NFPA® 70 and NFPA® 70E Battery-Related Codes Update

William Cantor, P.E.
TPI,
Exton, PA

Stephen W. McCluer
Senior Manager/External Codes and Standards
Schneider Electric (Retired)
Dallas, TX

Abstract

Two code documents have a dramatic impact on the acceptance or rejection of a battery installation by an inspector. These are the *National Electrical Code* ® (NEC®/NFPA 70®)[1] and the *Standard for Electrical Safety in the Workplace*® (NFPA 70E®)[2]. This paper will examine recent battery-related changes in both documents as well as changes in the NFPA 70E Handbook® and changes that have been proposed for the next edition on the NEC.

In the year since Battcon-2014, NFPA 70E-2015 has been published. With respect to batteries, a number of changes have been made that are favorable to the battery industry in that they improve the ability to conduct maintenance while simultaneously improving the overall safety of personnel. Included in the NFPA 70E-2015 Handbook[3] are common sense guidelines for developing a battery maintenance safety program, the development of which was enabled by the IEEE Stationary Battery Committee Codes Working Group (CWG).

NPFA 70® (National Electrical Code®)[1] is in the midst of an update cycle for the 2017 version (to be released in the fall of 2016). The Stationary Battery Committee Codes Working Group submitted over 35 Public Inputs (PIs). Additional PIs submitted by other interested parties may affect future battery system installations as well.

This paper attempts to look two years into the future to anticipate how codes will influence the design, operation and maintenance of battery systems in the last years of this decade.

Batteries in the National Electrical Code® (NEC®) – Impact on Installation

The National Electrical Code® (NFPA 70®)[1], published by the National Fire Protection Association (NFPA®), is focused on "the practical safeguarding of persons and property from hazards arising from the use of electricity". A version of the NEC® is enforced in most jurisdictions in all 50 states in the USA and in several other countries. To fully understand how batteries are addressed, understanding the structure of the NEC® is required. The core of the NEC® is in the first four chapters which apply generally. Chapters 5-7 supplement or amend the first four chapters. Chapter 8, which covers communications circuits, is unique. Chapter 8 is not subject to the requirements of Chapters 1 through 7 except where specifically referenced by Chapter 8. Chapter 8 applies to communication equipment which, by definition, includes related power equipment including batteries.

Within each chapter are "Articles" for specific topics. See Table 1 for examples.

Topic	Where addressed in the NEC	
Working space around battery systems	Article 110	
Uses not permitted in battery rooms - Nonmetallic sheathed cable - Underground feeder and branch circuit cable - Flexible metal conduit - Flexible metal tubing - LV suspended ceiling power distribution - Lighting track	Chapter 3 - 334.1 - 340.12 - 348.12 - 360.12 - 393.12 - 410.151	Chapters 1-4 apply generally to all electrical installations
Storage batteries	Article 480	
Hazardous locations, use of chargers	Articles 503, 511, and 513.	
Health care facilities, use of batteries	Article 517.	
Modular data centers, work space around batteries	Article 646.	
Photovoltaic battery systems	Article 690	Chapters 5-7 supplement or modify Chapters 1-4
Wind system batteries	Article 694	
Emergency system, use of batteries	Article 700	
Legally Required standby systems, use of batteries	Article 701	
[Energy storage systems (ESS)]	[Proposed New Article 706]	
Critical operations power systems, use of batteries	Article 708	
Communication circuits and equipment which includes related dc systems and batteries	Article 800	Chapter 8

Table 1. Batteries in the NEC

The current edition of the NEC® is 2014, although earlier editions may be enforced in some jurisdictions. The NEC® is on a 3-year revision cycle, so the next edition will be 2017 (released in fall 2016). The opportunity to submit public inputs (PI's) closed in November of 2014. Some 5000 PI's were submitted and reviewed by 19 different code-making panels (CMPs) in January of 2015. CMPs are responsible for writing specific sections of the Code. For example, CMP-13 is responsible for battery systems in Article 480.

