Public Input No. 130-NFPA 70E-2024 [Global Input]

Replace all references to "Soft Grounding" with "Capacitor Soft Discharging." References in the following Articles and Annexes should apply:

360.5(B)

R.6.8, R.11.1, R.11.4, R.11.6, R.11.7, R.12.1, R.16.2

Statement of Problem and Substantiation for Public Input

The term soft grounding in itself can create a hazard for some applications of capacitors. Not all capacitors are connected to ground and no discharge will occur if terminals of ungrounded capacitors are grounded. Energy storage systems incorporating supercapacitors could be connected to a Power Conditioning System (PCS) that requires an ungrounded dc storage system. PCS's that are rated 500kW and above commonly require an ungrounded dc bus and an ungrounded delta or wye source. These PCS systems can incorporate capacitors that will store no energy with respect to ground. This proposal is intended to ensure that capacitors are safely discharged whether they are grounded or not.

This proposal has been submitted on behalf of an EDLC task group consisting of Steve Edley, Dave Wright, Troy Brandon, Curtis Ashton, Lloyd Gordon

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 129-NFPA 70E-2024 [Definition: Grounding, Soft (High-Z). (Soft Grounding)]	Definition for the new term.

Submitter Information Verification

Submitter Full Name: Steve Edley
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City:
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Submittal Date: Sun Jun 02 21:53:18 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: The current language is consistent with the of the use of the phrase elsewhere in this Standard.

Public Input No. 142-NFPA 70E-2024 [Global Input]

Article 370 Safety-Related Work Practices for Solar Photovoltaic (PV) Energy Supply Stations

370.1 Scope

This article covers electrical safety-related work practices used by employees while working on or with large-scale solar energy electric supply stations and installations[i], including exposed solar photovoltaic (PV) modules, their interconnected systems and equipment, where these pose an electrical hazard.

The work practices covered apply to solar energy PV electric supply stations with a nameplate generating capacity of at least 5 MW.

> **Informational Note: See Informative NFPA 70E Annex D for recognized methods for making a reasonable estimate of the arc flash incident heat energy associated with the electrical characteristics specific to solar photovoltaic energy sources.**
>
> **Informational Note: High daytime temperatures and high incident energy levels exist in every section of large-scale solar installations. See Informative NFPA 70E Annex O 0.2.4 (1), & (13) for safety-by-design methods used to reduce the risk of exposure to electrical hazards associated with photovoltaic sources and systems.**
>
> **Informational Note: See the following standards and documents for additional information with respect to safety related considerations associated with photovoltaic energy sources, including:**

(1) NFPA 70, *National Electrical Code*, Article 690, Solar Photovoltaic (PV) Systems, 2023

(2) NFPA 70, *National Electrical Code*, Article 691, Large-Scale Photovoltaic (PV) Electric Supply Stations, 2023

(3) IEEE 937, *Recommended Practice for Installation and Maintenance of Lead-Acid Batteries for Photovoltaic Systems*, 2019

(4) IEEE 1361, *IEEE Guide for Selecting, Charging, Testing, and Evaluating Lead-Acid Batteries Used in Stand-Alone Photovoltaic (PV) Systems*, 2014

(5) IEEE 1526, *IEEE Recommended Practice for Testing the Performance of Stand-Alone Photovoltaic Systems*, 2020

(6) IEEE 1562, *IEEE Recommended Practice for Sizing Stand-Alone Photovoltaic (PV) Systems*, 2021

(7) IEEE 2778, *IEEE Guide for Solar Power Plant Grounding for Personnel Protection*, 2020

(8) IEEE Std C95.1, *IEEE Standard for Safety Levels with Respect to Human Exposure to Electrical, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz*, 2019

370.3 Safety Procedures

(A) General Safety Hazards *(Associated with Solar Energy Installations)*

(1) Electrical Hazard Thresholds. Exposure levels shall not exceed those identified in the following list unless appropriate controls are implemented:

(1) AC: 50 volts and 5 milliamperes

(2) DC: 100 volts and 40 milliamperes

(3) Thermal: 1000 watts short-circuit power

(2) Photovoltaic System Risk Assessment. Prior to working on a photovoltaic module or interconnected system, a risk assessment shall be performed to identify thermal, electrical shock, and arc flash hazards and assess the risks associated with the work to be performed.

(3) Electric Shock Risk Assessment. An electric shock risk assessment shall be performed in accordance with 130.4.

(4) Arc Flash Risk Assessment. The arc flash risk assessment method selected shall utilize an industry-recognized method for obtaining a reasonable estimate of the arc flash incident energy associated with photovoltaic sources of energy.

(1) Direct Current Arc Flash Hazard Estimation. For photovoltaic systems that output a direct current, arc flash risk analysis methods of estimation should account for the non-linear nature of solar/PV modules, including the arc impedance.

> **Informational Note: Paragraph D.5.2. Detailed Arcing and Energy Calculations Method under Informative Annex D contains information on industry-recognized and applicable methods of estimating the available incident energy and the arc flash boundary based upon the particular electrical characteristics of photovoltaic systems.**

(5) Photovoltaic Array Requirements.

(1) Equipment operation and maintenance. PV modules, systems and equipment shall be operated and maintained in accordance with the manufacturer's instructions.

(2) Personnel access and approach. The photovoltaic array, inclusive of any interconnected modules, shall be accessible only to authorized personnel.

(3) Illumination. Employees shall ensure the use of sufficient illumination to perform the work safely.

(4) Testing interconnected PV module cable connectors before disconnection. PV module cable connectors shall be tested for absence of load current prior to disconnecting. An adequately rated non-contact test instrument capable of measuring amperage ("amp clamp") shall be used to perform this test. The functionality of the test instrument shall be verified before and after this test has been performed.

(6) Apparel.

(1) Prohibited Clothing. Personnel shall not wear thermally or electrically conductive objects, clothing articles, jewelry and other like items during work on a PV module or system.

(2) Protective Clothing and Equipment. Insulated protective equipment shall be worn by employees while working on or with interconnected PV modules or system components.

(7) Abnormal Conditions. Work during abnormal conditions shall be addressed by procedure and shall include the following, where applicable:

(1) Electrical Safety Plan. An electrical safety plan shall address abnormal conditions where these have been recognized to exist in the solar array. It shall be developed by a qualified and competent person. The plan shall cover the types of work to be performed on, or near, PV modules, systems and equipment as these relate to the abnormal conditions. A detailed job briefing that, at a minimum, includes each of the above requirements shall be conducted and reviewed with all persons involved with the work prior to commencing work during an abnormal condition.

(2) Ground Fault Condition Testing. Where a ground fault condition is known to have occurred and has not been satisfactorily resolved, applicable tests shall be performed to demonstrate the absence of an active ground fault condition before working on or with the photovoltaic systems and equipment associated with the ground fault condition.

(3) Active Faulting PV Equipment. Equipment that is actively faulting shall not be approached, operated or handled, except in emergency, and then only by qualified personnel trained in emergency procedures using adequately rated protective means in accordance with the applicable established emergency procedure.

(4) Wet Conditions. Working on photovoltaic modules or interconnected systems and equipment while in a wet, damp or submersed condition shall not be permitted, unless the employer assesses the risk and ensures that safety-related work practices are used by employees to protect against the associated increased risk. The work practices used shall ensure that the insulating property of any insulated tools and equipment and personal protective equipment used to perform the work is not adversely affected. The work practices used shall not increase the risk of exposure to other electrical hazards.

> **Informational Note: See Informative Annex K for more information on electrical hazards.**

(1) Warning Signs. Warning signs or labels shall be posted in appropriate locations, to include the following:

(1) Permanent signage shall clearly designate areas where photovoltaic modules and interconnected equipment have been installed.

(2) Electrical hazard warnings indicating the electric shock hazard due to the module voltage and the arc flash hazard due to the prospective short-circuit current, and the thermal hazard.

(3) Notice for personnel to use and wear protective equipment and apparel appropriate to the hazard for the photovoltaic modules and system.

(4) Notice prohibiting access to unauthorized personnel.

(B) Photovoltaic Energy Source Hazards.

(1) PV Module Material Hazards. Information on the materials used in the manufacture of photovoltaic modules shall be made available to employees who work on or with photovoltaic systems and equipment.

(2) PV Electric Shock and Arc Flash Hazards. Working on a photovoltaic energy source or interconnected system, where hazardous voltage levels or arc flash hazards are recognized, shall be considered energized electrical work, and shall performed in accordance with the requirements of 130.2.

(3) Non-electrical activities that include the handling of PV modules. The following protective equipment shall be available to employees performing any type of service on a PV module or system:

(1) Safety glasses or goggles appropriate to the electrical and other hazards.

(2) Appropriate cut-resistant gloves shall be worn as protection for the hands during activities that involve the handling of PV modules.

(4) Activities that do not include PV module handling. Employees performing any activity not involving the handling of PV modules shall wear safety glasses.

(C) Tools and Equipment.

(1) Handles. Tools and equipment for work on PV modules shall be equipment with insulation rated for the maximum voltage of the equipment on which they are used in accordance with 130.7(D)(1).

(2) Contact. Bare or uncapped PV module electrical conductors shall be kept clear of unintended contact with tools, test equipment vegetation, structures, liquids and damp surfaces and other foreign objects. Conductors shall be capped, plugged or otherwise adequately insulated against contact when unattended.

370.4 Safety Training.

(A) General. The training requirements of this chapter shall apply to employees exposed to electrical hazards associated with work on or near solar energy sources, including the interconnected photovoltaic equipment, collection systems and associated power conversion system.

(B) Training requirements. Employees shall be trained to understand the specific electrical hazards associated with electrical energy from a photovoltaic module and arising from interconnecting multiple modules. Employees shall be trained in the safety-related work practices and requirements to provide protection from the electrical hazards associated with their respective job or task assignment.

370.5 Employee Training. Employees who operate and maintain repair solar installations and equipment shall be trained in the operating characteristics of the PV modules and equipment with which they will work.

(A) Qualified Persons. Only qualified personnel shall work with or on PV electrical supply installations/stations.

(1) Training. Qualified persons shall be trained and knowledgeable in the operation of photovoltaic energy sources and equipment and specific work methods and shall be trained to avoid the electrical hazards that are present. Such persons shall be familiar with the proper use of precautionary techniques and PPE. Training for a qualified person shall include the following:

(1) Procedures. Training in photovoltaic module safety requirements shall introduce any applicable procedures for installing, connecting, disconnecting, repairing, replacing, testing, handling, transport, storage and disposal of modules. Personnel shall complete training and demonstrate proficiency in safety-related work practices associated with performing any such activities before being assigned their tasks.

(2) Hazards. Training in photovoltaic modules and equipment shall include the hazards of working with continuously or potentially energized equipment, the associated risk and

applicable methods for avoiding such hazards and reducing risks appropriately and eliminating risks where feasible.

(3) PV energy systems. Qualified persons shall be trained in and knowledgeable of the basic principles of solar energy including photovoltaics, the types of PV systems and their components with which they will work, including the PV system design, and the applicable safety considerations when working with PV systems.

(4) Unintentional Grounding of PV modules. Employees who work on or near solar installations and interconnecting collection systems and equipment shall be trained to understand the hazards associated with an unintentional grounded condition along the applicable precautionary techniques to prevent such a condition from occurring.

(2) Unqualified Persons.

(1) Training. Unqualified persons shall be trained to identify electrical hazards to which they could be exposed and the proper methods of avoiding the hazards.

(2) In the solar array. Unqualified persons who may need to approach or enter the solar array shall be trained in, and be familiar with, applicable electrical safety-related work practices necessary to avoid electrical hazards they may encounter during their normal work activities.

370.6 Safeguarding of employees. Operation and maintenance of photovoltaic modules might require contact by employees with exposed energized surfaces of photovoltaic cells, circuit conductors, and their attachments. Safeguards such as safety-related work practices and other safeguards shall be used to protect employees from injury while working in the photovoltaic array. These safeguards shall be consistent with the nature and extent of the related electrical hazards. Safeguards might be different during daylight hours versus at night (for example, during non-daylight hours when irradiance conditions greatly reduce the output voltage and current from a solar module to levels that may be lower the thresholds indicated in 370.3(A)(1).)

370.7 Tools and Equipment. Tools and equipment used for installing, maintaining, servicing, repairing or replacement of solar installations, including interconnected PV equipment, shall conform to manufacturer's recommendations and meet the requirements of applicable codes and standards.

370.8 Responsibility for Electrical Safety. All personnel with access to hazardous voltage and current associated with PV energy sources shall be responsible for the following:

(A)Obtaining authorization for work with or on energized electrical equipment in accordance with the requirements of 130.2.

(B) Performing work in accordance with the applicable requirements of Chapter 1 safety-related work practices.

(C) Reporting photovoltaic equipment incidents, damage, inadequate barriers and/or warning signs to the employer.

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[i] Similar to NFPA 70-2023 Article 691, the scope of the work practices proposed apply to large-scale solar photovoltaic (PV) systems with a nameplate capacity of at least 5000 kilowatts, or 5 megawatts (MW).

Additional Proposed Changes

File Name	Description	Approved
Article_370_Solar_Photovoltaic_Supply_Station_Safe_Work_Practices.docx	Proposed New Article 370 Safety Related Work Practices for Solar Photovoltaic (PV) Energy Supply Stations	

Statement of Problem and Substantiation for Public Input

Current US solar power capacity is 179GW and growing rapidly. Most noteworthy are the abnormally high arc flash incident energy levels associated with both the DC inputs and AC outputs to (and backfeed from) the power supply station's AC collection system. Typical incident energy levels can range anywhere from 15 to 40+ cal/cm2 for a PV collection system. The arc flash hazard then increases as the energy reaches the Power Conversion System's (PCS) DC inputs. Similarly, arc flash energy levels at the PCS step-up medium voltage transformer (MVT) often reaches 20 to 100+ cal/cm2. Another trend that has become the norm across the solar industry has been the move towards higher operating voltages. here are multiple methods to calculate DC arc flash energy that are currently recognized within the NFPA 70E standard. However, there is not any industry-recognized guidance from IEEE (yet) for performing these studies. It is largely left up the Engineer of Record (EOR) to decide which methodology is appropriate. The challenge we face is that where established methods have been identified by NFPA 70E - and therefore tend to be used by the EOR – in most cases these methods produce overly-conservative results. The established methods may not be the best or even a realistic fit for certain scenarios (like solar PV systems). As a result, everything from operations and maintenance to the allocation of engineering resources is impacted. A revision to the NFPA 70E standard that incorporates work practices specific to solar/PV systems that provides corresponding guidance on which arc flash methodologies produce more reasonable estimates for use in specific scenarios (PV systems vs general DC systems), along with providing increased recognition to effective commercially available safety-by-design devices, would drive some consistency in results and work methods for Invenergy.
Utility-scale solar plants currently reach maximum voltages up to 1500DC. This trend similarly impacts the range of typical arc flash energy levels. the weather is a factor in the solar energy output, as all work must be performed in out-door settings, ambient temperatures, ground conditions, humidity and moisture levels affect a maintenance worker's ability to safely and comfortably perform maintenance tasks. Solar panels have unique safety considerations: the constant potential to produce – even during non-daylight hours, the I-V output of the PV panel fluctuates with the amount of sunlight, and many installations have onsite battery storage. As a result, electrical hazards and risk cannot fully be eliminated when working with solar photovoltaic equipment. Additionally, unless the inverter is off-grid there is always voltage on both sides of most isolators.

Submitter Information Verification

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Submittal Date: Mon Jun 03 11:25:34 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-102-NFPA 70E-2024

Statement: A new article for PV addresses the unique electrical hazards associated with work practices on PV installations.

First and/or second level subdivision titles were added to comply with the NEC Style Manual.

Article 370 Safety-Related Work Practices for Solar Photovoltaic (PV) Energy Supply Stations

370.1 Scope

This article covers electrical safety-related work practices used by employees while working on or with large-scale solar energy electric supply stations and installations[i], including exposed solar photovoltaic (PV) modules, their interconnected systems and equipment, where these pose an electrical hazard.

The work practices covered apply to solar energy PV electric supply stations with a nameplate generating capacity of at least 5 MW.

Informational Note: See Informative NFPA 70E Annex D for recognized methods for making a reasonable estimate of the arc flash incident heat energy associated with the electrical characteristics specific to solar photovoltaic energy sources.

Informational Note: High daytime temperatures and high incident energy levels exist in every section of large-scale solar installations. See Informative NFPA 70E Annex O 0.2.4 (1), & (13) for safety-by-design methods used to reduce the risk of exposure to electrical hazards associated with photovoltaic sources and systems.

Informational Note: See the following standards and documents for additional information with respect to safety related considerations associated with photovoltaic energy sources, including:

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(2) NFPA 70, *National Electrical Code*, Article 691, Large-Scale Photovoltaic (PV) Electric Supply Stations, 2023
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(5) IEEE 1526, *IEEE Recommended Practice for Testing the Performance of Stand-Alone Photovoltaic Systems*, 2020
(6) IEEE 1562, *IEEE Recommended Practice for Sizing Stand-Alone Photovoltaic (PV) Systems*, 2021
(7) IEEE 2778, *IEEE Guide for Solar Power Plant Grounding for Personnel Protection*, 2020
(8) IEEE Std C95.1, *IEEE Standard for Safety Levels with Respect to Human Exposure to Electrical, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz*, 2019

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370.3 Safety Procedures

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(1) Electrical Hazard Thresholds. Exposure levels shall not exceed those identified in the following list unless appropriate controls are implemented:

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(2) DC: 100 volts and 40 milliamperes

(3) Thermal: 1000 watts short-circuit power

(2) Photovoltaic System Risk Assessment. Prior to working on a photovoltaic module or interconnected system, a risk assessment shall be performed to identify thermal, electrical shock, and arc flash hazards and assess the risks associated with the work to be performed.

(3) Electric Shock Risk Assessment. An electric shock risk assessment shall be performed in accordance with 130.4.

(4) Arc Flash Risk Assessment. The arc flash risk assessment method selected shall utilize an industry-recognized method for obtaining a reasonable estimate of the arc flash incident energy associated with photovoltaic sources of energy.

(1) Direct Current Arc Flash Hazard Estimation. For photovoltaic systems that output a direct current, arc flash risk analysis methods of estimation should account for the non-linear nature of solar/PV modules, including the arc impedance.

> Informational Note: Paragraph D.5.2. Detailed Arcing and Energy Calculations Method under Informative Annex D contains information on industry-recognized and applicable methods of estimating the available incident energy and the arc flash boundary based upon the particular electrical characteristics of photovoltaic systems.

(5) Photovoltaic Array Requirements.

(1) Equipment operation and maintenance. PV modules, systems and equipment shall be operated and maintained in accordance with the manufacturer's instructions.

(2) Personnel access and approach. The photovoltaic array, inclusive of any interconnected modules, shall be accessible only to authorized personnel.

(3) Illumination. Employees shall ensure the use of sufficient illumination to perform the work safely.

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(4) Testing interconnected PV module cable connectors before disconnection. PV module cable connectors shall be tested for absence of load current prior to disconnecting. An adequately rated non-contact test instrument capable of measuring amperage ("amp clamp") shall be used to perform this test. The functionality of the test instrument shall be verified before and after this test has been performed.

(6) Apparel.

(1) Prohibited Clothing. Personnel shall not wear thermally or electrically conductive objects, clothing articles, jewelry and other like items during work on a PV module or system.

(2) Protective Clothing and Equipment. Insulated protective equipment shall be worn by employees while working on or with interconnected PV modules or system components.

(7) Abnormal Conditions. Work during abnormal conditions shall be addressed by procedure and shall include the following, where applicable:

(1) Electrical Safety Plan. An electrical safety plan shall address abnormal conditions where these have been recognized to exist in the solar array. It shall be developed by a qualified and competent person. The plan shall cover the types of work to be performed on, or near, PV modules, systems and equipment as these relate to the abnormal conditions. A detailed job briefing that, at a minimum, includes each of the above requirements shall be conducted and reviewed with all persons involved with the work prior to commencing work during an abnormal condition.

(2) Ground Fault Condition Testing. Where a ground fault condition is known to have occurred and has not been satisfactorily resolved, applicable tests shall be performed to demonstrate the absence of an active ground fault condition before working on or with the photovoltaic systems and equipment associated with the ground fault condition.

(3) Active Faulting PV Equipment. Equipment that is actively faulting shall not be approached, operated or handled, except in emergency, and then only by qualified personnel trained in emergency procedures using adequately rated protective means in accordance with the applicable established emergency procedure.

(4) Wet Conditions. Working on photovoltaic modules or interconnected systems and equipment while in a wet, damp or submersed condition shall not be permitted, unless the employer assesses the risk and ensures that safety-related work practices are used by employees to protect against the associated increased risk. The work practices used shall ensure that the insulating property of any insulated tools and equipment and personal

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protective equipment used to perform the work is not adversely affected. The work practices used shall not increase the risk of exposure to other electrical hazards.

Informational Note: See Informative Annex K for more information on electrical hazards.

(8) Warning Signs. Warning signs or labels shall be posted in appropriate locations, to include the following:

(1) Permanent signage shall clearly designate areas where photovoltaic modules and interconnected equipment have been installed.

(2) Electrical hazard warnings indicating the electric shock hazard due to the module voltage and the arc flash hazard due to the prospective short-circuit current, and the thermal hazard.

(3) Notice for personnel to use and wear protective equipment and apparel appropriate to the hazard for the photovoltaic modules and system.

(4) Notice prohibiting access to unauthorized personnel.

(B) Photovoltaic Energy Source Hazards.

(1) PV Module Material Hazards. Information on the materials used in the manufacture of photovoltaic modules shall be made available to employees who work on or with photovoltaic systems and equipment.

(2) PV Electric Shock and Arc Flash Hazards. Working on a photovoltaic energy source or interconnected system, where hazardous voltage levels or arc flash hazards are recognized, shall be considered energized electrical work, and shall performed in accordance with the requirements of 130.2.

(3) Non-electrical activities that include the handling of PV modules. The following protective equipment shall be available to employees performing any type of service on a PV module or system:

(1) Safety glasses or goggles appropriate to the electrical and other hazards.

(2) Appropriate cut-resistant gloves shall be worn as protection for the hands during activities that involve the handling of PV modules.

(4) Activities that do not include PV module handling. Employees performing any activity not involving the handling of PV modules shall wear safety glasses.

(C) Tools and Equipment.

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(1) Handles. Tools and equipment for work on PV modules shall be equipment with insulation rated for the maximum voltage of the equipment on which they are used in accordance with 130.7(D)(1).

(2) Contact. Bare or uncapped PV module electrical conductors shall be kept clear of unintended contact with tools, test equipment vegetation, structures, liquids and damp surfaces and other foreign objects. Conductors shall be capped, plugged or otherwise adequately insulated against contact when unattended.

370.4 Safety Training.

(A) General. The training requirements of this chapter shall apply to employees exposed to electrical hazards associated with work on or near solar energy sources, including the interconnected photovoltaic equipment, collection systems and associated power conversion system.

(B) Training requirements. Employees shall be trained to understand the specific electrical hazards associated with electrical energy from a photovoltaic module and arising from interconnecting multiple modules. Employees shall be trained in the safety-related work practices and requirements to provide protection from the electrical hazards associated with their respective job or task assignment.

370.5 Employee Training. Employees who operate and maintain repair solar installations and equipment shall be trained in the operating characteristics of the PV modules and equipment with which they will work.

(A) Qualified Persons. Only qualified personnel shall work with or on PV electrical supply installations/stations.

(1) Training. Qualified persons shall be trained and knowledgeable in the operation of photovoltaic energy sources and equipment and specific work methods and shall be trained to avoid the electrical hazards that are present. Such persons shall be familiar with the proper use of precautionary techniques and PPE. Training for a qualified person shall include the following:

(1) Procedures. Training in photovoltaic module safety requirements shall introduce any applicable procedures for installing, connecting, disconnecting, repairing, replacing, testing, handling, transport, storage and disposal of modules. Personnel shall complete training and demonstrate proficiency in safety-related work practices associated with performing any such activities before being assigned their tasks.

(2) Hazards. Training in photovoltaic modules and equipment shall include the hazards of working with continuously or potentially energized equipment, the associated risk and

applicable methods for avoiding such hazards and reducing risks appropriately and eliminating risks where feasible.

(3) PV energy systems. Qualified persons shall be trained in and knowledgeable of the basic principles of solar energy including photovoltaics, the types of PV systems and their components with which they will work, including the PV system design, and the applicable safety considerations when working with PV systems.

(4) Unintentional Grounding of PV modules. Employees who work on or near solar installations and interconnecting collection systems and equipment shall be trained to understand the hazards associated with an unintentional grounded condition along the applicable precautionary techniques to prevent such a condition from occurring.

(2) Unqualified Persons.

(1) Training. Unqualified persons shall be trained to identify electrical hazards to which they could be exposed and the proper methods of avoiding the hazards.

(2) In the solar array. Unqualified persons who may need to approach or enter the solar array shall be trained in, and be familiar with, applicable electrical safety-related work practices necessary to avoid electrical hazards they may encounter during their normal work activities.

370.6 Safeguarding of employees. Operation and maintenance of photovoltaic modules might require contact by employees with exposed energized surfaces of photovoltaic cells, circuit conductors, and their attachments. Safeguards such as safety-related work practices and other safeguards shall be used to protect employees from injury while working in the photovoltaic array. These safeguards shall be consistent with the nature and extent of the related electrical hazards. Safeguards might be different during daylight hours versus at night (for example, during non-daylight hours when irradiance conditions greatly reduce the output voltage and current from a solar module to levels that may be lower the thresholds indicated in 370.3(A)(1).)

370.7 Tools and Equipment. Tools and equipment used for installing, maintaining, servicing, repairing or replacement of solar installations, including interconnected PV equipment, shall conform to manufacturer's recommendations and meet the requirements of applicable codes and standards.

370.8 Responsibility for Electrical Safety. All personnel with access to hazardous voltage and current associated with PV energy sources shall be responsible for the following:

(A)Obtaining authorization for work with or on energized electrical equipment in accordance with the requirements of 130.2.

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(B) Performing work in accordance with the applicable requirements of Chapter 1 safety-related work practices.

(C) Reporting photovoltaic equipment incidents, damage, inadequate barriers and/or warning signs to the employer.

[i] Similar to NFPA 70-2023 Article 691, the scope of the work practices proposed apply to large-scale solar photovoltaic (PV) systems with a nameplate capacity of at least 5000 kilowatts, or 5 megawatts (MW).

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Public Input No. 176-NFPA 70E-2024 [Global Input]

1. There is a need to establish a finger-safe terminals requirement internally and externally on large Lithium-Ion batteries for occupational safety. Currently most automotive propulsion lithium-ion batteries have exposed terminals undercover which pose hazards to assembly and service operators.

2. There should be a requirement to be able to segment large propulsion batteries (400-800VDC) into smaller segments and open circuit for service and safe repair/disassembly purposed.

Statement of Problem and Substantiation for Public Input

Lack of occupational safety requirements in lithium-ion batteries for manufacturing, service, repair, secondary use, and recycling purposes.

Submitter Information Verification

Submitter Full Name: Deep Thakur
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Submittal Date: Mon Jun 03 14:39:29 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: The public input does not comply with the Regulations Governing the Development of NFPA Standards Paragraph 4.3.4.1.

Public Input No. 60-NFPA 70E-2024 [Section No. 90.1]

90.1 Scope. Article 90 establishes the following:

(A) Article 90 Scope. This article covers

~~the~~
use

~~,~~
and application, and arrangement , and enforcement of this standard.

(B) Workplaces Covered. [remainder of 90.3(A) unchanged]

(C) Workplaces Not Covered by This Code. This Code does not cover the following:

[remainder of relocated 90.3(B) unchanged]

Statement of Problem and Substantiation for Public Input

There is no longer a scope of the NFPA 70E standard. Rather, 90.1 presently establishes the scope of Article 90. This public input is an effort to editorially relocate what is covered and not covered into a scope statement.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 61-NFPA 70E-2024 [Section No. 90.3]	
Public Input No. 61-NFPA 70E-2024 [Section No. 90.3]	

Submitter Information Verification

Submitter Full Name: Palmer Hickman
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State:
Zip:
Submittal Date: Wed Feb 28 16:29:41 EST 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-104-NFPA 70E-2024
Statement: The NFPA 70E Technical Committee recognizes that the Correlating Committee on the National Electrical Code has purview over the scope of NFPA 70E, . This first revision changes the title of 90.3 to clearly indicate that the scope of the document outlines the workplaces covered and not covered.

Public Input No. 61-NFPA 70E-2024 [Section No. 90.3]

~~**90.3** Workplaces Covered and Not Covered.~~

~~**(A)** Workplaces Covered.~~

~~This standard addresses electrical safety-related work practices, safety-related maintenance requirements, and other administrative controls for employee workplaces that are necessary for the practical safeguarding of employees relative to the hazards associated with electrical energy during activities such as the installation, removal, inspection, operation, maintenance, and demolition of electric conductors, electric equipment, signaling and communications conductors and equipment, and raceways. This standard also includes safe work practices for employees performing other work activities that can expose them to electrical hazards as well as safe work practices for the following:~~

(1) ~~Installation of conductors and equipment that connect to the supply of electricity~~

(2) ~~Installations used by the electric utility, such as office buildings, warehouses, garages, machine shops, and recreational buildings that are not an integral part of a generating plant, substation, or control center~~

~~Informational Note: This standard addresses safety of workers whose job responsibilities involve interaction with energized electrical equipment and systems with potential exposure to electrical hazards. Concepts in this standard are often adapted to other workers whose exposure to electrical hazards is unintentional or not recognized as part of their job responsibilities. The highest risk for injury from electrical hazards for other workers involve unintentional contact with overhead power lines and electric shock from machines, tools, and appliances.~~

~~**(B)** Workplaces Not Covered.~~

~~This standard does not cover safety-related work practices for the following:~~

(1) ~~Installations in ships, watercraft other than floating buildings, railway rolling stock, aircraft, or automotive vehicles other than mobile homes and recreational vehicles~~

(2) ~~Installations of railways for generation, transformation, transmission, or distribution of power used exclusively for operation of rolling stock or installations used exclusively for signaling and communications purposes~~

(3) ~~Installations of communications equipment under the exclusive control of communications utilities located outdoors or in building spaces used exclusively for such installations~~

(4) ~~Installations under the exclusive control of an electric utility where such installations:~~

(5) ~~Consist of service drops or service laterals, and associated metering, or~~

(6) ~~Are located in legally established easements or rights-of-way designated by or recognized by public service commissions, utility commissions, or other regulatory agencies having jurisdiction for such installations, or~~

(7) ~~Are on property owned or leased by the electric utility for the purpose of communications, metering, generation, control, transformation, transmission, or distribution of electric energy, or~~

(8) ~~Are located by other written agreements either designated by or recognized by public service commissions, utility commissions, or other regulatory agencies having jurisdiction for such installations. These written agreements shall be limited to installations for the purpose of communications, metering, generation, control, transformation, transmission, or distribution of electric energy where legally established easements or rights-of-way cannot be obtained. These installations shall be limited to federal lands, Native American reservations through the U.S. Department of the Interior Bureau of Indian Affairs, military bases, lands controlled by port authorities and state agencies and departments, and lands owned by railroads.~~

Statement of Problem and Substantiation for Public Input

This recommendation is to relocate 90.3 into 90.1 so that what is covered and not covered is covered in a scope statement.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 60-NFPA 70E-2024 [Section No. 90.1]	
Public Input No. 60-NFPA 70E-2024 [Section No. 90.1]	

Submitter Information Verification

Submitter Full Name: Palmer Hickman
Organization: Electrical Training Alliance
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City:
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Submittal Date: Wed Feb 28 16:44:46 EST 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-104-NFPA 70E-2024

Statement: The NFPA 70E Technical Committee recognizes that the Correlating Committee on the National Electrical Code has purview over the scope of NFPA 70E, . This first revision changes the title of 90.3 to clearly indicate that the scope of the document outlines the workplaces covered and not covered.

Public Input No. 220-NFPA 70E-2024 [Section No. 90.3(A)]

(A) Workplaces Covered.

This standard addresses electrical safety-related work practices, safety-related maintenance requirements, and other administrative controls for employee workplaces that are necessary for the practical safeguarding of employees relative to the hazards associated with electrical energy during activities such as the installation, removal, inspection, operation, maintenance, and demolition of electric conductors, electric equipment, signaling and communications conductors and equipment, and raceways. This standard also includes safe work practices for employees performing other work activities that can expose them to electrical hazards as well as safe work practices for the following:

(1) Installation of conductors and equipment that connect to the supply of electricity

(2) Installations used by the electric utility, such as office buildings, warehouses, garages, machine shops, and recreational buildings that are not an integral part of a generating plant, substation, or control center

(3) Installations for the purpose of generation, control, transformation, transmission, or distribution of electric energy not owned or leased by an electric utility

Informational Note: This standard addresses safety of workers whose job responsibilities involve interaction with energized electrical equipment and systems with potential exposure to electrical hazards. Concepts in this standard are often adapted to other workers whose exposure to electrical hazards is unintentional or not recognized as part of their job responsibilities. The highest risk for injury from electrical hazards for other workers involve unintentional contact with overhead power lines and electric shock from machines, tools, and appliances.

Statement of Problem and Substantiation for Public Input

There are several utility-like installations that exist where it is unclear whether NFPA 70E applies or not. This confusion is made worse in several instances where the facility may have been started by an electric utility but is now under private ownership. An example is a privately owned co-gen plant that is owned by a private company for the purpose of manufacturing electricity that they sell to utility companies. These sites track the price of generating electricity and decide whether to run or not on a daily basis. There is zero reason these plants cannot follow the rules in NFPA 70E as they can shut down for any reason, at any time because they are not regulatorily obligated to provide electricity to the utility. If they can decide not to run because the price of natural gas is too high for them to turn a profit on any given day, why can't they decide to shut down when a procedure involves risk of injury to an employee?

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 221-NFPA 70E-2024 [Section No. 90.3(B)]	either/or relationship
Public Input No. 221-NFPA 70E-2024 [Section No. 90.3(B)]	

Submitter Information Verification

Submitter Full Name: Derek Vigstol
Organization: e-Hazard Management LLC
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City:
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Zip:
Submittal Date: Tue Jun 04 00:19:23 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: The proposed text is unnecessary in 90.3(A). The present wording of 90.3(B) only excludes these types of installations that are under the exclusive control of a utility.

Public Input No. 279-NFPA 70E-2024 [Section No. 90.3(A)]

(A) Workplaces Covered.

This standard addresses electrical safety-related work practices, safety-related maintenance requirements, and other administrative controls for employee workplaces that are necessary for the practical safeguarding of employees relative to the hazards associated with electrical energy during activities such as the installation, removal, inspection, operation, maintenance, and demolition of electric conductors, electric equipment, signaling and communications conductors and equipment, and raceways. This standard also includes safe work practices for employees performing other work activities that can expose them to electrical hazards as well as safe work practices for the following:

(1) Installation of conductors and equipment that connect to the supply of electricity

(2) Installations used by the electric utility, such as office buildings, warehouses, garages, machine shops, and recreational buildings that are not an integral part of a generating plant, substation, or control center

(3) Installations used by the communications utility, such as office buildings, warehouses, garages, machine shops, and recreational buildings that are not an integral part of communications equipment associated with the infrastructure network.

Informational Note: This standard addresses safety of workers whose job responsibilities involve interaction with energized electrical equipment and systems with potential exposure to electrical hazards. Concepts in this standard are often adapted to other workers whose exposure to electrical hazards is unintentional or not recognized as part of their job responsibilities. The highest risk for injury from electrical hazards for other workers involve unintentional contact with overhead power lines and electric shock from machines, tools, and appliances.

Additional Proposed Changes

File Name	Description	Approved
70E_PC_47_Hold.pdf	70E_PC47	

Statement of Problem and Substantiation for Public Input

NOTE: This Public Input appeared as “Reject but Hold” in Public Comment No. 47 of the (A2023) Second Draft Report for NFPA 70E and per the Regs. At 4.4.8.3.1 and needs to be reconsidered by the TC for the next edition of the document.

Communications utility companies have identical office buildings, warehouses, garages, machine shops,
recreational building, business office and similar structures that are not an integral part of the communications
equipment as used by electric utilities. However, they don’t have the same ‘covered’ requirements for such nonutility
locations as specified by electric utility companies. Therefore, the workers who maintain, repair or install
new electrical equipment into these buildings and structures that contain electrical infrastructure and distribution
systems needed to power these “non-communications loads” should be covered by NFPA 70E.

Submitter Information Verification

Submitter Full Name:	NFPA Holds
Organization:	Technical Committee on Electrical Safety in the Workplace
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State:	
Zip:	
Submittal Date:	Thu Jun 06 21:46:23 EDT 2024
Committee:	EEW-AAA

Committee Statement

Resolution: FR-2-NFPA 70E-2024

Statement: The addition of “s” to installations in item 1 is for clarity and consistency.

Item 3 adds electrical equipment that is owned by a communications utility but is not associated with the network infrastructure to the list of workplaces covered. The resulting text mirrors the existing language for electric utilities. This addition will expand the scope to help protect workers whose job responsibilities may involve interaction with energized electrical equipment and systems and the associated electrical hazards.

Public Comment No. 47-NFPA 70E-2022 [Section No. 90.3(A)]

(A) Workplaces Covered.

This standard addresses electrical safety-related work practices, safety-related maintenance requirements, and other administrative controls for employee workplaces that are necessary for the practical safeguarding of employees relative to the hazards associated with electrical energy during activities such as the installation, removal, inspection, operation, maintenance, and demolition of electric conductors, electric equipment, signaling and communications conductors and equipment, and raceways. This standard also includes safe work practices for employees performing other work activities that can expose them to electrical hazards as well as safe work practices for the following:

(1) Installation of conductors and equipment that connect to the supply of electricity

(2) Installations used by the electric utility, such as office buildings, warehouses, garages, machine shops, and recreational buildings that are not an integral part of a generating plant, substation, or control center

(3) Installations used by the communications utility, such as office buildings, warehouses, garages, machine shops, and recreational buildings that are not an integral part of communications equipment associated with the infrastructure network.

Informational Note: This standard addresses safety of workers whose job responsibilities involve interaction with energized electrical equipment and systems with potential exposure to electrical hazards. Concepts in this standard are often adapted to other workers whose exposure to electrical hazards is unintentional or not recognized as part of their job responsibilities. The highest risk for injury from electrical hazards for other workers involve unintentional contact with overhead power lines and electric shock from machines, tools, and appliances.

Statement of Problem and Substantiation for Public Comment

Communications utility companies have identical office buildings, warehouses, garages, machine shops, recreational building, business office and similar structures that are not an integral part of the communications equipment as used by electric utilities. However, they don't have the same 'covered' requirements for such non-utility locations as specified by electric utility companies. Therefore, the workers who maintain, repair or install new electrical equipment into these buildings and structures that contain electrical infrastructure and distribution systems needed to power these "non-communications loads" should be covered by NFPA 70E.

Related Item

• PI

Submitter Information Verification

Submitter Full Name: George Cole
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Zip:
Submittal Date: Wed May 18 18:18:43 EDT 2022
Committee:

Committee Statement

Committee Action: Rejected but held

Resolution: The text proposed by this public comment does not meet 4.4.4.2 of the Regulations Governing Committee Projects which requires public comments to be related to material that has received public review either through the submission of Public Input, Committee Input or Correlating Input or through the First Revisions.

Public Input No. 205-NFPA 70E-2024 [Section No. 90.3(B)]

(B) Workplaces Not Covered.

This standard does not cover safety-related work practices for the following:

(1) Installations in ships, watercraft other than floating buildings, railway rolling stock, aircraft, or automotive vehicles other than mobile homes and recreational vehicles

(2) Installations of railways for generation, transformation, transmission, or distribution of power used exclusively for operation of rolling stock or installations used exclusively for signaling and communications purposes

(3) Installations of communications equipment under the exclusive control of communications utilities located outdoors or in building spaces used exclusively for such installations

(4) Installations under the exclusive control of an electric utility where such installations comply with one of the following :

(5) Consist of service drops or service laterals, and associated metering

~~, or~~

a.

b. Are located in legally established easements or rights-of-way designated by or recognized by public service commissions, utility commissions, or other regulatory agencies having jurisdiction for such installations

~~, or~~

a.

b. Are on property owned or leased by the electric utility for the purpose of communications, metering, generation, control, transformation, transmission, or distribution of electric energy

~~, or~~

a. that are accessible only to qualifed employees.

Note: The types of installations covered by this paragraph include the generation, transmission, and distribution installations of electric utilities, as well as equivalent installations of industrial establishments.

b. Are located by other written agreements either designated by or recognized by public service commissions, utility commissions, or other regulatory agencies having jurisdiction for such installations. These written agreements shall be limited to installations for the purpose of communications, metering, generation, control, transformation, transmission, or distribution of electric energy where legally established easements or rights-of-way cannot be obtained. These installations shall be limited to federal lands, Native American reservations through the U.S. Department of the Interior Bureau of Indian Affairs, military bases, lands controlled by port authorities and state agencies and departments, and lands owned by railroads.

(6) Power generation, transmission, and distribution installations, includ

Statement of Problem and Substantiation for Public Input

The history of NFPA70E indicates that originally had the same scope as NFPA70. Whereas NFPA70 typically has parts for "installations over 1000 volts," 70E has not. The wording that has been proposed for (B) Not Covered, has been taken from 29CFR1910.269. 1910.269 has requirements for "equivalent installations of industrial establishments." This PI intends to modify the scope of 70E to begin where 1910.269 leaves off. I believe the NFPA style guide does not allow the referencing of another Code (or OSHA) in a requirement. For this reason, the wording in this PI has been crafted to match the scope of 1910.269 without referencing it.
Issue. If the service point of a company is at 69kV, 70E begins there. This PI proposes to allow 1910.269 to prevail until the system is no longer under the auspices of 1910.269. 70E would start downstream of that point.
I have been at meetings (IEEE safety workshop is one) where companies are trying to declare two service points. One where the utility transfers ownership to the customer, and two where 70E begins. This is not possible, but this is what is happening. By making a clear delineation that 70E begins where 1910.269 leaves off, the scope of the standard would be much more implementable.

Submitter Information Verification

Submitter Full Name: Eric Stromberg
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Affiliation: Self
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Submittal Date: Mon Jun 03 22:30:40 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: Installations of generation, transmission, and distribution not under the exclusive control of the electric utility are covered by the scope of the Standard. Inadequate substantiation was provided to exclude these installations from the Scope.

Public Input No. 221-NFPA 70E-2024 [Section No. 90.3(B)]

(B) Workplaces Not Covered.

This standard does not cover safety-related work practices for the following:

(1) Installations in ships, watercraft other than floating buildings, railway rolling stock, aircraft, or automotive vehicles other than mobile homes and recreational vehicles

(2) Installations of railways for generation, transformation, transmission, or distribution of power used exclusively for operation of rolling stock or installations used exclusively for signaling and communications purposes

(3) Installations of communications equipment under the exclusive control of communications utilities located outdoors or in building spaces used exclusively for such installations

(4) Installations under the exclusive control of an electric utility where such installations:

(5) Consist of service drops or service laterals, and associated metering, or

(6) Are located in legally established easements or rights-of-way designated by or recognized by public service commissions, utility commissions, or other regulatory agencies having jurisdiction for such installations, or

(7) Are on property owned or leased by the electric utility for the purpose of communications, metering, generation, control, transformation, transmission, or distribution of electric energy, or

(8) Are located by other written agreements either designated by or recognized by public service commissions, utility commissions, or other regulatory agencies having jurisdiction for such installations. These written agreements shall be limited to installations for the purpose of communications, metering, generation, control, transformation, transmission, or distribution of electric energy where legally established easements or rights-of-way cannot be obtained. These installations shall be limited to federal lands, Native American reservations through the U.S. Department of the Interior Bureau of Indian Affairs, military bases, lands controlled by port authorities and state agencies and departments, and lands owned by railroads.

(9) Installations of generation, transmission, and distribution equipment not under the control of an electric utility that operate exclusively for the purpose of supplying electricity to an electric utility.

Statement of Problem and Substantiation for Public Input

This PI is just new item (5). Terra struck again and underlined other content not being revised. This PI is the direct opposite of PI-220 and is an "either/or" relationship. There are several generation facilities that are not owned by utilities but generate electricity to sell to the utilities. It is unclear if NFPA 70E applies to these sites or not. They look and feel just like a utility owned power plant but are privately owned. These facilities are not governed by the same regulations for providing power as a utility is and can shut down for the simple reason that it costs too much money to run the generator on any given day. For example, does NFPA 70E apply to a privately owned natural gas fired generator, transformer, and distribution equipment that ties into the utility grid but is owned by an investment firm? If NFPA 70E does apply, please reject this PI and accept PI-220 that seeks to add these plants into what is covered. If NFPA 70E does not apply, please accept this PI and reject PI-220.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 220-NFPA 70E-2024 [Section No. 90.3(A)]	either/or relationship
Public Input No. 220-NFPA 70E-2024 [Section No. 90.3(A)]	

Submitter Information Verification

Submitter Full Name: Derek Vigstol
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Submittal Date: Tue Jun 04 00:35:36 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: Installations of generation, transmission, and distribution not under the exclusive control of the electric utility are covered by the scope of the Standard. Inadequate substantiation was provided to exclude these installations from the Scope.

Public Input No. 260-NFPA 70E-2024 [Section No. 90.3(B)]

(B) Workplaces Not Covered.

This standard does not cover safety-related work practices for the following:

(1) Installations in ships, watercraft other than floating buildings, railway rolling stock,or aircraft, ~~or automotive vehicles~~ other than mobile homes and recreational vehicles

(2) Installations of railways for generation, transformation, transmission, or distribution of power used exclusively for operation of rolling stock or installations used exclusively for signaling and communications purposes

(3) Installations of communications equipment under the exclusive control of communications utilities located outdoors or in building spaces used exclusively for such installations

(4) Installations under the exclusive control of an electric utility where such installations:

(5) Consist of service drops or service laterals, and associated metering, or

(6) Are located in legally established easements or rights-of-way designated by or recognized by public service commissions, utility commissions, or other regulatory agencies having jurisdiction for such installations, or

(7) Are on property owned or leased by the electric utility for the purpose of communications, metering, generation, control, transformation, transmission, or distribution of electric energy, or

(8) Are located by other written agreements either designated by or recognized by public service commissions, utility commissions, or other regulatory agencies having jurisdiction for such installations. These written agreements shall be limited to installations for the purpose of communications, metering, generation, control, transformation, transmission, or distribution of electric energy where legally established easements or rights-of-way cannot be obtained. These installations shall be limited to federal lands, Native American reservations through the U.S. Department of the Interior Bureau of Indian Affairs, military bases, lands controlled by port authorities and state agencies and departments, and lands owned by railroads.

Statement of Problem and Substantiation for Public Input

Delete "automotive vehicles" and relocate the word "or" that is the only change proposed by this public input. The scope, purpose and what is covered by NFPA 70E is for work practices in various occupancies. The installation requirements are covered elsewhere including some in the NEC. NFPA 70E scope needs to be expanded to include the servicing and repair work on vehicles that is done in occupancies that are already covered by the NEC and NFPA 70E
What is covered by the NEC has been expanded in previous editions to include exporting power from vehicles -apparently all types in 90.2(C)(6) so there is precedence or this. Commercial garages are covered in NEC Article 511 even though the requirements for the vehicles themselves are not.

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Submittal Date: Tue Jun 04 16:44:05 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: Inadequate substantiation has been provided to remove automotive vehicles from the exclusions, whether they be electric, internal combustion, or hybrid. The present provisions align with 90.2(D) of the NEC.

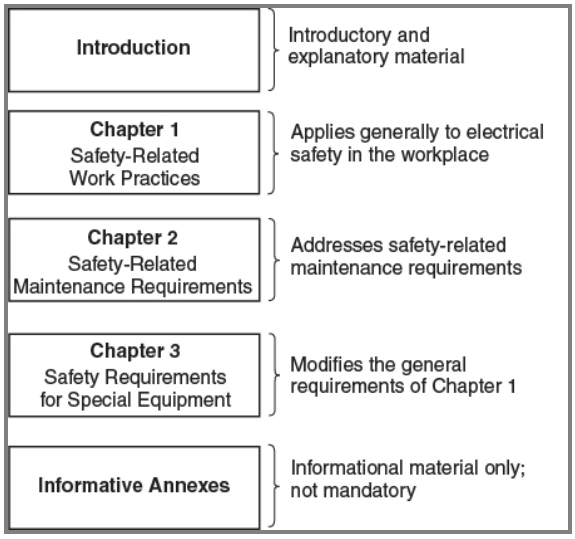
Public Input No. 62-NFPA 70E-2024 [Section No. 90.4]

90.4 Standard Arrangement.

This standard is divided into the introduction and three chapters, as shown in Figure 90.4. Chapter 1 applies generally, Chapter 2 addresses safety-related maintenance requirements, and Chapter 3 ~~supplements or~~ modifies Chapter 1 with safety requirements for special equipment.

Informative annexes are not part of the requirements of this standard but are included for informational purposes only.

Figure 90.4 Standard Arrangement.



Statement of Problem and Substantiation for Public Input

This public input attempts to make the language in 90.4 match the language in Figure 90.4. Either add "supplements or" to the explanatory text related to Chapter 3 in Figure 90.4 or remove "supplements or" in Section 90.4 for correlation.

Submitter Information Verification

Submitter Full Name: Palmer Hickman
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Submittal Date: Wed Feb 28 16:51:59 EST 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-3-NFPA 70E-2024

Statement: The text in the Chapter 3 row of Figure 90.4 is modified to align with the provisions in Section 90.4 for correlation and clarity.

Public Input No. 126-NFPA 70E-2024 [Article 100]

Article 100 Definitions

Scope. This article contains only those definitions essential to the proper application of this standard. It is not intended to include commonly defined general terms or commonly defined technical terms from related codes and standards. An article number in parentheses following the definition indicates that the definition only applies to that article.

Accessible (as applied to equipment).

Admitting close approach; not guarded by locked doors, elevation, or other effective means. [**70:**100]

Approved.

Acceptable to the authority having jurisdiction.

Arc Flash Suit.

A complete arc-rated clothing and equipment system that covers the entire body, except for the hands and feet.

> Informational Note: An arc flash suit may include pants or overalls, a jacket or a coverall, and a beekeeper-type hood fitted with a face shield.

Arc Rating.

The value attributed to materials that describes their performance to exposure to an electrical arc discharge. The arc rating is expressed in cal/cm^2 and is derived from the determined value of the arc thermal performance value (ATPV) or energy of breakopen threshold (E_{BT}) (should a material system exhibit a breakopen response below the ATPV value). Arc rating is reported as either ATPV or E_{BT}, whichever is the lower value.

> Informational Note No. 1: Arc-rated clothing or equipment indicates that it has been tested for exposure to an electric arc. Flame-resistant clothing without an arc rating has not been tested for exposure to an electric arc. All arc-rated clothing is also flame resistant.
>
> Informational Note No. 2: See ASTM F1959/F1959M, *Standard Test Method for Determining the Arc Rating of Materials for Clothing*, which defines ATPV as the incident energy (cal/cm^2) on a material or a multilayer system of materials that results in a 50 percent probability that sufficient heat transfer through the tested specimen is predicted to cause the onset of a second degree skin burn injury based on the Stoll curve.
>
> Informational Note No. 3: See ASTM F1959/F1959M, *Standard Test Method for Determining the Arc Rating of Materials for Clothing*, which defines E_{BT} as the incident energy (cal/cm^2) on a material or a material system that results in a 50 percent probability of breakopen. Breakopen is a material response evidenced by the formation of one or more holes of a defined size [an area of 1.6 cm^2 (0.5 in.^{2}) or an opening of 2.5 cm (1.0 in.) in any dimension] in the innermost layer of arc-rated material that would allow thermal energy to pass through the material.

Attachment Plug (Plug Cap) (Plug).

A device that, by insertion in a receptacle, establishes a connection between the conductors of the attached flexible cord and the conductors connected permanently to the receptacle. [**70:**100]

Authority Having Jurisdiction (AHJ).

An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

> Informational Note: The phrase “authority having jurisdiction,” or its acronym AHJ, is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

Authorized Personnel.

The person in charge of the premises, or other persons appointed or selected by the person in charge of the premises who performs certain duties associated with stationary storage batteries. (320)

Automatic.

Performing a function without the necessity of human intervention.

Balaclava.

An arc-rated head-protective fabric that protects the neck and head except for a small portion of the facial area.

> Informational Note: Some balaclava designs protect the neck and head area except for the eyes while others leave the eyes and nose area unprotected.

Barricade.

A physical obstruction such as tapes, cones, or A-frame-type wood or metal structures intended to provide a warning and to limit access.

Barrier.

A physical obstruction that is intended to prevent contact with equipment or energized electrical conductors and circuit parts.

Battery.

A system consisting of two or more electrochemical cells connected in series or parallel and capable of storing electrical energy received and that can give it back by reconversion. (320)

Battery Effect.

A voltage that exists on the electrolytic cell line after the power supply is disconnected. (310)

> Informational Note: Electrolytic cells can exhibit characteristics similar to an electrical storage battery and an electric shock hazard could exist after the power supply is disconnected from the cell line.

Battery Room.

A room specifically intended for the installation of batteries that have no other protective enclosure. (320)

Bonded (Bonding).

Connected to establish electrical continuity and conductivity. [**70:**100]

Bonding Conductor or Jumper.

A reliable conductor to ensure the required electrical conductivity between metal parts required to be electrically connected. [**70:**100]

Boundary, Arc Flash. (Arc Flash Boundary)

When an arc flash hazard exists, an approach limit from an arc source at which incident energy equals 1.2 cal/cm^2 (5 J/cm^2).

Informational Note: According to the Stoll skin burn injury model, the onset of a second degree burn on unprotected skin is likely to occur at an exposure of 1.2 cal/cm^2 (5 J/cm^2) for one second.

Boundary, Hearing Protection. (Hearing Protection Boundary)

Worker distance at which a 1 percent probability of ear damage exists from a 20 kPa (3.0 psi) shock wave. (360)

Boundary, Limited Approach. (Limited Approach Boundary)

An approach limit at a distance from an exposed energized electrical conductor or circuit part within which an electric shock hazard exists.

Boundary, Lung Protection. (Lung Protection Boundary)

Worker distance at which a 1 percent probability of lung damage exists from a 70 kPa (10 psi) shock wave. (360)

Boundary, Restricted Approach. (Restricted Approach Boundary)

An approach limit at a distance from an exposed energized electrical conductor or circuit part within which there is an increased likelihood of electric shock, due to electrical arc-over combined with inadvertent movement.

Building.

A structure that stands alone or that is cut off from adjoining structures by fire walls with all openings therein protected by approved fire doors. [**70:**100]

Cabinet.

An enclosure that is designed for either surface mounting or flush mounting and is provided with a frame, mat, or trim in which a swinging door or doors are or can be hung. [**70:**100]

Cell.

The basic electrochemical unit, characterized by an anode and a cathode used to receive, store, and deliver electrical energy. (320)

Cell, Valve-Regulated Lead Acid (VRLA). (Valve-Regulated Lead Acid Cell)

A lead-acid cell that is sealed with the exception of a valve that opens to the atmosphere when the internal pressure in the cell exceeds atmospheric pressure by a pre-selected amount, and that provides a means for recombination of internally generated oxygen and the suppression of hydrogen gas evolution to limit water consumption. (320)

Cell, Vented. (Vented Cell)

A type of cell in which the products of electrolysis and evaporation are allowed to escape freely into the atmosphere as they are generated. (Also called "*flooded cell*.") (320)

Charge Transfer.

Improper discharging of capacitor networks that results in transferring charge from one capacitor to another capacitor instead of fully discharging the stored energy. (360)

Circuit Breaker.

A device designed to open and close a circuit by nonautomatic means and to open the circuit automatically on a predetermined overcurrent without damage to itself when properly applied within its rating. [**70:**100]

Informational Note: The automatic opening means can be integral, direct acting with the circuit breaker, or remote from the circuit breaker.

Competent Person.

A person who meets all the requirements of *qualified person*, and who, in addition, is responsible for all work activities or safety procedures related to custom or special equipment and has detailed knowledge regarding the exposure to electrical hazards, the appropriate control methods to reduce the risk associated with those hazards, and the implementation of those methods. (350)

Conductive.

Suitable for carrying electric current.

Conductor, Bare. (Bare Conductor)

A conductor having no covering or electrical insulation whatsoever. [**70:**100]

Conductor, Covered. (Covered Conductor)

A conductor encased within material of composition or thickness that is not recognized by *NFPA 70*, *National Electrical Code*, as electrical insulation. [**70:**100]

Conductor, Insulated. (Insulated Conductor)

A conductor encased within material of composition and thickness that is recognized by *NFPA 70*, *National Electrical Code*, as electrical insulation. [**70:**100]

Controller.

A device or group of devices that serves to govern, in some predetermined manner, the electric power delivered to the apparatus to which it is connected. [**70:**100]

Current-Limiting Overcurrent Protective Device.

A device that, when interrupting currents in its current-limiting range, reduces the current flowing in the faulted circuit to a magnitude substantially less than that obtainable in the same circuit if the device were replaced with a solid conductor having comparable impedance.

Cutout.

An assembly of a fuse support with either a fuseholder, fuse carrier, or disconnecting blade. The fuseholder or fuse carrier may include a conducting element (fuse link), or may act as the disconnecting blade by the inclusion of a nonfusible member.

De-energized.

Free from any electrical connection to a source of potential difference and from electrical charge; not having a potential different from that of the earth.

Device.

A unit of an electrical system, other than a conductor, that carries or controls electric energy as its principal function. [**70:**100]

Dielectric Absorption.

The property of certain capacitors to recharge after being discharged. (360)

> Informational Note: A voltage recharge from 0.02 percent (polystyrene and polypropylene) up to 10 percent (some electrolytics) can occur a few minutes after the grounding or shorting device has been removed.

Discharge Time.

The time required to discharge a capacitor to below electrical hazard thresholds. (360)

Disconnecting Means.

A device, or group of devices, or other means by which the conductors of a circuit can be disconnected from their source of supply. [**70:**100]

Disconnecting (or Isolating) Switch (Disconnector, Isolator).

A mechanical switching device used for isolating a circuit or equipment from a source of power.

Dwelling Unit.

A single unit providing complete and independent living facilities for one or more persons, including permanent provisions for living, sleeping, cooking, and sanitation. [**70:**100]

Electrical Safety.

Identifying hazards associated with the use of electrical energy and taking precautions to reduce the risk associated with those hazards.

Electrical Safety Program.

A documented system consisting of electrical safety principles, policies, procedures, and processes that directs activities appropriate for the risk associated with electrical hazards.

Electrically Safe Work Condition.

A state in which an electrical conductor or circuit part has been disconnected from energized parts, locked/tagged in accordance with established standards, tested for the absence of voltage, and, if necessary, temporarily grounded for personnel protection.

Electrolyte.

A solid, liquid, or aqueous immobilized liquid medium that provides the ion transport mechanism between the positive and negative electrodes of a cell. (320)

Enclosed.

Surrounded by a case, housing, fence, or wall(s) that prevents persons from unintentionally contacting energized parts.

Enclosure.

The case or housing of apparatus — or the fence or walls surrounding an installation to prevent personnel from unintentionally contacting energized electrical conductors or circuit parts or to protect the equipment from physical damage.

Energized.

Electrically connected to, or is, a source of voltage. [**70:**100]

Equipment.

A general term, including fittings, devices, appliances, luminaires, apparatus, machinery, and the like, used as a part of, or in connection with, an electrical installation. [**70:**100]

Equipment, Arc-Resistant. (Arc-Resistant Equipment)

Equipment designed to withstand the effects of an internal arcing fault and that directs the internally released energy away from the employee.

> Informational Note No. 1: See IEEE C37.20.7, *Guide for Testing Switchgear Rated Up to 52 kV for Internal Arcing Faults*, as an example of a standard that provides information for arc-resistant equipment.
>
> Informational Note No. 2: See Informative Annex O.2.4(9) for information on arc-resistant equipment.

Exposed (as applied to energized electrical conductors or circuit parts).

Capable of being inadvertently touched or approached nearer than a safe distance by a person. It is applied to electrical conductors or circuit parts that are not suitably guarded, isolated, or insulated.

Exposed (as applied to wiring methods).

On or attached to the surface or behind panels designed to allow access. [**70:**100]

Fault Current.

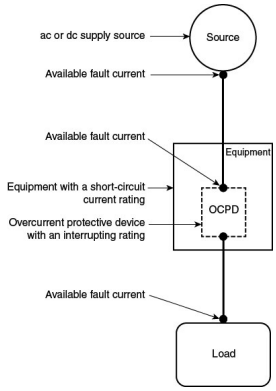
The amount of current delivered at a point on the system during a short-circuit condition.

Fault Current, Available. (Available Fault Current)

The largest amount of current capable of being delivered at a point on the system during a short-circuit condition.

Informational Note No. 1: See Informational Note Figure 100.0 A short circuit can occur during abnormal conditions such as a fault between circuit conductors or a ground fault.

Figure Informational Note Figure 100.0 Available Fault Current.



Informational Note No. 2: If the dc supply is a battery system, the term *available fault current* refers to the prospective short-circuit current.

Informational Note No. 3: The available fault current varies at different locations within the system due to the location of sources and system impedances.

Field Evaluated.

An evaluation of nonlisted or modified equipment in the field that is performed by persons or parties acceptable to the authority having jurisdiction. (330, 350)

Informational Note No. 1: The evaluation approval ensures that the equipment meets appropriate codes and standards or is similarly found suitable for a specified purpose.

Informational Note No. 2: See NFPA 791, *Recommended Practice and Procedures for Unlabeled Electrical Equipment Evaluation*, for additional information on recommended practices and procedures for the field evaluation of nonlisted equipment.

Informational Note No. 3: See NFPA 790, *Standard for Competency of Third-Party Field Evaluation Bodies*, for requirements on evaluating third-party entities.

Fitting.

An accessory such as a locknut, bushing, or other part of a wiring system that is intended primarily to perform a mechanical rather than an electrical function. [**70:**100]

Fuse.

An overcurrent protective device with a circuit-opening fusible part that is heated and severed by the passage of overcurrent through it.

Informational Note: A fuse comprises all the parts that form a unit capable of performing the prescribed functions. It may or may not be the complete device necessary to connect it into an electrical circuit.

Ground.

The earth. [**70:**100]

Ground Fault.

An unintentional, electrically conductive connection between an ungrounded conductor of an electrical circuit and the normally non–current-carrying conductors, metallic enclosures, metallic raceways, metallic equipment, or earth. [**70:**100]

Ground Stick.

A device that is used to ensure that the capacitor is discharged by applying it to all terminals of the capacitor element. (360)

> Informational Note: This is also called a ground hook and could incorporate power-rated discharge resistors for high-energy applications.

Grounded Conductor.

A system or circuit conductor that is intentionally grounded. [**70:**100]

Grounded (Grounding).

Connected (connecting) to ground or to a conductive body that extends the ground connection. [**70:**100]

Grounded, Solidly. (Solidly Grounded)

Connected to ground without inserting any resistor or impedance device. [**70:**100]

Ground-Fault Circuit Interrupter (GFCI).

A device intended for the protection of personnel that functions to de-energize a circuit or portion thereof within an established period of time when a current to ground exceeds the values established for a Class A device. [**70:**100]

> Informational Note: See UL 943, *Ground-Fault Circuit Interrupters*, for further information. Class A ground-fault circuit interrupters trip when the ground-fault current is 6 mA or higher and does not trip when the ground-fault current is less than 4 mA.

Grounding Conductor, Equipment (EGC). (Equipment Grounding Conductor)

The conductive path(s) that provides a ground-fault current path and connects normally non-current-carrying metal parts of equipment together and to the system grounded conductor or to the grounding electrode conductor, or both. [**70:**100]

> Informational Note No. 1: It is recognized that the equipment grounding conductor also performs bonding.
>
> Informational Note No. 2: See 250.118 of *NFPA 70*, *National Electrical Code*, for a list of acceptable equipment grounding conductors.

Grounding Electrode.

A conducting object through which a direct connection to earth is established. [**70:**100]

Grounding Electrode Conductor.

A conductor used to connect the system grounded conductor or the equipment to a grounding electrode or to a point on the grounding electrode system. [**70:**100]

Grounding, Hard (Low-Z). (Hard Grounding)

The practice of discharging a capacitor through a low impedance, also called Low-Z (impedance) grounding. (360)

Grounding, Soft (High-Z). (Soft Grounding)

The practice of connecting a capacitor to ground through a power resistor to avoid the hazards related with hard grounding. (360)

Guarded.

Covered, shielded, fenced, enclosed, or otherwise protected by means of suitable covers, casings, barriers, rails, screens, mats, or platforms to remove the likelihood of approach or contact by persons or objects to a point of danger. [**70:**100]

Hazard.

A source of possible injury or damage to health.

Hazard, Arc Blast (as applied to capacitors). (Arc Blast Hazard)

A source of possible injury or damage to health from the energy deposited into acoustical shock wave and high-velocity shrapnel. (360)

Hazard, Arc Flash. (Arc Flash Hazard)

A source of possible injury or damage to health associated with the release of energy caused by an electric arc.

> Informational Note No. 1: See 110.2(B) Exception No. 1 for further information regarding normal operation. The likelihood of occurrence of an arc flash incident increases when energized electrical conductors or circuit parts are exposed or when they are within equipment in a guarded or enclosed condition, provided a person is interacting with the equipment in such a manner that could cause an electric arc. An arc flash incident is not likely to occur under normal operating conditions when enclosed energized equipment has been properly installed and maintained.
>
> Informational Note No. 2: See Table 130.5(C) for examples of tasks that increase the likelihood of an arc flash incident occurring.

Hazard, Electric Shock. (Electric Shock Hazard)

A source of possible injury or damage to health associated with current through the body caused by contact or approach to exposed energized electrical conductors or circuit parts.

> Informational Note: Injury and damage to health resulting from electric shock is dependent on the magnitude of the electrical current, the power source frequency (e.g., 60 Hz, 50 Hz, dc), and the path and time duration of current through the body. The physiological reaction ranges from perception, muscular contractions, inability to let go, ventricular fibrillation, tissue burns, and death.

Hazard, Electrical. (Electrical Hazard)

A dangerous condition such that contact or equipment failure can result in electric shock, arc flash burn, thermal burn, or arc blast injury.

> Informational Note: Class 2 power supplies, listed low voltage lighting systems, and similar sources are examples of circuits or systems that are not considered an electrical hazard.

Hazardous.

Involving exposure to at least one hazard.

Hybrid SuperCapacitor (HSC).

Formerly known as a Li-ion capacitor (LiC) these cells (typically packaged into higher voltage modules with internal parallel cell packs connected in series, and usually with a cell balancing circuit board) consist of a cathode made of graphite intercalated with Lithium ions (similar to most Li-ion cells) and an anode made of activated carbon (both plates of an EDLC are made of activated carbon). They combine the high power attributes of EDLCs with better energy density characteristics that begin to approach the energy density characteristics of some batteries.

Incident Energy.

The amount of thermal energy impressed on a surface, a certain distance from the source, generated during an electrical arc event. Incident energy is typically expressed in calories per square centimeter (cal/cm^2).

Incident Energy Analysis.

A component of an arc flash risk assessment used to predict the incident energy of an arc flash for a specified set of conditions.

Insulated.

Separated from other conducting surfaces by a dielectric (including air space) offering a high resistance to the passage of current.

> Informational Note: When an object is said to be insulated, it is understood to be insulated for the conditions to which it is normally subject. Otherwise, it is, within the purpose of these rules, uninsulated.

Interrupter Switch.

A switch capable of making, carrying, and interrupting specified currents.

Interrupting Rating.

The highest current at rated voltage that a device is identified to interrupt under standard test conditions. [**70:**100]

> Informational Note: Equipment intended to interrupt current at other than fault levels may have its interrupting rating implied in other ratings, such as horsepower or locked rotor current.

Isolated (as applied to location).

Not readily accessible to persons unless special means for access are used. [**70:**100]

Labeled.

Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Laboratory.

A building, space, room, or group of rooms intended to serve activities involving procedures for investigation, diagnostics, product testing, or use of custom or special electrical components, systems, or equipment. (350)

Laser.

A device that produces radiant energy at wavelengths between 180 nm (nanometer) and 1 mm (millimeter) predominantly by controlled stimulated emission. Laser radiation can be highly coherent temporally, spatially, or both. (330)

Laser Energy Source.

Any device intended for use in conjunction with a laser to supply energy for the excitation of electrons, ions, or molecules. (330)

Laser Radiation.

All electromagnetic radiation emitted by a laser or laser system between 180 nm (nanometers) and 1 mm (millimeters) that is produced as a result of a controlled stimulated emission. (330)

Laser System.

A laser in combination with an appropriate laser energy source with or without additional incorporated components. (330)

Listed.

Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets appropriate designated standards or has been tested and found suitable for a specified purpose.

> Informational Note: The means for identifying listed equipment may vary for each organization concerned with product evaluation; some organizations do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

Luminaire.

A complete lighting unit consisting of a light source, such as a lamp or lamps, together with the parts designed to position the light source and connect it to the power supply. It may also include parts to protect the light source or the ballast or to distribute the light. A lampholder itself is not a luminaire. [**70:**100]

Maintenance, Condition of. (Condition of Maintenance)

The state of the electrical equipment considering the manufacturers' instructions, manufacturers' recommendations, and applicable industry codes, standards, and recommended practices.

Motor Control Center.

An assembly of one or more enclosed sections having a common power bus and principally containing motor control units. [**70:**100]

Outlet.

A point on the wiring system at which current is taken to supply utilization equipment. [**70:**100]

Overcurrent.

Any current in excess of the rated current of equipment or the ampacity of a conductor. It may result from overload, short circuit, or ground fault. [**70:**100]

> Informational Note: A current in excess of rating may be accommodated by certain equipment and conductors for a given set of conditions. Therefore, the rules for overcurrent protection are specific for particular situations.

Overload.

Operation of equipment in excess of normal, full-load rating, or of a conductor in excess of rated ampacity that, when it persists for a sufficient length of time, would cause damage or dangerous overheating. A fault, such as a short circuit or ground fault, is not an overload. [**70:**100]

Panelboard.

A single panel or group of panel units designed for assembly in the form of a single panel, including buses and automatic overcurrent devices, and equipped with or without switches for the control of light, heat, or power circuits; designed to be placed in a cabinet or cutout box placed in or against a wall, partition, or other support; and accessible only from the front. [**70:**100]

Pilot Cell.

One or more cells chosen to represent the operating parameters of the entire battery (sometimes called "temperature reference" cell). (320)

Premises Wiring (System).

Interior and exterior wiring, including power, lighting, control, and signal circuit wiring together with all their associated hardware, fittings, and wiring devices, both permanently and temporarily installed. This includes: (a) wiring from the service point or power source to the outlets; or (b) wiring from and including the power source to the outlets where there is no service point.

Such wiring does not include wiring internal to appliances, luminaires, motors, controllers, motor control centers, and similar equipment. [**70:**100]

> Informational Note: Power sources include, but are not limited to, interconnected or stand-alone batteries, solar photovoltaic systems, other distributed generation systems, or generators.

Protective Barrier.

Prevents user access to a hazardous voltage, current, or stored energy area. (330)

Protector.

A glove or mitten designed to be worn over rubber insulating gloves.

Qualified Person.

One who has demonstrated skills and knowledge related to the construction and operation of electrical equipment and installations and has received safety training to identify the hazards and reduce the associated risk.

Raceway.

An enclosed channel of metal or nonmetallic materials designed expressly for holding wires, cables, or busbars, with additional functions as permitted in this standard. [**70:**100]

Radiation, Ionizing. (Ionizing Radiation)

Radiation consisting of particles, X-rays, or gamma rays with sufficient energy to cause ionization of atoms or molecules through which it passes. (340)

Radiation, Nonionizing. (Nonionizing Radiation)

Static electric and magnetic (0 to 1 Hz), sub radiofrequency (1Hz to 3 kHz), radiofrequency (3 kHz to 300 GHz) fields, and infrared, visible light, and near ultraviolet (near UV) that cannot ionize an atom or molecule. (340)

Receptacle.

A contact device installed at the outlet for the connection of an attachment plug, or for the direct connection of electrical utilization equipment designed to mate with the corresponding contact device. A single receptacle is a single contact device with no other contact device on the same yoke. A multiple receptacle is two or more contact devices on the same yoke. [**70:**100]

Research and Development (R&D).

An activity in an installation specifically designated for research or development conducted with custom or special electrical equipment. (350)

Resistor, Bleeder. (Bleeder Resistor)

A resistor or resistor network connected in parallel with a capacitor’s terminals that dissipates the stored energy after power has been disconnected. (360)

Risk.

A combination of the likelihood of occurrence of injury or damage to health and the severity of injury or damage to health that results from a hazard.

Risk Assessment.

An overall process that identifies hazards, estimates the likelihood of occurrence of injury or damage to health, estimates the potential severity of injury or damage to health, and determines if protective measures are required.

> Informational Note: As used in this standard, *arc flash risk assessment* and *electric shock risk assessment* are types of risk assessments.

Safeguarding.

Safeguards for personnel include the consistent administrative enforcement of safe work practices. Safeguards include training in safe work practices, cell line design, safety equipment, PPE, operating procedures, and work checklists. (310)

Service Drop.

The overhead conductors between the utility electric supply system and the service point. [**70:**100]

Service Lateral.

The underground conductors between the utility electric supply system and the service point. [**70:**100]

Service Point.

The point of connection between the facilities of the serving utility and the premises wiring. [**70:**100]

> Informational Note: The service point can be described as the point of demarcation between where the serving utility ends and the premises wiring begins. The serving utility generally specifies the location of the service point based on the conditions of service.

Short-Circuit Current, Prospective. (Prospective Short-Circuit Current)

The highest level of fault current that could theoretically occur at a point on a circuit. This is the fault current that can flow in the event of a zero impedance short circuit and if no protection devices operate. (320)

> Informational Note: Some batteries have built-in management devices to limit maximum short-circuit current. The determination of the prospective short-circuit current for these batteries assumes that the internal battery management system protection devices are operable.

Short-Circuit Current Rating.

The prospective symmetrical fault current at a nominal voltage to which an apparatus or system is able to be connected without sustaining damage exceeding defined acceptance criteria. [**70:**100]

Single-Line Diagram.

A diagram that shows, by means of single lines and graphic symbols, the course of an electric circuit or system of circuits and the component devices or parts used in the circuit or system.

Special Permission.

The written consent of the authority having jurisdiction. [**70:**100]

Step Potential.

A ground potential gradient difference that can cause current flow from foot to foot through the body.

Structure.

That which is built or constructed. [**70:**100]

Switch, Isolating. (Isolating Switch)

A switch intended for isolating an electric circuit from the source of power. It has no interrupting rating, and it is intended to be operated only after the circuit has been opened by some other means. [**70:**100]

Switchboard.

A large single panel, frame, or assembly of panels on which are mounted on the face, back, or both, switches, overcurrent and other protective devices, buses, and usually instruments. These assemblies are generally accessible from the rear as well as from the front and are not intended to be installed in cabinets. [**70:**100]

Switchgear, Metal-Clad. (Metal-Clad Switchgear)

A switchgear assembly completely enclosed on all sides and top with sheet metal, having drawout switching and interrupting devices, and all live parts enclosed within grounded metal compartments.

Switchgear, Metal-Enclosed. (Metal-Enclosed Switchgear)

A switchgear assembly completely enclosed on all sides and top with sheet metal (except for ventilating openings and inspection windows), containing primary power circuit switching, interrupting devices, or both, with buses and connections. This assembly may include control and auxiliary devices. Access to the interior of the enclosure is provided by doors, removable covers, or both. Metal-enclosed switchgear is available in non-arc-resistant or arc-resistant constructions.

Switching Device.

A device designed to close, open, or both, one or more electric circuits.

Time Constant.

The time it takes for voltage to drop by ~63 percent (1/e) during discharge. (360)

Touch Potential.

A ground potential gradient difference that can cause current flow from hand to hand, hand to foot, or another path, other than foot to foot, through the body.

Ungrounded.

Not connected to ground or to a conductive body that extends the ground connection. [**70:**100]

Unqualified Person.

A person who is not a qualified person.

Utilization Equipment.

Equipment that utilizes electric energy for electronic, electromechanical, chemical, heating, lighting, or similar purposes. [**70:**100]

Voltage (of a Circuit).

The greatest root-mean-square (rms) (effective) difference of potential between any two conductors of the circuit concerned. [**70:**100]

> Informational Note: Some systems, such as three-phase 4-wire, single-phase 3-wire, and 3-wire direct-current, may have various circuits of various voltages.

Voltage, Nominal. (Nominal Voltage)

A nominal value assigned to a circuit or system for the purpose of conveniently designating its voltage class (e.g., 120/240 volts, 480Y/277 volts, 600 volts). [**70:**100]

> Informational Note No. 1: The actual voltage at which a circuit operates can vary from the nominal within a range that permits satisfactory operation of equipment.
>
> Informational Note No. 2: See ANSI C84.1, *Electric Power Systems and Equipment — Voltage Ratings (60 Hz)*.

Voltage, Nominal (as applied to cell or battery). (Nominal Voltage)

The value assigned to a cell or battery of a given voltage class for the purpose of convenient designation; the operating voltage of the cell or system may vary above or below this value. (320)

Informational Note: The most common cell voltages are 2.0 volts per cell for lead-acid batteries, 1.2 volts per cell for alkali batteries, and 3.2 to 3.8 volts per cell for Li-ion batteries. Nominal voltages might vary with different chemistries.

Working Distance.

The distance between a person's face and chest area and a prospective arc source.

Informational Note: See 130.5(G) for further information. Incident energy increases as the distance from the arc source decreases.

Working On (energized electrical conductors or circuit parts).

Intentionally coming in contact with energized electrical conductors or circuit parts with the hands, feet, or other body parts, with tools, probes, or with test equipment, regardless of the personal protective equipment (PPE) a person is wearing.

Informational Note: Examples of "working on" can include but are not limited to *diagnostic testing* (such as taking readings or measurements of electrical equipment, conductors, or circuit parts with approved test equipment that does not require making any physical change to the electrical equipment, conductors, or circuit parts) and *repair* or physical alteration of electrical equipment, conductors, or circuit parts (such as making or tightening connections, removing or replacing components, etc.).

Statement of Problem and Substantiation for Public Input

This is a definition in support of newly proposed Article 390 (see PI-125) on these devices. If PI-125 is accepted, this definition should appear here.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 125-NFPA 70E-2024 [New Article after 300]	new proposed article on HSCs
Public Input No. 125-NFPA 70E-2024 [New Article after 300]	
Public Input No. 127-NFPA 70E-2024 [Annex S]	

Submitter Information Verification

Submitter Full Name: Curtis Ashton
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Submittal Date: Sat Jun 01 22:45:14 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: The definition is not needed since the term is not used within the standard.

Public Input No. 192-NFPA 70E-2024 [New Article after 100]

TITLE OF NEW CONTENT

Shorting, Hard (Low-Z) (Hard Shorting) - The practice of discharging a capacitor from terminal to terminal through a low impedance, also called Low-Z (impedance). (360)

Shorting, Soft (High-Z). (Soft Shorting) - The practice of discharging a capacitor from terminal to terminal through a power resistor to avoid the hazards related with hard shorting, also called High-Z (impedance). (360)

Statement of Problem and Substantiation for Public Input

Although shorting capacitor terminals was covered in Annex R, the definitions of hard and soft shorting were not given. This is necessary for safing procedures in both Capacitors and super capacitors.

Submitter Information Verification

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Submittal Date: Mon Jun 03 18:40:29 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: The proposed definitions are not necessary as the terms are not used in the Standard and adding them would potentially set up conflicts with the defined terms of hard grounding and soft grounding.

Public Input No. 194-NFPA 70E-2024 [New Article after 100]

Shorting Stick
A device that is used to discharge a capacitor from terminal to terminal. (360)

Statement of Problem and Substantiation for Public Input

Although the shorting process was used in Annex R, it was not defined. It is a companion procedure to grounding, and is necessary when the capacitor is isolated or floating with respect to ground.

Submitter Information Verification

Submitter Full Name: Lloyd Gordon
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Submittal Date: Mon Jun 03 18:47:33 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-19-NFPA 70E-2024
Statement: This adds a clear, concise definition for shorting stick to improve understanding of the term used in Chapter 3 and Annex R.

Public Input No. 241-NFPA 70E-2024 [New Article after 100]

Hazard, Thermal (Thermal Hazard)

A source of possible injury or damage to health associated with current through conductive tools or jewelry in contact with the body from heating of the metal resulting in burns to the skin.

Statement of Problem and Substantiation for Public Input

The term "thermal hazard" is used in current Article 320.3(A)(2)Battery Risk Assessment, in Article 360.4(B)(2) Thermal Hazard risk assessment, and in Annex F, Figure F.7 - thermal hazard. In addition to its current use additional PIs will be submitted to further expand on Thermal Risk Assessment for all DC sources.
This term, currently in use, and expanding in use, is currently not defined in the NFPA 70E.

Submitter Information Verification

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Submittal Date: Tue Jun 04 14:20:17 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-20-NFPA 70E-2024
Statement: This adds a clear, concise definition for contact thermal hazard to improve understanding of the term.

Public Input No. 97-NFPA 70E-2024 [New Article after 100]

TITLE OF NEW CONTENT

Industrial Installation, Supervised. (Supervised Industrial Installation)

The industrial portions of a facility where all of the following conditions are met:

Conditions of maintenance and engineering supervision ensure that only qualified persons monitor and service the system.

The premises wiring system has 2500 kVA or greater of load used in industrial process(es), manufacturing activities, or both, as calculated in accordance with Article 220.

The premises has at least one service or feeder that is more than 150 volts to ground and more than 300 volts phase-to-phase.

This definition excludes installations in buildings used by the industrial facility for offices, warehouses, garages, machine shops, and recreational facilities that are not an integral part of the industrial plant, substation, or control center.

Statement of Problem and Substantiation for Public Input

The term "supervised industrial installations" is not defined in NFPA 70E. The proposed definition (from NFPA 70E) will provide a definition of the term.

The presently undefined term is used in:
130.5 (H) Equipment Labeling Exception No. 2: In supervised industrial installations...

Submitter Information Verification

Submitter Full Name: k James Phillips Jr
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City:
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Submittal Date: Mon May 27 04:58:13 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: The term “supervised industrial installation” is only used in 130.5 (H) Exception No. 2. The provisions of the exception outlines the applicable installations and the proposed definition extracted from the NEC is not necessary.

Public Input No. 249-NFPA 70E-2024 [Definition: Barricade.]

Barricade.

A physical obstruction such as tapes, cones, or A-frame-type wood or metal structures intended to provide a warning and to limit access. A barricade is a temporary method used during work to control access by an administrative control.

Statement of Problem and Substantiation for Public Input

The definitions of barrier and barricade are so similar, the worker may be confused.
This clarifies the type of control.

Submitter Information Verification

Submitter Full Name: Lloyd Gordon
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Submittal Date: Tue Jun 04 15:11:32 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: The existing definition is clear and broad enough to encompass multiple methods to provide warning and limit access. The additional proposed text to categorize a barricade as an administrative control is not necessary.

Public Input No. 248-NFPA 70E-2024 [Definition: Barrier.]

Barrier.

A physical obstruction that is intended to prevent contact with equipment or energized electrical conductors and circuit parts. A barrier is a part of the design and is an engineering control to prevent injury.

Statement of Problem and Substantiation for Public Input

The definitions of barrier and barricade are so similar, the worker may be confused. This clarifies the type of control.

Submitter Information Verification

Submitter Full Name: Lloyd Gordon
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Submittal Date: Tue Jun 04 15:08:22 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: The existing definition is clear and broad enough to encompass multiple methods intended to prevent contact with equipment or energized electrical conductors or circuit parts. The additional proposed text to categorize a barrier as an engineering control is not necessary.

Public Input No. 163-NFPA 70E-2024 [Definition: Competent Person.]

~~**Competent Person**~~ **Qualified Person, Research Laboratory (Research laboratory Qualified Person) .**

A person ~~who meets all the requirements of~~ ***qualified person*** ~~, and who, in addition, is~~ who is responsible for all work activities or safety procedures related to custom or special equipment and has detailed knowledge regarding the exposure to electrical hazards, the appropriate control methods to reduce the risk associated with those hazards, and the implementation of those methods. (350)

Statement of Problem and Substantiation for Public Input

The current definition of "competent person" includes a requirement that a competent person also be qualified. This is a violation of the NFPA Manual of Style for Technical Committee Documents, October 2023 Edition; section 7.2.3: "Definitions shall not contain requirements"

The term Competent Person is well established in the safety world and defined by OSHA in CFR 29 1926.32(f). Defining this term in NFPA 70E has the potential to create confusion amongst safety professionals when writing safety programs and procedures as they must use the term competent person for 2 different applications. Additionally, when implementing assured equipment grounding programs in accordance with Section 110.8(C) of 2024 NFPA 70E another conflict arises as CFR 29 1926.404(b)(1)(iii)(B) requires a competent person implement the assured grounding program.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 166-NFPA 70E-2024 [Section No. 350.5 [Excluding any Sub-Sections]]	

Submitter Information Verification

Submitter Full Name: Jeff Noren
Organization: NECA
Affiliation: NECA
Street Address:
City:
State:
Zip:
Submittal Date: Mon Jun 03 13:24:02 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-5-NFPA 70E-2024

Statement: The definition of competent person is deleted to correlate with other actions that removed the term from the standard.

Public Input No. 41-NFPA 70E-2023 [Definition: Competent Person.]

~~**Competent Person.**~~

~~A person who meets all the requirements of~~ *qualified person* ~~, and who, in addition, is responsible for all work activities or safety procedures related to custom or special equipment and has detailed knowledge regarding the exposure to electrical hazards, the appropriate control methods to reduce the risk associated with those hazards, and the implementation of those methods. (350)~~

Statement of Problem and Substantiation for Public Input

While only applicable to Article 350 per its parenthetical qualifier, this definition needs to be removed since its use differs so significantly from its common use in multiple OSHA standards both 29 CFR Parts 1910 and 1926. For example, per 1926.32(m), "[c]ompetent person means one who is capable of identifying existing and predictable hazards in the surroundings or working conditions which are unsanitary, hazardous, or dangerous to employees, and who has authorization to take prompt corrective measures to eliminate them" and in 1910.399 where competent person is defined as "[o]ne who is capable of identifying existing and predictable hazards in the surroundings or working conditions that are unsanitary, hazardous, or dangerous to employees and who has authorization to take prompt corrective measures to eliminate them." Per the scope of Article 100 in NFPA 70E, in part, Article 100 "...is not intended to include commonly defined general terms or commonly defined technical terms from related codes and standards." Competent person already a commonly defined general term or commonly defined technical terms from related codes and standards. Accordingly, a different and conflicting definition from that of a well-established commonly defined general term or commonly defined technical term from related codes and standards is not appropriate in NFPA 70E.

Submitter Information Verification

Submitter Full Name: Palmer Hickman
Organization: Electrical Training Alliance
Street Address:
City:
State:
Zip:

Submittal Date: Wed Dec 20 13:17:58 EST 2023
Committee: EEW-AAA

Committee Statement

Resolution: FR-5-NFPA 70E-2024
Statement: The definition of competent person is deleted to correlate with other actions that removed the term from the standard.

Public Input No. 42-NFPA 70E-2023 [Definition: Electrical Safety.]

~~**Electrical Safety.**~~

~~Identifying hazards associated with the use of electrical energy and taking precautions to reduce the risk associated with those hazards.~~

Statement of Problem and Substantiation for Public Input

Delete this definition as it is inaccurate and incomplete for use as a defined term as it is presently defined here. For example, in the context of NFPA 70E, Standard for "Electrical Safety" in the Workplace, the purpose of NFPA 70E, Standard for "Electrical Safety" in the Workplace in 90.2 stating that "[t]he purpose of this standard is to provide a practical safe working area for employees relative to the hazards arising from the use of electricity" and the presently defined term "electrical safety" which is "[i]dentifying hazards associated with the use of electrical energy and taking precautions to reduce the risk associated with those hazards" conflict and do not correlate. Further, per the Article 100 scope in part, these "definitions are not intended to include commonly defined general terms or commonly defined technical terms from related codes and standards." Accordingly, this definition needs to be deleted.

Submitter Information Verification

Submitter Full Name: Palmer Hickman
Organization: Electrical Training Alliance
Street Address:
City:
State:
Zip:

Submittal Date: Wed Dec 20 13:44:53 EST 2023
Committee: EEW-AAA

Committee Statement

Resolution: FR-6-NFPA 70E-2024
Statement: The definition is deleted as it does not correlate with other sections of the standard.

Public Input No. 49-NFPA 70E-2024 [Definition: Electrically Safe Work Condition.]

Electrically Safe Work Condition.

A state in which an electrical conductor or circuit part has been disconnected from energized parts, locked/tagged in accordance with established standards, tested for the absence of ~~voltage~~ electrical energy , and, if necessary, temporarily grounded for personnel protection.

Statement of Problem and Substantiation for Public Input

NFPA 70E is written to address voltage driven circuits, therefore the requirement to test for voltage. Series Circuits powered with a constant current are still widely used throughout the United States and the world. As presently written 70E is instructing an electrician working on a current powered circuit to measure voltage. Attempting to measure voltage on a current driven circuit could be an unsafe act. Current is measured to determine the proper operation of a current driven circuit and to determine if the circuit is energized. Replacing the term voltage with the term energy solves this problem. Please see documents attached to PI No. 48.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 52-NFPA 70E-2024 [Section No. 120.5(B)(6)]	series circuit
Public Input No. 48-NFPA 70E-2024 [Section No. 120.6]	series circuit
Public Input No. 50-NFPA 70E-2024 [Section No. 110.4(A)(1)]	series circuit
Public Input No. 51-NFPA 70E-2024 [Section No. 110.6(E)]	series circuit
Public Input No. 48-NFPA 70E-2024 [Section No. 120.6]	
Public Input No. 50-NFPA 70E-2024 [Section No. 110.4(A)(1)]	
Public Input No. 51-NFPA 70E-2024 [Section No. 110.6(E)]	
Public Input No. 52-NFPA 70E-2024 [Section No. 120.5(B)(6)]	

Submitter Information Verification

Submitter Full Name: Carl Johnson
Organization: AVCON, Inc.
Affiliation: none
Street Address:
City:
State:
Zip:

Submittal Date: Tue Jan 02 07:25:13 EST 2024
Committee: EEW-AAA

Committee Statement

Resolution: The definition must be interpreted in its entirety to be properly applied. For example, the phrase “disconnecting a conductor or circuit part from energized parts” is also included in

the definition and addresses the concerns of the submitter. The phrase “tested for the absence of voltage” is widely used, understood, and correlates with the provisions found in this standard as well as OSHA and other regulations.

Public Input No. 7-NFPA 70E-2023 [Definition: Electrically Safe Work Condition.]

Electrically Safe Work Condition.

A state in which an electrical conductor or circuit part has been disconnected from energized parts, locked/tagged in accordance with established standards, tested for the absence of voltage, and, if necessary, temporarily grounded for personnel protection.

Informational Note: See 110.2(C) and 120.2 through 120.6 for the requirements to establish and verify an electrically safe work condition.

Statement of Problem and Substantiation for Public Input

An informational note to this definition is added so that the user of NFPA 70E is aware that there is much more involved to create the state of an electrically safe work condition than what is contained in this definition. One would not have eliminated the hazard as contemplated in 110.3(H)(3)(1) and provided as a non-mandatory example of elimination in Table F.3 in Informative Annex F which is considered the most effective method in the hierarchy of risk control methods by meeting what is contained in the definition of electrically safe work condition.

Submitter Information Verification

Submitter Full Name: Palmer Hickman
Organization: Electrical Training Alliance
Street Address:
City:
State:
Zip:

Submittal Date: Thu Aug 24 10:24:39 EDT 2023
Committee: EEW-AAA

Committee Statement

Resolution: FR-7-NFPA 70E-2024
Statement: An informational note raises awareness of the sections that provide the necessary steps to establish and verify an electrically safe work condition.

Public Input No. 43-NFPA 70E-2023 [Definition: Enclosure.]

Enclosure.

The case or housing of apparatus — or the fence or walls surrounding an installation to prevent personnel from unintentionally contacting energized electrical conductors or circuit parts or to protect the equipment from physical damage.

Statement of Problem and Substantiation for Public Input

Delete the hyphen to make it clear that both the case or housing of apparatus or the fence or walls surrounding an installation are to to prevent personnel from unintentionally contacting energized electrical conductors or circuit parts or to protect the equipment from physical damage.

Submitter Information Verification

Submitter Full Name: Palmer Hickman
Organization: Electrical Training Alliance
Street Address:
City:
State:
Zip:

Submittal Date: Wed Dec 20 14:19:59 EST 2023
Committee: EEW-AAA

Committee Statement

Resolution: FR-8-NFPA 70E-2024
Statement: The definition is revised to make it clear that prevention of personnel contact and protection of equipment apply to both apparatus housings as well as the fences or walls of an installation.

Public Input No. 191-NFPA 70E-2024 [Definition: Ground Stick.]

Ground Stick.

A device that is used to ensure that the capacitor is discharged by applying it to all terminals of the capacitor element and to ground . (360)

Informational Note: This is also called a ground hook and could incorporate power-rated discharge resistors for high-energy applications.

Statement of Problem and Substantiation for Public Input

Just applying the ground stick to the capacitor terminals is insufficient, it must also connect them to ground and all terminals connected to ground. Although this is clear in Annex R, it needs to also be in the definition.

Submitter Information Verification

Submitter Full Name: Lloyd Gordon
Organization: Gordon
Street Address:
City:
State:
Zip:

Submittal Date: Mon Jun 03 18:35:51 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-9-NFPA 70E-2024
Statement: The definition is clarified to include “and to ground” to align with the actual application and use of a ground stick.

Public Input No. 129-NFPA 70E-2024 [Definition: Grounding, Soft (High-Z). (Soft Grounding)]

~~**Grounding, Soft (High-Z). (Soft Grounding)**~~ **Capacitor Soft Discharging**

The practice of ~~connecting a capacitor to ground~~ discharging capacitors through a power resistor to avoid the hazards related with ~~hard grounding.~~ short circuiting. Capacitors must either be discharged across their terminals or from their terminals to ground. (360)

Statement of Problem and Substantiation for Public Input

The term soft grounding in itself can create a hazard for some applications of capacitors. Not all capacitors are connected to ground and no discharge will occur if terminals of ungrounded capacitors are grounded. Energy storage systems incorporating supercapacitors could be connected to a Power Conditioning System (PCS) that requires an ungrounded dc storage system. PCS's that are rated 500kW and above commonly require an ungrounded dc bus and an ungrounded delta or wye source. These PCS systems can incorporate capacitors that will store no energy with respect to ground. This proposal is intended to ensure that capacitors are safely discharged whether they are grounded or not.

This proposal has been submitted on behalf of an EDLC task group consisting of Steve Edley, Dave Wright, Troy Brandon, Curtis Ashton, Lloyd Gordon

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 130-NFPA 70E-2024 [Global Input]	Locations where this definition needs to be updated.
Public Input No. 130-NFPA 70E-2024 [Global Input]	

Submitter Information Verification

Submitter Full Name: Steve Edley
Organization: Atlas Power Technologies Inc.
Affiliation: Atlas Power Technologies Inc.
Street Address:
City:
State:
Zip:

Submittal Date: Sun Jun 02 21:04:21 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-10-NFPA 70E-2024

Statement: The definition is modified, and an informational note is added for improved clarity. Not all capacitors are connected to ground and no discharge will occur if terminals of ungrounded capacitors are grounded.

Public Input No. 247-NFPA 70E-2024 [Definition: Hazard, Arc Blast (as applied to capacitors). (...]

Hazard, Arc Blast (as applied to capacitors). (Arc Blast Hazard)

A source of possible injury or damage to health from the energy deposited into an acoustical shock wave ~~and high-velocity shrapnel~~ (supersonic) . (360)

Statement of Problem and Substantiation for Public Input

There is confusion of the acoustic hazards of conventional capacitor arc vs all other dc arcs. Only the conventional capacitor can create a supersonic acoustic wave. The added word helps clarify. We have no threshold or controls for shrapnel, thus, it done not need to be listed. Protection from the supersonic shock wave, primarily by distance, will also protect against any possible shrapnel.

Submitter Information Verification

Submitter Full Name: Lloyd Gordon
Organization: Gordon
Street Address:
City:
State:
Zip:
Submittal Date: Tue Jun 04 15:02:16 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-12-NFPA 70E-2024 Shrapnel may be present during an arc blast hazard.
Statement: The modified definition provides clarity by denoting that only a conventional capacitor can create a supersonic acoustic wave.

Public Input No. 250-NFPA 70E-2024 [Definition: Hazard, Electric Shock. (Electric Shock Hazard)]

Hazard, Electric Shock. (Electric Shock Hazard)

A source of possible injury or damage to health associated with current through the body caused by contact or approach to exposed energized electrical conductors or circuit parts.

Informational Note: Injury and damage to health resulting from electric shock is dependent on the magnitude of the electrical current, the ~~power~~ source frequency (e.g., 60 Hz, 50 Hz, dc, rf), and the path and time duration of current through the body. The physiological reaction ranges from perception, muscular contractions, inability to let go, ventricular fibrillation, tissue burns, and death.

Statement of Problem and Substantiation for Public Input

"power source" is misleading. Many sources of shock would not be considered as a "power" source. need to include more than power frequency (50/60 Hz) and dc. subrf and rf are now well covered in Chapter 3.

Submitter Information Verification

Submitter Full Name: Lloyd Gordon
Organization: Gordon
Street Address:
City:
State:
Zip:
Submittal Date: Tue Jun 04 15:17:10 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-13-NFPA 70E-2024
Statement: The informational note is removed as it is incomplete and does not include all types of electric shock hazards.

Public Input No. 232-NFPA 70E-2024 [Definition: Hazard, Electrical. (Electrical Hazard)]

Hazard, Electrical. (Electrical Hazard)

~~A dangerous condition such that contact or equipment failure can result in electric shock, arc flash burn, thermal burn, or arc blast injury~~ A source of possible injury or damage to health associated with an electric shock hazard, an arc flash hazard, o a conduction thermal hazard .

Informational Note 1 : See Annex K for further information on the associated hazards.

Informational Note 2: Class 2 power supplies, listed low voltage lighting systems, and similar sources are examples of circuits or systems that are not considered an electrical hazard.

Statement of Problem and Substantiation for Public Input

The definition of electrical hazard:
1. Is outdated given current research into arc flash hazards
2. Does not match the related definitions of shock hazard or arc flash hazard
There is a parallel public input to update the content of Annex K.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 233-NFPA 70E-2024 [Annex K]	

Submitter Information Verification

Submitter Full Name: Daniel Roberts
Organization: Electrical Safety Solutions
Affiliation: Self
Street Address:
City:
State:
Zip:
Submittal Date: Tue Jun 04 10:17:33 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-14-NFPA 70E-2024
Statement: The definition is modified to align with the other hazard definitions and to correlate with the new definition of contact thermal hazard.

Public Input No. 251-NFPA 70E-2024 [Definition: Incident Energy.]

Incident Energy.

The amount of thermal energy impressed on a surface per unit area , a certain distance from the source, generated during an electrical arc event. Incident energy (density) is typically expressed in calories per square centimeter (cal/cm^2). The term "incident energy" is commonly used to refer to the incident energy density in arc flash discussions.

Statement of Problem and Substantiation for Public Input

Technically, the term "incident energy" is incorrect. Energy is measure in J or cal. I do not propose to try and change the widespread misuse of this term, but perhaps in the definition we can clarify that arc flash incident energy analysis is actually determining incident energy density at the working distance.

Submitter Information Verification

Submitter Full Name: Lloyd Gordon
Organization: Gordon
Street Address:
City:
State:
Zip:

Submittal Date: Tue Jun 04 15:21:22 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: The current definition is consistent with other standards related to arc flash and is well understood. The addition of the word density is not necessary as the per unit area is included in the units of calories per square centimeter.

Public Input No. 47-NFPA 70E-2023 [Definition: Premises Wiring (System).]

Premises Wiring (System).

Interior and exterior wiring, including power, lighting, control, and signal circuit wiring together with all their associated hardware, fittings, and wiring devices, both permanently and temporarily installed. This ~~includes: (a) wiring~~ includes one of the following:

- Wiring from the service point or power source to the outlets

~~; or (b) wiring~~

-
- Wiring from and including the power source to the outlets where there is no service point

-

-

Such wiring does not include wiring internal to appliances, luminaires, motors, controllers, motor control centers, and similar equipment. [**70:**100]

Informational Note: Power sources include, but are not limited to, interconnected or stand-alone batteries, solar photovoltaic systems, other distributed generation systems, or generators.

Statement of Problem and Substantiation for Public Input

This recommendation is to match the change in the 2023 NEC as this is an extracted definition.

Submitter Information Verification

Submitter Full Name: Palmer Hickman
Organization: Electrical Training Alliance
Street Address:
City:
State:
Zip:

Submittal Date: Wed Dec 20 16:42:17 EST 2023
Committee: EEW-AAA

Committee Statement

Resolution: FR-16-NFPA 70E-2024
Statement: This revision modifies the extracted definition of premises wiring (system) to match the 2023 National Electrical Code verbatim.

Public Input No. 5-NFPA 70E-2023 [Definition: Qualified Person.]

Qualified Person.

One who has ~~demonstrated skills~~ documented demonstration of and knowledge related to the construction and operation of electrical equipment and installations and has received safety training to identify the hazards and reduce the associated risk.

Statement of Problem and Substantiation for Public Input

This Public Input adds the need for qualified persons to have documentation of their training as stated in 110.4(A)(5). This recommendation is to correlate with that provision in 110.4(A)(5). One would not be a qualified person if the "demonstrated skills and knowledge" is not documented per 110.4(A)(5).

Submitter Information Verification

Submitter Full Name: Palmer Hickman
Organization: Electrical Training Alliance
Street Address:
City:
State:
Zip:

Submittal Date: Thu Aug 24 10:13:05 EDT 2023
Committee: EEW-AAA

Committee Statement

Resolution: The proposed additional text is not necessary in the definition. Requirements for documentation already exist in 110.4 and would be redundant here. Definitions are to be descriptive and must not contain requirements.

Public Input No. 6-NFPA 70E-2023 [Definition: Qualified Person.]

Qualified Person.

One who has demonstrated skills and knowledge related to the construction and operation of electrical equipment and installations and has received safety training to identify the hazards and reduce the associated risk.

Informational Note: See 110.4(A)(1) for the training that a qualified person is to be trained and knowledgeable in.

Statement of Problem and Substantiation for Public Input

An informational note is added to the definition of qualified person to inform users of NFPA 70E that there are requirements that one must meet to be considered a qualified person that are more stringent than what is addressed in the definition of qualified person.

Submitter Information Verification

Submitter Full Name: Palmer Hickman
Organization: Electrical Training Alliance
Street Address:
City:
State:
Zip:

Submittal Date: Thu Aug 24 10:18:22 EDT 2023
Committee: EEW-AAA

Committee Statement

Resolution: An informational note regarding the section or sections that specify the training requirements for a qualified person is unnecessary. It is understood that there will be prescribed training requirements for a qualified person – it is implied in the definition. Further, there are other requirements related to a qualified person throughout the standard.

Public Input No. 237-NFPA 70E-2024 [Definition: Risk Assessment.]

Risk Assessment.

An overall process that identifies hazards, determines the likelihood of exposure to identified hazards, estimates the likelihood of occurrence of injury or damage to health, estimates the potential severity of injury or damage to health, ~~and~~ determines if protective measures are required, and assesses the effectiveness of selected protective measures .

Informational Note: As used in this standard, *arc flash risk assessment* and *electric shock risk assessment* are types of risk assessments.

Statement of Problem and Substantiation for Public Input

This proposal serves two purposes:

1. It aligns with Public Input No. 235
2. The current definition may be interpreted that the initial selection of protective measures may achieve the level of safety desired. OSHA regulations and NFPA 70E requirements provide minimum protective measures. The additional text can help users ecognizes that the initial selection of protective measures may have residual risk that may be further reduced.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 235-NFPA 70E-2024 [Definition: Risk.]	

Submitter Information Verification

Submitter Full Name: H Floyd
Organization: Electrical Safety Group Inc
Street Address:
City:
State:
Zip:

Submittal Date: Tue Jun 04 11:56:12 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: The addition of “likelihood of exposure to identified hazards” does not add clarity to the definition as the concept of exposure is already addressed by the estimate of likelihood of occurrence of injury or damage to health. A risk assessment does not include determining the effectiveness of the selected protective measures. That is the function of the “monitor and review” step in risk management. See Annex F.1 Introduction to Risk Management and Figure F.1 Risk Management Process.

Public Input No. 235-NFPA 70E-2024 [Definition: Risk.]

Risk.

A combination of the likelihood of ~~occurrence of injury or damage to health~~ exposure to a hazard and the severity of injury or damage to health that ~~results~~ rmay result from exposure to a hazard.

Statement of Problem and Substantiation for Public Input

The current definition of Risk in NFPA 70E includes the likelihood of injury or damage to health. OSHA and safety & health standards, including ANSI/ASSP Z10-2019 and ISO 45001-2018, use "likelihood of exposure..". Exposure to a hazard or hazardous event precedes an injury and the OSHA definition emphasizes controlling exposure. This proposal better aligns the NFPA 70E definition with the definition provided by OSHA (OSHA publication 3885, page 19) and occupational safety and health management standards ANSI/ASSP Z10 and ISO 45001.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 237-NFPA 70E-2024 [Definition: Risk Assessment.]	

Submitter Information Verification

Submitter Full Name: H Floyd
Organization: Electrical Safety Group Inc
Street Address:
City:
State:
Zip:

Submittal Date: Tue Jun 04 11:22:05 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: The proposed revision does not add clarity to the existing definition as it simply reorganizes and repeats what is already succinctly stated, that is: both the “likelihood of the occurrence of injury or damage to health and the severity of injury or damage to health results from a hazard.” The concept of the likelihood of occurrence of injury or damage to health is addressed in Annex F, Figure F.6.

Public Input No. 46-NFPA 70E-2023 [Definition: Safeguarding.]

~~Safeguarding~~ **Safeguards for Personnel** .

~~Safeguards for personnel include the consistent~~ Consistent administrative enforcement of safe work ~~practices. Safeguards~~ practices which can include training in safe work practices, cell line design, safety equipment, PPE, operating procedures, and work checklists. (310)

Statement of Problem and Substantiation for Public Input

This recommendation is to both change the tense of the word being defined to the correct tense that correlates with the definition as well as comply with the NEC Style Manual. There is no need to repeat the term being defined in the definition. In fact, it is prohibited by the NEC Style Manual. See 2.1.2.5 which states, in part, that definitions "shall not contain the term that is being defined" and that definitions shall not contain requirements or recommendations." The word "can" was inserted so that the definition contains examples rather than a finite list which makes it a requirement.

Submitter Information Verification

Submitter Full Name: Palmer Hickman
Organization: Electrical Training Alliance
Street Address:
City:
State:
Zip:

Submittal Date: Wed Dec 20 16:19:57 EST 2023
Committee: EEW-AAA

Committee Statement

Resolution: FR-17-NFPA 70E-2024
Statement: The term and description for “safeguarding” is deleted as it not necessary to define commonly defined terms or phrases. The existing definition does not meet the NEC Style Manual as it only provides a list of examples.

Public Input No. 164-NFPA 70E-2024 [Definition: Unqualified Person.]

Unqualified Person.

~~A person who is not a qualified person~~

A person whose job duties may present risk of injury due to exposure to electrical hazards that have little or no experience with, or training in recognizing and protection from the hazards .

Statement of Problem and Substantiation for Public Input

The existing definition for an Unqualified Person says what that person is not, but does not say what that person is. The proposed text better clarifies what that person is.

Submitter Information Verification

Submitter Full Name: David Pace
Organization: Olin Corporation
Affiliation: Self
Street Address:
City:
State:
Zip:

Submittal Date: Mon Jun 03 13:31:12 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: The proposed revision does not improve the clarity of the Standard. An unqualified person must be trained to recognize job task associated hazards, but not necessarily to the same level of a qualified person.

Public Input No. 252-NFPA 70E-2024 [Definition: Voltage (of a Circuit).]

Voltage (of a Circuit).

The greatest root-mean-square (rms) (effective) difference of potential between any two conductors of the ac circuit concerned, or the greatest dc difference of potential between any two conductors of the dc circuit . [**70:**100]

Informational Note: Some systems, such as three-phase 4-wire, single-phase 3-wire, and 3-wire direct-current, may have various circuits of various voltages.

Statement of Problem and Substantiation for Public Input

The current definition ignores dc circuits, which have now become an important part of 70E. The "greatest difference in potential" is very applicable to ungrounded battery and PV systems where the system voltage is the greatest value from positive to negative terminals.

Submitter Information Verification

Submitter Full Name: Lloyd Gordon
Organization: Gordon
Street Address:
City:
State:
Zip:

Submittal Date: Tue Jun 04 15:27:56 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: The definition is accurate as stated. The rms value of a dc circuit is equal to the dc voltage.

Public Input No. 45-NFPA 70E-2023 [Definition: Working Distance.]

Working Distance.

The distance between a person's face ~~and chest~~ or chest area and a prospective arc source, whichever is the lesser distance .

Informational Note: See 130.5(G) for further information. Incident energy increases as the distance from the arc source decreases.

Statement of Problem and Substantiation for Public Input

The word "and" is replaced with "or" to recognize that the person's face may not always be the same distance from a prospective arc source as the chest area. Working distance must recognize this with the distance defined as the lesser distance when the face and chest area are not the same distance from the prospective arc source.

Submitter Information Verification

Submitter Full Name: Palmer Hickman
Organization: Electrical Training Alliance
Street Address:
City:
State:
Zip:

Submittal Date: Wed Dec 20 15:41:52 EST 2023
Committee: EEW-AAA

Committee Statement

Resolution: The distance of the face and chest from prospective arc sources is the same and therefore does not need to be differentiated in estimating incident energy.

Public Input No. 91-NFPA 70E-2024 [New Definition after Definition: Automatic.]

TITLE OF NEW CONTENT

Avoid Contact

Additional Proposed Changes

File Name	Description	Approved
PPE_Required_for_Low_Voltage_Testing.pdf	OSHA Letter of Interpretation June 22, 1998	

Statement of Problem and Substantiation for Public Input

Please define the term "Avoid Contact" as stated in tables 130.4(E)(a) and 130.4(E)(b). This is ambiguous and often confusing. Understanding this shock protection boundary is critical when exposed to levels such as 120-volts. NFPA 70E Annex K.1 states that 40% percent of electrical incidents involve 250-volts or less and were indicative of a misperception of electrical safety as only a high voltage issue. A better understanding of what is meant by avoiding contact to these levels of voltage may help to reduce these incidents. OSHA states in a letter of interpretation dated June 22, 1998, asking for clarification concerning the use of personal protective equipment when working on energized 120- or 240-volt equipment. Whether the probes are designed so that the employee's hand can slip off the end of the insulated handle; and 2. Whether there are other exposed energized parts that the employee's hand might contact during testing. If either of these conditions are present, the use of rubber insulating gloves or other electrical protective equipment would be warranted. The OSHA letter clarifies that if inadvertent contact with voltages as listed in tables 130.4(E)(a) and 130.4(E)(b) could be made PPE would need to be worn.

Submitter Information Verification

Submitter Full Name: Brian Hall
Organization: Rozel LLC
Affiliation: Director of Training
Street Address:
City:
State:
Zip:

Submittal Date: Fri May 24 09:03:57 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: This public input does not contain wording to be added, revised (and how revised), or deleted. See section 4.3.4 of the Regulations Governing the Development of NFPA Standards for public input contents.

Standard Interpretations / Training and PPE for employees performing tests on equipment.

- **Standard Number:** 1910.333(a)(1) ; 1910.335(a)(2)(i) ; 1910.331(a) ; 1910.334(c)(1)

OSHA requirements are set by statute, standards and regulations. Our interpretation letters explain these requirements and how they apply to particular circumstances, but they cannot create additional employer obligations. This letter constitutes OSHA's interpretation of the requirements discussed. Note that our enforcement guidance may be affected by changes to OSHA rules. Also, from time to time we update our guidance in response to new information. To keep apprised of such developments, you can consult OSHA's website at http://www.osha.gov.

June 22, 1998

Ms. Deborah Green
Group Environmental & Safety Engineer
PMI Food Equipment Group
World Headquarters
Troy, Ohio 45374

Dear Ms. Green:

This is in response to your letter of April 9, asking for clarification concerning the use of personal protective equipment when working on energized 120- or 240-volt equipment. Specifically, you asked if technicians who service your commercial food equipment (dishwashers, scales, ovens, etc.) in the field are required to wear low-voltage protective gloves. You also asked in your letter, if and under what circumstances low voltage gloves are required when working on energized parts.

29 CFR 1910.333(a)(1) Selection and use of work practices; Deenergized parts states: "Live parts to which an employee may be exposed shall be deenergized before the employee works on or near them, unless the employer can demonstrate that deenergizing introduces additional or increased hazards or is infeasible due to equipment design or operational limitations. Live parts that operate at less than 50 volts to ground need not be deenergized if there will be no increased exposure to electrical burns or to explosion due to electric arcs." Employees may perform testing on energized

parts of equipment, but the equipment may remain energized only as long as necessary to perform the test.

Paragraph (a)(2)(i) of 1910.335 requires employees to use insulated tools or handling equipment if the tools or equipment might contact energized parts. In the case of testing equipment, the probes need to be insulated for the voltage. (See also 1910.334(c).) Paragraph [1910.335(a)(1)(i)] requires employees to use appropriate electrical protective equipment (which includes rubber insulating gloves) when working in areas with potential electrical hazards. (Section 1910.137 contains requirements that electrical protective equipment must meet; 1910.138 does not apply.) Whether an employee needs to wear rubber insulating gloves while working with test equipment on energized circuits will depend on several factors including:

1. Whether the probes are designed so that the employee's hand can slip off the end of the insulated handle; and

2. Whether there are other exposed energized parts that the employee's hand might contact during testing.

If either of these conditions are present, the use of rubber insulating gloves or other electrical protective equipment would be warranted.

You should also be aware of other requirements that apply to this type of operation. The electrical standards at 29 CFR 1910 Subpart S include requirements for employee safety with respect to electrical hazards in general industry workplaces. According to paragraph 1910.332(a), employees who face a risk of electric shock from electrical hazards that are not reduced to a safe level by the electrical installation requirements of sections 1910.303 through 1910.308 must be trained in electrical safety-related work practices as required by sections 1910.331 through 1910.335. By paragraph 1910.332(a), employees are either qualified persons or unqualified persons when working on or near exposed energized parts. Qualified persons have training, whereas unqualified persons have little or no training, in avoiding the electrical hazards of working on or near exposed energized parts. Training requirements for "qualified persons" and "unqualified persons" are contained in section 1910.332.

Section 1910.334(c)(1) states "only qualified persons may perform testing work on electric circuits or equipment." As noted in the preceding paragraph, these qualified persons shall be capable of performing work safely on energized circuits. By 1910.333(c)(2), qualified persons must be capable of working safely on energized circuits and must be familiar with the proper use of special precautionary techniques, personal protective equipment, insulating and shielding materials, and insulated tools.

if you have any additional questions please contact [the Office of General Industry Enforcement at (202) 693-1850]. Thank you for your interest in Occupational Safety and Health.

Sincerely,

John B. Miles, Jr., Director
Directorate of Compliance Programs

[Corrected 3/13/2007]

UNITED STATES
DEPARTMENT OF LABOR

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OCCUPATIONAL SAFETY & HEALTH

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A - Z Index

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Public Input No. 162-NFPA 70E-2024 [New Definition after Definition: Cell.]

Cell Line Working Zone (CLWZ), The space envelope wherein operation or maintenance is normally performed on or in proximity to exposed energized surfaces of electrolytic cell lines or their attachments. Unless specified as being greater, the minimum space envelope dimensions of the cell line working zone includes any space:

a) Within 2.5 m (96 in) above energized surfaces of electrolytic cell lines or their energized attachments,

b) Within 2.5 m (96 in) of access areas below energized surfaces of electrolytic cell lines or their energized attachments,

c) Within 1.1 m (42 in) horizontally from energized surfaces or their energized attachments for electrolytic cell lines operating at 1000 V or less, and

d) Within 1.5 m (60 in) horizontally from energized surfaces or their energized attachments for electrolytic cell lines operating above 1000 V.

Statement of Problem and Substantiation for Public Input

Article 300 makes several references to "the cell line working zone" but there is no definition of what that is. A definition is needed so the reader understands within which areas or spaces the requirements of Article 300 apply. The text for the definition offered here is taken from IEEE 463, "Electrical Safety Practices in Electrolytic Cell Line Working Zones", a standard referenced in Article 310.1.

Submitter Information Verification

Submitter Full Name: David Pace
Organization: Olin Corporation
Affiliation: Self
Street Address:
City:
State:
Zip:

Submittal Date: Mon Jun 03 13:05:54 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-18-NFPA 70E-2024

Statement: This first revision adds a definition to improve the clarity and understanding of a term used in Article 310 and Informative Annex L. A new informational note provides a resource for obtaining additional information related to electrolytic cell lines.

Public Input No. 128-NFPA 70E-2024 [New Definition after Definition: Electrical Safety Program.]

Electric Double Layer Capacitor (EDLC).

A device having properties of both capacitors and electrochemical cells that stores energy in a non-Faradaic fashion in an electric field similar to a conventional capacitor, but instead of utilizing a dielectric, an electrode-electrolyte interface is used. Unlike rechargeable batteries that rely on a chemical storage mechanism, the physical separation of charge in the double layer at the electrode-electrolyte interface is the origin of the charge storage in EDLCs. The double layer capacitance of carbon materials is much greater than conventional capacitors owing to their high electrode surface area and nano-level thickness of the double layer. An EDLC cell includes two electrodes which are separated by a nonconductive, ion-permeable separator, an electrolyte ionically connecting both electrodes, and two current collectors directly attached to electrodes.

Statement of Problem and Substantiation for Public Input

A new Article is being proposed for EDLC's because this technology has unique safety risks that are not adequately addressed by Article 320 or Article 360. If the proposed new Article is adopted, then a definition is required for this technology. There has been significant confusion in the field regarding the application of Article 360 to several EDLC technologies (a subcategory of supercapacitors). This definition is intended to remove ambiguity over which technology is addressed by the new Article. This proposal has been submitted on behalf of an EDLC task group consisting of Steve Edley, Dave Wright, Troy Brandon, Curtis Ashton, Lloyd Gordon

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 131-NFPA 70E-2024 [New Article after 360]	

Submitter Information Verification

Submitter Full Name: Steve Edley
Organization: Atlas Power Technologies Inc.
Affiliation: Atlas Power Technologies Inc.
Street Address:
City:
State:
Zip:

Submittal Date: Sun Jun 02 20:05:01 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-21-NFPA 70E-2024

Statement: A definition is added to define the term electric double layer capacitor which is used in a new Chapter 3 article.

Public Input No. 118-NFPA 70E-2024 [New Definition after Definition: Field Evaluated.]

TITLE OF NEW CONTENT

Field Work. Tasks performed by employees and contractors in the workplace.

Statement of Problem and Substantiation for Public Input

Field Work is used in 110.3(L)(2) but is not defined. There is some confusion amongst AHJs as to the whether this applies to all workers in facilities or just to persons that perform work for an OEM that sells to customer locations such as field engineers, technicians, or service personnel. When the Field Work section [110.3(L)(2)] was added to NFPA 70E it was apparent from the public input (proposal) at the time that the intent by the submitter is as defined by the definition now proposed in this public input. Other committee members also pointed out at the time of the revision that it was not defined.

Submitter Information Verification

Submitter Full Name: Karl Cunningham
Organization: Self Employed
Street Address:
City:
State:
Zip:

Submittal Date: Sat Jun 01 06:01:37 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: The proposed definition would not add clarity for users of the standard. The term “field work” only appears once in Section 110.3(L)(2) and the provisions of the section are clear.

Public Input No. 206-NFPA 70E-2024 [New Definition after Definition: Motor Control Center.]

Operation, Normal (Normal Operation)

Operation of electrical equipment in a manner that performs the intended function of the equipment as specified by the equipment manufacturer.

Informational Note: An example of normal operation includes opening and closing of switches, circuit breakers and contactors to de-energize or energize electrical equipment.

Statement of Problem and Substantiation for Public Input

It is clear that in order for electrical equipment to be in a normal operating condition, it must meet all items listed in Exception No. 1 to section 110.2(B). However, that is only the applying to the condition of the equipment. The exception states that "normal operation" is permitted to be performed energized if the equipment is in a normal operating condition. There is a lot of confusion surrounding the act of normal operation. Adding a definition to clarify the act of normal operation will clarify exactly what is permitted to be performed while the equipment is energized and is in a normal operating condition.

Submitter Information Verification

Submitter Full Name: Derek Vigstol
Organization: e-Hazard Management LLC
Street Address:
City:
State:
Zip:

Submittal Date: Mon Jun 03 22:33:18 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: What constitutes normal operation is more appropriately located as requirements in 110.2(B)

Public Input No. 211-NFPA 70E-2024 [New Definition after Definition: Motor Control Center.]

Operating Condition, Normal

An operating condition of electrical equipment that is assigned to equipment meeting the following:

(1) The equipment is properly installed.

(2) The equipment is properly maintained.

(3) The equipment is rated for the available fault current.

(4) The equipment is used in accordance with instructions included in the listing and labeling and in accordance with manufacturer's instructions.

(5) The equipment doors are closed and secured.

(6) All equipment covers are in place and secured.

(7) There is no evidence of impending failure.

Informational Note No. 1: The phrase *properly installed* means that the equipment is installed in accordance with applicable industry codes and standards and the manufacturer's recommendations. The phrase *properly maintained* means that the equipment has been maintained in accordance with the manufacturer's recommendations and applicable industry codes and standards. The phrase *evidence of impending failure* means that there is evidence such as arcing, overheating, loose or bound equipment parts, visible damage, deterioration, or water damage.

Informational Note No. 2: See NEMA GD 1-2019, *Evaluating Water-Damaged Electrical Equipment* , as an example of a document that provides further information on evaluating electrical equipment that may have been exposed to water.

Statement of Problem and Substantiation for Public Input

Currently, a normal operating condition is spelled out in section 110.2(B) Exception No. 1. The list in the exception is really defining what a normal operating condition is. The NEC Style Manual requires all definitions to be located in Article 100. Adding a definition in Article 100 adds clarity to the document by providing a central location for the term to be defined so that when used in other locations of the document, users do not need to rely on an exception in a different section to define what a normal operating condition means. A good example is in Table 130.5(C) where normal operating condition is key in determining the likelihood of occurrence of an arc flash. If the user needs help understanding normal operating condition, they need to go to a completely different section of NFPA 70E to find what it means. Or does it make more sense to define this condition in Article 100?

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 212-NFPA 70E-2024 [Section No. 110.2(B)]	dependent on each other
Public Input No. 212-NFPA 70E-2024 [Section No. 110.2(B)]	

Submitter Information Verification

Submitter Full Name: Derek Vigstol

Organization: Vigstol

Street Address:
City:
State:
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Submittal Date: Mon Jun 03 22:52:18 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: The criteria that establishes a normal operating condition are more appropriately located as requirements in 110.2(B).

Public Input No. 265-NFPA 70E-2024 [New Definition after Definition: Pilot Cell.]

Point of Work

The general location such as a panelboard, enclosure or industrial control panel where work such as testing, troubleshooting and voltage measuring will be conducted.

Statement of Problem and Substantiation for Public Input

There is confusion about the term Point of Work. Since this term is not defined, people are not complying with all of the requirement in 120.6(7).

Submitter Information Verification

Submitter Full Name: Charles Miller
Organization: Lighthouse Educational Service
Street Address:
City:
State:
Zip:

Submittal Date: Tue Jun 04 17:34:29 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: Article 100 is used to define terms that are not commonly understood. The phrase “point of work” is clear and does not require further definition.

Public Input No. 157-NFPA 70E-2024 [New Definition after Definition: Premises Wiring (System).]

Point of Work

The specific location where work is being performed, the immediate vicinity where tasks are carried out, equipment is operated, and potential hazards exist. Ensuring safety at the point of work requires an electrical safety program with measures for mitigating risks, providing correct safety PPE and equipment, and training workers appropriately to assess the most feasible location for isolating electrical energy in order to maintain a safe working environment to prevent accidents or injuries.

Statement of Problem and Substantiation for Public Input

There is currently no formal definition of Point of Work in NFAP 70E. However, a July 28, 2006, OSHA Letter of Interpretation lays out two aspects related to Point of Work.

- Panels can be locked-out and tagged-out at the main isolator operator.
- If that does not sufficiently reduce workers' risk of voltage exposure, the employee safety program allows them to “assess, or on a case-by-case basis” the next step to ensure there are no energized live parts—a hazard risk analysis.

Submitter Information Verification

Submitter Full Name: Philip Allen
Organization: Grace Technologies, Inc.
Street Address:
City:
State:
Zip:

Submittal Date: Mon Jun 03 12:35:31 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: Article 100 is used to define terms that are not commonly understood. The phrase “point of work” is clear and does not require further definition.

Public Input No. 40-NFPA 70E-2023 [Article 100 [Excluding any Sub-Sections]]

Scope. This article contains only those definitions essential to ~~the proper application~~ the application of this standard. It is not intended to include commonly defined general terms or commonly defined technical terms from related codes and standards. An article number in parentheses following the definition indicates that the definition only applies to that article.

Statement of Problem and Substantiation for Public Input

The word "properly" is recommended for removal from this section as it is not necessary in the application of the scope of Article 100 and it is included in Table 3.2.1 Possibly Unenforceable and Vague Terms in the NEC Style Manual which, per 3.2.1, states, in part, that "...[t]he terms contained in Table 3.2.1 shall be reviewed in context, and if the resulting requirement is unenforceable or vague, the term shall not be used. In context, "properly" is not only unnecessary, it is unenforceable and vague in the context used.

Submitter Information Verification

Submitter Full Name: Palmer Hickman
Organization: Electrical Training Alliance
Street Address:
City:
State:
Zip:

Submittal Date: Wed Dec 20 13:09:21 EST 2023
Committee: EEW-AAA

Committee Statement

Resolution: FR-4-NFPA 70E-2024
Statement: This removes the word “proper” from this section. The resulting text is more closely aligned with the language found in the National Electrical Code.

Public Input No. 38-NFPA 70E-2023 [Section No. 105.2]

105.2 Purpose.

~~These practices~~ The Article 105 practices and procedures are intended to provide for employee safety relative to electrical hazards in the workplace.

Informational Note: See Informative Annex K for general categories of electrical hazards.

Statement of Problem and Substantiation for Public Input

It is unclear what "these practices and procedures" are in the existing text of this section. While the assumption can be made that these are the practices and procedures are those covered in the Article 105 scope in 105.1, this requirement is not a second sentence in 105.1 where the context is obvious.

Submitter Information Verification

Submitter Full Name: Palmer Hickman
Organization: Electrical Training Alliance
Street Address:
City:
State:
Zip:

Submittal Date: Wed Dec 20 13:00:11 EST 2023
Committee: EEW-AAA

Committee Statement

Resolution: Section 105.2 has been deleted as it is inaccurate, given the change in scope of Article 105, and it is unnecessary.

Public Input No. 8-NFPA 70E-2023 [Section No. 105.3(A)]

(A) Employer Responsibility.

The employer shall have the following responsibilities:

(1) Establish, document, and implement the safety-related work practices and procedures required by this standard.

(2) Provide ~~employees with training~~ and document employee training in the employer's safety-related work practices and procedures.

Statement of Problem and Substantiation for Public Input

The phrase "and document" is added to correlate this requirement with requirements such as those in110.4(A)(5) which requires that employee training be documented, including the qualified person training per 110.4(A)(1), unqualified person training per 110.4(A)(2), and training and retraining per 110.4(A)(3), for example. See also 110.4(B)(3) for the required documentation of lockout/tagout training.

Submitter Information Verification

Submitter Full Name: Palmer Hickman
Organization: Electrical Training Alliance
Street Address:
City:
State:
Zip:

Submittal Date: Thu Aug 24 10:35:48 EDT 2023
Committee: EEW-AAA

Committee Statement

Resolution: FR-32-NFPA 70E-2024
Statement: The revision is made to correlate 105.3(A) with similar requirements throughout the standard to document employee training.

Public Input No. 39-NFPA 70E-2023 [Section No. 105.5]

105.5 Organization.

Chapter 1 of this standard is divided into five articles. Article 100 provides definitions for terms used in one or more of the chapters of this ~~document~~ standard . Article 105 provides for application of safety-related work practices and procedures. Article 110 provides general requirements for electrical safety-related work practices and procedures. Article 120 provides requirements for establishing and verifying an electrically safe work condition. Article 130 provides requirements for work involving electrical hazards.

Statement of Problem and Substantiation for Public Input

The recommendations are made to correlate the requirements in this section. "Standard" replaces "document" as "standard" is used in the first sentence and 70E is a standard. "And verify" is added as 120.6, along with 110.2(C). both establishes and verifies an electrically safe work condition.

Submitter Information Verification

Submitter Full Name: Palmer Hickman
Organization: Electrical Training Alliance
Street Address:
City:
State:
Zip:

Submittal Date: Wed Dec 20 13:05:15 EST 2023
Committee: EEW-AAA

Committee Statement

Resolution: FR-33-NFPA 70E-2024 "And verifying" is not added to the reference to Article 120 as the current language correlates with Section 120.1 Scope statement “This article covers requirements for establishing an electrically safe work condition.”

Statement: The revision is made to correlate 105.5 with the terminology used in corresponding sections of the standard.

“Document” is revised to "standard" to correlate with the use of the word “standard” in first sentence of 105.5 and with 90.2.

The word provide” is replaced with covers in the references to Articles 105, 110, 120 and 130 to correlate with the scope statements in those articles.

Public Input No. 116-NFPA 70E-2024 [Section No. 110.2(B)]

(B) When Required.

Energized electrical conductors and circuit parts operating at voltages equal to or greater than 50 volts shall be put into an electrically safe work condition before an employee performs work if any of the following conditions exist:

(1) The employee is within the limited approach boundary.

(2) The employee interacts with equipment where conductors or circuit parts are not exposed but an increased likelihood of injury from an exposure to an arc flash hazard exists.

Informational Note: See 120.2 through 120.6 for requirements to establish and verify an electrically safe work condition for the period of time for which the state is maintained.

Exception No. 1: Normal operation of electric equipment shall be permitted where a normal operating condition exists. A normal operating condition exists when all of the following conditions are satisfied:

(1) The equipment is properly installed.

(2) The equipment is properly maintained.

(3) The equipment is rated for the available fault current.

(4) The equipment is used in accordance with instructions included in the listing and labeling and in accordance with manufacturer's instructions.

(5) The equipment doors are closed and secured.

(6) All equipment covers are in place and secured.

(7) There is no evidence of impending failure.

Informational Note No. 1: The phrase *properly installed* means that the equipment is installed in accordance with applicable industry codes and standards and the manufacturer's recommendations. The phrase *properly maintained* means that the equipment has been maintained in accordance with the manufacturer's recommendations and applicable industry codes and standards. The phrase *evidence of impending failure* means that there is evidence such as arcing, overheating, loose or bound equipment parts, visible damage, deterioration, or water damage.

Informational Note No. 2: See NEMA GD 1-2019, *Evaluating Water-Damaged Electrical Equipment*, as an example of a document that provides further information on evaluating electrical equipment that may have been exposed to water.

Exception No. 2: An energized disconnecting means or isolating element shall be permitted to be operated to achieve an electrically safe work condition or to return equipment to service that has been placed in an electrically safe work condition. The equipment supplying the disconnecting means or isolating element shall not be required to be placed in an electrically safe work condition provided a risk assessment is performed and there is no unacceptable risk identified.

Exception No. 3: Energized work shall be permitted where the employer can demonstrate that the task to be performed is infeasible in a de-energized state due to equipment design or operational limitations.

Informational Note: Examples of work that might be performed within the limited approach boundary of exposed energized electrical conductors or circuit parts because of infeasibility due to equipment design or operational limitations include performing diagnostics and testing (e.g., start-up or troubleshooting) of electric circuits that can only be performed with the circuit energized and work on circuits that form an integral part of a continuous process that would otherwise need to be completely shut down in order to permit work on one circuit or piece of equipment.

Exception No. 4: Energized work shall be permitted where the employer can demonstrate that de-energizing introduces additional hazards or increased risk.

Informational Note: Examples of additional hazards or increased risk include, but are not limited to, ~~interruption of life-support equipment,~~ deactivation of emergency alarm systems, and shutdown of hazardous location ventilation equipment.

Exception No. 5: Energized electrical conductors and circuit parts that operate at less than 50 volts shall not be required to be de-energized where the capacity of the source and any overcurrent protection between the energy source and the worker are considered and it is determined that there will be no increased exposure to electrical burns or to explosion due to electric arcs.

Statement of Problem and Substantiation for Public Input

During live work one must consider the risks of causing a failure to the electrical supply which, in the case of the exception for interruption of life support equipment would interrupt that same life support equipment. There are multiple instances of incidents involving live working on critical switchgear supplying emergency rooms, intensive care units, and operating rooms that were interrupted when the worker made a mistake. Suggesting this exception in the informational note leads qualified workers to err in judgement of when to perform live work.

Submitter Information Verification

Submitter Full Name: Karl Cunningham
Organization: Self Employed
Street Address:
City:
State:
Zip:

Submittal Date: Sat Jun 01 02:11:00 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: Exception No. 4 Informational Note is not revised as it provides examples only of some situations when an employer must first demonstrate that de-energizing could introduce additional hazards or increased risk before permitting work to proceed with the equipment energized.

Public Input No. 165-NFPA 70E-2024 [Section No. 110.2(B)]

(B) When Required.

Energized electrical conductors and circuit parts ~~operating at voltages equal to or greater than 50 volts~~ that present the risk of injury due to exposure to electrical hazards shall be put into an electrically safe work condition before an employee performs work if any of the following conditions exist:

(1) The employee is within the limited approach boundary.

(2) The employee interacts with equipment where conductors or circuit parts are not exposed but an increased likelihood of injury from an exposure to an arc flash hazard exists.

Informational Note: See 120.2 through 120.6 for requirements to establish and verify an electrically safe work condition for the period of time for which the state is maintained.

Exception No. 1: Normal operation of electric equipment shall be permitted where a normal operating condition exists. A normal operating condition exists when all of the following conditions are satisfied:

(1) The equipment is properly installed.

(2) The equipment is properly maintained.

(3) The equipment is rated for the available fault current.

(4) The equipment is used in accordance with instructions included in the listing and labeling and in accordance with manufacturer's instructions.

(5) The equipment doors are closed and secured.

(6) All equipment covers are in place and secured.

(7) There is no evidence of impending failure.

Informational Note No. 1: The phrase *properly installed* means that the equipment is installed in accordance with applicable industry codes and standards and the manufacturer's recommendations. The phrase *properly maintained* means that the equipment has been maintained in accordance with the manufacturer's recommendations and applicable industry codes and standards. The phrase *evidence of impending failure* means that there is evidence such as arcing, overheating, loose or bound equipment parts, visible damage, deterioration, or water damage.

Informational Note No. 2: See NEMA GD 1-2019, *Evaluating Water-Damaged Electrical Equipment*, as an example of a document that provides further information on evaluating electrical equipment that may have been exposed to water.

Exception No. 2: An energized disconnecting means or isolating element shall be permitted to be operated to achieve an electrically safe work condition or to return equipment to service that has been placed in an electrically safe work condition. The equipment supplying the disconnecting means or isolating element shall not be required to be placed in an electrically safe work condition provided a risk assessment is performed and there is no unacceptable risk identified.

Exception No. 3: Energized work shall be permitted where the employer can demonstrate that the task to be performed is infeasible in a de-energized state due to equipment design or operational limitations.

Informational Note: Examples of work that might be performed within the limited approach boundary of exposed energized electrical conductors or circuit parts because of infeasibility due to equipment design or operational limitations include performing diagnostics and testing (e.g., start-up or troubleshooting) of electric circuits that can only be performed with the circuit energized and work on circuits that form an integral part of a continuous process that would otherwise need to be completely shut down in order to permit work on one circuit or piece of equipment.

Exception No. 4: Energized work shall be permitted where the employer can demonstrate that de-energizing introduces additional hazards or increased risk.

Informational Note: Examples of additional hazards or increased risk include, but are not limited to, interruption of life-support equipment, deactivation of emergency alarm systems, and shutdown of hazardous location ventilation equipment.

Exception No. 5: Energized electrical conductors and circuit parts that operate at less than 50 volts shall not be required to be de-energized where the capacity of the source and any overcurrent protection between the energy source and the worker are considered and it is determined that there will be no increased exposure to electrical burns or to explosion due to electric arcs.

Statement of Problem and Substantiation for Public Input

An attempt was made in previous cycles to use the phrase "where electrical hazards exist" to recognize that an electrical hazard may still exist even below 50 volts. This revision continues that effort. "Electrical Hazards" as defined includes both electric shock and arc flash hazards.

Submitter Information Verification

Submitter Full Name: David Pace
Organization: Olin Corporation
Affiliation: Self
Street Address:
City:
State:
Zip:

Submittal Date: Mon Jun 03 13:38:29 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-34-NFPA 70E-2024 The threshold of equal to or greater than 50 volts is not deleted as it is a well-established threshold, it is easy to identify and apply, and it is used throughout NFPA 70E. The phrase “risk of” should not be used when referring to a possibility or likelihood of occurrence in order to maintain clarity and consistency when referring risk in the standard.

Statement: The phrase “or where an electrical hazard exists” has been added to the requirement to address situations where an electrical hazard might exist below 50 volts.

.

Public Input No. 203-NFPA 70E-2024 [Section No. 110.2(B)]

(B) When Required.

Energized electrical conductors and circuit parts operating at voltages equal to or greater than 50 volts shall be put into an electrically safe work condition before an employee performs work if any of the following conditions exist:

(1) The employee is within the limited approach boundary.

(2) The employee interacts with equipment where conductors or circuit parts are not exposed but an increased likelihood of injury from an exposure to an arc flash hazard exists.

Informational Note: See 120.2 through 120.6 for requirements to establish and verify an electrically safe work condition for the period of time for which the state is maintained.

Exception No. 1: Normal operation of electric equipment shall be permitted where a normal operating condition exists. A normal operating condition exists when all of the following conditions are satisfied:

(1) The equipment is properly installed.

(2) The equipment is properly maintained.

(3) The equipment is rated for the available fault current.

(4) The equipment is used in accordance with instructions included in the listing and labeling and in accordance with manufacturer's instructions.

(5) The equipment doors are closed and secured.

(6) All equipment covers are in place and secured.

(7) There is no evidence of impending failure.

Informational Note No. 1: The phrase *properly installed* means that the equipment is installed in accordance with applicable industry codes and standards and the manufacturer's recommendations. The phrase *properly maintained* means that the equipment has been maintained in accordance with the manufacturer's recommendations and applicable industry codes and standards. The phrase *evidence of impending failure* means that there is evidence such as arcing, overheating, loose or bound equipment parts, visible damage, deterioration, or water damage.

Informational Note No. 2: See NEMA GD 1-2019, *Evaluating Water-Damaged Electrical Equipment*, as an example of a document that provides further information on evaluating electrical equipment that may have been exposed to water.

Exception No. 2: An energized disconnecting means or isolating element shall be permitted to be operated to achieve an electrically safe work condition or to return equipment to service that has been placed in an electrically safe work condition. The equipment supplying the disconnecting means or isolating element shall not be required to be placed in an electrically safe work condition provided a risk assessment is performed and there is no unacceptable risk identified.~~Exception No~~

Exception No . 3: Racking in or out of circuit breakers shall be permitted while the equipment containing the circuit breaker being racked is energized and the employer can demonstrate that the equipment is in a normal operating condition and the circuit breaker cannot be racked while in the closed position.

Exception No. 4: Energized work shall be permitted where the employer can demonstrate that the task to be performed is infeasible in a de-energized state due to equipment design or operational limitations.

Informational Note: Examples of work that might be performed within the limited approach boundary of exposed energized electrical conductors or circuit parts because of infeasibility due to equipment design or operational limitations include performing diagnostics and testing (e.g., start-up or troubleshooting) of electric circuits that can only be performed with the circuit energized and work on circuits that form an integral part of a continuous process that would otherwise need to be completely shut down in order to permit work on one circuit or piece of equipment.

Exception No. ~~4~~ 5 : Energized work shall be permitted where the employer can demonstrate that de-energizing introduces additional hazards or increased risk.

Informational Note: Examples of additional hazards or increased risk include, but are not limited to, interruption of life-support equipment, deactivation of emergency alarm systems, and shutdown of hazardous location ventilation equipment.

Exception No. ~~5~~ 6 : Energized electrical conductors and circuit parts that operate at less than 50 volts shall not be required to be de-energized where the capacity of the source and any overcurrent protection between the energy source and the worker are considered and it is determined that there will be no increased exposure to electrical burns or to explosion due to electric arcs.

Statement of Problem and Substantiation for Public Input

There is considerable confusion in the industry as to whether racking of circuit breakers is considered normal operation or not. If racking is not considered normal operation of a circuit breaker, then the employer must demonstrate an additional hazard/increased risk or de-energize the bus before racking of the circuit breaker. If it is considered normal operation, this new exception to 110.2(B) will add clarity to those that question whether racking can occur with energized bus. If racking is not permitted while the bus is energized, unless additional hazards/increased risk can be demonstrated, then this new exception is not needed and the statement from the committee will clarify that racking on/off of energized bus still needs to be justified by an additional hazard or increased risk.

Submitter Information Verification

Submitter Full Name: Derek Vigstol
Organization:
Street Address:
City:
State:
Zip:
Submittal Date: Mon Jun 03 22:13:15 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: The exception to permit insertion or removal (racking) of draw-out type circuit breakers in or out of energized equipment is not added as a general exception as it is up to the manufacturer to classify whether doing so is “normal operation.”

Public Input No. 212-NFPA 70E-2024 [Section No. 110.2(B)]

(B) When Required.

Energized electrical conductors and circuit parts operating at voltages equal to or greater than 50 volts shall be put into an electrically safe work condition before an employee performs work if any of the following conditions exist:

(1) The employee is within the limited approach boundary.

(2) The employee interacts with equipment where conductors or circuit parts are not exposed but an increased likelihood of injury from an exposure to an arc flash hazard exists.

Informational Note: See 120.2 through 120.6 for requirements to establish and verify an electrically safe work condition for the period of time for which the state is maintained.

Exception No. 1: Normal operation of electric equipment shall be permitted where it can be demonstrated that a normal operating condition exists.- ~~A normal operating condition exists when all of the following conditions are satisfied:~~

(1) ~~The equipment is properly installed.~~

(2) ~~The equipment is properly maintained.~~

(3) ~~The equipment is rated for the available fault current.~~

(4) ~~The equipment is used in accordance with instructions included in the listing and labeling and in accordance with manufacturer's instructions.~~

(5) ~~The equipment doors are closed and secured.~~

(6) ~~All equipment covers are in place and secured.~~

(7) ~~There is no evidence of impending failure.~~

~~Informational Note No. 1:~~

~~The phrase *properly installed* means that the equipment is installed in accordance with applicable industry codes and standards and the manufacturer's recommendations. The phrase *properly maintained* means that the equipment has been maintained in accordance with the manufacturer's recommendations and applicable industry codes and standards. The phrase *evidence of impending failure* means that there is evidence such as arcing, overheating, loose or bound equipment parts, visible damage, deterioration, or water damage.~~

~~Informational Note No. 2: See NEMA GD 1-2019, *Evaluating Water-Damaged Electrical Equipment*, as an example of a document that provides further information on evaluating electrical equipment that may have been exposed to water.~~

Exception No. 2: An energized disconnecting means or isolating element shall be permitted to be operated to achieve an electrically safe work condition or to return equipment to service that has been placed in an electrically safe work condition. The equipment supplying the disconnecting means or isolating element shall not be required to be placed in an electrically safe work condition provided a risk assessment is performed and there is no unacceptable risk identified.

Exception No. 3: Energized work shall be permitted where the employer can demonstrate that the task to be performed is infeasible in a de-energized state due to equipment design or operational limitations.

Informational Note: Examples of work that might be performed within the limited approach boundary of exposed energized electrical conductors or circuit parts because of infeasibility due to equipment design or operational limitations include performing diagnostics and testing (e.g., start-up or troubleshooting) of electric circuits that can only be performed with the circuit energized and work on circuits that form an integral part of a continuous process that would otherwise need to be completely shut down in order to permit work on one circuit or piece of equipment.

Exception No. 4: Energized work shall be permitted where the employer can demonstrate that de-energizing introduces additional hazards or increased risk.

Informational Note: Examples of additional hazards or increased risk include, but are not limited to, interruption of life-support equipment, deactivation of emergency alarm systems, and shutdown of hazardous location ventilation equipment.

Exception No. 5: Energized electrical conductors and circuit parts that operate at less than 50 volts shall not be required to be de-energized where the capacity of the source and any overcurrent protection between the energy source and the worker are considered and it is determined that there will be no increased exposure to electrical burns or to explosion due to electric arcs.

Statement of Problem and Substantiation for Public Input

This PI only seeks to delete that part of the exception that defines what a normal operating condition is. If NFPA 70E is going to define what a normal operating condition is, then it needs to be a definition in Article 100. This is in accordance with the NEC Style Manual. This PI is linked to PI-211. Also, the text in the exception was revised to add clarity and align this exception with the language in other exceptions that the employer must be able to demonstrate this condition exists in order to permit normal operation to be performed while the equipment is still energized.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 211-NFPA 70E-2024 [New Definition after Definition: Motor Control Center.]	Dependent on each other
Public Input No. 211-NFPA 70E-2024 [New Definition after Definition: Motor Control Center.]	

Submitter Information Verification

Submitter Full Name: Derek Vigstol
Organization: e-Hazard Management LLC
Street Address:
City:
State:
Zip:

Submittal Date: Mon Jun 03 23:04:54 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: “Normal operating condition” is not deleted in 110.2(B) and relocated to Article 100 as the description does and must contain requirements to be useful. Per NEC Style Manual Section 2.1.2.5 Style “Definitions shall not contain requirements or recommendations.”

Public Input No. 261-NFPA 70E-2024 [Section No. 110.2(B)]

(B) When Required.

~~Energized electrical~~ Electrical conductors and circuit parts operating at voltages equal to or greater than 50 volts shall be ~~put~~ deenergized by putting them into an electrically safe work condition before an employee performs work if any of the following conditions exist:

(1) The employee is within the limited approach boundary.

(2) The employee interacts with equipment where conductors or circuit parts are not exposed but an increased likelihood of injury from an exposure to an arc flash hazard exists.

Informational Note: See 120.2 through 120.6 for requirements to establish and verify an electrically safe work condition for the period of time for which the state is maintained.

Exception No. 1: Normal operation of electric equipment shall be permitted where a normal operating condition exists. A normal operating condition exists when all of the following conditions are satisfied:

(1) The equipment is properly installed.

(2) The equipment is properly maintained.

(3) The equipment is rated for the available fault current.

(4) The equipment is used in accordance with instructions included in the listing and labeling and in accordance with manufacturer's instructions.

(5) The equipment doors are closed and secured.

(6) All equipment covers are in place and secured.

(7) There is no evidence of impending failure.

Informational Note No. 1: The phrase *properly installed* means that the equipment is installed in accordance with applicable industry codes and standards and the manufacturer's recommendations. The phrase *properly maintained* means that the equipment has been maintained in accordance with the manufacturer's recommendations and applicable industry codes and standards. The phrase *evidence of impending failure* means that there is evidence such as arcing, overheating, loose or bound equipment parts, visible damage, deterioration, or water damage.

Informational Note No. 2: See NEMA GD 1-2019, *Evaluating Water-Damaged Electrical Equipment*, as an example of a document that provides further information on evaluating electrical equipment that may have been exposed to water.

Exception No. 2: An energized disconnecting means or isolating element shall be permitted to be operated to achieve an electrically safe work condition or to return equipment to service that has been placed in an electrically safe work condition. The equipment supplying the disconnecting means or isolating element shall not be required to be placed in an electrically safe work condition provided a risk assessment is performed and there is no unacceptable risk identified.

Exception No. 3: Energized work shall be permitted where the employer can demonstrate that the task to be performed is infeasible in a de-energized state due to equipment design or operational limitations.

Informational Note: Examples of work that might be performed within the limited approach boundary of exposed energized electrical conductors or circuit parts because of infeasibility due to equipment design or operational limitations include performing diagnostics and testing (e.g., start-up or troubleshooting) of electric circuits that can only be performed with the circuit energized and work on circuits that form an integral part of a continuous process that would otherwise need to be completely shut down in order to permit work on one circuit or piece of equipment.

Exception No. 4: Energized work shall be permitted where the employer can demonstrate that de-energizing introduces additional hazards or increased risk.

Informational Note: Examples of additional hazards or increased risk include, but are not limited to, interruption of life-support equipment, deactivation of emergency alarm systems, and shutdown of hazardous location ventilation equipment.

Exception No. 5: Energized electrical conductors and circuit parts that operate at less than 50 volts shall not be required to be de-energized where the capacity of the source and any overcurrent protection between the energy source and the worker are considered and it is determined that there will be no increased exposure to electrical burns or to explosion due to electric arcs.

Statement of Problem and Substantiation for Public Input

This didn't make sense. Needs clarification.

Submitter Information Verification

Submitter Full Name: Erica Sudac
Organization: Los Alamos National Laboratory
Affiliation: Self
Street Address:
City:
State:
Zip:

Submittal Date: Tue Jun 04 16:46:15 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: The phrase “put into an electrically safe work condition” is not revised as it is consistent with similar phrasing throughout the standard. See 130.1. The proposed revision is redundant and does not add clarity.

Public Input No. 262-NFPA 70E-2024 [Section No. 110.2(B)]

(B) When Required.

~~Energized~~ All energized electrical conductors and circuit parts operating at voltages equal to or greater than 50 volts shall be put into an electrically safe work condition before an employee performs work if any of the following conditions exist:

(1) The employee is within the limited approach boundary.

(2) The employee interacts with equipment where conductors or circuit parts are not exposed but an increased likelihood of injury from an exposure to an arc flash hazard exists.

Informational Note: See 120.2 through 120.6 for requirements to establish and verify an electrically safe work condition for the period of time for which the state is maintained.

Exception No. 1: Normal operation of electric equipment shall be permitted where a normal operating condition exists. A normal operating condition exists when all of the following conditions are satisfied:

(1) The equipment is properly installed.

(2) The equipment is properly maintained.

(3) The equipment is rated for the available fault current.

(4) The equipment is used in accordance with instructions included in the listing and labeling and in accordance with manufacturer's instructions.

(5) The equipment doors are closed and secured.

(6) All equipment covers are in place and secured.

(7) There is no evidence of impending failure.

Informational Note No. 1: The phrase *properly installed* means that the equipment is installed in accordance with applicable industry codes and standards and the manufacturer's recommendations. The phrase *properly maintained* means that the equipment has been maintained in accordance with the manufacturer's recommendations and applicable industry codes and standards. The phrase *evidence of impending failure* means that there is evidence such as arcing, overheating, loose or bound equipment parts, visible damage, deterioration, or water damage.

Informational Note No. 2: See NEMA GD 1-2019, *Evaluating Water-Damaged Electrical Equipment*, as an example of a document that provides further information on evaluating electrical equipment that may have been exposed to water.

Exception No. 2: An energized disconnecting means or isolating element shall be permitted to be operated to achieve an electrically safe work condition or to return equipment to service that has been placed in an electrically safe work condition. The equipment supplying the disconnecting means or isolating element shall not be required to be placed in an electrically safe work condition provided a risk assessment is performed and there is no unacceptable risk identified.

Exception No. 3: Energized work shall be permitted where the employer can demonstrate that the task to be performed is infeasible in a de-energized state due to equipment design or operational limitations.

Informational Note: Examples of work that might be performed within the limited approach boundary of exposed energized electrical conductors or circuit parts because of infeasibility due to equipment design or operational limitations include performing diagnostics and testing (e.g., start-up or troubleshooting) of electric circuits that can only be performed with the circuit energized and work on circuits that form an integral part of a continuous process that would otherwise need to be completely shut down in order to permit work on one circuit or piece of equipment.

Exception No. 4: Energized work shall be permitted where the employer can demonstrate that de-energizing introduces additional hazards or increased risk.

Informational Note: Examples of additional hazards or increased risk include, but are not limited to, interruption of life-support equipment, deactivation of emergency alarm systems, and shutdown of hazardous location ventilation equipment.

Exception No. 5: Energized electrical conductors and circuit parts that operate at less than 50 volts shall not be required to be de-energized where the capacity of the source and any overcurrent protection between the energy source and the worker are considered and it is determined that there will be no increased exposure to electrical burns or to explosion due to electric arcs.

Statement of Problem and Substantiation for Public Input

The intent of this public input is to restore the concept that was in Informational note No 2 to 110.1 in the 2021 edition of NFPA 70E. This note and another one was removed by the correlating committee because it apparently conflicted with the NEC style Manual. Even though I believe the 70E committee did not suggest that action. The wording in that informational note was very helpful when explaining what an electrically safe work condition is because it included the word "all". Because this applies only to within the limited approach boundary that would be the extent of the exposed energized parts, operating at 50 volts or more, that would need to be put in an electrically safe work condition.

Submitter Information Verification

Submitter Full Name: Paul Dobrowsky
Organization: Innovative Technology Services
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City:
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Submittal Date: Tue Jun 04 16:50:47 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: The use of “all” as a determiner (i.e. qualifier) before the subject “energized electrical conductors and circuit parts” is unnecessary as the requirement is clear as currently phrased.

Public Input No. 92-NFPA 70E-2024 [Section No. 110.2(B)]

(B) When Required.

Energized electrical conductors and circuit parts operating at voltages equal to or greater than 50 volts shall be put into an electrically safe work condition before an employee performs work if any of the following conditions exist:

(1) The employee is within the ~~limited approach~~ restricted approach boundary.

(2) The employee interacts with equipment where conductors or circuit parts are not exposed but an increased likelihood of injury from an exposure to an arc flash hazard exists.

Informational Note: See 120.2 through 120.6 for requirements to establish and verify an electrically safe work condition for the period of time for which the state is maintained.

Exception No. 1: Normal operation of electric equipment shall be permitted where a normal operating condition exists. A normal operating condition exists when all of the following conditions are satisfied:

(1) The equipment is properly installed.

(2) The equipment is properly maintained.

(3) The equipment is rated for the available fault current.

(4) The equipment is used in accordance with instructions included in the listing and labeling and in accordance with manufacturer's instructions.

(5) The equipment doors are closed and secured.

(6) All equipment covers are in place and secured.

(7) There is no evidence of impending failure.

Informational Note No. 1: The phrase *properly installed* means that the equipment is installed in accordance with applicable industry codes and standards and the manufacturer's recommendations. The phrase *properly maintained* means that the equipment has been maintained in accordance with the manufacturer's recommendations and applicable industry codes and standards. The phrase *evidence of impending failure* means that there is evidence such as arcing, overheating, loose or bound equipment parts, visible damage, deterioration, or water damage.

Informational Note No. 2: See NEMA GD 1-2019, *Evaluating Water-Damaged Electrical Equipment*, as an example of a document that provides further information on evaluating electrical equipment that may have been exposed to water.

Exception No. 2: An energized disconnecting means or isolating element shall be permitted to be operated to achieve an electrically safe work condition or to return equipment to service that has been placed in an electrically safe work condition. The equipment supplying the disconnecting means or isolating element shall not be required to be placed in an electrically safe work condition provided a risk assessment is performed and there is no unacceptable risk identified.

Exception No. 3: Energized work shall be permitted where the employer can demonstrate that the task to be performed is infeasible in a de-energized state due to equipment design or operational limitations.

Informational Note: Examples of work that might be performed within the limited approach boundary of exposed energized electrical conductors or circuit parts because of infeasibility due to equipment design or operational limitations include performing diagnostics and testing (e.g., start-up or troubleshooting) of electric circuits that can only be performed with the circuit energized and work on circuits that form an integral part of a continuous process that would otherwise need to be completely shut down in order to permit work on one circuit or piece of equipment.

Exception No. 4: Energized work shall be permitted where the employer can demonstrate that de-energizing introduces additional hazards or increased risk.

Informational Note: Examples of additional hazards or increased risk include, but are not limited to, interruption of life-support equipment, deactivation of emergency alarm systems, and shutdown of hazardous location ventilation equipment.

Exception No. 5: Energized electrical conductors and circuit parts that operate at less than 50 volts shall not be required to be de-energized where the capacity of the source and any overcurrent protection between the energy source and the worker are considered and it is determined that there will be no increased exposure to electrical burns or to explosion due to electric arcs.

Statement of Problem and Substantiation for Public Input

Based on the current language of this section, a person would need to de-energize the equipment if working on a 24-volt PLC input if they were within 3'6 inches of exposed and energized 480-volts. Another example was passed on to me by a client who works for a large steel manufacturer. If he were working in a control cabinet of a 38kv SF6 breaker and because he is within 8' of the exposed energized conductor located at the top of the insulators, he would need to deenergize the breaker. It would make more sense to require de-energization if within the restricted approach boundary. NFPA 70E 130.2(A)(1) requires an energized work permit if working with the restricted approach not the limited approach. It would make sense that 110.2(B)(1) and 130.2(A)(1) align.

Submitter Information Verification

Submitter Full Name: Brian Hall
Organization: Rozel LLC
Affiliation: Director of Training
Street Address:
City:
State:
Zip:

Submittal Date: Fri May 24 09:20:51 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: Use of the limited approach boundary to trigger the requirement to place electrical conductors and circuit parts into an electrically safe work condition has existed in the standard since the 2009 edition and existed in prior editions where the limited approach boundary was referred to as “working on or near.” Insufficient technical substantiation has been provided to revise the requirement to apply only when the employee is within the restricted approach boundary.

Public Input No. 30-NFPA 70E-2023 [Section No. 110.2(C)]

(C) Requirements Until Established.

~~Electrical conductors and circuit parts shall not be considered to be in an electrically safe work condition until all of the applicable requirements of 120.2 through 120.6 have been met.~~

Safe work practices applicable to the circuit voltage and energy level shall be used until such time that electrical conductors and circuit parts are in an electrically safe work condition.

Statement of Problem and Substantiation for Public Input

This recommendation is to relocate the deleted text to the current 120.6 as a new first sentence. This relocation makes the requirements of 120.6 technically correct as the relocated language will require that one has both established and verified an electrically safe work condition when all of 120.6 has been accomplished with the relocated requirements that all applicable requirements of Article 120 have been met.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 31-NFPA 70E-2023 [Section No. 120.6]	
Public Input No. 31-NFPA 70E-2023 [Section No. 120.6]	

Submitter Information Verification

Submitter Full Name: Palmer Hickman
Organization: Electrical Training Alliance
Street Address:
City:
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Submittal Date: Wed Nov 15 09:11:08 EST 2023
Committee: EEW-AAA

Committee Statement

Resolution: The first sentence in 110.2(C) regarding when an electrically safe work condition is considered to be established is not relocated to 120.6 as it provides the context for the second sentence regarding the use of safe work practices until the condition is established.

Public Input No. 117-NFPA 70E-2024 [Section No. 110.3(C)]

(C) Condition of Maintenance.

The electrical safety program shall include elements that consider condition of maintenance of electrical equipment and systems.

Informational Note: See NFPA 70B, *Standard for Electrical Equipment Maintenance*, for more detail on evaluating condition of maintenance.

Statement of Problem and Substantiation for Public Input

NFPA 70B is now a standard and contains more detailed instructions on evaluating condition of maintenance. As such, a reference to it should assist the qualified workers and safety professionals in how to include condition of maintenance in their electrical safety program.

Submitter Information Verification

Submitter Full Name: Karl Cunningham
Organization: Self Employed
Street Address:
City:
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Zip:

Submittal Date: Sat Jun 01 05:55:15 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-39-NFPA 70E-2024
Statement: An informational note is added to 110.3(C) Condition of Maintenance to refer the user to Annex S Assessing the Condition of Maintenance. The reference is made to Annex S rather than to NFPA 70B as the guidance provided by Annex S already includes a reference to 70B.

Public Input No. 216-NFPA 70E-2024 [Section No. 110.3(I)(1)]

(1) Job Safety Planning.

The job safety plan shall be in accordance with the following:

(1) Be completed by a qualified person

(2) Be documented

(3) Include the following information:

(4) A description of the job and the individual tasks

(5) Identification of the electrical hazards associated with each task

(6) An electric shock risk assessment in accordance with 130.4 for tasks involving an electric shock hazard

(7) An arc flash risk assessment in accordance with 130.5 for tasks involving an arc flash hazard

(8) Work procedures involved, special precautions, and energy source controls

(9) An emergency response plan

Informational Note No. 1 : See Figure I.2 for an example of a job safety planning checklist.

Informational Note No. 2: An emergency response plan could include actions to be taken during an electrical injury emergency, contingency plans for when equipment is unintentionally de-energized while performing energized work due to additional hazards or increased risk, and roles and responsibilities during response efforts.

Statement of Problem and Substantiation for Public Input

Only adding a second informational note here to provide examples of what an emergency response plan might entail. Many safety management teams understand the need to determine a response to an injured employee, but they miss that when work is performed under exception no. 4 to section 110.2(B), an unplanned de-energization could lead to the additional hazard/increased risk they were trying to avoid in the first place. A plan must be in place to respond to mitigating the additional hazard/increased risk as well as the response to an injured employee.

Submitter Information Verification

Submitter Full Name: Derek Vigstol
Organization: e-Hazard Management LLC
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State:
Zip:

Submittal Date: Mon Jun 03 23:30:46 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-40-NFPA 70E-2024

Statement: An informational note is added to provide guidance regarding the information that would be typically included in an emergency response plan, including the planned response to unintentional de-energization.

Public Input No. 161-NFPA 70E-2024 [New Section after 110.3(L)]

Point of Work.

The electrical safety program shall include elements that consider how to determine the point of work in electrical equipment.

Statement of Problem and Substantiation for Public Input

Determining the right point of work isolation location within the electrical system requires detailed system knowledge by qualified workers who understand and have experience with the system. Developing a comprehensive definition that covers all the unique cases within a facility is impractical and should be part of the plant's electrical safety program.

Submitter Information Verification

Submitter Full Name: Philip Allen
Organization: Grace Technologies, Inc.
Street Address:
City:
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Zip:

Submittal Date: Mon Jun 03 12:53:59 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: Determining the point of work is related to testing for the absence of voltage while establishing an electrically safe work condition. The requirement for a qualified worker to test for the absence of voltage at each point of work is adequately addressed in 120.6(7).

Public Input No. 264-NFPA 70E-2024 [Section No. 110.3(L)(3)]

(3) Lockout/Tagout Program ~~and Procedure~~ Audit.

The lockout/tagout program shall be audited to verify that the principles of the lockout/tagout program are in compliance with this standard. Audits shall be performed at intervals not to exceed 3 years.

(4) **Lockout/Tagout Procedures Audit.**

The lockout/tagout

~~program and~~
procedures required by 120.2 through 120.6 shall be audited by a qualified person at intervals not to exceed 1 year. The audit shall cover at least one lockout/tagout in progress. The audit shall be designed to identify and correct deficiencies in the following:

(1) The lockout/tagout program and procedures

(2) The lockout/tagout training

(3) Worker execution of the lockout/tagout procedure

Statement of Problem and Substantiation for Public Input

This PI is submitted to align 110.3(L)(3) with 29 CFR 1910.147(C)(6) which requires periodic inspections of procedures at least annually and to align a Lockout program audit (not required by 1910.147) to align with 110.3(L)(1) Electrical Safety Program Audit on a 3-year cycle. See OSHA letter of interpretation November 30, 2010 to Mr Jimmy Hill, Marshall Space Flight Center for clarification of annual inspection requirements of procedures- not program. "

Question 6: Is the periodic inspection of a lockout procedure required to be performed while the actual lockout sequence is being performed, or can it be a review of the written lockout procedure with the "authorized employee" at a later date?

