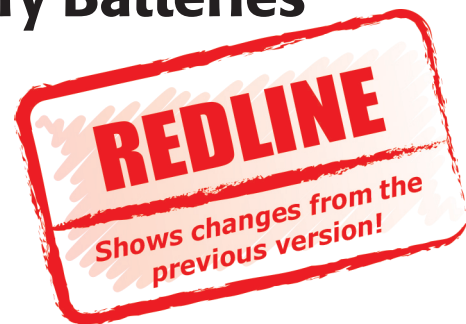


IEEE Recommended Practice for Personnel Qualifications for Installation and Maintenance of Stationary Batteries



IEEE Power and Energy Society

Sponsored by the
Energy Storage and Stationary Battery Committee

IEEE
3 Park Avenue
New York, NY 10016-5997
USA

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IEEE Recommended Practice for Personnel Qualifications for Installation and Maintenance of Stationary Batteries

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Abstract: The areas of recommended knowledge for installers and maintainers of stationary batteries and related systems, to the extent that they affect the battery, are defined in this recommended practice. Design of the dc system and sizing of the dc battery charger(s) are beyond the scope of this document. Only lead-acid and nickel-cadmium battery technologies are covered in this recommended practice. An outline (not necessarily in training order) of the items that should be covered by training programs for stationary battery installation and maintenance personnel is provided. Certifying trained personnel and providing its own battery technician training programs will not be performed by IEEE.

Keywords: battery, certification, classroom, competent, course, curriculum, education, experience, IEEE 1657™, inspect, install, instruct, knowledge, level, maintenance, monitor, preventative, proactive, proficient, qualification, routine, service, skill, student, teach, technician, test

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Introduction

This introduction is not part of IEEE Std 1657™-2018, IEEE Recommended Practice for Personnel Qualifications for Installation and Maintenance of Stationary Batteries.

Although ac and dc electricity follow the same physical laws, there are differences. Training of electricians worldwide is fairly standardized through apprenticeship programs, classroom and self-paced training courses, etc. Although electricians are trained on dc, they spend most of their time working on ac systems. As a result, an electrician hired to work on dc systems (especially battery systems) may not have the expertise, training, or experience to install or work on batteries. The Energy Storage and Stationary Battery (ESSB) committee of the IEEE Power and Energy Society (PES) recognizes that specific training on battery system installation and maintenance is necessary. The committee also recognizes that training of battery maintenance and installation technicians is generally nonexistent or, at the least, nonstandard. With those concerns in mind, the committee has written this recommended guide for training to specify the types of knowledge a battery installation or maintenance technician should possess in order to safely and competently work on primarily stationary standby lead-acid and nickel-cadmium (Ni-Cd) batteries (although the document does give some minimal guidance on other battery chemistries, and most of the principles herein are usually applicable to stationary cycling applications as well).

Acknowledgments

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1. Overview

1.1 Scope

This recommended practice defines the areas of recommended knowledge for installers and maintainers of stationary standby batteries (primarily lead-acid and Ni-Cd standby batteries) and related systems to the extent that they affect the battery. ~~Design, personnel safety and reliability~~ of any related systems. Designing the dc system (including any connected ac inverters) and sizing of the dc battery charger(s) are beyond the scope of this recommended practice. ~~This document covers lead-acid and nickel-cadmium (Ni-Cd)~~ While some of the battery technologies information covered by this practice applies to small off-grid cycling applications, information relative to large energy storage cycling applications is limited.

1.2 Purpose

The purpose of this recommended practice is to provide an outline ([curriculum](#)) of the necessary items that should be covered by training programs for stationary battery installation and maintenance personnel. The order in which the items in this document are covered is at the discretion of the training developer/provider.

1.3 How to use this document

This recommended practice is written as a syllabus for the benefit of the course developers and instructors. It assumes that the developers and instructors will arrange the sequence and create the content of the training to fit personal preference and the needs of the audience. The guidelines included here detail the minimum skill levels that would be expected for a battery technician. Nothing precludes the instructor from creating a more extensive curriculum.

This recommended practice further assumes that all material covered will be tested and scored to demonstrate the students' grasp of the material. Such testing should utilize both written and hands-on demonstration as appropriate for the particular skill. No test guidelines are included in this document; however, suggestions regarding items appropriate for hands-on testing instead of written testing can be found in Annex B.

This recommended practice is written to address multiple skill levels. These levels are explained in detail in Clause 4. This document does not provide content for the courses as it would be impossible to cover the material adequately in a single document. It does include references to standards and other documents that go into great detail on their respective topics. It is assumed that the course developers and instructors will have access to those documents (the students will need access to some, but not all, of the referenced documents). Where information on a topic is not easily available, such information is included in this recommended practice in an annex.