NEC® Article 480 –Proposed changes for storage batteries

This section summarizes some of the proposals that passed the first round of the CMP review. This summary is based on preliminary material and is subject to change. All of the proposed changes will be available for review during the public comment period which is July through September 2015.

Twenty-four changes were proposed for Article 480, of which half were submitted by the IEEE Stationary Battery Committee's Codes Working Group. Tentatively approved changes include:

- **Corrosion prevention** – Reference to mating of dissimilar metals will be removed. Antioxidant material suitable for the battery connection must be used when recommended by the battery manufacturer.
- **Battery terminal conductors** – An informational note will clarify that pre-formed conductors are acceptable to prevent stress on battery terminals, as are fine-stranded cables (e.g., "welding cable"). Manufacturer guidance is recommended.

- **Remote disconnect activation** - There was some confusion in the wording in this section and there were other proposals that would allow disconnects to not be in sight of the battery. The existing wording was improved to clearly state that the battery disconnect must be in sight of the battery.
- **Disconnect labeling** – The intention was to make the labeling consistent with the requirement of 70E. To that end, a new information note directs the user to NFPA® 70E for guidance on how to calculate fault current. Wording was also added to require an arc-flash warning label (Section 110.16). Also, “short circuit current” was replaced with “fault current”.
- **Insulation of batteries** - This section was essentially deleted. The following sentence was added: “Batteries constructed of an electrically conductive container shall have insulating support if a voltage is present between the container and ground”[4]. This scenario most likely does not apply to any battery that is currently in production, but was added just in case there was a battery produced that had a voltage to ground.
- **Battery support systems** – The term “racks and trays” will be replaced with the more inclusive term “battery support systems.” This section was lead-acid centric and was modified to be more generic. For battery chemistries with corrosive electrolyte, the structure that supports the battery must be resistant to deteriorating action by the electrolyte. Metallic structures must be provided with non-conducting support members for the cells, or else they must be constructed with a continuous insulating material. Paint alone is not considered to be an insulating material.
- **Ventilation** – A new informational note will direct readers to IEEE 1635/ASHRAE 21 for guidance on ventilation of various types of batteries in a variety of enclosures and operating conditions. The intent is to maximize battery reliability as well as the safety of personnel and equipment.
- **Top terminal batteries** – The working space requirement for batteries on open racks will be expanded to include top terminal batteries in cabinets. While the wording that refers to the manufacturer’s instructions for guidance was retained, a note was added to refer to IEEE 1187 which does have very specific guidance for required clearance for cabinetized batteries.
- **Egress** – The listed panic hardware of doors in a battery room will be required to display the listing label.
- **Vented cell flame arresters** – Vented cells are required to have a flame arrester. Text about the purpose of the flame arrester will be moved to an informational note because the authority having jurisdiction (AHJ) cannot determine if the flame arrester is properly designed.
- **Pressure-release valves** – This paragraph was referring to VRLA cells, although it was written generically. The wording was changed to make having a pressure relief valve only mandatory for battery designs where a battery is constructed such that an excessive accumulation of pressure could occur within the cell during operation.

Some proposals that failed to get through the code-making panel include:

- Listing batteries according to their application
- Sizing of high-rate battery cables
- Raising the safety level from 50 Vdc to 60 Vdc for prime movers
- Raising the safety level from 50 Vdc to 100 Vdc for battery disconnects
- Changing terminology from “live parts” to “energized conductive components”

Issues Surrounding the Battery Disconnect Requirement in Article 480

The issue on the minimum voltage for safety (battery disconnects and other dc requirements) was thrown back to the correlating committee since it affects multiple parts of the code. However, the original intent of setting the minimum voltage level of 50 volts for the battery disconnect requirement is unknown. The thinking by many is that the level is based on the minimum voltage shock level. However, electric shock is only one of many battery hazards and installing a battery disconnect does not eliminate or reduce the shock hazard for maintenance personnel working on the battery, which cannot be de-energized. Additionally, even at 50 volts, a battery short circuit can create significant currents which may result in an arc flash or fire.