Reply: The periodic inspections must contain at least two components: 1) an inspection of each energy control procedure, and 2) a review of each employee's responsibilities under the energy control procedure being inspected. Each energy control procedure must be separately inspected at least annually to ensure that the energy control program is being properly utilized. At a minimum, these inspections must provide for the demonstration of the procedures and must be performed while authorized employees perform servicing and/or maintenance activities on machines or equipment.

See also letter of interpretation June 20, 1996 to Mr Neil Wasser

Question 4a: What must the periodic inspection encompass? Would an employer be in compliance with the periodic inspection requirements by selecting days throughout the year to perform periodic inspections?

Also, do periodic inspections have to be performed on all 600 energy control procedures and involve all authorized employees?

Reply: Under the requirements of paragraph 1910.147(c)(6)(i), the employer is required to conduct a periodic inspection of the energy control procedure [required under paragraph 1910.147(c)(4)]. OSHA interprets this to mean that each energy control procedure must be separately inspected at least annually.

Also, under the requirements of paragraph 1910.147(c)(6)(i), the periodic inspection must include a

review of the employee's responsibilities under the energy control procedure being inspected. OSHA interprets this to mean that there must be a review between an authorized employee designated by the employer as the "inspector" and all other authorized employees (and all affected employee when tagout is used to control energy) of the employee's responsibilities under the periodic inspection being inspected.

Submitter Information Verification

Submitter Full Name: Mark McNellis
Organization: Sandia National Laboratories
Street Address:
City:
State:
Zip:

Submittal Date: Tue Jun 04 17:21:06 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-42-NFPA 70E-2024

Statement: This revision aligns the requirement to audit lockout/tagout procedures with 29 CFR 1910.147(C)(6), which requires periodic inspections of procedures at least annually. The revision also aligns the requirement to audit the lockout program, which is not required by 1910.147, with the requirement to audit the electrical safety program at intervals not to exceed 3 years.

The reference to 120.6 has been revised to 120.5 with respect to lockout/tagout procedures as 120.6 does not specify requirements for procedures.

Third level subdivisions have been created to comply with the NEC Style Manual Section 2.1.6.

Public Input No. 13-NFPA 70E-2023 [Section No. 110.4(A)(1)]

(1) Qualified Person.

A qualified person shall be trained and knowledgeable in the construction and operation of equipment or a specific work method and be trained to identify and avoid the electrical hazards that might be present with respect to that equipment or work method.

(a) Such persons shall also be familiar with the proper use of applicable precautionary techniques, electrical policies, procedures, PPE, insulating materials, shielding materials, and insulated tools and test equipment.

(b) A person shall be qualified for ~~certain equipment~~ the equipment and tasks ~~to be performed~~ they will perform .

(c) Such persons permitted to work within the limited approach boundary shall, at a minimum, be additionally trained in all of the following:

(4) Skills and techniques necessary to distinguish exposed energized electrical conductors and circuit parts from other parts of electrical equipment

(5) Skills and techniques necessary to determine the nominal voltage of exposed energized electrical conductors and circuit parts

(6) Approach distances specified in Table 130.4(E)(a) and Table 130.4(E)(b) and the corresponding voltages to which the qualified person will be exposed

(7) Decision-making process necessary to be able to do the following:

(8) Perform the job safety planning

(9) Identify electrical hazards

(10) Assess the associated risk

(11) Select the appropriate risk control methods from the hierarchy of controls identified in 110.3(H)(3) , including PPE

(l) An employee who is undergoing on-the-job training for the purpose of obtaining the skills and knowledge necessary to be considered a qualified person, and who in the course of such training demonstrates an ability to perform specific duties safely at his or her level of training, and who is under the direct supervision of a qualified person shall be considered to be a qualified person for the performance of those specific duties.

(m) Employees shall be trained to select an appropriate test instrument and shall demonstrate how to use a device to verify the absence of voltage, including interpreting indications provided by the device. The training shall include information that enables the employee to understand all limitations of each test instrument that might be used.

(n) The employer shall determine through regular supervision or through inspections conducted on at least an annual basis that each employee is complying with the safety-related work practices required by this standard.

Statement of Problem and Substantiation for Public Input

This Public Input is an attempt at an editorial revision to this requirement to provide more clarity. The phrase "for certain equipment and tasks" seems somewhat ambiguous. The recommended revision is proposed to add clarity and remove ambiguity.

Submitter Information Verification

Submitter Full Name: Palmer Hickman
Organization: Electrical Training Alliance
Street Address:
City:
State:
Zip:

Submittal Date: Wed Aug 30 11:16:09 EDT 2023
Committee: EEW-AAA

Committee Statement

Resolution: FR-43-NFPA 70E-2024

Statement: The revision to 110.4(A)(1)(b) in the 2024 edition replaced the word “can” in accordance with NEC Style Manual 3.1.1 which states: “The terms may or can shall not be used in mandatory rules.” In previous editions 110.4(A)(1)(b) was phrased as follows: “A person can be considered qualified with respect to certain equipment and tasks but still be unqualified for others.” This revision clarifies and the restores the concept contained in the 2021 and earlier editions that a person might be qualified with respect to certain equipment and tasks but unqualified for others.

The First Revision edits 110.4(A)(1)(e) from “verify” to “test for” to make the wording consistent with 110.6 and 120.6(7).

Public Input No. 254-NFPA 70E-2024 [Section No. 110.4(A)(1)]

(1) Qualified Person.

A qualified person shall be trained and knowledgeable in the construction and operation of equipment or a specific work method and be trained to identify and avoid the electrical hazards that might be present with respect to that equipment or work method.

(a) Such persons shall also be familiar with the proper use of applicable precautionary techniques, electrical policies, procedures, PPE, insulating materials, shielding materials, and insulated tools and test equipment.

(b) A person shall be qualified for certain equipment and tasks to be performed.

(c) Such persons permitted to work within the limited approach boundary shall, at a minimum, be additionally trained in all of the following:

(4) Skills and techniques necessary to distinguish exposed energized electrical conductors and circuit parts from other parts of electrical equipment

(5) Skills and techniques necessary to determine the nominal voltage of exposed energized electrical conductors and circuit parts

(6) Approach distances specified in Table 130.4(E)(a) and Table 130.4(E)(b) and the corresponding voltages to which the qualified person will be exposed

(7) Decision-making process necessary to be able to do the following:

(8) Perform the job safety planning

(9) Identify electrical hazards

(10) Assess the associated risk

(11) Select the appropriate risk control methods from the hierarchy of controls identified in 110.3(H)(3) , including PPE

(l) An employee who is undergoing on-the-job training for the purpose of obtaining the skills and knowledge necessary to be considered a qualified person, and who in the course of such training demonstrates an ability to perform specific duties safely at his or her level of training, and who is under the direct supervision of a qualified person shall be considered to be a qualified person for the performance of those specific duties.

(m) Employees shall be trained to select an appropriate test instrument and shall demonstrate how to use a device to ~~verify~~ test for the absence of voltage, including interpreting indications provided by the device. The training shall include information that enables the employee to understand all limitations of each test instrument that might be used.

(n) The employer shall determine through regular supervision or through inspections conducted on at least an annual basis that each employee is complying with the safety-related work practices required by this standard.

Statement of Problem and Substantiation for Public Input

Change "verify" to "test for". The change is only for 110.4(A)(1)(e) but Terra does not allow limiting the change to only that subdivision and it underlines many other items that are not proposed to be

changed by this public input.
This proposed changed is intended to make the wording consistent with that in 110.6 and 120.6(7).

Submitter Information Verification

Submitter Full Name: Paul Dobrowsky
Organization: Innovative Technology Services
Street Address:
City:
State:
Zip:

Submittal Date: Tue Jun 04 15:41:32 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-43-NFPA 70E-2024

Statement: The revision to 110.4(A)(1)(b) in the 2024 edition replaced the word “can” in accordance with NEC Style Manual 3.1.1 which states: “The terms may or can shall not be used in mandatory rules.” In previous editions 110.4(A)(1)(b) was phrased as follows: “A person can be considered qualified with respect to certain equipment and tasks but still be unqualified for others.” This revision clarifies and the restores the concept contained in the 2021 and earlier editions that a person might be qualified with respect to certain equipment and tasks but unqualified for others.

The First Revision edits 110.4(A)(1)(e) from “verify” to “test for” to make the wording consistent with 110.6 and 120.6(7).

Public Input No. 50-NFPA 70E-2024 [Section No. 110.4(A)(1)]

(1) Qualified Person.

A qualified person shall be trained and knowledgeable in the construction and operation of equipment or a specific work method and be trained to identify and avoid the electrical hazards that might be present with respect to that equipment or work method.

(a) Such persons shall also be familiar with the proper use of applicable precautionary techniques, electrical policies, procedures, PPE, insulating materials, shielding materials, and insulated tools and test equipment.

(b) A person shall be qualified for certain equipment and tasks to be performed.

(c) Such persons permitted to work within the limited approach boundary shall, at a minimum, be additionally trained in all of the following:

(4) Skills and techniques necessary to distinguish exposed energized electrical conductors and circuit parts from other parts of electrical equipment

(5) Skills and techniques necessary to determine the nominal voltage of exposed energized electrical conductors and circuit parts

(6) Approach distances specified in Table 130.4(E)(a) and Table 130.4(E)(b) and the corresponding voltages to which the qualified person will be exposed

(7) Decision-making process necessary to be able to do the following:

(8) Perform the job safety planning

(9) Identify electrical hazards

(10) Assess the associated risk

(11) Select the appropriate risk control methods from the hierarchy of controls identified in 110.3(H)(3) , including PPE

(l) An employee who is undergoing on-the-job training for the purpose of obtaining the skills and knowledge necessary to be considered a qualified person, and who in the course of such training demonstrates an ability to perform specific duties safely at his or her level of training, and who is under the direct supervision of a qualified person shall be considered to be a qualified person for the performance of those specific duties.

(m) Employees shall be trained to select an appropriate test instrument and shall demonstrate how to use a device to verify the absence of ~~voltage~~ energy , including interpreting indications provided by the device. The training shall include information that enables the employee to understand all limitations of each test instrument that might be used.

(n) The employer shall determine through regular supervision or through inspections conducted on at least an annual basis that each employee is complying with the safety-related work practices required by this standard.

Statement of Problem and Substantiation for Public Input

NFPA 70E is written to address voltage driven circuits, therefore the requirement to test for voltage. Series Circuits powered with a constant current are still widely used throughout the United States and

the world. As presently written 70E is instructing an electrician working on a current powered circuit to measure voltage. Attempting to measure voltage on a current driven circuit could be an unsafe act. Current is measured to determine the proper operation of a current driven circuit and to determine if the circuit is energized. Replacing the term voltage with the term energy solves this problem. Please see documents attached to PI No. 48.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 48-NFPA 70E-2024 [Section No. 120.6]	series circuit
Public Input No. 49-NFPA 70E-2024 [Definition: Electrically Safe Work Condition.]	series circuit
Public Input No. 51-NFPA 70E-2024 [Section No. 110.6(E)]	series circuit
Public Input No. 52-NFPA 70E-2024 [Section No. 120.5(B)(6)]	series circuit
Public Input No. 48-NFPA 70E-2024 [Section No. 120.6]	
Public Input No. 49-NFPA 70E-2024 [Definition: Electrically Safe Work Condition.]	
Public Input No. 51-NFPA 70E-2024 [Section No. 110.6(E)]	
Public Input No. 52-NFPA 70E-2024 [Section No. 120.5(B)(6)]	

Submitter Information Verification

Submitter Full Name: Carl Johnson
Organization: AVCON, Inc.
Affiliation: none
Street Address:
City:
State:
Zip:

Submittal Date: Tue Jan 02 07:36:26 EST 2024
Committee: EEW-AAA

Committee Statement

Resolution: The phrase “verify the absence of voltage” is not revised to “verify the absence of energy” as the term “energy” is too broad for the purposes of the application of this requirement. To be “qualified” to work on constant current lighting a person would need to have “knowledge related to the construction and operation of electrical equipment and installations” of such a system and would need to have “safety training to identify the hazards and reduce the associated risk,” including the correct method to verify that the system is in an electrically safe work condition.

Public Input No. 253-NFPA 70E-2024 [New Section after 110.4(C)(4)]

110.4(D) Secondary Hazard Training

Several secondary hazards are created by electrical equipment including electric fields, magnetic fields, and rf fields (known as Nonionizing Radiation) and x-ray (known as Ionizing Radiation).

Utility and facility transformers are large motors can be a significant hazard to any worker with medical electronics. Ionizing radiation is generated in any vacuum device that contains over 10 kV circuits, such as a MV vacuum breaker.

As determined by management, training in Nonionizing Radiation and/or Ionizing Radiation safety shall be provided as needed.

Statement of Problem and Substantiation for Public Input

previously, Nonionizing Radiation hazards (EM fields) was only mentioned in Article 340 Power Electronics, and Ionizing Radiation hazards (x-rays) was only mentioned in Article 330 Lasers, although there are several types of electrical equipment in both facility, utility and special equipment that can generate x-rays. I am not sure where in Chapter 1 this should go, to cover the whole document, but training seemed to be logical.

Submitter Information Verification

Submitter Full Name: Lloyd Gordon
Organization: Gordon
Street Address:
City:
State:
Zip:

Submittal Date: Tue Jun 04 15:37:30 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: The information on radiation hazards is not added to 110.4 as radiation hazards are addressed in Chapter 3.

Public Input No. 243-NFPA 70E-2024 [Section No. 110.6(D)]

(D) Visual Inspection and Repair.

Test instruments and equipment and all associated test leads, cables, power cords, probes, and connectors shall be visually inspected for external defects and damage before each use. If there is a defect or evidence of damage that might expose an employee to injury, the defective or damaged item shall be removed from service. No employee shall use it until a person(s) qualified to perform the repairs and tests that are necessary to render the equipment safe has done so.

Exception No. 1 to (D):

Permanently installed devices shall have terminations validated for proper connection to the intended voltage source before testing that source for the absence of voltage.

Statement of Problem and Substantiation for Public Input

This exception would resolve confusion I am seeing by customers that an "instrument" also includes permanently installed devices. Which, if a lead from a permanently installed device needs to be inspected for wear prior to use, that defeats all of the safety improvements that these devices bring. However, ensuring gathered data through said permanently installed device is critical to be trusted. Therefore, adding an exception for permanently installed devices to validate they are connected would be a reasonable task for a device to accomplish to ensure proper connection of test leads.

Submitter Information Verification

Submitter Full Name: Alan Bond
Organization: Panduit Corp
Street Address:
City:
State:
Zip:

Submittal Date: Tue Jun 04 14:32:59 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-46-NFPA 70E-2024

Statement: This revision clarifies that the inspection and repair requirements in this section apply to portable test instruments and equipment only.

Second level subdivisions and titles were added to comply with the NEC Style Manual Section 2.1.6.

Public Input No. 167-NFPA 70E-2024 [Section No. 110.6(E)]

(E) Operation Verification.

When test instruments are used for testing the absence of voltage on conductors or circuit parts ~~operating at voltages equal to or greater than 50 volts~~ where an electricl hazard exists , the operation of the test instrument shall be verified on any known voltage source before and after an absence of voltage test is performed.

Statement of Problem and Substantiation for Public Input

An attempt was made in previous cycles to use the phrase "where electrical hazards exist" to recognize that an electrical hazard may still exist even below 50 volts. This revision continues that effort. "Electrical Hazards" as defined includes both electric shock and arc flash hazards.

Submitter Information Verification

Submitter Full Name: David Pace
Organization: Olin Corporation
Affiliation: Self
Street Address:
City:
State:
Zip:

Submittal Date: Mon Jun 03 14:00:01 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: The phrase “operating at voltages equal to or greater than 50 volts” is not revised to “that present the risk of injury due to exposure to electrical hazards” The context of the requirement in this section to verify the operation of a test instrument applies specifically to voltage and not to electrical hazards in general.

Public Input No. 246-NFPA 70E-2024 [Section No. 110.6(E)]

(E) Operation Verification.

~~When~~ All test instruments ~~are used~~ and equipment used for testing the absence of voltage on conductors or circuit parts operating at voltages equal to or greater than 50 volts, the operation of the test instrument shall be verified on any known voltage source before and after an absence of voltage test is performed.

Statement of Problem and Substantiation for Public Input

Over the last decade, new technologies have been developed which are intended to reduce the human exposure and risk associated with absence of voltage testing. This section, Operation Verification, is for instruments, which are commonly referred to as handheld testers. To align with these new technologies, as well as definitions laid out in NFPA 70E, including "equipment" would ensure that these new technologies, which are not referred to as "instruments", also have their operation verified before and after being utilized for testing for the absence of voltage.

Submitter Information Verification

Submitter Full Name: Alan Bond
Organization: Panduit Corp
Street Address:
City:
State:
Zip:

Submittal Date: Tue Jun 04 14:55:16 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: The revision to add “and equipment” to the requirement is not made as it is already addressed in 120.6(7).

Public Input No. 51-NFPA 70E-2024 [Section No. 110.6(E)]

(E) Operation Verification.

When test instruments are used for testing the absence of ~~voltage~~ energy on conductors or circuit parts operating at voltages equal to or greater than 50 volts, the operation of the test instrument shall be verified on any known ~~voltage~~ energy source before and after an absence of ~~voltage~~ energy test is performed.

The energy source shall match the circuit type; voltage driven or current driven.

Informational Note. The test instrument range/function used during the verification process should the same range/function used for the absence of energy test.

Statement of Problem and Substantiation for Public Input

NFPA 70E is written to address voltage driven circuits, therefore the requirement to test for voltage. Series Circuits powered with a constant current are still widely used throughout the United States and the world. As presently written 70E is instructing an electrician working on a current powered circuit to measure voltage. Attempting to measure voltage on a current driven circuit could be an unsafe act. Current is measured to determine the proper operation of a current driven circuit and to determine if the circuit is energized. Replacing the term voltage with the term energy solves this problem. Please see documents attached to PI No. 48.

I have witnessed test instruments with manual range selection have the range switch fail for a single voltage range setting. If the instrument test is completed on one range setting and the absence of energy test is performed in a different range setting there is a possibility of the user not detecting a bad meter.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 48-NFPA 70E-2024 [Section No. 120.6]	series circuit
Public Input No. 49-NFPA 70E-2024 [Definition: Electrically Safe Work Condition.]	series circuit
Public Input No. 50-NFPA 70E-2024 [Section No. 110.4(A)(1)]	series circuit
Public Input No. 52-NFPA 70E-2024 [Section No. 120.5(B)(6)]	series circuit
Public Input No. 48-NFPA 70E-2024 [Section No. 120.6]	
Public Input No. 49-NFPA 70E-2024 [Definition: Electrically Safe Work Condition.]	
Public Input No. 50-NFPA 70E-2024 [Section No. 110.4(A)(1)]	
Public Input No. 52-NFPA 70E-2024 [Section No. 120.5(B)(6)]	

Submitter Information Verification

Submitter Full Name: Carl Johnson
Organization: AVCON, Inc.
Affiliation: none
Street Address:
City:
State:

Zip:

Submittal Date: Tue Jan 02 07:38:35 EST 2024

Committee: EEW-AAA

Committee Statement

Resolution: The phrase “verify the absence of voltage” is not revised to “verify the absence of energy” as the term “energy” is too broad for the purposes of the application of this requirement. To be “qualified” to work on constant current lighting a person would need to have “knowledge related to the construction and operation of electrical equipment and installations” of such a system and would need to have “safety training to identify the hazards and reduce the associated risk,” including the correct method of verify that the system is in an electrically safe work condition.

Public Input No. 171-NFPA 70E-2024 [Section No. 110.7(D)]

(D) Conductive or Wet Work Locations.

Portable cord-and-plug-connected electric equipment used in conductive or wet work locations shall be approved for use in those locations. ~~In~~ Ground fault circuit interrupter (GFCI) protection shall used where portable cord-and-plug connected electric equipment is used in work locations where employees are likely to contact ~~or be drenched~~ water or conductive liquids. Portable cord-and-plug connected electric equipment is prohibited from being used in work locations where employees are likely to be drenched with water or conductive liquids, ~~ground-fault circuit-interrupter protection for personnel shall be used~~ whether using GFCI protection or not .

Informational Note: The risk assessment procedure can also include identifying when the use of portable tools and equipment powered by sources other than 120 volts ac, such as batteries, air, and hydraulics, should be used to minimize the potential for injury from electrical hazards for tasks performed in conductive or wet locations.

Statement of Problem and Substantiation for Public Input

Using portable cord-and-plug connected electric equipment in work locations where employees are likely to be drenched with water or conductive liquids should be prohibited. Where employees are likely to be drenched with water or conductive liquids, using electric equipment is not safe, even with the use of GFCI protection. Even if the GFCI trips, a shock will be received and in this case the current will be much higher than if dry. Also, employees are likely to remove the GFCI protection if it keeps tripping. This document should not give guidance on using this equipment when drenched in water or conductive fluids.

Submitter Information Verification

Submitter Full Name: David Pace
Organization: Olin Corporation
Affiliation: Self
Street Address:
City:
State:
Zip:

Submittal Date: Mon Jun 03 14:15:22 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: The second sentence has not been revised as it has been deleted by a first revision.

Public Input No. 272-NFPA 70E-2024 [Sections 110.8(B), 110.8(C)]

Sections 110.8(B), 110.8(C)

(B) Maintenance and Construction.

GFCI protection shall be provided where an employee is operating or using cord sets (extension cords) or cord- and plug-connected tools related to maintenance and construction activity supplied by 120-volt, 15-, 20-, or 30-ampere circuits. ~~Where employees operate or use equipment supplied by greater than~~

Informational Note No. 1: See Informative Annex O. Where an assured equipment grounding conductor program is used, a special purpose ground-fault circuit interrupter may provide additional protection.

(C) Outdoors.

GFCI protection shall be provided when an employee is outdoors and operating or using cord sets (extension cords) or cord- and plug-connected equipment supplied by 120-volt, 15-, 20-, or 30-ampere circuits

~~, GFCI protection or an assured equipment grounding conductor program shall be implemented.~~

.

Informational Note No. 1: See Informative

~~Annex O GFCI protection shall be provided when an employee is outdoors and operating or using cord sets (extension cords) or cord- and plug-connected equipment supplied by 120-volt, 15-, 20-, or 30-ampere circuits. Where employees working outdoors~~

Annex O . Where an assured equipment grounding conductor program is used, a special purpose ground-fault circuit interrupter may provide additional protection.

Informational Note No. 2: See applicable state, federal, or local codes and standards such as *NFPA 70* , *National Electrical Code* , Section 590.6(B)(2) for more information regarding implementation of an assured equipment grounding conductor program.

~~**(C)** Outdoors.~~

110.8(D) Temporary Circuits Greater than 125-Volt, 15, 20, or 30 Amperes

Where employees operate or use equipment supplied by greater than

~~120~~

125 -volt, 15

-

, 20

-

, or 30-

~~ampere circuits~~

ampere circuits , GFCI protection or an assured equipment grounding conductor program shall be implemented.

Informational Note No.

~~1: See Informative Annex O. Where an assured equipment grounding conductor program is used, a special purpose ground-fault circuit interrupter may provide additional protection. Informational Note No. 2: See~~

1: See applicable state, federal, or local codes and standards such as

~~*NFPA 70*~~

NFPA 70 , National Electrical Code ,

~~Section 590~~

Section 590 .6(B)(2) for more information regarding implementation of an assured equipment grounding conductor program.

110.8(E) Testing Ground-Fault Circuit -Interrupter Protection Devices

GFCI protection devices shall be tested in accordance with the manufacturer's instructions.

Additional Proposed Changes

File Name	Description	Approved
70E_PC_13_Hold.pdf	70E_PC13	

Statement of Problem and Substantiation for Public Input

NOTE: This Public Input appeared as "Reject but Hold" in Public Comment No. 13 of the (A2023) Second Draft Report for NFPA 70E and per the Regs. At 4.4.8.3.1 and needs to be reconsidered by the TC for the next edition of the document.

I appreciate the 70E technical committee finally adding informational note #2 to articles 110.8(B) and 110.8(C)
which points the reader back to either federal OSHA regulations and NEC article 590.6(B)(2) for the specific
directions required for the implementation of the assured equipment grounding conductor program of temporary
circuits greater than 125V, 15, 20 or 30A.

However, to reduce identical information redundancy, rather than repeating the information in both 110.8(B) for
"maintenance and construction" and 110.8(C) for "outdoors" the statement "...greater than 125V, 15, 20, 30
ampere circuits, GFCI protection or an assured equipment grounding conductor program shall be implemented."

should have its own new section 110.8(D). This will require the existing 110.8(D) "Testing GFCI Devices" to be
moved to a new section 110.8(E).

Submitter Information Verification

Submitter Full Name:	NFPA Holds
Organization:	Technical Committee on Electrical Safety in the Workplace
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Thu Jun 06 21:19:13 EDT 2024
Committee:	EEW-AAA

Committee Statement

Resolution: FR-48-NFPA 70E-2024

Statement: The requirement to use GFCI protection in conductive or wet work locations is relocated from 110.7(D) to 110.8 to consolidate it with similar GFCI requirements

The requirements of this section are editorially revised to be simpler to identify and apply.

Public Comment No. 13-NFPA 70E-2022 [Sections 110.8(B), 110.8(C)]

Sections 110.8(B), 110.8(C)

(B) Maintenance and Construction.

GFCI protection shall be provided where an employee is operating or using cord sets (extension cords) or cord- and plug-connected tools related to maintenance and construction activity supplied by 120-volt, 15-, 20-, or 30-ampere circuits. ~~Where employees operate or use equipment supplied by greater than 120-volt, 15-, 20-, or 30-ampere circuits, GFCI protection or an assured equipment grounding conductor program shall be implemented.~~

Informational Note No. 1: See Informative Annex O. Where an assured equipment grounding conductor program is used, a special purpose ground-fault circuit interrupter may provide additional protection. ~~Informational Note No. 2: See applicable state, federal, or local codes and standards such as *NFPA 70* , *National Electrical Code* , Section 590.6~~

~~(~~

~~B)(2) for more information regarding implementation of an assured equipment grounding conductor program.~~

~~(~~

C) Outdoors.

GFCI protection shall be provided when an employee is outdoors and operating or using cord sets (extension cords) or cord- and plug-connected equipment supplied by 120-volt, 15-, 20-, or 30-ampere circuits.

Informational Note No. 1: See Informative Annex O Where

~~employees working outdoors~~

an assured equipment grounding conductor program is used, a special purpose ground-fault circuit interrupter may provide additional protection.

110.8(D) Temporary Circuits Greater than 125-Volt, 15, 20, or 30 Amperes

Where employees operate or use equipment supplied by greater than

~~120~~
125 -volt, 15

-
, 20

-,
or 30-ampere circuits, GFCI protection or an assured equipment grounding conductor program shall be implemented.

Informational Note No.

~~1: See Informative Annex O Where an assured equipment grounding conductor program is used, a special purpose ground-fault circuit interrupter may provide additional protection. Informational Note No. 2: See~~
2: See applicable state, federal, or local codes and standards such as *NFPA 70* , *National Electrical Code* , Section 590.6(B)(2) for more information regarding implementation of an assured equipment grounding conductor program.

110.8(E) Testing Ground-Fault Circuit -Interrupter Protection Devices

GFCI protection devices shall be tested in accordance with the manufacturer's instructions.

Additional Proposed Changes

File Name	Description	Approved
Article_110.8_GFCI_Protection_03-20-2022.docx	To reduce redundancy of identical information, move the information regarding if the temporary circuit is greater that 125V, 15, 20 or 30A then GFCI protection or the assured equipment grounding conductor program out from both 110.8(B) "maintenance and construction" and 110.8(C) "outdoors" into its own new section 110.8(D) titled "Temporary Circuits Greater than 125-Volt, 15, 20 or 30 Amperes". This will renumber the current 110.8(D) "Testing Ground-Fault Circuit Interrupter Protection Devices" to a new position as 110.8(E).	

Statement of Problem and Substantiation for Public Comment

I appreciate the 70E technical committee finally adding informational note #2 to articles 110.8(B) and 110.8(C) which points the reader back to either federal OSHA regulations and NEC article 590.6(B)(2) for the specific directions required for the implementation of the assured equipment grounding conductor program of temporary circuits greater than 125V, 15, 20 or 30A.
However, to reduce identical information redundancy, rather than repeating the information in both 110.8(B) for "maintenance and construction" and 110.8(C) for "outdoors" the statement "...greater than 125V, 15, 20, 30 ampere circuits, GFCI protection or an assured equipment grounding conductor program shall be implemented." should have its own new section 110.8(D). This will require the existing 110.8(D) "Testing GFCI Devices" to be moved to a new section 110.8(E).

Related Item

• PI

Submitter Information Verification

Submitter Full Name: George Cole
Organization: PVNGS/APS
Street Address:
City:
State:
Zip:
Submittal Date: Sat Mar 19 20:53:58 EDT 2022
Committee: EEW-AAA

Committee Statement

Committee Action: Rejected but held

Resolution: The text proposed by this public comment does not meet 4.4.4.2 of the Regulations Governing Committee Projects which requires public comments to be related to material that has received public review either through the submission of Public Input, Committee Input or Correlating Input or through the First Revisions.

2024 NFPA 70E Public Input article 110.8
George Cole

110.8(D) Temporary Circuits Greater than 125-Volt, 15, 20, or 30 Amperes

Where employees operate or use equipment supplied by greater than 125-volt, 15, 20 or 30-ampere circuits, GFCI protection or an assured equipment grounding conductor program shall be implemented.

Informational Note No. 2: See applicable state, federal, or local codes and standards such as *NFPA 70*, *National Electrical Code*, Section 590.6(B)(2) for more information regarding implementation of an assured equipment grounding conductor program.

110.8(E) Testing Ground-Fault Circuit -Interrupter Protection Devices

GFCI protection devices shall be tested in accordance with the manufacturer's instructions.

Public Input No. 4-NFPA 70E-2023 [Article 120]

Article 120 Establishing and Verifying an Electrically Safe Work Condition

120.1 Scope.

This article covers requirements for establishing and verifying an electrically safe work condition.

120.2 Lockout/Tagout Program.

(A) General.

Each employer shall establish, document, and implement a lockout/tagout program. The lockout/tagout program shall specify lockout/tagout procedures to safeguard workers from exposure to electrical hazards. The lockout/tagout program and procedures shall also incorporate the following:

(1) Be applicable to the experience and training of the workers and conditions in the workplace

(2) Meet the requirements of 120.2 through 120.6

(3) Apply to fixed, permanently installed equipment, temporarily installed equipment, and portable equipment

(B) Employer Responsibilities.

The employer shall be responsible for the following:

(1) Providing the equipment necessary to execute lockout/tagout procedures

(2) Providing lockout/tagout training to workers in accordance with 110.4(B)

(3) Auditing the lockout/tagout program in accordance with 110.3(L)(3)

(4) Auditing execution of the lockout/tagout procedures in accordance with 110.3(L)(3)

Informational Note: See Informative Annex G for an example of a lockout/tagout program.

120.3 Lockout/Tagout Principles.

(A) Employee Involvement.

Each person who could be exposed directly or indirectly to a source of electrical energy shall be involved in the lockout/tagout procedure.

Informational Note: An example of direct exposure is the qualified electrician who works on the motor starter control, the power circuits, or the motor. An example of indirect exposure is the person who works on the coupling between the motor and compressor.

(B) Lockout/Tagout Procedure.

A lockout/tagout procedure shall be developed on the basis of the existing electrical equipment and system and shall use suitable documentation including up-to-date drawings and diagrams. The procedure shall meet the requirements of applicable codes, standards, and regulations for lockout and tagging of electrical sources.

(C) Control of Energy.

All sources of electrical energy shall be controlled in such a way as to minimize employee exposure to electrical hazards.

(D) Electrical Circuit Interlocks.

Documentation, including up-to-date drawings and diagrams, shall be reviewed to ensure that no electrical circuit interlock operation can result in re-energizing the circuit being worked on.

(E) Control Devices.

Locks/tags shall be installed only on circuit disconnecting means. Control devices, such as push-buttons or selector switches, shall not be used as the primary isolating device.

(F) Identification.

The lockout/tagout device shall be unique and readily identifiable as a lockout/tagout device.

(G) Coordination.

The following items are necessary for coordinating the lockout/tagout procedure:

(1) The electrical lockout/tagout procedure shall be coordinated with all other employer's procedures for control of exposure to electrical energy sources such that all employer's procedural requirements are adequately addressed on a site basis.

(2) The procedure for control of exposure to electrical hazards shall be coordinated with other procedures for control of other hazardous energy based on similar or identical concepts.

(3) Electrical lockout/tagout devices shall be permitted to be similar to lockout/tagout devices for control of other hazardous energy sources, such as pneumatic, hydraulic, thermal, and mechanical, if such devices are used only for control of hazardous energy and for no other purpose.

(H) Forms of Control of Hazardous Electrical Energy.

Two forms of hazardous electrical energy control shall be permitted: simple lockout/tagout and complex lockout/tagout *[see 120.5]*. For the simple lockout/tagout, the qualified person shall be in charge. For the complex lockout/tagout, the person in charge shall have overall responsibility.

120.4 Lockout/Tagout Equipment.

(A) Lock Application.

Energy isolation devices for machinery or equipment installed after January 2, 1990, shall be capable of accepting a lockout device.

(B) Lockout/Tagout Device.

Each employer shall supply, and employees shall use, lockout/tagout devices and equipment necessary to execute the requirements of 120.4. Locks and tags used for control of exposure to electrical hazards shall be unique, shall be readily identifiable as lockout/tagout devices, and shall be used for no other purpose.

(C) Lockout Device.

The lockout device shall meet the following requirements:

(1) A lockout device shall include a lock — either keyed or combination.

(2) The lockout device shall include a method of identifying the individual who installed the lockout device.

(3) A lockout device shall be permitted to be only a lock, if the lock is readily identifiable as a lockout device, in addition to having a means of identifying the person who installed the lock, provided that all of the following conditions exist:

(4) Only one circuit or piece of equipment is de-energized.

(5) The lockout period does not extend beyond the work shift.

(6) Employees exposed to the hazards associated with re-energizing the circuit or equipment are familiar with this procedure.

(7) Lockout devices shall be attached to prevent operation of the disconnecting means without resorting to undue force or the use of tools.

(8) Where a tag is used in conjunction with a lockout device, the tag shall contain a statement prohibiting unauthorized operation of the disconnecting means or unauthorized removal of the device.

(9) Lockout devices shall be suitable for the environment and for the duration of the lockout.

(10) Whether keyed or combination locks are used, the key or combination shall remain in the possession of the individual installing the lock or the person in charge, when provided by the established procedure.

(D) Tagout Device.

The tagout device shall meet the following requirements:

(1) A tagout device shall include a tag together with an attachment means.

(2) The tagout device shall be readily identifiable as a tagout device and suitable for the environment and duration of the tagout.

(3) A tagout device attachment means shall be capable of withstanding at least 222.4 N (50 lb) of force exerted at a right angle to the disconnecting means surface. The tag attachment means shall be nonreusable, attachable by hand, self-locking, nonreleasable, and equal to an all-environmental tolerant nylon cable tie.

(4) Tags shall contain a statement prohibiting unauthorized operation of the disconnecting means or removal of the tag.

(5) A hold card tagging tool on an overhead conductor in conjunction with a hotline tool to install the tagout device safely on a disconnect that is isolated from the work(s) shall be permitted. Where a hold card is used, the tagout procedure shall include the method of accounting for personnel who are working under the protection of the hold card.

120.5 Lockout/Tagout Procedures.

The employer shall maintain a copy of the procedures required by this section and shall make the procedures available to all employees.

(A) Planning.

The procedure shall require planning, including the requirements of 120.5(A)(1) through 120.5(B)(14).

(1) Locating Sources.

Up-to-date single-line drawings shall be considered a primary reference source for such information. When up-to-date drawings are not available, the employer shall be responsible for ensuring that an equally effective means of locating all sources of energy is employed.

Informational Note: Locating sources of supply could include identifying situations where a neutral conductor continues to carry current after phase conductors have been de-energized.

(2) Exposed Persons.

The plan shall identify persons who might be exposed to an electrical hazard and the PPE required during the execution of the job or task.

(3) Person in Charge.

The plan shall identify the person in charge and his or her responsibility in the lockout/tagout.

(4) Simple Lockout/Tagout Procedure.

All lockout/tagout procedures that involve only a qualified person(s) de-energizing one set of conductors or circuit part source for the sole purpose of safeguarding employees from exposure to electrical hazards shall be considered to be a simple lockout/tagout. Simple lockout/tagout procedures shall not be required to be written for each application. Each worker shall be responsible for his or her own lockout/tagout.

Exception: Lockout/tagout is not required for work on cord- and plug-connected equipment for which exposure to the hazards of unexpected energization of the equipment is controlled by the unplugging of the equipment from the energy source, provided that the plug is under the exclusive control of the employee performing the servicing and maintenance for the duration of the work.

(5) Complex Lockout/Tagout.

(a) A complex lockout/tagout procedure shall be permitted where one or more of the following exists:

(2) Multiple energy source

(3) Multiple crews

(4) Multiple crafts

(5) Multiple locations

(6) Multiple employers

(7) Multiple disconnecting means

(8) Particular sequences

(9) Job or task that continues for more than one work period

(j) All complex lockout/tagout procedures shall require a written plan of execution that identifies the person in charge.

(k) The complex lockout/tagout procedure shall vest primary responsibility in an authorized employee for employees working under the protection of a group lockout or tagout device, such as an operation lock or lockbox. The person in charge shall be held accountable for safe execution of the complex lockout/tagout.

(l) Each authorized employee shall affix a personal lockout or tagout device to the group lockout device, group lockbox, or comparable mechanism when he or she begins work and shall remove those devices when he or she stops working on the machine or equipment being serviced or maintained.

(m) All complex lockout/tagout plans shall identify the method to account for all persons who might be exposed to electrical hazards in the course of the lockout/tagout.

(B) Elements of Control.

The procedure shall identify elements of control.

(1) De-energizing Equipment (Shutdown).

The procedure shall establish the person who performs the switching and where and how to de-energize the load.

(2) Stored Energy.

The procedure shall include requirements for releasing stored electric or mechanical energy that might endanger personnel. All capacitors shall be discharged, and high-capacitance elements shall also be short-circuited and grounded before the associated equipment is touched or worked on. Springs shall be released or physical restraint shall be applied when necessary to immobilize mechanical equipment and pneumatic and hydraulic pressure reservoirs. Other sources of stored energy shall be blocked or otherwise relieved to the extent that the circuit cannot be unintentionally energized.

> Informational Note: See 360.3, 360.5, and Informative Annex R for more information on methods and procedures to place capacitors in an electrically safe work condition.

(3) Disconnecting Means.

The procedure shall identify how to verify that the circuit is de-energized (open).

(4) Responsibility.

The procedure shall identify the person who is responsible for verifying that the lockout/tagout procedure is implemented and who is responsible for ensuring that the task is completed prior to removing locks/tags. A mechanism to accomplish lockout/tagout for multiple (complex) jobs/tasks where required, including the person responsible for coordination, shall be included.

(5) Verification.

The procedure shall verify that equipment cannot be restarted. The equipment operating controls, such as push-buttons, selector switches, and electrical interlocks, shall be operated or otherwise it shall be verified that the equipment cannot be restarted.

(6) Testing.

The procedure shall establish the following:

(1) Test instrument to be used, the required PPE, and the person who will use it to verify proper operation of the test instrument on a known voltage source before and after use

(2) Requirement to define the boundary of the electrically safe work condition

(3) Requirement to test before touching every exposed conductor or circuit part(s) within the defined boundary of the work area

(4) Requirement to retest for absence of voltage when circuit conditions change or when the job location has been left unattended

(5) Planning considerations that include methods of verification where there is no accessible exposed point to take voltage measurements

(7) Grounding.

Grounding requirements for the circuit shall be established, including whether the temporary protective grounding equipment shall be installed for the duration of the task or is temporarily established by the procedure. Grounding needs or requirements shall be permitted to be covered in other work rules and might not be part of the lockout/tagout procedure.

(8) Shift Change.

A method shall be identified in the procedure to transfer responsibility for lockout/tagout to another person or to the person in charge when the job or task extends beyond one shift.

(9) Coordination.

The procedure shall establish how coordination is accomplished with other jobs or tasks in progress, including related jobs or tasks at remote locations as well as the person responsible for coordination.

(10) Accountability for Personnel.

A method shall be identified in the procedure to account for all persons who could be exposed to hazardous energy during the lockout/tagout.

(11) Lockout/Tagout Application.

The procedure shall clearly identify when and where lockout applies, in addition to when and where tagout applies, and shall address the following:

(1) Lockout shall be defined as installing a lockout device on all sources of hazardous energy such that operation of the disconnecting means is prohibited, and forcible removal of the lock is required to operate the disconnecting means.

(2) Tagout shall be defined as installing a tagout device on all sources of hazardous energy, such that operation of the disconnecting means is prohibited. The tagout device shall be installed in the same position available for the lockout device.

(3) Where it is not possible to attach a lock to existing disconnecting means, the disconnecting means shall not be used as the only means to put the circuit in an electrically safe work condition.

(4) The use of tagout procedures without a lock shall be permitted only in cases where equipment design precludes the installation of a lock on an energy isolation device(s). When tagout is employed, at least one additional safety measure shall be employed. In such cases, the procedure shall clearly establish responsibilities and accountability for each person who might be exposed to electrical hazards.

> Informational Note: Examples of additional safety measures include the removal of an isolating circuit element such as fuses, blocking of the controlling switch, or opening an extra disconnecting device to reduce the likelihood of inadvertent energization.

(12) Removal of Lockout/Tagout Devices.

The procedure shall identify the details for removing locks or tags when the installing individual is unavailable. When locks or tags are removed by someone other than the installer, the employer shall attempt to locate that person prior to removing the lock or tag. When the lock or tag is removed because the installer is unavailable, the installer shall be informed prior to returning to work.

(13) Release for Return to Service.

The procedure shall identify steps to be taken when the job or task requiring lockout/tagout is completed. Before electric circuits or equipment are re-energized, tests and visual inspections shall be conducted to verify that all tools, mechanical restraints and electrical jumpers, short circuits, and temporary protective grounding equipment have been removed, so that the circuits and equipment are in a condition to be safely energized. When applicable, the employees responsible for operating the machines or process shall be notified when circuits and equipment are ready to be energized, and such employees shall provide assistance as necessary to safely energize the circuits and equipment. The procedure shall contain a statement requiring the area to be inspected to ensure that nonessential items have been removed. One such step shall ensure that all personnel are clear of exposure to dangerous conditions resulting from re-energizing the service and that blocked mechanical equipment or grounded equipment is cleared and prepared for return to service.

(14) Temporary Release for Testing/Positioning.

The procedure shall clearly identify the steps and qualified persons' responsibilities when the job or task requiring lockout/tagout is to be interrupted temporarily for testing or positioning of equipment; then the steps shall be identical to the steps for return to service.

Informational Note: See 110.6 for requirements when using test instruments and equipment.

120.6 Process for Establishing and Verifying an Electrically Safe Work Condition.

Establishing and verifying an electrically safe work condition shall include all of the following steps, which shall be performed in the order presented, if feasible:

(1) Determine all possible sources of electrical supply to the specific equipment. Check applicable up-to-date drawings, diagrams, and identification tags.

(2) After properly interrupting the load current, open the disconnecting device(s) for each source.

(3) Wherever possible, visually verify that all blades of the disconnecting devices are fully open or that drawout-type circuit breakers are withdrawn to the test or fully disconnected position.

(4) Release stored electrical energy.

(5) Block or relieve stored nonelectrical energy in devices to the extent the circuit parts cannot be unintentionally energized by such devices.

(6) Apply lockout/tagout devices in accordance with a documented and established procedure.

(7) Use an adequately rated portable test instrument to test each phase conductor or circuit part at each point of work to test for the absence of voltage. Test each phase conductor or circuit part both phase-to-phase and phase-to-ground. Before and after each test, determine that the test instrument is operating satisfactorily through verification on any known voltage source.

Exception No. 1 to 7: *An adequately rated permanently mounted absence of voltage tester shall be permitted to be used to test for the absence of voltage of the conductors or circuit parts at the work location, provided it meets all of the following requirements: (1) It is permanently mounted and installed in accordance with the manufacturer's instructions and tests the conductors and circuit parts at the point of work; (2) It is listed and labeled for the purpose of testing for the absence of voltage; (3) It tests each phase conductor or circuit part both phase-to-phase and phase-to-ground; (4) The test device is verified as operating satisfactorily on any known voltage source before and after testing for the absence of voltage.*

Exception No. 2 to 7: *On electrical systems over 1000 volts, noncontact capacitive test instruments shall be permitted to be used to test each phase conductor.*

Informational Note No. 1: See UL 61010-1, *Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use, Part 1: General Requirements* , for rating, overvoltage category, and design requirements for voltage measurement and test instruments intended for use on electrical systems 1000 volts and below.

Informational Note No. 2: See UL 1436, *Outlet Circuit Testers and Other Similar Indicating Devices* , for additional information on rating and design requirements for permanently mounted absence of voltage testers.

Informational Note No. 3: See IEC 61243-1, *Live Working — Voltage Detectors — Part 1: Capacitive type to be used for voltages exceeding 1kV a.c.* , or IEC 61243-2, *Live Working — Voltage Detectors — Part 2: Resistive type to be used for voltages of 1kV to 36 kV a.c.* , or IEC 61243-3, *Live Working — Voltage Detectors — Part 3: Two-pole low voltage type* , for additional information on rating and design requirements for voltage detectors.

(8) Where the possibility of induced voltages or stored electrical energy exists, ground all circuit conductors and circuit parts before touching them. Where it could be reasonably anticipated that the conductors or circuit parts being de-energized could contact other exposed energized conductors or circuit parts, apply temporary protective grounding equipment in accordance with the following:

(9) *Placement.* Temporary protective grounding equipment shall be placed at such locations and arranged in such a manner as to prevent each employee from being exposed to an electric shock hazard (i.e., hazardous differences in electrical potential). The location, sizing, and application of temporary protective grounding equipment shall be identified as part of the employer's job planning.

(10) *Capacity.* Temporary protective grounding equipment shall be capable of conducting the maximum fault current that could flow at the point of grounding for the time necessary to clear the fault.

Informational Note: See ASTM F855, *Standard Specification for Temporary Protective Grounds to be Used on De-energized Electric Power Lines and Equipment* , which is an example of a standard that contains information on capacity of temporary protective grounding equipment.

(11) *Impedance.* Temporary protective grounding equipment and connections shall have an impedance low enough to cause immediate operation of protective devices in case of unintentional energizing of the electric conductors or circuit parts.

Statement of Problem and Substantiation for Public Input

The article title and scope should reflect what the article covers. Accordingly, "and verifying" is added to the article title and scope since the article both establishes and verifies an electrically safe work condition per 120.6.

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Submittal Date: Thu Aug 24 10:09:30 EDT 2023
Committee: EEW-AAA

Committee Statement

Resolution: Verifying is inherent to the electrically safe work condition and therefore the proposed text is redundant and does not add clarity.

Public Input No. 18-NFPA 70E-2023 [Section No. 120.3(C)]

(C) Control of Energy.

All sources of electrical energy shall be controlled in such a way as to eliminate or minimize employee exposure to electrical hazards.

Statement of Problem and Substantiation for Public Input

The addition of "eliminate" or, seemingly aligns with Article 120's topic of establishing an electrically safe work condition, which of course is done by eliminating electrical hazards. Furthermore, to "eliminate or minimize" coincides with 110.3(H)(3) more-so than "minimize" alone does.

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Submittal Date: Mon Sep 11 10:27:49 EDT 2023
Committee: EEW-AAA

Committee Statement

Resolution: FR-24-NFPA 70E-2024

Statement: The addition of eliminate aligns with the requirements of establishing an electrically safe work condition.

Public Input No. 185-NFPA 70E-2024 [Section No. 120.4(C)]

(C) Lockout Device.

The lockout device shall meet the following requirements:

(1) A lockout device shall include a lock — ~~either keyed or combination~~ p hysical mechanism which permits ready access to authorized personnel by means of physical key, numerical combination, or uniquely identifiable digital code/frequency .

(2) The lockout device shall include a method of identifying the individual who installed the lockout device.

(3) A lockout device shall be permitted to be only a lock, if the lock is readily identifiable as a lockout device, in addition to having a means of identifying the person who installed the lock, provided that all of the following conditions exist:

(4) Only one circuit or piece of equipment is de-energized.

(5) The lockout period does not extend beyond the work shift.

(6) Employees exposed to the hazards associated with re-energizing the circuit or equipment are familiar with this procedure.

(7) Lockout devices shall be attached to prevent operation of the disconnecting means without resorting to undue force or the use of tools.

(8) Lockout devices shall be independently connected to a cloud network, local area network or private cloud network without the reliance on a worker's mobile device.

(9) Where a tag is used in conjunction with a lockout device, the tag shall contain a statement prohibiting unauthorized operation of the disconnecting means or unauthorized removal of the device.

(10) Lockout devices shall be suitable for the environment and for the duration of the lockout.

(11) Whether keyed , or combination , or digital access locks are used, the key , or combination , or digital code/frequency shall remain in the possession of the individual installing the lock or the person in charge, when provided by the established procedure.

Statement of Problem and Substantiation for Public Input

This provides for the inclusion of digital lockout tagout devices,

The purpose of the addition of (5) is to ensure that the latest status or changes in status can be reported/monitored without the physical presence of a worker or the presence of a separate mobile phone.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 187-NFPA 70E-2024 [Section No. 120.5(A)(5)]	
Public Input No. 226-NFPA 70E-2024 [Section No. 120.5(B)(4)]	
Public Input No. 227-NFPA 70E-2024 [Section No. 120.5(B)(8)]	
Public Input No. 228-NFPA 70E-2024 [Section No. 120.5(B)(12)]	
Public Input No. 229-NFPA 70E-2024 [Section No. G.2.0]	

Public Input No. 230-NFPA 70E-2024 [Section No. G.9.4]

Submitter Information Verification

Submitter Full Name:	Brad Ruffkess
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Submittal Date:	Mon Jun 03 16:30:41 EDT 2024
Committee:	EEW-AAA

Committee Statement

Resolution: Insufficient substantiation was provided to determine the reliability, assurance of exclusive control, or effective procedures of a digital key as compared to a physical key. As written, it creates conflicts within the document, for example list item 5 in the existing text cannot apply to keyed locks.

Public Input No. 177-NFPA 70E-2024 [Section No. 120.4(D)]

(D) Tagout Device.

The tagout device shall meet the following requirements:

(1) A tagout device shall include a tag together with an attachment means.

(2) The tagout device shall be readily identifiable as a tagout device and suitable for the environment and duration of the tagout.

(3) A tagout device attachment means shall be capable of withstanding at least 222.4 N (50 lb) of force exerted at a right angle to the disconnecting means surface. The tag attachment means shall be nonreusable, attachable by hand, self-locking, and nonreleasable, ~~and equal to an all-environmental tolerant nylon cable tie~~ such as a cable tie, and shall be suitable for the environment where used .

(4) Tags shall contain a statement prohibiting unauthorized operation of the disconnecting means or removal of the tag.

(5) A hold card tagging tool on an overhead conductor in conjunction with a hotline tool to install the tagout device safely on a disconnect that is isolated from the work(s) shall be permitted. Where a hold card is used, the tagout procedure shall include the method of accounting for personnel who are working under the protection of the hold card.

Statement of Problem and Substantiation for Public Input

Specifying nylon is too restrictive and in some cases may not be suitable for the environment where used.

Submitter Information Verification

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Submittal Date: Mon Jun 03 14:47:32 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-25-NFPA 70E-2024

Statement: Specifying nylon is too restrictive, as other types of fasteners may be appropriate to attach tagout devices. Revisions are made to Item 3 to comply with the NEC Style Manual.

Public Input No. 63-NFPA 70E-2024 [Section No. 120.5(A)(1)]

(1) Locating Sources.

Up-to-date single-line drawings shall be considered a primary reference source for such information. When up-to-date drawings are not available, the employer shall be responsible for ensuring that an equally effective means of locating all sources of energy is employed.

Informational Note: ~~Locating sources~~ Determining sources of supply could include identifying situations where a ~~neutral conductor~~ grounded conductor continues to carry current after phase conductors have been ~~de-energized.~~ placed into an electrically safe work condition. This could occur if single or three phase loads remain energized or could become energized and are fed from an alternate source with a shared neutral connection within the work location, or during abnormal conditions.

Statement of Problem and Substantiation for Public Input

The original public input to add this note surrounding neutral conductors surrounding incidents that occurred and were identified at the IEEE ESW conference within White Paper presentations left out the fact that the hazard can occur if ground is also part of the of current that is interrupted causing the shock hazard. Since breaking the neutral conductor, or the connection to ground causes the same hazard, it is better to call it a grounded conductor versus neutral. Also, wording was reworked to call out placing the phase conductors into an electrically safe work condition versus just using the word "de-energized" since the phase conductors meet the requirements of an ESWC. Lastly, some more information was given surrounding the fact that this is caused by loads ,single and three phase, that are sharing the neutral conductors and are fed from an alternate source.

Submitter Information Verification

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Submittal Date: Tue Mar 05 12:55:29 EST 2024
Committee: EEW-AAA

Committee Statement

Resolution: Changing neutral conductor to grounded conductor does not add clarity or useability and is inconsistent with the parent text. Replacing “de-energized” with “placed into an electrically safe work condition” is technically incorrect, as a conductor can be de-energized but still not be an electrically safe work condition.

Public Input No. 187-NFPA 70E-2024 [Section No. 120.5(A)(5)]

(5) Complex Lockout/Tagout.

(a) A complex lockout/tagout procedure shall be permitted where one or more of the following exists:

(2) Multiple energy source

(3) Multiple crews

(4) Multiple crafts

(5) Multiple locations

(6) Multiple employers

(7) Multiple disconnecting means

(8) Particular sequences

(9) Job or task that continues for more than one work period

(j) All complex lockout/tagout procedures shall require a written plan of execution that identifies the person in charge.

(k) The complex lockout/tagout procedure shall vest primary responsibility in an authorized employee for employees working under the protection of a group lockout or tagout device, such as an operation lock or lockbox. The person in charge shall be held accountable for safe execution of the complex lockout/tagout.

(l) Each authorized employee shall affix a personal lockout or tagout device to the group lockout device, group lockbox, or comparable mechanism when he or she begins work and shall remove those devices when he or she stops working on the machine or equipment being serviced or maintained. In the event that a digital lockout device is used, a single lockout device that follows the same rules for lockout/tagout where the device or system can identify the person in charge and records the status of any authorized employee or employees working under the protection of the group lockout device.

(m) All complex lockout/tagout plans shall identify the method to account for all persons who might be exposed to electrical hazards in the course of the lockout/tagout.

Statement of Problem and Substantiation for Public Input

The goal here is that a single connected physical device with the proper physical controls and online data records should be able to accomplish the task done by a group lockout device

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 185-NFPA 70E-2024 [Section No. 120.4(C)]	
Public Input No. 226-NFPA 70E-2024 [Section No. 120.5(B)(4)]	
Public Input No. 227-NFPA 70E-2024 [Section No. 120.5(B)(8)]	
Public Input No. 228-NFPA 70E-2024 [Section No. 120.5(B)(12)]	

Public Input No. 229-NFPA 70E-2024 [Section No. G.2.0]

Public Input No. 230-NFPA 70E-2024 [Section No. G.9.4]

Submitter Information Verification

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Submittal Date:	Mon Jun 03 16:45:52 EDT 2024
Committee:	EEW-AAA

Committee Statement

Resolution: The proposed text is not a complete statement and adds requirements for digital locks which are not currently addressed in NFPA 70E. Insufficient substantiation was provided to determine the reliability, assurance of exclusive control, or effective procedures of a digital key as compared to a physical key.

Public Input No. 266-NFPA 70E-2024 [Section No. 120.5(A)(5)]

(5) Complex Lockout/Tagout.

(a) A complex lockout/tagout procedure shall be ~~permitted~~ required where one or more of the following exists:

(2) Multiple energy source

(3) Multiple crews

(4) Multiple crafts

(5) Multiple locations

(6) Multiple employers

(7) Multiple disconnecting means

(8) Particular sequences

(9) Job or task that continues for more than one work period

(j) All complex lockout/tagout procedures shall require a written plan of execution that identifies the person in charge.

(k) The complex lockout/tagout procedure shall vest primary responsibility in an authorized employee for employees working under the protection of a group lockout or tagout device, such as an operation lock or lockbox. The person in charge shall be held accountable for safe execution of the complex lockout/tagout.

(l) Each authorized employee shall affix a personal lockout or tagout device to the group lockout device, group lockbox, or comparable mechanism when he or she begins work and shall remove those devices when he or she stops working on the machine or equipment being serviced or maintained.

(m) All complex lockout/tagout plans shall identify the method to account for all persons who might be exposed to electrical hazards in the course of the lockout/tagout.

Statement of Problem and Substantiation for Public Input

Currently 120.5(B) indicates that when certain conditions identified in 120.5(A)(5)(a) are met, that a complex LOTO with a written plan is required, Stating that complex LOTO "shall be permitted" makes complex LOTO optional and suggestive in nature. If this is this case, the recommendation for a written plan should be an informational note, which is not the intent of the article.
Changing the word "permitted" to "required accurately reflects the intent of the article

Submitter Information Verification

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Submittal Date: Tue Jun 04 17:44:55 EDT 2024

Committee: EEW-AAA

Committee Statement

Resolution: The proposed text is too restrictive. This standard intends for the complex LO/TO method to be permissive instead of a mandatory requirement.

Public Input No. 226-NFPA 70E-2024 [Section No. 120.5(B)(4)]

(4) Responsibility.

The procedure shall identify the person who is responsible for verifying that the lockout/tagout procedure is implemented and who is responsible for ensuring that the task is completed prior to removing locks/tags. A mechanism to accomplish lockout/tagout for multiple (complex) jobs/tasks where required, including the person responsible for coordination, shall be included.

Statement of Problem and Substantiation for Public Input

Benefit: The changes made in earlier sections make it possible for checks to be validated across digital systems with completing a task or inspection in another system as a digital requirement for the locks being released.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 185-NFPA 70E-2024 [Section No. 120.4(C)]	
Public Input No. 187-NFPA 70E-2024 [Section No. 120.5(A)(5)]	

Submitter Information Verification

Submitter Full Name:	Brad Ruffkess
Organization:	BoxLock, Inc.
Affiliation:	Rosendin (Tyler Westfall), McCarthy Renewables (John King), BoxLock, Inc.
Street Address:	
City:	
State:	
Zip:	

Submittal Date:	Tue Jun 04 09:10:43 EDT 2024
Committee:	EEW-AAA

Committee Statement

Resolution: This public input did not provide a suggested revision as required in Section 4.3.4.1(c) of the NFPA regulations.

Public Input No. 282-NFPA 70E-2024 [Section No. 120.5(B)(6)]

(6) Testing.

The procedure shall establish the following:

(1) Test instrument to be used, the required PPE, and the person who will use it to verify proper operation of the test instrument on a known voltage source before and after use

(2) Requirement to define the boundary of the electrically safe work condition

(3) Requirement to test before touching every exposed conductor or circuit part(s) within the defined boundary of the work area

(4) Requirement to retest for absence of voltage when circuit conditions change or when the job location has been left unattended

(5) Planning considerations that include methods of verification where there is no accessible exposed point to take voltage measurements

(6) Requirement to test for absence of voltage if moving from the original defined work area of the same equipment to a different area that has not been previously tested for the absence of voltage, for example moving from one compartment, enclosure or part to a different compartment, enclosure or part.

Additional Proposed Changes

File Name	Description	Approved
70E_PC_67_Hold.pdf	70E_PC67	

Statement of Problem and Substantiation for Public Input

NOTE: This Public Input appeared as “Reject but Hold” in Public Comment No. 67 of the (A2023) Second Draft Report for NFPA 70E and per the Regs. At 4.4.8.3.1 and needs to be reconsidered by the TC for the next edition of the document.

There are many types of electrical equipment, such as 'main-tie-main', switchgear and similar that has more than
one source that can provide power to the equipment which can remain energized. For example, switchgear with
a primary and alternate sources where the primary source can be placed into an ESWC with temporary protective grounds attached. However, the cubicle being fed by the alternate source may not be able to be deenergized
and placed into an ESWC for a variety of reasons. During routine clean and inspections of such switchgear, the energized enclosures must be identified and flagged off IAW article 130.7(E), 130.7(F) and
annex Q Q.6.9, however due to human errors sometime an energized cubicle might not be flagged off. During October 2021, my power plant had an electrician seriously injured when he inadvertently opened a
cubicle containing energized parts. The primary feed was verified to be in an ESWC and he had properly
flagged off the cubicle with the energized 13.8kV from the alternate source. However he inadvertently opened
an adjacent cubicle which contained the two sets of potential transformers, one for the primary source which was
ESWC but the one for the alternate source was still energized.
Also the Los Alamos National Laboratory suffered a very similar arc flash event during routine clean

and
inspection of switchgear. The details of this serious injury accident was presented by Tommy Martinez and
Julian Trujillo during the 2020 IEEE Electrical Safety Workshop conference in Reno, NV, see ESW2020-31 for
details.
Therefore, it is imperative that workers reperform absence of voltage testing as they move from one part to a
different part of the same equipment during normal routine maintenance. In both cases, if this was performed
then these near fatal events would have been prevented.
Therefore

Submitter Information Verification

Submitter Full Name:	NFPA Holds
Organization:	Technical Committee on Electrical Safety in the Workplace
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Thu Jun 06 22:04:04 EDT 2024
Committee:	EEW-AAA

Committee Statement

Resolution: The proposed requirement is already addressed by List Items 2 and 3.

Public Comment No. 67-NFPA 70E-2022 [Section No. 120.5(B)(6)]

(6) Testing.

The procedure shall establish the following:

(1) Test instrument to be used, the required PPE, and the person who will use it to verify proper operation of the test instrument on a known voltage source before and after use

(2) Requirement to define the boundary of the electrically safe work condition

(3) Requirement to test before touching every exposed conductor or circuit part(s) within the defined boundary of the work area

(4) Requirement to retest for absence of voltage when circuit conditions change or when the job location has been left unattended

(5) Planning considerations that include methods of verification where there is no accessible exposed point to take voltage measurements

(6) Requirement to test for absence of voltage if moving from the original defined work area of the same equipment to a different area that has not been previously tested for the absence of voltage, for example moving from one compartment, enclosure or part to a different compartment, enclosure or part.

Statement of Problem and Substantiation for Public Comment

There are many types of electrical equipment, such as 'main-tie-main', switchgear and similar that has more than one source that can provide power to the equipment which can remain energized. For example, switchgear with a primary and alternate sources where the primary source can be placed into an ESWC with temporary protective grounds attached. However, the cubicle being fed by the alternate source may not be able to be de-energized and placed into an ESWC for a variety of reasons. During routine clean and inspections of such switchgear, the energized enclosures must be identified and flagged off IAW article 130.7(E), 130.7(F) and annex Q Q.6.9, however due to human errors sometime an energized cubicle might not be flagged off.
During October 2021, my power plant had an electrician seriously injured when he inadvertently opened a cubicle containing energized parts. The primary feed was verified to be in an ESWC and he had properly flagged off the cubicle with the energized 13.8kV from the alternate source. However he inadvertently opened an adjacent cubicle which contained the two sets of potential transformers, one for the primary source which was ESWC but the one for the alternate source was still energized.
Also the Los Alamos National Laboratory suffered a very similar arc flash event during routine clean and inspection of switchgear. The details of this serious injury accident was presented by Tommy Martinez and Julian Trujillo during the 2020 IEEE Electrical Safety Workshop conference in Reno, NV, see ESW2020-31 for details.
Therefore, it is imperative that workers reperform absence of voltage testing as they move from one part to a different part of the same equipment during normal routine maintenance. In both cases, if this was performed then these near fatal events would have been prevented.
Therefore

Related Public Comments for This Document

Related Comment	Relationship
Public Comment No. 66-NFPA 70E-2022 [Section No. 120.5(B)(7)]	Related comments

Related Item

• pi

Submitter Information Verification

Submitter Full Name: George Cole
Organization: PVNGS/APS
Street Address:

City:
State:
Zip:
Submittal Date: Fri May 27 23:08:08 EDT 2022
Committee: EEW-AAA

Committee Statement

Committee Action: Rejected but held

Resolution: The text proposed by this public comment does not meet 4.4.4.2 of the Regulations Governing Committee Projects which requires public comments to be related to material that has received public review either through the submission of Public Input, Committee Input or Correlating Input or through the First Revisions.

Public Input No. 52-NFPA 70E-2024 [Section No. 120.5(B)(6)]

(6) Testing.

The procedure shall establish the following:

(1) Test instrument to be used, the required PPE, and the person who will use it to verify proper operation of the test instrument on a known voltage source before and after use

(2) Requirement to define the boundary of the electrically safe work condition

(3) Requirement to test before touching every exposed conductor or circuit part(s) within the defined boundary of the work area

(4) Requirement to retest for absence of ~~voltage~~ energy when circuit conditions change or when the job location has been left unattended

(5) Planning considerations that include methods of verification where there is no accessible exposed point to take voltage measurements

Statement of Problem and Substantiation for Public Input

NFPA 70E is written to address voltage driven circuits, therefore the requirement to test for voltage. Series Circuits powered with a constant current are still widely used throughout the United States and the world. As presently written 70E is instructing an electrician working on a current powered circuit to measure voltage. Attempting to measure voltage on a current driven circuit could be an unsafe act. Current is measured to determine the proper operation of a current driven circuit and to determine if the circuit is energized. Replacing the term voltage with the term energy solves this problem. Please see documents attached to PI No. 48.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 48-NFPA 70E-2024 [Section No. 120.6]	series circuit
Public Input No. 49-NFPA 70E-2024 [Definition: Electrically Safe Work Condition.]	series circuit
Public Input No. 50-NFPA 70E-2024 [Section No. 110.4(A)(1)]	series circuit
Public Input No. 51-NFPA 70E-2024 [Section No. 110.6(E)]	series circuit
Public Input No. 48-NFPA 70E-2024 [Section No. 120.6]	
Public Input No. 49-NFPA 70E-2024 [Definition: Electrically Safe Work Condition.]	
Public Input No. 50-NFPA 70E-2024 [Section No. 110.4(A)(1)]	
Public Input No. 51-NFPA 70E-2024 [Section No. 110.6(E)]	

Submitter Information Verification

Submitter Full Name: Carl Johnson
Organization: AVCON, Inc.
Affiliation: none
Street Address:
City:

State:
Zip:
Submittal Date: Tue Jan 02 07:42:06 EST 2024
Committee: EEW-AAA

Committee Statement

Resolution: Changing “voltage” to “energy” makes the requirement less clear for most applications. To be qualified to work on constant current lighting a person would need to have “knowledge related to the construction and operation of electrical equipment and installations” of such a system and would need to have “safety training to identify the hazards and reduce the associated risk,” including the correct method to verify that the system is in an electrically safe work condition.

Public Input No. 75-NFPA 70E-2024 [Section No. 120.5(B)(6)]

(6) Testing.

The procedure shall establish the following:

(1) Test instrument to be used, the required PPE, and the person who will use it to verify proper operation of the test instrument on a known voltage source before and after use

(2) Requirement to define the boundary of the electrically safe work condition

(3) Requirement to test ~~before touching every~~ each exposed conductor or circuit ~~part(s)~~ part for absence of voltage before touching it when it is within the defined boundary of the work area

(4) Requirement to retest for absence of voltage when circuit conditions change or when the job location has been left unattended

(5) Planning considerations that include methods of verification where there is no accessible exposed point to take voltage measurements

Statement of Problem and Substantiation for Public Input

This recommendation is to clarify that the "test" described in (6)(3) is in fact a test for absence of voltage test. Since it differs from (6)(4) where "retest for absence of voltage" is clear that it is a (re)test for absence of voltage. These should be correlated through this first revision unless the "test" described in (6)(3) is in fact a test for something other than an absence of voltage test. If so, the committee statement should explain the type of test this is.

Submitter Information Verification

Submitter Full Name: Palmer Hickman
Organization: Electrical Training Alliance
Street Address:
City:
State:
Zip:

Submittal Date: Thu Apr 04 19:02:38 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-26-NFPA 70E-2024
Statement: The change modifies list item 3 for clarity.

Public Input No. 281-NFPA 70E-2024 [Section No. 120.5(B)(7)]

(7) **Temporary Protective** Grounding.

~~Grounding~~ Temporary protective grounding requirements for the circuit shall be established, including whether the temporary protective grounding equipment shall be installed for the duration of the task or is temporarily established by the procedure. ~~Grounding~~ Temporary protective grounding needs or requirements shall be permitted to be covered in other work rules and might not be part of the lockout/tagout procedure.

Additional Proposed Changes

File Name	Description	Approved
70E_PC_66_Hold.pdf	70E_PC66	

Statement of Problem and Substantiation for Public Input

NOTE: This Public Input appeared as “Reject but Hold” in Public Comment No. 66 of the (A2023) Second Draft Report for NFPA 70E and per the Regs. At 4.4.8.3.1 and needs to be reconsidered by the TC for the next edition of the document.

The term "Grounding" is ambiguous and can mislead the reader to think this is referring to general grounding
and bonding of electrical equipment IAW article 250 of the NEC (NFPA 70) which is permanently installed during
initial installation. Since we're speaking of electrical safety work practices, the correct term is "Temporary
Protective Grounding" which is used throughout NFPA 70E.

Submitter Information Verification

Submitter Full Name:	NFPA Holds
Organization:	Technical Committee on Electrical Safety in the Workplace
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Thu Jun 06 22:01:58 EDT 2024
Committee:	EEW-AAA

Committee Statement

Resolution: FR-27-NFPA 70E-2024

Statement: As used in the context of this requirement the term "grounding" is ambiguous and is replaced with "temporary protective grounding". This change correlates with 120.6(8), Revisions are made to comply with the NEC Style Manual.

Public Comment No. 66-NFPA 70E-2022 [Section No. 120.5(B)(7)]

(7) Temporary Protective Grounding.

~~Grounding~~ Temporary protective grounding requirements for the circuit shall be established, including whether the temporary protective grounding equipment shall be installed for the duration of the task or is temporarily established by the procedure. ~~Grounding~~ Temporary protective grounding needs or requirements shall be permitted to be covered in other work rules and might not be part of the lockout/tagout procedure.

Statement of Problem and Substantiation for Public Comment

The term "Grounding" is ambiguous and can mislead the reader to think this is referring to general grounding and bonding of electrical equipment IAW article 250 of the NEC (NFPA 70) which is permanently installed during initial installation. Since we're speaking of electrical safety work practices, the correct term is "Temporary Protective Grounding" which is used throughout NFPA 70E.

Related Public Comments for This Document

Related Comment	Relationship
Public Comment No. 67-NFPA 70E-2022 [Section No. 120.5(B)(6)]	

Related Item

- pi

Submitter Information Verification

Submitter Full Name: George Cole
Organization: PVNGS/APS
Street Address:
City:
State:
Zip:
Submittal Date: Fri May 27 22:55:22 EDT 2022
Committee: EEW-AAA

Committee Statement

Committee Action: Rejected but held

Resolution: The text proposed by this public comment does not meet 4.4.4.2 of the Regulations Governing Committee Projects which requires public comments to be related to material that has received public review either through the submission of Public Input, Committee Input or Correlating Input or through the First Revisions.

Public Input No. 227-NFPA 70E-2024 [Section No. 120.5(B)(8)]

(8) Shift Change.

A method shall be identified in the procedure to transfer responsibility for lockout/tagout to another person or to the person in charge when the job or task extends beyond one shift.

Statement of Problem and Substantiation for Public Input

Benefit: The changes in the prior sections should allow for a lockout device to be digitally transferred (initiated by current authorized worker and accepted by receiving authorized or responsible worker)

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 185-NFPA 70E-2024 [Section No. 120.4(C)]	
Public Input No. 187-NFPA 70E-2024 [Section No. 120.5(A)(5)]	

Submitter Information Verification

Submitter Full Name:	Brad Ruffkess
Organization:	BoxLock, Inc.
Affiliation:	Rosendin (Tyler Westfall), McCarthy Renewables (John King), BoxLock, Inc.
Street Address:	
City:	
State:	
Zip:	

Submittal Date:	Tue Jun 04 09:11:59 EDT 2024
Committee:	EEW-AAA

Committee Statement

Resolution: This public input did not provide a suggested revision as required in Section 4.3.4.1(c) of the NFPA regulations.

Public Input No. 228-NFPA 70E-2024 [Section No. 120.5(B)(12)]

(12) Removal of Lockout/Tagout Devices.

The procedure shall identify the details for removing locks or tags when the installing individual is unavailable. When locks or tags are removed by someone other than the installer, the employer shall attempt to locate that person prior to removing the lock or tag. When the lock or tag is removed because the installer is unavailable, the installer shall be informed prior to returning to work.

Statement of Problem and Substantiation for Public Input

Benefit: The changes proposed in prior sections make it possible that this process can be automated so that all parties must consent online without the need for the installer to be physically present and not destructive to the lockout device. The result would be a digital log of the recorded consent and resulting actions.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 185-NFPA 70E-2024 [Section No. 120.4(C)]	
Public Input No. 187-NFPA 70E-2024 [Section No. 120.5(A)(5)]	
Public Input No. 230-NFPA 70E-2024 [Section No. G.9.4]	

Submitter Information Verification

Submitter Full Name:	Brad Ruffkess
Organization:	BoxLock, Inc.
Affiliation:	Rosendin (Tyler Westfall), McCarthy Renewables (John King), BoxLock, Inc.
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Tue Jun 04 09:13:41 EDT 2024
Committee:	EEW-AAA

Committee Statement

Resolution: This public input did not provide a suggested revision as required in Section 4.3.4.1(c) of the NFPA regulations.

Public Input No. 283-NFPA 70E-2024 [Section No. 120.5(B)(14)]

(14) Temporary Release for Testing/Positioning.

The procedure shall clearly identify the steps and qualified persons' responsibilities when the job or task requiring lockout/tagout is to be interrupted temporarily for testing or positioning of equipment; then the steps shall be identical to the steps for return to service.

(1) Upon completion of the testing or positioning of the equipment, then all the steps required to verify an electrically safe work condition exists shall be reperformed in accordance with 120.5

Informational Note: See 110.6 for requirements when using test instruments and equipment.

Additional Proposed Changes

File Name	Description	Approved
70E_PC_68_Hold.pdf	70E_PC68	

Statement of Problem and Substantiation for Public Input

NOTE: This Public Input appeared as "Reject but Hold" in Public Comment No. 68 of the (A2023) Second Draft Report for NFPA 70E and per the Regs. At 4.4.8.3.1 and needs to be reconsidered by the TC for the next edition of the document.

Once the LOTO has been temporarily released for testing or positioning of equipment (such as verifying rotation
direction of a new polyphase motor) and the LOTO has been reapplied, then all the steps required to verify and
establish an ESWC exists must be reperformed IAW 120.5. This is because the circuit or equipment was
temporarily reenergized by its normal source which is no different than when the equipment was first taken down
and placed under the original LOTO.

Submitter Information Verification

Submitter Full Name:	NFPA Holds
Organization:	Technical Committee on Electrical Safety in the Workplace
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Thu Jun 06 22:06:53 EDT 2024
Committee:	EEW-AAA

Committee Statement

Resolution: The requirements are already addressed in 120.6 and do not need to be repeated in 120.5(B)(14).

Public Comment No. 68-NFPA 70E-2022 [New Section after 120.5(B)(14)]

(14) Temporary Release for Testing/Positioning. The procedure shall clearly identify the steps and qualified persons' responsibilities when the job or task requiring lockout/tagout is to be interrupted temporarily for testing or positioning of equipment; then the steps shall be identical to the steps for return to service.

(1) Upon completion of the testing or positioning of the equipment, then all the steps required to verify an electrically safe work condition exists shall be reperformed in accordance with 120.5.

Statement of Problem and Substantiation for Public Comment

Once the LOTO has been temporarily released for testing or positioning of equipment (such as verifying rotation direction of a new polyphase motor) and the LOTO has been reapplied, then all the steps required to verify and establish an ESWC exists must be reperformed IAW 120.5. This is because the circuit or equipment was temporarily reenergized by its normal source which is no different than when the equipment was first taken down and placed under the original LOTO.

Related Item

- pi

Submitter Information Verification

Submitter Full Name: George Cole
Organization: PVNGS/APS
Street Address:
City:
State:
Zip:
Submittal Date: Fri May 27 23:40:18 EDT 2022
Committee: EEW-AAA

Committee Statement

Committee Action: Rejected but held

Resolution: The text proposed by this public comment does not meet 4.4.4.2 of the Regulations Governing Committee Projects which requires public comments to be related to material that has received public review either through the submission of Public Input, Committee Input or Correlating Input or through the First Revisions.

Public Input No. 159-NFPA 70E-2024 [New Section after 120.6]

Informational Note No. 4

The single main short circuit protection device may be considered the ‘point of work’ for a given enclosure.

Statement of Problem and Substantiation for Public Input

Qualified workers have always done the absence of voltage testing on the line side or load side of the main short circuit protection device.

Submitter Information Verification

Submitter Full Name: Philip Allen
Organization: Grace Technologies, Inc.
Street Address:
City:
State:
Zip:

Submittal Date: Mon Jun 03 12:47:01 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: The overcurrent protection device may not always be the disconnecting device and does not consider back fed equipment, other sources, or the possibility of misidentified equipment.

Public Input No. 274-NFPA 70E-2024 [New Section after 120.6]

120.6(8)(d) Method and Sequence of Attachment and Removal .

Temporary protective grounding cables shall be attached to the ground end connection first then attach the other end to the normally energized line or part through the use of a live-line-tool of adequate length to keep the employee out of the restricted approach boundary. When removing temporary protective grounding cable, the connection to the normally energized line or part shall be removed first through the use of a live-line-tool of adequate length to keep the employee out of the restricted approach boundary, then the ground connection removed.

For lines or equipment normally energized at 600 volts or less, the use of insulting equipment such as insulating rubber gloves may be used in lieu of live-line-tools however the sequence of attachment and removal shall be the same.

Additional Proposed Changes

File Name	Description	Approved
70E_PC_19_Hold.pdf	70E_PC19	

Statement of Problem and Substantiation for Public Input

NOTE: This Public Input appeared as “Reject but Hold” in Public Comment No. 19 of the (A2023) Second Draft Report for NFPA 70E and per the Regs. At 4.4.8.3.1 and needs to be reconsidered by the TC for the next edition of the document.

Article 120.6(8) is a conditional last step when establishing and verifying an electrically safe work condition
exists "where the possibility of induced voltages or stored electrical energy exists..." or "where it could be
reasonably anticipated that the conductors or circuit parts being de-energized could contact other exposed
energized conductors or circuit parts..."

Since these two conditions pose a significant risk of electric shock to the worker applying or removing the
temporary protective grounds (TPG), it only makes sense that proven protective methods derived from OSHA
1910.269(n)(6)9i) and (n)(6)(ii) for the safe installation and removal of TPG be added as a new sub-step
120.6(8)(d). Linemen and electricians who work for electric utility companies are very familiar with TPG, even
within power generation plants which have identical medium voltage distribution equipment such as metal
enclosed switch gear, bus ducts, open air transformers, etc. commonly found in many large industrial facilities
and mining operations. During 2014 OSHA added "electric generation" to the scope of 1910.269(n) "Grounding
for the Protection of Employees" for good reason.

Some have argued against this claiming induction hazard inside power plants and especially with medium
voltage switch gear is "minimal" however this belief is a myth. Because several years ago at my power

generating plant, a very experienced but careless power plant electrician removed the ground connection clamp
end of a TPG cable first inside a metal clad 13.8kV switch gear cubicle while the other ends were still attached to
the normally energized underground shielded cables going to the load using standard leather work gloves.
When the grounding clamp was unscrewed and pulled away from the grounding point, the individual received a
very nasty electric shock due to induction. Thankfully he wasn't seriously injured, probably because the leather
gloves provided some level of resistance, but this event could have easily been a fatality. Therefore, the specific
sequence and the use of live line tools to keep the worker outside of the restricted approach boundary is an
essential element to help keep workers safe especially when they're establishing and verifying an ESWC exists.

Submitter Information Verification

Submitter Full Name:	NFPA Holds
Organization:	Technical Committee on Electrical Safety in the Workplace
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Thu Jun 06 21:34:34 EDT 2024
Committee:	EEW-AAA

Committee Statement

Resolution: The proposed text is a detailed work procedure that should be part of the employer’s job planning to meet the requirements of 120.6(8)(a).

Public Comment No. 19-NFPA 70E-2022 [New Section after 120.6]

TITLE OF NEW CONTENT

120.6(8)(d) *Method and Sequence of Attachment and Removal* .

Temporary protective grounding cables shall be attached to the ground end connection first then attach the other end to the normally energized line or part through the use of a live-line-tool of adequate length to keep the employee out of the restricted approach boundary. When removing temporary protective grounding cable, the connection to the normally energized line or part shall be removed first through the use of a live-line-tool of adequate length to keep the employee out of the restricted approach boundary, then the ground connection removed.

For lines or equipment normally energized at 600 volts or less, the use of insulting equipment such as insulating rubber gloves may be used in lieu of live-line-tools however the sequence of attachment and removal shall be the same.

Additional Proposed Changes

File Name	Description	Approved
New_Article_120.6_8_d_Method_and_Sequence_of_Attachment_and_Removal_03-24-2022.docx	New article 120.6(8)(d) for Method and Sequence of Attachment and Removal of temporary ground cables	

Statement of Problem and Substantiation for Public Comment

Article 120.6(8) is a conditional last step when establishing and verifying an electrically safe work condition exists "where the possibility of induced voltages or stored electrical energy exists..." or "where it could be reasonably anticipated that the conductors or circuit parts being de-energized could contact other exposed energized conductors or circuit parts..."
Since these two conditions pose a significant risk of electric shock to the worker applying or removing the temporary protective grounds (TPG), it only makes sense that proven protective methods derived from OSHA 1910.269(n)(6)9i) and (n)(6)(ii) for the safe installation and removal of TPG be added as a new sub-step 120.6(8)(d). Linemen and electricians who work for electric utility companies are very familiar with TPG, even within power generation plants which have identical medium voltage distribution equipment such as metal enclosed switch gear, bus ducts, open air transformers, etc. commonly found in many large industrial facilities and mining operations. During 2014 OSHA added "electric generation" to the scope of 1910.269(n) "Grounding for the Protection of Employees" for good reason.
Some have argued against this claiming induction hazard inside power plants and especially with medium voltage switch gear is "minimal" however this belief is a myth. Because several years ago at my power generating plant, a very experienced but careless power plant electrician removed the ground connection clamp end of a TPG cable first inside a metal clad 13.8kV switch gear cubicle while the other ends were still attached to the normally energized underground shielded cables going to the load using standard leather work gloves. When the grounding clamp was unscrewed and pulled away from the grounding point, the individual received a very nasty electric shock due to induction. Thankfully he wasn't seriously injured, probably because the leather gloves provided some level of resistance, but this event could have easily been a fatality. Therefore, the specific sequence and the use of live line tools to keep the worker outside of the restricted approach boundary is an essential element to help keep workers safe especially when they're establishing and verifying an ESWC exists.

Related Public Comments for This Document

Related Comment	Relationship
Public Comment No. 14-NFPA 70E-2022 [Section No. 120.6]	This PI is directly related to my other PI for updates to 120.6 ESWC

Related Item

• PI

Submitter Information Verification

Submitter Full Name: George Cole
Organization: PVNGS/APS
Street Address:
City:
State:
Zip:
Submittal Date: Thu Mar 24 21:32:43 EDT 2022
Committee: EEW-AAA

Committee Statement

Committee Action: Rejected but held

Resolution: The text proposed by this public comment does not meet 4.4.4.2 of the Regulations Governing Committee Projects which requires public comments to be related to material that has received public review either through the submission of Public Input, Committee Input or Correlating Input or through the First Revisions.

2024 NFPA 70E New Article 120.6(8)(d) "*Method and Sequence of Attachment and Removal*"
George T. Cole

120.6(8)(d) *Method and Sequence of Attachment and Removal*. Temporary protective grounding cables shall be attached to the ground end connection first then attach the other end to the normally energized line or part through the use of a live-line-tool of adequate length to keep the employee out of the restricted approach boundary. When removing temporary protective grounding cable, the connection to the normally energized line or part shall be removed first through the use of a live-line-tool of adequate length to keep the employee out of the restricted approach boundary, then the ground connection removed.

For lines or equipment normally energized at 600 volts or less, the use of insulting equipment such as insulating rubber gloves may be used in lieu of live-line-tools however the sequence of attachment and removal shall be the same.

Public Input No. 119-NFPA 70E-2024 [Section No. 120.6]

120.6 Process for Establishing and Verifying an Electrically Safe Work Condition.

Establishing and verifying an electrically safe work condition shall include all of the following steps, which shall be performed in the order presented, if feasible:

(1) Determine all possible sources of electrical supply to the specific equipment. Check applicable up-to-date drawings, diagrams, and identification tags.

(2) After properly interrupting the load current, open the disconnecting device(s) for each source.

(3) Wherever possible, visually verify that all blades of the disconnecting devices are fully open or that drawout-type circuit breakers are withdrawn to the test or fully disconnected position.

(4) ~~Release stored electrical energy.~~

(5) ~~Block or relieve stored nonelectrical energy in devices to the extent the circuit parts cannot be unintentionally energized by such devices.~~

(6) Apply lockout/tagout devices in accordance with a documented and established procedure.

(7) Use an adequately rated portable test instrument to test each phase conductor or circuit part at each point of work to test for the absence of voltage. Test each phase conductor or circuit part both phase-to-phase and phase-to-ground. Before and after each test, determine that the test instrument is operating satisfactorily through verification on any known voltage source.

Exception No. 1 to 7: *An adequately rated permanently mounted absence of voltage tester shall be permitted to be used to test for the absence of voltage of the conductors or circuit parts at the work location, provided it meets all of the following requirements: (1) It is permanently mounted and installed in accordance with the manufacturer's instructions and tests the conductors and circuit parts at the point of work; (2) It is listed and labeled for the purpose of testing for the absence of voltage; (3) It tests each phase conductor or circuit part both phase-to-phase and phase-to-ground; (4) The test device is verified as operating satisfactorily on any known voltage source before and after testing for the absence of voltage.*

Exception No. 2 to 7: *On electrical systems over 1000 volts, noncontact capacitive test instruments shall be permitted to be used to test each phase conductor.*

Informational Note No. 1: See UL 61010-1, *Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use, Part 1: General Requirements* , for rating, overvoltage category, and design requirements for voltage measurement and test instruments intended for use on electrical systems 1000 volts and below.

Informational Note No. 2: See UL 1436, *Outlet Circuit Testers and Other Similar Indicating Devices* , for additional information on rating and design requirements for permanently mounted absence of voltage testers.

Informational Note No. 3: See IEC 61243-1, *Live Working — Voltage Detectors — Part 1: Capacitive type to be used for voltages exceeding 1kV a.c.* , or IEC 61243-2, *Live Working — Voltage Detectors — Part 2: Resistive type to be used for voltages of 1kV to 36 kV a.c.* , or IEC 61243-3, *Live Working — Voltage Detectors — Part 3: Two-pole low voltage type* , for additional information on rating and design requirements for voltage detectors.

(8) Release stored electrical energy.

(9) Informational Note: It is often necessary to repeat step 5 absence of voltage test with an AC tester and then again with a DC tester as part of or after releasing stored electrical energy in step 6.

(10) Block or relieve stored nonelectrical energy in devices to the extent the circuit parts cannot be unintentionally energized by such devices.

(11) Where the possibility of induced voltages or stored electrical energy exists, ground all circuit conductors and circuit parts before touching them. Where it could be reasonably anticipated that the conductors or circuit parts being de-energized could contact other

exposed energized conductors or circuit parts, apply temporary protective grounding equipment in accordance with the following:

(12) *Placement.* Temporary protective grounding equipment shall be placed at such locations and arranged in such a manner as to prevent each employee from being exposed to an electric shock hazard (i.e., hazardous differences in electrical potential). The location, sizing, and application of temporary protective grounding equipment shall be identified as part of the employer's job planning.

(13) *Capacity.* Temporary protective grounding equipment shall be capable of conducting the maximum fault current that could flow at the point of grounding for the time necessary to clear the fault.

Informational Note: See ASTM F855, *Standard Specification for Temporary Protective Grounds to be Used on De-energized Electric Power Lines and Equipment* , which is an example of a standard that contains information on capacity of temporary protective grounding equipment.

(14) *Impedance.* Temporary protective grounding equipment and connections shall have an impedance low enough to cause immediate operation of protective devices in case of unintentional energizing of the electric conductors or circuit parts.

Statement of Problem and Substantiation for Public Input

The failure to apply lockout as the immediate step after isolating the power encourages poor procedure. An example is for when the disconnecting device is far removed from the equipment to be worked. Thus, any steps involved in removing stored energy and proving absence of voltage would have to be repeated again since the control of hazardous energy was not established. The informational note is added to clarify that proving absence of voltage must be performed for AC and DC since hazardous DC energy is often stored by AC equipment through capacitors and parasitic capacitance. Encouraging immediate lock-out for the control of hazardous energy, when feasible (already stated in 120.6) is the logical way to establish control of hazardous energy and develop habitual safe work practice as it is more often capable of being performed in this order.

Submitter Information Verification

Submitter Full Name: Karl Cunningham
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Submittal Date: Sat Jun 01 06:25:24 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-28-NFPA 70E-2024
Statement: Changes to the charging statement of 120.6 clarify the intent of the process where "to the extent feasible," applies to the order presented.

List item No. 7 is reordered for clarity.

Separating list item 8 into two list items meets NEC Style Manual Section 3.5.1.2.

Public Input No. 178-NFPA 70E-2024 [Section No. 120.6]

120.6 Process for Establishing and Verifying an Electrically Safe Work Condition.

Establishing and verifying an electrically safe work condition shall include all of the following steps, which shall be performed in the order presented, if feasible:

(1) Determine all possible sources of electrical supply to the specific equipment. Check applicable up-to-date drawings, diagrams, and identification tags.

(2) After properly interrupting the load current, open the disconnecting device(s) for each source.

(3) Wherever possible, visually verify that all blades of the disconnecting devices are fully open or that drawout-type circuit breakers are withdrawn to the test or fully disconnected position.

(4) Release stored electrical energy.

(5) Block or relieve stored nonelectrical energy in devices to the extent the circuit parts cannot be unintentionally energized by such devices.

(6) Apply lockout/tagout devices in accordance with a documented and established procedure.

(7) Use an adequately rated portable test instrument to test each phase conductor or circuit part at each point of work to test for the absence of voltage. Test each phase conductor or circuit part both phase-to-phase and phase-to-ground. Before and after each test, determine that the test instrument is operating satisfactorily through verification on any known voltage source.

Exception No. 1 to 7: *An adequately rated permanently mounted absence of voltage tester shall be permitted to be used to test for the absence of voltage of the conductors or circuit parts at the work location, provided it meets all of the following requirements: (1) It is permanently mounted and installed in accordance with the manufacturer's instructions and tests the conductors and circuit parts at the point of work; (2) It is listed and labeled for the purpose of testing for the absence of voltage; (3) It tests each phase conductor or circuit part both phase-to-phase and phase-to-ground; (4) The test device is verified as operating satisfactorily on any known voltage source before and after testing for the absence of voltage.*

Exception No. 2 to 7: *On electrical systems over 1000 volts, noncontact capacitive test instruments shall be permitted to be used to test each phase conductor.*

Informational Note No. 1: See UL 61010-1, *Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use, Part 1: General Requirements* , for rating, overvoltage category, and design requirements for voltage measurement and test instruments intended for use on electrical systems 1000 volts and below.

Informational Note No. 2: See UL 1436, *Outlet Circuit Testers and Other Similar Indicating Devices* , for additional information on rating and design requirements for permanently mounted absence of voltage testers.

Informational Note No. 3: See IEC 61243-1, *Live Working — Voltage Detectors — Part 1: Capacitive type to be used for voltages exceeding 1kV a.c.* , or IEC 61243-2, *Live Working — Voltage Detectors — Part 2: Resistive type to be used for voltages of 1kV to 36 kV a.c.* , or IEC 61243-3, *Live Working — Voltage Detectors — Part 3: Two-pole low voltage type* , for additional information on rating and design requirements for voltage detectors.

(8) Where the possibility of induced voltages or stored electrical energy exists, ground all circuit conductors and circuit parts before touching them. Where it could be reasonably anticipated that the conductors or circuit parts being de-energized could contact other exposed energized conductors or circuit parts, apply temporary protective grounding equipment in accordance with the following:

(9) *Placement.* Temporary protective grounding equipment shall be placed at such locations and arranged in such a manner as to prevent each employee from being exposed to an electric shock hazard (i.e., hazardous differences in electrical potential). The location, sizing, and application of temporary protective grounding equipment shall be identified as part of the employer's job planning.

(10) *Capacity.* Temporary protective grounding equipment shall be capable of conducting the maximum fault current that could flow at the point of grounding for the time necessary to clear the fault.

Informational Note: See ASTM F855, *Standard Specification for Temporary Protective Grounds to be Used on De-energized Electric Power Lines and Equipment*, which is an example of a standard that contains information on capacity of temporary protective grounding equipment.

(11) *Impedance.* Temporary protective grounding equipment and connections shall have an impedance low enough to cause immediate operation of protective devices in case of unintentional energizing of the electric conductors or circuit parts.

(12) *Testing*. Temporary protective grounding equipment shall be periodically tested to ensure that defective grounding jumper assemblies are detected and removed from service in a timely manner. Grounding jumper assemblies shall be re-tested after performing any maintenance to ensure its integrity.

Informational Note: See ASTM F2249, *Standard Specification for In-Service Test Methods for Temporary Grounding Jumper Assemblies Used on De-Energized Electric Power Lines and Equipment* which is an example of standard that contains information on testing of temporary protective grounding equipment.

Statement of Problem and Substantiation for Public Input

I'm not sure what happened here but my PI is only adding a new 120.6(8)(d) and an informational note after that. All other edits are not mine.
Temporary protective grounding equipment is required to be periodically tested to ensure that defective grounding jumper assemblies are detected and removed from service in a timely manner. Also, grounding jumper assemblies are required to be re-tested after performing any maintenance to ensure its integrity. Adding this text and Informational Note referencing ASTM F2249, Standard Specification for In-Service Test Methods for Temporary Grounding Jumper Assemblies Used on De-Energized Electric Power Lines and Equipment will communicate this requirement and provide a source of information the reader can use to satisfy this requirement.

Submitter Information Verification

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Submittal Date: Mon Jun 03 15:16:21 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: The testing requirements for temporary protective grounding equipment and the informational note are currently in 250.4(B).

Public Input No. 219-NFPA 70E-2024 [Section No. 120.6]

120.6 Process for Establishing and Verifying an Electrically Safe Work Condition.

Establishing and verifying an electrically safe work condition shall include all of the following steps, which shall be performed in the order presented, if feasible:

(1) Determine all possible sources of electrical supply to the specific equipment. Check applicable up-to-date drawings, diagrams, and identification tags.

(2) After properly interrupting the load current, open the disconnecting device(s) for each source.

(3) Wherever possible, visually verify that all blades of the disconnecting devices are fully open or that drawout-type circuit breakers are withdrawn to the test or fully disconnected position.

(4) Release stored electrical energy.

(5) Block or relieve stored nonelectrical energy in devices to the extent the circuit parts cannot be unintentionally energized by such devices.

(6) Apply lockout/tagout devices in accordance with a documented and established procedure.

(7) Use an adequately rated portable test instrument to test each phase conductor or circuit part at ~~each~~ the point of work to test for the absence of voltage. Test each phase conductor or circuit part both phase-to-phase and phase-to-ground. Before and after each test, determine that the test instrument is operating satisfactorily through verification on any known voltage source.

Exception No. 1 to 7: *An adequately rated permanently mounted absence of voltage tester shall be permitted to be used to test for the absence of voltage of the conductors or circuit parts at the work location, provided it meets all of the following requirements: (1) It is permanently mounted and installed in accordance with the manufacturer's instructions and tests the conductors and circuit parts at the point of work; (2) It is listed and labeled for the purpose of testing for the absence of voltage; (3) It tests each phase conductor or circuit part both phase-to-phase and phase-to-ground; (4) The test device is verified as operating satisfactorily on any known voltage source before and after testing for the absence of voltage.*

Exception No. 2 to 7: *On electrical systems over 1000 volts, noncontact capacitive test instruments shall be permitted to be used to test each phase conductor instead of testing phase-to-phase and phase-to-ground .*

Informational Note No. 1: See UL 61010-1, *Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use, Part 1: General Requirements* , for rating, overvoltage category, and design requirements for voltage measurement and test instruments intended for use on electrical systems 1000 volts and below.

Informational Note No. 2: See UL 1436, *Outlet Circuit Testers and Other Similar Indicating Devices* , for additional information on rating and design requirements for permanently mounted absence of voltage testers.

Informational Note No. 3: See IEC 61243-1, *Live Working — Voltage Detectors — Part 1: Capacitive type to be used for voltages exceeding 1kV a.c.* , or IEC 61243-2, *Live Working — Voltage Detectors — Part 2: Resistive type to be used for voltages of 1kV to 36 kV a.c.* , or IEC 61243-3, *Live Working — Voltage Detectors — Part 3: Two-pole low voltage type* , for additional information on rating and design requirements for voltage detectors.

(8) Where the possibility of induced voltages or stored electrical energy exists, ground all circuit conductors and circuit parts before touching them. Where it could be reasonably anticipated that the conductors or circuit parts being de-energized could contact other exposed energized conductors or circuit parts, apply temporary protective grounding equipment in accordance with the following:

(9) *Placement.* Temporary protective grounding equipment shall be placed at such locations and arranged in such a manner as to prevent each employee from being exposed to an electric shock hazard (i.e., hazardous differences in electrical potential).

The location, sizing, and application of temporary protective grounding equipment shall be identified as part of the employer's job planning.

(10) *Capacity.* Temporary protective grounding equipment shall be capable of conducting the maximum fault current that could flow at the point of grounding for the time necessary to clear the fault.

Informational Note: See ASTM F855, *Standard Specification for Temporary Protective Grounds to be Used on De-energized Electric Power Lines and Equipment*, which is an example of a standard that contains information on capacity of temporary protective grounding equipment.

(11) *Impedance.* Temporary protective grounding equipment and connections shall have an impedance low enough to cause immediate operation of protective devices in case of unintentional energizing of the electric conductors or circuit parts.

Statement of Problem and Substantiation for Public Input

Only two small revision suggestions here. Terra has struck again with all the underlined text. In item #7 it is suggested to replace the word "each" so that the requirement is to test for absence of voltage at the point of work. This is to clarify some confusion that has surrounded the term "each." The example that comes up often is retrofitting ballasts to LED drivers. This will happen at "each" luminaire. Is an absence of voltage test, complete with all required PPE, really required to be performed at each luminaire or can the employer define the circuit as the point of work and allow the test for absence of voltage to be performed at the first luminaire to show the circuit is in an electrically safe work condition.

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Submittal Date: Tue Jun 04 00:04:13 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: Each location where a qualified person could contact energized parts must be tested for absence of voltage within the defined electrically safe work condition required in 120.5(B)(6)(2).

Public Input No. 24-NFPA 70E-2023 [Section No. 120.6]

120.6 Process for Establishing and Verifying an Electrically Safe Work Condition.

Establishing and verifying an electrically safe work condition shall include all of the following steps, which shall be performed in the order presented, if feasible:

(1) Determine all possible sources of electrical supply to the specific equipment. Check applicable up-to-date drawings, diagrams, and identification tags.

(2) After properly interrupting the load current, open the disconnecting device(s) for each source.

(3) Wherever possible, visually verify that all blades of the disconnecting devices are fully open or that drawout-type circuit breakers are withdrawn to the test or fully disconnected position.

(4) Release stored electrical energy.

(5) Block or relieve stored nonelectrical energy in devices to the extent the circuit parts cannot be unintentionally energized by such devices.

(6) Apply lockout/tagout devices in accordance with a documented and established procedure.

(7) Use an adequately rated portable test instrument to test each phase conductor or circuit part at each point of work to test for the absence of voltage. Test each phase conductor or circuit part both phase-to-phase and phase-to-ground. Before and after each test, determine that the test instrument is operating satisfactorily through verification on any known voltage source.

Exception No. 1 to 7: *An adequately rated permanently mounted absence of voltage tester shall be permitted to be used to test for the absence of voltage of the conductors or circuit parts at the work location, provided it meets all of the following requirements: (1) It is permanently mounted and installed in accordance with the manufacturer's instructions and tests the conductors and circuit parts at the point of work; (2) It is listed and labeled for the purpose of testing for the absence of voltage; (3) It tests each phase conductor or circuit part both phase-to-phase and phase-to-ground; (4) The test device is verified as operating satisfactorily on any known voltage source before and after testing for the absence of voltage.*

Exception No. 2 to 7: *On electrical systems over 1000 volts, noncontact capacitive test instruments shall be permitted to be used to test each phase conductor.*

Informational Note No. 1: See UL 61010-1, *Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use, Part 1: General Requirements* , for rating, overvoltage category, and design requirements for voltage measurement and test instruments intended for use on electrical systems 1000 volts and below.

Informational Note No. 2: See UL 1436, *Outlet Circuit Testers and Other Similar Indicating Devices* , for additional information on rating and design requirements for permanently mounted absence of voltage testers.

Informational Note No. 3: See IEC 61243-1, *Live Working — Voltage Detectors — Part 1: Capacitive type to be used for voltages exceeding 1kV a.c.* , or IEC 61243-2, *Live Working — Voltage Detectors — Part 2: Resistive type to be used for voltages of 1kV to 36 kV a.c.* , or IEC 61243-3, *Live Working — Voltage Detectors — Part 3: Two-pole low voltage type* , for additional information on rating and design requirements for voltage detectors.

(8) Where the possibility of induced voltages or stored electrical energy exists, ground all circuit conductors and circuit parts before touching them.

(9) Where it could be reasonably anticipated that the conductors or circuit parts being de-energized could contact other exposed energized conductors or circuit parts, apply temporary protective grounding equipment in accordance with the following:

(10) *Placement.* Temporary protective grounding equipment shall be placed at such locations and arranged in such a manner as to prevent each employee from being exposed to an electric shock hazard (i.e., hazardous differences in electrical potential).

The location, sizing, and application of temporary protective grounding equipment shall be identified as part of the employer's job planning.

(11) *Capacity.* Temporary protective grounding equipment shall be capable of conducting the maximum fault current that could flow at the point of grounding for the time necessary to clear the fault.

Informational Note: See ASTM F855, *Standard Specification for Temporary Protective Grounds to be Used on De-energized Electric Power Lines and Equipment* , which is an example of a standard that contains information on capacity of temporary protective grounding equipment.

(12) *Impedance.* Temporary protective grounding equipment and connections shall have an impedance low enough to cause immediate operation of protective devices in case of unintentional energizing of the electric conductors or circuit parts.

Statement of Problem and Substantiation for Public Input

While it may not be clear in the way that Terra shows what is being recommended, the recommendation is only to move the second sentence of 120.6(8) into a new 120.6(9) since the first sentence and second sentence in the existing 120.6(8) contain two distinctly different concepts. The first sentence addresses what must be done where the possibility of induced voltages or stored electrical energy exists (ground all circuit conductors and circuit parts before touching them) and the second sentence addresses what action to take where it could be reasonably anticipated that the conductors or circuit parts being de-energized could contact other exposed energized conductors or circuit parts (apply temporary protective grounding equipment...). Accordingly, it is recommended that these two concepts be separated to make it clear that these two sentences address two separate work practices concerns.

Submitter Information Verification

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Submittal Date: Thu Sep 28 15:17:16 EDT 2023
Committee: EEW-AAA

Committee Statement

Resolution: FR-28-NFPA 70E-2024

Statement: Changes to the charging statement of 120.6 clarify the intent of the process where "to the extent feasible," applies to the order presented.

List item No. 7 is reordered for clarity.

Separating list item 8 into two list items meets NEC Style Manual Section 3.5.1.2.

Public Input No. 25-NFPA 70E-2023 [Section No. 120.6]

120.6 Process for Establishing and Verifying an Electrically Safe Work Condition.

Establishing and verifying an electrically safe work condition shall include all of the following steps, which shall be performed in the order presented, if feasible:

(1) Determine all possible sources of electrical supply to the specific equipment. Check applicable up-to-date drawings, diagrams, and identification tags.

(2) After properly interrupting the load current, open the disconnecting device(s) for each source.

(3) Wherever possible, visually verify that all blades of the disconnecting devices are fully open or that drawout-type circuit breakers are withdrawn to the test or fully disconnected position.

(4) Apply lockout/tagout devices in accordance with a documented and established procedure.

(5) Release stored electrical energy.

(6) Block or relieve stored nonelectrical energy in devices to the extent the circuit parts cannot be unintentionally energized by such devices.

(7) ~~Apply lockout/tagout devices in accordance with a documented and established procedure.~~

(8) Use an adequately rated portable test instrument to test each phase conductor or circuit part at each point of work to test for the absence of voltage. Test each phase conductor or circuit part both phase-to-phase and phase-to-ground. Before and after each test, determine that the test instrument is operating satisfactorily through verification on any known voltage source.

Exception No. 1 to 7: *An adequately rated permanently mounted absence of voltage tester shall be permitted to be used to test for the absence of voltage of the conductors or circuit parts at the work location, provided it meets all of the following requirements: (1) It is permanently mounted and installed in accordance with the manufacturer's instructions and tests the conductors and circuit parts at the point of work; (2) It is listed and labeled for the purpose of testing for the absence of voltage; (3) It tests each phase conductor or circuit part both phase-to-phase and phase-to-ground; (4) The test device is verified as operating satisfactorily on any known voltage source before and after testing for the absence of voltage.*

Exception No. 2 to 7: *On electrical systems over 1000 volts, noncontact capacitive test instruments shall be permitted to be used to test each phase conductor.*

Informational Note No. 1: See UL 61010-1, *Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use, Part 1: General Requirements* , for rating, overvoltage category, and design requirements for voltage measurement and test instruments intended for use on electrical systems 1000 volts and below.

Informational Note No. 2: See UL 1436, *Outlet Circuit Testers and Other Similar Indicating Devices* , for additional information on rating and design requirements for permanently mounted absence of voltage testers.

Informational Note No. 3: See IEC 61243-1, *Live Working — Voltage Detectors — Part 1: Capacitive type to be used for voltages exceeding 1kV a.c.* , or IEC 61243-2, *Live Working — Voltage Detectors — Part 2: Resistive type to be used for voltages of 1kV to 36 kV a.c.* , or IEC 61243-3, *Live Working — Voltage Detectors — Part 3: Two-pole low voltage type* , for additional information on rating and design requirements for voltage detectors.

(9) Where the possibility of induced voltages or stored electrical energy exists, ground all circuit conductors and circuit parts before touching them. Where it could be reasonably anticipated that the conductors or circuit parts being de-energized could contact other exposed energized conductors or circuit parts, apply temporary protective grounding equipment in accordance with the following:

(10) *Placement.* Temporary protective grounding equipment shall be placed at such locations and arranged in such a manner as to prevent each employee from being exposed to an electric shock hazard (i.e., hazardous differences in electrical potential).

The location, sizing, and application of temporary protective grounding equipment shall be identified as part of the employer's job planning.

(11) *Capacity.* Temporary protective grounding equipment shall be capable of conducting the maximum fault current that could flow at the point of grounding for the time necessary to clear the fault.

Informational Note: See ASTM F855, *Standard Specification for Temporary Protective Grounds to be Used on De-energized Electric Power Lines and Equipment* , which is an example of a standard that contains information on capacity of temporary protective grounding equipment.

(12) *Impedance.* Temporary protective grounding equipment and connections shall have an impedance low enough to cause immediate operation of protective devices in case of unintentional energizing of the electric conductors or circuit parts.

Statement of Problem and Substantiation for Public Input

The order of steps shown for establishing an electrically safe work condition is in violation of OSHA1910.147(d)(5)(i) "Following the application of lockout or tagout devices to energy isolating devices, all potentially hazardous stored or residual energy shall be relieved, disconnected, restrained, and otherwise rendered safe." Lockout / tagout devices should be applied BEFORE release of stored energy, not after.

Submitter Information Verification

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Submittal Date: Thu Oct 19 09:55:35 EDT 2023
Committee: EEW-AAA

Committee Statement

Resolution: FR-28-NFPA 70E-2024

Statement: Changes to the charging statement of 120.6 clarify the intent of the process where "to the extent feasible," applies to the order presented.

List item No. 7 is reordered for clarity.

Separating list item 8 into two list items meets NEC Style Manual Section 3.5.1.2.

Public Input No. 256-NFPA 70E-2024 [Section No. 120.6]

120.6 Process for Establishing and Verifying an Electrically Safe Work Condition.

Establishing and verifying an electrically safe work condition shall include all of the following steps, which shall be performed in the order presented, if feasible:

(1) Determine all possible sources of electrical supply to the specific equipment. Check applicable up-to-date drawings, diagrams, and identification tags.

(2) Note: It's not always possible to determine all possible sources of electrical supply due to miswiring issues. Some sources are not evident until a neutral is lifted.

(3) After properly interrupting the load current, open the disconnecting device(s) for each source.

(4) Wherever possible, visually verify that all blades of the disconnecting devices are fully open or that drawout-type circuit breakers are withdrawn to the test or fully disconnected position.

(5) Release stored electrical energy.

(6) Block or relieve stored nonelectrical energy in devices to the extent the circuit parts cannot be unintentionally energized by such devices.

(7) Apply lockout/tagout devices in accordance with a documented and established procedure.

(8) Use an adequately rated portable test instrument to test each phase conductor or circuit part at each point of work to test for the absence of voltage. Test each phase conductor or circuit part both phase-to-phase and phase-to-ground. Before and after each test, determine that the test instrument is operating satisfactorily through verification on any known voltage source.

Exception No. 1 to 7: An adequately rated permanently mounted absence of voltage tester shall be permitted to be used to test for the absence of voltage of the conductors or circuit parts at the work location, provided it meets all of the following requirements: (1) It is permanently mounted and installed in accordance with the manufacturer's instructions and tests the conductors and circuit parts at the point of work; (2) It is listed and labeled for the purpose of testing for the absence of voltage; (3) It tests each phase conductor or circuit part both phase-to-phase and phase-to-ground; (4) The test device is verified as operating satisfactorily on any known voltage source before and after testing for the absence of voltage.

Exception No. 2 to 7: On electrical systems over 1000 volts, noncontact capacitive test instruments shall be permitted to be used to test each phase conductor.

Informational Note No. 1: See UL 61010-1, *Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use, Part 1: General Requirements* , for rating, overvoltage category, and design requirements for voltage measurement and test instruments intended for use on electrical systems 1000 volts and below.

Informational Note No. 2: See UL 1436, *Outlet Circuit Testers and Other Similar Indicating Devices* , for additional information on rating and design requirements for permanently mounted absence of voltage testers.

Informational Note No. 3: See IEC 61243-1, *Live Working — Voltage Detectors — Part 1: Capacitive type to be used for voltages exceeding 1kV a.c.* , or IEC 61243-2, *Live Working — Voltage Detectors — Part 2: Resistive type to be used for voltages of 1kV to 36 kV a.c.* , or IEC 61243-3, *Live Working — Voltage Detectors — Part 3: Two-pole low voltage type* , for additional information on rating and design requirements for voltage detectors.

(9) Where the possibility of induced voltages or stored electrical energy exists, ground all circuit conductors and circuit parts before touching them. Where it could be reasonably anticipated that the conductors or circuit parts being de-energized could contact other exposed energized conductors or circuit parts, apply temporary protective grounding equipment in accordance with the following:

(10) *Placement.* Temporary protective grounding equipment shall be placed at such locations and arranged in such a manner as to prevent each employee from being exposed to an electric shock hazard (i.e., hazardous differences in electrical potential). The location, sizing, and application of temporary protective grounding equipment shall be identified as part of the employer's job planning.

(11) *Capacity.* Temporary protective grounding equipment shall be capable of conducting the maximum fault current that could flow at the point of grounding for the time necessary to clear the fault.

Informational Note: See ASTM F855, *Standard Specification for Temporary Protective Grounds to be Used on De-energized Electric Power Lines and Equipment* , which is an example of a standard that contains information on capacity of temporary protective grounding equipment.

(12) *Impedance.* Temporary protective grounding equipment and connections shall have an impedance low enough to cause immediate operation of protective devices in case of unintentional energizing of the electric conductors or circuit parts.

Statement of Problem and Substantiation for Public Input

Individuals may still be at risk of electrical shock even if correctly identified sources are disconnected due to miswiring issues like shared neutrals.

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Submittal Date: Tue Jun 04 16:03:14 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: Section 120.5(A)(1) Locating Sources addresses the concerns of the submitter, and the existing informational note references neutral conductors.

Public Input No. 268-NFPA 70E-2024 [Section No. 120.6]

120.6 Process for Establishing and Verifying an Electrically Safe Work Condition.

Establishing and verifying an electrically safe work condition shall include all of the following steps, which shall be performed in the order presented, if feasible:

(1) Determine all possible sources of electrical supply to the specific equipment. Check applicable up-to-date drawings, diagrams, and identification tags.

(2) After properly interrupting the load current, open the disconnecting device(s) for each source.

Informational Note No. 1 to (2): It may be necessary to verify presence of voltage before disconnecting the device(s) for each source to ensure before step (7) verification of absence of voltage to ensure the proper disconnect was opened.

(3) Wherever possible, visually verify that all blades of the disconnecting devices are fully open or that drawout-type circuit breakers are withdrawn to the test or fully disconnected position.

(4) Release stored electrical energy.

(5) Block or relieve stored nonelectrical energy in devices to the extent the circuit parts cannot be unintentionally energized by such devices.

(6) Apply lockout/tagout devices in accordance with a documented and established procedure.

(7) Use an adequately rated portable test instrument to test each phase conductor or circuit part at each point of work to test for the absence of voltage. Test each phase conductor or circuit part both phase-to-phase and phase-to-ground. Before and after each test, determine that the test instrument is operating satisfactorily through verification on any known voltage source.

Exception No.

~~1~~

2 to 7: An adequately rated permanently mounted absence of voltage tester shall be permitted to be used to test for the absence of voltage of the conductors or circuit parts at the work location, provided it meets all of the following requirements: (1) It is permanently mounted and installed in accordance with the manufacturer's instructions and tests the conductors and circuit parts at the point of work; (2) It is listed and labeled for the purpose of testing for the absence of voltage; (3) It tests each phase conductor or circuit part both phase-to-phase and phase-to-ground; (4) The test device is verified as operating satisfactorily on any known voltage source before and after testing for the absence of voltage.

Exception No.

~~2~~

3 to 7: On electrical systems over 1000 volts, noncontact capacitive test instruments shall be permitted to be used to test each phase conductor.

Informational Note No. 1: See UL 61010-1, *Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use, Part 1: General Requirements* , for rating, overvoltage category, and design requirements for voltage measurement and test instruments intended for use on electrical systems 1000 volts and below.

Informational Note No. 2: See UL 1436, *Outlet Circuit Testers and Other Similar Indicating Devices* , for additional information on rating and design requirements for permanently mounted absence of voltage testers.

Informational Note No. 3: See IEC 61243-1, *Live Working — Voltage Detectors — Part 1: Capacitive type to be used for voltages exceeding 1kV a.c.* , or IEC 61243-2, *Live Working — Voltage Detectors — Part 2: Resistive type to be used for voltages of 1kV to 36 kV a.c.* , or IEC 61243-3, *Live Working — Voltage Detectors — Part 3: Two-pole low voltage type* , for additional information on rating and design requirements for voltage detectors.

(8) Where the possibility of induced voltages or stored electrical energy exists, ground all circuit conductors and circuit parts before touching them. Where it could be reasonably anticipated that the conductors or circuit parts being de-energized could contact other exposed energized conductors or circuit parts, apply temporary protective grounding equipment in accordance with the following:

(9) *Placement.* Temporary protective grounding equipment shall be placed at such locations and arranged in such a manner as to prevent each employee from being exposed to an electric shock hazard (i.e., hazardous differences in electrical potential). The location, sizing, and application of temporary protective grounding equipment shall be identified as part of the employer's job planning.

(10) *Capacity.* Temporary protective grounding equipment shall be capable of conducting the maximum fault current that could flow at the point of grounding for the time necessary to clear the fault.

Informational Note: See ASTM F855, *Standard Specification for Temporary Protective Grounds to be Used on De-energized Electric Power Lines and Equipment* , which is an example of a standard that contains information on capacity of temporary protective grounding equipment.

(11) *Impedance.* Temporary protective grounding equipment and connections shall have an impedance low enough to cause immediate operation of protective devices in case of unintentional energizing of the electric conductors or circuit parts.

Statement of Problem and Substantiation for Public Input

This public input is made to raise attention to the fact that in some cases we are assuming we opened the correct disconnect if we are only measuring to determine the absence of voltage after opening disconnects. There may be a lot of value in measuring for presence of voltage before opening the supplying disconnect to ensure the proper disconnect was actually opened.

Submitter Information Verification

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Submittal Date: Tue Jun 04 19:14:07 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: Adding this text does not improve clarity. See 130.8(P) and 130.12 which address the concerns of the submitter.

Public Input No. 28-NFPA 70E-2023 [Section No. 120.6]

120.6 Process for Establishing and Verifying an Electrically Safe Work Condition.

Establishing and verifying an electrically safe work condition shall include all of the following steps, which shall be performed in the order presented, if feasible:

(1) Determine all possible sources of electrical supply to the specific equipment. Check applicable up-to-date drawings, diagrams, and identification tags.

(2) Exposed employees shall be notified by the employee in charge of the application of lockout devices or tagout devices. Such notification shall be given before the controls are applied.

(3) After properly interrupting the load current, open the disconnecting device(s) for each source.

(4) Wherever possible, visually verify that all blades of the disconnecting devices are fully open or that drawout-type circuit breakers are withdrawn to the test or fully disconnected position.

(5) Release stored electrical energy.

(6) Block or relieve stored nonelectrical energy in devices to the extent the circuit parts cannot be unintentionally energized by such devices.

(7) Apply lockout/tagout devices in accordance with a documented and established procedure.

(8) Use an adequately rated portable test instrument to test each phase conductor or circuit part at each point of work to test for the absence of voltage. Test each phase conductor or circuit part both phase-to-phase and phase-to-ground. Before and after each test, determine that the test instrument is operating satisfactorily through verification on any known voltage source.

Exception No. 1 to 7: An adequately rated permanently mounted absence of voltage tester shall be permitted to be used to test for the absence of voltage of the conductors or circuit parts at the work location, provided it meets all of the following requirements: (1) It is permanently mounted and installed in accordance with the manufacturer's instructions and tests the conductors and circuit parts at the point of work; (2) It is listed and labeled for the purpose of testing for the absence of voltage; (3) It tests each phase conductor or circuit part both phase-to-phase and phase-to-ground; (4) The test device is verified as operating satisfactorily on any known voltage source before and after testing for the absence of voltage.

Exception No. 2 to 7: On electrical systems over 1000 volts, noncontact capacitive test instruments shall be permitted to be used to test each phase conductor.

Informational Note No. 1: See UL 61010-1, *Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use, Part 1: General Requirements* , for rating, overvoltage category, and design requirements for voltage measurement and test instruments intended for use on electrical systems 1000 volts and below.

Informational Note No. 2: See UL 1436, *Outlet Circuit Testers and Other Similar Indicating Devices* , for additional information on rating and design requirements for permanently mounted absence of voltage testers.

Informational Note No. 3: See IEC 61243-1, *Live Working — Voltage Detectors — Part 1: Capacitive type to be used for voltages exceeding 1kV a.c.* , or IEC 61243-2, *Live Working — Voltage Detectors — Part 2: Resistive type to be used for voltages of 1kV to 36 kV a.c.* , or IEC 61243-3, *Live Working — Voltage Detectors — Part 3: Two-pole low voltage type* , for additional information on rating and design requirements for voltage detectors.

(9) Where the possibility of induced voltages or stored electrical energy exists, ground all circuit conductors and circuit parts before touching them. Where it could be reasonably anticipated that the conductors or circuit parts being de-energized could contact other exposed energized conductors or circuit parts, apply temporary protective grounding equipment in accordance with the following:

(10) *Placement.* Temporary protective grounding equipment shall be placed at such locations and arranged in such a manner as to prevent each employee from being exposed to an electric shock hazard (i.e., hazardous differences in electrical potential). The location, sizing, and application of temporary protective grounding equipment shall be identified as part of the employer's job planning.

(11) *Capacity.* Temporary protective grounding equipment shall be capable of conducting the maximum fault current that could flow at the point of grounding for the time necessary to clear the fault.

Informational Note: See ASTM F855, *Standard Specification for Temporary Protective Grounds to be Used on De-energized Electric Power Lines and Equipment* , which is an example of a standard that contains information on capacity of temporary protective grounding equipment.

(12) *Impedance.* Temporary protective grounding equipment and connections shall have an impedance low enough to cause immediate operation of protective devices in case of unintentional energizing of the electric conductors or circuit parts.

(13) After lockout or tagout devices have been removed and before a machine or equipment is started, exposed employees shall be notified that the lockout or tagout device(s) have been removed.

Statement of Problem and Substantiation for Public Input

While it may not be clear in Terra, the only recommendation is to add a new 120.6(2) and renumber the rest of 120.6 and add a new 120.(10). The intent is to add a critical missing OSHA requirement that notifies employees that are impacted. Per 1910.147(c)(9), "Affected employees shall be notified by the employer or authorized employee of the application and removal of lockout devices or tagout devices. Notification shall be given before the controls are applied, and after they are removed from the machine or equipment." Per 1910.147(e)(2)(ii) "After lockout or tagout devices have been removed and before a machine or equipment is started, affected employees shall be notified that the lockout or tagout device(s) have been removed." The word "exposed" employee is used rather than "affected" employee and "employee in charge" is used in this recommendation rather than "authorized employee" as 70E uses different terminology than OSHA. This concept should additionally be added in the 120.5 procedures.

Submitter Information Verification

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Submittal Date: Sat Nov 04 16:41:57 EDT 2023
Committee: EEW-AAA

Committee Statement

Resolution: Requirements to notify employees of application or removal of lockout tagout devices are included in other portions of Section 120.5.

Public Input No. 31-NFPA 70E-2023 [Section No. 120.6]

120.6 Process for Establishing and Verifying an Electrically Safe Work Condition.

Electrical conductors and circuit parts shall not be considered to be in an electrically safe work condition until all of the applicable requirements of 120.2 through 120.6 have been met. Establishing and verifying an electrically safe work condition shall additionally include all of the following steps, which shall be performed in the order presented, if feasible:

(1) Determine all possible sources of electrical supply to the specific equipment. Check applicable up-to-date drawings, diagrams, and identification tags.

(2) After properly interrupting the load current, open the disconnecting device(s) for each source.

(3) Wherever possible, visually verify that all blades of the disconnecting devices are fully open or that drawout-type circuit breakers are withdrawn to the test or fully disconnected position.

(4) Release stored electrical energy.

(5) Block or relieve stored nonelectrical energy in devices to the extent the circuit parts cannot be unintentionally energized by such devices.

(6) Apply lockout/tagout devices in accordance with a documented and established procedure.

(7) Use an adequately rated portable test instrument to test each phase conductor or circuit part at each point of work to test for the absence of voltage. Test each phase conductor or circuit part both phase-to-phase and phase-to-ground. Before and after each test, determine that the test instrument is operating satisfactorily through verification on any known voltage source.

Exception No. 1 to 7: An adequately rated permanently mounted absence of voltage tester shall be permitted to be used to test for the absence of voltage of the conductors or circuit parts at the work location, provided it meets all of the following requirements: (1) It is permanently mounted and installed in accordance with the manufacturer's instructions and tests the conductors and circuit parts at the point of work; (2) It is listed and labeled for the purpose of testing for the absence of voltage; (3) It tests each phase conductor or circuit part both phase-to-phase and phase-to-ground; (4) The test device is verified as operating satisfactorily on any known voltage source before and after testing for the absence of voltage.

Exception No. 2 to 7: On electrical systems over 1000 volts, noncontact capacitive test instruments shall be permitted to be used to test each phase conductor.

Informational Note No. 1: See UL 61010-1, *Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use, Part 1: General Requirements* , for rating, overvoltage category, and design requirements for voltage measurement and test instruments intended for use on electrical systems 1000 volts and below.

Informational Note No. 2: See UL 1436, *Outlet Circuit Testers and Other Similar Indicating Devices* , for additional information on rating and design requirements for permanently mounted absence of voltage testers.

Informational Note No. 3: See IEC 61243-1, *Live Working — Voltage Detectors — Part 1: Capacitive type to be used for voltages exceeding 1kV a.c.* , or IEC 61243-2, *Live Working — Voltage Detectors — Part 2: Resistive type to be used for voltages of 1kV to 36 kV a.c.* , or IEC 61243-3, *Live Working — Voltage Detectors — Part 3: Two-pole low voltage type* , for additional information on rating and design requirements for voltage detectors.

(8) Where the possibility of induced voltages or stored electrical energy exists, ground all circuit conductors and circuit parts before touching them. Where it could be reasonably anticipated that the conductors or circuit parts being de-energized could contact other exposed energized conductors or circuit parts, apply temporary protective grounding equipment in accordance with the following:

(9) *Placement.* Temporary protective grounding equipment shall be placed at such locations and arranged in such a manner as to prevent each employee from being exposed to an electric shock hazard (i.e., hazardous differences in electrical potential).

The location, sizing, and application of temporary protective grounding equipment shall be identified as part of the employer's job planning.

(10) *Capacity.* Temporary protective grounding equipment shall be capable of conducting the maximum fault current that could flow at the point of grounding for the time necessary to clear the fault.

Informational Note: See ASTM F855, *Standard Specification for Temporary Protective Grounds to be Used on De-energized Electric Power Lines and Equipment*, which is an example of a standard that contains information on capacity of temporary protective grounding equipment.

(11) *Impedance.* Temporary protective grounding equipment and connections shall have an impedance low enough to cause immediate operation of protective devices in case of unintentional energizing of the electric conductors or circuit parts.

Statement of Problem and Substantiation for Public Input

Although perhaps not clear in Terra, the only recommendation is to revise the requirements of Section 120.6 - none of the list items are recommended for revision in this Public Input. Section 110.2(C) for the 2024 edition states that "[e]lectrical conductors and circuit parts shall not be considered to be in an electrically safe work condition until all of the applicable requirements of 120.2 through 120.6 have been met." Accordingly, this recommendation is to relocate the deleted text to the current 120.6 as a new first sentence. This relocation makes the requirements of 120.6 technically correct as the relocated language will require that one has both established and verified an electrically safe work condition when all of 120.6 has been accomplished with the relocated requirements that all applicable requirements of Article 120 have been met.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 30-NFPA 70E-2023 [Section No. 110.2(C)]	
Public Input No. 30-NFPA 70E-2023 [Section No. 110.2(C)]	

Submitter Information Verification

Submitter Full Name: Palmer Hickman
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Submittal Date: Wed Nov 15 09:19:00 EST 2023
Committee: EEW-AAA

Committee Statement

Resolution: The requirements in 120.2 – 120.6 are mandatory and do not need to be repeated in 120.6. The proposed requirement exists and is better located in 110.2(C).

Public Input No. 33-NFPA 70E-2023 [Section No. 120.6]

120.6 Process for Establishing and Verifying an Electrically Safe Work Condition.

Establishing and verifying an electrically safe work condition shall include all of the following steps, which shall be performed in the order presented, if feasible:

(1) Determine all possible sources of electrical supply to the specific equipment. Check applicable up-to-date drawings, diagrams, and identification tags.

(2) After properly interrupting the load current, open the disconnecting device(s) for each source.

(3) Wherever possible, visually verify that all blades of the disconnecting devices are fully open or that drawout-type circuit breakers are withdrawn to the test or fully disconnected position.

(4) Release stored electrical energy.

(5) Block or relieve stored nonelectrical energy in devices to the extent the circuit parts cannot be unintentionally energized by such devices.

(6) Apply lockout/tagout devices in accordance with a documented and established procedure.

(7) Use an adequately rated portable test instrument to test each phase conductor or circuit part at each point of work to test for the absence of voltage. Test each phase conductor or circuit part both phase-to-phase and phase-to-ground. Before and after each test, determine that the test instrument is operating satisfactorily through verification on any known voltage source.

Exception No. 1 to 7: An adequately rated permanently mounted absence of voltage tester shall be permitted to be used to test for the absence of voltage of the conductors or circuit parts at the work location, provided it meets all of the following requirements: (1) It is permanently mounted and installed in accordance with the manufacturer's instructions and tests the conductors and circuit parts at the point of work; (2) It is listed and labeled for the purpose of testing for the absence of voltage; (3) It tests each phase conductor or circuit part both phase-to-phase and phase-to-ground; (4) The test device is verified as operating satisfactorily on any known voltage source before and after testing for the absence of voltage.

Exception No. 2 to 7: On electrical systems over 1000 volts, noncontact capacitive test instruments shall be permitted to be used to test each phase conductor. Such a test instrument shall be permitted to be used in lieu of test equipment that would fulfill the other "test for absence of voltage" requirements of 120.6(7), including the requirement to test "both phase-to phase and phase-to-ground."

Informational Note No. 1: See UL 61010-1, *Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use, Part 1: General Requirements* , for rating, overvoltage category, and design requirements for voltage measurement and test instruments intended for use on electrical systems 1000 volts and below.

Informational Note No. 2: See UL 1436, *Outlet Circuit Testers and Other Similar Indicating Devices* , for additional information on rating and design requirements for permanently mounted absence of voltage testers.

Informational Note No. 3: See IEC 61243-1, *Live Working — Voltage Detectors — Part 1: Capacitive type to be used for voltages exceeding 1kV a.c.* , or IEC 61243-2, *Live Working — Voltage Detectors — Part 2: Resistive type to be used for voltages of 1kV to 36 kV a.c.* , or IEC 61243-3, *Live Working — Voltage Detectors — Part 3: Two-pole low voltage type* , for additional information on rating and design requirements for voltage detectors.

(8) Where the possibility of induced voltages or stored electrical energy exists, ground all circuit conductors and circuit parts before touching them. Where it could be reasonably anticipated that the conductors or circuit parts being de-energized could contact other exposed energized conductors or circuit parts, apply temporary protective grounding equipment in accordance with the following:

(9) *Placement.* Temporary protective grounding equipment shall be placed at such locations and arranged in such a manner as to prevent each employee from being

exposed to an electric shock hazard (i.e., hazardous differences in electrical potential). The location, sizing, and application of temporary protective grounding equipment shall be identified as part of the employer's job planning.

(10) *Capacity.* Temporary protective grounding equipment shall be capable of conducting the maximum fault current that could flow at the point of grounding for the time necessary to clear the fault.

Informational Note: See ASTM F855, *Standard Specification for Temporary Protective Grounds to be Used on De-energized Electric Power Lines and Equipment* , which is an example of a standard that contains information on capacity of temporary protective grounding equipment.

(11) *Impedance.* Temporary protective grounding equipment and connections shall have an impedance low enough to cause immediate operation of protective devices in case of unintentional energizing of the electric conductors or circuit parts.

Statement of Problem and Substantiation for Public Input

On electrical systems over 1000 volts, noncontact capacitive test instruments shall be permitted to be used to test each phase conductor per this exception. However, there is not an exception that allows such a test instrument to be permitted to be used in lieu of test equipment that would fulfill the other "test for absence of voltage" requirements of 120.6(7), including the requirement to test "both phase-to phase and phase-to-ground." This recommendation is attempt to broaden the exception to actually be an exception to what is required in 120.6(7).

Submitter Information Verification

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Submittal Date: Wed Nov 15 11:51:51 EST 2023
Committee: EEW-AAA

Committee Statement

Resolution: FR-28-NFPA 70E-2024

Statement: Changes to the charging statement of 120.6 clarify the intent of the process where "to the extent feasible," applies to the order presented.

List item No. 7 is reordered for clarity.

Separating list item 8 into two list items meets NEC Style Manual Section 3.5.1.2.

Public Input No. 36-NFPA 70E-2023 [Section No. 120.6]

120.6 Process for Establishing and Verifying an Electrically Safe Work Condition.

Establishing and verifying an electrically safe work condition shall include all of the following steps~~, which shall be performed in the order presented, if feasible~~ :

(1) Determine all possible sources of electrical supply to the specific equipment. Check applicable up-to-date drawings, diagrams, and identification tags.

(2) After properly interrupting the load current, open the disconnecting device(s) for each source.

(3) Wherever possible, visually verify that all blades of the disconnecting devices are fully open or that drawout-type circuit breakers are withdrawn to the test or fully disconnected position.

(4) Release stored electrical energy by soft grounding and then hard grounding .

(5) Block or relieve stored nonelectrical energy in devices to the extent the circuit parts cannot be unintentionally energized by such devices.

(6) Apply lockout/tagout devices in accordance with a documented and established procedure.

(7) Use an adequately rated portable test instrument to test each phase conductor or circuit part at each point of work to test for the absence of voltage. Test each phase conductor or circuit part both phase-to-phase and phase-to-ground. Before and after each test, determine that the test instrument is operating satisfactorily through verification on any known voltage source.

Exception No. 1 to 7: An adequately rated permanently mounted absence of voltage tester shall be permitted to be used to test for the absence of voltage of the conductors or circuit parts at the work location, provided it meets all of the following requirements: (1) It is permanently mounted and installed in accordance with the manufacturer's instructions and tests the conductors and circuit parts at the point of work; (2) It is listed and labeled for the purpose of testing for the absence of voltage; (3) It tests each phase conductor or circuit part both phase-to-phase and phase-to-ground; (4) The test device is verified as operating satisfactorily on any known voltage source before and after testing for the absence of voltage.

Exception No. 2 to 7: On electrical systems over 1000 volts, noncontact capacitive test instruments shall be permitted to be used to test each phase conductor.

Informational Note No. 1: See UL 61010-1, *Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use, Part 1: General Requirements* , for rating, overvoltage category, and design requirements for voltage measurement and test instruments intended for use on electrical systems 1000 volts and below.

Informational Note No. 2: See UL 1436, *Outlet Circuit Testers and Other Similar Indicating Devices* , for additional information on rating and design requirements for permanently mounted absence of voltage testers.

Informational Note No. 3: See IEC 61243-1, *Live Working — Voltage Detectors — Part 1: Capacitive type to be used for voltages exceeding 1kV a.c.* , or IEC 61243-2, *Live Working — Voltage Detectors — Part 2: Resistive type to be used for voltages of 1kV to 36 kV a.c.* , or IEC 61243-3, *Live Working — Voltage Detectors — Part 3: Two-pole low voltage type* , for additional information on rating and design requirements for voltage detectors.

(8) Where the possibility of induced voltages or stored electrical energy exists, ground all circuit conductors and circuit parts before touching them. Where it could be reasonably anticipated that the conductors or circuit parts being de-energized could contact other exposed energized conductors or circuit parts, apply temporary protective grounding equipment in accordance with the following:

(9) *Placement.* Temporary protective grounding equipment shall be placed at such locations and arranged in such a manner as to prevent each employee from being exposed to an electric shock hazard (i.e., hazardous differences in electrical potential). The location, sizing, and application of temporary protective grounding equipment shall be identified as part of the employer's job planning.

(10) *Capacity.* Temporary protective grounding equipment shall be capable of conducting the maximum fault current that could flow at the point of grounding for the time necessary to clear the fault.

Informational Note: See ASTM F855, *Standard Specification for Temporary Protective Grounds to be Used on De-energized Electric Power Lines and Equipment* , which is an example of a standard that contains information on capacity of temporary protective grounding equipment.

(11) *Impedance.* Temporary protective grounding equipment and connections shall have an impedance low enough to cause immediate operation of protective devices in case of unintentional energizing of the electric conductors or circuit parts.

Statement of Problem and Substantiation for Public Input

Our electrical service firm practically applies the processes of establishing and verifying an electrically safe work condition 1-3 times a week in heavy commercial and industrial environments. When performing this work, there is limited maintenance data or history available for the low and medium-voltage electrical distribution equipment.

Section 120.6 outlines the required steps, in the order presented, to establish and verify an electrically safe work condition. The section assumes that when an insulated or molded circuit breaker disconnection device is opened without visual verification, all phases are disconnected and de-energized. Furthermore, the sequence of steps assumes that the only remaining energy source is stored electrical energy from capacitors or cables and components holding a charge.

Our company has encountered instances where, upon opening an insulated or molded case circuit breaker disconnecting device, one or more phases remained energized due to an internal disconnecting device malfunction.

As per section 120.6, the process of establishing and verifying an electrically safe work condition can be hazardous if step (4), "releasing stored electrical energy," is performed without visually confirming the disconnection in step (3) due to the disconnecting device being an insulated or molded case circuit breaker.

To avoid the hazard of attempting to release stored electrical energy from an energized bus with a hard grounding (Low-Z) discharge device, our company follows this specific set of steps in this order when establishing and verifying an electrically safe work condition.

(1) Determine all possible sources of electrical supply to the specific equipment. Check applicable, up-to-date drawings, diagrams, and identification tags.

(2) After properly interrupting the load current, open the disconnecting device(s) for each source.

(3) Wherever possible, visually verify that all blades of the disconnecting devices are fully open or that drawout-type circuit breakers are withdrawn to the test or fully disconnected position.

(4) Block or relieve stored nonelectrical energy in devices to the extent the circuit parts cannot be unintentionally energized by such devices.

(5) Apply lockout/tagout devices in accordance with a documented and established procedure.

(6) Use a properly rated noncontact capacitive test instrument to test each phase conductor or circuit part. Before and after each test, determine whether the noncontact capacitive test instrument operates satisfactorily through verification on any known voltage source.

(7) Release stored electrical energy by soft grounding utilizing a resistive discharge stick, then hard ground with a ground stick

(8) Use an adequately rated portable test instrument to test each phase conductor or circuit part at

each point of work to test for the absence of voltage. Test each phase conductor or circuit part both phase-to-phase and phase-to-ground. Before and after each test, determine that the test instrument is operating satisfactorily through verification on any known voltage source.

(9) Where the possibility of induced voltages or stored electrical energy exists, ground all circuit conductors and circuit parts before touching them. Where it could be reasonably anticipated that the conductors or circuit parts being de-energized could contact other exposed energized conductors or circuit parts, apply temporary protective grounding equipment in accordance with the following:

Removing the phrase "which shall be performed in the order presented, if feasible" will allow users to modify the sequence of steps based on their specific needs. This change will not only minimize potential hazards, but also ensure that the establishment and verification of an electrically safe work condition is successful.

The added text "by soft grounding and then hard grounding" informs the user that there are established procedures for discharging stored electrical energy that don't involve using only a low-impedance device.

Submitter Information Verification

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Submittal Date: Tue Nov 28 23:41:13 EST 2023
Committee: EEW-AAA

Committee Statement

Resolution: FR-29-NFPA 70E-2024

Statement: Exception No. 2 to 7 was editorially revised for clarity. An informational note was added to provide information on why presence of voltage rather than absence of voltage was used in this exception. Informational notes were editorially corrected to reference the applicable exception.

Public Input No. 48-NFPA 70E-2024 [Section No. 120.6]

120.6 Process for Establishing and Verifying an Electrically Safe Work Condition.

Establishing and verifying an electrically safe work condition shall include all of the following steps, which shall be performed in the order presented, if feasible:

(1) Determine all possible sources of electrical supply to the specific equipment. Check applicable up-to-date drawings, diagrams, and identification tags.

(2) After properly interrupting the load current, open the disconnecting device(s) for each source.

(3) Wherever possible, visually verify that all blades of the disconnecting devices are fully open or that drawout-type circuit breakers are withdrawn to the test or fully disconnected position.

(4) Release stored electrical energy.

(5) Block or relieve stored nonelectrical energy in devices to the extent the circuit parts cannot be unintentionally energized by such devices.

(6) Apply lockout/tagout devices in accordance with a documented and established procedure.

(7) Use an adequately rated portable test instrument to test each phase conductor or circuit part at each point of work to test for the absence of ~~voltage. Test each~~ electrical energy. Before and after each test, determine that the test instrument is operating satisfactorily through verification on any known energy source.
When testing voltage driven circuits test each phase conductor or circuit part both phase-to-phase and phase-to-ground

~~. Before and after each test, determine that the test instrument is operating satisfactorily through verification on any known voltage source~~
to confirm the absence of voltage.

When testing current driven circuits test each conductor or circuit part to confirm the absence of current/amperage .

Exception No. 1 to 7: An adequately rated permanently mounted absence of voltage tester shall be permitted to be used to test for the absence of voltage of the conductors or circuit parts at the work location, provided it meets all of the following requirements: (1) It is permanently mounted and installed in accordance with the manufacturer's instructions and tests the conductors and circuit parts at the point of work; (2) It is listed and labeled for the purpose of testing for the absence of voltage; (3) It tests each phase conductor or circuit part both phase-to-phase and phase-to-ground; (4) The test device is verified as operating satisfactorily on any known voltage source before and after testing for the absence of voltage.

Exception No. 2 to 7: On electrical systems over 1000 volts, noncontact capacitive test instruments shall be permitted to be used to

~~test~~

test for the absence of voltage on each phase conductor. ***Noncontact capacitive test instruments shall not be used to test for the absence of energy on a current driven circuit.***

Informational Note No. 1: See UL 61010-1, *Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use, Part 1: General Requirements* , for rating, overvoltage category, and design requirements for voltage measurement and test instruments intended for use on electrical systems 1000 volts and below.

Informational Note No. 2: See UL 1436, *Outlet Circuit Testers and Other Similar Indicating Devices* , for additional information on rating and design requirements for permanently mounted absence of voltage testers.

Informational Note No. 3: See IEC 61243-1, *Live Working — Voltage Detectors — Part 1: Capacitive type to be used for voltages exceeding 1kV a.c.* , or IEC 61243-2, *Live Working — Voltage Detectors — Part 2: Resistive type to be used for voltages of 1kV to 36 kV a.c.* , or IEC 61243-3, *Live Working — Voltage Detectors — Part 3:*

Two-pole low voltage type , for additional information on rating and design requirements for voltage detectors.

Informational Note 4: An airfield lighting series circuit is an ungrounded current loop, operating at up to 4,545 volts (open circuit >9,000 volts). Absence of energy testing of an airfield lighting series circuit is performed with an ammeter. To determine that the airfield lighting series circuit is de-energized a true RMS ammeter should be used.

See Federal Aviation Administration (FAA) Advisory Circular (AC) 150/5340-26C, *Maintenance of Airport Visual Aid Facilities* , June 20, 2014.

(8) Where the possibility of induced voltages or stored electrical energy exists, ground all circuit conductors and circuit parts before touching them. Where it could be reasonably anticipated that the conductors or circuit parts being de-energized could contact other exposed energized conductors or circuit parts, apply temporary protective grounding equipment in accordance with the following:

(9) *Placement.* Temporary protective grounding equipment shall be placed at such locations and arranged in such a manner as to prevent each employee from being exposed to an electric shock hazard (i.e., hazardous differences in electrical potential). The location, sizing, and application of temporary protective grounding equipment shall be identified as part of the employer's job planning.

(10) *Capacity.* Temporary protective grounding equipment shall be capable of conducting the maximum fault current that could flow at the point of grounding for the time necessary to clear the fault.

Informational Note: See ASTM F855, *Standard Specification for Temporary Protective Grounds to be Used on De-energized Electric Power Lines and Equipment* , which is an example of a standard that contains information on capacity of temporary protective grounding equipment.

(11) *Impedance.* Temporary protective grounding equipment and connections shall have an impedance low enough to cause immediate operation of protective devices in case of unintentional energizing of the electric conductors or circuit parts.

Additional Proposed Changes

File Name	Description	Approved
Chap_13_UFC_3-535-01_Visual_Air_navag_Facil_-_25_APRIL_2023.pdf	This material is taken from the DOD's Unified Facilities Requirements. The material describes the characteristics of an airfield lighting series circuit.	
Part_2.4_150-5340-26C_Maint_of_Airport_Visual_Aid_Facil.pdf	This document is from FAA Advisory Circular 150/5340-26C discussing the electrical hazards associated with an airfield lighting series circuit.	
Part_2.2_AAAE_Airfield_Lgt_Course_Mod_1a.pdf	portion of the Association American Airport Executives (AAAE) airfield lighting maintenance course. The material has been RED-LINED to highlight characteristics of an airfield lighting series circuit.	

NFPA_70E_Series_Circuit_R1.pdf	PDF version of a PPT describing the scale of an airfield lighting series circuit and some photos demonstrating what an electrician will encounter on an active airfield

Statement of Problem and Substantiation for Public Input

Airfield lighting series circuits and street lighting series circuits are in used extensively throughout the United States and the world. The power source for this type series circuit is a constant current regulator. A constant current regulator is designed to raise or lower its output voltage to maintain a specific current through the load. Voltage measurements cannot not be safely performed in the field. Current is measured to determine the proper operation of the circuit and to determine if the circuit is energized.

Airfield lighting series circuits are used at virtually all airports. Runways or taxiways with a length more than 3,000 feet will use the series circuit technology. Airfield lighting series circuits may be up to 40,000 feet in length.

Small general aviation airports may have three to six airfield lighting series circuits. Medium sized airports may have 25 or more airfield lighting series circuits. Large air carrier airports may have 100 or more airfield lighting series circuits. According to https://www.statista.com/statistics/183496/number-of-airports-in-the-united-states-since-1990/ there are more than 5,100 public use airports in the United States.

Many metropolitan areas continue to use series street lighting circuits. However most new installation using LED fixtures appear to be voltage driven circuits.

Depending upon the Technical Committee members location in the United States I may be able to arrange a site visit to an airport so you can “see” with your own eyes the issue. As currently written 70E is instructing an airfield lighting electrician to measure voltage, this would be an unsafe act in the airfield lighting world.

Attached are four PDF documents:

- Chap 13 UFC 3-535-01 Visual Air navag Facil - 25 APRIL 2023.pdf – This material is taken from the DOD’s Unified Facilities Requirements. The material describes the characteristics of an airfield lighting series circuit.
- Part 2.4 150-5340-26C Maint of Airport Visual Aid Facil.pdf – This document is from FAA Advisory Circular 150/5340-26C discussing the electrical hazards associated with an airfield lighting series circuit.
- Part 2.2 AAAE Airfield Lgt Course Mod 1a.pdf – is a portion of the Association American Airport Executives (AAAE) airfield lighting maintenance course. The material has been RED-LINED to highlight characteristics of an airfield lighting series circuit.
- NFPA 70E Series Circuit R1.pdf is PDF version of a PPT describing the scale of an airfield lighting series circuit and some photos demonstrating what an electrician will encounter on an active airfield.

Please also watch a portion of a video sponsored by the Alaska DOT and Ted Stevens Anchorage International Airport titled: "TSIA- Airfield Lighting Safety Program".
https://www.youtube.com/watch?v=BdxM9WjOFXc&t=1024s The relevant information is contained in the video between 30:25 to 40:00 voltage vs current explanation.

I am available to discuss this issue if desired. Please make initial contact through email. cjohnson@avconinc.com. I am requesting an opportunity to address the Technical Committee during the first revision process. I have worked with Dr. John Tobias on the NFPA 780 TC for more than a decade. I believe John will vouch for my credibility.
Sincerely,

Carl S. Johnson II
Senior Aviation Lighting Specialist
AVCON, INC.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 49-NFPA 70E-2024 [Definition: Electrically Safe Work Condition.]	Series Circuit
Public Input No. 50-NFPA 70E-2024 [Section No. 110.4(A)(1)]	Series Circuit
Public Input No. 51-NFPA 70E-2024 [Section No. 110.6(E)]	Series Circuit
Public Input No. 52-NFPA 70E-2024 [Section No. 120.5(B)(6)]	Series Circuit
Public Input No. 49-NFPA 70E-2024 [Definition: Electrically Safe Work Condition.]	
Public Input No. 50-NFPA 70E-2024 [Section No. 110.4(A)(1)]	
Public Input No. 51-NFPA 70E-2024 [Section No. 110.6(E)]	
Public Input No. 52-NFPA 70E-2024 [Section No. 120.5(B)(6)]	

Submitter Information Verification

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Submittal Date: Tue Jan 02 07:10:17 EST 2024
Committee: EEW-AAA

Committee Statement

Resolution: Changing this to energy makes the requirement less clear for most applications. To be “qualified” to work on constant current lighting a person would need to have “knowledge related to the construction and operation of electrical equipment and installations” of such a system and would need to have “safety training to identify the hazards and reduce the associated risk,” including the correct method to verify that the system is in an electrically safe work condition.

CHAPTER 13 \1\ CHARACTERISTICS OF AIRFIELD GROUND LIGHTING

13-1 GENERAL.

Airfield ground lighting (AGL) typically includes separate series-circuited lighting systems that provide visual guidance to the pilot for aircraft operations. The systems usually have brightness control for adapting to various visibility conditions. The types of lighting systems installed for a particular runway are an important part in determining the conditions under which aircraft operations are allowed (e.g., Visual Flight Rules (VFR), Category I, Category II, or Category III). The various lighting systems that may be installed for a runway are shown in Figure 13-1. Not included in this figure are the several approach lighting systems (ALS) which may also be installed. Details for lighted approach aids, runway lighting systems, and taxiway lighting are provided in Chapter 3, Chapter 4 and Chapter 5, respectively.

13-1.1 Airfield ground lighting is characterized by constant current series electrical circuits, which provide constant current for intensity control of lighting components. This system allows for selectively changing the brightness of the lighting components by increasing or decreasing the level of the constant current in the series loop. While some older systems use constant voltage for shorter length series circuits, most systems today are constant current type. The series circuit provides energy at constant current to each device (such as a light or sign) on the circuit, supplied from a CCR.

13-1.2 The major parts of a series circuit are: the CCR (power source), the primary circuit cable, isolation transformers, and lighting components (such as lights and signs). The isolation transformers are connected in series on the primary side, with connected loads on the secondary side of each isolation transformer (Figure 13-2). The system is characterized as follows:

- A constant current is delivered along the entire loop on the primary side of the isolation transformers, independent of the number of lighting loads. Power is provided by the CCR.
- The magnitude of the voltage along the series circuit primary depends on the number and size of connected lighting loads. The voltage along the primary cable will measure different at each point. (Calculating voltages for the constant current series circuit is illustrated later in this chapter.)
- The circuit is considered high voltage on the primary side, which typically may be several thousand volts (5kV cable is used), and low voltage on the secondary side or load side of the isolating transformers, which typically is less than 30V.

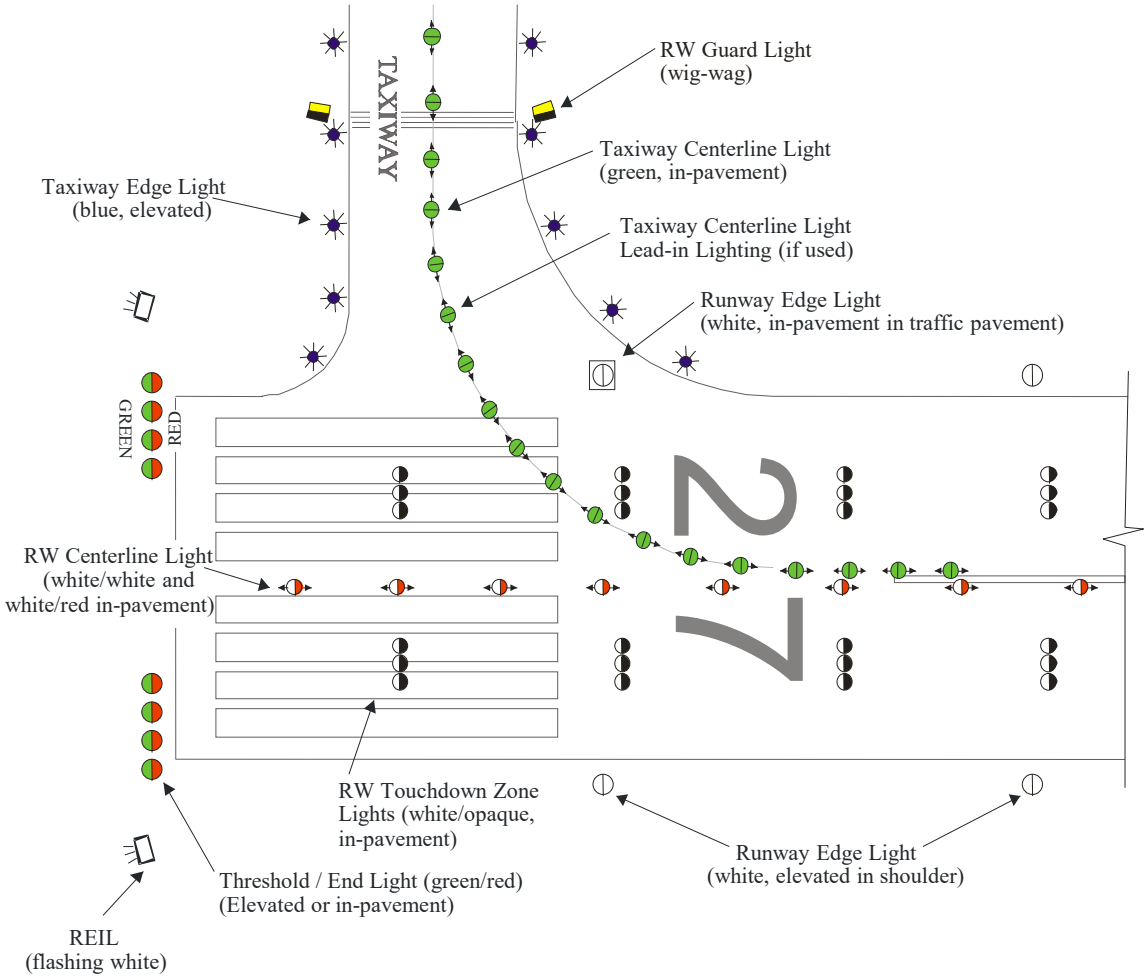
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RED LINE in margin indicates information relative to this PI.

- The isolation transformer provides an effective short for the primary circuit in the event of a lamp filament failure, which opens the secondary circuit. This prevents failure of a connected light from causing an open condition on the series primary circuit.

- A constant current series circuit can also be used to power equipment with specific voltage requirements. In this case a power adapter is used. The power adapter also serves to isolate the device from the primary side similar to an isolation transformer. Examples of equipment which may be connected to series lighting circuits include: wind cones, PAPI, REIL, and others which typically may require 120/240V power. NOTE: The lighting circuit must be ON for the equipment to receive power with this type of arrangement.

Figure 13-1 Typical AGL Layout



NOTES:

1. RW EDGE LIGHTING: For high intensity system (HIRL) bidirectional, white/white, with yellow on rollout for last 2,000' (610M) (L-862 elevated, with L-850C for in-pavement). Runway edge lights are spaced about 200' (61M) apart.

2. THRESHOLD/END (T/E) LIGHTS: Group of 4 or 5, spaced 10' (3M) apart symmetrical about centerline. Outer light in each group lines up with RW edge lights. Groups may be wing-out bars, where inner light in each group lines up with RW edge lights.

   T/E lights show green to aircraft approaching for landing, and red to landing aircraft coming to end of the RW.

3. RW CENTERLINE LIGHTS: Bi-directional white/white, with alternating red/white and white/white from 3,000' to 2,000' (915M to 610M) from end of RW, and red/white for last 2,000' (610M) of RW.

4. RW TOUCHDOWN ZONE LIGHTS: Uni-directional, with white towards approaching aircraft.

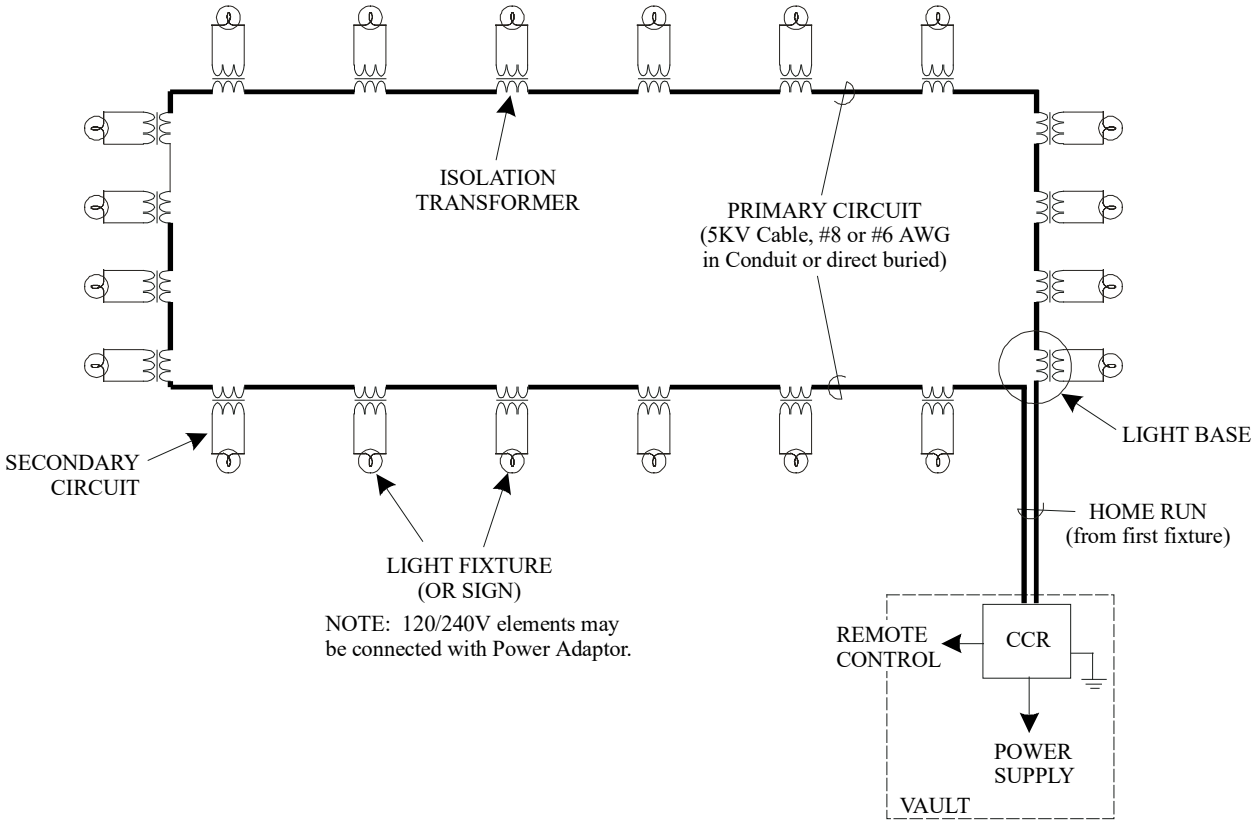
5. TW EDGE LIGHTS: Omni-directional blue (L-861T).

6. TW CENTERLINE LIGHTING: Bi-directional green/green, but may be green/yellow or yellow/yellow for some conditions.

7. REIL: Runway End Identifier Lights, discharge type flashing white lights (about 90 times/min.), Aimed 15 deg outward and 10 deg above horizontal.

8. RW GUARD LIGHT: Uni-directional, flashing yellow. Elevated outside TW, or may be bar of in-pavement across pavement (L-804).

Figure 13-2 Typical AGL Series Lighting Circuit



13-1.3 Parallel circuits are briefly discussed as these may be used to serve facilities such as wind cones, PAPI, REIL, and others. This may be directly from a power source, or via power adapter from a series lighting circuit.

13-2 POWER.

Upstream power for the CCR feeding the AGL may be from a variety of sources. Equipment vaults for AGL may be fed from a variety of sources, and in many cases have emergency standby generator power with automatic transfer in case of outages. Older systems typically feed the CCR at 2400V, while newer installations feed vault CCRs at 480V; 2400V input CCR equipment is for replacement only. The upstream power distribution feeding the CCR is not covered in this section.

13-3 CONTROL AND MONITORING SYSTEMS.

Traditional control/monitoring systems, both military and commercial, are relay systems. L-821 relay panels are very reliable and are suitable for nearly all military airfields. Typically, cables required for these types of systems are multi-pair (50 or more pairs) cables to connect the airfield lighting vault on the airfield with the air traffic control tower. On many air bases, the distance between the two facilities is great, resulting in a costly cable installation with the cable vulnerable to possible damage or failure of one or more pairs in the cable. In addition, these

communications cables require separate duct systems to eliminate interference from the power cables. The traditional relay panel and multi-conductor control cable can also be simplified by using a multiplexer, which requires only one pair cable to communicate between the vault and tower (or other station). A multiplexer can also be built into a PLC system.

13-3.1 Some airfield control/monitoring systems have been installed using Programmable Logic Controllers (PLCs). The PLC industrial systems use high I/O modules that reduce the need for multi-pair cable installation. Cables with 2 to 6 pairs are typically needed, although fiber optic cable can also be used.

13-3.2 PC-based systems are currently being used, with computers (Windows 7 operating system is approved by AF Chief Information Officer) located in the tower, the vault, and/or other work stations. These systems have the capability of displaying the necessary information on a monitor. This is the most flexible system in use today, with off-the-shelf units readily available. Typically, standard operating software is used, and off-the-shelf graphics software is tailored for a specific site. The communications cable requirements are 2 to 6 pairs of cable or fiber optics. Fiber optic cable eliminates the need for separate ducts since there will be no interference between power cable and fiber optic cable. The control panel typically is a touch-screen type. At the time of this writing the essential system PCs are recommended to have the following characteristics: 19" (480 millimeter) rack mount form factor, fully enclosed metal housing, redundant hot-swappable solid state software and data storage devices, redundant hot-swappable cooling system, redundant hot-swappable power supplies. The systems incorporate uninterruptible power supplies (UPS) for primary power to all system components required for normal operation for a duration of fifteen minutes.

13-3.3 Compared to the traditional FAA Type L-821 control/monitoring systems, the PLC or PC-based systems are easily expanded and provide data for the air traffic controller and maintenance personnel. Refer to FAA AC 150/5345-56. Some industrial standards the PLCs meet are NEMA ICS1, NEMA ICS2, NEMA ICS 3, UL 508, ANSI/IEEE C 37.90.1-1989, CAN/CSA C22.2 No. 142, MIL-STD-461B, MIL-STD-810 and ISO 9000.

13-3.4 Often, the computerized system is based on one specific manufacturer’s equipment. This limits the facility to one manufacturer for both service and parts. A good system design will avoid this by establishing competitive parameters in the procurement document.

13-3.5 Considerations for the design of a computerized control/monitoring system are in paragraph 13-18.6.

13-3.6 Factors for consideration when selecting a control system:

- Monitoring AGL equipment: the PLC based system must be customized for each type of CCR.

- For PC based systems, software has been developed and tested, and is easily configured to monitor AGL equipment. Software developed for PC systems is specific for the task and works with all types of CCRs and other related AGL equipment.

- With PLC systems there are established industrial standards and criteria for mean-time-between-failure (MTBF).

13-4 CONSTANT CURRENT SERIES CIRCUITS.

A constant current series circuit is an ungrounded system, where circuit elements are connected in a string with the same current flowing to each element. The circuit is one continuous loop starting and ending at the power source (the constant current regulator for the AGL circuit). The CCR maintains a constant current independent of the load on the circuit.

