NFPA 70E®

Standard for Electrical Safety in the Workplace®

2009 Edition

NFPA, 1 Batterymarch Park, Quincy, MA 02169-7471
An International Codes and Standards Organization

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NFPA 70E®

Standard for

Electrical Safety in the Workplace®

2009 Edition

This edition of *NFPA 70E*, *Standard for Electrical Safety in the Workplace*, was prepared by the Technical Committee on Electrical Safety in the Workplace and released by the Technical Correlating Committee on National Electrical Code®, and acted on by NFPA® at its June Association Technical Meeting held June 2–5, 2008, in Las Vegas, NV. It was issued by the Standards Council on July 24, 2008, with an effective date of September 5, 2008, and supersedes all previous editions.

This edition of *NFPA 70E* was approved as an American National Standard on September 5, 2008.

Foreword to *NFPA 70E*

The Standards Council of the National Fire Protection Association announced on January 7, 1976, the formal appointment of a new electrical standards development committee. Entitled the Committee on Electrical Safety Requirements for Employee Workplaces, *NFPA 70E*, this new committee reported to the Association through the Technical Correlating Committee on National Electrical Code®. This committee was formed to assist OSHA in preparing electrical safety standards that would serve OSHA's needs and that could be expeditiously promulgated through the provisions of Section 6(b) of the Occupational Safety and Health Act. OSHA found that in attempting to utilize the latest edition of *NFPA 70®*, *National Electrical Code® (NEC®)*, it was confronted with the following problem areas:

(1) Updating to a new edition of the *NEC* would have to be through the OSHA 6(b) procedures. OSHA adopted the 1968 and then the 1971 *NEC* under Section 6(a) procedures of the Occupational Safety and Health Act of 1970. Today, however, OSHA can only adopt or modify a standard by the procedures of Section 6(b) of the OSHA Act, which provide for public notice, opportunity for public comment, and public hearings. The adoption of a new edition of the *NEC* by these procedures would require extensive effort and application of resources by OSHA and others. Even so, going through the "6(b)" procedures might result in requirements substantially different from those of the *NEC*, thereby creating the problem of conflict between the OSHA standard and other national and local standards.

(2) The *NEC* is intended for use primarily by those who design, install, and inspect electrical installations. OSHA's electrical regulations address the employer and employee in their workplace. The technical content and complexity of the *NEC* is extremely difficult for the average employer and employee to understand.

(3) Some of the detailed provisions within the *NEC* are not directly related to employee safety and therefore are of little value for OSHA's needs.

(4) Requirements for electrical safety-related work practices and maintenance of the electrical system considered critical to safety are not found in the *NEC*, which is essentially an electrical installation document. However, OSHA must also consider and develop these safety areas in its regulations.

With these problem areas, it became apparent that a need existed for a new standard, tailored to fulfill OSHA's responsibilities, that would still be fully consistent with the *NEC*.

The foregoing issues led to the concept that a document be put together by a competent group, one representing all interests, that would extract suitable portions from the *NEC* and from other documents applicable to electrical safety. This concept and an offer of assistance was submitted in May 1975 to the Assistant Secretary of Labor for OSHA, who responded, "The concept, procedures, and scope of the effort discussed with my staff for preparing the subject standard appear to have great merit, and an apparent need exists for this proposed consensus document which OSHA could consider for promulgation under the provisions of Section 6(b) of the Act. OSHA does have an interest in this effort and believes the proposed standard would serve a useful purpose." With this positive encouragement from

OSHA, a proposal to prepare such a document was presented to the NFPA Electrical Section, which unanimously supported a recommendation that the *NEC* Correlating Committee examine the feasibility of developing a document to be used as a basis for evaluating electrical safety in the workplace. In keeping with the recommendation of the Electrical Section and Correlating Committee, the Standards Council authorized the establishment of a committee to carry out this examination.

The committee found it feasible to develop a standard for electrical installations that would be compatible with the OSHA requirements for safety for the employee in locations covered by the *NEC*. The new standard was visualized as consisting of four major parts: Part I, Installation Safety Requirements; Part II, Safety-Related Work Practices; Part III, Safety-Related Maintenance Requirements; and Part IV, Safety Requirements for Special Equipment. Although desirable, it was not considered essential for all of the parts to be completed before the standard was published and made available. Each part is recognized as being an important aspect of electrical safety in the workplace, but the parts are sufficiently independent of each other to permit their separate publication. The new standard was named *NFPA 70E*, *Standard for Electrical Safety Requirements for Employee Workplaces*. The first edition was published in 1979 and included only Part I.

The second edition was published in 1981. It included Part I as originally published and a new Part II. In 1983, the third edition included Part I and Part II as originally published and a new Part III. In 1988, the fourth edition was published with only minor revisions.

The fifth edition, published in 1995, included major revisions to Part I, updating it to conform to the 1993 edition of the *National Electrical Code (NEC)*. In Part II of the fifth edition, the concepts of "limits of approach" and establishment of an "Arc" were introduced. In 2000, the sixth edition included a complete Part I update to the 1999 *NEC*, as well as a new Part IV. Part II continued to focus on establishing Flash Protection Boundaries and the use of personal protective equipment. Also, added to Part II for 2000 were charts to assist the user in applying appropriate protective clothing and personal protective equipment for common tasks.

The seventh edition, published in 2004, reflected several significant changes to the document. The major changes emphasized safe work practices. Clarity and usability of the document were also enhanced. The name of the document was changed to *NFPA 70E*, *Standard for Electrical Safety in the Workplace*. The entire document was reformatted to comply with the *NEC Style Manual*, providing a unique designation for each requirement. The existing parts were renamed as chapters and were reorganized with the safety-related work practices relocated to the front of the document to highlight the emphasis, followed by safety-related maintenance requirements, safety requirements for special equipment, and safety-related installation requirements. The chapter on safety-related work practices also was reorganized to emphasize working on live parts as the last alternative work practice. An energized electrical work permit and related requirements were incorporated into the document. Several definitions were modified or added to enhance usability of the document, and Chapter 4 was updated to correlate with the 2002 *NEC*.

Essential to the proper use of Chapter 4 of this standard is the understanding that it is not intended to be applied as a design, installation, modification, or construction standard for an electrical installation or system. Its content was intentionally limited in comparison to the content of the *NEC* in order to apply to an electrical installation or system as part of an employee's workplace. This standard is compatible with corresponding provisions of the *NEC* but is not intended to, nor can it, be used in lieu of the *NEC*.

It can be debated that all of the requirements of the *NEC*, when traced through a chain of events, relate to an electrical hazard, but, for practical purposes, inclusion has not been made of those provisions that, in general, are not directly associated with employee safety. In determining what provisions should be included in Chapter 4, the following guidelines were used:

(1) Its provisions should give protection to the employee from electrical hazards.

(2) Its provisions should be excerpted from the *NEC* in a manner that maintains their intent as they apply to employee safety. In some cases it has been judged essential to the meaning of the excerpted passages to retain some material not applying to employee safety.

(3) The provisions should be selected in a manner that will reduce the need for frequent revision yet avoid technical obsolescence.

(4) Compliance with the provisions should be determined by means of an inspection during the normal state of employee occupancy without removal of parts requiring shutdown of the electrical installation or damaging the building structure or finish.

(5) The provisions should not be encumbered with unnecessary details.

(6) The provisions should be written to enhance their understanding by the employer and employee.

(7) The provisions must not add any requirements not found in the *NEC*, nor must the intent of the *NEC* be changed if the wording is changed.

Chapter 4 of *NFPA 70E* was therefore intended to serve a very specific need of OSHA and is in no way intended to be used as a substitute for the *NEC*. Omission of any requirements presently in the *NEC* does not in any way affect the *NEC*, nor should these omitted requirements be considered as unimportant. They are essential to the *NEC* and its intended application, that is, its use by those who design, install, and inspect electrical installations. *NFPA 70E*, on the other hand, is intended for use by employers, employees, and OSHA.

For 2009, over 1300 proposals and comments were reviewed by the committee upgrading requirements throughout the document. Among the most significant, Chapter 4 has been deleted because it was a duplicate of *National Electrical Code* installation requirements. Since the *NEC* and *NFPA 70E* are on different revision cycles there was always the risk that the contents of Chapter 4 of *NFPA 70E* were not up to date with the *NEC*. Article 350 was added for R&D facilities. Other changes include significant revisions to Annexes D, F, and J and the addition of Annexes M, N, and O.

This 2009 edition includes the following usability features as aids to the user. Changes other than editorial are highlighted with gray shading within sections and with vertical ruling for large blocks of changed or new text and for new tables and changed or new figures. Where one or more complete paragraphs have been deleted, the deletion is indicated by a bullet (•) between the paragraphs that remain. The index now has dictionary-style headers with helpful identifiers at the top of every index page.

A reference in brackets [ ] following a section or paragraph indicates material that has been extracted from another NFPA document. As an aid to the user, the complete title and edition of the source documents for extracts are given in Annex A. Extracted text may be edited for consistency and style and may include the revision of internal paragraph references and other references as appropriate. Requests for interpretations or revisions of extracted text shall be sent to the technical committee responsible for the source document.

Information on referenced publications can be found in Annex A and Annex B.

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Committee Scope: This Committee shall have primary responsibility for documents on minimizing the risk of electricity as a source of electric shock and as a potential ignition source of fires and explosions. It shall also be responsible for text to minimize the propagation of fire and explosions due to electrical installations.

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Committee Scope: This Committee shall have primary responsibility for documents on electrical safety requirements to provide a practical safe working area for employees in their pursuit of gainful employment relative to the hazards arising from the use of electricity, as covered in the scope of *NFPA 70, National Electrical Code*. This Committee shall have primary jurisdiction but shall report to the Association through the Technical Correlating Committee of the National Electrical Code.

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ARTICLE 90
Introduction

90.1 Purpose. The purpose of this standard is to provide a practical safe working area for employees relative to the hazards arising from the use of electricity.

90.2 Scope.

(A) Covered. This standard addresses electrical safety requirements for employee workplaces that are necessary for the practical safeguarding of employees during activities such as the installation, operation, maintenance, and demolition of electric conductors, electric equipment, signaling and communications conductors and equipment, and raceways for the following:

(1) Public and private premises, including buildings, structures, mobile homes, recreational vehicles, and floating buildings
(2) Yards, lots, parking lots, carnivals, and industrial substations
• (3) Installations of conductors and equipment that connect to the supply of electricity
(4) 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

(B) Not Covered. This standard does not cover 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 underground in mines and self-propelled mobile surface mining machinery and its attendant electrical trailing cable
(3) 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
(4) Installations of communications equipment under the exclusive control of communications utilities located outdoors or in building spaces used exclusively for such installations
(5) Installations under the exclusive control of an electric utility where such installations:
   a. Consist of service drops or service laterals, and associated metering, or
   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
   c. 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.

90.3 Standard Arrangement. This standard is divided into the introduction and three chapters, as shown in Figure 90.3. Chapter 1 applies generally for safety-related work practices; Chapter 3 supplements or modifies Chapter 1 with safety requirements for special equipment.

Chapter 2 applies to safety-related maintenance requirements for electrical equipment and installations in workplaces.

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

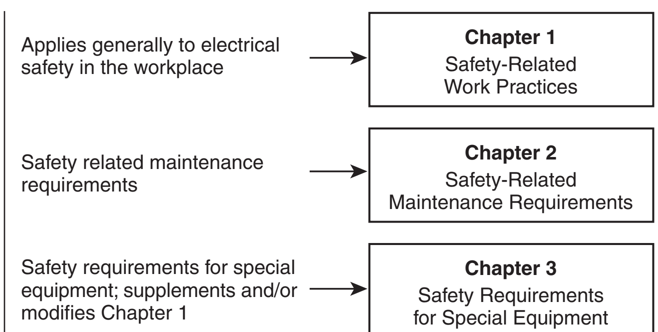

Figure 90.3 Standard Arrangement.

90.4 Organization. This standard is divided into the following three chapters and fifteen annexes:

(1) Chapter 1, Safety-Related Work Practices
(2) Chapter 2, Safety-Related Maintenance Requirements
(3) Chapter 3, Safety Requirements for Special Equipment
(4) Annex A, Referenced Publications
(5) Annex B, Informational References

(6) Annex C, Limits of Approach
(7) Annex D, Incident Energy and Flash Protection Boundary Calculation Methods
(8) Annex E, Electrical Safety Program
(9) Annex F, Hazard/Risk Evaluation Procedure
(10) Annex G, Sample Lockout/Tagout Procedure
(11) Annex H, Simplified, Two-Category, Flame-Resistant (FR) Clothing System
(12) Annex I, Job Briefing and Planning Checklist
(13) Annex J, Energized Electrical Work Permit
(14) Annex K, General Categories of Electrical Hazards
(15) Annex L, Typical Application of Safeguards in the Cell Line Working Zone
(16) Annex M, Layering of Protective Clothing and Total System Arc Rating
(17) Annex N, Example Industrial Procedures and Policies for Working Near Overhead Electrical Lines and Equipment
(18) Annex O, Safety-Related Design Requirements

90.5 Mandatory Rules, Permissive Rules, and Explanatory Material.

(A) Mandatory Rules. Mandatory rules of this standard are those that identify actions that are specifically required or prohibited and are characterized by the use of the terms *shall* or *shall not*.

(B) Permissive Rules. Permissive rules of this standard are those that identify actions that are allowed but not required, are normally used to describe options or alternative methods, and are characterized by the use of the terms *shall be permitted* or *shall not be required.*

(C) Explanatory Material. Explanatory material, such as references to other standards, references to related sections of this standard, or information related to a Code rule, is included in this standard in the form of fine print notes (FPNs). Fine print notes are informational only and are not enforceable as requirements of this standard.

Brackets containing section references to another NFPA document are for informational purposes only and are provided as a guide to indicate the source of the extracted text. These bracketed references immediately follow the extracted text.

FPN: The format and language used in this standard follow guidelines established by NFPA and published in the *NEC Style Manual*. Copies of this manual can be obtained from NFPA.

90.6 Formal Interpretations. To promote uniformity of interpretation and application of the provisions of this standard, formal interpretation procedures have been established and are found in the NFPA Regulations Governing Committee Projects.

Chapter 1 Safety-Related Work Practices

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. In general, only those terms that are used in two or more articles are defined in Article 100. Other definitions are included in the article in which they are used but may be referenced in Article 100. The definitions in this article shall apply wherever the terms are used throughout this standard.

• **Accessible (as applied to equipment).** Admitting close approach; not guarded by locked doors, elevation, or other effective means. [**70,** 2008]

Accessible (as applied to wiring methods). Capable of being removed or exposed without damaging the building structure or finish or not permanently closed in by the structure or finish of the building. [**70,** 2008]

Accessible, Readily (Readily Accessible). Capable of being reached quickly for operation, renewal, or inspections without requiring those to whom ready access is requisite to climb over or remove obstacles or to resort to portable ladders, and so forth. [**70,** 2008]

Ampacity. The current, in amperes, that a conductor can carry continuously under the conditions of use without exceeding its temperature rating. [**70,** 2008]

Appliance. Utilization equipment, generally other than industrial, that is normally built in standardized sizes or types and is installed or connected as a unit to perform one or more functions such as clothes washing, air conditioning, food mixing, deep frying, and so forth. [**70,** 2008]

Approved. Acceptable to the authority having jurisdiction.

Arc Flash Hazard. A dangerous condition associated with the possible release of energy caused by an electric arc.

FPN No. 1: An arc flash hazard may exist 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. Under normal operating conditions, enclosed energized equipment that has been properly installed and maintained is not likely to pose an arc flash hazard.

FPN No. 2: See Table 130.7(C)(9) for examples of activities that could pose an arc flash hazard.

FPN No. 3: See 130.3 for arc flash hazard analysis information.

Arc Flash Hazard Analysis. A study investigating a worker's potential exposure to arc-flash energy, conducted for the purpose of injury prevention and the determination of safe work practices, arc flash protection boundary, and the appropriate levels of PPE.

Arc Flash Suit. A complete FR clothing and equipment system that covers the entire body, except for the hands and feet. This includes pants, jacket, and 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) derived from the determined value of ATPV or E_{BT}.

FPN: *Breakopen* is a material response evidenced by the formation of one or more holes in the innermost layer of flame-resistant material that would allow flame 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,** 2008]

Authority Having Jurisdiction (AHJ). An organization, office, or individual responsible for enforcing the requirements of a code or standard, or approving equipment, materials, an installation, or a procedure.

FPN: 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.

Automatic. Self-acting, operating by its own mechanism when actuated by some impersonal influence, as, for example, a change in current, pressure, temperature, or mechanical configuration. [**70,** 2008]

Balaclava (Sock Hood). An arc-rated FR hood that protects the neck and head except for facial area of the eyes and nose.

Bare-Hand Work. A technique of performing work on energized electrical conductors or circuit parts, after the employee has been raised to the potential of the conductor or circuit part.

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

Barrier. A physical obstruction that is intended to prevent contact with equipment or energized electrical conductors and circuit parts or to prevent unauthorized access to a work area.

• **Bonded (Bonding).** Connected to establish electrical continuity and conductivity. [**70,** 2008]

Bonding Jumper. A reliable conductor to ensure the required electrical conductivity between metal parts required to be electrically connected. [**70,** 2008]

Boundary, Arc Flash Protection. When an arc flash hazard exists, an approach limit at a distance from a prospective arc source within which a person could receive a second degree burn if an electrical arc flash were to occur.

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

Boundary, Prohibited Approach. An approach limit at a distance from an exposed energized electrical conductor or circuit part within which work is considered the same as making contact with the electrical conductor or circuit part.

Boundary, Restricted Approach. An approach limit at a distance from an exposed energized electrical conductor or circuit part within which there is an increased risk of shock, due to electrical arc over combined with inadvertent movement, for personnel working in close proximity to the energized electrical conductor or circuit part.

Branch Circuit. The circuit conductors between the final overcurrent device protecting the circuit and the outlet(s). [**70,** 2008]

Branch-Circuit Overcurrent Device. A device capable of providing protection for service, feeder, and branch circuits and equipment over the full range of overcurrents between its rated current and its interrupting rating. Branch-circuit overcurrent protective devices are provided with interrupting ratings appropriate for the intended use but no less than 5,000 amperes. [**70,** 2008]

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,** 2008]

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,** 2008]

• **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,** 2008]

FPN: The automatic opening means can be integral, direct acting with the circuit breaker, or remote from the circuit breaker. [**70,** 2008]

• **Conductive.** Suitable for carrying electric current.

Conductor, Bare. A conductor having no covering or electrical insulation whatsoever. [**70,** 2008]

Conductor, Covered. A conductor encased within material of composition or thickness that is not recognized by this standard as electrical insulation. [**70,** 2008]

Conductor, Insulated. A conductor encased within material of composition and thickness that is recognized by this standard as electrical insulation. [**70,** 2008]

• **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,** 2008]

• **Coordination (Selective).** Localization of an overcurrent condition to restrict outages to the circuit or equipment affected, accomplished by the choice of overcurrent protective devices and their ratings or settings. [**70,** 2008]

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.

Cutout Box. An enclosure designed for surface mounting that has swinging doors or covers secured directly to and telescoping with the walls of the box proper. [**70,** 2008]

• **Deenergized.** 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 that carries or controls electric energy as its principal function. [**70,** 2008]

• **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,** 2008]

Disconnecting (or Isolating) Switch (Disconnector, Isolator). A mechanical switching device used for isolating a circuit or equipment from a source of power.

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

FPN: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.

Electrical Safety. Recognizing hazards associated with the use of electrical energy and taking precautions so that hazards do not cause injury or death.

• **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 to ensure the absence of voltage, and grounded if determined necessary.

Enclosed. Surrounded by a case, housing, fence, or wall(s) that prevents persons from accidentally contacting energized electrical conductors or circuit parts. [**70,** 2008]

Enclosure. The case or housing of apparatus, or the fence or walls surrounding an installation to prevent personnel from accidentally contacting energized electrical conductors or circuit parts or to protect the equipment from physical damage. [**70,** 2008]

Energized. Electrically connected to, or is, a source of voltage. [**70,** 2008]

Equipment. A general term, including material, fittings, devices, appliances, luminaires, apparatus, machinery, and the like used as a part of, or in connection with, an electrical installation. [**70,** 2008]

Explosionproof Apparatus. Apparatus enclosed in a case that is capable of withstanding an explosion of a specified gas or vapor that may occur within it and of preventing the ignition of a specified gas or vapor surrounding the enclosure by sparks, flashes, or explosion of the gas or vapor within, and that operates at such an external temperature that a surrounding flammable atmosphere will not be ignited thereby. [**70,** 2008]

FPN: For further information, see ANSI/UL 1203-2006, *Explosion-Proof and Dust-Ignition-Proof Electrical Equipment for Use in Hazardous (Classified) Locations.*

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,** 2008]

• **Externally Operable.** Capable of being operated without exposing the operator to contact with energized electrical conductors or circuit parts.