2. Normative references

~~Because this recommended practice is for the use of the training provider to establish a curriculum, there are~~ No [additional](#) documents ~~that are indispensable~~ [absolutely required](#) for the application of this document. ~~Therefore, no normative~~ [Because a training syllabus created with this document will vary based on the selected training topics and the technicians' levels, and because the instructor's knowledge base can also vary, the bibliographic references are listed in this clause, the following clauses may or may not be necessary. As such, the documents cited found in this recommended practice are](#) [the bibliography \(see Annex J\) are not listed as normative and are listed as a reference for the instructor\(s\) to use in teaching the course\(s\) or provide backup for the material found here. Therefore, such documents are listed in the bibliography \(see Annex I\).](#)

3. Definitions, acronyms, and abbreviations

3.1 Definitions

Because this recommended practice is for the use of the training provider to establish a curriculum, there are no definitions that cannot already be found elsewhere that are necessary to apply this document. However, instructors teaching courses based on the curriculum developed from this guide will find the terms in this document's glossary (see Annex ~~H~~ [I](#)) useful, [and especially the IEEE Std 1881™, IEEE Standard Glossary of Stationary Battery Terminology \[B59\].¹](#)

3.2 Acronyms and abbreviations

AED	automatic emergency defibrillator
AGM	absorbed glass mat
AWG	American wire ~~gage~~ gauge
BOL	bill of lading

¹[The numbers in brackets correspond to those of the bibliography in Annex J.](#)

BOM bill of material

[CEN](#) [Comité Européen de Normalization \(European Committee for Standardization\)](#)

[CERCLA](#) [Comprehensive Environmental Response, Compensation, and Liability Act](#)

CFR Code of Federal Regulations

CPR cardio-pulmonary resuscitation

DLO diesel locomotive (cable)

DLRO digital low-resistance ohmmeter

[EAB](#) [IEEE Educational Activities Board](#)

EDLC electric/electrochemical double-layer capacitor

EMF electromotive force (equivalent to voltage) EMI -electromagnetic interference

[EOD](#) [end-of-discharge](#)

EPO emergency power-off

ESD electrostatic discharge

[ESSB](#) [Energy Storage and Stationary Battery \(a technical committee of the IEEE PES\)](#)

ferro ferroresonant

FET field-effect transistor

HVAC heating, ventilation, and air conditioning

I-t time-current

[ICC](#) [International Code Council](#)

[IEC](#) [International Electro-technical Commission](#)

[IFC[®] International Fire Code²](#)

IGBT insulated-gate bipolar ~~junction~~ transistor

IR infrared

[ISO International Organization for Standardization](#)

IT information technology

I-t time-current

kA IC kiloamp interrupt current rating

LC inductive-capacitive (circuit)

Li lithium

Li-ion lithium-ion

LVD low-voltage disconnect

Mag Amp magnetic amplifier

MGN multigrounded neutral

MOP method of procedure

MOSFET metal-oxide semiconductor field-effect transistor

~~MSDS material safety data sheet~~

mvpdc minimum voltage per cell

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[NETA](#) [InterNational Electrical Testing Association](#)

[NFPA®](#) [National Fire Protection Association](#)

Ni-Cd nickel-cadmium

Ni-MH nickel-metal hydride

OCV open-circuit voltage

OJT on-the-job training

PBE plastic-bonded electrode

PPE personal protective equipment

[PSOC](#) [partial state-of-charge](#)

PV photovoltaic

PWM pulse-width modulation

[RC](#) [resistive-capacitive](#)

RCL resistive-capacitive-inductive (circuit)

[RCRA](#) [Resource Conservation and Recovery Act](#)

RHH rubberized, extra high temperature (wire/cable insulation)

RHW rubberized, high-temperature, water-resistant (wire/cable insulation)

RMA returned material authorization

[SAE](#) [Society of Automotive Engineers](#)

SCR silicon-controlled rectifier

SDS safety data sheet (formerly known as an MSDS)

SI Système Internationale d'Unités

SK special knowledge for a battery installer or maintenance technician

SLA sealed lead-acid (an improper term for VRLA)

SMR switch-mode rectifier

SOC state of charge

SOW statement of work

TC tray cable

THHN thermoplastic, extra high temperature, nylon-coated (wire/cable insulation)

THWN thermoplastic, high-temperature, water-resistant, nylon-coated (wire/cable insulation)

UFCTM Uniform Fire Code (Trademark of the NFPA)

UPS uninterruptible power supply

VLA vented (or flooded) lead-acid

VRLA valve-regulated lead-acid

XHHW thermoset, cross-linked, extra high temperature, water-resistant (wire/cable insulation)

4. Skill levels

4.1 General

The training outlined in this recommended practice is comprehensive and potentially time-consuming. It may be helpful to break up the training into skill-level modules, separated by time and successful on-the-job experience.

This recommended practice identifies several basic skill levels for technicians. Some industries have pre-established levels that may not correspond exactly to the levels used in this document. The “special knowledge” items can be used to build sublevels under the main levels and/or to serve as an additional level. Higher level technicians can supervise lower level technicians.

Installation and maintenance tasks may be performed by the same person, but the training for each may be done separately by level because some of the skills are different (see Clause 9). “Technician” is the generic term used in this recommended practice to apply to either installation or maintenance personnel.

Although the skill levels are noted in the text detail, the skills are not necessarily listed in priority order or training order. A summary of tasks and levels is provided as a quicker reference guide in Annex F.

If all of the skills defined in a paragraph are related to only one level, the level is noted at the end of the paragraph. If different skill levels are discussed in a paragraph, each level is noted at the end of the applicable sentence. If all of the skills defined in a list are related to only one level, the level is noted at the end of the sentence introducing the list. If different skill levels are discussed within the list, each level is noted at the end of the applicable list item.

4.2 Technician skill levels

4.2.1 Laborer

In some cases, laborers are called in to help with battery work. They must have at least some rudimentary battery safety training before they begin working on or near batteries. Items they should know are identified in the text by an “(L0)” designation. Laborers always require supervision by a Level 2 or higher technician.