13-4.1 Circuit Failure.

With constant current, a short-circuit across the output of the CCR is a no-load condition, and an open-circuit is an overload. In a simple series circuit, a lamp failure would cause an open-circuit. For this reason a bypass device such as an isolating transformer is installed between the primary side and secondary side as part of each light fixture connection, or for connecting other loads such as guidance signs. In certain cases, such as for approach lights where 5 steady-burning lights are on a single secondary circuit isolated from the primary series circuit by one or more isolation transformers, a film disc cutout may be used. Film disc cutouts operate in such a way that when a lamp burns out, the film-disc cutout shorts the failed lamp, thereby allowing current to flow to the remaining connected fixtures.

13-4.2 Advantages of Series Lighting Circuits.

- All lamps operate at the same current, hence same intensity.

- Single-conductor cable of one size and insulation voltage rating can be used throughout the circuit.

- Intensity control of lights can be obtained over a wide range.

- A single ground fault along the circuit will not affect light operation.

- Ground faults are easily located.

13-4.3 Major Disadvantages of Series Lighting Circuits.

- Installation costs are high when considering the CCR and isolating transformers.

- Poor efficiency in use of electrical power.

- All components on the primary side must be insulated for full voltage.

- An open-circuit anywhere on the primary side makes the entire circuit inoperative and could damage cable insulation or the CCR.

- Locating faults such as open-circuit conditions can be time-consuming and may be difficult.

13-4.4 Typical Usage.

Series circuits are usually used for runway and taxiway lighting systems and most steady-burning lights of approach lighting systems because they provide more uniform intensity and better intensity control of the lights.

13-5 CONSTANT CURRENT REGULATORS.

The power input to the AGL circuits is controlled by the CCR to which the circuit is connected. While the CCR produces constant current to the circuits depending on the brightness step setting, the voltage input to the circuit varies with the actual load.

13-5.1 Basically, there are three types of constant current regulators used at airports:

- Resonant network circuit (ferro-resonant type using a resonant network control system to produce output current).

- Saturable reactor (ferro-resonant type, where the amount of reactor saturation via closed control loop determines output current).

- Silicon controlled rectifier (SCR) (uses SCR type thyristors to convert constant voltage source to constant current output, with solid state control circuiting). These are not ferro-resonant and are not approved for new installations.

13-5.2 The first two types have been reliable over the years, but fluctuations in input voltage will cause corresponding changes in the output current. Most CCRs now manufactured are SCR type.

13-5.3 Tests have shown that, as circuit load increases toward the rated capacity of a CCR, harmonic distortion is reduced and the wave form approaches a sine wave. This suggests that loading closer to rated capacity results in better circuit performance. However, lamp failures and other factors may increase the output voltage, and this needs to be considered when matching circuit load to CCR size.

13-5.4 CCRs have “taps” for adjustment to accommodate loads. Some manufacturers have introduced taps which automatically adjust to the circuit load, while others use manual taps which are typically set when the CCR is installed, but can be changed later to accommodate changes in the load.

13-5.5 The allowable tolerances in CCR output current are shown in FAA AC 150/5345-10. The allowable tolerances are small, because small changes result in large changes in light output. For a 6.6 amp circuit, reducing the current by 3 percent (to 6.4 amps) will reduce the light output over 15 percent, and reducing the current by 6 percent (to 6.2 amps) will reduce the light output by over 30 percent. The impact is the opposite on lamp life, where a current lower than maximum will significantly increase lamp life, and a higher current will reduce lamp life. The percent of full brightness obtained at each of the nominal current levels for 3 and 5 step systems can be found in paragraph 12-1.11.

13-5.6 15KW through 30KW CCRs may be selected for either 20 or 6.6 amperes output current. Intensity steps are either 5-step or 3-step for all CCRs.

13-5.7 50 kW and 70 kW regulators operating with 20A output current are not approved for new installations and are allowed for replacement only. Regulators with 2400V input are not approved for new installations.

13-6 REGULATOR SIZING.

13-6.1 For steady burning loads such as edge, centerline and touchdown zone lights sizing the regulator is fairly straight forward. Steady burning lights and circuit conductors are resistive loads and therefore will vary as the current varies. Current transformers are impedance loads and have the same electrical characteristics as resistive loads. See Figure 13-3A for calculating the load as the current varies; i.e., at the lowest brightness step. Using Ohms Law (P=IE), the maximum load at the lowest brightness level for a five-step regulator is determined by the ratio of the currents; i.e., (2.8/6.6) or (8.5/20) or 42.4% of the regulator rating. For a three-step regulator it is 4.8/6.6, or 72.7% of the regulator rating. It can be seen that these load percentages are greater than the ones calculated in Figure 13-3A. Therefore, a regulator fully loaded only with lights (and associated transformers) will not overload at the lowest current level.

Figure 13-3A Calculation of Steady Burning Load at the Lowest Brightness Level

DATA:

P = Steady Burning Light Load

I = Regulator Current

R = Steady Burning Light Load Resistance

Subscript $_H$ is the value at the Highest Brightness Step

Subscript $_L$ is the value at the Lowest Brightness Step

Ohms Law: $P = I^2 \times R$

CALCULATIONS:

$$P_H = (I_H)^2 \times R \rightarrow R = P_H / I_H)^2$$

$$P_L = (I_L)^2 \times R \rightarrow R = P_L / (I_L)^2$$

The resistance of the lamp filaments remains constant, therefore

$$P_L / (I_L)^2 = P_H / I_H)^2 \rightarrow P_L = P_H \times (I_L)^2 / I_H)^2 \rightarrow P_L = P_H \times (I_L / I_H)^2$$

The effective load of the steady burning fixtures at the lowest brightness step (P_L) is the load at the highest brightness step (P_H) times the squared ratio of the low (I_L) and high (I_H) currents.

For a 6.6A five step regulator the current ratio squared is $(2.8/6.6)^2$ or 0.18 or 18%.

For a 20A five step regulator the current ratio squared is $(8.5/20)^2$ or 0.18 or 18%.

For a three step regulator the current ratio squared is $(4.8/6.6)^2$ or 0.53 or 53%.

SUMMARY:

For five step regulators the load of steady burning lights at the lowest brightness step is 18% of the load at the highest brightness step.

For three step regulators the load of steady burning lights at the lowest brightness step is 53% of the load at the highest brightness step.

13-6.2 When loads such as REILs, PAPIs, windsocks and airfield signage are connected to a series circuit, consideration must be given to accommodate the effect of these loads on the regulator. Loads such as these have unique power requirements. PAPIs, signs and windsocks must maintain a constant level of light output and require a constant input voltage. When they are connected to a series circuit that has varying current levels the power from the current regulator must be converted to a constant voltage source within the equipment. Airfield signs are required to maintain a constant level of illuminance on the sign face and electronics are needed to operate them from a varying current source. The commonality with all these loads is that they present a constant load to the regulator regardless of current level on the circuit. When the circuit is a combination of steady burning lights and signs or other constant loads, the engineer must insure that the calculated load at the lowest brightness level does not exceed the percentage of the regulator rating as indicated above. Figure 13-3B shows an example where the regulator is over loaded at the lowest brightness step. Although most regulators will continue to operate when over loaded there are risks associated with that. Depending on the degree of overloading, negative effects may include the regulator's inability to stay within the FAA current tolerances. The result would be improper brightness levels. Operating an overloaded regulator can also lead to the premature failure of critical components because the regulator will raise the output voltage to maintain the required current level.

13-6.3 In its Advisory Circulars, the FAA does not address the load imposed on the CCRs by the constant current to constant voltage adapters necessary for REIL operation, or the REIL that are connected into series circuits. With the constant flashing of the lights and the resulting discharging of the capacitor, the REIL place a very short, but heavy, pulsing load on the regulator. Occasionally, this type of pulsing load results in pulsation of the illumination of the steady burning lights on the circuit. This "reflective" pulsation depends on the characteristics of the regulator powering the circuit and on the characteristics of the REIL connected into the circuit. The design engineer needs to ascertain from the regulator manufacturer which type of CCR will handle the overall series circuit load with the addition of the REIL pulse-type load without adverse effect. It has been shown that the problem will be minimized if the REIL are connected into series circuits that have primarily incandescent loads and the circuit load approaches the capacity of the regulator.

13-6.3.1 The actual regulator capacity needed to operate the REIL properly is much greater than the rated load indicated in the typical product literature. Usually the average power requirement is provided; however, the regulator has to accommodate the instantaneous, or pulsing, load to provide the flashing characteristics of the REIL. That REIL may be rated to require only 400 watts to operate, but may actually require up to 4 kilowatts of regulator capacity to meet the pulsing load requirements when also including the impact of the series circuit adapters between the series circuit and the REIL. The series circuit adapters convert 6.6 amps to 120 volts for REIL operation, and often have low efficiency that imposes higher than expected loads on the regulator. The proper sizing of the regulator requires careful consideration of the types of loads on the circuit and the true impact of those loads on the regulator.

Figure 13-3B Sample Calculation of CCR with High Signage Load

DATA:

CCR: 30KW, 480V input, 5-step (2.8A – 6.6A)

Cable: AWG #6, 5kV, L-824 Type C, 20,000 feet primary circuit

Circuit Loads:		
Steady Burn Lights	13,000 W
Transformer Losses (26% of Light Load)	3,380VA
Signage	13,000 VA
Cable losses (19 VA / 1,000')	383 VA

Circuit power factor is assumed to be 0.85.

CALCULATIONS:

1. Total connected load, VA = 13,000 + 3,380 + 13,000 + 383 = 29,763 VA
2. CCR Rated Load @ Lowest Brightness Step: (Reference paragraph 15-6.1)

   30KW x (2.8/6.6) = 12.72 KW or 14.97 KVA

3. Calculated Load @ Lowest Brightness Step: Reference Figure 3-13A(Reference Figure 15-3A)

   (Lights + Losses) x $(2.8/6.6)^2$ + Signage =
   ((13,000 + 3,380 + 383) x 0.18) + 13,000 = 16,017 VA

Because the signage load does not change for the various brightness steps the resulting demand on the regulator at the low step (16.02 KVA) is higher than the rated load for the regulator at the low step (14.97 KVA). While the load at the highest step (29.76 KVA) is less than the rating of the regulator, it will be overloaded at the lowest step; therefore, do not operate in this load configuration.

Loads such as signs, REILs, PAPIs and windsocks are constant regardless of the brightness level and must be carefully considered in circuit design and regulator sizing.

Where:

E = volts (V)	W = Wattage of light fixtures
I = Current, in amperes (A)	VA = Volt-Amps
P = Power Load	kW = kilowatts
	kVA = kilovolt-amps
	P.F. = Power Factor

Ohms Law: P = IE, E=IR, $P=I^2R$

13-6.3.2 As described in paragraph 13-6.1, the REIL can impose significant loads on the CCR powering the circuits to which they may be connected. It is preferable, if the budget permits, to have separate circuits with 240/120 volt service to power the REILs, thereby eliminating any adverse impacts on series lighting circuits.

13-6.3.3 Sample calculations and comparison with test data, as well as guidance for setting taps, are shown in Figure 13-4. A table format for calculating airfield lighting series

circuit loads is shown in Table 13-1. Carefully consider the notes in Table 13-1 when determining load values.

13-6.3.4 Normally the airfield signage load on a circuit is less than the steady burning light load. When the sign load is significant on a circuit, care must be taken to prevent overloading the regulator at the lowest brightness step. Figure 13-3B shows an example calculation where the sign load is high enough to present a problem.

13-7 CABLE.

The primary series circuit utilizes FAA L-824 Type B or C cable. L-823 connectors are used for connections. For 6.6 ampere primary series AGL circuits, an AWG #8 conductor is normally used. An AWG #6 conductor is used with 20 ampere circuits. For the secondary side lighting loads, a two-conductor AWG #10, 600V insulation is normally used.

13-7.1 The cable is installed in conduit, although it may be direct buried (L-824 cable is rated for direct burial). It is important that insulation is intact and that proper connections are made. Deteriorated or damaged cable can result in current leakage and may present a high voltage hazard to maintenance personnel. While installation in conduit may cost more, this method usually provides longer circuit life, and makes troubleshooting and replacement of cable segments easier. Where cable is installed in the regulator vault it must be in conduit, wireway or conduit or wireway in a floor trench with a solid top. L-824 cable is not rated for installation in cable tray.

13-7.2 The types of faults associated with series circuit cable are open circuit conditions and shorts-to-ground. An open circuit condition will turn off all the lights. A single short-to-ground will not impact the lighting, but multiple shorts-to-ground can cause dimming of lights or outages for portions of the circuit or for the entire circuit.

Figure 13-4 Sample Calculation of CCR Test Data

(1 of 2)

SAMPLE CALCULATIONS, CCR TESTING

DATA: CCR: 30KW, 480V input, 5-step (2.8A - 6.6A), with Power Factor of 0.43

Cable: AWG #8, 5kV, L-824 Type C, 20,000 feet primary circuit

Circuit Load: 70 Edge lights @ 120W (100W transformer)
16 Threshold/end lights @ 200W (200W transformer)

10 signs @ 100VA (at step 5) }
5 signs @ 200VA (at step 5) } *(at the input to the isolation transformer*)
3 signs @ 300VA (at step 5) }

1 REIL system (2 units) @ 400W, connected by power adapter. [Note that in this example the REIL is only adjusted for PF. Some REIL may require further adjustment, based on manufacturer's information.]

Cable losses (resistance) @25°C: 0.68Ω/1,000'
Fixture losses (obtain from Mfg - This example assumes 18 percent for 120W, and 11 percent for 200W lights)

CALCULATIONS:

1. CCR rated output voltage, V_{RMS} = 30KW/6.6A = 4,545V

2.Total connected load, KVA = $\frac{[W_{lamps} + W_{REIL} + VA_{signs}]/PF + Fixture\ Loss + Cable\ loss}{1{,}000}$

Fixture losses = (70 x 120 x 0.18) + (16 x 200 x 0.11) = 1,864W

Cable losses = I^2R = $[6.6]^2$ x (0.68 x 20) = 592W

TOTAL KVA = $\frac{[(70x120) + (16x200) + (400) + (10x100 + 5x200 + 3x300)]/0.43 + 1{,}864 + 592}{1{,}000}$

= 17.57 KVA

where:

KVA = kilovolt-amperes
V = volts
A = amperes
KW = kilowatts
CCR = Constant Current Regulator
R = Resistance in Ohms, Ω
V_{RMS} = Rated output voltage of CCR
W_{lamps} = Wattage of light fixtures
W_{REIL} = Wattage of REIL
PF = Power Factor
I = Current, in amperes

Figure 13-4 Sample Calculation of CCR Test Data (Cont.)

(2 of 2)

SAMPLE CALCULATIONS, CCR TESTING (Cont.)

NOTE: Traditional method for determining the load KW assumes that the CCR powers a unity power factor lamp circuit. With REILs, new type signs, and runway guard lights (wig-wags), a unity power factor is not representative, and power factor must be considered.

MEASURED RESULTS (Case 1):

- Output current at Step 5 = 6.52A
- Output voltage at Step 5 = 2,880V

Total KVA Load based on measurements = 6.52A x 2.88kV = 18.8KVA

CONCLUSIONS: The output current is within FAA tolerance. The total KVA measured is slightly higher than the calculated load. This may be due to slightly higher actual fixture losses than assumed values. Overall, the CCR is operating satisfactorily.

MEASURED RESULTS (Case 2):

- Output current at Step 5 = 6.52A
- Output voltage at Step 5 = 1,880V

Total KVA Load based on measurements = 6.52A x 1.88kV = 12.3KVA

CONCLUSIONS: The output current is within FAA tolerance. The total KVA measured is significantly less than the calculated load. The results suggest a partial shorting of the load.

MEASURED RESULTS (Case 3):

- Output current at Step 5 = 6.30A
- Output voltage at Step 5 = 2,550V

From test results, Total KVA Load = 6.30A x 2.55kV = 16.1KVA

CONCLUSIONS: The output current is below that allowed by FAA tolerance. The total KVA measured is below the normal value (2,880V) as found in first test. Results indicate faulty CCR. Perform a short circuit test on the CCR before it is used.

NOTE: Analysis compares KVA with KW. This is because the rated output of the CCR is specified in KW in compliance with FAA AC 150/5345-10. However, load measurements result in KVA. The requirement for total load in KVA to be below the CCR output in KW under operational conditions ensures that the CCR is not overloaded.

Table 13-1 AGL Series Circuit Load Calculation Data Sheet

CKT No.	Regulator (CCR) (Runway or Taxiway, Etc.)	CKT Type (Amps)	Cable Size (AWG)	CCR Rating (KVA) (1)	CCR Input (V)	Steady Burning Light Load (KVA) (2)	Sign Load (KVA) (3)	Other Loads (KVA) (4)	Total Connected Load (KVA)	Transformer Losses (KVA) (5)	Cable Length FT or M)	Cable Losses (KVA) (6)	Calculated CCR Load (KVA)

NOTES:
(1) CCR rating may be in KW. To determine KVA, divide KW by power factor (PF) and CFR efficiency (EF) based on full load. Obtain PF and EF from manufacturer.
(2) To determine KVA for steady burning lights by summing "[no. of fixtures] x [lamp wattage] / 1000" for all lights on circuit. Steady burning lights can be runway edge lights, threshold/end lights, centerline lights, touchdown zone lights, taxiway edge and centerline lights, and approach lights.
(3) Determine KVA for signs based on manufacturer rating or specified limit VA for each size and length (modules or width) of sign on circuit.
(4) Other loads may be pulsing lights such as REIL. Determine KVA based on manufacturer data for each type.
(5) Isolation transformer losses may be estimated at 26% of connected load.
(6) Determine cable losses based on cable length and manufacturer cable data on conductor resistance. Loss per unit length is typically based on the relationship $I^2R = W$ and assumed PF of unity for the cable.
Typical values for cable losses are: 34VA / 1,000ft (34VA / 300M) for 6.6A circuits with uncoated stranded #8 AWG conductor, and
196VA / 1,000ft (196VA / 300M) for 20A circuits with uncoated stranded #6 AWG conductor.
Refer to Paragraph 5-3.2.3, Color Coding.

13-8 TRANSFORMERS.

The isolation transformer provides: electrical isolation between the high voltage series circuit and the low voltage secondary feeding the lighting load (such as a fixture or sign), constant current output for a constant current input at the correct ratio, and an effective short circuit in the event of an open condition in the light fixture, for example with lamp filament failure.

13-8.1 Isolation Transformers.

With the isolation transformer, only low voltage is brought to the light fixture (via the secondary circuit), and failure of the light does not cause an open condition on the primary circuit that would result in other lights and other connected loads to be shut off.

Isolation transformers for AGL are covered by FAA Specification L-830 (for 60 Hz) and FAA Specification L-831 (for 50 Hz), and are typically 6.6 amperes on the secondary side, with either 6.6 amperes or 20 amperes on the primary side for series lighting circuits at the highest intensity step. The wattage of the isolation transformer is approximately matched to the connected load on the secondary side.

13-8.2 Transformer Load.

Ensure the load powered by the transformer is within ±10 percent of the transformer wattage rating to maintain isolation transformer efficiency. Light fixture manufacturers have their fixtures certified using a specified wattage for the isolation transformers. Use the light fixture manufacturer's recommended size for isolation transformers.

\4\ 13-8.3 Series Circuit Selector Switches.

Use switches in accordance with FAA AC 150/5345-5, Type L-847. Series circuit selector switches can be high-maintenance equipment and should be avoided whenever possible.

13-8.4 Control Cables.

Control cables for 120 VAC control systems must be multi-conductor, 600 volts, 12 AWG copper, rated for direct earth burial. Cables for 48 VDC control circuits must be multi-conductor, stranded 19 AWG copper, with 300 volt polyvinyl insulation suitable for installation in wet locations and meeting REA Bulletin 345-14 or 345-67. Color-code all conductors.

13-8.5 Constant Current Regulators (CCR).

Use CCRs per FAA AC 150/5345-10 of a suitable type and style. The size selected should normally provide for approximately 20 percent expansion of the load.

c. Perform an electrical hazard analysis consisting of:

1. A **shock hazard analysis** to determine the voltage(s) to which personnel will be exposed, boundary requirements and the personal protective equipment (PPE) necessary to minimize the possibility of electric shock to personnel.

2. A **flash hazard analysis** must be completed to protect personnel from the possibility of being injured by an arc flash. The analysis determines the flash protection boundary and the PPE that personnel within the flash protection boundary must use.

d. Implement the requirements of the shock and flash hazard analysis prior to starting any work.

e. Complete the work safely and return the system to safe operating status.

f. Close out the energized equipment work permit.

2.3 Safety Procedures and Guidelines.

Most airport visual aid equipment is exposed to weather and may develop electrical shock hazards through damage from lightning or electrical cable insulation deterioration from exposure. Begin maintenance procedures only after a visual inspection is made for possible hazards. Due to the hazards associated with lightning, lighted navigational aids should not be serviced during periods of local thunderstorm activity. Each airport should develop and implement procedures to be followed in the event of an accident. Precious seconds are saved rendering medical assistance to injured personnel when action plans are already in place. Rehearse and review action plans regularly.

2.4 Electrical Hazards of Series Lighting Circuits.

Airport lighting circuits are very dangerous. This is especially true for maintenance personnel with little or no experience working on constant current series circuits. Airport lighting circuits can operate at potentials of several thousand volts depending on the size of the regulator driving the circuit and the load.

2.4.1 Basic Rules.

There are three basic rules to remember when working on and around airport lighting circuits:

a. **ALWAYS** assume that the circuit is energized until you have proven otherwise. **ALWAYS** check for current before disconnecting the series circuit connector, removing the S1 cutout, or opening the primary series circuit by any other means. Make it a required practice to check the circuit with an ammeter prior to breaking the connection – **NO EXCEPTIONS.** Never attempt to measure voltage in a series lighting circuit using ordinary volt meters. An inductive voltage measuring device (sometimes referred to as a "ticker") such as is described in Chapter 4 may be used to detect the presence of induced voltage on a series lighting cable after checking for the presence of current. Always use a true RMS clamp-on type ammeter to verify if the circuit is energized. **ALWAYS** check

the operation of the test equipment on a known live circuit before and after measurements are taken.

b. **NEVER** under any circumstances open or break a live airfield series circuit. The voltage generated in the circuit can reach levels many times normal before the regulator's open circuit protection can shut it down. As long as a current flow can be maintained, even if it is through you, the regulator will continue to operate. This is one of the reasons that series circuits can be so hazardous to work around - there is no personnel protection provided such as might be found on parallel interior wiring.

c. **NEVER** enter a manhole with energized conductors and never handle cables or transformers in light bases while there is current present. Cables or connectors can have cracked insulation where it is not visible or may be deteriorated and fall apart, exposing you to live circuit conductors.

2.4.2 Induced Voltages.

Series circuits are typically run from the lighting vault in duct banks where the wires are lying parallel to each other in close proximity. Voltages may be induced in an otherwise un-energized conductor and may be a hazard when troubleshooting and testing. Circuits that have a load that varies due to flashing action of runway guard lights or REIL strobes are particularly prone to induce voltages in other conductors due to the pulsing characteristics of the voltage and current in these circuits. Always remember that there may be a possibility of an induced voltage in any conductor. Never work on or in close proximity to live circuits within any duct or manhole.

2.4.3 Re-lamping.

The most common lighting maintenance task on the airfield is re-lamping of incandescent runway and taxiway lighting fixtures.

Note: See paragraph 5.3.2 for information about light emitting diode (LED) light fixtures.

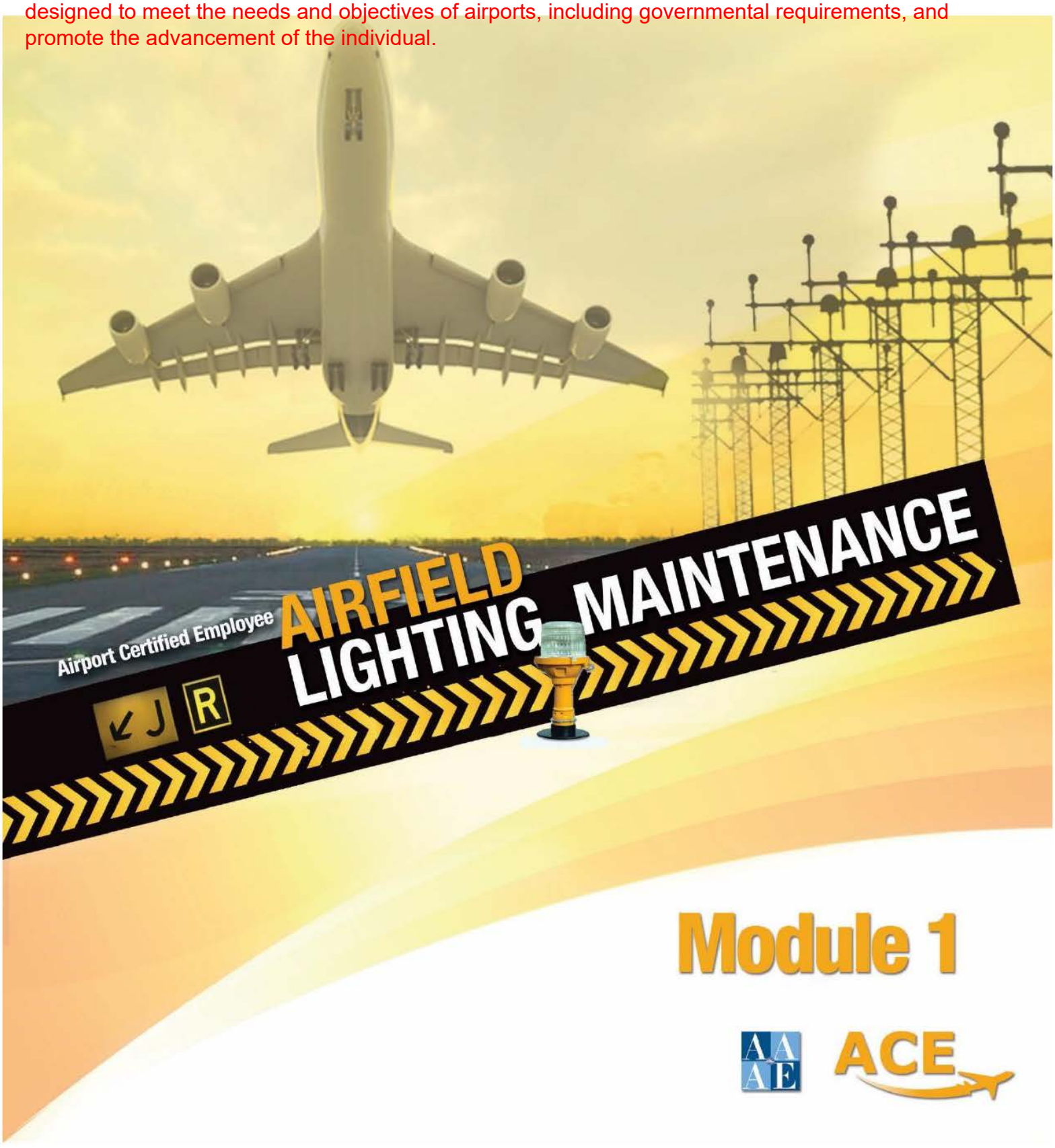
Depending on the type of light fixture, this may be accomplished in the field or, in the case of most in-pavement lights, the entire light fixture is removed, replaced, and brought to the maintenance shop for refurbishing. The greatest unseen danger to you is re-lamping or removing the fixture with the circuit energized. This has always been a common practice by airport electricians for convenience and the dangers are often overlooked. There are two primary hazards associated with this practice:

a. The first hazard occurs when there is a short circuit between the isolation transformer primary and secondary windings. Remember that isolation transformers are not designed for personnel protection. They are designed to isolate the secondary winding from the primary circuit to allow continued operation with a lamp burned out. A transformer with a primary to secondary short may not cause a circuit malfunction and could remain unnoticed during normal operation.

A short from the isolation transformer primary to secondary winding exposes you to the full voltage present on the primary circuit and can be especially dangerous if another

American Association of Airport Executives (AAAE) Certification.
Airport Certified Employee (ACE) - Airfield Lighting Maintenance

AAAE certification programs set the standard for industry knowledge and training. Each program is designed to meet the needs and objectives of airports, including governmental requirements, and promote the advancement of the individual.



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https://www.aaae.org/AAAEMemberResponsive/PD/AC/ACE/Airfield_Lighting_Maintenance/Airfield_Lighting.aspx

2.2 Theory of Operation

As previously stated, the series lighting circuit is a constant current, variable voltage circuit as opposed to a conventional parallel circuit which has a constant voltage output with the current varying at different points in the circuit depending on the circuit layout. Maximum current output on series lighting circuits in the United States is limited to either 6.6 amps or 20 amps depending on the circuit load and the CCR being used. Circuits rated at 6.6A are limited to 30 kW in size due to the fact that at maximum load and maximum current output, the CCR would have an output of 4545 volts which is just below the operating rating of the cable and transformers. If circuits greater in size than 30kW are required, the circuit is changed to 20 amp to reduce the output voltage. For example, the maximum output voltage on a 50kW 20 amp CCR would be 2500 volts. For this reason, and to prolong the life of the cable and transformers, it is at times recommended that the size of the circuits be limited to 20kW or less at 6.6A. Constant current regulators with a 20 amp output are only available as 5 step models and 50 and 70 kW units are limited to replacement units only per FAA AC 150/5345-10F. This change is due to the development of light fixtures which utilize smaller wattage lamps than previous models and therefore present a smaller load to the circuit.

Electrical current flow in the series lighting circuit is from one output terminal on the CCR to the other through the various sized isolation transformers (loads) in the field circuit. The CCR varies the output voltage depending on the amount of load in the circuit and the selected brightness step. The output side of the transformer winding in a CCR is not connected to ground at any point, therefore the voltage to ground is said to be “floating”. Since there is no true current path to ground and back to the source (CCR) as in a normal parallel circuit, there will be no current flow to ground if only one point in the circuit is grounded. However, when two or more locations in the series circuit become grounded, the current will flow through the ground around the load thereby resulting in a section of lights being extinguished. We will cover the theoretical and practical aspects of the behavior of voltage and current in a series circuit in more detail later in this chapter.

2.3 Advantages

The series circuit concept was first used in street lighting systems many years ago and is still in use in some areas today. It has proven to offer several advantages for airport lighting in that it provides:

- An illumination of even intensity to provide the proper visual cues to the pilot.
- The ability to deliver light output at variable intensities under various weather conditions.
- The compact design of the lamp filaments used with the constant current system is much more rugged and provides lamps that are more easily focused in an optical system.
- This system allows standardization of economical cables and cable sizes (#6 and #8 AWG). Relatively small cables can be used to deliver substantial power over very long circuits, typically two to five miles in length.
- A single ground fault in the system will not affect light operation.
- Ground faults may be easily located.
- The ability to easily add, remove or modify the load with the primary concern being the loading of the CCR. We must remember however, that by adding load to a series circuit, we are also increasing the output voltage of the CCR and thereby increasing the voltage stresses on the existing circuit cables and transformers.

2.4 Components of the System

The series lighting circuit uses a variable voltage, constant current AC source to supply electrical energy to the various loads connected to the circuit. The series circuit is comprised of a set of similar building block components in addition to the constant current regulator source. Each of these building blocks consists of the lighting fixture or sign, series isolation transformer and modular connector kit. These building block components are connected to each other and to the CCR by the 5 kV cable which can be either shielded (screened) or non-shielded. Non-shielded cable is typically used at installations in the United States and Canada. Shielded cables are sometimes used in European installations. The perceived benefits and drawbacks of each are the subject of much debate. There are other variables that can be found in various parts of the world such as Canada where isolation transformers are equipped with a grounding terminal that is internally attached to one side of the secondary winding of the transformer. This enables the secondary of the transformer to be grounded in an effort to help provide personnel protection in the event of a primary to secondary short in the transformer windings.

Series isolation transformers are available in several configurations of input current (6.6 or 20 amp), output current (6.6 or 20 amp) and load size (10/15 to 500 watt). Transformers with outputs of 1500 watts are also available for approach lighting systems where multiple lamps are connected to a single transformer. Cable used for series lighting circuits is sized either at #8AWG or #6AWG, the latter being used in 20 amp circuits to provide for less resistance and thereby reducing the I^2R (current squared × resistance = watts) losses in the circuit.

Constant current regulators are available in ratings from 1 kW to 70 kW and with 3 or 5 step outputs per FAA specifications. The 1 and 2 kW sizes were added in the latest edition of FAA AC 150/5345-10 to allow for smaller CCRs for LED circuits. Constant current regulators in other countries may have up to 7 or 8 brightness steps and operate with an output of 6 or 12 amps. Constant current regulators rated for 6.6 amp output are available in 3 or 5 step configurations but 20 amp CCRs are available as 5 step output only per FAA Advisory Circular 150/5345-10.

The last component normally installed as part of a typical airport series lighting system is the counterpoise system. This system provides protection from lightning damage to the circuit. The counterpoise system typically consists of #8 or #6 AWG conductor that is installed a few inches above the circuit conductors or conduit and is attached to ground rods at even spacing around the circuit. The ground rods are normally located at distances not to exceed 500 ft. Depending on the configuration of the system, the counterpoise conductor may be connected to the base cans or mounting stakes or routed around the lights with no connection. The FAA Advisory Circular 150/5340-30, *Design and Installation Details for Airport Visual Aids*, latest addition, should be consulted for the latest requirements for counterpoise installation in the United States.

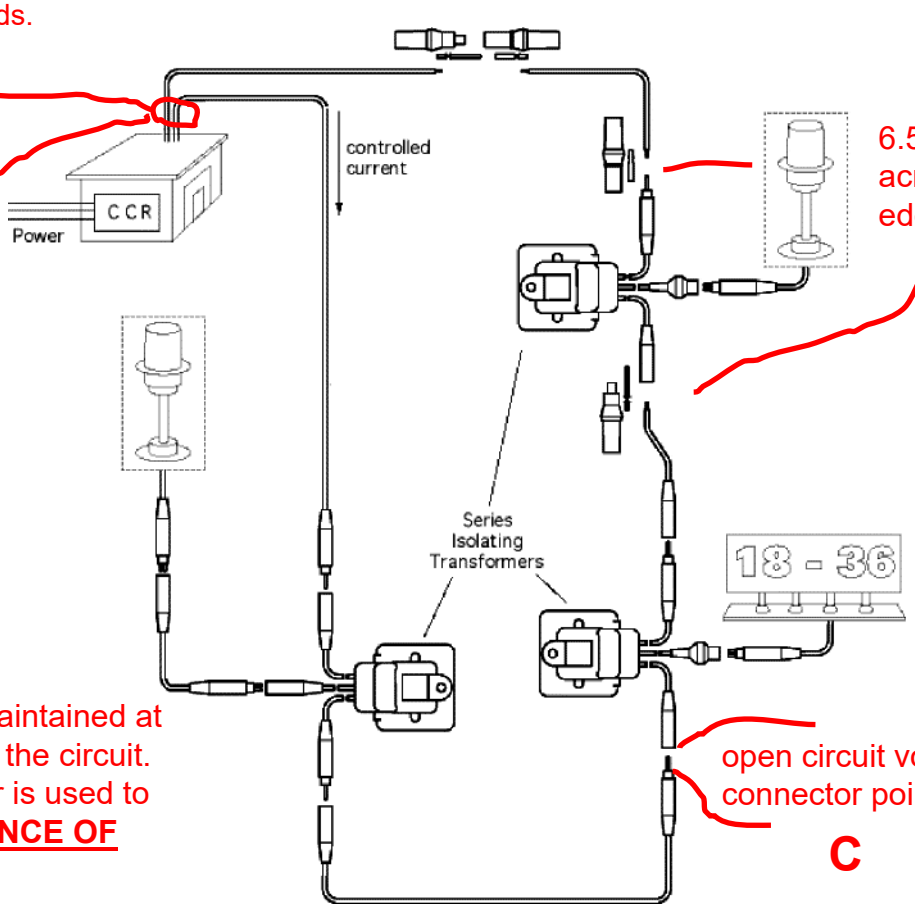
Constant current regulators are manufactured in several designs and styles. Basic types are Resonant Network, Thyristor Controlled (better known as series type), Ferro-Resonant and those employing a Saturable Core Reactor.

Series isolation transformers and CCRs are covered in detail in the following chapters of this training course.

A If there was a way to safely expose the conductors (w/o creating and open circuit) on both sides of the series isolating transformer the voltage drop across a LED runway edge light would be approximately 6.5 volts. Indicating it would be safe to work.

B A fully loaded 30 kW, 6.6 amp constant current regulator (CCR) would have a nominal output voltage of 4,545 volts.

C An open circuited 30 kW CCR would have an output voltage of 9,090 volts for two seconds until the open circuit trip functions. The CCR is designed to raise the output voltage is accordance with the load. The CCR sees an open circuit as an increase in load and raises the output voltage until the overvoltage circuit turns the CCR off after 2 seconds.

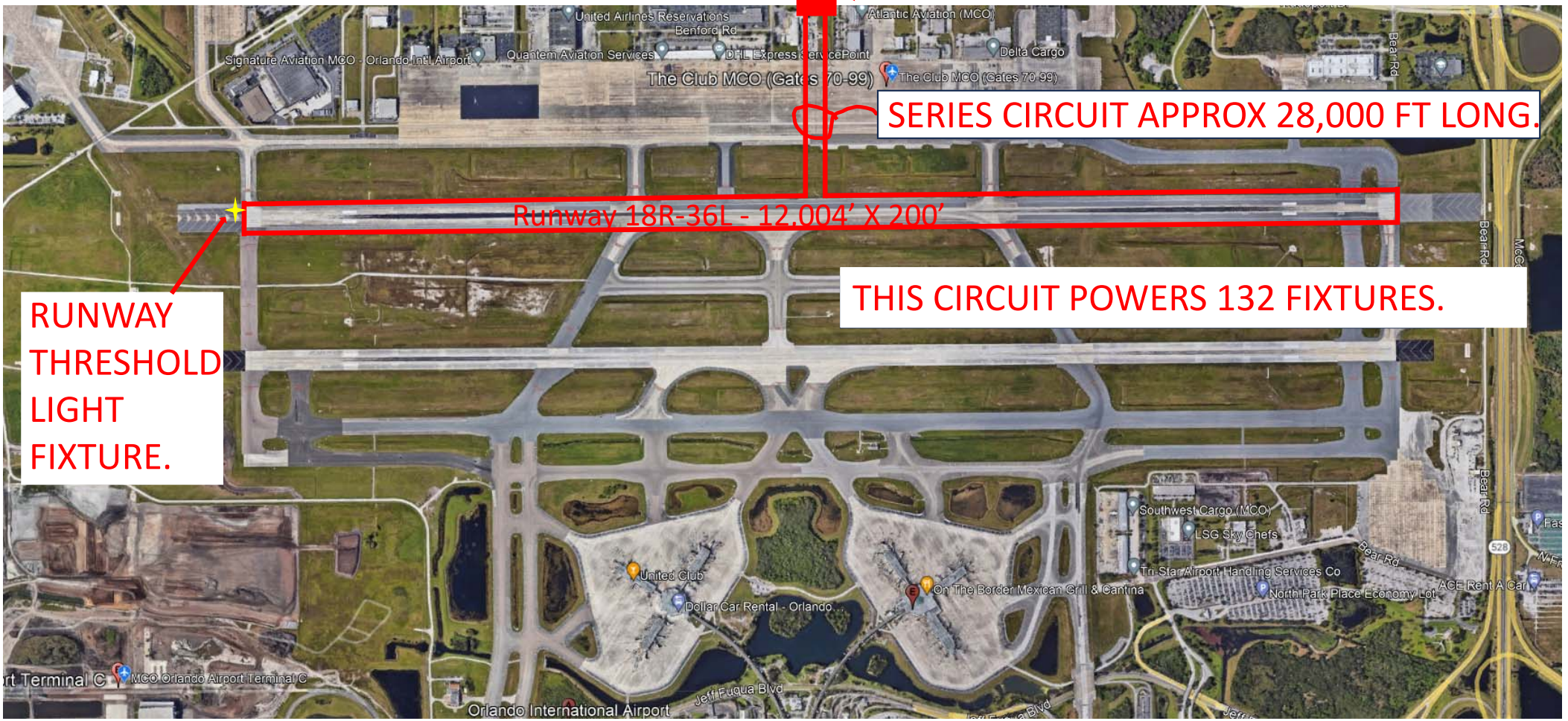


The CCR nominal output voltage is determined by the quantity and VA load of the fixtures connected to the individual circuit.

Figure 2-6 – Typical Series Lighting Circuit
Drawing courtesy of Amerace Ltd.

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LOCATION OF CONSTANT CURRENT REGULATOR.



FIXTURE TO BE REPAIRED IS MORE THAN 6,OOO FEET FROM THE POWER SOURCE. ABSENCE OF ENERGY MUST BE VERIFIED.



BLOW-UP OF RUNWAY 36L THRESHOLD AREA.

TYPICAL RUNWAY THRESHOLD LIGHT FIXTURE.

RUNWAY THRESHOLD LIGHT FIXTURE.





RUNWAY THRESHOLD
LIGHT FIXTURE BASE OPENED
TO EXPOSE WIRING

Voltage drop across this threshold fixture = 48 volts.
Three – 105-watt halogen lamps at 6.6 amps.

Airfield lighting series circuits are an ungrounded system. Green wire in photo is a bonding jumper used for lightning protection, NFPA 780.

A qualified person would be committing an unsafe act (very possibly fatal act) attempting to open the circuit at a series circuit airfield lighting fixture to test the voltage. Open circuit voltage may reach >9,000 volts. A true RMS clamp-on or open jaw ammeter must be used to determine if the circuit contains energy.

Public Input No. 76-NFPA 70E-2024 [Section No. 120.6]

120.6 Process for Establishing and Verifying an Electrically Safe Work Condition.

Establishing and verifying an electrically safe work condition shall include all of the following steps, which shall be performed in the order presented, if feasible:

(1) Determine all possible sources of electrical supply to the specific equipment. Check applicable up-to-date drawings, diagrams, and identification tags.

(2) After properly interrupting the load current, open the disconnecting device(s) for each source.

(3) Wherever possible, visually verify that all blades of the disconnecting devices are fully open or that drawout-type circuit breakers are withdrawn to the test or fully disconnected position.

(4) Release stored electrical energy.

(5) Block or relieve stored nonelectrical energy in devices to the extent the circuit parts cannot be unintentionally energized by such devices.

(6) Apply lockout/tagout devices in accordance with a documented and established procedure.

(7) Use an adequately rated portable test instrument to test each phase conductor or circuit part at each point of work to test for the absence of voltage. Test each phase conductor or circuit part both phase-to-phase and phase-to-ground. Before and after each test, determine that the test instrument is operating satisfactorily through verification on any known voltage source.

Exception No. 1 to 7: *An adequately rated permanently mounted absence of voltage tester shall be permitted to be used to test for the absence of voltage of the conductors or circuit parts at the work location, provided it meets all of the following requirements: (1) It is permanently mounted and installed in accordance with the manufacturer's instructions and tests the conductors and circuit parts at the point of work; (2) It is listed and labeled for the purpose of testing for the absence of voltage; (3) It tests each phase conductor or circuit part both phase-to-phase and phase-to-ground; (4) The test device is verified as operating satisfactorily on any known voltage source before and after testing for the absence of voltage.*

Exception No. 2 to 7: *On electrical systems over 1000 volts, noncontact capacitive test instruments shall be permitted to be used to test each phase conductor.*

Informational Note No. 1: See UL 61010-1, *Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use, Part 1: General Requirements* , for rating, overvoltage category, and design requirements for voltage measurement and test instruments intended for use on electrical systems 1000 volts and below.

Informational Note No. 2: See UL 1436, *Outlet Circuit Testers and Other Similar Indicating Devices* , for additional information on rating and design requirements for permanently mounted absence of voltage testers.

Informational Note No. 3: See IEC 61243-1, *Live Working — Voltage Detectors — Part 1: Capacitive type to be used for voltages exceeding 1kV a.c.* , or IEC 61243-2, *Live Working — Voltage Detectors — Part 2: Resistive type to be used for voltages of 1kV to 36 kV a.c.* , or IEC 61243-3, *Live Working — Voltage Detectors — Part 3: Two-pole low voltage type* , for additional information on rating and design requirements for voltage detectors.

Informational Note No. 4: After all the above steps have been taken, there could still be an unknown source that is connected to the system through a neutral conductor. Extra care should be taken to ensure hazardous voltage does not appear when disconnecting neutral conductors.

(8) Where the possibility of induced voltages or stored electrical energy exists, ground all circuit conductors and circuit parts before touching them. Where it could be reasonably anticipated that the conductors or circuit parts being de-energized could contact other exposed energized conductors or circuit parts, apply temporary protective grounding equipment in accordance with the following:

(9) _ *Placement.* Temporary protective grounding equipment shall be placed at such locations and arranged in such a manner as to prevent each employee from being exposed to an electric shock hazard (i.e., hazardous differences in electrical potential). The location, sizing, and application of temporary protective grounding equipment shall be identified as part of the employer's job planning.

(10) _ *Capacity.* Temporary protective grounding equipment shall be capable of conducting the maximum fault current that could flow at the point of grounding for the time necessary to clear the fault.

Informational Note: See ASTM F855, _ *Standard Specification for Temporary Protective Grounds to be Used on De-energized Electric Power Lines and Equipment* , which is an example of a standard that contains information on capacity of temporary protective grounding equipment.

(11) _ *Impedance.* Temporary protective grounding equipment and connections shall have an impedance low enough to cause immediate operation of protective devices in case of unintentional energizing of the electric conductors or circuit parts.

Statement of Problem and Substantiation for Public Input

My public input is to add informational note 4. It looks like Terraview added more 'new' lines.
there have been workers who have died due to the lifting of neutrals. Many times, these are due to wiring errors where the neutral of one system is mistakenly swapped with the neutral of another system. There is no way of knowing this until neutrals are disconnected.
Perhaps this note fits better under parenthetical one.

Submitter Information Verification

Submitter Full Name: Eric Stromberg
Organization: Los Alamos National Laboratory
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City:
State:
Zip:

Submittal Date: Wed Apr 10 22:05:11 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: Section 120.5(A)(1) Informational Note addresses the issue of neutral conductors as another hazard.

Public Input No. 90-NFPA 70E-2024 [Section No. 120.6]

120.6 Process for Establishing and Verifying an Electrically Safe Work Condition.

Establishing and verifying an electrically safe work condition shall include all of the following steps, which shall be performed in the order presented, if feasible:

(1) Determine all possible sources of electrical supply to the specific equipment. Check applicable up-to-date drawings, diagrams, and identification tags.

(2) After properly interrupting the load current, open the disconnecting device(s) for each source.

(3) Wherever possible, visually verify that all blades of the disconnecting devices are fully open or that drawout-type circuit breakers are withdrawn to the test or fully disconnected position.

(4) Release stored electrical energy.

(5) Block or relieve stored nonelectrical energy in devices to the extent the circuit parts cannot be unintentionally energized by such devices.

(6) Apply lockout/tagout devices in accordance with a documented and established procedure.

(7) Use an adequately rated portable test instrument to test each phase / circuit conductor(s) or circuit part(s) at each point of work to test for the absence of voltage ~~. Test each phase conductor or circuit part both phase-to-phase and phase-to-ground. Before and~~ / absence of energy. Before and after each test, determine that the test instrument is operating satisfactorily through verification on any known voltage and / or energy source.

(8) Test between each phase / circuit conductor(s) or circuit part(s): phase-to-phase, phase-to-neutral, phase-to-ground, and neutral-to-ground.

(9) When making a connection in or around equipment between phase / circuit conductor(s) or circuit part(s), test for the absence of voltage between the components being connected.

(10) When breaking or disconnecting a connection in or around equipment, test the phase / circuit conductor(s) or circuit part(s) for the absence of energy with a properly rated clamp meter (placing the clamp meter around the components or conductors being disconnected)

Exception No. 1 to 7: An adequately rated permanently mounted absence of voltage tester shall be permitted to be used to test for the absence of voltage of the conductors or circuit parts at the work location, provided it meets all of the following requirements: (1) It is permanently mounted and installed in accordance with the manufacturer's instructions and tests the conductors and circuit parts at the point of work; (2) It is listed and labeled for the purpose of testing for the absence of voltage; (3) It tests each phase conductor or circuit part both phase-to-phase and phase-to-ground; (4) The test device is verified as operating satisfactorily on any known voltage source before and after testing for the absence of voltage.

Exception No. 2 to 7: On electrical systems over 1000 volts, noncontact capacitive test instruments shall be permitted to be used to test each phase conductor.

Informational Note No. 1: See UL 61010-1, *Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use, Part 1: General Requirements* , for rating, overvoltage category, and design requirements for voltage measurement and test instruments intended for use on electrical systems 1000 volts and below.

Informational Note No. 2: See UL 1436, *Outlet Circuit Testers and Other Similar Indicating Devices* , for additional information on rating and design requirements for permanently mounted absence of voltage testers.

Informational Note No. 3: See IEC 61243-1, *Live Working — Voltage Detectors — Part 1: Capacitive type to be used for voltages exceeding 1kV a.c.* , or IEC 61243-2, *Live Working — Voltage Detectors — Part 2: Resistive type to be used for voltages of 1kV to 36 kV a.c.* , or IEC 61243-3, *Live Working — Voltage Detectors — Part 3: Two-pole low voltage type* , for additional information on rating and design requirements for voltage detectors

Informational Note No . 4. Steps 7(a) - 7(c) are intended to minimize hazards associated with an exposure to obejctionable current flow as well as back feeding sources / circuits. These circuit configurations create potential for injury to a person should they unknowingly disconnect an objectionable current path and / or back feed path. .

(1) Where the possibility of induced voltages or stored electrical energy exists, ground all circuit conductors and circuit parts before touching them. Where it could be reasonably anticipated that the conductors or circuit parts being de-energized could contact other exposed energized conductors or circuit parts, apply temporary protective grounding equipment in accordance with the following:

(2) *Placement.* Temporary protective grounding equipment shall be placed at such locations and arranged in such a manner as to prevent each employee from being exposed to an electric shock hazard (i.e., hazardous differences in electrical potential). The location, sizing, and application of temporary protective grounding equipment shall be identified as part of the employer's job planning.

(3) *Capacity.* Temporary protective grounding equipment shall be capable of conducting the maximum fault current that could flow at the point of grounding for the time necessary to clear the fault.

Informational Note: See ASTM F855, *Standard Specification for Temporary Protective Grounds to be Used on De-energized Electric Power Lines and Equipment* , which is an example of a standard that contains information on capacity of temporary protective grounding equipment.

(4) *Impedance.* Temporary protective grounding equipment and connections shall have an impedance low enough to cause immediate operation of protective devices in case of unintentional energizing of the electric conductors or circuit parts.

Additional Proposed Changes

File Name	Description	Approved
120.5_Revision.docx		

Statement of Problem and Substantiation for Public Input

In certain instances when testing the phase conductors, phase-to-phase and phase-to-ground provide an absence of voltage check, but in my professional opinion although these steps may have been performed, a true absence of "energy" has not been established. The current procedure as it now stands does not account for "objectionable current" and as discussed in the Mike Holt video starting at 8:17 (https://www.youtube.com/watch?v=skX9XI3de5U) led to an unfortunate fatality. Knowing when and where to test for "objectionable current" is up for debate (IE: would not apply to new construction, but would apply to existing in service locations and depend on the scope and location of work), but this particular topic needs to be addressed or at least open the discussion for awareness and safe work practices to be added when establishing a safe work boundary and verifying an electrically safe work condition.

Submitter Information Verification

Submitter Full Name: Stephen Rodriguez
Organization: Vyking Electric
Street Address:
City:
State:
Zip:
Submittal Date: Thu May 23 13:26:12 EDT 2024

Committee: EEW-AAA

Committee Statement

Resolution: Changing voltage to energy makes the requirement less clear for most applications. To be qualified to work on constant current lighting a person would need to have knowledge related to the construction and operation of electrical equipment and installations of such a system and would need to have safety training to identify the hazards and reduce the associated risk, including the correct method to verify that the system is in an electrically safe work condition. The proposed steps, 7a – c are detailed prescriptive work practices which do not belong in the standard. Exception No. 1 to 7. This addition does not add clarity to the section. No substantiation was provided for restricting the use of permanently installed absence of voltage testers. Proposed informational note No. 4 The addition of the informational note does not add clarity. Section 120.5(A)(1) Locating Sources addresses the concerns of neutral conductors.

Public Input No. 1-NFPA 70E-2023 [Section No. 130.1]

130.1 Scope.

This article covers requirements for work involving electrical hazards such as the electrical safety-related work practices, assessments, precautions, and procedures when an electrically safe work condition cannot be established.

~~Safety-related work practices shall be used to safeguard employees from injury while they are exposed to electrical hazards from electrical conductors or circuit parts that are or can become energized.~~

~~When energized electrical conductors and circuit parts operating at voltages equal to or greater than 50 volts are not put into an electrically safe work condition, and work is performed as permitted in accordance with 110.2(B) , all of the following requirements shall apply:~~

(1) ~~Only qualified persons shall be permitted to work on electrical conductors or circuit parts that have not been put into an electrically safe work condition.~~

(2) ~~An energized electrical work permit shall be completed as required by 130.2 .~~

(3) ~~An electric shock risk assessment shall be performed as required by 130.4 .~~

(4) ~~An arc flash risk assessment shall be performed as required by 130.5 .~~

~~All requirements of Article 130 shall apply whether an incident energy analysis is completed or if Table 130.7(C)(15)(a) , Table 130.7(C)(15)(b) , and Table 130.7(C)(15)(c) are used in lieu of an incident energy analysis.~~

Statement of Problem and Substantiation for Public Input

130.1 contained more than the scope of Article 130. The deleted text in this Public Input needs to be relocated somewhere else other than 130.1 as it is presently incorrectly part of the scope of Article 130. The text that is recommended for deletion is not the scope of Article 130 and should be relocated to 130.2 with the present 130.2 relocated to the available 130.3.

Submitter Information Verification

Submitter Full Name: Palmer Hickman
Organization: Electrical Training Alliance
Street Address:
City:
State:
Zip:

Submittal Date: Thu Aug 24 09:47:50 EDT 2023
Committee: EEW-AAA

Committee Statement

Resolution: FR-59-NFPA 70E-2024
Statement: Section 130.1 contained more than the scope of Article 130. Text was relocated as a new 130.2 to comply with the NEC Style Manual.

First and/or second level subdivision titles were added to comply with the NEC Style Manual.

Public Input No. 20-NFPA 70E-2023 [Section No. 130.1]

130.1 Scope.

This article covers requirements for work involving electrical hazards such as the electrical safety-related work practices, assessments, precautions, and procedures when an electrically safe work condition cannot be established.

Safety-related work practices shall be used to safeguard employees from injury while they are exposed to electrical hazards from electrical conductors or circuit parts that are or can become energized.

When energized electrical conductors and circuit parts operating at voltages equal to or greater than 50 volts are not put into an electrically safe work condition, and energized work is performed as permitted in accordance with the exceptions to 110.2(B), all of the following requirements shall apply:

(1) Only qualified persons shall be permitted to work on electrical conductors or circuit parts that have not been put into an electrically safe work condition.

(2) An energized electrical work permit shall be completed as required by 130.2.

(3) An electric shock risk assessment shall be performed as required by 130.4.

(4) An arc flash risk assessment shall be performed as required by 130.5.

All requirements of Article 130 shall apply whether an incident energy analysis is completed or if Table 130.7(C)(15)(a), Table 130.7(C)(15)(b), and Table 130.7(C)(15)(c) are used in lieu of an incident energy analysis.

Statement of Problem and Substantiation for Public Input

This recommended revision is intended to provide additional clarity to this requirement. It is to clarify that energized work is only permitted when one of the exceptions apply. The five exceptions allowing energized work are exceptions to the general requirement of 110.2(B) which requires that an electrically safe work condition be established equal to or above 50 volts when either condition (1) or (2) exists.

Submitter Information Verification

Submitter Full Name: Palmer Hickman
Organization: Electrical Training Alliance
Street Address:
City:
State:
Zip:

Submittal Date: Wed Sep 20 10:15:23 EDT 2023
Committee: EEW-AAA

Committee Statement

Resolution: The existing definition of “working on” clearly defines energized work.

Public Input No. 35-NFPA 70E-2023 [Section No. 130.1]

130.1 Scope.

This article covers requirements for work involving electrical hazards such as the electrical safety-related work practices, assessments, precautions, and procedures when an electrically safe work condition cannot be established.

Safety-related work practices shall be used to safeguard employees from injury while they are exposed to electrical hazards from electrical conductors or circuit parts that are or can become energized.

When energized electrical conductors and circuit parts operating at voltages equal to or greater than 50 volts are not put into an electrically safe work condition, and work is performed as permitted in accordance with 110.2(B), all of the following requirements shall apply:

(1) Only qualified persons shall be permitted to work on electrical conductors or circuit parts that have not been put into an electrically safe work condition.

(2) An energized electrical work permit shall be completed as required by 130.2.

(3) An electric shock risk assessment shall be performed as required by 130.4.

(4) An arc flash risk assessment shall be performed as required by 130.5.

All requirements of Article 130 shall apply whether an incident energy analysis is completed or if Table 130.7(C)(15)(a), Table 130.7(C)(15)(b), and Table 130.7(C)(15)(c) are used in lieu of an incident energy analysis.

Additional Proposed Changes

File Name	Description	Approved
NFPA_70e_2024_suggested_rev_to_artice_130_DDB.docx		

Statement of Problem and Substantiation for Public Input

Currently, it seems that there is no manner for an unqualified person to interact on any electrical equipment in normal operating condition. The specific example for me is to open or close a switch in good working condition, such as 110.B.2 exception 1 details. Since this expection specifically mentions that the equipment is excluded from the need for an electrically safe condition, that leads to section 130.1 which states only qualified persons may interact with the equipment. I don't believe this is the intent of the code. My proposed remedy is to provide continue to recognize an energized switch interaction as non electrically safe, but allow for unqualified (or my propoesd minimally qualified) persons to perform specific normal tasks. An alternate idea which I did not attempt to write up would be to reclassify this normal task on normal condition equipment as an electrically safe condition. I think this would make sense to include in article 110.B.2.

Submitter Information Verification

Submitter Full Name: Drake Bernhard
Organization: Grain Processing Corporation
Street Address:
City:
State:
Zip:

Submittal Date: Tue Nov 21 14:06:51 EST 2023
Committee: EEW-AAA

Committee Statement

Resolution: The exception is not necessary because the definition of “working on” does not include normal operation.

Public Input No. 54-NFPA 70E-2024 [Section No. 130.1]

130.1 Scope.

This article covers requirements for work involving electrical hazards such as the electrical safety-related work practices, assessments, precautions, and procedures when an electrically safe work condition cannot be established.

Safety-related work practices shall be used to safeguard employees from injury while they are exposed to electrical hazards from electrical conductors or circuit parts that are or can become energized.

When energized electrical conductors and circuit parts operating at voltages equal to or greater than 50 volts are not put into an electrically safe work condition, and work is performed as permitted in accordance with 110.2(B), all of the following requirements shall apply:

(1) Only qualified persons shall be permitted to work on electrical conductors or circuit parts that have not been put into an electrically safe work condition.

(2) A second qualified person shall be present for energized electrical work and shall be trained in CPR/ First Aid so that they are immediately available to provide and summon aid in the event of shock or arc flash incident. The second qualified person should be able to point out Human Performance Errors (See Annex Q).

(3) An energized electrical work permit shall be completed as required by 130.2.

(4) An electric shock risk assessment shall be performed as required by 130.4.

(5) An arc flash risk assessment shall be performed as required by 130.5.

All requirements of Article 130 shall apply whether an incident energy analysis is completed or if Table 130.7(C)(15)(a), Table 130.7(C)(15)(b), and Table 130.7(C)(15)(c) are used in lieu of an incident energy analysis.

Statement of Problem and Substantiation for Public Input

To whom it may concern,

I respectfully request the inclusion of language specifying when 2 people would be required for energized electrical work be included in future revisions of NFPA 70E.

NFPA 70E refers to, but does not currently provide any guidance about, when 2 people should be required for energized electrical work.
References: (Article 110.3(H)(1) Informational Note No.1, 110.4(C)(1) & (2), Annex Q Q.3, Q.6.7)

OSHA 1910.269(l)(2)(i)(E) & 1926.960 (b)(3)(i)(E) similarly state at least two employees shall be present while any employees perform the following types of work:
“Other work that exposes an employee to electrical hazards greater than, or equal to, the electrical hazards posed by operations listed specifically in paragraphs (… listed above) this section”.

All other operations are listed as “energized at more than 600 volts”.

The purpose of the 2 person requirement is to provide “the immediate availability of a person trained in CPR” in the event a worker receives a shock that stops the heart or causes fibrillation that would require an AED or other immediate emergency response.

The 600 Volt OSHA limit seems arbitrary since it is well known that it is the amount of current, duration, and path of current that determines the severity of injury from shock and current as low as 1A can

cause fibrillation regardless of Voltage.

Additionally, in the event of an arc flash incident, having a second person immediately available who is First Aid/ CPR trained or who can immediately summon emergency response seems imperative.

Submitter Information Verification

Submitter Full Name: Melissa Vaughn
Organization:
Street Address:
City:
State:
Zip:
Submittal Date: Wed Jan 31 11:46:01 EST 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-101-NFPA 70E-2024

Statement: The 2-person requirement is to provide the immediate availability of emergency response if an employee is performing work under an energized electrical work permit.

First and/or second level subdivision titles were added to comply with the NEC Style Manual.

Public Input No. 255-NFPA 70E-2024 [New Section after 130.2]

130.2(D) Tasks done in compliance with 110.2(B) Exception No 1, Exception No 2, or Exception No 5 shall be permitted without an energized electrical work permit.

Statement of Problem and Substantiation for Public Input

Add an exemption for tasks that are allowed to be done while equipment remains energized as permitted by exceptions to creating and electrically safe work condition in 110.2(B). Presently an energized electrical work permit is literally required for anything that is not included in the exemptions. Exception No 1 allows normal operation which includes operating a snap switch for a lighting outlet. It is not realistic to require an energized electrical work permit for that. Exception No 2 allows operation for establishing and electrically safe work condition or reenergizing equipment. It seems that if the goal is to create an electrically safe work condition that is the original intent and an energized electrical work permit should not be required. Exception No 5 would include work on Class 2 circuits that are not considered an electric shock hazard based on the definition so it seems an energized electrical work permit would not be realistic there either. This is being proposed as a separate subdivision (D) because (C) has additional requirements that are not needed.

Submitter Information Verification

Submitter Full Name: Paul Dobrowsky
Organization: Innovative Technology Services
Street Address:
City:
State:
Zip:

Submittal Date: Tue Jun 04 16:00:09 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: The proposed text is already meet by the 110.2(B) and 130.2(A).

Public Input No. 2-NFPA 70E-2023 [Section No. 130.2]

130.2 ~~2~~ 3 Energized Electrical Work Permit.

(A) When Required.

When work is performed as permitted in accordance with 110.2(B), an energized electrical work permit shall be required and documented under any of the following conditions:

(1) When work is performed within the restricted approach boundary

(2) When the employee interacts with the equipment when conductors or circuit parts are not exposed but an increased likelihood of injury from an exposure to an arc flash hazard exists

(B) Elements of Work Permit.

The work permit shall include, but not be limited to, the following items:

(1) Description of the circuit and equipment to be worked on and their location

(2) Description of the work to be performed

(3) Justification for why the work must be performed in an energized condition *[see 110.2(B)]*

(4) Description of the safe work practices to be employed *(see 130.1)*

(5) Results of the electric shock risk assessment *[see 130.4(A)]*

(6) Voltage to which personnel will be exposed

(7) Limited approach boundary *[see 130.4(F) , Table 130.4(E)(a) , and Table 130.4(E)(b)]*

(8) Restricted approach boundary *[see 130.4(G) , Table 130.4(E)(a) , and Table 130.4(E)(b)]*

(9) Personal and other protective equipment required by this standard to safely perform the assigned task and to protect against the electric shock hazard *[see 130.4(F) , 130.5(G) , 130.7(C)(1) through (C)(15), and 130.7(D)]*

(10) Results of the arc flash risk assessment *[see 130.5(A)]*

(11) Available incident energy at the working distance or arc flash PPE category *[see 130.5(F)]*

(12) Personal and other protective equipment required by this standard to protect against the arc flash hazard *[see 130.5(F) , 130.7(C)(1) through (C)(15), Table 130.7(C)(15)(c) , and 130.7(D)]*

(13) Arc flash boundary *[see 130.5(E)]*

(14) Means employed to restrict the access of unqualified persons from the work area *[see 130.8(O)]*

(15) Evidence of completion of a job briefing, including a discussion of any job-specific hazards *[see 110.3(I)]*

(16) Energized work approval (authorizing or responsible management, safety officer, or owner, etc.) signature(s)

Informational Note: See Informative Annex Figure J.1 for an example of an acceptable energized work permit.

(C) Exemptions to Work Permit.

Electrical work shall be permitted without an energized electrical work permit if a qualified person is provided with and uses appropriate safe work practices and PPE in accordance with Chapter 1 under any of the following conditions:

(1) Testing, troubleshooting, or voltage measuring

(2) Thermography, ultrasound, or visual inspections if the restricted approach boundary is not crossed

(3) Access to and egress from an area with energized electrical equipment if no electrical work is performed and the restricted approach boundary is not crossed

(4) General housekeeping and miscellaneous non-electrical tasks if the restricted approach boundary is not crossed

Statement of Problem and Substantiation for Public Input

This Public Input is only a recommendation to renumber this existing 130.2 as 130.3 to allow the text of existing 130.1 that is not part of the Article 130 scope to be relocated as 130.2.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 3-NFPA 70E-2023 [Section No. 130.2]	

Submitter Information Verification

Submitter Full Name: Palmer Hickman
Organization: Electrical Training Alliance
Street Address:
City:
State:
Zip:
Submittal Date: Thu Aug 24 09:51:19 EDT 2023
Committee: EEW-AAA

Committee Statement

Resolution: The NFPA publishing system automatically adjusts section numbers for the addition or deletion of sections created by a first revision.

Public Input No. 3-NFPA 70E-2023 [Section No. 130.2]

~~When work~~

130.2 ~~Energized Electrical Work Permit.~~

~~(A)~~ ~~When Required.~~

2 General

Safety-related work practices shall be used to safeguard employees from injury while they are exposed to electrical hazards from electrical conductors or circuit parts that are or can become energized.

When energized electrical conductors and circuit parts operating at voltages equal to or greater than 50 volts are not put into an electrically safe work condition, and work is performed as permitted in accordance with 110.2(B) ,

~~an energized electrical work permit shall be required and documented under any~~

all of the following

~~conditions when~~

requirements shall apply :

- ~~When work is performed within the restricted approach boundary~~

~~When the employee interacts with the equipment~~

(1) Only qualified persons shall be permitted to work on electrical conductors or circuit parts

~~are not exposed but an increased likelihood of injury from an exposure to an arc flash hazard exists~~

~~(B)~~ ~~Elements of Work Permit.~~

~~The work permit shall include, but not be limited to, the following items:~~

- ~~Description of the circuit and equipment to be worked on and their location~~
- ~~Description of the work to be performed~~
- ~~Justification for why the work must be performed in an energized condition~~ ~~*[see 110.2(B)]*~~
- ~~Description of the safe work practices to be employed~~ ~~*(see 130.1)*~~
- ~~Results of the electric shock risk assessment~~ ~~*[see 130.4(A)]*~~

(1) ~~Voltage to which personnel will be exposed~~

(2) ~~Limited approach boundary~~ ~~*[see 130.4(F) , Table 130.4(E)(a) , and Table 130.4(E)(b)]*~~

(3) ~~Restricted approach boundary~~ ~~*[see 130.4(G) , Table 130.4(E)(a) , and Table 130.4(E)(b)]*~~

(4) ~~Personal and other protective equipment required by this standard to safely perform the assigned task and to protect against the electric shock hazard~~ ~~*[see 130.4(F) , 130.5(G) , 130.7(C)(1) through (C)(15), and 130.7(D)]*~~

~~Results of the arc flash risk assessment~~ ~~*[see 130.5(A)]*~~

- ~~Available incident energy at the working distance or arc flash PPE category~~ ~~*[see 130.5(F)]*~~

~~Personal and other protective equipment required by this standard to protect against the arc flash hazard [see 130.5(F) , 130.7(C)(1) through (C)(15)~~

(1) ~~that have not been put into an electrically safe work condition.~~

(2) ~~An energized electrical work permit shall be completed as required by~~ ~~130.2~~ ~~.~~

(3) ~~An electric shock risk assessment shall be performed as required by~~ ~~130.4~~ ~~.~~

(4) ~~An arc flash risk assessment shall be performed as required by~~ ~~130.5~~ ~~.~~

~~All requirements of Article 130 shall apply whether an incident energy analysis is completed or if Table 130.7(C)(15)(a) , Table 130.7(C)(15)(c~~

~~b) , and Table 130.7(D)]~~

- ~~Arc flash boundary *[see 130.5(E)]*~~
- ~~Means employed to restrict the access of unqualified persons from the work area *[see 130.8(O)]*~~
- ~~Evidence of completion of a job briefing, including a discussion of any job-specific hazards *[see 110.3(I)]*~~
- ~~Energized work approval (authorizing or responsible management, safety officer, or owner, etc.) signature(s)~~

~~Informational Note: See Informative Annex Figure J.1 for an example of an acceptable energized work permit.~~

~~**(C)** Exemptions to Work Permit.~~

~~Electrical work shall be permitted without an energized electrical work permit if a qualified person is provided with and uses appropriate safe work practices and PPE in accordance with Chapter 1 under any of the following conditions:~~

(1) ~~Testing, troubleshooting, or voltage measuring~~

(2) ~~Thermography, ultrasound, or visual inspections if the restricted approach boundary is not crossed~~

(3) ~~Access to and egress from an area with energized electrical equipment if no electrical work is performed and the restricted approach boundary is not crossed~~

(4) ~~General housekeeping and miscellaneous non-electrical tasks if the restricted approach boundary is not crossed~~

C)(15)(c) are used in lieu of an incident energy analysis.

Statement of Problem and Substantiation for Public Input

This Public Input relocates text from 130.1 to 130.2 that was not the scope of Article 130 and therefore should have not been located in 130.1. The text that was formerly in 130.2 is shown as strikethrough as a companion public input is to relocate that former 130.2 text as 130.3. An additional option for consideration would be to make this recommendation located as 130.3 and leave the existing content of 130.2 where it was for the 2024 edition. However, if that is the case then the recommended title of "General" of this Public Input may not work as the section title if it ends up as 130.3.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2-NFPA 70E-2023 [Section No. 130.2]	Relocated text for correlation between the two actions.

Submitter Information Verification

Submitter Full Name: Palmer Hickman
Organization: Electrical Training Alliance
Street Address:

City:
State:
Zip:
Submittal Date: Thu Aug 24 09:53:55 EDT 2023
Committee: EEW-AAA

Committee Statement

Resolution: FR-59-NFPA 70E-2024

Statement: Section 130.1 contained more than the scope of Article 130. Text was relocated as a new 130.2 to comply with the NEC Style Manual.

First and/or second level subdivision titles were added to comply with the NEC Style Manual.

Public Input No. 9-NFPA 70E-2023 [Section No. 130.2(B)]

(B) Elements of Work Permit.

The work permit shall include, but not be limited to, the following items:

(1) Description of the circuit and equipment to be worked on and their location

(2) Description of the work to be performed

(3) Justification for why the work must be performed in an energized condition *[see 110.2(B)]*

(4) Description of the safe work practices to be employed *(see 130.1)*

(5) Results of the electric shock risk assessment *[see 130.4(A)]*

(6) Voltage to which personnel will be exposed

(7) Limited approach boundary *[see 130.4(F) , Table 130.4(E)(a) , and Table 130.4(E)(b)]*

(8) Restricted approach boundary *[see 130.4(G) , Table 130.4(E)(a) , and Table 130.4(E)(b)]*

(9) Personal and other protective equipment required by this standard to safely perform the assigned task and to protect against the electric shock hazard *[see 130.4(F) , 130.5(G) , 130.7(C)(1) through (C)(15), and 130.7(D)]*

(10) Results of the arc flash risk assessment *[see 130.5(A)]*

~~Available incident~~

a. Incident energy at the working distance or arc flash PPE category *[see 130.5(F)]*

b. Personal and other protective equipment required by this standard to protect against the arc flash hazard *[see 130.5(F) , 130.7(C)(1) through (C)(15), Table 130.7(C)(15)(c) , and 130.7(D)]*

c. Arc flash boundary *[see 130.5(E)]*

(11) Means employed to restrict the access of unqualified persons from the work area *[see 130.8(O)]*

(12) Evidence of completion of a job briefing, including a discussion of any job-specific hazards *[see 110.3(I)]*

(13) Energized work approval (authorizing or responsible management, safety officer, or owner, etc.) signature(s)

Informational Note: See Informative Annex Figure J.1 for an example of an acceptable energized work permit.

Statement of Problem and Substantiation for Public Input

The word "available" is deleted as that word is unnecessary and possibly even inaccurate. Note that the neither the definition of incident energy nor the requirements of 130.5(F)(1) or 130.5(G) indicate that it is "available" incident energy being considered. Rather it is perhaps an "exposure level" as stated in 130.5(G). Nonetheless, removing the word "available" correlates this requirement with the use of incident energy elsewhere.

Submitter Information Verification

Submitter Full Name: Palmer Hickman
Organization: Electrical Training Alliance
Street Address:
City:
State:
Zip:
Submittal Date: Thu Aug 24 10:46:01 EDT 2023
Committee: EEW-AAA

Committee Statement

Resolution: FR-60-NFPA 70E-2024
Statement: This revision is made to correlate with the definition of incident energy.

Public Input No. 179-NFPA 70E-2024 [Section No. 130.4(C)]

(C) Additional Protective Measures.

If additional protective measures are required, they shall be selected and implemented according to the hierarchy of risk control identified in 110.3(H)(3). When the additional protective measures include the use of PPE, the following shall be determined:

(1) The voltage to which personnel will be exposed

(2) The electric shock boundary requirements

(3) The personal and other protective equipment required by this standard to protect against the electric shock hazard

Statement of Problem and Substantiation for Public Input

The proposed text clarifies which boundary requirements are involved.

Submitter Information Verification

Submitter Full Name: David Pace
Organization: Olin Corporation
Affiliation: Self
Street Address:
City:
State:
Zip:

Submittal Date: Mon Jun 03 15:36:43 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-61-NFPA 70E-2024

Statement: The revised text clarifies which boundary requirements are involved. The section was revised to comply with the NEC Style Manual.

Public Input No. 120-NFPA 70E-2024 [Section No. 130.4(E)]

(E) Electric Shock Protection Boundaries.

The electric shock protection boundaries identified as limited approach boundary and restricted approach boundary shall be applicable where personnel are approaching exposed energized electrical conductors or circuit parts. Table 130.4(E)(a) shall be used for the distances associated with various ac system voltages. Table 130.4(E)(b) shall be used for the distances associated with various dc system voltages.

Informational Note: In certain instances, the arc flash boundary might be a greater distance from the energized electrical conductors or circuit parts than the limited approach boundary. The electric shock protection boundaries and the arc flash boundary are independent of each other.

Table 130.4(E)(a) Electric Shock Protection Approach Boundaries to Exposed Energized Electrical Conductors or Circuit Parts for Alternating-Current Systems

(1)	(2)	(3)	(4)	
	-	Limited Approach Boundary[b]		
Nominal System Voltage Range, Phase to Phase[a]	Exposed Movable Conductor[c]	Exposed Fixed Circuit Part		Restricted Approach Boundary[b,d]; Includes Inadvertent Movement Adder
Less than 50 V	Not specified	Not specified	Not specified	
50 V–150 V[e]	3.1 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	Avoid contact	
151 V–750 V	3.1 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	0.31 m (1 ft 0 in.)	
751 V–5 kV	3.1 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	0.63 m (2 ft 1 in.)	
5.1 kV–15 kV	3.1 m (10 ft 0 in.)	1.5 m (5 ft 0 in.)	0.~~65 m~~ 68 m (2 ft ~~2 in~~ 3 in .)	
15.1 kV–36 kV	3.1 m (10 ft 0 in.)	1.8 m (6 ft 0 in.)	0.~~77 m (2 ft 7 in.~~ 89 m (3 ft)	
36.1 kV–46 kV	3.1 m (10 ft 0 in.)	2.5 m (8 ft 0 in.)	0.~~84 m (2 ft 10 in~~ 98 m (3 ft 3 in .)	
46.1 kV–72.5 kV	3.1 m (10 ft 0 in.)	2.5 m (8 ft 0 in.)	1.~~0 m (3 ft 4 in.~~ 2 m (4 ft)	
72.6 kV–121 kV	3.3 m (10 ft 8 in.)	2.5 m (8 ft 0 in.)	1.~~2 m (3 ft 9 in~~ 42 m (4 ft 8 in .)	
121.1 kV–145 kV	3.4 m (11 ft 0 in.)	3.1 m (10 ft 0 in.)	1.~~3 m (4 ft 4 in~~ 64 m (5 ft 5 in .)	
145.1 kV–169 kV	3.6 m (11 ft 8 in.)	3.6 m (11 ft 8 in.)	1.~~5 m (4 ft 10 in~~ 94 m (6 ft 5 in .)	
169.1 kV–242 kV	4.0 m (13 ft 0 in.)	4.0 m (13 ft 0 in.)~~2~~	3 .~~1 m (6 ft 8 in~~ 08 m (10 ft 2 in .)	
242.1 kV–362 kV	4.7 m (15 ft 4 in.)	4.7 m (15 ft 4 in.)	~~3~~ 5 .~~5 m~~ 52 m (~~11 ft~~ 18 ft 2 in.)	
362.1 kV–420 kV	5.8 m (19 ft 0 in.)	5.8 m (19 ft 0 in.)~~4~~	6 .~~3 m (14 ft 0 in~~ 81 m (22 ft 5 in .)	

(1)	(2)	(3)	(4)	
	-	Limited Approach Boundary[b]		
Nominal System Voltage Range, Phase to Phase[a]	Exposed Movable Conductor[c]	Exposed Fixed Circuit Part		Restricted Approach Boundary[b,d]; Includes Inadvertent Movement Adder
420.1 kV–550 kV	5.8 m (19 ft 0 in.)	5.8 m (19 ft 0 in.)~~5~~	8 ~~.1 m (16 ft 8 in~~ 24 m (27 ft 1 in .)	
550.1 kV–800 kV	7.2 m (23 ft 9 in.)	7.2 m (23 ft 9 in.)~~6~~	11 ~~.9 m (22 ft 7 in~~ 38 m (37 ft 5 in .)	

Notes:

(1) For arc flash boundary, see 130.5(E).

(2) All dimensions are distance from exposed energized electrical conductors or circuit part to employee.

[a]For single-phase systems above 250 volts, select the range that is equal to the system's maximum phase-to-ground voltage multiplied by 1.732.

[b]See definition in Article 100 and text in 130.4(F)(3) and Informative Annex C for elaboration.

[c]*Exposed movable conductors* describes a condition in which the distance between the conductor and a person is not under the control of the person. The term is normally applied to overhead line conductors supported by poles.

[d]The restricted approach boundary in Column 4 is based on an elevation not exceeding 900 m (3000 ft). For higher elevations, adjustment of the restricted approach boundary shall be considered.

[e]This includes circuits where the exposure does not exceed 120 volts nominal.

Table 130.4(E)(b) Electric Shock Protection Approach Boundaries to Exposed Energized Electrical Conductors or Circuit Parts for Direct-Current Voltage Systems

(1)	(2)	(3)	(4)[b]
Nominal Potential Difference	Limited Approach Boundary		Restricted Approach Boundary; Includes Inadvertent Movement Adder
	Exposed Movable Conductor*[a]	Exposed Fixed Circuit Part	
Less than 50 V	Not specified	Not specified	Not specified
50 V–300 V	3.1 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	Avoid contact
301 V–1 kV	3.1 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	0.3 m (1 ft 0 in.)
1.1 kV–5 kV	3.1 m (10 ft 0 in.)	1.5 m (5 ft 0 in.)	0.~~5 m (1 ft 5 in~~ 64 m (2 ft 2 in .)
5.1 kV–15 kV	3.1 m (10 ft 0 in.)	1.5 m (5 ft 0 in.)	0.~~7 m~~ 89 m (2 ft ~~2 in~~ 11 in .)
15.1 kV–45 kV	3.1 m (10 ft 0 in.)	2.5 m (8 ft 0 in.)	0.~~8 m~~ 89 m (2 ft ~~9 in~~ 11 in .)
45.1 kV– 75 kV	3.1 m (10 ft 0 in.)	2.5 m (8 ft 0 in.)	1.0 m (3 ft 6 in.)
75.1 kV–150 kV	3.3 m (10 ft 8 in.)	3.1 m (10 ft 0 in.)	1.~~2 m (3 ft 10 in~~ 37 m (4 ft 7 in .)
150.1 kV–250 kV	3.6 m (11 ft 8 in.)	3.6 m (11 ft 8 in.)	1.6 m (5 ft 3 in.)
250.1 kV–500 kV	6.0 m (20 ft 0 in.)	6.0 m (20 ft 0 in.)	3.5 m (11 ft 6 in.)
500.1 kV–800 kV	8.0 m (26 ft 0 in.)	8.0 m (26 ft 0 in.)	5.0 m (16 ft 5 in.)

Note: All dimensions are distance from exposed energized electrical conductors or circuit parts to worker.

*[a] *Exposed movable conductor* describes a condition in which the distance between the conductor and a person is not under the control of the person. The term is normally applied to overhead line conductors supported by poles.

[b] The restricted approach boundary in Column 4 is based on an elevation not exceeding 900 m (3000 ft). For higher elevations, adjustment of the restricted approach boundary shall be considered.

Statement of Problem and Substantiation for Public Input

The Restricted Approach Boundaries appear to be the boundaries for phase-to-ground voltages and not the phase-to-phase voltages when compared to IEEE NESC C2 tables and OSHA 1910.269. Values are changed to align.

Submitter Information Verification

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Organization: Self Employed
Street Address:
City:
State:
Zip:

Submittal Date: Sat Jun 01 06:49:46 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: For work covered by 70E, the table is based on the person being at ground potential. Thus, all exposures are phase to ground exposures.

Public Input No. 180-NFPA 70E-2024 [Section No. 130.4(E)]

(E) Electric Shock Protection Boundaries.

The electric shock protection boundaries identified as limited approach boundary and restricted approach boundary shall be applicable where personnel are approaching exposed energized electrical conductors or circuit parts. Table 130.4(E)(a) shall be used for the distances associated with various ac system voltages. Table 130.4(E)(b) shall be used for the distances associated with various dc system voltages.

Informational Note: In certain instances, the arc flash boundary might be a greater distance from the energized electrical conductors or circuit parts than the limited approach boundary. The electric shock protection boundaries and the arc flash boundary are independent of each other.

Table 130.4(E)(a) Electric Shock Protection Approach Boundaries to Exposed Energized Electrical Conductors or Circuit Parts for Alternating-Current Systems

(1)	(2)	(3)	(4)	
		Limited Approach Boundary[b]		
Nominal System Voltage Range, Phase to Phase[a]	Exposed Movable Conductor[c]	Exposed Fixed Circuit Part		Restricted Approach Boundary[b,d]; Includes Inadvertent Movement Adder
Less than 50 V	Not specified	Not specified	Not specified	
~~50 V–150 V~~ 50 V–240 V[e]	3.1 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	Avoid contact~~151 V–750 V~~	
241 V–750 V	3.1 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	0.31 m (1 ft 0 in.)	
751 V–5 kV	3.1 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	0.63 m (2 ft 1 in.)	
5.1 kV–15 kV	3.1 m (10 ft 0 in.)	1.5 m (5 ft 0 in.)	0.65 m (2 ft 2 in.)	
15.1 kV–36 kV	3.1 m (10 ft 0 in.)	1.8 m (6 ft 0 in.)	0.77 m (2 ft 7 in.)	
36.1 kV–46 kV	3.1 m (10 ft 0 in.)	2.5 m (8 ft 0 in.)	0.84 m (2 ft 10 in.)	
46.1 kV–72.5 kV	3.1 m (10 ft 0 in.)	2.5 m (8 ft 0 in.)	1.0 m (3 ft 4 in.)	
72.6 kV–121 kV	3.3 m (10 ft 8 in.)	2.5 m (8 ft 0 in.)	1.2 m (3 ft 9 in.)	
121.1 kV–145 kV	3.4 m (11 ft 0 in.)	3.1 m (10 ft 0 in.)	1.3 m (4 ft 4 in.)	
145.1 kV–169 kV	3.6 m (11 ft 8 in.)	3.6 m (11 ft 8 in.)	1.5 m (4 ft 10 in.)	
169.1 kV–242 kV	4.0 m (13 ft 0 in.)	4.0 m (13 ft 0 in.)	2.1 m (6 ft 8 in.)	
242.1 kV–362 kV	4.7 m (15 ft 4 in.)	4.7 m (15 ft 4 in.)	3.5 m (11 ft 2 in.)	
362.1 kV–420 kV	5.8 m (19 ft 0 in.)	5.8 m (19 ft 0 in.)	4.3 m (14 ft 0 in.)	
420.1 kV–550 kV	5.8 m (19 ft 0 in.)	5.8 m (19 ft 0 in.)	5.1 m (16 ft 8 in.)	
550.1 kV–800 kV	7.2 m (23 ft 9 in.)	7.2 m (23 ft 9 in.)	6.9 m (22 ft 7 in.)	

Notes:

(1) For arc flash boundary, see 130.5(E).

(2) All dimensions are distance from exposed energized electrical conductors or circuit part to employee.

[a]For single-phase systems above 250 volts, select the range that is equal to the system's maximum phase-to-ground voltage multiplied by 1.732.

[b]See definition in Article 100 and text in 130.4(F)(3) and Informative Annex C for elaboration.

[c]*Exposed movable conductors* describes a condition in which the distance between the conductor and a person is not under the control of the person. The term is normally applied to overhead line conductors supported by poles.

[d]The restricted approach boundary in Column 4 is based on an elevation not exceeding 900 m (3000 ft). For higher elevations, adjustment of the restricted approach boundary shall be considered.

[e]This includes circuits where the exposure does not exceed ~~120 volts~~ 240 volts nominal.

Table 130.4(E)(b) Electric Shock Protection Approach Boundaries to Exposed Energized Electrical Conductors or Circuit Parts for Direct-Current Voltage Systems

(1)	(2)	(3)	(4)[b]
Nominal Potential Difference	Limited Approach Boundary		Restricted Approach Boundary; Includes Inadvertent Movement Adder
	Exposed Movable Conductor*[a]	Exposed Fixed Circuit Part	
Less than 50 V	Not specified	Not specified	Not specified
50 V–300 V	3.1 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	Avoid contact
301 V–1 kV	3.1 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	0.3 m (1 ft 0 in.)
1.1 kV–5 kV	3.1 m (10 ft 0 in.)	1.5 m (5 ft 0 in.)	0.5 m (1 ft 5 in.)
5.1 kV–15 kV	3.1 m (10 ft 0 in.)	1.5 m (5 ft 0 in.)	0.7 m (2 ft 2 in.)
15.1 kV–45 kV	3.1 m (10 ft 0 in.)	2.5 m (8 ft 0 in.)	0.8 m (2 ft 9 in.)
45.1 kV– 75 kV	3.1 m (10 ft 0 in.)	2.5 m (8 ft 0 in.)	1.0 m (3 ft 6 in.)
75.1 kV–150 kV	3.3 m (10 ft 8 in.)	3.1 m (10 ft 0 in.)	1.2 m (3 ft 10 in.)
150.1 kV–250 kV	3.6 m (11 ft 8 in.)	3.6 m (11 ft 8 in.)	1.6 m (5 ft 3 in.)
250.1 kV–500 kV	6.0 m (20 ft 0 in.)	6.0 m (20 ft 0 in.)	3.5 m (11 ft 6 in.)
500.1 kV–800 kV	8.0 m (26 ft 0 in.)	8.0 m (26 ft 0 in.)	5.0 m (16 ft 5 in.)

Note: All dimensions are distance from exposed energized electrical conductors or circuit parts to worker.

*[a]*Exposed movable conductor* describes a condition in which the distance between the conductor and a person is not under the control of the person. The term is normally applied to overhead line conductors supported by poles.

[b]The restricted approach boundary in Column 4 is based on an elevation not exceeding 900 m (3000 ft). For higher elevations, adjustment of the restricted approach boundary shall be considered.

Statement of Problem and Substantiation for Public Input

The proposed text extends the existing requirement/allowed use of the table to 240 volts nominal which would include 120/208/240 volts circuits in other installations such as panelboards. Currently, the existing text basically applies to 120 volt lighting/switches/receptacles/control power circuits which is overly restrictive.

Submitter Information Verification

Submitter Full Name: David Pace
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Zip:
Submittal Date: Mon Jun 03 15:44:21 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: This change would result in many unintended consequences creating correlation issues involving other provisions in NFPA 70E including Informative Annex C.2.1.4.

Public Input No. 214-NFPA 70E-2024 [Section No. 130.4(E)]

(E) Electric Shock Protection Boundaries.

The electric shock protection boundaries identified as limited approach boundary and restricted approach boundary shall be applicable where personnel are approaching exposed energized electrical conductors or circuit parts. Table 130.4(E)(a) shall be used for the distances associated with various ac system voltages. Table 130.4(E)(b) shall be used for the distances associated with various dc system voltages.

Informational Note: In certain instances, the arc flash boundary might be a greater distance from the energized electrical conductors or circuit parts than the limited approach boundary. The electric shock protection boundaries and the arc flash boundary are independent of each other.

Table 130.4(E)(a) Electric Shock Protection Approach Boundaries to Exposed Energized Electrical Conductors or Circuit Parts for Alternating-Current Systems

(1)	(2)	(3)	(4)	
		Limited Approach Boundary[b]		
Nominal System Voltage Range, ~~Phase~~ Line to ~~Phase~~ Line [a]	Exposed Movable Conductor[c]	Exposed Fixed Circuit Part		Restricted Approach Boundary[b,d]; Includes Inadvertent Movement Adder
Less than 50 V	Not specified	Not specified	Not specified	
50 V–150 V[e]	3.1 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	Avoid contact	
151 V–750 V	3.1 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	0.31 m (1 ft 0 in.)	
751 V–5 kV	3.1 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	0.63 m (2 ft 1 in.)	
5.1 kV–15 kV	3.1 m (10 ft 0 in.)	1.5 m (5 ft 0 in.)	0.65 m (2 ft 2 in.)	
15.1 kV–36 kV	3.1 m (10 ft 0 in.)	1.8 m (6 ft 0 in.)	0.77 m (2 ft 7 in.)	
36.1 kV–46 kV	3.1 m (10 ft 0 in.)	2.5 m (8 ft 0 in.)	0.84 m (2 ft 10 in.)	
46.1 kV–72.5 kV	3.1 m (10 ft 0 in.)	2.5 m (8 ft 0 in.)	1.0 m (3 ft 4 in.)	
72.6 kV–121 kV	3.3 m (10 ft 8 in.)	2.5 m (8 ft 0 in.)	1.2 m (3 ft 9 in.)	
121.1 kV–145 kV	3.4 m (11 ft 0 in.)	3.1 m (10 ft 0 in.)	1.3 m (4 ft 4 in.)	
145.1 kV–169 kV	3.6 m (11 ft 8 in.)	3.6 m (11 ft 8 in.)	1.5 m (4 ft 10 in.)	
169.1 kV–242 kV	4.0 m (13 ft 0 in.)	4.0 m (13 ft 0 in.)	2.1 m (6 ft 8 in.)	
242.1 kV–362 kV	4.7 m (15 ft 4 in.)	4.7 m (15 ft 4 in.)	3.5 m (11 ft 2 in.)	
362.1 kV–420 kV	5.8 m (19 ft 0 in.)	5.8 m (19 ft 0 in.)	4.3 m (14 ft 0 in.)	
420.1 kV–550 kV	5.8 m (19 ft 0 in.)	5.8 m (19 ft 0 in.)	5.1 m (16 ft 8 in.)	

(1)	(2)	(3)	(4)	
	-	Limited Approach Boundary[b]		
Nominal System Voltage Range, ~~Phase~~ Line to ~~Phase~~ Line [a]	Exposed Movable Conductor[c]	Exposed Fixed Circuit Part		Restricted Approach Boundary[b,d]; Includes Inadvertent Movement Adder
550.1 kV–800 kV	7.2 m (23 ft 9 in.)	7.2 m (23 ft 9 in.)	6.9 m (22 ft 7 in.)	

Notes:

(1) For arc flash boundary, see 130.5(E).

(2) All dimensions are distance from exposed energized electrical conductors or circuit part to employee.

[a]For single-phase systems above 250 volts, select the range that is equal to the system's maximum phase-to-ground voltage multiplied by 1.732.

[b]See definition in Article 100 and text in 130.4(F)(3) and Informative Annex C for elaboration.

[c]*Exposed movable conductors* describes a condition in which the distance between the conductor and a person is not under the control of the person. The term is normally applied to overhead line conductors supported by poles.

[d]The restricted approach boundary in Column 4 is based on an elevation not exceeding 900 m (3000 ft). For higher elevations, adjustment of the restricted approach boundary shall be considered.

[e]This includes circuits where the exposure does not exceed 120 volts nominal, including line-to-neutral .

Table 130.4(E)(b) Electric Shock Protection Approach Boundaries to Exposed Energized Electrical Conductors or Circuit Parts for Direct-Current Voltage Systems

(1)	(2)	(3)	(4)[b]
Nominal Potential Difference	Limited Approach Boundary		Restricted Approach Boundary; Includes Inadvertent Movement Adder
	Exposed Movable Conductor*[a]	Exposed Fixed Circuit Part	
Less than 50 V	Not specified	Not specified	Not specified
50 V–300 V	3.1 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	Avoid contact
301 V–1 kV	3.1 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	0.3 m (1 ft 0 in.)
1.1 kV–5 kV	3.1 m (10 ft 0 in.)	1.5 m (5 ft 0 in.)	0.5 m (1 ft 5 in.)
5.1 kV–15 kV	3.1 m (10 ft 0 in.)	1.5 m (5 ft 0 in.)	0.7 m (2 ft 2 in.)
15.1 kV–45 kV	3.1 m (10 ft 0 in.)	2.5 m (8 ft 0 in.)	0.8 m (2 ft 9 in.)
45.1 kV– 75 kV	3.1 m (10 ft 0 in.)	2.5 m (8 ft 0 in.)	1.0 m (3 ft 6 in.)
75.1 kV–150 kV	3.3 m (10 ft 8 in.)	3.1 m (10 ft 0 in.)	1.2 m (3 ft 10 in.)
150.1 kV–250 kV	3.6 m (11 ft 8 in.)	3.6 m (11 ft 8 in.)	1.6 m (5 ft 3 in.)
250.1 kV–500 kV	6.0 m (20 ft 0 in.)	6.0 m (20 ft 0 in.)	3.5 m (11 ft 6 in.)
500.1 kV–800 kV	8.0 m (26 ft 0 in.)	8.0 m (26 ft 0 in.)	5.0 m (16 ft 5 in.)

Note: All dimensions are distance from exposed energized electrical conductors or circuit parts to worker.

*[a] *Exposed movable conductor* describes a condition in which the distance between the conductor and a person is not under the control of the person. The term is normally applied to overhead line conductors supported by poles.

[b] The restricted approach boundary in Column 4 is based on an elevation not exceeding 900 m (3000 ft). For higher elevations, adjustment of the restricted approach boundary shall be considered.

Statement of Problem and Substantiation for Public Input

The column heading for systems voltages is "Phase to Phase." This constrains this table to three phase systems, or 'single-phase' systems fed from two phases of a three phase system. Single winding systems, such as 120/240, do not have phase conductors. They have line conductors, so are inadvertently excluded from this table. There is a note on the table that gives direction for single phase systems where the phase to neutral is 250 volts or more. But what about when the voltage is less than 250? The addition to note (d) is necessary because the intent is to include 120 line to neutral, even though the column heading is phase to phase. Without the added note (e), 120/240 volt systems are excluded from this table because these systems do not have phase conductors. But since this is a table for shock hazards, these systems should be included. Changing "Phase" to "Line" addresses this. "Line" includes both single-phase systems and three-phase systems. "Phase" only addresses three-phase systems.

Submitter Information Verification

Submitter Full Name: Eric Stromberg
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Affiliation: Self
Street Address:
City:
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Submittal Date: Mon Jun 03 23:10:59 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-68-NFPA 70E-2024

Statement: The word "employee" was replaced with "personnel" to correlate to the existing word in 130.4E.

An informational note is added to note (d) to Tables 130.4(E)(a) and 130.4(E)(b) to direct users to more information on altitude impacts.

Note e was revised to indicate that the line vs. phase issue applies only at the lowest voltage range.

Public Input No. 284-NFPA 70E-2024 [Section No. 130.4(E)]

(E) Electric Shock Protection Boundaries.

The electric shock protection boundaries identified as limited approach boundary and restricted approach boundary shall be applicable where personnel are approaching exposed energized electrical conductors or circuit parts. Table 130.4(E)(a) shall be used for the distances associated with various ac system voltages. Table 130.4(E)(b) shall be used for the distances associated with various dc system voltages.

Informational Note: In certain instances, the arc flash boundary might be a greater distance from the energized electrical conductors or circuit parts than the limited approach boundary. The electric shock protection boundaries and the arc flash boundary are independent of each other.

Table 130.4(E)(a) Electric Shock Protection Approach Boundaries to Exposed Energized Electrical Conductors or Circuit Parts for Alternating-Current Systems

(1)	(2)	(3)	(4)	
		Limited Approach Boundary[b]		
Nominal System Voltage Range, ~~Phase~~ Line to ~~Phase~~ Line [a]	Exposed Movable Conductor[c]	Exposed Fixed Circuit Part		Restricted Approach Boundary[b,d]; Includes Inadvertent Movement Adder
Less than 50 V	Not specified	Not specified	Not specified	
50 V–150 V[e]	3.1 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	Avoid contact	
151 V–750 V	3.1 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	0.31 m (1 ft 0 in.)	
751 V–5 kV	3.1 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	0.63 m (2 ft 1 in.)	
5.1 kV–15 kV	3.1 m (10 ft 0 in.)	1.5 m (5 ft 0 in.)	0.65 m (2 ft 2 in.)	
15.1 kV–36 kV	3.1 m (10 ft 0 in.)	1.8 m (6 ft 0 in.)	0.77 m (2 ft 7 in.)	
36.1 kV–46 kV	3.1 m (10 ft 0 in.)	2.5 m (8 ft 0 in.)	0.84 m (2 ft 10 in.)	
46.1 kV–72.5 kV	3.1 m (10 ft 0 in.)	2.5 m (8 ft 0 in.)	1.0 m (3 ft 4 in.)	
72.6 kV–121 kV	3.3 m (10 ft 8 in.)	2.5 m (8 ft 0 in.)	1.2 m (3 ft 9 in.)	
121.1 kV–145 kV	3.4 m (11 ft 0 in.)	3.1 m (10 ft 0 in.)	1.3 m (4 ft 4 in.)	
145.1 kV–169 kV	3.6 m (11 ft 8 in.)	3.6 m (11 ft 8 in.)	1.5 m (4 ft 10 in.)	
169.1 kV–242 kV	4.0 m (13 ft 0 in.)	4.0 m (13 ft 0 in.)	2.1 m (6 ft 8 in.)	
242.1 kV–362 kV	4.7 m (15 ft 4 in.)	4.7 m (15 ft 4 in.)	3.5 m (11 ft 2 in.)	
362.1 kV–420 kV	5.8 m (19 ft 0 in.)	5.8 m (19 ft 0 in.)	4.3 m (14 ft 0 in.)	
420.1 kV–550 kV	5.8 m (19 ft 0 in.)	5.8 m (19 ft 0 in.)	5.1 m (16 ft 8 in.)	

(1)	(2)	(3)	(4)	
Nominal System Voltage Range, ~~Phase~~ Line to ~~Phase~~ Line [a]	-	Limited Approach Boundary[b]		Restricted Approach Boundary[b,d]; Includes Inadvertent Movement Adder
	Exposed Movable Conductor[c]	Exposed Fixed Circuit Part		
550.1 kV–800 kV	7.2 m (23 ft 9 in.)	7.2 m (23 ft 9 in.)	6.9 m (22 ft 7 in.)	

Notes:

(1) For arc flash boundary, see 130.5(E).

(2) All dimensions are distance from exposed energized electrical conductors or circuit part to employee.

[a]For single-phase systems above 250 volts, select the range that is equal to the system's maximum phase-to-ground voltage multiplied by 1.732.

[b]See definition in Article 100 and text in 130.4(F)(3) and Informative Annex C for elaboration.

[c]*Exposed movable conductors* describes a condition in which the distance between the conductor and a person is not under the control of the person. The term is normally applied to overhead line conductors supported by poles.

[d]The restricted approach boundary in Column 4 is based on an elevation not exceeding 900 m (3000 ft). For higher elevations, adjustment of the restricted approach boundary shall be considered.

[e]This includes circuits where the exposure does not exceed 120 volts nominal.

Table 130.4(E)(b) Electric Shock Protection Approach Boundaries to Exposed Energized Electrical Conductors or Circuit Parts for Direct-Current Voltage Systems

(1)	(2)	(3)	(4)[b]
Nominal Potential Difference	Limited Approach Boundary		Restricted Approach Boundary; Includes Inadvertent Movement Adder
	Exposed Movable Conductor*[a]	Exposed Fixed Circuit Part	
Less than 50 V	Not specified	Not specified	Not specified
50 V–300 V	3.1 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	Avoid contact
301 V–1 kV	3.1 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	0.3 m (1 ft 0 in.)
1.1 kV–5 kV	3.1 m (10 ft 0 in.)	1.5 m (5 ft 0 in.)	0.5 m (1 ft 5 in.)
5.1 kV–15 kV	3.1 m (10 ft 0 in.)	1.5 m (5 ft 0 in.)	0.7 m (2 ft 2 in.)
15.1 kV–45 kV	3.1 m (10 ft 0 in.)	2.5 m (8 ft 0 in.)	0.8 m (2 ft 9 in.)
45.1 kV– 75 kV	3.1 m (10 ft 0 in.)	2.5 m (8 ft 0 in.)	1.0 m (3 ft 6 in.)
75.1 kV–150 kV	3.3 m (10 ft 8 in.)	3.1 m (10 ft 0 in.)	1.2 m (3 ft 10 in.)
150.1 kV–250 kV	3.6 m (11 ft 8 in.)	3.6 m (11 ft 8 in.)	1.6 m (5 ft 3 in.)
250.1 kV–500 kV	6.0 m (20 ft 0 in.)	6.0 m (20 ft 0 in.)	3.5 m (11 ft 6 in.)
500.1 kV–800 kV	8.0 m (26 ft 0 in.)	8.0 m (26 ft 0 in.)	5.0 m (16 ft 5 in.)

Note: All dimensions are distance from exposed energized electrical conductors or circuit parts to worker.

*[a] *Exposed movable conductor* describes a condition in which the distance between the conductor and a person is not under the control of the person. The term is normally applied to overhead line conductors supported by poles.

[b] The restricted approach boundary in Column 4 is based on an elevation not exceeding 900 m (3000 ft). For higher elevations, adjustment of the restricted approach boundary shall be considered.

Additional Proposed Changes

File Name	Description	Approved
70E_PC_71_Hold.pdf	70E_PC71	

Statement of Problem and Substantiation for Public Input

NOTE: This Public Input appeared as “Reject but Hold” in Public Comment No. 71 of the (A2023) Second Draft Report for NFPA 70E and per the Regs. At 4.4.8.3.1 and needs to be reconsidered by the TC for the next edition of the document.

Single winding (single phase) systems do not have phases, they have lines. Phases only exist on three phase
systems where the phases are in time displacement with one another.

Using the title "Phase to Phase" makes it appear that this table does not apply to single phase (single winding)
systems. But it must apply because it is a shock table. Digging down in the notes shows that the intent is for
this table to apply. Changing the wording from phase to line encompasses all systems, and addresses the
majority of my previous PI on this.

Submitter Information Verification

Submitter Full Name:	NFPA Holds
Organization:	Technical Committee on Electrical Safety in the Workplace
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Thu Jun 06 22:12:02 EDT 2024
Committee:	EEW-AAA

Committee Statement

Resolution: The proposed revision does not improve clarity or usability of this table.

Public Comment No. 71-NFPA 70E-2022 [Section No. 130.4(E)]

(E) Shock Protection Boundaries.

The shock protection boundaries identified as limited approach boundary and restricted approach boundary shall be applicable where personnel are approaching exposed energized electrical conductors or circuit parts. Table 130.4(E)(a) shall be used for the distances associated with various ac system voltages. Table 130.4(E)(b) shall be used for the distances associated with various dc system voltages.

Informational Note: In certain instances, the arc flash boundary might be a greater distance from the energized electrical conductors or circuit parts than the limited approach boundary. The shock protection boundaries and the arc flash boundary are independent of each other.

Table 130.4(E)(a) Shock Protection Approach Boundaries to Exposed Energized Electrical Conductors or Circuit Parts for Alternating-Current Systems

(1)	(2)	(3)	(4)	
		Limited Approach Boundary[b]		
Nominal System Voltage Range, ~~Phase to~~ Phase Line to Line [a]	Exposed Movable Conductor[c]	Exposed Fixed Circuit Part		Restricted Approach Boundary[b]; Includes Inadvertent Movement Adder
Less than 50 V	Not specified	Not specified	Not specified	
50 V–150 V[d]	3.0 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	Avoid contact	
151 V–750 V	3.0 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	0.3 m (1 ft 0 in.)	
-	-	-	-	
751 V–15 kV	3.0 m (10 ft 0 in.)	1.5 m (5 ft 0 in.)	0.7 m (2 ft 2 in.)	
15.1 kV–36 kV	3.0 m (10 ft 0 in.)	1.8 m (6 ft 0 in.)	0.8 m (2 ft 9 in.)	
36.1 kV–46 kV	3.0 m (10 ft 0 in.)	2.5 m (8 ft 0 in.)	0.8 m (2 ft 9 in.)	
-	-	-	-	
46.1 kV–72.5 kV	3.0 m (10 ft 0 in.)	2.5 m (8 ft 0 in.)	1.0 m (3 ft 6 in.)	
72.6 kV–121 kV	3.3 m (10 ft 8 in.)	2.5 m (8 ft 0 in.)	1.0 m (3 ft 6 in.)	
138 kV–145 kV	3.4 m (11 ft 0 in.)	3.0 m (10 ft 0 in.)	1.2 m (3 ft 10 in.)	
-	-	-	-	
161 kV–169 kV	3.6 m (11 ft 8 in.)	3.6 m (11 ft 8 in.)	1.3 m (4 ft 3 in.)	
230 kV–242 kV	4.0 m (13 ft 0 in.)	4.0 m (13 ft 0 in.)	1.7 m (5 ft 8 in.)	
345 kV–362 kV	4.7 m (15 ft 4 in.)	4.7 m (15 ft 4 in.)	2.8 m (9 ft 2 in.)	
-	-	-	-	
500 kV–550 kV	5.8 m (19 ft 0 in.)	5.8 m (19 ft 0 in.)	3.6 m (11 ft 8 in.)	
765 kV–800 kV	7.2 m (23 ft 9 in.)	7.2 m (23 ft 9 in.)	4.9 m (15 ft 11 in.)	

Notes:

(1) For arc flash boundary, see 130.5(E).

(2) All dimensions are distance from exposed energized electrical conductors or circuit part to employee.

[a]For single-phase systems above 250 volts, select the range that is equal to the system's maximum phase-to-ground voltage multiplied by 1.732.

[b]See definition in Article 100 and text in 130.4(F)(3) and Informative Annex C for elaboration.

[c]*Exposed movable conductors* describes a condition in which the distance between the conductor and a person is not under the control of the person. The term is normally applied to overhead line conductors supported by poles.

[d]This includes circuits where the exposure does not exceed 120 volts nominal.

Table 130.4(E)(b) Shock Protection Approach Boundaries to Exposed Energized Electrical Conductors or Circuit Parts for Direct-Current Voltage Systems

(1)	(2)	(3)	(4)
Nominal Potential Difference	Limited Approach Boundary		Restricted Approach Boundary; Includes Inadvertent Movement Adder
	Exposed Movable Conductor*	Exposed Fixed Circuit Part	
Less than 50 V	Not specified	Not specified	Not specified
50 V–300 V	3.0 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	Avoid contact
301 V–1 kV	3.0 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	0.3 m (1 ft 0 in.)
1.1 kV–5 kV	3.0 m (10 ft 0 in.)	1.5 m (5 ft 0 in.)	0.5 m (1 ft 5 in.)
5.1 kV–15 kV	3.0 m (10 ft 0 in.)	1.5 m (5 ft 0 in.)	0.7 m (2 ft 2 in.)
15.1 kV–45 kV	3.0 m (10 ft 0 in.)	2.5 m (8 ft 0 in.)	0.8 m (2 ft 9 in.)
45.1 kV– 75 kV	3.0 m (10 ft 0 in.)	2.5 m (8 ft 0 in.)	1.0 m (3 ft 6 in.)
75.1 kV–150 kV	3.3 m (10 ft 8 in.)	3.0 m (10 ft 0 in.)	1.2 m (3 ft 10 in.)
150.1 kV–250 kV	3.6 m (11 ft 8 in.)	3.6 m (11 ft 8 in.)	1.6 m (5 ft 3 in.)
250.1 kV–500 kV	6.0 m (20 ft 0 in.)	6.0 m (20 ft 0 in.)	3.5 m (11 ft 6 in.)
500.1 kV–800 kV	8.0 m (26 ft 0 in.)	8.0 m (26 ft 0 in.)	5.0 m (16 ft 5 in.)

Note: All dimensions are distance from exposed energized electrical conductors or circuit parts to worker.

**Exposed movable conductor* describes a condition in which the distance between the conductor and a person is not under the control of the person. The term is normally applied to overhead line conductors supported by poles.

Statement of Problem and Substantiation for Public Comment

Single winding (single phase) systems do not have phases, they have lines. Phases only exist on three phase systems where the phases are in time displacement with one another.
Using the title "Phase to Phase" makes it appear that this table does not apply to single phase (single winding) systems. But it must apply because it is a shock table. Digging down in the notes shows that the intent is for this table to apply. Changing the wording from phase to line encompasses all systems, and addresses the majority of my previous PI on this.

Related Item

• 74-NFPA 70E-2021

Submitter Information Verification

Submitter Full Name: Eric Stromberg
Organization: Strategic Management Solutions, Inc.
Affiliation: Self
Street Address:
City:
State:
Zip:
Submittal Date: Sun May 29 12:40:06 EDT 2022

Committee: EEW-AAA

Committee Statement

Committee Action: Rejected but held

Resolution: The text proposed by this public comment does not meet 4.4.4.2 of the Regulations Governing Committee Projects which requires public comments to be related to material that has received public review either through the submission of Public Input, Committee Input or Correlating Input or through the First Revisions.

Public Input No. 73-NFPA 70E-2024 [Section No. 130.4(E)]

(E) Electric Shock Protection Boundaries.

The electric shock protection boundaries identified as limited approach boundary and restricted approach boundary shall be applicable where personnel are approaching exposed energized electrical conductors or circuit parts. Table 130.4(E)(a) shall be used for the distances associated with various ac system voltages. Table 130.4(E)(b) shall be used for the distances associated with various dc system voltages.

Informational Note: In certain instances, the arc flash boundary might be a greater distance from the energized electrical conductors or circuit parts than the limited approach boundary. The electric shock protection boundaries and the arc flash boundary are independent of each other.

Table 130.4(E)(a) Electric Shock Protection Approach Boundaries to Exposed Energized Electrical Conductors or Circuit Parts for Alternating-Current Systems

(1)	(2)	(3)	(4)	
		Limited Approach Boundary[b]		
Nominal System Voltage Range, Phase to Phase[a]	Exposed Movable Conductor[c]	Exposed Fixed Circuit Part		Restricted Approach Boundary[b,d]; Includes Inadvertent Movement Adder
Less than 50 V	Not specified	Not specified	Not specified	
50 V–150 V[e]	3.1 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	Avoid contact	
151 V–750 V	3.1 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	0.31 m (1 ft 0 in.)	
751 V–5 kV	3.1 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	0.63 m (2 ft 1 in.)	
5.1 kV–15 kV	3.1 m (10 ft 0 in.)	1.5 m (5 ft 0 in.)	0.65 m (2 ft 2 in.)	
15.1 kV–36 kV	3.1 m (10 ft 0 in.)	1.8 m (6 ft 0 in.)	0.77 m (2 ft 7 in.)	
36.1 kV–46 kV	3.1 m (10 ft 0 in.)	2.5 m (8 ft 0 in.)	0.84 m (2 ft 10 in.)	
46.1 kV–72.5 kV	3.1 m (10 ft 0 in.)	2.5 m (8 ft 0 in.)	1.0 m (3 ft 4 in.)	
72.6 kV–121 kV	3.3 m (10 ft 8 in.)	2.5 m (8 ft 0 in.)	1.2 m (3 ft 9 in.)	
121.1 kV–145 kV	3.4 m (11 ft 0 in.)	3.1 m (10 ft 0 in.)	1.3 m (4 ft 4 in.)	
145.1 kV–169 kV	3.6 m (11 ft 8 in.)	3.6 m (11 ft 8 in.)	1.5 m (4 ft 10 in.)	
169.1 kV–242 kV	4.0 m (13 ft 0 in.)	4.0 m (13 ft 0 in.)	2.1 m (6 ft 8 in.)	
242.1 kV–362 kV	4.7 m (15 ft 4 in.)	4.7 m (15 ft 4 in.)	3.5 m (11 ft 2 in.)	
362.1 kV–420 kV	5.8 m (19 ft 0 in.)	5.8 m (19 ft 0 in.)	4.3 m (14 ft 0 in.)	
420.1 kV–550 kV	5.8 m (19 ft 0 in.)	5.8 m (19 ft 0 in.)	5.1 m (16 ft 8 in.)	
550.1 kV–800 kV	7.2 m (23 ft 9 in.)	7.2 m (23 ft 9 in.)	6.9 m (22 ft 7 in.)	

Notes:

(1) For arc flash boundary, see 130.5(E).

(2) All dimensions are distance from exposed energized electrical conductors or circuit part to ~~employee~~ worker .

[a]For single-phase systems above 250 volts, select the range that is equal to the system's maximum phase-to-ground voltage multiplied by 1.732.

[b]See definition in Article 100 and text in 130.4(F)(3) and Informative Annex C for elaboration.

[c]*Exposed movable conductors* describes a condition in which the distance between the conductor and a person is not under the control of the person. The term is normally applied to overhead line conductors supported by poles.

[d]The restricted approach boundary in Column 4 is based on an elevation not exceeding 900 m (3000 ft). For higher elevations, adjustment of the restricted approach boundary shall be considered.

[e]This includes circuits where the exposure does not exceed 120 volts nominal.

Table 130.4(E)(b) Electric Shock Protection Approach Boundaries to Exposed Energized Electrical Conductors or Circuit Parts for Direct-Current Voltage Systems

(1)	(2)	(3)	(4)[b]
Nominal Potential Difference	Limited Approach Boundary		Restricted Approach Boundary; Includes Inadvertent Movement Adder
	Exposed Movable Conductor*[a]	Exposed Fixed Circuit Part	
Less than 50 V	Not specified	Not specified	Not specified
50 V–300 V	3.1 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	Avoid contact
301 V–1 kV	3.1 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	0.3 m (1 ft 0 in.)
1.1 kV–5 kV	3.1 m (10 ft 0 in.)	1.5 m (5 ft 0 in.)	0.5 m (1 ft 5 in.)
5.1 kV–15 kV	3.1 m (10 ft 0 in.)	1.5 m (5 ft 0 in.)	0.7 m (2 ft 2 in.)
15.1 kV–45 kV	3.1 m (10 ft 0 in.)	2.5 m (8 ft 0 in.)	0.8 m (2 ft 9 in.)
45.1 kV– 75 kV	3.1 m (10 ft 0 in.)	2.5 m (8 ft 0 in.)	1.0 m (3 ft 6 in.)
75.1 kV–150 kV	3.3 m (10 ft 8 in.)	3.1 m (10 ft 0 in.)	1.2 m (3 ft 10 in.)
150.1 kV–250 kV	3.6 m (11 ft 8 in.)	3.6 m (11 ft 8 in.)	1.6 m (5 ft 3 in.)
250.1 kV–500 kV	6.0 m (20 ft 0 in.)	6.0 m (20 ft 0 in.)	3.5 m (11 ft 6 in.)
500.1 kV–800 kV	8.0 m (26 ft 0 in.)	8.0 m (26 ft 0 in.)	5.0 m (16 ft 5 in.)

Note: All dimensions are distance from exposed energized electrical conductors or circuit parts to worker.

*[a]*Exposed movable conductor* describes a condition in which the distance between the conductor and a person is not under the control of the person. The term is normally applied to overhead line conductors supported by poles.

[b]The restricted approach boundary in Column 4 is based on an elevation not exceeding 900 m (3000 ft). For higher elevations, adjustment of the restricted approach boundary shall be considered.

Statement of Problem and Substantiation for Public Input

Section/Paragraph Referenced: Table 130.4(E)(a) "Electric Shock Protection Approach Boundaries to Exposed Energized Electrical Conductors or Circuit Parts for Alternating-Current Systems" and Table 130.4(E)(b) "Electric Shock Protection Approach Boundaries to Exposed Energized Electrical Conductors or Circuit Parts for Direct-Current Voltage Systems."

Suggested Change:
Replace the term "employee" with "worker" in Table 130.4(E)(a) to match the terminology used in Table

130.4(E)(b), thereby standardizing the language across both AC and DC electric shock protection approach boundaries tables.

Rationale for Change:
The current use of "employee" in Table 130.4(E)(a) and "worker" in Table 130.4(E)(b) introduces inconsistency in terminology that could potentially lead to confusion about the applicability and scope of these important safety measures. Standardizing the language by using the term "worker" in both tables will clarify that the safety protocols are universally applicable to all individuals working in proximity to energized electrical conductors or circuit parts, regardless of the type of electrical system (AC or DC) they are interacting with.

The term "worker" is broadly inclusive and effectively encompasses any person performing work in these environments, making it an ideal choice for consistent application across NFPA 70E. This change will enhance the clarity and coherence of the document, thereby facilitating better understanding, compliance, and safety outcomes for all individuals involved in electrical work.

Conclusion:
Adopting consistent terminology across NFPA 70E by standardizing the use of "worker", maintaining consistency where employee should be used in lieu, with explanation elsewhere in the standard, will reinforce the universal applicability of electric shock protection measures, improving the document's clarity and the effectiveness of its safety protocols.

Submitter Information Verification

Submitter Full Name: Evan Banda
Organization: Champion Electric Inc
Street Address:
City:
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Zip:

Submittal Date: Tue Mar 26 13:42:57 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-68-NFPA 70E-2024

Statement: The word "employee" was replaced with "personnel" to correlate to the existing word in 130.4E.

An informational note is added to note (d) to Tables 130.4(E)(a) and 130.4(E)(b) to direct users to more information on altitude impacts.

Note e was revised to indicate that the line vs. phase issue applies only at the lowest voltage range.

Public Input No. 217-NFPA 70E-2024 [Section No. 130.4(F)(3)]

(3) Entering the Limited Approach Boundary.

~~Where there is a need for an~~ Qualified persons shall be permitted to enter the limited approach boundary where it can be demonstrated that the work to be performed is in accordance 110.2(B).

Exception: An unqualified person(s) shall be permitted to cross the limited approach boundary ~~;~~ ~~a qualified person shall advise the unqualified person~~ to perfom work in accordance with 110.2(B) when advised by a qualified person (s) of the possible hazards and continuously ~~escort the unqualified~~ escorted by a qualified person(s) while inside the limited approach boundary. ~~Under no circumstance shall unqualified person(s) be permitted to cross the restricted approach boundary.~~

Statement of Problem and Substantiation for Public Input

Section 110.2(B) requires an electrically safe work condition to be established if an employee is inside the limited approach boundary unless the work meets one of the exceptions. The way this is currently written, it is being understood that a qualified person can escort an unqualified person into the limited approach boundary without meeting section 110.2(B) as long as the unqualified person needs something and is advised on the hazards and escorted. The most common example is an engineer needs to see a label. So, an unqualified person can be escorted into the limited approach boundary to read a label but a qualified person must create an electrically safe work condition if working within the limited approach boundary even if not crossing the restricted approach boundary. This revision is meant to clarify that escorting unqualified persons into the limited approach boundary still needs to meet the exception in 110.2(B). Also, added in that qualified persons are permitted to enter the limited approach boundary if the work meets section 110.2(B), primarily the exceptions.

Submitter Information Verification

Submitter Full Name: Derek Vigstol
Organization: e-Hazard Management LLC
Street Address:
City:
State:
Zip:

Submittal Date: Mon Jun 03 23:43:20 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: There is no need to address a qualified person within the limited approach boundary. There is no need to change the existing requirement to an exception for an unqualified person crossing the limited approach boundary. The committee affirms that the requirement “Under no circumstance shall unqualified person(s) be permitted to cross the restricted approach boundary” is properly located.

Public Input No. 218-NFPA 70E-2024 [Section No. 130.4(G)]

(G) Restricted Approach Boundary.

No qualified person shall approach or take any conductive object closer to exposed energized electrical conductors or circuit parts than the restricted approach boundary set forth in Table 130.4(E)(a) and Table 130.4(E)(b), unless one of the following conditions applies:

(1) The qualified person is insulated or guarded from energized electrical conductors or circuit parts operating at 50 volts or more. Insulating gloves and sleeves are considered insulation only with regard to the energized parts upon which work is performed.

(2) The energized electrical conductors or circuit parts are insulated from the qualified person and from any other conductive object at a different potential.

Under no circumstance shall unqualified person(s) be permitted to cross the restricted approach boundary.

Statement of Problem and Substantiation for Public Input

Why is there a requirement about unqualified persons crossing the restricted approach boundary in the section on limited approach boundary entrance? This is a simple clarification suggestion. This moves all requirements for who can and cannot cross the restricted approach boundary into the section on restricted approach boundary.

Submitter Information Verification

Submitter Full Name: Derek Vigstol
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Street Address:
City:
State:
Zip:

Submittal Date: Tue Jun 04 00:00:26 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: The committee affirms the best location for this statement “Under no circumstance shall unqualified person(s) be permitted to cross the restricted approach boundary” is 130.4(F)(3).

Public Input No. 67-NFPA 70E-2024 [Section No. 130.5(B)]

(B) Estimate of Likelihood and Severity.

The estimate of the likelihood of occurrence of injury or damage to health and the potential severity of injury or damage to health shall take into consideration the following:

(1) The design of the electrical equipment ~~, including its overcurrent protective device and its operating time~~ being worked on, and the operating time of the protecting overcurrent device.

(2) The electrical equipment operating condition and condition of maintenance

Informational Note 1 : In most cases, closed doors do not provide enough protection to eliminate the need for PPE in situations in which the state of the equipment is known to readily change (e.g., doors open or closed, rack in or rack-out).

Informational Note 2: The protecting overcurrent device is typically located in an enclosure separate from the equipment being worked on.

Statement of Problem and Substantiation for Public Input

The text as written in unclear as to which overcurrent device should be consulted. It is common for workers to work on overcurrent devices. The device being worked on also has an operating time. The revised wording attempts to make it clear that the workers need to consider a different device located at a separate location from the equipment they are working on. The added informational note helps to further emphasize this.

Submitter Information Verification

Submitter Full Name: Jesse Thomas
Organization: Wichita Electrical JATC
Affiliation: IBEW l.u.#271
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Submittal Date: Wed Mar 20 15:45:49 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-36-NFPA 70E-2024

Statement: The revision clarifies that the overcurrent protective device that is to be taken into consideration when estimating the potential severity of injury or damage to health is that which is intended to interrupt a fault in the electrical equipment referred to in list item (1).

Public Input No. 10-NFPA 70E-2023 [Section No. 130.5(C)]

(C) Additional Protective Measures.

If additional protective measures are required they shall be selected and implemented according to the hierarchy of risk control identified in 110.3(H)(3). When the additional protective measures include the use of PPE, the following shall be determined:

(1) Appropriate safety-related work practices

(2) The arc flash boundary

(3) The PPE to be used within the arc flash boundary

Table 130.5(C) shall be permitted to be used to estimate the likelihood of occurrence of an arc flash event to determine if additional protective measures are required.

Table 130.5(C) Estimate of the Likelihood of Occurrence of an Arc Flash Incident for ac and dc Systems

Task	Operating Condition[a]	Likelihood of Occurrence[b]
Reading a panel meter while operating a meter switch.	Any	No
Performing infrared thermography and other noncontact inspections outside the restricted approach boundary. This activity does not include opening of doors or covers.	-	-
Working on control circuits with exposed energized electrical conductors and circuit parts, nominal 125 volts ac or dc, or below without any other exposed energized equipment over nominal 125 volts ac or dc, including opening of hinged covers to gain access.	-	-
Examination of insulated cable with no manipulation of cable.	-	-
For dc systems, maintenance on a single cell of a battery system or multi-cell units in an open rack.	-	-
For ac systems, work on energized electrical conductors and circuit parts, including electrical testing.	Any	Yes
Operation of a CB or switch the first time after installation or completion of maintenance in the equipment.	-	-
For dc systems, working on energized electrical conductors and circuit parts of series-connected battery cells, including electrical testing.	-	-
Removal or installation of CBs or switches.	-	-
Opening hinged door(s) or cover(s) or removal of bolted covers (to expose bare, energized electrical conductors and circuit parts). For dc systems, this includes bolted covers, such as battery terminal covers.	-	-
Application of temporary protective grounding equipment, after voltage test.	-	-
Working on control circuits with exposed energized electrical conductors and circuit parts, greater than 120 volts.	-	-
Insertion or removal of individual starter buckets from motor control center (MCC).	-	-
Insertion or removal (racking) of circuit breakers (CBs) or starters from cubicles, doors open or closed.	-	-
Insertion or removal of plug-in devices into or from busways.	-	-
Examination of insulated cable with manipulation of cable.	-	-
Working on exposed energized electrical conductors and circuit parts of equipment directly supplied by a	-	-

Task	Operating Condition[a]	Likelihood of Occurrence[b]	
panelboard or motor control center.			
Insertion or removal of revenue meters (kW-hour, at primary voltage and current).	-	-	
Insertion or removal of covers for battery intercell connector(s).	-	-	
For dc systems, working on exposed energized electrical conductors and circuit parts of utilization equipment directly supplied by a dc source.	-	-	
Opening voltage transformer or control power transformer compartments.	-	-	
Operation of outdoor disconnect switch (hookstick operated) at 1 kV through 15 kV.	-	-	
Operation of outdoor disconnect switch (gang-operated, from grade) at 1 kV through 15 kV.	-	-	
Operation of a CB, switch, contactor, or starter.	Normal	No	
	-	Abnormal	Yes
Voltage testing on individual battery cells or individual multi-cell units.	-	-	
Removal or installation of covers for equipment such as wireways, junction boxes, and cable trays that does not expose bare, energized electrical conductors and circuit parts.	-	-	
Opening a panelboard hinged door or cover to access dead front overcurrent devices.	-	-	
Removal of battery nonconductive intercell connector covers.	-	-	
Maintenance and testing on individual battery cells or individual multi-cell units in an open rack	-	-	
Insertion or removal of individual cells or multi-cell units of a battery system in an open rack.	-	-	
Arc-resistant equipment with the DOORS CLOSED and SECURED, and where the available fault current and fault clearing time does not exceed that of the arc-resistant rating of the equipment in one of the following conditions:	-	-	
(1) Insertion or removal of individual starter buckets	-	-	
(2) Insertion or removal (racking) of CBs from cubicles	-	-	
(3) Insertion or removal (racking) of ground and test device	-	-	
(4) Insertion or removal (racking) of voltage transformers on or off the bus	-	-	
-	-	-	

[a]Equipment is considered to be in a “normal operating condition” if all of the conditions in 110.2(B), Exception No. 1 are satisfied.

[b]As defined in this standard, the two components of risk are the likelihood of occurrence of injury or damage to health and the severity of injury or damage to health that results from a hazard. Risk assessment is an overall process that involves estimating both the likelihood of occurrence and severity to determine if additional protective measures are required. The estimate of the likelihood of occurrence contained in this table does not cover every possible

condition or situation, nor does it address severity of injury or damage to health. Where this table identifies “No” as an estimate of likelihood of occurrence, it means that an arc flash incident is not likely to occur. Where this table identifies “Yes” as an estimate of likelihood of occurrence, it means an arc flash incident should be considered likely to occur. The likelihood of occurrence must be combined with the potential severity of the arcing incident to determine if additional protective measures are required to be selected and implemented according to the hierarchy of risk control identified in 110.3(H).

Informational Note No. 1: See IEEE C37.20.7, *Guide for Testing Switchgear Rated Up to 52 kV for Internal Arcing Faults*, as an example of a standard that provides information for arc-resistant equipment referred to in Table 130.5(C).

Informational Note No. 2: Improper or inadequate maintenance can result in increased fault clearing time of the overcurrent protective device, thus increasing the incident energy. Where equipment is not properly installed or maintained, PPE selection based on incident energy analysis or the PPE category method might not provide adequate protection from arc flash hazards.

Informational Note No. 3: Both larger and smaller ~~available~~ fault currents could result in higher incident energy. If the ~~available~~ fault current increases without a decrease in the fault clearing time of the overcurrent protective device, the incident energy will increase. If the ~~available~~ fault current decreases, resulting in a longer fault clearing time for the overcurrent protective device, incident energy could also increase.

Informational Note No. 4: See Informative Annex O for safety-related design requirements. The occurrence of an arcing fault inside an enclosure produces a variety of physical phenomena very different from a bolted fault. For example, the arc energy resulting from an arc developed in the air will cause a sudden pressure increase and localized overheating. Equipment and design practices are available to minimize the energy levels and the number of procedures that could expose an employee to high levels of incident energy. Proven designs such as arc-resistant switchgear, remote racking (insertion or removal), remote opening and closing of switching devices, high-resistance grounding of low-voltage and 5000-volt (nominal) systems, current limitation, and specification of covered bus or covered conductors within equipment are available to reduce the risk associated with an arc flash incident.

Informational Note No. 5: See 205.4, 225.1, 225.2, and 225.3 for additional direction for performing maintenance on overcurrent protective devices.

Informational Note No. 6: See IEEE 1584, *Guide for Performing Arc Flash Hazard Calculations*, for more information regarding incident energy and the arc flash boundary for three-phase systems.

Statement of Problem and Substantiation for Public Input

"Largest" is removed to make this informational note technically correct based on the fact that the definition of "available fault current" states, in part, that it is the largest amount of current capable of being delivered..." Accordingly, the term or phrase "available fault current" only means the largest amount. There cannot be lower largest amounts of current as described in this informational not. It seems as though what is being described is actually "fault current" rather than "available fault current" which, by definition, means "largest" amount.

Submitter Information Verification

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Submittal Date: Thu Aug 24 10:56:31 EDT 2023

Committee: EEW-AAA

Committee Statement

Resolution: FR-37-NFPA 70E-2024

Statement: The section was revised to comply with the NEC Style Manual Sections 3.5.1.2 Multiple Requirements and 2.1.6.3 Subdivisions and 2.1.6.3.2 Subdivision Titles.

The revision in Informational Note No. 3 clarifies the application of this informational note and correlates the note with the related definition of fault current.

Public Input No. 144-NFPA 70E-2024 [Section No. 130.5(C)]

(C) Additional Protective Measures.

If additional protective measures are required they shall be selected and implemented according to the hierarchy of risk control identified in 110.3(H)(3). When the additional protective measures include the use of PPE, the following shall be determined:

(1) Appropriate safety-related work practices

(2) The arc flash boundary

(3) The PPE to be used within the arc flash boundary

Table 130.5(C) shall be permitted to be used to estimate the likelihood of occurrence of an arc flash event to determine if additional protective measures are required.

Table 130.5(C) Estimate of the Likelihood of Occurrence of an Arc Flash Incident for ac and dc Systems

Task	Operating Condition[a]	Likelihood of Occurrence[b]
Reading a panel meter while operating a meter switch.	Any	No
Performing infrared thermography and other noncontact inspections outside the restricted approach boundary. This activity does not include opening of doors or covers.	-	-
Working on control circuits with exposed energized electrical conductors and circuit parts, nominal 125 volts ac or dc, or below without any other exposed energized equipment over nominal 125 volts ac or dc, including opening of hinged covers to gain access.	-	-
Examination of insulated cable with no manipulation of cable.	-	-
For dc systems, maintenance on a single cell of a battery system or multi-cell units in an open rack.	-	-
For ac systems, work on energized electrical conductors and circuit parts, including electrical testing.	Any	Yes
Operation of a CB or switch the first time after installation or completion of maintenance in the equipment.	-	-
For dc systems, working on energized electrical conductors and circuit parts of series-connected battery cells, including electrical testing.	-	-
Removal or installation of CBs or switches.	-	-
Opening hinged door(s) or cover(s) or removal of bolted covers (to expose bare, energized electrical conductors and circuit parts). For dc systems, this includes bolted covers, such as battery terminal covers.	-	-
Application of temporary protective grounding equipment, after voltage test.	-	-
Working on control circuits with exposed energized electrical conductors and circuit parts, greater than 120 volts.	-	-
Insertion or removal of individual starter buckets from motor control center (MCC).	-	-
Insertion or removal (racking) of circuit breakers (CBs) or starters from cubicles, doors open or closed.	-	-
Insertion or removal of plug-in devices into or from busways.	-	-
Examination of insulated cable with manipulation of cable.	-	-
Working on exposed energized electrical conductors and circuit parts of equipment directly supplied by a	-	-

Task	Operating Condition[a]	Likelihood of Occurrence[b]	
panelboard or motor control center.			
Insertion or removal of revenue meters (kW-hour, at primary voltage and current).	-	-	
~~Insertion or removal of covers for battery intercell connector(s).~~	-	-	
For dc systems, working on exposed energized electrical conductors and circuit parts of utilization equipment directly supplied by a dc source.	-	-	
Opening voltage transformer or control power transformer compartments.	-	-	
Operation of outdoor disconnect switch (hookstick operated) at 1 kV through 15 kV.	-	-	
Operation of outdoor disconnect switch (gang-operated, from grade) at 1 kV through 15 kV.	-	-	
Operation of a CB, switch, contactor, or starter.	Normal	No	
	-	Abnormal	Yes
Voltage testing on individual battery cells or individual multi-cell units.	-	-	
Removal or installation of covers for equipment such as wireways, junction boxes, and cable trays that does not expose bare, energized electrical conductors and circuit parts.	-	-	
Opening a panelboard hinged door or cover to access dead front overcurrent devices.	-	-	
Removal of battery nonconductive intercell connector covers.	-	-	
Maintenance and testing on individual battery cells or individual multi-cell units in an open rack	-	-	
Insertion or removal of individual cells or multi-cell units of a battery system in an open rack.	-	-	
Arc-resistant equipment with the DOORS CLOSED and SECURED, and where the available fault current and fault clearing time does not exceed that of the arc-resistant rating of the equipment in one of the following conditions:	-	-	
(1) Insertion or removal of individual starter buckets	-	-	
(2) Insertion or removal (racking) of CBs from cubicles	-	-	
(3) Insertion or removal (racking) of ground and test device	-	-	
(4) Insertion or removal (racking) of voltage transformers on or off the bus	-	-	
-	-	-	

[a]Equipment is considered to be in a “normal operating condition” if all of the conditions in 110.2(B), Exception No. 1 are satisfied.

[b]As defined in this standard, the two components of risk are the likelihood of occurrence of injury or damage to health and the severity of injury or damage to health that results from a hazard. Risk assessment is an overall process that involves estimating both the likelihood of occurrence and severity to determine if additional protective measures are required. The

estimate of the likelihood of occurrence contained in this table does not cover every possible condition or situation, nor does it address severity of injury or damage to health. Where this table identifies “No” as an estimate of likelihood of occurrence, it means that an arc flash incident is not likely to occur. Where this table identifies “Yes” as an estimate of likelihood of occurrence, it means an arc flash incident should be considered likely to occur. The likelihood of occurrence must be combined with the potential severity of the arcing incident to determine if additional protective measures are required to be selected and implemented according to the hierarchy of risk control identified in 110.3(H).

Informational Note No. 1: See IEEE C37.20.7, *Guide for Testing Switchgear Rated Up to 52 kV for Internal Arcing Faults*, as an example of a standard that provides information for arc-resistant equipment referred to in Table 130.5(C).

Informational Note No. 2: Improper or inadequate maintenance can result in increased fault clearing time of the overcurrent protective device, thus increasing the incident energy. Where equipment is not properly installed or maintained, PPE selection based on incident energy analysis or the PPE category method might not provide adequate protection from arc flash hazards.

Informational Note No. 3: Both larger and smaller available fault currents could result in higher incident energy. If the available fault current increases without a decrease in the fault clearing time of the overcurrent protective device, the incident energy will increase. If the available fault current decreases, resulting in a longer fault clearing time for the overcurrent protective device, incident energy could also increase.

Informational Note No. 4: See Informative Annex O for safety-related design requirements. The occurrence of an arcing fault inside an enclosure produces a variety of physical phenomena very different from a bolted fault. For example, the arc energy resulting from an arc developed in the air will cause a sudden pressure increase and localized overheating. Equipment and design practices are available to minimize the energy levels and the number of procedures that could expose an employee to high levels of incident energy. Proven designs such as arc-resistant switchgear, remote racking (insertion or removal), remote opening and closing of switching devices, high-resistance grounding of low-voltage and 5000-volt (nominal) systems, current limitation, and specification of covered bus or covered conductors within equipment are available to reduce the risk associated with an arc flash incident.

Informational Note No. 5: See 205.4, 225.1, 225.2, and 225.3 for additional direction for performing maintenance on overcurrent protective devices.

Informational Note No. 6: See IEEE 1584, *Guide for Performing Arc Flash Hazard Calculations*, for more information regarding incident energy and the arc flash boundary for three-phase systems.

Statement of Problem and Substantiation for Public Input

The removed entry is identical to an entry below it in the table identifying "Removal of battery nonconductive intercell connector covers." as having a low likelihood of arc flash occurrence if the equipment condition is normal. This activity is clearly low risk if the equipment condition is normal so the proposed change resolves the conflict with the most rational outcome.

Most battery work does not involve a high likelihood of arc flash occurrence because batteries tend to operate in an ungrounded state and have high circuit separation, meaning that the locations where an arc could occur are extremely limited. Only when the battery is in an abnormal condition (e.g. ground fault) or when the work is being done on the breaker / combiner circuit or dc load circuit while energized is there a high likelihood of arc flash occurrence. Both of these cases are identified in this table already so this entry adds nothing. Also see D. M. Rosewater, "Reducing Risk When Performing Energized Work on Batteries," in IEEE Transactions on Industry Applications, vol. 60, no. 2, pp. 2732-2741, March-April 2024, doi: 10.1109/TIA.2023.3332828. This reference is open access and available online: https://ieeexplore.ieee.org/document/10316636

Submitter Information Verification

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Submittal Date:	Mon Jun 03 11:30:47 EDT 2024
Committee:	EEW-AAA

Committee Statement

Resolution: There are two completely separate suggested revisions seen in PI-144 and PI-145. The two requirements referenced here are not identical, as one applies to insertion and removal of covers that are not necessarily non-conductive, and does present a likelihood of occurrence. Only when the equipment is in normal condition, and the cover that is being removed is non-conductive, will the occurrence be considered to be unlikely.

Public Input No. 145-NFPA 70E-2024 [Section No. 130.5(C)]

(C) Additional Protective Measures.

If additional protective measures are required they shall be selected and implemented according to the hierarchy of risk control identified in 110.3(H)(3). When the additional protective measures include the use of PPE, the following shall be determined:

(1) Appropriate safety-related work practices

(2) The arc flash boundary

(3) The PPE to be used within the arc flash boundary

Table 130.5(C) shall be permitted to be used to estimate the likelihood of occurrence of an arc flash event to determine if additional protective measures are required.

Table 130.5(C) Estimate of the Likelihood of Occurrence of an Arc Flash Incident for ac and dc Systems

Task	Operating Condition[a]	Likelihood of Occurrence[b]
Reading a panel meter while operating a meter switch.	Any	No
Performing infrared thermography and other noncontact inspections outside the restricted approach boundary. This activity does not include opening of doors or covers.	-	-
Working on control circuits with exposed energized electrical conductors and circuit parts, nominal 125 volts ac or dc, or below without any other exposed energized equipment over nominal 125 volts ac or dc, including opening of hinged covers to gain access.	-	-
Examination of insulated cable with no manipulation of cable.	-	-
For dc systems, maintenance on a single cell of a battery system or multi-cell units in an open rack.	-	-
For ac systems, work on energized electrical conductors and circuit parts, including electrical testing.	Any	Yes
Operation of a CB or switch the first time after installation or completion of maintenance in the equipment.	-	-
~~For dc systems, working on energized electrical conductors and circuit parts of series-connected battery cells, including electrical testing.~~	-	-
Removal or installation of CBs or switches.	-	-
Opening hinged door(s) or cover(s) or removal of bolted covers (to expose bare, energized electrical conductors and circuit parts). For dc systems, this includes bolted covers, such as battery terminal covers.	-	-
Application of temporary protective grounding equipment, after voltage test.	-	-
Working on control circuits with exposed energized electrical conductors and circuit parts, greater than 120 volts.	-	-
Insertion or removal of individual starter buckets from motor control center (MCC).	-	-
Insertion or removal (racking) of circuit breakers (CBs) or starters from cubicles, doors open or closed.	-	-
Insertion or removal of plug-in devices into or from busways.	-	-
Examination of insulated cable with manipulation of cable.	-	-

Task	Operating Condition[a]	Likelihood of Occurrence[b]
Working on exposed energized electrical conductors and circuit parts of equipment directly supplied by a panelboard or motor control center.	-	-
Insertion or removal of revenue meters (kW-hour, at primary voltage and current).	-	-
Insertion or removal of covers for battery intercell connector(s).	-	-
For dc systems, working on exposed energized electrical conductors and circuit parts of utilization equipment directly supplied by a dc source.	-	-
Opening voltage transformer or control power transformer compartments.	-	-
Operation of outdoor disconnect switch (hookstick operated) at 1 kV through 15 kV.	-	-
Operation of outdoor disconnect switch (gang-operated, from grade) at 1 kV through 15 kV.	-	-
Operation of a CB, switch, contactor, or starter.	Normal	No
-	-	Abnormal Yes
Voltage testing on individual battery cells or individual multi-cell units.	-	-
Removal or installation of covers for equipment such as wireways, junction boxes, and cable trays that does not expose bare, energized electrical conductors and circuit parts.	-	-
Opening a panelboard hinged door or cover to access dead front overcurrent devices.	-	-
Removal of battery nonconductive intercell connector covers.	-	-
Maintenance and testing on individual battery cells or individual multi-cell units in an open rack	-	-
Insertion or removal of individual cells or multi-cell units of a battery system in an open rack.	-	-
Arc-resistant equipment with the DOORS CLOSED and SECURED, and where the available fault current and fault clearing time does not exceed that of the arc-resistant rating of the equipment in one of the following conditions:	-	-
(1) Insertion or removal of individual starter buckets	-	-
(2) Insertion or removal (racking) of CBs from cubicles	-	-
(3) Insertion or removal (racking) of ground and test device	-	-
(4) Insertion or removal (racking) of voltage transformers on or off the bus	-	-
-	-	-

[a]Equipment is considered to be in a “normal operating condition” if all of the conditions in 110.2(B), Exception No. 1 are satisfied.

[b]As defined in this standard, the two components of risk are the likelihood of occurrence of injury or damage to health and the severity of injury or damage to health that results from a hazard. Risk assessment is an overall process that involves estimating both the likelihood of

occurrence and severity to determine if additional protective measures are required. The estimate of the likelihood of occurrence contained in this table does not cover every possible condition or situation, nor does it address severity of injury or damage to health. Where this table identifies “No” as an estimate of likelihood of occurrence, it means that an arc flash incident is not likely to occur. Where this table identifies “Yes” as an estimate of likelihood of occurrence, it means an arc flash incident should be considered likely to occur. The likelihood of occurrence must be combined with the potential severity of the arcing incident to determine if additional protective measures are required to be selected and implemented according to the hierarchy of risk control identified in 110.3(H).

Informational Note No. 1: See IEEE C37.20.7, *Guide for Testing Switchgear Rated Up to 52 kV for Internal Arcing Faults*, as an example of a standard that provides information for arc-resistant equipment referred to in Table 130.5(C).

Informational Note No. 2: Improper or inadequate maintenance can result in increased fault clearing time of the overcurrent protective device, thus increasing the incident energy. Where equipment is not properly installed or maintained, PPE selection based on incident energy analysis or the PPE category method might not provide adequate protection from arc flash hazards.

Informational Note No. 3: Both larger and smaller available fault currents could result in higher incident energy. If the available fault current increases without a decrease in the fault clearing time of the overcurrent protective device, the incident energy will increase. If the available fault current decreases, resulting in a longer fault clearing time for the overcurrent protective device, incident energy could also increase.

Informational Note No. 4: See Informative Annex O for safety-related design requirements. The occurrence of an arcing fault inside an enclosure produces a variety of physical phenomena very different from a bolted fault. For example, the arc energy resulting from an arc developed in the air will cause a sudden pressure increase and localized overheating. Equipment and design practices are available to minimize the energy levels and the number of procedures that could expose an employee to high levels of incident energy. Proven designs such as arc-resistant switchgear, remote racking (insertion or removal), remote opening and closing of switching devices, high-resistance grounding of low-voltage and 5000-volt (nominal) systems, current limitation, and specification of covered bus or covered conductors within equipment are available to reduce the risk associated with an arc flash incident.

Informational Note No. 5: See 205.4, 225.1, 225.2, and 225.3 for additional direction for performing maintenance on overcurrent protective devices.

Informational Note No. 6: See IEEE 1584, *Guide for Performing Arc Flash Hazard Calculations*, for more information regarding incident energy and the arc flash boundary for three-phase systems.

Statement of Problem and Substantiation for Public Input

The removed entry “For dc systems, working on energized electrical conductors and circuit parts of series-connected battery cells, including electrical testing.” Is an identical task to “Voltage testing on individual battery cells or individual multi-cell units.” Which is identified below as having a low likelihood of arc flash occurrence when the equipment condition is normal.

Most battery work does not involve a high likelihood of arc flash occurrence because batteries tend to operate in an ungrounded state and have high circuit separation, meaning that the locations where an arc could occur are extremely limited. Only when the battery is in an abnormal condition (e.g. ground fault) or when the work is being done on the breaker / combiner circuit or dc load circuit while energized is there a high likelihood of arc flash occurrence. Both of these cases are identified in this table already so this entry adds nothing. Also see D. M. Rosewater, "Reducing Risk When Performing Energized Work on Batteries," in IEEE Transactions on Industry Applications, vol. 60, no. 2, pp. 2732-2741, March-April 2024, doi: 10.1109/TIA.2023.3332828. This reference is open access and available online: https://ieeexplore.ieee.org/document/10316636

Submitter Information Verification

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Submittal Date:	Mon Jun 03 11:43:24 EDT 2024
Committee:	EEW-AAA

Committee Statement

Resolution: There are two completely separate suggested revisions seen in PI-144 and PI-145. The two requirements referenced here are not identical, as the first involves working on energized electrical conductors and circuit parts with the equipment in any condition, while the second is only conducting voltage testing with the equipment in normal condition. Working on equipment involves more than simple voltage testing.

Public Input No. 263-NFPA 70E-2024 [Section No. 130.5(C)]

(C) Additional Protective Measures.

If additional protective measures are required they shall be selected and implemented according to the hierarchy of risk control identified in 110.3(H)(3). When the additional protective measures include the use of PPE, the following shall be determined:

(1) Appropriate safety-related work practices

(2) The arc flash boundary

(3) The PPE to be used within the arc flash boundary

Table 130.5(C) shall be permitted to be used to estimate the likelihood of occurrence of an arc flash event to determine if additional protective measures are required.

Table 130.5(C) Estimate of the Likelihood of Occurrence of an Arc Flash Incident for ac and dc Systems

Task	Operating Condition[a]	Likelihood of Occurrence[b]
Reading a panel meter while operating a meter switch.	Any	No
Performing infrared thermography and other noncontact inspections outside the restricted approach boundary. This activity does not include opening of doors or covers.	-	-
Working on control circuits with exposed energized electrical conductors and circuit parts, nominal 125 volts ac or dc, or below without any other exposed energized equipment over nominal 125 volts ac or dc, including opening of hinged covers to gain access.	-	-
Examination of insulated cable with no manipulation of cable.	-	-
For dc systems, maintenance on a single cell of a battery system or multi-cell units in an open rack.	-	-
For ac systems, work on energized electrical conductors and circuit parts, including electrical testing.	Any	Yes
Operation of a CB or switch the first time after installation or completion of maintenance in the equipment.	-	-
For dc systems, working on energized electrical conductors and circuit parts of series-connected battery cells, including electrical testing.	-	-
Removal or installation of CBs or switches.	-	-
Opening hinged door(s) or cover(s) or removal of bolted covers (to expose bare, energized electrical conductors and circuit parts). For dc systems, this includes bolted covers, such as battery terminal covers.	-	-
Application of temporary protective grounding equipment, after voltage test.	-	-
Working on control circuits with exposed energized electrical conductors and circuit parts, greater than 120 volts.	-	-
Insertion or removal of individual starter buckets from motor control center (MCC).	-	-
Insertion or removal (racking) of circuit breakers (CBs) or starters from cubicles, doors open or closed.	-	-
Insertion or removal of plug-in devices into or from busways.	-	-
Examination of insulated cable with manipulation of cable.	-	-
Working on exposed energized electrical conductors and circuit parts of equipment directly supplied by a	-	-

Task	Operating Condition[a]	Likelihood of Occurrence[b]	
panelboard or motor control center.			
Insertion or removal of revenue meters (kW-hour, at primary voltage and current).	-	-	
Insertion or removal of covers for battery intercell connector(s).	-	-	
For dc systems, working on exposed energized electrical conductors and circuit parts of utilization equipment directly supplied by a dc source.	-	-	
Opening voltage transformer or control power transformer compartments.	-	-	
Operation of outdoor disconnect switch (hookstick operated) at 1 kV through 15 kV.	-	-	
Operation of outdoor disconnect switch (gang-operated, from grade) at 1 kV through 15 kV.	-	-	
Operation of a CB, switch, contactor, or starter.	Normal	No (c)	
-		Abnormal	Yes
Voltage testing on individual battery cells or individual multi-cell units.	-	-	
Removal or installation of covers for equipment such as wireways, junction boxes, and cable trays that does not expose bare, energized electrical conductors and circuit parts.	-	-	
Opening a panelboard hinged door or cover to access dead front overcurrent devices.	-	-	
Removal of battery nonconductive intercell connector covers.	-	-	
Maintenance and testing on individual battery cells or individual multi-cell units in an open rack	-	-	
Insertion or removal of individual cells or multi-cell units of a battery system in an open rack.	-	-	
Arc-resistant equipment with the DOORS CLOSED and SECURED, and where the available fault current and fault clearing time does not exceed that of the arc-resistant rating of the equipment in one of the following conditions:	-	-	
(1) Insertion or removal of individual starter buckets	-	-	
(2) Insertion or removal (racking) of CBs from cubicles	-	-	
(3) Insertion or removal (racking) of ground and test device	-	-	
(4) Insertion or removal (racking) of voltage transformers on or off the bus	-	-	
-	-	-	

[a]Equipment is considered to be in a “normal operating condition” if all of the conditions in 110.2(B), Exception No. 1 are satisfied.

[b]As defined in this standard, the two components of risk are the likelihood of occurrence of injury or damage to health and the severity of injury or damage to health that results from a hazard. Risk assessment is an overall process that involves estimating both the likelihood of occurrence and severity to determine if additional protective measures are required. The estimate of the likelihood of occurrence contained in this table does not cover every possible

condition or situation, nor does it address severity of injury or damage to health. Where this table identifies “No” as an estimate of likelihood of occurrence, it means that an arc flash incident is not likely to occur. Where this table identifies “Yes” as an estimate of likelihood of occurrence, it means an arc flash incident should be considered likely to occur. The likelihood of occurrence must be combined with the potential severity of the arcing incident to determine if additional protective measures are required to be selected and implemented according to the hierarchy of risk control identified in 110.3(H).

Informational Note No. 1: See IEEE C37.20.7, *Guide for Testing Switchgear Rated Up to 52 kV for Internal Arcing Faults*, as an example of a standard that provides information for arc-resistant equipment referred to in Table 130.5(C).

Informational Note No. 2: Improper or inadequate maintenance can result in increased fault clearing time of the overcurrent protective device, thus increasing the incident energy. Where equipment is not properly installed or maintained, PPE selection based on incident energy analysis or the PPE category method might not provide adequate protection from arc flash hazards.

Informational Note No. 3: Both larger and smaller available fault currents could result in higher incident energy. If the available fault current increases without a decrease in the fault clearing time of the overcurrent protective device, the incident energy will increase. If the available fault current decreases, resulting in a longer fault clearing time for the overcurrent protective device, incident energy could also increase.

Informational Note No. 4: See Informative Annex O for safety-related design requirements. The occurrence of an arcing fault inside an enclosure produces a variety of physical phenomena very different from a bolted fault. For example, the arc energy resulting from an arc developed in the air will cause a sudden pressure increase and localized overheating. Equipment and design practices are available to minimize the energy levels and the number of procedures that could expose an employee to high levels of incident energy. Proven designs such as arc-resistant switchgear, remote racking (insertion or removal), remote opening and closing of switching devices, high-resistance grounding of low-voltage and 5000-volt (nominal) systems, current limitation, and specification of covered bus or covered conductors within equipment are available to reduce the risk associated with an arc flash incident.

Informational Note No. 5: See 205.4, 225.1, 225.2, and 225.3 for additional direction for performing maintenance on overcurrent protective devices.

Informational Note No. 6: See IEEE 1584, *Guide for Performing Arc Flash Hazard Calculations*, for more information regarding incident energy and the arc flash boundary for three-phase systems.

(c) While operation of a CB, switch, contactor, or starter under normal operating conditions does not have a liklihood of arc flash occurrence, use of basic PPE such as long-sleeve cotton shirt, long pants, leather gloves and safety glasses is recommended.

Statement of Problem and Substantiation for Public Input

Some organizations require the use of PPE for operating electrical equipment under normal conditions when there is not a likelihood of arc flash occurrence. A recommendation of PPE in NFPA 70E for this activity would provide a reference in a consensus standard.

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Submittal Date: Tue Jun 04 17:12:57 EDT 2024

Committee: EEW-AAA

Committee Statement

Resolution: The NFPA 70E standard provides adequate guidance to determine when PPE should be used as a protective measure. The standard does not recognize cotton garments as PPE. Providing recommendations in a table note is a violation of the NEC Style Manual as table notes are mandatory text.

Public Input No. 56-NFPA 70E-2024 [Section No. 130.5(C)]

(C) Additional Protective Measures.

If additional protective measures are required they shall be selected and implemented according to the hierarchy of risk control identified in 110.3(H)(3). When the additional protective measures include the use of PPE, the following shall be determined:

(1) Appropriate safety-related work practices

(2) The arc flash boundary

(3) The PPE to be used within the arc flash boundary

Table 130.5(C) shall be permitted to be used to estimate the likelihood of occurrence of an arc flash event to determine if additional protective measures are required.

Table 130.5(C) Estimate of the Likelihood of Occurrence of an Arc Flash Incident for ac and dc Systems

Task	Operating Condition[a]	Likelihood of Occurrence[b]
Reading a panel meter while operating a meter switch.	Any	No
Performing infrared thermography and other noncontact inspections outside the restricted approach boundary. This activity does not include opening of doors or covers.	-	-
Working on control circuits with exposed energized electrical conductors and circuit parts, nominal 125 volts ac or dc, or below without any other exposed energized equipment over nominal 125 volts ac or dc, including opening of hinged covers to gain access.	-	-
Examination of insulated cable with no manipulation of cable.	-	-
For dc systems, maintenance on a single cell of a battery system or multi-cell units in an open rack.	-	-
For ac systems, work on energized electrical conductors and circuit parts, including electrical testing.	Any	Yes
Operation of a CB or switch the first time after installation or completion of maintenance in the equipment.	-	-
For dc systems, working on energized electrical conductors and circuit parts of series-connected battery cells, including electrical testing.	-	-
Removal or installation of CBs or switches.	-	-
Opening hinged door(s) or cover(s) or removal of bolted covers (to expose bare, energized electrical conductors and circuit parts). For dc systems, this includes bolted covers, such as battery terminal covers.	-	-
Application of temporary protective grounding equipment, after voltage test.	-	-
Working on control circuits with exposed energized electrical conductors and circuit parts, greater than ~~120 volts~~ 125 volts .	-	-
Insertion or removal of individual starter buckets from motor control center (MCC).	-	-
Insertion or removal (racking) of circuit breakers (CBs) or starters from cubicles, doors open or closed.	-	-
Insertion or removal of plug-in devices into or from busways.	-	-
Examination of insulated cable with manipulation of cable.	-	-
Working on exposed energized electrical conductors and circuit parts of equipment directly supplied by a	-	-

Task	Operating Condition[a]	Likelihood of Occurrence[b]	
panelboard or motor control center.			
Insertion or removal of revenue meters (kW-hour, at primary voltage and current).	-	-	
Insertion or removal of covers for battery intercell connector(s).	-	-	
For dc systems, working on exposed energized electrical conductors and circuit parts of utilization equipment directly supplied by a dc source.	-	-	
Opening voltage transformer or control power transformer compartments.	-	-	
Operation of outdoor disconnect switch (hookstick operated) at 1 kV through 15 kV.	-	-	
Operation of outdoor disconnect switch (gang-operated, from grade) at 1 kV through 15 kV.	-	-	
Operation of a CB, switch, contactor, or starter.	Normal	No	
	-	Abnormal	Yes
Voltage testing on individual battery cells or individual multi-cell units.	-	-	
Removal or installation of covers for equipment such as wireways, junction boxes, and cable trays that does not expose bare, energized electrical conductors and circuit parts.	-	-	
Opening a panelboard hinged door or cover to access dead front overcurrent devices.	-	-	
Removal of battery nonconductive intercell connector covers.	-	-	
Maintenance and testing on individual battery cells or individual multi-cell units in an open rack	-	-	
Insertion or removal of individual cells or multi-cell units of a battery system in an open rack.	-	-	
Arc-resistant equipment with the DOORS CLOSED and SECURED, and where the available fault current and fault clearing time does not exceed that of the arc-resistant rating of the equipment in one of the following conditions:	-	-	
(1) Insertion or removal of individual starter buckets	-	-	
(2) Insertion or removal (racking) of CBs from cubicles	-	-	
(3) Insertion or removal (racking) of ground and test device	-	-	
(4) Insertion or removal (racking) of voltage transformers on or off the bus	-	-	
-	-	-	

[a]Equipment is considered to be in a “normal operating condition” if all of the conditions in 110.2(B), Exception No. 1 are satisfied.

[b]As defined in this standard, the two components of risk are the likelihood of occurrence of injury or damage to health and the severity of injury or damage to health that results from a hazard. Risk assessment is an overall process that involves estimating both the likelihood of occurrence and severity to determine if additional protective measures are required. The estimate of the likelihood of occurrence contained in this table does not cover every possible

condition or situation, nor does it address severity of injury or damage to health. Where this table identifies “No” as an estimate of likelihood of occurrence, it means that an arc flash incident is not likely to occur. Where this table identifies “Yes” as an estimate of likelihood of occurrence, it means an arc flash incident should be considered likely to occur. The likelihood of occurrence must be combined with the potential severity of the arcing incident to determine if additional protective measures are required to be selected and implemented according to the hierarchy of risk control identified in 110.3(H).

Informational Note No. 1: See IEEE C37.20.7, *Guide for Testing Switchgear Rated Up to 52 kV for Internal Arcing Faults*, as an example of a standard that provides information for arc-resistant equipment referred to in Table 130.5(C).

Informational Note No. 2: Improper or inadequate maintenance can result in increased fault clearing time of the overcurrent protective device, thus increasing the incident energy. Where equipment is not properly installed or maintained, PPE selection based on incident energy analysis or the PPE category method might not provide adequate protection from arc flash hazards.

Informational Note No. 3: Both larger and smaller available fault currents could result in higher incident energy. If the available fault current increases without a decrease in the fault clearing time of the overcurrent protective device, the incident energy will increase. If the available fault current decreases, resulting in a longer fault clearing time for the overcurrent protective device, incident energy could also increase.

Informational Note No. 4: See Informative Annex O for safety-related design requirements. The occurrence of an arcing fault inside an enclosure produces a variety of physical phenomena very different from a bolted fault. For example, the arc energy resulting from an arc developed in the air will cause a sudden pressure increase and localized overheating. Equipment and design practices are available to minimize the energy levels and the number of procedures that could expose an employee to high levels of incident energy. Proven designs such as arc-resistant switchgear, remote racking (insertion or removal), remote opening and closing of switching devices, high-resistance grounding of low-voltage and 5000-volt (nominal) systems, current limitation, and specification of covered bus or covered conductors within equipment are available to reduce the risk associated with an arc flash incident.

Informational Note No. 5: See 205.4, 225.1, 225.2, and 225.3 for additional direction for performing maintenance on overcurrent protective devices.

Informational Note No. 6: See IEEE 1584, *Guide for Performing Arc Flash Hazard Calculations*, for more information regarding incident energy and the arc flash boundary for three-phase systems.

Statement of Problem and Substantiation for Public Input

There are two tasks in Table 130.5(C) that begin "Working on control circuits with exposed energized electrical conductors and circuit parts..." The first task establishes a threshold of 125V for likelihood of arc flash occurrence. The second task establishes the threshold as 120V. Changing the second one to 125V would make the thresholds identified in the two tasks consistent, eliminating the discrepancy.

Submitter Information Verification

Submitter Full Name: Drew Lange
Organization: NASA
Street Address:
City:
State:
Zip:
Submittal Date: Thu Feb 08 07:56:27 EST 2024
Committee: EEW-AAA

Committee Statement

Resolution: The two tasks, and voltage ranges in Table 130.5(C) referenced in this public input are completely different. The first addresses nominal voltage at 125 volts or below and the second addresses voltages greater than 120 volts which could include for example, control circuits at 277 volts.

Public Input No. 100-NFPA 70E-2024 [Section No. 130.5(F)]

(F) Arc Flash PPE.

One of the following methods shall be used for the selection of arc flash PPE:

(1) The incident energy analysis method in accordance with 130.5(G)

(2) The arc flash PPE category method in accordance with 130.7(C)(15)

Either, but not both, methods shall be permitted to be used on the same piece of equipment. The results of an incident energy analysis to specify an arc flash PPE category in Table 130.7(C)(15)(c) shall not be permitted.

Exception: Where the equipment manufacturer has performed testing to determine task specific incident energy information, that verified value shall be permitted for the selection of arc flash PPE.

Informational Note: Incident energy released during an arc flash event can be measured in a lab using calorimeters. See UL RP 2986 Recommended Practice for Measuring Incident Energy Exposure for further information.