Feeder. All circuit conductors between the service equipment, the source of a separately derived system, or other power supply source and the final branch-circuit overcurrent device. [**70,** 2008]

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,** 2008]

Flame-Resistant (FR). The property of a material whereby combustion is prevented, terminated, or inhibited following the application of a flaming or non-flaming source of ignition, with or without subsequent removal of the ignition source.

FPN: Flame resistance can be an inherent property of a material, or it can be imparted by a specific treatment applied to the material.

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

FPN: 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,** 2008]

Grounded (Grounding). Connected (connecting) to ground or to a conductive body that extends the ground connection. [**70,** 2008]

Grounded, Solidly. Connected to ground without inserting any resistor or impedance device. [**70,** 2008]

Grounded Conductor. A system or circuit conductor that is intentionally grounded. [**70,** 2008]

• **Ground Fault.** An unintentional, electrically conducting connection between an ungrounded conductor of an electrical circuit and the normally non–current-carrying conductors, metallic enclosures, metallic raceways, metallic equipment, or earth.

Ground-Fault Circuit-Interrupter (GFCI). A device intended for the protection of personnel that functions to deenergize 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,** 2008]

FPN: Class A ground-fault circuit-interrupters trip when the current to ground is 6 mA or higher and do not trip when the current to ground is less than 4 mA. For further information, see UL 943, *Standard for Ground-Fault Circuit Interrupters*.

Grounding Conductor. A conductor used to connect equipment or the grounded circuit of a wiring system to a grounding electrode or electrodes. [**70,** 2008]

Grounding Conductor, Equipment (EGC). The conductive path installed to connect normally non–current-carrying metal parts of equipment together and to the system grounded conductor or to the grounding electrode conductor, or both. [**70,** 2008]

FPN No. 1: It is recognized that the equipment grounding conductor also performs bonding.

FPN No. 2: See *NFPA 70*, Section 250.118 for a list of acceptable equipment grounding conductors.

Grounding Electrode. A conducting object through which a direct connection to earth is established. [**70,** 2008]

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,** 2008]

• **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,** 2008]

• **Incident Energy.** The amount of energy impressed on a surface, a certain distance from the source, generated during an electrical arc event. One of the units used to measure incident energy is calories per centimeter squared (cal/cm^2).

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

FPN: 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 intended to interrupt under standard test conditions. [**70,** 2008]

FPN: 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,** 2008]

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.

• **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 services meets appropriate designated standards or has been tested and found suitable for a specified purpose.

FPN: The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. Use of the system employed by the listing organization allows the authority having jurisdiction to identify a listed product.

Live Parts. Energized conductive components. [**70,** 2008]

• **Luminaire.** A complete lighting unit consisting of a lamp or lamps, together with the parts designed to distribute the light, to position and protect the lamps and ballast (where applicable), and to connect the lamps to the power supply. It may also include parts to protect the light source or the ballast or to distribute the light. A lampholder is not a luminaire. [**70,** 2008]

• **Motor Control Center.** An assembly of one or more enclosed sections having a common power bus and principally containing motor control units. [**70,** 2008]

Neutral Conductor. The conductor connected to the neutral point of a system that is intended to carry current under normal conditions. [**70,** 2008]

Neutral Point. The common point on a wye-connection in a polyphase system or midpoint on a single-phase, 3-wire system, or midpoint of a single-phase portion of a 3-phase delta system, or a midpoint of a 3-wire, direct-current system. [**70,** 2008]

FPN: At the neutral point of the system, the vectorial sum of the nominal voltages from all other phases within the system that utilize the neutral, with respect to the neutral point, is zero potential.

• **Open Wiring on Insulators.** An exposed wiring method using cleats, knobs, tubes, and flexible tubing for the protection and support of single insulated conductors run in or on buildings.

Outlet. A point on the wiring system at which current is taken to supply utilization equipment. [**70,** 2008]

• **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,** 2008]

FPN: 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,** 2008]

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,** 2008]

• **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,** 2008]

• **Qualified Person.** One who has skills and knowledge related to the construction and operation of the electrical equipment and installations and has received safety training to recognize and avoid the hazards involved. [**70,** 2008]

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. Raceways include, but are not limited to, rigid metal conduit, rigid nonmetallic conduit, intermediate metal conduit, liquidtight flexible conduit, flexible metallic tubing, flexible metal conduit, electrical metallic tubing, electrical nonmetallic tubing, underfloor raceways, cellular concrete floor raceways, cellular metal floor raceways, surface raceways, wireways, and busways. [**70,** 2008]

Receptacle. A receptacle is a contact device installed at the outlet for the connection of an attachment plug. 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,** 2008]

• **Separately Derived System.** A premises wiring system whose power is derived from a source of electric energy or equipment other than a service. Such systems have no direct electrical connection, including a solidly connected grounded circuit conductor, to supply conductors originating in another system. [**70,** 2008]

Service. The conductors and equipment for delivering electric energy from the serving utility to the wiring system of the premises served. [**70,** 2008]

• **Service Conductors.** The conductors from the service point to the service disconnecting means. [**70,** 2008]

Service Drop. The overhead service conductors from the last pole or other aerial support to and including the splices, if any, connecting to the service-entrance conductors at the building or other structure. [**70,** 2008]

• **Service-Entrance Conductors, Overhead System.** The service conductors between the terminals of the service equipment and a point usually outside the building, clear of building walls, where joined by tap or splice to the service drop. [**70,** 2008]

Service-Entrance Conductors, Underground System. The service conductors between the terminals of the service equipment and the point of connection to the service lateral. [**70,** 2008]

FPN: Where service equipment is located outside the building walls, there may be no service-entrance conductors, or they may be entirely outside the building.

Service Equipment. The necessary equipment, usually consisting of a circuit breaker(s) or switch(es) and fuse(s), and their accessories, connected to the load end of service conductors to a building or other structure, or an otherwise designated area, and intended to constitute the main control and cutoff of the supply. [**70,** 2008]

Service Lateral. The underground service conductors between the street main, including any risers at a pole or other structure or from transformers, and the first point of connection to the service-entrance conductors in a terminal box or meter or other enclosure, inside or outside the building wall. Where there is no terminal box, meter, or other enclosure, the point of connection is considered to be the point of entrance of the service conductors into the building. [**70,** 2008]

Service Point. The point of connection between the facilities of the serving utility and the premises wiring. [**70,** 2008]

Shock Hazard. A dangerous condition associated with the possible release of energy caused by contact or approach to energized electrical conductors or circuit parts.

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,** 2008]

• **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,** 2008]

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,** 2008]

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

Switchgear, Metal-Clad. 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. 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.

Switch, Isolating. 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,** 2008]

• **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. Switchboards are generally accessible from the rear as well as from the front and are not intended to be installed in cabinets. [**70,** 2008]

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

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,** 2008]

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,** 2008]

Ventilated. Provided with a means to permit circulation of air sufficient to remove an excess of heat, fumes, or vapors. [**70,** 2008]

• **Voltage (of a Circuit).** The greatest root-mean-square (rms) (effective) difference of potential between any two conductors of the circuit concerned. [**70,** 2008]

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

Voltage, Nominal. 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). The actual voltage at which a circuit operates can vary from the nominal within a range that permits satisfactory operation of equipment. [**70,** 2008]

FPN: See ANSI C84.1-2006, *Electric Power Systems and Equipment — Voltage Ratings (60 Hz).*

Voltage to Ground. For grounded circuits, the voltage between the given conductor and that point or conductor of the circuit that is grounded; for ungrounded circuits, the greatest voltage between the given conductor and any other conductor of the circuit. [**70,** 2008]

• **Working On (energized electrical conductors or circuit parts).** 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 a person is wearing. There are two categories of "working on": *Diagnostic (testing)* is taking readings or measurements of electrical equipment with approved test equipment that does not require making any physical change to the equipment; *repair* is any physical alteration of electrical equipment (such as making or tightening connections, removing or replacing components, etc.).

ARTICLE 110
General Requirements for Electrical Safety-Related Work Practices

110.1 Scope. Chapter 1 covers electrical safety-related work practices and procedures for employees who are exposed to an electrical hazard in workplaces covered in the scope of this standard. Electric circuits and equipment not included in the scope of this standard might present a hazard to employees not qualified to work near such facilities. Requirements have been included in Chapter 1 to protect unqualified employees from such hazards.

110.2 Purpose. These practices and procedures are intended to provide for employee safety relative to electrical hazards in the workplace.

FPN: For general categories of electrical hazards, see Annex K.

110.3 Responsibility. The safety-related work practices contained in Chapter 1 shall be implemented by employees. The employer shall provide the safety-related work practices and shall train the employee who shall then implement them.

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

110.5 Relationships with Contractors (Outside Service Personnel, etc.).

(A) Host Employer Responsibilities.

(1) The host employer shall inform contract employers of:

a. Known hazards that are covered by this standard, that are related to the contract employer's work, and that might not be recognized by the contract employer or its employees
b. Information about the employer's installation that the contract employer needs to make the assessments required by Chapter 1

(2) The host employer shall report observed contract-employer-related violations of this standard to the contract employer.

(B) Contract Employer Responsibilities.

(1) The contract employer shall ensure that each of his or her employees is instructed in the hazards communicated to the contract employer by the host employer. This instruction is in addition to the basic training required by this standard.

(2) The contract employer shall ensure that each of his or her employees follows the work practices required by this standard and safety-related work rules required by the host employer.

(3) The contract employer shall advise the host employer of:

a. Any unique hazards presented by the contract employer's work,
b. Any unanticipated hazards found during the contract employer's work that the host employer did not mention, and
c. The measures the contractor took to correct any violations reported by the host employer under paragraph (A)(2) of this section and to prevent such violation from recurring in the future.

110.6 Training Requirements.

(A) Safety Training. The training requirements contained in this section shall apply to employees who face a risk of electrical hazard that is not reduced to a safe level by the applicable electrical installation requirements. Such employees shall be trained to understand the specific hazards associated with electrical energy. They shall be trained in safety-related work practices and procedural requirements as necessary to provide protection from the electrical hazards associated with their respective job or task assignments. Employees shall be trained to identify and understand the relationship between electrical hazards and possible injury.

FPN: For further information concerning installation requirements, see *NFPA 70®*, *National Electrical Code®*, 2008 edition.

(B) Type of Training. The training required by this section shall be classroom or on-the-job type, or a combination of the two. The degree of training provided shall be determined by the risk to the employee.

(C) Emergency Procedures. Employees exposed to shock hazards shall be trained in methods of release of victims from contact with exposed energized electrical conductors or circuit parts. Employees shall be regularly instructed in methods of first aid and emergency procedures, such as approved methods of resuscitation, if their duties warrant such training. Training of employees in approved methods of resuscitation, including cardiopulmonary resuscitation, shall be certified by the employer annually.

(D) Employee Training.

(1) Qualified Person. A qualified person shall be trained and knowledgeable of the construction and operation of equipment or a specific work method and be trained to recognize 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 the special precautionary techniques, personal protective equipment, including arc-flash, insulating and shielding materials, and insulated tools and test equipment. A person can be considered qualified with respect to certain equipment and methods but still be unqualified for others.

(b) Such persons permitted to work within the Limited Approach Boundary of exposed energized electrical conductors and circuit parts operating at 50 volts or more shall, at a minimum, be additionally trained in all of the following:

(1) The skills and techniques necessary to distinguish exposed energized electrical conductors and circuit parts from other parts of electrical equipment
(2) The skills and techniques necessary to determine the nominal voltage of exposed energized electrical conductors and circuit parts
(3) The approach distances specified in Table 130.2(C) and the corresponding voltages to which the qualified person will be exposed
(4) The decision-making process necessary to determine the degree and extent of the hazard and the personal protective equipment and job planning necessary to perform the task safely

(c) An employee who is undergoing on-the-job training and who, in the course of such training, has demonstrated an ability to perform 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 duties.

(d) Tasks that are performed less often than once per year shall require retraining before the performance of the work practices involved.

(e) Employees shall be trained to select an appropriate voltage detector 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 specific voltage detector that may be used.

(2) Unqualified Persons. Unqualified persons shall be trained in and be familiar with any of the electrical safety-related practices that might not be addressed specifically by Chapter 1 but are necessary for their safety.

(3) Retraining. An employee shall receive additional training (or retraining) under any of the following conditions:

(a) If the supervision or annual inspections indicate that the employee is not complying with the safety-related work practices

(b) If new technology, new types of equipment, or changes in procedures necessitate the use of safety-related work practices that are different from those that the employee would normally use

(c) If he or she must employ safety-related work practices that are not normally used during his or her regular job duties

(E) Training Documentation. The employer shall document that each employee has received the training required by paragraph 110.6(D). This documentation shall be made when the employee demonstrates proficiency in the work practices involved and shall be maintained for the duration of the employee's employment. The documentation shall contain each employee's name and dates of training.

FPN: Employment records that indicate that an employee has received the required training are an acceptable means of meeting this requirement.

110.7 Electrical Safety Program.

(A) General. The employer shall implement and document an overall electrical safety program that directs activity appropriate for the voltage, energy level, and circuit conditions.

FPN No. 1: Safety-related work practices are just one component of an overall electrical safety program.

FPN No. 2: ANSI/AIHA Z10-2005, *American National Standard for Occupational Safety and Health Management Systems*, provides a framework for establishing a comprehensive electrical safety program as a component of an employer's occupational safety and health program.

(B) Awareness and Self-Discipline. The electrical safety program shall be designed to provide an awareness of the potential electrical hazards to employees who might from time to time work in an environment influenced by the presence of electrical energy. The program shall be developed to provide the required self-discipline for employees who occasionally must perform work that may involve electrical hazards. The program shall instill safety principles and controls.

(C) Electrical Safety Program Principles. The electrical safety program shall identify the principles upon which it is based.

FPN: For examples of typical electrical safety program principles, see Annex E.

(D) Electrical Safety Program Controls. An electrical safety program shall identify the controls by which it is measured and monitored.

FPN: For examples of typical electrical safety program controls, see Annex E.

(E) Electrical Safety Program Procedures. An electrical safety program shall identify the procedures for working within the Limited Approach Boundary of energized electrical conductors and circuit parts operating at 50 volts or more or where an electrical hazard exists before work is started.

FPN: For an example of a typical electrical safety program procedure, see Annex E.

(F) Hazard/Risk Evaluation Procedure. An electrical safety program shall identify a hazard/risk evaluation procedure to be used before work is started within the Limited Approach Boundary of energized electrical conductors and circuit parts operating at 50 volts or more or where an electrical hazard exists. The procedure shall identify the hazard/risk process that shall be used by employees to evaluate tasks before work is started.

FPN No. 1: The hazard/risk evaluation procedure may include identifying when a second person could be required and the training and equipment that person should have.

FPN No. 2: For an example of a Hazard/Risk Analysis Evaluation Procedure Flow Chart, see Annex F.

FPN No. 3: For an example of a Hazard/Risk Evaluation Procedure, see Annex F.

(G) Job Briefing.

(1) General. Before starting each job, the employee in charge shall conduct a job briefing with the employees involved. The briefing shall cover such subjects as hazards associated with the job, work procedures involved, special precautions, energy source controls, and personal protective equipment requirements.

(2) Repetitive or Similar Tasks. If the work or operations to be performed during the work day or shift are repetitive and similar, at least one job briefing shall be conducted before the start of the first job of the day or shift. Additional job briefings shall be held if changes that might affect the safety of employees occur during the course of the work.

(3) Routine Work. A brief discussion shall be satisfactory if the work involved is routine and if the employee, by virtue of training and experience, can reasonably be expected to recognize and avoid the hazards involved in the job. A more extensive discussion shall be conducted if either of the following apply:

(1) The work is complicated or particularly hazardous.
(2) The employee cannot be expected to recognize and avoid the hazards involved in the job.

FPN: For an example of a job briefing form and planning checklist, see Annex I.

(H) Electrical Safety Auditing. An electrical safety program shall be audited to help ensure that the principles and procedures of the electrical safety program are being followed. The frequency of audit shall be determined by the employer, based on the complexity of the procedures and the type of work being covered. Where the audit determines that the principles and procedures of the electrical safety program are not being followed, appropriate revisions shall be made.

110.8 Working While Exposed to Electrical Hazards.

(A) 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. The specific safety-related work practices shall be consistent with the nature and extent of the associated electrical hazards.

(1) Energized Electrical Conductors and Circuit Parts — Safe Work Condition. Energized electrical conductors and circuit parts to which an employee might be exposed shall be put into an electrically safe work condition before an employee works within the Limited Approach Boundary of those conductors or parts, unless work on energized components can be justified according to 130.1.

(2) Energized Electrical Conductors and Circuit Parts — Unsafe Work Condition. 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.

(B) Working Within the Limited Approach Boundary of Exposed Electrical Conductors or Circuit Parts that Are or Might Become Energized. Prior to working within the Limited Approach Boundary of exposed electrical conductors and circuit parts operating at 50 volts or more, lockout/tagout devices shall be applied in accordance with 120.1, 120.2, and 120.3. If, for reasons indicated in 130.1, lockout/tagout devices cannot be applied, 130.2(A) through 130.2(D)(2) shall apply to the work.

(1) Electrical Hazard Analysis. If the energized electrical conductors or circuit parts operating at 50 volts or more are not placed in an electrically safe work condition, other safety-related work practices shall be used to protect employees who might be exposed to the electrical hazards involved. Such work practices shall protect each employee from arc flash and from contact with energized electrical conductors or circuit parts operating at 50 volts or more directly with any part of the body or indirectly through some other conductive object. Work practices that are used shall be suitable for the conditions under which the work is to be performed and for the voltage level of the energized electrical conductors or circuit parts. Appropriate safety-related work practices shall be determined before any person is exposed to the electrical hazards involved by using both shock hazard analysis and arc flash hazard analysis.

(a) Shock Hazard Analysis. A shock hazard analysis shall determine the voltage to which personnel will be exposed, boundary requirements, and the personal protective equipment necessary in order to minimize the possibility of electrical shock to personnel.

FPN: See 130.2 for the requirements of conducting a shock hazard analysis.

(b) Arc Flash Hazard Analysis. An arc flash hazard analysis shall determine the Arc Flash Protection Boundary and the personal protective equipment that people within the Arc Flash Protection Boundary shall use.

FPN: See 130.3 for the requirements of conducting an arc flash hazard analysis.

(2) Energized Electrical Work Permit. When working on energized electrical conductors or circuit parts that are not placed in an electrically safe work condition (i.e., for the reasons of increased or additional hazards or infeasibility per 130.1), work to be performed shall be considered energized electrical work and shall be performed by written permit only.

FPN: See 130.1(B) for the requirements of an energized electrical work permit.

(3) Unqualified Persons. Unqualified persons shall not be permitted to enter spaces that are required to be accessible to qualified employees only, unless the electric conductors and equipment involved are in an electrically safe work condition.

(4) Safety Interlocks. Only qualified persons following the requirements for working inside the Restricted Approach Boundary as covered by 130.2(C) 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.

110.9 Use of Equipment.

(A) Test Instruments and Equipment.

(1) Rating. Test instruments, equipment, and their accessories shall be rated for circuits and equipment to which they will be connected.

FPN: See ANSI/ISA-61010-1 (82.02.01)/UL 61010-1, *Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use – Part 1: General Requirements*, for rating and design requirements for voltage measurement and test instruments intended for use on electrical systems 1000 volts and below.

(2) Design. Test instruments, equipment, and their accessories shall be designed for the environment to which they will be exposed, and for the manner in which they will be used.

(3) Visual Inspection. 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, and no employee shall use it until repairs and tests necessary to render the equipment safe have been made.

(4) Operation Verification. When test instruments are used for the testing for the absence of voltage on conductors or circuit parts operating at 50 volts or more, the operation of the test instrument shall be verified before and after an absence of voltage test is performed.

(B) Portable Electric Equipment. This section applies to the use of cord-and-plug-connected equipment, including cord sets (extension cords).

(1) Handling. Portable equipment shall be handled in a manner that will not cause damage. Flexible electric cords connected to equipment shall not be used for raising or lowering the equipment. Flexible cords shall not be fastened with staples or hung in such a fashion as could damage the outer jacket or insulation.

(2) Grounding-Type Equipment.

(a) A flexible cord used with grounding-type utilization equipment shall contain an equipment grounding conductor.