4.2.2 Level 1

Level 1 battery technicians should know basic safety and additional core skills. Items they should know are identified in the text by an “(L1)” designation. They also need to be trained on all of the laborer (L0) items. Level 1 technicians often require higher level supervision for specific tasks.

4.2.3 Level 2

Level 2 battery technicians should know battery basics, including the basics of maintenance and installation. Level 2 technicians should have on-the-job training (OJT) as a Level 1 (generally at least 6 six months) or previous experience (verified by observation by a Level 3 technician or qualified instructor) before becoming a Level 2. Items that a Level 2 technician should know are denoted in the text by an “(L2)” designation. Level 2 technicians sometimes require higher level supervision for specific tasks.

4.2.4 Level 3

Level 3 battery technicians should be able to perform work independently, except for areas requiring specialized knowledge. Level 3 technicians should generally have at least one year of OJT as a Level 2 or previous equivalent experience (verified by observation by an experienced Level 3 technician or qualified instructor) before becoming a Level 3. Items that a Level 3 technician should know are denoted in the text by an “(L3)” designation.

4.2.5 Specialized knowledge

Items in the text that are application specific are denoted by an “(SK)” designation. The instructor can pick and choose which, if any, of these subjects are covered in the curriculum, depending on the needs of the audience.

4.3 Instructor knowledge and skills

The training outlined in this recommended practice is comprehensive, and few instructors are going to have a good grasp of all of the subject matter or the qualifications necessary for certain subjects. There may likely be multiple course writers and instructors. At least some of the modules (e.g., cardio-pulmonary resuscitation [CPR], defibrillation, infrared [IR] thermography) should be subcontracted to subject matter experts or qualified organizations. Instructors should have appropriate teaching skills, but qualification in those skills is beyond the scope of this document. Course developers and instructors with field experience are preferred.

4.4 Accreditation

It is recommended that the training provider be accredited by an outside organization through the IEEE Educational Activities Board (EAB), the Council of Occupational Education, or similarly recognized accrediting organizations. The accreditation process validates the achievement of learning and program objectives and assures that a program meets certain standards, such as the curriculum proposed in this recommended practice.

5. Safety

5.1 Work environment

Emphasize the use of caution when working on batteries because they present ~~a shock hazard~~ [multiple hazards](#).

Emphasize inspecting the battery room for electrical and other physical hazards. The following things should be considered to improve the work environment in the battery room/area:

- ~~Need to remove~~ [Removing](#) any standing water from the battery room (L1)
- ~~Need to remove~~ [Removing](#) any obstacles that may be considered a trip hazard (L1)
- ~~Need to ensure~~ [Ensuring](#) unobstructed egress from the battery area (L1)

- ~~Need to avoid~~ [Avoiding](#) smoking or anything that produces sparks or flames in the battery area (~~L1~~ [L0/1](#))⁵
- Ensuring that metal racks are connected to ground in accordance with applicable code (L1)
- Keeping the area around the battery terminals clear of all tools and other foreign objects (L1)
- ~~Use of~~ [Using](#) Class “C” dry chemical fire extinguishers instead of water around battery systems (L1)
- Ensuring that arc-flash boundaries [have been determined and](#) are observed ~~for~~ ~~systems operating above nominal 50 V~~ (see NFPA 70E-~~[B60]~~¹-2015 [\[B68\]](#)⁶ and [Annex H](#)) (L2)

5.2 Personal protective equipment (PPE)

5.2.1 [General hazard evaluation](#)

[There are multiple hazards associated with batteries. The hazards include, but are not limited to, chemical, electrical, arc flash, and thermal. When selecting PPE, all hazards should be considered and a risk assessment should be conducted. An example of a hazard risk assessment is shown in Figure H.1. Additional guidance can be found in NFPA 70E-2015 \[B68\] and in the associated handbook, NFPA70EHB-2015 \[B69\].](#)

⁵[Avoiding smoking and flames near batteries is critically important to know for anyone working on batteries, and thus is a Level 0 for installers. Because there are no Level 0 maintenance technicians \(maintenance technicians are not supposed to work on batteries until they are at least Level 1 trained\), this item is listed as both Level 0 and Level 1.](#)

⁶[The numbers in brackets correspond to the numbers of the bibliography in Annex I.](#)

¹~~The numbers in brackets correspond to the numbers of the bibliography in Annex I.~~

5.2.2 Eyewashes

Emphasize the following points relative to eyewashes:

- When permanent eyewash stations are necessary and what their size and location requirements are (see ANSI Z358.1 [B4 B5]) (L2)
- Why the permanent eyewash stations need to be maintained and with what frequency (L2)
- When portable eyewash bottles are appropriate and how they should be maintained (L1)

5.2.3 Gloves

Refer to the following documents relative to gloves (L3):

- [European Committee for Standardization \(CEN – Comité Européen de Normalization\) documents EN 388 \[B22\], EN 407 \[B23\], and EN 420 \[B24\] for general glove requirements, including mechanical strength against cut and abrasion \(EN 388\), and thermal/heat hazards \(EN 407\).](#)
- Code of Federal Regulations Title 29 Part 1910.138 (29 CFR 1910.138) [issued by the US. Occupational Safety and Health Administration (OSHA)] [B23 B25], [CEN EN 374 \[B21\]](#), [CEN EN 420 \[B24\]](#), and NFPA 70E ~~B60~~ 2015 [B68] for acid-resistant gloves
- ASTM D 120a [B18 B16] and [IEC 60903 \[B37\]](#) for electrical-insulating gloves and sleeves
- [Annex H of this recommended practice](#)