Statement of Problem and Substantiation for Public Input

The present language in 130.5(F) permits two methods to be used for the selection of arc flash PPE: 1) Estimation using an incident energy analysis (aka Calculation) method or 2) arc flash PPE category (aka Table) method. Some equipment is specifically evaluated for performance using standardized test methods and calorimeters. The language in the standard needs to be clear that users are permitted to use information obtained through testing in their arc flash risk assessment and for selection of arc flash PPE. The proposed exception and informational note will clarify this type of information is permitted to be used without altering the existing provisions of this section.

Submitter Information Verification

Submitter Full Name: Rodney West
Organization: Schneider Electric
Street Address:
City:
State:
Zip:

Submittal Date: Wed May 29 15:23:56 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-38-NFPA 70E-2024

Statement: This revision adds an exception with multiple conditions that allows workers to use arc flash information that was obtained through third party verified testing to select arc flash PPE without altering the existing provisions of this section. The new exception permits additional methods to be utilized for specific tasks in specific situations.

The section was revised to comply with the NEC Style Manual Sections 3.5.1.2 Multiple Requirements and 2.1.6.3 Subdivisions and 2.1.6.3.2 Subdivision Titles.

Public Input No. 271-NFPA 70E-2024 [Section No. 130.5(G)]

(G) Incident Energy Analysis Method.

The incident energy exposure level shall be based on the working distance of the employee's face and chest areas from a prospective arc source for the specific task to be performed. Arc-rated clothing and other PPE shall be used by the employee based on the incident energy exposure associated with the specific task. Recognizing that incident energy increases as the distance from the arc flash decreases, additional PPE shall be used for any parts of the body that are closer than the working distance at which the incident energy was determined.

The incident energy analysis shall take into consideration the characteristics of the overcurrent protective device and its fault clearing time, including its condition of maintenance.

The incident energy analysis shall be updated when changes occur in the electrical distribution system that could affect the results of the analysis. The incident energy analysis shall also be reviewed for accuracy at intervals not to exceed 5 years.

> Informational Note: Changes that could affect the results of the incident energy analysis include changes made by utilities or other entities, such as transformer sizing, as well as modifications to protective devices or changes to protective settings.

Table 130.5(G) identifies arc-rated clothing and other PPE requirements and shall be permitted to be used with the incident energy analysis method of selecting arc flash PPE.

> Informational Note No. 1: See Informative Annex D for information on estimating the incident energy.
>
> Informational Note No. 2: See Informative Annex H for information on selection of arc-rated clothing and other PPE.

Table 130.5(G) Selection of Arc-Rated Clothing and Other PPE When the Incident Energy Analysis Method Is Used

Incident energy exposures equal to 1.2 cal/cm^2 up to and including 12 cal/cm^2
Arc-rated clothing with an arc rating equal to or greater than the estimated incident energy[a]
Arc-rated long-sleeve shirt and pants or arc-rated coverall or arc flash suit (SR)
Arc-rated face shield and arc-rated balaclava or arc flash suit hood (SR)[b]
Arc-rated outerwear (e.g., jacket, parka, rainwear, hard hat liner, high-visibility apparel) (AN)[e]
Heavy-duty leather gloves, arc-rated gloves, or rubber insulating gloves with protectors (SR)[c]
Hard hat
Safety glasses or safety goggles (SR)
Hearing protection
Leather footwear[d]
Incident energy exposures greater than 12 cal/cm^2
Arc-rated clothing with an arc rating equal to or greater than the estimated incident energy[a]
Arc-rated long-sleeve shirt and pants or arc-rated coverall or arc flash suit (SR)
Arc-rated arc flash suit hood
Arc-rated outerwear (e.g., jacket, parka, rainwear, hard hat liner, high-visibility apparel) (AN)[e]
Arc-rated gloves or rubber insulating gloves with protectors (SR)[c]
Hard hat
Safety glasses or safety goggles (SR)
Hearing protection
Leather footwear[d]

SR: Selection of one in group is required.

AN: As needed.

[a]Arc ratings can be for a single layer, such as an arc-rated shirt and pants or a coverall, or for an arc flash suit or a multi-layer system if tested as a combination consisting of an arc-rated shirt and pants, coverall, and arc flash suit.

[b]Face shields with a wrap-around guarding to protect the face, chin, forehead, ears, and neck area are required by 130.7(C)(10)(c). Where the back of the head is inside the arc flash boundary, a balaclava or an arc flash hood shall be required for full head and neck protection.

[c]Rubber insulating gloves with protectors provide arc flash protection in addition to electric shock protection. Higher class rubber insulating gloves with protectors, due to their increased material thickness, provide increased arc flash protection.

[d]Footwear other than leather or dielectric shall be permitted to be used provided it has been tested to demonstrate no ignition, melting, or dripping at the estimated incident energy exposure.

[e]The arc rating of outer layers worn over arc-rated clothing as protection from the elements or for other safety purposes, and that are not used as part of a layered system, shall not be required to be equal to or greater than the estimated incident energy exposure.

Additional Proposed Changes

File Name	Description	Approved
70E_PC_10_Hold.pdf	70E_PC10	

Statement of Problem and Substantiation for Public Input

NOTE: This Public Input appeared as “Reject but Hold” in Public Comment No. 10 of the (A2023) Second Draft Report for NFPA 70E and per the Regs. At 4.4.8.3.1 and needs to be reconsidered by the TC for the next edition of the document.

In Table 130.5(G); within the 1.2 cal/cm2 up to and including 12 cal/cm2, it contains "arc flash suit hood". Within
the greater than 12 cal/cm2 portion, it's a arc-rated arc flash suit hood. Changing one if not both of these would
standardize the nomenclature and eliminate any possible confusion, currently there are three different terms
utilized with Table 130.7(C)(15)(c) PPE, Category 1; "arc flash suit hood", Category 2; "Arc-rated flash suit
hood" and Categories; 3 & 4 "Arc-rated arc flash suit hood".
Furthermore in 130.7(C)(10)(b)(1 & 2) it's a "arc-rated hood"

Submitter Information Verification

Submitter Full Name:	NFPA Holds
Organization:	Technical Committee on Electrical Safety in the Workplace
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Thu Jun 06 21:17:53 EDT 2024
Committee:	EEW-AAA

Committee Statement

Resolution: This public input sought to delete the 4 cal/cm2 requirement in 130.7(C)(10) or modify the permissive table in 130.5(G). Neither of these suggestions are necessary or provide clarity. The use of Table 130.5(G) is permitted, it is not required. However, the threshold of 4 cal/cm2 for foot protection is required.

Public Comment No. 10-NFPA 70E-2022 [Section No. 130.5(G)]

(G) Incident Energy Analysis Method.

The incident energy exposure level shall be based on the working distance of the employee's face and chest areas from a prospective arc source for the specific task to be performed. Arc-rated clothing and other PPE shall be used by the employee based on the incident energy exposure associated with the specific task. Recognizing that incident energy increases as the distance from the arc flash decreases, additional PPE shall be used for any parts of the body that are closer than the working distance at which the incident energy was determined.

The incident energy analysis shall take into consideration the characteristics of the overcurrent protective device and its fault clearing time, including its condition of maintenance.

The incident energy analysis shall be updated when changes occur in the electrical distribution system that could affect the results of the analysis. The incident energy analysis shall also be reviewed for accuracy at intervals not to exceed 5 years.

Informational Note: Changes that could affect the results of the incident energy analysis include changes made by utilities or other entities, such as transformer sizing, as well as modifications to protective devices or changes to protective settings.

Table 130.5(G) identifies the arc-rated clothing and other PPE requirements and shall be permitted to be used with the incident energy analysis method of selecting arc flash PPE.

Informational Note No. 1: See Informative Annex D for information on estimating the incident energy.

Informational Note No. 2: See Informative Annex H for information on selection of arc-rated clothing and other PPE.

Table 130.5(G) Selection of Arc-Rated Clothing and Other PPE When the Incident Energy Analysis Method Is Used

Incident energy exposures equal to 1.2 cal/cm^2 up to and including 12 cal/cm^2
Arc-rated clothing with an arc rating equal to or greater than the estimated incident energy[a]
Arc-rated long-sleeve shirt and pants or arc-rated coverall or arc flash suit (SR)
Arc-rated face shield and arc-rated balaclava or arc flash suit hood (SR)[b]
Arc-rated outerwear (e.g., jacket, parka, rainwear, hard hat liner, high-visibility apparel) (AN)[e]
Heavy-duty leather gloves, arc-rated gloves, or rubber insulating gloves with protectors (SR)[c]
Hard hat
Safety glasses or safety goggles (SR)
Hearing protection
Leather footwear[d]
Incident energy exposures greater than 12 cal/cm^2
Arc-rated clothing with an arc rating equal to or greater than the estimated incident energy[a]
Arc-rated long-sleeve shirt and pants or arc-rated coverall or arc flash suit (SR)
Arc-rated arc flash suit hood
Arc-rated outerwear (e.g., jacket, parka, rainwear, hard hat liner, high-visibility apparel) (AN)[e]
Arc-rated gloves or rubber insulating gloves with protectors (SR)[c]
Hard hat
Safety glasses or safety goggles (SR)
Hearing protection
Leather footwear[d]

SR: Selection of one in group is required.

AN: As needed.

[a]Arc ratings can be for a single layer, such as an arc-rated shirt and pants or a coverall, or for an arc flash suit or a multi-layer system if tested as a combination consisting of an arc-rated shirt and pants, coverall, and arc flash suit.

[b]Face shields with a wrap-around guarding to protect the face, chin, forehead, ears, and neck area are

required by 130.7(C)(10)(c). Where the back of the head is inside the arc flash boundary, a balaclava or an arc flash hood shall be required for full head and neck protection.

[c]Rubber insulating gloves with protectors provide arc flash protection in addition to shock protection. Higher class rubber insulating gloves with protectors, due to their increased material thickness, provide increased arc flash protection.

[d]Footwear other than leather or dielectric shall be permitted to be used provided it has been tested to demonstrate no ignition, melting, or dripping at the estimated incident energy exposure.

[e]The arc rating of outer layers worn over arc-rated clothing as protection from the elements or for other safety purposes, and that are not used as part of a layered system, shall not be required to be equal to or greater than the estimated incident energy exposure.

Statement of Problem and Substantiation for Public Comment

In Table 130.5(G); within the 1.2 cal/cm2 up to and including 12 cal/cm2, it contains "arc flash suit hood". Within the greater than 12 cal/cm2 portion, it's a arc-rated arc flash suit hood. Changing one if not both of these would standardize the nomenclature and eliminate any possible confusion, currently there are three different terms utilized with Table 130.7(C)(15)(c) PPE, Category 1; "arc flash suit hood", Category 2; "Arc-rated flash suit hood" and Categories; 3 & 4 "Arc-rated arc flash suit hood".

Furthermore in 130.7(C)(10)(b)(1 & 2) it's a "arc-rated hood"

Related Item

• Table 130.5(G) Hoods

Submitter Information Verification

Submitter Full Name: Daryl Colloms
Organization: DENSO
Street Address:
City:
State:
Zip:
Submittal Date: Tue Mar 15 14:45:40 EDT 2022
Committee: EEW-AAA

Committee Statement

Committee Action: Rejected but held

Resolution: The text proposed by this public comment does not meet 4.4.4.2 of the Regulations Governing Committee Projects which requires public comments to be related to material that has received public review either through the submission of Public Input, Committee Input or Correlating Input or through the First Revisions.

Public Input No. 160-NFPA 70E-2024 [New Section after 130.5(H)]

Point of Work Labeling

Electrical equipment shall be marked with a label close by the air-gap isolator on the exterior of equipment such as switchboards, panelboards, industrial control panels, and motor control centers stating “ELECTRICAL ISOLATION POINT OF WORK LOCATION”. For other configurations where the “Electrical Isolation Point of Work” is non-obvious, then the qualified person shall do a risk assessment and determine another point of work location to isolate the electrical energy.

Statement of Problem and Substantiation for Public Input

Including the labeling requirement reduces risk and ensures that the isolation point of the single enclosure has been verified and is obvious.
The principle of “test each phase conductor or circuit part at each point of work” is still valid.
Unless the location of the isolator and the downstream circuits is not 100% obvious (non-obvious), then a new point of work isolation location should be determined.

Submitter Information Verification

Submitter Full Name: Philip Allen
Organization: Grace Technologies, Inc.
Street Address:
City:
State:
Zip:

Submittal Date: Mon Jun 03 12:50:51 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: The requirement for a qualified worker to test for the absence of voltage at each point of work is adequately addressed in 120.6(7).

Public Input No. 37-NFPA 70E-2023 [Section No. 130.5(H)]

(H) Equipment Labeling.

Electrical equipment ~~such as switchboards, panelboards, industrial control panels, meter socket enclosures, and motor control centers that are in other than dwelling units and that are~~ that is likely to require examination, adjustment, servicing, or maintenance while energized shall be marked with a label containing all the following information:

(1) Nominal system voltage

(2) Arc flash boundary

(3) At least one of the following:

(4) Available incident energy and the corresponding working distance, or the arc flash PPE category in Table 130.7(C)(15)(a) or Table 130.7(C)(15)(b) for the equipment, but not both

(5) Minimum arc rating of clothing

(6) Site-specific level of PPE

Exception No. 1: Unless changes in electrical distribution system(s) render the label inaccurate, labels applied prior to the effective date of this edition of the standard shall be acceptable if they complied with the requirements for equipment labeling in the standard in effect at the time the labels were applied.

Exception No. 2: In supervised industrial installations where conditions of maintenance and engineering supervision ensure that only qualified persons monitor and service the system, the information required in 130.5(H)(1) through 130.5(H)(3) shall be permitted to be documented in a manner that is readily available to persons likely to perform examination, servicing, maintenance, and operation of the equipment while energized.

The method of calculating and the data to support the information for the label shall be documented. The data shall be reviewed for accuracy at intervals not to exceed 5 years. Where the review of the data identifies a change that renders the label inaccurate, the label shall be updated.

The label shall be of sufficient durability to withstand the environment involved.

The owner of the electrical equipment shall be responsible for the documentation, installation, and maintenance of the marked label.

Statement of Problem and Substantiation for Public Input

The language stricken has caused many facilities to perform incomplete incident energy calculations and labeling of equipment. All 3-phase equipment presents some level of arc flash hazard as does a lot of high voltage single phase equipment. Personnel servicing variable speed drives, transformers, and motors also need to be aware of the arc flash hazard via labeling. Even though the language does not specifically exclude it, in practice many companies are excluding it.

The stricken lanuage also removes the single and two-family dwelling units which is already considered in the scope of NFPA 70E.

Submitter Information Verification

Submitter Full Name: Karl Cunningham

Organization: Self Employed
Street Address:
City:
State:
Zip:
Submittal Date: Tue Dec 12 10:50:50 EST 2023
Committee: EEW-AAA

Committee Statement

Resolution: Deletion of the equipment identified in 130.5(H) will not improve clarity and could create confusion. No equipment list could possibly be all inclusive. The modifier “such as” and the equipment list presently provided is extremely useful to user of the standard.

Public Input No. 68-NFPA 70E-2024 [Section No. 130.5(H)]

(H) Equipment Labeling.

Electrical equipment such as switchboards, panelboards, industrial control panels, meter socket enclosures, and motor control centers that are in other than dwelling units and that are likely to require examination, adjustment, servicing, or maintenance while energized shall be marked with a label containing all the following information:

(1) Statement noting that this electrical equipment is required (with some exception) to be put in an Electrically Safe Working Condition before any work can be performed

(2) Nominal system voltage

(3) Arc flash boundary

(4) At least one of the following:

(5) Available incident energy and the corresponding working distance, or the arc flash PPE category in Table 130.7(C)(15)(a) or Table 130.7(C)(15)(b) for the equipment, but not both

(6) Minimum arc rating of clothing

(7) Site-specific level of PPE

Exception No. 1: Unless changes in electrical distribution system(s) render the label inaccurate, labels applied prior to the effective date of this edition of the standard shall be acceptable if they complied with the requirements for equipment labeling in the standard in effect at the time the labels were applied.

Exception No. 2: In supervised industrial installations where conditions of maintenance and engineering supervision ensure that only qualified persons monitor and service the system, the information required in 130.5(H)(1) through 130.5(H)(3) shall be permitted to be documented in a manner that is readily available to persons likely to perform examination, servicing, maintenance, and operation of the equipment while energized.

The method of calculating and the data to support the information for the label shall be documented. The data shall be reviewed for accuracy at intervals not to exceed 5 years. Where the review of the data identifies a change that renders the label inaccurate, the label shall be updated.

The label shall be of sufficient durability to withstand the environment involved.

The owner of the electrical equipment shall be responsible for the documentation, installation, and maintenance of the marked label.

Statement of Problem and Substantiation for Public Input

The labels should include a reminder that OSHA regulations at 1910.333(a)(1) stipulate, "Live parts to which an employee may be exposed shall be deenergized."

Submitter Information Verification

Submitter Full Name: Jesse Thomas
Organization: Wichita Electrical JATC
Affiliation: IBEW l.u.#271

Street Address:
City:
State:
Zip:
Submittal Date: Wed Mar 20 16:07:50 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: The proposed additional list item requiring a warning to place equipment in an electrically safe work condition is unnecessary. The requirement to place equipment in an electrically safe work condition is already adequately addressed in other sections of the standard.

Public Input No. 17-NFPA 70E-2023 [Section No. 130.7(A)]

(A) General.

Employees exposed to electrical hazards when the risk associated with that hazard is not adequately reduced by the applicable electrical installation requirements shall be provided with, and shall use, personal protective equipment that is designed and constructed for the specific part of the body to be protected and for the work to be performed.

Informational Note: The PPE requirements of 130.7 are intended to protect a person from arc flash and electric shock hazards. While some situations could result in burns to the skin, even with the protection selected, burn injury should be reduced and survivable. Due to the explosive effect of some arc events, physical trauma injuries could occur. The PPE requirements of 130.7 do not address protection against physical trauma other than exposure to the thermal effects of an arc flash.

Statement of Problem and Substantiation for Public Input

This Public Input is to clarify that what is being discussed in the sentence being revised in this general requirement (per its subdivision title - general) is only addressing personal protective equipment even though 130.7 and 130.7(A) cover both personal and other protective equipment. While personal protective equipment is, I am not aware of "other" protective equipment (covered in 130.7(D)) that is "designed and constructed for the specific part of the body to be protected and the work to be performed."

Submitter Information Verification

Submitter Full Name: Palmer Hickman
Organization: Electrical Training Alliance
Street Address:
City:
State:
Zip:

Submittal Date: Tue Sep 05 13:33:00 EDT 2023
Committee: EEW-AAA

Committee Statement

Resolution: FR-49-NFPA 70E-2024

Statement: The addition of the word “personal” clarifies the application of the requirement. The protective equipment in the requirement in the context used, is personal protective equipment.

Public Input No. 15-NFPA 70E-2023 [Section No. 130.7(B)]

(B) Care of Equipment.

Protective equipment shall be maintained in a safe, clean, and reliable condition and in accordance with manufacturers' instructions. The protective equipment shall be visually inspected before each use. Protective equipment shall be stored in a manner to prevent damage from physically damaging conditions and from moisture, dust, or other deteriorating agents.

Informational Note No1 : See 130.7(C)(~~14)~~ ~~and~~ 7)(a), (c) and (d) and Table 130.7(C)(7)(a) and Table 130.7(~~E)~~ ~~for~~ C)(7)(b) for specific requirements for periodic testing of electrical protective equipment.

Informational Note No. 2: See 130.7(C)(14) for standards for PPE and 130.7(E) for standards for other protective equipment.

Statement of Problem and Substantiation for Public Input

This revision is intended to be an editorial correction to the informational note since, while 130.7(C)(7)(a), (c) and (d) and Table 130.7(C)(7)(a) and Table 130.7(C)(7)(b) do address what is stated in the informational note, neither130.7(C)(14) nor 130.7(E) address "specific requirements for periodic testing of electrical protective equipment. The existing informational note is revised and now identified as Informational Note No. 1. New Informational Note No. 2 retains the subdivision reference from the "old" existing informational note and incorporates the title of 130.7(C)(14) - Standards for PPE - and the title of 130.7(E) - Standards for Other Protective Equipment - to accurately convey what these subdivisions cover per their existing subdivision titles.

Submitter Information Verification

Submitter Full Name: Palmer Hickman
Organization: Electrical Training Alliance
Street Address:
City:
State:
Zip:

Submittal Date: Thu Aug 31 13:46:33 EDT 2023
Committee: EEW-AAA

Committee Statement

Resolution: FR-50-NFPA 70E-2024

Statement: The existing informational note did not address requirements for periodic testing of electrical protective equipment and this revision modifies Informational Note No. 1 to reference the applicable requirements. The existing reference in Informational Note No.1 is relocated and modified as new Informational Note No. 2 addressing other protective equipment.

The section was revised to comply with the NEC Style Manual Section 3.5.1.2 Multiple Requirements.

Public Input No. 275-NFPA 70E-2024 [Section No. 130.7(C)(6)]

(6) Body Protection.

Employees shall wear arc-rated clothing wherever there is possible exposure to an electric arc flash equal or above the threshold incident energy level for a second degree burn [1.2 cal/cm^2 (5 J/cm^2)].

Additional Proposed Changes

File Name	Description	Approved
70E_PC_20_Hold.pdf	70E_PC20	

Statement of Problem and Substantiation for Public Input

NOTE: This Public Input appeared as “Reject but Hold” in Public Comment No. 20 of the (A2023) Second Draft Report for NFPA 70E and per the Regs. At 4.4.8.3.1 and needs to be reconsidered by the TC for the next edition of the document.

The comment will resolve the discrepancy between the Table 130.5(G) and 130.7(C)(6)

Since in the Table 130.5(G) the requirement to wear arc rated clothing are defined when energy exposures are
equal to 1.2 cal/cm2' (in fact this is the minimum incident energy required to produce a second-degree burn.)
while the 130.7 (C)(6) states that "employees shall wear arc rated clothing wherever there is possible exposure
to and electric arc above the threshold energy 1.2 cal/cm2.

This discrepancy leaves room for interpretation when to wear arc rated clothing.

Submitter Information Verification

Submitter Full Name:	NFPA Holds
Organization:	Technical Committee on Electrical Safety in the Workplace
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Thu Jun 06 21:37:57 EDT 2024
Committee:	EEW-AAA

Committee Statement

Resolution: FR-51-NFPA 70E-2024

Statement: Stating the requirement in terms of incident energy correlates with the definition of arc flash boundary, which is “an approach limit from an arc source at which incident energy

equals 1.2 cal/cm2 (5 J/cm2).”

This revision also correlates with Table 130.5(G), which requires arc flash protection when the incident energy exposure is equal to or greater than 1.2 cal/cm2.

Public Comment No. 20-NFPA 70E-2022 [Section No. 130.7(C)(6)]

(6) Body Protection.

Employees shall wear arc-rated clothing wherever there is possible exposure to an electric arc flash equal or above the threshold incident energy level for a second degree burn [1.2 cal/cm^2 (5 J/cm^2)].

Additional Proposed Changes

File Name	Description	Approved
NFPA70E_2021_discrepancy_when_to_use_arc_rated_PPE.JPG	NFPA70E 2021 discrepancy when to use arc rated PPE	

Statement of Problem and Substantiation for Public Comment

The comment will resolve the discrepancy between the Table 130.5(G) and 130.7(C)(6)

Since in the Table 130.5(G) the requirement to wear arc rated clothing are defined when energy exposures are equal to 1.2 cal/cm2' (in fact this is the minimum incident energy required to produce a second-degree burn.) while the 130.7 (C)(6) states that "employees shall wear arc rated clothing wherever there is possible exposure to and electric arc above the threshold energy 1.2 cal/cm2.

This discrepancy leaves room for interpretation when to wear arc rated clothing.

Related Item

• No Public Comments are available

Submitter Information Verification

Submitter Full Name: Pierluca Cerrato
Organization: ASML
Street Address:
City:
State:
Zip:
Submittal Date: Fri Mar 25 10:23:22 EDT 2022
Committee: EEW-AAA

Committee Statement

Committee Action: Rejected but held

Resolution: The text proposed by this public comment does not meet 4.4.4.2 of the Regulations Governing Committee Projects which requires public comments to be related to material that has received public review either through the submission of Public Input, Committee Input or Correlating Input or through the First Revisions.

NFPA 70E 2021 Discrepancy when Arc rated PPE is required

130.5 (G)

Table 130.5(G) Selection of Arc-Rated Clothing and Other PPE When the Incident Energy Analysis Method Is Used

Incident energy exposures equal to 1.2 cal/cm² up to and including 12 cal/cm²
Arc-rated clothing with an arc rating equal to or greater than the estimated incident energy[a]
Arc-rated long-sleeve shirt and pants or arc-rated coverall or arc flash suit (SR)
Arc-rated face shield and arc-rated balaclava or arc flash suit hood (SR)[b]
Arc-rated outerwear (e.g., jacket, parka, rainwear, hard hat liner, high-visibility apparel) (AN)[c]
Heavy-duty leather gloves, arc-rated gloves, or rubber insulating gloves with leather protectors (SR)[c]
Hard hat
Safety glasses or safety goggles (SR)
Hearing protection
Leather footwear[d]

130.7 (C) (6)

(6) Body Protection. Employees shall wear arc-rated clothing wherever there is possible exposure to an electric arc flash above the threshold incident energy level for a second degree burn [1.2 cal/cm² (5 J/cm²)].

Public Input No. 98-NFPA 70E-2024 [Section No. 130.7(C)(6)]

(6) Body Protection.

Employees shall wear arc-rated clothing wherever there is possible exposure to an electric arc flash ~~above the~~ equal to or greater than the threshold incident energy level for a second degree burn [1.2 cal/cm^2 (5 J/cm^2)].

Statement of Problem and Substantiation for Public Input

Using the word "above" in the following existing text "there is a possible exposure to an electric arc flash above the threshold incident energy level" is not inclusive of 1.2 cal/cm2 which contradicts other language.

Example of the contradiction is "Table 130.5(G) Incident energy exposures equal to 1.2 cal/cm2 up to 12 cal/cm2" - In this language 1.2 cal/cm2 is included.

Submitter Information Verification

Submitter Full Name: k James Phillips Jr
Organization: Brainfiller
Street Address:
City:
State:
Zip:

Submittal Date: Mon May 27 05:03:47 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-51-NFPA 70E-2024

Statement: Stating the requirement in terms of incident energy correlates with the definition of arc flash boundary, which is “an approach limit from an arc source at which incident energy equals 1.2 cal/cm2 (5 J/cm2).”

This revision also correlates with Table 130.5(G), which requires arc flash protection when the incident energy exposure is equal to or greater than 1.2 cal/cm2.

Public Input No. 278-NFPA 70E-2024 [New Section after 130.7(C)(7)]

Table 130.7(C)(7)(b), Rubber Insulating Equipment, Maximum Test Intervals

Floor mattng If insulating value is suspect

Additional Proposed Changes

File Name	Description	Approved
70E_PC_24_Hold.pdf	70E_PC24	

Statement of Problem and Substantiation for Public Input

NOTE: This Public Input appeared as “Reject but Hold” in Public Comment No. 24 of the (A2023) Second Draft Report for NFPA 70E and per the Regs. At 4.4.8.3.1 and needs to be reconsidered by the TC for the next edition of the document.

Rubber "switchboard" floor matting is commonly used in many installations to help minimize employee exposure
to step and touch hazards.

There is no periodic retesting for rubber floor matting per ASTM D178 just like there is none for rubber covers
and line hose which are both listed in Table 130.7(C)(7)(b)

Submitter Information Verification

Submitter Full Name:	NFPA Holds
Organization:	Technical Committee on Electrical Safety in the Workplace
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Thu Jun 06 21:44:44 EDT 2024
Committee:	EEW-AAA

Committee Statement

Resolution: Table 130.7(C)(7)(b) contains requirements for maximum test intervals for rubber insulating equipment. “Matting” is not added because there are no methods for in-service testing of insulative matting and matting is not referenced in the standard.

Public Comment No. 24-NFPA 70E-2022 [New Section after 130.7(C)(7)]

Table 130.7(C)(7)(b), Rubber Insulating Equipment, Maximum Test Intervals

Floor matting	If insulating value is suspect

Additional Proposed Changes

File Name	Description	Approved
New_addition_to_Table_130.7_C_7_b_for_rubber_switchboard_matting.docx	Add rubber switchboard floor matting to Table 130.7(C)(7)(b)	

Statement of Problem and Substantiation for Public Comment

Rubber "switchboard" floor matting is commonly used in many installations to help minimize employee exposure to step and touch hazards.
There is no periodic retesting for rubber floor matting per ASTM D178 just like there is none for rubber covers and line hose which are both listed in Table 130.7(C)(7)(b)

Related Public Comments for This Document

Related Comment	Relationship
Public Comment No. 23-NFPA 70E-2022 [New Section after 130.7(E)]	Rubber floor matting per ASTM D178

Related Item

- PI

Submitter Information Verification

Submitter Full Name: George Cole
Organization: PVNGS/APS
Street Address:
City:
State:
Zip:
Submittal Date: Mon Mar 28 21:17:31 EDT 2022
Committee: EEW-AAA

Committee Statement

Committee Action: Rejected but held

Resolution: The text proposed by this public comment does not meet 4.4.4.2 of the Regulations Governing Committee Projects which requires public comments to be related to material that has received public review either through the submission of Public Input, Committee Input or Correlating Input or through the First Revisions.

2024 NFPA 70E new addition to Table 130.7(C)(7)(b)
George T. Cole

Add the following to **Table 130.7(C)(7)(b), Rubber Insulating Equipment, Maximum Test Intervals**

Rubber Insulating Equipment	When to Test
Floor matting	If insulating value is suspect

Public Input No. 270-NFPA 70E-2024 [Section No. 130.7(C)(7)]

(7) Hand and Arm Protection.

Hand and arm protection shall be provided in accordance with 130.7(C)(7)(a), (C)(7)(b), and (C)(7)(c).

(a) *Electric Shock Protection.* Employees shall wear rubber insulating gloves with protectors where there is a danger of hand injury from electric shock due to contact with exposed energized electrical conductors or circuit parts. Employees shall wear rubber insulating gloves with protectors and rubber insulating sleeves where there is a danger of hand and arm injury from electric shock due to contact with exposed energized electrical conductors or circuit parts. Rubber insulating gloves shall be rated for the voltage for which the gloves will be exposed. Rubber insulating gloves shall be permitted to be used without protectors, under the following conditions:

(2) There shall be no activity performed that risks cutting or damaging the glove.

(3) The rubber insulating gloves shall be electrically retested before reuse.

(4) The voltage rating of the rubber insulating gloves shall be reduced by 50 percent for class 00 and by one whole class for classes 0 through 4.

(e) *Arc Flash Protection.* Hand and arm protection shall be worn where there is possible exposure to arc flash burn. The apparel described in 130.7(C)(10)(d) shall be required for protection of hands from burns. Arm protection shall be accomplished by the apparel described in 130.7(C)(6).

(f) *Maintenance and Use.* Electrical protective equipment shall be maintained in a safe, reliable condition. Insulating equipment shall be inspected for damage before each day's use and immediately following any incident that can reasonably be suspected of having caused damage. Insulating gloves shall be given an air test, along with the inspection. Maximum use voltages for rubber insulating gloves shall not exceed that specified in Table 130.7(C)(7)(a). The top of the cuff of the protector glove shall be shorter than the rolled top of the cuff of the insulating glove by at least the distance specified in Table 130.7(C)(7)(a).

(g) *Periodic Electrical Tests*. Rubber insulating equipment shall be subjected to periodic electrical tests. Test voltages shall be in accordance with applicable state, federal, or local codes and standards. The maximum intervals between tests shall not exceed that specified in Table 130.7(C)(7)(b).

Informational Note: See OSHA 29 CFR 1910.137; ASTM F478, *Standard Specification for In-Service Care of Insulating Line Hose and Covers*; ASTM F479, *Standard Specification for In-Service Care of Insulating Blankets*; and ASTM F496, *Standard Specification for In-Service Care of Insulating Gloves and Sleeves*, which contain information related to in-service and testing requirements for rubber insulating equipment.

Table 130.7(C)(7)(a) Maximum Use Voltage for Rubber Insulating Gloves

Class Designation of Glove or Sleeve	Maximum ac Use Voltage rms, volts	Maximum dc Use Voltage avg, volts	Distances Between Protector Cuff and Rubber Insulating Glove Cuff, minimum
00	500	750	13 mm (0.5 in.)
0	1,000	1,500	13 mm (0.5 in.)
1	7,500	11,250	25 mm (1 in.)
2	17,000	25,500	51 mm (2 in.)
3	26,500	39,750	76 mm (3 in.)
4	36,000	54,000	102 mm (4 in.)

Table 130.7(C)(7)(b) Rubber Insulating Equipment, Maximum Test Intervals

Rubber Insulating Equipment	When to Test
Blankets	Before first issue; every 12 months thereafter*
Covers	If insulating value is suspect
Gloves	Before first issue; every 6 months thereafter*
Line hose	If insulating value is suspect
Sleeves	Before first issue; every 12 months thereafter*
Matting	If insulating value is suspect

*New insulating equipment is not permitted to be placed into service unless it has been electrically tested within the previous 12 months. Insulating equipment that has been issued for service is not new and is required to be retested in accordance with the intervals in this table.

Additional Proposed Changes

File Name	Description	Approved
70E_PC_6_Hold.pdf	70E_PC6	

Statement of Problem and Substantiation for Public Input

NOTE: This Public Input appeared as “Reject but Hold” in Public Comment No. 6 of the (A2023) Second Draft Report for NFPA 70E and per the Regs. At 4.4.8.3.1 and needs to be reconsidered by the TC for the next edition of the document.

The problem is where do I find out when or if there is a testing interval for rubber insulating matting? This would
clarify when or if rubber insulating matting (ASTM D178) should be tested.

Submitter Information Verification

Submitter Full Name: NFPA Holds

Organization: Technical Committee on Electrical Safety in the Workplace

Street Address:

City:

State:

Zip:

Submittal Date: Thu Jun 06 21:15:37 EDT 2024

Committee: EEW-AAA

Committee Statement

Resolution: Table 130.7(C)(7)(b) contains requirements for maximum test intervals for rubber insulating equipment. “Matting” is not added because there are no methods for in-service testing of insulative matting and matting is not referenced in the standard.

Public Comment No. 6-NFPA 70E-2022 [Section No. 130.7(C)(7)]

(7) Hand and Arm Protection.

Hand and arm protection shall be provided in accordance with 130.7(C)(7)(a), (C)(7)(b), and (C)(7)(c).

(a) *Shock Protection.* Employees shall wear rubber insulating gloves with protectors where there is a danger of hand injury from electric shock due to contact with exposed energized electrical conductors or circuit parts. Employees shall wear rubber insulating gloves with protectors and rubber insulating sleeves where there is a danger of hand and arm injury from electric shock due to contact with exposed energized electrical conductors or circuit parts. Rubber insulating gloves shall be rated for the voltage for which the gloves will be exposed. Rubber insulating gloves shall be permitted to be used without protectors, under the following conditions:

(2) There shall be no activity performed that risks cutting or damaging the glove.

(3) The rubber insulating gloves shall be electrically retested before reuse.

(4) The voltage rating of the rubber insulating gloves shall be reduced by 50 percent for class 00 and by one whole class for classes 0 through 4.

(e) *Arc Flash Protection.* Hand and arm protection shall be worn where there is possible exposure to arc flash burn. The apparel described in 130.7(C)(10)(d) shall be required for protection of hands from burns. Arm protection shall be accomplished by the apparel described in 130.7(C)(6).

(f) *Maintenance and Use.* Electrical protective equipment shall be maintained in a safe, reliable condition. Insulating equipment shall be inspected for damage before each day's use and immediately following any incident that can reasonably be suspected of having caused damage. Insulating gloves shall be given an air test, along with the inspection. Maximum use voltages for rubber insulating gloves shall not exceed that specified in Table 130.7(C)(7)(a). The top of the cuff of the protector glove shall be shorter than the rolled top of the cuff of the insulating glove by at least the distance specified in Table 130.7(C)(7)(a).

(g) *Periodic Electrical Tests*. Rubber insulating equipment shall be subjected to periodic electrical tests. Test voltages shall be in accordance with applicable state, federal, or local codes and standards. The maximum intervals between tests shall not exceed that specified in Table 130.7(C)(7)(b).

Informational Note: See OSHA 29 CFR 1910.137; ASTM F478, *Standard Specification for In-Service Care of Insulating Line Hose and Covers*; ASTM F479, *Standard Specification for In-Service Care of Insulating Blankets*; and ASTM F496, *Standard Specification for In-Service Care of Insulating Gloves and Sleeves*, which contain information related to in-service and testing requirements for rubber insulating equipment.

Table 130.7(C)(7)(a) Maximum Use Voltage for Rubber Insulating Gloves

Class Designation of Glove or Sleeve	Maximum ac Use Voltage rms, volts	Maximum dc Use Voltage avg, volts	Distances Between Protector Cuff and Rubber Insulating Glove Cuff, minimum
00	500	750	13 mm (0.5 in.)
0	1,000	1,500	13 mm (0.5 in.)
1	7,500	11,250	25 mm (1 in.)
2	17,000	25,500	51 mm (2 in.)
3	26,500	39,750	76 mm (3 in.)
4	36,000	54,000	102 mm (4 in.)

Table 130.7(C)(7)(b) Rubber Insulating Equipment, Maximum Test Intervals

Rubber Insulating Equipment	When to Test
Blankets	Before first issue; every 12 months thereafter*
Covers	If insulating value is suspect
Gloves	Before first issue; every 6 months thereafter*
Line hose	If insulating value is suspect
Sleeves	Before first issue; every 12 months thereafter*
Matting	If insulating value is suspect

*New insulating equipment is not permitted to be placed into service unless it has been electrically tested

within the previous 12 months. Insulating equipment that has been issued for service is not new and is required to be retested in accordance with the intervals in this table.

Statement of Problem and Substantiation for Public Comment

The problem is where do I find out when or if there is a testing interval for rubber insulating matting? This would clarify when or if rubber insulating matting (ASTM D178) should be tested.

Related Item

• Rubber Insulating Matting

Submitter Information Verification

Submitter Full Name: Daryl Colloms
Organization: DENSO
Street Address:
City:
State:
Zip:
Submittal Date: Mon Mar 07 12:30:40 EST 2022
Committee: EEW-AAA

Committee Statement

Committee Action: Rejected but held

Resolution: The text proposed by this public comment does not meet 4.4.4.2 of the Regulations Governing Committee Projects which requires public comments to be related to material that has received public review either through the submission of Public Input, Committee Input or Correlating Input or through the First Revisions.

Public Input No. 280-NFPA 70E-2024 [Section No. 130.7(C)(7)]

(7) Hand and Arm Protection.

Hand and arm protection shall be provided in accordance with 130.7(C)(7)(a), (C)(7)(b), and (C)(7)(c).

(a) *Electric Shock Protection.* Employees shall wear rubber insulating gloves with protectors where there is a danger of hand injury from electric shock due to contact with exposed energized electrical conductors or circuit parts. Employees shall wear rubber insulating gloves with protectors and rubber insulating sleeves where there is a danger of hand and arm injury from electric shock due to contact with exposed energized electrical conductors or circuit parts. Rubber insulating gloves shall be rated for the voltage for which the gloves will be exposed. Rubber insulating gloves shall be permitted to be used without protectors, under the following conditions:

(2) There shall be no activity performed that risks cutting or damaging the glove.

(3) The rubber insulating gloves shall be electrically retested before reuse.

(4) The voltage rating of the rubber insulating gloves shall be reduced by 50 percent for class 00 and by one whole class for classes 0 through 4.

(e) *Arc Flash Protection.* Hand and arm protection shall be worn where there is possible exposure to arc flash burn. The apparel described in 130.7(C)(10)(d) shall be required for protection of hands from burns. Arm protection shall be accomplished by the apparel described in 130.7(C)(6).

(f) *Maintenance and Use.* Electrical protective equipment shall be maintained in a safe, reliable condition. Insulating equipment shall be inspected for damage before each day's use and immediately following any incident that can reasonably be suspected of having caused damage. Insulating gloves shall be given an air test, along with the inspection. Maximum use voltages for rubber insulating gloves shall not exceed that specified in Table 130.7(C)(7)(a). The top of the cuff of the protector glove shall be shorter than the rolled top of the cuff of the insulating glove by at least the distance specified in Table 130.7(C)(7)(a).

(g) *Periodic Electrical Tests*. Rubber insulating equipment shall be subjected to periodic electrical tests. Test voltages shall be in accordance with applicable state, federal, or local codes and standards. The maximum intervals between tests shall not exceed that specified in Table 130.7(C)(7)(b).

Informational Note: See OSHA 29 CFR 1910.137; ASTM F478, *Standard Specification for In-Service Care of Insulating Line Hose and Covers*; ASTM F479, *Standard Specification for In-Service Care of Insulating Blankets*; and ASTM F496, *Standard Specification for In-Service Care of Insulating Gloves and Sleeves*, which contain information related to in-service and testing requirements for rubber insulating equipment.

Table 130.7(C)(7)(a) Maximum Use Voltage for Rubber Insulating Gloves

Class Designation of Glove or Sleeve	Maximum ac Use Voltage rms, volts	Maximum dc Use Voltage avg, volts	Distances Between Protector Cuff and Rubber Insulating Glove Cuff, minimum
00	500	750	13 mm (0.5 in.)
0	1,000	1,500	13 mm (0.5 in.)
1	7,500	11,250	25 mm (1 in.)
2	17,000	25,500	51 mm (2 in.)
3	26,500	39,750	76 mm (3 in.)
4	36,000	54,000	102 mm (4 in.)

Table 130.7(C)(7)(b) Rubber Insulating Equipment, Maximum Test Intervals

Rubber Insulating Equipment	When to Test
Blankets	Before first issue; every 12 months thereafter*
Covers	If insulating value is suspect
Gloves	Before first issue; every 6 months thereafter*
Line hose	If insulating value is suspect
Sleeves	Before first issue; every 12 months thereafter*

*New insulating equipment is not permitted to be placed into service unless it has been electrically tested within the previous 12 months. Insulating equipment that has been issued for service is not new and is required to be retested in accordance with the intervals in this table.

(e) Thermal Hand Protection . Hand protection shall, unless justified, be worn where there is possible exposure to

a thermal electrical hazard. Light-duty leather gloves, heavy-duty leather gloves, or arc-rated leather gloves shall

be worn where required for thermal protection. Shock and arc flash PPE provide protection from thermal

hazards.

The employer may justify alternative hand protection or proscription of thermal hand protection based on

increased exposure to chemical or other hazards.

Informational note 1: Thermal hazards can be present in electrical systems where the limited and restricted

approach boundaries are not defined. Specifically, ac and dc systems below their shock threshold voltage with

more than 1000 watts of available short circuit power can still expose a worker to a thermal electrical hazard.

Thermal hazards are common in batteries where an accidental short circuit could cause thermal burns. Using

insulated tools when working around batteries significantly reduces the risk of short circuit, and therefor thermal

burns, but does not prevent short circuits caused by things other than the worker’s tools. See Article 320 for more

information about safety requirements related to batteries and battery rooms.

Informational note 2: Assembly of small lithium-ion batteries is an example where the fire risks associated with an

accidental short circuit are much greater than the thermal burn risks to the worker. The manual dexterity lost by

warring thermal hand protection can increase the likelihood of a short circuit leading to greater overall risk to the worker.

Additional Proposed Changes

File Name	Description	Approved

70E_PC_57_Hold.pdf 70E_PC57

Statement of Problem and Substantiation for Public Input

NOTE: This Public Input appeared as “Reject but Hold” in Public Comment No. 57 of the (A2023) Second Draft Report for NFPA 70E and per the Regs. At 4.4.8.3.1 and needs to be reconsidered by the TC for the next edition of the document.

Changes to article 320 (FR-101 and FR-102) identify a thermal hazard but to not identify proper thermal hand
protection. This addition simply corrects that oversight.

Submitter Information Verification

Submitter Full Name:	NFPA Holds
Organization:	Technical Committee on Electrical Safety in the Workplace
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Thu Jun 06 21:53:12 EDT 2024
Committee:	EEW-AAA

Committee Statement

Resolution: FR-103-NFPA 70E-2024

Statement: This revision adds general PPE requirements for the hands, where exposed to a contact thermal hazard. See new definition for thermal contact hazard.

Public Comment No. 57-NFPA 70E-2022 [Section No. 130.7(C)(7)]

(7) Hand and Arm Protection.

Hand and arm protection shall be provided in accordance with 130.7(C)(7)(a), (C)(7)(b), and (C)(7)(c).

(a) *Shock Protection.* Employees shall wear rubber insulating gloves with protectors where there is a danger of hand injury from electric shock due to contact with exposed energized electrical conductors or circuit parts. Employees shall wear rubber insulating gloves with protectors and rubber insulating sleeves where there is a danger of hand and arm injury from electric shock due to contact with exposed energized electrical conductors or circuit parts. Rubber insulating gloves shall be rated for the voltage for which the gloves will be exposed. Rubber insulating gloves shall be permitted to be used without protectors, under the following conditions:

(2) There shall be no activity performed that risks cutting or damaging the glove.

(3) The rubber insulating gloves shall be electrically retested before reuse.

(4) The voltage rating of the rubber insulating gloves shall be reduced by 50 percent for class 00 and by one whole class for classes 0 through 4.

(e) *Arc Flash Protection.* Hand and arm protection shall be worn where there is possible exposure to arc flash burn. The apparel described in 130.7(C)(10)(d) shall be required for protection of hands from burns. Arm protection shall be accomplished by the apparel described in 130.7(C)(6).

(f) *Maintenance and Use.* Electrical protective equipment shall be maintained in a safe, reliable condition. Insulating equipment shall be inspected for damage before each day's use and immediately following any incident that can reasonably be suspected of having caused damage. Insulating gloves shall be given an air test, along with the inspection. Maximum use voltages for rubber insulating gloves shall not exceed that specified in Table 130.7(C)(7)(a). The top of the cuff of the protector glove shall be shorter than the rolled top of the cuff of the insulating glove by at least the distance specified in Table 130.7(C)(7)(a).

(g) *Periodic Electrical Tests*. Rubber insulating equipment shall be subjected to periodic electrical tests. Test voltages shall be in accordance with applicable state, federal, or local codes and standards. The maximum intervals between tests shall not exceed that specified in Table 130.7(C)(7)(b).

Informational Note: See OSHA 29 CFR 1910.137; ASTM F478, *Standard Specification for In-Service Care of Insulating Line Hose and Covers*; ASTM F479, *Standard Specification for In-Service Care of Insulating Blankets*; and ASTM F496, *Standard Specification for In-Service Care of Insulating Gloves and Sleeves*, which contain information related to in-service and testing requirements for rubber insulating equipment.

Table 130.7(C)(7)(a) Maximum Use Voltage for Rubber Insulating Gloves

Class Designation of Glove or Sleeve	Maximum ac Use Voltage rms, volts	Maximum dc Use Voltage avg, volts	Distances Between Protector Cuff and Rubber Insulating Glove Cuff, minimum
00	500	750	13 mm (0.5 in.)
0	1,000	1,500	13 mm (0.5 in.)
1	7,500	11,250	25 mm (1 in.)
2	17,000	25,500	51 mm (2 in.)
3	26,500	39,750	76 mm (3 in.)
4	36,000	54,000	102 mm (4 in.)

Table 130.7(C)(7)(b) Rubber Insulating Equipment, Maximum Test Intervals

Rubber Insulating Equipment	When to Test
Blankets	Before first issue; every 12 months thereafter*
Covers	If insulating value is suspect
Gloves	Before first issue; every 6 months thereafter*
Line hose	If insulating value is suspect
Sleeves	Before first issue; every 12 months thereafter*

*New insulating equipment is not permitted to be placed into service unless it has been electrically tested within the previous 12 months. Insulating equipment that has been issued for service is not new and is

required to be retested in accordance with the intervals in this table.

(e) *Thermal Hand Protection* . Hand protection shall, unless justified, be worn where there is possible exposure to a thermal electrical hazard. Light-duty leather gloves, heavy-duty leather gloves, or arc-rated leather gloves shall be worn where required for thermal protection. Shock and arc flash PPE provide protection from thermal hazards.

The employer may justify alternative hand protection or proscription of thermal hand protection based on increased exposure to chemical or other hazards.

Informational note 1: Thermal hazards can be present in electrical systems where the limited and restricted approach boundaries are not defined. Specifically, ac and dc systems below their shock threshold voltage with more than 1000 watts of available short circuit power can still expose a worker to a thermal electrical hazard. Thermal hazards are common in batteries where an accidental short circuit could cause thermal burns. Using insulated tools when working around batteries significantly reduces the risk of short circuit, and therefor thermal burns, but does not prevent short circuits caused by things other than the worker's tools. See Article 320 for more information about safety requirements related to batteries and battery rooms.

Informational note 2: Assembly of small lithium-ion batteries is an example where the fire risks associated with an accidental short circuit are much greater than the thermal burn risks to the worker. The manual dexterity lost by warring thermal hand protection can increase the likelihood of a short circuit leading to greater overall risk to the worker.

Statement of Problem and Substantiation for Public Comment

Changes to article 320 (FR-101 and FR-102) identify a thermal hazard but to not identify proper thermal hand protection. This addition simply corrects that oversight.

Related Public Comments for This Document

Related Comment	Relationship
Public Comment No. 60-NFPA 70E-2022 [Section No. 320.3(A)(2)]	

Related Item

• FR-101 • FR-102

Submitter Information Verification

Submitter Full Name: David Rosewater
Organization: Sandia National Laboratories
Affiliation: IEEE Energy Storage and Stationary Battery Committee
Street Address:
City:
State:
Zip:
Submittal Date: Fri May 27 12:33:47 EDT 2022
Committee: EEW-AAA

Committee Statement

Committee Action: Rejected but held

Resolution: The text proposed by this public comment does not meet 4.4.4.2 of the Regulations Governing Committee Projects which requires public comments to be related to material that has received public review either through the submission of Public Input, Committee Input or Correlating Input or through the First Revisions.

Public Input No. 121-NFPA 70E-2024 [Section No. 130.7(C)(10)]

(10) Arc Flash Protective Equipment.

(a) *Arc Flash Suits.* Arc flash suit design shall permit easy and rapid removal by the wearer. The entire arc flash suit, including the hood's face shield, shall have an arc rating that is suitable for the arc flash exposure. When exterior air is supplied into the hood, the air hoses and pump housing shall be either covered by arc-rated materials or constructed of nonmelting and nonflammable materials.

(b) *Head Protection.*

(3) An arc-rated hood or an arc-rated balaclava with an arc-rated face shield shall be used when the back of the head is within the arc flash boundary.

(4) An arc-rated hood shall be used when the anticipated incident energy exposure exceeds 12 cal/cm^2 (50.2 J/cm^2).

(e) *Face Protection.* Face shields shall have an arc rating suitable for the arc flash exposure. Face shields with a wrap-around guarding to protect the face, chin, forehead, ears, and neck area shall be used. Face shields without an arc rating shall not be used. Eye protection (safety glasses or goggles) shall always be worn under face shields or hoods.

Informational Note: Face shields made with energy-absorbing formulations that can provide higher levels of protection from the radiant energy of an arc flash are available, but these shields are tinted and can reduce visual acuity and color perception. Additional illumination of the task area might be necessary when these types of arc-protective face shields are used.

(f) *Hand Protection.* Gloves shall have an arc rating suitable for the arc flash exposure. Arc flash exposure for hands shall consider the actual working distance of the hands.

(7) Heavy-duty leather gloves or arc-rated gloves shall be worn where required for arc flash protection.

Informational Note: Heavy-duty leather gloves are made entirely of leather with minimum thickness of 0.03 in. (0.7 mm) and are unlined or lined with nonflammable, nonmelting fabrics. Heavy-duty leather gloves meeting this requirement have been shown to have ATPV values in excess of 10 cal/cm^2 (41.9 J/cm^2).

(8) Where insulating rubber gloves are used for electric shock protection, protectors shall be worn over the rubber gloves.

Informational Note: The protectors worn over rubber insulating gloves provide additional arc flash protection for the hands for arc flash protection exposure.

(i) *Foot Protection.* Leather footwear or dielectric footwear or both provide some arc flash protection to the feet and shall be used in all exposures greater than 4 cal/cm^2 (16.75 J/cm^2). Footwear other than leather or dielectric shall be permitted to be used provided it has been tested to demonstrate no ignition, melting, or dripping at the estimated incident energy exposure or the minimum arc rating for the respective arc flash PPE category.

Additional Proposed Changes

File Name	Description	Approved
Arc_Flash_Inceident.jpg	ARc Flash Hand Burn	

Statement of Problem and Substantiation for Public Input

Arc flash clothing, head, and face protection (130.7(C)(10)(a), (b) and (c) each require that they shall have arc flash rating that is suitable for the arc flash exposure yet we currently exclude this requirements for hand protection. The hands are often more exposed and closer to the hazard than any other part of the body. They need to be protected from this exposure. An example of an accident is pictured where the hands were protected with leather gloves for calculated 3.7 cal/cm2 arc flash where the worker received 3rd degree burns is provided.

Submitter Information Verification

Submitter Full Name: Karl Cunningham
Organization: Self Employed
Street Address:
City:
State:
Zip:

Submittal Date: Sat Jun 01 07:14:36 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: The requirement for suitably rated arc flash protection for the hands and the possibility that the hands could be closer than the assumed working distance that is used to determine incident energy is already addressed in 130.5(G), which states: “Arc-rated clothing and other PPE shall be used by the worker and selected on the basis of the incident energy exposure associated with the specific task. Recognizing that incident energy increases as the distance from the arc flash decreases, additional PPE shall be used for any parts of the body that are closer than the working distance at which the incident energy was determined.”

Public Input No. 258-NFPA 70E-2024 [Section No. 130.7(C)(10)]

(10) Arc Flash Protective Equipment.

(a) *Arc Flash Suits.* Arc flash suit design shall permit easy and rapid removal by the wearer. The entire arc flash suit, including the hood's face shield, shall have an arc rating that is suitable for the arc flash exposure. When exterior air is supplied into the hood, the air hoses and pump housing shall be either covered by arc-rated materials or constructed of nonmelting and nonflammable materials.

(b) *Head Protection.*

(3) An arc-rated hood or an arc-rated balaclava with an arc-rated face shield shall be used when the back of the head is within the arc flash boundary.

(4) An arc-rated hood shall be used when the anticipated incident energy exposure exceeds 12 cal/cm^2 (50.2 J/cm^2).

(e) *Face Protection.* Face shields shall have an arc rating suitable for the arc flash exposure. Face shields with a wrap-around guarding to protect the face, chin, forehead, ears, and neck area shall be used. Face shields without an arc rating shall not be used. ~~Eye protection (safety glasses or goggles) shall always be worn under face shields or hoods.~~

Informational Note: Face shields made with energy-absorbing formulations that can provide higher levels of protection from the radiant energy of an arc flash are available, but these shields are tinted and can reduce visual acuity and color perception. Additional illumination of the task area might be necessary when these types of arc-protective face shields are used.

(f) *Hand Protection.*

(7) Heavy-duty leather gloves or arc-rated gloves shall be worn where required for arc flash protection.

Informational Note: Heavy-duty leather gloves are made entirely of leather with minimum thickness of 0.03 in. (0.7 mm) and are unlined or lined with nonflammable, nonmelting fabrics. Heavy-duty leather gloves meeting this requirement have been shown to have ATPV values in excess of 10 cal/cm^2 (41.9 J/cm^2).

(8) Where insulating rubber gloves are used for electric shock protection, protectors shall be worn over the rubber gloves.

Informational Note: The protectors worn over rubber insulating gloves provide additional arc flash protection for the hands for arc flash protection exposure.

(i) *Foot Protection.* Leather footwear or dielectric footwear or both provide some arc flash protection to the feet and shall be used in all exposures greater than 4 cal/cm^2 (16.75 J/cm^2). Footwear other than leather or dielectric shall be permitted to be used provided it has been tested to demonstrate no ignition, melting, or dripping at the estimated incident energy exposure or the minimum arc rating for the respective arc flash PPE category.

Statement of Problem and Substantiation for Public Input

Using both safety glasses and a face shield presents unique issues that at detrimental to working in a live electrical cabinet. Using both when the bend radius do not match gives glare and some parallax error. This leads to squinting and movement of the head to get a better view and distracts from the work. The shield in both the switching hood and the face shield meet ANSI standards for safety glasses. In areas of humidity the proximity of the safety glasses to the face and the trapped air from breathing cause the safety glasses to fog and decrease visibility - increasing the potential for errors.

Submitter Information Verification

Submitter Full Name: Ron White
Organization: Johnson and Johnson
Affiliation: Self
Street Address:
City:
State:
Zip:

Submittal Date: Tue Jun 04 16:37:09 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: While face shields may be shown to meet ANSI/ISEA Z87.1, face shields do not necessarily provide protection from flying objects going under or around the face shield.

Public Input No. 26-NFPA 70E-2023 [Section No. 130.7(C)(10)]

(10) Arc Flash Protective Equipment.

(a) *Arc Flash Suits.* Arc flash suit design shall permit easy and rapid removal by the wearer. The entire arc flash suit, including the hood's face shield, shall have an arc rating that is suitable for the arc flash exposure. When exterior air is supplied into the hood, the air hoses and pump housing shall be either covered by arc-rated materials or constructed of nonmelting and nonflammable materials.

(b) *Head Protection.*

(3) An arc-rated hood or an arc-rated balaclava with an arc-rated face shield shall be used when the back of the head is within the arc flash boundary.

(4) An arc-rated hood shall be used when the anticipated incident energy exposure exceeds 12 cal/cm^2 (50.2 J/cm^2).

(e) *Face Protection.* Face shields shall have an arc rating suitable for the arc flash exposure. Face shields with a wrap-around guarding to protect the face, chin, forehead, ears, and neck area shall be used. Face shields without an arc rating shall not be used. Eye protection (safety glasses or goggles) shall always be worn under face shields or hoods.

Exception: Where face shields or hoods offer eye protection that meets the requirements of ANSI/ISEA Z87.1, safety glasses or goggles shall not be required to be worn under the face shield or hood.

Informational Note: Face shields made with energy-absorbing formulations that can provide higher levels of protection from the radiant energy of an arc flash are available, but these shields are tinted and can reduce visual acuity and color perception. Additional illumination of the task area might be necessary when these types of arc-protective face shields are used. Some newer faceshields or hoods offer rated eye protection in addition to arc flash protection.

(f) *Hand Protection.*

(7) Heavy-duty leather gloves or arc-rated gloves shall be worn where required for arc flash protection.

Informational Note: Heavy-duty leather gloves are made entirely of leather with minimum thickness of 0.03 in. (0.7 mm) and are unlined or lined with nonflammable, nonmelting fabrics. Heavy-duty leather gloves meeting this requirement have been shown to have ATPV values in excess of 10 cal/cm^2 (41.9 J/cm^2).

(8) Where insulating rubber gloves are used for electric shock protection, protectors shall be worn over the rubber gloves.

Informational Note: The protectors worn over rubber insulating gloves provide additional arc flash protection for the hands for arc flash protection exposure.

(i) *Foot Protection.* Leather footwear or dielectric footwear or both provide some arc flash protection to the feet and shall be used in all exposures greater than 4 cal/cm^2 (16.75 J/cm^2). Footwear other than leather or dielectric shall be permitted to be used provided it has been tested to demonstrate no ignition, melting, or dripping at the estimated incident energy exposure or the minimum arc rating for the respective arc flash PPE category.

Statement of Problem and Substantiation for Public Input

The requirement for always wearing eye protection under the arc flash faceshield or hood was based on older technology. Newer faceshields and hoods are coming out with stamped Z87.1 eye protection built-in. This public input offers an exception to the rule, provided the faceshield or hood is properly rated.

Submitter Information Verification

Submitter Full Name: Mark Scott
Organization: Lawrence Berkeley National Lab
Street Address:
City:
State:
Zip:

Submittal Date: Thu Nov 02 11:54:20 EDT 2023
Committee: EEW-AAA

Committee Statement

Resolution: While face shields may be shown to meet ANSI/ISEA Z87.1, face shields do not necessarily provide protection from flying objects going under or around the face shield.

Public Input No. 285-NFPA 70E-2024 [Section No. 130.7(C)(10)]

NOTE: This Public Input appeared as “Reject but Hold” in Public Comment No. 142 of the (A2023) Second Draft Report for NFPA 70E and per the Regs. At 4.4.8.3.1 and needs to be reconsidered by the TC for the next edition of the document.

(10) Arc Flash Protective Equipment.

(a) *Arc Flash Suits.* Arc flash suit design shall permit easy and rapid removal by the wearer. The entire arc flash suit, including the hood’s face shield, shall have an arc rating that is suitable for the arc flash exposure. When exterior air is supplied into the hood, the air hoses and pump housing shall be either covered by arc-rated materials or constructed of nonmelting and nonflammable materials.

(b) *Head Protection.*

(3) An arc-rated hood or an arc-rated balaclava with an arc-rated face shield shall be used when the back of the head is within the arc flash boundary.

(4) An arc-rated hood shall be used when the anticipated incident energy exposure exceeds 12 cal/cm^2 (50.2 J/cm^2).

(e) *Face Protection.* Face shields shall have an arc rating suitable for the arc flash exposure. Face shields with a wrap-around guarding to protect the face, chin, forehead, ears, and neck area shall be used. Face shields without an arc rating shall not be used. Eye protection (safety glasses or goggles) shall always be worn under face shields or hoods.

Informational Note: Face shields made with energy-absorbing formulations that can provide higher levels of protection from the radiant energy of an arc flash are available, but these shields are tinted and can reduce visual acuity and color perception. Additional illumination of the task area might be necessary when these types of arc-protective face shields are used.

(f) *Hand Protection.*

(7) Heavy-duty leather gloves or arc-rated gloves shall be worn where required for arc flash protection.

Informational Note: Heavy-duty leather gloves are made entirely of leather with minimum thickness of 0.03 in. (0.7 mm) and are unlined or lined with nonflammable, nonmelting fabrics. Heavy-duty leather gloves meeting this requirement have been shown to have ATPV values in excess of 10 cal/cm^2 (41.9 J/cm^2).

(8) Where insulating rubber gloves are used for electric shock protection, protectors shall be worn over the rubber gloves.

Informational Note: The protectors worn over rubber insulating gloves provide additional arc flash protection for the hands for arc flash protection exposure.

(i) *Foot Protection.* Leather footwear or dielectric footwear or both provide some arc flash protection to the feet and shall be used in all exposures greater than 4 cal/cm^2 (16.75 J/cm^2). Footwear other than leather or dielectric shall be permitted to be used provided it has been tested to demonstrate no ignition, melting, or dripping at the estimated incident energy exposure or the minimum arc rating for the respective arc flash PPE category.

Additional Proposed Changes

File Name	Description	Approved
70E_PC_142_Hold.pdf	70E_PC142	

Statement of Problem and Substantiation for Public Input

NOTE: This Public Input appeared as “Reject but Hold” in Public Comment No. 142 of the (A2023) Second Draft Report for NFPA 70E and per the Regs. At 4.4.8.3.1 and needs to be reconsidered by the TC for the next edition of the document.

Leather protectors for rubber insulating gloves are now commercially available with an arc rating and an
accompanying APTV designation. Therefore a new informational note #1 should be added to article 130.7(F)
(8)(d)(2) informing readers that these new products offer greater protection of the hands from arc flash hazards
than traditional leather protectors because of the arc rating provides a known level of protection.
My power plant had a significant arc flash incident during April 2021 in a 480 volt MCC that had an incident
energy level of approximately 12 cal/cm2 at 18". The electricians were wearing a 40 cal/cm2 arc flash suit and
hood to protect their body. However they were wearing class 0 rubber insulating gloves with a new arc rated
leather protectors with an APTV of 36 cal/cm2. When the arc flash occured, the hands of the electricians were
directly next to the arc source and well within the working distance. While the AR leather protector suffered a
great deal of heat damage, no part of the protector suffered breakopen nor did the threads of the fingers fail.
When the protector was turned inside out, there was no visible sign of heat transfer to the interior portion and the
rubber glove fingers were totally unaffected by the heat, consequently the worker did not even suffer a first
degree burn.

Submitter Information Verification

Submitter Full Name:	NFPA Holds
Organization:	Technical Committee on Electrical Safety in the Workplace
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Thu Jun 06 22:14:18 EDT 2024
Committee:	EEW-AAA

Committee Statement

Resolution: The requirement for suitably rated arc flash protection for the hands and the possibility that the hands could be closer than the assumed working distance that is used to determine incident energy is already addressed in 130.5(G), which states: “Arc-rated clothing and other PPE shall be used by the worker and selected on the basis of the incident energy exposure associated with the specific task. Recognizing that incident energy increases as the distance from the arc flash decreases, additional PPE shall be used for any parts of the body that are closer than the working distance at which the incident energy was determined.”

Public Comment No. 142-NFPA 70E-2022 [Section No. 130.7(C)(10)]

(10) Arc Flash Protective Equipment.

(a) *Arc Flash Suits.* Arc flash suit design shall permit easy and rapid removal by the wearer. The entire arc flash suit, including the hood's face shield, shall have an arc rating that is suitable for the arc flash exposure. When exterior air is supplied into the hood, the air hoses and pump housing shall be either covered by arc-rated materials or constructed of nonmelting and nonflammable materials.

(b) *Head Protection.*

(3) An arc-rated hood or an arc-rated balaclava with an arc-rated face shield shall be used when the back of the head is within the arc flash boundary.

(4) An arc-rated hood shall be used when the anticipated incident energy exposure exceeds 12 cal/cm^2 (50.2 J/cm^2).

(e) *Face Protection.* Face shields shall have an arc rating suitable for the arc flash exposure. Face shields with a wrap-around guarding to protect the face, chin, forehead, ears, and neck area shall be used. Face shields without an arc rating shall not be used. Eye protection (safety glasses or goggles) shall always be worn under face shields or hoods.

Informational Note: Face shields made with energy-absorbing formulations that can provide higher levels of protection from the radiant energy of an arc flash are available, but these shields are tinted and can reduce visual acuity and color perception. Additional illumination of the task area might be necessary when these types of arc-protective face shields are used.

(f) *Hand Protection.*

(7) Heavy-duty leather gloves or arc-rated gloves shall be worn where required for arc flash protection.

Informational Note: Heavy-duty leather gloves are made entirely of leather with minimum thickness of 0.03 in. (0.7 mm) and are unlined or lined with nonflammable, nonmelting fabrics. Heavy-duty leather gloves meeting this requirement have been shown to have ATPV values in excess of 10 cal/cm^2 (41.9 J/cm^2).

(8) Where insulating rubber gloves are used for shock protection, protectors shall be worn over the rubber gloves.

Informational Note: The protectors worn over rubber insulating gloves provide additional arc flash protection for the hands for arc flash protection exposure.

Informational Note 1: Arc rated protectors with an APTV rating worn over rubber insulating gloves provide a greater level of arc flash protection for the hands than offered by standard leather protectors for arc flash protection exposure.

(i) *Foot Protection.* Leather footwear or dielectric footwear or both provide some arc flash protection to the feet and shall be used in all exposures greater than 4 cal/cm^2 (16.75 J/cm^2). Footwear other than leather or dielectric shall be permitted to be used provided it has been tested to demonstrate no ignition, melting, or dripping at the estimated incident energy exposure or the minimum arc rating for the respective arc flash PPE category.

Statement of Problem and Substantiation for Public Comment

Leather protectors for rubber insulating gloves are now commercially available with an arc rating and an accompanying APTV designation. Therefore a new informational note #1 should be added to article 130.7(F)(8)(d)(2) informing readers that these new products offer greater protection of the hands from arc flash hazards than traditional leather protectors because of the arc rating provides a known level of protection.
My power plant had a significant arc flash incident during April 2021 in a 480 volt MCC that had an incident energy level of approximately 12 cal/cm2 at 18". The electricians were wearing a 40 cal/cm2 arc flash suit and hood to protect their body. However they were wearing class 0 rubber insulating gloves with a new arc rated leather protectors with an APTV of 36 cal/cm2. When the arc flash occured, the hands of the electricians were directly next to the arc source and well within the working distance. While the AR leather protector suffered a great deal of heat damage, no part of the protector suffered breakopen nor did the threads of the fingers fail. When the protector was turned inside out, there was no visible sign of heat transfer to the interior portion and the rubber glove fingers were totally unaffected by the heat, consequently the worker did not even suffer a first degree burn.

Related Item

• PI

Submitter Information Verification

Submitter Full Name: George Cole
Organization: PVNGS/APS
Street Address:
City:
State:
Zip:
Submittal Date: Tue May 31 20:37:57 EDT 2022
Committee: EEW-AAA

Committee Statement

Committee Action: Rejected but held

Resolution: The text proposed by this public comment does not meet 4.4.4.2 of the Regulations Governing Committee Projects which requires public comments to be related to material that has received public review either through the submission of Public Input, Committee Input or Correlating Input or through the First Revisions.

Public Input No. 86-NFPA 70E-2024 [Section No. 130.7(C)(10)]

(10) Arc Flash Protective Equipment.

(a) *Arc Flash Suits.* Arc flash suit design shall permit easy and rapid removal by the wearer. The entire arc flash suit, including the hood's face shield, shall have an arc rating that is suitable for the arc flash exposure. When exterior air is supplied into the hood, the air hoses and pump housing shall be either covered by arc-rated materials or constructed of nonmelting and nonflammable materials.

(b) *Head Protection.*

(3) An arc-rated hood or an arc-rated balaclava with an arc-rated face shield shall be used when the back of the head is within the arc flash boundary.

(4) An arc-rated hood shall be used when the anticipated incident energy exposure exceeds 12 cal/cm^2 (50.2 J/cm^2).

(e) *Face Protection.* Face shields shall have an arc rating suitable for the arc flash exposure. Face shields with a wrap-around guarding to protect the face, chin, forehead, ears, and neck area shall be used. Face shields without an arc rating shall not be used. Eye protection (safety glasses or goggles) shall always be worn under face shields or hoods.

Informational Note: Face shields made with energy-absorbing formulations that can provide higher levels of protection from the radiant energy of an arc flash are available, but these shields are tinted and can reduce visual acuity and color perception. Additional illumination of the task area might be necessary when these types of arc-protective face shields are used.

(f) *Hand Protection.*

(7) Heavy-duty leather gloves or arc-rated gloves shall be worn where required for arc flash protection.

Informational Note: Heavy-duty leather gloves are made entirely of leather with minimum thickness of 0.03 in. (0.7 mm) and are unlined or lined with nonflammable, nonmelting fabrics. Heavy-duty leather gloves meeting this requirement have been shown to have ATPV values in excess of 10 cal/cm^2 (41.9 J/cm^2).

(8) Where insulating rubber gloves are used for electric shock protection, protectors shall be worn over the rubber gloves.

Informational Note: The protectors worn over rubber insulating gloves provide additional arc flash protection for the hands for arc flash protection exposure.

(i) *Foot Protection.* Leather footwear or dielectric footwear or both provide some arc flash protection to the feet and shall be used in all exposures greater than 4 cal/cm^2 (16.75 J/cm^2) The statement "shall be used in all exposures greater than 4 cal" is contradictory with Table 130 .5(G) which states leather footwear is required above 1.2 cal. Footwear other than leather or dielectric shall be permitted to be used provided it has been tested to demonstrate no ignition, melting, or dripping at the estimated incident energy exposure or the minimum arc rating for the respective arc flash PPE category.

Statement of Problem and Substantiation for Public Input

Either remove the reference to 4 cal in in 130.7 or elaborate in Table 130.5(G) and maybe expand footnote "d" to speak to the 4 cal requirement.

Submitter Information Verification

Submitter Full Name: Nic Houston
Organization: UCOR
Street Address:
City:
State:
Zip:
Submittal Date: Tue May 14 05:50:09 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: This public input sought to delete the 4 cal/cm2 requirement in 130.7(C)(10) or modify the permissive table in 130.5(G). Neither of these suggestions are necessary or provide clarity. The use of Table 130.5(G) is permitted, it is not required. However, the threshold of 4 cal/cm2 for foot protection is required.

Public Input No. 181-NFPA 70E-2024 [Section No. 130.7(C)(12)]

(12) Clothing and Other Apparel Not Permitted.

Clothing and other apparel (such as hard hat liners and hair nets) made from materials that do not meet the requirements of 130.7(C)(11) regarding melting or made from materials that do not meet the flammability requirements shall not be permitted to be worn.

Informational Note: Some flame-resistant fabrics, such as non-flame-resistant modacrylic and nondurable flame-retardant treatments of cotton, are not recommended for industrial electrical or utility applications.

Exception No. 1: Nonmelting, flammable (non-arc-rated) materials shall be permitted to be used as underlayers to arc-rated clothing, as described in 130.7(C)(11).

Exception No. 2: Where the work to be performed inside the arc flash boundary exposes the worker to multiple hazards, such as the addition of airborne contaminants, ~~and the~~ a job risk assessment ~~identifies that the level of protection is adequate to address the arc flash hazard, non-arc-rated PPE shall be permitted.~~ shall be conducted to determine the proper risk control methiods needed to provide the worker proper protection form all hazards.

Statement of Problem and Substantiation for Public Input

The proposed text re-states the requirement that a job risk assessment be conducted and more generally allows the proper risk control methods to be determined based on the results of that assessment.,

Submitter Information Verification

Submitter Full Name: David Pace
Organization: Olin Corporation
Affiliation: Self
Street Address:
City:
State:
Zip:

Submittal Date: Mon Jun 03 16:05:22 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: Exception No. 2 is a very specific exception that permits non-arc rated PPE only when the protection is adequate to address the arc flash hazard. Where the arc flash hazard is low enough that non arc-rated PPE is acceptable, then other PPE (for example, dust masks or respirators) that don't meet the requirements of 130.7(C)(11) should be acceptable, but without the exception as currently written, they would not be acceptable.

Public Input No. 184-NFPA 70E-2024 [Section No. 130.7(C)(14)]

(14) Standards for PPE.

(a) *General.* PPE shall conform to applicable state, federal, or local codes and standards.

Informational Note No. 1: See Informational Note Table 130.7(C)(14) for a list of examples of standards that contain information on the care, inspection, testing, and manufacturing of PPE.

Informational Note No. 2: See 130.7(C)(11) and 130.7(C)(12) for requirements on non-arc-rated or flammable fabrics not covered by any of the standards in Informational Note Table 130.7(C)(14).

(b) *Conformity Assessment.* All suppliers or manufacturers of PPE shall demonstrate conformity with an appropriate product standard by one of the following methods:

(3) Self-declaration with a Supplier's Declaration of Conformity

(4) Self-declaration under a registered quality management system and product testing by an accredited laboratory and a Supplier's Declaration of Conformity

(5) Certification by an accredited independent third-party certification organization

Informational Note No. 1: See Informative Annex H.4 and ANSI/ISEA 125, *American National Standard for Conformity Assessment of Safety and Personal Protective Equipment*, for examples of a process for conformity assessment to an appropriate product standard.

Informational Note No. 2: See ISO 17065, *Conformity assessment — Requirements for bodies certifying products, processes, and services*, for an example of a process to accredit independent third-party certification organizations.

(f) *Marking.* All suppliers or manufacturers of PPE shall provide the following information on the PPE, on the smallest unit container, or contained within the manufacturer's instructions:

(7) Name of manufacturer

(8) Product performance standards to which the product conforms

(9) Conformity assessment method used by the supplier

(10) Arc rating where appropriate for the equipment

(11) One or more identifiers such as model, serial number, lot number, or traceability code

(12) Care instructions

Table Informational Note Table 130.7(C)(14) Standards for PPE

Subject	Document Title	Document Number	
Clothing — Arc Rated	Standard Performance Specification for Flame Resistant and Electric Arc Rated Protective Clothing Worn by Workers Exposed to Flames and Electric Arcs	ASTM F1506	
	-	Standard Guide for Industrial Laundering of Flame, Thermal, and Arc Resistant Clothing	ASTM F1449
	-	Standard Guide for Home Laundering Care and Maintenance of Flame, Thermal and Arc Resistant Clothing	ASTM F2757

Subject	Document Title	Document Number	
	-	Live working — Protective clothing against the thermal hazards of an electric arc — Part 1-1: Test methods — Method 1: Determination of the arc rating (ELIM, ATPV, and/or EBT) of clothing materials and of protective clothing using an open arc	IEC 61482–1–1
	-	Live working — Protective clothing against the thermal hazards of an electric arc — Part 2: Requirements	IEC 61482–2
Aprons — Insulating	Standard Specification for Electrically Insulating Aprons	ASTM F2677	
Eye and Face Protection — General	American National Standard for Occupational and Educational Professional Eye and Face Protection	ANSI/ISEA Z87.1	
Face — Arc Rated	Standard Test Method for Determining the Arc Rating and Standard Specification for Personal Eye or Face Protective Products	ASTM F2178	
Fall Protection	Standard Specification for Personal Climbing Equipment	ASTM F887	
Footwear — Dielectric Specification	Standard Specification for Dielectric Footwear	ASTM F1117	
Footwear — Dielectric Test Method	Standard Test Method for Determining Dielectric Strength of Dielectric Footwear	ASTM F1116	
Footwear — Standard Performance Specification	Standard Specification for Performance Requirements for Protective (Safety) Toe Cap Footwear	ASTM F2413	
Footwear — Standard Test Method	Standard Test Methods for Foot Protections	ASTM F2412	
Gloves — Arc Rated	Standard Test Method for Determining Arc Ratings of Hand Protective Products Developed and Used for Electrical Arc Flash Protection	ASTM F2675/F2675M	
Gloves — Leather Protectors	Standard Specification for Leather Protectors for Rubber Insulating Gloves and Mittens	ASTM F696	
Gloves — Non-Leather Protectors	Standard Specification for Protectors for Rubber Insulating Gloves Meeting Specific Performance Requirements	ASTM F3258	

Subject	Document Title	Document Number
Gloves — Rubber Insulating	Standard Specification for Rubber Insulating Gloves	ASTM D120
Gloves and Sleeves — In-Service Care	Standard Specification for In-Service Care of Insulating Gloves and Sleeves	ASTM F496
Head Protection — Hard Hats	American National Standard for Head Protection	ANSI/ISEA Z89.1
Rainwear — Arc Rated	Standard Specification for Arc and Flame Resistant Rainwear	ASTM F1891
Rubber Protective Products — Visual Inspection	Standard Guide for Visual Inspection of Electrical Protective Rubber Products	ASTM F1236
Sleeves — Insulating	Standard Specification for Rubber Insulating Sleeves	ASTM D1051

Statement of Problem and Substantiation for Public Input

this PI only involves the addition of the new c (3) to require communication of which conformity method was used by the supplier. This is similar to the "CE" marking on test equipment as it allows the user to understand that device was self certified by the manufacturer as being compliant with applicable standards.

Submitter Information Verification

Submitter Full Name: David Pace
Organization: Olin Corporation
Affiliation: Self
Street Address:
City:
State:
Zip:

Submittal Date: Mon Jun 03 16:27:14 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-53-NFPA 70E-2024
Statement: This adds the “conformity assessment method used by the supplier” to the marking information that suppliers or manufacturers must provide to assist the purchaser of the PPE to make an informed decision on choosing PPE that is appropriate for their particular purchase.

Public Input No. 59-NFPA 70E-2024 [Section No. 130.7(C)(14)]

(14) Standards for PPE.

(a) *General.* PPE shall conform to applicable state, federal, or local codes and standards.

Informational Note No. 1: See Informational Note Table 130.7(C)(14) for a list of examples of standards that contain information on the care, inspection, testing, and manufacturing of PPE.

Informational Note No. 2: See 130.7(C)(11) and 130.7(C)(12) for requirements on non-arc-rated or flammable fabrics not covered by any of the standards in Informational Note Table 130.7(C)(14).

(b) *Conformity Assessment.* All suppliers or manufacturers of PPE shall demonstrate conformity with an appropriate product standard~~ by one of the following methods:~~

(3) ~~Self-declaration with a Supplier's Declaration of Conformity~~

(4) ~~Self-declaration under a registered quality management system and product testing by an accredited laboratory and a Supplier's Declaration of Conformity~~

~~Certification by an~~ , Listing and Certification program by an International accredited independent third-party certification organization that Inspects the manufacturing facility where the certified product is manufactured and undergoes through annual recertification compliance.

(5)

Informational Note No. 1: See Informative Annex H.4 and ANSI/ISEA 125, *American National Standard for Conformity Assessment of Safety and Personal Protective Equipment* , for examples of a process for conformity assessment to an appropriate product standard.

Informational Note No. 2: See ISO 17065, *Conformity assessment — Requirements for bodies certifying products, processes, and services* , for an example of a process to accredit independent third-party certification organizations.

(f) *Marking.* All suppliers or manufacturers of PPE shall provide the following information on the PPE, on the smallest unit container, or contained within the manufacturer's instructions:

(7) Name of manufacturer

(8) Product performance standards to which the product conforms

(9) Arc rating where appropriate for the equipment

(10) One or more identifiers such as model, serial number, lot number, or traceability code

(11) Care instructions

Table Informational Note Table 130.7(C)(14) Standards for PPE

Subject	Document Title	Document Number	
Clothing — Arc Rated	Standard Performance Specification for Flame Resistant and Electric Arc Rated Protective Clothing Worn by Workers Exposed to Flames and Electric Arcs	ASTM F1506	
	-	Standard Guide for Industrial Laundering of Flame, Thermal, and Arc Resistant Clothing	ASTM F1449
	-	Standard Guide for Home Laundering Care and Maintenance of Flame,	ASTM F2757

Subject	Document Title	Document Number	
		Thermal and Arc Resistant Clothing	
	-	Live working — Protective clothing against the thermal hazards of an electric arc — Part 1-1: Test methods — Method 1: Determination of the arc rating (ELIM, ATPV, and/or EBT) of clothing materials and of protective clothing using an open arc	IEC 61482–1–1
	-	Live working — Protective clothing against the thermal hazards of an electric arc — Part 2: Requirements	IEC 61482–2
Aprons — Insulating	Standard Specification for Electrically Insulating Aprons	ASTM F2677	
Eye and Face Protection — General	American National Standard for Occupational and Educational Professional Eye and Face Protection	ANSI/ISEA Z87.1	
Face — Arc Rated	Standard Test Method for Determining the Arc Rating and Standard Specification for Personal Eye or Face Protective Products	ASTM F2178	
Fall Protection	Standard Specification for Personal Climbing Equipment	ASTM F887	
Footwear — Dielectric Specification	Standard Specification for Dielectric Footwear	ASTM F1117	
Footwear — Dielectric Test Method	Standard Test Method for Determining Dielectric Strength of Dielectric Footwear	ASTM F1116	
Footwear — Standard Performance Specification	Standard Specification for Performance Requirements for Protective (Safety) Toe Cap Footwear	ASTM F2413	
Footwear — Standard Test Method	Standard Test Methods for Foot Protections	ASTM F2412	
Gloves — Arc Rated	Standard Test Method for Determining Arc Ratings of Hand Protective Products Developed and Used for Electrical Arc Flash Protection	ASTM F2675/F2675M	
Gloves — Leather Protectors	Standard Specification for Leather Protectors for Rubber Insulating Gloves and Mittens	ASTM F696	
Gloves — Non-Leather Protectors	Standard Specification for Protectors for Rubber Insulating Gloves Meeting Specific Performance Requirements	ASTM F3258	

Subject	Document Title	Document Number
Gloves — Rubber Insulating	Standard Specification for Rubber Insulating Gloves	ASTM D120
Gloves and Sleeves — In-Service Care	Standard Specification for In-Service Care of Insulating Gloves and Sleeves	ASTM F496
Head Protection — Hard Hats	American National Standard for Head Protection	ANSI/ISEA Z89.1
Rainwear — Arc Rated	Standard Specification for Arc and Flame Resistant Rainwear	ASTM F1891
Rubber Protective Products — Visual Inspection	Standard Guide for Visual Inspection of Electrical Protective Rubber Products	ASTM F1236
Sleeves — Insulating	Standard Specification for Rubber Insulating Sleeves	ASTM D1051

Statement of Problem and Substantiation for Public Input

Non-compliances and standards evasion based on current uncontrolled manufacturing that still results on having non-compliant and non safety PPE in all industries and in multiple countries currently.

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Committee: EEW-AAA

Committee Statement

Resolution: FR-54-NFPA 70E-2024

Statement: Arc-rated PPE is important for worker safety. While most arc-rated PPE manufacturers are reliable, merely relying upon self-certification by the arc-rated PPE manufacturer is insufficient to ensure that the PPE provides the appropriate level of protection. All other PPE must conform to 130.7(C)(14)(a).

Public Input No. 11-NFPA 70E-2023 [Section No. 130.7(C)(15)]

(15) Arc Flash PPE Category Method.

The requirements of 130.7(C)(15) shall apply when the arc flash PPE category method is used for the selection of arc flash PPE.

Informational Note: For both ac and dc systems, the arc flash PPE category of the protective clothing and equipment is generally based on determination of the estimated exposure level.

(a) *Alternating Current (ac) Equipment.* When the arc flash risk assessment performed in accordance with 130.5 indicates that arc flash PPE is required and the arc flash PPE category method is used for the selection of PPE for ac systems in lieu of the incident energy analysis of 130.5(G), Table 130.7(C)(15)(a) shall be used to determine the arc flash PPE category. The estimated maximum available fault current, maximum fault-clearing times, and minimum working distances for various ac equipment types or classifications are listed in Table 130.7(C)(15)(a). An incident energy analysis shall be required in accordance with 130.5(G) for the following:

(2) Power systems with greater than the

~~estimated maximum available~~

(1) estimated available fault current

(2) Power systems with longer than the maximum fault clearing times

(3) Less than the minimum working distance

(c) *Direct Current (dc) Equipment.* When the arc flash risk assessment performed in accordance with 130.5(G) indicates that arc flash PPE is required and the arc flash PPE category method is used for the selection of PPE for dc systems in lieu of the incident energy analysis of 130.5(G), Table 130.7(C)(15)(b) shall be used to determine the arc flash PPE category. The estimated maximum available fault current, maximum arc duration, and working distances for dc equipment are listed in 130.7(C)(15)(b). An incident energy analysis shall be required in accordance with 130.5(G) for the following:

(4) Power systems with greater than the estimated maximum available fault current

(5) Power systems with longer than the maximum arc duration

(6) Less than the minimum working distance

(g) *Protective Clothing and Personal Protective Equipment (PPE).* Once the arc flash PPE category has been identified from Table 130.7(C)(15)(a) or Table 130.7(C)(15)(b), Table 130.7(C)(15)(c) shall be used to determine the required PPE. Table 130.7(C)(15)(c) lists the requirements for PPE based on arc flash PPE categories 1 through 4. This clothing and equipment shall be used when working within the arc flash boundary. The use of PPE other than or in addition to that listed shall be permitted provided it meets 130.7(C)(7).

Informational Note No. 1: See Informative Annex H for a suggested simplified approach to ensure adequate PPE for electrical workers within facilities with large and diverse electrical systems.

Informational Note No. 2: The PPE requirements of this section are intended to protect a person from arc flash hazards. While some situations could result in burns to the skin even with the protection described in Table 130.7(C)(15)(c), burn injury should be reduced and survivable. Due to the explosive effect of some arc events, physical trauma injuries could occur. The PPE requirements of this section do not address protection against physical trauma other than exposure to the thermal effects of an arc flash.

Informational Note No. 3: The arc rating for a particular clothing system can be obtained from the arc-rated clothing manufacturer.

Table 130.7(C)(15)(a) Arc Flash PPE Categories for Alternating Current (ac) Systems

Equipment	Arc Flash PPE Category	Arc Flash Boundary
Panelboards or other equipment rated 240 volts and below	1	485 mm (19 in.)
Parameters: Maximum of 25 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
Panelboards or other equipment rated greater than 240 volts and up to 600 volts	2	900 mm (3 ft)
Parameters: Maximum of 25 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class motor control centers (MCCs)	2	1.5 m (5 ft)
Parameters: Maximum of 65 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class motor control centers (MCCs)	4	4.3 m (14 ft)
Parameters: Maximum of 42 kA available fault current; maximum of 0.33 sec (20 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class switchgear (with power circuit breakers or fused switches) and 600-volt class switchboards	4	6 m (20 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.5 sec (30 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
Other 600-volt class (277 volts through 600 volts, nominal) equipment	2	1.5 m (5 ft)
Parameters: Maximum of 65 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
NEMA E2 (fused contactor) motor starters, 2.3 kV through 7.2 kV	4	12 m (40 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault	-	-

Equipment	Arc Flash PPE Category	Arc Flash Boundary
clearing time; minimum working distance 910 mm (36 in.)		
Metal-clad switchgear, 1 kV through 15 kV	4	12 m (40 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	-	-
Metal enclosed interrupter switchgear, fused or unfused type construction, 1 kV through 15 kV Parameters: Maximum of 35 kA available fault current; maximum of 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	4	12 m (40 ft)
Other equipment 1 kV through 15 kV Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	4	12 m (40 ft)
Arc-resistant equipment up to 600-volt class Parameters: DOORS CLOSED and SECURED; with an available fault current and a fault clearing time that does not exceed the arc-resistant rating of the equipment*	N/A	N/A
Arc-resistant equipment 1 kV through 15 kV	N/A	N/A
Parameters: DOORS CLOSED and SECURED; with an available fault current and a fault clearing time that does not exceed the arc-resistant rating of the equipment*	-	-

N/A: Not applicable

Note:

For equipment rated 600 volts and below and protected by upstream current-limiting fuses or current-limiting molded case circuit breakers sized at 200 amperes or less, the arc flash PPE category can be reduced by one number but not below arc flash PPE category 1.

*For DOORS OPEN refer to the corresponding non-arc-resistant equipment section of this table.

Informational Note No. 1 to Table 130.7(C)(15)(a): The following are typical fault clearing times of overcurrent protective devices:

(1) 0.5 cycle fault clearing time is typical for current-limiting fuses and current-limiting molded case circuit breakers when the fault current is within the current limiting range.

(2) 1.5 cycle fault clearing time is typical for molded case circuit breakers rated less than 1000 volts with an instantaneous integral trip.

(3) 3.0 cycle fault clearing time is typical for insulated case circuit breakers rated less than 1000 volts with an instantaneous integral trip or relay operated trip.

(4) 5.0 cycle fault clearing time is typical for relay operated circuit breakers rated 1 kV to 35 kV when the relay operates in the instantaneous range (i.e., “no intentional delay”).

(5) 20 cycle fault clearing time is typical for low-voltage power and insulated case circuit breakers with a short time fault clearing delay for motor inrush.

(6) 30 cycle fault clearing time is typical for low-voltage power and insulated case circuit breakers with a short time fault clearing delay without instantaneous trip.

Informational Note No. 2 to Table 130.7(C)(15)(a): See Table 1 of IEEE 1584, *Guide for Performing Arc Flash Hazard Calculations*, for further information regarding list items (2) through (4) in Informational Note No. 1.

Informational Note No. 3 to Table 130.7(C)(15)(a): See IEEE C37.20.7, *Guide for Testing Switchgear Rated Up to 52 kV for Internal Arcing Faults*, for an example of a standard that provides information for arc-resistant equipment referred to in Table 130.7(C)(15)(a).

Informational Note No. 4 to Table 130.7(C)(15)(a): See Informative Annex O.2.4(9) for information on arc-resistant equipment.

Table 130.7(C)(15)(b) Arc Flash PPE Categories for dc Systems

Equipment	**Arc Flash PPE Category**	**Arc Flash Boundary**
Storage batteries, dc switchboards, and other dc supply sources	-	-
Parameters: Greater than 150 volts and less than or equal to 600 volts	-	-
Maximum arc duration and minimum working distance: 2 sec @ 455 mm (18 in.)	-	-
Available fault current less than 1.5 kA	2	900 mm
		- - (3 ft)
Available fault current greater than or equal to 1.5 kA and less than 3 kA	2	1.2 m
		- - (4 ft)
Available fault current greater than or equal to 3 kA and less than 7 kA	3	1.8 m
		- - (6 ft.)
Available fault current greater than or equal to 7 kA and less than 10 kA	4	2.5 m
		- - (8 ft)

Notes:

(1) Apparel that can be expected to be exposed to electrolyte must meet both of the following conditions:

(a) Be evaluated for electrolyte protection

Informational Note: See ASTM F1296, *Standard Guide for Evaluating Chemical Protective Clothing*, for information on evaluating apparel for protection from electrolyte.

(b) Be arc rated

Informational Note: See ASTM F1891, *Standard Specification for Arc and Flame Resistant Rainwear*, for information on evaluating arc-rated apparel.

(2) A two-second arc duration is assumed if there is no overcurrent protective device (OCPD) or if the fault clearing time is not known. If the fault clearing time is known and is less than 2 seconds, an incident energy analysis could provide a more representative result.

Informational Note No. 1: See D.5 for the basis for table values and alternative methods to determine dc incident energy. Methods should be used with good engineering judgment. When determining available fault current, the effects of cables and any other impedances in the circuit should be included. Power system modeling is the best method to determine the available short-circuit current at the point of the arc. Battery cell short-circuit current can be obtained from the battery manufacturer.

Informational Note No. 2: The methods for estimating the dc arc flash incident energy that were used to determine the categories for this table are based on open-air incident energy calculations. Open-air calculations were used because many battery systems and other dc process systems are in open areas or rooms. If the specific task is within an enclosure, it would be prudent to consider additional PPE protection beyond the value shown in this table.

Informational Note No. 3: See the following references for dc voltages below 150 volts nominal:

(1) J. G. Hildreth and K. Feeney, “Arc Flash Hazards Station Battery Systems,” 2018 IEEE Power & Energy Society General Meeting (PESGM), 2018, pp. 1–5.

(2) US Department of Energy Bonneville Power Administration Engineering and Technical Services Report BPA F 5450.05, “DC Arc Flash: 125V, 1300 amp-hour battery,” May 11, 2017, doi: 10.1109/PESGM.2018.8586181.

(3) K. Gray, S. Robert, and T. L. Gauthier, "Low Voltage 100–500 Vdc Arc Flash Testing," 2020 IEEE IAS Electrical Safety Workshop (ESW), 2020, pp. 1–7, doi: 10.1109/ESW42757.2020.9188336.

Table 130.7(C)(15)(c) Personal Protective Equipment (PPE)

Arc-Flash PPE Category	PPE	
1	**Arc-Rated Clothing, Minimum Arc Rating of 4 cal/cm^2 (16.75 J/cm^2)**[a]	
	-	Arc-rated long-sleeve shirt and pants or arc-rated coverall
	-	Arc-rated face shield[b] or arc flash suit hood
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]

Arc-Flash PPE Category	PPE	
	-	Heavy-duty leather gloves, arc-rated gloves, or rubber insulating gloves with protectors (SR)[d]
	-	Leather footwear[e] (AN)
2	**Arc-Rated Clothing, Minimum Arc Rating of 8 cal/cm^2 (33.5 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt and pants or arc-rated coverall
	-	Arc-rated flash suit hood or arc-rated face shield[b] and arc-rated balaclava
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Heavy-duty leather gloves, arc-rated gloves, or rubber insulating gloves with protectors (SR)[d]
	-	Leather footwear[e]
3	**Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 25 cal/cm^2 (104.7 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt (AR)
	-	Arc-rated pants (AR)
	Arc-rated coverall (AR)	
	-	Arc-rated arc flash suit jacket (AR)
	Arc-rated arc flash suit pants (AR)	
	-	Arc-rated arc flash suit hood
	-	Arc-rated gloves or rubber insulating gloves with protectors (SR)[d]
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**

Arc-Flash PPE Category	PPE	
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Leather footwear[e]
4	**Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 40 cal/cm^2 (167.5 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt (AR)
	-	Arc-rated pants (AR)
	Arc-rated coverall (AR)	
	-	Arc-rated arc flash suit jacket (AR)
	Arc-rated arc flash suit pants (AR)	
	-	Arc-rated arc flash suit hood
	-	Arc-rated gloves or rubber insulating gloves with protectors (SR)[d]
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Leather footwear[e]

AN: As needed (optional). AR: As required. SR: Selection required.

[a] *Arc rating* is defined in Article 100.

[b] Face shields are to have wrap-around guarding to protect not only the face but also the forehead, ears, and neck, or, alternatively, an arc-rated arc flash suit hood is required to be worn.

[c] Other types of hearing protection are permitted to be used in lieu of or in addition to ear canal inserts provided they are worn under an arc-rated arc flash suit hood.

[d] Rubber insulating gloves with protectors provide arc flash protection in addition to electric shock protection. Higher class rubber insulating gloves with protectors, due to their increased material thickness, provide increased arc flash protection.

[e] Footwear other than leather or dielectric shall be permitted to be used provided it has been tested to demonstrate no ignition, melting or dripping at the minimum arc rating for the respective arc flash PPE category.

[f]The arc rating of outer layers worn over arc-rated clothing as protection from the elements or for other safety purposes, and that are not used as part of a layered system, shall not be required to be equal to or greater than the estimated incident energy exposure.

Statement of Problem and Substantiation for Public Input

The recommendation is to remove the word "maximum" in (15)(a)(1) since the meaning as it now reads is the maximum largest available fault current since the definition of available fault current indicates that it the the "largest amount of current." It is incorrect and unnecessary to have both "maximum" and "largest" in (1).

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Submittal Date: Thu Aug 24 11:03:07 EDT 2023
Committee: EEW-AAA

Committee Statement

Resolution: FR-55-NFPA 70E-2024

Statement: The qualifier “maximum” is deleted in front of “available fault current” in 130.7(C)(15)(a)(1) and 130.7(C)(15)(b)(1).

This revision is necessary to correlate with the definition of Available Fault Current. There is no such thing as the maximum largest.

The section was revised to comply with the NEC Style Manual Section 3.5.1.2 Multiple Requirements.

Table 130.7(C)(15)(a): This revision correlates with revisions in the parent text of 130.7(C)(15)(a) and 130.7(C)(15)(b). In both of these revisions the qualifier “maximum” which was used to describe available fault current was deleted. The defined term “Fault Current, Available (Available Fault Current”, in Article 100 clarifies that it is the largest amount of current capable of being delivered at a point on the system during a short-circuit condition. A similar revision is made to all references of available fault current and fault clearing time in Table 130.7(C)(15)(a) for clarity and usability.

Table 130.7(C)(15(a) Informational Note No. 1: List items (2) through (6) are modified for clarity and correlation with list item (1).

Table 130.7(C)(15(a) Informational Note No.2: Table 1 of IEEE 1584 as referenced in the informational note is from the 2002 edition. The table is not included in the 2018 Edition of IEEE 1584. The year of the edition is added for clarification.

Table 130.7(C)(15)(c): The modifiers “arc-rated” and “arc” are added to the table for correlation and clarity.

Public Input No. 12-NFPA 70E-2023 [Section No. 130.7(C)(15)]

(15) Arc Flash PPE Category Method.

The requirements of 130.7(C)(15) shall apply when the arc flash PPE category method is used for the selection of arc flash PPE.

Informational Note: For both ac and dc systems, the arc flash PPE category of the protective clothing and equipment is generally based on determination of the estimated exposure level.

(a) *Alternating Current (ac) Equipment.* When the arc flash risk assessment performed in accordance with 130.5 indicates that arc flash PPE is required and the arc flash PPE category method is used for the selection of PPE for ac systems in lieu of the incident energy analysis of 130.5(G), Table 130.7(C)(15)(a) shall be used to determine the arc flash PPE category. The estimated maximum available fault current, maximum fault-clearing times, and minimum working distances for various ac equipment types or classifications are listed in Table 130.7(C)(15)(a). An incident energy analysis shall be required in accordance with 130.5(G) for the following:

(2) Power systems with greater than the estimated maximum available fault current

(3) Power systems with longer than the maximum fault clearing times

(4) Less than the minimum working distance

(e) *Direct Current (dc) Equipment.* When the arc flash risk assessment performed in accordance with 130.5(G) indicates that arc flash PPE is required and the arc flash PPE category method is used for the selection of PPE for dc systems in lieu of the incident energy analysis of 130.5(G), Table 130.7(C)(15)(b) shall be used to determine the arc flash PPE category. The estimated maximum available fault current, maximum arc duration, and working distances for dc equipment are listed in 130.7(C)(15)(b). An incident energy analysis shall be required in accordance with 130.5(G) for the following:

(6) Power systems with greater than the

~~estimated maximum available~~

(1) estimated available fault current

(2) Power systems with longer than the maximum arc duration

(3) Less than the minimum working distance

(g) *Protective Clothing and Personal Protective Equipment (PPE).* Once the arc flash PPE category has been identified from Table 130.7(C)(15)(a) or Table 130.7(C)(15)(b), Table 130.7(C)(15)(c) shall be used to determine the required PPE. Table 130.7(C)(15)(c) lists the requirements for PPE based on arc flash PPE categories 1 through 4. This clothing and equipment shall be used when working within the arc flash boundary. The use of PPE other than or in addition to that listed shall be permitted provided it meets 130.7(C)(7).

Informational Note No. 1: See Informative Annex H for a suggested simplified approach to ensure adequate PPE for electrical workers within facilities with large and diverse electrical systems.

Informational Note No. 2: The PPE requirements of this section are intended to protect a person from arc flash hazards. While some situations could result in burns to the skin even with the protection described in Table 130.7(C)(15)(c), burn injury should be reduced and survivable. Due to the explosive effect of some arc events, physical trauma injuries could occur. The PPE requirements of this section do not address protection against physical trauma other than exposure to the thermal effects of an arc flash.

Informational Note No. 3: The arc rating for a particular clothing system can be obtained from the arc-rated clothing manufacturer.

Table 130.7(C)(15)(a) Arc Flash PPE Categories for Alternating Current (ac) Systems

Equipment	Arc Flash PPE Category	Arc Flash Boundary
Panelboards or other equipment rated 240 volts and below	1	485 mm (19 in.)
Parameters: Maximum of 25 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
Panelboards or other equipment rated greater than 240 volts and up to 600 volts	2	900 mm (3 ft)
Parameters: Maximum of 25 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class motor control centers (MCCs)	2	1.5 m (5 ft)
Parameters: Maximum of 65 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class motor control centers (MCCs)	4	4.3 m (14 ft)
Parameters: Maximum of 42 kA available fault current; maximum of 0.33 sec (20 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class switchgear (with power circuit breakers or fused switches) and 600-volt class switchboards	4	6 m (20 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.5 sec (30 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
Other 600-volt class (277 volts through 600 volts, nominal) equipment	2	1.5 m (5 ft)
Parameters: Maximum of 65 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
NEMA E2 (fused contactor) motor starters, 2.3 kV through 7.2 kV	4	12 m (40 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault	-	-

Equipment	Arc Flash PPE Category	Arc Flash Boundary
clearing time; minimum working distance 910 mm (36 in.)		
Metal-clad switchgear, 1 kV through 15 kV	4	12 m (40 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	-	-
Metal enclosed interrupter switchgear, fused or unfused type construction, 1 kV through 15 kV Parameters: Maximum of 35 kA available fault current; maximum of 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	4	12 m (40 ft)
Other equipment 1 kV through 15 kV Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	4	12 m (40 ft)
Arc-resistant equipment up to 600-volt class Parameters: DOORS CLOSED and SECURED; with an available fault current and a fault clearing time that does not exceed the arc-resistant rating of the equipment*	N/A	N/A
Arc-resistant equipment 1 kV through 15 kV	N/A	N/A
Parameters: DOORS CLOSED and SECURED; with an available fault current and a fault clearing time that does not exceed the arc-resistant rating of the equipment*	-	-

N/A: Not applicable

Note:

For equipment rated 600 volts and below and protected by upstream current-limiting fuses or current-limiting molded case circuit breakers sized at 200 amperes or less, the arc flash PPE category can be reduced by one number but not below arc flash PPE category 1.

*For DOORS OPEN refer to the corresponding non-arc-resistant equipment section of this table.

Informational Note No. 1 to Table 130.7(C)(15)(a): The following are typical fault clearing times of overcurrent protective devices:

(1) 0.5 cycle fault clearing time is typical for current-limiting fuses and current-limiting molded case circuit breakers when the fault current is within the current limiting range.

(2) 1.5 cycle fault clearing time is typical for molded case circuit breakers rated less than 1000 volts with an instantaneous integral trip.

(3) 3.0 cycle fault clearing time is typical for insulated case circuit breakers rated less than 1000 volts with an instantaneous integral trip or relay operated trip.

(4) 5.0 cycle fault clearing time is typical for relay operated circuit breakers rated 1 kV to 35 kV when the relay operates in the instantaneous range (i.e., “no intentional delay”).

(5) 20 cycle fault clearing time is typical for low-voltage power and insulated case circuit breakers with a short time fault clearing delay for motor inrush.

(6) 30 cycle fault clearing time is typical for low-voltage power and insulated case circuit breakers with a short time fault clearing delay without instantaneous trip.

Informational Note No. 2 to Table 130.7(C)(15)(a): See Table 1 of IEEE 1584, *Guide for Performing Arc Flash Hazard Calculations*, for further information regarding list items (2) through (4) in Informational Note No. 1.

Informational Note No. 3 to Table 130.7(C)(15)(a): See IEEE C37.20.7, *Guide for Testing Switchgear Rated Up to 52 kV for Internal Arcing Faults*, for an example of a standard that provides information for arc-resistant equipment referred to in Table 130.7(C)(15)(a).

Informational Note No. 4 to Table 130.7(C)(15)(a): See Informative Annex O.2.4(9) for information on arc-resistant equipment.

Table 130.7(C)(15)(b) Arc Flash PPE Categories for dc Systems

Equipment	**Arc Flash PPE Category**	**Arc Flash Boundary**
Storage batteries, dc switchboards, and other dc supply sources	-	-
Parameters: Greater than 150 volts and less than or equal to 600 volts	-	-
Maximum arc duration and minimum working distance: 2 sec @ 455 mm (18 in.)	-	-
Available fault current less than 1.5 kA	2	900 mm
		- - (3 ft)
Available fault current greater than or equal to 1.5 kA and less than 3 kA	2	1.2 m
		- - (4 ft)
Available fault current greater than or equal to 3 kA and less than 7 kA	3	1.8 m
		- - (6 ft.)
Available fault current greater than or equal to 7 kA and less than 10 kA	4	2.5 m
		- - (8 ft)

Notes:

(1) Apparel that can be expected to be exposed to electrolyte must meet both of the following conditions:

(a) Be evaluated for electrolyte protection

Informational Note: See ASTM F1296, *Standard Guide for Evaluating Chemical Protective Clothing*, for information on evaluating apparel for protection from electrolyte.

(b) Be arc rated

Informational Note: See ASTM F1891, *Standard Specification for Arc and Flame Resistant Rainwear*, for information on evaluating arc-rated apparel.

(2) A two-second arc duration is assumed if there is no overcurrent protective device (OCPD) or if the fault clearing time is not known. If the fault clearing time is known and is less than 2 seconds, an incident energy analysis could provide a more representative result.

Informational Note No. 1: See D.5 for the basis for table values and alternative methods to determine dc incident energy. Methods should be used with good engineering judgment. When determining available fault current, the effects of cables and any other impedances in the circuit should be included. Power system modeling is the best method to determine the available short-circuit current at the point of the arc. Battery cell short-circuit current can be obtained from the battery manufacturer.

Informational Note No. 2: The methods for estimating the dc arc flash incident energy that were used to determine the categories for this table are based on open-air incident energy calculations. Open-air calculations were used because many battery systems and other dc process systems are in open areas or rooms. If the specific task is within an enclosure, it would be prudent to consider additional PPE protection beyond the value shown in this table.

Informational Note No. 3: See the following references for dc voltages below 150 volts nominal:

(1) J. G. Hildreth and K. Feeney, “Arc Flash Hazards Station Battery Systems,” 2018 IEEE Power & Energy Society General Meeting (PESGM), 2018, pp. 1–5.

(2) US Department of Energy Bonneville Power Administration Engineering and Technical Services Report BPA F 5450.05, “DC Arc Flash: 125V, 1300 amp-hour battery,” May 11, 2017, doi: 10.1109/PESGM.2018.8586181.

(3) K. Gray, S. Robert, and T. L. Gauthier, "Low Voltage 100–500 Vdc Arc Flash Testing," 2020 IEEE IAS Electrical Safety Workshop (ESW), 2020, pp. 1–7, doi: 10.1109/ESW42757.2020.9188336.

Table 130.7(C)(15)(c) Personal Protective Equipment (PPE)

Arc-Flash PPE Category	PPE	
1	**Arc-Rated Clothing, Minimum Arc Rating of 4 cal/cm^2 (16.75 J/cm^2)**[a]	
	-	Arc-rated long-sleeve shirt and pants or arc-rated coverall
	-	Arc-rated face shield[b] or arc flash suit hood
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]

Arc-Flash PPE Category	PPE	
	-	Heavy-duty leather gloves, arc-rated gloves, or rubber insulating gloves with protectors (SR)[d]
	-	Leather footwear[e] (AN)
2	**Arc-Rated Clothing, Minimum Arc Rating of 8 cal/cm^2 (33.5 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt and pants or arc-rated coverall
	-	Arc-rated flash suit hood or arc-rated face shield[b] and arc-rated balaclava
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Heavy-duty leather gloves, arc-rated gloves, or rubber insulating gloves with protectors (SR)[d]
	-	Leather footwear[e]
3	**Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 25 cal/cm^2 (104.7 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt (AR)
	-	Arc-rated pants (AR)
	Arc-rated coverall (AR)	
	-	Arc-rated arc flash suit jacket (AR)
	Arc-rated arc flash suit pants (AR)	
	-	Arc-rated arc flash suit hood
	-	Arc-rated gloves or rubber insulating gloves with protectors (SR)[d]
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**

Arc-Flash PPE Category	PPE	
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Leather footwear[e]
4	**Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 40 cal/cm^2 (167.5 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt (AR)
	-	Arc-rated pants (AR)
	Arc-rated coverall (AR)	
	-	Arc-rated arc flash suit jacket (AR)
	Arc-rated arc flash suit pants (AR)	
	-	Arc-rated arc flash suit hood
	-	Arc-rated gloves or rubber insulating gloves with protectors (SR)[d]
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Leather footwear[e]

AN: As needed (optional). AR: As required. SR: Selection required.

[a] *Arc rating* is defined in Article 100.

[b] Face shields are to have wrap-around guarding to protect not only the face but also the forehead, ears, and neck, or, alternatively, an arc-rated arc flash suit hood is required to be worn.

[c] Other types of hearing protection are permitted to be used in lieu of or in addition to ear canal inserts provided they are worn under an arc-rated arc flash suit hood.

[d] Rubber insulating gloves with protectors provide arc flash protection in addition to electric shock protection. Higher class rubber insulating gloves with protectors, due to their increased material thickness, provide increased arc flash protection.

[e] Footwear other than leather or dielectric shall be permitted to be used provided it has been tested to demonstrate no ignition, melting or dripping at the minimum arc rating for the respective arc flash PPE category.

[f]The arc rating of outer layers worn over arc-rated clothing as protection from the elements or for other safety purposes, and that are not used as part of a layered system, shall not be required to be equal to or greater than the estimated incident energy exposure.

Statement of Problem and Substantiation for Public Input

The recommendation in this Public Input is to remove the word "maximum" from (1) as it is redundant to the word "largest" in the definition of "available fault current." As worded presently, it literally means maximum largest fault current.

Submitter Information Verification

Submitter Full Name: Palmer Hickman
Organization: Electrical Training Alliance
Street Address:
City:
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Submittal Date: Thu Aug 24 11:08:18 EDT 2023
Committee: EEW-AAA

Committee Statement

Resolution: FR-55-NFPA 70E-2024

Statement: The qualifier “maximum” is deleted in front of “available fault current” in 130.7(C)(15)(a)(1) and 130.7(C)(15)(b)(1).

This revision is necessary to correlate with the definition of Available Fault Current. There is no such thing as the maximum largest.

The section was revised to comply with the NEC Style Manual Section 3.5.1.2 Multiple Requirements.

Table 130.7(C)(15)(a): This revision correlates with revisions in the parent text of 130.7(C)(15)(a) and 130.7(C)(15)(b). In both of these revisions the qualifier “maximum” which was used to describe available fault current was deleted. The defined term “Fault Current, Available (Available Fault Current”, in Article 100 clarifies that it is the largest amount of current capable of being delivered at a point on the system during a short-circuit condition. A similar revision is made to all references of available fault current and fault clearing time in Table 130.7(C)(15)(a) for clarity and usability.

Table 130.7(C)(15(a) Informational Note No. 1: List items (2) through (6) are modified for clarity and correlation with list item (1).

Table 130.7(C)(15(a) Informational Note No.2: Table 1 of IEEE 1584 as referenced in the informational note is from the 2002 edition. The table is not included in the 2018 Edition of IEEE 1584. The year of the edition is added for clarification.

Table 130.7(C)(15)(c): The modifiers “arc-rated” and “arc” are added to the table for correlation and clarity.

Public Input No. 155-NFPA 70E-2024 [Section No. 130.7(C)(15)]

(15) Arc Flash PPE Category Method.

The requirements of 130.7(C)(15) shall apply when the arc flash PPE category method is used for the selection of arc flash PPE.

Informational Note: For both ac and dc systems, the arc flash PPE category of the protective clothing and equipment is generally based on determination of the estimated exposure level.

(a) *Alternating Current (ac) Equipment.* When the arc flash risk assessment performed in accordance with 130.5 indicates that arc flash PPE is required and the arc flash PPE category method is used for the selection of PPE for ac systems in lieu of the incident energy analysis of 130.5(G), Table 130.7(C)(15)(a) shall be used to determine the arc flash PPE category. The estimated maximum available fault current, maximum fault-clearing times, and minimum working distances for various ac equipment types or classifications are listed in Table 130.7(C)(15)(a). An incident energy analysis shall be required in accordance with 130.5(G) for the following:

(2) Power systems with greater than the estimated maximum available fault current

(3) Power systems with longer than the maximum fault clearing times

(4) Less than the minimum working distance

(e) *Direct Current (dc) Equipment.* When the arc flash risk assessment performed in accordance with 130.5(G) indicates that arc flash PPE is required and the arc flash PPE category method is used for the selection of PPE for dc systems in lieu of the incident energy analysis of 130.5(G), Table 130.7(C)(15)(b) shall be used to determine the arc flash PPE category. The estimated maximum available fault current, maximum arc duration, and working distances for dc equipment are listed in 130.7(C)(15)(b). An incident energy analysis shall be required in accordance with 130.5(G) for the following:

(6) Power systems with greater than the estimated maximum available fault current

(7) Power systems with longer than the maximum arc duration

(8) Less than the minimum working distance

(i) *Protective Clothing and Personal Protective Equipment (PPE).* Once the arc flash PPE category has been identified from Table 130.7(C)(15)(a) or Table 130.7(C)(15)(b), Table 130.7(C)(15)(c) shall be used to determine the required PPE. Table 130.7(C)(15)(c) lists the requirements for PPE based on arc flash PPE categories 1 through 4. This clothing and equipment shall be used when working within the arc flash boundary. The use of PPE other than or in addition to that listed shall be permitted provided it meets 130.7(C)(7).

Informational Note No. 1: See Informative Annex H for a suggested simplified approach to ensure adequate PPE for electrical workers within facilities with large and diverse electrical systems.

Informational Note No. 2: The PPE requirements of this section are intended to protect a person from arc flash hazards. While some situations could result in burns to the skin even with the protection described in Table 130.7(C)(15)(c), burn injury should be reduced and survivable. Due to the explosive effect of some arc events, physical trauma injuries could occur. The PPE requirements of this section do not address protection against physical trauma other than exposure to the thermal effects of an arc flash.

Informational Note No. 3: The arc rating for a particular clothing system can be obtained from the arc-rated clothing manufacturer.

Table 130.7(C)(15)(a) Arc Flash PPE Categories for Alternating Current (ac) Systems

Equipment	Arc Flash PPE Category	Arc Flash Boundary
Panelboards or other equipment rated 240 volts and below	1	485 mm (19 in.)
Parameters: Maximum of 25 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
Panelboards or other equipment rated greater than 240 volts and up to 600 volts	2	900 mm (3 ft)
Parameters: Maximum of 25 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class motor control centers (MCCs)	2	1.5 m (5 ft)
Parameters: Maximum of 65 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class motor control centers (MCCs)	4	4.3 m (14 ft)
Parameters: Maximum of 42 kA available fault current; maximum of 0.33 sec (20 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class switchgear (with power circuit breakers or fused switches) and 600-volt class switchboards	4	6 m (20 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.5 sec (30 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
Other 600-volt class (277 volts through 600 volts, nominal) equipment	2	1.5 m (5 ft)
Parameters: Maximum of 65 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
NEMA E2 (fused contactor) motor starters, 2.3 kV through 7.2 kV	4	12 m (40 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault	-	-

Equipment	Arc Flash PPE Category	Arc Flash Boundary
clearing time; minimum working distance 910 mm (36 in.)		
Metal-clad switchgear, 1 kV through 15 kV	4	12 m (40 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	-	-
Metal enclosed interrupter switchgear, fused or unfused type construction, 1 kV through 15 kV Parameters: Maximum of 35 kA available fault current; maximum of 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	4	12 m (40 ft)
Other equipment 1 kV through 15 kV Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	4	12 m (40 ft)
Arc-resistant equipment up to 600-volt class Parameters: DOORS CLOSED and SECURED; with an available fault current and a fault clearing time that does not exceed the arc-resistant rating of the equipment*	N/A	N/A
Arc-resistant equipment 1 kV through 15 kV	N/A	N/A
Parameters: DOORS CLOSED and SECURED; with an available fault current and a fault clearing time that does not exceed the arc-resistant rating of the equipment*	-	-

N/A: Not applicable

Note:

For equipment rated 600 volts and below and protected by upstream current-limiting fuses or current-limiting molded case circuit breakers sized at 200 amperes or less, the arc flash PPE category can be reduced by one number but not below arc flash PPE category 1.

*For DOORS OPEN refer to the corresponding non-arc-resistant equipment section of this table.

Informational Note No. 1 to Table 130.7(C)(15)(a): The following are typical fault clearing times of overcurrent protective devices:

(1) 0.5 cycle fault clearing time is typical for current-limiting fuses and current-limiting molded case circuit breakers when the fault current is within the current limiting range.

(2) 1.5 cycle fault clearing time is typical for molded case circuit breakers rated less than 1000 volts with an instantaneous integral trip.

(3) 3.0 cycle fault clearing time is typical for insulated case circuit breakers rated less than 1000 volts with an instantaneous integral trip or relay operated trip.

(4) 5.0 cycle fault clearing time is typical for relay operated circuit breakers rated 1 kV to 35 kV when the relay operates in the instantaneous range (i.e., “no intentional delay”).

(5) 20 cycle fault clearing time is typical for low-voltage power and insulated case circuit breakers with a short time fault clearing delay for motor inrush.

(6) 30 cycle fault clearing time is typical for low-voltage power and insulated case circuit breakers with a short time fault clearing delay without instantaneous trip.

Informational Note No. 2 to Table 130.7(C)(15)(a): See Table 1 of IEEE 1584, *Guide for Performing Arc Flash Hazard Calculations*, for further information regarding list items (2) through (4) in Informational Note No. 1.

Informational Note No. 3 to Table 130.7(C)(15)(a): See IEEE C37.20.7, *Guide for Testing Switchgear Rated Up to 52 kV for Internal Arcing Faults*, for an example of a standard that provides information for arc-resistant equipment referred to in Table 130.7(C)(15)(a).

Informational Note No. 4 to Table 130.7(C)(15)(a): See Informative Annex O.2.4(9) for information on arc-resistant equipment.

Table 130.7(C)(15)(b) Arc Flash PPE Categories for dc Systems

Equipment	**Arc Flash PPE Category**	**Arc Flash Boundary**
Storage batteries, dc switchboards, and other dc supply sources	-	-
Parameters: Greater than 150 volts ~~and~~ , less than or equal to 600 volts ~~, and where exposed conductor separation is less than 1mm / volt~~ [a] -	-	
Maximum arc duration and minimum working distance: 2 sec @ 455 mm (18 in.)	-	-
Available fault current less than 1.5 kA	2	900 mm
		- - (3 ft)
Available fault current greater than or equal to 1.5 kA and less than 3 kA	2	1.2 m
		- - (4 ft)
Available fault current greater than or equal to 3 kA and less than 7 kA	3	1.8 m
		- - (6 ft.)

Equipment	Arc Flash PPE Category	Arc Flash Boundary		
Available fault current greater than or equal to 7 kA and less than 10 kA	4	2.5 m		
		-	-	(8 ft)

[a] 1mm / V assumes a theoretically infinite short circuit current.

Notes:

(1) Apparel that can be expected to be exposed to electrolyte must meet both of the following conditions:

(a) Be evaluated for electrolyte protection

Informational Note: See ASTM F1296, *Standard Guide for Evaluating Chemical Protective Clothing*, for information on evaluating apparel for protection from electrolyte.

(b) Be arc rated

Informational Note: See ASTM F1891, *Standard Specification for Arc and Flame Resistant Rainwear*, for information on evaluating arc-rated apparel.

(2) A two-second arc duration is assumed if there is no overcurrent protective device (OCPD) or if the fault clearing time is not known. If the fault clearing time is known and is less than 2 seconds, an incident energy analysis could provide a more representative result.

Informational Note No. 1: See D.5 for the basis for table values and alternative methods to determine dc incident energy. Methods should be used with good engineering judgment. When determining available fault current, the effects of cables and any other impedances in the circuit should be included. Power system modeling is the best method to determine the available short-circuit current at the point of the arc. Battery cell short-circuit current can be obtained from the battery manufacturer.

Informational Note No. 2: The methods for estimating the dc arc flash incident energy that were used to determine the categories for this table are based on open-air incident energy calculations. Open-air calculations were used because many battery systems and other dc process systems are in open areas or rooms. If the specific task is within an enclosure, it would be prudent to consider additional PPE protection beyond the value shown in this table.

Informational Note No. 3: See the following references for dc voltages below 150 volts nominal:

(1) J. G. Hildreth and K. Feeney, “Arc Flash Hazards Station Battery Systems,” 2018 IEEE Power & Energy Society General Meeting (PESGM), 2018, pp. 1–5.

(2) US Department of Energy Bonneville Power Administration Engineering and Technical Services Report BPA F 5450.05, “DC Arc Flash: 125V, 1300 amp-hour battery,” May 11, 2017, doi: 10.1109/PESGM.2018.8586181.

(3) K. Gray, S. Robert, and T. L. Gauthier, "Low Voltage 100–500 Vdc Arc Flash Testing," 2020 IEEE IAS Electrical Safety Workshop (ESW), 2020, pp. 1–7, doi: 10.1109/ESW42757.2020.9188336.

Table 130.7(C)(15)(c) Personal Protective Equipment (PPE)

Arc-Flash PPE Category	PPE
1	**Arc-Rated Clothing, Minimum Arc Rating of 4 cal/cm^2 (16.75 J/cm^2)**[a]

Arc-Flash PPE Category	PPE	
	-	Arc-rated long-sleeve shirt and pants or arc-rated coverall
	-	Arc-rated face shield[b] or arc flash suit hood
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Heavy-duty leather gloves, arc-rated gloves, or rubber insulating gloves with protectors (SR)[d]
	-	Leather footwear[e] (AN)
2	**Arc-Rated Clothing, Minimum Arc Rating of 8 cal/cm^2 (33.5 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt and pants or arc-rated coverall
	-	Arc-rated flash suit hood or arc-rated face shield[b] and arc-rated balaclava
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Heavy-duty leather gloves, arc-rated gloves, or rubber insulating gloves with protectors (SR)[d]
	-	Leather footwear[e]
3	**Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 25 cal/cm^2 (104.7 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt (AR)

Arc-Flash PPE Category	PPE	
	-	Arc-rated pants (AR) -
	Arc-rated coverall (AR)	
	-	Arc-rated arc flash suit jacket (AR) -
	Arc-rated arc flash suit pants (AR)	
	-	Arc-rated arc flash suit hood
	-	Arc-rated gloves or rubber insulating gloves with protectors (SR)[d]
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Leather footwear[e]
4	**Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 40 cal/cm^2 (167.5 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt (AR)
	-	Arc-rated pants (AR) -
	Arc-rated coverall (AR)	
	-	Arc-rated arc flash suit jacket (AR) -
	Arc-rated arc flash suit pants (AR)	
	-	Arc-rated arc flash suit hood
	-	Arc-rated gloves or rubber insulating gloves with protectors (SR)[d]
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Leather footwear[e]

AN: As needed (optional). AR: As required. SR: Selection required.

[a] *Arc rating* is defined in Article 100.

[b] Face shields are to have wrap-around guarding to protect not only the face but also the forehead, ears, and neck, or, alternatively, an arc-rated arc flash suit hood is required to be worn.

[c] Other types of hearing protection are permitted to be used in lieu of or in addition to ear canal inserts provided they are worn under an arc-rated arc flash suit hood.

[d] Rubber insulating gloves with protectors provide arc flash protection in addition to electric shock protection. Higher class rubber insulating gloves with protectors, due to their increased material thickness, provide increased arc flash protection.

[e] Footwear other than leather or dielectric shall be permitted to be used provided it has been tested to demonstrate no ignition, melting or dripping at the minimum arc rating for the respective arc flash PPE category.

[f] The arc rating of outer layers worn over arc-rated clothing as protection from the elements or for other safety purposes, and that are not used as part of a layered system, shall not be required to be equal to or greater than the estimated incident energy exposure.

Statement of Problem and Substantiation for Public Input

Batteries, PV, and other dc circuits commonly have equipment designs that separate exposed conductors to reduce the risk of short-circuit, shock, and arc flash. It is critical to know where an electric arc could happen to control the hazard effectively. The proposed change to the table enables workers to focus electrical safety controls where they are most needed.

The following peer reviewed journal article derived 1mm / V from the published minimum voltage of thousands of arc experiments over a range of arc gaps. This rule conservatively overestimates the experimental maximum arc gap in battery systems from 105 V to 520 V dc. D. M. Rosewater, "Reducing Risk When Performing Energized Work on Batteries," in IEEE Transactions on Industry Applications, vol. 60, no. 2, pp. 2732-2741, March-April 2024, doi: 10.1109/TIA.2023.3332828. This reference is open access and available online: https://ieeexplore.ieee.org/document/10316636 Authors in the following conference paper support this rule in their research conclusions: W. Cantor, L. Gordon, S. Marri “NFPA 70E Proposed DC Arc Flash Updated Guidance” 2024 IEEE IAS Electrical Safety Workshop, Tucson, AZ.

This public input is a combined effort from the Energy Facility Contractors Group (EFCOG), a working group of electrical safety professionals at Department of Energy National Labs, and the IEEE PES Energy Storage and Stationary Battery (ESSB) committee’s safety codes working group, a group of stationary battery and energy storage industry professionals.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 115-NFPA 70E-2024 [New Section after D.5.1]	Same material in the IE calculation method annex

Submitter Information Verification

Submitter Full Name:	David Rosewater
Organization:	Sandia National Laboratories
Affiliation:	Energy Facility Contractor Group and the IEEE PES Energy Storage and Stationary Battery committee
Street Address:	

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Submittal Date: Mon Jun 03 12:02:13 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-58-NFPA 70E-2024

Statement: A new task “working on battery equipment below 600 V where the exposed electrical conductors are separated by more than 1 millimeter per volt” is added to provide clarity with respect to impact of separation distance on the likelihood of an arc-flash.

The following peer reviewed journal article derived 1mm / V from the published minimum voltage of thousands of arc experiments over a range of arc gaps. D. M. Rosewater, "Reducing Risk When Performing Energized Work on Batteries," in IEEE Transactions on Industry Applications, vol. 60, no. 2, pp. 2732-2741, March-April 2024, doi: 10.1109/TIA.2023.3332828.

Public Input No. 19-NFPA 70E-2023 [Section No. 130.7(C)(15)]

(15) Arc Flash PPE Category Method.

The requirements of 130.7(C)(15) shall apply when the arc flash PPE category method is used for the selection of arc flash PPE.

Informational Note: For both ac and dc systems, the arc flash PPE category of the protective clothing and equipment is generally based on determination of the estimated exposure level.

(a) *Alternating Current (ac) Equipment.* When the arc flash risk assessment performed in accordance with 130.5 indicates that arc flash PPE is required and the arc flash PPE category method is used for the selection of PPE for ac systems in lieu of the incident energy analysis of 130.5(G), Table 130.7(C)(15)(a) shall be used to determine the arc flash PPE category. The estimated maximum available fault current, maximum fault-clearing times, and minimum working distances for various ac equipment types or classifications are listed in Table 130.7(C)(15)(a). An incident energy analysis shall be required in accordance with 130.5(G) for the following:

(2) Power systems with greater than the estimated maximum available fault current

(3) Power systems with longer than the maximum fault clearing times

(4) Less than the minimum working distance

(e) *Direct Current (dc) Equipment.* When the arc flash risk assessment performed in accordance with 130.5(G) indicates that arc flash PPE is required and the arc flash PPE category method is used for the selection of PPE for dc systems in lieu of the incident energy analysis of 130.5(G), Table 130.7(C)(15)(b) shall be used to determine the arc flash PPE category. The estimated maximum available fault current, maximum arc duration, and working distances for dc equipment are listed in 130.7(C)(15)(b). An incident energy analysis shall be required in accordance with 130.5(G) for the following:

(6) Power systems with greater than the estimated maximum available fault current

(7) Power systems with longer than the maximum arc duration

(8) Less than the minimum working distance

(i) *Protective Clothing and Personal Protective Equipment (PPE).* Once the arc flash PPE category has been identified from Table 130.7(C)(15)(a) or Table 130.7(C)(15)(b), Table 130.7(C)(15)(c) shall be used to determine the required PPE. Table 130.7(C)(15)(c) lists the requirements for PPE based on arc flash PPE categories 1 through 4. This clothing and equipment shall be used when working within the arc flash boundary. The use of PPE other than or in addition to that listed shall be permitted provided it meets 130.7(C)(7).

Informational Note No. 1: See Informative Annex H for a suggested simplified approach to ensure adequate PPE for electrical workers within facilities with large and diverse electrical systems.

Informational Note No. 2: The PPE requirements of this section are intended to protect a person from arc flash hazards. While some situations could result in burns to the skin even with the protection described in Table 130.7(C)(15)(c), burn injury should be reduced and survivable. Due to the explosive effect of some arc events, physical trauma injuries could occur. The PPE requirements of this section do not address protection against physical trauma other than exposure to the thermal effects of an arc flash.

Informational Note No. 3: The arc rating for a particular clothing system can be obtained from the arc-rated clothing manufacturer.

Table 130.7(C)(15)(a) Arc Flash PPE Categories for Alternating Current (ac) Systems

Equipment	Arc Flash PPE Category	Arc Flash Boundary
Panelboards or other equipment rated 240 volts and below	1	485 mm (19 in.)
Parameters: Maximum of 25 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
Panelboards or other equipment rated greater than 240 volts and up to 600 volts	2	900 mm (3 ft)
Parameters: Maximum of 25 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class motor control centers (MCCs)	2	1.5 m (5 ft)
Parameters: Maximum of 65 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class motor control centers (MCCs)	4	4.3 m (14 ft)
Parameters: Maximum of 42 kA available fault current; maximum of 0.33 sec (20 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class switchgear (with power circuit breakers or fused switches) and 600-volt class switchboards	4	6 m (20 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.5 sec (30 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
Other 600-volt class (277 volts through 600 volts, nominal) equipment	2	1.5 m (5 ft)
Parameters: Maximum of 65 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
NEMA E2 (fused contactor) motor starters, 2.3 kV through 7.2 kV	4	12 m (40 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault	-	-

Equipment	Arc Flash PPE Category	Arc Flash Boundary
clearing time; minimum working distance 910 mm (36 in.)		
Metal-clad switchgear, 1 kV through 15 kV	4	12 m (40 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	-	-
Metal enclosed interrupter switchgear, fused or unfused type construction, 1 kV through 15 kV Parameters: Maximum of 35 kA available fault current; maximum of 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	4	12 m (40 ft)
Other equipment 1 kV through 15 kV Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	4	12 m (40 ft)
Arc-resistant equipment up to 600-volt class Parameters: DOORS CLOSED and SECURED; with an available fault current and a fault clearing time that does not exceed the arc-resistant rating of the equipment*	N/A	N/A
Arc-resistant equipment 1 kV through 15 kV	N/A	N/A
Parameters: DOORS CLOSED and SECURED; with an available fault current and a fault clearing time that does not exceed the arc-resistant rating of the equipment*	-	-

N/A: Not applicable

Note:

For equipment rated 600 volts and below and protected by upstream current-limiting fuses or current-limiting molded case circuit breakers sized at 200 amperes or less, the arc flash PPE category can be reduced by one number but not below arc flash PPE category 1.

*For DOORS OPEN refer to the corresponding non-arc-resistant equipment section of this table.

Informational Note No. 1 to Table 130.7(C)(15)(a): The following are typical fault clearing times of overcurrent protective devices:

(1) 0.5 cycle fault clearing time is typical for current-limiting fuses and current-limiting molded case circuit breakers when the fault current is within the current limiting range.

(2) 1.5 cycle fault clearing time is typical for molded case circuit breakers rated less than 1000 volts with an instantaneous integral trip.

(3) 3.0 cycle fault clearing time is typical for insulated case circuit breakers rated less than 1000 volts with an instantaneous integral trip or relay operated trip.

(4) 5.0 cycle fault clearing time is typical for relay operated circuit breakers rated 1 kV to 35 kV when the relay operates in the instantaneous range (i.e., “no intentional delay”).

(5) 20 cycle fault clearing time is typical for low-voltage power and insulated case circuit breakers with a short time fault clearing delay for motor inrush.

(6) 30 cycle fault clearing time is typical for low-voltage power and insulated case circuit breakers with a short time fault clearing delay without instantaneous trip.

Informational Note No. 2 to Table 130.7(C)(15)(a): See Table 1 of IEEE 1584, *Guide for Performing Arc Flash Hazard Calculations*, for further information regarding list items (2) through (4) in Informational Note No. 1.

Informational Note No. 3 to Table 130.7(C)(15)(a): See IEEE C37.20.7, *Guide for Testing Switchgear Rated Up to 52 kV for Internal Arcing Faults*, for an example of a standard that provides information for arc-resistant equipment referred to in Table 130.7(C)(15)(a).

Informational Note No. 4 to Table 130.7(C)(15)(a): See Informative Annex O.2.4(9) for information on arc-resistant equipment.

Table 130.7(C)(15)(b) Arc Flash PPE Categories for dc Systems

Equipment	**Arc Flash PPE Category**	**Arc Flash Boundary**
Storage batteries, dc switchboards, and other dc supply sources	-	-
Parameters: Greater than 150 volts and less than or equal to 600 volts	-	-
Maximum arc duration and minimum working distance: 2 sec @ 455 mm (18 in.)	-	-
Available fault current less than 1.5 kA	2	900 mm
		- - (3 ft)
Available fault current greater than or equal to 1.5 kA and less than 3 kA	2	1.2 m
		- - (4 ft)
Available fault current greater than or equal to 3 kA and less than 7 kA	3	1.8 m
		- - (6 ft.)
Available fault current greater than or equal to 7 kA and less than 10 kA	4	2.5 m
		- - (8 ft)

Notes:

(1) Apparel that can be expected to be exposed to electrolyte must meet both of the following conditions:

(a) Be evaluated for electrolyte protection

Informational Note: See ASTM F1296, *Standard Guide for Evaluating Chemical Protective Clothing*, for information on evaluating apparel for protection from electrolyte.

(b) Be arc rated

Informational Note: See ASTM F1891, *Standard Specification for Arc and Flame Resistant Rainwear*, for information on evaluating arc-rated apparel.

(2) A two-second arc duration is assumed if there is no overcurrent protective device (OCPD) or if the fault clearing time is not known. If the fault clearing time is known and is less than 2 seconds, an incident energy analysis could provide a more representative result.

Informational Note No. 1: See D.5 for the basis for table values and alternative methods to determine dc incident energy. Methods should be used with good engineering judgment. When determining available fault current, the effects of cables and any other impedances in the circuit should be included. Power system modeling is the best method to determine the available short-circuit current at the point of the arc. Battery cell short-circuit current can be obtained from the battery manufacturer.

Informational Note No. 2: The methods for estimating the dc arc flash incident energy that were used to determine the categories for this table are based on open-air incident energy calculations. Open-air calculations were used because many battery systems and other dc process systems are in open areas or rooms. If the specific task is within an enclosure, it would be prudent to consider additional PPE protection beyond the value shown in this table.

Informational Note No. 3: See the following references for dc voltages below 150 volts nominal:

(1) J. G. Hildreth and K. Feeney, “Arc Flash Hazards Station Battery Systems,” 2018 IEEE Power & Energy Society General Meeting (PESGM), 2018, pp. 1–5.

(2) US Department of Energy Bonneville Power Administration Engineering and Technical Services Report BPA F 5450.05, “DC Arc Flash: 125V, 1300 amp-hour battery,” May 11, 2017, doi: 10.1109/PESGM.2018.8586181.

(3) K. Gray, S. Robert, and T. L. Gauthier, "Low Voltage 100–500 Vdc Arc Flash Testing," 2020 IEEE IAS Electrical Safety Workshop (ESW), 2020, pp. 1–7, doi: 10.1109/ESW42757.2020.9188336.

Table 130.7(C)(15)(c) Personal Protective Equipment (PPE)

Arc-Flash PPE Category	PPE	
1	**Arc-Rated Clothing, Minimum Arc Rating of 4 cal/cm^2 (16.75 J/cm^2)**[a]	
	-	Arc-rated long-sleeve shirt and pants or arc-rated coverall
	-	Arc-rated face shield[b] or arc-rated arc flash suit hood
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]

Arc-Flash PPE Category	PPE	
	-	Heavy-duty leather gloves, arc-rated gloves, or rubber insulating gloves with protectors (SR)[d]
	-	Leather footwear[e] (AN)
2	**Arc-Rated Clothing, Minimum Arc Rating of 8 cal/cm^2 (33.5 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt and pants or arc-rated coverall
	-	Arc-rated arc flash suit hood or arc-rated face shield[b] and arc-rated balaclava
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Heavy-duty leather gloves, arc-rated gloves, or rubber insulating gloves with protectors (SR)[d]
	-	Leather footwear[e]
3	**Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 25 cal/cm^2 (104.7 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt (AR)
	-	Arc-rated pants (AR)
	Arc-rated coverall (AR)	
	-	Arc-rated arc flash suit jacket (AR)
	Arc-rated arc flash suit pants (AR)	
	-	Arc-rated arc flash suit hood
	-	Arc-rated gloves or rubber insulating gloves with protectors (SR)[d]
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**

Arc-Flash PPE Category	PPE	
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Leather footwear[e]
4	**Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 40 cal/cm^2 (167.5 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt (AR)
	-	Arc-rated pants (AR)
	Arc-rated coverall (AR)	
	-	Arc-rated arc flash suit jacket (AR)
	Arc-rated arc flash suit pants (AR)	
	-	Arc-rated arc flash suit hood
	-	Arc-rated gloves or rubber insulating gloves with protectors (SR)[d]
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Leather footwear[e]

AN: As needed (optional). AR: As required. SR: Selection required.

[a] *Arc rating* is defined in Article 100.

[b] Face shields are to have wrap-around guarding to protect not only the face but also the forehead, ears, and neck, or, alternatively, an arc-rated arc flash suit hood is required to be worn.

[c] Other types of hearing protection are permitted to be used in lieu of or in addition to ear canal inserts provided they are worn under an arc-rated arc flash suit hood.

[d] Rubber insulating gloves with protectors provide arc flash protection in addition to electric shock protection. Higher class rubber insulating gloves with protectors, due to their increased material thickness, provide increased arc flash protection.

[e] Footwear other than leather or dielectric shall be permitted to be used provided it has been tested to demonstrate no ignition, melting or dripping at the minimum arc rating for the respective arc flash PPE category.

[f]The arc rating of outer layers worn over arc-rated clothing as protection from the elements or for other safety purposes, and that are not used as part of a layered system, shall not be required to be equal to or greater than the estimated incident energy exposure.

Statement of Problem and Substantiation for Public Input

Changing Category 1's "arc flash suit hood" & Category 2's "arc-rated flash suit hood" to "Arc-rated arc flash suit hood" as it is currently given in Category 3 & Category 4 would standardize the nomenclature within Table 130.7(C)(15)(c) across all four categories eliminating the utilization of different variations.

Submitter Information Verification

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Submittal Date: Mon Sep 11 11:05:38 EDT 2023
Committee: EEW-AAA

Committee Statement

Resolution: FR-55-NFPA 70E-2024

Statement: The qualifier “maximum” is deleted in front of “available fault current” in 130.7(C)(15)(a)(1) and 130.7(C)(15)(b)(1).

This revision is necessary to correlate with the definition of Available Fault Current. There is no such thing as the maximum largest.

The section was revised to comply with the NEC Style Manual Section 3.5.1.2 Multiple Requirements.

Table 130.7(C)(15)(a): This revision correlates with revisions in the parent text of 130.7(C)(15)(a) and 130.7(C)(15)(b). In both of these revisions the qualifier “maximum” which was used to describe available fault current was deleted. The defined term “Fault Current, Available (Available Fault Current”, in Article 100 clarifies that it is the largest amount of current capable of being delivered at a point on the system during a short-circuit condition. A similar revision is made to all references of available fault current and fault clearing time in Table 130.7(C)(15)(a) for clarity and usability.

Table 130.7(C)(15(a) Informational Note No. 1: List items (2) through (6) are modified for clarity and correlation with list item (1).

Table 130.7(C)(15(a) Informational Note No.2: Table 1 of IEEE 1584 as referenced in the informational note is from the 2002 edition. The table is not included in the 2018 Edition of IEEE 1584. The year of the edition is added for clarification.

Table 130.7(C)(15)(c): The modifiers “arc-rated” and “arc” are added to the table for correlation and clarity.

Public Input No. 198-NFPA 70E-2024 [Section No. 130.7(C)(15)]

(15) Arc Flash PPE Category Method.

The requirements of 130.7(C)(15) shall apply when the arc flash PPE category method is used for the selection of arc flash PPE.

Informational Note: For both ac and dc systems, the arc flash PPE category of the protective clothing and equipment is generally based on determination of the estimated exposure level.

(a) *Alternating Current (ac) Equipment.* When the arc flash risk assessment performed in accordance with 130.5 indicates that arc flash PPE is required and the arc flash PPE category method is used for the selection of PPE for ac systems in lieu of the incident energy analysis of 130.5(G), Table 130.7(C)(15)(a) shall be used to determine the arc flash PPE category. The estimated maximum available fault current, maximum fault-clearing times, and minimum working distances for various ac equipment types or classifications are listed in Table 130.7(C)(15)(a). An incident energy analysis shall be required in accordance with 130.5(G) for the following:

(2) Power systems with greater than the estimated maximum available fault current

(3) Power systems with longer than the maximum fault clearing times

(4) Less than the minimum working distance

(e) *Direct Current (dc) Equipment.* When the arc flash risk assessment performed in accordance with 130.5(G) indicates that arc flash PPE is required and the arc flash PPE category method is used for the selection of PPE for dc systems in lieu of the incident energy analysis of 130.5(G), Table 130.7(C)(15)(b) shall be used to determine the arc flash PPE category. The estimated maximum available fault current, maximum arc duration, and working distances for dc equipment are listed in 130.7(C)(15)(b). An incident energy analysis shall be required in accordance with 130.5(G) for the following:

(6) Power systems with greater than the estimated maximum available fault current

(7) Power systems with longer than the maximum arc duration

(8) Less than the minimum working distance

(i) *Protective Clothing and Personal Protective Equipment (PPE).* Once the arc flash PPE category has been identified from Table 130.7(C)(15)(a) or Table 130.7(C)(15)(b), Table 130.7(C)(15)(c) shall be used to determine the required PPE. Table 130.7(C)(15)(c) lists the requirements for PPE based on arc flash PPE categories 1 through 4. This clothing and equipment shall be used when working within the arc flash boundary. The use of PPE other than or in addition to that listed shall be permitted provided it meets 130.7(C)(7).

Informational Note No. 1: See Informative Annex H for a suggested simplified approach to ensure adequate PPE for electrical workers within facilities with large and diverse electrical systems.

Informational Note No. 2: The PPE requirements of this section are intended to protect a person from arc flash hazards. While some situations could result in burns to the skin even with the protection described in Table 130.7(C)(15)(c), burn injury should be reduced and survivable. Due to the explosive effect of some arc events, physical trauma injuries could occur. The PPE requirements of this section do not address protection against physical trauma other than exposure to the thermal effects of an arc flash.

Informational Note No. 3: The arc rating for a particular clothing system can be obtained from the arc-rated clothing manufacturer.

Table 130.7(C)(15)(a) Arc Flash PPE Categories for Alternating Current (ac) Systems

Equipment	Arc Flash PPE Category	Arc Flash Boundary
Panelboards or other equipment rated 240 volts and below	1	485 mm (19 in.)
Parameters: Maximum of 25 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
Panelboards or other equipment rated greater than 240 volts and up to 600 volts	2	900 mm (3 ft)
Parameters: Maximum of 25 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class motor control centers (MCCs)	2	1.5 m (5 ft)
Parameters: Maximum of 65 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class motor control centers (MCCs)	4	4.3 m (14 ft)
Parameters: Maximum of 42 kA available fault current; maximum of 0.33 sec (20 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class switchgear (with power circuit breakers or fused switches) and 600-volt class switchboards	4	6 m (20 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.5 sec (30 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
Other 600-volt class (277 volts through 600 volts, nominal) equipment	2	1.5 m (5 ft)
Parameters: Maximum of 65 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
NEMA E2 (fused contactor) motor starters, 2.3 kV through 7.2 kV	4	12 m (40 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault	-	-

Equipment	Arc Flash PPE Category	Arc Flash Boundary
clearing time; minimum working distance 910 mm (36 in.)		
Metal-clad switchgear, 1 kV through 15 kV	4	12 m (40 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	-	-
Metal enclosed interrupter switchgear, fused or unfused type construction, 1 kV through 15 kV Parameters: Maximum of 35 kA available fault current; maximum of 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	4	12 m (40 ft)
Other equipment 1 kV through 15 kV Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	4	12 m (40 ft)
Arc-resistant equipment up to 600-volt class Parameters: DOORS CLOSED and SECURED; with an available fault current and a fault clearing time that does not exceed the arc-resistant rating of the equipment*	N/A	N/A
Arc-resistant equipment 1 kV through 15 kV	N/A	N/A
Parameters: DOORS CLOSED and SECURED; with an available fault current and a fault clearing time that does not exceed the arc-resistant rating of the equipment*	-	-

N/A: Not applicable

Note:

For equipment rated 600 volts and below and protected by upstream current-limiting fuses or current-limiting molded case circuit breakers sized at 200 amperes or less, the arc flash PPE category can be reduced by one number but not below arc flash PPE category 1.

*For DOORS OPEN refer to the corresponding non-arc-resistant equipment section of this table.

Informational Note No. 1 to Table 130.7(C)(15)(a): The following are typical fault clearing times of overcurrent protective devices:

(1) 0.5 cycle fault clearing time is typical for current-limiting fuses and current-limiting molded case circuit breakers when the fault current is within the current limiting range.

(2) 1.5 cycle fault clearing time is typical for molded case circuit breakers rated less than 1000 volts with an instantaneous integral trip.

(3) 3.0 cycle fault clearing time is typical for insulated case circuit breakers rated less than 1000 volts with an instantaneous integral trip or relay operated trip.

(4) 5.0 cycle fault clearing time is typical for relay operated circuit breakers rated 1 kV to 35 kV when the relay operates in the instantaneous range (i.e., “no intentional delay”).

(5) 20 cycle fault clearing time is typical for low-voltage power and insulated case circuit breakers with a short time fault clearing delay for motor inrush.

(6) 30 cycle fault clearing time is typical for low-voltage power and insulated case circuit breakers with a short time fault clearing delay without instantaneous trip.

Informational Note No. 2 to Table 130.7(C)(15)(a): See Table 1 of IEEE 1584, *Guide for Performing Arc Flash Hazard Calculations*, for further information regarding list items (2) through (4) in Informational Note No. 1.

Informational Note No. 3 to Table 130.7(C)(15)(a): See IEEE C37.20.7, *Guide for Testing Switchgear Rated Up to 52 kV for Internal Arcing Faults*, for an example of a standard that provides information for arc-resistant equipment referred to in Table 130.7(C)(15)(a).

Informational Note No. 4 to Table 130.7(C)(15)(a): See Informative Annex O.2.4(9) for information on arc-resistant equipment.

Table 130.7(C)(15)(b) Arc Flash PPE Categories for dc Systems

Equipment	**Arc Flash PPE Category**	**Arc Flash Boundary**		
Storage batteries, dc switchboards, and other dc supply sources	-	-	, except capacitors	
Parameters: Greater than 150 volts and less than or equal to 600 volts	-	-		
Maximum arc duration and minimum working distance: 2 sec @ 455 mm (18 in.)	-	-		
Available fault current less than 1.5 kA	2	900 mm		
		-	-	(3 ft)
Available fault current greater than or equal to 1.5 kA and less than 3 kA	2	1.2 m		
		-	-	(4 ft)
Available fault current greater than or equal to 3 kA and less than 7 kA	3	1.8 m		
		-	-	(6 ft.)
Available fault current greater than or equal to 7 kA and less than 10 kA	4	2.5 m		
		-	-	(8 ft)

Notes:

(1) Apparel that can be expected to be exposed to electrolyte must meet both of the following conditions:

(a) Be evaluated for electrolyte protection

Informational Note: See ASTM F1296, *Standard Guide for Evaluating Chemical Protective Clothing*, for information on evaluating apparel for protection from electrolyte.

(b) Be arc rated

Informational Note: See ASTM F1891, *Standard Specification for Arc and Flame Resistant Rainwear*, for information on evaluating arc-rated apparel.

(2) A two-second arc duration is assumed if there is no overcurrent protective device (OCPD) or if the fault clearing time is not known. If the fault clearing time is known and is less than 2 seconds, an incident energy analysis could provide a more representative result.

Informational Note No. 1: See D.5 for the basis for table values and alternative methods to determine dc incident energy. Methods should be used with good engineering judgment. When determining available fault current, the effects of cables and any other impedances in the circuit should be included. Power system modeling is the best method to determine the available short-circuit current at the point of the arc. Battery cell short-circuit current can be obtained from the battery manufacturer.

Informational Note No. 2: The methods for estimating the dc arc flash incident energy that were used to determine the categories for this table are based on open-air incident energy calculations. Open-air calculations were used because many battery systems and other dc process systems are in open areas or rooms. If the specific task is within an enclosure, it would be prudent to consider additional PPE protection beyond the value shown in this table.

Informational Note No. 3: See the following references for dc voltages below 150 volts nominal:

(1) J. G. Hildreth and K. Feeney, “Arc Flash Hazards Station Battery Systems,” 2018 IEEE Power & Energy Society General Meeting (PESGM), 2018, pp. 1–5.

(2) US Department of Energy Bonneville Power Administration Engineering and Technical Services Report BPA F 5450.05, “DC Arc Flash: 125V, 1300 amp-hour battery,” May 11, 2017, doi: 10.1109/PESGM.2018.8586181.

(3) K. Gray, S. Robert, and T. L. Gauthier, "Low Voltage 100–500 Vdc Arc Flash Testing," 2020 IEEE IAS Electrical Safety Workshop (ESW), 2020, pp. 1–7, doi: 10.1109/ESW42757.2020.9188336.

Table 130.7(C)(15)(c) Personal Protective Equipment (PPE)

Arc-Flash PPE Category	PPE	
1	**Arc-Rated Clothing, Minimum Arc Rating of 4 cal/cm^2 (16.75 J/cm^2)**[a]	
	-	Arc-rated long-sleeve shirt and pants or arc-rated coverall
	-	Arc-rated face shield[b] or arc flash suit hood
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]

Arc-Flash PPE Category	PPE	
	-	Heavy-duty leather gloves, arc-rated gloves, or rubber insulating gloves with protectors (SR)[d]
	-	Leather footwear[e] (AN)
2	**Arc-Rated Clothing, Minimum Arc Rating of 8 cal/cm^2 (33.5 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt and pants or arc-rated coverall
	-	Arc-rated flash suit hood or arc-rated face shield[b] and arc-rated balaclava
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Heavy-duty leather gloves, arc-rated gloves, or rubber insulating gloves with protectors (SR)[d]
	-	Leather footwear[e]
3	**Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 25 cal/cm^2 (104.7 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt (AR)
	-	Arc-rated pants (AR)
	Arc-rated coverall (AR)	
	-	Arc-rated arc flash suit jacket (AR)
	Arc-rated arc flash suit pants (AR)	
	-	Arc-rated arc flash suit hood
	-	Arc-rated gloves or rubber insulating gloves with protectors (SR)[d]
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**

Arc-Flash PPE Category	PPE	
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Leather footwear[e]
4	**Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 40 cal/cm^2 (167.5 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt (AR)
	-	Arc-rated pants (AR)
	Arc-rated coverall (AR)	
	-	Arc-rated arc flash suit jacket (AR)
	Arc-rated arc flash suit pants (AR)	
	-	Arc-rated arc flash suit hood
	-	Arc-rated gloves or rubber insulating gloves with protectors (SR)[d]
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Leather footwear[e]

AN: As needed (optional). AR: As required. SR: Selection required.

[a] *Arc rating* is defined in Article 100.

[b] Face shields are to have wrap-around guarding to protect not only the face but also the forehead, ears, and neck, or, alternatively, an arc-rated arc flash suit hood is required to be worn.

[c] Other types of hearing protection are permitted to be used in lieu of or in addition to ear canal inserts provided they are worn under an arc-rated arc flash suit hood.

[d] Rubber insulating gloves with protectors provide arc flash protection in addition to electric shock protection. Higher class rubber insulating gloves with protectors, due to their increased material thickness, provide increased arc flash protection.

[e] Footwear other than leather or dielectric shall be permitted to be used provided it has been tested to demonstrate no ignition, melting or dripping at the minimum arc rating for the respective arc flash PPE category.

[f]The arc rating of outer layers worn over arc-rated clothing as protection from the elements or for other safety purposes, and that are not used as part of a layered system, shall not be required to be equal to or greater than the estimated incident energy exposure.

Statement of Problem and Substantiation for Public Input

Equipment covered by Table 130.7(C)(15)(b)
Storage batteries, dc switchboards, and other dc supply sources, except capacitors

Capacitors is a class of dc source, but not a dc power system. Capacitor arc flash incident energy analysis is covered in Article 360 and Annex R. No method in Annex D.5 is applicable to capacitors.

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Committee Statement

Resolution: FR-79-NFPA 70E-2024

Statement: This revision corrects the title of Reference (1) and makes an editorial correction that assigned the doi reference to the wrong citation.

DC circuit modeling is a more appropriate term. The term "power system modeling" is used for ac systems to include transformer impedances, system ac impedances (resistance and inductance) and over current protection, etc. A dc circuit model uses the short circuit current of a source, such as a battery, the busbar and connection resistances, and any dc overcurrent protection.

Capacitor is a class of dc source, but not a dc power system. Capacitor arc flash incident energy analysis is covered in Article 360 and Informational Annex R with methods not used to develop this table. This revision only affects capacitors covered in Article 360. Arc flash protection from hazards associated with supercapacitors can be determined with this table.

The revised language is clearer and explains why additional PPE may be needed.

Public Input No. 200-NFPA 70E-2024 [Section No. 130.7(C)(15)]

(15) Arc Flash PPE Category Method.

The requirements of 130.7(C)(15) shall apply when the arc flash PPE category method is used for the selection of arc flash PPE.

Informational Note: For both ac and dc systems, the arc flash PPE category of the protective clothing and equipment is generally based on determination of the estimated exposure level.

(a) *Alternating Current (ac) Equipment.* When the arc flash risk assessment performed in accordance with 130.5 indicates that arc flash PPE is required and the arc flash PPE category method is used for the selection of PPE for ac systems in lieu of the incident energy analysis of 130.5(G), Table 130.7(C)(15)(a) shall be used to determine the arc flash PPE category. The estimated maximum available fault current, maximum fault-clearing times, and minimum working distances for various ac equipment types or classifications are listed in Table 130.7(C)(15)(a). An incident energy analysis shall be required in accordance with 130.5(G) for the following:

(2) Power systems with greater than the estimated maximum available fault current

(3) Power systems with longer than the maximum fault clearing times

(4) Less than the minimum working distance

(e) *Direct Current (dc) Equipment.* When the arc flash risk assessment performed in accordance with 130.5(G) indicates that arc flash PPE is required and the arc flash PPE category method is used for the selection of PPE for dc systems in lieu of the incident energy analysis of 130.5(G), Table 130.7(C)(15)(b) shall be used to determine the arc flash PPE category. The estimated maximum available fault current, maximum arc duration, and working distances for dc equipment are listed in 130.7(C)(15)(b). An incident energy analysis shall be required in accordance with 130.5(G) for the following:

(6) Power systems with greater than the estimated maximum available fault current

(7) Power systems with longer than the maximum arc duration

(8) Less than the minimum working distance

(i) *Protective Clothing and Personal Protective Equipment (PPE).* Once the arc flash PPE category has been identified from Table 130.7(C)(15)(a) or Table 130.7(C)(15)(b), Table 130.7(C)(15)(c) shall be used to determine the required PPE. Table 130.7(C)(15)(c) lists the requirements for PPE based on arc flash PPE categories 1 through 4. This clothing and equipment shall be used when working within the arc flash boundary. The use of PPE other than or in addition to that listed shall be permitted provided it meets 130.7(C)(7).

Informational Note No. 1: See Informative Annex H for a suggested simplified approach to ensure adequate PPE for electrical workers within facilities with large and diverse electrical systems.

Informational Note No. 2: The PPE requirements of this section are intended to protect a person from arc flash hazards. While some situations could result in burns to the skin even with the protection described in Table 130.7(C)(15)(c), burn injury should be reduced and survivable. Due to the explosive effect of some arc events, physical trauma injuries could occur. The PPE requirements of this section do not address protection against physical trauma other than exposure to the thermal effects of an arc flash.

Informational Note No. 3: The arc rating for a particular clothing system can be obtained from the arc-rated clothing manufacturer.

Table 130.7(C)(15)(a) Arc Flash PPE Categories for Alternating Current (ac) Systems

Equipment	Arc Flash PPE Category	Arc Flash Boundary
Panelboards or other equipment rated 240 volts and below	1	485 mm (19 in.)
Parameters: Maximum of 25 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
Panelboards or other equipment rated greater than 240 volts and up to 600 volts	2	900 mm (3 ft)
Parameters: Maximum of 25 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class motor control centers (MCCs)	2	1.5 m (5 ft)
Parameters: Maximum of 65 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class motor control centers (MCCs)	4	4.3 m (14 ft)
Parameters: Maximum of 42 kA available fault current; maximum of 0.33 sec (20 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class switchgear (with power circuit breakers or fused switches) and 600-volt class switchboards	4	6 m (20 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.5 sec (30 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
Other 600-volt class (277 volts through 600 volts, nominal) equipment	2	1.5 m (5 ft)
Parameters: Maximum of 65 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
NEMA E2 (fused contactor) motor starters, 2.3 kV through 7.2 kV	4	12 m (40 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault	-	-

Equipment	Arc Flash PPE Category	Arc Flash Boundary
clearing time; minimum working distance 910 mm (36 in.)		
Metal-clad switchgear, 1 kV through 15 kV	4	12 m (40 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	-	-
Metal enclosed interrupter switchgear, fused or unfused type construction, 1 kV through 15 kV Parameters: Maximum of 35 kA available fault current; maximum of 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	4	12 m (40 ft)
Other equipment 1 kV through 15 kV Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	4	12 m (40 ft)
Arc-resistant equipment up to 600-volt class Parameters: DOORS CLOSED and SECURED; with an available fault current and a fault clearing time that does not exceed the arc-resistant rating of the equipment*	N/A	N/A
Arc-resistant equipment 1 kV through 15 kV	N/A	N/A
Parameters: DOORS CLOSED and SECURED; with an available fault current and a fault clearing time that does not exceed the arc-resistant rating of the equipment*	-	-

N/A: Not applicable

Note:

For equipment rated 600 volts and below and protected by upstream current-limiting fuses or current-limiting molded case circuit breakers sized at 200 amperes or less, the arc flash PPE category can be reduced by one number but not below arc flash PPE category 1.

*For DOORS OPEN refer to the corresponding non-arc-resistant equipment section of this table.

Informational Note No. 1 to Table 130.7(C)(15)(a): The following are typical fault clearing times of overcurrent protective devices:

(1) 0.5 cycle fault clearing time is typical for current-limiting fuses and current-limiting molded case circuit breakers when the fault current is within the current limiting range.

(2) 1.5 cycle fault clearing time is typical for molded case circuit breakers rated less than 1000 volts with an instantaneous integral trip.

(3) 3.0 cycle fault clearing time is typical for insulated case circuit breakers rated less than 1000 volts with an instantaneous integral trip or relay operated trip.

(4) 5.0 cycle fault clearing time is typical for relay operated circuit breakers rated 1 kV to 35 kV when the relay operates in the instantaneous range (i.e., “no intentional delay”).

(5) 20 cycle fault clearing time is typical for low-voltage power and insulated case circuit breakers with a short time fault clearing delay for motor inrush.

(6) 30 cycle fault clearing time is typical for low-voltage power and insulated case circuit breakers with a short time fault clearing delay without instantaneous trip.

Informational Note No. 2 to Table 130.7(C)(15)(a): See Table 1 of IEEE 1584, *Guide for Performing Arc Flash Hazard Calculations*, for further information regarding list items (2) through (4) in Informational Note No. 1.

Informational Note No. 3 to Table 130.7(C)(15)(a): See IEEE C37.20.7, *Guide for Testing Switchgear Rated Up to 52 kV for Internal Arcing Faults*, for an example of a standard that provides information for arc-resistant equipment referred to in Table 130.7(C)(15)(a).

Informational Note No. 4 to Table 130.7(C)(15)(a): See Informative Annex O.2.4(9) for information on arc-resistant equipment.

Table 130.7(C)(15)(b) Arc Flash PPE Categories for dc Systems

Equipment	**Arc Flash PPE Category**	**Arc Flash Boundary**
Storage batteries, dc switchboards, and other dc supply sources	-	-
Parameters: Greater than 150 volts and less than or equal to 600 volts	-	-
Maximum arc duration and minimum working distance: 2 sec @ 455 mm (18 in.)	-	-
Available fault current less than 1.5 kA	2	900 mm
		- - (3 ft)
Available fault current greater than or equal to 1.5 kA and less than 3 kA	2	1.2 m
		- - (4 ft)
Available fault current greater than or equal to 3 kA and less than 7 kA	3	1.8 m
		- - (6 ft.)
Available fault current greater than or equal to 7 kA and less than 10 kA	4	2.5 m
		- - (8 ft)

Notes:

(1) Apparel that can be expected to be exposed to electrolyte must meet both of the following conditions:

(a) Be evaluated for electrolyte protection

Informational Note: See ASTM F1296, *Standard Guide for Evaluating Chemical Protective Clothing*, for information on evaluating apparel for protection from electrolyte.

(b) Be arc rated

Informational Note: See ASTM F1891, *Standard Specification for Arc and Flame Resistant Rainwear*, for information on evaluating arc-rated apparel.

(2) A two-second arc duration is assumed if there is no overcurrent protective device (OCPD) or if the fault clearing time is not known. If the fault clearing time is known and is less than 2 seconds, an incident energy analysis could provide a more representative result.

Informational Note No. 1: See D.5 for the basis for table values and alternative methods to determine dc incident energy. Methods should be used with good engineering judgment. When determining available fault current, the effects of cables and any other impedances in the circuit should be included. ~~Power system modeling~~ Circuit modeling of the dc circuit is the best method to determine the available short-circuit current at the point of the arc. Battery cell short-circuit current can be obtained from the battery manufacturer.