(b) Attachment plugs and receptacles shall not be connected or altered in a manner that would interrupt continuity of the equipment grounding conductor.

Additionally, these devices shall not be altered in order to allow use in a manner that was not intended by the manufacturer.

(c) Adapters that interrupt the continuity of the equipment grounding conductor shall not be used.

(3) Visual Inspection of Portable Cord-and-Plug-Connected Equipment and Flexible Cord Sets.

(a) Frequency of Inspection. Before each use, portable cord-and-plug-connected equipment shall be visually inspected for external defects (such as loose parts or deformed and missing pins) and for evidence of possible internal damage (such as a pinched or crushed outer jacket).

Exception: Cord-and-plug-connected equipment and flexible cord sets (extension cords) that remain connected once they are put in place and are not exposed to damage shall not be required to be visually inspected until they are relocated.

(b) Defective Equipment. 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, and no employee shall use it until repairs and tests necessary to render the equipment safe have been made.

(c) Proper Mating. When an attachment plug is to be connected to a receptacle, the relationship of the plug and receptacle contacts shall first be checked to ensure that they are of mating configurations.

(d) Conductive Work Locations. Portable electric equipment used in highly conductive work locations (such as those inundated with water or other conductive liquids) or in job locations where employees are likely to contact water or conductive liquids shall be approved for those locations. In job locations where employees are likely to contact or be drenched with water or conductive liquids, ground-fault circuit-interrupter protection for personnel shall also be used.

(4) Connecting Attachment Plugs.

(a) Employees' hands shall not be wet when plugging and unplugging flexible cords and cord-and-plug-connected equipment if energized equipment is involved.

(b) Energized plug and receptacle connections shall be handled only with insulating protective equipment if the condition of the connection could provide a conductive path to the employee's hand (if, for example, a cord connector is wet from being immersed in water).

(c) Locking-type connectors shall be secured after connection.

(C) GFCI Protection Devices. GFCI protection devices shall be tested per manufacturer's instructions.

(D) Overcurrent Protection Modification. Overcurrent protection of circuits and conductors shall not be modified, even on a temporary basis, beyond that permitted by applicable portions of electrical codes and standards dealing with overcurrent protection.

FPN: For further information concerning electrical codes and standards dealing with overcurrent protection, refer to Article 240 of *NFPA 70, National Electrical Code*.

ARTICLE 120
Establishing an Electrically Safe Work Condition

120.1 Process of Achieving an Electrically Safe Work Condition. An electrically safe work condition shall be achieved when performed in accordance with the procedures of 120.2 and verified by the following process:

(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) Use an adequately rated voltage detector to test each phase conductor or circuit part to verify they are deenergized. Test each phase conductor or circuit part both phase-to-phase and phase-to-ground. Before and after each test, determine that the voltage detector is operating satisfactorily.

FPN: See ANSI/ISA-61010-1 (82.02.01)/ UL 61010-1, *Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use – Part 1: General Requirements*, for rating and design requirements for voltage measurement and test instruments intended for use on electrical systems 1000 V and below.

(6) Where the possibility of induced voltages or stored electrical energy exists, ground the phase conductors or circuit parts before touching them. Where it could be reasonably anticipated that the conductors or circuit parts being deenergized could contact other exposed energized conductors or circuit parts, apply ground connecting devices rated for the available fault duty.

120.2 Deenergized Electrical Conductors or Circuit Parts That Have Lockout/Tagout Devices Applied. Each employer shall identify, document, and implement lockout/tagout procedures conforming to Article 120 to safeguard employees from exposure to electrical hazards. The lockout/tagout procedure shall be appropriate for the experience and training of the employees and conditions as they exist in the workplace.

(A) General. All electrical circuit conductors and circuit parts shall be considered energized until the source(s) of energy is (are) removed, at which time they shall be considred deenergized. All electrical conductors and circuit parts shall not be considered to be in an electrically safe work condition until all of the applicable requirements of Article 120 have been met.

FPN: See 120.1 for the six-step procedure to verify an electrically safe work condition.

Electrical conductors and circuit parts that have been disconnected, but not under lockout/tagout, tested, and grounded (where appropriate) shall not be considered to be in an electrically safe work condition, and safe work practices appropriate for the circuit voltage and energy level shall be used. Lockout/tagout requirements shall apply to fixed, permanently installed equipment, to temporarily installed equipment, and to portable equipment.

(B) Principles of Lockout/Tagout Execution.

(1) Employee Involvement. Each person who could be exposed directly or indirectly to a source of electrical energy shall be involved in the lockout/tagout process.

FPN: 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.

(2) Training. All persons who could be exposed shall be trained to understand the established procedure to control the energy and their responsibility in executing the procedure. New (or reassigned) employees shall be trained (or retrained) to understand the lockout/tagout procedure as related to their new assignment.

(3) Plan. A plan shall be developed on the basis of the existing electrical equipment and system and shall utilize up-to-date diagrammatic drawing representation(s).

(4) Control of Energy. All sources of electrical energy shall be controlled in such a way as to minimize employee exposure to electrical hazards.

(5) Identification. The lockout/tagout device shall be unique and readily identifiable as a lockout/tagout device.

(6) Voltage. Voltage shall be removed and absence of voltage verified.

(7) Coordination. The established electrical lockout/tagout procedure shall be coordinated with all of the employer's procedures associated with lockout/tagout of other energy sources.

(C) Responsibility.

(1) Procedures. The employer shall establish lockout/tagout procedures for the organization, provide training to employees, provide equipment necessary to execute the details of the procedure, audit execution of the procedures to ensure employee understanding/compliance, and audit the procedure for improvement opportunity and completeness.

(2) Form of Control. Three forms of hazardous electrical energy control shall be permitted: individual employee control, simple lockout/tagout, and complex lockout/tagout. *[See 120.2(D).]* For the individual employee control and the simple lockout/tagout, the qualified person shall be in charge. For the complex lockout/tagout, the person in charge shall have overall responsibility.

FPN: For an example of a lockout/tagout procedure, see Annex G.

(3) Audit Procedures. An audit shall be conducted at least annually by a qualified person and shall cover at least one lockout/tagout in progress and the procedure details. The audit shall be designed to correct deficiencies in the procedure or in employee understanding.

(D) Hazardous Electrical Energy Control Procedure.

(1) Individual Qualified Employee Control Procedure. The individual qualified employee control procedure shall be permitted when equipment with exposed conductors and circuit parts is deenergized for minor maintenance, servicing, adjusting, cleaning, inspection, operating conditions, and the like. The work shall be permitted to be performed without the placement of lockout/tagout devices on the disconnecting means, provided the disconnecting means is adjacent to the conductor, circuit parts, and equipment on which the work is performed, the disconnecting means is clearly visible to the individual qualified employee involved in the work, and the work does not extend beyond one shift.

(2) Simple Lockout/Tagout Procedure. All lockout/ tagout procedures that are not under individual qualified employee control according to 120.2(D)(1) or complex lockout/tagout according to 120.2(D)(3) shall be considered to be simple lockout/tagout procedures. All lockout/tagout procedures that involve only a qualified person(s) deenergizing one set of conductors or circuit part source for the sole purpose of performing work within the Limited Approach Boundary electrical equipment shall be considered to be a simple lockout/tagout. Simple lockout/tagout plans shall not be required to be written for each application. Each worker shall be responsible for his or her own lockout/tagout.

(3) Complex Lockout/Tagout Procedure.

(a) A complex lockout/tagout plan shall be permitted where one or more of the following exist:

(1) Multiple energy sources
(2) Multiple crews
(3) Multiple crafts
(4) Multiple locations
(5) Multiple employers
(6) Different disconnecting means
(7) Particular sequences
(8) A job or task that continues for more than one work period

(b) All complex lockout/tagout procedures shall require a written plan of execution that identifies the person in charge.

(c) The complex lockout/tagout procedure shall vest primary responsibility in an authorized employee for a set number of employees working under the protection of a group lockout or tagout device (such as an operation lock). The person in charge shall be held accountable for safe execution of the complex lockout/tagout.

(d) 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.

(e) The complex lockout/tagout procedure shall address all the concerns of employees who might be exposed. 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.

(4) Coordination.

(a) The established 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.

(b) The procedure for control of exposure to electrical hazards shall be coordinated with other procedures for control of other hazardous energy sources such that they are based on similar/identical concepts.

(c) The electrical lockout/tagout procedure shall always include voltage testing requirements where there might be direct exposure to electrical energy hazards.

(d) 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, provided such devices are used only for control of hazardous energy and for no other purpose.

(5) Training and Retraining. Each employer shall provide training as required to ensure employees' understanding of the lockout/tagout procedure content and their duty in executing such procedures.

(E) Equipment.

(1) Lock Application. Energy isolation devices for machinery or equipment installed after January 2, 1990, shall be capable of accepting a lockout device.

(2) Lockout/Tagout Device. Each employer shall supply, and employees shall use, lockout/tagout devices and equipment necessary to execute the requirements of 120.2(E). Locks and tags used for control of exposure to electrical energy hazards shall be unique, shall be readily identifiable as lockout/tagout devices, and shall be used for no other purpose.

(3) Lockout Device.

(a) A lockout device shall include a lock (either keyed or combination).

(b) The lockout device shall include a method of identifying the individual who installed the lockout device.

(c) A lockout device shall be permitted to be only a lock, provided the lock is readily identifiable as a lockout device, in addition to having a means of identifying the person who installed the lock.

(d) Lockout devices shall be attached to prevent operation of the disconnecting means without resorting to undue force or the use of tools.

(e) 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.

(f) Lockout devices shall be suitable for the environment and for the duration of the lockout.

(g) 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.

(4) Tagout Device.

(a) A tagout device shall include a tag together with an attachment means.

(b) The tagout device shall be readily identifiable as a tagout device and suitable for the environment and duration of the tagout.

(c) A tagout device attachment means shall be capable of withstanding at least 224.4 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, equal to an all-environmental tolerant nylon cable tie.

(d) Tags shall contain a statement prohibiting unauthorized operation of the disconnecting means or removal of the tag.

Exception to (a), (b), and (c): 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 worker(s).

(5) Electrical Circuit Interlocks. Up-to-date diagrammatic drawings shall be consulted to ensure that no electrical circuit interlock operation can result in reenergizing the circuit being worked on.

(6) Control Devices. Locks/tags shall be installed only on circuit disconnecting means. Control devices, such as pushbuttons or selector switches, shall not be used as the primary isolating device.

(F) Procedures. The employer shall maintain a copy of the procedures required by this section and shall make the procedures available to all employees.

(1) Planning. The procedure shall require planning, including 120.2(F)(1)(a) through 120.2(F)(2)(n).

(a) 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 sources of energy is employed.

(b) Exposed Persons. The plan shall identify persons who might be exposed to an electrical hazard and the personal protective equipment required during the execution of the job or task.

(c) Person In Charge. The plan shall identify the person in charge and his or her responsibility in the lockout/tagout.

(d) Individual Qualified Employee Control. Individual qualified employee control shall be in accordance with 120.2(D)(1).

(e) Simple Lockout/Tagout. Simple lockout/tagout procedure shall be in accordance with 120.2(D)(2).

(f) Complex Lockout/Tagout. Complex lockout/tagout procedure shall be in accordance with 120.2(D)(3).

(2) Elements of Control. The procedure shall identify elements of control.

(a) Deenergizing Equipment (Shutdown). The procedure shall establish the person who performs the switching and where and how to deenergize the load.

(b) 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.

(c) Disconnecting Means. The procedure shall identify how to verify that the circuit is deenergized (open).

(d) Responsibility. The procedure shall identify the person who is responsible to verify that the lockout/tagout procedure is implemented and who is responsible to ensure 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.

(e) Verification. The procedure shall verify that equipment cannot be restarted. The equipment operating controls, such as pushbuttons, selector switches, and electrical interlocks, shall be operated or otherwise it shall be verified that the equipment cannot be restarted.

(f) Testing. The procedure shall establish the following:

(1) What voltage detector will be used, the required personal protective equipment, and who will use it to verify proper operation of the voltage detector before and after use
(2) A requirement to define the boundary of the work area
(3) A requirement to test before touching every exposed conductor or circuit part(s) within the defined boundary of the work area
(4) A requirement to retest for absence of voltage when circuit conditions change or when the job location has been left unattended
(5) Where there is no accessible exposed point to take voltage measurements, planning considerations shall include methods of verification.

(g) Grounding. Grounding requirements for the circuit shall be established, including whether the grounds shall be installed for the duration of the task or temporarily are 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.

(h) 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.

(i) Coordination. The procedure shall establish how coordination is accomplished with other jobs or tasks in progress, including related jobs or tasks at remote locations, including the person responsible for coordination.

(j) 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.

(k) 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.

FPN: 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.

(l) 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.

(m) 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 reenergized, appropriate tests and visual inspections shall be conducted to verify that all tools, mechanical restraints and electrical jumpers, shorts, and grounds have been removed, so that the circuits and equipment are in a condition to be safely energized. Where appropriate, 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 reenergizing the service and that blocked mechanical equipment or grounded equipment is cleared and prepared for return to service.

(n) 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.

FPN: See 110.9 and 130.4 for requirements when using test instruments and equipment.

120.3 Temporary Protective Grounding Equipment.

(A) Placement. Temporary protective grounds shall be placed at such locations and arranged in such a manner as to prevent each employee from being exposed to hazardous differences in electrical potential.

(B) Capacity. Temporary protective grounds 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.

(C) Equipment Approval. Temporary protective grounding equipment shall meet the requirements of ASTM F 855, *Standard Specification for Temporary Protective Grounds to be Used on De-energized Electric Power Lines and Equipment*.

(D) Impedance. Temporary protective grounds shall have an impedance low enough to cause immediate operation of protective devices in case of accidental energizing of the electric conductors or circuit parts.

ARTICLE 130
Work Involving Electrical Hazards

130.1 Justification for Work.

(A) General. Energized electrical conductors and circuit parts to which an employee might be exposed shall be put into an electrically safe work condition before an employee works within the Limited Approach Boundary of those conductors or parts.

(1) Greater Hazard. Energized work shall be permitted where the employer can demonstrate that deenergizing introduces additional or increased hazards.

(2) Infeasibility. Energized work shall be permitted where the employer can demonstrate that the task to be performed is infeasible in a deenergized state due to equipment design or operational limitations.

(3) Less Than 50 Volts. Energized electrical conductors and circuit parts that operate at less than 50 volts to ground shall not be required to be deenergized 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.

FPN No. 1: Examples of increased or additional hazards include, but are not limited to, interruption of life support equipment, deactivation of emergency alarm systems, and shutdown of hazardous location ventilation equipment.

FPN No. 2: 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.

FPN No. 3: The occurrence of 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 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 at-risk procedures that require an employee to be exposed to high level energy sources. 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 5 kV (nominal) systems, current limitation, and specification of covered bus within equipment are techniques available to reduce the hazard of the system.

(B) Energized Electrical Work Permit.

(1) Where Required. When working on energized electrical conductors or circuit parts that are not placed in an electrically safe work condition (i.e., for the reasons of increased or additional hazards or infeasibility per 130.1), work to be performed shall be considered energized electrical work and shall be performed by written permit only.

(2) Elements of Work Permit. The energized electrical work permit shall include, but not be limited to, the following items:

(1) A description of the circuit and equipment to be worked on and their location
(2) Justification for why the work must be performed in an energized condition (130.1)
(3) A description of the safe work practices to be employed [110.8(B)]
(4) Results of the shock hazard analysis [110.8(B)(1)(a)]
(5) Determination of shock protection boundaries [130.2(B) and Table 130.2(C)]
(6) Results of the arc flash hazard analysis (130.3)
(7) The arc flash protection boundary [130.3(A)]
(8) The necessary personal protective equipment to safely perform the assigned task [130.3(B), 130.7(C)(9), and Table 130.7(C)(9)]
(9) Means employed to restrict the access of unqualified persons from the work area [110.8(A)(2)]
(10) Evidence of completion of a job briefing, including a discussion of any job-specific hazards [110.7(G)]
(11) Energized work approval (authorizing or responsible management, safety officer, or owner, etc.) signature(s)

(3) Exemptions to Work Permit. Work performed within the Limited Approach Boundary of energized electrical conductors or circuit parts by qualified persons related to tasks such as testing, troubleshooting, voltage measuring, etc., shall be permitted to be performed without an energized electrical work permit, provided appropriate safe work practices and personal protective equipment in accordance with Chapter 1 are provided and used. If the purpose of crossing the Limited Approach Boundary is only for visual inspection and the Restricted Approach Boundary will not be crossed, then an energized electrical work permit shall not be required.

FPN: For an example of an acceptable energized electrical work permit, see Annex J.

130.2 Approach Boundaries to Energized Electrical Conductors or Circuit Parts.

(A) Shock Hazard Analysis. A shock hazard analysis shall determine the voltage to which personnel will be exposed, boundary requirements, and the personal protective equipment necessary in order to minimize the possibility of electric shock to personnel.

(B) Shock Protection Boundaries. The shock protection boundaries identified as Limited, Restricted, and Prohibited Approach Boundaries are applicable to the situation in which approaching personnel are exposed to energized electrical conductors or circuit parts. See Table 130.2(C) for the distances associated with various system voltages.

FPN: In certain instances, the Arc Flash Protection Boundary might be a greater distance from the exposed energized electrical conductors or circuit parts than the Limited Approach Boundary. The Shock Protection Boundaries and the Arc Flash Hazard Boundary are independent of each other.

(C) Approach to Exposed Energized Electrical Conductors or Circuit Parts Operating at 50 Volts or More. No qualified person shall approach or take any conductive object closer to exposed energized electrical conductors or circuit parts operating at 50 volts or more than the Restricted Approach Boundary set forth in Table 130.2(C), unless any of the following apply:

(1) The qualified person is insulated or guarded from the energized electrical conductors or circuit parts operating at 50 volts or more and no uninsulated part of the qualified person's body crosses the Prohibited Approach Boundary set forth in Table 130.2(C). Insulating gloves or insulating gloves and sleeves are considered insulation only with regard to the energized parts upon which work is being performed. If there is a need for an uninsulated part of the qualified person's body to cross the Prohibited Approach Boundary, a combination of Sections 130.2(C)(1), 130.2(C)(2), and 130.2(C)(3) shall be used to protect the uninsulated body parts.
(2) The energized electrical conductors or circuit part operating at 50 volts or more are insulated from the qualified person and from any other conductive object at a different potential.
(3) The qualified person is insulated from any other conductive object as during live-line bare-hand work.

(D) Approach by Unqualified Persons. Unqualified persons shall not be permitted to enter spaces that are required to be accessible to qualified employees only, unless the electric conductors and equipment involved are in an electrically safe work condition.

(1) Working At or Close to the Limited Approach Boundary. Where one or more unqualified persons are working at or close to the Limited Approach Boundary, the designated person in charge of the work space where the electrical hazard exists shall advise the unqualified person(s) of the electrical hazard and warn him or her to stay outside of the Limited Approach Boundary.

(2) Entering the Limited Approach Boundary. Where there is a need for an unqualified person(s) to cross the Limited Approach Boundary, a qualified person shall advise him or her of the possible hazards and continuously escort the unqualified person(s) while inside the Limited Approach Boundary. Under no circumstance shall the escorted unqualified person(s) be permitted to cross the Restricted Approach Boundary.

130.3 Arc Flash Hazard Analysis.

An arc flash hazard analysis shall determine the Arc Flash Protection Boundary

Table 130.2(C) Approach Boundaries to Energized Electrical Conductors or Circuit Parts for Shock Protection (All dimensions are distance from energized electrical conductor or circuit part to employee.)