The practical implication of the battery disconnect requirement is that traditional 48 volt battery systems are exempt. The vast majority of 48 volt battery systems have been installed in telecommunications facilities and for the most part have been very safe.

One problem with the requirement is that 48 volt battery systems operate at voltages above 50 volts. Traditionally 48 volt systems have been constructed of 24 lead acid cells. Lead acid cells at open circuit are about 2 volts although in reality the voltage depends on the specific gravity and most VRLA cells have an open circuit voltage of 2.15 volts which equates to 51.6 volts at open circuit. This situation becomes even more confusing when non lead-acid technologies are used with different open circuit voltages.

Before the “with a nominal voltage” wording was added in the last code cycle (2014 edition), individual inspectors could rightly (arguably) require a 48 volt system to have a battery disconnect. Even with the modified wording, a VRLA battery that is over 50 volts on open circuit could be required to have a battery disconnect.

While a battery system can be operated at practically any voltage, the vast majority of systems are in one of three categories: (1) telecommunications [48 volts], (2) Utility/switchgear [120/125 volts], and (3) UPS [can vary but typically 480 volts]. Raising the minimum voltage to 100 volts would clearly exempt 48 volt system without affecting the other traditional battery systems. This change would completely reduce the confusion of exempting 48 volt batteries.

One hundred volts is the accepted minimum dc shock voltage (NFPA 70E) and generally understood by arc flash experts to be the minimum voltage for dc arc flash.

A battery disconnect does allow an individual to remove an energized source easily. This disconnect is also a potential point of failure which is one of the reasons why the telecommunications industry has traditionally not used battery disconnects. Changing the voltage to 100 volts will alleviate a lot of confusion with how the requirement is applied to 48 volt systems without unnecessarily relieving any other major class of battery system of the disconnect requirement.

Another option would be to eliminate the voltage requirement completely, but to allow an exception to organizations that have a depowering plan to de-energize circuits in case of an emergency (for systems under 100 volts). Many telecommunication organizations that do not use battery disconnects do have depowering plans.

Sizing of High-Rate Battery Cables

The proposal for sizing of high-rate battery cables was not an IEEE Stationary Battery Committee CWG proposal. However, the concept of allowing smaller size cables for short-time dc discharges could save the industry significant amounts of money. Currently, dc cables for all discharge times are sized per the NEC® ac continuous rating tables. The proposal was specific to UPS type installations where the maximum time of discharge is around 15 minutes. The proposal was rejected because there was no substantiation on what the ratings should be. If substantiation can be found, this proposal has a chance to be accepted in the future.

NEC® Other Articles - Proposed changes for storage batteries

Proposed changes pertaining to battery systems in other parts of the NEC® include:

- **Top clearance** - An exception will be added to Section 110.26 regarding the height of working space directing the reader to go to Article 480 for batteries
- **Insulating covers** - Per Section 110.27, only "qualified persons" will be permitted to remove insulating covers over exposed conducting parts. Only one polarity is permitted to be exposed at one time.
- **Emergency system battery maintenance** – The term "battery" will disappear in all-inclusive statements in Articles 700 (Emergency systems) and 701 (Legally required standby systems). Emergency system equipment must be maintained in accordance with manufacturer instructions and industry standards.
- **Emergency system minimum voltage** - The existing requirement for the battery to hold up the load for 1.5 hours above a minimum voltage of 87.5% of the nominal voltage will be changed to hold up the load above the minimum voltage required by the load equipment manufacturer.

New Articles in the NEC impacting battery systems

Two new Articles have been proposed for NEC®-2017. At the time of this writing, the specifics of what will be included are still very fluid, but the general nature of the new Articles can be described.