Informational Note No. 2: The methods for estimating the dc arc flash incident energy that were used to determine the categories for this table are based on open-air incident energy calculations. Open-air calculations were used because many battery systems and other dc process systems are in open areas or rooms. If the specific task is within an enclosure, it would be prudent to consider additional PPE protection beyond the value shown in this table.

Informational Note No. 3: See the following references for dc voltages below 150 volts nominal:

(1) J. G. Hildreth and K. Feeney, “Arc Flash Hazards Station Battery Systems,” 2018 IEEE Power & Energy Society General Meeting (PESGM), 2018, pp. 1–5.

(2) US Department of Energy Bonneville Power Administration Engineering and Technical Services Report BPA F 5450.05, “DC Arc Flash: 125V, 1300 amp-hour battery,” May 11, 2017, doi: 10.1109/PESGM.2018.8586181.

(3) K. Gray, S. Robert, and T. L. Gauthier, "Low Voltage 100–500 Vdc Arc Flash Testing," 2020 IEEE IAS Electrical Safety Workshop (ESW), 2020, pp. 1–7, doi: 10.1109/ESW42757.2020.9188336.

Table 130.7(C)(15)(c) Personal Protective Equipment (PPE)

Arc-Flash PPE Category	PPE	
1	**Arc-Rated Clothing, Minimum Arc Rating of 4 cal/cm^2 (16.75 J/cm^2)**[a]	
	-	Arc-rated long-sleeve shirt and pants or arc-rated coverall
	-	Arc-rated face shield[b] or arc flash suit hood
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)

Arc-Flash PPE Category	PPE	
	-	Hearing protection (ear canal inserts)[c]
	-	Heavy-duty leather gloves, arc-rated gloves, or rubber insulating gloves with protectors (SR)[d]
	-	Leather footwear[e] (AN)
2	**Arc-Rated Clothing, Minimum Arc Rating of 8 cal/cm^2 (33.5 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt and pants or arc-rated coverall
	-	Arc-rated flash suit hood or arc-rated face shield[b] and arc-rated balaclava
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Heavy-duty leather gloves, arc-rated gloves, or rubber insulating gloves with protectors (SR)[d]
	-	Leather footwear[e]
3	**Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 25 cal/cm^2 (104.7 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt (AR)
	-	Arc-rated pants (AR)
	Arc-rated coverall (AR)	
	-	Arc-rated arc flash suit jacket (AR)
	Arc-rated arc flash suit pants (AR)	
	-	Arc-rated arc flash suit hood
	-	Arc-rated gloves or rubber insulating gloves with protectors (SR)[d]
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or

Arc-Flash PPE Category	PPE	
		hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Leather footwear[e]
4	**Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 40 cal/cm^2 (167.5 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt (AR)
	-	Arc-rated pants (AR)
	Arc-rated coverall (AR)	
	-	Arc-rated arc flash suit jacket (AR)
	Arc-rated arc flash suit pants (AR)	
	-	Arc-rated arc flash suit hood
	-	Arc-rated gloves or rubber insulating gloves with protectors (SR)[d]
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Leather footwear[e]

AN: As needed (optional). AR: As required. SR: Selection required.

[a]*Arc rating* is defined in Article 100.

[b]Face shields are to have wrap-around guarding to protect not only the face but also the forehead, ears, and neck, or, alternatively, an arc-rated arc flash suit hood is required to be worn.

[c]Other types of hearing protection are permitted to be used in lieu of or in addition to ear canal inserts provided they are worn under an arc-rated arc flash suit hood.

[d]Rubber insulating gloves with protectors provide arc flash protection in addition to electric shock protection. Higher class rubber insulating gloves with protectors, due to their increased material thickness, provide increased arc flash protection.

[e]Footwear other than leather or dielectric shall be permitted to be used provided it has been tested to demonstrate no ignition, melting or dripping at the minimum arc rating for the respective arc flash PPE category.

[f]The arc rating of outer layers worn over arc-rated clothing as protection from the elements or for other safety purposes, and that are not used as part of a layered system, shall not be required to be equal to or greater than the estimated incident energy exposure.

Statement of Problem and Substantiation for Public Input

The term "Power System modeling" is used for ac system to include transformer impedances, system ac impedances (resistance and inductance) and over current protection, etc. The modeling tools are different than dc. A dc circuit model used the short circuit current of a source, such as a battery, the buss and connection resistances, and any dc overcurrent protection. DC circuit modeling is a more appropriate term.

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Committee: EEW-AAA

Committee Statement

Resolution: FR-79-NFPA 70E-2024

Statement: This revision corrects the title of Reference (1) and makes an editorial correction that assigned the doi reference to the wrong citation.

DC circuit modeling is a more appropriate term. The term "power system modeling" is used for ac systems to include transformer impedances, system ac impedances (resistance and inductance) and over current protection, etc. A dc circuit model uses the short circuit current of a source, such as a battery, the busbar and connection resistances, and any dc overcurrent protection.

Capacitor is a class of dc source, but not a dc power system. Capacitor arc flash incident energy analysis is covered in Article 360 and Informational Annex R with methods not used to develop this table. This revision only affects capacitors covered in Article 360. Arc flash protection from hazards associated with supercapacitors can be determined with this table.

The revised language is clearer and explains why additional PPE may be needed.

Public Input No. 201-NFPA 70E-2024 [Section No. 130.7(C)(15)]

(15) Arc Flash PPE Category Method.

The requirements of 130.7(C)(15) shall apply when the arc flash PPE category method is used for the selection of arc flash PPE.

Informational Note: For both ac and dc systems, the arc flash PPE category of the protective clothing and equipment is generally based on determination of the estimated exposure level.

(a) *Alternating Current (ac) Equipment.* When the arc flash risk assessment performed in accordance with 130.5 indicates that arc flash PPE is required and the arc flash PPE category method is used for the selection of PPE for ac systems in lieu of the incident energy analysis of 130.5(G), Table 130.7(C)(15)(a) shall be used to determine the arc flash PPE category. The estimated maximum available fault current, maximum fault-clearing times, and minimum working distances for various ac equipment types or classifications are listed in Table 130.7(C)(15)(a). An incident energy analysis shall be required in accordance with 130.5(G) for the following:

(2) Power systems with greater than the estimated maximum available fault current

(3) Power systems with longer than the maximum fault clearing times

(4) Less than the minimum working distance

(e) *Direct Current (dc) Equipment.* When the arc flash risk assessment performed in accordance with 130.5(G) indicates that arc flash PPE is required and the arc flash PPE category method is used for the selection of PPE for dc systems in lieu of the incident energy analysis of 130.5(G), Table 130.7(C)(15)(b) shall be used to determine the arc flash PPE category. The estimated maximum available fault current, maximum arc duration, and working distances for dc equipment are listed in 130.7(C)(15)(b). An incident energy analysis shall be required in accordance with 130.5(G) for the following:

(6) Power systems with greater than the estimated maximum available fault current

(7) Power systems with longer than the maximum arc duration

(8) Less than the minimum working distance

(i) *Protective Clothing and Personal Protective Equipment (PPE).* Once the arc flash PPE category has been identified from Table 130.7(C)(15)(a) or Table 130.7(C)(15)(b), Table 130.7(C)(15)(c) shall be used to determine the required PPE. Table 130.7(C)(15)(c) lists the requirements for PPE based on arc flash PPE categories 1 through 4. This clothing and equipment shall be used when working within the arc flash boundary. The use of PPE other than or in addition to that listed shall be permitted provided it meets 130.7(C)(7).

Informational Note No. 1: See Informative Annex H for a suggested simplified approach to ensure adequate PPE for electrical workers within facilities with large and diverse electrical systems.

Informational Note No. 2: The PPE requirements of this section are intended to protect a person from arc flash hazards. While some situations could result in burns to the skin even with the protection described in Table 130.7(C)(15)(c), burn injury should be reduced and survivable. Due to the explosive effect of some arc events, physical trauma injuries could occur. The PPE requirements of this section do not address protection against physical trauma other than exposure to the thermal effects of an arc flash.

Informational Note No. 3: The arc rating for a particular clothing system can be obtained from the arc-rated clothing manufacturer.

Table 130.7(C)(15)(a) Arc Flash PPE Categories for Alternating Current (ac) Systems

Equipment	Arc Flash PPE Category	Arc Flash Boundary
Panelboards or other equipment rated 240 volts and below	1	485 mm (19 in.)
Parameters: Maximum of 25 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
Panelboards or other equipment rated greater than 240 volts and up to 600 volts	2	900 mm (3 ft)
Parameters: Maximum of 25 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class motor control centers (MCCs)	2	1.5 m (5 ft)
Parameters: Maximum of 65 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class motor control centers (MCCs)	4	4.3 m (14 ft)
Parameters: Maximum of 42 kA available fault current; maximum of 0.33 sec (20 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class switchgear (with power circuit breakers or fused switches) and 600-volt class switchboards	4	6 m (20 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.5 sec (30 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
Other 600-volt class (277 volts through 600 volts, nominal) equipment	2	1.5 m (5 ft)
Parameters: Maximum of 65 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
NEMA E2 (fused contactor) motor starters, 2.3 kV through 7.2 kV	4	12 m (40 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault	-	-

Equipment	Arc Flash PPE Category	Arc Flash Boundary
clearing time; minimum working distance 910 mm (36 in.)		
Metal-clad switchgear, 1 kV through 15 kV	4	12 m (40 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	-	-
Metal enclosed interrupter switchgear, fused or unfused type construction, 1 kV through 15 kV Parameters: Maximum of 35 kA available fault current; maximum of 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	4	12 m (40 ft)
Other equipment 1 kV through 15 kV Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	4	12 m (40 ft)
Arc-resistant equipment up to 600-volt class Parameters: DOORS CLOSED and SECURED; with an available fault current and a fault clearing time that does not exceed the arc-resistant rating of the equipment*	N/A	N/A
Arc-resistant equipment 1 kV through 15 kV	N/A	N/A
Parameters: DOORS CLOSED and SECURED; with an available fault current and a fault clearing time that does not exceed the arc-resistant rating of the equipment*	-	-

N/A: Not applicable

Note:

For equipment rated 600 volts and below and protected by upstream current-limiting fuses or current-limiting molded case circuit breakers sized at 200 amperes or less, the arc flash PPE category can be reduced by one number but not below arc flash PPE category 1.

*For DOORS OPEN refer to the corresponding non-arc-resistant equipment section of this table.

Informational Note No. 1 to Table 130.7(C)(15)(a): The following are typical fault clearing times of overcurrent protective devices:

(1) 0.5 cycle fault clearing time is typical for current-limiting fuses and current-limiting molded case circuit breakers when the fault current is within the current limiting range.

(2) 1.5 cycle fault clearing time is typical for molded case circuit breakers rated less than 1000 volts with an instantaneous integral trip.

(3) 3.0 cycle fault clearing time is typical for insulated case circuit breakers rated less than 1000 volts with an instantaneous integral trip or relay operated trip.

(4) 5.0 cycle fault clearing time is typical for relay operated circuit breakers rated 1 kV to 35 kV when the relay operates in the instantaneous range (i.e., “no intentional delay”).

(5) 20 cycle fault clearing time is typical for low-voltage power and insulated case circuit breakers with a short time fault clearing delay for motor inrush.

(6) 30 cycle fault clearing time is typical for low-voltage power and insulated case circuit breakers with a short time fault clearing delay without instantaneous trip.

Informational Note No. 2 to Table 130.7(C)(15)(a): See Table 1 of IEEE 1584, *Guide for Performing Arc Flash Hazard Calculations*, for further information regarding list items (2) through (4) in Informational Note No. 1.

Informational Note No. 3 to Table 130.7(C)(15)(a): See IEEE C37.20.7, *Guide for Testing Switchgear Rated Up to 52 kV for Internal Arcing Faults*, for an example of a standard that provides information for arc-resistant equipment referred to in Table 130.7(C)(15)(a).

Informational Note No. 4 to Table 130.7(C)(15)(a): See Informative Annex O.2.4(9) for information on arc-resistant equipment.

Table 130.7(C)(15)(b) Arc Flash PPE Categories for dc Systems

Equipment	**Arc Flash PPE Category**	**Arc Flash Boundary**
Storage batteries, dc switchboards, and other dc supply sources	-	-
Parameters: Greater than 150 volts and less than or equal to 600 volts	-	-
Maximum arc duration and minimum working distance: 2 sec @ 455 mm (18 in.)	-	-
Available fault current less than 1.5 kA	2	900 mm
		- - (3 ft)
Available fault current greater than or equal to 1.5 kA and less than 3 kA	2	1.2 m
		- - (4 ft)
Available fault current greater than or equal to 3 kA and less than 7 kA	3	1.8 m
		- - (6 ft.)
Available fault current greater than or equal to 7 kA and less than 10 kA	4	2.5 m
		- - (8 ft)

Notes:

(1) Apparel that can be expected to be exposed to electrolyte must meet both of the following conditions:

(a) Be evaluated for electrolyte protection

Informational Note: See ASTM F1296, *Standard Guide for Evaluating Chemical Protective Clothing*, for information on evaluating apparel for protection from electrolyte.

(b) Be arc rated

Informational Note: See ASTM F1891, *Standard Specification for Arc and Flame Resistant Rainwear*, for information on evaluating arc-rated apparel.

(2) A two-second arc duration is assumed if there is no overcurrent protective device (OCPD) or if the fault clearing time is not known. If the fault clearing time is known and is less than 2 seconds, an incident energy analysis could provide a more representative result.

Informational Note No. 1: See D.5 for the basis for table values and alternative methods to determine dc incident energy. Methods should be used with good engineering judgment. When determining available fault current, the effects of cables and any other impedances in the circuit should be included. Power system modeling is the best method to determine the available short-circuit current at the point of the arc. Battery cell short-circuit current can be obtained from the battery manufacturer.

Informational Note No. 2: The methods for estimating the dc arc flash incident energy that were used to determine the categories for this table are based on open-air incident energy calculations. Open-air calculations were used because many battery systems and other dc process systems are in open areas or rooms. If the specific task is within an enclosure, ~~it would be prudent to consider~~ consideration should be made for additional PPE protection beyond the value shown in this table, as the incident energy may be higher .

Informational Note No. 3: See the following references for dc voltages below 150 volts nominal:

(1) J. G. Hildreth and K. Feeney, “Arc Flash Hazards Station Battery Systems,” 2018 IEEE Power & Energy Society General Meeting (PESGM), 2018, pp. 1–5.

(2) US Department of Energy Bonneville Power Administration Engineering and Technical Services Report BPA F 5450.05, “DC Arc Flash: 125V, 1300 amp-hour battery,” May 11, 2017, doi: 10.1109/PESGM.2018.8586181.

(3) K. Gray, S. Robert, and T. L. Gauthier, "Low Voltage 100–500 Vdc Arc Flash Testing," 2020 IEEE IAS Electrical Safety Workshop (ESW), 2020, pp. 1–7, doi: 10.1109/ESW42757.2020.9188336.

Table 130.7(C)(15)(c) Personal Protective Equipment (PPE)

Arc-Flash PPE Category	PPE	
1	**Arc-Rated Clothing, Minimum Arc Rating of 4 cal/cm^2 (16.75 J/cm^2)**[a]	
	-	Arc-rated long-sleeve shirt and pants or arc-rated coverall
	-	Arc-rated face shield[b] or arc flash suit hood
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)

Arc-Flash PPE Category	PPE	
	-	Hearing protection (ear canal inserts)[c]
	-	Heavy-duty leather gloves, arc-rated gloves, or rubber insulating gloves with protectors (SR)[d]
	-	Leather footwear[e] (AN)
2	**Arc-Rated Clothing, Minimum Arc Rating of 8 cal/cm^2 (33.5 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt and pants or arc-rated coverall
	-	Arc-rated flash suit hood or arc-rated face shield[b] and arc-rated balaclava
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Heavy-duty leather gloves, arc-rated gloves, or rubber insulating gloves with protectors (SR)[d]
	-	Leather footwear[e]
3	**Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 25 cal/cm^2 (104.7 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt (AR)
	-	Arc-rated pants (AR)
	Arc-rated coverall (AR)	
	-	Arc-rated arc flash suit jacket (AR)
	Arc-rated arc flash suit pants (AR)	
	-	Arc-rated arc flash suit hood
	-	Arc-rated gloves or rubber insulating gloves with protectors (SR)[d]
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or

Arc-Flash PPE Category	PPE	
		hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Leather footwear[e]
4	**Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 40 cal/cm^2 (167.5 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt (AR)
	-	Arc-rated pants (AR)
	Arc-rated coverall (AR)	
	-	Arc-rated arc flash suit jacket (AR)
	Arc-rated arc flash suit pants (AR)	
	-	Arc-rated arc flash suit hood
	-	Arc-rated gloves or rubber insulating gloves with protectors (SR)[d]
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Leather footwear[e]

AN: As needed (optional). AR: As required. SR: Selection required.

[a]*Arc rating* is defined in Article 100.

[b]Face shields are to have wrap-around guarding to protect not only the face but also the forehead, ears, and neck, or, alternatively, an arc-rated arc flash suit hood is required to be worn.

[c]Other types of hearing protection are permitted to be used in lieu of or in addition to ear canal inserts provided they are worn under an arc-rated arc flash suit hood.

[d]Rubber insulating gloves with protectors provide arc flash protection in addition to electric shock protection. Higher class rubber insulating gloves with protectors, due to their increased material thickness, provide increased arc flash protection.

[e]Footwear other than leather or dielectric shall be permitted to be used provided it has been tested to demonstrate no ignition, melting or dripping at the minimum arc rating for the respective arc flash PPE category.

[f]The arc rating of outer layers worn over arc-rated clothing as protection from the elements or for other safety purposes, and that are not used as part of a layered system, shall not be required to be equal to or greater than the estimated incident energy exposure.

Statement of Problem and Substantiation for Public Input

Recent tests show that the enclosure for battery systems may make little difference. The point of this change is to replace the word "prudent" as it implies the energy will be higher.

Submitter Information Verification

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Submittal Date: Mon Jun 03 22:07:40 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-79-NFPA 70E-2024

Statement: This revision corrects the title of Reference (1) and makes an editorial correction that assigned the doi reference to the wrong citation.

DC circuit modeling is a more appropriate term. The term "power system modeling" is used for ac systems to include transformer impedances, system ac impedances (resistance and inductance) and over current protection, etc. A dc circuit model uses the short circuit current of a source, such as a battery, the busbar and connection resistances, and any dc overcurrent protection.

Capacitor is a class of dc source, but not a dc power system. Capacitor arc flash incident energy analysis is covered in Article 360 and Informational Annex R with methods not used to develop this table. This revision only affects capacitors covered in Article 360. Arc flash protection from hazards associated with supercapacitors can be determined with this table.

The revised language is clearer and explains why additional PPE may be needed.

Public Input No. 202-NFPA 70E-2024 [Section No. 130.7(C)(15)]

(15) Arc Flash PPE Category Method.

The requirements of 130.7(C)(15) shall apply when the arc flash PPE category method is used for the selection of arc flash PPE.

Informational Note: For both ac and dc systems, the arc flash PPE category of the protective clothing and equipment is generally based on determination of the estimated exposure level.

(a) *Alternating Current (ac) Equipment.* When the arc flash risk assessment performed in accordance with 130.5 indicates that arc flash PPE is required and the arc flash PPE category method is used for the selection of PPE for ac systems in lieu of the incident energy analysis of 130.5(G), Table 130.7(C)(15)(a) shall be used to determine the arc flash PPE category. The estimated maximum available fault current, maximum fault-clearing times, and minimum working distances for various ac equipment types or classifications are listed in Table 130.7(C)(15)(a). An incident energy analysis shall be required in accordance with 130.5(G) for the following:

(2) Power systems with greater than the estimated maximum available fault current

(3) Power systems with longer than the maximum fault clearing times

(4) Less than the minimum working distance

(e) *Direct Current (dc) Equipment.* When the arc flash risk assessment performed in accordance with 130.5(G) indicates that arc flash PPE is required and the arc flash PPE category method is used for the selection of PPE for dc systems in lieu of the incident energy analysis of 130.5(G), Table 130.7(C)(15)(b) shall be used to determine the arc flash PPE category. The estimated maximum available fault current, maximum arc duration, and working distances for dc equipment are listed in 130.7(C)(15)(b). An incident energy analysis shall be required in accordance with 130.5(G) for the following:

(6) Power systems with greater than the estimated maximum available fault current

(7) Power systems with longer than the maximum arc duration

(8) Less than the minimum working distance

(i) *Protective Clothing and Personal Protective Equipment (PPE).* Once the arc flash PPE category has been identified from Table 130.7(C)(15)(a) or Table 130.7(C)(15)(b), Table 130.7(C)(15)(c) shall be used to determine the required PPE. Table 130.7(C)(15)(c) lists the requirements for PPE based on arc flash PPE categories 1 through 4. This clothing and equipment shall be used when working within the arc flash boundary. The use of PPE other than or in addition to that listed shall be permitted provided it meets 130.7(C)(7).

Informational Note No. 1: See Informative Annex H for a suggested simplified approach to ensure adequate PPE for electrical workers within facilities with large and diverse electrical systems.

Informational Note No. 2: The PPE requirements of this section are intended to protect a person from arc flash hazards. While some situations could result in burns to the skin even with the protection described in Table 130.7(C)(15)(c), burn injury should be reduced and survivable. Due to the explosive effect of some arc events, physical trauma injuries could occur. The PPE requirements of this section do not address protection against physical trauma other than exposure to the thermal effects of an arc flash.

Informational Note No. 3: The arc rating for a particular clothing system can be obtained from the arc-rated clothing manufacturer.

Table 130.7(C)(15)(a) Arc Flash PPE Categories for Alternating Current (ac) Systems

Equipment	Arc Flash PPE Category	Arc Flash Boundary
Panelboards or other equipment rated 240 volts and below	1	485 mm (19 in.)
Parameters: Maximum of 25 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
Panelboards or other equipment rated greater than 240 volts and up to 600 volts	2	900 mm (3 ft)
Parameters: Maximum of 25 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class motor control centers (MCCs)	2	1.5 m (5 ft)
Parameters: Maximum of 65 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class motor control centers (MCCs)	4	4.3 m (14 ft)
Parameters: Maximum of 42 kA available fault current; maximum of 0.33 sec (20 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class switchgear (with power circuit breakers or fused switches) and 600-volt class switchboards	4	6 m (20 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.5 sec (30 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
Other 600-volt class (277 volts through 600 volts, nominal) equipment	2	1.5 m (5 ft)
Parameters: Maximum of 65 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
NEMA E2 (fused contactor) motor starters, 2.3 kV through 7.2 kV	4	12 m (40 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault	-	-

Equipment	Arc Flash PPE Category	Arc Flash Boundary
clearing time; minimum working distance 910 mm (36 in.)		
Metal-clad switchgear, 1 kV through 15 kV	4	12 m (40 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	-	-
Metal enclosed interrupter switchgear, fused or unfused type construction, 1 kV through 15 kV Parameters: Maximum of 35 kA available fault current; maximum of 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	4	12 m (40 ft)
Other equipment 1 kV through 15 kV Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	4	12 m (40 ft)
Arc-resistant equipment up to 600-volt class Parameters: DOORS CLOSED and SECURED; with an available fault current and a fault clearing time that does not exceed the arc-resistant rating of the equipment*	N/A	N/A
Arc-resistant equipment 1 kV through 15 kV	N/A	N/A
Parameters: DOORS CLOSED and SECURED; with an available fault current and a fault clearing time that does not exceed the arc-resistant rating of the equipment*	-	-

N/A: Not applicable

Note:

For equipment rated 600 volts and below and protected by upstream current-limiting fuses or current-limiting molded case circuit breakers sized at 200 amperes or less, the arc flash PPE category can be reduced by one number but not below arc flash PPE category 1.

*For DOORS OPEN refer to the corresponding non-arc-resistant equipment section of this table.

Informational Note No. 1 to Table 130.7(C)(15)(a): The following are typical fault clearing times of overcurrent protective devices:

(1) 0.5 cycle fault clearing time is typical for current-limiting fuses and current-limiting molded case circuit breakers when the fault current is within the current limiting range.

(2) 1.5 cycle fault clearing time is typical for molded case circuit breakers rated less than 1000 volts with an instantaneous integral trip.

(3) 3.0 cycle fault clearing time is typical for insulated case circuit breakers rated less than 1000 volts with an instantaneous integral trip or relay operated trip.

(4) 5.0 cycle fault clearing time is typical for relay operated circuit breakers rated 1 kV to 35 kV when the relay operates in the instantaneous range (i.e., “no intentional delay”).

(5) 20 cycle fault clearing time is typical for low-voltage power and insulated case circuit breakers with a short time fault clearing delay for motor inrush.

(6) 30 cycle fault clearing time is typical for low-voltage power and insulated case circuit breakers with a short time fault clearing delay without instantaneous trip.

Informational Note No. 2 to Table 130.7(C)(15)(a): See Table 1 of IEEE 1584, *Guide for Performing Arc Flash Hazard Calculations*, for further information regarding list items (2) through (4) in Informational Note No. 1.

Informational Note No. 3 to Table 130.7(C)(15)(a): See IEEE C37.20.7, *Guide for Testing Switchgear Rated Up to 52 kV for Internal Arcing Faults*, for an example of a standard that provides information for arc-resistant equipment referred to in Table 130.7(C)(15)(a).

Informational Note No. 4 to Table 130.7(C)(15)(a): See Informative Annex O.2.4(9) for information on arc-resistant equipment.

Table 130.7(C)(15)(b) Arc Flash PPE Categories for dc Systems

Equipment	**Arc Flash PPE Category**	**Arc Flash Boundary**
Storage batteries, dc switchboards, and other dc supply sources	-	-
Parameters: Greater than 150 volts and less than or equal to 600 volts	-	-
Maximum arc duration and minimum working distance: 2 sec @ 455 mm (18 in.)	-	-
Available fault current less than 1.5 kA	2	900 mm
		- - (3 ft)
Available fault current greater than or equal to 1.5 kA and less than 3 kA	2	1.2 m
		- - (4 ft)
Available fault current greater than or equal to 3 kA and less than 7 kA	3	1.8 m
		- - (6 ft.)
Available fault current greater than or equal to 7 kA and less than 10 kA	4	2.5 m
		- - (8 ft)

Notes:

(1) Apparel that can be expected to be exposed to electrolyte must meet both of the following conditions:

(a) Be evaluated for electrolyte protection

Informational Note: See ASTM F1296, *Standard Guide for Evaluating Chemical Protective Clothing*, for information on evaluating apparel for protection from electrolyte.

(b) Be arc rated

Informational Note: See ASTM F1891, *Standard Specification for Arc and Flame Resistant Rainwear*, for information on evaluating arc-rated apparel.

(2) A two-second arc duration is assumed if there is no overcurrent protective device (OCPD) or if the fault clearing time is not known. If the fault clearing time is known and is less than 2 seconds, an incident energy analysis could provide a more representative result.

Informational Note No. 1: See D.5 for the basis for table values and alternative methods to determine dc incident energy. Methods should be used with good engineering judgment. When determining available fault current, the effects of cables and any other impedances in the circuit should be included. Power system modeling is the best method to determine the available short-circuit current at the point of the arc. Battery cell short-circuit current can be obtained from the battery manufacturer.

Informational Note No. 2: The methods for estimating the dc arc flash incident energy that were used to determine the categories for this table are based on open-air incident energy calculations. Open-air calculations were used because many battery systems and other dc process systems are in open areas or rooms. If the specific task is within an enclosure, it would be prudent to consider additional PPE protection beyond the value shown in this table.

Informational Note No. 3: See the following references for dc voltages below 150 volts nominal:

(1) J. G. Hildreth and K. Feeney, “Arc Flash Hazards Station Battery Systems,” 2018 IEEE Power & Energy Society General Meeting (PESGM), 2018, pp. 1–5.

(2) US Department of Energy Bonneville Power Administration Engineering and Technical Services Report BPA F 5450.05, “DC Arc Flash: 125V, 1300 amp-hour battery,” May 11, 2017, doi: 10.1109/PESGM.2018.8586181.

(3) K. Gray, S. Robert, and T. L. Gauthier, "Low Voltage 100–500 Vdc Arc Flash Testing," 2020 IEEE IAS Electrical Safety Workshop (ESW), 2020, pp. 1–7, doi: 10.1109/ESW42757.2020.9188336.

Informational Note No. 4: The methods for estimating the dc arc flash incident energy that were used to determine the categories for this table assume a static arc with a constant length across the gap. These methods do not take into account the gap distance, the voltage, or the dynamic behavior of the arc. Recent tests have shown that arc lifetimes may be much less than 2 seconds, depending on the gap and voltage. Extinction by magnetic force arc elongation may also result in much lower incident energies for higher currents. Thus, this table significantly over estimates incident energies for the higher current. See Annex D.5 for discussion of these issues. The gap distance of the initial arc is a strong factor in the arc lifetime. See the following references for arc lifetimes and incident energies:

(1) L. Gordon, "Modeling the Dynamic Behavior of DC Arcs", IEEE Trans. on Industry Applications, Vol. 60, No. 1, Jan/Feb 2024, pp 1946 - 1955.

(2) Electric Power Research Institute (EPRI) Technical Report 3002014124, "DC Arc Flash on Photovoltaic (PV) Equipment, 2018.

(3) W. Fechalos and P. Blake, "DC Arc-Flash in Stationary Battery Systems", proceedings of Battcon 2023, paper No. 18.

(4) R. Veeraraghavan, "DC Arc-Flash Analysis," presentation for Symposium #1 (DC Arc Flash) at the 2017 winter meeting of the IEEE PES ESSB (Energy Storage and Stationary Battery committee, New Orleans, LA.

Table 130.7(C)(15)(c) Personal Protective Equipment (PPE)

Arc-Flash PPE Category	PPE	
1	**Arc-Rated Clothing, Minimum Arc Rating of 4 cal/cm^2 (16.75 J/cm^2)**[a]	
	-	Arc-rated long-sleeve shirt and pants or arc-rated coverall
	-	Arc-rated face shield[b] or arc flash suit hood
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Heavy-duty leather gloves, arc-rated gloves, or rubber insulating gloves with protectors (SR)[d]
	-	Leather footwear[e] (AN)
2	**Arc-Rated Clothing, Minimum Arc Rating of 8 cal/cm^2 (33.5 J/cm^2)**[a]	
	-	Arc-rated long-sleeve shirt and pants or arc-rated coverall
	-	Arc-rated flash suit hood or arc-rated face shield[b] and arc-rated balaclava
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Heavy-duty leather gloves, arc-rated gloves, or rubber insulating gloves with protectors (SR)[d]
	-	Leather footwear[e]
3	**Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required**	

Arc-Flash PPE Category	PPE	
	Minimum Arc Rating of 25 cal/cm^2 (104.7 J/cm^2)[a]	
	-	Arc-rated long-sleeve shirt (AR)
	-	Arc-rated pants (AR)
	Arc-rated coverall (AR)	
	-	Arc-rated arc flash suit jacket (AR)
	Arc-rated arc flash suit pants (AR)	
	-	Arc-rated arc flash suit hood
	-	Arc-rated gloves or rubber insulating gloves with protectors (SR)[d]
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Leather footwear[e]
4	**Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 40 cal/cm^2 (167.5 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt (AR)
	-	Arc-rated pants (AR)
	Arc-rated coverall (AR)	
	-	Arc-rated arc flash suit jacket (AR)
	Arc-rated arc flash suit pants (AR)	
	-	Arc-rated arc flash suit hood
	-	Arc-rated gloves or rubber insulating gloves with protectors (SR)[d]
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)

Arc-Flash PPE Category	PPE	
	-	Hearing protection (ear canal inserts)[c]
	-	Leather footwear[e]

AN: As needed (optional). AR: As required. SR: Selection required.

[a]*Arc rating* is defined in Article 100.

[b]Face shields are to have wrap-around guarding to protect not only the face but also the forehead, ears, and neck, or, alternatively, an arc-rated arc flash suit hood is required to be worn.

[c]Other types of hearing protection are permitted to be used in lieu of or in addition to ear canal inserts provided they are worn under an arc-rated arc flash suit hood.

[d]Rubber insulating gloves with protectors provide arc flash protection in addition to electric shock protection. Higher class rubber insulating gloves with protectors, due to their increased material thickness, provide increased arc flash protection.

[e]Footwear other than leather or dielectric shall be permitted to be used provided it has been tested to demonstrate no ignition, melting or dripping at the minimum arc rating for the respective arc flash PPE category.

[f]The arc rating of outer layers worn over arc-rated clothing as protection from the elements or for other safety purposes, and that are not used as part of a layered system, shall not be required to be equal to or greater than the estimated incident energy exposure.

Statement of Problem and Substantiation for Public Input

Many dc arc tests have been conducted over the past 6 years to provide more data on dc arc behavior. This Informational Note provides background for the proposed changes to the numbers in the table and to point the user to the revised Annex D.5.

Submitter Information Verification

Submitter Full Name: Lloyd Gordon
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Submittal Date: Mon Jun 03 22:11:16 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: The proposed information is addressing the methods used to develop the table in Informative Annex D, which is already referenced in Informational Note No. 1

Public Input No. 204-NFPA 70E-2024 [Section No. 130.7(C)(15)]

(15) Arc Flash PPE Category Method.

The requirements of 130.7(C)(15) shall apply when the arc flash PPE category method is used for the selection of arc flash PPE.

Informational Note: For both ac and dc systems, the arc flash PPE category of the protective clothing and equipment is generally based on determination of the estimated exposure level.

(a) *Alternating Current (ac) Equipment.* When the arc flash risk assessment performed in accordance with 130.5 indicates that arc flash PPE is required and the arc flash PPE category method is used for the selection of PPE for ac systems in lieu of the incident energy analysis of 130.5(G), Table 130.7(C)(15)(a) shall be used to determine the arc flash PPE category. The estimated maximum available fault current, maximum fault-clearing times, and minimum working distances for various ac equipment types or classifications are listed in Table 130.7(C)(15)(a). An incident energy analysis shall be required in accordance with 130.5(G) for the following:

(2) Power systems with greater than the estimated maximum available fault current

(3) Power systems with longer than the maximum fault clearing times

(4) Less than the minimum working distance

(e) *Direct Current (dc) Equipment.* When the arc flash risk assessment performed in accordance with 130.5(G) indicates that arc flash PPE is required and the arc flash PPE category method is used for the selection of PPE for dc systems in lieu of the incident energy analysis of 130.5(G), Table 130.7(C)(15)(b) shall be used to determine the arc flash PPE category. The estimated maximum available fault current, maximum arc duration, and working distances for dc equipment are listed in 130.7(C)(15)(b). An incident energy analysis shall be required in accordance with 130.5(G) for the following:

(6) Power systems with greater than the estimated maximum available fault current

(7) Power systems with longer than the maximum arc duration

(8) Less than the minimum working distance

(i) *Protective Clothing and Personal Protective Equipment (PPE).* Once the arc flash PPE category has been identified from Table 130.7(C)(15)(a) or Table 130.7(C)(15)(b), Table 130.7(C)(15)(c) shall be used to determine the required PPE. Table 130.7(C)(15)(c) lists the requirements for PPE based on arc flash PPE categories 1 through 4. This clothing and equipment shall be used when working within the arc flash boundary. The use of PPE other than or in addition to that listed shall be permitted provided it meets 130.7(C)(7).

Informational Note No. 1: See Informative Annex H for a suggested simplified approach to ensure adequate PPE for electrical workers within facilities with large and diverse electrical systems.

Informational Note No. 2: The PPE requirements of this section are intended to protect a person from arc flash hazards. While some situations could result in burns to the skin even with the protection described in Table 130.7(C)(15)(c), burn injury should be reduced and survivable. Due to the explosive effect of some arc events, physical trauma injuries could occur. The PPE requirements of this section do not address protection against physical trauma other than exposure to the thermal effects of an arc flash.

Informational Note No. 3: The arc rating for a particular clothing system can be obtained from the arc-rated clothing manufacturer.

Table 130.7(C)(15)(a) Arc Flash PPE Categories for Alternating Current (ac) Systems

Equipment	Arc Flash PPE Category	Arc Flash Boundary
Panelboards or other equipment rated 240 volts and below	1	485 mm (19 in.)
Parameters: Maximum of 25 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
Panelboards or other equipment rated greater than 240 volts and up to 600 volts	2	900 mm (3 ft)
Parameters: Maximum of 25 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class motor control centers (MCCs)	2	1.5 m (5 ft)
Parameters: Maximum of 65 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class motor control centers (MCCs)	4	4.3 m (14 ft)
Parameters: Maximum of 42 kA available fault current; maximum of 0.33 sec (20 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class switchgear (with power circuit breakers or fused switches) and 600-volt class switchboards	4	6 m (20 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.5 sec (30 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
Other 600-volt class (277 volts through 600 volts, nominal) equipment	2	1.5 m (5 ft)
Parameters: Maximum of 65 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
NEMA E2 (fused contactor) motor starters, 2.3 kV through 7.2 kV	4	12 m (40 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault	-	-

Equipment	Arc Flash PPE Category	Arc Flash Boundary
clearing time; minimum working distance 910 mm (36 in.)		
Metal-clad switchgear, 1 kV through 15 kV	4	12 m (40 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	-	-
Metal enclosed interrupter switchgear, fused or unfused type construction, 1 kV through 15 kV Parameters: Maximum of 35 kA available fault current; maximum of 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	4	12 m (40 ft)
Other equipment 1 kV through 15 kV Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	4	12 m (40 ft)
Arc-resistant equipment up to 600-volt class Parameters: DOORS CLOSED and SECURED; with an available fault current and a fault clearing time that does not exceed the arc-resistant rating of the equipment*	N/A	N/A
Arc-resistant equipment 1 kV through 15 kV	N/A	N/A
Parameters: DOORS CLOSED and SECURED; with an available fault current and a fault clearing time that does not exceed the arc-resistant rating of the equipment*	-	-

N/A: Not applicable

Note:

For equipment rated 600 volts and below and protected by upstream current-limiting fuses or current-limiting molded case circuit breakers sized at 200 amperes or less, the arc flash PPE category can be reduced by one number but not below arc flash PPE category 1.

*For DOORS OPEN refer to the corresponding non-arc-resistant equipment section of this table.

Informational Note No. 1 to Table 130.7(C)(15)(a): The following are typical fault clearing times of overcurrent protective devices:

(1) 0.5 cycle fault clearing time is typical for current-limiting fuses and current-limiting molded case circuit breakers when the fault current is within the current limiting range.

(2) 1.5 cycle fault clearing time is typical for molded case circuit breakers rated less than 1000 volts with an instantaneous integral trip.

(3) 3.0 cycle fault clearing time is typical for insulated case circuit breakers rated less than 1000 volts with an instantaneous integral trip or relay operated trip.

(4) 5.0 cycle fault clearing time is typical for relay operated circuit breakers rated 1 kV to 35 kV when the relay operates in the instantaneous range (i.e., “no intentional delay”).

(5) 20 cycle fault clearing time is typical for low-voltage power and insulated case circuit breakers with a short time fault clearing delay for motor inrush.

(6) 30 cycle fault clearing time is typical for low-voltage power and insulated case circuit breakers with a short time fault clearing delay without instantaneous trip.

Informational Note No. 2 to Table 130.7(C)(15)(a): See Table 1 of IEEE 1584, *Guide for Performing Arc Flash Hazard Calculations*, for further information regarding list items (2) through (4) in Informational Note No. 1.

Informational Note No. 3 to Table 130.7(C)(15)(a): See IEEE C37.20.7, *Guide for Testing Switchgear Rated Up to 52 kV for Internal Arcing Faults*, for an example of a standard that provides information for arc-resistant equipment referred to in Table 130.7(C)(15)(a).

Informational Note No. 4 to Table 130.7(C)(15)(a): See Informative Annex O.2.4(9) for information on arc-resistant equipment.

Table 130.7(C)(15)(b) Arc Flash PPE Categories for dc Systems

~~.2 m~~ - ~~(6 ft~~ ~~(8 ft~~

Equipment	**Arc Flash PPE Category**	**Arc Flash Boundary**
Storage batteries, dc switchboards, and other dc supply sources	-	-
Parameters: Greater than 150 volts and less than or equal to 600 volts	-	-
Maximum arc duration and minimum working distance: 2 sec @ 455 mm (18 in.)	-	-
Available fault current less than ~~1.5 kA~~	~~2~~	~~900 mm~~
-	-	~~(3 ft)~~
~~Available fault current greater than or equal to 1.5 kA and less than~~ 3 kA	~~2~~	1
770 mm		
		- (~~4 ft~~ 30 in)
Available fault current greater than or equal to 3 kA and less than 7 kA	~~3~~ 2	~~1~~ 0 ~~.8 m~~
-	-	
9 m		
		(3 ft .)
Available fault current greater than or equal to 7 kA and less than 10 kA	~~4~~ 2	1. 2 ~~.5 m~~ - - m

Equipment	Arc Flash PPE Category	Arc Flash Boundary
		(4 ft)

Notes:

(1) Apparel that can be expected to be exposed to electrolyte must meet both of the following conditions:

(a) Be evaluated for electrolyte protection

Informational Note: See ASTM F1296, *Standard Guide for Evaluating Chemical Protective Clothing*, for information on evaluating apparel for protection from electrolyte.

(b) Be arc rated

Informational Note: See ASTM F1891, *Standard Specification for Arc and Flame Resistant Rainwear*, for information on evaluating arc-rated apparel.

(2) A two-second arc duration is assumed if there is no overcurrent protective device (OCPD) or if the fault clearing time is not known. If the fault clearing time is known and is less than 2 seconds, an incident energy analysis could provide a more representative result.

Informational Note No. 1: See D.5 for the basis for table values and alternative methods to determine dc incident energy. Methods should be used with good engineering judgment. When determining available fault current, the effects of cables and any other impedances in the circuit should be included. Power system modeling is the best method to determine the available short-circuit current at the point of the arc. Battery cell short-circuit current can be obtained from the battery manufacturer.

Informational Note No. 2: The methods for estimating the dc arc flash incident energy that were used to determine the categories for this table are based on open-air incident energy calculations. Open-air calculations were used because many battery systems and other dc process systems are in open areas or rooms. If the specific task is within an enclosure, it would be prudent to consider additional PPE protection beyond the value shown in this table.

Informational Note No. 3: See the following references for dc voltages below 150 volts nominal:

(1) J. G. Hildreth and K. Feeney, “Arc Flash Hazards Station Battery Systems,” 2018 IEEE Power & Energy Society General Meeting (PESGM), 2018, pp. 1–5.

(2) US Department of Energy Bonneville Power Administration Engineering and Technical Services Report BPA F 5450.05, “DC Arc Flash: 125V, 1300 amp-hour battery,” May 11, 2017, doi: 10.1109/PESGM.2018.8586181.

(3) K. Gray, S. Robert, and T. L. Gauthier, "Low Voltage 100–500 Vdc Arc Flash Testing," 2020 IEEE IAS Electrical Safety Workshop (ESW), 2020, pp. 1–7, doi: 10.1109/ESW42757.2020.9188336.

Table 130.7(C)(15)(c) Personal Protective Equipment (PPE)

Arc-Flash PPE Category	PPE	
1	**Arc-Rated Clothing, Minimum Arc Rating of 4 cal/cm^2 (16.75 J/cm^2)**[a]	
	-	Arc-rated long-sleeve shirt and pants or arc-rated coverall
	-	Arc-rated face shield[b] or arc flash suit hood

Arc-Flash PPE Category	PPE	
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Heavy-duty leather gloves, arc-rated gloves, or rubber insulating gloves with protectors (SR)[d]
	-	Leather footwear[e] (AN)
2	**Arc-Rated Clothing, Minimum Arc Rating of 8 cal/cm^2 (33.5 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt and pants or arc-rated coverall
	-	Arc-rated flash suit hood or arc-rated face shield[b] and arc-rated balaclava
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Heavy-duty leather gloves, arc-rated gloves, or rubber insulating gloves with protectors (SR)[d]
	-	Leather footwear[e]
3	**Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 25 cal/cm^2 (104.7 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt (AR)
	-	Arc-rated pants (AR)
	Arc-rated coverall (AR)	
	-	Arc-rated arc flash suit jacket (AR)

Arc-Flash PPE Category	PPE	
	Arc-rated arc flash suit pants (AR)	
	-	Arc-rated arc flash suit hood
	-	Arc-rated gloves or rubber insulating gloves with protectors (SR)[d]
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Leather footwear[e]
4	**Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 40 cal/cm^2 (167.5 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt (AR)
	-	Arc-rated pants (AR)
	Arc-rated coverall (AR)	
	-	Arc-rated arc flash suit jacket (AR)
	Arc-rated arc flash suit pants (AR)	
	-	Arc-rated arc flash suit hood
	-	Arc-rated gloves or rubber insulating gloves with protectors (SR)[d]
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Leather footwear[e]

AN: As needed (optional). AR: As required. SR: Selection required.

[a] *Arc rating* is defined in Article 100.

[b]Face shields are to have wrap-around guarding to protect not only the face but also the forehead, ears, and neck, or, alternatively, an arc-rated arc flash suit hood is required to be worn.

[c]Other types of hearing protection are permitted to be used in lieu of or in addition to ear canal inserts provided they are worn under an arc-rated arc flash suit hood.

[d]Rubber insulating gloves with protectors provide arc flash protection in addition to electric shock protection. Higher class rubber insulating gloves with protectors, due to their increased material thickness, provide increased arc flash protection.

[e]Footwear other than leather or dielectric shall be permitted to be used provided it has been tested to demonstrate no ignition, melting or dripping at the minimum arc rating for the respective arc flash PPE category.

[f]The arc rating of outer layers worn over arc-rated clothing as protection from the elements or for other safety purposes, and that are not used as part of a layered system, shall not be required to be equal to or greater than the estimated incident energy exposure.

Additional Proposed Changes

File Name	Description	Approved
Proposed_Value_Changes_to_Table_130.7_C_15_b_.docx	Changes to values in Table 130.7(C)(15)(b) in case they are not clear in TerraView	
DC_Arc_Flash_Test_Summary.docx	Data to justify Changes in Values of Table 130.7(C)(15)(b)	

Statement of Problem and Substantiation for Public Input

The changes in the Arc Flash Boundary and Arc Flash PPE Category are based on 22 actual tests from over 10 publications of dc arc flash testing. This PI was assembled by the DC Arc Flash Study Group including Bobby Gray, Bill Cantor, Curtis Ashton, David Rosewater, and Lloyd Gordon. References include:

L. Gordon, "Modeling the Dynamic Behavior of DC Arcs", IEEE Trans. on Industry Applications, Vol. 60, No. 1, Jan/Feb 2024, pp. 1946 - 1955.

Cheng, K., et al, “Arc Hazard Assessment for DC Applications in the Transit Industry”, proceedings of the American Public Transport Association (APTA) Rail Conference, Boston, MA, 2011.

C. Keyes and C. Maurice, “DC Arc Hazard Assessment Phase II”, Kinectrics, Toronto, ON, Canada, Report K-012623-RA-0001-R00, 2007.

Cheng, K., et al, “DC Arc-Flash Testing and Analysis at 600 V”, proceedings of the IEEE IAS Electrical Safety Workshop (ESW), Reno, NV, 2020.

Electric Power Research Institute (EPRI) Technical Report 3002014124, “DC Arc Flash on Photovoltaic (PV) Equipment”, 2018.

W. Fechalos and P. Blake, “DC Arc-Flash in Stationary Battery Systems”, proceedings of Battcon 2023, paper No. 18.

Gaunce, A., et al, “DC Arc-Flash: Testing and Modeling Incidents in a 125-V Substation Battery Backup System, IEEE Transactions on Industry Applications, Vol. 56, No. 3, pp. 2138-2147, May/Jun 2020.

K. Gray and R. Hallé, “Sustainability of an Electric Arc-Flash at a Voltage of 240 VAC and 140 Vdc”, proceedings of the IEEE IAS ESW, Reno, NV, 2023.

Gray, K., et al, “Low Voltage 100-500 Vdc Arc-Flash Testing”, proceedings of the IEEE IAS ESW, 2020.

J. Hildreth and K. Feeney, “Arc-Flash Hazards of 125 Vdc Station Battery Systems”, proceedings of the IEEE Power and Energy Society General Meeting (PES GM), paper No. 8586181, Portland, OR, 2018.

Veeraraghavan, R. (ETAP), “DC Arc-Flash Analysis”, presentation for Symposium #1 (DC Arc-Flash)

at the 2017 winter meeting of the IEEE PES ESSB (Energy Storage and Stationary Battery committee, New Orleans, LA.

K.S. Cheng and C. Keyes, “DC Arc-Flash Hazard Analysis Service for Pacific Northwest National Laboratory (PNNL)”, Kinectrics, Toronto, ON, Canada, Report K-418079-RA-001-00, Oct 2011.

Submitter Information Verification

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Submittal Date: Mon Jun 03 22:26:14 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: The substantiation does not provide evidence of the integrity of the testing methods cited in the references. Additionally, there is not an evident link between the summarized data and the specific testing criteria supporting the conclusions to reduce the protection to the worker.

Table 130.7(C)(15)(b) Arc Flash PPE Categories for dc Systems

Equipment	Arc Flash PP Category	Arc Flash Boundary
Storage batteries, dc switchboards, and other dc supply sources Parameters: Greater than 150 volts and less than or equal to 600 volts Maximum arc duration and minimum working distance: 2 sec @ 455 mm (18 in.)		
Available fault current less than 1.53 kA	21	900 0.5 mm (19 in3 ft)
Available fault current greater than or equal to 1.5 kA and less than 3 kA	2	1.2 m (4 ft)
Available fault current greater than or equal to 3 kA and less than 7 kA	23	0.91.8 m (36 ft)
Available fault current greater than or equal to 7 kA and less than 10 kA	24	1.22.5 m (48 ft)

Notes:

(1) Apparel that can be expected to be exposed to electrolyte must been both of the following conditions:

(a) Be evaluated for electrolyte protection

Informational Note: See ASTM F1296, *Standard Guide for Evaluating Chemical Protective Clothing*, for information on evaluating apparel for protection from electrolyte.

(b) Be arc rated

Informational Note: See ASTM F1891, *Standard Specification for Arc and Flame Resistant Rainwear*, for information on evaluating arc-rated apparel.

(2) A two-second arc duration is assumed if there is no overcurrent protective device (OCPD) or if the fault clearing time is not known. If the fault clearing time is known and is less than 2 seconds, an incident energy analysis could provide a more representative result.

Informational Note No. 1: See D.5 for the basis for table values and alternative methods to determine dc incident energy. Methods should be used with good engineering judgement. When determining available fault current, the effects of cables and any other impedances in the circuit should be included. Power System modeling is the best method to determine the available short-circuit current at the point of the arc. Battery cell short-circuit current can be obtained from the battery manufacturer.

Informational Note No. 2: The methods for estimating the dc arc flash incident energy that were used to determine the categories for this table are based on open air incident energy calculations. Open air calculations were used because many battery systems and other dc process systems are in open areas or rooms. If the specific task is within an enclosure, it would be prudent to consider additional PPE protection beyond the value shown in this table.

Informational Note No. 3: See the following references for dc voltages below 150 volts nominal:

(1) J. G. Hildreth and K. Feeney, "Arc Flash Hazards Station Battery Systems," 2018 IEEE Power & Energy Society General Meeting (PESGM), 2018, pp. 1-5.

Commented [LG1]: This is copied from the ac table, we use 1000 V in Annex D.5

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(2) US Department of Energy Bonneville Power Administration Engineering and Technical Services Report BPA E 5450.5, "DC Arc Flash: 125V, 1300 amp-hour battery," May 11, 2017, doi: 10.1109/PESGM.2018.8586181.
(3) K. Gray, S. Robert, and T. L. Gauthier, "Low Voltage 100-500 Vdc Arc Flash Testing," 2020 IEEE IAS Electrical Safety Workshop (ESW), 2020, pp. 1-7, doi: 10.1109/ESW42757.2020.9188336.

D.5 Direct-Current Incident Energy Calculations.

D.5.1 Maximum Power Method. The following method of estimating dc arc flash incident energy that follows was published in the *IEEE Transactions on Industry Applications* (*see reference 2 of D.5.2).* This method is based on the concept that the maximum power possible in a dc arc will occur when the arcing voltage is one-half the system voltage. Testing completed for Bruce Power *(see reference 3 of D.5.3)* has shown that this calculation is conservatively high in estimating the arc flash value. This method applies to dc systems rated up to 1000 volts.

[D.5.1]

$$I_{arc} = 0.5 \times I_{bf}$$

$$IE_m = 0.01 \times V_{sys} \times I_{arc} \times T_{arc}/D^2$$

where:
I_{arc} = arcing current, amperes
I_{bf} = system bolted fault current, amperes
IE_m = estimated dc arc flash incident energy at the maximum power point, cal/cm^2
V_{sys} = system voltage, volts
T_{arc} = arcing time, sec
D = working distance, cm

For exposures wher ethe arc is in a box or enclosure, it would be prudent to consider additional PPE protection beyond the values shown in Table 130.7(C)(15)(b).

D.5.2 Detailed Arcing Current and Energy Calculations Method. A thorough theoretical review of c arcing current and energy was published in the IEEE Transactions on Industry Applications. Readers are advised to refer to that paper (see reference 1) for those detailed calculations.

References:
1. "DC Arc Models and Incident Energy Calculations," Ammerman, R.F., et al., *IEEE Transactions on Industry Applications,* Vol. 46, No. 5.
2. "Arc Flash Calculations for Exposures to DC System," Doan, D.R., *IEEE Transactions on Industry Applications,* Vol. 46, No. 6.
3. "DC Arc Hazard Assessment Phase II," Copyright Material, Kinectrics Inc., Report No. K-012*623-RA-00020R00.*

D.5.3 Short Circuit Current. The determination of short circuit current is necessary in order to use Table 130.7(C)(15)(b). The arcing current is calculated at 50 percent of the dc short-circuit value. The current that a battery will deliver depends on the total impedance of the short-circuit path. A conservative

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approach in determining the short-circuit current that the battery will deliver at 25 C is to assume that the ixiumum available short-circuit current is 10 times the 1 minute ampere rating (to 1.75 volts per cell at 25 C and the specific gravity of 1.215) of the battery. A more accurate value for the short-circuit current for the specific application can be obtained from the battery manufacturer.

References:

1. IEEE 946, *Recommended Practice for the Design of DC Auxiliary Power Systems for Generating Stations.*

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Published tests (hundreds of individual tests) at different voltages and currents to justify going to HRC 1 for < 3 kA and HRC 2 for 3-10 kA:

- Cheng, K., et al, “Arc Hazard Assessment for DC Applications in the Transit Industry”, proceedings of the American Public Transport Association (APTA) Rail Conference, Boston, MA, 2011.
- C. Keyes and C. Maurice, “DC Arc Hazard Assessment Phase II”, Kinectrics, Toronto, ON, Canada, Report K-012623-RA-0001-R00, 2007.
- Cheng, K., et al, “DC Arc-Flash Testing and Analysis at 600 V”, proceedings of the IEEE IAS Electrical Safety Workshop (ESW), Reno, NV, 2020.
- Electric Power Research Institute (EPRI) Technical Report 3002014124, “DC Arc Flash on Photovoltaic (PV) Equipment”, 2018.
- W. Fechalos and P. Blake, “DC Arc-Flash in Stationary Battery Systems”, proceedings of Battcon 2023, paper No. 18.
- Gaunce, A., et al, “DC Arc-Flash: Testing and Modeling Incidents in a 125-V Substation Battery Backup System, IEEE Transactions on Industry Applications, Vol. 56, No. 3, pp. 2138-2147, May/Jun 2020.
- K. Gray and R. Hallé, “Sustainability of an Electric Arc-Flash at a Voltage of 240 VAC and 140 Vdc”, proceedings of the IEEE IAS ESW, Reno, NV, 2023.
- Gray, K., et al, “Low Voltage 100-500 Vdc Arc-Flash Testing”, proceedings of the IEEE IAS ESW, 2020.
- J. Hildreth and K. Feeney, “Arc-Flash Hazards of 125 Vdc Station Battery Systems”, proceedings of the IEEE Power and Energy Society General Meeting (PES GM), paper No. 8586181, Portland, OR, 2018.
- Veeraraghavan, R. (ETAP), “DC Arc-Flash Analysis”, presentation for Symposium #1 (DC Arc-Flash) at the 2017 winter meeting of the IEEE PES ESSB (Energy Storage and Stationary Battery committee, New Orleans, LA.
- K.S. Cheng and C. Keyes, “DC Arc-Flash Hazard Analysis Service for Pacific Northwest National Laboratory (PNNL)”, Kinectrics, Toronto, ON, Canada, Report K-418079-RA-001-00, Oct 2011.

Compilation of the tests from those sources 10 kA and below:

V_{nom}	V_{flt}	V_{arc}	I_{sc}	I_{arc}	t_{arc}	arc in box	IE_{act}
350			1000				0.5
480		378	1510			N	1.4
480		329	1510			N	0.6
240		189	1530	1475		N	0.34
120		77	1560	1500		N	0.8
120	130		1893	910		Y	0.52
240	258		4801	3000	0.240	Y	0.30
480	516		4801	3750	0.25	Y	1.1
480	516		4801	3190	0.87	Y	6.2
480	516		4801	3190	0.68	Y	4.6
480	516		4801	3440	0.59	Y	2.5
480	516		4801	3800	0.56	Y	1.9
480	516		4801	3340	0.82	Y	3.2
480	516		4801	3190	2.03	Y	3.8
120	141	53	5700	4100	0.034	N	0.1
100	105	65	7000	2900	0.043	Y	0.1
100	105	64	7000	3400	0.060	Y	0.1
100	104	83	7000	2000	0.084	Y	0.1
100	106	58	7000	4000	0.326	Y	0.24
100	106	57	7000	4000	0.286	Y	0.24
100	106	59	7000	3900	0.214	Y	0.16
120	130		7400	2380		Y	0.67

Public Input No. 234-NFPA 70E-2024 [Section No. 130.7(C)(15)]

(15) Arc Flash PPE Category Method.

The requirements of 130.7(C)(15) shall apply when the arc flash PPE category method is used for the selection of arc flash PPE.

Informational Note: For both ac and dc systems, the arc flash PPE category of the protective clothing and equipment is generally based on determination of the estimated exposure level.

(a) *Alternating Current (ac) Equipment.* When the arc flash risk assessment performed in accordance with 130.5 indicates that arc flash PPE is required and the arc flash PPE category method is used for the selection of PPE for ac systems in lieu of the incident energy analysis of 130.5(G), Table 130.7(C)(15)(a) shall be used to determine the arc flash PPE category. The estimated maximum available fault current, maximum fault-clearing times, and minimum working distances for various ac equipment types or classifications are listed in Table 130.7(C)(15)(a). An incident energy analysis shall be required in accordance with 130.5(G) for the following:

(2) Power systems with greater than the estimated maximum available fault current

(3) Power systems with longer than the maximum fault clearing times

(4) Less than the minimum working distance

(e) *Direct Current (dc) Equipment.* When the arc flash risk assessment performed in accordance with 130.5(G) indicates that arc flash PPE is required and the arc flash PPE category method is used for the selection of PPE for dc systems in lieu of the incident energy analysis of 130.5(G), Table 130.7(C)(15)(b) shall be used to determine the arc flash PPE category. The estimated maximum available fault current, maximum arc duration, and working distances for dc equipment are listed in 130.7(C)(15)(b). An incident energy analysis shall be required in accordance with 130.5(G) for the following:

(6) Power systems with greater than the estimated maximum available fault current

(7) Power systems with longer than the maximum arc duration

(8) Less than the minimum working distance

(i) *Protective Clothing and Personal Protective Equipment (PPE).* Once the arc flash PPE category has been identified from Table 130.7(C)(15)(a) or Table 130.7(C)(15)(b), Table 130.7(C)(15)(c) shall be used to determine the required PPE. Table 130.7(C)(15)(c) lists the requirements for PPE based on arc flash PPE categories 1 through 4. This clothing and equipment shall be used when working within the arc flash boundary. The use of PPE other than or in addition to that listed shall be permitted provided it meets 130.7(C)(7).

Informational Note No. 1: See Informative Annex H for a suggested simplified approach to ensure adequate PPE for electrical workers within facilities with large and diverse electrical systems.

Informational Note No. 2: The PPE requirements of this section are intended to protect a person from arc flash hazards. While some situations could result in burns to the skin even with the protection described in Table 130.7(C)(15)(c), burn injury should be reduced and survivable. Due to the explosive effect of some arc events, physical trauma injuries could occur. The PPE requirements of this section do not address protection against physical trauma other than exposure to the thermal effects of an arc flash.

Informational Note No. 3: The arc rating for a particular clothing system can be obtained from the arc-rated clothing manufacturer.

Table 130.7(C)(15)(a) Arc Flash PPE Categories for Alternating Current (ac) Systems

Equipment	Arc Flash PPE Category	Arc Flash Boundary
Panelboards or other equipment rated 240 volts and below	1	485 mm (19 in.)
Parameters: Maximum of 25 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
Panelboards or other equipment rated greater than 240 volts and up to 600 volts	2	900 mm (3 ft)
Parameters: Maximum of 25 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class motor control centers (MCCs)	2	1.5 m (5 ft)
Parameters: Maximum of 65 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class motor control centers (MCCs)	4	4.3 m (14 ft)
Parameters: Maximum of 42 kA available fault current; maximum of 0.33 sec (20 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class switchgear (with power circuit breakers or fused switches) and 600-volt class switchboards	4	6 m (20 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.5 sec (30 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
Other 600-volt class (277 volts through 600 volts, nominal) equipment	2	1.5 m (5 ft)
Parameters: Maximum of 65 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
NEMA E2 (fused contactor) motor starters, 2.3 kV through 7.2 kV	4	12 m (40 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault	-	-

Equipment	Arc Flash PPE Category	Arc Flash Boundary
clearing time; minimum working distance 910 mm (36 in.)		
Metal-clad switchgear, 1 kV through 15 kV	4	12 m (40 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	-	-
Metal enclosed interrupter switchgear, fused or unfused type construction, 1 kV through 15 kV Parameters: Maximum of 35 kA available fault current; maximum of 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	4	12 m (40 ft)
Other equipment 1 kV through 15 kV Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	4	12 m (40 ft)
Arc-resistant equipment up to 600-volt class Parameters: DOORS CLOSED and SECURED; with an available fault current and a fault clearing time that does not exceed the arc-resistant rating of the equipment*	N/A	N/A
Arc-resistant equipment 1 kV through 15 kV	N/A	N/A
Parameters: DOORS CLOSED and SECURED; with an available fault current and a fault clearing time that does not exceed the arc-resistant rating of the equipment*	-	-

N/A: Not applicable

Note:

For equipment rated 600 volts and below and protected by upstream current-limiting fuses or current-limiting molded case circuit breakers sized at 200 amperes or less, the arc flash PPE category can be reduced by one number but not below arc flash PPE category 1.

*For DOORS OPEN refer to the corresponding non-arc-resistant equipment section of this table.

Informational Note No. 1 to Table 130.7(C)(15)(a): The following are typical fault clearing times of overcurrent protective devices:

(1) 0.5 cycle fault clearing time is typical for current-limiting fuses and current-limiting molded case circuit breakers when the fault current is within the current limiting range.

(2) 1.5 cycle fault clearing time is typical for molded case circuit breakers rated less than 1000 volts with an instantaneous integral trip when the fault current is within the instantaneous trip region .

(3) 3.0 cycle fault clearing time is typical for insulated case circuit breakers rated less than 1000 volts with an instantaneous integral trip or relay operated trip when the fault current is within the instantaneous trip region .

(4) 5.0 cycle fault clearing time is typical for relay operated circuit breakers rated 1 kV to 35 kV when the relay operates in the instantaneous range (i.e., “no intentional delay”) when the fault current is within the instantaneous trip region .

(5) 20 cycle fault clearing time is typical for low-voltage power and insulated case circuit breakers with a short time fault clearing delay for motor inrush when the fault current is within the short-time fault learing region .

(6) 30 cycle fault clearing time is typical for low-voltage power and insulated case circuit breakers with a short time fault clearing delay without instantaneous trip when the fault current is within the short time fault clearing region .

Informational Note No. 2 to Table 130.7(C)(15)(a): See Table 1 of IEEE 1584, *Guide for Performing Arc Flash Hazard Calculations*, for further information regarding list items (2) through (4) in Informational Note No. 1.

Informational Note No. 3 to Table 130.7(C)(15)(a): See IEEE C37.20.7, *Guide for Testing Switchgear Rated Up to 52 kV for Internal Arcing Faults*, for an example of a standard that provides information for arc-resistant equipment referred to in Table 130.7(C)(15)(a).

Informational Note No. 4 to Table 130.7(C)(15)(a): See Informative Annex O.2.4(9) for information on arc-resistant equipment.

Table 130.7(C)(15)(b) Arc Flash PPE Categories for dc Systems

Equipment	**Arc Flash PPE Category**	**Arc Flash Boundary**
Storage batteries, dc switchboards, and other dc supply sources	-	-
Parameters: Greater than 150 volts and less than or equal to 600 volts	-	-
Maximum arc duration and minimum working distance: 2 sec @ 455 mm (18 in.)	-	-
Available fault current less than 1.5 kA	2	900 mm
		- - (3 ft)
Available fault current greater than or equal to 1.5 kA and less than 3 kA	2	1.2 m
		- - (4 ft)
Available fault current greater than or equal to 3 kA and less than 7 kA	3	1.8 m
		- - (6 ft.)
Available fault current greater than or equal to 7 kA and less than 10 kA	4	2.5 m
		- - (8 ft)

Notes:

(1) Apparel that can be expected to be exposed to electrolyte must meet both of the following conditions:

(a) Be evaluated for electrolyte protection

Informational Note: See ASTM F1296, *Standard Guide for Evaluating Chemical Protective Clothing*, for information on evaluating apparel for protection from electrolyte.

(b) Be arc rated

Informational Note: See ASTM F1891, *Standard Specification for Arc and Flame Resistant Rainwear*, for information on evaluating arc-rated apparel.

(2) A two-second arc duration is assumed if there is no overcurrent protective device (OCPD) or if the fault clearing time is not known. If the fault clearing time is known and is less than 2 seconds, an incident energy analysis could provide a more representative result.

Informational Note No. 1: See D.5 for the basis for table values and alternative methods to determine dc incident energy. Methods should be used with good engineering judgment. When determining available fault current, the effects of cables and any other impedances in the circuit should be included. Power system modeling is the best method to determine the available short-circuit current at the point of the arc. Battery cell short-circuit current can be obtained from the battery manufacturer.

Informational Note No. 2: The methods for estimating the dc arc flash incident energy that were used to determine the categories for this table are based on open-air incident energy calculations. Open-air calculations were used because many battery systems and other dc process systems are in open areas or rooms. If the specific task is within an enclosure, it would be prudent to consider additional PPE protection beyond the value shown in this table.

Informational Note No. 3: See the following references for dc voltages below 150 volts nominal:

(1) J. G. Hildreth and K. Feeney, “Arc Flash Hazards Station Battery Systems,” 2018 IEEE Power & Energy Society General Meeting (PESGM), 2018, pp. 1–5.

(2) US Department of Energy Bonneville Power Administration Engineering and Technical Services Report BPA F 5450.05, “DC Arc Flash: 125V, 1300 amp-hour battery,” May 11, 2017, doi: 10.1109/PESGM.2018.8586181.

(3) K. Gray, S. Robert, and T. L. Gauthier, "Low Voltage 100–500 Vdc Arc Flash Testing," 2020 IEEE IAS Electrical Safety Workshop (ESW), 2020, pp. 1–7, doi: 10.1109/ESW42757.2020.9188336.

Table 130.7(C)(15)(c) Personal Protective Equipment (PPE)

Arc-Flash PPE Category	PPE	
1	**Arc-Rated Clothing, Minimum Arc Rating of 4 cal/cm^2 (16.75 J/cm^2)**[a]	
	-	Arc-rated long-sleeve shirt and pants or arc-rated coverall
	-	Arc-rated face shield[b] or arc flash suit hood
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat

Arc-Flash PPE Category	PPE	
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Heavy-duty leather gloves, arc-rated gloves, or rubber insulating gloves with protectors (SR)[d]
	-	Leather footwear[e] (AN)
2	**Arc-Rated Clothing, Minimum Arc Rating of 8 cal/cm^2 (33.5 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt and pants or arc-rated coverall
	-	Arc-rated flash suit hood or arc-rated face shield[b] and arc-rated balaclava
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Heavy-duty leather gloves, arc-rated gloves, or rubber insulating gloves with protectors (SR)[d]
	-	Leather footwear[e]
3	**Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 25 cal/cm^2 (104.7 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt (AR)
	-	Arc-rated pants (AR)
	Arc-rated coverall (AR)	
	-	Arc-rated arc flash suit jacket (AR)
	Arc-rated arc flash suit pants (AR)	
	-	Arc-rated arc flash suit hood
	-	Arc-rated gloves or rubber insulating gloves with protectors (SR)[d]

Arc-Flash PPE Category	PPE	
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Leather footwear[e]
4	**Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 40 cal/cm^2 (167.5 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt (AR)
	-	Arc-rated pants (AR)
	Arc-rated coverall (AR)	
	-	Arc-rated arc flash suit jacket (AR)
	Arc-rated arc flash suit pants (AR)	
	-	Arc-rated arc flash suit hood
	-	Arc-rated gloves or rubber insulating gloves with protectors (SR)[d]
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Leather footwear[e]

AN: As needed (optional). AR: As required. SR: Selection required.

[a] *Arc rating* is defined in Article 100.

[b] Face shields are to have wrap-around guarding to protect not only the face but also the forehead, ears, and neck, or, alternatively, an arc-rated arc flash suit hood is required to be worn.

[c] Other types of hearing protection are permitted to be used in lieu of or in addition to ear canal inserts provided they are worn under an arc-rated arc flash suit hood.

[d]Rubber insulating gloves with protectors provide arc flash protection in addition to electric shock protection. Higher class rubber insulating gloves with protectors, due to their increased material thickness, provide increased arc flash protection.

[e]Footwear other than leather or dielectric shall be permitted to be used provided it has been tested to demonstrate no ignition, melting or dripping at the minimum arc rating for the respective arc flash PPE category.

[f]The arc rating of outer layers worn over arc-rated clothing as protection from the elements or for other safety purposes, and that are not used as part of a layered system, shall not be required to be equal to or greater than the estimated incident energy exposure.

Statement of Problem and Substantiation for Public Input

This change aligns the notes in the table with the language in Note 1. The clearing times are only applicable when the fault current is in that region of the trip curve. This detail was added for note 1 to the table but unfortunately left out for the remainder of the clearing times. This change brings all the notes in alignment.

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Committee: EEW-AAA

Committee Statement

Resolution: FR-55-NFPA 70E-2024

Statement: The qualifier “maximum” is deleted in front of “available fault current” in 130.7(C)(15)(a)(1) and 130.7(C)(15)(b)(1).

This revision is necessary to correlate with the definition of Available Fault Current. There is no such thing as the maximum largest.

The section was revised to comply with the NEC Style Manual Section 3.5.1.2 Multiple Requirements.

Table 130.7(C)(15)(a): This revision correlates with revisions in the parent text of 130.7(C)(15)(a) and 130.7(C)(15)(b). In both of these revisions the qualifier “maximum” which was used to describe available fault current was deleted. The defined term “Fault Current, Available (Available Fault Current”, in Article 100 clarifies that it is the largest amount of current capable of being delivered at a point on the system during a short-circuit condition. A similar revision is made to all references of available fault current and fault clearing time in Table 130.7(C)(15)(a) for clarity and usability.

Table 130.7(C)(15(a) Informational Note No. 1: List items (2) through (6) are modified for clarity and correlation with list item (1).

Table 130.7(C)(15(a) Informational Note No.2: Table 1 of IEEE 1584 as referenced in the informational note is from the 2002 edition. The table is not included in the 2018 Edition of IEEE 1584. The year of the edition is added for clarification.

Table 130.7(C)(15)(c): The modifiers “arc-rated” and “arc” are added to the table for correlation and clarity.

Public Input No. 244-NFPA 70E-2024 [Section No. 130.7(C)(15)]

(15) Arc Flash PPE Category Method.

The requirements of 130.7(C)(15) shall apply when the arc flash PPE category method is used for the selection of arc flash PPE.

Informational Note: For both ac and dc systems, the arc flash PPE category of the protective clothing and equipment is generally based on determination of the estimated exposure level.

(a) *Alternating Current (ac) Equipment.* When the arc flash risk assessment performed in accordance with 130.5 indicates that arc flash PPE is required and the arc flash PPE category method is used for the selection of PPE for ac systems in lieu of the incident energy analysis of 130.5(G), Table 130.7(C)(15)(a) shall be used to determine the arc flash PPE category. The estimated maximum available fault current, maximum fault-clearing times, and minimum working distances for various ac equipment types or classifications are listed in Table 130.7(C)(15)(a). An incident energy analysis shall be required in accordance with 130.5(G) for the following:

(2) Power systems with greater than the estimated maximum available fault current

(3) Power systems with longer than the maximum fault clearing times

(4) Less than the minimum working distance

(e) *Direct Current (dc) Equipment.* When the arc flash risk assessment performed in accordance with 130.5(G) indicates that arc flash PPE is required and the arc flash PPE category method is used for the selection of PPE for dc systems in lieu of the incident energy analysis of 130.5(G), Table 130.7(C)(15)(b) shall be used to determine the arc flash PPE category. The estimated maximum available fault current, maximum arc duration, and working distances for dc equipment are listed in 130.7(C)(15)(b). An incident energy analysis shall be required in accordance with 130.5(G) for the following:

(6) Power systems with greater than the estimated maximum available fault current

(7) Power systems with longer than the maximum arc duration

(8) Less than the minimum working distance

(i) *Protective Clothing and Personal Protective Equipment (PPE).* Once the arc flash PPE category has been identified from Table 130.7(C)(15)(a) or Table 130.7(C)(15)(b), Table 130.7(C)(15)(c) shall be used to determine the required PPE. Table 130.7(C)(15)(c) lists the requirements for PPE based on arc flash PPE categories 1 through 4. This clothing and equipment shall be used when working within the arc flash boundary. The use of PPE other than or in addition to that listed shall be permitted provided it meets 130.7(C)(7).

Informational Note No. 1: See Informative Annex H for a suggested simplified approach to ensure adequate PPE for electrical workers within facilities with large and diverse electrical systems.

Informational Note No. 2: The PPE requirements of this section are intended to protect a person from arc flash hazards. While some situations could result in burns to the skin even with the protection described in Table 130.7(C)(15)(c), burn injury should be reduced and survivable. Due to the explosive effect of some arc events, physical trauma injuries could occur. The PPE requirements of this section do not address protection against physical trauma other than exposure to the thermal effects of an arc flash.

Informational Note No. 3: The arc rating for a particular clothing system can be obtained from the arc-rated clothing manufacturer.

Table 130.7(C)(15)(a) Arc Flash PPE Categories for Alternating Current (ac) Systems

Equipment	Arc Flash PPE Category	Arc Flash Boundary
Panelboards or other equipment rated 240 volts and below	1	485 mm (19 in.)
Parameters: Maximum of 25 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
Panelboards or other equipment rated greater than 240 volts and up to 600 volts	2	900 mm (3 ft)
Parameters: Maximum of 25 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class motor control centers (MCCs)	2	1.5 m (5 ft)
Parameters: Maximum of 65 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class motor control centers (MCCs)	4	4.3 m (14 ft)
Parameters: Maximum of 42 kA available fault current; maximum of 0.33 sec (20 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class switchgear (with power circuit breakers or fused switches) and 600-volt class switchboards	4	6 m (20 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.5 sec (30 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
Other 600-volt class (277 volts through 600 volts, nominal) equipment	2	1.5 m (5 ft)
Parameters: Maximum of 65 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
NEMA E2 (fused contactor) motor starters, 2.3 kV through 7.2 kV	4	12 m (40 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault	-	-

Equipment	Arc Flash PPE Category	Arc Flash Boundary
clearing time; minimum working distance 910 mm (36 in.)		
Metal-clad switchgear, 1 kV through 15 kV	4	12 m (40 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	-	-
Metal enclosed interrupter switchgear, fused or unfused type construction, 1 kV through 15 kV Parameters: Maximum of 35 kA available fault current; maximum of 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	4	12 m (40 ft)
Other equipment 1 kV through 15 kV Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	4	12 m (40 ft)
Arc-resistant equipment up to 600-volt class Parameters: DOORS CLOSED and SECURED; with an available fault current and a fault clearing time that does not exceed the arc-resistant rating of the equipment*	N/A	N/A
Arc-resistant equipment 1 kV through 15 kV	N/A	N/A
Parameters: DOORS CLOSED and SECURED; with an available fault current and a fault clearing time that does not exceed the arc-resistant rating of the equipment*	-	-

N/A: Not applicable

Note:

For equipment rated 600 volts and below and protected by upstream current-limiting fuses or current-limiting molded case circuit breakers sized at 200 amperes or less, the arc flash PPE category can be reduced by one number but not below arc flash PPE category 1.

*For DOORS OPEN refer to the corresponding non-arc-resistant equipment section of this table.

Informational Note No. 1 to Table 130.7(C)(15)(a): The following are typical fault clearing times of overcurrent protective devices:

(1) 0.5 cycle fault clearing time is typical for current-limiting fuses and current-limiting molded case circuit breakers ~~when the fault current is within the current limiting range~~ .

(2) 1.5 cycle fault clearing time is typical for molded case circuit breakers rated less than 1000 volts with an instantaneous integral trip.

(3) 3.0 cycle fault clearing time is typical for insulated case circuit breakers rated less than 1000 volts with an instantaneous integral trip or relay operated trip.

(4) 5.0 cycle fault clearing time is typical for relay operated circuit breakers rated 1 kV to 35 kV when the relay operates in the instantaneous range (i.e., “no intentional delay”).

(5) 20 cycle fault clearing time is typical for low-voltage power and insulated case circuit breakers with a short time fault clearing delay for motor inrush.

(6) 30 cycle fault clearing time is typical for low-voltage power and insulated case circuit breakers with a short time fault clearing delay without instantaneous trip.

Informational Note No. 2 to Table 130.7(C)(15)(a): See Table 1 of IEEE 1584, *Guide for Performing Arc Flash Hazard Calculations*, for further information regarding list items (2) through (4) in Informational Note No. 1.

Informational Note No. 3 to Table 130.7(C)(15)(a): See IEEE C37.20.7, *Guide for Testing Switchgear Rated Up to 52 kV for Internal Arcing Faults*, for an example of a standard that provides information for arc-resistant equipment referred to in Table 130.7(C)(15)(a).

Informational Note No. 4 to Table 130.7(C)(15)(a): See Informative Annex O.2.4(9) for information on arc-resistant equipment.

Table 130.7(C)(15)(b) Arc Flash PPE Categories for dc Systems

Equipment	**Arc Flash PPE Category**	**Arc Flash Boundary**
Storage batteries, dc switchboards, and other dc supply sources	-	-
Parameters: Greater than 150 volts and less than or equal to 600 volts	-	-
Maximum arc duration and minimum working distance: 2 sec @ 455 mm (18 in.)	-	-
Available fault current less than 1.5 kA	2	900 mm
		- - (3 ft)
Available fault current greater than or equal to 1.5 kA and less than 3 kA	2	1.2 m
		- - (4 ft)
Available fault current greater than or equal to 3 kA and less than 7 kA	3	1.8 m
		- - (6 ft.)
Available fault current greater than or equal to 7 kA and less than 10 kA	4	2.5 m
		- - (8 ft)

Notes:

(1) Apparel that can be expected to be exposed to electrolyte must meet both of the following conditions:

(a) Be evaluated for electrolyte protection

Informational Note: See ASTM F1296, *Standard Guide for Evaluating Chemical Protective Clothing*, for information on evaluating apparel for protection from electrolyte.

(b) Be arc rated

Informational Note: See ASTM F1891, *Standard Specification for Arc and Flame Resistant Rainwear*, for information on evaluating arc-rated apparel.

(2) A two-second arc duration is assumed if there is no overcurrent protective device (OCPD) or if the fault clearing time is not known. If the fault clearing time is known and is less than 2 seconds, an incident energy analysis could provide a more representative result.

Informational Note No. 1: See D.5 for the basis for table values and alternative methods to determine dc incident energy. Methods should be used with good engineering judgment. When determining available fault current, the effects of cables and any other impedances in the circuit should be included. Power system modeling is the best method to determine the available short-circuit current at the point of the arc. Battery cell short-circuit current can be obtained from the battery manufacturer.

Informational Note No. 2: The methods for estimating the dc arc flash incident energy that were used to determine the categories for this table are based on open-air incident energy calculations. Open-air calculations were used because many battery systems and other dc process systems are in open areas or rooms. If the specific task is within an enclosure, it would be prudent to consider additional PPE protection beyond the value shown in this table.

Informational Note No. 3: See the following references for dc voltages below 150 volts nominal:

(1) J. G. Hildreth and K. Feeney, “Arc Flash Hazards Station Battery Systems,” 2018 IEEE Power & Energy Society General Meeting (PESGM), 2018, pp. 1–5.

(2) US Department of Energy Bonneville Power Administration Engineering and Technical Services Report BPA F 5450.05, “DC Arc Flash: 125V, 1300 amp-hour battery,” May 11, 2017, doi: 10.1109/PESGM.2018.8586181.

(3) K. Gray, S. Robert, and T. L. Gauthier, "Low Voltage 100–500 Vdc Arc Flash Testing," 2020 IEEE IAS Electrical Safety Workshop (ESW), 2020, pp. 1–7, doi: 10.1109/ESW42757.2020.9188336.

Table 130.7(C)(15)(c) Personal Protective Equipment (PPE)

Arc-Flash PPE Category	PPE	
1	**Arc-Rated Clothing, Minimum Arc Rating of 4 cal/cm^2 (16.75 J/cm^2)**[a]	
	-	Arc-rated long-sleeve shirt and pants or arc-rated coverall
	-	Arc-rated face shield[b] or arc flash suit hood
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]

Arc-Flash PPE Category	PPE	
	-	Heavy-duty leather gloves, arc-rated gloves, or rubber insulating gloves with protectors (SR)[d]
	-	Leather footwear[e] (AN)
2	**Arc-Rated Clothing, Minimum Arc Rating of 8 cal/cm^2 (33.5 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt and pants or arc-rated coverall
	-	Arc-rated flash suit hood or arc-rated face shield[b] and arc-rated balaclava
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Heavy-duty leather gloves, arc-rated gloves, or rubber insulating gloves with protectors (SR)[d]
	-	Leather footwear[e]
3	**Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 25 cal/cm^2 (104.7 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt (AR)
	-	Arc-rated pants (AR)
	Arc-rated coverall (AR)	
	-	Arc-rated arc flash suit jacket (AR)
	Arc-rated arc flash suit pants (AR)	
	-	Arc-rated arc flash suit hood
	-	Arc-rated gloves or rubber insulating gloves with protectors (SR)[d]
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**

Arc-Flash PPE Category	PPE	
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Leather footwear[e]
4	**Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 40 cal/cm^2 (167.5 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt (AR)
	-	Arc-rated pants (AR)
	Arc-rated coverall (AR)	
	-	Arc-rated arc flash suit jacket (AR)
	Arc-rated arc flash suit pants (AR)	
	-	Arc-rated arc flash suit hood
	-	Arc-rated gloves or rubber insulating gloves with protectors (SR)[d]
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Leather footwear[e]

AN: As needed (optional). AR: As required. SR: Selection required.

[a] *Arc rating* is defined in Article 100.

[b] Face shields are to have wrap-around guarding to protect not only the face but also the forehead, ears, and neck, or, alternatively, an arc-rated arc flash suit hood is required to be worn.

[c] Other types of hearing protection are permitted to be used in lieu of or in addition to ear canal inserts provided they are worn under an arc-rated arc flash suit hood.

[d] Rubber insulating gloves with protectors provide arc flash protection in addition to electric shock protection. Higher class rubber insulating gloves with protectors, due to their increased material thickness, provide increased arc flash protection.

[e] Footwear other than leather or dielectric shall be permitted to be used provided it has been tested to demonstrate no ignition, melting or dripping at the minimum arc rating for the respective arc flash PPE category.

[f]The arc rating of outer layers worn over arc-rated clothing as protection from the elements or for other safety purposes, and that are not used as part of a layered system, shall not be required to be equal to or greater than the estimated incident energy exposure.

Statement of Problem and Substantiation for Public Input

This revision removes the language ". . . when the fault current is within the current limiting region." to align with notes 2, 3, 4, 5 and 6 which would require the same language as the clearing times for those notes are only applicable when the fault current is in a specific region of the trip curve.

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Committee: EEW-AAA

Committee Statement

Resolution: The text that is recommended to be deleted must be retained to correlate with the separate revision made to Table 130.7(C)(15)(a) Notes.

Public Input No. 269-NFPA 70E-2024 [Section No. 130.7(C)(15)]

NOTE: This Public Input appeared as “Reject but Hold” in Public Comment No. 7 of the (A2023) Second Draft Report for NFPA 70E and per the Regs. At 4.4.8.3.1 and needs to be reconsidered by the TC for the next edition of the document.

(15) Arc Flash PPE Category Method.

The requirements of 130.7(C)(15) shall apply when the arc flash PPE category method is used for the selection of arc flash PPE.

Informational Note: For both ac and dc systems, the arc flash PPE category of the protective clothing and equipment is generally based on determination of the estimated exposure level.

(a) *Alternating Current (ac) Equipment.* When the arc flash risk assessment performed in accordance with 130.5 indicates that arc flash PPE is required and the arc flash PPE category method is used for the selection of PPE for ac systems in lieu of the incident energy analysis of 130.5(G), Table 130.7(C)(15)(a) shall be used to determine the arc flash PPE category. The estimated maximum available fault current, maximum fault-clearing times, and minimum working distances for various ac equipment types or classifications are listed in Table 130.7(C)(15)(a). An incident energy analysis shall be required in accordance with 130.5(G) for the following:

(2) Power systems with greater than the estimated maximum available fault current

(3) Power systems with longer than the maximum fault clearing times

(4) Less than the minimum working distance

(e) *Direct Current (dc) Equipment.* When the arc flash risk assessment performed in accordance with 130.5(G) indicates that arc flash PPE is required and the arc flash PPE category method is used for the selection of PPE for dc systems in lieu of the incident energy analysis of 130.5(G), Table 130.7(C)(15)(b) shall be used to determine the arc flash PPE category. The estimated maximum available fault current, maximum arc duration, and working distances for dc equipment are listed in 130.7(C)(15)(b). An incident energy analysis shall be required in accordance with 130.5(G) for the following:

(6) Power systems with greater than the estimated maximum available fault current

(7) Power systems with longer than the maximum arc duration

(8) Less than the minimum working distance

(i) *Protective Clothing and Personal Protective Equipment (PPE).* Once the arc flash PPE category has been identified from Table 130.7(C)(15)(a) or Table 130.7(C)(15)(b), Table 130.7(C)(15)(c) shall be used to determine the required PPE. Table 130.7(C)(15)(c) lists the requirements for PPE based on arc flash PPE categories 1 through 4. This clothing and equipment shall be used when working within the arc flash boundary. The use of PPE other than or in addition to that listed shall be permitted provided it meets 130.7(C)(7).

Informational Note No. 1: See Informative Annex H for a suggested simplified approach to ensure adequate PPE for electrical workers within facilities with large and diverse electrical systems.

Informational Note No. 2: The PPE requirements of this section are intended to protect a person from arc flash hazards. While some situations could result in burns to the skin even with the protection described in Table 130.7(C)(15)(c), burn injury should be reduced and survivable. Due to the explosive effect of some arc events, physical trauma injuries could occur. The PPE requirements of this section do not address protection against physical trauma other than exposure to the thermal effects of an arc flash.

Informational Note No. 3: The arc rating for a particular clothing system can be obtained from the arc-rated clothing manufacturer.

Table 130.7(C)(15)(a) Arc Flash PPE Categories for Alternating Current (ac) Systems

Equipment	Arc Flash PPE Category	Arc Flash Boundary
Panelboards or other equipment rated 240 volts and below	1	485 mm (19 in.)
Parameters: Maximum of 25 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
Panelboards or other equipment rated greater than 240 volts and up to 600 volts	2	900 mm (3 ft)
Parameters: Maximum of 25 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class motor control centers (MCCs)	2	1.5 m (5 ft)
Parameters: Maximum of 65 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class motor control centers (MCCs)	4	4.3 m (14 ft)
Parameters: Maximum of 42 kA available fault current; maximum of 0.33 sec (20 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class switchgear (with power circuit breakers or fused switches) and 600-volt class switchboards	4	6 m (20 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.5 sec (30 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
Other 600-volt class (277 volts through 600 volts, nominal) equipment	2	1.5 m (5 ft)
Parameters: Maximum of 65 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
NEMA E2 (fused contactor) motor starters, 2.3 kV through 7.2 kV	4	12 m (40 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault	-	-

Equipment	Arc Flash PPE Category	Arc Flash Boundary
clearing time; minimum working distance 910 mm (36 in.)		
Metal-clad switchgear, 1 kV through 15 kV	4	12 m (40 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	-	-
Metal enclosed interrupter switchgear, fused or unfused type construction, 1 kV through 15 kV Parameters: Maximum of 35 kA available fault current; maximum of 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	4	12 m (40 ft)
Other equipment 1 kV through 15 kV Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	4	12 m (40 ft)
Arc-resistant equipment up to 600-volt class Parameters: DOORS CLOSED and SECURED; with an available fault current and a fault clearing time that does not exceed the arc-resistant rating of the equipment*	N/A	N/A
Arc-resistant equipment 1 kV through 15 kV	N/A	N/A
Parameters: DOORS CLOSED and SECURED; with an available fault current and a fault clearing time that does not exceed the arc-resistant rating of the equipment*	-	-

N/A: Not applicable

Note:

For equipment rated 600 volts and below and protected by upstream current-limiting fuses or current-limiting molded case circuit breakers sized at 200 amperes or less, the arc flash PPE category can be reduced by one number but not below arc flash PPE category 1.

*For DOORS OPEN refer to the corresponding non-arc-resistant equipment section of this table.

Informational Note No. 1 to Table 130.7(C)(15)(a): The following are typical fault clearing times of overcurrent protective devices:

(1) 0.5 cycle fault clearing time is typical for current-limiting fuses and current-limiting molded case circuit breakers when the fault current is within the current limiting range.

(2) 1.5 cycle fault clearing time is typical for molded case circuit breakers rated less than 1000 volts with an instantaneous integral trip.

(3) 3.0 cycle fault clearing time is typical for insulated case circuit breakers rated less than 1000 volts with an instantaneous integral trip or relay operated trip.

(4) 5.0 cycle fault clearing time is typical for relay operated circuit breakers rated 1 kV to 35 kV when the relay operates in the instantaneous range (i.e., “no intentional delay”).

(5) 20 cycle fault clearing time is typical for low-voltage power and insulated case circuit breakers with a short time fault clearing delay for motor inrush.

(6) 30 cycle fault clearing time is typical for low-voltage power and insulated case circuit breakers with a short time fault clearing delay without instantaneous trip.

Informational Note No. 2 to Table 130.7(C)(15)(a): See Table 1 of IEEE 1584, *Guide for Performing Arc Flash Hazard Calculations*, for further information regarding list items (2) through (4) in Informational Note No. 1.

Informational Note No. 3 to Table 130.7(C)(15)(a): See IEEE C37.20.7, *Guide for Testing Switchgear Rated Up to 52 kV for Internal Arcing Faults*, for an example of a standard that provides information for arc-resistant equipment referred to in Table 130.7(C)(15)(a).

Informational Note No. 4 to Table 130.7(C)(15)(a): See Informative Annex O.2.4(9) for information on arc-resistant equipment.

Table 130.7(C)(15)(b) Arc Flash PPE Categories for dc Systems

Equipment	**Arc Flash PPE Category**	**Arc Flash Boundary**
Storage batteries, dc switchboards, and other dc supply sources	-	-
Parameters: Greater than 150 volts and less than or equal to 600 volts	-	-
Maximum arc duration and minimum working distance: 2 sec @ 455 mm (18 in.)	-	-
Available fault current less than 1.5 kA	2	900 mm
		- - (3 ft)
Available fault current greater than or equal to 1.5 kA and less than 3 kA	2	1.2 m
		- - (4 ft)
Available fault current greater than or equal to 3 kA and less than 7 kA	3	1.8 m
		- - (6 ft.)
Available fault current greater than or equal to 7 kA and less than 10 kA	4	2.5 m
		- - (8 ft)

Notes:

(1) Apparel that can be expected to be exposed to electrolyte must meet both of the following conditions:

(a) Be evaluated for electrolyte protection

Informational Note: See ASTM F1296, *Standard Guide for Evaluating Chemical Protective Clothing*, for information on evaluating apparel for protection from electrolyte.

(b) Be arc rated

Informational Note: See ASTM F1891, *Standard Specification for Arc and Flame Resistant Rainwear*, for information on evaluating arc-rated apparel.

(2) A two-second arc duration is assumed if there is no overcurrent protective device (OCPD) or if the fault clearing time is not known. If the fault clearing time is known and is less than 2 seconds, an incident energy analysis could provide a more representative result.

Informational Note No. 1: See D.5 for the basis for table values and alternative methods to determine dc incident energy. Methods should be used with good engineering judgment. When determining available fault current, the effects of cables and any other impedances in the circuit should be included. Power system modeling is the best method to determine the available short-circuit current at the point of the arc. Battery cell short-circuit current can be obtained from the battery manufacturer.

Informational Note No. 2: The methods for estimating the dc arc flash incident energy that were used to determine the categories for this table are based on open-air incident energy calculations. Open-air calculations were used because many battery systems and other dc process systems are in open areas or rooms. If the specific task is within an enclosure, it would be prudent to consider additional PPE protection beyond the value shown in this table.

Informational Note No. 3: See the following references for dc voltages below 150 volts nominal:

(1) J. G. Hildreth and K. Feeney, “Arc Flash Hazards Station Battery Systems,” 2018 IEEE Power & Energy Society General Meeting (PESGM), 2018, pp. 1–5.

(2) US Department of Energy Bonneville Power Administration Engineering and Technical Services Report BPA F 5450.05, “DC Arc Flash: 125V, 1300 amp-hour battery,” May 11, 2017, doi: 10.1109/PESGM.2018.8586181.

(3) K. Gray, S. Robert, and T. L. Gauthier, "Low Voltage 100–500 Vdc Arc Flash Testing," 2020 IEEE IAS Electrical Safety Workshop (ESW), 2020, pp. 1–7, doi: 10.1109/ESW42757.2020.9188336.

Table 130.7(C)(15)(c) Personal Protective Equipment (PPE)

Arc-Flash PPE Category	PPE	
1	**Arc-Rated Clothing, Minimum Arc Rating of 4 cal/cm^2 (16.75 J/cm^2)**[a]	
	-	Arc-rated long-sleeve shirt and pants or arc-rated coverall
	-	Arc-rated face shield[b] or arc flash suit hood
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]

Arc-Flash PPE Category	PPE	
	-	Heavy-duty leather gloves, arc-rated gloves, or rubber insulating gloves with protectors (SR)[d]
	-	Leather footwear[e] (AN)
2	**Arc-Rated Clothing, Minimum Arc Rating of 8 cal/cm^2 (33.5 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt and pants or arc-rated coverall
	-	Arc-rated flash suit hood or arc-rated face shield[b] and arc-rated balaclava
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Heavy-duty leather gloves, arc-rated gloves, or rubber insulating gloves with protectors (SR)[d]
	-	Leather footwear[e]
3	**Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 25 cal/cm^2 (104.7 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt (AR)
	-	Arc-rated pants (AR)
	Arc-rated coverall (AR)	
	-	Arc-rated arc flash suit jacket (AR)
	Arc-rated arc flash suit pants (AR)	
	-	Arc-rated arc flash suit hood
	-	Arc-rated gloves or rubber insulating gloves with protectors (SR)[d]
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**

Arc-Flash PPE Category	PPE	
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Leather footwear[e]
4	**Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 40 cal/cm^2 (167.5 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt (AR)
	-	Arc-rated pants (AR)
	Arc-rated coverall (AR)	
	-	Arc-rated arc flash suit jacket (AR)
	Arc-rated arc flash suit pants (AR)	
	-	Arc-rated arc flash suit hood
	-	Arc-rated gloves or rubber insulating gloves with protectors (SR)[d]
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Leather footwear[e]

AN: As needed (optional). AR: As required. SR: Selection required.

[a] *Arc rating* is defined in Article 100.

[b] Face shields are to have wrap-around guarding to protect not only the face but also the forehead, ears, and neck, or, alternatively, an arc-rated arc flash suit hood is required to be worn.

[c] Other types of hearing protection are permitted to be used in lieu of or in addition to ear canal inserts provided they are worn under an arc-rated arc flash suit hood.

[d] Rubber insulating gloves with protectors provide arc flash protection in addition to electric shock protection. Higher class rubber insulating gloves with protectors, due to their increased material thickness, provide increased arc flash protection.

[e] Footwear other than leather or dielectric shall be permitted to be used provided it has been tested to demonstrate no ignition, melting or dripping at the minimum arc rating for the respective arc flash PPE category.

[f]The arc rating of outer layers worn over arc-rated clothing as protection from the elements or for other safety purposes, and that are not used as part of a layered system, shall not be required to be equal to or greater than the estimated incident energy exposure.

Additional Proposed Changes

File Name	Description	Approved
70E_PC_7_Hold.pdf	70E_PC7	

Statement of Problem and Substantiation for Public Input

NOTE: This Public Input appeared as “Reject but Hold” in Public Comment No. 7 of the (A2023) Second Draft Report for NFPA 70E and per the Regs. At 4.4.8.3.1 and needs to be reconsidered by the TC for the next edition of the document.

It would standardize the nomenclature and eliminate any possible confusion, currently there are three different
terms utilized with Table 130.7(C)(15)(c) PPE, Category 1; "arc flash suit hood", Category 2; "Arc-rated flash suit
hood" and Categories; 3 & 4 "Arc-rated arc flash suit hood".
Furthermore in 130.7(C)(10)(b)(1 & 2) it's a "arc-rated hood"

Submitter Information Verification

Submitter Full Name:	NFPA Holds
Organization:	Technical Committee on Electrical Safety in the Workplace
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Thu Jun 06 21:12:45 EDT 2024
Committee:	EEW-AAA

Committee Statement

Resolution: FR-55-NFPA 70E-2024

Statement: The qualifier “maximum” is deleted in front of “available fault current” in 130.7(C)(15)(a)(1) and 130.7(C)(15)(b)(1).

This revision is necessary to correlate with the definition of Available Fault Current. There is no such thing as the maximum largest.

The section was revised to comply with the NEC Style Manual Section 3.5.1.2 Multiple Requirements.

Table 130.7(C)(15)(a): This revision correlates with revisions in the parent text of 130.7(C)(15)(a) and 130.7(C)(15)(b). In both of these revisions the qualifier “maximum” which was used to describe available fault current was deleted. The defined term “Fault Current, Available (Available Fault Current”, in Article 100 clarifies that it is the largest amount of current capable of being delivered at a point on the system during a short-circuit condition. A similar revision is made to all references of available fault current and fault clearing time in Table 130.7(C)(15)(a) for clarity and usability.

Table 130.7(C)(15(a) Informational Note No. 1: List items (2) through (6) are modified for

clarity and correlation with list item (1).

Table 130.7(C)(15(a) Informational Note No.2: Table 1 of IEEE 1584 as referenced in the informational note is from the 2002 edition. The table is not included in the 2018 Edition of IEEE 1584. The year of the edition is added for clarification.

Table 130.7(C)(15)(c): The modifiers “arc-rated” and “arc” are added to the table for correlation and clarity.

Public Comment No. 7-NFPA 70E-2022 [Section No. 130.7(C)(15)]

(15) Arc Flash PPE Category Method.

The requirements of 130.7(C)(15) shall apply when the arc flash PPE category method is used for the selection of arc flash PPE.

Informational Note: For both ac and dc systems, the arc flash PPE category of the protective clothing and equipment is generally based on determination of the estimated exposure level.

(a) *Alternating Current (ac) Equipment.* When the arc flash risk assessment performed in accordance with 130.5 indicates that arc flash PPE is required and the arc flash PPE category method is used for the selection of PPE for ac systems in lieu of the incident energy analysis of 130.5(G), Table 130.7(C)(15)(a) shall be used to determine the arc flash PPE category. The estimated maximum available fault current, maximum fault-clearing times, and minimum working distances for various ac equipment types or classifications are listed in Table 130.7(C)(15)(a). An incident energy analysis shall be required in accordance with 130.5(G) for the following:

(2) Power systems with greater than the estimated maximum available fault current

(3) Power systems with longer than the maximum fault clearing times

(4) Less than the minimum working distance

(e) *Direct Current (dc) Equipment.* When the arc flash risk assessment performed in accordance with 130.5(G) indicates that arc flash PPE is required and the arc flash PPE category method is used for the selection of PPE for dc systems in lieu of the incident energy analysis of 130.5(G), Table 130.7(C)(15)(b) shall be used to determine the arc flash PPE category. The estimated maximum available fault current, maximum arc duration, and working distances for dc equipment are listed in 130.7(C)(15)(b). An incident energy analysis shall be required in accordance with 130.5(G) for the following:

(6) Power systems with greater than the estimated maximum available fault current

(7) Power systems with longer than the maximum arc duration

(8) Less than the minimum working distance

(i) *Protective Clothing and Personal Protective Equipment (PPE).* Once the arc flash PPE category has been identified from Table 130.7(C)(15)(a) or Table 130.7(C)(15)(b), Table 130.7(C)(15)(c) shall be used to determine the required PPE. Table 130.7(C)(15)(c) lists the requirements for PPE based on arc flash PPE categories 1 through 4. This clothing and equipment shall be used when working within the arc flash boundary. The use of PPE other than or in addition to that listed shall be permitted provided it meets 130.7(C)(7).

Informational Note No. 1: See Informative Annex H for a suggested simplified approach to ensure adequate PPE for electrical workers within facilities with large and diverse electrical systems.

Informational Note No. 2: The PPE requirements of this section are intended to protect a person from arc flash hazards. While some situations could result in burns to the skin even with the protection described in Table 130.7(C)(15)(c), burn injury should be reduced and survivable. Due to the explosive effect of some arc events, physical trauma injuries could occur. The PPE requirements of this section do not address protection against physical trauma other than exposure to the thermal effects of an arc flash.

Informational Note No. 3: The arc rating for a particular clothing system can be obtained from the arc-rated clothing manufacturer.

Table 130.7(C)(15)(a) Arc Flash PPE Categories for Alternating Current (ac) Systems

Equipment	Arc Flash PPE Category	Arc Flash Boundary
Panelboards or other equipment rated 240 volts and below	1	485 mm (19 in.)
Parameters: Maximum of 25 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance	-	-

Equipment	Arc Flash PPE Category	Arc Flash Boundary
455 mm (18 in.)		
Panelboards or other equipment rated greater than 240 volts and up to 600 volts	2	900 mm (3 ft)
Parameters: Maximum of 25 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class motor control centers (MCCs)	2	1.5 m (5 ft)
Parameters: Maximum of 65 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class motor control centers (MCCs)	4	4.3 m (14 ft)
Parameters: Maximum of 42 kA available fault current; maximum of 0.33 sec (20 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class switchgear (with power circuit breakers or fused switches) and 600-volt class switchboards	4	6 m (20 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.5 sec (30 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
Other 600-volt class (277 volts through 600 volts, nominal) equipment	2	1.5 m (5 ft)
Parameters: Maximum of 65 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
NEMA E2 (fused contactor) motor starters, 2.3 kV through 7.2 kV	4	12 m (40 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	-	-
Metal-clad switchgear, 1 kV through 15 kV	4	12 m (40 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	-	-

Equipment	Arc Flash PPE Category	Arc Flash Boundary
Metal enclosed interrupter switchgear, fused or unfused type construction, 1 kV through 15 kV Parameters: Maximum of 35 kA available fault current; maximum of 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	4	12 m (40 ft)
Other equipment 1 kV through 15 kV Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	4	12 m (40 ft)
Arc-resistant equipment up to 600-volt class Parameters: DOORS CLOSED and SECURED; with an available fault current and a fault clearing time that does not exceed the arc-resistant rating of the equipment*	N/A	N/A
Arc-resistant equipment 1 kV through 15 kV Parameters: DOORS CLOSED and SECURED; with an available fault current and a fault clearing time that does not exceed the arc-resistant rating of the equipment*	N/A -	N/A -

N/A: Not applicable

Note:

For equipment rated 600 volts and below and protected by upstream current-limiting fuses or current-limiting molded case circuit breakers sized at 200 amperes or less, the arc flash PPE category can be reduced by one number but not below arc flash PPE category 1.

*For DOORS OPEN refer to the corresponding non-arc-resistant equipment section of this table.

Informational Note No. 1 to Table 130.7(C)(15)(a): The following are typical fault clearing times of overcurrent protective devices:

(1) 0.5 cycle fault clearing time is typical for current-limiting fuses and current-limiting molded case circuit breakers when the fault current is within the current limiting range.

(2) 1.5 cycle fault clearing time is typical for molded case circuit breakers rated less than 1000 volts with an instantaneous integral trip.

(3) 3.0 cycle fault clearing time is typical for insulated case circuit breakers rated less than 1000 volts with an instantaneous integral trip or relay operated trip.

(4) 5.0 cycle fault clearing time is typical for relay operated circuit breakers rated 1 kV to 35 kV when the relay operates in the instantaneous range (i.e., “no intentional delay”).

(5) 20 cycle fault clearing time is typical for low-voltage power and insulated case circuit breakers with a short time fault clearing delay for motor inrush.

(6) 30 cycle fault clearing time is typical for low-voltage power and insulated case circuit breakers with a short time fault clearing delay without instantaneous trip.

Informational Note No. 2 to Table 130.7(C)(15)(a): See Table 1 of IEEE 1584, *Guide for Performing Arc Flash Hazard Calculations*, for further information regarding list items (2) through (4) in Informational Note No. 1.

Informational Note No. 3 to Table 130.7(C)(15)(a): See IEEE C37.20.7, *Guide for Testing Switchgear Rated Up to 52 kV for Internal Arcing Faults* , for an example of a standard that provides information for arc-resistant equipment referred to in Table 130.7(C)(15)(a).

Informational Note No. 4 to Table 130.7(C)(15)(a): See O.2.4(9) for information on arc-resistant equipment.

Table 130.7(C)(15)(b) Arc Flash PPE Categories for dc Systems

Equipment	Arc Flash PPE Category	Arc Flash Boundary
-	-	-
-	-	-
-	-	-
-	-	-
-	-	-
-	-	-
-	-	-
-	-	-
-	-	-
Storage batteries, dc switchboards, and other dc supply sources	-	-
Parameters: Greater than 150 volts and less than or equal to 600 volts	-	-
Maximum arc duration and minimum working distance: 2 sec @ 455 mm (18 in.)	-	-
Available fault current less than 1.5 kA	2	900 mm
		- - (3 ft)
Available fault current greater than or equal to 1.5 kA and less than 3 kA	2	1.2 m
		- - (4 ft)
Available fault current greater than or equal to 3 kA and less than 7 kA	3	1.8 m
		- - (6 ft.)
Available fault current greater than or equal to 7 kA and less than 10 kA	4	2.5 m
		- - (8 ft)

Notes:

(1) Apparel that can be expected to be exposed to electrolyte must meet both of the following conditions:

(a) Be evaluated for electrolyte protection

Informational Note: See ASTM F1296, *Standard Guide for Evaluating Chemical Protective Clothing*, for information on evaluating apparel for protection from electrolyte.

(b) Be arc rated

Informational Note: See ASTM F1891, *Standard Specification for Arc and Flame Resistant Rainwear*, for information on evaluating arc-rated apparel.

(2) A two-second arc duration is assumed if there is no overcurrent protective device (OCPD) or if the fault clearing time is not known. If the fault clearing time is known and is less than 2 seconds, an incident energy analysis could provide a more representative result.

Informational Note No. 1: See D.5 for the basis for table values and alternative methods to determine dc incident energy. Methods should be used with good engineering judgment. When determining available fault current, the effects of cables and any other impedances in the circuit should be included. Power system modeling is the best method to determine the available short-circuit current at the point of the arc. Battery cell short-circuit current can be obtained from the battery manufacturer.

Informational Note No. 2: The methods for estimating the dc arc flash incident energy that were used to determine the categories for this table are based on open-air incident energy calculations. Open-air calculations were used because many battery systems and other dc process systems are in open areas or rooms. If the specific task is within an enclosure, it would be prudent to consider additional PPE protection beyond the value shown in this table.

Informational Note No. 3: See the following references for dc voltages below 150 volts nominal:

(1) J. G. Hildreth and K. Feeney, “Arc Flash Hazards Station Battery Systems,” 2018 IEEE Power & Energy Society General Meeting (PESGM), 2018, pp. 1–5,

(2) US Department of Energy Bonneville Power Administration Engineering and Technical Services Report BPA F 5450.05, “DC Arc Flash: 125V, 1300 amp-hour battery,” May 11, 2017, doi: 10.1109/PESGM.2018.8586181.

(3) K. Gray, S. Robert, and T. L. Gauthier, "Low Voltage 100–500 Vdc Arc Flash Testing," 2020 IEEE IAS Electrical Safety Workshop (ESW), 2020, pp. 1–7, doi: 10.1109/ESW42757.2020.9188336.

Table 130.7(C)(15)(c) Personal Protective Equipment (PPE)

Arc-Flash PPE Category	PPE	
1	**Arc-Rated Clothing, Minimum Arc Rating of 4 cal/cm^2 (16.75 J/cm^2)**[a]	
	-	Arc-rated long-sleeve shirt and pants or arc-rated coverall
	-	Arc-rated face shield[b] or arc-rated arc flash suit ~~hood~~ hood
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Heavy-duty leather gloves, arc-rated gloves, or rubber insulating gloves with protectors (SR)[d]
	-	Leather footwear[e] (AN)
2	**Arc-Rated Clothing, Minimum Arc Rating of 8 cal/cm^2 (33.5 J/cm^2)**[a]	
	-	Arc-rated long-sleeve shirt and pants or arc-rated coverall

Arc-Flash PPE Category	PPE	
	-	Arc-rated arc flash suit hood or arc-rated face shield[b] and arc-rated balaclava
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Heavy-duty leather gloves, arc-rated gloves, or rubber insulating gloves with protectors (SR)[d]
	-	Leather footwear[e]
3	**Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 25 cal/cm^2 (104.7 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt (AR)
	-	Arc-rated pants (AR)
	Arc-rated coverall (AR)	
	-	Arc-rated arc flash suit jacket (AR)
	Arc-rated arc flash suit pants (AR)	
	-	Arc-rated arc flash suit hood
	-	Arc-rated gloves or rubber insulating gloves with protectors (SR)[d]
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Leather footwear[e]
4	**Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 40 cal/cm^2 (167.5 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt (AR)
	-	Arc-rated pants (AR)
	Arc-rated coverall (AR)	
	-	Arc-rated arc flash suit jacket (AR)

Arc-Flash PPE Category	PPE	
	Arc-rated arc flash suit pants (AR)	
	–	Arc-rated arc flash suit hood
	–	Arc-rated gloves or rubber insulating gloves with protectors (SR)[d]
	–	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	–	**Protective Equipment**
	–	Hard hat
	–	Safety glasses or safety goggles (SR)
	–	Hearing protection (ear canal inserts)[c]
	–	Leather footwear[e]

AN: As needed (optional). AR: As required. SR: Selection required.

[a]*Arc rating* is defined in Article 100.

[b]Face shields are to have wrap-around guarding to protect not only the face but also the forehead, ears, and neck, or, alternatively, an arc-rated arc flash suit hood is required to be worn.

[c]Other types of hearing protection are permitted to be used in lieu of or in addition to ear canal inserts provided they are worn under an arc-rated arc flash suit hood.

[d]Rubber insulating gloves with protectors provide arc flash protection in addition to shock protection. Higher class rubber insulating gloves with protectors, due to their increased material thickness, provide increased arc flash protection.

[e]Footwear other than leather or dielectric shall be permitted to be used provided it has been tested to demonstrate no ignition, melting or dripping at the minimum arc rating for the respective arc flash PPE category.

[f]The arc rating of outer layers worn over arc-rated clothing as protection from the elements or for other safety purposes, and that are not used as part of a layered system, shall not be required to be equal to or greater than the estimated incident energy exposure.

Statement of Problem and Substantiation for Public Comment

It would standardize the nomenclature and eliminate any possible confusion, currently there are three different terms utilized with Table 130.7(C)(15)(c) PPE, Category 1; "arc flash suit hood", Category 2; "Arc-rated flash suit hood" and Categories; 3 & 4 "Arc-rated arc flash suit hood".

Furthermore in 130.7(C)(10)(b)(1 & 2) it's a "arc-rated hood"

Related Item

• Arc-rated arc flash suit hood

Submitter Information Verification

Submitter Full Name: Daryl Colloms
Organization: DENSO
Street Address:
City:
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Submittal Date: Mon Mar 07 13:21:17 EST 2022

Committee: EEW-AAA

Committee Statement

Committee Action: Rejected but held

Resolution: The text proposed by this public comment does not meet 4.4.4.2 of the Regulations Governing Committee Projects which requires public comments to be related to material that has received public review either through the submission of Public Input, Committee Input or Correlating Input or through the First Revisions.

Public Input No. 58-NFPA 70E-2024 [Section No. 130.7(C)(15)]

(15) Arc Flash PPE Category Method.

The requirements of 130.7(C)(15) shall apply when the arc flash PPE category method is used for the selection of arc flash PPE.

Informational Note: For both ac and dc systems, the arc flash PPE category of the protective clothing and equipment is generally based on determination of the estimated exposure level.

(a) *Alternating Current (ac) Equipment.* When the arc flash risk assessment performed in accordance with 130.5 indicates that arc flash PPE is required and the arc flash PPE category method is used for the selection of PPE for ac systems in lieu of the incident energy analysis of 130.5(G), Table 130.7(C)(15)(a) shall be used to determine the arc flash PPE category. The estimated maximum available fault current, maximum fault-clearing times, and minimum working distances for various ac equipment types or classifications are listed in Table 130.7(C)(15)(a). An incident energy analysis shall be required in accordance with 130.5(G) for the following:

(2) Power systems with greater than the estimated maximum available fault current

(3) Power systems with longer than the maximum fault clearing times

(4) Less than the minimum working distance

(e) *Direct Current (dc) Equipment.* When the arc flash risk assessment performed in accordance with 130.5(G) indicates that arc flash PPE is required and the arc flash PPE category method is used for the selection of PPE for dc systems in lieu of the incident energy analysis of 130.5(G), Table 130.7(C)(15)(b) shall be used to determine the arc flash PPE category. The estimated maximum available fault current, maximum arc duration, and working distances for dc equipment are listed in 130.7(C)(15)(b). An incident energy analysis shall be required in accordance with 130.5(G) for the following:

(6) Power systems with greater than the estimated maximum available fault current

(7) Power systems with longer than the maximum arc duration

(8) Less than the minimum working distance

(i) *Protective Clothing and Personal Protective Equipment (PPE).* Once the arc flash PPE category has been identified from Table 130.7(C)(15)(a) or Table 130.7(C)(15)(b), Table 130.7(C)(15)(c) shall be used to determine the required PPE. Table 130.7(C)(15)(c) lists the requirements for PPE based on arc flash PPE categories 1 through 4. This clothing and equipment shall be used when working within the arc flash boundary. The use of PPE other than or in addition to that listed shall be permitted provided it meets 130.7(C)(7).

Informational Note No. 1: See Informative Annex H for a suggested simplified approach to ensure adequate PPE for electrical workers within facilities with large and diverse electrical systems.

Informational Note No. 2: The PPE requirements of this section are intended to protect a person from arc flash hazards. While some situations could result in burns to the skin even with the protection described in Table 130.7(C)(15)(c), burn injury should be reduced and survivable. Due to the explosive effect of some arc events, physical trauma injuries could occur. The PPE requirements of this section do not address protection against physical trauma other than exposure to the thermal effects of an arc flash.

Informational Note No. 3: The arc rating for a particular clothing system can be obtained from the arc-rated clothing manufacturer.

Table 130.7(C)(15)(a) Arc Flash PPE Categories for Alternating Current (ac) Systems

Equipment	Arc Flash PPE Category	Arc Flash Boundary
Panelboards or other equipment rated 240 volts and below	1	485 mm (19 in.)
Parameters: Maximum of 25 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
Panelboards or other equipment rated greater than 240 volts and up to 600 volts	2	900 mm (3 ft)
Parameters: Maximum of 25 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class motor control centers (MCCs)	2	1.5 m (5 ft)
Parameters: Maximum of 65 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class motor control centers (MCCs)	4	4.3 m (14 ft)
Parameters: Maximum of 42 kA available fault current; maximum of 0.33 sec (20 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class switchgear (with power circuit breakers or fused switches) and 600-volt class switchboards	4	6 m (20 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.5 sec (30 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
Other 600-volt class (277 volts through 600 volts, nominal) equipment	2	1.5 m (5 ft)
Parameters: Maximum of 65 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
NEMA E2 (fused contactor) motor starters, 2.3 kV through 7.2 kV	4	12 m (40 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault	-	-

Equipment	Arc Flash PPE Category	Arc Flash Boundary
clearing time; minimum working distance 910 mm (36 in.)		
Metal-clad switchgear, 1 kV through 15 kV	4	12 m (40 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	-	-
Metal enclosed interrupter switchgear, fused or unfused type construction, 1 kV through 15 kV Parameters: Maximum of 35 kA available fault current; maximum of 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	4	12 m (40 ft)
Other equipment 1 kV through 15 kV Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	4	12 m (40 ft)
Arc-resistant equipment up to 600-volt class Parameters: DOORS CLOSED and SECURED; with an available fault current and a fault clearing time that does not exceed the arc-resistant rating of the equipment*	N/A	N/A
Arc-resistant equipment 1 kV through 15 kV	N/A	N/A
Parameters: DOORS CLOSED and SECURED; with an available fault current and a fault clearing time that does not exceed the arc-resistant rating of the equipment*	-	-

N/A: Not applicable

Note:

For equipment rated 600 volts and below and protected by upstream current-limiting fuses or current-limiting molded case circuit breakers sized at 200 amperes or less, the arc flash PPE category can be reduced by one number but not below arc flash PPE category 1.

*For DOORS OPEN refer to the corresponding non-arc-resistant equipment section of this table.

Informational Note No. 1 to Table 130.7(C)(15)(a): The following are typical fault clearing times of overcurrent protective devices:

(1) 0.5 cycle fault clearing time is typical for current-limiting fuses and current-limiting molded case circuit breakers when the fault current is within the current limiting range.

(2) 1.5 cycle fault clearing time is typical for molded case circuit breakers rated less than 1000 volts with an instantaneous integral trip.

(3) 3.0 cycle fault clearing time is typical for insulated case circuit breakers rated less than 1000 volts with an instantaneous integral trip or relay operated trip.

(4) 5.0 cycle fault clearing time is typical for relay operated circuit breakers rated 1 kV to 35 kV when the relay operates in the instantaneous range (i.e., “no intentional delay”).

(5) 20 cycle fault clearing time is typical for low-voltage power and insulated case circuit breakers with a short time fault clearing delay for motor inrush.

(6) 30 cycle fault clearing time is typical for low-voltage power and insulated case circuit breakers with a short time fault clearing delay without instantaneous trip.

Informational Note No. 2 to Table 130.7(C)(15)(a): See Table 1 of IEEE 1584, *Guide for Performing Arc Flash Hazard Calculations*, for further information regarding list items (2) through (4) in Informational Note No. 1.

Informational Note No. 3 to Table 130.7(C)(15)(a): See IEEE C37.20.7, *Guide for Testing Switchgear Rated Up to 52 kV for Internal Arcing Faults*, for an example of a standard that provides information for arc-resistant equipment referred to in Table 130.7(C)(15)(a).

Informational Note No. 4 to Table 130.7(C)(15)(a): See Informative Annex O.2.4(9) for information on arc-resistant equipment.

Table 130.7(C)(15)(b) Arc Flash PPE Categories for dc Systems

Equipment	**Arc Flash PPE Category**	**Arc Flash Boundary**
Storage batteries, dc switchboards, and other dc supply sources	-	-
Parameters: Greater than 150 volts and less than or equal to 600 volts	-	-
Maximum arc duration and minimum working distance: 2 sec @ 455 mm (18 in.)	-	-
Available fault current less than 1.5 kA	2	900 mm
		- - (3 ft)
Available fault current greater than or equal to 1.5 kA and less than 3 kA	2	1.2 m
		- - (4 ft)
Available fault current greater than or equal to 3 kA and less than 7 kA	3	1.8 m
		- - (6 ft.)
Available fault current greater than or equal to 7 kA and less than 10 kA	4	2.5 m
		- - (8 ft)

Notes:

(1) Apparel that can be expected to be exposed to electrolyte must meet both of the following conditions:

(a) Be evaluated for electrolyte protection

Informational Note: See ASTM F1296, *Standard Guide for Evaluating Chemical Protective Clothing*, for information on evaluating apparel for protection from electrolyte.

(b) Be arc rated

Informational Note: See ASTM F1891, *Standard Specification for Arc and Flame Resistant Rainwear*, for information on evaluating arc-rated apparel.

(2) A two-second arc duration is assumed if there is no overcurrent protective device (OCPD) or if the fault clearing time is not known. If the fault clearing time is known and is less than 2 seconds, an incident energy analysis could provide a more representative result.

Informational Note No. 1: See D.5 for the basis for table values and alternative methods to determine dc incident energy. Methods should be used with good engineering judgment. When determining available fault current, the effects of cables and any other impedances in the circuit should be included. Power system modeling is the best method to determine the available short-circuit current at the point of the arc. Battery cell short-circuit current can be obtained from the battery manufacturer.

Informational Note No. 2: The methods for estimating the dc arc flash incident energy that were used to determine the categories for this table are based on open-air incident energy calculations. Open-air calculations were used because many battery systems and other dc process systems are in open areas or rooms. If the specific task is within an enclosure, it would be prudent to consider additional PPE protection beyond the value shown in this table.

Informational Note No. 3: See the following references for dc voltages below 150 volts nominal:

(1) J. G. Hildreth and K. Feeney, “Arc Flash Hazards of 125Vdc Station Battery Systems,” 2018 IEEE Power & Energy Society General Meeting (PESGM), 2018, pp. 1–5, doi: 10 .1109/PESGM.2018.8586181.

(2) US Department of Energy Bonneville Power Administration Engineering and Technical Services Report BPA F 5450.05, “DC Arc Flash: 125V, 1300 amp-hour battery,” May 11, 2017~~, doi: 10 .1109/PESGM.2018.8586181.~~

(3) K. Gray, S. Robert, and T. L. Gauthier, "Low Voltage 100–500 Vdc Arc Flash Testing," 2020 IEEE IAS Electrical Safety Workshop (ESW), 2020, pp. 1–7, doi: 10.1109/ESW42757.2020.9188336.

Table 130.7(C)(15)(c) Personal Protective Equipment (PPE)

Arc-Flash PPE Category	**PPE**	
1	**Arc-Rated Clothing, Minimum Arc Rating of 4 cal/cm^2 (16.75 J/cm^2)**[a]	
	-	Arc-rated long-sleeve shirt and pants or arc-rated coverall
	-	Arc-rated face shield[b] or arc flash suit hood
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)

Arc-Flash PPE Category	PPE	
	-	Hearing protection (ear canal inserts)[c]
	-	Heavy-duty leather gloves, arc-rated gloves, or rubber insulating gloves with protectors (SR)[d]
	-	Leather footwear[e] (AN)
2	**Arc-Rated Clothing, Minimum Arc Rating of 8 cal/cm^2 (33.5 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt and pants or arc-rated coverall
	-	Arc-rated flash suit hood or arc-rated face shield[b] and arc-rated balaclava
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Heavy-duty leather gloves, arc-rated gloves, or rubber insulating gloves with protectors (SR)[d]
	-	Leather footwear[e]
3	**Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 25 cal/cm^2 (104.7 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt (AR)
	-	Arc-rated pants (AR)
	Arc-rated coverall (AR)	
	-	Arc-rated arc flash suit jacket (AR)
	Arc-rated arc flash suit pants (AR)	
	-	Arc-rated arc flash suit hood
	-	Arc-rated gloves or rubber insulating gloves with protectors (SR)[d]
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or

Arc-Flash PPE Category	PPE	
		hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Leather footwear[e]
4	**Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 40 cal/cm^2 (167.5 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt (AR)
	-	Arc-rated pants (AR)
	Arc-rated coverall (AR)	
	-	Arc-rated arc flash suit jacket (AR)
	Arc-rated arc flash suit pants (AR)	
	-	Arc-rated arc flash suit hood
	-	Arc-rated gloves or rubber insulating gloves with protectors (SR)[d]
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Leather footwear[e]

AN: As needed (optional). AR: As required. SR: Selection required.

[a]*Arc rating* is defined in Article 100.

[b]Face shields are to have wrap-around guarding to protect not only the face but also the forehead, ears, and neck, or, alternatively, an arc-rated arc flash suit hood is required to be worn.

[c]Other types of hearing protection are permitted to be used in lieu of or in addition to ear canal inserts provided they are worn under an arc-rated arc flash suit hood.

[d]Rubber insulating gloves with protectors provide arc flash protection in addition to electric shock protection. Higher class rubber insulating gloves with protectors, due to their increased material thickness, provide increased arc flash protection.

[e]Footwear other than leather or dielectric shall be permitted to be used provided it has been tested to demonstrate no ignition, melting or dripping at the minimum arc rating for the respective arc flash PPE category.

[f]The arc rating of outer layers worn over arc-rated clothing as protection from the elements or for other safety purposes, and that are not used as part of a layered system, shall not be required to be equal to or greater than the estimated incident energy exposure.

Statement of Problem and Substantiation for Public Input

The citation for the Hildreth and Feeney paper referenced in the informational note had some minor errors, including that the doi reference had moved to the next bullet down. Locating these reference papers online is easier with the correct citations.

Submitter Information Verification

Submitter Full Name: Nick Bramhall
Organization: Safe Arc Solutions Ltd
Street Address:
City:
State:
Zip:

Submittal Date: Wed Feb 14 10:14:57 EST 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-79-NFPA 70E-2024

Statement: This revision corrects the title of Reference (1) and makes an editorial correction that assigned the doi reference to the wrong citation.

DC circuit modeling is a more appropriate term. The term "power system modeling" is used for ac systems to include transformer impedances, system ac impedances (resistance and inductance) and over current protection, etc. A dc circuit model uses the short circuit current of a source, such as a battery, the busbar and connection resistances, and any dc overcurrent protection.

Capacitor is a class of dc source, but not a dc power system. Capacitor arc flash incident energy analysis is covered in Article 360 and Informational Annex R with methods not used to develop this table. This revision only affects capacitors covered in Article 360. Arc flash protection from hazards associated with supercapacitors can be determined with this table.

The revised language is clearer and explains why additional PPE may be needed.

Public Input No. 71-NFPA 70E-2024 [Section No. 130.7(C)(15)]

(15) Arc Flash PPE Category Method.

The requirements of 130.7(C)(15) shall apply when the arc flash PPE category method is used for the selection of arc flash PPE.

Informational Note: For both ac and dc systems, the arc flash PPE category of the protective clothing and equipment is generally based on determination of the estimated exposure level.

(a) *Alternating Current (ac) Equipment.* When the arc flash risk assessment performed in accordance with 130.5 indicates that arc flash PPE is required and the arc flash PPE category method is used for the selection of PPE for ac systems in lieu of the incident energy analysis of 130.5(G), Table 130.7(C)(15)(a) shall be used to determine the arc flash PPE category. The estimated maximum available fault current, maximum fault-clearing times, and minimum working distances for various ac equipment types or classifications are listed in Table 130.7(C)(15)(a). An incident energy analysis shall be required in accordance with 130.5(G) for the following:

(2) Power systems with greater than the estimated maximum available fault current

(3) Power systems with longer than the maximum fault clearing times

(4) Less than the minimum working distance

(e) *Direct Current (dc) Equipment.* When the arc flash risk assessment performed in accordance with 130.5(G) indicates that arc flash PPE is required and the arc flash PPE category method is used for the selection of PPE for dc systems in lieu of the incident energy analysis of 130.5(G), Table 130.7(C)(15)(b) shall be used to determine the arc flash PPE category. The estimated maximum available fault current, maximum arc duration, and working distances for dc equipment are listed in 130.7(C)(15)(b). An incident energy analysis shall be required in accordance with 130.5(G) for the following:

(6) Power systems with greater than the estimated maximum available fault current

(7) Power systems with longer than the maximum arc duration

(8) Less than the minimum working distance

(i) *Protective Clothing and Personal Protective Equipment (PPE).* Once the arc flash PPE category has been identified from Table 130.7(C)(15)(a) or Table 130.7(C)(15)(b), Table 130.7(C)(15)(c) shall be used to determine the required PPE. Table 130.7(C)(15)(c) lists the requirements for PPE based on arc flash PPE categories 1 through 4. This clothing and equipment shall be used when working within the arc flash boundary. The use of PPE other than or in addition to that listed shall be permitted provided it meets 130.7(C)(7).

Informational Note No. 1: See Informative Annex H for a suggested simplified approach to ensure adequate PPE for electrical workers within facilities with large and diverse electrical systems.

Informational Note No. 2: The PPE requirements of this section are intended to protect a person from arc flash hazards. While some situations could result in burns to the skin even with the protection described in Table 130.7(C)(15)(c), burn injury should be reduced and survivable. Due to the explosive effect of some arc events, physical trauma injuries could occur. The PPE requirements of this section do not address protection against physical trauma other than exposure to the thermal effects of an arc flash.

Informational Note No. 3: The arc rating for a particular clothing system can be obtained from the arc-rated clothing manufacturer.

Table 130.7(C)(15)(a) Arc Flash PPE Categories for Alternating Current (ac) Systems

Equipment	Arc Flash PPE Category	Arc Flash Boundary
Panelboards or other equipment rated 240 volts and below	1	485 mm (19 in.)
Parameters: Maximum of 25 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
Panelboards or other equipment rated greater than 240 volts and up to 600 volts	2	900 mm (3 ft)
Parameters: Maximum of 25 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class motor control centers (MCCs)	2	1.5 m (5 ft)
Parameters: Maximum of 65 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class motor control centers (MCCs)	4	4.3 m (14 ft)
Parameters: Maximum of 42 kA available fault current; maximum of 0.33 sec (20 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class switchgear (with power circuit breakers or fused switches) and 600-volt class switchboards	4	6 m (20 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.5 sec (30 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
Other 600-volt class (277 volts through 600 volts, nominal) equipment	2	1.5 m (5 ft)
Parameters: Maximum of 65 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
NEMA E2 (fused contactor) motor starters, 2.3 kV through 7.2 kV	4	12 m (40 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault	-	-

Equipment	Arc Flash PPE Category	Arc Flash Boundary
clearing time; minimum working distance 910 mm (36 in.)		
Metal-clad switchgear, 1 kV through 15 kV	4	12 m (40 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	-	-
Metal enclosed interrupter switchgear, fused or unfused type construction, 1 kV through 15 kV Parameters: Maximum of 35 kA available fault current; maximum of 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	4	12 m (40 ft)
Other equipment 1 kV through 15 kV Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	4	12 m (40 ft)
Arc-resistant equipment up to 600-volt class Parameters: DOORS CLOSED and SECURED; with an available fault current and a fault clearing time that does not exceed the arc-resistant rating of the equipment*	N/A	N/A
Arc-resistant equipment 1 kV through 15 kV	N/A	N/A
Parameters: DOORS CLOSED and SECURED; with an available fault current and a fault clearing time that does not exceed the arc-resistant rating of the equipment*	-	-

N/A: Not applicable

Note:

For equipment rated 600 volts and below and protected by upstream current-limiting fuses or current-limiting molded case circuit breakers sized at 200 amperes or less, the arc flash PPE category can be reduced by one number but not below arc flash PPE category 1.

*For DOORS OPEN refer to the corresponding non-arc-resistant equipment section of this table.

Informational Note No. 1 to Table 130.7(C)(15)(a): The following are typical fault clearing times of overcurrent protective devices:

(1) 0.5 cycle fault clearing time is typical for current-limiting fuses and current-limiting molded case circuit breakers when the fault current is within the current limiting range.

(2) 1.5 cycle fault clearing time is typical for molded case circuit breakers rated less than 1000 volts with an instantaneous integral trip.

(3) 3.0 cycle fault clearing time is typical for insulated case circuit breakers rated less than 1000 volts with an instantaneous integral trip or relay operated trip.

(4) 5.0 cycle fault clearing time is typical for relay operated circuit breakers rated 1 kV to 35 kV when the relay operates in the instantaneous range (i.e., “no intentional delay”).

(5) 20 cycle fault clearing time is typical for low-voltage power and insulated case circuit breakers with a short time fault clearing delay for motor inrush.

(6) 30 cycle fault clearing time is typical for low-voltage power and insulated case circuit breakers with a short time fault clearing delay without instantaneous trip.

Informational Note No. 2 to Table 130.7(C)(15)(a): ~~See Table 1 of~~ IEEE 1584, *Guide for Performing Arc Flash Hazard Calculations*, for further information regarding list items (2) through (4) in Informational Note No. 1.

Informational Note No. 3 to Table 130.7(C)(15)(a): See IEEE C37.20.7, *Guide for Testing Switchgear Rated Up to 52 kV for Internal Arcing Faults*, for an example of a standard that provides information for arc-resistant equipment referred to in Table 130.7(C)(15)(a).

Informational Note No. 4 to Table 130.7(C)(15)(a): See Informative Annex O.2.4(9) for information on arc-resistant equipment.

Table 130.7(C)(15)(b) Arc Flash PPE Categories for dc Systems

Equipment	**Arc Flash PPE Category**	**Arc Flash Boundary**
Storage batteries, dc switchboards, and other dc supply sources	-	-
Parameters: Greater than 150 volts and less than or equal to 600 volts	-	-
Maximum arc duration and minimum working distance: 2 sec @ 455 mm (18 in.)	-	-
Available fault current less than 1.5 kA	2	900 mm
		- - (3 ft)
Available fault current greater than or equal to 1.5 kA and less than 3 kA	2	1.2 m
		- - (4 ft)
Available fault current greater than or equal to 3 kA and less than 7 kA	3	1.8 m
		- - (6 ft.)
Available fault current greater than or equal to 7 kA and less than 10 kA	4	2.5 m
		- - (8 ft)

Notes:

(1) Apparel that can be expected to be exposed to electrolyte must meet both of the following conditions:

(a) Be evaluated for electrolyte protection

Informational Note: See ASTM F1296, *Standard Guide for Evaluating Chemical Protective Clothing*, for information on evaluating apparel for protection from electrolyte.

(b) Be arc rated

Informational Note: See ASTM F1891, *Standard Specification for Arc and Flame Resistant Rainwear*, for information on evaluating arc-rated apparel.

(2) A two-second arc duration is assumed if there is no overcurrent protective device (OCPD) or if the fault clearing time is not known. If the fault clearing time is known and is less than 2 seconds, an incident energy analysis could provide a more representative result.

Informational Note No. 1: See D.5 for the basis for table values and alternative methods to determine dc incident energy. Methods should be used with good engineering judgment. When determining available fault current, the effects of cables and any other impedances in the circuit should be included. Power system modeling is the best method to determine the available short-circuit current at the point of the arc. Battery cell short-circuit current can be obtained from the battery manufacturer.

Informational Note No. 2: The methods for estimating the dc arc flash incident energy that were used to determine the categories for this table are based on open-air incident energy calculations. Open-air calculations were used because many battery systems and other dc process systems are in open areas or rooms. If the specific task is within an enclosure, it would be prudent to consider additional PPE protection beyond the value shown in this table.

Informational Note No. 3: See the following references for dc voltages below 150 volts nominal:

(1) J. G. Hildreth and K. Feeney, “Arc Flash Hazards Station Battery Systems,” 2018 IEEE Power & Energy Society General Meeting (PESGM), 2018, pp. 1–5.

(2) US Department of Energy Bonneville Power Administration Engineering and Technical Services Report BPA F 5450.05, “DC Arc Flash: 125V, 1300 amp-hour battery,” May 11, 2017, doi: 10.1109/PESGM.2018.8586181.

(3) K. Gray, S. Robert, and T. L. Gauthier, "Low Voltage 100–500 Vdc Arc Flash Testing," 2020 IEEE IAS Electrical Safety Workshop (ESW), 2020, pp. 1–7, doi: 10.1109/ESW42757.2020.9188336.

Table 130.7(C)(15)(c) Personal Protective Equipment (PPE)

Arc-Flash PPE Category	PPE	
1	**Arc-Rated Clothing, Minimum Arc Rating of 4 cal/cm^2 (16.75 J/cm^2)**[a]	
	-	Arc-rated long-sleeve shirt and pants or arc-rated coverall
	-	Arc-rated face shield[b] or arc flash suit hood
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]

Arc-Flash PPE Category	PPE	
	-	Heavy-duty leather gloves, arc-rated gloves, or rubber insulating gloves with protectors (SR)[d]
	-	Leather footwear[e] (AN)
2	**Arc-Rated Clothing, Minimum Arc Rating of 8 cal/cm^2 (33.5 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt and pants or arc-rated coverall
	-	Arc-rated flash suit hood or arc-rated face shield[b] and arc-rated balaclava
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Heavy-duty leather gloves, arc-rated gloves, or rubber insulating gloves with protectors (SR)[d]
	-	Leather footwear[e]
3	**Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 25 cal/cm^2 (104.7 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt (AR)
	-	Arc-rated pants (AR)
	Arc-rated coverall (AR)	
	-	Arc-rated arc flash suit jacket (AR)
	Arc-rated arc flash suit pants (AR)	
	-	Arc-rated arc flash suit hood
	-	Arc-rated gloves or rubber insulating gloves with protectors (SR)[d]
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**

Arc-Flash PPE Category	PPE	
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Leather footwear[e]
4	**Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 40 cal/cm^2 (167.5 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt (AR)
	-	Arc-rated pants (AR)
	Arc-rated coverall (AR)	
	-	Arc-rated arc flash suit jacket (AR)
	Arc-rated arc flash suit pants (AR)	
	-	Arc-rated arc flash suit hood
	-	Arc-rated gloves or rubber insulating gloves with protectors (SR)[d]
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Leather footwear[e]

AN: As needed (optional). AR: As required. SR: Selection required.

[a] *Arc rating* is defined in Article 100.

[b] Face shields are to have wrap-around guarding to protect not only the face but also the forehead, ears, and neck, or, alternatively, an arc-rated arc flash suit hood is required to be worn.

[c] Other types of hearing protection are permitted to be used in lieu of or in addition to ear canal inserts provided they are worn under an arc-rated arc flash suit hood.

[d] Rubber insulating gloves with protectors provide arc flash protection in addition to electric shock protection. Higher class rubber insulating gloves with protectors, due to their increased material thickness, provide increased arc flash protection.

[e] Footwear other than leather or dielectric shall be permitted to be used provided it has been tested to demonstrate no ignition, melting or dripping at the minimum arc rating for the respective arc flash PPE category.

[f]The arc rating of outer layers worn over arc-rated clothing as protection from the elements or for other safety purposes, and that are not used as part of a layered system, shall not be required to be equal to or greater than the estimated incident energy exposure.

Statement of Problem and Substantiation for Public Input

Section/Paragraph: Table 130.7(C)(15)(a), Informational Note 2

Public Input:
I wish to address the reference made in Table 1, Informational Note 2 of Table 130.7(C)(15)(a) in the current edition of NFPA 70E. This table references the 2002 Edition of IEEE 1584, which includes "typical" power circuit breaker fault clearing times. This reference is outdated and potentially misleading for several reasons.

First, the referenced "typical" opening times from the 2002 Edition of IEEE 1584 were removed in its 2018 Edition. The opening time of a circuit breaker is a critical variable in determining the incident energy level during an arc flash event. Assuming a "typical" value without considering the specific characteristics of the electrical system in question can result in underestimating the potential hazard.

Second, Table 1 in the 2018 Edition of IEEE 1584, which this note references, contains other data such as coefficients for one of the arc flash calculation equations and therefore would not be related to circuit breaker opening times. This could cause confusion and misinterpretation of the standards.

Recommendation:
To prevent the potential for misunderstanding and to ensure the safety standards reflect current knowledge and practices, I recommend either removing this reference from NFPA 70E or updating it to align with the latest edition of IEEE 1584. If an update is preferred, a clarification should be made to distinguish the purpose and content of Table 1 in the 2018 Edition of IEEE 1584 from the outdated concept of "typical" opening times, and another reference should be used if any.

Furthermore, to assist practitioners in accurately assessing arc flash hazards, consider guidance that could be provided on how to obtain or calculate specific opening times for their electrical systems, rather than relying on assumed "typical" values. This approach would enhance the reliability of arc flash hazard assessments and contribute to safer work practices around electrical equipment.

Conclusion:
Aligning NFPA 70E with the current understanding and standards of electrical safety is paramount to ensuring the effectiveness of arc flash hazard assessments. Updating or removing the reference to outdated "typical" opening times will help practitioners make more accurate and informed decisions regarding electrical safety and arc flash prevention.

Submitter Information Verification

Submitter Full Name: Evan Banda
Organization: Champion Electric Inc
Street Address:
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Submittal Date: Tue Mar 26 11:40:41 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: The reference to “Table 1” is not removed from Table 130.7(C)(15)(a) Informational Note No. 2 as IEEE 1584-2002 Table 1 is the source of the information provided in Table 130.7(C)(15)(a) Informational Note No. 1.

Public Input No. 72-NFPA 70E-2024 [Section No. 130.7(C)(15)]

(15) Arc Flash PPE Category Method.

The requirements of 130.7(C)(15) shall apply when the arc flash PPE category method is used for the selection of arc flash PPE.

Informational Note: For both ac and dc systems, the arc flash PPE category of the protective clothing and equipment is generally based on determination of the estimated exposure level.

(a) *Alternating Current (ac) Equipment.* When the arc flash risk assessment performed in accordance with 130.5 indicates that arc flash PPE is required and the arc flash PPE category method is used for the selection of PPE for ac systems in lieu of the incident energy analysis of 130.5(G), Table 130.7(C)(15)(a) shall be used to determine the arc flash PPE category. The estimated maximum available fault current, maximum fault-clearing times, and minimum working distances for various ac equipment types or classifications are listed in Table 130.7(C)(15)(a). An incident energy analysis shall be required in accordance with 130.5(G) for the following:

(2) Power systems with greater than the estimated maximum available fault current

(3) Power systems with longer than the maximum fault clearing times

(4) Less than the minimum working distance

(e) *Direct Current (dc) Equipment.* When the arc flash risk assessment performed in accordance with 130.5(G) indicates that arc flash PPE is required and the arc flash PPE category method is used for the selection of PPE for dc systems in lieu of the incident energy analysis of 130.5(G), Table 130.7(C)(15)(b) shall be used to determine the arc flash PPE category. The estimated maximum available fault current, maximum arc duration, and working distances for dc equipment are listed in 130.7(C)(15)(b). An incident energy analysis shall be required in accordance with 130.5(G) for the following:

(6) Power systems with greater than the estimated maximum available fault current

(7) Power systems with longer than the maximum arc duration

(8) Less than the minimum working distance

(i) *Protective Clothing and Personal Protective Equipment (PPE).* Once the arc flash PPE category has been identified from Table 130.7(C)(15)(a) or Table 130.7(C)(15)(b), Table 130.7(C)(15)(c) shall be used to determine the required PPE. Table 130.7(C)(15)(c) lists the requirements for PPE based on arc flash PPE categories 1 through 4. This clothing and equipment shall be used when working within the arc flash boundary. The use of PPE other than or in addition to that listed shall be permitted provided it meets 130.7(C)(7).

Informational Note No. 1: See Informative Annex H for a suggested simplified approach to ensure adequate PPE for electrical workers within facilities with large and diverse electrical systems.

Informational Note No. 2: The PPE requirements of this section are intended to protect a person from arc flash hazards. While some situations could result in burns to the skin even with the protection described in Table 130.7(C)(15)(c), burn injury should be reduced and survivable. Due to the explosive effect of some arc events, physical trauma injuries could occur. The PPE requirements of this section do not address protection against physical trauma other than exposure to the thermal effects of an arc flash.

Informational Note No. 3: The arc rating for a particular clothing system can be obtained from the arc-rated clothing manufacturer.

Table 130.7(C)(15)(a) Arc Flash PPE Categories for Alternating Current (ac) Systems

Equipment	Arc Flash PPE Category	Arc Flash Boundary
Panelboards or other equipment rated 240 volts and below	1	485 mm (19 in.)
Parameters: Maximum of 25 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
Panelboards or other equipment rated greater than 240 volts and up to 600 volts	2	900 mm (3 ft)
Parameters: Maximum of 25 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class motor control centers (MCCs)	2	1.5 m (5 ft)
Parameters: Maximum of 65 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class motor control centers (MCCs)	4	4.3 m (14 ft)
Parameters: Maximum of 42 kA available fault current; maximum of 0.33 sec (20 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class switchgear (with power circuit breakers or fused switches) and 600-volt class switchboards	4	6 m (20 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.5 sec (30 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
Other 600-volt class (277 volts through 600 volts, nominal) equipment	2	1.5 m (5 ft)
Parameters: Maximum of 65 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
NEMA E2 (fused contactor) motor starters, 2.3 kV through 7.2 kV	4	12 m (40 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault	-	-

Equipment	Arc Flash PPE Category	Arc Flash Boundary
clearing time; minimum working distance 910 mm (36 in.)		
Metal-clad switchgear, 1 kV through 15 kV	4	12 m (40 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	-	-
Metal enclosed interrupter switchgear, fused or unfused type construction, 1 kV through 15 kV Parameters: Maximum of 35 kA available fault current; maximum of 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	4	12 m (40 ft)
Other equipment 1 kV through 15 kV Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	4	12 m (40 ft)
Arc-resistant equipment up to 600-volt class Parameters: DOORS CLOSED and SECURED; with an available fault current and a fault clearing time that does not exceed the arc-resistant rating of the equipment*	N/A	N/A
Arc-resistant equipment 1 kV through 15 kV	N/A	N/A
Parameters: DOORS CLOSED and SECURED; with an available fault current and a fault clearing time that does not exceed the arc-resistant rating of the equipment*	-	-

N/A: Not applicable

Note:

For equipment rated 600 volts and below and protected by upstream current-limiting fuses or current-limiting molded case circuit breakers sized at 200 amperes or less, the arc flash PPE category can be reduced by one number but not below arc flash PPE category 1.

*For DOORS OPEN refer to the corresponding non-arc-resistant equipment section of this table.

Informational Note No. 1 to Table 130.7(C)(15)(a): The following are typical fault clearing times of overcurrent protective devices:

(1) 0.5 cycle fault clearing time is typical for current-limiting fuses and current-limiting molded case circuit breakers when the fault current is within the current limiting range.

(2) 1.5 cycle fault clearing time is typical for molded case circuit breakers rated less than 1000 volts with an instantaneous integral trip.

(3) 3.0 cycle fault clearing time is typical for insulated case circuit breakers rated less than 1000 volts with an instantaneous integral trip or relay operated trip.

(4) 5.0 cycle fault clearing time is typical for relay operated circuit breakers rated 1 kV to 35 kV when the relay operates in the instantaneous range (i.e., “no intentional delay”).

(5) 20 cycle fault clearing time is typical for low-voltage power and insulated case circuit breakers with a short time fault clearing delay for motor inrush.

(6) 30 cycle fault clearing time is typical for low-voltage power and insulated case circuit breakers with a short time fault clearing delay without instantaneous trip.

Informational Note No. 2 to Table 130.7(C)(15)(a): See Table 1 of IEEE 1584, *Guide for Performing Arc Flash Hazard Calculations*, for further information regarding list items (2) through (4) in Informational Note No. 1.

Informational Note No. 3 to Table 130.7(C)(15)(a): See IEEE C37.20.7, *Guide for Testing Switchgear Rated Up to 52 kV for Internal Arcing Faults*, for an example of a standard that provides information for arc-resistant equipment referred to in Table 130.7(C)(15)(a).

Informational Note No. 4 to Table 130.7(C)(15)(a): See Informative Annex O.2.4(9) for information on arc-resistant equipment.

Table 130.7(C)(15)(b) Arc Flash PPE Categories for dc Systems

Equipment	**Arc Flash PPE Category**	**Arc Flash Boundary**
Storage batteries, dc switchboards, and other dc supply sources	-	-
Parameters: Greater than 150 volts and less than or equal to 600 volts	-	-
Maximum arc duration and minimum working distance: 2 sec @ 455 mm (18 in.)	-	-
Available fault current less than 1.5 kA	2	900 mm
		- - (3 ft)
Available fault current greater than or equal to 1.5 kA and less than 3 kA	2	1.2 m
		- - (4 ft)
Available fault current greater than or equal to 3 kA and less than 7 kA	3	1.8 m
		- - (6 ft.)
Available fault current greater than or equal to 7 kA and less than 10 kA	4	2.5 m
		- - (8 ft)

Notes:

(1) Apparel that can be expected to be exposed to electrolyte must meet both of the following conditions:

(a) Be evaluated for electrolyte protection

Informational Note: See ASTM F1296, *Standard Guide for Evaluating Chemical Protective Clothing*, for information on evaluating apparel for protection from electrolyte.

(b) Be arc rated

Informational Note: See ASTM F1891, *Standard Specification for Arc and Flame Resistant Rainwear*, for information on evaluating arc-rated apparel.

(2) A two-second arc duration is assumed if there is no overcurrent protective device (OCPD) or if the fault clearing time is not known. If the fault clearing time is known and is less than 2 seconds, an incident energy analysis could provide a more representative result.

Informational Note No. 1: See D.5 for the basis for table values and alternative methods to determine dc incident energy. Methods should be used with good engineering judgment. When determining available fault current, the effects of cables and any other impedances in the circuit should be included. Power system modeling is the best method to determine the available short-circuit current at the point of the arc. Battery cell short-circuit current can be obtained from the battery manufacturer.

Informational Note No. 2: The methods for estimating the dc arc flash incident energy that were used to determine the categories for this table are based on open-air incident energy calculations. Open-air calculations were used because many battery systems and other dc process systems are in open areas or rooms. If the specific task is within an enclosure, it would be prudent to consider additional PPE protection beyond the value shown in this table.

Informational Note No. 3: See the following references for dc voltages below 150 volts nominal:

(1) J. G. Hildreth and K. Feeney, “Arc Flash Hazards Station Battery Systems,” 2018 IEEE Power & Energy Society General Meeting (PESGM), 2018, pp. 1–5.

(2) US Department of Energy Bonneville Power Administration Engineering and Technical Services Report BPA F 5450.05, “DC Arc Flash: 125V, 1300 amp-hour battery,” May 11, 2017, doi: 10.1109/PESGM.2018.8586181.

(3) K. Gray, S. Robert, and T. L. Gauthier, "Low Voltage 100–500 Vdc Arc Flash Testing," 2020 IEEE IAS Electrical Safety Workshop (ESW), 2020, pp. 1–7, doi: 10.1109/ESW42757.2020.9188336.

Table 130.7(C)(15)(c) Personal Protective Equipment (PPE)

Arc-Flash PPE Category	PPE	
1	**Arc-Rated Clothing, Minimum Arc Rating of 4 cal/cm^2 (16.75 J/cm^2)**[a]	
	-	Arc-rated long-sleeve shirt and pants or arc-rated coverall
	-	Arc-rated face shield[b] or arc flash suit hood
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]

Arc-Flash PPE Category	PPE	
	-	Heavy-duty leather gloves, arc-rated gloves, or rubber insulating gloves with protectors (SR)[d]
	-	Leather footwear[e] (AN)
2	**Arc-Rated Clothing, Minimum Arc Rating of 8 cal/cm^2 (33.5 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt and pants or arc-rated coverall
	-	Arc-rated flash suit hood or arc-rated face shield[b] and arc-rated balaclava
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Heavy-duty leather gloves, arc-rated gloves, or rubber insulating gloves with protectors (SR)[d]
	-	Leather footwear[e]
3	**Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 25 cal/cm^2 (104.7 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt (AR)
	-	Arc-rated pants (AR)
	Arc-rated coverall (AR)	
	-	Arc-rated arc flash suit jacket (AR)
	Arc-rated arc flash suit pants (AR)	
	-	Arc-rated arc flash suit hood
	-	Arc-rated gloves or rubber insulating gloves with protectors (SR)[d]
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**

Arc-Flash PPE Category	PPE	
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Leather footwear[e]
4	**Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 40 cal/cm^2 (167.5 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt (AR)
	-	Arc-rated pants (AR)
	Arc-rated coverall (AR)	
	-	Arc-rated arc flash suit jacket (AR)
	Arc-rated arc flash suit pants (AR)	
	-	Arc-rated arc flash suit hood
	-	Arc-rated gloves or rubber insulating gloves with protectors (SR)[d]
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Leather footwear[e]

AN: As needed (optional). AR: As required. SR: Selection required.

[a] *Arc rating* is defined in Article 100.

[b] Face shields are to have wrap-around guarding to protect not only the face but also the forehead, ears, and neck, or, alternatively, an arc-rated arc flash suit hood is required to be worn.

[c] Other types of hearing protection are permitted to be used in lieu of or in addition to ear canal inserts provided they are worn under an arc-rated arc flash suit hood.

[d] Rubber insulating gloves with protectors provide arc flash protection in addition to electric shock protection. Higher class rubber insulating gloves with protectors, due to their increased material thickness, provide increased arc flash protection.

[e] Footwear other than leather or dielectric shall be permitted to be used provided it has been tested to demonstrate no ignition, melting or dripping at the minimum arc rating for the respective arc flash PPE category.

[f]The arc rating of outer layers worn over arc-rated clothing as protection from the elements or for other safety purposes, and that are not used as part of a layered system, shall not be required to be equal to or greater than the estimated incident energy exposure.

Statement of Problem and Substantiation for Public Input

Section/Paragraph: Section 130.7(C)(15) Arc Flash PPE Category Method
Input:
In the current NFPA 70E text, Section 130.7(C)(15) introduces the Arc Flash Personal Protective Equipment (PPE) Category Method but ambiguously refers to "maximum fault-clearing times," "maximum arc duration" (for DC systems), and "fault clearing time." This vagueness does not clarify whether these terms refer to conditions of a bolted fault or an arcing fault. Since this section's primary focus is arc flash risk assessment and mitigation, it would be logical to interpret all fault condition references as relating to arcing faults, which are directly relevant to arc flash hazards. Nonetheless, the table's design as a reference tool, combined with the readily available fault current labeling and the straightforward reference to breaker opening times linked with available fault currents, might lead users to overlook the need for calculating arcing fault currents. This oversight could mistakenly lead practitioners to use bolted fault information when determining fault clearing times, bypassing necessary calculations. This misinterpretation underscores the need for explicit language distinguishing between bolted and arcing faults to prevent incorrect application of the table and ensure accurate arc flash hazard assessments.
The current language does not explicitly make this distinction, leading to potential misinterpretation and misapplication of the standards. For instance, "available fault current" and "fault clearing time" parameters are critical in determining the appropriate arc flash PPE category. The use of values associated with a bolted fault, which typically presents a higher current magnitude than an arcing fault due to its lower impedance path, without clear guidance, can result in inaccurate arc flash hazard assessments.
Recommendation:
To eliminate ambiguity and ensure the accurate application of NFPA 70E standards, I recommend the following modifications to the text of Section 130.7(C)(15):
1. Clarify Terms: Introduce a preliminary statement or note within Section 130.7(C)(15) that explicitly states that unless otherwise mentioned, all references to "fault current" and "fault clearing time" within this section pertain to arcing fault conditions (or "bolted" as applicable). This clarification will ensure that the assessments and protective measures are appropriately aligned with the specific hazards arc flash presents.
2. Specific Language for "Fault Clearing Time": Amend the text to specify "arcing fault clearing time" or "bolted fault clearing time" instead of the generic "fault clearing time." This change would apply to all instances where "fault clearing time" is mentioned in the context of arc flash PPE selection and risk assessment. For example, within the parameters listed under the various equipment types in Table 130.7(C)(15)(a) and (b), replacing "maximum fault clearing time" with "maximum arcing fault clearing time."
3. Educational Note: Add an informational note explaining the difference between bolted fault and arcing fault, including why arcing fault parameters are more relevant to the arc flash PPE category determination process. This note could also direct the reader to resources for further information on the distinctions and implications of these fault types.
Conclusion:
These recommended changes aim to enhance the clarity and precision of NFPA 70E standards regarding arc flash risk assessment and PPE selection. By explicitly distinguishing between bolted and arcing faults, we can provide clearer guidance to practitioners, ensuring the safety standards are applied correctly and effectively in the field.

Submitter Information Verification

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Submittal Date: Tue Mar 26 12:58:07 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: This public input did not provide a suggested revision as required in Section 4.3.4.1(c) of the NFPA regulations.

Public Input No. 96-NFPA 70E-2024 [Section No. 130.7(C)(15)]

(15) Arc Flash PPE Category Method.

The requirements of 130.7(C)(15) shall apply when the arc flash PPE category method is used for the selection of arc flash PPE.

Informational Note: For both ac and dc systems, the arc flash PPE category of the protective clothing and equipment is generally based on determination of the estimated exposure level.

(a) *Alternating Current (ac) Equipment.* When the arc flash risk assessment performed in accordance with 130.5 indicates that arc flash PPE is required and the arc flash PPE category method is used for the selection of PPE for ac systems in lieu of the incident energy analysis of 130.5(G), Table 130.7(C)(15)(a) shall be used to determine the arc flash PPE category. The estimated maximum available fault current, maximum fault-clearing times, and minimum working distances for various ac equipment types or classifications are listed in Table 130.7(C)(15)(a). An incident energy analysis shall be required in accordance with 130.5(G) for the following:

(2) Power systems with greater than the estimated maximum available fault current

(3) Power systems with longer than the maximum fault clearing times

(4) Less than the minimum working distance

(e) *Direct Current (dc) Equipment.* When the arc flash risk assessment performed in accordance with 130.5(G) indicates that arc flash PPE is required and the arc flash PPE category method is used for the selection of PPE for dc systems in lieu of the incident energy analysis of 130.5(G), Table 130.7(C)(15)(b) shall be used to determine the arc flash PPE category. The estimated maximum available fault current, maximum arc duration, and working distances for dc equipment are listed in 130.7(C)(15)(b). An incident energy analysis shall be required in accordance with 130.5(G) for the following:

(6) Power systems with greater than the estimated maximum available fault current

(7) Power systems with longer than the maximum arc duration

(8) Less than the minimum working distance

(i) *Protective Clothing and Personal Protective Equipment (PPE).* Once the arc flash PPE category has been identified from Table 130.7(C)(15)(a) or Table 130.7(C)(15)(b), Table 130.7(C)(15)(c) shall be used to determine the required PPE. Table 130.7(C)(15)(c) lists the requirements for PPE based on arc flash PPE categories 1 through 4. This clothing and equipment shall be used when working within the arc flash boundary. The use of PPE other than or in addition to that listed shall be permitted provided it meets 130.7(C)(7).

Informational Note No. 1: See Informative Annex H for a suggested simplified approach to ensure adequate PPE for electrical workers within facilities with large and diverse electrical systems.

Informational Note No. 2: The PPE requirements of this section are intended to protect a person from arc flash hazards. While some situations could result in burns to the skin even with the protection described in Table 130.7(C)(15)(c), burn injury should be reduced and survivable. Due to the explosive effect of some arc events, physical trauma injuries could occur. The PPE requirements of this section do not address protection against physical trauma other than exposure to the thermal effects of an arc flash.

Informational Note No. 3: The arc rating for a particular clothing system can be obtained from the arc-rated clothing manufacturer.

Table 130.7(C)(15)(a) Arc Flash PPE Categories for Alternating Current (ac) Systems

Equipment	Arc Flash PPE Category	Arc Flash Boundary
Panelboards or other equipment rated 240 volts and below	1	485 mm (19 in.)
Parameters: Maximum of 25 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
Panelboards or other equipment rated greater than 240 volts and up to 600 volts	2	900 mm (3 ft)
Parameters: Maximum of 25 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class motor control centers (MCCs)	2	1.5 m (5 ft)
Parameters: Maximum of 65 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class motor control centers (MCCs)	4	4.3 m (14 ft)
Parameters: Maximum of 42 kA available fault current; maximum of 0.33 sec (20 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
600-volt class switchgear (with power circuit breakers or fused switches) and 600-volt class switchboards	4	6 m (20 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.5 sec (30 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
Other 600-volt class (277 volts through 600 volts, nominal) equipment	2	1.5 m (5 ft)
Parameters: Maximum of 65 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	-	-
NEMA E2 (fused contactor) motor starters, 2.3 kV through 7.2 kV	4	12 m (40 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault	-	-

Equipment	Arc Flash PPE Category	Arc Flash Boundary
clearing time; minimum working distance 910 mm (36 in.)		
Metal-clad switchgear, 1 kV through 15 kV	4	12 m (40 ft)
Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	-	-
Metal enclosed interrupter switchgear, fused or unfused type construction, 1 kV through 15 kV Parameters: Maximum of 35 kA available fault current; maximum of 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	4	12 m (40 ft)
Other equipment 1 kV through 15 kV Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	4	12 m (40 ft)
Arc-resistant equipment up to 600-volt class Parameters: DOORS CLOSED and SECURED; with an available fault current and a fault clearing time that does not exceed the arc-resistant rating of the equipment*	N/A	N/A
Arc-resistant equipment 1 kV through 15 kV	N/A	N/A
Parameters: DOORS CLOSED and SECURED; with an available fault current and a fault clearing time that does not exceed the arc-resistant rating of the equipment*	-	-

N/A: Not applicable

Note:

For equipment rated 600 volts and below and protected by upstream current-limiting fuses or current-limiting molded case circuit breakers sized at 200 amperes or less, the arc flash PPE category can be reduced by one number but not below arc flash PPE category 1.

*For DOORS OPEN refer to the corresponding non-arc-resistant equipment section of this table.

Informational Note No. 1 to Table 130.7(C)(15)(a): The following are typical fault clearing times of overcurrent protective devices:

(1) 0.5 cycle fault clearing time is typical for current-limiting fuses and current-limiting molded case circuit breakers when the fault current is within the current limiting range.

(2) 1.5 cycle fault clearing time is typical for molded case circuit breakers rated less than 1000 volts with an instantaneous integral trip.

(3) 3.0 cycle fault clearing time is typical for insulated case circuit breakers rated less than 1000 volts with an instantaneous integral trip or relay operated trip.

(4) 5.0 cycle fault clearing time is typical for relay operated circuit breakers rated 1 kV to 35 kV when the relay operates in the instantaneous range (i.e., “no intentional delay”).

(5) 20 cycle fault clearing time is typical for low-voltage power and insulated case circuit breakers with a short time fault clearing delay for motor inrush.

(6) 30 cycle fault clearing time is typical for low-voltage power and insulated case circuit breakers with a short time fault clearing delay without instantaneous trip.

Informational Note No. 2 to Table 130.7(C)(15)(a): See Table 1 of IEEE 1584-2002 , *Guide for Performing Arc Flash Hazard Calculations*, for further information regarding list items (2) through (4) in Informational Note No. 1.

Informational Note No. 3 to Table 130.7(C)(15)(a): See IEEE C37.20.7, *Guide for Testing Switchgear Rated Up to 52 kV for Internal Arcing Faults*, for an example of a standard that provides information for arc-resistant equipment referred to in Table 130.7(C)(15)(a).

Informational Note No. 4 to Table 130.7(C)(15)(a): See Informative Annex O.2.4(9) for information on arc-resistant equipment.