(1)	(2)	(3)	(4)	(5)
	Limited Approach Boundary[1]		Restricted Approach Boundary[1]; Includes Inadvertent Movement Adder	
Nominal System Voltage Range, Phase to Phase[2]	Exposed Movable Conductor[3]	Exposed Fixed Circuit Part		Prohibited Approach Boundary[1]
Less than 50	Not specified	Not specified	Not specified	Not specified
50 to 300	3.05 m (10 ft 0 in.)	1.07 m (3 ft 6 in.)	Avoid contact	Avoid contact
301 to 750	3.05 m (10 ft 0 in.)	1.07 m (3 ft 6 in.)	304.8 mm (1 ft 0 in.)	25.4 mm (0 ft 1 in.)
751 to 15 kV	3.05 m (10 ft 0 in.)	1.53 m (5 ft 0 in.)	660.4 mm (2 ft 2 in.)	177.8 mm (0 ft 7 in.)
15.1 kV to 36 kV	3.05 m (10 ft 0 in.)	1.83 m (6 ft 0 in.)	787.4 mm (2 ft 7 in.)	254 mm (0 ft 10 in.)
36.1 kV to 46 kV	3.05 m (10 ft 0 in.)	2.44 m (8 ft 0 in.)	838.2 mm (2 ft 9 in.)	431.8 mm (1 ft 5 in.)
46.1 kV to 72.5 kV	3.05 m (10 ft 0 in.)	2.44 m (8 ft 0 in.)	991 mm (3 ft 3 in.)	661 mm (2 ft 2 in.)
72.6 kV to 121 kV	3.25 m (10 ft 8 in.)	2.44 m (8 ft 0 in.)	1.016 m (3 ft 4 in.)	838 mm (2 ft 9 in.)
138 kV to 145 kV	3.36 m (11 ft 0 in.)	3.05 m (10 ft 0 in.)	1.168 m (3 ft 10 in.)	1.016 m (3 ft 4 in.)
161 kV to 169 kV	3.56 m (11 ft 8 in.)	3.56 m (11 ft 8 in.)	1.295 m (4 ft 3 in.)	1.143 m (3 ft 9 in.)
230 kV to 242 kV	3.97 m (13 ft 0 in.)	3.97 m (13 ft 0 in.)	1.727 m (5 ft 8 in.)	1.575 m (5 ft 2 in.)
345 kV to 362 kV	4.68 m (15 ft 4 in.)	4.68 m (15 ft 4 in.)	2.794 m (9 ft 2 in.)	2.642 m (8 ft 8 in.)
500 kV to 550 kV	5.8 m (19 ft 0 in.)	5.8 m (19 ft 0 in.)	3.607 m (11 ft 10 in.)	3.454 m (11 ft 4 in.)
765 kV to 800 kV	7.24 m (23 ft 9 in.)	7.24 m (23 ft 9 in.)	4.852 m (15 ft 11 in.)	4.699 m (15 ft 5 in.)

Note: For Arc Flash Protection Boundary, see 130.3(A).
[1] See definition in Article 100 and text in 130.2(D)(2) and Annex C for elaboration.
[2] For single-phase systems, select the range that is equal to the system's maximum phase-to-ground voltage multiplied by 1.732.
[3] 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.

and the personal protective equipment that people within the Arc Flash Protection Boundary shall use.

The arc flash hazard analysis shall be updated when a major modification or renovation takes place. It shall be reviewed periodically, not to exceed five years, to account for changes in the electrical distribution system that could affect the results of the arc flash hazard analysis.

The arc flash hazard analysis shall take into consideration the design of the overcurrent protective device and its opening time, including its condition of maintenance.

Exception No. 1: An arc flash hazard analysis shall not be required where all of the following conditions exist:

(1) The circuit is rated 240 volts or less.
(2) The circuit is supplied by one transformer.
(3) The transformer supplying the circuit is rated less than 125 kVA.

Exception No. 2: The requirements of 130.7(C)(9), 130.7(C)(10), and 130.7(C)(11) shall be permitted to be used in lieu of a detailed incident energy analysis.

FPN No. 1: Improper or inadequate maintenance can result in increased opening time of the overcurrent protective device, thus increasing the incident energy.

FPN No. 2: For additional direction for performing maintenance on overcurrent protective devices, see Chapter 2, Safety-Related Maintenance Requirements.

(A) Arc Flash Protection Boundary.

(1) Voltage Levels Between 50 Volts and 600 Volts. In those cases where detailed arc flash hazard analysis calculations are not performed for systems that are between 50 volts and 600 volts, the Arc Flash Protection Boundary shall be 4.0 ft, based on the product of clearing time of 2 cycles (0.033 sec) and the available bolted fault current of 50 kA or any combination not exceeding 100 kA cycles (1667 ampere seconds). When the product of clearing times and bolted fault current exceeds 100 kA cycles, the Arc Flash Protection Boundary shall be calculated.

(2) Voltage Levels Above 600 Volts. At voltage levels above 600 volts, the Arc Flash Protection Boundary shall be the distance at which the incident energy equals 5 J/cm^2 (1.2 cal/cm^2). For situations where fault-clearing time is equal to or less than 0.1 sec, the Arc Flash Protection Boundary shall be the distance at which the incident energy level equals 6.24 J/cm^2 (1.5 cal/cm^2).

FPN: For information on estimating the Arc Flash Protection Boundary, see Annex D.

(B) Protective Clothing and Other Personal Protective Equipment (PPE) for Application with an Arc Flash Hazard Analysis. Where it has been determined that work will be performed within the Arc Flash Protection Boundary identified by 130.3(A), one of the following methods shall be used for the selection of protective clothing and other personal protective equipment:

(1) Incident Energy Analysis. The incident energy analysis shall determine, and the employer shall document, the incident energy exposure of the worker (in calories per square centimeter). 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 FR clothing and other personal protective equipment (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 distance at which the incident energy was determined.

FPN: For information on estimating the incident energy, see Annex D.

(2) Hazard/Risk Categories. The requirements of 130.7(C)(9), 130.7(C)(10), and 130.7(C)(11) shall be permitted to be used for the selection and use of personal and other protective equipment.

(C) Equipment Labeling. Equipment shall be field marked with a label containing the available incident energy or required level of PPE.

130.4 Test Instruments and Equipment Use. Only qualified persons shall perform testing work within the Limited Approach Boundary of energized electrical conductors or circuit parts operating at 50 volts or more.

130.5 Work Within the Limited Approach Boundary of Uninsulated Overhead Lines.

(A) Uninsulated and Energized. Where work is performed in locations containing uninsulated energized overhead lines that are not guarded or isolated, precautions shall be taken to prevent employees from contacting such lines directly with any unguarded parts of their body or indirectly through conductive materials, tools, or equipment. Where the work to be performed is such that contact with uninsulated energized overhead lines is possible, the lines shall be deenergized and visibly grounded at the point of work, or suitably guarded.

(B) Deenergizing or Guarding. If the lines are to be deenergized, arrangements shall be made with the person or organization that operates or controls the lines to deenergize them and visibly ground them at the point of work. If arrangements are made to use protective measures, such as guarding, isolating, or insulation, these precautions shall prevent each employee from contacting such lines directly with any part of his or her body or indirectly through conductive materials, tools, or equipment.

(C) Employer and Employee Responsibility. The employer and employee shall be responsible for ensuring that guards or protective measures are satisfactory for the conditions. Employees shall comply with established work methods and the use of protective equipment.

(D) Approach Distances for Unqualified Persons. When unqualified persons are working on the ground or in an elevated position near overhead lines, the location shall be such that the employee and the longest conductive object the employee might contact do not come closer to any unguarded, energized overhead power line than the Limited Approach Boundary in Table 130.2(C), Column 2.

FPN: Objects that are not insulated for the voltage involved should be considered to be conductive.

(E) Vehicular and Mechanical Equipment.

(1) Elevated Equipment. Where any vehicle or mechanical equipment structure will be elevated near energized overhead lines, they shall be operated so that the Limited Approach Boundary distance of Table 130.2(C), Column 2, is maintained. However, under any of the following conditions, the clearances shall be permitted to be reduced:

(1) If the vehicle is in transit with its structure lowered, the Limited Approach Boundary to overhead lines in Table 130.2(C), Column 2, shall be permitted to be reduced by 1.83 m (6 ft). If insulated barriers, rated for the voltages involved, are installed and they are not part of an attachment to the vehicle, the clearance shall be permitted to be reduced to the design working dimensions of the insulating barrier.

(2) If the equipment is an aerial lift insulated for the voltage involved, and if the work is performed by a qualified person, the clearance (between the uninsulated portion of the aerial lift and the power line) shall be permitted to be reduced to the Restricted Approach Boundary given in Table 130.2(C), Column 4.

(2) Equipment Contact. Employees standing on the ground shall not contact the vehicle or mechanical equipment or any of its attachments, unless either of the following conditions apply:

(1) The employee is using protective equipment rated for the voltage.

(2) The equipment is located so that no uninsulated part of its structure (that portion of the structure that provides

a conductive path to employees on the ground) can come closer to the line than permitted in 130.5(E)(1).

(3) Equipment Grounding. If any vehicle or mechanical equipment capable of having parts of its structure elevated near energized overhead lines is intentionally grounded, employees working on the ground near the point of grounding shall not stand at the grounding location whenever there is a possibility of overhead line contact. Additional precautions, such as the use of barricades, dielectric overshoe footwear, or insulation, shall be taken to protect employees from hazardous ground potentials (step and touch potential).

FPN: Upon contact of the elevated structure with the energized lines, hazardous ground potentials can develop within a few feet or more outward from the grounded point.

130.6 Other Precautions for Personnel Activities.

(A) Alertness.

(1) When Hazardous. Employees shall be instructed to be alert at all times when they are working within the Limited Approach Boundary of energized electrical conductors or circuit parts operating at 50 volts or more and in work situations where electrical hazards might exist.

(2) When Impaired. Employees shall not be permitted to work within the Limited Approach Boundary of energized electrical conductors or circuit parts operating at 50 volts or more, or where other 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 may 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 containing electrical hazards 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 within the Limited Approach Boundary of energized electrical conductors or circuit parts operating at 50 volts or more or 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 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 accidental contact with energized electrical conductors or circuit parts. Such materials and equipment 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 130.2.

(F) Confined or Enclosed Work Spaces. When an employee works in a confined or enclosed space (such as a manhole or vault) that contains exposed energized electrical conductors or circuit parts operating at 50 volts or more or where an electrical hazard exists, the employer shall provide, and the employee shall use, protective shields, protective barriers, or insulating materials as necessary to avoid inadvertent contact with these parts and the effects of the electrical hazards. 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 rating at 50 volts or more or where an electrical hazard exists.

(G) Housekeeping Duties. Where energized electrical conductors or circuit parts present an electrical contact hazard, employees shall not perform housekeeping duties inside the Limited Approach Boundary where there is a possibility of contact, 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.

(H) Occasional Use of Flammable Materials. Where flammable materials are present only occasionally, electric equipment capable of igniting them may not be used, unless measures are taken to prevent hazardous conditions from developing. Such materials include, but are not limited to, flammable gases, vapors, or liquids; combustible dust; and ignitible fibers or flyings.

FPN: Electrical installation requirements for locations where flammable materials are present on a regular basis are contained in *NFPA 70, National Electrical Code*.

(I) Anticipating Failure. When there is evidence that electric equipment could fail and injure employees, the electric equipment shall be deenergized unless the employer can demonstrate that deenergizing introduces additional or increased hazards or is infeasible because of equipment design or operational limitation. Until the equipment is deenergized or repaired, employees shall be protected from hazards associated with the impending failure of the equipment.

(J) 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.

(K) Reclosing Circuits After Protective Device Operation. After a circuit is deenergized by a circuit protective device, the circuit shall not be manually reenergized until it has been determined that the equipment and circuit can be safely energized. The repetitive manual reclosing of circuit breakers or reenergizing circuits through replaced fuses shall be prohibited. 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 reenergized.

130.7 Personal and Other Protective Equipment.

(A) General. Employees working in areas where electrical hazards are present shall be provided with, and shall use, protective equipment that is designed and constructed for the specific part of the body to be protected and for the work to be performed.

FPN No. 1: The PPE requirements of 130.7 are intended to protect a person from arc flash and 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.

FPN No. 2: When incident energy exceeds 40 cal/cm^2 at the working distance, greater emphasis may be necessary with respect to de-energizing before working within the Limited Approach Boundary of the exposed electrical conductors or circuit parts.

(B) Care of Equipment. Protective equipment shall be maintained in a safe, reliable condition. 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.

FPN: Specific requirements for periodic testing of electrical protective equipment are given in 130.7(C)(8) and 130.7(F).

(C) Personal Protective Equipment.

(1) General. When an employee is working within the Arc Flash Protection Boundary he or she shall wear protective clothing and other personal protective equipment in accordance with 130.3. All parts of the body inside the Arc Flash Protection Boundary shall be protected.

(2) Movement and Visibility. When flame-resistant (FR) clothing is worn to protect an employee, it shall cover all ignitible clothing and shall allow for movement and visibility.

(3) Head, Face, Neck, and Chin (Head Area) Protection. Employees shall wear nonconductive head protection wherever there is a danger of head injury from electric shock or burns due to contact with energized electrical conductors or circuit parts or from flying objects resulting from electrical explosion. Employees shall wear nonconductive protective equipment for the face, neck, and chin whenever there is a danger of injury from exposure to electric arcs or flashes or from flying objects resulting from electrical explosion. If employees use hairnets and/or beard nets, these items must be non-melting and flame resistant.

FPN: See 130.7(C)(13)(b) for arc flash protective requirements.

(4) Eye Protection. Employees shall wear protective equipment for the eyes whenever there is danger of injury from electric arcs, flashes, or from flying objects resulting from electrical explosion.

(5) Body Protection. Employees shall wear FR clothing wherever there is possible exposure to an electric arc flash above the threshold incident-energy level for a second-degree burn [5 J/cm^2 (1.2 cal/cm^2)].

FPN: Such clothing can be provided as an arc flash suit jacket and arc flash suit pants, shirts and pants, or as coveralls, or as a combination of jacket and pants, or, for increased protection, as coveralls with jacket and pants. Various weight fabrics are available. Generally, the higher degree of protection is provided by heavier weight fabrics and/or by layering combinations of one or more layers of FR clothing. In some cases, one or more layers of FR clothing are worn over flammable, non-melting clothing.

(6) Hand and Arm Protection. Hand and arm protection shall be provided in accordance with (a), (b), and (c) below.

(a) Shock Protection. Employees shall wear rubber insulating gloves with leather protectors where there is a danger of hand injury from electric shock due to contact with energized electrical conductors or circuit parts. Employees shall wear rubber insulating gloves with leather protectors and rubber insulating sleeves where there is a danger of hand and arm injury from electric shock due to contact with energized electrical conductors or circuit parts. Rubber insulating gloves shall be rated for the voltage for which the gloves will be exposed.

Exception: Where it is necessary to use rubber insulating gloves without leather protectors, the requirements of ASTM F 496, Standard Specification for In-Service Care of Insulating Gloves and Sleeves, shall be met.

FPN: Table 130.7(C)(9) provides further information on tasks where rubber insulating gloves are required.

(b) 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)(13)(c) shall be required for protection of hands from burns. Arm protection shall be accomplished by the apparel described in 130.7(C)(5).

(c) 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. Electrical protective equipment shall be subjected to periodic electrical tests. Test voltages and the maximum intervals between tests shall be in accordance with Table 130.7(C)(6)(c).

FPN: See OSHA 1910.137 and ASTM F 496, *Standard Specification for In-Service Care of Insulating Gloves and Sleeves.*

Table 130.7(C)(6)(c) Rubber Insulating Equipment, Maximum Test Intervals

Rubber Insulating Equipment	When to Test	Governing Standard* for Test Voltage
Blankets	Before first issue; every 12 months thereafter†	ASTM F 479
Covers	If insulating value is suspect	ASTM F 478
Gloves	Before first issue; every 6 months thereafter†	ASTM F 496
Line hose	If insulating value is suspect	ASTM F 478
Sleeves	Before first issue; every 12 months thereafter†	ASTM F 496

*ASTM F 478, *Standard Specification for In-Service Care of Insulating Line Hose and Covers*; ASTM F 479, *Standard Specification for In-Service Care of Insulating Blankets*; ASTM F 496, *Standard Specification for In-Service Care of Insulating Gloves and Sleeves.*

†If the insulating equipment has been electrically tested but not issued for service, it may not be placed into service unless it has been electrically tested within the previous 12 months.

(7) Foot Protection. Where insulated footwear is used as protection against step and touch potential, dielectric overshoes shall be required. Insulated soles shall not be used as primary electrical protection.

(8) Standards for Personal Protective Equipment (PPE). Personal protective equipment (PPE) shall conform to the standards given in Table 130.7(C)(8).

FPN: Non-FR or flammable fabrics are not covered by a standard in Table 130.7(C)(8). See 130.7(C)(14) and 130.7(C)(15).

Table 130.7(C)(8) Standards on Protective Equipment

Subject	Number and Title
Head protection	ANSI Z89.1, *Requirements for Protective Headwear for Industrial Workers*, 2003
Eye and face protection	ANSI Z87.1, *Practice for Occupational and Educational Eye and Face Protection*, 2003
Gloves	ASTM D 120, *Standard Specification for Rubber Insulating Gloves*, 2002a (R 2006)
Sleeves	ASTM D 1051, *Standard Specification for Rubber Insulating Sleeves*, 2007
Gloves and sleeves	ASTM F 496, *Standard Specification for In-Service Care of Insulating Gloves and Sleeves*, 2006
Leather protectors	ASTM F 696, *Standard Specification for Leather Protectors for Rubber Insulating Gloves and Mittens*, 2006
Footwear	ASTM F 1117, *Standard Specification for Dielectric Overshoe Footwear*, 2003 ASTM F 2412, *Standard Test Methods for Foot Protection*, 2005 ASTM F 2413, *Standard Specification for Performance Requirements for Foot Protection*, 2005
Visual inspection	ASTM F 1236, *Standard Guide for Visual Inspection of Electrical Protective Rubber Products*, 1996 (R 2007)
Apparel	ASTM F 1506, *Standard Performance Specification for Flame Resistant Textile Materials for Wearing Apparel for Use by Electrical Workers Exposed to Momentary Electric Arc and Related Thermal Hazards*, 2002a
Raingear	ASTM F 1891, *Standard Specification for Arc and Flame Resistant Rainwear*, 2006
Face protective products	ASTM F 2178, *Standard Test Method for Determining the Arc Rating and Standard Specification for Face Protective Products*, 2006
Fall protection	ASTM F 887, *Standard Specifications for Personal Climbing Equipment*, 2005

(9) Selection of Personal Protective Equipment When Required for Various Tasks. Where selected in lieu of the incident energy analysis of 130.3(B)(1), Table 130.7(C)(9) shall be used to determine the hazard/risk category and requirements for use of rubber insulating gloves and insulated and insulating hand tools for a task. The assumed maximum short-circuit current capacities and maximum fault clearing times for various tasks are listed in the notes to Table 130.7(C)(9). For tasks not listed, or for power systems with greater than the assumed maximum short-circuit current capacity or with longer than the assumed maximum fault clearing times, an arc flash hazard analysis shall be required in accordance with 130.3.

FPN No. 1: The work tasks and protective equipment identified in Table 130.7(C)(9) were identified by a task group and the protective clothing and equipment selected was based on the collective experience of the task group. The protective clothing and equipment is generally based on determination of estimated exposure levels.

In several cases where the risk of an arc flash incident is considered low, very low, or extremely low by the task group, the hazard/risk category number has been reduced by 1, 2, or 3 numbers, respectively. The collective experience of the task group is that in most cases closed doors do not provide enough protection to eliminate the need for PPE for instances where the state of the equipment is known to readily change (e.g., doors open or closed, rack in or rack out). The premise used by the Task Group is considered to be reasonable, based on the consensus judgment of the full NFPA 70E Technical Committee.

FPN No. 2: Both larger and smaller available short-circuit currents could result in higher available arc flash energies. If the available short-circuit current increases without a decrease in the opening time of the overcurrent protective device, the arc flash energy will increase. If the available short-circuit current decreases, resulting in a longer opening time for the overcurrent protective device, arc flash energies could also increase.

FPN No. 3: Energized electrical conductors or circuit parts that operate at less than 50 volts may need to be deenergized to satisfy an "electrically safe work condition." Consideration should be given to the capacity of the source, any overcurrent protection between the energy source and the worker, and whether the work task related to the source operating at less than 50 volts increases exposure to electrical burns or to explosion from an electric arc.

FPN No. 4: See 130.1(B)(2)(6) for requirements on documenting the available short-circuit current and fault clearing time.

