was allowed was that the NFPA 855 Committee and the NFPA Standards Council determined that the need was too great to send the standard back to Committee and wait another two to three years before it would be released. The first edition was therefore published in December 2019 without the scope.

Creation and Release of NFPA 855-2023

On September 1, 2022, the second edition of NFPA 855 was approved as an American National Standard and released for publication by the NFPA Standards Council with a September 1, 2022, effective date[14]. It is now available in printed copy as well as accessible for viewing without charge via the NFPA website.

This new release builds upon lessons learned from the McMicken incident in Surprise AZ and other lithium battery fire events across the globe. It continues to contain certain carve-outs for lead-acid and nickel-cadmium designs with some notable improvements, and more adroitly addresses other ES battery technologies.[15].

Other important updates were made in the 2023 edition[16]. These include:

- Requirement for UL listings for all devices used in energy storage applications, including inverters, UPS devices, and all alternate technologies. Chapter 13 has been added to address flywheel ESS.
- Further clarification is made on UL 9540A testing requirements in response to international incidents of ESS fires. This includes requirements for fire detection and suppression, explosion control and conflagration, exhaust ventilation, gas detection, and thermal runaway. The requirements for fire and explosion testing (formally large-scale fire testing) have been updated.
- Chapter 14 has been improved and now only applies to the storage of lithium metal or Li-ion batteries.
- Requirements from Chapters 4 and 10 specific to electrochemical ESS have been consolidated and reorganized in Chapter 9.
- Residential ESS requirements for PV plus storage are addressed.
- Information has been added in Annex B to provide guidance on the hazards associated with several major battery types.
- Annex G has been added as a guide for suppression and safety of lithium-ion battery ESS.

It would be impossible to address every tenet outlined in NFPA 855 in this paper but let us turn our attention to a few of the major impacts of NFPA 855.

The threshold quantities for all battery technologies are listed in Table 1.3**.** Threshold quantities per each fire area or outdoor installation remain unchanged except for sodium-nickel-chloride batteries. If sodium-nickel-chloride batteries are UL 1973 listed, their threshold quantity rises from 20kWh to 70kWh. Lead-acid and nickel-cadmium cells remain at 70 kWh while all types of lithium-ion batteries and flow batteries remain at 20kWh.

For those accustomed to calculating battery capacity in ampere hours (Ah), the following formula is used to convert Ah to kWh.

Table 1.3 in NFPA 855, Chapter 1 states: "ESS units rated in amp-hrs, kWh equals nominal rated voltage multiplied by amp-hr nameplate rating divided by 1000. For batteries rated in watts per cell, kWh equals the nameplate watts per cell multiplied by the number of cells divided by 1000 and multiplied by the nameplate minutes rating divided by 60."

Taking the standard formula for ampere-hour conversion, that would be:

$$\frac{nominal\ rated\ voltage \times Ah\ nameplate\ rating}{1000} = kWh$$

An example would be if we take a 120 Vdc nominally rated 60-cell string of 400 ampere hour nameplate rated batteries and multiply them together, we obtain a total of 48,000. Dividing that by 1000 gives us 48kWh.

$$\frac{120Vdc\ \times 400Ah}{1000} = 48kWh$$

This is below the threshold and NFPA 855 would not apply. However, if this were the lithium-ion or flow battery, the 20kWh threshold would be exceeded.

But if I needed an 800 ampere-hour nameplate rated 60 cell string battery at the same 120 Vdc nominally rated voltage and I didn't want to parallel two 400 Vdc 60 cell strings, the resultant factor is 96,000. Dividing that factor by 1000 gives me 96kWh.

In this instance the batteries would exceed the threshold limit and therefore be subject to the requirements of NFPA 855 except where exempted, e.g., NFPA 855 exempts lead-acid and nickel-cadmium systems where the batteries are used for backup of controls in an electric utility's substation or generating station under the exclusive control of that utility.

When UPS batteries are rated in watts per cell, NFPA 855 provides an alternate formula as noted above:

$$\frac{nameplate\ watts\ per\ cell \times numberof\ \ cells}{1000} \times \frac{nameplate\ minute\ rating}{60} = kWh$$

Assume a 540W/cell at the 15-minute rate nameplate rating and a 240-cell string for illustrative purposes only. When the formula above is applied, the result is 129.6 x 15/60 =32.4kWh. In this case, the threshold for lead-acid batteries is not exceeded. However, if four (4) strings are needed for a large UPS, then the resultant 129.6kWh exceeds the 70kWh threshold and NFPA 855 applies unless the UPS is exempted.