Table 130.7(C)(15)(b) Arc Flash PPE Categories for dc Systems

Equipment	**Arc Flash PPE Category**	**Arc Flash Boundary**
Storage batteries, dc switchboards, and other dc supply sources	-	-
Parameters: Greater than 150 volts and less than or equal to 600 volts	-	-
Maximum arc duration and minimum working distance: 2 sec @ 455 mm (18 in.)	-	-
Available fault current less than 1.5 kA	2	900 mm
		- - (3 ft)
Available fault current greater than or equal to 1.5 kA and less than 3 kA	2	1.2 m
		- - (4 ft)
Available fault current greater than or equal to 3 kA and less than 7 kA	3	1.8 m
		- - (6 ft.)
Available fault current greater than or equal to 7 kA and less than 10 kA	4	2.5 m
		- - (8 ft)

Notes:

(1) Apparel that can be expected to be exposed to electrolyte must meet both of the following conditions:

(a) Be evaluated for electrolyte protection

Informational Note: See ASTM F1296, *Standard Guide for Evaluating Chemical Protective Clothing*, for information on evaluating apparel for protection from electrolyte.

(b) Be arc rated

Informational Note: See ASTM F1891, *Standard Specification for Arc and Flame Resistant Rainwear*, for information on evaluating arc-rated apparel.

(2) A two-second arc duration is assumed if there is no overcurrent protective device (OCPD) or if the fault clearing time is not known. If the fault clearing time is known and is less than 2 seconds, an incident energy analysis could provide a more representative result.

Informational Note No. 1: See D.5 for the basis for table values and alternative methods to determine dc incident energy. Methods should be used with good engineering judgment. When determining available fault current, the effects of cables and any other impedances in the circuit should be included. Power system modeling is the best method to determine the available short-circuit current at the point of the arc. Battery cell short-circuit current can be obtained from the battery manufacturer.

Informational Note No. 2: The methods for estimating the dc arc flash incident energy that were used to determine the categories for this table are based on open-air incident energy calculations. Open-air calculations were used because many battery systems and other dc process systems are in open areas or rooms. If the specific task is within an enclosure, it would be prudent to consider additional PPE protection beyond the value shown in this table.

Informational Note No. 3: See the following references for dc voltages below 150 volts nominal:

(1) J. G. Hildreth and K. Feeney, “Arc Flash Hazards Station Battery Systems,” 2018 IEEE Power & Energy Society General Meeting (PESGM), 2018, pp. 1–5.

(2) US Department of Energy Bonneville Power Administration Engineering and Technical Services Report BPA F 5450.05, “DC Arc Flash: 125V, 1300 amp-hour battery,” May 11, 2017, doi: 10.1109/PESGM.2018.8586181.

(3) K. Gray, S. Robert, and T. L. Gauthier, "Low Voltage 100–500 Vdc Arc Flash Testing," 2020 IEEE IAS Electrical Safety Workshop (ESW), 2020, pp. 1–7, doi: 10.1109/ESW42757.2020.9188336.

Table 130.7(C)(15)(c) Personal Protective Equipment (PPE)

Arc-Flash PPE Category	PPE	
1	**Arc-Rated Clothing, Minimum Arc Rating of 4 cal/cm^2 (16.75 J/cm^2)**[a]	
	-	Arc-rated long-sleeve shirt and pants or arc-rated coverall
	-	Arc-rated face shield[b] or arc flash suit hood
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]

Arc-Flash PPE Category	PPE	
	-	Heavy-duty leather gloves, arc-rated gloves, or rubber insulating gloves with protectors (SR)[d]
	-	Leather footwear[e] (AN)
2	**Arc-Rated Clothing, Minimum Arc Rating of 8 cal/cm^2 (33.5 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt and pants or arc-rated coverall
	-	Arc-rated flash suit hood or arc-rated face shield[b] and arc-rated balaclava
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Heavy-duty leather gloves, arc-rated gloves, or rubber insulating gloves with protectors (SR)[d]
	-	Leather footwear[e]
3	**Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 25 cal/cm^2 (104.7 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt (AR)
	-	Arc-rated pants (AR)
	Arc-rated coverall (AR)	
	-	Arc-rated arc flash suit jacket (AR)
	Arc-rated arc flash suit pants (AR)	
	-	Arc-rated arc flash suit hood
	-	Arc-rated gloves or rubber insulating gloves with protectors (SR)[d]
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**

Arc-Flash PPE Category	PPE	
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Leather footwear[e]
4	**Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 40 cal/cm^2 (167.5 J/cm^2)[a]**	
	-	Arc-rated long-sleeve shirt (AR)
	-	Arc-rated pants (AR)
	Arc-rated coverall (AR)	
	-	Arc-rated arc flash suit jacket (AR)
	Arc-rated arc flash suit pants (AR)	
	-	Arc-rated arc flash suit hood
	-	Arc-rated gloves or rubber insulating gloves with protectors (SR)[d]
	-	Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f]
	-	**Protective Equipment**
	-	Hard hat
	-	Safety glasses or safety goggles (SR)
	-	Hearing protection (ear canal inserts)[c]
	-	Leather footwear[e]

AN: As needed (optional). AR: As required. SR: Selection required.

[a] *Arc rating* is defined in Article 100.

[b] Face shields are to have wrap-around guarding to protect not only the face but also the forehead, ears, and neck, or, alternatively, an arc-rated arc flash suit hood is required to be worn.

[c] Other types of hearing protection are permitted to be used in lieu of or in addition to ear canal inserts provided they are worn under an arc-rated arc flash suit hood.

[d] Rubber insulating gloves with protectors provide arc flash protection in addition to electric shock protection. Higher class rubber insulating gloves with protectors, due to their increased material thickness, provide increased arc flash protection.

[e] Footwear other than leather or dielectric shall be permitted to be used provided it has been tested to demonstrate no ignition, melting or dripping at the minimum arc rating for the respective arc flash PPE category.

[f]The arc rating of outer layers worn over arc-rated clothing as protection from the elements or for other safety purposes, and that are not used as part of a layered system, shall not be required to be equal to or greater than the estimated incident energy exposure.

Statement of Problem and Substantiation for Public Input

The referenced Table 1 from IEEE 1584 is from the 2002 Edition. This table and data do not exist in the 2018 Edition. Since the year was not specified as written, it is implied the reference is to the 2018 Edition which is incorrect. This proposed change of adding the year 2002, corrects this situation.

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Submittal Date: Mon May 27 04:51:59 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-55-NFPA 70E-2024

Statement: The qualifier “maximum” is deleted in front of “available fault current” in 130.7(C)(15)(a)(1) and 130.7(C)(15)(b)(1).

This revision is necessary to correlate with the definition of Available Fault Current. There is no such thing as the maximum largest.

The section was revised to comply with the NEC Style Manual Section 3.5.1.2 Multiple Requirements.

Table 130.7(C)(15)(a): This revision correlates with revisions in the parent text of 130.7(C)(15)(a) and 130.7(C)(15)(b). In both of these revisions the qualifier “maximum” which was used to describe available fault current was deleted. The defined term “Fault Current, Available (Available Fault Current”, in Article 100 clarifies that it is the largest amount of current capable of being delivered at a point on the system during a short-circuit condition. A similar revision is made to all references of available fault current and fault clearing time in Table 130.7(C)(15)(a) for clarity and usability.

Table 130.7(C)(15(a) Informational Note No. 1: List items (2) through (6) are modified for clarity and correlation with list item (1).

Table 130.7(C)(15(a) Informational Note No.2: Table 1 of IEEE 1584 as referenced in the informational note is from the 2002 edition. The table is not included in the 2018 Edition of IEEE 1584. The year of the edition is added for clarification.

Table 130.7(C)(15)(c): The modifiers “arc-rated” and “arc” are added to the table for correlation and clarity.

Public Input No. 168-NFPA 70E-2024 [Section No. 130.7(D)(1)]

(1) Insulated Tools and Equipment.

Tools and handling equipment used within the restricted approach boundary, or where they present an electrical contact hazard, shall be insulated. Insulated tools shall be protected from damage to the insulating material.

Informational Note: See 130.4(E), Electric Shock Protection Boundaries.

(a) *Requirements for Insulated Tools.* The following requirements shall apply to insulated tools:

(2) Insulated tools shall be rated for the voltages on which they are used.

(3) Insulated tools shall be designed and constructed for the environment to which they are exposed and the manner in which they are used.

(4) Insulated tools and equipment shall be inspected prior to each use. The inspection shall look for damage to the insulation or damage that can limit the tool from performing its intended function or could increase the potential for an incident (e.g., damaged tip on a screwdriver).

(e) *Fuse or Fuseholder Handling Equipment.* Fuse or fuseholder handling equipment, insulated for the circuit voltage, shall be used to remove or install a fuse if the fuse terminals are energized.

(f) *Ropes and Handlines.* Ropes and handlines used within the limited approach boundary shall be nonconductive.

(g) *Fiberglass-Reinforced Plastic Rods.* Fiberglass-reinforced plastic rod and tube used for live line tools shall meet the requirements of applicable state, federal, or local codes and standards.

Informational Note: See ASTM F711, *Standard Specification for Fiberglass-Reinforced Plastic (FRP) Rod and Tube Used in Live Line Tools*, for further information concerning visual inspection and testing of fiberglass-reinforced plastic rods and tubes.

(h) *Portable Ladders.* Portable ladders shall have nonconductive side rails when used within the limited approach boundary or where the employee or ladder could contact exposed energized electrical conductors or circuit parts. Nonconductive ladders shall meet the requirements of applicable state, federal, or local codes and standards.

Informational Note: See Informational Note Table 130.7(E) for a list of standards that contain information on portable ladders.

Statement of Problem and Substantiation for Public Input

Tools which could be accidentally dropped by the employee and fall into the restricted approach boundary pose an accidental contact hazard. Use of insulated tools would be required in this scenario even if the point of work is outside of the restricted approach boundary. This change aligns with current requirements in article 130.8(D) Conductive Articles Being Worn.

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Committee: EEW-AAA

Committee Statement

Resolution: FR-56-NFPA 70E-2024

Statement: This revision requires that tools and handling equipment that may present an electrical contact hazard, such as where they could fall into energized conductors or circuit parts, be insulated.

Revisions are also made to comply with the NEC Style Manual 3.5.1.2 Multiple Requirements.

The requirement to protect insulated tools from damage is moved from the second level subdivision to a list item in the third level subdivision (a) Requirements for Insulated Tools for two reasons: (1) to comply with the NEC Style Manual 3.5.1.2 Multiple Requirements, and (2) the requirement is specific to insulated tools.

Public Input No. 186-NFPA 70E-2024 [Section No. 130.7(D)(2)]

(2) Barriers.

Exposed energized electrical conductors or circuit parts ~~operating at 50 volts or more~~ where an electrical hazard exists shall be guarded by a barrier in accordance with 130.7(D)(2)(a) through 130.7(D)(2)(c) to prevent unintentional contact while an employee is working within the restricted approach boundary of those conductors or circuit parts. Barriers shall be supported to remain in place and shall prevent unintentional contact by a person, tool, or equipment.

(a) *Rubber Insulating Equipment.* Rubber insulating equipment used for protection from unintentional contact with energized conductors or circuit parts shall be rated for the voltage and shall meet the requirements of applicable state, federal, or local codes and standards.

Informational Note: See Informational Note Table 130.7(E) for a list of examples of standards that contain information on rubber insulating equipment.

(b) *Voltage-Rated Plastic Guard Equipment.* Plastic guard equipment for protection of employees from unintentional contact with energized conductors or circuit parts, or for protection of employees or energized equipment or material from contact with ground, shall be rated for the voltage and shall meet the requirements of applicable state, federal, or local codes and standards.

Informational Note: See Informational Note Table 130.7(E) for a list of examples of standards that contain information on voltage-rated plastic guard equipment.

(c) *Physical or Mechanical Barriers.* Physical or mechanical (field-fabricated) barriers shall be installed no closer than the restricted approach boundary distance given in Table 130.4(E)(a) and Table 130.4(E)(b). While the barrier is being installed, the restricted approach boundary distance specified in Table 130.4(E)(a) and Table 130.4(E)(b) shall be maintained, or the energized conductors or circuit parts shall be placed in an electrically safe work condition.

Statement of Problem and Substantiation for Public Input

An attempt was made in previous cycles to use the phrase "where electrical hazards exist" to recognize that an electrical hazard may still exist even below 50 volts. This revision continues that effort. "Electrical Hazards" as defined includes both electric shock and arc flash hazards.

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Submittal Date: Mon Jun 03 16:34:02 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: The suggested revision seeks to modify the general rule in 110.2(B) which focuses the intent of the NFPA 70E Standard to electrical conductors and circuit parts operating at voltages equal to or greater than 50 volts. See 110.2(B) Exception No. 5 for specific reference to requirements for systems that operate at less than 50 volts. The deletion of “operating at 50 volts or more” in 130.7(D)(2) could create confusion.

Public Input No. 277-NFPA 70E-2024 [New Section after 130.7(E)]

Table 130.7(G) Informational Note: Standards on Other Protective Equipment

Add the following two ASTM standards to Table 130.7(G)

1. Rubber Floor Mattng Standard Specification for Rubber Insulating Mattng ASTM D178

2. Temporary Protective Grounds – EPZ Bonding Mats Standard Specification for Temporary Protective

Equipotential Bond Mat To Be Used on De-Energized Equipment ASTM F2715

Additional Proposed Changes

File Name	Description	Approved
70E_PC_23_Hold.pdf	70E_PC23	

Statement of Problem and Substantiation for Public Input

NOTE: This Public Input appeared as “Reject but Hold” in Public Comment No. 23 of the (A2023) Second Draft Report for NFPA 70E and per the Regs. At 4.4.8.3.1 and needs to be reconsidered by the TC for the next edition of the document.

Including two additional ASTM standards (ASTM F2715 and ASTM D178) to Table 130.7(G) will help the users
of 70E to find the associated standards quickly and easily for commonly used electrical safety other protective
equipment.

Rubber "Switchboard matting" per ASTM D178 and Equipotential conductive mats per ASTM F2715 are now
commonly used by many companies.

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Committee:	EEW-AAA

Committee Statement

Resolution: Matting is not added to Table 130.7(E) because matting is not required or referenced in 130.7(D).

Public Comment No. 23-NFPA 70E-2022 [New Section after 130.7(E)]

Table 130.7(G) Informational Note: Standards on Other Protective Equipment

Add the following two ASTM standards to Table 130.7(G)

1. Rubber Floor Matting Standard Specification for Rubber Insulating Matting ASTM D178

2. Temporary Protective Grounds – EPZ Bonding Mats Standard Specification for Temporary Protective Equipotential Bond Mat To Be Used on De-Energized Equipment ASTM F2715

Additional Proposed Changes

File Name	Description	Approved
New_addition_to_Table_130.7_G_for_ASTM_F2715_and_ASTM_D178.docx	Add ASTM F2715 and ASTM D178 to Table 130.7(G)	

Statement of Problem and Substantiation for Public Comment

Including two additional ASTM standards (ASTM F2715 and ASTM D178) to Table 130.7(G) will help the users of 70E to find the associated standards quickly and easily for commonly used electrical safety other protective equipment.
Rubber "Switchboard matting" per ASTM D178 and Equipotential conductive mats per ASTM F2715 are now commonly used by many companies.

Related Public Comments for This Document

Related Comment	Relationship
Public Comment No. 24-NFPA 70E-2022 [New Section after 130.7(C)(7)]	

Related Item

• PI

Submitter Information Verification

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Submittal Date: Mon Mar 28 20:34:28 EDT 2022
Committee: EEW-AAA

Committee Statement

Committee Action: Rejected but held

Resolution: The text proposed by this public comment does not meet 4.4.4.2 of the Regulations Governing Committee Projects which requires public comments to be related to material that has received public review either through the submission of Public Input, Committee Input or Correlating Input or through the First Revisions.

2024 NFPA 70E new additions to Table 130.7(G)
George T. Cole

Add the following two ASTM standards to Table 130.7(G)

Subject	Document	Document Number
Rubber Floor Matting	Standard Specification for Rubber Insulating Matting	ASTM D178
Temporary Protective Grounds – EPZ Bonding Mats	Standard Specification for Temporary Protective Equipotential Bond Mat To Be Used on De-Energized Equipment	ASTM F2715

Public Input No. 21-NFPA 70E-2023 [Section No. 130.8]

130.8 Other Precautions for ~~Personnel Activities~~ Employee Activities .

(A) Alertness.

(1) Where Electrical Hazards Might Exist.

Employees shall be instructed to be alert at all times where electrical hazards might exist.

(2) When Impaired.

Employees shall not be permitted to work where electrical hazards exist while their alertness is recognizably impaired due to illness, fatigue, or other reasons.

(3) Changes in Scope.

Employees shall be instructed to be alert for changes in the job or task that could lead the person outside of the electrically safe work condition or expose the person to additional hazards that were not part of the original plan.

(B) Blind Reaching.

Employees shall be instructed not to reach blindly into areas that might contain exposed energized electrical conductors or circuit parts where an electrical hazard exists.

(C) Illumination.

(1) General.

Employees shall not enter spaces where electrical hazards exist unless illumination is provided that enables the employees to perform the work safely.

(2) Obstructed View of Work Area.

Where lack of illumination or an obstruction precludes observation of the work to be performed, employees shall not perform any task where an electrical hazard exists.

(D) Conductive Articles Being Worn.

Conductive articles of jewelry and clothing (such as watchbands, bracelets, rings, key chains, necklaces, metalized aprons, cloth with conductive thread, metal headgear, or metal frame glasses) shall not be worn within the restricted approach boundary or where they present an electrical contact hazard with exposed energized electrical conductors or circuit parts.

(E) Conductive Materials, Tools, and Equipment Being Handled.

(1) General.

Conductive materials, tools, and equipment that are in contact with any part of an employee's body shall be handled in a manner that prevents unintentional contact with energized electrical conductors or circuit parts. Such materials and equipment shall include, but are not limited to, long conductive objects, such as ducts, pipes and tubes, conductive hose and rope, metal-lined rules and scales, steel tapes, pulling lines, metal scaffold parts, structural members, bull floats, and chains.

(2) Approach to Energized Electrical Conductors and Circuit Parts.

Means shall be employed to ensure that conductive materials approach exposed energized electrical conductors or circuit parts no closer than that permitted by 130.4(F) .

(F) Confined or Enclosed Work Spaces.

When an employee works in a confined or enclosed space (such as a manhole or vault) where an electrical hazard exists, the employer shall provide, and the employee shall use, protective shields, protective barriers, or insulating materials as necessary to protect against electrical hazards.

(G) Doors and Hinged Panels.

Doors, hinged panels, and the like shall be secured to prevent their swinging into an employee and causing the employee to contact exposed energized electrical conductors or circuit parts where an electrical hazard exists if movement of the door, hinged panel, and the like is likely to create a hazard.

(H) Clear Spaces.

Working space required by other codes and standards shall not be used for storage. This space shall be kept clear to permit safe operation and maintenance of electrical equipment.

(I) Housekeeping Duties.

Employees shall not perform housekeeping duties inside the limited approach boundary where there is a possibility of contact with energized electrical conductors or circuit parts, unless adequate safeguards (such as insulating equipment or barriers) are provided to prevent contact. Electrically conductive cleaning materials (including conductive solids such as steel wool, metalized cloth, and silicone carbide, as well as conductive liquid solutions) shall not be used inside the limited approach boundary unless procedures to prevent electrical contact are followed.

(J) Occasional Use of Flammable Materials.

Where flammable materials are present only occasionally, electric equipment capable of igniting them shall not be permitted to be used, unless measures are taken to prevent hazardous conditions from developing. Such materials shall include, but are not limited to, flammable gases, vapors, or liquids, combustible dust, and ignitible fibers or flyings.

> Informational Note: See *NFPA 70* , *National Electrical Code* , for electrical installation requirements for locations where flammable materials are present on a regular basis.

(K) Anticipating Failure.

When there is evidence that electric equipment could fail and injure employees, the electric equipment shall be de-energized, unless the employer can demonstrate that de-energizing introduces additional hazards or increased risk or is infeasible because of equipment design or operational limitation. Until the equipment is de-energized or repaired, employees shall be protected from hazards associated with the impending failure of the equipment by suitable barricades and other alerting techniques necessary for safety of the employees.

> Informational Note: See 130.8(O) for alerting techniques.

(L) Routine Opening and Closing of Circuits.

Load-rated switches, circuit breakers, or other devices specifically designed as disconnecting means shall be used for the opening, reversing, or closing of circuits under load conditions. Cable connectors not of the load-break type, fuses, terminal lugs, and cable splice connections shall not be permitted to be used for such purposes, except in an emergency.

(M) Reclosing Circuits After Protective Device Operation.

After a circuit is de-energized by the automatic operation of a circuit protective device, the circuit shall not be manually re-energized until a qualified person or persons determines the equipment and circuit can be safely energized. Manually reclosing circuit breakers or re-energizing circuits through replaced fuses shall be prohibited until the fault has been cleared.

Exception: When it is determined from the design of the circuit and the overcurrent devices involved that the automatic operation of a device was caused by an overload rather than a fault condition, examination of the circuit or connected equipment shall not be required before the circuit is re-energized.

(N) Safety Interlocks.

Only qualified persons following the requirements for working inside the restricted approach boundary as covered by 130.4(G) shall be permitted to defeat or bypass an electrical safety interlock over which the person has sole control, and then only temporarily while the qualified person is working on the equipment. The safety interlock system shall be returned to its operable condition when the work is completed.

(O) Alerting Techniques.

(1) Safety Signs and Tags.

Safety signs, safety symbols, or tags shall be used where necessary to warn employees about electrical hazards that might endanger them. Such signs and tags shall meet the requirements of applicable state, federal, or local codes and standards.

Informational Note No. 1: Safety signs, tags, and barricades used to identify energized "look-alike" equipment can be employed as an additional preventive measure.

Informational Note No. 2: See Informational Note Table 130.7(E) , for a list of examples of standards that contain information on safety signs and tags.

(2) Barricades.

Barricades shall be used in conjunction with safety signs where it is necessary to prevent or limit employee access to work areas containing energized conductors or circuit parts. Conductive barricades shall not be used where it might increase the likelihood of exposure to an electrical hazard. Barricades shall be placed no closer than the limited approach boundary given in Table 130.4(E)(a) and Table 130.4(E)(b) . Where the arc flash boundary is greater than the limited approach boundary, barricades shall not be placed closer than the arc flash boundary.

(3) Attendants.

If signs and barricades do not provide sufficient warning and protection from electrical hazards, an attendant shall be stationed to warn and protect employees. The primary duty and responsibility of an attendant providing manual signaling and alerting shall be to keep unqualified employees outside a work area where the unqualified employee might be exposed to electrical hazards. An attendant shall remain in the area as long as there is a potential for employees to be exposed to the electrical hazards.

(P) Look-Alike Equipment.

Where work performed on equipment that is de-energized and placed in an electrically safe condition exists in a work area with other energized equipment that is similar in size, shape, and construction, one of the alerting methods in 130.8(O) , or shall be employed to prevent the employee from entering look-alike equipment.

Statement of Problem and Substantiation for Public Input

It appears that Terra has indicated much more is part of this recommendation than there is. The only change recommended is to change the word "personnel" to "employee" in the title of 130.8 for correlation. Although the title of 130.8 presently uses the word "personnel," the rest of the provisions of 130.8 use the word "employee" rather than "personnel." Further, from a correlation standpoint, it is worth nothing that 90.2 indicates that "[t]he purpose of this standard is to provide a practical safe working area for employees..." and that the scope of Article 105 states, in part, that "[t]his article covers the application...for employees..." and that the purpose of Article 105, in part, states that "[t]these practices and procedures are intended to provide for employee safety..." per 105.2, for example.

Submitter Information Verification

Submitter Full Name: Palmer Hickman
Organization: Electrical Training Alliance
Street Address:
City:
State:
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Submittal Date: Tue Sep 26 11:09:27 EDT 2023
Committee: EEW-AAA

Committee Statement

Resolution: FR-63-NFPA 70E-2024

Statement: Section 130.8 title is revised to be more generic to account for the diverse requirements of this section, some of which do not involve personnel or employee activities.

Public Input No. 66-NFPA 70E-2024 [Section No. 130.8(I)]

(I) Housekeeping Duties.

Employees shall not perform housekeeping duties inside the limited approach boundary where there is a possibility of contact with energized electrical conductors or circuit parts, unless adequate safeguards (such as insulating equipment or barriers) are provided to prevent contact. Electrically conductive cleaning materials (including conductive solids such as steel wool, metalized cloth, and ~~silicone~~ silicon carbide, as well as conductive liquid solutions) shall not be used inside the limited approach boundary unless procedures to prevent electrical contact are followed.

Statement of Problem and Substantiation for Public Input

This is a simple typo. There is no such thing as "silicone" carbide.

Submitter Information Verification

Submitter Full Name: Jesse Thomas
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City:
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Submittal Date: Wed Mar 20 14:21:47 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-64-NFPA 70E-2024
Statement: The word “silicone” was editorially corrected to “silicon”. The section was revised to comply with the NEC Style Manual.

Public Input No. 169-NFPA 70E-2024 [Section No. 130.8(K)]

(K) Anticipating Failure.

When there is evidence that electric equipment could fail and injure employees, the electric equipment shall be ~~de-energized~~ placed in an electrically safe work condition , unless the employer can demonstrate that de-energizing introduces additional hazards or increased risk or is infeasible because of equipment design or operational limitation. Until the equipment is ~~de-energized or~~ place in an electrically safe work condition or repaired, employees shall be protected from hazards associated with the impending failure of the equipment by suitable barricades and other alerting techniques necessary for safety of the employees.

Informational Note: See 130.8(O) for alerting techniques.

Statement of Problem and Substantiation for Public Input

This change aligns with the requirements of article 110.2 and the priority of NFPA 70E.

Submitter Information Verification

Submitter Full Name: Jeff Noren
Organization: NECA
Affiliation: NECA
Street Address:
City:
State:
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Submittal Date: Mon Jun 03 14:05:16 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: It is not always necessary to take all the steps necessary to establish an electrically safe work condition to avoid employee exposure to anticipated failure.

Public Input No. 276-NFPA 70E-2024 [New Section after 130.8(P)]

130.8(Q) Current Transformers. The secondary side of current transformers shall not be open circuited while the transformer's primary side is energized. If the current transformer's primary side cannot be deenergized, then the secondary circuit shall be bridged or shorted to prevent the secondary terminals from experiencing a dangerous open-circuit condition before employees are permitted to perform work on any part of the current transformer.

Additional Proposed Changes

File Name	Description	Approved
70E_PC_22_Hold.pdf	70E_PC22	

Statement of Problem and Substantiation for Public Input

NOTE: This Public Input appeared as "Reject but Hold" in Public Comment No. 22 of the (A2023) Second Draft Report for NFPA 70E and per the Regs. At 4.4.8.3.1 and needs to be reconsidered by the TC for the next edition of the document.

Current Transformers (CTs) are very common devices in industrial plants and facilities and are used for countless of different applications, such as SCADA, metering, load controllers, protective relaying, etc. However
as useful as CTs are in today's electrical equipment, they pose a significant electric shock risk to employees if
the secondary side is open circuited while the primary side is still energized, especially if current is flowing.
CT safety is addressed by OSHA regulations for electric generation, transmission and distribution sectors via
29CFR 1910.269(w)(2) subpart R and 1926.967(b) subpart V however the parallel OSHA standards for electric
utilization equipment per 1910 subpart S and 1926 subpart K, does not contain any instructions for CT safety.
If the secondary side of a CT is open circuited by removing its burden while the primary is energized, very high
hazardous voltages will develop at the secondary terminals and leads which can quickly exceed the insulation
rating of the leads which poses an extremely dangerous electric shock risks to employees.
There are countless articles by reputable organizations and authors that validate this position. The following is
just one of them.
https://voltage-disturbance.com/power-engineering/open-circuit-current-transformer-characteristics/

Submitter Information Verification

Submitter Full Name:	NFPA Holds
Organization:	Technical Committee on Electrical Safety in the Workplace
Street Address:	
City:	
State:	

Zip:

Submittal Date: Thu Jun 06 21:39:46 EDT 2024

Committee: EEW-AAA

Committee Statement

Resolution: This is part of qualified person’s training and is not necessary to be included in the standard.

Public Comment No. 22-NFPA 70E-2022 [New Section after 130.8(P)]

130.8 (A) CURRENT TRANSFORMERS

130.8(Q) *Current Transformers.* The secondary side of current transformers shall not be open circuited while the transformer's primary side is energized. If the current transformer's primary side cannot be deenergized, then the secondary circuit shall be bridged or shorted to prevent the secondary terminals from experiencing a dangerous open-circuit condition before employees are permitted to perform work on any part of the current transformer.

Additional Proposed Changes

File Name	Description	Approved
New_Article_130.8_Q_Current_Transformers_03-28-2022.docx	New section 130.8(A) Current Transformers safety practices	

Statement of Problem and Substantiation for Public Comment

Current Transformers (CTs) are very common devices in industrial plants and facilities and are used for countless of different applications, such as SCADA, metering, load controllers, protective relaying, etc. However as useful as CTs are in today's electrical equipment, they pose a significant electric shock risk to employees if the secondary side is open circuited while the primary side is still energized, especially if current is flowing.
CT safety is addressed by OSHA regulations for electric generation, transmission and distribution sectors via 29CFR 1910.269(w)(2) subpart R and 1926.967(b) subpart V however the parallel OSHA standards for electric utilization equipment per 1910 subpart S and 1926 subpart K, does not contain any instructions for CT safety.
If the secondary side of a CT is open circuited by removing its burden while the primary is energized, very high hazardous voltages will develop at the secondary terminals and leads which can quickly exceed the insulation rating of the leads which poses an extremely dangerous electric shock risks to employees.
There are countless articles by reputable organizations and authors that validate this position. The following is just one of them.
https://voltage-disturbance.com/power-engineering/open-circuit-current-transformer-characteristics/

Related Item

• PI

Submitter Information Verification

Submitter Full Name: George Cole
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Zip:
Submittal Date: Mon Mar 28 20:01:19 EDT 2022
Committee: EEW-AAA

Committee Statement

Committee Action: Rejected but held

Resolution: The text proposed by this public comment does not meet 4.4.4.2 of the Regulations Governing Committee Projects which requires public comments to be related to material that has received public review either through the submission of Public Input, Committee Input or Correlating Input or through the First Revisions.

2024 NFPA 70E New Article 130.8(A) *"Current Transformers"*
George T. Cole

130.8(Q) *Current Transformers.* The secondary side of current transformers shall not be open circuited while the transformer's primary side is energized. If the current transformer's primary side cannot be deenergized, then the secondary circuit shall be bridged or shorted to prevent the secondary terminals from experiencing a dangerous open-circuit condition before employees are permitted to perform work on any part of the current transformer.

Public Input No. 29-NFPA 70E-2023 [Section No. 130.8(P)]

(P) Look-Alike Equipment.

Where work performed on equipment that is de-energized and placed in an electrically safe condition exists in a work area with other energized equipment that is similar in size, shape, and construction, one of the alerting methods in 130.8(O), ~~or~~ shall be employed to prevent the employee from entering look-alike equipment.

Statement of Problem and Substantiation for Public Input

The word "or" is deleted. It is neither necessary nor correct in the context of the sentence.

Submitter Information Verification

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Submittal Date: Sun Nov 05 11:34:35 EST 2023
Committee: EEW-AAA

Committee Statement

Resolution: FR-66-NFPA 70E-2024
Statement: The sentence structure was editorially corrected.

“One” alerting method was changed to “one or more” to allow more than one alerting method to be used.

Public Input No. 64-NFPA 70E-2024 [Section No. 130.8(P)]

(P) Look-Alike Equipment.

Where work performed on equipment that is de-energized and placed in an electrically safe condition exists in a work area with other energized equipment that is similar in size, shape, and construction, one of the alerting methods in 130.8(O)~~, or~~ shall be employed to prevent the employee from entering look-alike equipment.

Statement of Problem and Substantiation for Public Input

This recommendation is to editorially revise this requirement by removing the word "or" and the comma before the word "or" to make this requirement read correctly. The requirement does not read correctly as written in my opinion.

Submitter Information Verification

Submitter Full Name: Palmer Hickman
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Submittal Date: Thu Mar 14 16:27:51 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-66-NFPA 70E-2024
Statement: The sentence structure was editorially corrected.

“One” alerting method was changed to “one or more” to allow more than one alerting method to be used.

Public Input No. 170-NFPA 70E-2024 [Section No. 130.12]

130.12 Cutting, Removing, or Rerouting of Electrical Conductors and Circuit Parts.

Where electrical conductors and circuit parts are de-energized in order to cut, remove, reroute, or otherwise work on them and the conductor terminations or circuit parts are not within sight from the point of work, such as where the electrical conductors or circuit parts are remote from the source of supply in a junction or pull box, additional ~~steps to~~ risk reduction methods to verify absence of voltage or identify the electrical conductors and circuit parts shall be taken prior to cutting, removing, rerouting, or otherwise work on the conductors and circuit parts.

Informational Note No. 1: ~~Additional steps to be~~ Examples of a dditional risk reduction methods that may be taken where conductors are de-energized in order to cut, remove, or reroute them include, but are not limited to~~, remotely~~ :

(1) Marking or flagging of conductors, conductors are verified by two qualified employees remotely spiking the conductors~~, pulling conductors~~

(2) Pulling conductors that have been disconnected form energized parts to visually verify movement~~, remotely cutting the conductors, or other~~

(3) Remotely cutting the conductor

(4) Other approved methods.

Nonshielded conductors could be additionally verified with a noncontact test instrument, and shielded conductors could be verified with devices that identify the conductors.

Informational Note No. 2: De-energizing is only one of several steps in lockout/tagout procedures and in establishing an electrically safe work condition.

Statement of Problem and Substantiation for Public Input

Changing “additional steps” to “risk reduction methods” implies that the job safety planning addresses the hazards associated with cutting, removing, rerouting electrical conductors, and that any additional steps included would be for the protection of the employees from the hazards involved and must not increase the hazard to the employee.

Marking or flagging of conductors, and conductors verified by two qualified employees, are two suggestions for visual management and reducing human error.

Pulling disconnected conductors is safer than pulling conductors attached to their energy source, ensuring that this risk reduction method starts at the energy source and not downstream where conductors are out of sight from the point of work.

Submitter Information Verification

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Submittal Date: Mon Jun 03 14:09:34 EDT 2024

Committee: EEW-AAA

Committee Statement

Resolution: FR-67-NFPA 70E-2024=

Statement: Verify was changed to "to 'test for"' in two places to be consistent with 120.6(7)

Item (4) was deleted as it does not provide clarity.

Editorial changes were made throughout the text to improve clarity and to comply with the NEC Style Manual.

Public Input No. 259-NFPA 70E-2024 [Chapter 2]

Chapter 2 Safety-Related Maintenance Requirements

Article 200 Introduction

200.1 Scope.

Chapter 2 addresses the requirements that follow.

(1) Chapter 2 covers practical safety-related maintenance requirements for electrical equipment and installations in workplaces as included in 90.3(A) . These requirements identify only that maintenance directly associated with employee safety.

(2) Chapter 2 does not prescribe specific maintenance methods or testing procedures. It is left to the employer to choose from the various maintenance methods available to satisfy the requirements of Chapter 2 .

(3) For the purpose of Chapter 2 , maintenance shall be defined as preserving or restoring the condition of electrical equipment and installations, or parts of either, for the safety of employees who work where exposed to electrical hazards. Repair or replacement of individual portions or parts of equipment shall be permitted without requiring modification or replacement of other portions or parts that are in a safe condition.

Informational Note: See NFPA 70B, *Recommended Practice for Electrical Equipment Maintenance* ; ANSI/NETA MTS, *Standard for Maintenance Testing Specifications for Electrical Power Distribution Equipment and Systems* ; and IEEE 3007.2, *Recommended Practice for the Maintenance of Industrial and Commercial Power Systems* , for guidance on maintenance frequency, methods, and tests.

Article 205 General

205.1 Scope.

This article covers general maintenance requirements for electrical equipment.

205.2 Qualified Persons.

Employees who perform maintenance on electrical equipment and installations shall be qualified persons as required in Chapter 1 and shall be trained in, and familiar with, the specific maintenance procedures and tests required.

205.3 Single-Line Diagram.

A single-line diagram, where provided for the electrical system, shall be maintained in a legible condition and shall be kept current.

205.4 General Maintenance Requirements.

Electrical equipment shall be maintained in accordance with manufacturers' instructions or industry consensus standards to reduce the risk associated with failure. The equipment owner or the owner's designated representative shall be responsible for maintenance of the electrical equipment and documentation.

Informational Note No. 1: Common industry practice is to apply test or calibration decals to equipment to indicate the test or calibration date and overall condition of equipment that has been tested and maintained in the field. These decals provide the employee immediate indication of last maintenance date and if the tested device or system was found acceptable on the date of test. This local information can assist the employee in the assessment of overall electrical equipment maintenance status.

Informational Note No. 2: Noncontact diagnostic methods in addition to scheduled maintenance activities of electrical equipment can assist in the identification of electrical anomalies.

205.5 Overcurrent Protective Devices.

Overcurrent protective devices shall be maintained in accordance with the manufacturers' instructions or industry consensus standards. Maintenance, tests, and inspections shall be documented.

205.6 Spaces About Electrical Equipment.

All working space and clearances required by electrical codes and standards shall be maintained.

Informational Note: See Article 110, Parts II and III, of *NFPA 70* , *National Electrical Code* , for further information concerning spaces about electrical equipment.

205.7 Grounding and Bonding.

Equipment, raceway, cable tray, and enclosure bonding and grounding shall be maintained to ensure electrical continuity.

205.8 Guarding of Energized Conductors and Circuit Parts.

Enclosures shall be maintained to guard against unintentional contact with exposed energized conductors and circuit parts and other electrical hazards. Covers and doors shall be in place with all associated fasteners and latches secured.

205.9 Safety Equipment.

Locks, interlocks, and other safety equipment shall be maintained in proper working condition to accomplish the control purpose.

205.10 Clear Spaces.

Access to working space and escape passages shall be kept clear and unobstructed.

205.11 Identification of Components.

Identification of components, where required, and safety-related instructions (operating or maintenance), if posted, shall be securely attached and maintained in legible condition.

205.12 Warning Signs.

Warning signs, where required, shall be visible, securely attached, and maintained in legible condition.

205.13 Identification of Circuits.

Circuit or voltage identification shall be securely affixed and maintained in updated and legible condition.

205.14 Single and Multiple Conductors and Cables.

Electrical cables and single and multiple conductors shall be maintained free of damage, shorts, and ground that would expose employees to an electrical hazard.

205.15 Flexible Cords and Cables.

Flexible cords and cables shall be maintained to preserve insulation integrity.

(1) Damaged Cords and Cables.

Cords and cables shall not have worn, frayed, or damaged areas that would expose employees to an electrical hazard.

(2) Strain Relief.

Strain relief of cords and cables shall be maintained to prevent pull from being transmitted directly to joints or terminals.

(3) Repair and Replacement.

Cords and cord caps for portable electrical equipment shall be repaired and replaced by qualified personnel and checked for proper polarity, grounding, and continuity prior to returning to service.

205.16 Overhead Line Clearances.

For overhead electric lines under the employer's control, grade elevation shall be maintained to preserve no less than the minimum designed vertical and horizontal clearances necessary to minimize risk of unintentional contact.

Article 210 Substations, Switchgear Assemblies, Switchboards, Panelboards, Motor Control Centers, and Disconnect Switches

210.1 Scope.

This article covers maintenance requirements for substations, switchgear assemblies, switchboards, panelboards, motor control centers, and disconnect switches.

210.2 Enclosures.

Enclosures shall be kept free of material that would expose employees to an electrical hazard.

210.3 Area Enclosures.

Fences, physical protection, enclosures, or other protective means, where required to guard against unauthorized access or unintentional contact with exposed energized conductors and circuit parts, shall be maintained.

210.4 Conductors.

Current-carrying conductors (buses, switches, disconnects, joints, and terminations) and bracing shall be maintained to perform as follows:

(1) Conduct rated current without overheating

(2) Withstand available fault current

210.5 Insulation Integrity.

Insulation integrity shall be maintained to support the voltage impressed.

210.6 Protective Devices.

Protective devices shall be maintained to adequately withstand or interrupt available fault current.

> Informational Note: Improper or inadequate maintenance can result in increased opening time of the overcurrent protective device, thus increasing the incident energy.

Article 215 Premises Wiring

215.1 Scope.

This article covers maintenance requirements for premises wiring.

215.2 Covers for Wiring System Components.

Covers for wiring system components shall be in place with all associated hardware, and there shall be no unprotected openings.

215.3 Open Wiring Protection.

Open wiring protection, such as location or barriers, shall be maintained to prevent unintentional contact.

215.4 Raceways and Cable Trays.

Raceways and cable trays shall be maintained to provide physical protection and support for conductors.

Article 220 Controller Equipment

220.1 Scope.

This article covers maintenance requirements for controllers, which includes electrical equipment that governs the starting, stopping, direction of motion, acceleration, speed, and protection of rotating equipment and other power utilization apparatus in the workplace.

220.2 Protection and Control Circuitry.

Protection and control circuitry used to guard against unintentional contact with exposed energized conductors and circuit parts and to prevent other electrical or mechanical hazards shall be maintained.

Article 225 Fuses and Circuit Breakers

225.1 Scope.

This article covers maintenance requirements for fuses and circuit breakers.

225.2 Fuses.

Fuses shall be maintained free of breaks or cracks in fuse cases, ferrules, and insulators. Fuse clips shall be maintained to provide adequate contact with fuses. Fuseholders for current-limiting fuses shall not be modified to allow the insertion of fuses that are not current-limiting. Non-current limiting fuses shall not be modified to allow their insertion into current-limiting fuseholders.

225.3 Molded-Case Circuit Breakers.

Molded-case circuit breakers shall be maintained free of cracks in cases and cracked or broken operating handles.

225.4 Circuit Breaker Testing After Electrical Faults.

Circuit breakers that interrupt faults approaching their interrupting ratings shall be inspected and tested in accordance with the manufacturer's instructions.

Article 230 Rotating Equipment

230.1 Scope.

This article covers maintenance requirements for rotating equipment.

230.2 Terminal Boxes.

Terminal chambers, enclosures, and terminal boxes shall be maintained to guard against unintentional contact with exposed energized conductors and circuit parts and other electrical hazards.

230.3 Guards, Barriers, and Access Plates.

Guards, barriers, and access plates shall be maintained to prevent employees from contacting moving or energized parts.

Article 235 Hazardous (Classified) Locations

235.1 Scope.

This article covers maintenance requirements in those areas identified as hazardous (classified) locations.

Informational Note No. 1: These locations need special types of equipment and installation to ensure safe performance under conditions of proper use and maintenance. It is important that inspection authorities and users exercise more than ordinary care with regard to installation and maintenance. The maintenance for specific equipment and materials is covered elsewhere in Chapter 2 and is applicable to hazardous (classified) locations. Other maintenance will ensure that the form of construction and of installation that makes the equipment and materials suitable for the particular location are not compromised.

Informational Note No. 2: The maintenance needed for specific hazardous (classified) locations depends on the classification of the specific location. The design principles and equipment characteristics — for example, use of positive pressure ventilation, explosionproof, nonincendive, intrinsically safe, and purged and pressurized equipment — that were applied in the installation to meet the requirements of the area classification must also be known. With this information, the employer and the inspection authority are able to determine whether the installation as maintained has retained the condition necessary for a safe workplace.

235.2 Maintenance Requirements for Hazardous (Classified) Locations.

Equipment and installations in these locations shall be maintained such that the following criteria are met:

(1) No energized parts are exposed.

Exception to (1): Intrinsically safe and nonincendive circuits shall be permitted to be exposed.

(2) There are no breaks in conduit systems, fittings, or enclosures from damage, corrosion, or other causes.

(3) All bonding jumpers are securely fastened and intact.

(4) All fittings, boxes, and enclosures with bolted covers have all bolts installed and bolted tight.

(5) All threaded conduit are wrenchtight and enclosure covers are tightened in accordance with the manufacturer's instructions.

(6) There are no open entries into fittings, boxes, or enclosures that would compromise the protection characteristics.

(7) All close-up plugs, breathers, seals, and drains are securely in place.

(8) Marking of luminaires (lighting fixtures) for maximum lamp wattage and temperature rating is legible and not exceeded.

(9) Required markings are secure and legible.

Article 240 Batteries and Battery Rooms

240.1 Scope.

This article covers maintenance requirements for batteries and battery rooms.

240.2 Ventilation.

When forced or natural ventilation systems are required by the battery system design and are present, they shall be examined and maintained to prevent buildup of explosive mixtures. This maintenance shall include a functional test of any associated detection and alarm systems.

Informational Note: "Natural ventilation" implies there are no mechanical mechanisms. Maintenance includes activities such as inspection and removal of any obstructions to natural air flow.

240.3 Eye and Body Wash Apparatus.

Eye and body wash apparatus shall be maintained in operable condition.

Article 245 Portable Electric Tools and Equipment

245.1 Scope.

This article covers maintenance requirements for portable electrical tools and equipment.

245.2 Maintenance Requirements for Portable Electric Tools and Equipment.

Attachment plugs, receptacles, cover plates, and cord connectors shall be maintained such that the following criteria are met:

(1) There are no breaks, damage, or cracks exposing energized conductors and circuit parts.

(2) There are no missing cover plates.

(3) Terminations have no stray strands or loose terminals.

(4) There are no missing, loose, altered, or damaged blades, pins, or contacts.

(5) Polarity is correct.

Article 250 Personal Safety and Protective Equipment

250.1 Scope.

This article covers maintenance requirements for personal safety and protective equipment.

250.2 Maintenance Requirements for Personal Safety and Protective Equipment.

Personal safety and protective equipment such as the following shall be maintained in a safe working condition:

(1) Grounding equipment

(2) Hot sticks (live line tools)

(3) Rubber gloves, sleeves, and protectors

(4) Test instruments

(5) Blanket and similar insulating equipment

(6) Insulating mats and similar insulating equipment

(7) Protective barriers

(8) External circuit breaker rack-out devices

(9) Portable lighting units

(10) Temporary protective grounding equipment

(11) Dielectric footwear

(12) Protective clothing

(13) Bypass jumpers

(14) Insulated and insulating hand tools

~~**250.3** Inspection and Testing of Protective Equipment and Protective Tools.~~

~~**(A)** Visual.~~

~~Safety and protective equipment and protective tools shall be visually inspected for damage and defects before initial use and at intervals thereafter, as service conditions require, but in no case shall the interval exceed 1 year, unless specified otherwise by the applicable state, federal, or local codes and standards.~~

~~**(B)** Testing.~~

~~The insulation of protective equipment and protective tools, such as items specified in 250.2(1) through 250.2(14) , that is used as primary protection from electric shock hazards and requires an insulation system to ensure protection of personnel, shall be verified by the appropriate test and visual inspection to ascertain that insulating capability has been retained before initial use, and at intervals thereafter, as service conditions and applicable standards and instructions require, but in no case shall the interval exceed 3 years.~~

~~**250.4** Grounding Equipment.~~

~~**(A)** Inspection.~~

~~Personal protective ground cable sets shall be inspected for cuts in the protective sheath and damage to the conductors. Clamps and connector strain relief devices shall be checked for tightness. These inspections shall be made at intervals thereafter as service conditions require, but in no case shall the interval exceed 1 year.~~

~~**(B)** Testing.~~

~~Prior to being returned to service, temporary protective grounding equipment that has been repaired or modified shall be tested. Temporary protective grounding equipment shall be tested as service conditions require.~~

> ~~Informational Note: See ASTM F2249, *Standard Specification for In-Service Test Methods for Temporary Grounding Jumper Assemblies Used on De-energized Electric Power Lines and Equipment* , for guidance for inspecting and testing temporary protective grounding equipment.~~

~~**(C)** Grounding and Testing Devices.~~

~~Grounding and testing devices shall be stored in a clean and dry area. Grounding and testing devices shall be properly inspected and tested before each use.~~

> ~~Informational Note: See IEEE C37.20.6, *Standard for 4.76 kV to 38 kV Rated Ground and Test Devices Used in Enclosures,* Section 9.5 for guidance on testing of grounding and testing devices.~~

~~**250.5** Test Instruments.~~

~~Test instruments and associated test leads used to verify the absence or presence of voltage shall be maintained to assure functional integrity. The maintenance program shall include functional verification as described in 110.6(E) .~~

Statement of Problem and Substantiation for Public Input

With the elevation of NFPA 70B to a Standard, there no longer is a need to have electrical safety related maintenance requirements in 70E. This proposed action is similar that when the 70E committee deleted safety related installation requirements primarily because they were already in the NEC. Electrical safety maintenance requirements are in the 70B standard and because of differing revision cycles, the wording in will almost certainly never be the same in both 70B and 70E, Chapter 2. Chapter 2 served a purpose but is no longer needed in 70E. Electrical safety maintenance requirements are critical to an overall electrical safety program, and they now are available in the new 70B standard.

Submitter Information Verification

Submitter Full Name: David Pace

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Submittal Date: Tue Jun 04 16:42:56 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: NFPA 70B became a standard in 2023 and requires more time to mature as a standard before considering the deletion of the safety-related maintenance requirements in NFPA 70E.

Public Input No. 143-NFPA 70E-2024 [Section No. 205.1]

205.1 Scope.

This article covers general safety-related maintenance requirements for electrical equipment.

Statement of Problem and Substantiation for Public Input

During the last revision cycle of NFPA 70E, the phrase "safety-related" was removed from each of the Scope statements in Chapter 2. In my opinion, this change was an oversimplification for each of the scope statements and "safety-related" should be reinserted for clarity and useability. While the title of Chapter2 is "Safety-Related Maintenance Requirements", this does not mean "safety-related" should be deleted from each scope statement. Using the same argument would also suggest deletion of the phrase" maintenance requirements" as well since it's in the title of the chapter. The scope statements for each Article within Chapter 2 should reinforce that the maintenance requirements identified are safety-related. This becomes even more important given the recent escalation of NFPA 70B to a Standard.

Submitter Information Verification

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Submittal Date: Mon Jun 03 11:30:08 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-22-NFPA 70E-2024

Statement: Adding the term “safety-related” to the scope statement for each article within Chapter 2 helps usability and reinforces that the specific maintenance requirements identified are safety-related.

Public Input No. 132-NFPA 70E-2024 [Sections 205.2, 205.3, 205.4, 205.5]

Sections 205.2, 205.3, 205.4, 205.5

~~**205.2** Qualified Persons.~~

~~Employees who perform maintenance on electrical equipment and installations shall be qualified persons as required in Chapter 1 and shall be trained in, and familiar with, the specific maintenance procedures and tests required.~~

~~**205.3** Single-Line Diagram.~~

~~A single-line diagram, where provided for the electrical system, shall be maintained in a legible condition and shall be kept current.~~

~~**205.4** General Maintenance Requirements.~~

~~Electrical equipment shall be maintained in accordance with manufacturers' instructions or industry consensus standards to reduce the risk associated with failure. The equipment owner or the owner's designated representative shall be responsible for maintenance of the electrical equipment and documentation.~~

~~Informational Note No. 1: Common industry practice is to apply test or calibration decals to equipment to indicate the test or calibration date and overall condition of equipment that has been tested and maintained in the field. These decals provide the employee immediate indication of last maintenance date and if the tested device or system was found acceptable on the date of test. This local information can assist the employee in the assessment of overall electrical equipment maintenance status.~~

~~Informational Note No. 2: Noncontact diagnostic methods in addition to scheduled maintenance activities of electrical equipment can assist in the identification of electrical anomalies.~~

~~**205.5** Overcurrent Protective Devices.~~

~~Overcurrent protective devices shall be maintained in accordance with the manufacturers' instructions or industry consensus standards. Maintenance, tests, and inspections shall be documented.~~

Statement of Problem and Substantiation for Public Input

These items are covered in NFPA 70B Standard for Electrical Equipment Maintenance and do not need to be duplicated in 70E.

Submitter Information Verification

Submitter Full Name: Karl Cunningham
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Submittal Date: Mon Jun 03 01:29:42 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: NFPA 70B became a standard in 2023 and requires more time to mature as a standard before considering the deletion of the safety-related maintenance requirements in NFPA 70E.

Public Input No. 133-NFPA 70E-2024 [Section No. 205.7]

~~**205.7** Grounding and Bonding.~~

~~Equipment, raceway, cable tray, and enclosure bonding and grounding shall be maintained to ensure electrical continuity.~~

Statement of Problem and Substantiation for Public Input

This item is covered in NFPA 70B Standard for Electrical Equipment Maintenance and does not need to be duplicated in 70E.

Submitter Information Verification

Submitter Full Name: Karl Cunningham
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Submittal Date: Mon Jun 03 01:33:03 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: NFPA 70B became a standard in 2023 and requires more time to mature as a standard before considering the deletion of the safety-related maintenance requirements in NFPA 70E.

Public Input No. 146-NFPA 70E-2024 [Section No. 210.1]

210.1 Scope.

This article covers safety-related maintenance requirements for substations, switchgear assemblies, switchboards, panelboards, motor control centers, and disconnect switches.

Statement of Problem and Substantiation for Public Input

During the last revision cycle of NFPA 70E, the phrase "safety-related" was removed from each of the Scope statements in Chapter 2. In my opinion, this change was an oversimplification for each of the scope statements and "safety-related" should be reinserted for clarity and useability. While the title of Chapter2 is "Safety-Related Maintenance Requirements", this does not mean "safety-related" should be deleted from each scope statement. Using the same argument would also suggest deletion of the phrase" maintenance requirements" as well since it's in the title of the chapter. The scope statements for each Article within Chapter 2 should reinforce that the maintenance requirements identified are safety-related. This becomes even more important given the recent escalation of NFPA 70B to a Standard.

Submitter Information Verification

Submitter Full Name: Louis Barrios
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Submittal Date: Mon Jun 03 11:43:57 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-22-NFPA 70E-2024
Statement: Adding the term “safety-related” to the scope statement for each article within Chapter 2 helps usability and reinforces that the specific maintenance requirements identified are safety-related.

Public Input No. 134-NFPA 70E-2024 [Section No. 210.2]

~~**210.2** Enclosures.~~

~~Enclosures shall be kept free of material that would expose employees to an electrical hazard.~~

Statement of Problem and Substantiation for Public Input

These items are covered in NFPA 70B Standard for Electrical Equipment Maintenance and do not need to be duplicated in 70E.

Submitter Information Verification

Submitter Full Name: Karl Cunningham
Organization: Self Employed
Street Address:
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Submittal Date: Mon Jun 03 01:41:07 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: NFPA 70B became a standard in 2023 and requires more time to mature as a standard before considering the deletion of the safety-related maintenance requirements in NFPA 70E.

Public Input No. 135-NFPA 70E-2024 [Section No. 210.4]

~~**210.4** Conductors.~~

~~Current-carrying conductors (buses, switches, disconnects, joints, and terminations) and bracing shall be maintained to perform as follows:~~

(1) ~~Conduct rated current without overheating~~

(2) ~~Withstand available fault current~~

Statement of Problem and Substantiation for Public Input

These items are covered in NFPA 70B Standard for Electrical Equipment Maintenance and do not need to be duplicated in 70E.

Submitter Information Verification

Submitter Full Name: Karl Cunningham
Organization: Self Employed
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Submittal Date: Mon Jun 03 01:42:14 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: NFPA 70B became a standard in 2023 and requires more time to mature as a standard before considering the deletion of the safety-related maintenance requirements in NFPA 70E.

Public Input No. 147-NFPA 70E-2024 [Section No. 215.1]

215.1 Scope.

This article covers safety-related maintenance requirements for premises wiring.

Statement of Problem and Substantiation for Public Input

During the last revision cycle of NFPA 70E, the phrase "safety-related" was removed from each of the Scope statements in Chapter 2. In my opinion, this change was an oversimplification for each of the scope statements and "safety-related" should be reinserted for clarity and useability. While the title of Chapter2 is "Safety-Related Maintenance Requirements", this does not mean "safety-related" should be deleted from each scope statement. Using the same argument would also suggest deletion of the phrase" maintenance requirements" as well since it's in the title of the chapter. The scope statements for each Article within Chapter 2 should reinforce that the maintenance requirements identified are safety-related. This becomes even more important given the recent escalation of NFPA 70B to a Standard.

Submitter Information Verification

Submitter Full Name: Louis Barrios
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Submittal Date: Mon Jun 03 11:45:48 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-22-NFPA 70E-2024

Statement: Adding the term “safety-related” to the scope statement for each article within Chapter 2 helps usability and reinforces that the specific maintenance requirements identified are safety-related.

Public Input No. 148-NFPA 70E-2024 [Section No. 220.1]

220.1 Scope.

This article covers safety-related maintenance requirements for controllers, which includes electrical equipment that governs the starting, stopping, direction of motion, acceleration, speed, and protection of rotating equipment and other power utilization apparatus in the workplace.

Statement of Problem and Substantiation for Public Input

During the last revision cycle of NFPA 70E, the phrase "safety-related" was removed from each of the Scope statements in Chapter 2. In my opinion, this change was an oversimplification for each of the scope statements and "safety-related" should be reinserted for clarity and useability. While the title of Chapter2 is "Safety-Related Maintenance Requirements", this does not mean "safety-related" should be deleted from each scope statement. Using the same argument would also suggest deletion of the phrase" maintenance requirements" as well since it's in the title of the chapter. The scope statements for each Article within Chapter 2 should reinforce that the maintenance requirements identified are safety-related. This becomes even more important given the recent escalation of NFPA 70B to a Standard.

Submitter Information Verification

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Submittal Date: Mon Jun 03 11:46:59 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-22-NFPA 70E-2024
Statement: Adding the term “safety-related” to the scope statement for each article within Chapter 2 helps usability and reinforces that the specific maintenance requirements identified are safety-related.

Public Input No. 149-NFPA 70E-2024 [Section No. 225.1]

225.1 Scope.

This article covers safety-related maintenance requirements for fuses and circuit breakers.

Statement of Problem and Substantiation for Public Input

During the last revision cycle of NFPA 70E, the phrase "safety-related" was removed from each of the Scope statements in Chapter 2. In my opinion, this change was an oversimplification for each of the scope statements and "safety-related" should be reinserted for clarity and useability. While the title of Chapter2 is "Safety-Related Maintenance Requirements", this does not mean "safety-related" should be deleted from each scope statement. Using the same argument would also suggest deletion of the phrase" maintenance requirements" as well since it's in the title of the chapter. The scope statements for each Article within Chapter 2 should reinforce that the maintenance requirements identified are safety-related. This becomes even more important given the recent escalation of NFPA 70B to a Standard.

Submitter Information Verification

Submitter Full Name: Louis Barrios
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Submittal Date: Mon Jun 03 11:48:24 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-22-NFPA 70E-2024

Statement: Adding the term “safety-related” to the scope statement for each article within Chapter 2 helps usability and reinforces that the specific maintenance requirements identified are safety-related.

Public Input No. 136-NFPA 70E-2024 [Sections 225.2, 225.3]

~~**Sections 225.2, 225.3**~~

~~**225.2** Fuses.~~

~~Fuses shall be maintained free of breaks or cracks in fuse cases, ferrules, and insulators. Fuse clips shall be maintained to provide adequate contact with fuses. Fuseholders for current-limiting fuses shall not be modified to allow the insertion of fuses that are not current-limiting. Non-current limiting fuses shall not be modified to allow their insertion into current-limiting fuseholders.~~

~~**225.3** Molded-Case Circuit Breakers.~~

~~Molded-case circuit breakers shall be maintained free of cracks in cases and cracked or broken operating handles.~~

Statement of Problem and Substantiation for Public Input

These items are covered in NFPA 70B Standard for Electrical Equipment Maintenance and do not need to be duplicated in 70E.

Submitter Information Verification

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Submittal Date: Mon Jun 03 01:44:36 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: NFPA 70B became a standard in 2023 and requires more time to mature as a standard before considering the deletion of the safety-related maintenance requirements in NFPA 70E.

Public Input No. 150-NFPA 70E-2024 [Section No. 230.1]

230.1 Scope.

This article covers safety-related maintenance requirements for rotating equipment.

Statement of Problem and Substantiation for Public Input

During the last revision cycle of NFPA 70E, the phrase "safety-related" was removed from each of the Scope statements in Chapter 2. In my opinion, this change was an oversimplification for each of the scope statements and "safety-related" should be reinserted for clarity and useability. While the title of Chapter2 is "Safety-Related Maintenance Requirements", this does not mean "safety-related" should be deleted from each scope statement. Using the same argument would also suggest deletion of the phrase" maintenance requirements" as well since it's in the title of the chapter. The scope statements for each Article within Chapter 2 should reinforce that the maintenance requirements identified are safety-related. This becomes even more important given the recent escalation of NFPA 70B to a Standard.

Submitter Information Verification

Submitter Full Name: Louis Barrios
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Submittal Date: Mon Jun 03 11:49:56 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-22-NFPA 70E-2024

Statement: Adding the term “safety-related” to the scope statement for each article within Chapter 2 helps usability and reinforces that the specific maintenance requirements identified are safety-related.

Public Input No. 137-NFPA 70E-2024 [Article 235]

~~**Article 235** Hazardous (Classified) Locations~~

~~**235.1** Scope.~~

~~This article covers maintenance requirements in those areas identified as hazardous (classified) locations.~~

~~Informational Note No. 1: These locations need special types of equipment and installation to ensure safe performance under conditions of proper use and maintenance. It is important that inspection authorities and users exercise more than ordinary care with regard to installation and maintenance. The maintenance for specific equipment and materials is covered elsewhere in Chapter 2 and is applicable to hazardous (classified) locations. Other maintenance will ensure that the form of construction and of installation that makes the equipment and materials suitable for the particular location are not compromised.~~

~~Informational Note No. 2: The maintenance needed for specific hazardous (classified) locations depends on the classification of the specific location. The design principles and equipment characteristics — for example, use of positive pressure ventilation, explosionproof, nonincendive, intrinsically safe, and purged and pressurized equipment — that were applied in the installation to meet the requirements of the area classification must also be known. With this information, the employer and the inspection authority are able to determine whether the installation as maintained has retained the condition necessary for a safe workplace.~~

~~**235.2** Maintenance Requirements for Hazardous (Classified) Locations.~~

~~Equipment and installations in these locations shall be maintained such that the following criteria are met:~~

(1) ~~No energized parts are exposed.~~

~~*Exception to (1): Intrinsically safe and nonincendive circuits shall be permitted to be exposed.*~~

(2) ~~There are no breaks in conduit systems, fittings, or enclosures from damage, corrosion, or other causes.~~

(3) ~~All bonding jumpers are securely fastened and intact.~~

(4) ~~All fittings, boxes, and enclosures with bolted covers have all bolts installed and bolted tight.~~

(5) ~~All threaded conduit are wrenchtight and enclosure covers are tightened in accordance with the manufacturer's instructions.~~

(6) ~~There are no open entries into fittings, boxes, or enclosures that would compromise the protection characteristics.~~

(7) ~~All close-up plugs, breathers, seals, and drains are securely in place.~~

(8) ~~Marking of luminaires (lighting fixtures) for maximum lamp wattage and temperature rating is legible and not exceeded.~~

(9) ~~Required markings are secure and legible.~~

Statement of Problem and Substantiation for Public Input

These items are covered in NFPA 70B Standard for Electrical Equipment Maintenance and do not need to be duplicated in 70E.

Submitter Information Verification

Submitter Full Name: Karl Cunningham
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Submittal Date: Mon Jun 03 01:52:35 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: NFPA 70B became a standard in 2023 and requires more time to mature as a standard before considering the deletion of the safety-related maintenance requirements in NFPA 70E.

Public Input No. 151-NFPA 70E-2024 [Section No. 235.1]

235.1 Scope.

This article covers safety-related maintenance requirements in those areas identified as hazardous (classified) locations.

Informational Note No. 1: These locations need special types of equipment and installation to ensure safe performance under conditions of proper use and maintenance. It is important that inspection authorities and users exercise more than ordinary care with regard to installation and maintenance. The maintenance for specific equipment and materials is covered elsewhere in Chapter 2 and is applicable to hazardous (classified) locations. Other maintenance will ensure that the form of construction and of installation that makes the equipment and materials suitable for the particular location are not compromised.

Informational Note No. 2: The maintenance needed for specific hazardous (classified) locations depends on the classification of the specific location. The design principles and equipment characteristics — for example, use of positive pressure ventilation, explosionproof, nonincendive, intrinsically safe, and purged and pressurized equipment — that were applied in the installation to meet the requirements of the area classification must also be known. With this information, the employer and the inspection authority are able to determine whether the installation as maintained has retained the condition necessary for a safe workplace.

Statement of Problem and Substantiation for Public Input

During the last revision cycle of NFPA 70E, the phrase "safety-related" was removed from each of the Scope statements in Chapter 2. In my opinion, this change was an oversimplification for each of the scope statements and "safety-related" should be reinserted for clarity and useability. While the title of Chapter2 is "Safety-Related Maintenance Requirements", this does not mean "safety-related" should be deleted from each scope statement. Using the same argument would also suggest deletion of the phrase" maintenance requirements" as well since it's in the title of the chapter. The scope statements for each Article within Chapter 2 should reinforce that the maintenance requirements identified are safety-related. This becomes even more important given the recent escalation of NFPA 70B to a Standard.

Submitter Information Verification

Submitter Full Name: Louis Barrios
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Submittal Date: Mon Jun 03 11:52:06 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-22-NFPA 70E-2024

Statement: Adding the term “safety-related” to the scope statement for each article within Chapter 2 helps usability and reinforces that the specific maintenance requirements identified are safety-related.

Public Input No. 152-NFPA 70E-2024 [Section No. 240.1]

240.1 Scope.

This article covers safety-related maintenance requirements for batteries and battery rooms.

Statement of Problem and Substantiation for Public Input

During the last revision cycle of NFPA 70E, the phrase "safety-related" was removed from each of the Scope statements in Chapter 2. In my opinion, this change was an oversimplification for each of the scope statements and "safety-related" should be reinserted for clarity and useability. While the title of Chapter2 is "Safety-Related Maintenance Requirements", this does not mean "safety-related" should be deleted from each scope statement. Using the same argument would also suggest deletion of the phrase" maintenance requirements" as well since it's in the title of the chapter. The scope statements for each Article within Chapter 2 should reinforce that the maintenance requirements identified are safety-related. This becomes even more important given the recent escalation of NFPA 70B to a Standard.

Submitter Information Verification

Submitter Full Name: Louis Barrios
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Street Address:
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Submittal Date: Mon Jun 03 11:53:29 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-22-NFPA 70E-2024

Statement: Adding the term “safety-related” to the scope statement for each article within Chapter 2 helps usability and reinforces that the specific maintenance requirements identified are safety-related.

Public Input No. 138-NFPA 70E-2024 [Article 245]

~~**Article 245** Portable Electric Tools and Equipment~~

~~**245.1** Scope.~~

~~This article covers maintenance requirements for portable electrical tools and equipment.~~

~~**245.2** Maintenance Requirements for Portable Electric Tools and Equipment.~~

~~Attachment plugs, receptacles, cover plates, and cord connectors shall be maintained such that the following criteria are met:~~

(1) ~~There are no breaks, damage, or cracks exposing energized conductors and circuit parts.~~

(2) ~~There are no missing cover plates.~~

(3) ~~Terminations have no stray strands or loose terminals.~~

(4) ~~There are no missing, loose, altered, or damaged blades, pins, or contacts.~~

(5) ~~Polarity is correct.~~

Statement of Problem and Substantiation for Public Input

These items are covered in NFPA 70B Standard for Electrical Equipment Maintenance and do not need to be duplicated in 70E.

Submitter Information Verification

Submitter Full Name: Karl Cunningham
Organization: Self Employed
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Submittal Date: Mon Jun 03 01:56:00 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: NFPA 70B became a standard in 2023 and requires more time to mature as a standard before considering the deletion of the safety-related maintenance requirements in NFPA 70E.

Public Input No. 153-NFPA 70E-2024 [Section No. 245.1]

245.1 Scope.

This article covers safety-related maintenance requirements for portable electrical tools and equipment.

Statement of Problem and Substantiation for Public Input

During the last revision cycle of NFPA 70E, the phrase "safety-related" was removed from each of the Scope statements in Chapter 2. In my opinion, this change was an oversimplification for each of the scope statements and "safety-related" should be reinserted for clarity and useability. While the title of Chapter2 is "Safety-Related Maintenance Requirements", this does not mean "safety-related" should be deleted from each scope statement. Using the same argument would also suggest deletion of the phrase" maintenance requirements" as well since it's in the title of the chapter. The scope statements for each Article within Chapter 2 should reinforce that the maintenance requirements identified are safety-related. This becomes even more important given the recent escalation of NFPA 70B to a Standard.

Submitter Information Verification

Submitter Full Name: Louis Barrios
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Street Address:
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Submittal Date: Mon Jun 03 11:55:06 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-22-NFPA 70E-2024
Statement: Adding the term “safety-related” to the scope statement for each article within Chapter 2 helps usability and reinforces that the specific maintenance requirements identified are safety-related.

Public Input No. 154-NFPA 70E-2024 [Section No. 250.1]

250.1 Scope.

This article covers safety-related maintenance requirements for personal safety and protective equipment.

Statement of Problem and Substantiation for Public Input

During the last revision cycle of NFPA 70E, the phrase "safety-related" was removed from each of the Scope statements in Chapter 2. In my opinion, this change was an oversimplification for each of the scope statements and "safety-related" should be reinserted for clarity and useability. While the title of Chapter2 is "Safety-Related Maintenance Requirements", this does not mean "safety-related" should be deleted from each scope statement. Using the same argument would also suggest deletion of the phrase" maintenance requirements" as well since it's in the title of the chapter. The scope statements for each Article within Chapter 2 should reinforce that the maintenance requirements identified are safety-related. This becomes even more important given the recent escalation of NFPA 70B to a Standard.

Submitter Information Verification

Submitter Full Name: Louis Barrios
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Street Address:
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Submittal Date: Mon Jun 03 11:56:13 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-22-NFPA 70E-2024
Statement: Adding the term “safety-related” to the scope statement for each article within Chapter 2 helps usability and reinforces that the specific maintenance requirements identified are safety-related.

Public Input No. 236-NFPA 70E-2024 [Chapter 3]

Chapter 3 Safety Requirements for Special Equipment

Article 300 Introduction

300.1 Scope.

Chapter 3 covers special electrical equipment in the workplace and modifies the general requirements of Chapter 1.

300.2 Responsibility.

~~The~~ A. In addition to the general safety-related work practices in Chapter 1, the employer shall provide safety-related work practices and employee training on the applicable material covered in this chapter .

B. The employee shall follow those work practices.

~~Article 310~~

300.3 Organization.

Chapter 3 of this standard is divided into Articles. Article 300 applies generally to electrical hazards associated with special equipment within the scope of Chapter 3. Article 310 applies to dc electrical hazards. Article 320 applies to capacitor electrical hazards. Article 330 covers electrical hazards from 1 Hz to 110 kHz, other than dc and 50/60 Hz. Article 350 applies to electrolytic cells. Article 360 applies to batteries and battery rooms. Article 370 applies to lasers. Article 380 applies to power electronics. Article 390 applies to Research and Development Laboratories. Article 400 applies to electrical double-layer capacitors. Article 410 applies to photovoltaic systems.

Article 310 DC Electrical Hazards

This article covers the electrical safety-related requirements for the practical safeguarding of employees while working with direct current (dc) that present an electrical hazard.

310.2 DC Electrical Hazard Thresholds

(A) Electrical Thermal Hazard Thresholds

For dc systems, hazardous power is considered greater than or equal to 1000 W.

(B) Electrical Shock Thresholds.

For dc systems, hazardous voltage is considered greater than or equal to 100 volts dc and 40 mA.

(C) Electrical Arc Flash Hazard Thresholds.

For dc systems, hazardous arc flash is considered for systems greater than or equal to 150 volts dc and greater than or equal to 1.2 cal/cm2 incident energy.

320 Capacitor Electrical Hazards

Current Article 360, no changes except as modified by approved 2027 PIs.

330 Electrical Hazards 1 Hz to 110 MHz (not including dc and 50/60 Hz)

Current Article 340, no changes except as modified by approved 2027 PIs

340 Electrical Hazards for Mixed Frequencies

This is reserved for addressing mixed frequencie, such as rectifed ac power, VFD modulated outputs, etc.

Article 350 Safety-Related Work Practices for Electrolytic Cells

310.1 Scope.

The requirements of this article shall apply to the electrical safety-related work practices used in the types of electrolytic cell areas.

Informational Note No. 1: See Informative Annex L for a typical application of safeguards in the cell line working zone.

Informational Note No. 2: See *NFPA 70*, *National Electrical Code*, Article 668 for further information about electrolytic cells.

Informational Note No. 3: See IEEE 463, *Electrical Safety Practices in Electrolytic Cell Line Working Zones*, for further information about electrical safety-related work practices in electrolytic cell lines.

310.3 Safety Training.

(A) General.

The training requirements of this chapter shall apply to employees exposed to electrical hazards in the cell line working zone and shall supplement or modify the requirements of 110.2, 110.4, 130.1, and 130.9.

(B) Training Requirements.

Employees shall be trained to understand the specific electrical hazards associated with electrical energy on the cell line. Employees shall be trained in safety-related work practices and procedural requirements to provide protection from the electrical hazards associated with their respective job or task assignment.

310.4 Employee Training.

(A) Qualified Persons.

(1) Training.

Qualified persons shall be trained and knowledgeable in the operation of cell line working zone equipment and specific work methods and shall be trained to avoid the electrical hazards that are present. Such persons shall be familiar with the proper use of precautionary techniques and PPE. Training for a qualified person shall include the following:

(1) Skills and techniques to avoid an electric shock hazard:

(2) Between exposed energized surfaces, which might include temporarily insulating or guarding parts to permit the employee to work on exposed energized parts

(3) Between exposed energized surfaces and grounded equipment, other grounded objects, or the earth itself, that might include temporarily insulating or guarding parts to permit the employee to work on exposed energized parts

(4) Method of determining the cell line working zone area boundaries

(2) Qualified Persons.

Qualified persons shall be permitted to work within the cell line working zone.

(B) Unqualified Persons.

(1) Training.

Unqualified persons shall be trained to identify electrical hazards to which they could be exposed and the proper methods of avoiding the hazards.

(2) In Cell Line Working Zone.

When there is a need for an unqualified person to enter the cell line working zone to perform a specific task, that person shall be advised of the electrical hazards by the designated qualified person in charge to ensure that the unqualified person is safeguarded.

310.5 Safeguarding of Employees in the Cell Line Working Zone.

(A) General.

Operation and maintenance of electrolytic cell lines might require contact by employees with exposed energized surfaces such as buses, electrolytic cells, and their attachments. The approach distances referred to in Table 130.4(E)(a) and Table 130.4(E)(b) shall not apply to work performed by qualified persons in the cell line working zone. Safeguards such as safety-related work practices and other safeguards shall be used to protect employees from injury while working in the cell line working zone. These safeguards shall be consistent with the nature and extent of the related electrical hazards. Safeguards might be different for energized cell lines and de-energized cell lines. Hazardous battery effect voltages shall be dissipated to consider a cell line de-energized.

Informational Note No. 1: Exposed energized surfaces might not present an electrical hazard. Electric shock hazards are related to current through the body, producing possible injury or damage to health. Electric shock severity is a function of many factors, including skin and body resistance, current path through the body, paths in parallel with the body, and system voltage. Arc flash burns and arc blasts are a function of the arcing current and the duration of arc exposure.

Informational Note No. 2: A cell line or group of cell lines operated as a unit for the production of a particular metal, gas, or chemical compound might differ from other cell lines producing the same product because of variations in the particular raw materials used, output capacity, use of proprietary methods or process practices, or other modifying factors. Detailed standard electrical safety-related work practice requirements could become overly restrictive without accomplishing the stated purpose of Chapter 1.

(B) Signs.

Permanent signs shall clearly designate electrolytic cell areas.

(C) Arc Flash Risk Assessment.

The requirements of 130.5, Arc Flash Risk Assessment, shall not be required for electrolytic cell line working zones.

(1) General.

Each task performed in the electrolytic cell line working zone shall be analyzed for the likelihood of arc flash injury. If there is a likelihood of personal injury, appropriate measures shall be taken to protect persons exposed to the arc flash hazards, including one or more of the following:

(1) Providing appropriate PPE *[see 310.5(D)(2)]* to prevent injury from the arc flash hazard

(2) Altering work procedures to reduce the likelihood of occurrence of an arc flash incident

(3) Scheduling the task so that work can be performed when the cell line is de-energized

(2) Routine Tasks.

Arc flash risk assessment shall be done for all routine tasks performed in the cell line work zone. The results of the arc flash risk assessment shall be used in training employees in job procedures that minimize the possibility of arc flash hazards. The training shall be included in the requirements of 310.3.

(3) Nonroutine Tasks.

Before a nonroutine task is performed in the cell line working zone, an arc flash risk assessment shall be done. If an arc flash hazard is a possibility during nonroutine work, appropriate instructions shall be given to employees involved on how to minimize the risk associated with arc flash.

(4) Arc Flash Hazards.

If the likelihood of occurrence of an arc flash hazard exists for either routine or nonroutine tasks, employees shall use appropriate safeguards.

(D) Safeguards.

Safeguards shall include one or a combination of the following means.

(1) Insulation.

Insulation shall be suitable for the specific conditions, and its components shall be permitted to include glass, porcelain, epoxy coating, rubber, fiberglass, and plastic and, when dry, such materials as concrete, tile, brick, and wood. Insulation shall be permitted to be applied to energized or grounded surfaces.

(2) Personal Protective Equipment (PPE).

PPE shall provide protection from electrical hazards. PPE shall include one or more of the following, as determined by authorized management:

(1) Footwear for wet service

(2) Gloves for wet service

(3) Sleeves for wet service

(4) Footwear for dry service

(5) Gloves for dry service

(6) Sleeves for dry service

(7) Electrically insulated head protection

(8) Protective clothing

(9) Eye protection with nonconductive frames

(10) Face shield (polycarbonate or similar nonmelting type)

(a) *PPE.* Personal and other protective equipment shall be appropriate for conditions, as determined by authorized management.

(b) *Testing of PPE.* PPE shall be verified with regularity and by methods that are consistent with the exposure of employees to electrical hazards.

(3) Barriers.

Barriers shall be devices that prevent contact with energized or grounded surfaces that could present an electrical hazard.

(4) Voltage Equalization.

Voltage equalization shall be permitted by bonding a conductive surface to an exposed energized surface, either directly or through a resistance, so that there is insufficient voltage to create an electrical hazard.

(5) Isolation.

Isolation shall be established by placing equipment or other items in locations such that employees are unable to simultaneously contact exposed conductive surfaces that could present an electrical hazard.

(6) Safe Work Practices.

Employees shall be trained in safe work practices. The training shall include why the work practices in a cell line working zone are different from similar work situations in other areas of the plant. Employees shall comply with established safe work practices and the safe use of protective equipment.

(a) *Attitude Awareness.* Safe work practice training shall include attitude awareness instruction. Simultaneous contact with energized parts and ground can cause serious electrical shock. Of special importance is the need to be aware of body position where contact may be made with energized parts of the electrolytic cell line and grounded surfaces.

(b) *Bypassing of Safety Equipment.* Safe work practice training shall include techniques to prevent bypassing the protection of safety equipment. Clothing may bypass protective equipment if the clothing is wet. Trouser legs should be kept at appropriate length, and shirt sleeves should be a good fit so as not to drape while reaching. Jewelry and other metal accessories that may bypass protective equipment shall not be worn while working in the cell line working zone.

(7) Tools.

Tools and other devices used in the energized cell line work zone shall be selected to prevent bridging between surfaces at hazardous potential difference.

Informational Note: Tools and other devices of magnetic material could be difficult to handle in the area of energized cells due to their strong dc magnetic fields.

(8) Portable Cutout-Type Switches.

Portable cell cutout switches that are connected shall be considered as energized and as an extension of the cell line working zone. Appropriate procedures shall be used to ensure proper cutout switch connection and operation.

(9) Cranes and Hoists.

Cranes and hoists shall meet the requirements of applicable codes and standards to safeguard employees. Insulation required for safeguarding employees, such as insulated crane hooks, shall be periodically tested.

(10) Attachments.

Attachments that extend the cell line electrical hazards beyond the cell line working zone shall use one or more of the following:

(1) Temporary or permanent extension of the cell line working zone

(2) Barriers

(3) Insulating breaks

(4) Isolation

(11) Pacemakers and Metallic Implants.

Employees with implanted pacemakers, ferromagnetic medical devices, or other electronic devices vital to life shall not be permitted in cell areas unless written permission is obtained from the employee's physician.

Informational Note: The American Conference of Governmental Industrial Hygienists (ACGIH) and IEEE 463, *Electrical Safety Practices in Electrolytic Cell Line Working Zones*, recommend that persons with implanted pacemakers should not be exposed to magnetic flux densities above 5 gauss.

(12) Testing.

Equipment safeguards for employee protection shall be tested to ensure they are in a safe working condition.

310.6 Portable Tools and Equipment.

Informational Note: The order of preference for the energy source for portable hand-held equipment is considered to be as follows:

(1) Battery power

(2) Pneumatic power

(3) Portable generator

(4) Nongrounded-type receptacle connected to an ungrounded source

(A) Portable Electrical Equipment.

The grounding requirements of 110.7(B) shall not be permitted within an energized cell line working zone. Portable electrical equipment and associated power supplies shall meet the requirements of applicable codes and standards.

(B) Auxiliary Nonelectric Connections.

Auxiliary nonelectric connections such as air, water, and gas hoses shall meet the requirements of applicable codes and standards. Pneumatic-powered tools and equipment shall be supplied with nonconductive air hoses in the cell line working zone.

(C) Welding Machines.

Welding machine frames shall be considered at cell potential when within the cell line working zone. Safety-related work practices shall require that the cell line not be grounded through the welding machine or its power supply. Welding machines located outside the cell line working zone shall be barricaded to prevent employees from touching the welding machine and ground simultaneously where the welding cables are in the cell line working zone.

(D) Portable Test Equipment.

Test equipment in the cell line working zone shall be suitable for use in areas of large magnetic fields and orientation.

Informational Note: Test equipment that is not suitable for use in such magnetic fields could result in an incorrect response. When such test equipment is removed from the cell line working zone, its performance might return to normal, giving the false impression that the results were correct.

~~**Article 320**~~ Article 360 Safety Requirements Related to Batteries and Battery Rooms

320.1 Scope.

This article covers electrical safety requirements for the practical safeguarding of employees while working with exposed stationary storage batteries that exceed 100 volts, nominal, or exceed a short-circuit power of 1000 watts.

Informational Note: See the following documents for additional information on best practices for safely working on stationary batteries:

(1) NFPA 1, *Fire Code*, Chapter 52, Stationary Storage Battery Systems, 2021

(2) *NFPA 70*, *National Electrical Code*, Article 480, Storage Batteries, 2020

(3) IEEE 450, *IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications*, 2020

(4) IEEE 937, *Recommended Practice for Installation and Maintenance of Lead-Acid Batteries for Photovoltaic Systems*, 2019

(5) IEEE 1106, *IEEE Recommended Practice for Installation, Maintenance, Testing, and Replacement of Vented Nickel-Cadmium Batteries for Stationary Applications*, 2005 (R 2011)

(6) IEEE 1184, *IEEE Guide for Batteries for Uninterruptible Power Supply Systems*, 2015

(7) IEEE 1188, *IEEE Recommended Practice for Maintenance, Testing, and Replacement of Valve-Regulated Lead-Acid (VRLA) Batteries for Stationary Applications*, 1188a-2014

(8) IEEE 1657, *Recommended Practice for Personnel Qualifications for Installation and Maintenance of Stationary Batteries,* 2018

(9) OSHA 29 CFR 1910.305(j)(7), “Storage batteries”

(10) OSHA 29 CFR 1926.441, “Batteries and battery charging”

(11) DHHS (NIOSH) Publication No. 94-110, *Applications Manual for the Revised NIOSH Lifting Equation,* 1994

(12) IEEE/ASHRAE 1635, *Guide for the Ventilation and Thermal Management of Batteries for Stationary Applications*, 2018

(13) NFPA 855, *Standard for the Installation of Stationary Energy Storage Systems*, 2020

(14) UL 9540, *Energy Storage Systems and Equipment*, 2020

(15) UL 9540A, *Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems*, 2019

320.3 Safety Procedures.

(A) General Safety Hazards.

(1) Electrical Hazard Thresholds.

Exposure levels shall not exceed those identified in the following list unless appropriate controls are implemented:

(1) AC: 50 volts and 5 milliamperes

(2) DC: 100 volts and 40 milliamperes

(3) Thermal: 1000 watts short-circuit power

Informational Note No. 1: Available short-circuit power is calculated by multiplying the battery’s nominal voltage by its available short-circuit current at the battery terminals then dividing the result by two.

Informational Note 2: See Department of Energy, *DOE Electrical Safety Handbook*, DOE-HDBK-1092, for electrical hazard thresholds.

(2) Battery Risk Assessment.

Prior to any work on a battery system, a risk assessment shall be performed to identify the chemical, thermal, electrical shock, and arc flash hazards and assess the risks associated with the type of tasks to be performed.

Informational Note: See Informative Annex F Figure F.7 for an example of a risk assessment method for work on batteries.

(3) Battery Room or Enclosure Requirements.

(a) *Personnel Access to Energized Batteries.* Each battery room or battery enclosure shall be accessible only to authorized personnel.

(b) *Illumination.* Employees shall not enter spaces containing batteries unless illumination is provided that enables the employees to perform the work safely.

Informational Note: Battery terminals are normally exposed and pose possible electric shock hazard. Batteries are also installed in steps or tiers that can cause obstructions.

(4) Apparel.

Personnel shall not wear electrically conductive objects such as jewelry while working on a battery system.

(5) Abnormal Battery Conditions.

Instrumentation that provides alarms for early warning of abnormal conditions of battery operation, if present, shall be tested annually.

Informational Note: See IEEE 1491, *Guide for the Selection and Use of Battery Monitoring Equipment in Stationary Applications*, for guidance on battery monitoring systems. Battery monitoring systems typically include alarms for such conditions as overvoltage, undervoltage, overcurrent, ground fault, and overtemperature. The type of conditions monitored will vary depending upon the battery technology.

(6) Warning Signs.

The following warning signs or labels shall be posted in appropriate locations:

(1) Electrical hazard warnings indicating the electric shock hazard due to the battery voltage and the arc flash hazard due to the prospective short-circuit current, and the thermal hazard.

Informational Note No.1: Because internal resistance, prospective short-circuit current, or both are not always provided on battery container labels or data sheets, and because many variables can be introduced into a battery layout, the battery manufacturer should be consulted for accurate data. Variables can include, but are not limited to, the following:

(1) Series connections

(2) Parallel connections

(3) Charging methodology

(4) Temperature

(5) Charge status

(6) Dc distribution cable size and length

Informational Note No. 2: See 130.5(H) for requirements for equipment labeling.

(2) Chemical hazard warnings, applicable to the worst case when multiple battery types are installed in the same space, indicating the following:

(3) Potential presence of explosive gas (when applicable to the battery type)

(4) Prohibition of open flame and smoking

(5) Danger of chemical burns from the electrolyte (when applicable to the battery type)

(6) Notice for personnel to use and wear protective equipment and apparel appropriate to the hazard for the battery

(7) Notice prohibiting access to unauthorized personnel

(B) Electrolyte Hazards.

(1) Battery Activities That Include Handling of Liquid Electrolyte.

The following protective equipment shall be available to employees performing any type of service on a battery with liquid electrolyte:

(1) Goggles and face shield appropriate for the electrical hazard and the chemical hazard

(2) Gloves and aprons appropriate for the chemical hazards

(3) Portable or stationary eye wash facilities and equipment within the work area that are capable of drenching or flushing of the eyes and body for the duration necessary to mitigate injury from the electrolyte hazard.

Informational Note: See ANSI/ISEA Z358.1, *American National Standard for Emergency Eye Wash and Shower Equipment*, for guidelines for the use and maintenance of eye wash facilities for vented batteries in nontelecom environments.

(2) Activities That Do Not Include Handling of Electrolyte.

Employees performing any activity not involving the handling of electrolyte shall wear safety glasses.

> Informational Note: Battery maintenance activities usually do not involve handling electrolyte. Batteries that are hermetically sealed (such as most lithium batteries) or immobilized electrolyte (such as valve-regulated lead acid batteries) present little or no electrolyte hazard. Most modern density meters expose a worker to a quantity of electrolyte too minute to be considered hazardous, if at all. Such work would not be considered handling electrolyte. However, if specific gravity readings are taken using a bulb hydrometer, the risk of exposure is higher — this could be considered to be handling electrolyte, and the requirements of 320.3(B)(1) would apply.

(C) Tools and Equipment.

(1) Handles.

Tools and equipment for work on batteries shall be equipped with insulated handles rated for the voltage on which they are used in accordance with 130.7(D)(1).

(2) Contact.

Battery terminals and all electrical conductors shall be kept clear of unintended contact with tools, test equipment, liquid containers, and other foreign objects. The length and insulation of tools for work on batteries shall be selected to minimize the likelihood of inadvertent contact.

(3) Nonsparking Tools.

Nonsparking tools shall be required when the risk assessment required by 110.3(H) justifies their use.

(D) Cell Flame Arresters and Cell Ventilation.

When present, battery cell ventilation openings shall be unobstructed. Cell flame arresters shall be inspected for proper installation and unobstructed ventilation and shall be replaced when necessary in accordance with the manufacturer's instructions.

~~Article 330~~ Article 370 Safety-Related Work Practices: Lasers

330.1 Scope.

This article covers safety-related work practices for maintaining lasers and their associated equipment.

> Informational Note No. 1: See ANSI Z136.1, *Standard for Safe Use of Lasers*, for information on laser safety requirements for laser use.
>
> Informational Note No. 2: See 21 CFR Part 1040, “Performance Standards for Light-Emitting Products,” Sections 1040.10 “Laser products” and 1040.11, “Specific purpose laser products” for laser product requirements for laser manufacturers.

330.3 Electrical Hazard Thresholds.

Exposure levels shall not exceed those identified in the following list unless appropriate controls are implemented:

(1) AC: 50 volts and 5 milliamperes

(2) DC: 100 volts and 40 milliamperes

(3) Capacitor stored energy:

(4) Less than 100 volts and greater than 100 joules of stored energy

(5) Greater than or equal to 100 volts and greater than 1.0 joule of stored energy

(6) Greater than or equal to 400 volts and greater than 0.25 joule of stored energy

Informational Note No. 1: See Department of Energy, *DOE Electrical Safety Handbook*, DOE-HDBK-1092, for information on electrical safety thresholds.

Informational Note No. 2: See 360.3 and Informative Annex R for information on capacitor hazards and controls.

330.4 Electrical Safety Training.

(A) Personnel to Be Trained.

Employers shall provide training for all personnel who work on or are near lasers or laser systems with user-accessible hazardous voltage, current, or stored energy (e.g., flashlamp-pumped lasers).

(B) Electrical Safety Training for Work on or with Lasers.

Training in electrical safe work practices shall include, but is not limited to, the following:

(1) Chapter 1 electrical safe work practices

(2) Electrical hazards associated with laser equipment

(3) Stored energy hazards, including capacitors and capacitor banks

(4) Ionizing radiation, including X-rays at voltages greater than 10 kV in a vacuum

(5) Assessing the listing status of electrical equipment and the need for field evaluation of nonlisted equipment

330.5 Safeguarding of Persons from Electrical Hazards Associated with Lasers and Laser Systems.

(A) Temporary Guarding.

Temporary guarding (e.g., covers, protective insulating barriers) shall be used to limit exposure to any electrical hazard when the permanent laser enclosure covers are removed for maintenance and testing.

(B) Work Requiring an Electrically Safe Work Condition.

Work that might expose employees to electrical hazards shall be performed with the equipment in an electrically safe work condition in accordance with 120.2, 120.3, and 110.2(B).

(C) Energized Electrical Testing.

Energized electrical testing, troubleshooting, and voltage testing shall not require an energized work permit in accordance with 130.2(C).

(D) Warning Signs and Labels.

Electrical safety warning signs and labels shall be posted as applicable on electrical equipment doors, covers, and protective barriers. The warning signs and labels shall adequately warn of the hazard using effective words, colors, and symbols. These signs and labels shall be permanently affixed to the equipment and shall be of sufficient durability to withstand the environment involved.

(E) Listing.

Laser system electrical equipment with the potential to expose workers to electrical hazards shall be listed or field evaluated prior to use.

330.6 Responsibility for Electrical Safety.

All persons with access to hazardous voltage, current, or stored energy shall be responsible for the following:

(1) Obtaining authorization for work with or on hazardous electrical equipment in lasers and laser systems

(2) Use of Chapter 1 safety-related work practices

(3) Reporting laser equipment failures, accidents, inadequate barriers, and inadequate signage to the employer

~~**Article 340**~~ Article 380 Safety-Related Work Practices: Power Electronic Equipment

340.1 Scope.

This article covers safety-related work practices around power electronic equipment, including the following:

(1) Electric arc welding equipment

(2) High-power radio, radar, and television transmitting towers and antennas

(3) Industrial dielectric and radio frequency (RF) induction heaters

(4) Shortwave or RF diathermy devices

(5) Equipment that includes rectifiers and inverters such as the following:

(6) Motor drives

(7) Uninterruptible power supply systems

(8) Lighting controllers

(9) Generators producing sub RF (1 kHz to 3 kHz) and RF (3 kHz to 100 MHz) fields

(10) Ionizing radiation field generators including X-rays, magnetrons, klystrons, thyratrons, vacuum tubes, and similar high-voltage vacuum devices

(11) Nonionizing radiation field generating equipment, including:

(12) Antennas and RF transmission lines

(13) Radar equipment

(14) Industrial scientific and medical equipment

(15) RF induction and dielectric heaters

(16) Industrial microwave heaters and diathermy radiators

(17) Magnetic resonance imagers (MRIs)

(18) Large electromagnets

Informational Note: See the following standards for specific guidance on safety-related work practices around power electronic equipment:

(1) IEEE C95.1, *IEEE Standard for Safety Levels with Respect to Human Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz*, 2019

(2) International Electrotechnical Commission IEC 60479-1, *Effects of Current on Human Beings and Livestock, Part 1: General Aspects*

(3) International Commission on Radiological Protection (ICRP) Publication 33, *Protection Against Ionizing Radiation from External Sources Used in Medicine*

340.3 Application.

The purpose of this article is to provide guidance for safety personnel in preparing specific safety-related work practices within their industry.

340.4 Electrical Hazard Thresholds.

Exposure levels shall not exceed those identified in the following list unless appropriate controls are implemented:

(1) DC (0 Hz to 1 Hz): 100 volts and 40 milliamperes

(2) 60/50 Hz power: 50 volts and 5 milliampere

(3) AC (1 Hz to 3 kHz): 50 volts and 3 milliamperes

(4) AC (3 kHz to 100 kHz): 1 x f mA, f in kHz

(5) AC (100 kHz to 3 MHz): 100 mA

(6) AC (3 MHz to 30 MHz):$100\ (f/3)^{*0.3}$, f in MHz

(7) AC (30 MHz to 110 MHz): 200 mA

Informational Note No. 1: See IEEE Std C95.1-2019, *IEEE Standard for Safety Levels with Respect to Human Exposure to Electrical, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz*, for information regarding hazard thresholds for workers trained in sub RF and RF contact electric shock.

Informational Note No. 2: RF electric shock thresholds depend on current and frequency, not voltage.

340.5 Specific Measures for Personnel Safety.

(A) Employer Responsibility.

The employer shall be responsible for the following:

(1) Proper training and supervision by properly qualified personnel, including the following:

(2) Identification of associated hazards

(3) Strategies to reduce the risk associated with the hazards

(4) Methods of avoiding or protecting against the hazard

(5) Necessity of reporting any incident that resulted in, or could have resulted in, injury or damage to health

(6) Properly installed equipment

(7) Proper access to the equipment

(8) Availability of the correct tools for operation and maintenance

(9) Proper identification and guarding of dangerous equipment

(10) Provision of complete and accurate circuit diagrams and other published information to the employee prior to the employee starting work (The circuit diagrams should be marked to indicate the components that present an electrical hazard.)

(11) Maintenance of clear and clean work areas around the equipment to be worked on

(12) Provision of adequate and proper illumination of the work area

(B) Employee Responsibility.

The employee shall be responsible for the following:

(1) Understanding the hazards associated with the work

(2) Being continuously alert and aware of the possible hazards

(3) Using the proper tools and procedures for the work

(4) Informing the employer of malfunctioning protective measures, such as faulty or inoperable enclosures and locking schemes

(5) Examining all documents provided by the employer relevant to the work to identify the location of components that present an electrical hazard

(6) Maintaining good housekeeping around the equipment and work space

(7) Reporting any incident that resulted in, or could have resulted in, injury or damage to health

(8) Using and appropriately maintaining the PPE and tools required to perform the work safely

~~**Article 350**~~ Article 390 Safety-Related Work Requirements: Research and Development Laboratories

350.1 Scope.

The requirements of this article shall apply to the electrical installations in those areas, with custom or special electrical equipment, designated by the facility management for research and development (R&D) or as laboratories.

350.3 Applications of Other Articles.

The electrical system for R&D and laboratory applications shall meet the requirements of the remainder of this document, except as amended by Article 350.

Informational Note: Examples of these applications include low-voltage–high-current power systems; high-voltage–low-current power systems; dc power supplies; capacitors; cable trays for signal cables and other systems, such as steam, water, air, gas, or drainage; and custom-made electronic equipment.

350.4 Electrical Safety Authority (ESA).

Each laboratory or R&D system application shall be permitted to assign an ESA to ensure the use of appropriate electrical safety-related work practices and controls. The ESA shall be permitted to be an electrical safety committee, engineer, or equivalent qualified individual. The ESA shall be permitted to delegate authority to an individual or organization within their control.

(A) Responsibility.

The ESA shall act in a manner similar to an authority having jurisdiction for R&D electrical systems and electrical safe work practices.

(B) Qualifications.

The ESA shall be competent in the following:

(1) The requirements of this standard

(2) Electrical system requirements applicable to the R&D laboratories

350.5 Specific Measures and Controls for Personnel Safety.

Each laboratory or R&D system application shall designate a competent person as defined in this article to ensure the use of appropriate electrical safety-related work practices and controls.

(A) Job Briefings.

Job briefings shall be performed in accordance with 110.3(I).

Exception: Prior to starting work, a brief discussion shall be permitted if the task and hazards are documented and the employee has reviewed applicable documentation and is qualified for the task.

(B) Personnel Protection.

Safety-related work practices shall be used to safeguard employees from injury while they are exposed to electrical hazards from exposed electrical conductors or circuit parts that are or can become energized. The specific safety-related work practices shall be consistent with the electrical hazard(s) and the associated risk. For calibration and adjustment of equipment as it pertains to sensors, motor controllers, control hardware, and other devices that need to be installed inside equipment or control cabinet, surrounded by electrical hazards, the ESA shall define the required PPE based on the risk and exposure.

Use of electrical insulating blankets, covers, or barriers shall be permitted to prevent inadvertent contact to exposed terminals and conductors. Insulated/nonconductive adjustment and alignment tools shall be used where feasible.

350.6 Approval Requirements.

The equipment or systems used in the R&D area or in the laboratory shall be listed or field evaluated prior to use.

> Informational Note: Laboratory and R&D equipment or systems can pose unique electrical hazards that might require mitigation. Such hazards include ac and dc, low voltage and high amperage, high voltage and low current, large electromagnetic fields, induced voltages, pulsed power, multiple frequencies, and similar exposures.

350.7 Custom Built, Non-Listed Research Equipment, 1000 Volts or less AC or DC.

(A) Equipment Marking and Documentation.

(1) Marking.

Marking of equipment shall be required for, but not limited to, equipment fabricated, designed, or developed for research testing and evaluation of electrical systems. Marking shall sufficiently list all voltages entering and leaving control cabinets, enclosures, and equipment.

Caution, Warning, or Danger labels shall be affixed to the exterior describing specific hazards and safety concerns.

> Informational Note: See ANSI Z535, *Series of Standards for Safety Signs and Tags*, for more information on precautionary marking of electrical systems or equipment.

(2) Documentation.

Sufficient documentation shall be provided and readily available to personnel that install, operate, and maintain equipment that describes operation, shutdown, safety concerns, and nonstandard installations.

Schematics, drawings, and bill of materials describing power feeds, voltages, currents, and parts used for construction, maintenance, and operation of the equipment shall be provided.

(3) Shutdown Procedures.

Safety requirements and emergency shutdown procedures of equipment shall include lockout/tagout (LOTO) requirements. If equipment-specific LOTO is required, then documentation outlining this procedure and PPE requirements shall be made readily available.

(4) Specific Hazards.

Specific hazards, other than electrical, associated with research equipment shall be documented and readily available.

(5) Approvals.

Drawings, standard operational procedures, and equipment shall be approved by the ESA on site before initial startup. Assembly of equipment shall comply with national standards where applicable unless research application requires exceptions. Equipment that does not meet the applicable standards shall be required to be approved by the ESA. Proper safety shutdown procedures and PPE requirements shall be considered in the absence of grounding and/or bonding.

(B) Tools, Training, and Maintenance.

Documentation shall be provided if special tools, unusual PPE, or other equipment is necessary for proper maintenance and operation of equipment. The ESA shall make the determination of appropriate training and qualifications required to perform specific tasks.

350.8 Custom Built, Unlisted Research Equipment, >1000 V AC or DC.

Installations shall comply with all requirements of 350.7.

In the event that research equipment requires PPE beyond what is commercially available, the ESA shall determine safe work practices and PPE to be used.

350.9 Electrical Hazard Thresholds.

Exposure levels shall not exceed those identified in the following list unless appropriate controls are implemented as approved by the ESA:

(1) AC: 50 volts and 5 milliamperes

(2) DC: 100 volts and 40 milliamperes

Informational Note No. 1: See Department of Energy, *DOE Electrical Safety Handbook*, DOE-HDBK-1092, for information on electrical hazard thresholds.

Informational Note No. 2: See 360.3 and Informative Annex R for information on capacitor hazards and controls.

350.10 Establishing an Electrically Safe Work Condition.

Energized electrical conductors and circuit parts shall be put into an electrically safe work condition before an employee performs work.

Exception: At the discretion of the ESA, alternative methods of ensuring worker safety shall be permitted to be employed for the following conditions:

(1) Minor tool changes and adjustments, and other normal production operations that are routine, repetitive, or sequential and integral to the use of the equipment for production

(2) Minor changes to the unit under test and other minor servicing activities, to include the activities listed under 350.10 Exception condition (1), that take place during research and development

(3) Work on cord-and-plug-connected equipment for which exposure to the hazards of unexpected energization or start up is controlled by the following:

(4) Unplugging the equipment from the energy source

(5) The employee performing the work maintaining exclusive control of the plug

~~**Article 360**~~ Article 310 Safety-Related Requirements for Capacitors

360.1 Scope.

This article covers the electrical safety-related requirements for the practical safeguarding of employees while working with capacitors that present an electrical hazard.

Informational Note: See Informative Annex R for more information on working safely with capacitors.

360.3 Stored Energy Hazard Thresholds.

Appropriate controls shall be applied where any of the following hazard thresholds are exceeded:

(1) Less than 100 volts and greater than 100 joules of stored energy

(2) Greater than or equal to 100 volts and greater than 1.0 joule of stored energy

(3) Greater than or equal to 400 volts and greater than 0.25 joules of stored energy

360.4 Specific Measures for Personnel Safety.

(A) Qualification and Training.

The following qualifications and training shall be required for personnel safety:

(1) Employees who perform work on electrical equipment with capacitors that exceed the energy thresholds in 360.3 shall be qualified and shall be trained in, and familiar with, the specific hazards and controls required for safe work.

(2) Unqualified persons who perform work on electrical equipment with capacitors shall be trained in, and familiar with, any electrical safety-related work practices necessary for their safety.

(B) Performing a Risk Assessment for Capacitors.

The risk assessment process for capacitors shall follow the overall risk assessment procedures in Chapter 1. If additional protective measures are required, they shall be selected and implemented according to the hierarchy of risk control identified in 110.3(H)(3). When the additional protective measures include the use of PPE, the following shall be determined:

(1) Capacitor voltage and stored energy for the worker exposure. An exposure shall be considered to exist when a conductor or circuit part that could potentially remain energized with hazardous stored energy is exposed.

(2) Thermal hazard. The appropriate thermal PPE shall be selected and used if the stored energy of the exposed part is greater 100 joules.

(3) Electric shock hazard. The appropriate electric shock PPE in accordance with 130.7 shall be selected and used if the voltage is greater than or equal to 100 volts.

(4) Arc flash and arc blast hazard at the appropriate working distance. The appropriate protection for the arc flash and arc blast hazard shall be selected, as follows:

a. Arc flash PPE in accordance with 130.7 shall be selected and used if the incident energy exceeds 1.2 cal/cm^2 (5 J/cm^2) at the working distance.

b. Hearing protection shall be required where the stored energy exceeds 100 joules.

c. The lung protection boundary shall be determined if stored energy is above 122 kJ. Employees shall not enter the lung protection boundary.

d. Alerting techniques in accordance with 130.8(O) shall be used to warn employees of the hazards.

(5) Required test and grounding method. Soft grounding shall be used for stored energy greater than 1000 joules. If capacitors are equipped with bleed resistors, or if using a soft grounding system, the required discharge wait time shall be determined where applicable.

(6) Develop a written procedure that captures all of the required steps to place the equipment in an electrically safe work condition. Include information about the amount of stored energy available, how long to wait after de-energization before opening the enclosure, how to test for absence of voltage, and what to do if there is still stored energy present.

Informational Note No. 1: See Informative Annex R for more information on calculating capacitor stored energy, arc flash, and arc blast boundaries.

Informational Note No. 2: Heavy duty leather with a minimum thickness of 0.03 in. (0.7 mm) provides protection from thermal hazards.

360.5 Establishing an Electrically Safe Work Condition for a Capacitor(s).

(A) Written Procedure.

Where a conductor or circuit part is connected to a capacitor(s) operating at or above the thresholds in 360.3, a written procedure shall be used to document the necessary steps and sequence to discharge the capacitor(s) and place the equipment into an electrically safe work condition. The written procedure shall incorporate the results of the risk assessment performed in 360.5(B) and specify the following at a minimum:

(B) Safe Work Practices.

In order to place the capacitor(s) into an electrically safe work condition, a qualified person shall use the appropriate safe work practices and PPE and shall apply the following process for establishing and verifying an electrically safe work condition:

(1) Determine all possible sources of electrical supply to the specific equipment. Check applicable up-to-date drawings, diagrams, and identification tags.

(2) After properly interrupting the load current, open the disconnecting device(s) for each source.

(3) Wherever possible, visually verify that all blades of the disconnecting devices are fully open or that drawout-type circuit breakers are withdrawn to the fully disconnected position.

(4) Apply lockout/tagout devices in accordance with a documented and established policy.

(5) If bleed resistors or automatic discharge systems are applicable, wait the prescribed time for the capacitors to discharge to less than the thresholds in 360.3 and proceed to step (6). For systems without bleed resistors or automatic discharge systems, discharge the capacitors with an adequately rated grounding device (e.g., ground stick). Soft grounding shall be performed above 1000 joules, and remote soft grounding shall be performed above 100 kJ.

(6) Verify that the capacitors are discharged. For capacitors less than 1000 joules, verification shall be permitted to be done either by testing or by grounding. For capacitors between 1000 joules and less than 100 kJ, verification shall be done using testing or soft grounding, then hard grounding. Above 100 kJ, an engineered and redundant system shall be used for remote testing and grounding. An adequately rated grounding device (ground stick) or portable test instrument shall be used to test between each capacitor terminal and from each terminal to ground to assure that the capacitor is de-energized.

(7) When test instruments are used for testing the absence of voltage, the operation of the test instrument shall be verified on a known dc voltage source before and after each absence of voltage procedure is performed. If voltage remains, determine and correct the cause, and repeat step (5) to discharge the capacitors. Where recharging can occur due to dielectric absorption or induced voltages, all the capacitor terminals shall be connected together and grounded with a bare or transparent-insulated wire.

(8) For series capacitors the shorting wires shall be attached across each individual capacitor, and to case.

For single capacitors or for a parallel capacitor bank, the grounding device shall be permitted to be left attached to the capacitor terminals for the duration of the work (e.g., a ground stick).

Exception: Lockout/tagout shall not be required for work on cord- and plug-connected equipment for which exposure to the hazards of unexpected energization of the equipment is controlled by the unplugging of the equipment from the energy source, provided that the plug is under the exclusive control of the employee performing the servicing and maintenance for the duration of the work.

360.6 Ground Sticks.

Ground sticks shall be provided for qualified persons to safely discharge any residual stored energy contained in capacitors or to hold the capacitor potential at 0 volts. The ground sticks shall be designed, constructed, installed, and periodically inspected so that the full energy and voltage of the capacitors can be safely discharged.

(A) Visual Inspection.

The ground stick shall be visually inspected for defects before each use. All mechanical connections shall be examined for loose connections. Resistors shall be visually inspected for cracks or other defects and electrically tested for proper resistance. The following shall occur if defects or contamination are found:

(1) If any defect or contamination that could adversely affect the insulating qualities or mechanical integrity of the ground stick is present, the tool shall be removed from service.

(2) If the defect or contamination exists on the ground stick, then it shall be replaced or repaired and tested before returning to service.

(3) If the defect or contamination exists on the cable, then it shall be replaced or repaired and tested before returning to service.

(B) Electrical Testing.

All ground sticks shall be electrically tested as follows:

(1) The ground stick cable shall be tested to verify that the impedance is less than 0.1 ohms to ground every 2 years.

(2) The testing shall be documented.

Exception: The test shall be performed annually if the ground stick is utilized outdoors or in other adverse conditions.

(3) Soft grounding (High-Z) ground sticks with resistors shall be measured and compared to the specified value before each use.

(C) Storage and Disposal.

Any residual charge from capacitors shall be removed by discharging before servicing or removal.

(1) All uninstalled capacitors capable of storing 10 joules or greater at their rated voltage shall be short-circuited with a conductor of appropriate size.

(2) When an uninstalled capacitor is discovered without the shorting conductor attached to the terminals, it shall be treated as energized and charged to its full rated voltage until determined safe by a qualified person.

Informational Note: A capacitor that develops an internal open circuit could retain substantial charge internally even though the terminals are short-circuited. Such a capacitor can be hazardous to transport, because the damaged internal wiring could reconnect and discharge the capacitor through the short-circuiting conductor. Any capacitor that shows a significant change in capacitance after a fault could have this problem. Action should be taken to reduce the risk associated with this hazard when it is discovered.

Statement of Problem and Substantiation for Public Input

This PI addresses ONLY the reordering of the chapters within Chapter 3. It introduces NO technical changes.
All technical changes proposed for Chapter 3 are in other PIs.

The current order of existing articles in chapter 3 is:
310 Safety-Related Work Practices for Electrolytic Cells
320 Safety Requirements Related to Batteries and Battery Rooms
330 Safety-Related Work Practices Lasers
340 Safety-Related Work Practices: Power Electronic Equipment
350 Safety-Related Work Requirements: Research and Development Laboratories
360 Safety-Related Work Requirements for Capacitors

The proposed order in this PI, with no technical changes is:

310 DC Electrical Hazards
320 Safety-Related Work Requirements for Capacitors
330 Electrical Hazards 1 Hz to 110 MHz (excluding dc and 50/60 Hz)
340 Electrical Hazards of Mixed Electrical Frequencies - future submission
350 Safety-Related Work Practices for Electrolytic Cells
360 Safety Requirements Related to Batteries and Battery Rooms
370 Safety-Related Work Practices Lasers
380 Safety-Related Work Practices: Power Electronic Equipment
390 Safety-Related Work Requirements: Research and Development Laboratories
400 Safety-Related Work Requirements: Electrical Double-Layer Capacitors - submitted PI
410 Safety-Related Work Requirements for Photovoltaic Systems - submitted PI

If the 2027 PIs to eliminate the current article 330-Lasers and rename current article 340-Power Electronics to 330 then the order would be:

310 DC Electrical Hazards
320 Safety-Related Work Requirements for Capacitors
330 Electrical Hazards 1 Hz to 110 MHz (excluding dc and 50/60 Hz)
340 Electrical Hazards of Mixed Electrical Frequencies - future submission
350 Safety-Related Work Practices for Electrolytic Cells
360 Safety Requirements Related to Batteries and Battery Rooms
370 Safety-Related Work Requirements: Research and Development Laboratories
380 Safety-Related Work Requirements: Electrical Double-Layer Capacitors - submitted PI
390 Safety-Related Work Requirements for Photovoltaic Systems - submitted PI

Justification for the reorder:
Chapter 3 evolved over 25 years, starting with electrolytic cells and batteries, later adding lasers and power electronics, later adding R&D and capacitors.
Almost all special equipment has dc and capacitors, and much of it has subrf and rf hazards.
The thresholds for dc, capacitors, and subrf were often repeated in the different chapters on special equipment and became out of sync.
It flows much better to introduce the unique electrical hazards for special equipment that are not adequately covered in Chapter 1, then to cover the Safety-Related Work Requirements for each class of special equipment, referring to those common hazards.
In general safe work practices that are common across the various special equipment classes, are in Chapter 1. Gradually, the requirements in each of the cases of special equipment should cover only those that are unique to that class of equipment.

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Submittal Date: Tue Jun 04 11:48:55 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-80-NFPA 70E-2024

Statement: This First Revision is editorial only without technical changes to Chapter 3. Since its inception, Chapter 3 has evolved using a patchwork of subjects generally developed in isolation from other parts of Chapter 3 and the remainder of the Standard. This revision is the result of work over two cycles attempting to harmonize common methods of special equipment and comply with correlating committee direction to avoid redundancy whenever practicable. It provides improved usability and makes future additions to

Chapter 3 more efficient in addressing only those unique circumstances for the added special equipment.

Public Input No. 125-NFPA 70E-2024 [New Article after 300]

Article 390 Electrical Safety for Hybrid SuperCapacitors

380.1 **Scope:**

This article covers electrical safety requirements for the practical safeguarding of employees while working with exposed hybrid supercapacitors that exceed 100 volts nominal or 10 kJ.

380.2 **Specific Measures for Personnel Safety.**

(A) Qualification and Training.

The following qualifications and training shall be required for personnel safety:

(1) Employees who perform work on electrical equipment with HSCs that exceed 100V or 10 kJ shall be qualified and shall be trained in, and familiar with, the specific hazards and controls required for safe work.

(2) Unqualified persons who perform work on electrical equipment with HSCs shall be trained in, and familiar with, any electrical safety-related work practices necessary for their safety.

(B) Performing a Risk Assessment for HSCs .

The risk assessment process for HSCs shall follow the overall risk assessment procedures in Chapter **1** . If additional protective measures are required, they shall be selected and implemented according to the hierarchy of risk control identified in **110.3(H)(3)** . When the additional protective measures include the use of PPE, the following shall be determined:

(1) The HSC system's voltage and stored energy for the worker exposure. An exposure shall be considered to exist when a conductor or circuit part that could potentially remain energized with hazardous stored energy exposed.

(2) Thermal hazard. The appropriate thermal PPE shall be selected and used if the stored energy of the exposed part is greater than 10 kJ.

(3) Electric shock hazard. The appropriate electric shock PPE in accordance with **130.7** shall be selected and used if the voltage is greater than or equal to 100 volts.

(4) Arc flash and arc blast hazard at the appropriate working distance. The appropriate protection for the arc flash and arc blast hazard shall be selected, as follows:

(5) Arc flash PPE in accordance with **130.7** shall be selected and used if the incident energy exceeds 1.2 cal/cm^2 (5 J/cm^2) at the working distance.

(6) Acoustic Hazard. Hearing protection shall be required where the incident energy exceeds 4 cal/cm^2 (16.7 J/cm^2) at the working distance

(7) Alerting techniques in accordance with **130.8(O)** shall be used to warn employees of the hazards.

380.3 **Establishing an Electrically Safe Work Condition for HSCs.**

(A) Written Procedure.

Where a conductor or circuit part is connected to an HSC system operating above 100V or 10 kJ, a written procedure shall be used to document the necessary steps and sequence to discharge the HSCs and place the equipment into an electrically safe work condition. The written procedure shall incorporate the results of the risk assessment performed in **380.2(B)** and be in accordance with 120.

(B) Storage and Disposal.

Any residual charge from damaged HSCs shall be removed by discharging before removal. HSCs should be shipped at 30% state-of-charge (SOC) or less. HSCs should be stored at 30% SOC or less unless there are deluge sprinkler systems and early warning thermal detection fire detection technology installed in the facility, or they are stored outdoors in a metal shipping container at least 10 feet (3 m) away from other containers, building walls, roadways, walkways, etc.

Statement of Problem and Substantiation for Public Input

While they've been on the market for a little less than a decade, hybrid supercapacitors (HSCs, formerly called Li-ion capacitors or LiCs) have only recently been gaining acceptance in a wider variety of applications. They behave somewhat like supercapacitors (also known as ultracapacitors, or more properly called EDLCs) in that they have high power capabilities, but superior energy density. Their gravimetric and volumetric energy density falls between that of EDLCs and batteries. So, the safety requirements proposed in this new section are a combination of EDLC-type safety requirements as proposed in the new Article 380, and batteries (see Article 320). Their internal resistance (ESR) and impedance falls between that of batteries and EDLCs, and thus the rise time of a short circuit current falls in between that of a battery and an EDLC, neither of which have the acoustic shock wave issues of the incredibly fast rise times of conventional electrolytic capacitors (see Article 360).

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 126-NFPA 70E-2024 [Article 100]	Chapter 1 definition for HSC/LiC
Public Input No. 127-NFPA 70E-2024 [Annex S]	supplemental Annex to better describe the technology
Public Input No. 126-NFPA 70E-2024 [Article 100]	
Public Input No. 127-NFPA 70E-2024 [Annex S]	

Submitter Information Verification

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Submittal Date: Sat Jun 01 20:03:16 EDT 2024

Committee: EEW-AAA

Committee Statement

Resolution: The content of the proposed article provides no new information not already found in Article 320 for hazards related to batteries.

Public Input No. 245-NFPA 70E-2024 [New Article after 300]

Article 410 Safety-Related Requirements for Photovoltaic Systems

410.1 Scope. This article covers electrical safety requirements for the practical safeguarding of employees while working on DC Photovoltaic (PV) systems.

410.2 Energy Hazard Thresholds. Appropriate controls shall be applied where any of the following thresholds are exceeded:

(1) DC thermal hazard: 1000 W for workers wearing jewelry or using small tools, 10 kW for using larger tools

(2) DC shock hazard: 100 volts and 40 milliamperes

(3) DC arc flash hazard: 150 volts and 1.2 cal/cm ^{2}

410.3 PV Risk Assessment. Prior to any work on an energized PV array, a risk assessment shall be performed to identify the thermal, electrical shock, and arc flash hazards and assess the risks associated with the type of tasks to be performed.

410.4 Specific Work Procedures

(1) No work shall be performed on exposed PV terminals greater than the shock or arc flash thresholds.

(2) Before manipulating any connectors on an energized system (plugging or unplugging) a risk assessment shall be performed that determines the maximum open circuit voltage that would be generated and the maximum current to be interrupted. This risk assessmennt will determine if the action can be performed safely, and what PPE would be required.

(3) Robust procedures for plugging and unplugging connectors on an energized PV system shall be developed that considers the possibility of making wrong connections and creating a short circuit, and the controls necessary to prevent such a situation.

Statement of Problem and Substantiation for Public Input

PV systems are still somewhat new. Accidents and incidents are happening, but there is little published data. PV arrays have different hazard characteristics and different work procedures than battery systems. This article is a placeholder and more information is forthcoming. A big issue is the uncertainly of current dc arc flash incident energy analysis methods in use. Several PV industries are requesting rules for maintenance and repair.

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Submittal Date: Tue Jun 04 14:38:06 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-102-NFPA 70E-2024

Statement: A new article for PV addresses the unique electrical hazards associated with work practices on PV installations.

First and/or second level subdivision titles were added to comply with the NEC Style Manual.

Public Input No. 173-NFPA 70E-2024 [Section No. 310.1]

310.1 Scope.

The requirements of this article shall apply to the electrical safety-related work practices used in the types of electrolytic cell areas.

Informational Note No. ~~1~~ 1 : See ~~Informative Annex L for a typical application of safeguards in the cell line working zone.~~ ~~Informational Note No. 2:~~ ~~See~~ *NFPA 70*, *National Electrical Code*, Article 668 for further information about electrolytic cells.

Informational Note No. ~~3~~ 2 : See IEEE 463, *Electrical Safety Practices in Electrolytic Cell Line Working Zones*, for further information about electrical safety-related work practices in electrolytic cell lines.

Statement of Problem and Substantiation for Public Input

Informational Note No.1 is deleted and added after Section 310.5(D) as both Section 310.5(D) and Annex L apply to the application of safeguards in electrolytic cell lines. See Companion PIs

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 172-NFPA 70E-2024 [Section No. 310.5(D)(2)]	
Public Input No. 174-NFPA 70E-2024 [Sections L.1, L.2]	
Public Input No. 172-NFPA 70E-2024 [Section No. 310.5(D)(2)]	
Public Input No. 174-NFPA 70E-2024 [Sections L.1, L.2]	

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Committee: EEW-AAA

Committee Statement

Resolution: Moving the informational note from its current position in 310.1 does not add additional clarity or readability for the user.

Public Input No. 172-NFPA 70E-2024 [Section No. 310.5(D)(2)]

(2) Personal Protective Equipment (PPE).

PPE shall provide protection from electrical hazards. PPE shall include one or more of the following, as determined by authorized management:

(1) Footwear for wet service

(2) Gloves for wet service

(3) Sleeves for wet service

(4) Footwear for dry service

(5) Gloves for dry service

(6) Sleeves for dry service

(7) Electrically insulated head protection

(8) Protective clothing

(9) Eye protection with nonconductive frames

(10) Face shield (polycarbonate or similar nonmelting type)

(a) *PPE.* Personal and other protective equipment shall be appropriate for conditions, as determined by authorized management.

(b) *Testing of PPE.* PPE shall be verified with regularity and by methods that are consistent with the exposure of employees to electrical hazards.

Informational Note: See Annex L for information on the application of safeguards in electrolytic areas where electrical hazards exist.

Statement of Problem and Substantiation for Public Input

There are instances that arise in certain settings where ARC/FR clothing is required and additional chemical resistant coveralls for chemical reaction exposure is needed.
This Informational Note pointing to Annex L was in 310.1 Scope, the informational note would be more effective located after 310.5(D) as the Annex material directly applies to the application of safeguards.
There are two other related PIs to accomplish the following:

1. Deletes the Info note after 310.1.
2. Adding the proposed language regarding the need to consider contamination and potential chemical reaction to Annex L.1. See additional proposed PI in the next line.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 173-NFPA 70E-2024 [Section No. 310.1]	
Public Input No. 174-NFPA 70E-2024 [Sections L.1, L.2]	
Public Input No. 173-NFPA 70E-2024 [Section No. 310.1]	
Public Input No. 174-NFPA 70E-2024 [Sections L.1, L.2]	

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Committee: EEW-AAA

Committee Statement

Resolution: Moving the informational note from its current position in 310.1 does not add additional clarity or readability for the user.

Public Input No. 103-NFPA 70E-2024 [Section No. 320.1]

320.1 Scope.

This article covers electrical safety requirements for the practical safeguarding of employees while working with exposed stationary storage batteries that exceed ~~100 volts, nominal, or exceed a short-circuit power of 1000 watts.~~ . one or more of the hazard thresholds listed in 320.3(A)(1) .

Informational Note: See the following documents for additional information on best practices for safely working on stationary batteries:

(1) NFPA 1, *Fire Code*, Chapter 52, Stationary Storage Battery Systems, 2021

(2) *NFPA 70*, *National Electrical Code*, Article 480, Storage Batteries, 2020

(3) IEEE 450, *IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications*, 2020

(4) IEEE 937, *Recommended Practice for Installation and Maintenance of Lead-Acid Batteries for Photovoltaic Systems*, 2019

(5) IEEE 1106, *IEEE Recommended Practice for Installation, Maintenance, Testing, and Replacement of Vented Nickel-Cadmium Batteries for Stationary Applications*, 2005 (R 2011)

(6) IEEE 1184, *IEEE Guide for Batteries for Uninterruptible Power Supply Systems*, 2015

(7) IEEE 1188, *IEEE Recommended Practice for Maintenance, Testing, and Replacement of Valve-Regulated Lead-Acid (VRLA) Batteries for Stationary Applications*, 1188a-2014

(8) IEEE 1657, *Recommended Practice for Personnel Qualifications for Installation and Maintenance of Stationary Batteries,* 2018

(9) OSHA 29 CFR 1910.305(j)(7), “Storage batteries”

(10) OSHA 29 CFR 1926.441, “Batteries and battery charging”

(11) DHHS (NIOSH) Publication No. 94-110, *Applications Manual for the Revised NIOSH Lifting Equation,* 1994

(12) IEEE/ASHRAE 1635, *Guide for the Ventilation and Thermal Management of Batteries for Stationary Applications*, 2018

(13) NFPA 855, *Standard for the Installation of Stationary Energy Storage Systems*, 2020

(14) UL 9540, *Energy Storage Systems and Equipment*, 2020

(15) UL 9540A, *Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems*, 2019

Statement of Problem and Substantiation for Public Input

The goal of this change is to make it clear that the requirements of this section apply to batteries below 100 V dc, if their short circuit power exceeds 1000W.

This public input is a combined effort from the Energy Facility Contractors Group (EFCOG), a working group of electrical safety professionals at Department of Energy National Labs, and the IEEE PES Energy Storage and Stationary Battery (ESSB) committee’s safety codes working group, a group of stationary battery and energy storage industry professionals.

Submitter Information Verification

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Submittal Date:	Fri May 31 11:20:12 EDT 2024
Committee:	EEW-AAA

Committee Statement

Resolution: FR-81-NFPA 70E-2024

Statement: The change improves the intent and ensures the scope covers all hazards as outlined in the hazard thresholds of the article.

This adds a reference to an informative UL standard related to an existing reference and update the reference dates.

Public Input No. 122-NFPA 70E-2024 [Section No. 320.1]

320.1 Scope.

This article covers electrical safety requirements for the practical safeguarding of employees while working with exposed stationary storage batteries that exceed 100 volts, nominal, or exceed a short-circuit power of 1000 watts.

Informational Note: See the following documents for additional information on best practices for safely working on stationary batteries:

(1) NFPA 1, *Fire Code*, Chapter 52, Stationary Storage Battery Systems, 2021

(2) *NFPA 70*, *National Electrical Code*, Article 480, Storage Batteries, 2020

(3) IEEE 450, *IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications*, 2020

(4) IEEE 937, *Recommended Practice for Installation and Maintenance of Lead-Acid Batteries for Photovoltaic Systems*, 2019

(5) IEEE 1106, *IEEE Recommended Practice for Installation, Maintenance, Testing, and Replacement of Vented Nickel-Cadmium Batteries for Stationary Applications*, 2005 (R 2011)

(6) IEEE 1184, *IEEE Guide for Batteries for Uninterruptible Power Supply Systems*, 2015

(7) IEEE 1188, *IEEE Recommended Practice for Maintenance, Testing, and Replacement of Valve-Regulated Lead-Acid (VRLA) Batteries for Stationary Applications*, 1188a-2014

(8) IEEE 1657, *Recommended Practice for Personnel Qualifications for Installation and Maintenance of Stationary Batteries,* 2018

(9) OSHA 29 CFR 1910.305(j)(7), “Storage batteries”

(10) OSHA 29 CFR 1926.441, “Batteries and battery charging”

(11) DHHS (NIOSH) Publication No. 94-110, *Applications Manual for the Revised NIOSH Lifting Equation,* 1994

(12) IEEE/ASHRAE 1635, *Guide for the Ventilation and Thermal Management of Batteries for Stationary Applications*, 2018

(13) NFPA 855, *Standard for the Installation of Stationary Energy Storage Systems*, 2020

(14) ANSI/CAN/ UL 9540, *Energy Storage Systems and Equipment*, ~~2020~~ 2023

(15) UL 9540A, *Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems*, 2019

(16) UL 9540B Outline of Investigation for Large Scale Fire Test for Residential Battery Energy Storage Systems, 2024.

Statement of Problem and Substantiation for Public Input

Update UL scope references to most current editions and add UL 9540B to fill an additional test requirement for large residential ESS.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 123-NFPA 70E-2024 [Section No. A.3.9]	

Submitter Information Verification

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Submittal Date: Sat Jun 01 12:27:54 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-81-NFPA 70E-2024

Statement: The change improves the intent and ensures the scope covers all hazards as outlined in the hazard thresholds of the article.

This adds a reference to an informative UL standard related to an existing reference and update the reference dates.

Public Input No. 139-NFPA 70E-2024 [Section No. 320.1]

320.1 Scope.

This article covers electrical safety requirements for the practical safeguarding of employees while working with exposed stationary or portable storage batteries that exceed 100 volts, nominal, or exceed a short-circuit power of 1000 watts.

Informational Note: See the following documents for additional information on best practices for safely working on stationary batteries:

(1) NFPA 1, *Fire Code*, Chapter 52, Stationary Storage Battery Systems, 2021

(2) *NFPA 70*, *National Electrical Code*, Article 480, Storage Batteries, 2020

(3) IEEE 450, *IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications*, 2020

(4) IEEE 937, *Recommended Practice for Installation and Maintenance of Lead-Acid Batteries for Photovoltaic Systems*, 2019

(5) IEEE 1106, *IEEE Recommended Practice for Installation, Maintenance, Testing, and Replacement of Vented Nickel-Cadmium Batteries for Stationary Applications*, 2005 (R 2011)

(6) IEEE 1184, *IEEE Guide for Batteries for Uninterruptible Power Supply Systems*, 2015

(7) IEEE 1188, *IEEE Recommended Practice for Maintenance, Testing, and Replacement of Valve-Regulated Lead-Acid (VRLA) Batteries for Stationary Applications*, 1188a-2014

(8) IEEE 1657, *Recommended Practice for Personnel Qualifications for Installation and Maintenance of Stationary Batteries,* 2018

(9) OSHA 29 CFR 1910.305(j)(7), “Storage batteries”

(10) OSHA 29 CFR 1926.441, “Batteries and battery charging”

(11) DHHS (NIOSH) Publication No. 94-110, *Applications Manual for the Revised NIOSH Lifting Equation,* 1994

(12) IEEE/ASHRAE 1635, *Guide for the Ventilation and Thermal Management of Batteries for Stationary Applications*, 2018

(13) NFPA 855, *Standard for the Installation of Stationary Energy Storage Systems*, 2020

(14) UL 9540, *Energy Storage Systems and Equipment*, 2020

(15) UL 9540A, *Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems*, 2019

Statement of Problem and Substantiation for Public Input

NFPA 70E needs to address the hazards of Electric Vehicle Batteries and their associated assembly processes.

Submitter Information Verification

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Committee: EEW-AAA

Committee Statement

Resolution: The committee reaffirms that Article 320 covers exposed stationary batteries. Adding portable batteries to the scope of the article has not been adequately substantiated to demonstrate that all the requirements in Article 320 are applicable to portable batteries.

Public Input No. 114-NFPA 70E-2024 [New Section after 320.3]

Establishing a Lower Risk Work Condition in Batteries

(A) General

Each employer whose employees perform work on batteries shall establish, document, and implement a battery hazardous energy control program. The battery hazardous energy control program shall specify procedures to safeguard workers from exposure to battery electrical hazards. Employees performing work within the restricted approach boundary of a battery shall plan work to minimize exposure to shock and arc flash hazards. Employees performing battery circuit manipulation shall plan work through a sectionalizing procedure or other risk reduction methods.

Exception 1: Work within the restricted approach boundary of an installed battery charger shall not be considered battery circuit manipulation.

Informational note No. 1: Work within the restricted approach boundary of an installed battery charger is more appropreatly controlled through complex lockout/tagout according to 120.5(A)(5) as it can be deenergized and an electrically safe work condision can be established.

Exception 2: A sectionalizing procedure is not required for batteries below 100 volts dc or 40 milliamperes.

Informational note No 2: Battery circuit manipulation is a category of work tasks in battery systems that involves bolting, unbolting, connecting, disconnecting, or otherwise increasing or decreasing the series or parallel combination of cells that make up a battery. This may or may not involve work within the limited or restricted approach boundary. Battery circuit manipulation is normally performed only a few times in the equipment lifecycle of a battery during installation and assembly, maintenance involving the replacement of cells, refurbishment, or decommissioning and removal.

(B) Battery Sectionalizing Principles

Each person who could be exposed directly or indirectly to a battery electrical hazard shall be involved in the sectionalizing procedure. The battery charger shall either be placed into bypass mode or turned off, deenergized, and locked out prior to sectionalizing the battery. The battery shall be disconnected from any electrical load it serves prior to sectionalizing the battery. Control devices, such as push buttons or selector switches, shall not be used as the primary isolating device for the charger. A sectionalizing procedure shall be developed based on the existing battery system and shall use suitable documentation including up-to-date drawings and diagrams. The disconnecting means, which may include bus bars or other circuit elements not uniquely or readily identifiable as a lockout/tagout device, shall be identified in the sectionalizing procedure. Two forms of hazardous energy control shall be permitted in battery systems: simple sectionalizing and complex sectionalizing. For simple sectionalizing, the qualified person shall be in charge. For complex sectionalizing, the person in charge shall have overall responsibility.

(C) Battery Sectionalizing Equipment

Battery sectionalizing equipment shall meet the requirements of lockout/tagout equipment specified in 120.4 with the following addition. Removal or disconnection of non-unique intercell busbars, wires, or other circuit elements are permitted for use as lockout devices in battery systems if the following conditions are met:

(1) The circuit elements are identified in the sectionalizing procedure.

(2) The visibility of the circuit element's presence or absent in the circuit is unobstructed.

(3) Once removed, the circuit elements are, individually or in groups, secured against reinstallation and tagged with REMOVED FOR SECTIONALIZING.

(4) Any similar circuit elements in the work area have been identified and either removed or secured against reinstallation and marked DO NOT USE.

Informational note 1: Locked cabinets or boxes and nylon cable ties are commonly used to secure non-unique circuit elements against reinstallation and to attach the appropriate tag.

Informational note 2: It is best practice to mark or tag both sides of a circuit element before removal or disconnection to ensure that it is reinstalled properly after completion of work.

(D) Battery Sectionalizing Procedure

The employer shall maintain a copy of battery sectionalizing procedures required by this section and shall make the procedures available to all employees.

(1) General.

The sectionalizing procedure shall require planning, including the requirements of 320.4 (D)(1) through 320.4 (E)(4). Up-to-date battery circuit drawings shall be considered a primary reference source for identifying circuit elements to remove or disconnect in the sectionalizing procedure to reduce shock and arc flash hazard. When up-to-date battery circuit drawings are not available the employer shall be responsible for ensuring that an equally effective means of identifying circuit elements is employed. The plan shall identify persons who might be exposed to an electrical hazard and the PPE required during the execution of the job or task. The plan shall identify the person in charge and their responsibility in the sectionalizing procedure. The sectionalizing procedure shall identify the means and order that battery circuit connections or disconnections are to be made and any resulting changes in the following:

(1) DC voltage,

(2) Available short circuit power,

(3) Limited approach boundary,

(4) Restricted approach boundary,

(5) Shock PPE,

(6) Arc flash incident energy,

(7) Arc flash boundary, and

(8) Arc flash PPE.

(2) Simple Battery Sectionalizing Procedure. A battery sectionalizing procedure that involves only a qualified person(s) sectionalizing a single battery with a single charger for the sole purpose of safeguarding employees from exposure to battery electrical hazards shall be considered to be a simple battery sectionalizing procedure. Simple battery sectionalizing procedures shall not be required to be written for each application. Each worker shall be responsible for their own battery sectionalizing procedure.

(3) Complex Battery Sectionalizing Procedure.

(a) A complex battery sectionalizing procedure shall be permitted where one or more of the following exists:

(1) Any electrical work on a battery and its charger (non-battery electrical work covered by traditional LOTO),

(2) Multiple battery strings connected in parallel,

(3) Multiple battery chargers connected in parallel,

(4) Multiple single-string batteries with chargers located near each other,

(5) Multiple energy sources (excluding the battery),

(6) Multiple crews,

(7) Multiple crafts,

(8) Multiple locations,

(9) Multiple employers,

(10) Multiple disconnecting means,

(11) Multiple sequences, or

(12) Job or task that requires more than one work period.

(b) All complex sectionalizing procedures shall require a written plan of execution that identifies the person in charge.

(c) The complex sectionalizing procedure shall vest primary responsibility in an authorized employee for employees working under the protection of a group lockout or tagout device such as an operation lock or lockbox. The person in charge shall be held accountable for safe execution of the complex sectionalizing procedure.

(d) Each authorized employee shall affix a personal lock-out or tagout device to the group lockout device, group lockbox, or comparable mechanism when he or she begins work and shall remove those devices when he or she stops working on the battery being serviced or maintained.

(e) Al complex sectionalizing plans shall identify the method to account for all persons who might be exposed to electrical hazards in the course of the sectionalizing.

(E) Elements of Control

(1) General. The procedure shall not de-energize the batteries. The procedure shall not release the energy stored in the batteries. The procedure shall not require that the batteries be operated (charged or discharged) prior to or after sectionalizing.

> Exception 1: If the job or task involves one or more battery cells being removed for shipping, recycling, refurbishment, storage, or similar activity then the procedure may require that batteries be operated (charged or discharged) to achieve the state-of-charge required for such activities prior to sectionalizing.
>
> Informational Note 1: Discharging or disassembling batteries to a 'de-energized' state can be damaging to the battery, hazardous to the worker, or both.
>
> Informational Note 2: Batteries are commonly required to be at a partial state-of-charge during shipping to reduce their potential fire hazard if damaged or short-circuited.

(2) Testing. Testing for absence of voltage is not required to establish a lower risk work condition in batteries.

> Exception: Testing for absence of voltage per 120.4(B)(6) is required for all energy sources in the working area other than batteries including where the shock risk assessment has identified the potential for a hazardous ac voltage from the battery circuit to the bonded enclosure.
>
> Informational note 1: Batteries will retain voltage after sectionalizing. However, the voltage that a worker is exposed to, and risk of electrical injury will be substantially reduced.
>
> Informational note 2: Voltage and resistance testing with an appropriately rated meter can be helpful in double checking that the battery circuit is in the expected configuration at a given stage of sectionalizing.

(3) Process for Establishing and Verifying a Lower Risk Work Condition in Batteries. Establishing and verifying a lower risk work condition in batteries shall include all of the following steps, which shall be performed in the order presented, if feasible:

(1) Determine the number, configuration, and voltage of batteries in series and parallel, and the number, configuration, and voltage of battery chargers. Determine if there are any batteries or chargers nearby that could be confused for the battery being worked on. Check applicable up-to-date drawings, diagrams, and identification tags.

(2) Isolate the battery bank from all loads and sources.

> Informational note: this may include placing battery chargers in bypass mode.

(1) Where possible, visually verify that all blades of the disconnecting devices are fully open or that drawout type circuit breakers are withdrawn to the test or fully disconnected position.

(2) Apply lockout/tagout devices to the battery charger disconnection means.

(3) Sectionalize the battery in accordance with a documented and established procedure.

(4) When required by 320.4(E)(2), verify the absence of voltage with an adequately rated portable meter.

(4) Release for Return to Service.

The procedure shall identify steps to be taken when the job or task requiring battery sectionalizing is completed. The procedure shall identify any wires or flexible circuit elements that could be reinstalled improperly resulting in a battery short circuit. Reinstallation of these circuit elements shall be identified in the procedure as having an elevated risk of short circuit. When returning a battery to service, employees shall wear the identified PPE prior to making any circuit connection that increases the level of shock, thermal, or arc flash hazard.

Statement of Problem and Substantiation for Public Input

The requirements for Establishing an Electrically Safe Work Condition in Article 120 are designed primarily for electricians installing and modifying ac/dc power circuits. Electrical LOTO requires a worker to establish an electrically safe work condition by isolating equipment from its energy source and locking the point of isolation to prevent unexpected energization. It then requires a worker to test the circuit to verify zero energy within the work area before starting work. These requirements are based on sound and robust principles of electrical safety to eliminate or reduce the hazard as much as possible before work. Batteries, however, are their own sources of electrical energy and cannot be deenergized like ac/dc power circuits. The requirements of LOTO are not directly applicable to battery systems as they are always energized.

The principles of hazardous energy control on which LOTO programs are built can be applied to batteries. Instead of establishing an electrically safe work condition, a worker can perform a battery sectionalizing procedure and establish a lower risk working condition. Instead of verifying zero energy, all electrical work on batteries is energized electrical work that is controlled based on the magnitude and type of risk. Therefore, sectionalizing a battery into lower voltage, lower energy, segments can almost entirely eliminate the shock and arc flash hazards, and substantially reduce the thermal hazards of a large battery system. The remaining hazards can be controlled through basic PPE such as insulated tools, safety glasses, and leather gloves.

The principles of battery sectionalizing are presented in [1].

[1] D. M. Rosewater, "Reducing Risk When Performing Energized Work on Batteries," in IEEE Transactions on Industry Applications, vol. 60, no. 2, pp. 2732-2741, March-April 2024, doi: 10.1109/TIA.2023.3332828.
This reference is open access and available online: https://ieeexplore.ieee.org/document/10316636

This public input is a combined effort from the Energy Facility Contractors Group (EFCOG), a working group of electrical safety professionals at Department of Energy National Labs, and the IEEE PES Energy Storage and Stationary Battery (ESSB) committee's safety codes working group, a group of stationary battery and energy storage industry professionals.

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Submittal Date: Fri May 31 13:58:44 EDT 2024

Committee: EEW-AAA

Committee Statement

Resolution: FR-91-NFPA 70E-2024

Statement: The requirements in Article 120 to establish an electrically safe work condition are designed to reduce the risk when installing and modifying ac/dc power circuits. Electrical LOTO requires a worker to establish an electrically safe work condition by isolating equipment from its source of electric supply and locking the point of isolation to prevent unexpected energization. Batteries, however, are their own sources of electrical energy and cannot be deenergized like ac/dc power circuits. The requirements of LOTO are not directly applicable to battery systems as they are always energized. The principles of hazardous energy control on which LOTO programs are built can be applied to batteries requiring a worker to perform a battery sectionalizing procedure and establish a lower risk working condition. Sectionalizing a battery into lower voltage, lower energy, segments can substantially reduce contact thermal, electric shock, and arc flash hazards.

First and/or second level subdivision titles were added to comply with the NEC Style Manual.

Public Input No. 104-NFPA 70E-2024 [Section No. 320.3(A)(1)]

(1) Electrical Hazard Thresholds.

Exposure levels shall not exceed those identified in the following list unless appropriate controls are implemented:

(1) AC: 50 volts and 5 milliamperes

(2) DC: 100 volts and 40 milliamperes

(3) Thermal: 1000 watts short-circuit power

Informational Note No. 1: Available short-circuit power is calculated by multiplying the battery's nominal voltage by its available short-circuit current at the battery terminals then dividing the result by ~~two~~ four .

Informational Note 2: See Department of Energy, *DOE Electrical Safety Handbook*, DOE-HDBK-1092, for electrical hazard thresholds.

Statement of Problem and Substantiation for Public Input

The above formula for maximum power calculates the power generated by the battery, not consumed by a load. The thermal hazard threshold should be based on the maximum power that could be consumed by a short-circuit load and turned into heat. According to the Maximum Power Transfer Theorem, the maximum power that can be transferred to a load resistor occurs when the load resistance exactly matches the source resistance. That means half of the power generated by the battery is used up by the internal resistance of the battery and so does not pose a hazard to the worker. The formula for how much power is dissipated in the load resistor is Pmax = V^2 / (4 Rload) = V * I / 4. The following links provide basic electronics tutorials on the Maximum Power Transfer Theorem.

https://www.electronics-tutorial.net/dccircuits/maximum-power-transfer-theorem/
https://info.triadmagnetics.com/blog/maximum-power-theorem
Atkin, Keith (2013-08-22). "Energy transfer and a recurring mathematical function". Physics Education. 48 (5): 616–620. doi:10.1088/0031-9120/48/5/616. ISSN 0031-9120. S2CID 122189586.

This public input is a combined effort from the Energy Facility Contractors Group (EFCOG), a working group of electrical safety professionals at Department of Energy National Labs, and the IEEE PES Energy Storage and Stationary Battery (ESSB) committee's safety codes working group, a group of stationary battery and energy storage industry professionals.

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Submittal Date: Fri May 31 11:34:56 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-82-NFPA 70E-2024

Statement: The formula for maximum power calculates the power generated by the battery, not consumed by a load. The contact thermal hazard threshold should be based on the maximum power that could be consumed by a short-circuit load and turned into heat. According to the Maximum Power Transfer Theorem, the maximum power that can be transferred to a load resistor occurs when the load resistance exactly matches the source resistance. That means half of the power generated by the battery is used up by the internal resistance of the battery and so does not pose a hazard to the worker. The formula for how much power is dissipated into the load resistor is Pmax = V^2 / (4 Rload) = V * I / 4.

Public Input No. 140-NFPA 70E-2024 [Section No. 320.3(A)(1)]

(1) Electrical Hazard Thresholds.

Exposure levels shall not exceed those identified in the following list unless appropriate controls are implemented:

(1) AC: 50 volts and 5 milliamperes

(2) DC: ~~100 volts and 40 milliamperes~~ 50 volts

(3) Thermal: 1000 watts short-circuit power

Informational Note No. 1: Available short-circuit power is calculated by multiplying the battery's nominal voltage by its available short-circuit current at the battery terminals then dividing the result by two.

Informational Note 2: See Department of Energy, *DOE Electrical Safety Handbook*, DOE-HDBK-1092, for electrical hazard thresholds.

Statement of Problem and Substantiation for Public Input

Align the DC threshold with OSHA to 50 volts.

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Submittal Date: Mon Jun 03 09:23:05 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: The substantiation does not supersede the research data supporting the established threshold.

Public Input No. 242-NFPA 70E-2024 [Section No. 320.3(A)(1)]

(1) Electrical Hazard Thresholds.

Exposure levels shall not exceed those identified in the following list unless appropriate controls are implemented:

(1) AC: 50 volts and 5 milliamperes

(2) DC: 100 volts and 40 milliamperes

(3) Thermal: 1000 watts short-circuit power for workers wearing jewelry or using small tools, 10 kW for work with large tools or other conductive objects that can bridge terminals to create a short circuit through the tool.

Informational Note No. 1: Available short-circuit power is calculated by multiplying the battery's nominal voltage by its available short-circuit current at the battery terminals then dividing the result by two.

Informational Note 2: See Department of Energy, *DOE Electrical Safety Handbook*, DOE-HDBK-1092, for electrical hazard thresholds.

Statement of Problem and Substantiation for Public Input

The 1000 W thermal hazard threshold was developed assuming a metal object the size of a ring were to contact and bridge low voltage (< 50 V ac, < 100 V dc) and cause a 2nd degree thermal burn on the hand. This was deemed low by many and the simple requirement was to not wear jewelry.
The next threshold, 10 kW is the limit for more robust tools that might be used on battery systems, such as wrenches, sockets, etc. Any work above 10 kV requires special "battery" tools and/or wearing leather gloves.

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Submittal Date: Tue Jun 04 14:28:56 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: The proposed revision is too specific to be useful or enforceable.

Public Input No. 108-NFPA 70E-2024 [New Section after 320.3(A)(2)]

Battery Electric Shock Risk Assessment

(A) **Estimate of Likelihood and Severity.**

The estimate of likelihood of occurrence of injury or damage to health and the potential severity of injury or damage to health from battery shock hazards shall take into consideration all the following:

(1) The dc voltage to which personnel will be exposed.

(2) The design of the equipment including the spacing separation of exposed electrical conductors.

(3) The potential for hazardous ac voltage on the battery enclosure or rack.

(4) The equipment operating condition and the condition of maintenance.

(B) **Additional Protective Measures**

If additional protective measures are required, they shall be selected and implemented according to the hierarchy of risk controls identified in 110.3(H)(3). If protective measures include the use of shock protection PPE, they shall be selected so as not to conflict with PPE requirements for chemical hazards. Boundary requirements established in 130.4 shall apply when personnel approach exposed energized electrical conductors or circuit parts operating at not less than 100 volts and 40 milliamperes between battery terminals or between a single terminal and a grounded surface.

Statement of Problem and Substantiation for Public Input

Electric shock risk assessment is different enough in battery systems for additional requirements to apply (see ref [1] below). First, physical separation of exposed conductors is critical to understanding where a shock hazard is present in battery systems. The existing requirements in 130.4 do not account for reduced risk of shock when the positive and negative voltages of a battery are separated farther than can be reached by a worker. Second, the potential for a hazardous ac voltage from the battery circuit to the bonded enclosure due to the absence of an isolation transformer is becoming more common due to the cost and losses of isolation transformers. The existing requirements in 130.4 identify a circuit as either ac or dc and so a mixed signal hazard is often missed in risk assessments.

These changes point to the hierarchy of risk controls to control shock hazard with additional protective measures. Lastly, the final sentence modifies the requirements in 130.4 to make it clear when the shock hazard boundaries are defined in batteries. Currently, is it well understood that 100 V and 40 milliamperes is the shock hazard threshold for batteries, where the LAB, RAB, and PPE requirements are defined in 130.4. However, some have interpreted the scope of 320 to indicate that its modification to 130 only starts applying to batteries above 100 volts, leaving shock hazard analysis for batteries between 50 volts and 100 volts unmodified. This is confusing and has led to inconsistent safety requirements. The proposed sentence clarifies the requirements of the existing code.

[1] D. M. Rosewater, "Reducing Risk When Performing Energized Work on Batteries," in IEEE Transactions on Industry Applications, vol. 60, no. 2, pp. 2732-2741, March-April 2024, doi: 10.1109/TIA.2023.3332828.
Reference is open access and available online: https://ieeexplore.ieee.org/document/10316636/

This public input is a combined effort from the Energy Facility Contractors Group (EFCOG), a working group of electrical safety professionals at Department of Energy National Labs, and the IEEE PES

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Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 112-NFPA 70E-2024 [Sections 320.3(B), 320.3(C)]	Reorganized content into battery risk assessment
Public Input No. 112-NFPA 70E-2024 [Sections 320.3(B), 320.3(C)]	

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Submittal Date:	Fri May 31 12:29:21 EDT 2024
Committee:	EEW-AAA

Committee Statement

Resolution: FR-86-NFPA 70E-2024

Statement: Electric shock risk assessment is different enough in battery systems from general dc sources for additional requirements to apply. The existing requirements in 130.4 do not account for reduced risk of shock when the positive and negative voltages of a battery are separated farther than can be reached by a worker. The existing requirements in 130.4 identify a circuit only as either ac or dc and so unique conditions applicable to batteries are often overlooked shock risk assessments.

Public Input No. 109-NFPA 70E-2024 [New Section after 320.3(A)(2)]

Battery Thermal Risk Assessment

(A) **Estimate of Likelihood and Severity.**

The estimate of likelihood of occurrence of injury or damage to health and the potential severity of injury or damage to health from thermal hazards shall take into consideration all the following:

(1) The available short circuit power to which personnel will be exposed.

(2) The work task and tools.

Informational note No. 1: Assembling a battery string or returning a battery to service commonly involves manipulating wires or flexible circuit elements that could be installed improperly resulting in a battery short circuit.

Informational note No. 2: Electrical measurements with undamaged, insulated probes, and specific-gravity measurements on the electrolyte have a low liklyhood of resulting in a short circuit.

(1) The design of the equipment including the spacing of exposed electrical conductors in relation to length of potential shorting materials used in the task .

(2) The equipment operating condition and the condition of maintenance.

(B) **Additional Protective Measures**

If additional protective measures are required, they shall be selected and implemented according to the hierarchy of risk controls identified in 110.3(H)(3). When the additional protective measures include the use of PPE, the following shall be determined and made available to the employee:

(1) Proper hand protection based on performance characteristics relative to the task, conditions present, duration of use, and available short-circuit power of the battery. . If hand protection required by the shock risk assessment and arc flash risk assessment is adequate for thermal hazard protection

(2) Proper eye protection which may include safety glasses or face shield.

(3) Tools equipped with handles rated for the voltage on which they are used in accordance with 130.7(D)(1). The length of tools for work on batteries shall be selected to minimize the likelihood of short circuit.

(4) Employees shall keep battery terminals and all electrical conductors clear of unintended contact with tools, test equipment, liquid containers, and other foreign objects.

Statement of Problem and Substantiation for Public Input

Burns on the hands from accidentally short circuiting a battery is the most common electrical injury associated with batteries. Article 320.3(A)(1) specifies the thermal hazard threshold is 1000 watts short-circuit power. However, the code does not specify any thermal PPE requirements. The proposed changes clarify the requirements for thermal risk assessment and PPE in batteries [1].

This also pulls in the eye protection requirements of 320.3(B)(2) Activities the do not include handling

of Electrolyte for a more logical organization of the whole section.

[1] D. M. Rosewater, "Reducing Risk When Performing Energized Work on Batteries," in IEEE Transactions on Industry Applications, vol. 60, no. 2, pp. 2732-2741, March-April 2024, doi: 10.1109/TIA.2023.3332828.
This reference is open access and available online: https://ieeexplore.ieee.org/document/10316636

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 112-NFPA 70E-2024 [Sections 320.3(B), 320.3(C)]	Reorganized content into battery risk assessment
Public Input No. 112-NFPA 70E-2024 [Sections 320.3(B), 320.3(C)]	

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Committee: EEW-AAA

Committee Statement

Resolution: FR-85-NFPA 70E-2024
Statement: The changes clarify the requirements for contact thermal risk assessment and PPE involving batteries currently missing from the Standard.

Public Input No. 110-NFPA 70E-2024 [New Section after 320.3(A)(2)]

Battery Arc Flash Risk Assessment

(A) **General**

An electric arc flash risk assessment shall be performed on stationary storage battery systems operating at 150 volts or more before a person interacts with the system in a matter likely to create an arc flash hazard. The requirements of 130.5 shall apply if it has been determined that the likelihood of an arc flash hazard exceeds an acceptable threshold.

(B) **Estimate of Likelihood and Severity.**

The estimate of likelihood of occurrence of injury or damage to health and the potential severity of injury or damage to health from battery arc flash hazards shall take into consideration all the following:

(1) The dc voltage and available fault current to which personnel will be exposed

(2) The work task

Informational note: See Table 130(C).

(1) The design of the battery including the separation distance of exposed electrical conductors, and any overcurrent protection devices and their operating times

Informational note: see Annex D

(1) The equipment operating condition and the condition of maintenance

(C) **Additional Protective Measures**

If additional protective measures are required, they shall be selected and implemented according to the hierarchy of risk controls identified in 110.3(H)(3). If protective measures include the use of arc flash PPE, the following shall be determined:

(1) The specific location of the gap where an arc could occur.

(2) The arc flash boundary

(3) The PPE to be used within the arc flash boundary

Statement of Problem and Substantiation for Public Input

Arc flash hazard analysis is different enough in battery systems for additional requirements to apply. In most facilities electrical equipment, the primary driver for separation distance between exposed electrical conductors is the dielectric strength of air. The large size of stationary batteries means that the separation of exposed conductors is a critical factor in considering exactly which gap within a battery system can sustain an electric arc. The proposed changes clarify how to perform an electric arc flash risk assessment in batteries. Accounting for separation distance is critical to understanding and controlling the hazard appropriately. The following peer reviewed journal article derived 1mm / V from the published minimum voltage of thousands of arc experiments over a range of arc gaps [1]. This rule, which is the subject of a PI for annex D, conservatively overestimates the experimental maximum arc gap in battery systems from 105 V to 520 V dc.

[1] D. M. Rosewater, "Reducing Risk When Performing Energized Work on Batteries," in IEEE

Transactions on Industry Applications, vol. 60, no. 2, pp. 2732-2741, March-April 2024, doi: 10.1109/TIA.2023.3332828.
This reference is open access and available online: https://ieeexplore.ieee.org/document/10316636

The following peer reviewed journal article concluded that “There is no exposure to an arc flash hazard resulting from working on ≤ 150 V dc systems” based on a meta-analysis of decades of published experimental data [2].

[2] L. B. Gordon, "Modeling the Dynamic Behavior of DC Arcs," in IEEE Transactions on Industry Applications, vol. 60, no. 1, pp. 1946-1955, Jan.-Feb. 2024, doi: 10.1109/TIA.2023.3311780.

The 150 volt threshold was accepted by the NFPA 70E committee in the 2024 edition through Table 130.7(C)(15)(b) stating in the committee report justifying why they accepted the change: “Recent test data indicates that the probability of sustaining an arc for 125-volt dc nominal systems is minimal for available fault currents less than 17,000 amps. Technical references support this change include, Kinectrics report referenced in Informative Annex D.5.2 and those listed in new informational Note No.3 ”

There is experimental analysis to support this conclusion [3].

[3] C. S. Weimann, R. J. Kerestes and B. M. Grainger, "Comparative Analysis of Experimental DC Arc Flash Results to Industry Estimation Methods," in IEEE Open Journal of Industry Applications, vol. 1, pp. 181-193, 2020, doi: 10.1109/OJIA.2020.3031768.

This public input is a combined effort from the Energy Facility Contractors Group (EFCOG), a working group of electrical safety professionals at Department of Energy National Labs, and the IEEE PES Energy Storage and Stationary Battery (ESSB) committee’s safety codes working group, a group of stationary battery and energy storage industry professionals.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 115-NFPA 70E-2024 [New Section after D.5.1]	Proposed rule that arc cannot be sustained above 1mm/volt separation and so has reduced risk.
Public Input No. 112-NFPA 70E-2024 [Sections 320.3(B), 320.3(C)]	Reorganized content into battery risk assessment
Public Input No. 112-NFPA 70E-2024 [Sections 320.3(B), 320.3(C)]	
Public Input No. 115-NFPA 70E-2024 [New Section after D.5.1]	

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Committee:	EEW-AAA

Committee Statement

Resolution: FR-87-NFPA 70E-2024

Statement: The changes clarify how to perform an electric arc flash risk assessment for work involving batteries. For example, accounting for separation distance is critical to understanding and controlling the hazard appropriately.

Public Input No. 113-NFPA 70E-2024 [New Section after 320.3(A)(2)]

Battery Chemical Risk Assessment

(A) **Estemate of Liklyhood and Severity**

The estimate of likelihood of occurrence of injury or damage to health and the potential severity of injury or damage to health from chemical hazards shall take into consideration all the following:

(1) The design of the equipment

(2) The safety data sheet of the battery and electrolyte

(3) The equipment operating condition and the condition of maintenance.

Informational Note: Many batteries are sealed, preventing the worker from exposure to chemical hazards of the electrolyte unless the battery has been damaged.

(B) **Additional Protective Measures**

If additional protective measures are required, they shall be selected and implemented according to the hierarchy of risk controls identified in 110.3(H)(3). When the additional protective measures include the use of PPE, the following shall be determined:

(1) Proper hand and eye/face protection based on performance characteristics relative to the task, conditions present, duration of use, and chemical hazards

(2) Gloves and aprons appropriate for the chemical hazards

(3) Portable or stationary eye wash facilities and equipment within the work area that are capable of drenching or flushing of the eyes and body for the duration necessary to mitigate injury from the chemical hazards.

Informational note No. 1: See ANSI/ISEA Z358.1, American National Standard for Emergency Eye Wash and Shower Equipment, for guidelines for the use and maintenance of eye wash facilities for vented batteries in nontelecom environments.

Informational note No. 2: Where electrolyte is pumped or otherwise stored above atmospheric pressure, including head pressure in large storage tanks, additional protective equipment for the head neck and arms may be required to protect employees.

Statement of Problem and Substantiation for Public Input

This section consolidates 320(B)(1) into the risk assessment section and includes review of the data necessary to identify required controls. The first informational note provides information that engineered controls may be available.
Informational note 2 identifies that the chemical PPE requirements for flow batteries may exceed those for non-flow batteries.

This public input is a combined effort from the Energy Facility Contractors Group (EFCOG), a working group of electrical safety professionals at Department of Energy National Labs, and the IEEE PES Energy Storage and Stationary Battery (ESSB) committee's safety codes working group, a group of stationary battery and energy storage industry professionals.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 112-NFPA 70E-2024 [Sections 320.3(B), 320.3(C)]	Reorganized content into battery risk assessment
Public Input No. 112-NFPA 70E-2024 [Sections 320.3(B), 320.3(C)]	

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Submittal Date: Fri May 31 13:40:35 EDT 2024

Committee: EEW-AAA

Committee Statement

Resolution: FR-84-NFPA 70E-2024

Statement: This section consolidates 320(B)(1) into the risk assessment section. The first informational note provides information that engineered controls may be available. Informational Note 2 identifies that the chemical PPE requirements for flow batteries may exceed those for non-flow batteries.

Public Input No. 105-NFPA 70E-2024 [Section No. 320.3(A)(2)]

(2) Battery Risk Assessment.

~~Prior~~
Prior to any work on a battery system,

~~a risk assessment shall be performed to identify the~~
a chemical, thermal, electrical shock, and arc flash

~~hazards and assess the risks associated with the type of tasks to be performed.Informational Note~~
risk assessment shall be performed and documented:

(1) To identify the hazards

(2) To estimate the likelihood of occurrence of injury or damage to health and potential severity of injury or damage to health

(3) To determine if additional protective measures are required, including the use of PPE.

Informational Note 1 : See Informative Annex F Figure F.7 for an example of a risk assessment method for work on batteries.

Informational Note 2: Batteries commonly have multiple electrical risk assessments based on the number of cells connected in series or parallel at the time when work is performed.

Statement of Problem and Substantiation for Public Input

The recommended changes to 320.3(A)(2) make the format consistent with 130.4 and 130.5 as well as adding the requirements to document the results for audit and enforceability purposes. Adding informational note 2 helps workers understand that to establish a lower risk working condition there are often intermediate steps where a worker is exposed to a lower and lower level of electrical risk. For example, one 800 V battery may be split into two 400 V strings, four 200 V strings, eight 100 V strings, or sixteen 50 V strings. Each configuration requires a different electrical risk assessment and different PPE to work on safely.

This public input is a combined effort from the Energy Facility Contractors Group (EFCOG), a working group of electrical safety professionals at Department of Energy National Labs, and the IEEE PES Energy Storage and Stationary Battery (ESSB) committee's safety codes working group, a group of stationary battery and energy storage industry professionals.

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Committee: EEW-AAA

Committee Statement

Resolution: FR-83-NFPA 70E-2024

Statement: The changes to 320.3(A)(2) make the format consistent with 130.4 and 130.5 as well as the NEC Style Manual and includes the requirement for documenting risk assessments not covered elsewhere. Adding informational note 2 reminds users that to establish a lower risk working condition there are often intermediate steps where a worker is exposed to a different level of electrical risk. For example, one 800 V battery may be split into two 400 V strings, four 200 V strings, eight 100 V strings, or sixteen 50 V strings. Each configuration requires a different electrical risk assessment and different PPE to work on safely.

Public Input No. 106-NFPA 70E-2024 [Section No. 320.3(A)(5)]

(5) ~~Abnormal Battery Conditions~~ Testing .

(1) Instrumentation that provides alarms for early warning of abnormal conditions of battery operation, if present, shall be tested annually.

(2) If practicable, ground-fault detectors and indicators installed in ungrounded or impedance grounded battery circuits exceeding 100 volts between conductors or to ground shall be tested annually or considered grounded for the purpose of the battery risk assessment.