Table 130.7(C)(9) Hazard/Risk Category Classifications and Use of Rubber Insulating Gloves and Insulated and Insulating Hand Tools

Tasks Performed on Energized Equipment	Hazard/Risk Category	Rubber Insulating Gloves	Insulated and Insulating Hand Tools
Panelboards or Other Equipment Rated 240 V and Below — Note 1			
Perform infrared thermography and other non-contact inspections outside the restricted approach boundary	0	N	N
Circuit breaker (CB) or fused switch operation with covers on	0	N	N
CB or fused switch operation with covers off	0	N	N
Work on energized electrical conductors and circuit parts, including voltage testing	1	Y	Y
Remove/install CBs or fused switches	1	Y	Y
Removal of bolted covers (to expose bare, energized electrical conductors and circuit parts)	1	N	N
Opening hinged covers (to expose bare, energized electrical conductors and circuit parts)	0	N	N
Work on energized electrical conductors and circuit parts of utilization equipment fed directly by a branch circuit of the panelboard	1	Y	Y
Panelboards or Switchboards Rated >240 V and up to 600 V (with molded case or insulated case circuit breakers) — Note 1			
Perform infrared thermography and other non-contact inspections outside the restricted approach boundary	1	N	N
CB or fused switch operation with covers on	0	N	N

Table 130.7(C)(9) ***Continued***

Tasks Performed on Energized Equipment	Hazard/Risk Category	Rubber Insulating Gloves	Insulated and Insulating Hand Tools
CB or fused switch operation with covers off	1	Y	N
Work on energized electrical conductors and circuit parts, including voltage testing	2*	Y	Y
Work on energized electrical conductors and circuit parts of utilization equipment fed directly by a branch circuit of the panelboard or switchboard	2*	Y	Y
600 V Class Motor Control Centers (MCCs) — Note 2 (except as indicated)			
Perform infrared thermography and other non-contact inspections outside the restricted approach boundary	1	N	N
CB or fused switch or starter operation with enclosure doors closed	0	N	N
Reading a panel meter while operating a meter switch	0	N	N
CB or fused switch or starter operation with enclosure doors open	1	N	N
Work on energized electrical conductors and circuit parts, including voltage testing	2*	Y	Y
Work on control circuits with energized electrical conductors and circuit parts 120 V or below, exposed	0	Y	Y
Work on control circuits with energized electrical conductors and circuit parts >120 V, exposed	2*	Y	Y
Insertion or removal of individual starter “buckets” from MCC — Note 3	4	Y	N
Application of safety grounds, after voltage test	2*	Y	N
Removal of bolted covers (to expose bare, energized electrical conductors and circuit parts) — Note 3	4	N	N
Opening hinged covers (to expose bare, energized electrical conductors and circuit parts) — Note 3	1	N	N
Work on energized electrical conductors and circuit parts of utilization equipment fed directly by a branch circuit of the motor control center	2*	Y	Y
600 V Class Switchgear (with power circuit breakers or fused switches) — Note 4			
Perform infrared thermography and other non-contact inspections outside the restricted approach boundary	2	N	N
CB or fused switch operation with enclosure doors closed	0	N	N
Reading a panel meter while operating a meter switch	0	N	N
CB or fused switch operation with enclosure doors open	1	N	N
Work on energized electrical conductors and circuit parts, including voltage testing	2*	Y	Y
Work on control circuits with energized electrical conductors and circuit parts 120 V or below, exposed	0	Y	Y
Work on control circuits with energized electrical conductors and circuit parts >120 V, exposed	2*	Y	Y

(continues)

Table 130.7(C)(9) ***Continued***

Tasks Performed on Energized Equipment	Hazard/Risk Category	Rubber Insulating Gloves	Insulated and Insulating Hand Tools
Insertion or removal (racking) of CBs from cubicles, doors open or closed	4	N	N
Application of safety grounds, after voltage test	2*	Y	N
Removal of bolted covers (to expose bare, energized electrical conductors and circuit parts)	4	N	N
Opening hinged covers (to expose bare, energized electrical conductors and circuit parts)	2	N	N
Other 600 V Class (277 V through 600 V, nominal) Equipment — Note 2 (except as indicated)			
Lighting or small power transformers (600 V, maximum)			
Removal of bolted covers (to expose bare, energized electrical conductors and circuit parts)	2*	N	N
Opening hinged covers (to expose bare, energized electrical conductors and circuit parts)	1	N	N
Work on energized electrical conductors and circuit parts, including voltage testing	2*	Y	Y
Application of safety grounds, after voltage test	2*	Y	N
Revenue meters (kW-hour, at primary voltage and current) Insertion or removal	2*	Y	N
Cable trough or tray cover removal or installation	1	N	N
Miscellaneous equipment cover removal or installation	1	N	N
Work on energized electrical conductors and circuit parts, including voltage testing	2*	Y	Y
Application of safety grounds, after voltage test	2*	Y	N
Insertion or removal of plug-in devices into or from busways	2*	Y	N
NEMA E2 (fused contactor) Motor Starters, 2.3 kV Through 7.2 kV			
Perform infrared thermography and other non-contact inspections outside the restricted approach boundary	3	N	N
Contactor operation with enclosure doors closed	0	N	N
Reading a panel meter while operating a meter switch	0	N	N
Contactor operation with enclosure doors open	2*	N	N
Work on energized electrical conductors and circuit parts, including voltage testing	4	Y	Y
Work on control circuits with energized electrical conductors and circuit parts 120 V or below, exposed	0	Y	Y
Work on control circuits with energized electrical conductors and circuit parts >120 V, exposed	3	Y	Y
Insertion or removal (racking) of starters from cubicles, doors open or closed	4	N	N
Application of safety grounds, after voltage test	3	Y	N

Table 130.7(C)(9) ***Continued***

Tasks Performed on Energized Equipment	Hazard/Risk Category	Rubber Insulating Gloves	Insulated and Insulating Hand Tools
Removal of bolted covers (to expose bare, energized electrical conductors and circuit parts)	4	N	N
Opening hinged covers (to expose bare, energized electrical conductors and circuit parts)	3	N	N
Insertion or removal (racking) of starters from cubicles of arc-resistant construction, tested in accordance with IEEE C37.20.7, doors closed only	0	N	N
Metal Clad Switchgear, 1 kV Through 38 kV			
Perform infrared thermography and other non-contact inspections outside the restricted approach boundary	3	N	N
CB operation with enclosure doors closed	2	N	N
Reading a panel meter while operating a meter switch	0	N	N
CB operation with enclosure doors open	4	N	N
Work on energized electrical conductors and circuit parts, including voltage testing	4	Y	Y
Work on control circuits with energized electrical conductors and circuit parts 120 V or below, exposed	2	Y	Y
Work on control circuits with energized electrical conductors and circuit parts >120 V, exposed	4	Y	Y
Insertion or removal (racking) of CBs from cubicles, doors open or closed	4	N	N
Application of safety grounds, after voltage test	4	Y	N
Removal of bolted covers (to expose bare, energized electrical conductors and circuit parts)	4	N	N
Opening hinged covers (to expose bare, energized electrical conductors and circuit parts)	3	N	N
Opening voltage transformer or control power transformer compartments	4	N	N
Arc-Resistant Switchgear Type 1 or 2 (for clearing times of <0.5 sec with a perspective fault current not to exceed the arc resistant rating of the equipment)			
CB operation with enclosure door closed	0	N	N
Insertion or removal (racking) of CBs from cubicles, doors closed	0	N	N
Insertion or removal of CBs from cubicles with door open	4	N	N
Work on control circuits with energized electrical conductors and circuit parts 120 V or below, exposed	2	Y	Y
Insertion or removal (racking) of ground and test device with door closed	0	N	N
Insertion or removal (racking) of voltage transformers on or off the bus door closed	0	N	N

(continues)

Table 130.7(C)(9) ***Continued***

Tasks Performed on Energized Equipment	Hazard/Risk Category	Rubber Insulating Gloves	Insulated and Insulating Hand Tools
Other Equipment 1 kV Through 38 kV			
Metal-enclosed interrupter switchgear, fused or unfused			
Switch operation of arc-resistant-type construction, tested in accordance with IEEE C37.20.7, doors closed only	0	N	N
Switch operation, doors closed	2	N	N
Work on energized electrical conductors and circuit parts, including voltage testing	4	Y	Y
Removal of bolted covers (to expose bare, energized electrical conductors and circuit parts)	4	N	N
Opening hinged covers (to expose bare, energized electrical conductors and circuit parts)	3	N	N
Outdoor disconnect switch operation (hookstick operated)	3	Y	Y
Outdoor disconnect switch operation (gang-operated, from grade)	2	Y	N
Insulated cable examination, in manhole or other confined space	4	Y	N
Insulated cable examination, in open area	2	Y	N

General Notes (applicable to the entire table):
(a) Rubber insulating gloves are gloves rated for the maximum line-to-line voltage upon which work will be done.
(b) Insulated and insulating hand tools are tools rated and tested for the maximum line-to-line voltage upon which work will be done, and are manufactured and tested in accordance with ASTM F 1505, *Standard Specification for Insulated and Insulating Hand Tools*.
(c) Y = yes (required), N = no (not required).
(d) For systems rated less than 1000 volts, the fault currents and upstream protective device clearing times are based on an 18 in. working distance.
(e) For systems rated 1 kV and greater, the Hazard/Risk Categories are based on a 36 in. working distance.
(f) For equipment protected by upstream current limiting fuses with arcing fault current in their current limiting range (½ cycle fault clearing time or less), the hazard/risk category required may be reduced by one number.
Specific Notes (as referenced in the table):
1. Maximum of 25 kA short circuit current available; maximum of 0.03 sec (2 cycle) fault clearing time.
2. Maximum of 65 kA short circuit current available; maximum of 0.03 sec (2 cycle) fault clearing time.
3. Maximum of 42 kA short circuit current available; maximum of 0.33 sec (20 cycle) fault clearing time.
4. Maximum of 35 kA short circuit current available; maximum of up to 0.5 sec (30 cycle) fault clearing time.

(10) Protective Clothing and Personal Protective Equipment Matrix. Once the Hazard/Risk Category has been identified from Table 130.7(C)(9) (including associated notes) and the requirements of 130.7(C)(9), Table 130.7(C)(10) shall be used to determine the required PPE for the task. Table 130.7(C)(10) lists the requirements for protective clothing and other protective equipment based on Hazard/Risk Category numbers 0 through 4. This clothing and equipment shall be used when working within the Arc Flash Protection Boundary.

FPN No. 1: See Annex H for a suggested simplified approach to ensure adequate PPE for electrical workers within facilities with large and diverse electrical systems.

FPN No. 2: The PPE requirements of this section are intended to protect a person from arc flash and shock hazards. While some situations could result in burns to the skin, even with the protection described in Table 130.7(C)(10), 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.

Table 130.7(C)(10) Protective Clothing and Personal Protective Equipment (PPE)

Hazard/Risk Category	Protective Clothing and PPE
Hazard/Risk Category 0	
Protective Clothing, Nonmelting (according to ASTM F 1506-00) or Untreated Natural Fiber	Shirt (long sleeve) Pants (long)
FR Protective Equipment	Safety glasses or safety goggles (SR) Hearing protection (ear canal inserts) Leather gloves (AN) (Note 2)
Hazard/Risk Category 1	
FR Clothing, Minimum Arc Rating of 4 (Note 1)	Arc-rated long-sleeve shirt (Note 3) Arc-rated pants (Note 3) Arc-rated coverall (Note 4) Arc-rated face shield or arc flash suit hood (Note 7) Arc-rated jacket, parka, or rainwear (AN)
FR Protective Equipment	Hard hat Safety glasses or safety goggles (SR) Hearing protection (ear canal inserts) Leather gloves (Note 2) Leather work shoes (AN)
Hazard/Risk Category 2	
FR Clothing, Minimum Arc Rating of 8 (Note 1)	Arc-rated long-sleeve shirt (Note 5) Arc-rated pants (Note 5) Arc-rated coverall (Note 6) Arc-rated face shield or arc flash suit hood (Note 7) Arc rated jacket, parka, or rainwear (AN)
FR Protective Equipment	Hard hat Safety glasses or safety goggles (SR) Hearing protection (ear canal inserts) Leather gloves (Note 2) Leather work shoes
Hazard/Risk Category 2*	
FR Clothing, Minimum Arc Rating of 8 (Note 1)	Arc-rated long-sleeve shirt (Note 5) Arc-rated pants (Note 5) Arc-rated coverall (Note 6) Arc-rated arc flash suit hood (Note 10) Arc-rated jacket, parka, or rainwear (AN)
FR Protective Equipment	Hard hat Safety glasses or safety goggles (SR) Hearing protection (ear canal inserts) Leather gloves (Note 2) Leather work shoes
Hazard/Risk Category 3	
FR Clothing, Minimum Arc Rating of 25 (Note 1)	Arc-rated long-sleeve shirt (AR) (Note 8) Arc-rated pants (AR) (Note 8) Arc-rated coverall (AR) (Note 8) Arc-rated arc flash suit jacket (AR) (Note 8) Arc-rated arc flash suit pants (AR) (Note 8) Arc-rated arc flash suit hood (Note 8) Arc-rated jacket, parka, or rainwear (AN)

(continues)

Table 130.7(C)(10) *Continued*

Hazard/Risk Category	Protective Clothing and PPE
FR Protective Equipment	Hard hat FR hard hat liner (AR) Safety glasses or safety goggles (SR) Hearing protection (ear canal inserts) Arc-rated gloves (Note 2) Leather work shoes
Hazard/Risk Category 4	
FR Clothing, Minimum Arc Rating of 40 (Note 1)	Arc-rated long-sleeve shirt (AR) (Note 9) Arc-rated pants (AR) (Note 9) Arc-rated coverall (AR) (Note 9) Arc-rated arc flash suit jacket (AR) (Note 9) Arc-rated arc flash suit pants (AR) (Note 9) Arc-rated arc flash suit hood (Note 9) Arc-rated jacket, parka, or rainwear (AN)
FR Protective Equipment	Hard hat FR hard hat liner (AR) Safety glasses or safety goggles (SR) Hearing protection (ear canal inserts) Arc-rated gloves (Note 2) Leather work shoes

AN = As needed (optional)
AR = As required
SR = Selection required
Notes:
1. See Table 130.7(C)(11). Arc rating for a garment or system of garments is expressed in cal/cm^2.
2. If rubber insulating gloves with leather protectors are required by Table 130.7(C)(9), additional leather or arc-rated gloves are not required. The combination of rubber insulating gloves with leather protectors satisfies the arc flash protection requirement.
3. The FR shirt and pants used for Hazard/ Risk Category 1 shall have a minimum arc rating of 4.
4. Alternate is to use FR coveralls (minimum arc rating of 4) instead of FR shirt and FR pants.
5. FR shirt and FR pants used for Hazard/ Risk Category 2 shall have a minimum arc rating of 8.
6. Alternate is to use FR coveralls (minimum arc rating of 8) instead of FR shirt and FR pants.
7. A face shield with a minimum arc rating of 4 for Hazard/Risk Category 1 or a minimum arc rating of 8 for Hazard/Risk Category 2, with 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.
8. An alternate is to use a total FR clothing system and hood, which shall have a minimum arc rating of 25 for Hazard/Risk Category 3.
9. The total clothing system consisting of FR shirt and pants and/or FR coveralls and/or arc flash coat and pants and hood shall have a minimum arc rating of 40 for Hazard/Risk Category 4.
10. Alternate is to use a face shield with a minimum arc rating of 8 and a balaclava (sock hood) with a minimum arc rating of 8 and which covers the face, head and neck except for the eye and nose areas.

(11) Protective Clothing Characteristics. Table 130.7(C)(11) lists examples of protective clothing systems and typical characteristics, including the degree of protection, for various clothing. The protective clothing selected for the corresponding Hazard/Risk Category number determined from Table 130.7(C)(9) (including associated notes) and the requirements of 130.7(C)(9) shall have an arc rating of at least the value listed in the last column of Table 130.7(C)(11).

FPN: The arc rating for a particular clothing system can be obtained from the FR clothing manufacturer.

Table 130.7(C)(11) Protective Clothing Characteristics

Hazard/Risk Category	Clothing Description	Required Minimum Arc Rating of PPE [J/cm^2(cal/cm^2)]
0	Nonmelting, flammable materials (i.e., untreated cotton, wool, rayon, or silk, or blends of these materials) with a fabric weight at least 4.5 oz/yd^2	N/A
1	Arc-rated FR shirt and FR pants or FR coverall	16.74 (4)
2	Arc-rated FR shirt and FR pants or FR coverall	33.47 (8)
3	Arc-rated FR shirt and pants or FR coverall, and arc flash suit selected so that the system arc rating meets the required minimum	104.6 (25)
4	Arc-rated FR shirt and pants or FR coverall, and arc flash suit selected so that the system arc rating meets the required minimum	167.36 (40)

Note: Arc rating is defined in Article 100 and can be either ATPV or E_{BT}. ATPV is defined in ASTM F 1959, *Standard Test Method for Determining the Arc Thermal Performance Value of Materials for Clothing*, as the incident energy on a material or a multilayer system of materials that results in a 50% 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, cal/cm^2. E_{BT} is defined in ASTM F 1959 as the incident energy on a material or material system that results in a 50% probability of breakopen. Arc rating is reported as either ATPV or E_{BT}, whichever is the lower value.

(12) Factors in Selection of Protective Clothing. Clothing and equipment that provide worker protection from shock and arc flash hazards shall be utilized. Clothing and equipment required for the degree of exposure shall be permitted to be worn alone or integrated with flammable, nonmelting apparel. If FR clothing is required, it shall cover associated parts of the body as well as all flammable apparel while allowing movement and visibility. All personal protective equipment shall be maintained in a sanitary and functionally effective condition. Personal protective equipment items will normally be used in conjunction with one another as a system to provide the appropriate level of protection.

FPN: Protective clothing includes shirts, pants, coveralls, jackets, and parkas worn routinely by workers who, under normal working conditions, are exposed to momentary electric arc and related thermal hazards. Flame-resistant rainwear worn in inclement weather is included in this category of clothing.

(a) Layering. Nonmelting, flammable fiber garments shall be permitted to be used as underlayers in conjunction with FR garments in a layered system for added protection. If nonmelting, flammable fiber garments are used as underlayers, the system arc rating shall be sufficient to prevent breakopen of the innermost FR layer at the expected arc exposure incident energy level to prevent ignition of flammable underlayers.

FPN: A typical layering system might include cotton underwear, a cotton shirt and trouser, and a FR coverall. Specific tasks might call for additional FR layers to achieve the required protection level.

(b) Outer Layers. Garments worn as outer layers over FR clothing, such as jackets or rainwear, shall also be made from FR material.

(c) Underlayers. Meltable fibers such as acetate, nylon, polyester, polypropylene, and spandex shall not be permitted in fabric underlayers (underwear) next to the skin.

Exception: An incidental amount of elastic used on nonmelting fabric underwear or socks shall be permitted.

FPN No. 1: FR garments (e.g., shirts, trousers, and coveralls) worn as underlayers that neither ignite nor melt and drip in the course of an exposure to electric arc and related thermal hazards generally provide a higher system arc rating than nonmelting, flammable fiber underlayers.

FPN No. 2: FR underwear or undergarments used as underlayers generally provide a higher system arc rating than nonmelting, flammable fiber underwear or undergarments used as underlayers.

(d) Coverage. Clothing shall cover potentially exposed areas as completely as possible. Shirt sleeves shall be fastened at the wrists, and shirts and jackets shall be closed at the neck.

(e) Fit. Tight-fitting clothing shall be avoided. Loose-fitting clothing provides additional thermal insulation because of air spaces. FR apparel shall fit properly such that it does not interfere with the work task.

(f) Interference. The garment selected shall result in the least interference with the task but still provide the necessary protection. The work method, location, and task could influence the protective equipment selected.

(13) 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 FR materials or constructed of nonmelting and nonflammable materials.

(b) Face Protection. Face shields shall have an arc rating suitable for the arc flash exposure. 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.

FPN: 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.

(c) Hand Protection.

(1) Leather or FR gloves shall be worn where required for arc flash protection.
(2) Where insulating rubber gloves are used for shock protection, leather protectors shall be worn over the rubber gloves.

FPN: Insulating rubber gloves and gloves made from layers of flame-resistant material provide hand protection against the arc flash hazard. Heavy-duty leather (e.g., greater than 12 oz/yd^2) gloves provide protection suitable up to Hazard/Risk Category 2. The leather protectors worn over insulating rubber gloves provide additional arc flash protection for the hands. During high arc flash exposures leather can shrink and cause a decrease in protection.

(d) Foot Protection. Heavy-duty leather work shoes provide some arc flash protection to the feet and shall be used in all tasks in Hazard/Risk Category 2 and higher and in all exposures greater than 4 cal/cm^2.

(14) Clothing Material Characteristics. FR clothing shall meet the requirements described in 130.7(C)(14) and 130.7(C)(15).

FPN No. 1: FR materials, such as flame-retardant treated cotton, meta-aramid, para-aramid, and poly-benzimidazole (PBI) fibers, provide thermal protection. These materials can ignite but will not continue to burn after the ignition source is removed. FR fabrics can reduce burn injuries during an arc flash exposure by providing a thermal barrier between the arc flash and the wearer.

FPN No. 2: Non-FR cotton, polyester-cotton blends, nylon, nylon-cotton blends, silk, rayon, and wool fabrics are flammable. These fabrics could ignite and continue to burn on the body, resulting in serious burn injuries.