Emphasize the following points relative to gloves:

- Differences between electrical-insulating gloves and acid-resistant gloves (L0)

- How to examine electrical-insulating gloves and sleeves prior to use, including date verification (L0)
- Selection of the appropriate class for the voltage available on the system (L1)

5.2.4 Basic face and eye protection

Emphasize the following points relative to basic face and eye protection:

- ~~Mandatory use of~~ Safety glasses with side shields ~~in~~ are the ~~vicinity of~~ minimum eye protection required for all battery work that does not include the “handling” of electrolyte, per 29 CFR 1910.133 (OSHA) [~~B23~~ B25] and NFPA 70E-2015 [B68] (L0)
- ~~Recommended use of~~ Face shields are required when ~~watering batteries~~ “handling” electrolyte (“handling” electrolyte does not include routine water additions and taking specific gravity readings with an electronic density meter; however, it could include taking readings with a bulb hydrometer), per NFPA 70E-2015 [B68] (L1)
- Mandatory use of face shields when handling hazardous waste from an electrolyte spill per IEEE Std 1578TM ~~B52~~ [B56] (L2)

5.2.5 Additional arc flash clothing

Refer to the following documents relative to arc flash clothing:

- NFPA 70E ~~B60~~ 2015 [B68]
- NTIS PB98-137730 [~~B64~~ B73]
- Annex H of this recommended practice

Emphasize the following points relative to arc-flash clothing:

- The fact that batteries are always electrically “hot,” even a disconnected, discharged, single cell (L1)

- The level of arc-flash/flammable-retardant clothing necessary based on ~~voltage~~ [the risk](#), per NFPA 70E ~~B60~~ [2015](#) [\[B68\]](#), [and the difference between arc-flash clothing and fire-resistant clothing](#) (L2)

5.2.6 Additional protective clothing and equipment

Refer to the following documents relative to PPE:

- 29 CFR 1910, Subpart I (OSHA) [~~B23~~ [B25](#)]
- NTIS PB98-137730 [~~B64~~ [B73](#)]

Cover the following topics relative to PPE: (L0)

- Aprons (acid-resistant)
- Insulating blankets
- On-site spill kits
- Protective footwear
- Clothing (e.g., voltage levels, level of corrosive protection, the amount of arc-flash protection provided)
- Insulated rescue hooks or other means for pulling personnel from live circuits
- Dust masks for heavy metal residue produced by abrasive action

5.2.7 Additional PPE considerations

Emphasize the following points relative to PPE: (L0)

- Proper care of PPE per manufacturer instructions and NTIS PB98-137730 [~~B64~~ [B73](#)]
- Cleaning and washing of hands, tools, and PPE on a frequent basis

5.3 Electrical shock hazards

5.3.1 Physiological effects of different voltage levels

Cover the increasing dangers (e.g., direct electric shock effects, recoil effects, arc-flash burns) as voltage levels rise. Annex C provides additional information. NFPA 70E ~~[B60]~~ is 2015 [B68] and IEC 60479 [B35] are also helpful as ~~a reference~~ [references](#) (L2).

5.3.2 AC coupling on uninterruptible power supplies (UPSs)

Cover the following topics relative to ac coupling on UPSs: (SK)

- Possibility of ac coupling across the battery in a UPS
- Use of an isolation transformer in a UPS

See Annex D for further information.

5.3.3 Safety around photovoltaic (PV) arrays

Cover the following topics relative to safety around PV arrays: (SK)

- Presence of voltage on the terminals of a PV array whenever any level of light (sunlight or other means of illumination) is present
- Applicable code requirements, such as the National Electrical Code[®] (NEC[®]) (NFPA 70, ~~2008 Edition~~ [2017](#)) Article 690 [~~B59~~ [B67](#)]
- Isolation of the ~~storage~~ battery from the PV array by means of an appropriate disconnect switch
- Applicable standards for PV “hot” work (see the NABCEP *Study Guide for Photovoltaic System Installers* [~~B65~~ [B62](#)])
- Hybrid PV systems

5.4 Insulation

5.4.1 General

Cover the following topics relative to insulation:

- Removal of jewelry and other ~~metallic~~ conductive objects ([including pens in pockets](#)) (L0)
- Insulation of the following:
 - Batteries (L1)
 - Cabling (L1)
 - Nearby metallic surfaces that are grounded or at a different potential (L2)
- Insulation ratings
 - Inspection for insulation damage (L1)
 - Abrasion and impact resistance (L2)
 - Appropriate insulation voltage ratings (L2)
 - Current withstand capability (L2)
 - Fire resistance (L2)
- Flexibility of insulation material (L2)
- Regulations and guidelines for insulation (L2)

Cover and elaborate on the following items relative to individual insulating materials:

- Tapes

- Electrical tape characteristics
 - Vinyl versus other materials (L2)
 - Proper taping techniques (L2)
- Color-coding for polarity and/or voltage (L2)
- The fact that Listed tape is typically fire-retardant (L2)
- Plastic sheeting and rolled materials
 - Rolled plastic sheeting used as an insulator (L1)
 - Methods to properly secure (using clips, tie wraps, [magnets](#), waxed string, etc.) insulating sheets (L2)
 - Use of standoffs when needed for insulating sheets (L3)
 - Ensuring that insulating material has been designed and tested to the appropriate standards (L3)
- Pressed woods
 - Insulation characteristics (L1)
 - Fire retardancy characteristics (L2)
- Rubber blankets
 - Insulation characteristics (L1)
 - Disadvantages of vulcanized rubber (L2)
 - Securing rubber blankets (L2)
 - Use of standoffs when needed for rubber blankets (L3)

- Testing standards for rubber blankets (e.g., ASTM D 1048 [~~B19~~ B17], ASTM D 1049e1 [~~B20~~ B18], ASTM F 479 [~~B21~~ B19]) (L3)
- Hard “papers” that are somewhat flexible (L2)
 - Insulation characteristics
 - Fire-retardancy characteristics
 - Methods of properly securing these insulating plastic “papers” (using tie wraps, waxed string, etc.)
- Terminal covers and insulated intercell connectors (L1)

5.4.2 Tools

Cover the following topics relative to tools:

- Safety concerns with uninsulated tools (L1)
- Insulation methods (see ASTM F 1505 [~~B22~~ B20])
 - Premanufactured insulated tools (designed and tested according to IEC 60900 [~~B31~~ B36]), which should be recommended (L1)
 - Taping (L2)
 - Dipping (L2)
- Potential arcing (L2)
 - Spatial relationship to energized equipment
 - Pre-work tool inspection
 - Inspection and protection of the work area for arcing hazards from dropped tools

- Nonsparking (brass or brass-tipped) tools (**L2**)

5.5 Ladder safety

Cover the following topics relative to ladder safety:

- Ladder types (**L1**)
 - Straight ladders
 - Extension ladders
 - Step ladders
 - Fixed ladders
- Ladder materials and considerations related to the materials (**L1**)
 - Fiberglass sides (nonconductive)
 - Wood (nonconductive, but possibly flammable)
 - Aluminum (conductive)
 - Plastic (seeANSIA14.5 [~~B2~~ B3]) sides (nonconductive, but possibly limited on load-bearing capacity)
 - Nonconductive versus conductive rungs (safety versus load-bearing capacity)
- Safety considerations when using ladders (**L1**)
 - Shoes, boots, gloves, etc.
 - Snag hazards
 - Ladder inspection prior to use
 - Work area inspection for potential hazards prior to use

- Proper positioning and securing of the ladder
- Proper body position while ascending and descending
- Carrying and handling tools and materials while on a ladder
- The maximum ascension height for the individual ladder
- Maintaining 3-point contact while ascending and descending
- Ladder specifications (L2)
 - Rated load capacity
 - Labeling
 - Categories (e.g., Types IA – III)

5.6 Lockout/tagout

5.6.1 General

Cover the following items related to lockout/tagout:

- Isolating from sources of energy as much as possible (L1)
- OSHA rules in 29 CFR 1910 and 29 CFR 1926 [~~B23~~ B25] and other local codes (L2)
- Individual company/facility lockout/tagout policies and training (L2)
- Step-by-step practices (L2)

5.6.2 Energized (hot) work

Cover the following topics relative to energized work:

- The fact that individual cells are always energized (L0)

- Special precautions to be taken when working with energized systems (see NFPA 70E [-2015 \[B60 B68\]](#)) (L2)

5.7 Electrostatic discharge (ESD) precautions

Cover the following topics relative to ESD precautions: (L1)

- Heightened risks associated with ESD ~~discharge~~ near a battery after initial or equalize/boost charging
- Necessity of discharging one's body (away from the battery vents) to an effectively grounded surface before working on a battery

5.8 Ventilation

Cover the following topics relative to ventilation:

- Need for proper ventilation for battery health and installation safety (L1)
- Differing ventilation needs of vented lead-acid (VLA)⁷, valve-regulated lead-acid (VRLA), and nickel-cadmium (Ni-Cd) batteries (see IEEE ~~P1635TM~~ [Std 1635](#)/ASHRAE ~~200 [B32 21 [B57]~~ for further information) (L2).

5.9 Working clearances, egress paths, and task lighting

Cover the following topics relative to working clearances, egress paths, and task lighting:

- Pre-work inspections for egress paths, trip hazards, and combustible materials (L1)
- Adequate task lighting, including the use of insulated portable sources of light (L1)

⁷Vented is the term preferred by the IEEE Power & Energy Society (PES) [Energy Storage and Stationary Batteries Battery \(ESSB\)](#) Committee for batteries with non-immobilized liquid electrolyte. It is the term that will be used throughout the remainder of this document. However, these cells are also commonly referred to as “flooded” or “wet” cells.