Informational Note: See IEEE 1491, *Guide for the Selection and Use of Battery Monitoring Equipment in Stationary Applications*, for guidance on battery monitoring systems. Battery monitoring systems typically include alarms for such conditions as overvoltage, undervoltage, overcurrent, ground fault, and overtemperature. The type of conditions monitored will vary depending upon the battery technology.

Statement of Problem and Substantiation for Public Input

The requirements in this section are testing requirements, not requirements for how workers should act under abnormal battery conditions, so the heading 'Testing' is more appropriate.
Article 480.13 of the NEC permits the batteries above 100 V to operate in an ungrounded state so long as a ground-fault detector and indicator are installed. However, a regular testing requirement is needed if these devices are to be relied on for worker safety.

This public input is a combined effort from the Energy Facility Contractors Group (EFCOG), a working group of electrical safety professionals at Department of Energy National Labs, and the IEEE PES Energy Storage and Stationary Battery (ESSB) committee's safety codes working group, a group of stationary battery and energy storage industry professionals.

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Submittal Date:	Fri May 31 12:07:43 EDT 2024
Committee:	EEW-AAA

Committee Statement

Resolution: The proposal introduces maintenance requirements that are not covered in Article 320.

Public Input No. 107-NFPA 70E-2024 [Section No. 320.3(A)(6)]

(6) Warning Signs.

The following warning signs or labels shall be posted in appropriate locations:

(1) Electrical hazard warnings indicating the electric shock hazard~~- due to the battery voltage and the arc flash hazard due to the prospective short-circuit current, and the thermal hazard.~~ , arc flash hazard, and thermal hazard according to the results of the battery risk assessment in 320.3(A)(2).

Informational Note No.1: Because internal resistance, prospective short-circuit current, or both are not always provided on battery container labels or data sheets, and because many variables can be introduced into a battery layout, the battery manufacturer should be consulted for accurate data. Variables can include, but are not limited to, the following:

(1) Series connections

(2) Parallel connections

(3) Charging methodology

(4) Temperature

(5) Charge status

(6) Dc distribution cable size and length

(7) Grounding configuration of the battery

(8) The potential for hazardous ac voltage on the battery enclosure or rack

Informational Note No. 2: See 130.5(H) for requirements for equipment labeling.

(2) Chemical hazard warnings, applicable to the worst case when multiple battery types are installed in the same space, indicating the following:

(3) Potential presence of explosive gas (when applicable to the battery type)

(4) Prohibition of open flame and smoking

(5) Danger of chemical burns from the electrolyte (when applicable to the battery type)

(6) Notice for personnel to use and wear protective equipment and apparel appropriate to the hazard for the battery

(7) Notice prohibiting access to unauthorized personnel

Statement of Problem and Substantiation for Public Input

This change clarifies where the information for the labels is required to come from. Not just the battery voltage and available fault current but all electrical hazards identified in the risk assessment.

Battery ground configuration is critical to understanding where shock hazards are in battery systems. Including the grounding configuration in the label will help workers avoid electrical hazards.

Even if a battery is ungrounded on the DC bus, ac voltage can be present that could pose a shock hazard. Current requirements in the standard do not make it clear that this voltage could be hazardous.

This public input is a combined effort from the Energy Facility Contractors Group (EFCOG), a working

group of electrical safety professionals at Department of Energy National Labs, and the IEEE PES Energy Storage and Stationary Battery (ESSB) committee's safety codes working group, a group of stationary battery and energy storage industry professionals.

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Submittal Date:	Fri May 31 12:16:14 EDT 2024
Committee:	EEW-AAA

Committee Statement

Resolution: FR-88-NFPA 70E-2024

Statement: Information for the warning signs includes all electrical hazards identified in the risk assessments. Battery ground configuration is critical to understanding where shock hazards are in battery systems. Including the grounding configuration in the label will help workers avoid electrical hazards. Even if a battery is ungrounded on the DC bus, ac voltage can be present that could pose a shock hazard. Existing requirements in this article do not make it clear that this voltage could be hazardous.

Public Input No. 112-NFPA 70E-2024 [Sections 320.3(B), 320.3(C)]

~~**Sections 320.3(B), 320.3(C)**~~

~~**(B)** Electrolyte Hazards.~~

~~**(1)** Battery Activities That Include Handling of Liquid Electrolyte.~~

~~The following protective equipment shall be available to employees performing any type of service on a battery with liquid electrolyte:~~

(1) ~~Goggles and face shield appropriate for the electrical hazard and the chemical hazard~~

(2) ~~Gloves and aprons appropriate for the chemical hazards~~

(3) ~~Portable or stationary eye wash facilities and equipment within the work area that are capable of drenching or flushing of the eyes and body for the duration necessary to mitigate injury from the electrolyte hazard.~~

~~Informational Note: See ANSI/ISEA Z358.1, *American National Standard for Emergency Eye Wash and Shower Equipment* , for guidelines for the use and maintenance of eye wash facilities for vented batteries in nontelecom environments.~~

~~**(2)** Activities That Do Not Include Handling of Electrolyte.~~

~~Employees performing any activity not involving the handling of electrolyte shall wear safety glasses.~~

~~Informational Note: Battery maintenance activities usually do not involve handling electrolyte. Batteries that are hermetically sealed (such as most lithium batteries) or immobilized electrolyte (such as valve-regulated lead acid batteries) present little or no electrolyte hazard. Most modern density meters expose a worker to a quantity of electrolyte too minute to be considered hazardous, if at all. Such work would not be considered handling electrolyte. However, if specific gravity readings are taken using a bulb hydrometer, the risk of exposure is higher — this could be considered to be handling electrolyte, and the requirements of 320.3(B)(1) would apply.~~

~~**(C)** Tools and Equipment.~~

~~**(1)** Handles.~~

~~Tools and equipment for work on batteries shall be equipped with insulated handles rated for the voltage on which they are used in accordance with 130.7(D)(1) .~~

~~**(2)** Contact.~~

~~Battery terminals and all electrical conductors shall be kept clear of unintended contact with tools, test equipment, liquid containers, and other foreign objects. The length and insulation of tools for work on batteries shall be selected to minimize the likelihood of inadvertent contact.~~

~~**(3)** Nonsparking Tools.~~

~~Nonsparking tools shall be required when the risk assessment required by 110.3(H) justifies their use.~~

Statement of Problem and Substantiation for Public Input

The content of these sections should be consolidated into the battery risk assessment to follow the organizational structure in chapter 1.

The only content that does not appear in our other PIs is the requirement to use non-sparking tools where justified by the risk assessment. This requirement is based on the potential fire hazard of a poorly ventilated, flooded, lead acid battery system. However, a well ventilated battery room is not considered a classified environment and so non-sparking tools offer no additional protection to workers. Where non-sparking tools would offer any protection, the more appropriate control would be to eliminate the hazard by ventilating the space. The use of insulated tools is more important to protect workers from accidental short circuit.

This public input is a combined effort from the Energy Facility Contractors Group (EFCOG), a working group of electrical safety professionals at Department of Energy National Labs, and the IEEE PES Energy Storage and Stationary Battery (ESSB) committee's safety codes working group, a group of stationary battery and energy storage industry professionals.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 108-NFPA 70E-2024 [New Section after 320.3(A)(2)]	Reorganized content into battery risk assessment
Public Input No. 109-NFPA 70E-2024 [New Section after 320.3(A)(2)]	Reorganized content into battery risk assessment
Public Input No. 110-NFPA 70E-2024 [New Section after 320.3(A)(2)]	Reorganized content into battery risk assessment
Public Input No. 113-NFPA 70E-2024 [New Section after 320.3(A)(2)]	Reorganized content into battery risk assessment
Public Input No. 108-NFPA 70E-2024 [New Section after 320.3(A)(2)]	
Public Input No. 109-NFPA 70E-2024 [New Section after 320.3(A)(2)]	
Public Input No. 110-NFPA 70E-2024 [New Section after 320.3(A)(2)]	
Public Input No. 113-NFPA 70E-2024 [New Section after 320.3(A)(2)]	

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Committee: EEW-AAA

Committee Statement

Resolution: FR-89-NFPA 70E-2024

Statement: The content of Sections 320.3(B) and 320.3(C) are consolidated into the battery risk assessment to follow the organizational structure in Chapter 1. The requirement for non-sparking tools is eliminated since this requirement is based on the potential fire or explosion hazard in a poorly ventilated, flooded, lead acid battery system. The use of insulated tools is more important to protect workers from accidental short circuit.

Public Input No. 111-NFPA 70E-2024 [Section No. 320.3(D)]

~~(D) Cell Flame Arresters and Cell Ventilation.~~

~~When present, battery cell ventilation openings shall be unobstructed. Cell flame arresters shall be inspected for proper installation and unobstructed ventilation and shall be replaced when necessary in accordance with the manufacturer's instructions.~~

Statement of Problem and Substantiation for Public Input

This material provides battery maintenance requirements that are potentially in conflict with or redundant to 240.

This public input is a combined effort from the Energy Facility Contractors Group (EFCOG), a working group of electrical safety professionals at Department of Energy National Labs, and the IEEE PES Energy Storage and Stationary Battery (ESSB) committee's safety codes working group, a group of stationary battery and energy storage industry professionals.

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Committee:	EEW-AAA

Committee Statement

Resolution: FR-90-NFPA 70E-2024

Statement: This language is moved from 320.3(D) because it involves maintenance of batteries and belongs in Article 240.

Public Input No. 225-NFPA 70E-2024 [Article 330]

Article 330 Safety-Related Work Practices: Lasers

330.1 Scope.

This article covers safety-related work practices for maintaining lasers and their associated equipment.

Informational Note No. 1: See ANSI Z136.1, *Standard for Safe Use of Lasers* , for information on laser safety requirements for laser use.

Informational Note No. 2: See 21 CFR Part 1040, "Performance Standards for Light-Emitting Products," Sections 1040.10 "Laser products" and 1040.11, "Specific purpose laser products" for laser product requirements for laser manufacturers.

330.3 Electrical Hazard Thresholds.

Exposure levels shall not exceed those identified in the following list unless appropriate controls are implemented:

(1) AC: 50 volts and 5 milliamperes

(2) DC: 100 volts and 40 milliamperes

(3) Capacitor stored energy:

(4) Less than 100 volts and greater than 100 joules of stored energy

(5) Greater than or equal to 100 volts and greater than 1.0 joule of stored energy

(6) Greater than or equal to 400 volts and greater than 0.25 joule of stored energy

Informational Note No. 1: See Department of Energy, *DOE Electrical Safety Handbook* ; DOE-HDBK-1092, for information on electrical safety thresholds.

Informational Note No. 2: See 360.3 and Informative Annex R for information on capacitor hazards and controls.

330.4 Electrical Safety Training.

(A) Personnel to Be Trained.

Employers shall provide training for all personnel who work on or are near lasers or laser systems with user-accessible hazardous voltage, current, or stored energy (e.g., flashlamp-pumped lasers).

(B) Electrical Safety Training for Work on or with Lasers.

Training in electrical safe work practices shall include, but is not limited to, the following:

(1) Chapter 1 electrical safe work practices

(2) Electrical hazards associated with laser equipment

(3) Stored energy hazards, including capacitors and capacitor banks

(4) Ionizing radiation, including X-rays at voltages greater than 10 kV in a vacuum

(5) Assessing the listing status of electrical equipment and the need for field evaluation of nonlisted equipment

~~**330.5** Safeguarding of Persons from Electrical Hazards Associated with Lasers and Laser Systems.~~

~~**(A)** Temporary Guarding.~~

~~Temporary guarding (e.g., covers, protective insulating barriers) shall be used to limit exposure to any electrical hazard when the permanent laser enclosure covers are removed for maintenance and testing.~~

~~**(B)** Work Requiring an Electrically Safe Work Condition.~~

~~Work that might expose employees to electrical hazards shall be performed with the equipment in an electrically safe work condition in accordance with 120.2 , 120.3 , and 110.2(B) .~~

~~**(C)** Energized Electrical Testing.~~

~~Energized electrical testing, troubleshooting, and voltage testing shall not require an energized work permit in accordance with 130.2(C) .~~

~~**(D)** Warning Signs and Labels.~~

~~Electrical safety warning signs and labels shall be posted as applicable on electrical equipment doors, covers, and protective barriers. The warning signs and labels shall adequately warn of the hazard using effective words, colors, and symbols. These signs and labels shall be permanently affixed to the equipment and shall be of sufficient durability to withstand the environment involved.~~

~~**(E)** Listing.~~

~~Laser system electrical equipment with the potential to expose workers to electrical hazards shall be listed or field evaluated prior to use.~~

~~**330.6** Responsibility for Electrical Safety.~~

~~All persons with access to hazardous voltage, current, or stored energy shall be responsible for the following:~~

(1) ~~Obtaining authorization for work with or on hazardous electrical equipment in lasers and laser systems~~

(2) ~~Use of Chapter 1 safety-related work practices~~

(3) ~~Reporting laser equipment failures, accidents, inadequate barriers, and inadequate signage to the employer~~

Statement of Problem and Substantiation for Public Input

Article 330 was added to NFPA 70E in 2000. At that time, there was no material in NFPA 70E that covered such special equipment. Article 330 - Lasers, and Article 340 - Power Electronics were created to cover a small portion of special equipment. Not covered were induction furnaces, dielectric heating, accelerators, capacitor banks, radiation generating devices, magnaforming equipment, discharge machining, impulse generators, radar, magnetic field generation, plasma generators, tesla coils, rf impulse generators, microwave generators, isotope separation, and so on. Lasers and Power Electronics are just two of dozens or hundreds of specialty equipment with unique hazards. However, all of this special equipment has in common the electrical hazards: ac power in, dc, capacitors, subrf, and rf.
Since these two articles were added to 70E, the following improvements have been made:
2009 - Article 350 to cover the special equipment in R&D laboratories
2012 - DC shock and arc flash
2021 - Capacitor hazards and safety, Article 360 and Annex R
2024 - added thermal hazards for high current/low voltage, and update all subrf and rf shock thresholds.

All electrical hazards found in lasers, including ac input power, dc, and capacitors are now covered in 70E. The hazards of lasers and all of the other special equipment is now covered in NFPA 70E.

Looking at each element of Article 330:

330.1 Scope - There are no unique electrical safety-related work practices for maintaining lasers that are not covered in the rest of NFPA 70E.
330.3 Electrical Hazard Thresholds - are identical to those covered throughout 70E, including ac, dc, and capacitor thresholds.
330.4 All electrical hazards in lasers are covered by the current NFPA 70E, elsewhere.
The ONLY unique training is for ionizing radiation. However, ionizing radiation (e.g., x-rays generated by electrical equipment) is found in a myriad of special equipment, including accelerators, isotope separation, radiation generating devices, impulse generators, radar, plasma generation, tesla coils, rf impulse generators, microwave generators, etc.
A PI will be submitted to cover training requirements for ionizing radiation for ALL special equipment. It is not unique to lasers.
330.5 Safeguarding of Persons from Electric Hazards Associated with Lasers and Laser Systems.
(A) Temporary Guarding - covered in Chapter 1, for ac, dc, and capacitors
(B) Work Requiring an Electrically Safe Work Condition - covered in Chapters 1 and Article 360 for ac, dc, and capacitors.
(C) Energized Electrical Testing excluding an EEWP - covered in Chapter 1 for ac, dc, and capacitors
(D) Warning Signs and Labels - covered in Chapter 1
(E) Listing - covered in Chapter 3, for all Special Equipment
330.6 Responsibility for Electrical Safety - obtaining authorization to work, reporting equipment failure and abnormal conditions - All covered in Chapter 1.

There is NO new requirements found in Article 330 - Safety-Related Work Practices: Lasers, that is not covered in Chapter 1 and Article 360.

Thus, the proposal is to eliminate Article 330.

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Submittal Date: Tue Jun 04 08:14:42 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-92-NFPA 70E-2024
Statement: There are no specific hazards or requirements in this article that are not already covered in other articles.

Public Input No. 231-NFPA 70E-2024 [Article 340]

~~**Article 340** Safety-Related Work Practices: Power Electronic Equipment~~ Article 340 Electrical Hazards 1 Hz to 110 MHz (not including 50/60 Hz)

340.1 Scope.

This article covers the hazards and safety-related work practices ~~around power electronic equipment, including the following~~ for equipment that includes ac waveforms from 1 Hz to 3 kHz (sub RF) and 3 kHz to 110 MHz (RF). It does not cover power frequencies of 50/60 Hz. Typical equipment includes (not all inclusive) :

(1) Electric arc welding equipment

(2) High-power radio, radar, and television transmitting towers and antennas

(3) Industrial dielectric and radio frequency (RF) induction heaters

(4) Shortwave or RF diathermy devices

(5) Equipment that includes rectifiers and inverters such as the following:

(6) Motor drives

(7) Uninterruptible power supply systems

(8) Lighting controllers

(9) Generators producing sub RF (1 kHz to 3 kHz) and RF (3 kHz to 100 MHz) fields

(10) Ionizing radiation field generators including X-rays, magnetrons, klystrons, thyratrons, vacuum tubes, and similar high-voltage vacuum devices

(11) Nonionizing radiation field generating equipment, including:

(12) Antennas and RF transmission lines

(13) Radar equipment

(14) Industrial scientific and medical equipment

(15) RF induction and dielectric heaters

(16) Industrial microwave heaters and diathermy radiators

(17) Magnetic resonance imagers (MRIs)

(18) Large electromagnets

Informational Note: See the following standards for specific guidance on safety-related work practices around ~~power electronic equipment~~ equipment containing sub RF and RF electrical hazards :

(1) IEEE C95.1, *IEEE Standard for Safety Levels with Respect to Human Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz*, 2019

(2) International Electrotechnical Commission IEC 60479-1, *Effects of Current on Human Beings and Livestock, Part 1: General Aspects*

(3) ~~International Commission on Radiological Protection (ICRP) Publication 33, *Protection Against Ionizing Radiation from External Sources Used in Medicine*~~

340.3 Application.

The purpose of this article is to provide guidance for safety personnel in preparing specific safety-related work practices for sub RF and RF electrical hazards within their industry or laboratory .

340.4 Electrical Hazard Thresholds.

Exposure levels shall not exceed those identified in the following list unless appropriate controls are implemented:

(1) ~~DC (0 Hz to 1 Hz): 100 volts and 40 milliamperes~~

(2) ~~60/50 Hz power: 50 volts and 5 milliampere~~

(3) AC (1 Hz to 3 kHz): 50 volts and 3 milliamperes (not including 50/60 Hz)

(4) AC (3 kHz to 100 kHz): 1 x f mA, f in kHz

(5) AC (100 kHz to 3 MHz): 100 mA

(6) AC (3 MHz to 30 MHz):$100\ (f/3)^{*0.3}$, f in MHz

(7) AC (30 MHz to 110 MHz): 200 mA

Informational Note No. ~~1:~~ ~~See IEEE Std C95.~~ 1 ~~-2019,~~ ~~*IEEE Standard for Safety Levels with Respect to Human Exposure to Electrical, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz*~~ ~~, for information regarding hazard thresholds for workers trained in sub RF and RF contact electric shock.~~ ~~Informational Note No. 2~~ : RF electric shock thresholds depend on current and frequency, not voltage.

340.5 Specific Measures for Personnel Safety.

~~**(A)** Employer Responsibility.~~

~~The employer shall be responsible for the following:~~

(1) ~~Proper training and supervision by properly qualified personnel, including the following:~~

(2) ~~Identification of associated hazards~~

(3) ~~Strategies to reduce the risk associated with the hazards~~

(4) ~~Methods of avoiding or protecting against the hazard~~

(5) ~~Necessity of reporting any incident that resulted in, or could have resulted in, injury or damage to health~~

(6) ~~Properly installed equipment~~

(7) ~~Proper access to the equipment~~

(8) ~~Availability of the correct tools for operation and maintenance~~

(9) ~~Proper identification and guarding of dangerous equipment~~

(10) ~~Provision of complete and accurate circuit diagrams and other published information to the employee prior to the employee starting work (The circuit diagrams should be marked to indicate the components that present an electrical hazard.)~~

(11) ~~Maintenance of clear and clean work areas around the equipment to be worked on~~

(12) ~~Provision of adequate and proper illumination of the work area~~

~~**(B)** Employee Responsibility.~~

~~The employee shall be responsible for the following:~~

- ~~Understanding the hazards associated with the work~~
- ~~Being continuously alert and aware of the possible hazards~~
- ~~Using the proper tools and procedures for the work~~
- ~~Informing the employer of malfunctioning protective measures, such as faulty or inoperable enclosures and locking schemes~~
- ~~Examining all documents provided by the employer relevant to the work to identify the location of components that present an electrical hazard~~
- ~~Maintaining good housekeeping around the equipment and work space~~
- ~~Reporting any incident that resulted in, or could have resulted in, injury or damage to health~~

~~Using and appropriately maintaining the PPE and tools required to perform the work safely~~

The employer and employee responsibilities, training requirements, and safe work practices are the same for working with subRF and RF hazards as found in Chapter 1, with the following exceptions.

(A) Use of Meters for Safety.

Meters used for safety purposes, including zero energy verification shall be rated for the frequency of measurement.

(B) Use of Dielectric PPE

Dielectric PPE shall be derated when used to protect against frequencies greater than 100 kHz.

(C) Exposure to Electromagetic Fields

Equipment that contains RF electrical hazards also may produce nonionizing radiation hazards, i.e., rf electromagnetic fields (EM). Risk assessment shall be performed to determine is there is a risk to EM exposure. Informational Note 1 in item 340.1 above is the Standard for EM exposure.

Statement of Problem and Substantiation for Public Input

Article 340 was added to NFPA 70E in 2000, well before dc and capacitor electrical hazards were added.
Since this article was added to 70E, the following improvements have been made:
2009 - Article 350 to cover the special equipment in R&D laboratories
2012 - DC shock and arc flash
2021 - Capacitor hazards and safety, Article 360 and Annex R
2024 - added thermal hazards for high current/low voltage, and updated all subrf and rf shock thresholds in the existing Article 340.

The current Article 340 merely lists a lot of equipment that uses sub rf and rf generated by power electronics. Power Electronics is a general term for circuits with active devices (e.g., IGBTs, SCRs, thyristers) that manage "substantial" power. Such power electronic devices also contain dc and capacitor hazards, which are covered elsewhere in 70E. Thus, the only new hazard introduced by the Power Electronics article is sub rf and rf electrical hazards.
However, other circuits and devices create sub rf and rf electrical hazards, such as oscillators, vacuum tube electronics, radar, microwave generators, etc. The coverage of sub rf and rf electrical hazards should NOT be limited to power electronics.

Thus, the title should be changed from Safety-Related Work Practices: Power Electronic Equipment to "Electrical Hazards 1 Hz to 110 MHz (not including 50/60 Hz).
340.1 Scope - The lists of sub rf and rf generating equipment in the current Article 340 can be retained in the renamed Article.
340.2 Application - can be retained, generalizing to subrf and rf standards in all equipment.
340.4 Electrical Hazard Thresholds - eliminate power (50/60 Hz) and dc hazard thresholds, as they are covered elsewhere.

340.5
(A) Specific Measures for Personnel Safety -
(B) Employee Responsibility
None of these requirements are unique to Article 340. Every single one is covered by requirements in Chapter 1.

There are NO unique Safety-Related Work Requirements currently in Article 340.
The unique feature of the article is the sub rf and rf electrical hazards.
Three new Safety-Related Work Requirements ARE added to the renamed article and all three deal with rf safety issues.

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Submittal Date: Tue Jun 04 09:38:18 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-93-NFPA 70E-2024

Statement: Power electronics is a general term for circuits with active devices (e.g., IGBTs, SCRs, thyristors) that manage substantial power. Such power electronic devices also contain dc and capacitor hazards, which are covered elsewhere in 70E. The unique hazard introduced by the power electronics article is sub rf and rf electrical hazards. However, other circuits and devices create sub rf and rf electrical hazards so sub rf and rf electrical hazards should not be limited to power electronics. The sections redundant to other sections in the standard are removed and only those unique to sub RF and RF electrical hazards are included.

Public Input No. 166-NFPA 70E-2024 [Section No. 350.5 [Excluding any Sub-Sections]]

Each laboratory or R&D system application shall ~~designate a competent person as defined in this article~~ have a designated research laboratory qualified person as defined in article 100 to ensure the use of appropriate electrical safety-related work practices and controls.

Statement of Problem and Substantiation for Public Input

This PI changes the language to reflect the definition is now in Article 100. Additionally, it reflects the proposed new term from companion PI-163.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 163-NFPA 70E-2024 [Definition: Competent Person.]	

Submitter Information Verification

Submitter Full Name: Jeff Noren
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Submittal Date: Mon Jun 03 13:58:51 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-94-NFPA 70E-2024
Statement: Using qualified person is appropriate in this section. The term competent person is no longer defined.

Public Input No. 44-NFPA 70E-2023 [Section No. 350.5 [Excluding any Sub-Sections]]

Each laboratory or R&D system application shall designate a ~~competent~~ person ~~as defined in this article~~ to ensure the use of appropriate electrical safety-related work practices and controls.

Statement of Problem and Substantiation for Public Input

This revision is necessary as "competent person" is not defined in this article.

Submitter Information Verification

Submitter Full Name: Palmer Hickman
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Submittal Date: Wed Dec 20 15:16:06 EST 2023
Committee: EEW-AAA

Committee Statement

Resolution: FR-94-NFPA 70E-2024
Statement: Using qualified person is appropriate in this section. The term competent person is no longer defined.

Public Input No. 131-NFPA 70E-2024 [New Article after 360]

Safety Related Requirements for Electric Double Layer Capacitors (EDLC's)

Refer to the attached document

Additional Proposed Changes

File Name	Description	Approved
70E_Article_380_PI_EDLC_Final.docx	Proposed new chapter for EDLC's and a new Annex with explanatory material for EDLC's	

Statement of Problem and Substantiation for Public Input

Electrical double-layer capacitors (EDLCs) are a category of supercapacitors having different risks from conventional capacitors, particularly when used in energy storage applications. This technology utilizes non-Faradaic energy storage which, depending upon the system implementation, can present electrocution, thermal and arc flash hazards. Conventional capacitor technologies have a risk of arc blast that can create a supersonic pressure wave and cause lung damage triggered by the rapid rate of rise of current during a fault. EDLC's do not have this risk due to the inherent design of the capacitor. This is explained in further detail in the proposed annex material. Unlike many battery technologies, EDLC's do not have the risk of thermal runaway or electrochemical exposure. This public input is to address the unique safety hazards associated with EDLC supercapacitors which have a combination of battery and capacitor hazards already identified in this code.

This proposal has been submitted on behalf of an EDLC task group consisting of Steve Edley, Dave Wright, Troy Brandon, Curtis Ashton, Lloyd Gordon

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 128-NFPA 70E-2024 [New Definition after Definition: Electrical Safety Program.]	Definition for the technology covered by the new proposed article.

Submitter Information Verification

Submitter Full Name: Steve Edley
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Submittal Date: Sun Jun 02 22:05:38 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-100-NFPA 70E-2024

Statement: Electrical double-layer capacitors (EDLCs) are a category of supercapacitors having different risks from conventional capacitors, particularly when used in energy storage applications. This technology utilizes non-Faradaic energy storage which, depending upon the system implementation, can present electrocution, thermal and arc flash hazards. Conventional capacitor technologies have a risk of arc blast that can create a supersonic pressure wave and cause lung damage triggered by the rapid rate of rise of current during a fault. EDLC's do not have this risk due to the inherent design of the capacitor. Unlike many battery technologies, EDLC's do not have the risk of thermal runaway or electrochemical exposure. This revision addresses the unique safety hazards associated with EDLC supercapacitors which have a combination of battery and capacitor hazards already identified in this standard.

First and/or second level subdivision titles were added to comply with the NEC Style Manual.

380.1 **Scope:**
This article covers electrical safety requirements for the practical safeguarding of employees while working with exposed electrical double layer-capacitors that exceed 100 volts nominal or a theoretical maximum power exceeding 1000 Watts.

380.2 **Specific Measures for Personnel Safety.**

(A) Qualification and Training.

The following qualifications and training shall be required for personnel safety:

(1) Employees who perform work on electrical equipment with ELDC's that fall within the scope of 380.1 shall be qualified and shall be trained in, and familiar with, the specific hazards and controls required for safe work.
(2) Unqualified persons who perform work on electrical equipment with EDLC's shall be trained in, and familiar with, any electrical safety-related work practices necessary for their safety.

(B) Performing a Risk Assessment for ELDC's**.**

The risk assessment process for ELDC's shall follow the overall risk assessment procedures in Chapter **1**. If additional protective measures are required, they shall be selected and implemented according to the hierarchy of risk control identified in **110.3(H)(3)**. When the additional protective measures include the use of PPE, the following shall be determined:

(1) The ELDC system's voltage and theoretical maximum power for the worker exposure. An exposure shall be considered to exist when a conductor or circuit part that could potentially remain energized with hazardous stored energy is exposed.
(2) Thermal hazard. The appropriate thermal PPE shall be selected and used if the theoretical maximum power of the exposed part is greater than 1000W.
(3) Electric shock hazard. The appropriate electric shock PPE in accordance with **130.7** shall be selected and used if the voltage is greater than or equal to 100 volts dc.
(4) Arc flash the appropriate working distance. The appropriate protection for the arc flash and arc blast hazard shall be selected, as follows:
    a. Arc flash PPE in accordance with **130.7** shall be selected and used if the voltage exceeds 150V and the incident energy exceeds 1.2 cal/cm^2 (5 J/cm^2) at the working distance.
    b. Alerting techniques in accordance with **130.8(O)** shall be used to warn employees of the hazards.

(5) Required test and discharge method. Unless a discharge method is provided by the manufacturer, an appropriately sized and safeguarded resistor shall be selected and a method described in order to fully discharge the EDLC system. The method shall include a description of how to test for the absence of voltage, the expected discharge time and what to do in the event there is still energy present. The method shall also include a means to prevent residual charge build up on the ELDC system after it has been discharged.

Note: ELDC's can build up a residual charge without an external circuit. In order to prevent this from becoming a safety risk the ELDC system can be shorted after discharging.

380.3 **Establishing an Electrically Safe Work Condition for ELDC's.**

(A) Written Procedure.

Where a conductor or circuit part is connected to an ELDC system operating within the scope of 380.1, a written procedure shall be used to document the necessary steps and sequence to safely work on that part. This may involve a procedure to discharge the ELDC's and place the equipment into an electrically safe work condition. The written procedure shall incorporate the results of the risk assessment performed in **380.2(B)** and be in accordance with 120.

(C) Storage and Disposal.

Any residual charge from capacitors shall be removed by discharging .

(1) All uninstalled capacitors within the scope of 380.1 shall be short-circuited with a conductor of appropriate size after being discharged.
(2) When an uninstalled capacitor is discovered without the shorting conductor attached to the terminals, it shall be treated as if charged to its full rated voltage until determined safe by a qualified person.

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Annex T

EDLC's are a category of supercapacitors having properties of both capacitors and electrochemical cells that store energy in a non-Faradaic fashion in an electric field similar to a conventional capacitor, but instead of utilizing a dielectric, an electrode-electrolyte interface is used. EDLC's have a much higher capacitance than

conventional capacitors. Arrays of EDLC cells can expose a worker to high voltages and high power levels presenting a risk of electrocution, thermal hazard and arc flash. In a load circuit fault, the current rises to the peak slower than conventional capacitors such as power factor correction capacitors and therefore do not present a risk of a supersonic acoustic shock blast that can cause lung damage. This is due to several factors.

Porous electrodes
EDLC's use highly porous carbon-based electrodes to achieve high surface area. This increases the area available to hold charge, but also means that the electrons must travel inside the electrode (electrode resistance) and the ions must travel through an intricate pore structure to reach the electrode surface (diffusion-controlled adsorption). This distribution of electric charge means much of the energy is not available immediately to feed a load circuit fault.

Double layer charge separation
In EDLC's, energy is stored at the interface between each electrode and the electrolyte. The movement and arrangement of ions that form this double layer is inherently slower than the purely electrostatic mechanism of conventional capacitors. This is because of the mobility of ions in the electrolyte which is affected by the diffusion coefficients and is slower than the change in shape of the electronic field in the dielectric in conventional capacitors.

Cell voltage
Another factor that can affect the rate of rise of current in a load circuit fault is that each cell is rated at lower voltage than commonly found with many other capacitor technologies, which can operate well above 100V. Most EDLC cells operate at less than 3Vdc. When connected in series to achieve higher voltages the equivalent series impedance of the EDLC stack is significantly higher than conventional capacitors. This impedance contributes to the limitation of the rate of rise of current feeding a fault.

380.1 **Scope:**
This article covers electrical safety requirements for the practical safeguarding of employees while working with exposed electrical double layer-capacitors that exceed 100 volts nominal or a theoretical maximum power exceeding 1000 Watts.

380.2 **Specific Measures for Personnel Safety.**

(A) Qualification and Training.

The following qualifications and training shall be required for personnel safety:

(1) Employees who perform work on electrical equipment with ELDC's that fall within the scope of 380.1 shall be qualified and shall be trained in, and familiar with, the specific hazards and controls required for safe work.
(2) Unqualified persons who perform work on electrical equipment with EDLC's shall be trained in, and familiar with, any electrical safety-related work practices necessary for their safety.

(B) Performing a Risk Assessment for ELDC's**.**

The risk assessment process for ELDC's shall follow the overall risk assessment procedures in Chapter **1**. If additional protective measures are required, they shall be selected and implemented according to the hierarchy of risk control identified in **110.3(H)(3)**. When the additional protective measures include the use of PPE, the following shall be determined:

(1) The ELDC system's voltage and theoretical maximum power for the worker exposure. An exposure shall be considered to exist when a conductor or circuit part that could potentially remain energized with hazardous stored energy is exposed.
(2) Thermal hazard. The appropriate thermal PPE shall be selected and used if the theoretical maximum power of the exposed part is greater than 1000W.
(3) Electric shock hazard. The appropriate electric shock PPE in accordance with **130.7** shall be selected and used if the voltage is greater than or equal to 100 volts dc.
(4) Arc flash the appropriate working distance. The appropriate protection for the arc flash and arc blast hazard shall be selected, as follows:
    a. Arc flash PPE in accordance with **130.7** shall be selected and used if the voltage exceeds 150V and the incident energy exceeds 1.2 cal/cm^2 (5 J/cm^2) at the working distance.
    b. Alerting techniques in accordance with **130.8(O)** shall be used to warn employees of the hazards.

(5) Required test and discharge method. Unless a discharge method is provided by the manufacturer, an appropriately sized and safeguarded resistor shall be selected and a method described in order to fully discharge the EDLC system. The method shall include a description of how to test for the absence of voltage, the expected discharge time and what to do in the event there is still energy present. The method shall also include a means to prevent residual charge build up on the ELDC system after it has been discharged.

Note: ELDC's can build up a residual charge without an external circuit. In order to prevent this from becoming a safety risk the ELDC system can be shorted after discharging.

380.3 **Establishing an Electrically Safe Work Condition for ELDC's.**

(A) Written Procedure.

Where a conductor or circuit part is connected to an ELDC system operating within the scope of 380.1, a written procedure shall be used to document the necessary steps and sequence to safely work on that part. This may involve a procedure to discharge the ELDC's and place the equipment into an electrically safe work condition. The written procedure shall incorporate the results of the risk assessment performed in **380.2(B)** and be in accordance with 120.

(C) Storage and Disposal.

Any residual charge from capacitors shall be removed by discharging .

(1) All uninstalled capacitors within the scope of 380.1 shall be short-circuited with a conductor of appropriate size after being discharged.
(2) When an uninstalled capacitor is discovered without the shorting conductor attached to the terminals, it shall be treated as if charged to its full rated voltage until determined safe by a qualified person.

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Annex T

EDLC's are a category of supercapacitors having properties of both capacitors and electrochemical cells that store energy in a non-Faradaic fashion in an electric field similar to a conventional capacitor, but instead of utilizing a dielectric, an electrode-electrolyte interface is used. EDLC's have a much higher capacitance than

conventional capacitors. Arrays of EDLC cells can expose a worker to high voltages and high power levels presenting a risk of electrocution, thermal hazard and arc flash. In a load circuit fault, the current rises to the peak slower than conventional capacitors such as power factor correction capacitors and therefore do not present a risk of a supersonic acoustic shock blast that can cause lung damage. This is due to several factors.

Porous electrodes
EDLC's use highly porous carbon-based electrodes to achieve high surface area. This increases the area available to hold charge, but also means that the electrons must travel inside the electrode (electrode resistance) and the ions must travel through an intricate pore structure to reach the electrode surface (diffusion-controlled adsorption). This distribution of electric charge means much of the energy is not available immediately to feed a load circuit fault.

Double layer charge separation
In EDLC's, energy is stored at the interface between each electrode and the electrolyte. The movement and arrangement of ions that form this double layer is inherently slower than the purely electrostatic mechanism of conventional capacitors. This is because of the mobility of ions in the electrolyte which is affected by the diffusion coefficients and is slower than the change in shape of the electronic field in the dielectric in conventional capacitors.

Cell voltage
Another factor that can affect the rate of rise of current in a load circuit fault is that each cell is rated at lower voltage than commonly found with many other capacitor technologies, which can operate well above 100V. Most EDLC cells operate at less than 3Vdc. When connected in series to achieve higher voltages the equivalent series impedance of the EDLC stack is significantly higher than conventional capacitors. This impedance contributes to the limitation of the rate of rise of current feeding a fault.

Public Input No. 182-NFPA 70E-2024 [Section No. 360.1]

360.1 Scope.

This article covers the electrical safety-related requirements for the practical safeguarding of employees while working with conventional capacitors that present an electrical hazard. It does not cover electric double layer capacitors (EDLCs), supercapacitors, or hybrid supercapacitors.

Informational Note: See Informative Annex R for more information on working safely with capacitors.

Statement of Problem and Substantiation for Public Input

Article 360 was written for the 2021 NFPA 70E for conventional, plate capacitors. At the time that is was written, circa 2019, other forms of capacitors were not as common, and were not considered. The characteristics and hazards of conventional, plate capacitors are unique and different than other classes of super capacitors and hybrids. Specifically, conventional, plate capacitors have a very low internal impedance for current flow, charge motion is only electrons, and energy can be delivered at very high rates, delivering current at the rate of 10*10 or 10*11 Amps/sec. This results in a super sonic acoustic wave (shock wave) that is unique only to such conventional capacitors and lightning. Thus, for the 2021 70E, Article 360 introduced the Hearing Protection Boundary and the Lung Protection Boundary. These boundaries were created only for shock waves and do not apply to other arc sources that can not deliver current fast enough.
Since the publication of Article 360 others have begun to misinterpret the intent of these two boundaries and apply them to acoustic arc sources that can not create a shock wave. This has resulted in the inappropriate over restriction of their use, such as EDLCs, etc. This was never the intent of Article 360 and this change of scope and some other changes will solve this conflict. For an analysis of the acoustic hazards of all arc sources that justify this PI see reference, "L. Gordon and J. Bradley, Modeling the Conversion of Electrical Energy to Acoustic Energy for Arcs and Applications for the Selection of PPE, 2024 IEEE Electrical Safety Workshop, March 5 - 8, 2024, Tucson, AZ, paper ESW-09, pp 57 - 65." This reference is accessible through IEEE Explore.

Submitter Information Verification

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Submittal Date: Mon Jun 03 16:18:59 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-95-NFPA 70E-2024
Statement: The characteristics and hazards of conventional plate capacitors are unique and different than other classes of super capacitors and hybrids. This change clarifies Article 360 does not apply to electrical elements other than conventional capacitors.

Public Input No. 210-NFPA 70E-2024 [Section No. 360.1]

360.1 Scope.

This article covers the electrical safety-related requirements for the practical safeguarding of employees while working with capacitors that present an electrical hazard. It does not cover capacitors that are a part of NRTL listed products that include instructions that deal with the discharge of capacitors before working on the equipment.

Informational Note 1 : An example of instructions are the instructions on a variable frequency drive that instructs the user to turn the vfd off, lead the display blank out, and then wait a number of seconds before the door is opened.

Informational Note 2: See Informative Annex R for more information on working safely with capacitors.

Statement of Problem and Substantiation for Public Input

This article was written for capacitors that are used in Research & Development and in pulsed power applications. These capacitors are significant and are installed individually in racks to perform a very unique function. These capacitor are extremely hazardous and are the scope of Article 360. Capacitors in listed products, however, have circuits to ensure that the capacitors are discharged before the equipment is worked on. Still, however, a worker should always be cautious.
This PI is an attempt to be parallel to the scope of Article 460 in NFPA70. Article 460 is for power factor correction installations. The language in 460 states "Surge capacitors or capacitors included as a component part of other apparatus and conforming with the requirements of such apparatus are excluded from these requirements."

Submitter Information Verification

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Submittal Date: Mon Jun 03 22:51:56 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: The concern is addressed in Chapter 2 requirements to follow manufacturer’s instructions while maintaining electrical equipment.

Public Input No. 188-NFPA 70E-2024 [Section No. 360.3]

360.3 Stored Energy Hazard Thresholds.

Appropriate controls shall be applied where any of the following hazard thresholds are exceeded:

(1) Less than 100 volts and greater than 100 joules of stored energy (thermal hazard)

(2) Greater than or equal to 100 volts and greater than 1.0 joule of stored energy (moderate shock hazard)

(3) Greater than or equal to 400 volts and greater than 0.25 joules of stored energy (high shock hazard)

(4) Greater than 1.2 cal/cm^2 incident energy at the working distance (arc flash hazard)

(5) Greater than 100 joules of stored energy irregardless of voltage (moderate acoustic hazard)

(6) Greater than 122 kJ of stored energy when dI/dt is greater than 10^9 A/sec (severe acoustic hazard)

Statement of Problem and Substantiation for Public Input

The list of capacitor hazard thresholds was incomplete, although most were listed later. By adding the injury mechanism (thermal, shock, arc flash and acoustic) it clarifies each threshold.
The arc flash threshold from existing section 360.4(B)(4) was added.
The acoustic thresholds from existing section 360.4(B)(4) were added.
An additional for the Lung Protection Boundary of dI/dt ≥ 10*9 was added. Otherwise, this boundary would be inappropriately applied to large, low voltage capacitor banks. Justification is found in see reference, "L. Gordon and J. Bradley, Modeling the Conversion of Electrical Energy to Acoustic Energy for Arcs and Applications for the Selection of PPE, 2024 IEEE Electrical Safety Workshop, March 5 - 8, 2024, Tucson, AZ, paper ESW-09, pp 57 - 65." This reference is accessible through IEEE Explore.

Submitter Information Verification

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Submittal Date: Mon Jun 03 17:28:50 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-96-NFPA 70E-2024
Statement: This revision adds thresholds for additional hazards covered in this article related to capacitors. The new thresholds correlate with the values in Informative Annex R.

Public Input No. 189-NFPA 70E-2024 [Section No. 360.4(B)]

(B) Performing a Risk Assessment for Capacitors.

The risk assessment process for capacitors shall follow the overall risk assessment procedures in Chapter 1. If additional protective measures are required, they shall be selected and implemented according to the hierarchy of risk control identified in 110.3(H)(3). When the additional protective measures include the use of PPE, the following shall be determined:

(1) Capacitor voltage and stored energy for the worker exposure. An exposure shall be considered to exist when a conductor or circuit part that could potentially remain energized with hazardous stored energy is exposed.

(2) Thermal hazard. The appropriate thermal PPE shall be selected and used if the stored energy of the exposed part is greater 100 joules.

(3) Electric shock hazard. The appropriate electric shock PPE in accordance with 130.7 shall be selected and used if the voltage is greater than or equal to 100 volts.

(4) Arc flash and arc blast hazard at the appropriate working distance. The appropriate protection for the arc flash and arc blast hazard shall be selected, as follows:

a. Arc flash PPE in accordance with 130.7 shall be selected and used if the incident energy exceeds 1.2 cal/cm^2 (5 J/cm^2) at the working distance.

b. Hearing protection shall be required where the stored energy exceeds 100 joules.

c. The lung protection boundary shall be determined if stored energy is above 122 kJ, and dI/dt is greater than 10^9 A/sec . The current risetime can be modeled using voltage, capacitance, and system impedances. Employees shall not enter the lung protection boundary.

d. Alerting techniques in accordance with 130.8(O) shall be used to warn employees of the hazards.

(5) Required test and grounding method. Soft grounding shall be used for stored energy greater than 1000 joules. If capacitors are equipped with bleed resistors, or if using a soft grounding system, the required discharge wait time shall be determined where applicable.

(6) Develop a written procedure that captures all of the required steps to place the equipment in an electrically safe work condition. Include information about the amount of stored energy available, how long to wait after de-energization before opening the enclosure, how to test for absence of voltage, and what to do if there is still stored energy present.

Informational Note No. 1: See Informative Annex R for more information on calculating capacitor stored energy, arc flash, and arc blast boundaries.

Informational Note No. 2: Heavy duty leather with a minimum thickness of 0.03 in. (0.7 mm) provides protection from thermal hazards.

Statement of Problem and Substantiation for Public Input

The Lung Protection Boundary was created in the 2021 NFPA 70E for large capacitor banks, that produce fast risetime, high currents. Such banks are almost always high voltage and very high power, on the order of 500 MW and above. Large, low-voltage banks could not produce such shock waves. The threshold of 10*9 A/s excludes such lower voltage, lower power capacitor banks. For justification see reference, "L. Gordon and J. Bradley, Modeling the Conversion of Electrical Energy to Acoustic Energy for Arcs and Applications for the Selection of PPE, 2024 IEEE Electrical Safety Workshop,

March 5 - 8, 2024, Tucson, AZ, paper ESW-09, pp 57 - 65." This reference is accessible through IEEE Explore.

Submitter Information Verification

Submitter Full Name: Lloyd Gordon
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Submittal Date: Mon Jun 03 17:47:51 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-97-NFPA 70E-2024

Statement: The lung protection boundary was created in the 2021 NFPA 70E for large capacitor banks, that produce fast risetime, high currents. Such banks are almost always high voltage and very high power, on the order of 500 MW and above. Large, low-voltage banks could not produce such shock waves. The di/dt threshold of 10*9 A/s excludes such lower voltage, lower power capacitor banks.

The section was revised to comply with the NEC Style Manual.

First and/or second level subdivision titles were added to comply with the NEC Style Manual.

Public Input No. 190-NFPA 70E-2024 [Section No. 360.5(B)]

(B) Safe Work Practices.

In order to place the capacitor(s) into an electrically safe work condition, a qualified person shall use the appropriate safe work practices and PPE and shall apply the following process for establishing and verifying an electrically safe work condition:

(1) Determine all possible sources of electrical supply to the specific equipment. Check applicable up-to-date drawings, diagrams, and identification tags.

(2) After properly interrupting the load current, open the disconnecting device(s) for each source.

(3) Wherever possible, visually verify that all blades of the disconnecting devices are fully open or that drawout-type circuit breakers are withdrawn to the fully disconnected position.

(4) Apply lockout/tagout devices in accordance with a documented and established policy.

(5) At this point, the sources that previously charged the capacitor(s) have been identified, isolated and locked out. However, the capacitors may still hold hazardous charge.

(6) If bleed resistors or automatic discharge systems are applicable, wait the prescribed time for the capacitors to discharge to less than the thresholds in 360.3 and proceed to step (6). For systems without bleed resistors or automatic discharge systems, discharge the capacitors with an adequately rated grounding device (e.g., ground stick). Soft grounding shall be performed above 1000 joules, and remote soft grounding shall be performed above 100 kJ.

(7) If the capacitor(s) are not referenced to ground through either terminal, a shorting stick shall be used to discharge the capacitor from terminal to terminal. A hard shorting stick may be used up to 1000 joules, a soft shorting stick (containing a discharge resistor) may be used up to 100 kJ, and remote soft shorting shall be performed above 100 kJ.

(8) Verify that the capacitors are discharged and grounded . For capacitors less than 1000 joules, verification shall be permitted to be done either by testing or by grounding. For capacitors between 1000 joules and less than 100 kJ, verification shall be done using testing or soft grounding, then hard grounding. Above 100 kJ, an engineered and redundant system shall be used for remote testing and grounding. An adequately rated grounding device (ground stick) or portable test instrument shall be used to test between each capacitor terminal and from each terminal to ground to assure that the capacitor is de-energized.

(9) When test instruments are used for testing the absence of voltage, the operation of the test instrument shall be verified on a known dc voltage source before and after each absence of voltage procedure is performed. If voltage remains, determine and correct the cause, and repeat step (5) to discharge the capacitors. Where recharging can occur due to dielectric absorption or induced voltages, all the capacitor terminals shall be connected together and grounded with a bare or transparent-insulated wire.

(10) For series capacitors or capacitors not connected to ground through either terminal the shorting wires shall be attached across each individual capacitor, and to ~~case~~ ground .

For single capacitors or for a parallel capacitor bank, the grounding device shall be permitted to be left attached to the capacitor terminals for the duration of the work (e.g., a ground stick).

Exception: Lockout/tagout shall not be required for work on cord- and plug-connected equipment for which exposure to the hazards of unexpected energization of the equipment is controlled by the unplugging of the equipment from the energy source, provided that the plug is under the exclusive control of the employee performing the servicing and maintenance for the duration of the work.

Statement of Problem and Substantiation for Public Input

Although the shorting stick process for capacitors not referenced to ground through either terminal (i.e., floating) was covered in Annex R, it is important to recognize this design situation in Article 360 and to introduce the concept of shorting sticks.
The line about locking out the sources, but still not safe is to emphasize the stored energy nature of capacitors, and that energy discharge is required.

Submitter Information Verification

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Submittal Date: Mon Jun 03 18:04:47 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-98-NFPA 70E-2024 RESPONSE TO PI 190: The line about locking out the sources, but still not safe is to emphasize the stored energy nature of capacitors, and that energy discharge is required.

Statement: Although the shorting stick process for capacitors not referenced to ground through either terminal (i.e., floating) was covered in Annex R, it is important to recognize this design situation in Article 360 and to introduce the concept of shorting sticks.

For large capacitor banks, attaching a shorting wire manually across each capacitor adds additional worker hazards, such as crawling down deep into a tank, using ladders, and trying to get to inaccessible points. On these large banks well engineered, approved and tested automatic discharge systems are installed. They are inspected after each capacitor bank use, zero voltage procedures are still followed, and these systems are regularly tested and maintained. The requirement, as previously written, did not consider such large capacitor banks, and created additional hazards by requiring the manual placement of grounding straps.

Public Input No. 197-NFPA 70E-2024 [Section No. 360.5(B)]

(B) Safe Work Practices.

In order to place the capacitor(s) into an electrically safe work condition, a qualified person shall use the appropriate safe work practices and PPE and shall apply the following process for establishing and verifying an electrically safe work condition:

(1) Determine all possible sources of electrical supply to the specific equipment. Check applicable up-to-date drawings, diagrams, and identification tags.

(2) After properly interrupting the load current, open the disconnecting device(s) for each source.

(3) Wherever possible, visually verify that all blades of the disconnecting devices are fully open or that drawout-type circuit breakers are withdrawn to the fully disconnected position.

(4) Apply lockout/tagout devices in accordance with a documented and established policy.

(5) If bleed resistors or automatic discharge systems are applicable, wait the prescribed time for the capacitors to discharge to less than the thresholds in 360.3 and proceed to step (6). For systems without bleed resistors or automatic discharge systems, discharge the capacitors with an adequately rated grounding device (e.g., ground stick). Soft grounding shall be performed above 1000 joules, and remote soft grounding shall be performed above 100 kJ.

(6) Verify that the capacitors are discharged. For capacitors less than 1000 joules, verification shall be permitted to be done either by testing or by grounding. For capacitors between 1000 joules and less than 100 kJ, verification shall be done using testing or soft grounding, then hard grounding. Above 100 kJ, an engineered and redundant system shall be used for remote testing and grounding. An adequately rated grounding device (ground stick) or portable test instrument shall be used to test between each capacitor terminal and from each terminal to ground to assure that the capacitor is de-energized.

(7) When test instruments are used for testing the absence of voltage, the operation of the test instrument shall be verified on a known dc voltage source before and after each absence of voltage procedure is performed. If voltage remains, determine and correct the cause, and repeat step (5) to discharge the capacitors. Where recharging can occur due to dielectric absorption or induced voltages, all the capacitor terminals shall be connected together and grounded with a bare or transparent-insulated wire.

(8) For series capacitors the shorting wires shall be attached across each individual capacitor, and to case.

For single capacitors or for a parallel capacitor bank, the grounding device shall be permitted to be left attached to the capacitor terminals for the duration of the work (e.g., a ground stick).

For single, series, or parallel capacitors an approved engineered discharge path that remains in place after zero energy is verified, may be used instead of additional shorting wires, as long as the engineered system is inspected after the zero energy verification and before the work begins. The engineered system shall ensure that all capacitor elements are shorted and grounded.

Exception: Lockout/tagout shall not be required for work on cord- and plug-connected equipment for which exposure to the hazards of unexpected energization of the equipment is controlled by the unplugging of the equipment from the energy source, provided that the plug is under the exclusive control of the employee performing the servicing and maintenance for the duration of the work.

Statement of Problem and Substantiation for Public Input

For large capacitor banks, attaching a shorting strap manually cross each capacitor adds additional worker hazards, such as crawling down deep into a tank, using ladders, and trying to get to inaccessible points. On these large banks well engineered, approved and tested automatic discharge systems are installed. They are inspected after each capacitor bank use, zero voltage procedures are still followed, and these systems are regularly tested and maintained. The requirement, as written, did not consider such large capacitor banks, and created additional hazards by requiring the manual placement of grounding straps. Pictures and examples can be provided.

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Submittal Date: Mon Jun 03 19:59:17 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-98-NFPA 70E-2024 RESPONSE TO PI 190: The line about locking out the sources, but still not safe is to emphasize the stored energy nature of capacitors, and that energy discharge is required.

Statement: Although the shorting stick process for capacitors not referenced to ground through either terminal (i.e., floating) was covered in Annex R, it is important to recognize this design situation in Article 360 and to introduce the concept of shorting sticks.

For large capacitor banks, attaching a shorting wire manually across each capacitor adds additional worker hazards, such as crawling down deep into a tank, using ladders, and trying to get to inaccessible points. On these large banks well engineered, approved and tested automatic discharge systems are installed. They are inspected after each capacitor bank use, zero voltage procedures are still followed, and these systems are regularly tested and maintained. The requirement, as previously written, did not consider such large capacitor banks, and created additional hazards by requiring the manual placement of grounding straps.

Public Input No. 196-NFPA 70E-2024 [Section No. 360.6]

360.6 Ground and Shorting Sticks.

Ground sticks shall be provided for qualified persons to safely discharge any residual stored energy contained in capacitors or to hold the capacitor potential at 0 volts. The ground sticks shall be designed, constructed, installed, and periodically inspected so that the full energy and voltage of the capacitors can be safely discharged. In the case that a capacitor is isolated or floating, two ground sticks are required, or a single shorting stick may be used to discharge the capacitor terminal to terminal. The shorted capacitor must still be brought to ground potential with a ground stick

(A) Visual Inspection.

The ground or shorting stick shall be visually inspected for defects before each use. All mechanical connections shall be examined for loose connections. Resistors shall be visually inspected for cracks or other defects and electrically tested for proper resistance. The following shall occur if defects or contamination are found:

(1) If any defect or contamination that could adversely affect the insulating qualities or mechanical integrity of the ground stick is present, the tool shall be removed from service.

(2) If the defect or contamination exists on the ground stick, then it shall be replaced or repaired and tested before returning to service.

(3) If the defect or contamination exists on the cable, then it shall be replaced or repaired and tested before returning to service.

(B) Electrical Testing.

All ground and shorting sticks shall be electrically tested as follows:

(1) The ground stick cable shall be tested to verify that the impedance is less than 0.1 ohms to ground every 2 years.

(2) The testing shall be documented.

Exception: The test shall be performed annually if the ground stick is utilized outdoors or in other adverse conditions.

(3) Soft grounding (High-Z) ground sticks with resistors shall be measured and compared to the specified value before each use.

(C) Storage and Disposal.

Any residual charge from capacitors shall be removed by discharging before servicing or removal.

(1) All uninstalled capacitors capable of storing 10 joules or greater at their rated voltage shall be short-circuited with a conductor of appropriate size.

(2) When an uninstalled capacitor is discovered without the shorting conductor attached to the terminals, it shall be treated as energized and charged to its full rated voltage until determined safe by a qualified person.

Informational Note: A capacitor that develops an internal open circuit could retain substantial charge internally even though the terminals are short-circuited. Such a capacitor can be hazardous to transport, because the damaged internal wiring could reconnect and discharge the capacitor through the short-circuiting conductor. Any capacitor that shows a significant change in capacitance after a fault could have this problem. Action should be taken to reduce the risk associated with this hazard when it is discovered.

Statement of Problem and Substantiation for Public Input

Although shorting sticks are discussed in Annex R, the requirements for training, inspection and proper use are the same as ground sticks. These requirements for shorting sticks need to be in the requirements of Article 360.

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Submittal Date: Mon Jun 03 19:46:19 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-99-NFPA 70E-2024

Statement: This section is revised to include the use of shorting sticks in addition to ground sticks. While shorting sticks are addressed in Informative Annex R, the safety concerns when using the safety devices justify regulating their use. Changing the resistance from 0.1 to 1 ohm aligns testing requirement of the ground stick cable. The new requirements are based on Informative Annex R.

The section was revised to comply with the NEC Style Manual.

First and/or second level subdivision titles were added to comply with the NEC Style Manual.

Public Input No. 239-NFPA 70E-2024 [Section No. 360.6(B)]

(B) Electrical Testing.

All ground sticks shall be electrically tested as follows:

(1) The ground stick cable shall be tested to verify that the impedance is less than ~~0.1 ohms~~ 1 ohms to ground every 2 years.

(2) The testing shall be documented.

Exception: The test shall be performed annually if the ground stick is utilized outdoors or in other adverse conditions.

(3) Soft grounding (High-Z) ground sticks with resistors shall be measured and compared to the specified value before each use.

Statement of Problem and Substantiation for Public Input

Requiring a resistance less than 0.1 ohm requires special meters, testing for less than 1 ohm can be used with standard VOMs. Showing continuity plus the regular inspection is sufficient to assure that there is a continuous path to ground through the cable. 0.1 ohm does add any safety benefit.

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Committee: EEW-AAA

Committee Statement

Resolution: FR-99-NFPA 70E-2024

Statement: This section is revised to include the use of shorting sticks in addition to ground sticks. While shorting sticks are addressed in Informative Annex R, the safety concerns when using the safety devices justify regulating their use. Changing the resistance from 0.1 to 1 ohm aligns testing requirement of the ground stick cable. The new requirements are based on Informative Annex R.

The section was revised to comply with the NEC Style Manual.

First and/or second level subdivision titles were added to comply with the NEC Style Manual.

Public Input No. 240-NFPA 70E-2024 [Section No. 360.6 [Excluding any Sub-Sections]]

Ground sticks shall be provided for qualified persons to safely discharge any residual stored energy contained in capacitors or to hold the capacitor potential at 0 volts ~~. The ground sticks~~ to prevent any recharging.

A. For a ground or shorting stick that will be used to remove the total capacitor or capacitor bank energy the ground/shorting stick shall be designed, constructed, installed, and periodically inspected so that the full energy and voltage of the capacitors can be safely discharged.

B. For a ground or shorting stick that will be used to remove remnant charge the ground/shorting stick shall be designed, constructed, installed, and periodically inspected so that it will remove the remnant charge remaining after the installed energy removal system has discharged the bank and been verified remotely.

C. For large energy storage, over 100 kV, the capacitor energy shall be removed and verified remotely. In this case, the ground/shorting stick is for visual indication that the system is in an electrically safe work condition and to add an additional method of preventing any recharging. In this case the the ground/shorting stick shall be designed, constructed, installed, and periodically inspected so that it provides and maintains a path to ground.

D. The distance from the closest conductive point at the tip of the ground stick to the hand guard in front of the user's hand shall be a minimum of 36 cm (1.2 ft) for dc voltages less than or equal to 40 kV, and for 40 kV to 200 kV have a distance of $d = 0.03 \times V_{max}$ (kV).

E. For ground sticks, dielectric PPE shall not be required as long as the ground stick is verified to be connected to a solid ground before use.

F. For shorting sticks, the closest conductive point at the tip of either shorting stick to the hand guard in front of the user's hand shall be a minimum of the Restricted Approach Boundary at the voltage to be used.

Statement of Problem and Substantiation for Public Input

Linemen's "hot sticks" are designed to be used outdoors in adverse environments (wet location, dirty) and must be able to hold off the full voltage across the length of the handle. They are tested to the ANSI/ASTM F711 standard to 100 kV/ft.
Ground sticks for capacitor safing procedures are used indoors in a clean, dry environment. In addition, the ground stick is grounded at the tip and, as long as the ground stick is grounded the handle never sees the full voltage except very briefly if discharging a fully charged capacitor. Ground sticks to be used only for safety indication on large capacitor banks never see full capacitor voltage or energy and must only guarantee a good connection to ground.
Since the tip is grounded, and for use on high energy systems, the Restricted Approach Boundary does not exist, and dielectric PPE is not required.

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Submittal Date: Tue Jun 04 13:10:10 EDT 2024

Committee: EEW-AAA

Committee Statement

Resolution: FR-99-NFPA 70E-2024

Statement: This section is revised to include the use of shorting sticks in addition to ground sticks. While shorting sticks are addressed in Informative Annex R, the safety concerns when using the safety devices justify regulating their use. Changing the resistance from 0.1 to 1 ohm aligns testing requirement of the ground stick cable. The new requirements are based on Informative Annex R.

The section was revised to comply with the NEC Style Manual.

First and/or second level subdivision titles were added to comply with the NEC Style Manual.

Public Input No. 123-NFPA 70E-2024 [Section No. A.3.9]

A.3.9 UL Publications.

Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062-2096.

UL 943, *Ground-Fault Circuit Interrupters*, ~~2006 (R 2012)~~ 2016, revised 2023 .

UL 943C, *Outline of Investigation for Special Purpose Ground-Fault Circuit-Interrupters*, 2012, revised 2015 .

UL 1436, *Outlet Circuit Testers and Other Similar Indicating Devices*, 2016.

ANSI/CAN/ UL 9540, *Energy Storage Systems and Equipment*, ~~2020~~ 2023 .

UL 9540A, *Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems*, 2019.

UL 9540B, Outline of Investigation for Large Scale Fire Test for Residential Battery Energy Storage Systems, 2024.

UL 61010-1, *Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use, Part 1: General Requirements*, 2012, revised 2023 .

UL 61010-2-033, *Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use — Part 2-033: Particular Requirements for Hand-Held Multimeters and Other Meters, for Domestic and Professional use, Capable of Measuring Mains Voltage*, ~~2014~~ 2020 .

Statement of Problem and Substantiation for Public Input

Update references to most current editions and add UL 9540B as an additional reference used in the body of the code providing the TC accepts the proposal as a First Revision.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 122-NFPA 70E-2024 [Section No. 320.1]	

Submitter Information Verification

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Committee: EEW-AAA

Committee Statement

Resolution: FR-69-NFPA 70E-2024
Statement: The UL references have been updated to reflect the current editions. UL 9540B, Outline of Investigation for Large Scale Fire Test for Residential Battery Energy Storage

Systems, was added as it now referenced within the body of the document.

Public Input No. 88-NFPA 70E-2024 [Section No. C.2.1 [Excluding any Sub-Sections]]

Columns 2 through ~~5~~ 4 of Table 130.4(E)(a) and Table 130.4(E)(b) show various distances from the exposed energized electrical conductors or circuit parts. They include dimensions that are added to a basic minimum air insulation distance. Those basic minimum air insulation distances are based on OSHA's 29 CFR 1910.269, Table R-3.

Statement of Problem and Substantiation for Public Input

Within the current, C.2.1 General Statement., it states "Columns 2 through 5 of Table 130.4(E)(a) and Table 130.4(E)(b)". When either of these two tables are referred to, no column "5" exists, only columns 1 through 4 do. Also, see C.2.1.2 Column 2., C.2.1.3 Column 3., & C.2.1.4 Column 4., which further shows, columns 2 through 4 should be referenced within the C.2.1.

Submitter Information Verification

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Submittal Date: Mon May 20 07:54:53 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-70-NFPA 70E-2024
Statement: The references to the columns in Tables 130.4(E)(a) and (E)(b) have been editorially revised to reference Columns 2 through 4.

Public Input No. 87-NFPA 70E-2024 [Section No. D.1]

D.1 Introduction.

Informative Annex D summarizes calculation methods available for calculating arc flash boundary and incident energy. It is important to investigate the limitations of any methods to be used. The limitations of methods summarized in Informative Annex D are described in Table D.1.

Table D.1 Limitation of Calculation Methods

Section	Source	Limitations/Parameters
D.2	Lee, "The Other Electrical Hazard: Electrical Arc Flash Burns"	Calculates incident energy and arc flash boundary for arc in open air; conservative over 600 volts and becomes more conservative as voltage increases
D.3	Doughty, et al., "Predicting Incident Energy to Better Manage the Electrical Arc Hazard on 600 V Power Distribution Systems"	Calculates incident energy for three-phase arc on systems rated 600 volts and below; applies to short-circuit currents between 16 kA and 50 kA
D.4	IEEE 1584, *Guide for Performing Arc Flash Hazard Calculations*	Calculates incident energy and arc flash boundary for 208 volts to 15 kV; three-phase; 50 Hz to 60 Hz; 500 amperes to 106,000 amperes short-circuit current (208 volts to 600 volts); 200 amperes to 65,000 amperes short-circuit current (600 volts to 15,000 volts); and conductor gaps of 6.35 mm to 76.2 mm (0.25 in. to 3 in.) for 208 volts to 600 volts and 13 mm to 152 mm (0.75 in. to 10 in.) for 601 volts to 15,000 volts
D.5	Doan, "Arc Flash Calculations for Exposure to DC Systems"	Calculates incident energy for dc systems rated up to 1000 volts dc

D.6 Marroquin, et al. ,High-Voltage Arc Flash Assessment and Applications (IEEE TRANSACTIONS ON INDUSTRY APPLICATIONS, VOL. 56, NO. 3, MAY/JUNE 2020)

Calculates incident energy for high voltage system rated at greater than 1kV based on V. V. Terzija and H. J. Konglin paper "Long arc in free air: Laboratory testing, modeling, simulation and model-parameters estimation," IEEE Proc.- Gener., Transmission and . Distribrution., vol. 149, no. 3, pp. 319–325, May 2002.

Please note that IEEE-1584-2018 no longer references the Lee method since its results are very conservative for high voltage enclosed applications. Based on Lee method, the incident energy for switchgears operating at 34.5kV typcially exceeds 40cal/cm2 resulting in excessive PPE requirements.

Statement of Problem and Substantiation for Public Input

Realstic arc flash incident energy results for 38kV rated equipement.

Submitter Information Verification

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Submittal Date: Sat May 18 09:14:09 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: No calculation method or other substantiation has been provided for the inclusion of this method.

Public Input No. 222-NFPA 70E-2024 [New Section after D.5]

D.5.2 Arc Extinction Observations Provides Voltage/Gap bounds

If erosion and magnetic forces cause a dc arc to elongate to a threshold, the arc self extinguishes. The extinction length is determined by the arc voltage and initial gap distance. Once the voltage drop in the arc exceeds the source voltage, the arc can no longer sustain.

An equation can be written, based on measurement, to provide a lower voltage bound for a given gap distance, below which, an arc can't be sustain.

$$V_{min} = 1.06 \times g + 100$$

Or

$$g_{min} = \frac{V - 100}{1.06}$$

Where:

V_{min} = voltage below which an arc can't be sustained

g = gap distance

g_{min} = gap above which an arc can't be sustained

V = system voltage

Using this equation gives the following

System voltage (volts)	gap distance, above which arc will extinguish	David
150	0.47 cm	15 cm
250	1.4 cm	25 cm
550	4.2 cm	55 cm
600	4.7 cm	60 cm
1000	8.5 cm	100 cm

References: see # 1 and #2 in D.5.9 below.

Statement of Problem and Substantiation for Public Input

Multiple data sets show that dc arcs self extinguish when the arc length is greater than a give gap distance. This equation was developed from the analysis by Ammerman.

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Committee: EEW-AAA

Committee Statement

Resolution: FR-71-NFPA 70E-2024

Statement: The direct-current incident energy calculation models have been revised by including updated testing information, supporting references, dc to ac arc flash characteristic comparisons and additional considerations for direct-current incident energy calculations.

The term “nominal” was added before voltage in the Maximum Power Method, D.5.3. formula to clarify the voltage used.

Public Input No. 223-NFPA 70E-2024 [New Section after D.5]

D.5.3 Modified Maximum Power Meth od

see reference #4

D.5.4 Stokes/Oppenlander Method

This is an empirical method based on tests for dc arcs from 0.1 A to 1 kA. (see reference #5)

D.5.5 Paukert Method

This is an empirical method based on data of dc arc measurements from 7 sources. It predicts high current arc characteristics. (see reference #6)

D.5.6 Kinectrics Physics Model

This is a physics model based on mass and energy conservation principles. It is used to compute plasma temperature and resistance using discretized energy balance equations for finite elements across the radius of the arc. It is an iterative technique. (see reference #7)

D.5.7 Ammerman/Sen Method

This is a circuit/thermal model that assumes complete conversion of electrical arc energy into thermal energy. Arc power is determined from an iterative technique constrained by arc power and circuit characteristics. (see reference #2)

Statement of Problem and Substantiation for Public Input

Multiple methods are now in use for dc arc incident energy analysis.

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Submittal Date: Tue Jun 04 06:58:00 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-71-NFPA 70E-2024

Statement: The direct-current incident energy calculation models have been revised by including updated testing information, supporting references, dc to ac arc flash characteristic comparisons and additional considerations for direct-current incident energy calculations.

The term “nominal” was added before voltage in the Maximum Power Method, D.5.3. formula to clarify the voltage used.

Public Input No. 208-NFPA 70E-2024 [Section No. D.5]

D.5 Direct-Current Incident Energy Calculations.

D.5. 1 Dynamic Behavior of DC Arcs

Direct-current arcs are similar to three-phase ac arcs, in that continuously flowing current maintains the hot plasma, as compared to single-phase ac arcs, which cool at current zeros, which contributes to self-extinction. However, dc arcs have a unique difference to three-phase ac arcs. The spatially varying magnetic fields of the three phases of a three phase arcs combine to give a net zero effect on the motion of the arc. However, the magnetic field of a dc arc provides a continuous orthogonal force on the arc, that causes the arc to move laterally and elongate.

All of the methods discussed below assume a static arc, not changing shape in time, but staying in a direct line path between the two electrodes. A lateral magnetic force, plus electrode erosion, results in self extinction that is not predicted by any of the static models. This static assumption is true for models based on circuit theory and plasma physics that does not include dynamic arc behavior. Only an empirical model, based on sufficient data, might predict arc behavior. However, much of the data obtained for the empirical methods is from laboratory tests and does not represent actual systems, including geometry, electrode materials, and gap distances.

This lack of accounting for the dynamic behavior of the arc is the primary reason that arc extinction times are not accounted for in the current models, and the models consistently give higher incident energy values than is measured. An example is that all of the below models will predict a higher incident energy for a higher current. However, tests show that the higher currents result in lower incident energy, due to a shorter arc lifetime due to the magnetic force rapidly elongating the arc.

Testing of dc arcs has not yet been sufficient nor consistently documented, to create adequate empirically-based models. The difficulty in modeling behavior due to magnetic forces is taking into account the geometry of the conductors, and the lack of knowledge of the erosion effects is failure to document the electrode geometries and materials, and the initial and final gap distance.

Nevertheless, there is now sufficient data and dynamic behavior studies to place bounds on the use of the current models. See reference #1.

D.5. 1 Maximum Power Method.

The following method of estimating dc arc flash incident energy that follows was published in the *IEEE Transactions on Industry Applications (see reference 2 of D.5.2)*. This method is based on the concept that the maximum power possible in a dc arc will occur when the arcing voltage is one-half the system voltage. Testing completed for Bruce Power *(see reference 3 of D.5.3)* has shown that this calculation is conservatively high in estimating the arc flash value. This method applies to dc systems rated up to 1000 volts.

$$I_{arc} = 0.5 \times I_{bf}$$
$$IE_m = 0.01 \times V_{sys} \times I_{arc} \times T_{arc} / D^2 \qquad \textbf{[D.5.1]}$$

where:

I_{arc} = arcing current, amperes

I_{bf} = system bolted fault current, amperes

IE_m = estimated dc arc flash incident energy at the maximum power point, cal/cm^2

V_{sys} = system voltage, volts

T_{arc} = arcing time, sec

D = working distance, cm

For exposures where the arc is in a box or enclosure, it would be prudent to consider additional PPE protection beyond the values shown in Table 130.7(C)(15)(b).

D.5.2 Detailed Arcing Current and Energy Calculations Method.

A thorough theoretical review of dc arcing current and energy was published in the *IEEE Transactions on Industry Applications*. Readers are advised to refer to that paper *(see reference 1)* for those detailed calculations.

References:

1. “DC-Arc Models and Incident-Energy Calculations,” Ammerman, R.F., et al., *IEEE Transactions on Industry Applications*, Vol. 46, No. 5.

2. “Arc Flash Calculations for Exposures to DC Systems,” Doan, D.R., *IEEE Transactions on Industry Applications*, Vol. 46, No. 6.

3. “DC Arc Hazard Assessment Phase II,” Copyright Material, Kinectrics Inc., Report No. K-012623-RA-0002-R00.

D.5.3 Short Circuit Current.

The determination of short circuit current is necessary in order to use Table 130.7(C)(15)(b). The arcing current is calculated at 50 percent of the dc short-circuit value. The current that a battery will deliver depends on the total impedance of the short-circuit path. A conservative approach in determining the short-circuit current that the battery will deliver at 25°C is to assume that the maximum available short-circuit current is 10 times the 1 minute ampere rating (to 1.75 volts per cell at 25°C and the specific gravity of 1.215) of the battery. A more accurate value for the short-circuit current for the specific application can be obtained from the battery manufacturer.

References:

1. IEEE 946, *Recommended Practice for the Design of DC Auxiliary Powers Systems for Generating Stations*.

Statement of Problem and Substantiation for Public Input

Substantial dc modeling and arc flash tests have been conducted in the past 14 years since the creation of Annex D.5. This introduction introduces the strengths and weaknesses of the existing modeling efforts to determine incident energy, and explains the reasons behind the difference in calculations and measurements.
The primary references, summarizing much of this work are:

(1) L. Gordon, "Modeling DC Arc Physics and Applications for DC Arc Flash Risk Assessment," Proceedings of the 2023 IEEE Electrical Safety Workshop, March 2023, Reno, NV, paper 2023-20.
(2) L. Gordon, “Modeling the Dynamic Behavior of DC Arcs”, IEEE Trans. on Industry App., Vol. 60, No. 1, Jan/Feb 2024, p 1946-1955.

Submitter Information Verification

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Submittal Date: Mon Jun 03 22:39:44 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-71-NFPA 70E-2024

Statement: The direct-current incident energy calculation models have been revised by including updated testing information, supporting references, dc to ac arc flash characteristic comparisons and additional considerations for direct-current incident energy calculations.

The term “nominal” was added before voltage in the Maximum Power Method, D.5.3. formula to clarify the voltage used.

Public Input No. 115-NFPA 70E-2024 [New Section after D.5.1]

D.5.1 Exposed Conductor Separation

Batteries, PV, and other dc circuits commonly have equipment designs that separate exposed conductors to reduce the risk of short-circuit, shock, and arc flash. It is unlikely that a dc arc can be sustained in ungrounded or impedance grounded dc systems below 600 volts between exposed conductors with separation greater than 1 millimeter per volt (see reference [1]).

[1] D. M. Rosewater, "Reducing Risk When Performing Energized Work on Batteries," in IEEE Transactions on Industry Applications, vol. 60, no. 2, pp. 2732-2741, March-April 2024, doi: 10.1109/TIA.2023.3332828.

Statement of Problem and Substantiation for Public Input

The maximum power method overprescribes PPE in many dc systems. It is critical to know where an electric arc could happen to control the hazard effectively. The proposed rule enables worker to focus electrical safety controls where they are most needed. The following peer reviewed journal article derived 1mm / V from the published minimum voltage of thousands of arc experiments over a range of arc gaps. This rule conservatively overestimates the experimental maximum arc gap in battery systems from 105 V to 520 V dc. D. M. Rosewater, "Reducing Risk When Performing Energized Work on Batteries," in IEEE Transactions on Industry Applications, vol. 60, no. 2, pp. 2732-2741, March-April 2024, doi: 10.1109/TIA.2023.3332828. This reference is open access and available online: https://ieeexplore.ieee.org/document/10316636
Authors in the following conference paper support this rule in their research conclusions: W. Cantor, L. Gordon, S. Marri “NFPA 70E Proposed DC Arc Flash Updated Guidance” 2024 IEEE IAS Electrical Safety Workshop, Tucson, AZ.

This public input is a combined effort from the Energy Facility Contractors Group (EFCOG), a working group of electrical safety professionals at Department of Energy National Labs, and the IEEE PES Energy Storage and Stationary Battery (ESSB) committee’s safety codes working group, a group of stationary battery and energy storage industry professionals.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 110-NFPA 70E-2024 [New Section after 320.3(A)(2)]	Proposed battery arc flash risk assessment
Public Input No. 110-NFPA 70E-2024 [New Section after 320.3(A)(2)]	
Public Input No. 155-NFPA 70E-2024 [Section No. 130.7(C)(15)]	

Submitter Information Verification

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Committee: EEW-AAA

Committee Statement

Resolution: FR-71-NFPA 70E-2024

Statement: The direct-current incident energy calculation models have been revised by including updated testing information, supporting references, dc to ac arc flash characteristic comparisons and additional considerations for direct-current incident energy calculations.

The term “nominal” was added before voltage in the Maximum Power Method, D.5.3. formula to clarify the voltage used.

Public Input No. 213-NFPA 70E-2024 [Section No. D.5.1]

D.5.1~~—~~ 2 _ Maximum Power Method.

The following method of estimating dc arc flash incident energy that follows was published in the *IEEE Transactions on Industry Applications (see reference 2 of D.5.2)*. This method is based on the concept that the maximum power possible in a dc arc will occur when the arcing voltage is one-half the system voltage. ~~Testing completed for Bruce Power *(see reference 3 of D.5.3)* has~~ Multiple tests conducted in the past 12 years have shown that this calculation is conservatively high in estimating the arc flash value. This method applies to dc systems rated up to 1000 volts.

$$I_{arc} = 0.5 \times I_{bf}$$
$$IE_m = 0.01 \times V_{sys} \times I_{arc} \times T_{arc} / D^2 \qquad \text{[D.5.1]}$$

where:

I_{arc} = arcing current, amperes

I_{bf} = system bolted fault current, amperes

IE_m = estimated dc arc flash incident energy at the maximum power point, cal/cm^2

V_{sys} = system voltage, volts

T_{arc} = arcing time, sec

D = working distance, cm

For exposures where the arc is in a box or enclosure, it would be prudent to consider additional PPE protection beyond the values shown in Table 130.7(C)(15)(b).

Statement of Problem and Substantiation for Public Input

The three references used in the 2012 70E in this section are now out of date. New ones will be added at the end. This effort on D.5 is composed of the team of Bobby Gray, Bill Cantor, Lloyd Gordon, David Rosewater, and Curtis Ashton.

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Submittal Date: Mon Jun 03 23:08:09 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-71-NFPA 70E-2024

Statement: The direct-current incident energy calculation models have been revised by including updated testing information, supporting references, dc to ac arc flash characteristic comparisons and additional considerations for direct-current incident energy calculations.

The term “nominal” was added before voltage in the Maximum Power Method, D.5.3. formula to clarify the voltage used.

Public Input No. 55-NFPA 70E-2024 [Section No. D.5.1]

D.5.1 Maximum Power Method.

The following method of estimating dc arc flash incident energy that follows was published in the *IEEE Transactions on Industry Applications (see reference 2 of D.5.2)*. This method is based on the concept that the maximum power possible in a dc arc will occur when the arcing voltage is one-half the system voltage. Testing completed for Bruce Power *(see reference 3 of D.5.3)* has shown that this calculation is conservatively high in estimating the arc flash value. This method applies to dc systems rated up to 1000 volts.

$$I_{arc} = 0.5 \times I_{bf}$$
$$IE_m = 0.01 \times V_{sys} \times I_{arc} \times T_{arc} / D^2 \qquad \textbf{[D.5.1]}$$

where:

I_{arc} = arcing current, amperes

I_{bf} = system bolted fault current, amperes

IE_m = estimated dc arc flash incident energy at the maximum power point, cal/cm^2

V_{sys} = nominal system voltage, volts

T_{arc} = arcing time, sec

D = working distance, cm

For exposures where the arc is in a box or enclosure, it would be prudent to consider additional PPE protection beyond the values shown in Table 130.7(C)(15)(b).

Statement of Problem and Substantiation for Public Input

Users often are trying to use maximum possible system voltage in this calculation, when the calculation almost always significantly exceeds actual tested arc flash energy in the hundreds of tests that have been done. In the hundreds of "low voltage": DC arc flash tests that have now been done (most of them in the last 7 years), the voltage of the arc is almost immediately reduced to a level below that of even the nominal voltage in most cases, and often continues to fall until the arc extinguishes. Having users take an already overly conservative formula, and make it even more conservative by using a voltage that is above what has actually been seen in real testing leads to overprotection. Anyone who has worn an arc flash suit knows that in some ways it can make you less safe by making you hot and sweaty (thus impairing vision through the face shield or hood as it fogs up), by lowering human body resistance due to the sweat, and by making the worker far less dextrous. It is highly important that PPE protect against the hazard, but overprotection can make the worker less safe, and comes from a place of fear rather than wise knowledge.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 78-NFPA 70E-2024 [Section No. D.5.1]	voltage used in both formulae
Public Input No. 78-NFPA 70E-2024 [Section No. D.5.1]	

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Committee Statement

Resolution: FR-71-NFPA 70E-2024

Statement: The direct-current incident energy calculation models have been revised by including updated testing information, supporting references, dc to ac arc flash characteristic comparisons and additional considerations for direct-current incident energy calculations.

The term “nominal” was added before voltage in the Maximum Power Method, D.5.3. formula to clarify the voltage used.

Public Input No. 78-NFPA 70E-2024 [Section No. D.5.1]

D.5.1 Maximum Power Method.

The following method of estimating dc arc flash incident energy that follows was published in the *IEEE Transactions on Industry Applications (see reference 2 of D.5.2)*. This method is based on the concept that the maximum power possible in a dc arc will occur when the arcing voltage is one-half the system voltage. Testing completed for Bruce Power *(see reference 3 of D.5.~~3~~ 2)* has shown that this calculation is conservatively high in estimating the arc flash value. This method applies to dc systems rated up to 1000 volts.

$$I_{arc} = 0.5 \times I_{bf}$$
$$IE_m = 0.01 \times V_{sys} \times I_{arc} \times T_{arc} / D^2 \qquad \textbf{[D.5.1]}$$

where:

I_{arc} = arcing current, amperes

I_{bf} = system bolted fault current, amperes

IE_m = estimated dc arc flash incident energy at the maximum power point, cal/cm^2

V_{sys} = system voltage, volts

T_{arc} = arcing time, sec

D = working distance, cm

Repeated experiments by multiple companies *(see reference 4 of D.5.2 for a summary of all of those different tests as well as bibliographic reference to the published results of most of them)* have shown that the maximum power method produces fairly accurate results at around 500 Vdc, where arc sustaining times average about 2 seconds. For lower voltages (which are quite common), the arc cannot sustain itself (even with close electrodes in an "optimal" configuration) for nearly that long, and the maximum sustaining time becomes lower and lower as the voltage goes down. Empirical derivation *(see reference 4 of D.5.2)* of a maximum sustaining time yields the following formula:

$$T_{arc} = 0.0043 \times V_{sys} \qquad \textbf{[D.5.2]}$$

Modifying the maximum power incident energy formula with this new value of T_{arc} yields results much closer *(see comparisons of values in reference 4 of D.5.2)* to the values seen in actual testing, and to the values produced by the iterative methods *(such as the one detailed in reference 1 of D.5.2.)*

For exposures where the arc is in a box or enclosure, it would be prudent to consider additional PPE protection beyond the values shown in Table 130.7(C)(15)(b).

Additional Proposed Changes

File Name	Description	Approved
ESW2024-11.pdf	IEEE IAS ESW 2024 paper on this subject of modifying the max power method for maximum arc sustaining time based on the voltage	

Statement of Problem and Substantiation for Public Input

It is well known due to hundreds of DC arc flash tests that the maximum power method is overly conservative at voltages much below 500 Vdc, and that the iterative methods (such as Stokes/Oppenlander, Ammerman/Sen, and Paukert) produce results that are closer to what has actually been seen in tests. Because of this, some have suggested getting rid of the maximum power method completely from this Annex. I believe this to be a bad move. The iterative methods are complex enough that most people who don't have math or physics degrees cannot run those iterative calculations by themselves without using a computer program. While the computer program is the best way to run the iterative methods to produce rapid and decently accurate results, the computer program is only as good as the programmer, and only as good as the inputs given by the user of the program. I have seen way too many ridiculous calculations of dc arc-flash energy produced by programs using the iterative method, usually because the user of the program does not know enough about the values they are inputting into the program to know whether the result they are getting is valid or not. Because the maximum power method can be used by anyone who knows how to use algebra, it can be used to easily check against iterative values produced by computer programs to see if both results are in the same "ballpark" so that ridiculous calculations don't end up on stickers requiring overprotection, which oftentimes makes a worker less safe (sweatier, less vision due to fogging of the helmet, and way less dextrous). However, except near 500 Vdc, the present version of the maximum power method is not accurate when compared to real observed arc flash energies from testing. Modifying the equation for a maximum arc sustaining time allows it to fall in line with accurate iterative calculation models so that the results of computer programs can be checked. There are also those who argue that an even more complex formulas than the iterative models are needed - one that takes into account various electrode separations and orientations. I would argue, that even if such formulae are developed, there still needs to be a relatively simple hand-calculation method available. I would also argue that in many cases in the arc flash world (especially in a battery cabinet, such as might be found in a DataCenter UPS), there can be a myriad of different possible electrode separations and orientations due to the many exposed battery terminals and the impossibility of knowing the size of the object that initiates the arc (loose screw, bent stab, breaking spring, dropped tool or other metallic object, etc.). I'm not arguing against having more complex methods and many calculations that can be run by a computer to get the worst-case scenario, but am simply arguing for keeping a modified maximum power method as a way to double-check computer calculations for accuracy on a "spot" basis.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 55-NFPA 70E-2024 [Section No. D.5.1]	
Public Input No. 55-NFPA 70E-2024 [Section No. D.5.1]	
Public Input No. 82-NFPA 70E-2024 [Section No. D.5.2]	

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Committee: EEW-AAA

Committee Statement

Resolution: FR-71-NFPA 70E-2024
Statement: The direct-current incident energy calculation models have been revised by including updated testing information, supporting references, dc to ac arc flash characteristic

comparisons and additional considerations for direct-current incident energy calculations.

The term “nominal” was added before voltage in the Maximum Power Method, D.5.3. formula to clarify the voltage used.

MODIFYING THE DC ARC-FLASH MAX POWER FORUMULA TO GIVE MORE REALISTIC PREDICTIONS OF MAXIMUM ARC-FLASH ENERGY

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Paper No. ESW-11

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Abstract – The maximum power formula (proposed by Dan Doan in a 2007 IEEE paper) for calculating dc arc-flash incident energy has been in NFPA 70E since 2012; however, repeated testing by multiple companies over the years has shown that it overestimates arc-flash energy by a factor of at least 2-10, especially at lower voltages (such as nominal 48, 125, or 250 Vdc). This paper analyzes the actual measured arc-flash energy from over 100 different tests at various voltages, and proposes modifications to the arc sustaining time in the maximum power transfer theorem equation(s) found in Annex D.5 of NFPA 70E. In addition, more realistic estimates for dc arc-flash boundary multipliers are developed for cases where the arc is “in a box”, than what has been found in previous editions of NFPA 70E. These are based on observations of dc arc-flash tests, calculations of reflected energy from the rear of typical cabinets using the maximum power method, and previous studies of "arc-in-a-box” energy multipliers for ac arc-flash.

Index Terms — DC arc-flash, arc sustaining time, maximum power transfer formula, arc-flash boundary.

I. INTRODUCTION

For the first 80 years or so of the “electric age” almost all research into the hazards of electricity was on electric shock (and attendant electrocution at high enough levels to cause death). During all this time people were also beingh injured and killed from arc-flash/blast in addition to electric shock / electrocution. However, research into incident energy on the human body from electric arc-flash didn’t begin in earnest until approximately 1973, with the first method to calculate that danger from ac not introduced until 1982 [1]. NFPA 70E [2] did not reference any methods for calculating this ac arc-flash energy until 1995 and later editions, followed by even more on ac calculations in the 2002 initial edition of IEEE 1584 [3] (since updated in 2018).

OSHA rules for electrical safety [4] only indirectly refer to electric arc hazards (they refer to electric arcs, but not specifically to arc-flash/blast) since they were published in 1992 (before there were standards calculations methods referenced in NFPA 70E [2] and before IEEE 1584 [3] existed).

Work on dc arc-flash did not begin in earnest until 1991 [5], and the first calculations referenced in NFPA 70E [2] for dc arc-flash incident energy did not appear until the 2012 edition (following some additional dc arc-flash testing and analysis in the years 2007-2011 [6, 7]). More recent dc arc-flash testing done from 2017-2022 [8, 9, 10, 11, 12, 13, 14, 15] provided more useful data, and helped in the decision to raise the dc special PPE arc-flash protection threshold (when using the table [PPE Category] method as opposed to the calculation method) to 150 V in the 2024 edition of NFPA 70E [2] by proving that in almost all cases where maximum short-circuit current from the battery is less than 17,000 A and the voltage is below 150 Vdc, 1.2 cal/cm^2 incident energies or greater at 18 inches or further away cannot be produced.

II. EXISTING DC ARC-FLASH MODELS

A. Stokes/Oppenlander Method [5]

In 1991, Stokes and Oppenlander published [5] the first dc arc-flash incident energy formulas (empirically derived from many gapped electrode tests at varying voltages, currents, gap widths, and electrode orientations). This method requires an initial guess and iterative equation solving. The research involved both ac and dc up to 1,000 V, but the dc was limited to smaller arc currents (less than 1,000 A). If the arcing current is too low relative to the voltage, these equations cannot be solved (even iteratively).

B. Paukert Method [16]

In 1993, more formulas (empirically derived from 7 different studies) to calculate dc arc-flash incident energy were published [16] and presented by Paukert. This method is also an iterative method, requiring an initial guess, and then iterative equation solving is repeatedly done.

C. Lab Physics Model

Most of the dc arc-flash testing (as well as significant amounts of ac arc-flash testing) that has been done was done at a lab [7, 10, 12, 13, 14, 17] facility in Toronto Canada. Between 1995 and 2007 (prior to most dc arc-flash testing), this lab used physics principles (rather than empirically derived/”fit” formulas from observed results) to develop a complex predictive model for incident arc-flash energy using complex iterative processes. Prior to running tests, they use this model to predict results, and then compare them to the actual observed testing data. It has been shown in much of the more recent testing [6, 8, 9, 10, 11, 12, 13, 14] referenced in this document that their slightly old (by now) theoretical physics model typically overestimates incident energy by at least a factor of 2.

D. Doan / Maximum Power Transfer Theorem [18]

In 2007, Dan Doan published [18] the maximum power transfer theorem for dc (building on earlier ac work), which in its present form (this paper proposes a modification/ improvement of the method to make it more accurate at lower voltages) is the most conservative of the methods (i.e., it typically overestimates the actual incident energy from dc arc-flash more than the iterative methods). Calculations are done using a simple formula (or two – see NFPA 70E [2] Annex D.5 for the 2 equations that have been combined into equation 1):

$$IE = 0.01 \times V_{nom} \times \frac{I_{sc}}{2} \times \frac{t}{d^2} \quad (1)$$

where

IE	is the incident energy in cal/cm²
V_{nom}	is the nominal dc voltage
I_{sc}	is the maximum (bolted fault) short circuit current (battery manufacturers typically publish this, and manufacturers can often provide it for other types of dc equipment)
t	is the time before an upstream OCPD (e.g., fuse or breaker) operates, or the maximum time that the arc can sustain itself (NFPA 70E [2] notes that the calculation time should probably not exceed 2 seconds, and IEEE 1584 [3] supports this because the person will have likely reacted and moved away within that time if space allows)
d	is the typical distance of the vital organs of the body from the electrical equipment that could have the arc-flash event, and is noted in NFPA 70E [2] for most of the dc voltages that most users deal with as 18 inches (equivalent to 45.72 cm, which is usually the value used since the incident energy is in SI units of cal/cm²)

Note that this is the only formula(s) for dc arc-flash calculations given in NFPA 70E [2]. The only other methods indirectly referenced for dc arc-flash calculations in NFPA 70E [2] (Annex D.5) are the Stokes/Oppenlander [5] and Paukert [16] iterative methods.

While not the most accurate method for a wide array of nominal voltages (actual testing has shown it to be fairly accurate when nominal dc voltages are near 480 though), this maximum power method is commonly used.

One big problem with this maximum power method is its overestimation of the risk at lower voltages. More PPE than is needed can make a user less safe by making them less dexterous, too hot and sweaty, etc. A smaller issue with this method (and all the other methods mentioned in this section are probably limited in the same way based on the data and assumptions used in those models) is that it is limited to dc voltages below 1,000 The majority of dc systems in the world today are below this voltage, but there are more and more being installed above that voltage, such as with grid scale solar and wind generation, especially with attendant battery energy storage systems.

Like the lab physics model, the maximum power transfer method is theoretical, and has not proven to be as accurate as empirically-derived formulas from actual testing, such as those from the Stokes, Paukert, and Ammerman models/methods.

A subsequent section in this paper will cover a proposed method of making this maximum power calculation more accurate at lower voltages by empirically deriving a formula for the arc sustaining time since this less-accurate method for incident energy and arc flash boundary calculations is still fairly commonly used.

E. Ammerman Method [19]

In 2009, Ammerman and colleagues (including P.K. Sen) published [19] another iterative method for determining dc arc-flash energy. While not referenced in NFPA 70E [2] Annex D.5, it may still be used, with engineering judgement.

III. DC ARC SUSTAINING TIME

Those who calculate dc arc-flash incident energy manually using the Maximum Power [18] formulas found in NFPA 70E [2] have usually used dc arc sustaining times of 2 seconds (in some cases longer in an effort to be more conservative), at least on the portions of the analyzed circuit where a fuse or breaker will not limit the time to less than that. The 2 second maximum time comes from NFPA 70E [2] and IEEE 1584 [3], where the assumption was made that if the "space" made it possible, human reaction would cause the person to back away from the arc flash within 2 seconds. In the opinion of the author, based on video observations of arc-flash testing and actual real arc-flashes, if space allows it, in larger arc flash incidents, the arc blast is likely to knock the person down or back out of the area within the 2 seconds as well.

The iterative methods [5, 16, 19] are more accurate than the maximum power method for many reasons, with one of those reasons being that they usually compute a more realistic arc sustaining time.

For those still using the maximum power method and a default 2 second (or more) arc sustaining time, dozens of individual [6, 7, 8, 9, 10, 11, 12, 13, 14, 20] real world tests (see Figure 1) have shown that 2 seconds is far longer than the actual arc sustaining time for dc arcs below approximately 480 Vdc.

The different lengths of arc sustaining time shown in Figure 1 for each of the different nominal tested voltages (nominal 100, 125, 250, and 480) are due to different maximum short circuit currents of the dc equipment under test, different starting electrode lengths, and orientation of the electrodes.

Using a more accurate arc sustaining time to calculate more realistic incident energy for lower dc voltages is important due to the sheer number of dc systems (or dc busses in UPSs) that operate below that level. Common lower dc bus nominal voltage levels found in many installed systems include: 12, 24, 36, 48, 125 (120), 192, 216, 250 (240), 288, and 380 (336, 360, and 384). Note that the latest edition (2024) of NFPA 70E [2] does not require special arc-flash protective clothing (other than safety glasses) for dc arc-flashes below 150 Vdc if the table (aka PPE Category) method is used, based on numerous tests [11, 12, 13, 14] run mostly over the last 7 years. The previous 4 editions of NFPA 70E [2] did not require special clothing below 100 Vdc (if the table / PPE Category method was used). However, arc-flash calculations below 150 (or even 100) Vdc are sometimes still used/desired, especially if the total potential short circuit current is 17,000 A or more, as will be shown later on in test results reviewed in this paper.

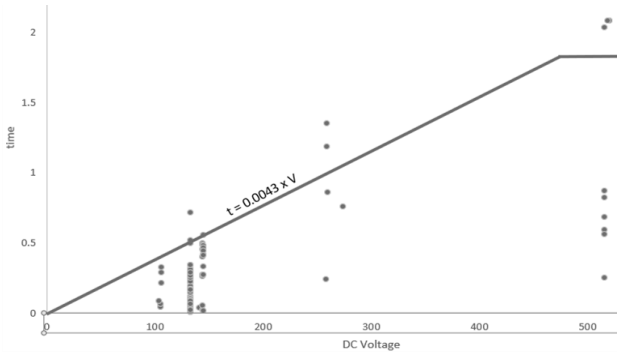


Fig. 1 Real World Testing DC Arc-Flash Sustaining Times along with Empirically-Derived Maximum Arc Time

One conclusion of all these tests is that existing maximum power transfer calculations for voltages below 480 Vdc have been severely overestimating maximum incident energy from dc arc-flashes at the standard 18 inch (45.72 mm) [2] vital body organ distance partially due to overestimation of the time that the arc can sustain itself. Curve fitting the results so that most of the points fit under the "curve"; and maximizing at 2 seconds of arc time [2, 3] yields the lines (along with a voltage-based formula) in Figure 1. The point at which the formula yields 2 seconds or longer arc sustaining times is nominal 465 Vdc, which is consistent with real world testing [6, 7, 8, 9, 10, 13].

None of the published testing data [6, 7, 8, 9, 10, 11, 12, 13, 14, 20] is at dc voltages lower than 100, partly because it has been known for at least a dozen years that dc arc-flashes below that voltage cannot produce incident energy above the 1.2 cal/cm^2 2nd-degree maximum burn threshold (as noted earlier in this section, that dc voltage has now been moved to 150 when using the table / PPE Category method) [2]. However, when testing has been done below that 100 Vdc level, although the arc sustaining time results have not been "published", the arc sustaining times observed were consistently below what is predicted by equation (2). For example, Fechalos and Blake, while presenting their 2023 Battcon paper [10] showed an example video of a 48 Vdc test, and the approximate duration of the arc-flash was about 100 milliseconds, which is about half of what equation (2) predicts for a maximum arc sustaining time at that nominal voltage.

$$t = 0.0043 \times V_{nom} \quad (2)$$

when

V_{nom} is ≤ 465 Vdc

$$t = 2 \quad (3)$$

when

V_{nom} is > 465 Vdc

Many actual test arc sustaining times fall below (see Figure 1) the values predicted by equations 2 and 3. This is mostly due to lack of an electrode separation distance variable in the equation(s). The author purposely did not include electrode separation, since in many dc systems, electrode separation can be highly variable, depending on the length of the object that initiates the arc. For example, in a cabinetized UPS monobloc battery system, there are a multitude of possibilities for distances between differing polarities (including ground), even at the same nominal voltage. Instead, the purpose of this work is to establish a reasonable upper bound on the maximum dc arc sustaining time based on the available data. This may overprotect in some cases, but at voltages below nominal 480 V where the maximum power method is presently being used with a 2 second (or more) arc sustaining time, this modification is going to greatly decrease the existing overcalculation of the risk. Perhaps future work can focus on additional variables in arc sustaining time (such as electrode separation and orientation)?

Finally, on the subject of dc arc sustaining time, in the experience of the author, many dc arc-flash calculations that have been done in existing industrial facilities (such as UPS battery cabinets in large data centers) neglect (usually due to the person running the calculations or inputting the circuit parameters into a computer program not accounting for OCPDs in parallel paths) the fact that any dc source fault current contribution flowing through a fuse or breaker towards an arc-flash/blast fault point will usually be time-limited by the I-t curve of the fuse/breaker(s) in the path. For example, for a worker in one battery cabinet of a UPS that has 4 parallel battery cabinets (with each cabinet having its own internal breaker at the top), the arc-flash incident energy from the cabinet where the work is being done will be time-limited only by the nominal voltage of the fault causing the arc-flash, as per equation (2) or (3). However, all parallel sources (the other 3 battery cabinets and the UPS dc charging source) that can contribute to the fault current will have to flow through one or two breakers. Assuming these breakers are sized and have any adjustable instantaneous trip settings correctly set, the high fault currents from these sources flowing towards the source should cause the breaker(s) to open on the instantaneous portion of their trip curve (typically within 16-60 milliseconds on average, depending on breaker model and manufacturer). This greatly limits the overall arc flash energy. In numerous calculations run by the author, the additional incident energy contributed by parallel sources flowing through properly sized and adjusted breakers (or through properly sized fuses) is usually no more than 7% of the total incident energy that has been negligently calculated (and posted on labels on cabinets or panels) without consideration of fuses or breakers in parallel paths.

IV. ARC-IN-A-BOX THEORY VS REALITY

When dc arc-flash calculations were introduced in Annex D of NFPA 70E [2] in 2012, guidance was given that arc-in-a-box (due to reflected energy off the sides, top, bottom, and rear of the box) could be 3 times or more the calculated arc-flash energy (because the models mentioned in Section II of this paper mostly assume spherical energy spread from the point of the arc, and do not normally take reflected energy into account). This assumption was based partly on testing in low voltage (600 V or lower at the time [21]) ac panelboards [3] that have very short depths (typically 4-6 inches {10-15 cm}), which causes fairly significant reflection of energy from the rear. It was also based on testing of medium voltage (1-36 kV) [21], and low voltage (≤ 600 V) [21] larger ac switchgear cabinets. This testing, and IEEE 1584 [3] guidance gives a multiplication factor of 1.6 for ac panelboards [22] (see Figure 2), regardless of distance from the arc-flash event. The multiplication factor varied [3, 22] for low voltage and medium voltage larger ac switchgear cabinets, from between 1.0 and 2.2 at the vital organ distance [2] of 18 inches (45.72 cm), up to a maximum

multiplying factor of 3.8-4.75 for these large switchgear cabinets at the typical maximum arc-flash boundary distance of 10 feet [2] (approximately 3 m).

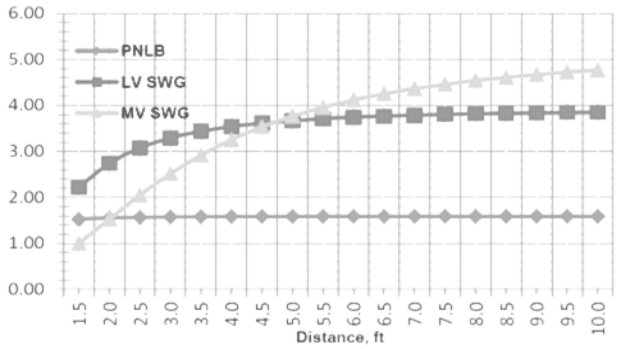


Fig. 2 AC arc-in-a-box Incident Energy Multiplication Factors vs. Distance [3, 22]

This guidance carried into the 2015 edition of NFPA 70E [2]. However, in the 2018 edition, the guidance had been changed from a multiplier of 3x for dc arc-in-a-box to "… it would be prudent to consider additional PPE protection beyond the values shown in Table 130.7(C)(15)(b)." This same "new" language is in the subsequent editions of NFPA 70E [2]. This change was made in the 2018 edition because actual testing up to that point [6, 7, 20], and testing since [8, 9, 10, 11, 12, 13, 14], had not shown nearly triple the difference between incident energies measured from dc arc-in-a-box vs open air, all other conditions (such as electrode spacing and orientation, maximum short circuit current, nominal voltage, etc.) being equal. In most cases the observed/measured incident energy at 18 inches (45.72 cm) [2] from dc arc-flash energy reflected from a "box" is more (although usually much less than triple) than it would be in open air, and in some cases it was less.

Because of a lack of dc arc-flash testing done/published for dc panelboards, there is no reason yet to use any factor for dc panelboards other than the 1.6 multiplication factor (see Figure 3) for ac panelboards [3, 22], since they tend to have similar dimensions to ac panelboards (being equipped with dc breakers or fuses rather than ac breakers or fuses).

The maximum power theorem formula(s) {see equation (1)} can also be used to determine the arc-flash boundary (the distance where the incident energy drops to the 2nd-degree burn threshold of 1.2 cal/cm^2 [2] or lower). See equation (4) for the algebraically modified formula and note that the incident energy value is now under a square root. This means that if the arc-flash energy from a panelboard is 1.6 times the value calculated by equation (1), the distance multiplier for determining the arc-flash boundary for dc panelboards should be the square root of 1.6 (√1.6 = 1.265).

$$d = \sqrt{\frac{0.01 \times V_{nom} \times \frac{I_{SC}}{2} \times t}{IE}} \quad (4)$$

Based on observations of dc arc-flash testing done with cabinets (such as UPS battery cabinets), there is some reflected energy, but nowhere near triple the energy at the critical body organ distance [2] of 18 inches (45.72 cm). In most cases, it should be much less than a 1.6 multiplier at that distance because of the depths of these cabinets compared to panelboards. Arc-flash energy decreases as it moves away from the source by the square of the distance [1, 2, 18]. In a sample calculation for a typical UPS battery cabinet 4 feet (1.2 m) wide by 33½ inches (0.85 m) deep by 7 feet (2.13 m) tall, most of the reflected (as opposed to the direct energy from the arc-flash) energy that will impinge on the body's vital organs, at approximately 18 [2] inches (45.72 cm) from the front of the battery, will be the direct reflection from the rear. That addition to incident energy for this cabinet, (based on the square of the distance) would be approximately $^1/_{30}^{th}$ (a multiplier of 1.03). There will be even less reflected additive energy from the top, bottom and sides of the cabinet due to their greater distances and oblique angles to the human body in front of the "box".

There have been more than 90 dc arc-flash tests [6, 7, 8, 9, 10, 11, 12, 13, 14, 20] yielding enough data to do comparisons like Figures 3 through 10. About 87% of those tests were arc-in-a-box tests (in medium/large cabinets), with the rest done in open air. Only two tests yielded actual measured arc-flash incident energy at 18 inches (45.72 cm) [2] that exceeded maximum power formula {equation (1)} calculations (without any arc-in-a-box multiplier), even when modified for lower arc-sustaining times per equation (2) at lower voltages. Those two cases [9] were on nominal 120 Vdc PV systems with maximum fault current (< 2,000 A) lower than typical for many dc applications, and the actual and calculated incident energies at 18 inches (45.72 cm) all fell below the 1.2 cal/cm^2 2nd-degree burn threshold, above which special PPE is required [2]. Also, for the limited comparisons (see Figure 3) that have been done [15] for actual dc arc-flash testing results vs iterative methods (Paukert [16] and Stokes [5] in this case), the actual incident energy measured (even in a "box") was less than or essentially equivalent to what was calculated by the iterative methods (except for one instance previously noted), without using an arc-flash multiplying factor.

IEEE 1584 [3] and other sources [22] note (see Figure 2) that the arc-in-a-box incident energy multiplier increases for switchgear cabinets at distances greater than 18 inches (45.72 cm). This is due to the decreasing ratio of reflected energy distance to body distance away from the cabinet; however, it does not affect incident energy calculations [2] at 18 inches (45.72 cm). For example, the multiplier in Figure 3 for MV switchgear cabinets at 18 inches (1.5 feet) is 1.0. It only becomes a "multiplier" at further distances (such as the arc-flash boundary distance in most cases). As such, the ac arc-in-a-box incident energy multiplier (2.2-3.8 at the high end per Figure 2) for low voltage ac switchgear at greater distances [3, 22] might be applied to the arc-flash boundary calculation for low voltage dc cabinets. Since most dc applications fall into the "low voltage" (which is now below nominal 1,500 Vdc [1,000 Vac] in the NEC® [21]) category, but most dc larger cabinets are more similar in size to a front-access medium voltage switchgear cabinet; the incident energy multiplier curves from Figure 2 can be averaged, and curve fit. Taking the square root of that curve yields the following formula for arc-flash boundary distance multipliers for larger dc cabinets:

$$m_{AB} = (0.55 \times \ln(d_{in})) - 0.6 \quad (5)$$

where

m_{AB} is the dc arc-flash boundary distance multiplier for large cabinets

d_{in} is the base arc-flash boundary distance (in inches) for arcs not in a box calculated from the maximum power formula

Based on this analysis, the author recommends either leaving existing language on dc arc-in-a-box multipliers in Annex D.5 of NFPA 70E [2] as is; or changing it to read something similar to the following: "For exposures where the arc is in a box or enclosure, it may be prudent to apply a multiplying factor up to 1.6 to the incident energy calculation for purposes of PPE for dc panelboards, and a corresponding distance multiplication factor up to 1.265 to the arc-flash boundary calculation. For larger dc enclosures, such as UPS battery cabinets, testing, calculations, and observation have shown that the reflected energy from the rear, sides, top, and bottom of these enclosures only adds very minimally to the incident energy at the vital body organ typical distance of 18 inches (45.72 cm) [2]. Thus, no multiplication factor for the calculation of incident energy is suggested. However, it may be prudent to apply a multiplier based on empirical equation (5) for calculation of the arc-flash boundary (with a maximum distance of 10 feet) for dc cabinets larger than a panelboard due to the relative contribution of reflected energy vs direct incident energy at greater distances for larger dc enclosures."

V. COMPARISON OF CALCULATIONS VS ACTUAL TEST RESULTS

Limited work has been done comparing tested incident energy at 18 inches (45.72 cm) [2] to the different dc arc-flash models. However, one paper [20] undertook calculations for 2 iterative methods (Paukert [16] and Stokes [5]), as well as the maximum power transfer theorem [18, 21], for 7 individual tests [9, 12, 13] from the many that have been reported. The results of this comparison, supplemented with the maximum power transfer theorem {equation (1)} modified for time by equations (2) and (3), are shown in Figure 3 (note that the clusters along the horizontal axes of each of Figures 3-10 represents an individual test).

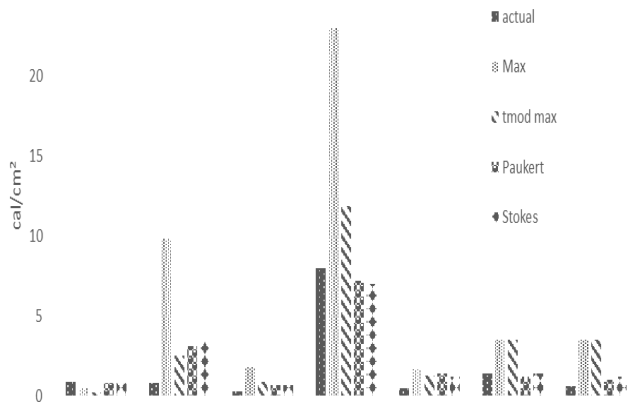


Fig. 3 Actual Incident Energy vs Existing and Proposed Methods

From this comparison of 7 incident energy measurements to 4 different calculation methods, it can be seen that at least 2 of the iterative methods [5, 16], as well as the maximum power formula(s) [2, 18] {see equation (1)} modified for maximum dc arc sustaining time by equations (2) and (3), provide a good upper bound for incident arc-flash energy at 18 inches (45.72 cm) [2] without requiring excessive PPE (which can actually make the user less safe by making them less dexterous and sweatier).

For the more than 90 individual tests [6, 7, 8, 9, 10, 11, 12, 13, 14, 20] for which enough useful data has been published for good comparison, the author ran calculations for dc arc-flash at 18 inches (45.72 cm) [2] with both the maximum power transfer theorem [2, 18], using equation (1) with a maximum time value of 2 seconds [2, 3], as well as with modified time values per equations (2) and (3). These 90+ test results can essentially be grouped into 4 nominal dc voltage "bins" of 100, 125, 250, and 480 Vdc.

Figure 4 compares a random sample (for readability) of 8 (of the more than 90) test's actual incident energies (measured at different nominal voltages, short circuit currents, electrode configurations, and electrode spacings), against the maximum power method calculated at 2 seconds and at the modified maximum arc sustaining time from equations (2) and (3):

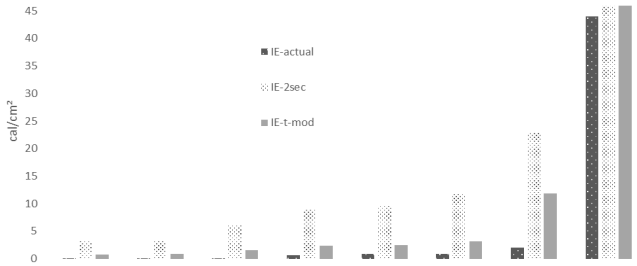


Fig. 4 Sample Comparison of Max Power Calculations (Modified for Time and Not) Against Actual Incident Energies

Figure 4 shows the large difference in accuracy (in most cases) of maximum power calculations when arc sustaining is modified for time (even when only based on voltage) versus calculations using a 2 second arc sustaining time.

Each of the nominal voltage "bins" (the bin for nominal 125 Vdc is further divided into various ranges of maximum short circuit current available in order to make the data more readable because there have been so many nominal 125 Vdc arc-flash tests run [7, 9, 11, 12, 13, 14, 20]) is represented by a different graph in Figures 5 through 10. In these graphs, for readability purposes, the generally highly overstated maximum power calculations at 2 seconds are not even shown (except at nominal 480 Vdc where the calculation {equation (3)] yields 2 seconds), since they would usually make the y-axis of the chart much taller.

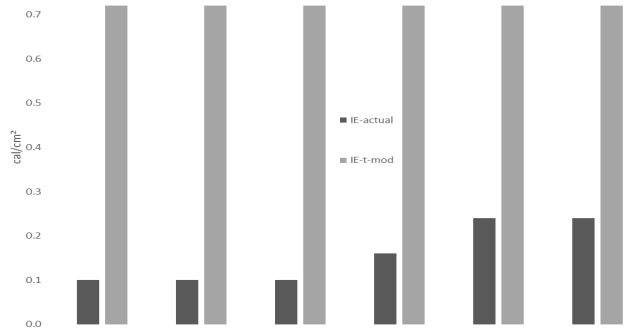


Fig. 5 Comparison of Measured Incident Energies for Nominal 100 Vdc Tests to Unmodified and Modified Maximum Power Theorem Formulas

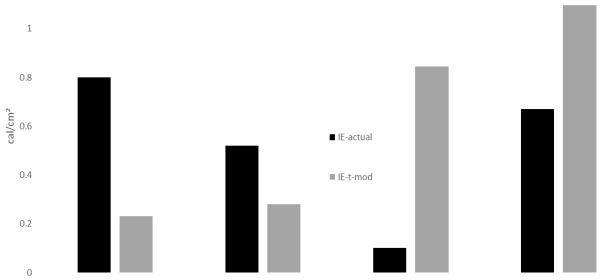


Fig. 6 Comparison of Measured Incident Energies for Nominal 125 Vdc Tests with Available Short Circuit Currents of Less than 7,500 A to Unmodified and Modified Maximum Power Theorem Formulas

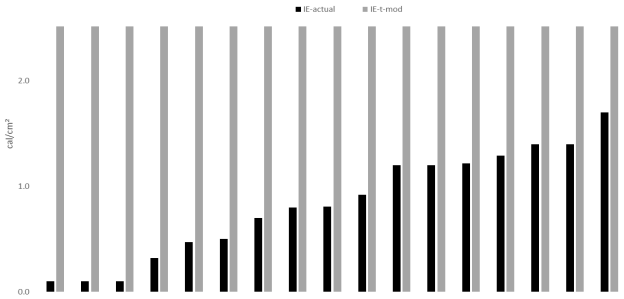


Fig. 7 Comparison of Measured Incident Energies for Nominal 125 Vdc Tests with Available Short Circuit Current of 17,000 A to Unmodified and Modified Maximum Power Theorem Formulas

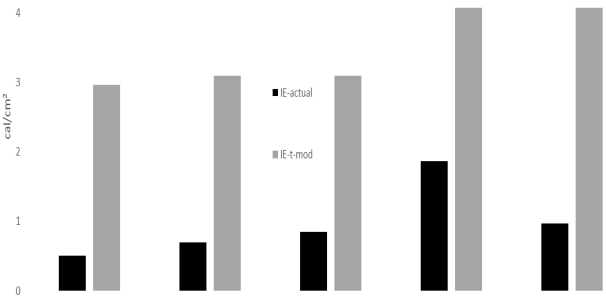


Fig. 8 Comparison of Measured Incident Energies for Nominal 125 Vdc Tests with Available Short Circuit Currents Greater than 17,000 A to Unmodified and Modified Maximum Power Theorem Formulas

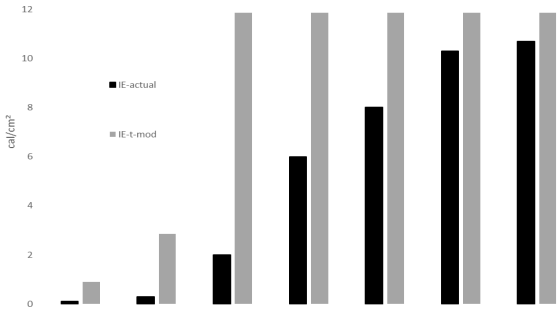


Fig. 9 Comparison of Measured Incident Energies for Nominal 250 Vdc Tests to Unmodified and Modified Maximum Power Theorem Formulas

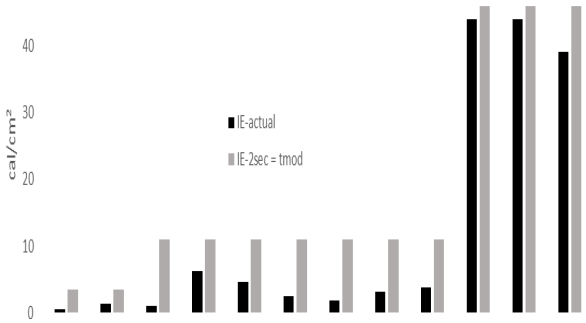


Fig. 10 Comparison of Measured Incident Energies for Nominal 480 Vdc Tests to Unmodified and Modified Maximum Power Theorem Formulas

With all of these figures, it can be seen that modifying the maximum power transfer theorem [2, 18] formula(s) {see Equation (1)} for time with the appropriate equation (2) or (3) yields acceptable upper bound results in almost all cases without requiring the excessive PPE at voltages below 465 Vdc that a maximum power transfer calculation using the NFPA 70E [2] / IEEE 1584 [3] typical maximum time of 2 seconds would produce. As was pointed out earlier in this paper, the existing maximum power transfer formula [18] {see equation (1)} in Annex D.5 of NFPA 70E [2], using the recommended 2 second maximum arc-flash exposure time [2, 3] is fairly accurate already around 480 Vdc nominal (see Figure 10).

There is some data published from tests done at other voltages (such as nominal 350, 600, and 1,000 Vdc) and also other testing done at the nominal voltages covered by these last Figures, but not enough to make a good graphing comparison. However, conclusions drawn from this limited data also support the conclusions of the preceding paragraph, and the overall conclusions in the succeeding section.

As noted, the latest NFPA 70E [2] raised the minimum dc voltage at which special arc-flash PPE is required to 150 when using the table (PPE Category) method, which lines up with the findings shown in Figures 5 and 6. While no special PPE is normally required, figures 7 and 8 show that it may sometimes be required in the rarer cases when available short circuit current is 17,000 A or more without overcurrent protection limiting the arcing time. Users may still run incident energy calculations for nominal dc voltages below 150, using an iterative method [5, 16, 19], the maximum power formula(s) [18] {the simplified equation (1) or the 2 equations shown in NFPA 70E Annex D.5 [18]} with a 2 second maximum arc exposure time [2, 3], or with the maximum power transfer formula(s) modified for time {see equation (2)}.

VI. CONCLUSIONS

the author supports continued use of the maximum power formula(s) for calculating dc arc-flash incident energies and arc-flash boundaries as an alternative method to the preferred iterative solutions, but proposes that it be supplemented with an empirically derived formula that estimates the typical maximum arc sustaining time based on nominal voltage. This additional formula causes the results to be more in line with measurements from real testing and more complex iterative dc arc-flash calculation models.

The author also proposes that present guidance in NFPA 70E [2] Annex D.5 on use of a multiplying factor for dc arc in a box incident energy remain the same; or be changed to use a multiplier of 1.6 [3, 22] for dc panelboards, but no multiplier for the arc-flash incident energy at 18" for larger cabinets (such as UPS battery cabinets) based on observations of actual testing [6, 7, 8, 9, 10, 11, 12, 13, 14, 20] and calculations. The distance multiplier for arc-flash boundary calculations for dc panelboards would be 1.265. The distance multiplier for large dc cabinets should be based on equation (5).

The author will be submitting these proposed NFPA 70E [2] changes as public inputs, either through a consensus body, such as the IEEE PES ESSB Codes Committee, or as an individual (himself).

VII. ACKNOWLEDGEMENTS

The author would like to thank Mike O'Brien for the initial idea of using testing data for maximum arc-flash sustaining time at lower voltages when using the Doan maximum power [18] formulas from Annex D.5 of NFPA 70E [2]. The author would also like to thank Lloyd Gordon for his previous research [23] into most of the dc arc-flash testing that has been done and the dc arc-flash calculations methods; as well as for his guidance and ideas on these subjects.

VIII. REFERENCES

[1] R. Lee, "The Other Electrical Hazard: Electric Arc Blast Burns", IEEE Transactions on Industry Applications, Vol. IA-18, No. 3, pp. 246-251, May/Jun 1982.

[2] NFPA® 70E, Standard for Electrical Safety in the Workplace,1995, 2012, 2015, 2018, and 2024 editions, Quincy, MA.

[3] IEEE 1584, Guide for Performing Arc-Flash Hazard Calculations, 2002 and 2018 editions, New York, NY, Institute of Electrical and Electronics Engineers.

[4] OSHA 29CFR1910, Part S – Electrical.

[5] A. Stokes and W. Oppenlander, "Electric Arcs in 1", Journal of Physical Discourses: Applied Physics, Vol. 24, 1991, pp. 26-35.

[6] Cheng, K., et al, "Arc Hazard Assessment for DC Applications in the Transit Industry", proceedings of the American Public Transport Association (APTA) Rail Conference, Boston, MA, 2011.

[7] C. Keyes and C. Maurice, "DC Arc Hazard Assessment Phase II", Kinectrics, Toronto, ON, Canada, Report K-012623-RA-0001-R00, 2007.

[8] Cheng, K., et al, "DC Arc-Flash Testing and Analysis at 600 V", proceedings of the IEEE IAS Electrical Safety Workshop (ESW), Reno, NV, 2020.

[9] Electric Power Research Institute (EPRI) Technical Report 3002014124, "DC Arc Flash on Photovoltaic (PV) Equipment", 2018.

[10] W. Fechalos and P. Blake, "DC Arc-Flash in Stationary Battery Systems", proceedings of Battcon 2023, paper No. 18.

[11] Gaunce, A., et al, "DC Arc-Flash: Testing and Modeling Incidents in a 125-V Substation Battery Backup System, IEEE Transactions on Industry Applications, Vol. 56, No. 3, pp. 2138-2147, May/Jun 2020.

[12] K. Gray and R. Hallé, "Sustainability of an Electric Arc-Flash at a Voltage of 240 VAC and 140 Vdc", proceedings of the IEEE IAS ESW, Reno, NV, 2023.

[13] Gray, K., et al, "Low Voltage 100-500 Vdc Arc-Flash Testing", proceedings of the IEEE IAS ESW, 2020.

[14] J. Hildreth and K. Feeney, "Arc-Flash Hazards of 125 Vdc Station Battery Systems", proceedings of the IEEE Power and Energy Society General Meeting (PES GM), paper No. 8586181, Portland, OR, 2018.

[15] Veeraraghavan, R. (ETAP), "DC Arc-Flash Analysis", presentation for Symposium #1 (DC Arc-Flash) at the 2017 winter meeting of the IEEE PES ESSB (Energy Storage and Stationary Battery committee, New Orleans, LA.

[16] J. Paukert, "The Arc Voltage and Arc Resistance of Low Voltage (LV) Fault Arcs", proceedings of the 7th International Symposium on Switching Arc Phenomena", pp. 49-51, 1993.

[17] K.S. Cheng and C. Keyes, "DC Arc-Flash Hazard Analysis Service for Pacific Northwest National Laboratory (PNNL)", Kinectrics, Toronto, ON, Canada, Report K-418079-RA-001-00, Oct 2011.

[18] D.R. Doan, "Arc-Flash Calculations for Exposures to DC Systems, proceedings of the IEEE IAS ESW, 2007.

[19] Ammerman, R., et al, "DC Arc Models and Incident Energy Calculations", proceedings of the Petroleum and Chemical Industry Conference (PCIC), 2009.

[20] Weimann, C.S., "Analytical and Experimental Validation for DC Arc-Flash Models", University of Pittsburgh Electrical Engineering Department Report ETD-07162020, 2018.

[21] NFPA® 70®, National Electrical Code® (NEC®), 2011, 2014, and 2023 editions, Quincy, MA: National Fire Protection Association.

[22] W. Fontaine and S. McCluer, "Arc in a Box: DC Arc-Flash Calculations Using a Simplified Approach", proceedings of Battcon 2014, paper No. 15.

[23] L.B. Gordon, "Modeling DC Arc Physics and Applications for DC Arc-Flash Risk Assessment", proceedings of the IEEE IAS ESW, Reno, NV, 2023.

IX. VITA

Curtis Ashton obtained a B.S.E.E degree from Arizona State University in 1992, while working for an electric utility, and then worked for 27 years for a large telecom and data center company as a power and grounding maintenance engineer. He has worked for the last 5 years for a dc services subsidiary (American Power Systems LLC) of East Penn Manufacturing (formerly Deka Batteries). Curtis is a past chair of the IEEE PES ESSB (Energy Storage and Stationary Battery) committee, and the primary author / working group chair of several of the battery standards produced by that technical committee. He is also a past vice-president of the IEEE Intelec Executive Committee (now IEEE PELS TC7); and a past vice-chair for ATIS-STEP; as well as being the primary author of several ANSI/ATIS power and grounding standards. Mr. Ashton is also an IEEE IAS member, and is on the NFPA 855 standard committee. He has been published many times, has presented in many locales across the globe, and has a patent to his name. Curtis is also a Master Electrician in Colorado and a Journeyman Electrician in New Mexico.

MODIFYING THE DC ARC-FLASH MAX POWER FORUMULA TO GIVE MORE REALISTIC PREDICTIONS OF MAXIMUM ARC-FLASH ENERGY

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Paper No. ESW-11

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Abstract – The maximum power formula (proposed by Dan Doan in a 2007 IEEE paper) for calculating dc arc-flash incident energy has been in NFPA 70E since 2012; however, repeated testing by multiple companies over the years has shown that it overestimates arc-flash energy by a factor of at least 2-10, especially at lower voltages (such as nominal 48, 125, or 250 Vdc). This paper analyzes the actual measured arc-flash energy from over 100 different tests at various voltages, and proposes modifications to the arc sustaining time in the maximum power transfer theorem equation(s) found in Annex D.5 of NFPA 70E. In addition, more realistic estimates for dc arc-flash boundary multipliers are developed for cases where the arc is “in a box”, than what has been found in previous editions of NFPA 70E. These are based on observations of dc arc-flash tests, calculations of reflected energy from the rear of typical cabinets using the maximum power method, and previous studies of "arc-in-a-box” energy multipliers for ac arc-flash.

Index Terms — DC arc-flash, arc sustaining time, maximum power transfer formula, arc-flash boundary.

I. INTRODUCTION

For the first 80 years or so of the “electric age” almost all research into the hazards of electricity was on electric shock (and attendant electrocution at high enough levels to cause death). During all this time people were also beingh injured and killed from arc-flash/blast in addition to electric shock / electrocution. However, research into incident energy on the human body from electric arc-flash didn’t begin in earnest until approximately 1973, with the first method to calculate that danger from ac not introduced until 1982 [1]. NFPA 70E [2] did not reference any methods for calculating this ac arc-flash energy until 1995 and later editions, followed by even more on ac calculations in the 2002 initial edition of IEEE 1584 [3] (since updated in 2018).

OSHA rules for electrical safety [4] only indirectly refer to electric arc hazards (they refer to electric arcs, but not specifically to arc-flash/blast) since they were published in 1992 (before there were standards calculations methods referenced in NFPA 70E [2] and before IEEE 1584 [3] existed).

Work on dc arc-flash did not begin in earnest until 1991 [5], and the first calculations referenced in NFPA 70E [2] for dc arc-flash incident energy did not appear until the 2012 edition (following some additional dc arc-flash testing and analysis in the years 2007-2011 [6, 7]). More recent dc arc-flash testing done from 2017-2022 [8, 9, 10, 11, 12, 13, 14, 15] provided more useful data, and helped in the decision to raise the dc special PPE arc-flash protection threshold (when using the table [PPE Category] method as opposed to the calculation method) to 150 V in the 2024 edition of NFPA 70E [2] by proving that in almost all cases where maximum short-circuit current from the battery is less than 17,000 A and the voltage is below 150 Vdc, 1.2 cal/cm^2 incident energies or greater at 18 inches or further away cannot be produced.

II. EXISTING DC ARC-FLASH MODELS

A. Stokes/Oppenlander Method [5]

In 1991, Stokes and Oppenlander published [5] the first dc arc-flash incident energy formulas (empirically derived from many gapped electrode tests at varying voltages, currents, gap widths, and electrode orientations). This method requires an initial guess and iterative equation solving. The research involved both ac and dc up to 1,000 V, but the dc was limited to smaller arc currents (less than 1,000 A). If the arcing current is too low relative to the voltage, these equations cannot be solved (even iteratively).

B. Paukert Method [16]

In 1993, more formulas (empirically derived from 7 different studies) to calculate dc arc-flash incident energy were published [16] and presented by Paukert. This method is also an iterative method, requiring an initial guess, and then iterative equation solving is repeatedly done.

C. Lab Physics Model

Most of the dc arc-flash testing (as well as significant amounts of ac arc-flash testing) that has been done was done at a lab [7, 10, 12, 13, 14, 17] facility in Toronto Canada. Between 1995 and 2007 (prior to most dc arc-flash testing), this lab used physics principles (rather than empirically derived/”fit” formulas from observed results) to develop a complex predictive model for incident arc-flash energy using complex iterative processes. Prior to running tests, they use this model to predict results, and then compare them to the actual observed testing data. It has been shown in much of the more recent testing [6, 8, 9, 10, 11, 12, 13, 14] referenced in this document that their slightly old (by now) theoretical physics model typically overestimates incident energy by at least a factor of 2.

D. Doan / Maximum Power Transfer Theorem [18]

In 2007, Dan Doan published [18] the maximum power transfer theorem for dc (building on earlier ac work), which in its present form (this paper proposes a modification/ improvement of the method to make it more accurate at lower voltages) is the most conservative of the methods (i.e., it typically overestimates the actual incident energy from dc arc-flash more than the iterative methods). Calculations are done using a simple formula (or two – see NFPA 70E [2] Annex D.5 for the 2 equations that have been combined into equation 1):

$$IE = 0.01 \times V_{nom} \times \frac{I_{sc}}{2} \times \frac{t}{d^2} \quad (1)$$

where

IE	is the incident energy in cal/cm²
V_{nom}	is the nominal dc voltage
I_{sc}	is the maximum (bolted fault) short circuit current (battery manufacturers typically publish this, and manufacturers can often provide it for other types of dc equipment)
t	is the time before an upstream OCPD (e.g., fuse or breaker) operates, or the maximum time that the arc can sustain itself (NFPA 70E [2] notes that the calculation time should probably not exceed 2 seconds, and IEEE 1584 [3] supports this because the person will have likely reacted and moved away within that time if space allows)
d	is the typical distance of the vital organs of the body from the electrical equipment that could have the arc-flash event, and is noted in NFPA 70E [2] for most of the dc voltages that most users deal with as 18 inches (equivalent to 45.72 cm, which is usually the value used since the incident energy is in SI units of cal/cm²)

Note that this is the only formula(s) for dc arc-flash calculations given in NFPA 70E [2]. The only other methods indirectly referenced for dc arc-flash calculations in NFPA 70E [2] (Annex D.5) are the Stokes/Oppenlander [5] and Paukert [16] iterative methods.

While not the most accurate method for a wide array of nominal voltages (actual testing has shown it to be fairly accurate when nominal dc voltages are near 480 though), this maximum power method is commonly used.

One big problem with this maximum power method is its overestimation of the risk at lower voltages. More PPE than is needed can make a user less safe by making them less dexterous, too hot and sweaty, etc. A smaller issue with this method (and all the other methods mentioned in this section are probably limited in the same way based on the data and assumptions used in those models) is that it is limited to dc voltages below 1,000 The majority of dc systems in the world today are below this voltage, but there are more and more being installed above that voltage, such as with grid scale solar and wind generation, especially with attendant battery energy storage systems.

Like the lab physics model, the maximum power transfer method is theoretical, and has not proven to be as accurate as empirically-derived formulas from actual testing, such as those from the Stokes, Paukert, and Ammerman models/methods.

A subsequent section in this paper will cover a proposed method of making this maximum power calculation more accurate at lower voltages by empirically deriving a formula for the arc sustaining time since this less-accurate method for incident energy and arc flash boundary calculations is still fairly commonly used.

E. Ammerman Method [19]

In 2009, Ammerman and colleagues (including P.K. Sen) published [19] another iterative method for determining dc arc-flash energy. While not referenced in NFPA 70E [2] Annex D.5, it may still be used, with engineering judgement.

III. DC ARC SUSTAINING TIME

Those who calculate dc arc-flash incident energy manually using the Maximum Power [18] formulas found in NFPA 70E [2] have usually used dc arc sustaining times of 2 seconds (in some cases longer in an effort to be more conservative), at least on the portions of the analyzed circuit where a fuse or breaker will not limit the time to less than that. The 2 second maximum time comes from NFPA 70E [2] and IEEE 1584 [3], where the assumption was made that if the "space" made it possible, human reaction would cause the person to back away from the arc flash within 2 seconds. In the opinion of the author, based on video observations of arc-flash testing and actual real arc-flashes, if space allows it, in larger arc flash incidents, the arc blast is likely to knock the person down or back out of the area within the 2 seconds as well.

The iterative methods [5, 16, 19] are more accurate than the maximum power method for many reasons, with one of those reasons being that they usually compute a more realistic arc sustaining time.

For those still using the maximum power method and a default 2 second (or more) arc sustaining time, dozens of individual [6, 7, 8, 9, 10, 11, 12, 13, 14, 20] real world tests (see Figure 1) have shown that 2 seconds is far longer than the actual arc sustaining time for dc arcs below approximately 480 Vdc.

The different lengths of arc sustaining time shown in Figure 1 for each of the different nominal tested voltages (nominal 100, 125, 250, and 480) are due to different maximum short circuit currents of the dc equipment under test, different starting electrode lengths, and orientation of the electrodes.

Using a more accurate arc sustaining time to calculate more realistic incident energy for lower dc voltages is important due to the sheer number of dc systems (or dc busses in UPSs) that operate below that level. Common lower dc bus nominal voltage levels found in many installed systems include: 12, 24, 36, 48, 125 (120), 192, 216, 250 (240), 288, and 380 (336, 360, and 384). Note that the latest edition (2024) of NFPA 70E [2] does not require special arc-flash protective clothing (other than safety glasses) for dc arc-flashes below 150 Vdc if the table (aka PPE Category) method is used, based on numerous tests [11, 12, 13, 14] run mostly over the last 7 years. The previous 4 editions of NFPA 70E [2] did not require special clothing below 100 Vdc (if the table / PPE Category method was used). However, arc-flash calculations below 150 (or even 100) Vdc are sometimes still used/desired, especially if the total potential short circuit current is 17,000 A or more, as will be shown later on in test results reviewed in this paper.

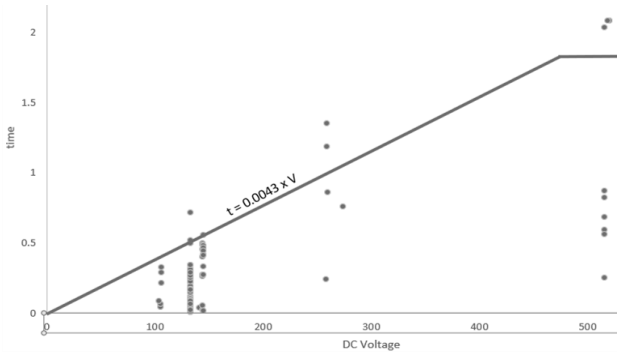


Fig. 1 Real World Testing DC Arc-Flash Sustaining Times along with Empirically-Derived Maximum Arc Time

One conclusion of all these tests is that existing maximum power transfer calculations for voltages below 480 Vdc have been severely overestimating maximum incident energy from dc arc-flashes at the standard 18 inch (45.72 mm) [2] vital body organ distance partially due to overestimation of the time that the arc can sustain itself. Curve fitting the results so that most of the points fit under the "curve"; and maximizing at 2 seconds of arc time [2, 3] yields the lines (along with a voltage-based formula) in Figure 1. The point at which the formula yields 2 seconds or longer arc sustaining times is nominal 465 Vdc, which is consistent with real world testing [6, 7, 8, 9, 10, 13].

None of the published testing data [6, 7, 8, 9, 10, 11, 12, 13, 14, 20] is at dc voltages lower than 100, partly because it has been known for at least a dozen years that dc arc-flashes below that voltage cannot produce incident energy above the 1.2 cal/cm^2 2nd-degree maximum burn threshold (as noted earlier in this section, that dc voltage has now been moved to 150 when using the table / PPE Category method) [2]. However, when testing has been done below that 100 Vdc level, although the arc sustaining time results have not been "published", the arc sustaining times observed were consistently below what is predicted by equation (2). For example, Fechalos and Blake, while presenting their 2023 Battcon paper [10] showed an example video of a 48 Vdc test, and the approximate duration of the arc-flash was about 100 milliseconds, which is about half of what equation (2) predicts for a maximum arc sustaining time at that nominal voltage.

$$t = 0.0043 \times V_{nom} \quad (2)$$

when

V_{nom} is ≤ 465 Vdc

$$t = 2 \quad (3)$$

when

V_{nom} is > 465 Vdc

Many actual test arc sustaining times fall below (see Figure 1) the values predicted by equations 2 and 3. This is mostly due to lack of an electrode separation distance variable in the equation(s). The author purposely did not include electrode separation, since in many dc systems, electrode separation can be highly variable, depending on the length of the object that initiates the arc. For example, in a cabinetized UPS monobloc battery system, there are a multitude of possibilities for distances between differing polarities (including ground), even at the same nominal voltage. Instead, the purpose of this work is to establish a reasonable upper bound on the maximum dc arc sustaining time based on the available data. This may overprotect in some cases, but at voltages below nominal 480 V where the maximum power method is presently being used with a 2 second (or more) arc sustaining time, this modification is going to greatly decrease the existing overcalculation of the risk. Perhaps future work can focus on additional variables in arc sustaining time (such as electrode separation and orientation)?

Finally, on the subject of dc arc sustaining time, in the experience of the author, many dc arc-flash calculations that have been done in existing industrial facilities (such as UPS battery cabinets in large data centers) neglect (usually due to the person running the calculations or inputting the circuit parameters into a computer program not accounting for OCPDs in parallel paths) the fact that any dc source fault current contribution flowing through a fuse or breaker towards an arc-flash/blast fault point will usually be time-limited by the I-t curve of the fuse/breaker(s) in the path. For example, for a worker in one battery cabinet of a UPS that has 4 parallel battery cabinets (with each cabinet having its own internal breaker at the top), the arc-flash incident energy from the cabinet where the work is being done will be time-limited only by the nominal voltage of the fault causing the arc-flash, as per equation (2) or (3). However, all parallel sources (the other 3 battery cabinets and the UPS dc charging source) that can contribute to the fault current will have to flow through one or two breakers. Assuming these breakers are sized and have any adjustable instantaneous trip settings correctly set, the high fault currents from these sources flowing towards the source should cause the breaker(s) to open on the instantaneous portion of their trip curve (typically within 16-60 milliseconds on average, depending on breaker model and manufacturer). This greatly limits the overall arc flash energy. In numerous calculations run by the author, the additional incident energy contributed by parallel sources flowing through properly sized and adjusted breakers (or through properly sized fuses) is usually no more than 7% of the total incident energy that has been negligently calculated (and posted on labels on cabinets or panels) without consideration of fuses or breakers in parallel paths.

IV. ARC-IN-A-BOX THEORY VS REALITY

When dc arc-flash calculations were introduced in Annex D of NFPA 70E [2] in 2012, guidance was given that arc-in-a-box (due to reflected energy off the sides, top, bottom, and rear of the box) could be 3 times or more the calculated arc-flash energy (because the models mentioned in Section II of this paper mostly assume spherical energy spread from the point of the arc, and do not normally take reflected energy into account). This assumption was based partly on testing in low voltage (600 V or lower at the time [21]) ac panelboards [3] that have very short depths (typically 4-6 inches {10-15 cm}), which causes fairly significant reflection of energy from the rear. It was also based on testing of medium voltage (1-36 kV) [21], and low voltage (≤ 600 V) [21] larger ac switchgear cabinets. This testing, and IEEE 1584 [3] guidance gives a multiplication factor of 1.6 for ac panelboards [22] (see Figure 2), regardless of distance from the arc-flash event. The multiplication factor varied [3, 22] for low voltage and medium voltage larger ac switchgear cabinets, from between 1.0 and 2.2 at the vital organ distance [2] of 18 inches (45.72 cm), up to a maximum

multiplying factor of 3.8-4.75 for these large switchgear cabinets at the typical maximum arc-flash boundary distance of 10 feet [2] (approximately 3 m).

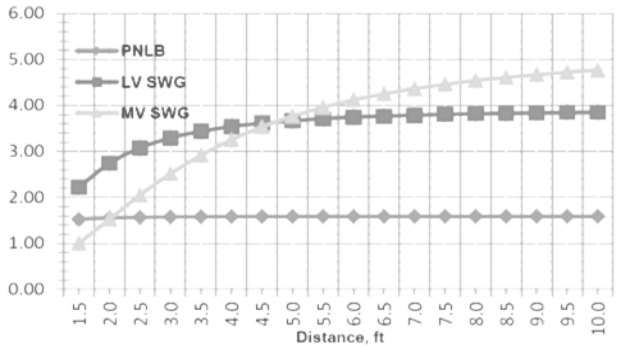


Fig. 2 AC arc-in-a-box Incident Energy Multiplication Factors vs. Distance [3, 22]

This guidance carried into the 2015 edition of NFPA 70E [2]. However, in the 2018 edition, the guidance had been changed from a multiplier of 3x for dc arc-in-a-box to "… it would be prudent to consider additional PPE protection beyond the values shown in Table 130.7(C)(15)(b)." This same "new" language is in the subsequent editions of NFPA 70E [2]. This change was made in the 2018 edition because actual testing up to that point [6, 7, 20], and testing since [8, 9, 10, 11, 12, 13, 14], had not shown nearly triple the difference between incident energies measured from dc arc-in-a-box vs open air, all other conditions (such as electrode spacing and orientation, maximum short circuit current, nominal voltage, etc.) being equal. In most cases the observed/measured incident energy at 18 inches (45.72 cm) [2] from dc arc-flash energy reflected from a "box" is more (although usually much less than triple) than it would be in open air, and in some cases it was less.

Because of a lack of dc arc-flash testing done/published for dc panelboards, there is no reason yet to use any factor for dc panelboards other than the 1.6 multiplication factor (see Figure 3) for ac panelboards [3, 22], since they tend to have similar dimensions to ac panelboards (being equipped with dc breakers or fuses rather than ac breakers or fuses).

The maximum power theorem formula(s) {see equation (1)} can also be used to determine the arc-flash boundary (the distance where the incident energy drops to the 2nd-degree burn threshold of 1.2 cal/cm^2 [2] or lower). See equation (4) for the algebraically modified formula and note that the incident energy value is now under a square root. This means that if the arc-flash energy from a panelboard is 1.6 times the value calculated by equation (1), the distance multiplier for determining the arc-flash boundary for dc panelboards should be the square root of 1.6 (√1.6 = 1.265).

$$d = \sqrt{\frac{0.01 \times V_{nom} \times \frac{I_{SC}}{2} \times t}{IE}} \quad (4)$$

Based on observations of dc arc-flash testing done with cabinets (such as UPS battery cabinets), there is some reflected energy, but nowhere near triple the energy at the critical body organ distance [2] of 18 inches (45.72 cm). In most cases, it should be much less than a 1.6 multiplier at that distance because of the depths of these cabinets compared to panelboards. Arc-flash energy decreases as it moves away from the source by the square of the distance [1, 2, 18]. In a sample calculation for a typical UPS battery cabinet 4 feet (1.2 m) wide by 33½ inches (0.85 m) deep by 7 feet (2.13 m) tall, most of the reflected (as opposed to the direct energy from the arc-flash) energy that will impinge on the body's vital organs, at approximately 18 [2] inches (45.72 cm) from the front of the battery, will be the direct reflection from the rear. That addition to incident energy for this cabinet, (based on the square of the distance) would be approximately $^1/_{30}^{th}$ (a multiplier of 1.03). There will be even less reflected additive energy from the top, bottom and sides of the cabinet due to their greater distances and oblique angles to the human body in front of the "box".

There have been more than 90 dc arc-flash tests [6, 7, 8, 9, 10, 11, 12, 13, 14, 20] yielding enough data to do comparisons like Figures 3 through 10. About 87% of those tests were arc-in-a-box tests (in medium/large cabinets), with the rest done in open air. Only two tests yielded actual measured arc-flash incident energy at 18 inches (45.72 cm) [2] that exceeded maximum power formula {equation (1)} calculations (without any arc-in-a-box multiplier), even when modified for lower arc-sustaining times per equation (2) at lower voltages. Those two cases [9] were on nominal 120 Vdc PV systems with maximum fault current (< 2,000 A) lower than typical for many dc applications, and the actual and calculated incident energies at 18 inches (45.72 cm) all fell below the 1.2 cal/cm^2 2nd-degree burn threshold, above which special PPE is required [2]. Also, for the limited comparisons (see Figure 3) that have been done [15] for actual dc arc-flash testing results vs iterative methods (Paukert [16] and Stokes [5] in this case), the actual incident energy measured (even in a "box") was less than or essentially equivalent to what was calculated by the iterative methods (except for one instance previously noted), without using an arc-flash multiplying factor.

IEEE 1584 [3] and other sources [22] note (see Figure 2) that the arc-in-a-box incident energy multiplier increases for switchgear cabinets at distances greater than 18 inches (45.72 cm). This is due to the decreasing ratio of reflected energy distance to body distance away from the cabinet; however, it does not affect incident energy calculations [2] at 18 inches (45.72 cm). For example, the multiplier in Figure 3 for MV switchgear cabinets at 18 inches (1.5 feet) is 1.0. It only becomes a "multiplier" at further distances (such as the arc-flash boundary distance in most cases). As such, the ac arc-in-a-box incident energy multiplier (2.2-3.8 at the high end per Figure 2) for low voltage ac switchgear at greater distances [3, 22] might be applied to the arc-flash boundary calculation for low voltage dc cabinets. Since most dc applications fall into the "low voltage" (which is now below nominal 1,500 Vdc [1,000 Vac] in the NEC® [21]) category, but most dc larger cabinets are more similar in size to a front-access medium voltage switchgear cabinet; the incident energy multiplier curves from Figure 2 can be averaged, and curve fit. Taking the square root of that curve yields the following formula for arc-flash boundary distance multipliers for larger dc cabinets:

$$m_{AB} = (0.55 \times \ln(d_{in})) - 0.6 \quad (5)$$

where

m_{AB} is the dc arc-flash boundary distance multiplier for large cabinets

d_{in} is the base arc-flash boundary distance (in inches) for arcs not in a box calculated from the maximum power formula

Based on this analysis, the author recommends either leaving existing language on dc arc-in-a-box multipliers in Annex D.5 of NFPA 70E [2] as is; or changing it to read something similar to the following: "For exposures where the arc is in a box or enclosure, it may be prudent to apply a multiplying factor up to 1.6 to the incident energy calculation for purposes of PPE for dc panelboards, and a corresponding distance multiplication factor up to 1.265 to the arc-flash boundary calculation. For larger dc enclosures, such as UPS battery cabinets, testing, calculations, and observation have shown that the reflected energy from the rear, sides, top, and bottom of these enclosures only adds very minimally to the incident energy at the vital body organ typical distance of 18 inches (45.72 cm) [2]. Thus, no multiplication factor for the calculation of incident energy is suggested. However, it may be prudent to apply a multiplier based on empirical equation (5) for calculation of the arc-flash boundary (with a maximum distance of 10 feet) for dc cabinets larger than a panelboard due to the relative contribution of reflected energy vs direct incident energy at greater distances for larger dc enclosures."

V. COMPARISON OF CALCULATIONS VS ACTUAL TEST RESULTS

Limited work has been done comparing tested incident energy at 18 inches (45.72 cm) [2] to the different dc arc-flash models. However, one paper [20] undertook calculations for 2 iterative methods (Paukert [16] and Stokes [5]), as well as the maximum power transfer theorem [18, 21], for 7 individual tests [9, 12, 13] from the many that have been reported. The results of this comparison, supplemented with the maximum power transfer theorem {equation (1)} modified for time by equations (2) and (3), are shown in Figure 3 (note that the clusters along the horizontal axes of each of Figures 3-10 represents an individual test).

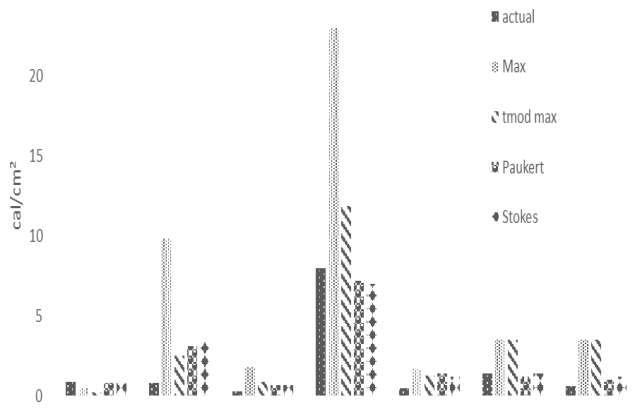


Fig. 3 Actual Incident Energy vs Existing and Proposed Methods

From this comparison of 7 incident energy measurements to 4 different calculation methods, it can be seen that at least 2 of the iterative methods [5, 16], as well as the maximum power formula(s) [2, 18] {see equation (1)} modified for maximum dc arc sustaining time by equations (2) and (3), provide a good upper bound for incident arc-flash energy at 18 inches (45.72 cm) [2] without requiring excessive PPE (which can actually make the user less safe by making them less dexterous and sweatier).

For the more than 90 individual tests [6, 7, 8, 9, 10, 11, 12, 13, 14, 20] for which enough useful data has been published for good comparison, the author ran calculations for dc arc-flash at 18 inches (45.72 cm) [2] with both the maximum power transfer theorem [2, 18], using equation (1) with a maximum time value of 2 seconds [2, 3], as well as with modified time values per equations (2) and (3). These 90+ test results can essentially be grouped into 4 nominal dc voltage "bins" of 100, 125, 250, and 480 Vdc.

Figure 4 compares a random sample (for readability) of 8 (of the more than 90) test's actual incident energies (measured at different nominal voltages, short circuit currents, electrode configurations, and electrode spacings), against the maximum power method calculated at 2 seconds and at the modified maximum arc sustaining time from equations (2) and (3):

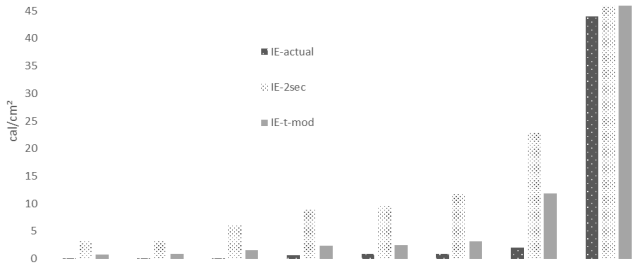


Fig. 4 Sample Comparison of Max Power Calculations (Modified for Time and Not) Against Actual Incident Energies

Figure 4 shows the large difference in accuracy (in most cases) of maximum power calculations when arc sustaining is modified for time (even when only based on voltage) versus calculations using a 2 second arc sustaining time.

Each of the nominal voltage "bins" (the bin for nominal 125 Vdc is further divided into various ranges of maximum short circuit current available in order to make the data more readable because there have been so many nominal 125 Vdc arc-flash tests run [7, 9, 11, 12, 13, 14, 20]) is represented by a different graph in Figures 5 through 10. In these graphs, for readability purposes, the generally highly overstated maximum power calculations at 2 seconds are not even shown (except at nominal 480 Vdc where the calculation {equation (3)] yields 2 seconds), since they would usually make the y-axis of the chart much taller.

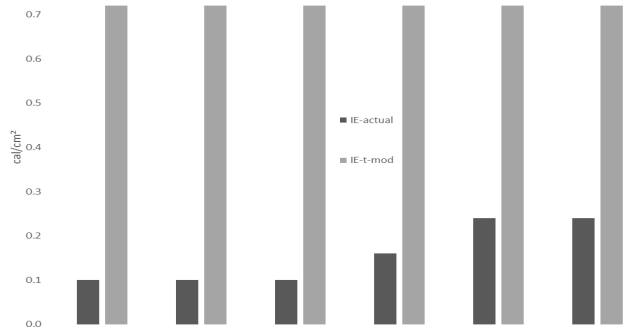


Fig. 5 Comparison of Measured Incident Energies for Nominal 100 Vdc Tests to Unmodified and Modified Maximum Power Theorem Formulas

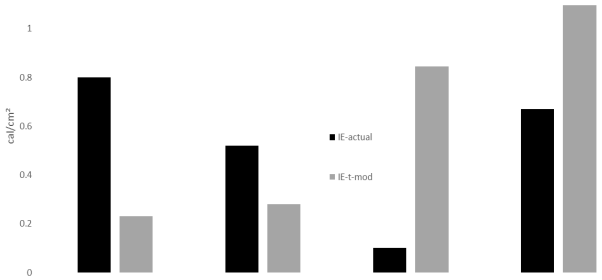


Fig. 6 Comparison of Measured Incident Energies for Nominal 125 Vdc Tests with Available Short Circuit Currents of Less than 7,500 A to Unmodified and Modified Maximum Power Theorem Formulas

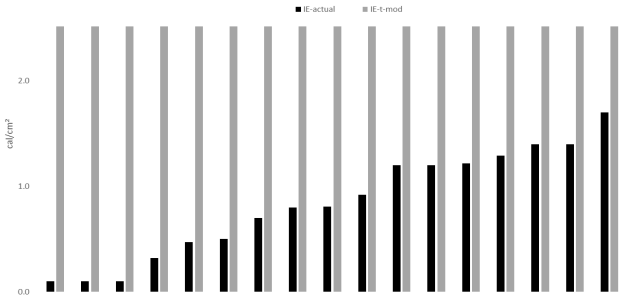


Fig. 7 Comparison of Measured Incident Energies for Nominal 125 Vdc Tests with Available Short Circuit Current of 17,000 A to Unmodified and Modified Maximum Power Theorem Formulas

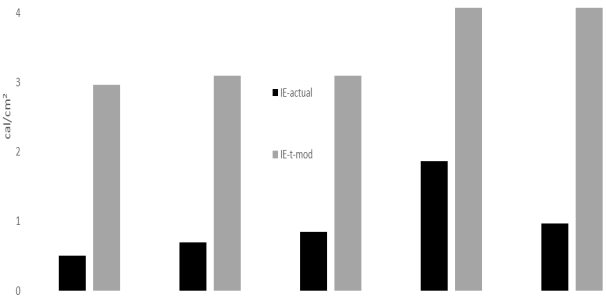


Fig. 8 Comparison of Measured Incident Energies for Nominal 125 Vdc Tests with Available Short Circuit Currents Greater than 17,000 A to Unmodified and Modified Maximum Power Theorem Formulas

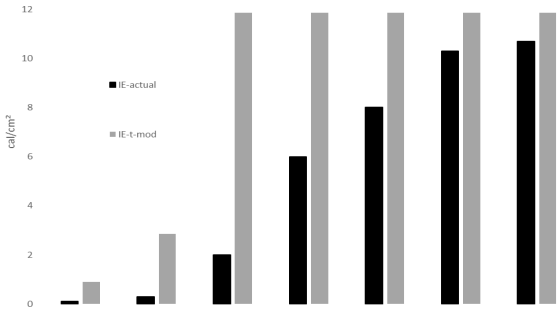


Fig. 9 Comparison of Measured Incident Energies for Nominal 250 Vdc Tests to Unmodified and Modified Maximum Power Theorem Formulas

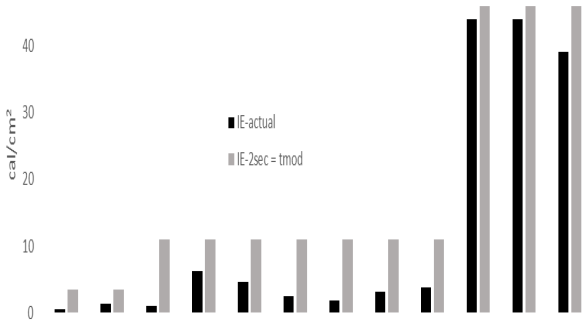


Fig. 10 Comparison of Measured Incident Energies for Nominal 480 Vdc Tests to Unmodified and Modified Maximum Power Theorem Formulas

With all of these figures, it can be seen that modifying the maximum power transfer theorem [2, 18] formula(s) {see Equation (1)} for time with the appropriate equation (2) or (3) yields acceptable upper bound results in almost all cases without requiring the excessive PPE at voltages below 465 Vdc that a maximum power transfer calculation using the NFPA 70E [2] / IEEE 1584 [3] typical maximum time of 2 seconds would produce. As was pointed out earlier in this paper, the existing maximum power transfer formula [18] {see equation (1)} in Annex D.5 of NFPA 70E [2], using the recommended 2 second maximum arc-flash exposure time [2, 3] is fairly accurate already around 480 Vdc nominal (see Figure 10).

There is some data published from tests done at other voltages (such as nominal 350, 600, and 1,000 Vdc) and also other testing done at the nominal voltages covered by these last Figures, but not enough to make a good graphing comparison. However, conclusions drawn from this limited data also support the conclusions of the preceding paragraph, and the overall conclusions in the succeeding section.

As noted, the latest NFPA 70E [2] raised the minimum dc voltage at which special arc-flash PPE is required to 150 when using the table (PPE Category) method, which lines up with the findings shown in Figures 5 and 6. While no special PPE is normally required, figures 7 and 8 show that it may sometimes be required in the rarer cases when available short circuit current is 17,000 A or more without overcurrent protection limiting the arcing time. Users may still run incident energy calculations for nominal dc voltages below 150, using an iterative method [5, 16, 19], the maximum power formula(s) [18] {the simplified equation (1) or the 2 equations shown in NFPA 70E Annex D.5 [18]} with a 2 second maximum arc exposure time [2, 3], or with the maximum power transfer formula(s) modified for time {see equation (2)}.

VI. CONCLUSIONS

the author supports continued use of the maximum power formula(s) for calculating dc arc-flash incident energies and arc-flash boundaries as an alternative method to the preferred iterative solutions, but proposes that it be supplemented with an empirically derived formula that estimates the typical maximum arc sustaining time based on nominal voltage. This additional formula causes the results to be more in line with measurements from real testing and more complex iterative dc arc-flash calculation models.

The author also proposes that present guidance in NFPA 70E [2] Annex D.5 on use of a multiplying factor for dc arc in a box incident energy remain the same; or be changed to use a multiplier of 1.6 [3, 22] for dc panelboards, but no multiplier for the arc-flash incident energy at 18" for larger cabinets (such as UPS battery cabinets) based on observations of actual testing [6, 7, 8, 9, 10, 11, 12, 13, 14, 20] and calculations. The distance multiplier for arc-flash boundary calculations for dc panelboards would be 1.265. The distance multiplier for large dc cabinets should be based on equation (5).

The author will be submitting these proposed NFPA 70E [2] changes as public inputs, either through a consensus body, such as the IEEE PES ESSB Codes Committee, or as an individual (himself).

VII. ACKNOWLEDGEMENTS

The author would like to thank Mike O'Brien for the initial idea of using testing data for maximum arc-flash sustaining time at lower voltages when using the Doan maximum power [18] formulas from Annex D.5 of NFPA 70E [2]. The author would also like to thank Lloyd Gordon for his previous research [23] into most of the dc arc-flash testing that has been done and the dc arc-flash calculations methods; as well as for his guidance and ideas on these subjects.

VIII. REFERENCES

[1] R. Lee, "The Other Electrical Hazard: Electric Arc Blast Burns", IEEE Transactions on Industry Applications, Vol. IA-18, No. 3, pp. 246-251, May/Jun 1982.

[2] NFPA® 70E, Standard for Electrical Safety in the Workplace,1995, 2012, 2015, 2018, and 2024 editions, Quincy, MA.

[3] IEEE 1584, Guide for Performing Arc-Flash Hazard Calculations, 2002 and 2018 editions, New York, NY, Institute of Electrical and Electronics Engineers.

[4] OSHA 29CFR1910, Part S – Electrical.

[5] A. Stokes and W. Oppenlander, "Electric Arcs in 1", Journal of Physical Discourses: Applied Physics, Vol. 24, 1991, pp. 26-35.

[6] Cheng, K., et al, "Arc Hazard Assessment for DC Applications in the Transit Industry", proceedings of the American Public Transport Association (APTA) Rail Conference, Boston, MA, 2011.

[7] C. Keyes and C. Maurice, "DC Arc Hazard Assessment Phase II", Kinectrics, Toronto, ON, Canada, Report K-012623-RA-0001-R00, 2007.

[8] Cheng, K., et al, "DC Arc-Flash Testing and Analysis at 600 V", proceedings of the IEEE IAS Electrical Safety Workshop (ESW), Reno, NV, 2020.

[9] Electric Power Research Institute (EPRI) Technical Report 3002014124, "DC Arc Flash on Photovoltaic (PV) Equipment", 2018.

[10] W. Fechalos and P. Blake, "DC Arc-Flash in Stationary Battery Systems", proceedings of Battcon 2023, paper No. 18.

[11] Gaunce, A., et al, "DC Arc-Flash: Testing and Modeling Incidents in a 125-V Substation Battery Backup System, IEEE Transactions on Industry Applications, Vol. 56, No. 3, pp. 2138-2147, May/Jun 2020.

[12] K. Gray and R. Hallé, "Sustainability of an Electric Arc-Flash at a Voltage of 240 VAC and 140 Vdc", proceedings of the IEEE IAS ESW, Reno, NV, 2023.

[13] Gray, K., et al, "Low Voltage 100-500 Vdc Arc-Flash Testing", proceedings of the IEEE IAS ESW, 2020.

[14] J. Hildreth and K. Feeney, "Arc-Flash Hazards of 125 Vdc Station Battery Systems", proceedings of the IEEE Power and Energy Society General Meeting (PES GM), paper No. 8586181, Portland, OR, 2018.

[15] Veeraraghavan, R. (ETAP), "DC Arc-Flash Analysis", presentation for Symposium #1 (DC Arc-Flash) at the 2017 winter meeting of the IEEE PES ESSB (Energy Storage and Stationary Battery committee, New Orleans, LA.

[16] J. Paukert, "The Arc Voltage and Arc Resistance of Low Voltage (LV) Fault Arcs", proceedings of the 7th International Symposium on Switching Arc Phenomena", pp. 49-51, 1993.