NFPA Official Definitions in Section 3.2 were reorganized slightly, but a provision for identifying a standby power application is defined now in section 3.3.2.3. In situations where a mix of BESS technologies are anticipated to be installed in the same fire space, e.g. lead-acid and lithium, which may result in a combination of standby and cycling applications, then Section 9.4.1.3 will apply.

If the potential to stack applications and one or more of these is going to be considered an energy storage type of application, or if the plan entails utilizing one battery technology for a certain application and another battery technology for different application(s) in the same fire space, then NFPA 855 requires calculating the maximum stored energy using the formula ascribed in Section 9.4.1.3.

This leads to the topic of maximum stored energy allowed before a hazard mitigation analysis (HMA) is required. Section 3.3.16 defines maximum stored energy as the "quantity of energy storage permitted in a fire area prior to the area being considered a high hazard occupancy."

The table defining Maximum Stored Energy is shown in Chapter 9. That table is:

Table 9.4.1 Maximum Stored Energy

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

[a] For ratings in amp-hrs, kWh should equal maximum rated voltage multiplied by amp-hr rating divided by 1000
[b] Nickel battery technologies include nickel cadmium (Ni-Cad), nickel metal hydride (Ni-MH) and nickel zinc (Ni-Zn)
[c] Includes vanadium, zinc-bromine, polysulfide, and other flowing electrolyte -type technologies.

Table 1: NFPA 855 2023 Edition, Chapter 9, Table 9.4.1

Another major area of concern for all ESS installers is size and separation of devices and container units. Section 9.4.2 deals with this issue. The first requirement as outlined in 9.4.2.1 is that "ESS shall be composed of groups with a stored energy of 50 kWh each." Each of these groups must be separated from other groups or walls by a minimum distance of 3-feet.[18]

The following section titled 9.4.2.4 *Lead-Acid and Nickel-Cadmium Battery Systems* and the four subsections that follow give lead-acid and nickel-cadmium batteries that [1] comply with NFPA 76 used in telecommunications installations, [2] used in substations under the exclusive control of the electric utility, [3] or used in conjunction with a UL 1778 listed UPS for use in standby applications an exemption from the requirements of Sections 9.4.2.1 and 9.4.2.2. Subsection 9.4.2.4 allows lead-acid and nickel-cadmium batteries that are UL 1973 listed used in stationary standby power applications to compose in groups up to 250 kWh each.[19]

Before concluding, permit me a minute to address NFPA 855, Chapter 15, *One and Two Family Dwellings and Townhouse Units*. I realize that the major emphasis of most SDO's, National Laboratories, and many conference tutorials as well as regional regulatory efforts (PUC's, etc.) has been directed at the grid-scale and in-front-of-the-meter (IFM) applications. The National Renewables Energy Laboratory (NREL) in Boulder CO along with SC 21 have been addressing both the grid and renewable interconnection requirements of energy storage and IEEE 2800 is addressing grid-interactive inverters.

Chapter 15 attempts to make an effort at addressing behind-the-meter (BTM) installations. There is also the effort of the International Residential Code (IRC) published by the ICC. In the opinion of a many of those involved in this area of energy storage from both the lithium and lead-acid communities, much work needs to be done with Chapter 15.

Several things stand out:[20]

1. Any installation rated at 1kWh or greater must comply with this chapter.
2. Individual units cannot exceed 20kWh.
3. The aggregate rating of the ESS cannot exceed 80kWh.

It appears that this Chapter may have been written with one BESS technology in mind. Whether accidental or intentional, it matters not for purposes of this discussion. What does matter is that with the increasing demand for electric power, whether in a single residence or a two family dwelling or its unintended extension to community solar or apartment complexes and even commercial campus environments, this leaves a majority of the interested providers unable to compete for inclusion. With safety, environmental sustainability, and the need to provide substantial electricity to homes caught in a Category 3 or 4 hurricane, the aftermath of an E3 or E4 tornado outbreak, or a massive wildfire engulfing a major area that results in multi-day loss of electric utility power, the need to address these Chapter 15 provisions is important.

CONCLUSION

NFPA 855 is recognized by most as the bellwether safety standard for energy storage systems in North America. It is referred to in both NFPA 1 and IFC standards. However, it is up to regional, state, and local jurisdictions to [1] recognize and accept the value of NFPA 855, and [2] bring the legal requirements of following the most current NFPA 1 or ICC IFC and IRC standards into fulfillment within their jurisdictions. The need to educate AHJ's and regulatory authorities on the beneficial safety results of implementing NFPA 855 requirements as part of their regulatory provisions is important.

Public inputs are being accepted by NFPA for the 2026 edition of NFPA 855 through June 1, 2023. The IEEE Energy Storage and Stationary Battery (ESSB) Committee Safety Codes and Standards Working Group will be providing their public inputs to as to make recommendations or address some of these concerns, but any individual can submit public input.

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