FPN No. 3: Rayon is a cellulose-based (wood pulp) synthetic fiber that is a flammable but nonmelting material.

Clothing made from flammable synthetic materials that melt at temperatures below 315°C (600°F), such as acetate, acrylic, nylon, polyester, polyethylene, polypropylene, and spandex, either alone or in blends, shall not be used.

FPN: These materials melt as a result of arc flash exposure conditions, form intimate contact with the skin, and aggravate the burn injury.

Exception: Fiber blends that contain materials that melt, such as acetate, acrylic, nylon, polyester, polyethylene, polypropylene, and spandex shall be permitted if such blends in fabrics meet the requirements of ASTM F 1506, Standard Performance Specification for Textile Material for Wearing Apparel for Use by Electrical Workers Exposed to Momentary Electric Arc and Related Thermal Hazards, and if such blends in fabrics do not exhibit evidence of a melting and sticking hazard during arc testing according to ASTM F 1959, Standard Test Method for Determining the Arc Thermal Performance Value of Materials for Clothing [see also 130.7(C)(15)].

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(15) 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)(14) regarding melting, or made from materials that do not meet the flammability requirements shall not be permitted to be worn.

FPN: Some flame-resistant fabrics, such as non-FR modacrylic and nondurable flame-retardant treatments of cotton, are not recommended for industrial electrical or utility applications.

Exception No. 1: Nonmelting, flammable (non-FR) materials shall be permitted to be used as underlayers to FR clothing, as described in 130.7(C)(14), and also shall be permitted to be used for Hazard/Risk Category 0 as described in Table 130.7(C)(10).

Exception No. 2: Where the work to be performed inside the Arc Flash Protection Boundary exposes the worker to multiple hazards, such as airborne contaminants, under special permission by the authority having jurisdiction and where it can be shown that the level of protection is adequate to address the arc flash hazard, non-FR Personnel Protective Equipment shall be permitted.

(16) Care and Maintenance of FR Clothing and FR Arc Flash Suits.

(a) Inspection. FR apparel shall be inspected before each use. Work clothing or arc flash suits that are contaminated, or damaged to the extent their protective qualities are impaired, shall not be used. Protective items that become contaminated with grease, oil, or flammable liquids or combustible materials shall not be used.

(b) Manufacturer's Instructions. The garment manufacturer's instructions for care and maintenance of FR apparel shall be followed.

(c) Storage. FR apparel shall be stored in a manner that prevents physical damage; damage from moisture, dust, or other deteriorating agents; or contamination from flammable or combustible materials.

(d) Cleaning, Repairing, and Affixing Items. When FR clothing is cleaned, manufacturer's instructions shall be followed to avoid loss of protection. When FR clothing is repaired, the same FR materials used to manufacture the FR clothing shall be used to provide repairs. When trim, name tags, and/or logos are affixed to FR clothing, guidance in ASTM F 1506, *Standard Performance Specification for Textile Material for Wearing Apparel for Use by Electrical Workers Exposed to Momentary Electric Arc and Related Thermal Hazards*, shall be followed [see Table 130.7(C)(8)].

(D) Other Protective Equipment.

(1) Insulated Tools and Equipment. Employees shall use insulated tools and/or handling equipment when working inside the Limited Approach Boundary of exposed energized electrical conductors or circuit parts where tools or handling equipment might make accidental contact. Table 130.7(C)(9) provides further information for tasks that require insulated and insulating hand tools. Insulated tools shall be protected from damage to the insulating material.

FPN: See 130.2(B), Shock Protection Boundaries.

(a) Requirements for Insulated Tools. The following requirements shall apply to insulated tools:

(1) Insulated tools shall be rated for the voltages on which they are used.
(2) Insulated tools shall be designed and constructed for the environment to which they are exposed and the manner in which they are used.
(3) Insulated tools and equipment shall be inspected prior to each use. The inspection shall look for damage to the insulation or damage that may limit the tool from performing its intended function or could increase the potential for an incident (e.g., damaged tip on a screwdriver).

(b) Fuse or Fuse Holding Equipment. Fuse or fuse holder handling equipment, insulated for the circuit voltage, shall be used to remove or install a fuse if the fuse terminals are energized.

(c) Ropes and Handlines. Ropes and handlines used within the Limited Approach Boundary of exposed energized electrical conductors or circuit parts operating at 50 volts or more, or used where an electrical hazard exists, shall be nonconductive.

(d) Fiberglass-Reinforced Plastic Rods. Fiberglass-reinforced plastic rod and tube used for live line tools shall meet the requirements of applicable portions of electrical codes and standards dealing with electrical installation requirements.

FPN: For further information concerning electrical codes and standards dealing with installation requirements, refer to ASTM F 711, *Standard Specification for Fiberglass-Reinforced Plastic (FRP) Rod and Tube Used in Live Line Tools.*

(e) Portable Ladders. Portable ladders shall have nonconductive side rails if they are used where the employee or ladder could contact exposed energized electrical conductors or circuit parts operating at 50 volts or more or where an electrical hazard exists. Nonconductive ladders shall meet the requirements of ANSI standards for ladders listed in Table 130.7(F).

(f) Protective Shields. Protective shields, protective barriers, or insulating materials shall be used to protect each employee from shock, burns, or other electrically related injuries while that employee is working within the Limited Approach Boundary of energized conductors or circuit parts that might be accidentally contacted or where dangerous electric heating or arcing might occur. When normally enclosed energized conductors or circuit parts are exposed for maintenance or repair, they shall be guarded to protect unqualified persons from contact with the energized conductors or circuit parts.

(g) Rubber Insulating Equipment. Rubber insulating equipment used for protection from accidental contact with energized conductors or circuit parts shall meet the requirements of the ASTM standards listed in Table 130.7(F).

(h) Voltage-Rated Plastic Guard Equipment. Plastic guard equipment for protection of employees from accidental contact with energized conductors or circuit parts, or for protection of employees or energized equipment or material from contact with ground, shall meet the requirements of the ASTM standards listed in Table 130.7(F).

(i) Physical or Mechanical Barriers. Physical or mechanical (field-fabricated) barriers shall be installed no closer than the Restricted Approach Boundary distance given in Table 130.2(C). While the barrier is being installed, the Restricted Approach Boundary distance specified in Table 130.2(C) shall be maintained, or the energized conductors or circuit parts shall be placed in an electrically safe work condition.

(E) Alerting Techniques.

(1) Safety Signs and Tags. Safety signs, safety symbols, or accident prevention 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 ANSI Z535, *Series of Standards for Safety Signs and Tags*, given in Table 130.7(F).

Table 130.7(F) Standards on Other Protective Equipment

Subject	Number and Title
Ladders	ANSI A14.1, *Safety Requirements for Portable Wood Ladders,* 2000 ANSI A14.3, *Safety Requirements for Fixed Ladders,* 2002 ANSI A14.4, *Safety Requirements for Job-Made Ladders,* 2002 ANSI A14.5, *Safety Requirement for Portable Reinforced Plastic Ladders,* 2000
Safety signs and tags	ANSI Z535, *Series of Standards for Safety Signs and Tags,* 2006
Blankets	ASTM D 1048, *Standard Specification for Rubber Insulating Blankets,* 2005
Covers	ASTM D 1049, *Standard Specification for Rubber Covers,* 1998 (R 2002)
Line hoses	ASTM D 1050, *Standard Specification for Rubber Insulating Line Hoses,* 2005
Line hoses and covers	ASTM F 478, *Standard Specification for In-Service Care of Insulating Line Hose and Covers,* 1999 (R 2007)
Blankets	ASTM F 479, *Standard Specification for In-Service Care of Insulating Blankets,* 2006
Fiberglass tools/ladders	ASTM F 711, *Standard Specification for Fiberglass-Reinforced Plastic (FRP) Rod and Tube Used in Line Tools,* 2002 (R 2007)
Plastic guards	ASTM F 712, *Standard Test Methods and Specifications for Electrically Insulating Plastic Guard Equipment for Protection of Workers,* 2006
Temporary grounding	ASTM F 855, *Standard Specification for Temporary Protective Grounds to Be Used on De-energized Electric Power Lines and Equipment,* 2004
Insulated hand tools	ASTM F 1505, *Standard Specification for Insulated and Insulating Hand Tools,* 2007

FPN: Safety signs, tags, and barricades used to identify energized "look-alike" equipment can be employed as an additional preventive measure.

(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 cause an electrical hazard. Barricades shall be placed no closer than the Limited Approach Boundary given in Table 130.2(C).

(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.

(4) Look-Alike Equipment. Where work performed on equipment that is deenergized 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 altering methods in 130.7(E)(1), (2), or (3) shall be employed to prevent the employee from entering look-alike equipment.

(F) Standards for Other Protective Equipment. Other protective equipment required in 130.7(D) shall conform to the standards given in Table 130.7(F).

Chapter 2 Safety-Related Maintenance Requirements

ARTICLE 200 Introduction

200.1 Scope. Chapter 2 addresses the following requirements:

(1) Chapter 2 covers practical safety-related maintenance requirements for electrical equipment and installations in workplaces as included in 90.2. 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 on, near, or with such equipment. 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.

FPN: Refer to NFPA 70B, *Recommended Practice for Electrical Equipment Maintenance*, and ANSI/NETA MTS-2007, *Standard for Maintenance Testing Specification*, for guidance on maintenance frequency, methods, and tests.

ARTICLE 205 General Maintenance Requirements

205.1 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.

205.2 Single Line Diagram. A single line diagram, where provided for the electrical system, shall be maintained.

205.3 General Maintenance Requirements. Overcurrent protective devices shall be maintained in accordance with the manufacturers' instructions or industry consensus standards.

205.4 Spaces About Electrical Equipment. All working space and clearances required by electrical codes and standards shall be maintained.

FPN: For further information concerning spaces about electrical equipment, see Article 110, Parts II and III, of *NFPA 70, National Electrical Code*.

205.5 Grounding and Bonding. Equipment, raceway, cable tray, and enclosure bonding and grounding shall be maintained to ensure electrical continuity.

205.6 Guarding of Energized Conductors and Circuit Parts. Enclosures shall be maintained to guard against accidental contact with energized conductors and circuit parts and other electrical hazards.

205.7 Safety Equipment. Locks, interlocks, and other safety equipment shall be maintained in proper working condition to accomplish the control purpose.

205.8 Clear Spaces. Access to working space and escape passages shall be kept clear and unobstructed.

205.9 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.

205.10 Warning Signs. Warning signs, where required, shall be visible, securely attached, and maintained in legible condition.

205.11 Identification of Circuits. Circuit or voltage identification shall be securely affixed and maintained in updated and legible condition.

205.12 Single and Multiple Conductors and Cables. Electrical cables and single and multiple conductors shall be maintained free of damage, shorts, and ground that would present a hazard to employees.

205.13 Flexible Cords and Cables. Flexible cords and cables shall be maintained to avoid strain and damage.

(1) Damaged Cords and Cables. Cords and cables shall not have worn, frayed, or damaged areas that present an electrical hazard to employees.

(2) Strain Relief. Strain relief of cords and cables shall be maintained to prevent pull from being transmitted directly to joints or terminals.

ARTICLE 210
Substations, Switchgear Assemblies, Switchboards, Panelboards, Motor Control Centers, and Disconnect Switches

210.1 Enclosures. Enclosures shall be kept free of material that would create a hazard.

210.2 Area Enclosures. Fences, physical protection, enclosures, or other protective means, where required to guard against unauthorized access or accidental contact with exposed energized conductors and circuit parts, shall be maintained.

210.3 Conductors. Current-carrying conductors (buses, switches, disconnects, joints, and terminations) and bracing shall be maintained to:

(1) Conduct rated current without overheating

(2) Withstand available fault current

210.4 Insulation Integrity. Insulation integrity shall be maintained to support the voltage impressed.

210.5 Protective Devices. Protective devices shall be maintained to adequately withstand or interrupt available fault current.

FPN: Failure to properly maintain protective devices can have an adverse effect on the arc flash hazard analysis incident energy values.

ARTICLE 215
Premises Wiring

215.1 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.

215.2 Open Wiring Protection. Open wiring protection, such as location or barriers, shall be maintained to prevent accidental contact.

215.3 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 shall apply to controllers, including 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 accidental contact with energized conductors and circuit parts and to prevent other electrical or mechanical hazards shall be maintained.

ARTICLE 225
Fuses and Circuit Breakers

225.1 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.

225.2 Molded-Case Circuit Breakers. Molded-case circuit breakers shall be maintained free of cracks in cases and cracked or broken operating handles.

225.3 Circuit Breaker Testing. 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 Terminal Boxes. Terminal chambers, enclosures, and terminal boxes shall be maintained to guard against accidental contact with energized conductors and circuit parts and other electrical hazards.

230.2 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.

FPN: 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.

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 apply:

(1) No energized parts are exposed.

Exception to (1): Intrinsically safe and nonincendive circuits.

(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 shall be wrenchtight and enclosure covers shall be 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 Ventilation. Ventilation systems, forced or natural, shall be maintained to prevent buildup of explosive mixtures. This maintenance shall include a functional test of any associated detection and alarm systems.

240.2 Eye and Body Wash Apparatus. Eye and body wash apparatus shall be maintained in operable condition.

240.3 Cell Flame Arresters and Cell Ventilation. Battery cell ventilation openings shall be unobstructed, and cell flame arresters shall be maintained.

ARTICLE 245
Portable Electric Tools and Equipment

245.1 Maintenance Requirements for Portable Electric Tools and Equipment. Attachment plugs, receptacles, cover plates, and cord connectors shall be maintained such that the following apply:

(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 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
(3) Rubber gloves, sleeves, and leather protectors
(4) Voltage test indicators
(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) Safety grounding equipment
(11) Dielectric footwear
(12) Protective clothing
(13) Bypass jumpers
(14) Insulated and insulating hand tools

250.2 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 respective ASTM standards.

(B) Testing. The insulation of protective equipment and protective tools, such as items (1) through (14) of 250.1, 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, unless specified otherwise by the respective ASTM standards.

250.3 Safety Grounding Equipment.

(A) Visual. 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, safety grounds that have been repaired or modified shall be tested.

FPN: Guidance for inspecting and testing safety grounds is provided in ASTM F 2249, *Standard Specification for In-Service Test Methods for Temporary Grounding Jumper Assemblies Used on De-Energized Electric Power Lines and 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.

FPN: Guidance for testing of grounding and testing devices is provided in Section 9.5 of IEEE C37.20.6-1997, *Standard for 4.76 kV to 38 kV-Rated Ground and Test Devices Used in Enclosures*.

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 employer shall provide safety-related work practices and employee training. The employee shall follow those work practices.

300.3 Organization. Chapter 3 of this standard is divided into articles. Article 300 applies generally. Article 310 applies to electrolytic cells. Article 320 applies to batteries and battery rooms. Article 330 applies to lasers. Article 340 applies to power electronic equipment. Article 350 applies to R&D laboratories.

FPN: The NFPA 70E Technical Committee might develop additional chapters for other types of special equipment in the future.

ARTICLE 310 Safety-Related Work Practices for Electrolytic Cells

310.1 Scope. The requirements of this chapter shall apply to the electrical safety–related work practices used in the types of electrolytic cell areas.

FPN No. 1: See Annex L for a typical application of safeguards in the cell line working zone.

FPN No. 2: For further information about electrolytic cells, see *NFPA 70, National Electrical Code*, Article 668.

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310.2 Definitions. For the purposes of this chapter, the following definitions shall apply.

Battery Effect. A voltage that exists on the cell line after the power supply is disconnected.

FPN: Electrolytic cells could exhibit characteristics similar to an electrical storage battery, and thus a hazardous voltage could exist after the power supply is disconnected from the cell line.

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, personal protective equipment, operating procedures, and work checklists.

310.3 Safety Training.

(A) General. The training requirements of this chapter shall apply to employees who are exposed to the risk of electrical hazard in the cell line working zone defined in 110.6 and shall supplement or modify the requirements of 110.8, 120.1, 130.1, and 130.5.

(B) Training Requirements. Employees shall be trained to understand the specific 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 personal protective equipment. Training for a qualified person shall include the following:

(1) The skills and techniques to avoid dangerous contact with hazardous voltages between energized surfaces and between energized surfaces and ground. Skills and techniques might include temporarily insulating or guarding parts to permit the employee to work on energized parts.
(2) The 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 recognize electrical hazards to which they may 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 by the designated qualified person in charge of the possible hazards to ensure 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 may require contact by employees with exposed energized surfaces such as buses, electrolytic cells, and their attachments. The approach distances referred to in Table 130.2(C) 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 deenergized cell lines. Hazardous battery effect voltages shall be dissipated to consider a cell line deenergized.

FPN No. 1: Exposed energized surfaces might not establish a hazardous condition. A hazardous electrical condition is related to current flow through the body causing shock and arc flash burns and arc blasts. Shock is a function of many factors, including resistance through the body and through skin, of return paths, of paths in parallel with the body, and of system voltages. Arc flash burns and arc blasts are a function of the current available at the point involved and the time of arc exposure.

FPN 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 of this standard.

(B) Signs. Permanent signs shall clearly designate electrolytic cell areas.

(C) Electrical Arc Flash Hazard Analysis. The requirements of 130.3, Arc Flash Hazard Analysis, shall not apply to electrolytic cell line work zones.

(1) Arc Flash Hazard Analysis Procedure. Each task performed in the electrolytic cell line working zone shall be analyzed for the risk of arc flash hazard injury. If there is risk of personal injury, appropriate measures shall be taken to protect persons exposed to the arc flash hazards. These measures shall include one or more of the following:

(1) Provide appropriate personal protective equipment *[see 310.5(D)(2)]* to prevent injury from the arc flash hazard.
(2) Alter work procedures to eliminate the possibility of the arc flash hazard.
(3) Schedule the task so that work can be performed when the cell line is deenergized.

(2) Routine Tasks. Arc flash hazard risk analysis shall be done for all routine tasks performed in the cell line work zone. The results of the arc flash hazard analysis 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 hazard risk analysis 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 possibility of a hazardous arc flash.

(4) Arc Flash Hazards. If the possibility 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, 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. Personal protective equipment shall provide protection from hazardous electrical conditions. Personal protective equipment shall include one or more of the following as determined by authorized management:

(1) Shoes, boots, or overshoes for wet service
(2) Gloves for wet service
(3) Sleeves for wet service
(4) Shoes 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) Faceshield (polycarbonate or similar nonmelting type)

(a) Standards for Personal Protective Equipment. Personal and other protective equipment shall be appropriate for conditions, as determined by authorized management, and shall not be required to meet the equipment standards in 130.7(C)(8) through 130.7(F) and in Table 130.7(C)(8) and Table 130.7(F).

(b) Testing of Personal Protective Equipment. Personal protective equipment shall be verified with regularity and by methods that are consistent with the exposure of employees to hazardous electrical conditions.

(3) Barriers. Barriers shall be devices that prevent contact with energized or grounded surfaces that could present a hazardous electrical condition.

(4) Voltage Equalization. Voltage equalization shall be permitted by bonding a conductive surface to an electrically energized surface, either directly or through a resistance, so that there is insufficient voltage to create an electrical hazard.

(5) Isolation. Isolation shall be the placement of equipment or items in locations such that employees are unable to simultaneously contact exposed conductive surfaces that could present a hazardous electrical condition.

(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.

FPN: Tools and other devices of magnetic material could be difficult to handle in energized cells' areas 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 668.32 of *NFPA 70, National Electrical Code*. 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 utilize 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.

FPN: The American Conference of Government Industrial Hygienists (ACGIH) recommends that persons with implanted pacemakers should not be exposed to magnetic flux densities above 10 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.

FPN: The order of preference for the energy source for portable handheld equipment is considered to be: (1) battery powered, (2) pneumatic, (3) a portable generator, (4) a nongrounded–type receptacle connected to an ungrounded source.

(A) Portable Electrical Equipment. The grounding requirements of 110.9(B)(2) shall not be permitted within an energized cell line working zone. Portable electrical equipment shall meet the requirements of 668.20 of *NFPA 70, National Electrical Code*. Power supplies for portable electric equipment shall meet the requirements of 668.21 of *NFPA 70, National Electrical Code*.

(B) Auxiliary Nonelectric Connections. Auxiliary nonelectric connections such as air, water, and gas hoses shall meet the requirements of 668.31 of *NFPA 70, National Electrical Code*. 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.

FPN: 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
Safety Requirements Related to Batteries and Battery Rooms

320.1 Scope. The requirements of this article shall apply to the safety requirements related to installations of stationary storage batteries and battery rooms with a stored capacity exceeding 1 kWh or a nominal voltage that exceeds 50 volts but does not exceed 650 volts.