Article 706: Electrical Energy Storage Systems (ESS) – This new Article applies to all permanently installed energy storage systems which may be stand-alone or interactive with other electric power production sources. This new Article attempts to pull in everything from Article 480 as well as battery requirements from other sections of the Code, primarily those pertaining to alternate energy systems and grid interconnection. This generic article would not necessarily be restricted to electrochemical storage systems. Flywheels, compressed air energy storage (CAES) or other energy storage technologies could be included. Whether Article 480 will remain or disappear is yet to be determined. As has been proposed so far, Part III of Article 706 would apply to ESS(s) that are comprised of sealed and non-sealed cells or batteries or system modules that are comprised of multiple sealed cells or batteries. Part IV would apply to ESS(s) composed of or containing flow batteries.

Article 712: DC Microgrids - A direct current microgrid is a power distribution system consisting of one or more interconnected dc power sources, dc-dc converters, dc loads, and ac loads powered by dc-ac inverters. A dc microgrid could be permitted to be directly connected to a primary source of 60 Hz electricity through a bidirectional multimode inverter or bidirectional utility interactive inverter. As presently drafted, Article 712 would defer to the previously described Article 706 for specifications on battery systems.

Batteries in NFPA 70E – Impact on Operation and Maintenance

NFPA® 70E is the *Standard for Electrical Safety in the Workplace.®* This document is in the "70"series of NFPA documents but, unlike the National Electrical Code® (which is mandatory in most jurisdictions of all 50 states in the USA), NFPA® 70E is a standard, which means that it is theoretically an option. In reality, because this document is a recognized best practice, failure to comply with its safety guidelines can result in penalties from organizations such as the U.S. Occupational Safety and Health Administration (OSHA). Whereas the NEC® is focused on safe electrical design and layout, NFPA 70E is focused on the safety of the worker.

Battery implications – Prior to the 2012 edition, requirements for direct current (dc) were almost nonexistent in NFPA® 70E. Thanks largely to efforts by the IEEE Stationary Battery Committee[5], requirements for dc in general and for batteries in particular show up in various places throughout the document. Further guidelines were added in the 2015 edition of NFPA® 70E. Important sections include:

- **DC Approach Boundaries** [Table 130.4(D)(b)] – The risk of electrical shock increases as an individual gets closer to an electrical hazard. This Table identifies limited approach and restricted approach boundaries based on the dc voltage, starting at 100 Vdc. The limited approach boundary is the closest an *unqualified* person is allowed to get to an energized conductor or part. An electrical safety program must include procedures to protect workers who get any closer than that. Essentially, there is not a dc shock hazard below 100 volts which is consistent with the research. Shock PPE is not necessary for battery maintenance for systems under 100 volts or in situations when a technician cannot reach across more than 100 volts.

- **DC Arc Flash Hazard Identification** [Table 130.7(C)(15)(A)(a) – DC arc flash is one of the least understood hazards associated with batteries.[6,7] This Table, which had been a separate table specifically for direct current in the 2012 edition, has been folded back into a table for both ac and dc. This Table identifies when arc flash personal protective equipment (PPE) is required, based upon the type of work being performed. Not all tasks require PPE. For example, no PPE is required when taking voltage readings on an individual cell or unit that has been properly installed and maintained. Other activities in which arc flash PPE is not required include "insertion or removal of individual cells or multi-cell units of a battery system in an open rack" and "maintenance on a single cell of a battery system or multi-cell units in an open rack"[2]. If a task is not listed in this Table, an incident energy analysis must be completed and neither the DC Arc Flash PPE table nor the PPE Categories table can be used.

- **DC Arc Flash PPE** [Table 130.7(C)(15)(B)] - In previous editions, this table was based on the arcing current which required users to determine the short circuit current and then estimate the arcing current before the table could be used. While it was not difficult to determine the arcing current (50% of short circuit current), in the current edition the table now uses short circuit current. This table is derived using the methods detailed in Annex D.5 which are based on the absolute maximum power that can be delivered to an arc. These resultant energy numbers are very conservative. The tables are even more conservative for all cases except at the upper range of the short circuit values.