[17] K.S. Cheng and C. Keyes, "DC Arc-Flash Hazard Analysis Service for Pacific Northwest National Laboratory (PNNL)", Kinectrics, Toronto, ON, Canada, Report K-418079-RA-001-00, Oct 2011.

[18] D.R. Doan, "Arc-Flash Calculations for Exposures to DC Systems, proceedings of the IEEE IAS ESW, 2007.

[19] Ammerman, R., et al, "DC Arc Models and Incident Energy Calculations", proceedings of the Petroleum and Chemical Industry Conference (PCIC), 2009.

[20] Weimann, C.S., "Analytical and Experimental Validation for DC Arc-Flash Models", University of Pittsburgh Electrical Engineering Department Report ETD-07162020, 2018.

[21] NFPA® 70®, National Electrical Code® (NEC®), 2011, 2014, and 2023 editions, Quincy, MA: National Fire Protection Association.

[22] W. Fontaine and S. McCluer, "Arc in a Box: DC Arc-Flash Calculations Using a Simplified Approach", proceedings of Battcon 2014, paper No. 15.

[23] L.B. Gordon, "Modeling DC Arc Physics and Applications for DC Arc-Flash Risk Assessment", proceedings of the IEEE IAS ESW, Reno, NV, 2023.

IX. VITA

Curtis Ashton obtained a B.S.E.E degree from Arizona State University in 1992, while working for an electric utility, and then worked for 27 years for a large telecom and data center company as a power and grounding maintenance engineer. He has worked for the last 5 years for a dc services subsidiary (American Power Systems LLC) of East Penn Manufacturing (formerly Deka Batteries). Curtis is a past chair of the IEEE PES ESSB (Energy Storage and Stationary Battery) committee, and the primary author / working group chair of several of the battery standards produced by that technical committee. He is also a past vice-president of the IEEE Intelec Executive Committee (now IEEE PELS TC7); and a past vice-chair for ATIS-STEP; as well as being the primary author of several ANSI/ATIS power and grounding standards. Mr. Ashton is also an IEEE IAS member, and is on the NFPA 855 standard committee. He has been published many times, has presented in many locales across the globe, and has a patent to his name. Curtis is also a Master Electrician in Colorado and a Journeyman Electrician in New Mexico.

Public Input No. 80-NFPA 70E-2024 [Section No. D.5.1]

D.5.1 Maximum Power Method.

The following method of estimating dc arc flash incident energy that follows was published in the *IEEE Transactions on Industry Applications (see reference 2 of D.5.2)*. This method is based on the concept that the maximum power possible in a dc arc will occur when the arcing voltage is one-half the system voltage. Testing completed for Bruce Power *(see reference 3 of D.5.3)* has shown that this calculation is conservatively high in estimating the arc flash value. This method applies to dc systems rated up to 1000 volts.

$$I_{arc} = 0.5 \times I_{bf}$$
$$IE_m = 0.01 \times V_{sys} \times I_{arc} \times T_{arc} / D^2 \quad \textbf{[D.5.1]}$$

where:

I_{arc} = arcing current, amperes

I_{bf} = system bolted fault current, amperes

IE_m = estimated dc arc flash incident energy at the maximum power point, cal/cm^2

V_{sys} = system voltage, volts

T_{arc} = arcing time, sec

D = working distance, cm

For exposures where the arc is in a box or enclosure, it would be prudent to consider additional PPE protection beyond the values shown in Table 130.7(C)(15)(b). While IEEE 1584 does not have arc-in-a-box/enclosure multipliers for dc panelboards and cabinets, reflected energy is reflected energy regardless of whether the initial source of the energy was ac or dc. Given that dc panelboards (fuse or breaker distribution boxes) are often of very similar dimensions to AC panelboards, the multiplier of 1.6 for calculated arc-flash energy from a dc distribution panelboard found in IEEE 1584 for ac panelboards could be assumed to be prudent. While there are larger dc distribution cabinets, most large dc enclosures contain batteries, and have quite a bit of depth to them relatively. Using typical distances of centralized large UPS battery cabinets, calculations show *(see reference 4 of D.5.2)* that typical reflected energy at the typical calculation distance of 18 inches in front of the cabinet for low voltage systems yields an approximate additional 3-4% energy. This essentially means that a mulitplier for arc-in-a-box is generally not needed for incident energy of large dc battery cabinets at 18" in front of it. However, due to ratios of direct vs reflected distance becoming closer the further the human is away from the box/enclosure, a multiplier for the arc-flash boundary for these large dc battery cabinets might be prudent. The following formula was derived *(see reference 4 of D.5.2)* for the arc-flash boundary distance multiplier from the large enclosure curves for ac switchgear in IEEE 1584.

$$K_{ab} = (0.55 \times \ln(d_{ab})) - 0.6 \quad \textbf{[D.5.3]}$$

where:

K_{ab} = arc-flash boundary distance multiplier for large dc battery cabinets

d_{ab} = calculated arc-flash boundary (in inches) without an arc-in-a-box/enclosure multiplier

Additional Proposed Changes

File Name	Description	Approved
ESW2024-11.pdf	IEEE IAS ESW2024-11 paper with support for the guidance on arc-in-a-box multipliers	

Statement of Problem and Substantiation for Public Input

The 2012 and 2015 editions of NFPA 70E suggested an arc-in-a-box multiplier of 3 for dc arc flashes. By the time work on the 2018 edition of NFPA 70E was done, enough dc arc flash testing had been done to prove that was overly conservative (and forcing people to oversuit sometimes makes them less safe - i.e., less dextrous, sweatier, and with a fogged-up faceshield), so the guidance in the 2018, 2021, and 2024 editions for arc-in-a-box multipliers for dc simply suggested putting on higher levels of PPE (which can still make the worker less safe for the same reasons just mentioned). Better guidance is needed. Although there are no published values on DC arc-in-a-box multipliers yet, and although the incident energy produced by dc and ac arc flashes is different due to the physics, the multiplicative effects of energy reflecting off enclosure walls does not change regardless of the energy source. Thus, guidance in IEEE 1584 for ac arc-in-a-box multipliers is used to provide further guidance here for dc arc-in-a-box/enclosure multipliers.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 82-NFPA 70E-2024 [Section No. D.5.2]	

Submitter Information Verification

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Submittal Date: Mon Apr 15 16:27:59 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: IEEE 1584-2018 scope and application is limited to 3 phase ac. It specifically excludes calculations for DC. Utilizing guidance of a 3-phase model to DC application is inappropriate.

MODIFYING THE DC ARC-FLASH MAX POWER FORUMULA TO GIVE MORE REALISTIC PREDICTIONS OF MAXIMUM ARC-FLASH ENERGY

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Paper No. ESW-11

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Abstract – The maximum power formula (proposed by Dan Doan in a 2007 IEEE paper) for calculating dc arc-flash incident energy has been in NFPA 70E since 2012; however, repeated testing by multiple companies over the years has shown that it overestimates arc-flash energy by a factor of at least 2-10, especially at lower voltages (such as nominal 48, 125, or 250 Vdc). This paper analyzes the actual measured arc-flash energy from over 100 different tests at various voltages, and proposes modifications to the arc sustaining time in the maximum power transfer theorem equation(s) found in Annex D.5 of NFPA 70E. In addition, more realistic estimates for dc arc-flash boundary multipliers are developed for cases where the arc is “in a box”, than what has been found in previous editions of NFPA 70E. These are based on observations of dc arc-flash tests, calculations of reflected energy from the rear of typical cabinets using the maximum power method, and previous studies of "arc-in-a-box” energy multipliers for ac arc-flash.

Index Terms — DC arc-flash, arc sustaining time, maximum power transfer formula, arc-flash boundary.

I. INTRODUCTION

For the first 80 years or so of the “electric age” almost all research into the hazards of electricity was on electric shock (and attendant electrocution at high enough levels to cause death). During all this time people were also beingh injured and killed from arc-flash/blast in addition to electric shock / electrocution. However, research into incident energy on the human body from electric arc-flash didn’t begin in earnest until approximately 1973, with the first method to calculate that danger from ac not introduced until 1982 [1]. NFPA 70E [2] did not reference any methods for calculating this ac arc-flash energy until 1995 and later editions, followed by even more on ac calculations in the 2002 initial edition of IEEE 1584 [3] (since updated in 2018).

OSHA rules for electrical safety [4] only indirectly refer to electric arc hazards (they refer to electric arcs, but not specifically to arc-flash/blast) since they were published in 1992 (before there were standards calculations methods referenced in NFPA 70E [2] and before IEEE 1584 [3] existed).

Work on dc arc-flash did not begin in earnest until 1991 [5], and the first calculations referenced in NFPA 70E [2] for dc arc-flash incident energy did not appear until the 2012 edition (following some additional dc arc-flash testing and analysis in the years 2007-2011 [6, 7]). More recent dc arc-flash testing done from 2017-2022 [8, 9, 10, 11, 12, 13, 14, 15] provided more useful data, and helped in the decision to raise the dc special PPE arc-flash protection threshold (when using the table [PPE Category] method as opposed to the calculation method) to 150 V in the 2024 edition of NFPA 70E [2] by proving that in almost all cases where maximum short-circuit current from the battery is less than 17,000 A and the voltage is below 150 Vdc, 1.2 cal/cm^2 incident energies or greater at 18 inches or further away cannot be produced.

II. EXISTING DC ARC-FLASH MODELS

A. Stokes/Oppenlander Method [5]

In 1991, Stokes and Oppenlander published [5] the first dc arc-flash incident energy formulas (empirically derived from many gapped electrode tests at varying voltages, currents, gap widths, and electrode orientations). This method requires an initial guess and iterative equation solving. The research involved both ac and dc up to 1,000 V, but the dc was limited to smaller arc currents (less than 1,000 A). If the arcing current is too low relative to the voltage, these equations cannot be solved (even iteratively).

B. Paukert Method [16]

In 1993, more formulas (empirically derived from 7 different studies) to calculate dc arc-flash incident energy were published [16] and presented by Paukert. This method is also an iterative method, requiring an initial guess, and then iterative equation solving is repeatedly done.

C. Lab Physics Model

Most of the dc arc-flash testing (as well as significant amounts of ac arc-flash testing) that has been done was done at a lab [7, 10, 12, 13, 14, 17] facility in Toronto Canada. Between 1995 and 2007 (prior to most dc arc-flash testing), this lab used physics principles (rather than empirically derived/”fit” formulas from observed results) to develop a complex predictive model for incident arc-flash energy using complex iterative processes. Prior to running tests, they use this model to predict results, and then compare them to the actual observed testing data. It has been shown in much of the more recent testing [6, 8, 9, 10, 11, 12, 13, 14] referenced in this document that their slightly old (by now) theoretical physics model typically overestimates incident energy by at least a factor of 2.

D. Doan / Maximum Power Transfer Theorem [18]

In 2007, Dan Doan published [18] the maximum power transfer theorem for dc (building on earlier ac work), which in its present form (this paper proposes a modification/ improvement of the method to make it more accurate at lower voltages) is the most conservative of the methods (i.e., it typically overestimates the actual incident energy from dc arc-flash more than the iterative methods). Calculations are done using a simple formula (or two – see NFPA 70E [2] Annex D.5 for the 2 equations that have been combined into equation 1):

$$IE = 0.01 \times V_{nom} \times \frac{I_{sc}}{2} \times \frac{t}{d^2} \quad (1)$$

where

IE	is the incident energy in cal/cm²
V_{nom}	is the nominal dc voltage
I_{sc}	is the maximum (bolted fault) short circuit current (battery manufacturers typically publish this, and manufacturers can often provide it for other types of dc equipment)
t	is the time before an upstream OCPD (e.g., fuse or breaker) operates, or the maximum time that the arc can sustain itself (NFPA 70E [2] notes that the calculation time should probably not exceed 2 seconds, and IEEE 1584 [3] supports this because the person will have likely reacted and moved away within that time if space allows)
d	is the typical distance of the vital organs of the body from the electrical equipment that could have the arc-flash event, and is noted in NFPA 70E [2] for most of the dc voltages that most users deal with as 18 inches (equivalent to 45.72 cm, which is usually the value used since the incident energy is in SI units of cal/cm²)

Note that this is the only formula(s) for dc arc-flash calculations given in NFPA 70E [2]. The only other methods indirectly referenced for dc arc-flash calculations in NFPA 70E [2] (Annex D.5) are the Stokes/Oppenlander [5] and Paukert [16] iterative methods.

While not the most accurate method for a wide array of nominal voltages (actual testing has shown it to be fairly accurate when nominal dc voltages are near 480 though), this maximum power method is commonly used.

One big problem with this maximum power method is its overestimation of the risk at lower voltages. More PPE than is needed can make a user less safe by making them less dexterous, too hot and sweaty, etc. A smaller issue with this method (and all the other methods mentioned in this section are probably limited in the same way based on the data and assumptions used in those models) is that it is limited to dc voltages below 1,000 The majority of dc systems in the world today are below this voltage, but there are more and more being installed above that voltage, such as with grid scale solar and wind generation, especially with attendant battery energy storage systems.

Like the lab physics model, the maximum power transfer method is theoretical, and has not proven to be as accurate as empirically-derived formulas from actual testing, such as those from the Stokes, Paukert, and Ammerman models/methods.

A subsequent section in this paper will cover a proposed method of making this maximum power calculation more accurate at lower voltages by empirically deriving a formula for the arc sustaining time since this less-accurate method for incident energy and arc flash boundary calculations is still fairly commonly used.

E. Ammerman Method [19]

In 2009, Ammerman and colleagues (including P.K. Sen) published [19] another iterative method for determining dc arc-flash energy. While not referenced in NFPA 70E [2] Annex D.5, it may still be used, with engineering judgement.

III. DC ARC SUSTAINING TIME

Those who calculate dc arc-flash incident energy manually using the Maximum Power [18] formulas found in NFPA 70E [2] have usually used dc arc sustaining times of 2 seconds (in some cases longer in an effort to be more conservative), at least on the portions of the analyzed circuit where a fuse or breaker will not limit the time to less than that. The 2 second maximum time comes from NFPA 70E [2] and IEEE 1584 [3], where the assumption was made that if the "space" made it possible, human reaction would cause the person to back away from the arc flash within 2 seconds. In the opinion of the author, based on video observations of arc-flash testing and actual real arc-flashes, if space allows it, in larger arc flash incidents, the arc blast is likely to knock the person down or back out of the area within the 2 seconds as well.

The iterative methods [5, 16, 19] are more accurate than the maximum power method for many reasons, with one of those reasons being that they usually compute a more realistic arc sustaining time.

For those still using the maximum power method and a default 2 second (or more) arc sustaining time, dozens of individual [6, 7, 8, 9, 10, 11, 12, 13, 14, 20] real world tests (see Figure 1) have shown that 2 seconds is far longer than the actual arc sustaining time for dc arcs below approximately 480 Vdc.

The different lengths of arc sustaining time shown in Figure 1 for each of the different nominal tested voltages (nominal 100, 125, 250, and 480) are due to different maximum short circuit currents of the dc equipment under test, different starting electrode lengths, and orientation of the electrodes.

Using a more accurate arc sustaining time to calculate more realistic incident energy for lower dc voltages is important due to the sheer number of dc systems (or dc busses in UPSs) that operate below that level. Common lower dc bus nominal voltage levels found in many installed systems include: 12, 24, 36, 48, 125 (120), 192, 216, 250 (240), 288, and 380 (336, 360, and 384). Note that the latest edition (2024) of NFPA 70E [2] does not require special arc-flash protective clothing (other than safety glasses) for dc arc-flashes below 150 Vdc if the table (aka PPE Category) method is used, based on numerous tests [11, 12, 13, 14] run mostly over the last 7 years. The previous 4 editions of NFPA 70E [2] did not require special clothing below 100 Vdc (if the table / PPE Category method was used). However, arc-flash calculations below 150 (or even 100) Vdc are sometimes still used/desired, especially if the total potential short circuit current is 17,000 A or more, as will be shown later on in test results reviewed in this paper.

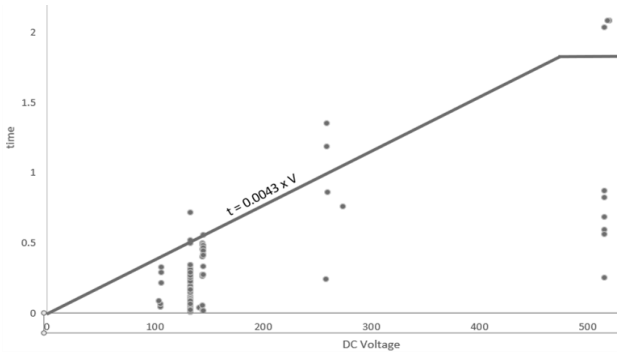


Fig. 1 Real World Testing DC Arc-Flash Sustaining Times along with Empirically-Derived Maximum Arc Time

One conclusion of all these tests is that existing maximum power transfer calculations for voltages below 480 Vdc have been severely overestimating maximum incident energy from dc arc-flashes at the standard 18 inch (45.72 mm) [2] vital body organ distance partially due to overestimation of the time that the arc can sustain itself. Curve fitting the results so that most of the points fit under the "curve"; and maximizing at 2 seconds of arc time [2, 3] yields the lines (along with a voltage-based formula) in Figure 1. The point at which the formula yields 2 seconds or longer arc sustaining times is nominal 465 Vdc, which is consistent with real world testing [6, 7, 8, 9, 10, 13].

None of the published testing data [6, 7, 8, 9, 10, 11, 12, 13, 14, 20] is at dc voltages lower than 100, partly because it has been known for at least a dozen years that dc arc-flashes below that voltage cannot produce incident energy above the 1.2 cal/cm^2 2nd-degree maximum burn threshold (as noted earlier in this section, that dc voltage has now been moved to 150 when using the table / PPE Category method) [2]. However, when testing has been done below that 100 Vdc level, although the arc sustaining time results have not been "published", the arc sustaining times observed were consistently below what is predicted by equation (2). For example, Fechalos and Blake, while presenting their 2023 Battcon paper [10] showed an example video of a 48 Vdc test, and the approximate duration of the arc-flash was about 100 milliseconds, which is about half of what equation (2) predicts for a maximum arc sustaining time at that nominal voltage.

$$t = 0.0043 \times V_{nom} \quad (2)$$

when

V_{nom} is ≤ 465 Vdc

$$t = 2 \quad (3)$$

when

V_{nom} is > 465 Vdc

Many actual test arc sustaining times fall below (see Figure 1) the values predicted by equations 2 and 3. This is mostly due to lack of an electrode separation distance variable in the equation(s). The author purposely did not include electrode separation, since in many dc systems, electrode separation can be highly variable, depending on the length of the object that initiates the arc. For example, in a cabinetized UPS monobloc battery system, there are a multitude of possibilities for distances between differing polarities (including ground), even at the same nominal voltage. Instead, the purpose of this work is to establish a reasonable upper bound on the maximum dc arc sustaining time based on the available data. This may overprotect in some cases, but at voltages below nominal 480 V where the maximum power method is presently being used with a 2 second (or more) arc sustaining time, this modification is going to greatly decrease the existing overcalculation of the risk. Perhaps future work can focus on additional variables in arc sustaining time (such as electrode separation and orientation)?

Finally, on the subject of dc arc sustaining time, in the experience of the author, many dc arc-flash calculations that have been done in existing industrial facilities (such as UPS battery cabinets in large data centers) neglect (usually due to the person running the calculations or inputting the circuit parameters into a computer program not accounting for OCPDs in parallel paths) the fact that any dc source fault current contribution flowing through a fuse or breaker towards an arc-flash/blast fault point will usually be time-limited by the I-t curve of the fuse/breaker(s) in the path. For example, for a worker in one battery cabinet of a UPS that has 4 parallel battery cabinets (with each cabinet having its own internal breaker at the top), the arc-flash incident energy from the cabinet where the work is being done will be time-limited only by the nominal voltage of the fault causing the arc-flash, as per equation (2) or (3). However, all parallel sources (the other 3 battery cabinets and the UPS dc charging source) that can contribute to the fault current will have to flow through one or two breakers. Assuming these breakers are sized and have any adjustable instantaneous trip settings correctly set, the high fault currents from these sources flowing towards the source should cause the breaker(s) to open on the instantaneous portion of their trip curve (typically within 16-60 milliseconds on average, depending on breaker model and manufacturer). This greatly limits the overall arc flash energy. In numerous calculations run by the author, the additional incident energy contributed by parallel sources flowing through properly sized and adjusted breakers (or through properly sized fuses) is usually no more than 7% of the total incident energy that has been negligently calculated (and posted on labels on cabinets or panels) without consideration of fuses or breakers in parallel paths.

IV. ARC-IN-A-BOX THEORY VS REALITY

When dc arc-flash calculations were introduced in Annex D of NFPA 70E [2] in 2012, guidance was given that arc-in-a-box (due to reflected energy off the sides, top, bottom, and rear of the box) could be 3 times or more the calculated arc-flash energy (because the models mentioned in Section II of this paper mostly assume spherical energy spread from the point of the arc, and do not normally take reflected energy into account). This assumption was based partly on testing in low voltage (600 V or lower at the time [21]) ac panelboards [3] that have very short depths (typically 4-6 inches {10-15 cm}), which causes fairly significant reflection of energy from the rear. It was also based on testing of medium voltage (1-36 kV) [21], and low voltage (≤ 600 V) [21] larger ac switchgear cabinets. This testing, and IEEE 1584 [3] guidance gives a multiplication factor of 1.6 for ac panelboards [22] (see Figure 2), regardless of distance from the arc-flash event. The multiplication factor varied [3, 22] for low voltage and medium voltage larger ac switchgear cabinets, from between 1.0 and 2.2 at the vital organ distance [2] of 18 inches (45.72 cm), up to a maximum

multiplying factor of 3.8-4.75 for these large switchgear cabinets at the typical maximum arc-flash boundary distance of 10 feet [2] (approximately 3 m).

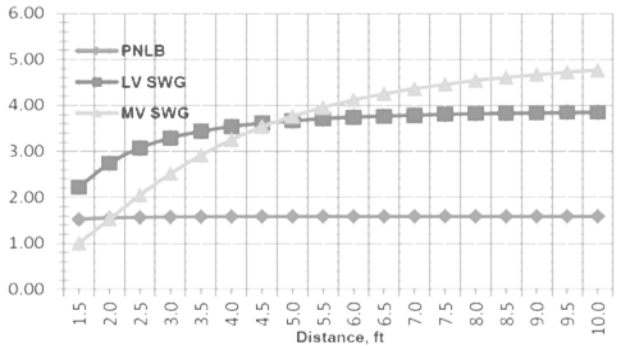


Fig. 2 AC arc-in-a-box Incident Energy Multiplication Factors vs. Distance [3, 22]

This guidance carried into the 2015 edition of NFPA 70E [2]. However, in the 2018 edition, the guidance had been changed from a multiplier of 3x for dc arc-in-a-box to "… it would be prudent to consider additional PPE protection beyond the values shown in Table 130.7(C)(15)(b)." This same "new" language is in the subsequent editions of NFPA 70E [2]. This change was made in the 2018 edition because actual testing up to that point [6, 7, 20], and testing since [8, 9, 10, 11, 12, 13, 14], had not shown nearly triple the difference between incident energies measured from dc arc-in-a-box vs open air, all other conditions (such as electrode spacing and orientation, maximum short circuit current, nominal voltage, etc.) being equal. In most cases the observed/measured incident energy at 18 inches (45.72 cm) [2] from dc arc-flash energy reflected from a "box" is more (although usually much less than triple) than it would be in open air, and in some cases it was less.

Because of a lack of dc arc-flash testing done/published for dc panelboards, there is no reason yet to use any factor for dc panelboards other than the 1.6 multiplication factor (see Figure 3) for ac panelboards [3, 22], since they tend to have similar dimensions to ac panelboards (being equipped with dc breakers or fuses rather than ac breakers or fuses).

The maximum power theorem formula(s) {see equation (1)} can also be used to determine the arc-flash boundary (the distance where the incident energy drops to the 2nd-degree burn threshold of 1.2 cal/cm^2 [2] or lower). See equation (4) for the algebraically modified formula and note that the incident energy value is now under a square root. This means that if the arc-flash energy from a panelboard is 1.6 times the value calculated by equation (1), the distance multiplier for determining the arc-flash boundary for dc panelboards should be the square root of 1.6 (√1.6 = 1.265).

$$d = \sqrt{\frac{0.01 \times V_{nom} \times \frac{I_{SC}}{2} \times t}{IE}} \quad (4)$$

Based on observations of dc arc-flash testing done with cabinets (such as UPS battery cabinets), there is some reflected energy, but nowhere near triple the energy at the critical body organ distance [2] of 18 inches (45.72 cm). In most cases, it should be much less than a 1.6 multiplier at that distance because of the depths of these cabinets compared to panelboards. Arc-flash energy decreases as it moves away from the source by the square of the distance [1, 2, 18]. In a sample calculation for a typical UPS battery cabinet 4 feet (1.2 m) wide by 33½ inches (0.85 m) deep by 7 feet (2.13 m) tall, most of the reflected (as opposed to the direct energy from the arc-flash) energy that will impinge on the body's vital organs, at approximately 18 [2] inches (45.72 cm) from the front of the battery, will be the direct reflection from the rear. That addition to incident energy for this cabinet, (based on the square of the distance) would be approximately $^1/_{30}^{th}$ (a multiplier of 1.03). There will be even less reflected additive energy from the top, bottom and sides of the cabinet due to their greater distances and oblique angles to the human body in front of the "box".

There have been more than 90 dc arc-flash tests [6, 7, 8, 9, 10, 11, 12, 13, 14, 20] yielding enough data to do comparisons like Figures 3 through 10. About 87% of those tests were arc-in-a-box tests (in medium/large cabinets), with the rest done in open air. Only two tests yielded actual measured arc-flash incident energy at 18 inches (45.72 cm) [2] that exceeded maximum power formula {equation (1)} calculations (without any arc-in-a-box multiplier), even when modified for lower arc-sustaining times per equation (2) at lower voltages. Those two cases [9] were on nominal 120 Vdc PV systems with maximum fault current (< 2,000 A) lower than typical for many dc applications, and the actual and calculated incident energies at 18 inches (45.72 cm) all fell below the 1.2 cal/cm^2 2nd-degree burn threshold, above which special PPE is required [2]. Also, for the limited comparisons (see Figure 3) that have been done [15] for actual dc arc-flash testing results vs iterative methods (Paukert [16] and Stokes [5] in this case), the actual incident energy measured (even in a "box") was less than or essentially equivalent to what was calculated by the iterative methods (except for one instance previously noted), without using an arc-flash multiplying factor.

IEEE 1584 [3] and other sources [22] note (see Figure 2) that the arc-in-a-box incident energy multiplier increases for switchgear cabinets at distances greater than 18 inches (45.72 cm). This is due to the decreasing ratio of reflected energy distance to body distance away from the cabinet; however, it does not affect incident energy calculations [2] at 18 inches (45.72 cm). For example, the multiplier in Figure 3 for MV switchgear cabinets at 18 inches (1.5 feet) is 1.0. It only becomes a "multiplier" at further distances (such as the arc-flash boundary distance in most cases). As such, the ac arc-in-a-box incident energy multiplier (2.2-3.8 at the high end per Figure 2) for low voltage ac switchgear at greater distances [3, 22] might be applied to the arc-flash boundary calculation for low voltage dc cabinets. Since most dc applications fall into the "low voltage" (which is now below nominal 1,500 Vdc [1,000 Vac] in the NEC® [21]) category, but most dc larger cabinets are more similar in size to a front-access medium voltage switchgear cabinet; the incident energy multiplier curves from Figure 2 can be averaged, and curve fit. Taking the square root of that curve yields the following formula for arc-flash boundary distance multipliers for larger dc cabinets:

$$m_{AB} = (0.55 \times \ln(d_{in})) - 0.6 \quad (5)$$

where

m_{AB} is the dc arc-flash boundary distance multiplier for large cabinets

d_{in} is the base arc-flash boundary distance (in inches) for arcs not in a box calculated from the maximum power formula

Based on this analysis, the author recommends either leaving existing language on dc arc-in-a-box multipliers in Annex D.5 of NFPA 70E [2] as is; or changing it to read something similar to the following: "For exposures where the arc is in a box or enclosure, it may be prudent to apply a multiplying factor up to 1.6 to the incident energy calculation for purposes of PPE for dc panelboards, and a corresponding distance multiplication factor up to 1.265 to the arc-flash boundary calculation. For larger dc enclosures, such as UPS battery cabinets, testing, calculations, and observation have shown that the reflected energy from the rear, sides, top, and bottom of these enclosures only adds very minimally to the incident energy at the vital body organ typical distance of 18 inches (45.72 cm) [2]. Thus, no multiplication factor for the calculation of incident energy is suggested. However, it may be prudent to apply a multiplier based on empirical equation (5) for calculation of the arc-flash boundary (with a maximum distance of 10 feet) for dc cabinets larger than a panelboard due to the relative contribution of reflected energy vs direct incident energy at greater distances for larger dc enclosures."

V. COMPARISON OF CALCULATIONS VS ACTUAL TEST RESULTS

Limited work has been done comparing tested incident energy at 18 inches (45.72 cm) [2] to the different dc arc-flash models. However, one paper [20] undertook calculations for 2 iterative methods (Paukert [16] and Stokes [5]), as well as the maximum power transfer theorem [18, 21], for 7 individual tests [9, 12, 13] from the many that have been reported. The results of this comparison, supplemented with the maximum power transfer theorem {equation (1)} modified for time by equations (2) and (3), are shown in Figure 3 (note that the clusters along the horizontal axes of each of Figures 3-10 represents an individual test).

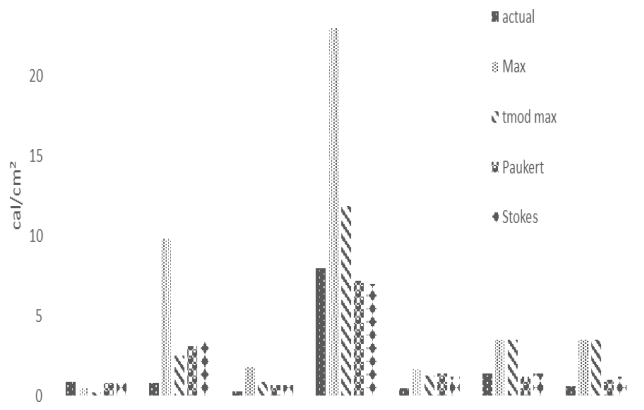


Fig. 3 Actual Incident Energy vs Existing and Proposed Methods

From this comparison of 7 incident energy measurements to 4 different calculation methods, it can be seen that at least 2 of the iterative methods [5, 16], as well as the maximum power formula(s) [2, 18] {see equation (1)} modified for maximum dc arc sustaining time by equations (2) and (3), provide a good upper bound for incident arc-flash energy at 18 inches (45.72 cm) [2] without requiring excessive PPE (which can actually make the user less safe by making them less dexterous and sweatier).

For the more than 90 individual tests [6, 7, 8, 9, 10, 11, 12, 13, 14, 20] for which enough useful data has been published for good comparison, the author ran calculations for dc arc-flash at 18 inches (45.72 cm) [2] with both the maximum power transfer theorem [2, 18], using equation (1) with a maximum time value of 2 seconds [2, 3], as well as with modified time values per equations (2) and (3). These 90+ test results can essentially be grouped into 4 nominal dc voltage "bins" of 100, 125, 250, and 480 Vdc.

Figure 4 compares a random sample (for readability) of 8 (of the more than 90) test's actual incident energies (measured at different nominal voltages, short circuit currents, electrode configurations, and electrode spacings), against the maximum power method calculated at 2 seconds and at the modified maximum arc sustaining time from equations (2) and (3):

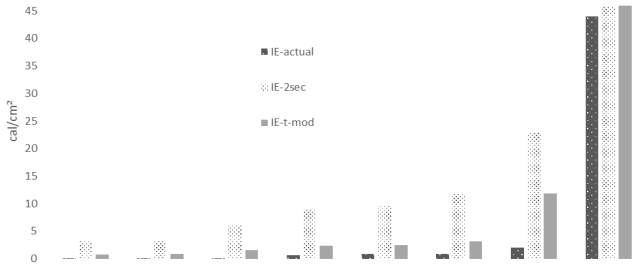


Fig. 4 Sample Comparison of Max Power Calculations (Modified for Time and Not) Against Actual Incident Energies

Figure 4 shows the large difference in accuracy (in most cases) of maximum power calculations when arc sustaining is modified for time (even when only based on voltage) versus calculations using a 2 second arc sustaining time.

Each of the nominal voltage "bins" (the bin for nominal 125 Vdc is further divided into various ranges of maximum short circuit current available in order to make the data more readable because there have been so many nominal 125 Vdc arc-flash tests run [7, 9, 11, 12, 13, 14, 20]) is represented by a different graph in Figures 5 through 10. In these graphs, for readability purposes, the generally highly overstated maximum power calculations at 2 seconds are not even shown (except at nominal 480 Vdc where the calculation {equation (3)] yields 2 seconds), since they would usually make the y-axis of the chart much taller.

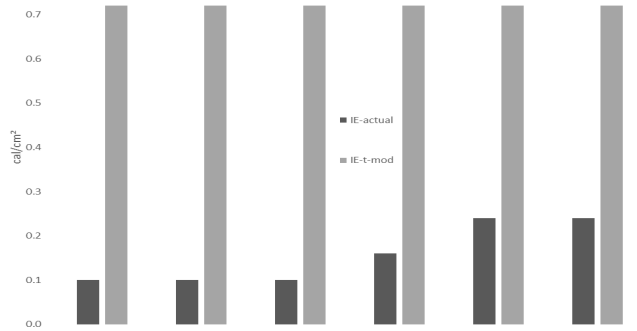


Fig. 5 Comparison of Measured Incident Energies for Nominal 100 Vdc Tests to Unmodified and Modified Maximum Power Theorem Formulas

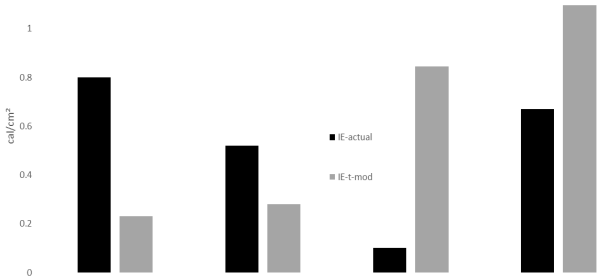


Fig. 6 Comparison of Measured Incident Energies for Nominal 125 Vdc Tests with Available Short Circuit Currents of Less than 7,500 A to Unmodified and Modified Maximum Power Theorem Formulas

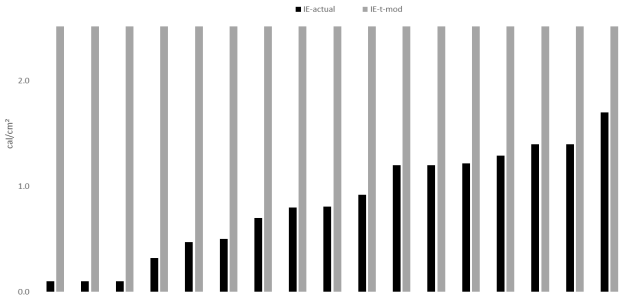


Fig. 7 Comparison of Measured Incident Energies for Nominal 125 Vdc Tests with Available Short Circuit Current of 17,000 A to Unmodified and Modified Maximum Power Theorem Formulas

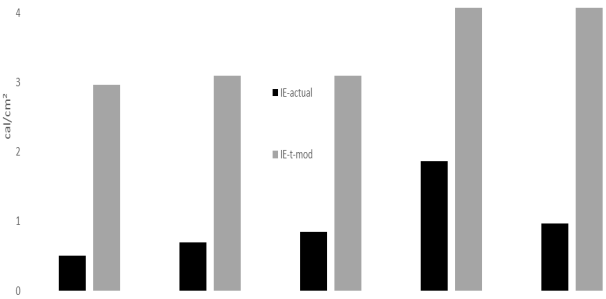


Fig. 8 Comparison of Measured Incident Energies for Nominal 125 Vdc Tests with Available Short Circuit Currents Greater than 17,000 A to Unmodified and Modified Maximum Power Theorem Formulas

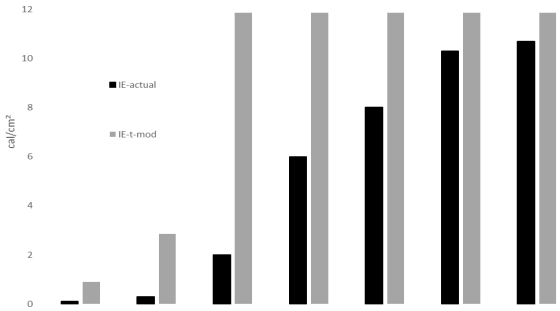


Fig. 9 Comparison of Measured Incident Energies for Nominal 250 Vdc Tests to Unmodified and Modified Maximum Power Theorem Formulas

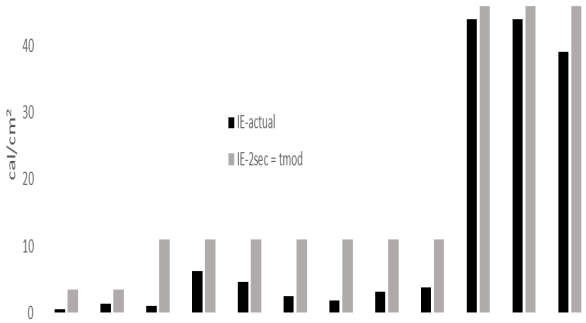


Fig. 10 Comparison of Measured Incident Energies for Nominal 480 Vdc Tests to Unmodified and Modified Maximum Power Theorem Formulas

With all of these figures, it can be seen that modifying the maximum power transfer theorem [2, 18] formula(s) {see Equation (1)} for time with the appropriate equation (2) or (3) yields acceptable upper bound results in almost all cases without requiring the excessive PPE at voltages below 465 Vdc that a maximum power transfer calculation using the NFPA 70E [2] / IEEE 1584 [3] typical maximum time of 2 seconds would produce. As was pointed out earlier in this paper, the existing maximum power transfer formula [18] {see equation (1)} in Annex D.5 of NFPA 70E [2], using the recommended 2 second maximum arc-flash exposure time [2, 3] is fairly accurate already around 480 Vdc nominal (see Figure 10).

There is some data published from tests done at other voltages (such as nominal 350, 600, and 1,000 Vdc) and also other testing done at the nominal voltages covered by these last Figures, but not enough to make a good graphing comparison. However, conclusions drawn from this limited data also support the conclusions of the preceding paragraph, and the overall conclusions in the succeeding section.

As noted, the latest NFPA 70E [2] raised the minimum dc voltage at which special arc-flash PPE is required to 150 when using the table (PPE Category) method, which lines up with the findings shown in Figures 5 and 6. While no special PPE is normally required, figures 7 and 8 show that it may sometimes be required in the rarer cases when available short circuit current is 17,000 A or more without overcurrent protection limiting the arcing time. Users may still run incident energy calculations for nominal dc voltages below 150, using an iterative method [5, 16, 19], the maximum power formula(s) [18] {the simplified equation (1) or the 2 equations shown in NFPA 70E Annex D.5 [18]} with a 2 second maximum arc exposure time [2, 3], or with the maximum power transfer formula(s) modified for time {see equation (2)}.

VI. CONCLUSIONS

the author supports continued use of the maximum power formula(s) for calculating dc arc-flash incident energies and arc-flash boundaries as an alternative method to the preferred iterative solutions, but proposes that it be supplemented with an empirically derived formula that estimates the typical maximum arc sustaining time based on nominal voltage. This additional formula causes the results to be more in line with measurements from real testing and more complex iterative dc arc-flash calculation models.

The author also proposes that present guidance in NFPA 70E [2] Annex D.5 on use of a multiplying factor for dc arc in a box incident energy remain the same; or be changed to use a multiplier of 1.6 [3, 22] for dc panelboards, but no multiplier for the arc-flash incident energy at 18" for larger cabinets (such as UPS battery cabinets) based on observations of actual testing [6, 7, 8, 9, 10, 11, 12, 13, 14, 20] and calculations. The distance multiplier for arc-flash boundary calculations for dc panelboards would be 1.265. The distance multiplier for large dc cabinets should be based on equation (5).

The author will be submitting these proposed NFPA 70E [2] changes as public inputs, either through a consensus body, such as the IEEE PES ESSB Codes Committee, or as an individual (himself).

VII. ACKNOWLEDGEMENTS

The author would like to thank Mike O'Brien for the initial idea of using testing data for maximum arc-flash sustaining time at lower voltages when using the Doan maximum power [18] formulas from Annex D.5 of NFPA 70E [2]. The author would also like to thank Lloyd Gordon for his previous research [23] into most of the dc arc-flash testing that has been done and the dc arc-flash calculations methods; as well as for his guidance and ideas on these subjects.

VIII. REFERENCES

[1] R. Lee, "The Other Electrical Hazard: Electric Arc Blast Burns", IEEE Transactions on Industry Applications, Vol. IA-18, No. 3, pp. 246-251, May/Jun 1982.

[2] NFPA® 70E, Standard for Electrical Safety in the Workplace,1995, 2012, 2015, 2018, and 2024 editions, Quincy, MA.

[3] IEEE 1584, Guide for Performing Arc-Flash Hazard Calculations, 2002 and 2018 editions, New York, NY, Institute of Electrical and Electronics Engineers.

[4] OSHA 29CFR1910, Part S – Electrical.

[5] A. Stokes and W. Oppenlander, "Electric Arcs in 1", Journal of Physical Discourses: Applied Physics, Vol. 24, 1991, pp. 26-35.

[6] Cheng, K., et al, "Arc Hazard Assessment for DC Applications in the Transit Industry", proceedings of the American Public Transport Association (APTA) Rail Conference, Boston, MA, 2011.

[7] C. Keyes and C. Maurice, "DC Arc Hazard Assessment Phase II", Kinectrics, Toronto, ON, Canada, Report K-012623-RA-0001-R00, 2007.

[8] Cheng, K., et al, "DC Arc-Flash Testing and Analysis at 600 V", proceedings of the IEEE IAS Electrical Safety Workshop (ESW), Reno, NV, 2020.

[9] Electric Power Research Institute (EPRI) Technical Report 3002014124, "DC Arc Flash on Photovoltaic (PV) Equipment", 2018.

[10] W. Fechalos and P. Blake, "DC Arc-Flash in Stationary Battery Systems", proceedings of Battcon 2023, paper No. 18.

[11] Gaunce, A., et al, "DC Arc-Flash: Testing and Modeling Incidents in a 125-V Substation Battery Backup System, IEEE Transactions on Industry Applications, Vol. 56, No. 3, pp. 2138-2147, May/Jun 2020.

[12] K. Gray and R. Hallé, "Sustainability of an Electric Arc-Flash at a Voltage of 240 VAC and 140 Vdc", proceedings of the IEEE IAS ESW, Reno, NV, 2023.

[13] Gray, K., et al, "Low Voltage 100-500 Vdc Arc-Flash Testing", proceedings of the IEEE IAS ESW, 2020.

[14] J. Hildreth and K. Feeney, "Arc-Flash Hazards of 125 Vdc Station Battery Systems", proceedings of the IEEE Power and Energy Society General Meeting (PES GM), paper No. 8586181, Portland, OR, 2018.

[15] Veeraraghavan, R. (ETAP), "DC Arc-Flash Analysis", presentation for Symposium #1 (DC Arc-Flash) at the 2017 winter meeting of the IEEE PES ESSB (Energy Storage and Stationary Battery committee, New Orleans, LA.

[16] J. Paukert, "The Arc Voltage and Arc Resistance of Low Voltage (LV) Fault Arcs", proceedings of the 7th International Symposium on Switching Arc Phenomena", pp. 49-51, 1993.

[17] K.S. Cheng and C. Keyes, "DC Arc-Flash Hazard Analysis Service for Pacific Northwest National Laboratory (PNNL)", Kinectrics, Toronto, ON, Canada, Report K-418079-RA-001-00, Oct 2011.

[18] D.R. Doan, "Arc-Flash Calculations for Exposures to DC Systems, proceedings of the IEEE IAS ESW, 2007.

[19] Ammerman, R., et al, "DC Arc Models and Incident Energy Calculations", proceedings of the Petroleum and Chemical Industry Conference (PCIC), 2009.

[20] Weimann, C.S., "Analytical and Experimental Validation for DC Arc-Flash Models", University of Pittsburgh Electrical Engineering Department Report ETD-07162020, 2018.

[21] NFPA® 70®, National Electrical Code® (NEC®), 2011, 2014, and 2023 editions, Quincy, MA: National Fire Protection Association.

[22] W. Fontaine and S. McCluer, "Arc in a Box: DC Arc-Flash Calculations Using a Simplified Approach", proceedings of Battcon 2014, paper No. 15.

[23] L.B. Gordon, "Modeling DC Arc Physics and Applications for DC Arc-Flash Risk Assessment", proceedings of the IEEE IAS ESW, Reno, NV, 2023.

IX. VITA

Curtis Ashton obtained a B.S.E.E degree from Arizona State University in 1992, while working for an electric utility, and then worked for 27 years for a large telecom and data center company as a power and grounding maintenance engineer. He has worked for the last 5 years for a dc services subsidiary (American Power Systems LLC) of East Penn Manufacturing (formerly Deka Batteries). Curtis is a past chair of the IEEE PES ESSB (Energy Storage and Stationary Battery) committee, and the primary author / working group chair of several of the battery standards produced by that technical committee. He is also a past vice-president of the IEEE Intelec Executive Committee (now IEEE PELS TC7); and a past vice-chair for ATIS-STEP; as well as being the primary author of several ANSI/ATIS power and grounding standards. Mr. Ashton is also an IEEE IAS member, and is on the NFPA 855 standard committee. He has been published many times, has presented in many locales across the globe, and has a patent to his name. Curtis is also a Master Electrician in Colorado and a Journeyman Electrician in New Mexico.

Public Input No. 81-NFPA 70E-2024 [Section No. D.5.1]

D.5.1 Maximum Power Method.

The following method of estimating dc arc flash incident energy that follows was published in the *IEEE Transactions on Industry Applications (see reference 2 of D.5.2)*. This method is based on the concept that the maximum power possible in a dc arc will occur when the arcing voltage is one-half the system voltage. Testing completed for Bruce Power *(see reference 3 of D.5.~~3~~ 2)* has shown that this calculation is conservatively high in estimating the arc flash value. This method applies to dc systems rated up to 1000 volts.

$$I_{arc} = 0.5 \times I_{bf}$$
$$IE_m = 0.01 \times V_{sys} \times I_{arc} \times T_{arc} / D^2 \qquad \textbf{[D.5.1]}$$

where:

I_{arc} = arcing current, amperes

I_{bf} = system bolted fault current, amperes

IE_m = estimated dc arc flash incident energy at the maximum power point, cal/cm^2

V_{sys} = system voltage, volts

T_{arc} = arcing time, sec

D = working distance, cm

For exposures where the arc is in a box or enclosure, it would be prudent to consider additional PPE protection beyond the values shown in Table 130.7(C)(15)(b).

Statement of Problem and Substantiation for Public Input

There is no longer a D.5.3 section (this is a carryover from a previous edition), so the referenced documents for this section are all now in D.5.2 (the correct section reference is found in other parts of the text in this section)

Submitter Information Verification

Submitter Full Name: Curtis Ashton
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Submittal Date: Mon Apr 15 16:55:51 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-71-NFPA 70E-2024

Statement: The direct-current incident energy calculation models have been revised by including updated testing information, supporting references, dc to ac arc flash characteristic comparisons and additional considerations for direct-current incident energy calculations.

The term “nominal” was added before voltage in the Maximum Power Method, D.5.3. formula to clarify the voltage used.

Public Input No. 195-NFPA 70E-2024 [Sections D.5.1, D.5.2]

Sections D.5.1, D.5.2

D.5.1 Maximum Power Method.

The following method of estimating dc arc flash incident energy that follows was published in the *IEEE Transactions on Industry Applications (see reference 2 of D.5.2)*. This method is based on the concept that the maximum power possible in a dc arc will occur when the arcing voltage is one-half the system voltage. Testing completed for Bruce Power *(see reference 3 of D.5.3)* has shown that this calculation is conservatively high in estimating the arc flash value. This method applies to dc systems rated up to 1000 volts.

$$I_{arc} = 0.5 \times I_{bf}$$
$$IE_m = 0.01 \times V_{sys} \times I_{arc} \times T_{arc} / D^2 \qquad \text{[D.5.1]}$$

where:

I_{arc} = arcing current, amperes

I_{bf} = system bolted fault current, amperes

IE_m = estimated dc arc flash incident energy at the maximum power point, cal/cm^2

V_{sys} = system voltage, volts

T_{arc} = arcing time, sec

D = working distance, cm

For exposures where the arc is in a box or enclosure, it would be prudent to consider additional PPE protection beyond the values shown in Table 130.7(C)(15)(b).

D.5.2 Detailed Arcing Current and Energy Calculations Method.

A thorough theoretical review of dc arcing current and energy was published in the *IEEE Transactions on Industry Applications*. Readers are advised to refer to that paper *(see reference 1)* for those detailed calculations.

References:

1. “DC-Arc Models and Incident-Energy Calculations,” Ammerman, R.F., et al., *IEEE Transactions on Industry Applications*, Vol. 46, No. 5.

2. “Arc Flash Calculations for Exposures to DC Systems,” Doan, D.R., *IEEE Transactions on Industry Applications*, Vol. 46, No. 6.

3. “DC Arc Hazard Assessment Phase II,” Copyright Material, Kinectrics Inc., Report No. K-012623-RA-0002-R00.

Additional Proposed Changes

File Name	Description	Approved
ASNZS5139-2019-1_compressed.pdf	AS/NZS 5139	

Statement of Problem and Substantiation for Public Input

It is recommended that NFPA 70E provide a clear direction on arc flash incident energy calculation for batteries placed in battery rooms. The current NFPA 70E does classify if the batteries placed in battery rooms are to be considered open-air or enclosures when determining the arc flash incident energy

using the maximum energy method.

Classifying batteries placed in battery rooms as open-air or enclosed applications can have a significant impact on the incident energy level. The arc flash incident energy level available in an enclosure can be three (3) times greater than the available arc flash incident energy in an open-air application.

AS/NZS 5139 Standard, Appendix F, uses a Multiplying Factor (MF) in determining the available arc flash incident energy for a DC system. The MF is 1 for open-air application, 1.5 for battery rooms (accounting for some incident energy reflections when batteries are placed near walls), and 3 for enclosure.

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Committee: EEW-AAA

Committee Statement

Resolution: No recommended text has been provided as required by Section 4.3.4 of the NFPA Regulations Governing Committee Standards.

Public Input No. 224-NFPA 70E-2024 [Section No. D.5.2]

D.5.2 ~~Detailed~~ 8 References for Arcing Current and Energy Calculations Method.

~~A thorough theoretical review of dc arcing current and energy was published in the *IEEE Transactions on Industry Applications*. Readers are advised to refer to that paper *(see reference 1)* for those detailed calculations.~~

~~References:~~

~~1. "DC-Arc Models and Incident-Energy Calculations," Ammerman, R.F., et al., IEEE Transactions~~ The following references for dc arc flash incident energy analysis are used for this Annex section, D.5

(1) L. Gordon, "Modeling the Dynamic Behavior of DC Arcs," IEEE Trans. on Industry Applications, Vol. 60, No. 1, Jan/Feb 2024, pp 1946-1955.

(2) R. F. Ammerman, T. Gammon, P. K. Sen, and J. P. Nelson, "DC arc models and incident energy calculations," in Proc. Petroleum Chem. Ind. Conf.,

2009, pp. 1–3.

(3) D. R. Doan, "Arc flash calculations for exposures to DC systems," IEEE Trans. on Industry Applications, Vol. 46, No.

~~5.~~

~~2. "Arc Flash Calculations for Exposures to DC Systems," Doan, D.R., *IEEE Transactions on Industry Applications*, Vol. 46, No. 6.~~

~~3. "DC Arc Hazard Assessment Phase II," Copyright Material, Kinectrics Inc., Report No.~~ 6, Nov/Dec 2010, pp. 2299-2302.

(4) C. Ashton, "Modifying the DC Arc-Flash Max Power Formula to Give More Realistic Predictions of Maximum Arc-Flash Energy, in Proc. Of IEEE Electrical Safety Workshop, March 2024, Tucson, pp. 71 – 77.

(5) A. Stokes and W. Oppenlander, "Electric arcs in open air," J. Phys. D: Appl. Phys., vol. 24, pp. 26–35, 1991.

(6) J. Paukert, "The arc voltage and arc resistance of LV fault arcs," in Proc. 7th Int. Symp. Switching Arc Phenomena, 1993, pp. 49–51

(7) C.Keyes and C. Maurice, "DC arc hazard assessment phase II,"Kinectrics, Toronto, ON, Canada, Tech. Rep. K-012623-RA-

~~0002~~

0001 -R00, Jul. 2007

Statement of Problem and Substantiation for Public Input

This is an updated list of models currently in use for dc arc flash incident energy analysis.

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Committee: EEW-AAA

Committee Statement

Resolution: FR-71-NFPA 70E-2024

Statement: The direct-current incident energy calculation models have been revised by including updated testing information, supporting references, dc to ac arc flash characteristic comparisons and additional considerations for direct-current incident energy calculations.

The term “nominal” was added before voltage in the Maximum Power Method, D.5.3. formula to clarify the voltage used.

Public Input No. 82-NFPA 70E-2024 [Section No. D.5.2]

D.5.2 Detailed Arcing Current and Energy Calculations Method.

A thorough theoretical review of dc arcing current and energy was published in the *IEEE Transactions on Industry Applications*. Readers are advised to refer to that paper *(see reference 1)* for those detailed calculations.

References:

1. “DC-Arc Models and Incident-Energy Calculations,” Ammerman, R.F., et al., *IEEE Transactions on Industry Applications*, Vol. 46, No. 5.

2. “Arc Flash Calculations for Exposures to DC Systems,” Doan, D.R., *IEEE Transactions on Industry Applications*, Vol. 46, No. 6.

3. “DC Arc Hazard Assessment Phase II,” Copyright Material, Kinectrics Inc., Report No. K-012623-RA-0002-R00.

4. "Modifying the DC Arc-Flash Max Power Formula to Give More Realistic Predictions of Maximum Arc-Flash Energy", proceedings of the IEEE IAS ESW, 2024.

5. IEEE 1584-2018, Guide for Performing Arc-Flash Hazard Calculations.

Additional Proposed Changes

File Name	Description	Approved
ESW2024-11.pdf	this is one of the files being added to the reference list that is also referenced in PIs 78 and 80 for section D.5.1	

Statement of Problem and Substantiation for Public Input

PIs 78 and 80 proposed changes to section D.5.1, supported by the references added here.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 78-NFPA 70E-2024 [Section No. D.5.1]	
Public Input No. 80-NFPA 70E-2024 [Section No. D.5.1]	

Submitter Information Verification

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Committee: EEW-AAA

Committee Statement

Resolution: There is no substantiation provided for the addition of new references. Section 5.2 addresses arc flash calculations for DC. Inclusion of IEEE 1584-2018 as a reference is not appropriate as the scope of IEEE 1584-2018 excludes calculations for DC.

MODIFYING THE DC ARC-FLASH MAX POWER FORUMULA TO GIVE MORE REALISTIC PREDICTIONS OF MAXIMUM ARC-FLASH ENERGY

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Paper No. ESW-11

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Abstract – The maximum power formula (proposed by Dan Doan in a 2007 IEEE paper) for calculating dc arc-flash incident energy has been in NFPA 70E since 2012; however, repeated testing by multiple companies over the years has shown that it overestimates arc-flash energy by a factor of at least 2-10, especially at lower voltages (such as nominal 48, 125, or 250 Vdc). This paper analyzes the actual measured arc-flash energy from over 100 different tests at various voltages, and proposes modifications to the arc sustaining time in the maximum power transfer theorem equation(s) found in Annex D.5 of NFPA 70E. In addition, more realistic estimates for dc arc-flash boundary multipliers are developed for cases where the arc is “in a box”, than what has been found in previous editions of NFPA 70E. These are based on observations of dc arc-flash tests, calculations of reflected energy from the rear of typical cabinets using the maximum power method, and previous studies of "arc-in-a-box” energy multipliers for ac arc-flash.

Index Terms — DC arc-flash, arc sustaining time, maximum power transfer formula, arc-flash boundary.

I. INTRODUCTION

For the first 80 years or so of the “electric age” almost all research into the hazards of electricity was on electric shock (and attendant electrocution at high enough levels to cause death). During all this time people were also beingh injured and killed from arc-flash/blast in addition to electric shock / electrocution. However, research into incident energy on the human body from electric arc-flash didn’t begin in earnest until approximately 1973, with the first method to calculate that danger from ac not introduced until 1982 [1]. NFPA 70E [2] did not reference any methods for calculating this ac arc-flash energy until 1995 and later editions, followed by even more on ac calculations in the 2002 initial edition of IEEE 1584 [3] (since updated in 2018).

OSHA rules for electrical safety [4] only indirectly refer to electric arc hazards (they refer to electric arcs, but not specifically to arc-flash/blast) since they were published in 1992 (before there were standards calculations methods referenced in NFPA 70E [2] and before IEEE 1584 [3] existed).

Work on dc arc-flash did not begin in earnest until 1991 [5], and the first calculations referenced in NFPA 70E [2] for dc arc-flash incident energy did not appear until the 2012 edition (following some additional dc arc-flash testing and analysis in the years 2007-2011 [6, 7]). More recent dc arc-flash testing done from 2017-2022 [8, 9, 10, 11, 12, 13, 14, 15] provided more useful data, and helped in the decision to raise the dc special PPE arc-flash protection threshold (when using the table [PPE Category] method as opposed to the calculation method) to 150 V in the 2024 edition of NFPA 70E [2] by proving that in almost all cases where maximum short-circuit current from the battery is less than 17,000 A and the voltage is below 150 Vdc, 1.2 cal/cm^2 incident energies or greater at 18 inches or further away cannot be produced.

II. EXISTING DC ARC-FLASH MODELS

A. Stokes/Oppenlander Method [5]

In 1991, Stokes and Oppenlander published [5] the first dc arc-flash incident energy formulas (empirically derived from many gapped electrode tests at varying voltages, currents, gap widths, and electrode orientations). This method requires an initial guess and iterative equation solving. The research involved both ac and dc up to 1,000 V, but the dc was limited to smaller arc currents (less than 1,000 A). If the arcing current is too low relative to the voltage, these equations cannot be solved (even iteratively).

B. Paukert Method [16]

In 1993, more formulas (empirically derived from 7 different studies) to calculate dc arc-flash incident energy were published [16] and presented by Paukert. This method is also an iterative method, requiring an initial guess, and then iterative equation solving is repeatedly done.

C. Lab Physics Model

Most of the dc arc-flash testing (as well as significant amounts of ac arc-flash testing) that has been done was done at a lab [7, 10, 12, 13, 14, 17] facility in Toronto Canada. Between 1995 and 2007 (prior to most dc arc-flash testing), this lab used physics principles (rather than empirically derived/”fit” formulas from observed results) to develop a complex predictive model for incident arc-flash energy using complex iterative processes. Prior to running tests, they use this model to predict results, and then compare them to the actual observed testing data. It has been shown in much of the more recent testing [6, 8, 9, 10, 11, 12, 13, 14] referenced in this document that their slightly old (by now) theoretical physics model typically overestimates incident energy by at least a factor of 2.

D. Doan / Maximum Power Transfer Theorem [18]

In 2007, Dan Doan published [18] the maximum power transfer theorem for dc (building on earlier ac work), which in its present form (this paper proposes a modification/ improvement of the method to make it more accurate at lower voltages) is the most conservative of the methods (i.e., it typically overestimates the actual incident energy from dc arc-flash more than the iterative methods). Calculations are done using a simple formula (or two – see NFPA 70E [2] Annex D.5 for the 2 equations that have been combined into equation 1):

$$IE = 0.01 \times V_{nom} \times \frac{I_{sc}}{2} \times \frac{t}{d^2} \quad (1)$$

where

IE	is the incident energy in cal/cm²
V_{nom}	is the nominal dc voltage
I_{sc}	is the maximum (bolted fault) short circuit current (battery manufacturers typically publish this, and manufacturers can often provide it for other types of dc equipment)
t	is the time before an upstream OCPD (e.g., fuse or breaker) operates, or the maximum time that the arc can sustain itself (NFPA 70E [2] notes that the calculation time should probably not exceed 2 seconds, and IEEE 1584 [3] supports this because the person will have likely reacted and moved away within that time if space allows)
d	is the typical distance of the vital organs of the body from the electrical equipment that could have the arc-flash event, and is noted in NFPA 70E [2] for most of the dc voltages that most users deal with as 18 inches (equivalent to 45.72 cm, which is usually the value used since the incident energy is in SI units of cal/cm²)

Note that this is the only formula(s) for dc arc-flash calculations given in NFPA 70E [2]. The only other methods indirectly referenced for dc arc-flash calculations in NFPA 70E [2] (Annex D.5) are the Stokes/Oppenlander [5] and Paukert [16] iterative methods.

While not the most accurate method for a wide array of nominal voltages (actual testing has shown it to be fairly accurate when nominal dc voltages are near 480 though), this maximum power method is commonly used.

One big problem with this maximum power method is its overestimation of the risk at lower voltages. More PPE than is needed can make a user less safe by making them less dexterous, too hot and sweaty, etc. A smaller issue with this method (and all the other methods mentioned in this section are probably limited in the same way based on the data and assumptions used in those models) is that it is limited to dc voltages below 1,000 The majority of dc systems in the world today are below this voltage, but there are more and more being installed above that voltage, such as with grid scale solar and wind generation, especially with attendant battery energy storage systems.

Like the lab physics model, the maximum power transfer method is theoretical, and has not proven to be as accurate as empirically-derived formulas from actual testing, such as those from the Stokes, Paukert, and Ammerman models/methods.

A subsequent section in this paper will cover a proposed method of making this maximum power calculation more accurate at lower voltages by empirically deriving a formula for the arc sustaining time since this less-accurate method for incident energy and arc flash boundary calculations is still fairly commonly used.

E. Ammerman Method [19]

In 2009, Ammerman and colleagues (including P.K. Sen) published [19] another iterative method for determining dc arc-flash energy. While not referenced in NFPA 70E [2] Annex D.5, it may still be used, with engineering judgement.

III. DC ARC SUSTAINING TIME

Those who calculate dc arc-flash incident energy manually using the Maximum Power [18] formulas found in NFPA 70E [2] have usually used dc arc sustaining times of 2 seconds (in some cases longer in an effort to be more conservative), at least on the portions of the analyzed circuit where a fuse or breaker will not limit the time to less than that. The 2 second maximum time comes from NFPA 70E [2] and IEEE 1584 [3], where the assumption was made that if the "space" made it possible, human reaction would cause the person to back away from the arc flash within 2 seconds. In the opinion of the author, based on video observations of arc-flash testing and actual real arc-flashes, if space allows it, in larger arc flash incidents, the arc blast is likely to knock the person down or back out of the area within the 2 seconds as well.

The iterative methods [5, 16, 19] are more accurate than the maximum power method for many reasons, with one of those reasons being that they usually compute a more realistic arc sustaining time.

For those still using the maximum power method and a default 2 second (or more) arc sustaining time, dozens of individual [6, 7, 8, 9, 10, 11, 12, 13, 14, 20] real world tests (see Figure 1) have shown that 2 seconds is far longer than the actual arc sustaining time for dc arcs below approximately 480 Vdc.

The different lengths of arc sustaining time shown in Figure 1 for each of the different nominal tested voltages (nominal 100, 125, 250, and 480) are due to different maximum short circuit currents of the dc equipment under test, different starting electrode lengths, and orientation of the electrodes.

Using a more accurate arc sustaining time to calculate more realistic incident energy for lower dc voltages is important due to the sheer number of dc systems (or dc busses in UPSs) that operate below that level. Common lower dc bus nominal voltage levels found in many installed systems include: 12, 24, 36, 48, 125 (120), 192, 216, 250 (240), 288, and 380 (336, 360, and 384). Note that the latest edition (2024) of NFPA 70E [2] does not require special arc-flash protective clothing (other than safety glasses) for dc arc-flashes below 150 Vdc if the table (aka PPE Category) method is used, based on numerous tests [11, 12, 13, 14] run mostly over the last 7 years. The previous 4 editions of NFPA 70E [2] did not require special clothing below 100 Vdc (if the table / PPE Category method was used). However, arc-flash calculations below 150 (or even 100) Vdc are sometimes still used/desired, especially if the total potential short circuit current is 17,000 A or more, as will be shown later on in test results reviewed in this paper.

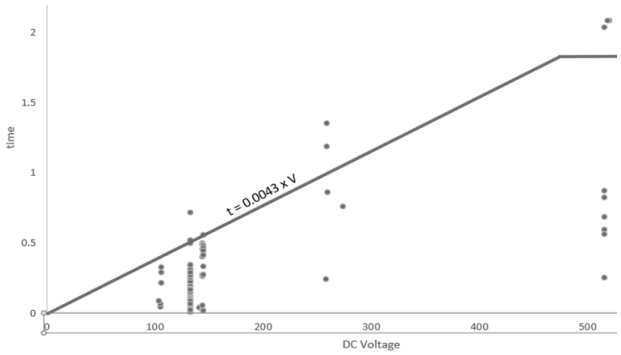


Fig. 1 Real World Testing DC Arc-Flash Sustaining Times along with Empirically-Derived Maximum Arc Time

One conclusion of all these tests is that existing maximum power transfer calculations for voltages below 480 Vdc have been severely overestimating maximum incident energy from dc arc-flashes at the standard 18 inch (45.72 mm) [2] vital body organ distance partially due to overestimation of the time that the arc can sustain itself. Curve fitting the results so that most of the points fit under the "curve"; and maximizing at 2 seconds of arc time [2, 3] yields the lines (along with a voltage-based formula) in Figure 1. The point at which the formula yields 2 seconds or longer arc sustaining times is nominal 465 Vdc, which is consistent with real world testing [6, 7, 8, 9, 10, 13].

None of the published testing data [6, 7, 8, 9, 10, 11, 12, 13, 14, 20] is at dc voltages lower than 100, partly because it has been known for at least a dozen years that dc arc-flashes below that voltage cannot produce incident energy above the 1.2 cal/cm^2 2nd-degree maximum burn threshold (as noted earlier in this section, that dc voltage has now been moved to 150 when using the table / PPE Category method) [2]. However, when testing has been done below that 100 Vdc level, although the arc sustaining time results have not been "published", the arc sustaining times observed were consistently below what is predicted by equation (2). For example, Fechalos and Blake, while presenting their 2023 Battcon paper [10] showed an example video of a 48 Vdc test, and the approximate duration of the arc-flash was about 100 milliseconds, which is about half of what equation (2) predicts for a maximum arc sustaining time at that nominal voltage.

$$t = 0.0043 \times V_{nom} \quad (2)$$

when

V_{nom} is ≤ 465 Vdc

$$t = 2 \quad (3)$$

when

V_{nom} is > 465 Vdc

Many actual test arc sustaining times fall below (see Figure 1) the values predicted by equations 2 and 3. This is mostly due to lack of an electrode separation distance variable in the equation(s). The author purposely did not include electrode separation, since in many dc systems, electrode separation can be highly variable, depending on the length of the object that initiates the arc. For example, in a cabinetized UPS monobloc battery system, there are a multitude of possibilities for distances between differing polarities (including ground), even at the same nominal voltage. Instead, the purpose of this work is to establish a reasonable upper bound on the maximum dc arc sustaining time based on the available data. This may overprotect in some cases, but at voltages below nominal 480 V where the maximum power method is presently being used with a 2 second (or more) arc sustaining time, this modification is going to greatly decrease the existing overcalculation of the risk. Perhaps future work can focus on additional variables in arc sustaining time (such as electrode separation and orientation)?

Finally, on the subject of dc arc sustaining time, in the experience of the author, many dc arc-flash calculations that have been done in existing industrial facilities (such as UPS battery cabinets in large data centers) neglect (usually due to the person running the calculations or inputting the circuit parameters into a computer program not accounting for OCPDs in parallel paths) the fact that any dc source fault current contribution flowing through a fuse or breaker towards an arc-flash/blast fault point will usually be time-limited by the I-t curve of the fuse/breaker(s) in the path. For example, for a worker in one battery cabinet of a UPS that has 4 parallel battery cabinets (with each cabinet having its own internal breaker at the top), the arc-flash incident energy from the cabinet where the work is being done will be time-limited only by the nominal voltage of the fault causing the arc-flash, as per equation (2) or (3). However, all parallel sources (the other 3 battery cabinets and the UPS dc charging source) that can contribute to the fault current will have to flow through one or two breakers. Assuming these breakers are sized and have any adjustable instantaneous trip settings correctly set, the high fault currents from these sources flowing towards the source should cause the breaker(s) to open on the instantaneous portion of their trip curve (typically within 16-60 milliseconds on average, depending on breaker model and manufacturer). This greatly limits the overall arc flash energy. In numerous calculations run by the author, the additional incident energy contributed by parallel sources flowing through properly sized and adjusted breakers (or through properly sized fuses) is usually no more than 7% of the total incident energy that has been negligently calculated (and posted on labels on cabinets or panels) without consideration of fuses or breakers in parallel paths.

IV. ARC-IN-A-BOX THEORY VS REALITY

When dc arc-flash calculations were introduced in Annex D of NFPA 70E [2] in 2012, guidance was given that arc-in-a-box (due to reflected energy off the sides, top, bottom, and rear of the box) could be 3 times or more the calculated arc-flash energy (because the models mentioned in Section II of this paper mostly assume spherical energy spread from the point of the arc, and do not normally take reflected energy into account). This assumption was based partly on testing in low voltage (600 V or lower at the time [21]) ac panelboards [3] that have very short depths (typically 4-6 inches {10-15 cm}), which causes fairly significant reflection of energy from the rear. It was also based on testing of medium voltage (1-36 kV) [21], and low voltage (≤ 600 V) [21] larger ac switchgear cabinets. This testing, and IEEE 1584 [3] guidance gives a multiplication factor of 1.6 for ac panelboards [22] (see Figure 2), regardless of distance from the arc-flash event. The multiplication factor varied [3, 22] for low voltage and medium voltage larger ac switchgear cabinets, from between 1.0 and 2.2 at the vital organ distance [2] of 18 inches (45.72 cm), up to a maximum

multiplying factor of 3.8-4.75 for these large switchgear cabinets at the typical maximum arc-flash boundary distance of 10 feet [2] (approximately 3 m).

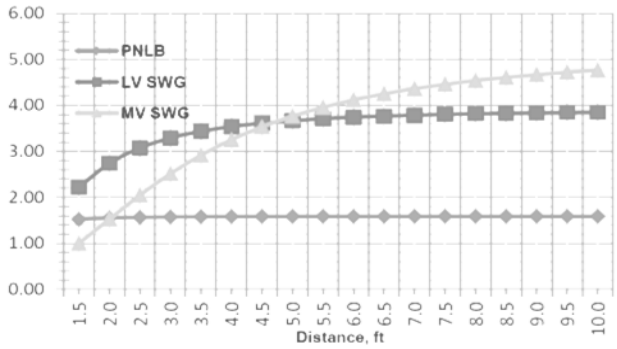


Fig. 2 AC arc-in-a-box Incident Energy Multiplication Factors vs. Distance [3, 22]

This guidance carried into the 2015 edition of NFPA 70E [2]. However, in the 2018 edition, the guidance had been changed from a multiplier of 3x for dc arc-in-a-box to "… it would be prudent to consider additional PPE protection beyond the values shown in Table 130.7(C)(15)(b)." This same "new" language is in the subsequent editions of NFPA 70E [2]. This change was made in the 2018 edition because actual testing up to that point [6, 7, 20], and testing since [8, 9, 10, 11, 12, 13, 14], had not shown nearly triple the difference between incident energies measured from dc arc-in-a-box vs open air, all other conditions (such as electrode spacing and orientation, maximum short circuit current, nominal voltage, etc.) being equal. In most cases the observed/measured incident energy at 18 inches (45.72 cm) [2] from dc arc-flash energy reflected from a "box" is more (although usually much less than triple) than it would be in open air, and in some cases it was less.

Because of a lack of dc arc-flash testing done/published for dc panelboards, there is no reason yet to use any factor for dc panelboards other than the 1.6 multiplication factor (see Figure 3) for ac panelboards [3, 22], since they tend to have similar dimensions to ac panelboards (being equipped with dc breakers or fuses rather than ac breakers or fuses).

The maximum power theorem formula(s) {see equation (1)} can also be used to determine the arc-flash boundary (the distance where the incident energy drops to the 2nd-degree burn threshold of 1.2 cal/cm^2 [2] or lower). See equation (4) for the algebraically modified formula and note that the incident energy value is now under a square root. This means that if the arc-flash energy from a panelboard is 1.6 times the value calculated by equation (1), the distance multiplier for determining the arc-flash boundary for dc panelboards should be the square root of 1.6 (√1.6 = 1.265).

$$d = \sqrt{\frac{0.01 \times V_{nom} \times \frac{I_{SC}}{2} \times t}{IE}} \quad (4)$$

Based on observations of dc arc-flash testing done with cabinets (such as UPS battery cabinets), there is some reflected energy, but nowhere near triple the energy at the critical body organ distance [2] of 18 inches (45.72 cm). In most cases, it should be much less than a 1.6 multiplier at that distance because of the depths of these cabinets compared to panelboards. Arc-flash energy decreases as it moves away from the source by the square of the distance [1, 2, 18]. In a sample calculation for a typical UPS battery cabinet 4 feet (1.2 m) wide by 33½ inches (0.85 m) deep by 7 feet (2.13 m) tall, most of the reflected (as opposed to the direct energy from the arc-flash) energy that will impinge on the body's vital organs, at approximately 18 [2] inches (45.72 cm) from the front of the battery, will be the direct reflection from the rear. That addition to incident energy for this cabinet, (based on the square of the distance) would be approximately $^1/_{30}^{th}$ (a multiplier of 1.03). There will be even less reflected additive energy from the top, bottom and sides of the cabinet due to their greater distances and oblique angles to the human body in front of the "box".

There have been more than 90 dc arc-flash tests [6, 7, 8, 9, 10, 11, 12, 13, 14, 20] yielding enough data to do comparisons like Figures 3 through 10. About 87% of those tests were arc-in-a-box tests (in medium/large cabinets), with the rest done in open air. Only two tests yielded actual measured arc-flash incident energy at 18 inches (45.72 cm) [2] that exceeded maximum power formula {equation (1)} calculations (without any arc-in-a-box multiplier), even when modified for lower arc-sustaining times per equation (2) at lower voltages. Those two cases [9] were on nominal 120 Vdc PV systems with maximum fault current (< 2,000 A) lower than typical for many dc applications, and the actual and calculated incident energies at 18 inches (45.72 cm) all fell below the 1.2 cal/cm^2 2nd-degree burn threshold, above which special PPE is required [2]. Also, for the limited comparisons (see Figure 3) that have been done [15] for actual dc arc-flash testing results vs iterative methods (Paukert [16] and Stokes [5] in this case), the actual incident energy measured (even in a "box") was less than or essentially equivalent to what was calculated by the iterative methods (except for one instance previously noted), without using an arc-flash multiplying factor.

IEEE 1584 [3] and other sources [22] note (see Figure 2) that the arc-in-a-box incident energy multiplier increases for switchgear cabinets at distances greater than 18 inches (45.72 cm). This is due to the decreasing ratio of reflected energy distance to body distance away from the cabinet; however, it does not affect incident energy calculations [2] at 18 inches (45.72 cm). For example, the multiplier in Figure 3 for MV switchgear cabinets at 18 inches (1.5 feet) is 1.0. It only becomes a "multiplier" at further distances (such as the arc-flash boundary distance in most cases). As such, the ac arc-in-a-box incident energy multiplier (2.2-3.8 at the high end per Figure 2) for low voltage ac switchgear at greater distances [3, 22] might be applied to the arc-flash boundary calculation for low voltage dc cabinets. Since most dc applications fall into the "low voltage" (which is now below nominal 1,500 Vdc [1,000 Vac] in the NEC® [21]) category, but most dc larger cabinets are more similar in size to a front-access medium voltage switchgear cabinet; the incident energy multiplier curves from Figure 2 can be averaged, and curve fit. Taking the square root of that curve yields the following formula for arc-flash boundary distance multipliers for larger dc cabinets:

$$m_{AB} = (0.55 \times \ln(d_{in})) - 0.6 \quad (5)$$

where

m_{AB} is the dc arc-flash boundary distance multiplier for large cabinets

d_{in} is the base arc-flash boundary distance (in inches) for arcs not in a box calculated from the maximum power formula

Based on this analysis, the author recommends either leaving existing language on dc arc-in-a-box multipliers in Annex D.5 of NFPA 70E [2] as is; or changing it to read something similar to the following: "For exposures where the arc is in a box or enclosure, it may be prudent to apply a multiplying factor up to 1.6 to the incident energy calculation for purposes of PPE for dc panelboards, and a corresponding distance multiplication factor up to 1.265 to the arc-flash boundary calculation. For larger dc enclosures, such as UPS battery cabinets, testing, calculations, and observation have shown that the reflected energy from the rear, sides, top, and bottom of these enclosures only adds very minimally to the incident energy at the vital body organ typical distance of 18 inches (45.72 cm) [2]. Thus, no multiplication factor for the calculation of incident energy is suggested. However, it may be prudent to apply a multiplier based on empirical equation (5) for calculation of the arc-flash boundary (with a maximum distance of 10 feet) for dc cabinets larger than a panelboard due to the relative contribution of reflected energy vs direct incident energy at greater distances for larger dc enclosures."

V. COMPARISON OF CALCULATIONS VS ACTUAL TEST RESULTS

Limited work has been done comparing tested incident energy at 18 inches (45.72 cm) [2] to the different dc arc-flash models. However, one paper [20] undertook calculations for 2 iterative methods (Paukert [16] and Stokes [5]), as well as the maximum power transfer theorem [18, 21], for 7 individual tests [9, 12, 13] from the many that have been reported. The results of this comparison, supplemented with the maximum power transfer theorem {equation (1)} modified for time by equations (2) and (3), are shown in Figure 3 (note that the clusters along the horizontal axes of each of Figures 3-10 represents an individual test).

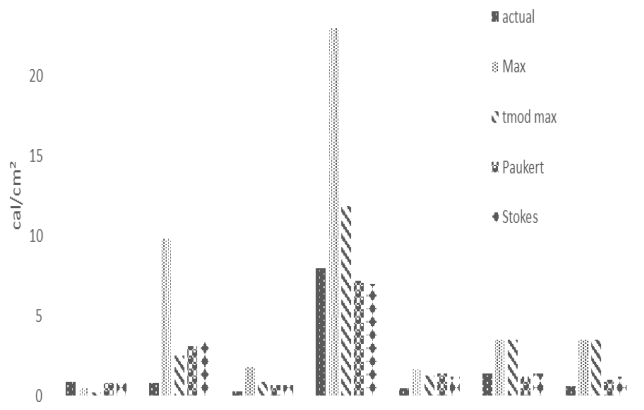


Fig. 3 Actual Incident Energy vs Existing and Proposed Methods

From this comparison of 7 incident energy measurements to 4 different calculation methods, it can be seen that at least 2 of the iterative methods [5, 16], as well as the maximum power formula(s) [2, 18] {see equation (1)} modified for maximum dc arc sustaining time by equations (2) and (3), provide a good upper bound for incident arc-flash energy at 18 inches (45.72 cm) [2] without requiring excessive PPE (which can actually make the user less safe by making them less dexterous and sweatier).

For the more than 90 individual tests [6, 7, 8, 9, 10, 11, 12, 13, 14, 20] for which enough useful data has been published for good comparison, the author ran calculations for dc arc-flash at 18 inches (45.72 cm) [2] with both the maximum power transfer theorem [2, 18], using equation (1) with a maximum time value of 2 seconds [2, 3], as well as with modified time values per equations (2) and (3). These 90+ test results can essentially be grouped into 4 nominal dc voltage "bins" of 100, 125, 250, and 480 Vdc.

Figure 4 compares a random sample (for readability) of 8 (of the more than 90) test's actual incident energies (measured at different nominal voltages, short circuit currents, electrode configurations, and electrode spacings), against the maximum power method calculated at 2 seconds and at the modified maximum arc sustaining time from equations (2) and (3):

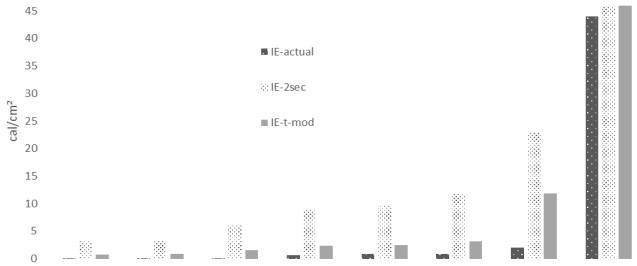


Fig. 4 Sample Comparison of Max Power Calculations (Modified for Time and Not) Against Actual Incident Energies

Figure 4 shows the large difference in accuracy (in most cases) of maximum power calculations when arc sustaining is modified for time (even when only based on voltage) versus calculations using a 2 second arc sustaining time.

Each of the nominal voltage "bins" (the bin for nominal 125 Vdc is further divided into various ranges of maximum short circuit current available in order to make the data more readable because there have been so many nominal 125 Vdc arc-flash tests run [7, 9, 11, 12, 13, 14, 20]) is represented by a different graph in Figures 5 through 10. In these graphs, for readability purposes, the generally highly overstated maximum power calculations at 2 seconds are not even shown (except at nominal 480 Vdc where the calculation {equation (3)] yields 2 seconds), since they would usually make the y-axis of the chart much taller.

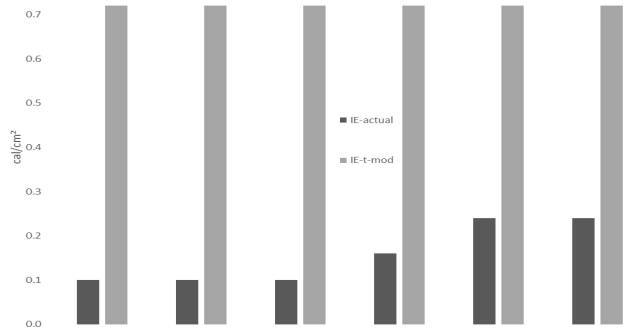


Fig. 5 Comparison of Measured Incident Energies for Nominal 100 Vdc Tests to Unmodified and Modified Maximum Power Theorem Formulas

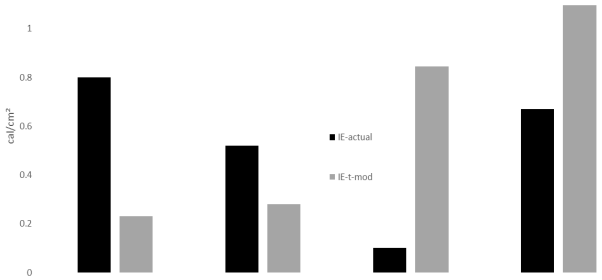


Fig. 6 Comparison of Measured Incident Energies for Nominal 125 Vdc Tests with Available Short Circuit Currents of Less than 7,500 A to Unmodified and Modified Maximum Power Theorem Formulas

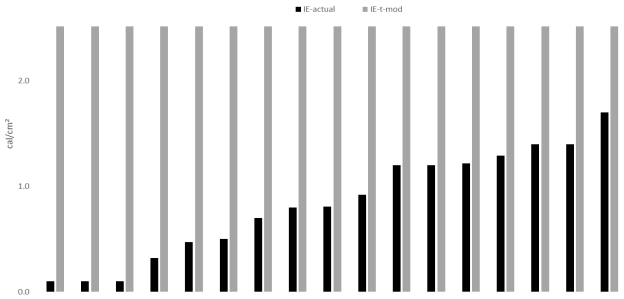


Fig. 7 Comparison of Measured Incident Energies for Nominal 125 Vdc Tests with Available Short Circuit Current of 17,000 A to Unmodified and Modified Maximum Power Theorem Formulas

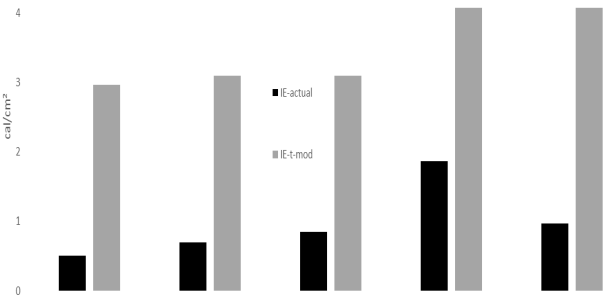


Fig. 8 Comparison of Measured Incident Energies for Nominal 125 Vdc Tests with Available Short Circuit Currents Greater than 17,000 A to Unmodified and Modified Maximum Power Theorem Formulas

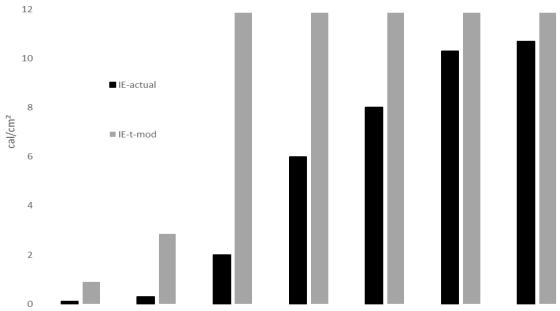


Fig. 9 Comparison of Measured Incident Energies for Nominal 250 Vdc Tests to Unmodified and Modified Maximum Power Theorem Formulas

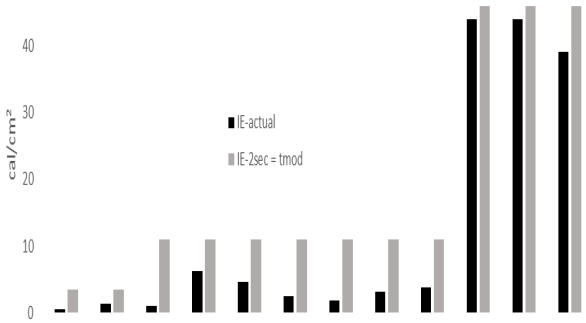


Fig. 10 Comparison of Measured Incident Energies for Nominal 480 Vdc Tests to Unmodified and Modified Maximum Power Theorem Formulas

With all of these figures, it can be seen that modifying the maximum power transfer theorem [2, 18] formula(s) {see Equation (1)} for time with the appropriate equation (2) or (3) yields acceptable upper bound results in almost all cases without requiring the excessive PPE at voltages below 465 Vdc that a maximum power transfer calculation using the NFPA 70E [2] / IEEE 1584 [3] typical maximum time of 2 seconds would produce. As was pointed out earlier in this paper, the existing maximum power transfer formula [18] {see equation (1)} in Annex D.5 of NFPA 70E [2], using the recommended 2 second maximum arc-flash exposure time [2, 3] is fairly accurate already around 480 Vdc nominal (see Figure 10).

There is some data published from tests done at other voltages (such as nominal 350, 600, and 1,000 Vdc) and also other testing done at the nominal voltages covered by these last Figures, but not enough to make a good graphing comparison. However, conclusions drawn from this limited data also support the conclusions of the preceding paragraph, and the overall conclusions in the succeeding section.

As noted, the latest NFPA 70E [2] raised the minimum dc voltage at which special arc-flash PPE is required to 150 when using the table (PPE Category) method, which lines up with the findings shown in Figures 5 and 6. While no special PPE is normally required, figures 7 and 8 show that it may sometimes be required in the rarer cases when available short circuit current is 17,000 A or more without overcurrent protection limiting the arcing time. Users may still run incident energy calculations for nominal dc voltages below 150, using an iterative method [5, 16, 19], the maximum power formula(s) [18] {the simplified equation (1) or the 2 equations shown in NFPA 70E Annex D.5 [18]} with a 2 second maximum arc exposure time [2, 3], or with the maximum power transfer formula(s) modified for time {see equation (2)}.

VI. CONCLUSIONS

the author supports continued use of the maximum power formula(s) for calculating dc arc-flash incident energies and arc-flash boundaries as an alternative method to the preferred iterative solutions, but proposes that it be supplemented with an empirically derived formula that estimates the typical maximum arc sustaining time based on nominal voltage. This additional formula causes the results to be more in line with measurements from real testing and more complex iterative dc arc-flash calculation models.

The author also proposes that present guidance in NFPA 70E [2] Annex D.5 on use of a multiplying factor for dc arc in a box incident energy remain the same; or be changed to use a multiplier of 1.6 [3, 22] for dc panelboards, but no multiplier for the arc-flash incident energy at 18" for larger cabinets (such as UPS battery cabinets) based on observations of actual testing [6, 7, 8, 9, 10, 11, 12, 13, 14, 20] and calculations. The distance multiplier for arc-flash boundary calculations for dc panelboards would be 1.265. The distance multiplier for large dc cabinets should be based on equation (5).

The author will be submitting these proposed NFPA 70E [2] changes as public inputs, either through a consensus body, such as the IEEE PES ESSB Codes Committee, or as an individual (himself).

VII. ACKNOWLEDGEMENTS

The author would like to thank Mike O'Brien for the initial idea of using testing data for maximum arc-flash sustaining time at lower voltages when using the Doan maximum power [18] formulas from Annex D.5 of NFPA 70E [2]. The author would also like to thank Lloyd Gordon for his previous research [23] into most of the dc arc-flash testing that has been done and the dc arc-flash calculations methods; as well as for his guidance and ideas on these subjects.

VIII. REFERENCES

[1] R. Lee, "The Other Electrical Hazard: Electric Arc Blast Burns", IEEE Transactions on Industry Applications, Vol. IA-18, No. 3, pp. 246-251, May/Jun 1982.

[2] NFPA® 70E, Standard for Electrical Safety in the Workplace,1995, 2012, 2015, 2018, and 2024 editions, Quincy, MA.

[3] IEEE 1584, Guide for Performing Arc-Flash Hazard Calculations, 2002 and 2018 editions, New York, NY, Institute of Electrical and Electronics Engineers.

[4] OSHA 29CFR1910, Part S – Electrical.

[5] A. Stokes and W. Oppenlander, "Electric Arcs in 1", Journal of Physical Discourses: Applied Physics, Vol. 24, 1991, pp. 26-35.

[6] Cheng, K., et al, "Arc Hazard Assessment for DC Applications in the Transit Industry", proceedings of the American Public Transport Association (APTA) Rail Conference, Boston, MA, 2011.

[7] C. Keyes and C. Maurice, "DC Arc Hazard Assessment Phase II", Kinectrics, Toronto, ON, Canada, Report K-012623-RA-0001-R00, 2007.

[8] Cheng, K., et al, "DC Arc-Flash Testing and Analysis at 600 V", proceedings of the IEEE IAS Electrical Safety Workshop (ESW), Reno, NV, 2020.

[9] Electric Power Research Institute (EPRI) Technical Report 3002014124, "DC Arc Flash on Photovoltaic (PV) Equipment", 2018.

[10] W. Fechalos and P. Blake, "DC Arc-Flash in Stationary Battery Systems", proceedings of Battcon 2023, paper No. 18.

[11] Gaunce, A., et al, "DC Arc-Flash: Testing and Modeling Incidents in a 125-V Substation Battery Backup System, IEEE Transactions on Industry Applications, Vol. 56, No. 3, pp. 2138-2147, May/Jun 2020.

[12] K. Gray and R. Hallé, "Sustainability of an Electric Arc-Flash at a Voltage of 240 VAC and 140 Vdc", proceedings of the IEEE IAS ESW, Reno, NV, 2023.

[13] Gray, K., et al, "Low Voltage 100-500 Vdc Arc-Flash Testing", proceedings of the IEEE IAS ESW, 2020.

[14] J. Hildreth and K. Feeney, "Arc-Flash Hazards of 125 Vdc Station Battery Systems", proceedings of the IEEE Power and Energy Society General Meeting (PES GM), paper No. 8586181, Portland, OR, 2018.

[15] Veeraraghavan, R. (ETAP), "DC Arc-Flash Analysis", presentation for Symposium #1 (DC Arc-Flash) at the 2017 winter meeting of the IEEE PES ESSB (Energy Storage and Stationary Battery committee, New Orleans, LA.

[16] J. Paukert, "The Arc Voltage and Arc Resistance of Low Voltage (LV) Fault Arcs", proceedings of the 7th International Symposium on Switching Arc Phenomena", pp. 49-51, 1993.

[17] K.S. Cheng and C. Keyes, "DC Arc-Flash Hazard Analysis Service for Pacific Northwest National Laboratory (PNNL)", Kinectrics, Toronto, ON, Canada, Report K-418079-RA-001-00, Oct 2011.

[18] D.R. Doan, "Arc-Flash Calculations for Exposures to DC Systems, proceedings of the IEEE IAS ESW, 2007.

[19] Ammerman, R., et al, "DC Arc Models and Incident Energy Calculations", proceedings of the Petroleum and Chemical Industry Conference (PCIC), 2009.

[20] Weimann, C.S., "Analytical and Experimental Validation for DC Arc-Flash Models", University of Pittsburgh Electrical Engineering Department Report ETD-07162020, 2018.

[21] NFPA® 70®, National Electrical Code® (NEC®), 2011, 2014, and 2023 editions, Quincy, MA: National Fire Protection Association.

[22] W. Fontaine and S. McCluer, "Arc in a Box: DC Arc-Flash Calculations Using a Simplified Approach", proceedings of Battcon 2014, paper No. 15.

[23] L.B. Gordon, "Modeling DC Arc Physics and Applications for DC Arc-Flash Risk Assessment", proceedings of the IEEE IAS ESW, Reno, NV, 2023.

IX. VITA

Curtis Ashton obtained a B.S.E.E degree from Arizona State University in 1992, while working for an electric utility, and then worked for 27 years for a large telecom and data center company as a power and grounding maintenance engineer. He has worked for the last 5 years for a dc services subsidiary (American Power Systems LLC) of East Penn Manufacturing (formerly Deka Batteries). Curtis is a past chair of the IEEE PES ESSB (Energy Storage and Stationary Battery) committee, and the primary author / working group chair of several of the battery standards produced by that technical committee. He is also a past vice-president of the IEEE Intelec Executive Committee (now IEEE PELS TC7); and a past vice-chair for ATIS-STEP; as well as being the primary author of several ANSI/ATIS power and grounding standards. Mr. Ashton is also an IEEE IAS member, and is on the NFPA 855 standard committee. He has been published many times, has presented in many locales across the globe, and has a patent to his name. Curtis is also a Master Electrician in Colorado and a Journeyman Electrician in New Mexico.

Public Input No. 215-NFPA 70E-2024 [Section No. D.5.3]

D.5.3 ~~—~~ **8** _ Short Circuit Current and Clearing Time .

The ~~determination of~~ short circuit current ~~is necessary in order to use~~ ~~Table 130.7(C)(15)(b)~~ ~~.~~ ~~The arcing current is calculated at 50 percent of the dc short-circuit value. The current that a battery will deliver depends on the total impedance of the short-circuit path. A conservative approach in determining the short-circuit current that the battery will deliver at 25°C is to assume that the maximum available short-circuit current is 10 times the 1-minute ampere rating (to 1.75 volts per cell at 25°C and the specific gravity of 1.215) of the battery. A more accurate value for the short-circuit current for the specific application can be obtained from the battery manufacturer.~~

~~References:~~

~~1. IEEE 946,~~ ~~*Recommended Practice for the Design of DC Auxiliary Powers Systems for Generating Stations*~~ ~~.~~

of the source (battery, EDLC, or PV) needs to be obtained from the manufacturer. The circuit clearing time needs to be determined by analysis of the Battery Management System, Solar Management System, and/or fusing. Clearing times from arc dynamics are still under study, but recent dc arc tests provide information to predict arc lifetime as a function of gap distance, voltage, and short circuit current.

Statement of Problem and Substantiation for Public Input

This section previously addressed only lead acid battery technologies. Today we need to incorporate all battery chemistries, EDLC characteristics and photovoltaic system behavior for dc sources. This effort is from the team Bobby Gray, Lloyd Gordon, David Rosewater, Bill Cantor and Curtis Ashton.

Submitter Information Verification

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City:
State:
Zip:

Submittal Date: Mon Jun 03 23:13:13 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-71-NFPA 70E-2024
Statement: The direct-current incident energy calculation models have been revised by including updated testing information, supporting references, dc to ac arc flash characteristic comparisons and additional considerations for direct-current incident energy calculations.

The term “nominal” was added before voltage in the Maximum Power Method, D.5.3. formula to clarify the voltage used.

Public Input No. 79-NFPA 70E-2024 [Section No. D.5.3]

D.5.3 Short Circuit Current.

The determination of short circuit current is necessary in order to use Table 130.7(C)(15)(b). The arcing current is calculated at 50 percent of the dc short-circuit value. The current that a battery will deliver depends on the total impedance of the short-circuit path. A conservative approach in determining the short-circuit current that the battery will deliver at 25°C is to assume that the maximum available short-circuit current is 10 times the 1 minute ampere rating (to 1.75 volts per cell at 25°C and the specific gravity of 1.215) of the battery. A more accurate value for the short-circuit current for the specific application can be obtained from the battery manufacturer.

References:

1. IEEE 946, *Recommended Practice for the Design of DC Auxiliary Powers Systems for ~~Generating Stations~~ Stationary Applications* .

Statement of Problem and Substantiation for Public Input

The latest edition of IEEE 946 was published in 2020, and its scope was greatly expanded to include DC systems in telecom and substations, in addition to generating stations. This did not change the guidance about calculating short circuit currents found in this document, but I feel it important to update the title so that people understand that it applies to a broader set of applicaitons.

Submitter Information Verification

Submitter Full Name: Curtis Ashton
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City:
State:
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Submittal Date: Mon Apr 15 16:16:50 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: Revising the informational note is not necessary as it has been removed as part of the Annex D.5 revisions.

Public Input No. 238-NFPA 70E-2024 [Section No. F.3]

F.3 Hierarchy of Risk Control.

The purpose of specifying and adhering to a hierarchy of risk control methods is to identify the most effective individual or combination of preventive or protective measures to reduce the risk associated with a hazard. Each risk control method is considered less effective than the one before it. Table F.3 lists the hierarchy of risk control identified in this and other safety standards and provides examples of each.

Table F.3 The Hierarchy of Risk Control Methods

Risk Control Method	Examples
(1) Elimination	~~Conductors and circuit parts in an electrically safe working condition~~ A change in process or workplace condition that removes the hazard or ensures that no worker can be exposed to a hazard under any foreseeable circumstances.
(2) Substitution	Reduce energy by replacing 120 V control circuitry with 24 Vac or Vdc control circuitry
(3) Engineering controls	Guard energized electrical conductors and circuit parts to reduce the likelihood of electrical contact or arcing faults
(4) Awareness	Signs alerting of the potential presence of hazards
(5) Administrative controls	Administrative controls change the way work is done by providing workers with relevant procedures or training, They're often used together with higher-level controls. They include: • Procedures- ~~and job planning tools~~ , such as equipment inspections, planned preventive maintenance, checklists, lockout/tagout/tryout, changing work schedules, pre- and post-task reviews, and rotation of workers • Training on topics such as hazard communication, permit-required work procedures, lockout/tagout/tryout, and safe work procedures
(6) PPE	Electric shock and arc flash PPE

Statement of Problem and Substantiation for Public Input

The existing text is not aligned with OSHA definition and examples of Elimination and Administrative Controls, specifically in how Lockout,Tagout, and Tryout (LOTOTO) is shown as an example of hazard elimination. The OSHA document 3885, "Recommendations for Safety and Health Programs" defines Elimination on page 19. The OSHA document "Identifying Hazard Control Options: The Hierarchy of Controls" on page 2 specifically states that lockout/tagout/tryout is an Administrative Control.

This proposal aligns Table F3 with definitions and examples provided by OSHA.

Submitter Information Verification

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State:
Zip:
Submittal Date: Tue Jun 04 12:12:51 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: The current wording is adequate and aligns with other requirements in the Standard such as 110.2(A)(1).

Public Input No. 74-NFPA 70E-2024 [Section No. F.3]

F.3 Hierarchy of Risk Control.

The purpose of specifying and adhering to a hierarchy of risk control methods is to identify the most effective individual or combination of preventive or protective measures to reduce the risk associated with a hazard. Each risk control method is considered less effective than the one before it. Table F.3 lists the hierarchy of risk control identified in this and other safety standards and provides examples of each.

Table F.3 The Hierarchy of Risk Control Methods

Risk Control Method	Examples
(1) Elimination	Conductors and circuit parts in an electrically safe working condition
(2) Substitution	Reduce ~~energy by~~ hazard by replacing 120 V control circuitry with 24 Vac or Vdc control circuitry
(3) Engineering controls	Guard energized electrical conductors and circuit parts to reduce the likelihood of electrical contact or arcing faults
(4) Awareness	Signs alerting of the potential presence of hazards
(5) Administrative controls	Procedures and job planning tools
(6) PPE	Electric shock and arc flash PPE

Statement of Problem and Substantiation for Public Input

Reducing "energy" is not the purpose of this change from a voltage about the shock threshold to a voltage below the shock threshold. It is reducing the hazard. So "hazard" is more appropriate.

Submitter Information Verification

Submitter Full Name: Karl Cunningham
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Zip:

Submittal Date: Wed Apr 03 05:48:00 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-72-NFPA 70E-2024
Statement: The word “energy” was replaced with “hazard” to more accurately reflect the concern.

Public Input No. 229-NFPA 70E-2024 [Section No. G.2.0]

2.0 Responsibility.

All employees shall be instructed in the safety significance of the lockout/tagout procedure. All new or transferred employees and all other persons whose work operations are or might be in the area shall be instructed in the purpose and use of this procedure. *[Name(s) of the person(s) or the job title(s) of the employee(s) with responsibility]* shall ensure that appropriate personnel receive instructions on their roles and responsibilities. All persons installing a lockout/tagout device shall physically or digitally sign their names and the date on the tag *[or state how the name of the individual or person in charge will be available]*.

Statement of Problem and Substantiation for Public Input

This clarifies that digital signatures are allowed.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 185-NFPA 70E-2024 [Section No. 120.4(C)]	
Public Input No. 187-NFPA 70E-2024 [Section No. 120.5(A)(5)]	

Submitter Information Verification

Submitter Full Name:	Brad Ruffkess
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Affiliation:	Rosendin (Tyler Westfall), McCarthy Renewables (John King), BoxLock, Inc.
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Tue Jun 04 09:28:45 EDT 2024
Committee:	EEW-AAA

Committee Statement

Resolution: The proposed text is not necessary at this time as there are no digital provisions in the body of the Standard. This aligns with other Technical Committee actions on digitally enabled lockout/tagout.

Public Input No. 230-NFPA 70E-2024 [Section No. G.9.4]

9.4

All complex lockout/tagout plans identify the method to account for all persons who might be exposed to electrical hazards in the course of the lockout/tagout.

One of the following methods is to be used:

(1) Each individual shall install his or her own personal lockout or tagout device.

(2) The person in charge shall lock his/her key in a lock box.

(3) A connected lockout or tagout device that implements the lockout tagout procedures

(4) The person in charge shall maintain a sign-in/sign-out log for all personnel entering the area.

(5) Another equally effective methodology shall be used.

Statement of Problem and Substantiation for Public Input

Introduces the option of a connected lockout tagout device that implements the appropriate procedures as a method for complex lockout tagout

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 185-NFPA 70E-2024 [Section No. 120.4(C)]	
Public Input No. 187-NFPA 70E-2024 [Section No. 120.5(A)(5)]	
Public Input No. 228-NFPA 70E-2024 [Section No. 120.5(B)(12)]	

Submitter Information Verification

Submitter Full Name:	Brad Ruffkess
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Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Tue Jun 04 09:31:10 EDT 2024
Committee:	EEW-AAA

Committee Statement

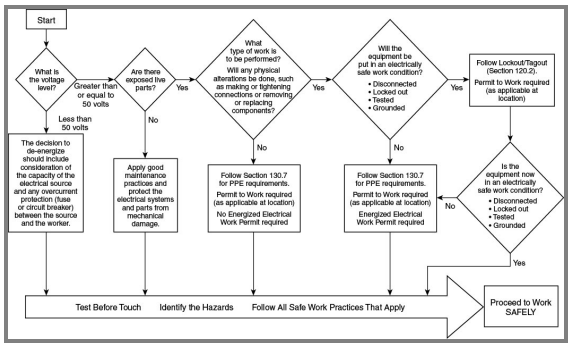
Resolution: The proposed text is not necessary at this time as there are no digital provisions in the body of the Standard. This aligns with other Technical Committee actions on digitally enabled lockout/tagout.

Public Input No. 70-NFPA 70E-2024 [Section No. J.2]

J.2 Energized Electrical Work Permit.

Figure J.2 illustrates items to consider when determining the need for an energized electrical work permit.

Figure J.2 Energized Electrical Work Permit Flow Chart.



Additional Proposed Changes

File Name	Description	Approved
annexJ.2.jpg	This is a revised version of the flow chart at annex J.	

Statement of Problem and Substantiation for Public Input

In the decision-tree/flow chart J.2, there are two destinations as possible outcomes to the question, "Do I need a permit?" if the system is over 50 volts. Both include references to 130.7 for PPE, which is good. Both also have essentially place-holders for employers to add their own answer to the same question. However, if a permit is required by 70e, then the employer should not be able to override this requirement.

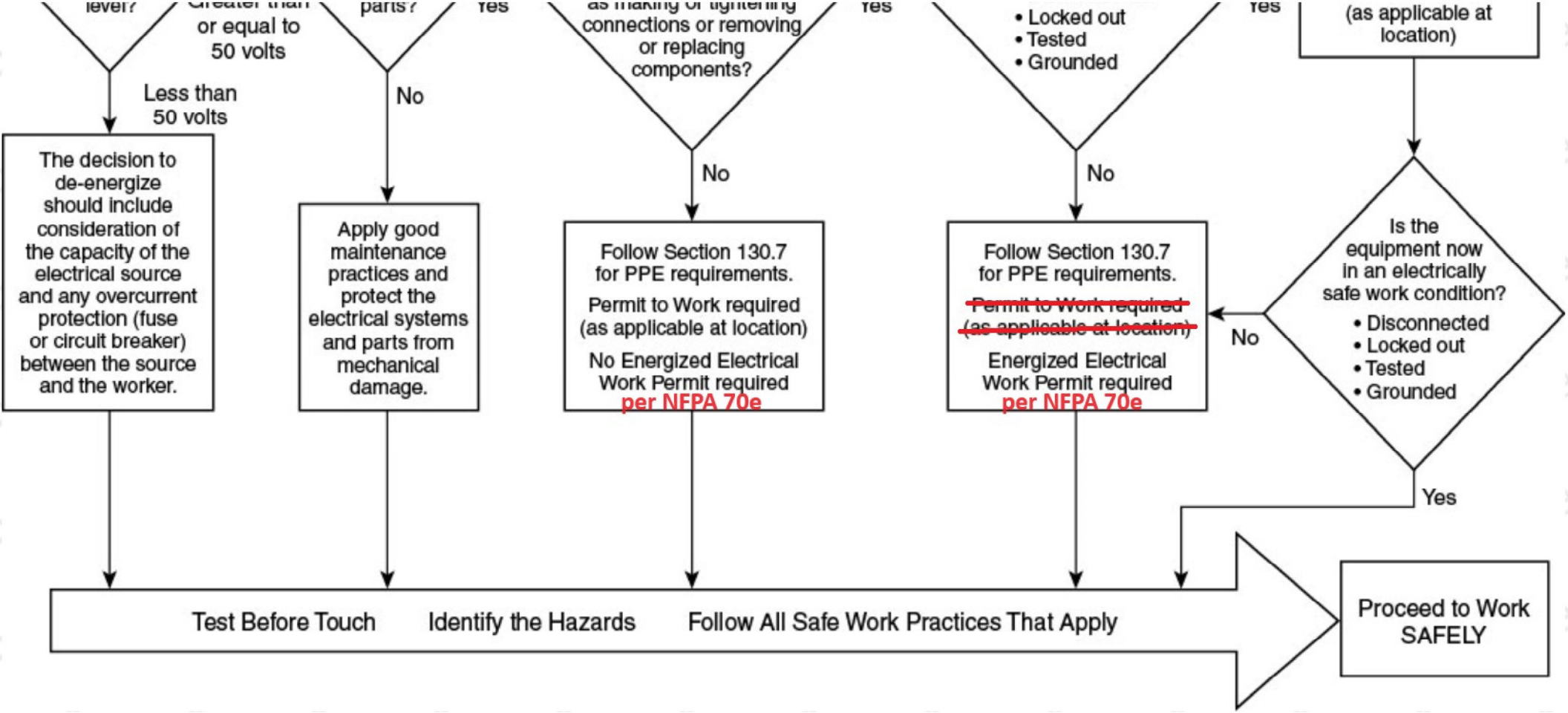
Submitter Information Verification

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Submittal Date: Wed Mar 20 16:42:17 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: This annex is informative only.

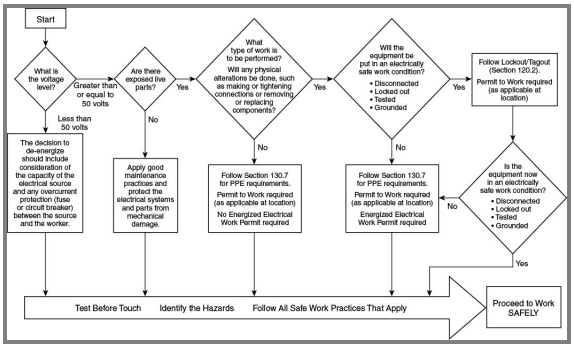

or equal to
50 volts
Less than
50 volts
No
connections or removing
or replacing
components?
No
• Locked out
• Tested
• Grounded
No
(as applicable at
location)
The decision to de-energize should include consideration of the capacity of the electrical source and any overcurrent protection (fuse or circuit breaker) between the source and the worker.
Apply good maintenance practices and protect the electrical systems and parts from mechanical damage.
Follow Section 130.7 for PPE requirements.
Permit to Work required (as applicable at location)
No Energized Electrical Work Permit required
per NFPA 70e
Follow Section 130.7 for PPE requirements.
Permit to Work required (as applicable at location)
Energized Electrical Work Permit required
per NFPA 70e
No
Is the equipment now in an electrically safe work condition?
• Disconnected
• Locked out
• Tested
• Grounded
Yes
Test Before Touch
Identify the Hazards
Follow All Safe Work Practices That Apply
Proceed to Work SAFELY

Public Input No. 93-NFPA 70E-2024 [Section No. J.2]

J.2 Energized Electrical Work Permit.

Figure J.2 illustrates items to consider when determining the need for an energized electrical work permit.

Figure J.2 Energized Electrical Work Permit Flow Chart.



Statement of Problem and Substantiation for Public Input

The second requirement in the flow chart asks are there any exposed live parts. This should also ask if there is an increased likelihood of an arc flash injury so that it aligns with the requirements of 130.2 (A) (2)

Submitter Information Verification

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City:
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Submittal Date: Fri May 24 10:28:20 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-73-NFPA 70E-2024
Statement: The flow chart was revised to correlate with 130.2(A) which requires consideration of possible injury from an arc flash.

Public Input No. 233-NFPA 70E-2024 [Annex K]

Informative Annex K General Categories of Electrical Hazards

This informative annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

K.1 General.

Electrical injuries represent a serious workplace health and safety issue to electrical and non-electrical workers. Data from the U.S. Bureau of Labor Statistics (BLS) indicate that there were nearly 6000 fatal electrical injuries to workers in the United States from 1992 through 2012. BLS data also indicate that there were 24,100 non-fatal electrical injuries from 2003 through 2012. From 1992 to 2013, the number of fatal workplace electrical injuries has fallen steadily and dramatically from 334 in 1992 to 139 in 2013. However, the trend with non-fatal electrical injuries is less consistent. Between 2003 and 2009, non-fatal injury totals ranged from 2390 in 2003 to 2620 in 2009, with a high of 2950 injuries in 2005. Non-fatal injury totals between 2010 through 2012 were the lowest over this 10-year period, with 1890 non-fatal injuries in 2010, 2250 in 2011, and 1700 in 2012.

~~There are two general categories of electric injury: electric shock and electrical burns. Electrical burns can be further subdivided into burns caused by radiant energy (arc burns), burns caused by exposure to ejected hot gases and materials (thermal burns), and burns caused by the conduction of electrical current through body parts (conduction burns). In addition, hearing damage can occur from acoustic energy, and traumatic injury can be caused by toxic gases and pressure waves associated with an arcing event.~~

About 98 percent of fatal occupational electric injuries are electric shock injuries. A corporate case study examining electrical injury reporting and safety practices found that 40 percent of electrical incidents involved 250 volts or less and were indicative of a misperception of electrical safety as a high-voltage issue. In addition, electrical incidents once again were found to involve a large share of non-electrical workers, with approximately one-half of incidents involving workers from outside electrical crafts. Research of electrical fatalities in construction found that the highest proportion of fatalities occurred in establishments with 10 or fewer employees and pointed out that smaller employers could have fewer formal training requirements and less structured training in safety practices.

There are two general categories of electrical hazards addressed extensively by the requirements of this standard: electric shock hazards and arc flash hazards. Each of these hazards are discussed separately in this Annex.

A third category of hazard is a thermal hazard related to the overheating of a conductor, circuit part or other conductive object caused by electric current. This type of hazard is referred to but not specifically addressed by the requirements of this standard.

K.2 Electric Shock.

Over 40 percent of all electrical fatalities in the U.S. involved overhead power line contact. This includes overhead power line fatalities from direct contact by a worker, contact through hand-carried objects, and contact through machines and vehicles. Comparing the ratio of total electrical fatalities to total electrical injuries (fatal and nonfatal), it was noticed that electrical injuries are more often fatal than many other injury categories. For example, from 2003 to 2009 there were 20,033 electrical injuries of which 1573 were fatalities. One worker died for every 12.74 electrical injuries. For the same period there were 1,718,219 fall injuries of which 5279 were fatalities — one worker died for every 325 injuries.

Of those, 1573 were electrical fatalities. A more detailed look at the demographics for 168 electrical fatalities in 2009 showed that 99 percent of deaths were the result of electrocution, and 70 percent occurred while the worker was performing a constructing, repairing, or cleaning activity.

Shock injuries can be divided into the thermal effect of electric current on the human body and the effect of electric current on the body's nervous system. The thermal effect can result in skin burns that might require skin grafting and, if deep enough into subcutaneous tissue, might require amputation of the affected body part. The immediate effect on the nervous system can include loss of voluntary muscle control, asphyxiation, ventricular fibrillation, and cardiac arrest.

The long-term effects of shock injuries, known as electric shock sequela are the topic of ongoing research (sequela: an after-effect of a disease, condition, or injury; plural: sequelae). These long-term effects can include psychological, neurological, and physical symptoms, which can occur and persist whether visible physical trauma occurred or not.

K.3 Arc Flash.

~~K.5~~

K.3.1 General

In the recently issued 29 CFR Subpart V, OSHA identified 99 injuries that involved burns from arcs from energized equipment faults or failures, resulting in 21 fatalities and 94 hospitalized injuries for the period January 1991 through December 1998.

Based on this data, OSHA estimated that an average of at least eight burn injuries from arcs occur each year involving employees doing work covered by OSHA rules, leading to 12 non-fatal injuries and two fatalities per year. Of the reports indicating the extent of the burn injury, 75 percent reported third-degree burns.

During the period involved, Federal OSHA only required non-fatal injuries to be reported when there were three or more workers hospitalized. OSHA found that there were six injuries for every fatality in California, which requires the reporting of every hospitalized injury.

Using that data, OSHA estimated that would be at least 36 injuries to every fatality, and probably many more. Also, many non-fatal electric shocks involve burns from associated electric arcs.

Starting January 1, 2015, Federal OSHA requires every hospitalized injury to be reported.

~~**K.4** Arc Blast.~~

~~The tremendous temperatures of the arc cause the explosive expansion of both the surrounding air and the metal in the arc path. For example, copper expands by a factor of 67,000 times when it turns from a solid to a vapor. The danger associated with this expansion is one of high pressures, sound, and shrapnel. The high pressures can easily exceed hundreds or even thousands of pounds per square foot, knocking workers off ladders, rupturing eardrums, and collapsing lungs. Finally, material and molten metal are expelled away from the arc at speeds exceeding 1120 km/hr (700 mph), fast enough for shrapnel to completely penetrate the human body.~~

Four types of energies are released by an arcing event, each with different effects on the human body.

K.3.2 Thermal energy

The thermal energy developed by an arcing event is conveyed radiantly (infrared energy), convectively (plasma and hot gases), and conductively (molten metal) from the arc to a worker. Depending on the thermal density of this energy, skin burns can result from direct exposure to the arc thermal energy, and from clothing ignition and burning, which can transfer additional thermal energy to the skin. Internal burns can occur in the upper respiratory system such as the mouth, throat, and nose due to inhalation of hot gases produced by the arc plasma and hot gas, and by burning clothing.

The ”arc flash” PPE requirements of this standard primarily address the thermal component of arc energy.

K.3.3 Mechanical energy (sudden pressure release)

At one time, it was proposed that the vaporization of copper or other metals by the arc produced life-threatening blast pressures. Recent research into arc blast phenomena does not support this theory. While it is true that copper expands several thousand times in volume when transitioning from metal to vapour, only a small amount of copper that is in or is immediately adjacent to the arc plasma stays in a vapour state. Beyond the plasma, the copper vapour drops below the vaporization temperature and condenses into molten copper or reacts chemically and becomes a copper compound.

Research has shown that what was considered to be “arc blast pressure” is primarily a function the instantaneous heating, expansion, and containment of the air surrounding the arc in an electrical equipment enclosure, which can cause the enclosure to fail. Enclosure failure can result in a sudden release of pressure and a mechanical transfer of energy caused by contact with ejected enclosure components.

Physical trauma can result from being struck by enclosure components. Most of the documented injuries have been from door ejections, broken parts of the equipment caused by the arcing event, and shattered insulators. Concussions and falls have also been recorded.

Research indicates that the pressures developed are substantially less than previously proposed, and that the pressure release is negligible for an open enclosure (i.e., if the enclosure door is open). Research has also shown that there is no correlation of pressure release to incident energy.

The release of mechanical energy should be considered in the risk assessment process. Protective measures could include operating equipment while standing to the side of the equipment or use of remote racking or other measures to prevent “line-of-fire” injuries.

The release of mechanical energy is normally prevented by arc-resistant equipment as such equipment contains and redirects any pressure away from the worker, provided the equipment is in the arc-resistant configuration.

Informational Note: See Hoagland et al. (2017 and 2019) for more information on the release of mechanical energy caused by an electric arc.

K.3.4 Acoustic (sound) energy

The instantaneous conversion of metals and gases to plasma can produce sound pressure levels in excess of 130 dB. According to the Centers for Disease Control and Prevention (CDC), an instantaneous sound pressure level of 120 dB or higher can cause immediate harm to hearing.

The acoustic energy component of arc energy is addressed to a limited extent by the requirement in this standard to use hearing protection when within the arc flash boundary.

Informational Note: See Gordon et al. “Modeling the Conversion of Electrical Energy to Acoustic Energy for Arcs and Applications for the Selection of PPE” for more information on the release of acoustic energy caused by an electric arc.

K.3.5 Light energy

The name of the phenomenon, “arc flash”, came from the intense light produced by an electric arc. The light emitted by an arc contains intense levels in the infrared (IR), visible (light), and ultraviolet (UV). These intense components impinging upon a worker and clothing are a significant portion of thermal injury discussed in K.3.2, for some cases up to 50 %. Documented test research indicates that the light intensity produced by an arcing event depends on a variety of factors such as voltage, current, arc length, and current risetime.

Tests also indicate that the relative luminosity (i.e., the brightness which is observed by someone in front of the arcing event) is affected by proximity to the arc, conductor configuration (vertical or horizontal), arc length, and whether the arc is in an enclosure, and if so, the enclosure dimensions.

The light energy component of arc energy is not currently specifically addressed by the requirements of this standard. However, AR PPE clothing protects from the light, especially the UV. AR rated face shields and suit hoods are also rated to block the arc UV.

Informational Note: See Lee et al. (2015) and Rau et al. (2017) for more information on the release of light energy caused by an electric arc.

K.4 Other Information.

For additional information, the following documents are available:

Occupational Injuries From Electrical Shock and Arc Flash Events Final Report, by Richard Campbell, and David Dini, Sponsored by The Fire Protection Research Foundation, Quincy, MA.

Occupational Electrical Injuries in the US, 2003–2009, by James Cawley and Brett C. Banner, ESFI.

Technical paper ESW 2012-24 presented at IEEE ESW conference, *Arc Flash Hazards, Incident Energy, PPE Ratings and Thermal Burn Injury — A Deeper Look*, by Tammy Gammon, Wei-Jen Lee, and Ben Johnson.

Technical Paper ESW 2015-17 presented at IEEE ESW conference, OSHA Subpart V, *Electric Power and Distribution*, April 11, 2014.

Hoagland, E. H., Maurice, C., Haines, A., and Maurice, A. 2017. Arc Flash Pressure Measurement by the Physical Method, Effect of Metal Vapor on Arc Blast, *IEEE Transactions on Industry Applications* , 53(2): 1576–1582.

Hoagland, E. H., Maurice, C., Haines, A., and Maurice, A. 2020. Arc Flash Pressure and Door Ejection Measurement, *IEEE Transactions on Industry Applications* , 56(4): 3297–3305.

Lee, W., Zhang, Z., Rau, S., Gammon, T., Johnson, B. C., and Beyreis, J. 2015. Arc Flash Light Intensity Measurement System Design, *IEEE Transactions on Industry Applications* , 51(5): 4267–4274.

Rau, S., Zhang, Z., Lee, W., and Dini, D. A. 2017. Arc Flash Visible Light Intensity as Viewed From Human Eyes, *IEEE Transactions on Industry Applications* , 53(5): 5068–5077.

Gordon, L, Bradley, J. “ Modeling the Conversion of Electrical Energy to Acoustic Energy for Arcs and Applications for the Selection of PPE” IEEE Paper No. ESW 2024-09 presented at the 2024 IEEE IAS Electrical Safety Workshop in Tucson, AZ .

Statement of Problem and Substantiation for Public Input

Given there has been much research into arc flash phenomenon much of the information in Annex K is out of date, incomplete, and in some cases inaccurate.
The new or revised information is consistent with the cited papers added to the Other Information section.
This public input has been prepared in collaboration with Dr. Lloyd Gordon.

Related Public Inputs for This Document

Related Input	Relationship

Public Input No. 232-NFPA 70E-2024 [Definition: Hazard, Electrical. (Electrical Hazard)]

Submitter Information Verification

Submitter Full Name: Daniel Roberts
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Affiliation: Self
Street Address:
City:
State:
Zip:

Submittal Date: Tue Jun 04 10:30:38 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-74-NFPA 70E-2024
Statement: Annex K was revised by updating the information regarding electrical injuries, updating the knowledge of electrical hazards and removing redundant information.

Public Input No. 99-NFPA 70E-2024 [Section No. K.1]

K.1 General.

~~Electrical injuries represent a serious workplace health and safety issue to electrical and non-electrical workers. Data from the U.S. Bureau of Labor Statistics (BLS) indicate that there were nearly 6000 fatal electrical injuries to workers~~

Contact with or exposure to electricity continues to be one of the leading causes of workplace fatalities and injuries in the United States

~~from 1992 through 2012. BLS data also indicate that there were 24,100 non-fatal electrical injuries from 2003 through 2012. From 1992 to 2013, the number of fatal workplace electrical injuries has fallen steadily and dramatically from 334 in 1992 to 139 in 2013. However, the trend with non-fatal electrical injuries is less consistent. Between 2003 and 2009, non-fatal injury totals ranged from 2390 in 2003 to 2620 in 2009, with a high of 2950 injuries in 2005. Non-fatal injury totals between 2010 through 2012 were the lowest over this 10-year period, with 1890 non-fatal injuries in 2010, 2250 in 2011, and 1700 in 2012.~~

. Between 2011 and 2022, there were a total of 1,322 workplace fatalities involving electricity. According to the Occupational Safety and Health Administration (OSHA), an average of 113 Americans died in the workplace between 2011 and 2020 due to contact with electricity. Of these fatalities, 30% were in occupations that can be considered electrical occupations with employees who have received training on electrical safety and the relevant codes and standards of working around electricity. 70% of the fatalities occurred in non-electrically related occupations. Working on or near energized equipment or parts was identified as the leading cause with 48% of the fatalities. Closely followed by contact with overhead power lines with 41%.

Electrical fatalities continue to stay consistent with an average 1.5% decrease in workplace electrical fatalities year over year. Electrical fatalities account for 6% of all workplace fatalities.

There are two general categories of electric injury: electric shock and electrical burns. Electrical burns can be further subdivided into burns caused by radiant energy (arc burns), burns caused by exposure to ejected hot gases and materials (thermal burns), and burns caused by the conduction of electrical current through body parts (conduction burns). In addition, hearing damage can occur from acoustic energy, and traumatic injury can be caused by toxic gases and pressure waves associated with an arcing event.

About 98 percent of fatal occupational electric injuries are electric shock injuries. A corporate case study examining electrical injury reporting and safety practices found that 40 percent of electrical incidents involved 250 volts or less and were indicative of a misperception of electrical safety as a high-voltage issue. In addition, electrical incidents once again were found to involve a large share of non-electrical workers, with approximately one-half of incidents involving workers from outside electrical crafts. Research of electrical fatalities in construction found that the highest proportion of fatalities occurred in establishments with 10 or fewer employees and pointed out that smaller employers could have fewer formal training requirements and less structured training in safety practices.

Statement of Problem and Substantiation for Public Input

The injury and fatality stats listed in Annex K.1 are old. Much of the data goes back to 2012. We have made significant progress reducing these injuries and fatalities and it would seem logical to list more timely data in this section in the 2027 edition.. There plenty of available data to support that although

we are on the right track there is still plenty of work to be done. The information that I have listed in my proposed change to K.1 was compiled with the help of Dan Daniel Majano of the Electrical Safety Foundation (ESFI). Much of this data was gleaned from his Technical paper ESW2022-12 presented during 2022 IEEE ESW conference in Jacksonville.

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Committee: EEW-AAA

Committee Statement

Resolution: FR-74-NFPA 70E-2024
Statement: Annex K was revised by updating the information regarding electrical injuries, updating the knowledge of electrical hazards and removing redundant information.

Public Input No. 69-NFPA 70E-2024 [Section No. K.2]

K.2 Electric Shock.

Over 40 percent of all electrical fatalities in the U.S. involved overhead power line contact. This includes overhead power line fatalities from direct contact by a worker, contact through hand-carried objects, and contact through machines and vehicles. Comparing the ratio of total electrical fatalities to total electrical injuries (fatal and nonfatal), it was noticed that electrical injuries are more often fatal than many other injury categories. For example, from 2003 to 2009 there were 20,033 electrical injuries of which 1573 were fatalities. One worker died for every 12.74 electrical injuries. For the same period there were 1,718,219 fall injuries of which 5279 were fatalities — one worker died for every 325 injuries.

~~Of those, 1573 were electrical fatalities.~~ A more detailed look at the demographics for 168 electrical fatalities in 2009 showed that 99 percent of deaths were the result of electrocution, and 70 percent occurred while the worker was performing a constructing, repairing, or cleaning activity.

Statement of Problem and Substantiation for Public Input

The statement being deleted is confusing and redundant. Beginning a paragraph with "Of those" makes a reader wonder which number mentioned previously is being referred to as "those." There are lots of data given in this annex and it is all very useful, but readers often get lost in all the numbers. Also, the number (1573) in the deleted statement is covered in the previous paragraph and as such is not needed.

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Committee Statement

Resolution: FR-74-NFPA 70E-2024
Statement: Annex K was revised by updating the information regarding electrical injuries, updating the knowledge of electrical hazards and removing redundant information.

Public Input No. 199-NFPA 70E-2024 [New Section after K.5]

TITLE OF NEW CONTENT

Technical paper ESW2022-12 presented at the IEEE ESW conference Who is Getting Hurt? Understanding the Cause of Fatal Electrical Injuries in the Workplace by Brett Brenner and Daniel Majano Electrical Safety Foundation International.

Statement of Problem and Substantiation for Public Input

The presentation listed is a great resource for more timely information concerning electrical injuries and fatalities.

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Committee: EEW-AAA

Committee Statement

Resolution: Referencing this paper does not contribute to the technical content in the annex.

Public Input No. 174-NFPA 70E-2024 [Sections L.1, L.2]

Sections L.1, L.2

L.1 Application of Safeguards.

This informative annex ~~permits a~~ provides typical application of safeguards in electrolytic areas where electrical hazards exist. Take, for example, an employee working on an energized cell. The employee uses manual contact to make adjustments and repairs. Consequently, the exposed energized cell and grounded metal floor could present an electrical hazard. Safeguards for this employee can be provided in the following ways:

(1) Protective boots can be worn that isolate the employee's feet from the floor and that provide a safeguard from the electrical hazard.

(2) Protective gloves can be worn that isolate the employee's hands from the energized cell and that provide a safeguard.

(3) If the work task causes severe deterioration, wear, or damage to personal protective equipment (PPE), the employee might have to wear both protective gloves and boots.

(4) A permanent or temporary insulating surface can be provided for the employee to stand on to provide a safeguard.

(5) The design of the installation can be modified to provide a conductive surface for the employee to stand on. If the conductive surface is bonded to the cell, a safeguard will be provided by voltage equalization.

(6) Safe work practices can provide safeguards. If protective boots are worn, the employee should not make long reaches over energized (or grounded) surfaces such that his or her elbow bypasses the safeguard. If such movements are required, protective sleeves, protective mats, or special tools should be used. Training on the nature of electrical hazards and proper use and condition of safeguards is, in itself, a safeguard.

(7) The energized cell can be temporarily bonded to ground.

L.2 ~~Electrical~~ 2 Non-Electrical Hazards for Consideration.

Electrolytic cells present other non-electrical hazards to the employee in which standard arc-rated clothing of materials may not be appropriate due to contamination and a potential chemical reaction. Additional protective safeguards or PPE may be necessary to ensure employee safety.

L.3 Electrical Power Receptacles.

Power supply circuits and receptacles in the cell line area for portable electric equipment should meet the requirements of 668.21 of *NFPA 70*, *National Electrical Code*. However, it is recommended that receptacles for portable electric equipment not be installed in electrolytic cell areas and that only pneumatic-powered portable tools and equipment be used.

Statement of Problem and Substantiation for Public Input

The first sentence of Annex L.1 uses the word permit, implying that the Annex material is essentially a permissive rule providing alternative methods for safeguarding other than those found in Article 310. This sentence appears to violate Section 2.1.11.1 of the NEC Style Manual, requiring Annex material to be nonmandatory, not forming part of the requirements of the document. Changing the text to "provides" accomplishes the same intent without implying permission/permissive rule.

Additionally, this PI adds a new section L.2 to this Annex to provide information related to the presence of non-electrical hazards in electrolytic cell lines. Electrolytic cells present other hazards to the

employee in which standard arc rated clothing or materials may not be appropriate due to contamination and a potential chemical reaction. This additional annex material provides additional guidance to employers to determine the appropriate PPE and/or safeguards necessary to provide protection from other non-electrical hazards present.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 172-NFPA 70E-2024 [Section No. 310.5(D)(2)]	
Public Input No. 173-NFPA 70E-2024 [Section No. 310.1]	
Public Input No. 172-NFPA 70E-2024 [Section No. 310.5(D)(2)]	
Public Input No. 173-NFPA 70E-2024 [Section No. 310.1]	

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Committee: EEW-AAA

Committee Statement

Resolution: FR-75-NFPA 70E-2024

Statement: The word “permits” was changed to “provides” as the annex material is providing a typical application of safeguards. Additional information was added to address non-electrical hazards of electrolytic cells.

Public Input No. 273-NFPA 70E-2024 [Annex N]

NOTE: This Public Input appeared as “Reject but Hold” in Public Comment No. 16 of the (A2023) Second Draft Report for NFPA 70E and per the Regs. At 4.4.8.3.1 and needs to be reconsidered by the TC for the next edition of the document.

Informative Annex N Example Industrial Procedures and Policies for Working Near Overhead Electrical Lines and Equipment

This informative annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

N.1 Introduction.

This informative annex is an example of an industrial procedure for working near overhead electrical systems. Areas covered include operations that could expose employees or equipment to contact with overhead electrical systems.

When working near electrical lines or equipment, avoid direct or indirect contact. Direct contact is contact with any part of the body. Indirect contact is when part of the body touches or is in dangerous proximity to any object in contact with energized electrical equipment. The following two assumptions should always be made:

(1) Lines are “live” (energized).

(2) Lines are operating at high voltage (over 1000 volts).

As the voltage increases, the minimum working clearances increase. Through arc-over, injuries or fatalities could occur, even if actual contact with high-voltage lines or equipment is not made. Potential for arc-over increases as the voltage increases.

N.2 Overhead Power Line Policy (OPP).

This informative annex applies to all overhead conductors, regardless of voltage, and requires the following:

(1) That employees not place themselves in close proximity to overhead power lines. “Close proximity” is within a distance of 3 m (10 ft) for systems up to 50 kV, and should be increased 100 mm (4 in.) for every 10 kV above 50 kV.

(2) That employees be informed of the hazards and precautions when working near overhead lines.

(3) That warning decals be posted on cranes and similar equipment regarding the minimum clearance of 3 m (10 ft).

(4) That a “spotter” be designated when equipment is working near overhead lines. This person’s responsibility is to observe safe working clearances around all overhead lines and to direct the operator accordingly.

(5) That warning cones be used as visible indicators of the 3 m (10 ft) safety zone when working near overhead power lines.

> Informational Note: “Working near,” for the purpose of this informative annex, is defined as working within a distance from any overhead power line that is less than the combined height or length of the lifting device plus the associated load length and the required minimum clearance distance [as stated in N.2(1)]. Required clearance is expressed as follows:
>
> Required clearance = lift equipment height or length + load length + at least 3 m (10 ft)

(6) That the local responsible person be notified at least 24 hours before any work begins to allow time to identify voltages and clearances or to place the line in an electrically safe work condition.

N.3 Policy.

All employees and contractors shall conform to the OPP. The first line of defense in preventing electrical contact accidents is to remain outside the limited approach boundary. Because most company and contractor employees are not qualified to determine the system voltage level, a qualified person shall be called to establish voltages and minimum clearances and take appropriate action to make the work zone safe.

N.4 Procedures.

N.4.1 General.

Prior to the start of all operations where potential contact with overhead electrical systems is possible, the person in charge shall identify overhead lines or equipment, reference their location with respect to prominent physical features, or physically mark the area directly in front of the overhead lines with safety cones, survey tape, or other means. Electrical line location shall be discussed at a pre-work safety meeting of all employees on the job (through a job briefing). All company employees and contractors shall attend this meeting and require their employees to conform to electrical safety standards. New or transferred employees shall be informed of electrical hazards and proper procedures during orientations.

On construction projects, the contractor shall identify and reference all potential electrical hazards and document such actions with the on-site employers. The location of overhead electrical lines and equipment shall be conspicuously marked by the person in charge. New employees shall be informed of electrical hazards and of proper precautions and procedures.

Where there is potential for contact with overhead electrical systems, local area management shall be called to decide whether to place the line in an electrically safe work condition or to otherwise protect the line against unintentional contact. Where there is a suspicion of lines with low clearance [height under 6 m (20 ft)], the local on-site electrical supervisor shall be notified to verify and take appropriate action.

All electrical contact incidents, including “near misses,” shall be reported to the local area health and safety specialist.

N.4.2 Look Up and Live Flags.

In order to prevent unintentional contact with all aerial lifts, cranes, boom trucks, service rigs, and similar equipment shall use look up and live flags. The flags are visual indicators that the equipment is currently being used or has been returned to its “stowed or cradled” position. The flags shall be yellow with black lettering and shall state in bold lettering “LOOK UP AND LIVE.”

The procedure for the use of the flag follows.

(1) When the boom or lift is in its stowed or cradled position, the flag shall be located on the load hook or boom end.

(2) Prior to operation of the boom or lift, the operator of the equipment shall assess the work area to determine the location of all overhead lines and communicate this information to all crews on site. Once completed, the operator shall remove the flag from the load hook or boom and transfer the flag to the steering wheel of the vehicle. Once the flag is placed on the steering wheel, the operator can begin to operate the equipment.

(3) After successfully completing the work activity and returning the equipment to its stowed or cradled position, the operator shall return the flag to the load hook.

(4) The operator of the equipment is responsible for the placement of the look up and live flag.

N.4.3 High Risk Tasks.

N.4.3.1 Heavy Mobile Equipment.

Prior to the start of each workday, a high-visibility marker (orange safety cones or other devices) shall be temporarily placed on the ground to mark the location of overhead wires. The supervisors shall discuss electrical safety with appropriate crew members at on-site tailgate safety talks. When working in the proximity of overhead lines, a spotter shall be positioned in a conspicuous location to direct movement and observe for contact with the overhead wires. The spotter, equipment operator, and all other employees working on the job location shall be alert for overhead wires and remain at least 3 m (10 ft) from the mobile equipment.

All mobile equipment shall display a warning decal regarding electrical contact. Independent truck drivers delivering materials to field locations shall be cautioned about overhead electrical lines before beginning work, and a properly trained on-site or contractor employee shall assist in the loading or off-loading operation. Trucks that have emptied their material shall not leave the work location until the boom, lift, or box is down and is safely secured.

N.4.3.2 Aerial Lifts, Cranes, and Boom Devices.

Where there is potential for near operation or contact with overhead lines or equipment, work shall not begin until a safety meeting is conducted and appropriate steps are taken to identify, mark, and warn against unintentional contact. The supervisor will review operations daily to ensure compliance.

Where the operator’s visibility is impaired, a spotter shall guide the operator. Hand signals shall be used and clearly understood between the operator and spotter. When visual contact is impaired, the spotter and operator shall be in radio contact. Aerial lifts, cranes, and boom devices shall have appropriate warning decals and shall use warning cones or similar devices to indicate the location of overhead lines and identify the 3 m (10 ft) minimum safe working boundary.

N.4.3.3 Tree Work.

Wires shall be treated as live and operating at high voltage until verified as otherwise by the local area on-site employer. The local maintenance organization or an approved electrical contractor shall remove branches touching wires before work begins. Limbs and branches shall not be dropped onto overhead wires. If limbs or branches fall across electrical wires, all work shall stop immediately and the local area maintenance organization is to be called. When climbing or working in trees, pruners shall try to position themselves so that the trunk or limbs are between their bodies and electrical wires. If possible, pruners shall not work with their backs toward electrical wires. An insulated bucket truck is the preferred method of pruning when climbing poses a greater threat of electrical contact. Personal protective equipment (PPE) shall be used while working on or near lines.

N.4.4 Underground Electrical Lines and Equipment.

Before excavation starts and where there exists reasonable possibility of contacting electrical or utility lines or equipment, the local area supervision (or USA DIG organization, when appropriate) shall be called and a request is to be made for identifying/marking the line location(s).

When USA DIG is called, their representatives will need the following:

(1) Minimum of two working days' notice prior to start of work, name of county, name of city, name and number of street or highway marker, and nearest intersection

(2) Type of work

(3) Date and time work is to begin

(4) Caller's name, contractor/department name and address

(5) Telephone number for contact

(6) Special instructions

Utilities that do not belong to USA DIG must be contacted separately. USA DIG might not have a complete list of utility owners. Utilities that are discovered shall be marked before work begins. Supervisors shall periodically refer their location to all workers, including new employees, subject to exposure.

N.4.5 Vehicles with Loads in Excess of 4.25 m (14 ft) in Height.

This policy requires that all vehicles with loads in excess of 4.25 m (14 ft) in height use specific procedures to maintain safe working clearances when in transit below overhead lines.

The specific procedures for moving loads in excess of 4.25 m (14 ft) in height or via routes with lower clearance heights are as follows:

(1) Prior to movement of any load in excess of 4.25 m (14 ft) in height, the local health and safety department, along with the local person in charge, shall be notified of the equipment move.

(2) An on-site electrician, electrical construction representative, or qualified electrical contractor should check the intended route to the next location before relocation.

(3) The new site is to be checked for overhead lines and clearances.

(4) Power lines and communication lines shall be noted, and extreme care used when traveling beneath the lines.

(5) The company moving the load or equipment will provide a driver responsible for measuring each load and ensuring each load is secured and transported in a safe manner.

(6) An on-site electrician, electrical construction representative, or qualified electrical contractor shall escort the first load to the new location, ensuring safe clearances, and a service company representative shall be responsible for subsequent loads to follow the same safe route.

If proper working clearances cannot be maintained, the job must be shut down until a safe route can be established or the necessary repairs or relocations have been completed to ensure that a safe working clearance has been achieved.

All work requiring movement of loads in excess of 4.25 m (14 ft) in height are required to begin only after a general work permit has been completed detailing all pertinent information about the move.

N.4.6 Emergency Response.

If an overhead line falls or is contacted, the following precautions should be taken:

(1) Keep everyone at least 3 m (10 ft) away.

(2) Use flagging to protect motorists, spectators, and other individuals from fallen or low wires.

(3) Call the local area electrical department or electric utility immediately.

(4) Place barriers around the area.

(5) Do not attempt to move the wire(s).

(6) Do not touch anything that is touching the wire(s).

(7) Be alert to water or other conductors present.

(8) Crews shall have emergency numbers readily available. These numbers shall include local area electrical department, utility, police/fire, and medical assistance.

(9) If an individual becomes energized, DO NOT TOUCH the individual or anything in contact with the person. Call for emergency medical assistance and call the local utility immediately. If the individual is no longer in contact with the energized conductors, CPR, rescue breathing, or first aid should be administered immediately, but only by a trained person. It is safe to touch the victim once contact is broken or the source is known to be de-energized.

(10) Wires that contact vehicles or equipment will cause arcing, smoke, and possibly fire. Occupants should remain in the cab and wait for the local area electrical department or utility. If it becomes necessary to exit the vehicle, leap with both feet as far away from the vehicle as possible, without touching the equipment. Jumping free of the vehicle is the last resort.

(11) If operating the equipment and an overhead wire is contacted, stop the equipment immediately and, if safe to do so, jump free and clear of the equipment. Maintain your balance, keep your feet together and either shuffle or bunny hop away from the vehicle another 3 m (10 ft) or more. Do not return to the vehicle or allow anyone else for any reason to return to the vehicle until the local utility has removed the power line from the vehicle and has confirmed that the vehicle is no longer in contact with the overhead lines.

Additional Proposed Changes

File Name	Description	Approved
70E_PC_16_Hold.pdf	70E_PC16	

Statement of Problem and Substantiation for Public Input

NOTE: This Public Input appeared as “Reject but Hold” in Public Comment No. 16 of the (A2023) Second Draft Report for NFPA 70E and per the Regs. At 4.4.8.3.1 and needs to be reconsidered by the TC for the next edition of the document.

Informational Annex N was first added to 70E during the 2009 edition and has essentially been unchanged since
then and is in need of an update. While overhead line work is outside of the scope of NFPA 70E, those employees who work near overhead lines and equipment are in great risks of injury and must be provided with a
practical method to establish some kind of safety procedure to help keep their workers safe from inadvertent
contact with or arc over from overhead lines. As an employee of the largest electric utility company in the State
of AZ, keeping other workers safe from inadvertent contact with our overhead lines and from digging into our
underground distribution lines is an ongoing challenge and unfortunately many people have been killed or
seriously injured. According to Electrical Safety Foundation International (ESFI) approximately 39% of

all
workplace electrical fatalities were caused by overhead power lines between 2011 and 2020.
https://www.esfi.org/overhead-powerline-safety/
Therefore I've submitted a substantially revised version of Annex N while using its original formatting which uses
many of the terms and definitions currently found and used in NFPA 70E or in one of the other Annexes such as
"limited approach boundary of exposed moveable conductors" from table 130.4(E), "pre-job briefing"and "job-site
review" from Annex Q, "Person in Charge" used throughout 70E and several others.
I've also included more instructions to coordinate with the local electric utility company whenever work is going
to be performed near overhead lines and increased the safety distance from 10 feet to 35 feet if a vehicle should
become energized. Since an energized vehicle not only poses touch potential hazards to workers but also step
potential hazards, a distance of 10 feet may not be adequate for extra high voltage (EHV) transmission lines
contact events. The 35 feet distance was derived from Electrical Safety Foundation International (ESFI). Also
ESFI uses the term "limited approach boundary" in their safety literature for overhead line safety practices
https://www.esfi.org/workplace-safety-overhead-power-line-contact/
https://www.esfi.org/workplace-safety-limits-of-approach-always-look-up/
https://www.esfi.org/downed-power-line-safety-always-assume-downed-lines-are-live/
The attached word document contains the details of the entire annex N to be revised. New text is shown in red
and strikeouts are used to indicate deletions of the original text.

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Committee:	EEW-AAA

Committee Statement

Resolution: The proposed text is outside the scope of NFPA 70E.

Public Input No. 156-NFPA 70E-2024 [Annex O]

Informative Annex O Employee Safety-Related Design ~~Concepts and Facility Owner Responsibilities~~ Concepts

This informative annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

O.1 Introduction.

This informative annex ~~addresses the responsibilities of the facility owner or manager or the employer having responsibility for facility ownership or operations management to perform a risk assessment during the design of electrical systems and installations.~~

~~**O.1.1**~~

~~This informative annex~~

covers employee safety-related design concepts for electrical equipment and installations in workplaces covered by the scope of this

~~standard.~~

Standard.

O.1.1

This informative annex discusses design considerations that have impact on the application of the safety-related work practices only.

O.1.2

This informative annex does not discuss specific design requirements. The facility owner or manager or the employer should choose design options that eliminate hazards or reduce risk and enhance the effectiveness of safety-related work practices.

O.2 General Design Considerations.

O.2.1

Employers, facility owners, and managers who have responsibility for facilities and installations having electrical energy as a potential hazard to employees and other personnel should ensure that electrical hazard risk assessments are performed during the design of electrical systems and installations.

O.2.2

Design option decisions should facilitate the ability to eliminate hazards or reduce risk by doing the following:

(1) Reducing the likelihood of exposure

(2) Reducing the magnitude or severity of exposure

(3) Enabling achievement of an electrically safe work condition

O.2.3 Incident Energy Reduction Methods.

The following methods have proved to be effective in reducing incident energy:

(1) Zone-selective interlocking. This is a method that allows two or more circuit breakers to communicate with each other so that a short circuit or ground fault will be cleared by the breaker closest to the fault with no intentional delay. Clearing the fault in the shortest time aids in reducing the incident energy.

(2) Differential relaying. The concept of this protection method is that current flowing into protected equipment must equal the current out of the equipment. If these two currents are not equal, a fault must exist within the equipment, and the relaying can be set to operate for a fast interruption. Differential relaying uses current transformers located on the line and load sides of the protected equipment and fast acting relay.

(3) Energy-reducing maintenance switching with a local status indicator. An energy-reducing maintenance switch allows a worker to set a circuit breaker trip unit to operate faster while the worker is working within an arc flash boundary, as defined in NFPA *70E*, and then to set the circuit breaker back to a normal setting after the work is complete.

(4) Energy-reducing active arc flash mitigation system. This system can reduce the arcing duration by creating a low impedance current path, located within a controlled compartment, to cause the arcing fault to transfer to the new current path, while the upstream breaker clears the circuit. The system works without compromising existing selective coordination in the electrical distribution system.

(5) Energy-reducing line side isolation. This is equipment that encloses the line side conductors and circuit parts and has been listed to provide both electric shock and arc flash protection from events on the line side of a circuit breaker or switch.

(6) Arc flash relay. An arc flash relay typically uses light sensors to detect the light produced by an arc flash event. Once a certain level of light is detected, the relay will issue a trip signal to an upstream overcurrent device.

(7) High-resistance grounding. A great majority of electrical faults are of the phase-to-ground type. High-resistance grounding will insert an impedance in the ground return path and will typically limit the fault current to 10 amperes and below (at 5 kV nominal or below), leaving insufficient fault energy and thereby helping reduce the arc flash hazard level. High-resistance grounding will not affect arc flash energy for line-to-line or line-to-line-to-line arcs.

(8) Current-limiting devices. Current-limiting protective devices reduce incident energy by clearing the fault faster and by reducing the current seen at the arc source. The energy reduction becomes effective for current above the current-limiting threshold of the current-limiting fuse or current limiting circuit breaker.

(9) Shunt-trip. Adding a shunt-trip that is signaled to open from an open-fuse relay to switches 800 amperes and greater reduces incident energy by opening the switch immediately when the first fuse opens. The reduced clearing time reduces incident energy. This is especially helpful for arcing currents that are not within the current-limiting threshold of the three current-limiting fuses.

O.2.4 Additional Safety-by-Design Methods.

The following methods have proven to be effective in reducing risk associated with an arc flash or electric shock hazard:

(1) Installing finger-safe components, covers, and insulating barriers reduces exposure to energized parts.

(2) Installing disconnects within sight of each motor or driven machine increases the likelihood that the equipment will be put into an electrically safe work condition before work has begun.

(3) Installing current limiting cable limiters can help reduce incident energy. Additionally, cable limiters can be used to provide short-circuit protection (and therefore incident energy reduction) for feeder tap conductors that are protected at up to 10 times their ampacity, a situation where the tap conductor can easily vaporize.

(4) Installing inspection windows for noncontact inspection reduces the need to open doors or remove covers.

(5) Installing a single service fused disconnect switch or circuit breaker provides protection for buses that would be unprotected if six disconnect switches are used.

(6) Installing metering to provide remote monitoring of voltage and current levels reduces exposure to electrical hazards by placing the worker farther away from the hazard.

(7) Installing Type 2 “no damage” current limiting protection to motor controllers reduces incident energy whenever the arcing current is within the current limiting threshold of the current-limiting fuse or current-limiting circuit breaker.

(8) Installing adjustable instantaneous trip protective devices and lowering the trip settings can reduce the incident energy.

(9) Installing arc-resistant equipment, designed to divert hot gases, plasma, and other products of an arc-flash out of the enclosure so that a worker is not exposed when standing in front of the equipment with all doors and covers closed and latched, reduces the risk of arc flash exposure.

(10) Installing provisions that provide remote racking of equipment, such as remote-controlled motorized remote racking of a circuit breaker or an MCC bucket, allows the worker to be located outside the arc-flash boundary. An extended length hand-operated racking tool also adds distance between the worker and the equipment, reducing the worker's exposure.

(11) Installing provisions that provide remote opening and closing of circuit breakers and switches could permit workers to operate the equipment from a safe distance, outside the arc flash boundary.

(12) Class C, D, and E special purpose ground fault circuit interrupters exist for circuits operating at voltages outside the range for Class A GFCI protection. See UL 943C for additional information.

(13) Installing high-impedance protected test points for voltage measurement through door.

Statement of Problem and Substantiation for Public Input

Over the past several revision cycles, Annex O has evolved into an excellent list of safety-related design concepts. This public input seeks to modify the title and introduction to emphasize the content of Annex O. To suggest that Annex O also includes "facility owner responsibilities" in its title and Introduction implies it also includes a set of requirements, not permitted in an informative annex.

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Zip:
Submittal Date: Mon Jun 03 12:06:48 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-76-NFPA 70E-2024
Statement: The modification to the introduction better reflects the content of Informative Annex O.

Public Input No. 175-NFPA 70E-2024 [Section No. R.4.3]

R.4.3 Arc Blast Hazard.

Capacitors can have a significant arc blast hazard due to the very high short-circuit current involved. The effects of the acoustic ~~electric~~ shock wave can rupture eardrums and collapse lungs. While hearing protection should be used above 100 joules to mitigate against hearing damage, there is no PPE for protection against lung collapse, which becomes a hazard above 122 kJ.

Statement of Problem and Substantiation for Public Input

Electric needs to be removed to accurately describe the effects. This appears to be an editorial error from the previous edition.

Submitter Information Verification

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Submittal Date: Mon Jun 03 14:35:21 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-78-NFPA 70E-2024
Statement: The word “electric” was removed as this section is concerned with acoustic shock waves.

Public Input No. 57-NFPA 70E-2024 [Section No. R.4.3]

R.4.3 Arc Blast Hazard.

Capacitors can have a significant arc blast hazard due to the very high short-circuit current involved. The effects of the acoustic ~~electric~~ shock wave can rupture eardrums and collapse lungs. While hearing protection should be used above 100 joules to mitigate against hearing damage, there is no PPE for protection against lung collapse, which becomes a hazard above 122 kJ.

Statement of Problem and Substantiation for Public Input

The word "electric" was added erroneously as part of a Global Change in the last revision cycle. Delete the word "electric"; it is not to have been added in front of the word "shock" in this instance. In this case, the "acoustic shock wave" is correct usage. The arc blast refers to a pressure wave in the air, not to electric shock.

Submitter Information Verification

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Submittal Date: Fri Feb 09 15:57:29 EST 2024
Committee: EEW-AAA

Committee Statement

Resolution: FR-78-NFPA 70E-2024
Statement: The word “electric” was removed as this section is concerned with acoustic shock waves.

Public Input No. 127-NFPA 70E-2024 [Annex S]

Informative Annex S Assessing the Condition of Maintenance

This informative annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

S.1 Introduction.

Electrical safety programs contain requirements to consider the condition of maintenance of electrical equipment and systems. The objective of these requirements is to emphasize the inherent risk to workers associated with performing tasks on electrical equipment that is not properly rated, not properly installed, has not been properly maintained, or otherwise exhibits evidence of an increased risk level for electrical workers or operators. Sections S.2 through S.8 describe methods of obtaining information that are useful when assessing the condition of maintenance of electrical equipment and systems.

S.2 Assess the Risk.

Safe work practices should always be used when gathering information to be used to assess the condition of maintenance of electrical equipment. Tasks such as opening hinged doors or removal of bolted covers might expose workers to energized conductors or circuit parts inside the equipment. Works should always follow the requirements of their electrical safety program when assessing the condition of electrical equipment.

S.3 Visual Inspection.

Visual inspection of equipment might be used to verify that it is installed in a professional and skillful manner in accordance with applicable industry codes and standards and the manufacturer's instructions. Visual inspections might also be used to identify evidence of issues or impending failure such as arcing, overheating, loose or bound mechanisms, missing hardware, visible damage, water or dust contamination, or corrosion damage.

S.4 Periodic Testing and Inspection.

Periodic testing and detailed inspection methods are used to help workers determine the condition of the equipment at the time of the test. Portable equipment is used to conduct manual tests and inspection such as infrared thermography, measure voltage and current, confirm overcurrent protective device operation, and conduct insulation resistance testing. Depending on the test or inspection, these tasks are performed with the equipment in an electrically safe work condition or with the equipment online.

S.5 Permanently Installed Monitoring.

Continuous monitoring of specific equipment conditions can be performed using an uninterrupted method of data collection. Examples include the use of permanently mounted counters, sensors, or controllers to measure a condition or state inside the equipment. Multiple types of data might be monitored, including voltage, current, temperature, humidity, cycle count, open/closed state, and others. The data could be used to actively alert personnel to the existence of a condition that is either above or below a predetermined control limit. Permanently installed monitoring systems often allow data collection without removing covers or opening doors and without exposing workers to electrical hazards. The use of real time data is useful when determining the condition of the equipment and is also used to modify (shorten or lengthen) the predetermined maintenance intervals for other inspections and tests.

S.6 Predictive Techniques.

Predictive techniques monitor conditions in equipment using sensors and analyze and interpret the data using analytical methods and algorithms. These proactive techniques identify trends or issues and notify personnel of recommended actions before the condition reaches an alarm point or alert them to urgent issues that are at or over a predetermined level. These technologies and methods often detect minor items before they propagate into major issues or equipment failure, enabling workers to interact with or operate the equipment while it is still in a normal operating condition as opposed to an abnormal condition.

S.7 Maintenance History.

The maintenance history of electrical equipment is an important factor to consider when assessing if the equipment has been properly maintained in accordance with the manufacturer's recommendations and applicable industry codes and standards. Ready access to maintenance history gives workers important information that is useful in making their assessment. There are various methods used to communicate the maintenance history, but the two most common are labels and digital methods.

S.7.1 Labels.

Labels, decals, or other markings might be color coded and placed on the exterior enclosure or surface of the electrical equipment or device to communicate the condition of maintenance as of the last assessment. Generally, these markings provide a simple method to categorize the condition of the equipment at the time of the inspection. One example is a three-level system, such as serviceable, limited service, or nonserviceable.

S.7.2 Digital and other Electronic Methods.

Digital technology is used as a method of storing and sharing maintenance-related information. This method stores information locally within the equipment itself, on its associated network, or remotely in a digital asset management system. In addition to recording the last inspection date, these methods are real time and can contain additional details. For example, digital logs record the date and time of the trip events of a circuit breaker and the reason for the trip.

S.8 Standard for Electrical Equipment Maintenance.

NFPA 70B is an example of a document that contains further information on the practical safeguarding of persons, property, and processes from the risks associated with failure, breakdown, or malfunction. NFPA 70B provides a means to establish and maintain an acceptable condition of maintenance of electrical equipment and systems to address safety and reliability.

Informative Annex U Hybrid SuperCapacitors (HSCs)

This informative annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

U.1 Introduction.

HSCs (formerly known as Li-ion capacitors of LiCs) are a cross between a Li-ion battery (the cathode is graphite intercalated with lithium ions, similar to the anodes of most Li-ion batteries) and a supercap (EDLC). In an EDLC, both the anode and cathode are made of activated carbon, but in an HSC/LiC only the anode is made of activated carbon. These devices combine the high momentary power capability of an EDLC (or regular electrolytic capacitor), but have longer duration discharge gravimetric and volumetric energy densities approaching (but not quite as good as) those of conventional batteries . Because only one of the "plates" is made of activated carbon, the individual cell voltages (both nominal and charging) exceed those possible in an EDLC, and approach those of some types of Li-ion cells.

U.2 Cell / Parallel Cell Pack Voltage Balancing Within a Module

Because these hybrid supercapacitors typically use a flammable non-aqueous electrolyte, balancing the voltage of individual cells (or "packs"of parallel cells) within a module is critical for safety. This is typically done by an electronics board mounted inside the pack, which also helps to ensure that the HSC is not overcharged or overdischarged, or charged outside of its operating temperature window (similar to the functions performed by a BMS in a Li-ion battery or a cell balancing board in an EDLC module/pack).

U.3 Higher Level BMS for Series Connections of Modules for Higher Voltage Applications

While the individual balancing circuit boards in modules handle cell/pack voltage balancing within each module, when multiple modules are placed in series to achieve higher voltages for some larger energy storage applications, a higher level BMS is typically used to balance voltages between modules and act as an aggregation and communication/control point for the individual module boards.

Statement of Problem and Substantiation for Public Input

This is an informative Annex intended to supplement the newly proposed Article 390. If PI 125 is not accepted, this new Annex U does not need to be included

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 125-NFPA 70E-2024 [New Article after 300]	new proposed Article on HSCs
Public Input No. 126-NFPA 70E-2024 [Article 100]	HSC/LiC definition
Public Input No. 125-NFPA 70E-2024 [New Article after 300]	

Submitter Information Verification

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Submittal Date: Sat Jun 01 22:55:18 EDT 2024
Committee: EEW-AAA

Committee Statement

Resolution: An annex on hybrid supercapacitor is not added to align with other actions taken that did not add a new supercapacitor article.

Public Input No. 32-NFPA 70E-2023 [Annex S]

Informative Annex S Assessing the Condition of Maintenance

This informative annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

S.1 Introduction.

Electrical safety programs contain requirements to consider the condition of maintenance of electrical equipment and systems. The objective of these requirements is to emphasize the inherent risk to workers associated with performing tasks on electrical equipment that is not properly rated, not properly installed, has not been properly maintained, or otherwise exhibits evidence of an increased risk level for electrical workers or operators. Sections S.2 through S.8 describe methods of obtaining information that are useful when assessing the condition of maintenance of electrical equipment and systems.

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Safe work practices should always be used when gathering information to be used to assess the condition of maintenance of electrical equipment. Tasks such as opening hinged doors or removal of bolted covers might expose workers to energized conductors or circuit parts inside the equipment. Works should always follow the requirements of their electrical safety program when assessing the condition of electrical equipment.

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S.4 Periodic Testing and Inspection.

Periodic testing and detailed inspection methods are used to help workers determine the condition of the equipment at the time of the test. Portable equipment is used to conduct manual tests and inspection such as infrared thermography, measure voltage and current, confirm overcurrent protective device operation, and conduct insulation resistance testing. Depending on the test or inspection, these tasks are performed with the equipment in an electrically safe work condition or with the equipment online.

S.5 Permanently Installed Monitoring.

Continuous monitoring of specific equipment conditions can be performed using an uninterrupted method of data collection. Examples include the use of permanently mounted counters, sensors, or controllers to measure a condition or state inside the equipment. Multiple types of data might be monitored, including voltage, current, temperature, humidity, cycle count, open/closed state, and others. The data could be used to actively alert personnel to the existence of a condition that is either above or below a predetermined control limit. Permanently installed monitoring systems often allow data collection without removing covers or opening doors and without exposing workers to electrical hazards. The use of real time data is useful when determining the condition of the equipment and is also used to modify (shorten or lengthen) the predetermined maintenance intervals for other inspections and tests.

~~**S.6** Predictive Techniques.~~

~~Predictive techniques monitor conditions in equipment using sensors and analyze and interpret the data using analytical methods and algorithms. These proactive techniques identify trends or issues and notify personnel of recommended actions before the condition reaches an alarm point or alert them to urgent issues that are at or over a predetermined level. These technologies and methods often detect minor items before they propagate into major issues or equipment failure, enabling workers to interact with or operate the equipment while it is still in a normal operating condition as opposed to an abnormal condition.~~

~~**S.7** Maintenance History.~~

~~The maintenance history of electrical equipment is an important factor to consider when assessing if the equipment has been properly maintained in accordance with the manufacturer's recommendations and applicable industry codes and standards. Ready access to maintenance history gives workers important information that is useful in making their assessment. There are various methods used to communicate the maintenance history, but the two most common are labels and digital methods.~~

~~**S.7.1** Labels.~~

~~Labels, decals, or other markings might be color coded and placed on the exterior enclosure or surface of the electrical equipment or device to communicate the condition of maintenance as of the last assessment. Generally, these markings provide a simple method to categorize the condition of the equipment at the time of the inspection. One example is a three-level system, such as serviceable, limited service, or nonserviceable.~~

~~**S.7.2** Digital and other Electronic Methods.~~

~~Digital technology is used as a method of storing and sharing maintenance-related information. This method stores information locally within the equipment itself, on its associated network, or remotely in a digital asset management system. In addition to recording the last inspection date, these methods are real time and can contain additional details. For example, digital logs record the date and time of the trip events of a circuit breaker and the reason for the trip.~~

~~**S.8** Standard for Electrical Equipment Maintenance.~~

~~NFPA 70B is an example of a document that contains further information on the practical safeguarding of persons, property, and processes from the risks associated with failure, breakdown, or malfunction. NFPA 70B provides a means to establish and maintain an acceptable condition of maintenance of electrical equipment and systems to address safety and reliability.~~

Statement of Problem and Substantiation for Public Input

This recommendation is to delete this informative annex. It is an extremely abbreviated version of NFPA 70B. The use of this incomplete information is inadequate and potentially dangerous if used.

Submitter Information Verification

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Submittal Date: Wed Nov 15 11:47:17 EST 2023
Committee: EEW-AAA

Committee Statement

Resolution: The informative annex is being retained as it describes items to consider with respect to the condition of maintenance. Section S.8 provides a reference to NFPA 70B.