FPN: For further information, refer to the following documents:

(1) NFPA 1, *Fire Code*, 2009
(2) *NFPA 70*, *National Electrical Code*, Article 480, Storage Batteries, 2008
(3) IEEE Std. 450, *IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications*, 2002
(4) IEEE Std. 484, *Recommended Practice for Installation Design and Installation of Vented Lead-Acid Batteries for Stationary Applications*, 2002
(5) IEEE 485, *IEEE Recommended Practice for Sizing Lead-Acid Storage Batteries for Stationary Applications*, 1997
(6) IEEE Std. 937, *Recommended Practice for Installation and Maintenance of Lead-Acid Batteries for Photovoltaic Systems*, 2007
(7) IEEE 1106, *IEEE Recommended Practice for Installation, Maintenance, Testing, and Replacement of Vented Nickel-Cadmium Batteries for Stationary Applications*, 2005
(8) IEEE 1184, *IEEE Guide for Batteries for Uninterruptible Power Supply Systems*, 2006
(9) IEEE Std. 1187, *Recommended Practice for Installation Design and Installation of Valve-Regulated Lead-Acid Storage Batteries for Stationary Applications*, 2002
(10) IEEE 1188, *IEEE Recommended Practice for Maintenance, Testing, and Replacement of Valve Regulated Lead-Acid (VRLA) Batteries for Stationary Applications*, 2005
(11) IEEE 1189, *IEEE Guide for Selection of Valve-Regulated Lead-Acid (VRLA) Batteries for Stationary Applications*, 1996
(12) IEEE 1375, *IEEE Guide for the Protection of Stationary Battery Systems*, 1998 (R 2003)
(13) OSHA 29 CFR 1926.441, "Batteries and battery charging"
(14) OSHA 29 CFR 1910.305(j)(7), "Storage batteries"

320.2 Definitions. For the purposes of this chapter, the following definitions shall apply.

Accessories. Items supplied with the battery to facilitate the continued operation of the battery.

Authorized Person. The person in charge of the premises, or other person appointed or selected by the person in charge of the premises, to perform certain duties associated with the battery installation on the premises.

Battery. An electrochemical system capable of storing under chemical form the electric energy received and which can give it back by reconversion.

Battery Enclosure. An enclosure containing batteries that is suitable for use in an area other than a battery room or an area restricted to authorized personnel.

Battery Room. Room specifically intended for the installation of batteries that have no other protective enclosure.

Capacity. The quantity of electricity (electric charge) usually expressed in ampere-hour (A-h) that a fully charged battery can deliver under specified conditions.

Cell. An assembly of electrodes and electrolyte that constitutes the basic unit of the battery.

Charging. An operation during which a battery receives electric energy that is converted to chemical energy from an external circuit. The quantity of electric energy then is known as the charge and is usually measured in ampere-hour.

Constant Current Charge. A charge during which the current is maintained at a constant value.

Constant Voltage Charge. A charge during which the voltage across the battery terminals is maintained at a constant value.

Container. A container for the plate pack and electrolyte of a cell of a material impervious to attack by the electrolyte.

Discharging. An operation during which a battery delivers current to an external circuit by the conversion of chemical energy to electric energy.

Electrolyte. A solid, liquid, or aqueous salt solution that permits ionic conduction between positive and negative electrodes of a cell.

Electrolyte Density. Density of the electrolyte, measured in kilograms per cubic meter at a specific temperature (density of pure water = 1000 kilograms per cubic meter at 4°Celsius).

FPN: The density of an electrolyte was formerly indicated by its specific gravity. Specific gravity is the ratio of the density of the electrolyte to the density of pure water. S.G. = (electrolyte density in kilograms per cubic meter)/1000.

Flame-Arrested Vent Plug. A vent plug design that provides protection against internal explosion when the cell or battery is exposed to a naked flame or external spark.

Gassing. The formation of gas produced by electrolyte.

Intercell and Interrow Connection. Connections made between rows of cells or at the positive and negative terminals of the battery that might include lead-plated terminal plates, cables with lead, plated lugs, and lead-plated rigid copper connectors, and for nickel-cadmium cells, nickel-plated copper intercell connections.

Intercell Connector Safety Cover. Insulated cover to shroud the terminals and intercell connectors from inadvertent contact by personnel or accidental short circuiting.

Nominal Voltage. An approximate value of voltage used to identify a type of battery.

Pilot Cell. A selected cell of a battery that is considered to be representative of the average state of the battery or part thereof.

Prospective Fault Current. The highest level of fault current that can 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.

Rate. The current expressed in amperes at which a battery is discharged.

Secondary Battery. Two or more rechargeable cells electrically connected and used as a source of energy.

Secondary Cell. A rechargeable assembly of electrodes and electrolytes that constitutes the basic unit of a battery.

Stepped Stand. Containers placed in rows and these rows are placed at different levels to form a stepped arrangement.

Terminal Post. A part provided for the connection of a cell or a battery to external conductors.

Tiered Stand. Where rows of containers are placed above containers of the same or another battery.

Valve-Regulated Lead Acid (VRLA) Battery. A battery that has no provision for the addition of water or electrolyte or for external measurement of electrolyte specific gravity.

Vented Battery. A battery in which the products of electrolysis and evaporation are allowed to escape freely to the atmosphere.

Vent Plug. A part closing the filling hole that is also employed to permit the escape of gas.

VRLA. Valve-regulated lead acid storage battery.

320.3 Battery Connections.

(A) Method of Connection.

FPN No. 1: Batteries usually consist of a number of identical cells connected in series. The voltage of a series connection of cells is the voltage of a single cell multiplied by the number of cells. If cells of sufficiently large capacity are available, then two or more series-connected strings of equal numbers of cells could be connected in parallel to achieve the desired rated capacity. The rated capacity of such a battery is the sum of the capacities of a group of cells comprising a single cell from each of the parallel branches.

FPN No. 2: Cells of unequal capacity should not be connected in series.

FPN No. 3: Parallel connections of batteries are not recommended for constant current-charging applications.

FPN No. 4: Cells connected in series have high voltages that could produce a shock hazard.

(B) Battery Short-Circuit Current. The battery manufacturer shall be consulted regarding the sizing of the battery short-circuit protection.

Exception: If information regarding the short-circuit protection of a battery is not available from the manufacturer, the prospective fault level at the battery terminals shall be considered to be twenty times the nominal battery capacity at the 3-hour rate.

FPN: Battery short-circuit current = (battery voltage)/(internal resistance).

(C) Connection Between Battery and DC Switching Equipment.

(1) General. Any cable, busbar, or busway forming the connection between the battery terminal and the dc switching equipment shall be rated to withstand the prospective short-circuit current.

FPN: The available short-circuit current should be assumed for a time period of at least 1 second.

Outside busbars and cables should be both of the following:

(1) Insulated from the battery terminals to a height of 3.75 m (12 ft 4 in.), or to the battery room ceiling, whichever is lower
(2) Clearly identified and segregated from any other supply circuits

(2) Cable. Cables shall be effectively clamped and sufficient support shall be provided throughout the length of cables to minimize sag and prevent undue strain from being imposed on the cable.

(3) Busbars.

FPN: Busbars should be insulated throughout their length by an insulating material not affected by the acid fumes that are present in a battery room. The steelwork supporting the busbar system should be installed so as not to restrict access to the battery for the purpose of maintenance.

(4) Busways.

FPN: Busways should be fully enclosed and able to withstand high levels of fault current without danger.

(D) DC Switching Equipment. Switching equipment shall comply with applicable installation requirements.

FPN: For further information concerning electrical installation requirements, refer to *NFPA 70, National Electrical Code*.

(E) Terminals and Connectors. Intercell and battery terminal connections shall be constructed of materials, either intrinsically resistant to corrosion or suitably protected by surface finish against corrosion. The joining of materials that are incompatible in a corrosive atmosphere shall be avoided.

FPN No. 1: To prevent mechanical stress on the battery terminal posts, the connection between the battery and any busbar system or large cable should be by insulated flexible cable of suitable rating.

FPN No. 2: The takeoff battery terminals and busbar connections should be shrouded or protected by physical barriers to prevent accidental contact.

(F) DC Systems Grounding and Ground-Fault Detection. One of the four types of available dc grounding systems, described as Type 1 through Type 4, shall be used.

• (1) Type 1. The ungrounded dc system in which neither pole of the battery is connected to ground

FPN: Work on such a system should be carried out with the battery isolated from the battery charger. If an intentional ground is placed at one end of the battery, an increased shock hazard would exist between the opposite end of the battery and ground. Also, if another ground develops within the system (e.g., dirt and acid touching the battery rack), it creates a short circuit that could cause a fire. An ungrounded dc system should be equipped with an alarm to indicate the presence of a ground fault.

(2) Type 2. The solidly grounded dc system where either the positive or negative pole of the battery is connected directly to ground

(3) Type 3. The resistance grounded dc system, where the battery is connected to ground through a resistance

FPN: The resistance is used to permit operation of a current relay, which in turn initiates an alarm.

(4) Type 4. A tapped solid ground, either at the center point or at another point to suit the load system

(G) Protection of DC Circuits. DC circuits shall be protected in accordance with the *NEC*.

(H) Alarms.

(1) Abnormal Battery Conditions. Alarms shall be provided for early warning of the following abnormal conditions of battery operation:

(1) For vented batteries:
   a. Overvoltage
   b. Undervoltage
   c. Overcurrent
   d. Ground fault
(2) For VRLA batteries, items (1)(a) through (1)(d) plus overtemperature, as measured at the pilot cell

(2) Warning Signal. The alarm system shall provide an audible alarm and visual indication at the battery location, and where applicable, at a remote manned control point.

320.4 Installations of Batteries. Installations using secondary batteries vary considerably in size, from large uninterruptible power supply systems, telecommunication systems, and demand load–leveling installations to small emergency lighting installations. Secondary batteries permanently installed in or on buildings, structures, or premises, having a nominal voltage exceeding 24 volts and a capacity exceeding 10 ampere-hours at the 1-hour rate, shall be installed in a battery room or battery enclosure.

(A) Location. Batteries shall be installed in one of the following:

(1) Dedicated battery rooms
(2) An area accessible only to authorized personnel
(3) An enclosure with lockable doors or a suitable housing that shall require a key or tool to gain access to the batteries and shall provide protection against electrical contact and damage to the battery

(B) Arrangement of Cells. The arrangement of cells in a battery system shall meet the following requirements:

(1) All cells shall be readily accessible for such inspection and maintenance as is required by the manufacturer.
(2) The space between adjacent containers shall be no less than that recommended by the battery manufacturer or, where manufacturer guidance is not available, shall be at least 12.5 mm (½ in.).
(3) Each cell shall be readily accessible without having to reach over another cell, or alternatively, all exposed energized surfaces shall be shrouded.

(C) Ventilation for Batteries of the Vented Type.

(1) Installation. Batteries shall be located in rooms or enclosures with outside vents or in well-ventilated rooms, so arranged to prevent the escape of fumes, gases, or electrolyte spray into other areas.

(2) Ventilation. Ventilation shall be provided so as to prevent liberated hydrogen gas from exceeding 1 percent concentration.

(a) Adequacy. Room ventilation shall be adequate to assure that pockets of trapped hydrogen gas do not occur, particularly at the ceiling, to prevent the accumulation of an explosive mixture.

(b) Equipment Considerations. Exhaust air shall not pass over electrical equipment unless the equipment is listed for the use.

(c) Location of Inlets. Inlets shall be no higher than the tops of the battery cells and outlets at the highest level in the room.

FPN: The maximum hydrogen evolution rate for batteries should be obtained for the condition when the maximum charging current available from a constant current battery charger is applied into a fully charged battery or the current that would be expected from a constant voltage charger in boost/equalize mode. If possible, contact manufacturer for hydrogen evolution rates.

(3) Mechanical Ventilation. Where mechanical ventilation is installed, the following shall be required:

(1) Airflow sensors shall be installed to initiate an alarm if the ventilation fan becomes inoperative.
(2) Control equipment for the exhaust fan shall be located more than 1.8 m (6 ft) from the battery and a minimum of 100 mm (4 in.) below the lowest point of the highest ventilation opening.
(3) Where mechanical ventilation is used in a dedicated battery room, all exhaust air shall be discharged outside the building.
(4) Fans used to remove air from a battery room shall not be located in the duct unless the fan is listed for the use.

(D) Ventilation for VRLA Type.

(1) Ventilation Requirements. Ventilation shall be provided so as to prevent liberated hydrogen gas from exceeding a 1 percent concentration.

(a) Adequacy. Ventilation shall be adequate to ensure that pockets of trapped hydrogen gas do not occur, particularly at the ceiling of a room or at the top of a cabinet, to prevent the accumulation of an explosive mixture.

(b) Exhaust. Exhaust air shall not pass over electrical equipment unless the equipment is listed for the use.

(c) Inlets. Inlets shall be no higher than the tops of the battery cells and outlets at the highest level in the room.

(2) Mechanical Ventilation. Where mechanical ventilation is installed, the following shall be required:

(1) Airflow sensors shall be installed to initiate an alarm if the ventilation fan becomes inoperative.
(2) Control equipment for the exhaust fan in dedicated battery rooms shall be located more than 1.8 m (6 ft) from the battery and a minimum of 100 mm (4 in.) below the lowest point of the highest ventilation opening.
(3) Where mechanical ventilation is used in a dedicated battery room, all exhaust air shall be discharged outside the building.
(4) Fans used to remove air from a battery room shall not be located in the duct unless the fan is listed for the use.

(3) Temperature Requirements. Thermal management shall be provided to maintain battery design temperature to prevent thermal runaway that can cause cell meltdown, leading to a fire or explosion.

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320.5 Battery Room Requirements.

(A) General. The battery room shall be accessible only to authorized personnel and shall be locked when unoccupied.

(1) Battery Rooms or Areas Restricted to Authorized Personnel.

(a) Doors. The battery room and enclosure doors shall open outward. The doors shall be equipped with quick-release, quick-opening hardware.

• (b) Foreign Piping. Foreign piping that is not protected against corrosion shall not pass through the battery room.

(c) Passageways. Passageways shall be of sufficient width to allow the replacement of all battery room equipment.

(d) Emergency Exits. Emergency exits shall be provided as required.

(e) Access. Access and entrance to working space about the battery shall be provided as required by 110.26 of *NFPA 70, National Electrical Code*.

FPN: Provision to include emergency services personnel and their equipment should be made.

(2) Battery Enclosures. All cells shall be readily accessible for inspection, cleaning, maintenance, and removal.

(3) Battery Room Floor Loading. Floor loading shall take into account the seismic activity.

(4) Battery Room Floor Construction and Finish. Battery systems containing free-flowing liquid electrolyte shall be provided with spill containment systems in accordance with the fire code.

FPN No. 1: The battery room floor should be of concrete construction. The floor should be graded so any spillage of electrolyte will drain to an area where the electrolyte could be neutralized before disposal. (The battery manufacturer should be consulted on the appropriate floor grading so as to reduce connection alignment problems.)

FPN No. 2: The floor should be covered with an electrolyte-resistant, durable, antistatic, and slip-resistant surface overall, to a height 100 mm (4 in.) on each wall. Where batteries are mounted against a wall, the wall behind and at each end of the battery should be coated to a distance of 500 mm (20 in.) around the battery with an electrolyte-resistant paint.

(B) Battery Layout and Floor Area. The battery layout and floor area shall meet the following requirements:

(1) Battery Layout. The installation shall be so designed that, unless there is a physical barrier, potential differences exceeding 120 volts shall be separated by a distance of not less than 900 mm (36 in.) measured in a straight line in any direction.

(2) Floor Area. The floor area shall allow for the following clearances:

(a) Aisle Width. The minimum aisle width shall be 900 mm (36 in.).

(b) Single-Row Batteries. In addition to the minimum aisle width, there shall be a minimum clearance of 25 mm (1 in.) between a cell and any wall or structure on the side not requiring access for maintenance. This required clearance does not preclude battery stands touching adjacent walls or structures, provided that the battery shelf has a free air space for no less than 90 percent of its length.

(c) Double-Row Batteries. The minimum aisle width shall be maintained on one end and both sides of the battery. The remaining end shall have a minimum clearance of 100 mm (4 in.) between any wall or structure and a cell.

(d) Tiered Batteries. Tiered batteries shall meet the requirements of 320.5(B)(2)(a), 320.5(B)(2)(b), and 320.5(B)(2)(c). In addition, there shall be a minimum clearance of 300 mm (12 in.) between the highest point of the battery located on the bottom tier and the lowest point of the underside of the upper runner bearers.

(e) Where a charger, or other associated electrical equipment, is located in a battery room, the aisle width between any battery and any part of the battery-charging equipment (including the doors when fully open) shall be at least 900 mm (36 in.).

(C) Takeoff Battery Terminals and Outgoing Busbars and Cables.

(1) Takeoff Battery Terminals. Outgoing busbars and cables shall meet the following requirements:

(1) Be insulated from the battery terminals to a height of 3.75 m (12 ft 4 in.) or the battery room ceiling, whichever is lower
(2) Be clearly identified and segregated from any other supply circuits
(3) Prevent mechanical stress on the battery posts

(2) Outgoing Busbars and Cables. The takeoff battery terminals and busbar connections shall comply with either of the following:

(1) Be shrouded
(2) Be protected by physical barriers to prevent accidental contact

(D) Intertier and Interrow Connections. The battery terminals and busbar and cable interconnections between rows shall comply with either of the following:

(1) Be shrouded
(2) Be protected by insulating barriers to prevent accidental contact

(E) Barriers. To avoid accidental contact with intercell connections, the following insulating barriers shall be installed:

(1) Double-Row Batteries. Insulating barriers between double-row batteries shall be installed for the entire length of the battery extending 100 mm (4 in.) past the end terminal unless those terminals are shrouded. The barrier shall extend vertically a minimum of 400 mm (16 in.) above the exposed portion of the intercell connections and a minimum of 25 mm (1 in.) below the top of the battery container.

(2) Batteries Above 120 Volts. Where the nominal voltage of the battery exceeds 120 volts, interblock barriers shall be installed to sectionalize the battery into voltage blocks not exceeding 120 volts. Barriers shall extend a minimum of 50 mm (2 in.) out from the exposed side of the battery and a minimum of 400 mm (16 in.) above the top of the container.

(F) Illumination.

(1) Battery Room Lighting. Battery room lighting shall be installed to provide a minimum level of illumination of 300 lux (30 ft-candles).

(2) Emergency Lighting. Emergency illumination shall be provided for safe egress from the battery room.

(G) Location of Luminaires and Switches. Luminaires shall not be installed directly over cells or exposed energized conductors and circuit parts. Switches for the controls of the luminaires shall be readily accessible.

(H) Power. General-purpose outlets shall be installed for the maintenance of the battery.

(I) Location of General-Purpose Outlets. General-purpose outlets shall be installed at least 1.8 m (6 ft) from the battery and a minimum of 100 mm (4 in.) below the lowest point of the highest ventilation opening.

320.6 Battery Enclosure Requirements.

(A) Enclosure Construction.

(1) General. Where enclosures are designed to accommodate the battery, the battery charger, and other equipment, separate compartments shall be provided for each.

(2) Ventilation. The ventilation openings for the battery compartment shall:

(a) Prevent the exchange of air within compartments containing electrical equipment

(b) Prevent accumulation of flammable gas in pockets exceeding 1 percent concentration

(B) Battery Takeoff Terminals and Outgoing Busbars and Cables. Outgoing busbars and cables shall be fully insulated, and the battery takeoff terminals shall comply with the following:

(1) Takeoff terminals shall prevent excessive mechanical stress on the battery posts.
(2) Takeoff terminals shall comply with either of the following:
    (1) Be fully shrouded
    (2) Have physical barriers installed between them

(C) Battery Compartment Circuits. Only circuits associated with the battery shall be installed within a battery compartment of the enclosure.

320.7 Protection.

(A) General.

(1) Marking. When the battery capacity exceeds 100 ampere-hours or where the nominal battery voltage is in excess of 50 volts, suitable warning notices indicating the battery voltage and the prospective short-circuit current of the installation shall be displayed.

(2) Overcurrent Protection. Each output conductor shall be individually protected by a fuse or circuit breaker positioned as close as practicable to the battery terminals.

(3) Protective Equipment. Protective equipment shall not be located in the battery compartment of the enclosure unless provided as part of a listed assembly.

(B) Switching and Control Equipment. Switching and control equipment shall comply with *NFPA 70, National Electrical Code*, and shall be listed for the application.