- **PPE Categories** [Table 130.7(C)(16)]- This Table describes what is required for PPE, including arc-rated outer clothing, underclothing, face shields, safety glasses, hearing protection, gloves and footwear. The table can only be used if the two previously mentioned tables were used **and** an incident energy analysis was not performed.

- **Batteries and Battery Rooms** [Article 320] – This Article covers electrical safety requirements for the practical safeguarding of employees while working with exposed stationary storage batteries that exceed 50 volts nominal. This Article is the heart of NFPA® 70E for battery workers. This Article requires that a battery risk assessment must be performed prior to any work to identify the chemical, electrical shock, and arc flash hazards associated with the task(s) about to be performed. The 70E handbook[3] provides a sample flow chart for conducting a risk assessment which was developed by the IEEE Codes Working Group and presented at Battcon 2013[7]. Other requirements include:

    - Instrumentation for early warning of abnormal conditions must be tested annually. (IEEE 1491 for battery monitoring is referenced)
    - Warning signs must be posted warning of voltage, arc flash, and thermal hazards. An informational note identifies the variables that can be considered in calculating the hazard for a complete system, including series and/or parallel connections, charging methodology, temperature, etc. An information notes refers the user to 130.5(D) for labeling requirements.
    - A revised section on electrolyte hazards. Requirements are split between activities that do include handling of electrolyte and activities that do not require electrolyte handling. An informational note and comments in the 70E handbook state that electrolyte is usually not handled during battery maintenance activities and in any case would only possibly apply (depending on the activity) to vented batteries with free flowing electrolyte (essentially vented lead-acid batteries). The only battery related activities noted (in the handbook) that are considered electrolyte handling are acid adjustments, removal of excess electrolyte and clean-up of a spill. Using an electronic density meter is also not considered electrolyte handling. The use of a bulb hydrometer may be considered handling of electrolyte. The bottom line is that almost all typical battery maintenance activities do not require handling electrolyte and are therefore exempt from requiring goggles, face shields, gloves, aprons or eyewash facilities. Only safety glasses are required for all battery maintenance activities where electrolyte is not being handled.
    - A section on ground fault detection, carried over from the previous edition, identifies four types of battery systems which may or may not require ground fault. People who are used to working with ac systems are often confused about when and how to use ground fault detection on a battery system.
    - Additional information was added concerning the inspection and replacement of flame arresters.

- **Effect of Electricity on the Human Body** (340.5) - This Section requires employer and employees to be aware of the effects of electricity on the human body.
    - A dc current of 2 mA is perceptible.
    - A dc current of 40 mA is considered the threshold of the let-go current.
    - A voltage of 30 V rms or 60 Vdc is considered safe, except when the skin is broken. If internal body resistance is <400 ohms, fatalities can occur.

    The Section goes on to describe the effects of short contact. The NFPA® 70E Handbook provides an excellent commentary on this Section and an easy-to-read table describing the quantitative effects of electric current on humans (average data). The data is based on limited experiments conducted on human subjects and animals and published by Charles F. Dalziel in 1961[8]. Another resource by Lawrence Berkley National Laboratory[9] is referenced in the Handbook. Both consider the weight and health of the person. The handbook generally finds that the human tolerance for dc current is more than double the tolerance for ac current. The data in NFPA® 70E Section 340.5 and the data in the 70E Handbook are inconsistent.

- **Approach Limits** [Annex C] - This Section describes in greater detail the approach boundaries stipulated in Table 130.4(D)(b). The 2015 edition deleted the category of “prohibited approach boundary” since it is basically the same as contact with a conductor. The three boundaries, from near to far, are:
  - Restricted approach boundary
  - Limited approach boundary
  - Arc flash boundary.