- Minimum egress aisle widths as required by OSHA (see 29 CFR 1910 and/or 29 CFR 1926 [~~B23~~ [B25](#)]) or other local applicable codes (**L2**)
- Working clearances required by the NEC [~~B59~~[B67](#)] or other applicable codes (**L3**)
- Possible arc-flash approach boundaries (see NFPA 70E-[2015](#) [~~B60~~[B68](#)]) (**L3**)

5.10 Battery weight concerns

Cover the following topics relative to battery weight:

- Proper methods for unpacking, hoisting, and securing batteries during hoisting (**L0**)
- Use of various types of battery hoisting equipment, along with their limitations and hazards (**L0**)
- Weight-bearing capacity of floors, ramps, and elevators relative to the batteries (**L1**)
- Floor protection before moving batteries (**L1**)
- Forklift operator certification (**SK**)

5.11 Battery fire [safety](#) concerns

Refer to the following documents relative to battery fires:

- ICC International Fire Code (IFC) [~~B30~~[B32](#)]
- ~~IFC/~~[NFPA](#) NFPA 1 [Fire Code \(formerly the](#) Uniform Fire Code ~~(or~~ UFC) [~~B54~~] [~~B58~~ [B62](#)]

Emphasize the following points relative to battery fires:

- Hazard potential in a battery fire, including, but not limited to, electrical shock, arc faults, stored energy, explosive and toxic gases, corrosive liquids and gases, and reactive liquids (**L1**)

- Awareness of the site prior to the start of work, including a means of egress and exit locations, fire alarm locations, emergency phone numbers, and the locations and types of fire extinguishers (L1)
- Appropriate action in the event of a fire, including notification and evacuation (L1)
- Fire suppression (including the proper suppression/control agents to use with batteries) (L3)
- Pros and cons of battery disconnects, as well as when to use them and how to operate them (L3)
- When remote controls for disconnecting means (i.e., emergency power-off [EPO] switches/buttons) are required (L3)
- How to properly operate hand-held fire extinguishers (SK)
- Appropriate assistance to fire fighters and first responders (SK)
- Specialty PPE for fighting fires in a battery area (SK)
- Emergency response team training where required (SK)
- Specific risks associated with Li-ion batteries (SK)

5.12 Safety signs

Cover the following topics relative to safety signs:

- Reading and following posted safety signs (L0)
- Minimum battery area signs ~~as required by~~ (for example, in the United States the following Codes dictate signs: OSHA-(see 29 CFR 1910 and/or 29 CFR 1926 [~~B23~~ B25]), NFPA1 [~~B58~~ B66], the NEC [~~B59~~], NFPA 70E [~~B60~~ B67], NFPA70E-2015 [B68], NFPA 101® [~~B61~~B70], NFPA 704 [~~B63~~ B72], ICC IFC [~~B30~~], ~~and any other applicable codes~~ B32]) (SK)

- Standardization of safety signs, such as that suggested by the ANSI Z535 family of documents ([B5], [B6], [B7], ~~and~~ [B8]), and [B9], or the IEC 60471/ISO 7000 standard [B34] (SK)

5.13 First aid

The technician should be trained in first aid, CPR, and possibly automatic emergency defibrillator (AED) use. A first aid course should be taught by a certified instructor. The instructor may know how to cover first aid, but may not know some of the specific items of emphasis for technicians handling batteries. Ensure that the following are the minimum items covered in a first aid course for battery technicians:

- Identification of first aid kit locations before beginning work and the provision of portable ones, if necessary (L1)
- Description of the symptoms and how to provide first aid (including demonstrations that involve the trainee) for the most common injuries that may occur from handling, servicing, and maintaining battery systems, such as the following:
 - Injuries from contact of the skin or eyes with acidic or caustic solutions (L1)
 - Strains, fractures, pinches, and crushing injuries due to battery weight (L1)
 - Electrical shock and arc flash/blast
 - How to safely remove someone from energized contact (L1)
 - Falling injuries due to recoil (L1)
 - Burns [both external (L1) and internal (L2)]
 - Cardiac arrest and ventricular fibrillation (L2)
 - Respiratory arrest (L2)
- Injuries from exposure to toxic vapors (e.g., acid mists, hydrogen sulfide) (L2)

- Discussion of the legal and liability issues associated with administering first aid, especially with respect to the use of defibrillator devices (see Lazar [B57B61]) (L2)
- Identification of special precautions that should be taken when treating somebody in “confined” and unventilated spaces (SK)

Some industries may determine that all of the above items are necessary training for Level 1 technicians before they begin working on batteries.

5.14 Spill containment and cleanup

Cover at least the following topics related to spill containment (more detail is found in IEEE Std 1578TM [B52 B56]):

- Selection and use of appropriate PPE for electrolyte spill cleanup (L2)
- Spill containment methods appropriate to the battery type and size (L2)
- Safe absorption and/or neutralization and disposal techniques (L2)
- Code requirements for spill management (SK)

6. Basic dc theory

6.1 Terminology

Cover the meaning of at least the following common electrical terms:

- AC and dc (L1)
- Common electrical units (e.g., amperes, watts, volts, ohms, mhos/siemens) (L1)
- Voltage and its synonyms (i.e., potential, electromotive force [EMF]) (L2)
- Current and electron flow (L2)

- Grounding, grounded (i.e., return, common, neutral), bonding, and earth reference (L2)
- Power and energy (L3)
- Ripple current and voltage (SK)

Cover the meaning and purpose of at least the following common hardware items external to the battery:

~~== Hydrometers (L1)~~

- Conductors (e.g., cable, intercell connectors, straps, terminals, bus) (L2)
- Overcurrent protection (i.e., breakers, fuses, disconnects) (L2)

~~== Torque values (L2)~~

- Maintenance bypass (L2)
- Spacers (L2)
- Seismic bracing (L2)