  Note that the arc flash boundary is the greatest distance from the energized part. To do work on an energized system, the worker should:
  - Perform an arc flash risk assessment
  - Be qualified to do the work
  - Have a documented plan justifying the need to do the work within the boundary. An energized electrical work permit (EEWP) signed by management is required to work inside the restricted space. (An EEWP form is provided in Annex J)
  - Minimize the likelihood of bodily contact with exposed energized conductors and circuit parts
  - Use PPE appropriate to the hazard, including insulated tools and equipment

- **Direct Current Incident Energy and Arc Flash Boundary Calculation Methods** [Annex D.5] - Calculations from this Section were used to derive Table 130.7(C)(15)(B). If an incident energy analysis is required or desired, these calculations should be used instead of the tables. The arcing current is based on 50 percent of the dc short circuit value. The methodology lacks quantified test data, and is therefore very conservative. Battery manufacturers can provide the short circuit current of a single cell, but the system short circuit current depends on the total impedance of the battery system. All calculations are based on an ambient temperature of 25 ˚C. Recognizing that values from battery manufactures are not always available, NFPA allows the use of a rule-of-thumb of 10 times the 1-minute rate to 1.75 VPC at 25˚C (over objections of the IEEE Stationary Battery Committee CWG).

- **Risk Assessment Procedure** [Annex F] - As stated earlier, a risk assessment must be performed before working on energized equipment such as batteries. Annex F is a fairly long chapter containing examples of how to conduct a risk assessment. The 70E Handbook includes some excellent commentary to help construct a risk assessment for any given site. A risk assessment always attempts to weigh the probability of an “event” against the severity of consequences (e.g., injury or death, fire, etc.) The Handbook tells how to create a “risk register”, and to quantify the risk. The information in the standard is generic in nature. An example specific to batteries that was presented at Battcon-2013[7] is faithful to the methodology of NFPA® 70E. This methodology is also shown in the NFPA® 70E-2015 handbook.

- **PPE Selection** [Annex H] – Personal Protective Equipment (PPE) should be the last option for protecting workers, following good engineering controls, procedures, and training. Unfortunately, the hazard – and therefore the risk – cannot be totally eliminated on a battery system, so some level of PPE is always required. PPE includes tools, but most people focus on clothing. Categories of PPE were previously discussed in Table 130.7(C)(16), but this Table can only apply when the category method is used. **If an incident energy analysis is used, the aforementioned PPE table cannot be used and this Annex must be utilized in order to determine the proper PPE**. Annex H attempts to tie the PPE requirement to the applicable section of the standard. For example, for face shields the text directs the user to five different sections under Section 130.7(C) that could apply.

- **Job Briefing and Planning Checklist** [Annex I] – Before any work is done on electrical equipment there must be a plan. Annex I provides a check list that follows the format of Identify – Ask – Check – Know – Think – and Prepare for an emergency. The check list could be used on any job, but realistically it should be modified for battery work applicable to any specific site.

- **Energized Electrical Work Permit and Flow Chart** [Annex J] – A complete EEWP form is provided in Annex J. This form requires a description of the equipment and work to be done, then it requires a number of steps to be completed by the "electrically qualified persons" who will actually do the work. One or more managers must sign off on the work, and will be held accountable if an accident occurs. A simple flow chart walks through the process of decision making.

Opportunities for change

As was previously mentioned, the 2017 version of NFPA®-70 is in the middle of the update process. The preliminary revisions discussed in the document will be available for public comment this summer (2015). The revision cycle for the next edition of NFPA® 70E (2018) has just begun. However, the deadline for public inputs is approaching quickly. The CWG will be submitting public inputs.

While any individual can provide public inputs to any NFPA document, battery practitioners interested in providing input are advised to contact the IEEE Stationary Battery Committee Codes Working Group (CWG). The CWG is open to anyone interested in improving any codes related to stationary batteries. Please contact one of the authors of this paper for information concerning CWG membership and participation guidelines.

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