~~== Rectifiers/chargers, inverters, and UPS (L3)~~

Provide a basic understanding of rudimentary electrochemical and battery terms (including hardware exclusive to the battery):

- Ampere-hour ratings (L2)
- Catalysts (L3)
- Cells, containers, and units (L1)
- Charging (L1)

- Cycles (L3)
- Deionized and distilled water (L2)
- Depth of discharge (L3)
- Discharging (L1)
- Dust caps (L2)
- Electrolysis (L3)
- Electrolyte (L1)
- End-of-discharge voltage (L2)
- Float and equalize/boost voltages (L2)
- Gel and absorbed glass mat (AGM) VRLA constructions (L2)
- Insulating terminal covers (L2)
- Neutralizers (L2)
- Ohmic values (i.e., conductance, resistance, impedance) (L2)
- Open-circuit voltage (OCV) (L2)
- Pilot cells (L2)
- Plates (L2)
- Polarity (L1)
- Polarization (SK)
- Posts (L1)
- Primary and secondary cells (L3)

- Recombination (L3)
- Sediment (L2)
- Self-discharge (L2)
- Separators (L2)
- Specific gravity (L2)
- State of charge (SOC) (L3)
- Strings (L1)
- Sulfation (L3)
- Thermal runaway (L3)
- Torque values (L2)
- Trickle and constant current charge regimes (SK)
- Valves (L2)
- Vented and VRLA cells (L1)
- Vents and flame arrestors (L1)
- Withdrawal tubes (L2)

Cover the meaning and purpose of at least the following electronics often connected to the dc bus:
(L3)

- Rectifiers/chargers
- Inverters
- UPS

Cover the purpose of at least the following test sets/tools commonly used with batteries:

- Hydrometers (L1)
- Digital multimeters (L1)
- Internal ohmic measurement devices (L2)

Identify commonly used terms that the technician should avoid, including the following:

- Battery jar⁸ (L1)
- Sealed lead-acid (SLA) cell or battery⁹ (L1)
- Maintenance-free cell or battery¹⁰ (L2)

6.2 Basic electrical components

Discuss the physical properties and ratings of at least the following electronic components and give examples of how they are used in dc systems:

- Resistors
 - Standard resistors (L2)
 - Precision resistors

⁸Glass jars were used as battery containers many decades ago, but plastics and metals are now used; thus, the IEEE PES ~~Stationary Batteries~~ [ESSB](#) committee encourages the use of the term *battery container* instead of jar.

⁹While truly “sealed” batteries do exist in other chemistries, they do not exist for lead-acid cells, and the use of this term to describe any lead-acid cell or battery is discouraged by the IEEE PES ~~Stationary Batteries~~ [ESSB](#) committee. The term *SLA* or *sealed* is often used to describe what is actually a VRLA battery (see Annex [H](#)). However, VRLA batteries do have one-way pressure relief valves; therefore, they are not sealed.

¹⁰A so-called “maintenance-free” battery is one that does not require (nor does it usually accept) water additions during its useful lifetime (this term may refer to vented/flooded cells that are designed with an initial overfill of water or to VRLA batteries). Note that the IEEE PES ~~Stationary Batteries~~ [ESSB](#) committee discourages the use of this term because all batteries require maintenance above and beyond water additions.

- Shunts (**L2**)
 - Small wattage precision resistors on circuit boards (**L3**)
- Variable resistors (**L3**)
 - Adjustment potentiometers
 - Large variacs
- Resistor power ratings (in watts) (**L3**)
- Protectors
 - Uses of fuses (**L2**)
 - Uses of breakers (**L2**)
 - Protector coordination using time-current (I-t) curves (see IEEE Std 1375 [B52]) (**L3**)
- Capacitors
 - Types of capacitors
 - Electrolytic capacitors (**L2**)
 - Electric/electrochemical double-layer capacitors (EDLCs), i.e., supercapacitors (**SK**)
 - Use of capacitors to absorb voltage variations (**L2**)
 - Methods of discharging capacitors to maximize safety (**L3**)
 - Need to precharge some capacitors in some rectifiers (**L3**)
- Inductors (**L3**)

- Basics of magnetic fields and induction
- Choking function of inductors for high-frequency currents
- Semiconductors (L3)
 - Diodes
 - Used for rectification
 - Used to block dc current flow in one direction
 - Used to provide a dc voltage offset in an ORing circuit
 - Transistors (especially when used as switching or current control devices)
 - Insulated-gate bipolar ~~junction~~ transistors (IGBTs) in inverters and chargers
 - Metal-oxide semiconductor field-effect transistors (MOSFETs) in inverters and chargers
 - Thyristors ~~in~~ Silicon-controlled rectifiers (SCRs)

6.3 Basic mathematics

6.3.1 Prerequisites

Verify that the technicians have sufficient proficiency in basic mathematics to manipulate formulas, including the following:

- Proficiency in addition, subtraction, multiplication, and division (L1)
- Understanding of basic multipliers (e.g., tera, giga, mega, kilo, milli, micro, nano) (L2)
- Basic knowledge of exponential notation (i.e., powers of 10) (L2)

- Understanding of variables and a basic proficiency in their manipulation (L2)
- Understanding of the concepts of rounding and significant digits (L2)
- Understanding of graphs and graphing for trending and data analysis (L3)
- Introductory-level understanding of logarithms (base 10) (e.g., their meaning and use) in order to use some graphs (L3)

Basic computer literacy is required to perform some battery testing and maintenance functions (L2).

6.3.2 Common formulas

Cover the following algebraic formulas:

- Ohm's Law (L2)
- DC power and watt heating formulas (L2)
- AC power formulas (L3)
- Power conversion efficiency formula (L3)
- Hydrogen evolution formulas (see Annex E) (L3)
- Link between specific gravity and open-circuit and minimum float voltage for lead-acid cells (see Annex E) (L2)
- Formulas relating short-circuit currents and internal cell resistances (see Annex E) (L3)

6.4 Basics of electrical circuits

Cover the following topics relative to electrical circuits:

- Series circuits (L1)
- Parallel circuits (L2)

- Series-parallel circuits (**L2**)
- Resistive-capacitive-inductive (RCL) circuits (**L3**)
- Necessity of a complete circuit to get current flow (**L1**)
- Kirchhoff's current and voltage laws (**L3**)

6.5 Basics of rectification

6.5.1 General

Cover the following basics of rectification with the technicians:

- AC sine wave as an input source
 - Single- and three-phase voltages (**L2**)
 - Amplitude and frequency (**L3**)
 - Power factor (**SK**)
 - How slight variations in input voltage affect dc output voltage (and current) (**SK**)
- Transformers used for voltage step-up/down (**L3**)
 - Transformer primary and secondary operation
 - Transformer configurations (i.e., Y [wye], delta [Δ], single phase, split phase)
- Creating dc voltage from ac input sources (**L3**)
 - Half-wave rectification
 - Full-wave rectification

- High-frequency rectification
- DC refinement (minimization of ripple) in the output stage of a rectifier (**L3**)
 - Circuit capacitance to minimize ripple
 - Inductive-capacitive (LC) filters to minimize ripple
- Control methods in rectifiers (**L2**)
 - Voltage control (including temperature compensation) of rectifiers
 - Load sharing with other rectifiers
 - Current limit settings on rectifiers
 - Rectifier output protection

6.5.2 Rectifier/charger types

6.5.2.1 Four common charger types

Cover each common charger type below:

- Magnetic amplifier (Mag Amp) rectifiers (**SK**)
 - Transformer-based construction of magnetic amplifiers
 - Saturable reactors in magnetic amplifiers
 - The dc control circuit for the reactor/amplifier
 - Common applications of this charger type (e.g., engine start battery chargers)
 - 400 Hz input applications
 - Advantages and disadvantages of Mag Amp rectifiers

- SCRs (**SK**)
 - How an SCR is constructed and operates
 - Advantages and disadvantages of SCRs
- Ferroresonant (ferro) rectifiers (**SK**)
 - Transformer-based construction of ferro rectifiers
 - The feedback circuit in ferro rectifiers
 - Advantages and disadvantages of ferro rectifiers
- Switch-mode rectifiers (SMRs) (**SK**)
 - Typical SMR construction
 - Pulse-width modulation (PWM) techniques
 - High-frequency dc-dc conversion
 - Output control of an SMR
 - Advantages and disadvantages of SMRs

6.5.2.2 Charging regimes

Cover the following charging regimes:

- Constant voltage (float) (**L1**)
- Constant current (**L2**)
- Cycling (**L3**)
- Temperature compensation of the charging voltage applied to the batteries (**L2**)

- Equalize/boost charging (L1)
- Charging from renewable energy sources (SK)

6.5.3 Controlling ripple

6.5.3.1 Filtering the charger output

Cover LC filtering as used on the output stages of rectifiers to limit ripple voltage and current. (L2)

Cover the fact that the amount of filtering provided (which directly influences the amplitude of the ripple) is dependent on the application and industry: (SK)

- Typical UPS charger and inverter filtering (or lack thereof)
- Typical telecommunications charger filtering
- Typical utility charger filtering

6.5.3.2 Batteries as filters

Cover the following topics relative to batteries as filters: (L2)

- The fact that batteries may be required in a dc circuit to act as a filter by the dc plant and/or rectifier manufacturer or the equipment being served
- The fact that [lead-acid and Ni-Cd](#) batteries function as ~~a capacitive~~ [an extra](#) filter for ripple and spikes on the dc bus
- The terminology of *battery eliminators* or *batteryless plants* as applied to rectifiers that can feed a load without the need of a battery [acting as a noise/ripple](#) filter (due to their output filtering [ability](#))

6.6 Basics of inverters

Cover the following basics of inverter operation only if the technician will be exposed to battery systems with inverters connected:

- Creating ac voltage from dc input sources at a block diagram level (L3)
 - Methods of creating ac waveforms in inverters and how these affect ripple
 - Efficiency and power factor of inverters
 - Effects of loading on inverters
 - Watts and volt-amperes
- Producing various waveform outputs
 - Sine wave versus square wave output (L2)
 - Single- and three-phase outputs (L2)
 - Frequency of the output waveform (L3)
- Operating configurations of inverters
 - DC-preferred (nonbypass) operation (L2)
 - Bypass operation (i.e., manual or automatic) (L3)
 - Neutral-to-ground tie or switched neutral configurations (SK)
- Operating the inverter in different modes (L3)
 - On-line versus off-line
 - Bypass versus normal
- Common alarms produced by inverters (L3)