(C) Ground-Fault Protection. For an ungrounded battery of nominal voltage in excess of 120 volts, a ground-fault detector shall be provided to initiate a ground-fault alarm.

(D) Main Isolating Switch. The battery installation shall have an isolating switch installed as close as practicable to the main terminals of the battery. Where a busway system is installed, the isolating switch may be incorporated into the end of the busway.

(E) Section Isolating Equipment. Where the battery section exceeds 250 volts, the installation shall include an isolating switch, plugs, or links, as required, to isolate sections of the battery, or part of the battery, for maintenance.

(F) Warning Signs. The following signs shall be posted in appropriate locations:

(1) Electrical hazard warning signs indicating the shock hazard due to the battery voltage and the arc hazard due to the prospective short-circuit current
(2) Chemical hazard warning signs indicating the danger of hydrogen explosion from open flame and smoking and the danger of chemical burns from the electrolyte
(3) Notice for personnel to use and wear protective equipment and apparel
(4) Notice prohibiting access to unauthorized personnel

320.8 Personnel Protective Equipment. The following protective equipment shall be available to employees performing battery maintenance:

(1) Goggle and face shields
(2) Chemical-resistant gloves
(3) Protective aprons
(4) Protective overshoes
(5) Portable or stationary water facilities for rinsing eyes and skin in case of electrolyte spillage

320.9 Tools and Equipment. Tools and equipment for work on batteries shall comply with the following:

(1) Be of the nonsparking type
(2) Be equipped with handles listed as insulated for the maximum working voltage

ARTICLE 330
Safety-Related Work Practices for Use of Lasers

330.1 Scope. The requirements of this article shall apply to the use of lasers in the laboratory and the workshop.

330.2 Definitions. For the purposes of this article, the following definitions shall apply.

Fail Safe. The design consideration in which failure of a component does not increase the hazard. In the failure mode, the system is rendered inoperative or nonhazardous.

Fail Safe Safety Interlock. An interlock that in the failure mode does not defeat the purpose of the interlock, for example, an interlock that is positively driven into the off position as soon as a hinged cover begins to open, or before a detachable cover is removed, and that is positively held in the off position until the hinged cover is closed or the detachable cover is locked in the closed position.

Laser. Any device that can be made to produce or amplify electromagnetic radiation in the wavelength range from 100 nm to 1 mm primarily by the process of controlled stimulated emission.

• **Laser Energy Source.** Any device intended for use in conjunction with a laser to supply energy for the excitation of electrons, ions, or molecules. General energy sources, such as electrical supply services or batteries, shall not be considered to constitute laser energy sources.

• **Laser Product.** Any product or assembly of components that constitutes, incorporates, or is intended to incorporate a laser or laser system.

Laser Radiation. All electromagnetic radiation emitted by a laser product between 100 nm and 1 mm that is produced as a result of a controlled stimulated emission.

Laser System. A laser in combination with an appropriate laser energy source with or without additional incorporated components.

330.3 Safety Training.

(A) Personnel to Be Trained. Employers shall provide training for all operator and maintenance personnel.

(B) Scope of Training. The training shall include, but is not limited to, the following:

(1) Familiarization with laser principles of operation, laser types, and laser emissions
(2) Laser safety, including the following:
 (1) System operating procedures
 (2) Hazard control procedures
 (3) The need for personnel protection
 (4) Accident reporting procedures
 (5) Biological effects of the laser upon the eye and the skin
 (6) Electrical and other hazards associated with the laser equipment, including the following:
  a. High voltages (> 1 kV) and stored energy in the capacitor banks
  b. Circuit components, such as electron tubes, with anode voltages greater than 5 kV emitting X-rays
  c. Capacitor bank explosions
  d. Production of ionizing radiation
  e. Poisoning from the solvent or dye switching liquids or laser media
  f. High sound intensity levels from pulsed lasers

(C) Proof of Qualification. Proof of qualification of the laser equipment operator shall be available and in possession of the operator at all times.

330.4 Safeguarding of Employees in the Laser Operating Area.

(A) Eye Protection. Employees shall be provided with eye protection as required by federal regulation.

(B) Warning Signs. Warning signs shall be posted at the entrances to areas or protective enclosures containing laser products.

(C) Master Control. High power laser equipment shall include a key-operated master control.

(D) High-power laser equipment shall include a failsafe laser radiation emission audible and visible warning when it is switched on or if the capacitor banks are charged.

(E) Beam shutters or caps shall be utilized, or the laser switched off, when laser transmission is not required. The laser shall be switched off when unattended for 30 minutes or more.

(F) Laser beams shall not be aimed at employees.

(G) Laser equipment shall bear a label indicating its maximum output.

(H) Personnel protective equipment shall be provided for users and operators of high-power laser equipment.

330.5 Employee Responsibility. Employees shall be responsible for the following:

(1) Obtaining authorization for laser use
(2) Obtaining authorization for being in a laser operating area
(3) Observing safety rules
(4) Reporting laser equipment failures and accidents to the employer

ARTICLE 340
Safety-Related Work Practices: Power Electronic Equipment

340.1 Scope. This article shall apply to 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 antenna
(3) Industrial dielectric and radio frequency (RF) induction heaters
(4) Shortwave or RF diathermy devices
(5) Process equipment that includes rectifiers and inverters such as the following:
 a. Motor drives
 b. Uninterruptible power supply systems
 c. Lighting controllers

340.2 Definition. For the purposes of this article, the following definition shall apply.

Radiation Worker. A person who is required to work in electromagnetic fields, the radiation levels of which exceed those specified for nonoccupational exposure.

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 Reference Standards. The following are reference standards for use in the preparation of specific guidance to employees:

(1) International Electrotechnical Commission IEC 60479, *Effects of Current Passing Through the Body*:
   a. 60479-1 Part 1: General aspects
   b. 60479-1-1 Chapter 1: Electrical impedance of the human body
   c. 60479-1-2 Chapter 2: Effects of ac in the range of 15 Hz to 100 Hz
   d. 60479-2 Part 2: Special aspects
   e. 60479-2-4 Chapter 4: Effects of ac with frequencies above 100 Hz
   f. 60479-2-5 Chapter 5: Effects of special waveforms of current
   g. 60479-2-6 Chapter 6: Effects of unidirectional single impulse currents of short duration

(2) International Commission on Radiological Protection (ICRP) Publication 15, *Protection Against Ionizing Radiation from External Sources*

340.5 Hazardous Effects of Electricity on the Human Body. Employer and employees shall be aware of the following hazards associated with power electronic equipment.

(1) Results of Power Frequency Current.
   a. At 5 mA, shock is perceptible.
   b. At 10 mA, a person may not be able to voluntarily let go of the hazard.
   c. At about 40 mA, the shock, if lasting for 1 second or longer, may be fatal due to ventricular fibrillation.
   d. Further increasing current leads to burns and cardiac arrest.

(2) Results of Direct Current.
   a. A dc current of 2 mA is perceptible.
   b. A dc current of 10 mA is considered the threshold of the let-go current.

(3) Results of Voltage. A voltage of 30 V rms, or 60 V dc, is considered safe except when the skin is broken. The internal body resistance can be as low as 500 ohms, so fatalities can occur.

(4) Results of Short Contact.
   a. For contact less than 0.1 second and with currents just greater than 0.5 mA, ventricular fibrillation may occur only if the shock is in a vulnerable part of the cardiac cycle.
   b. For contact of less than 0.1 second and with currents of several amperes, ventricular fibrillation may occur if the shock is in a vulnerable part of the cardiac cycle.
   c. For contact of greater than 0.8 second and with currents just greater than 0.5 A, cardiac arrest (reversible) may occur.
   d. For contact greater than 0.8 second and with currents of several amperes, burns and death are probable.

(5) Results of ac at Frequencies Above 100 Hz. When the threshold of perception increases from 10 kHz to 100 kHz, the threshold of let-go current increases from 10 mA to 100 mA.

(6) Effects of Waveshape. Contact with voltages from phase controls usually causes effects between those of ac and dc sources.

(7) Effects of Capacitive Discharge.
   a. A circuit of capacitance of 1 microfarad having a 10 kV capacitor charge may cause ventricular fibrillation.
   b. A circuit of capacitance of 20 microfarad having a 10 kV capacitor charge may be dangerous and probably cause ventricular fibrillation.

340.6 Hazards Associated with Power Electronic Equipment. Employer and employees shall be aware of the hazards associated with the following:

(1) High voltages within the power supplies
(2) Radio frequency energy–induced high voltages
(3) Effects of radio frequency (RF) fields in the vicinity of antennas and antenna transmission lines, which can introduce electrical shock and burns
(4) Ionizing (X-radiation) hazards from magnetrons, klystrons, thyratrons, cathode-ray tubes, and similar devices
(5) Non-ionizing RF radiation hazards from the following:
   a. Radar equipment
   b. Radio communication equipment, including broadcast transmitters
   c. Satellite–earth-transmitters
   d. Industrial scientific and medical equipment
   e. RF induction heaters and dielectric heaters
   f. Industrial microwave heaters and diathermy radiators

340.7 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:
   a. The nature of the associated hazard
   b. Strategies to minimize the hazard

c. Methods of avoiding or protecting against the hazard
d. The necessity of reporting any hazardous incident

(2) Properly installed equipment
(3) Proper access to the equipment
(4) Availability of the correct tools for operation and maintenance
(5) Proper identification and guarding of dangerous equipment
(6) 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 hazardous components.)
(7) Maintenance of clear and clean work areas around the equipment to be worked
(8) Provision of adequate and proper illumination of the work area

(B) Employee Responsibility. The employee is responsible for the following:

(1) Being continuously alert and aware of the possible hazards
(2) Using the proper tools and procedures for the work
(3) Informing the employer of malfunctioning protective measures, such as faulty or inoperable enclosures and locking schemes
(4) Examining all documents provided by the employer relevant to the work, especially those documents indicating the hazardous components location
(5) Maintaining good housekeeping around the equipment and work space
(6) Reporting any hazardous incident

ARTICLE 350
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.

350.2 Definitions. For the purposes of this article, the following definitions shall apply.

Competent Person. A person meeting all of the requirements of a qualified person, as defined in Article 100 in Chapter 1 of this document and, in addition, is responsible for all work activities or safety procedures related to custom or special equipment, and has detailed knowledge regarding the electrical hazard exposure, the appropriate controls for mitigating those hazards, and the implementation of those controls.

Field Evaluated. A thorough evaluation of nonlisted or modified equipment in the field that is performed by persons or parties acceptable to the authority having jurisdiction. The evaluation approval ensures that the equipment meets appropriate codes and standards, or is similarly found suitable for a specified purpose.

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.

Research and Development (R&D). An activity in an installation specifically designated for research or development conducted with custom or special electrical equipment.

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.

FPN: 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.

350.5 Specific Measures and Controls for Personnel Safety. Each laboratory or R&D system application shall be assigned a competent person as defined in this article to ensure the use of appropriate electrical safety-related work practices and controls.

350.6 Listing Requirements. The equipment or systems used in the R&D area or in the laboratory shall be listed or field evaluated prior to use.

FPN: 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.

Annex A Referenced Publications

A.1 General. The documents or portions thereof listed in this annex are referenced within this standard and shall be considered part of the requirements of this document.

A.2 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

NFPA 70®, *National Electrical Code*®, 2008.

A.3 Other Publications.

A.3.1 ANSI Publications. American National Standards Institute, Inc., 25 West 43rd Street, 4th Floor, New York, NY 10036.

ANSI A14.1, *Safety Requirements for Portable Wood Ladders,* 2000.

ANSI A14.3, *Safety Requirements for Fixed Ladders,* 2002.

ANSI A14.4, *Safety Requirements for Job-Made Ladders,* 2002.

ANSI A14.5, *Safety Requirement for Portable Reinforced Plastic Ladders,* 2000.

ANSI Z87.1, *Practice for Occupational and Educational Eye and Face Protection,* 2003.

ANSI Z89.1, *Requirements for Protective Headwear for Industrial Workers,* 2003.

ANSI Z535, *Series of Standards for Safety Signs and Tags,* 2006.

A.3.2 ASTM Publications. ASTM International, 100 Barr Harbor Drive, P.O Box C700, West Conshohocken, PA 19428-2959.

ASTM D 120, *Standard Specification for Rubber Insulating Gloves,* 2002a (R 2006).

ASTM D 1048, *Standard Specification for Rubber Insulating Blankets,* 2005.

ASTM D 1049, *Standard Specification for Rubber Covers,* 1998 (R 2002).

ASTM D 1050, *Standard Specification for Rubber Insulating Line Hoses,* 2005.

ASTM D 1051, *Standard Specification for Rubber Insulating Sleeves,* 2007.

ASTM F 478, *Standard Specification for In-Service Care of Insulating Line Hose and Covers,* 1999 (R 2007).

ASTM F 479, *Standard Specification for In-Service Care of Insulating Blankets,* 2006.

ASTM F 496, *Standard Specification for In-Service Care of Insulating Gloves and Sleeves,* 2006.

ASTM F 696, *Standard Specification for Leather Protectors for Rubber Insulating Gloves and Mittens,* 2006.

ASTM F 711, *Standard Specification for Fiberglass-Reinforced Plastic (FRP) Rod and Tube Used; in Line Tools,* 2002 (R 2007).

ASTM F 712, *Standard Test Methods and Specifications for Electrically Insulating Plastic Guard Equipment for Protection of Workers,* 2006.

ASTM F 855, *Standard Specification for Temporary Protective Grounds to Be Used on De-energized Electric Power Lines and Equipment,* 2004.

ASTM F 887, *Standard Specification for Personal Climbing Equipment*, 2005.

ASTM F 1117, *Standard Specification for Dielectric Overshoe Footwear,* 2003.

ASTM F 1236, *Standard Guide for Visual Inspection of Electrical Protective Rubber Products,* 2007.

ASTM F 1505, *Standard Specification for Insulated and Insulating Hand Tools,* 2007.

ASTM F 1506, *Standard Performance Specification for Flame Resistant Textile Materials for Wearing Apparel for Use by Electrical Workers Exposed to Momentary Electric Arc and Related Thermal Hazards,* 2002a.

ASTM F 1891, *Standard Specification for Arc and Flame Resistant Rainwear,* 2006.

ASTM F 1959, *Standard Test Method for Determining the Arc Thermal Performance Value of Materials for Clothing,* 2006.

ASTM F 2178, *Standard Test Method for Determining the Arc Rating and Standard Specification for Face Protective Products,* 2006.

ASTM F 2249, *Standard Specification for In-Service Test Methods for Temporary Grounding Jumper Assemblies Used on De-Energized Electric Power Lines and Equipment*, 2003.

ASTM F 2412, *Standard Test Methods for Foot Protections*, 2005.

ASTM F 2413, *Standard Specification for Performance Requirements for Foot Protection*, 2005.

A.3.3 ICRP Publications. International Commission on Radiological Protection, SE-171 16 Stockholm, Sweden.

ICRP 15, *Protection Against Ionizing Radiation from External Sources*.

A.3.4 IEC Publications. International Electrotechnical Commission, 3, rue de Varembé, P.O. Box 131, CH-1211 Geneva 20, Switzerland.

IEC 60479, *Effects of Current Passing Through the Body*, 1987.

60479-1 Part 1: General aspects

60479-1-1 Chapter 1: Electrical impedance of the human body

60479-1-2 Chapter 2: Effects of ac in the range of 15 Hz to 100 Hz

60479-2 Part 2: Special aspects

60479-2-4: Chapter 4: Effects of ac with frequencies above 100 Hz

60479-2-5 Chapter 5: Effects of special waveforms of current

60479-2-6 Chapter 6: Effects of unidirectional single impulse currents of short duration

A.3.5 IEEE Publications. Institute of Electrical and Electronics Engineers, IEEE Operations Center, 445 Hoes Lane, P. O. Box 1331, Piscataway, NJ 08855-1331.

IEEE C37.20.7, *Guide for Testing Metal-Enclosed Switchgear Rated up to 38 kV for Internal Arcing Faults*, 2007.

A.4 References for Extracts in Mandatory Sections.

NFPA 70®, *National Electrical Code®*, 2008.

Annex B Informational References

B.1 Referenced Publications. The following documents or portions thereof are referenced within this standard for informational purposes only and are thus not part of the requirements of this document unless also listed in Annex A.

B.1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

NFPA 1, *Fire Code*, 2009 edition.

• *NFPA 70*®, *National Electrical Code*®, 2008 edition.

NFPA 70B, *Recommended Practice for Electrical Equipment Maintenance,* 2006 edition.

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B.1.2 ANSI Publications. American National Standards Institute, Inc., 25 West 43rd Street, 4th Floor, New York, NY 10036.

ANSI/AIHA Z10, *American National Standard for Occupational Safety and Health Management Systems*, 2005.

ANSI/ASSE Z244.1, *Control of Hazardous Energy — Lockout/Tagout and Alternative Methods*, 2003.

ANSI/NETA MTS, *Standard for Maintenance Testing Specification,* 2007.

B.1.3 ASTM Publications. ASTM International, 100 Barr Harbor Drive, P.O. Box C 700, West Conshohocken, PA 19428-2959.

ASTM F 496, *Standard Specification for In-Service Care of Insulating Gloves and Sleeves*, 2006.

ASTM F 711, *Standard Specification for Fiberglass-Reinforced Plastic (FRP) Rod and Tube Used; in Line Tools*, 2002 (R 2007).

ASTM F 2249, *Standard Specification for In-Service Test Methods for Temporary Grounding Jumper Assemblies Used on De-Energized Electric Power Lines and Equipment*, 2003.

B.1.4 IEEE Publications. Institute of Electrical and Electronic Engineers, IEEE Operations Center, 445 Hoes Lane, P. O. Box 1331, Piscataway, NJ 08855-1331.

ANSI/IEEE C2, *National Electrical Safety Code,* 2007.

ANSI/IEEE C 37.20.6, *Standard for 4.76 kV to 38 kV-Rated Ground and Test Devices Used in Enclosures*, 2007.

ANSI/IEEE C84.1, *Electric Power Systems and Equipment — Voltage Ratings (60 Hz),* 1995.

IEEE 4, *Standard Techniques for High Voltage Testing,* 1978.

IEEE 4A, Amendment to IEEE 4, 2001.

IEEE 450, *IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications*, 2002.

IEEE 484, *Recommended Practice for Installation Design and Installation of Vented Lead-Acid Batteries for Stationary Applications,* 2002.

IEEE 485, *IEEE Recommended Practice for Sizing Lead-Acid Storage Batteries for Stationary Applications*, 1997.

IEEE 516, *Guide for Maintenance Methods on Energized Power Lines,* 2003.

IEEE 937, *Recommended Practice for Installation and Maintenance of Lead-Acid Batteries for Photovoltaic Systems,* 2007.

IEEE 1106, *IEEE Recommended Practice for Installation, Maintenance, Testing, and Replacement of Vented Nickel-Cadmium Batteries for Stationary Applications*, 2005.

IEEE 1184, *IEEE Guide for Batteries for Uninterruptible Power Supply Systems*, 2006.

IEEE 1187, *Recommended Practice for Installation Design and Installation of Valve-Regulated Lead-Acid Storage Batteries for Stationary Applications,* 2002.

IEEE 1188, *IEEE Recommended Practice for Maintenance, Testing, and Replacement of Valve-Regulated Lead-Acid (VRLA) Batteries for Stationary Applications*, 2005.

IEEE 1189, *IEEE Guide for Selection of Valve-Regulated Lead-Acid (VRLA) Batteries for Stationary Applications*, 2007.

IEEE 1375, *IEEE Guide for Protection of Stationary Battery Systems*, 1998 (R 2003).

IEEE 1584, *Guide for Performing Arc Flash Calculations,* 2002.

IEEE 1584a, *Guide for Performing Arc Flash Hazard Calculations, Amendment 1*, 2004.

Anderson, W. E., "Risk Analysis Methodology Applied to Industrial Machine Development," *IEEE Trans. on Industrial Applications,* Vol. 41, No. 1, January/February 2005, pp. 180–187.

Doughty, R. L., T. E. Neal, and H. L. Floyd II, "Predicting Incident Energy to Better Manage the Electric Arc Hazard on 600 V Power Distribution Systems," *Record of Conference Papers IEEE IAS 45th Annual Petroleum and Chemical Industry Conference*, September 28–30, 1998.

• Lee, Ralph, "The Other Electrical Hazard: Electrical Arc Flash Burns," IEEE *Trans. Industrial Applications*, Vol. 1A-18, No. 3, May/June 1982.

B.1.5 ISA Publications. Instrumentation, Systems, and Automation Society, 67 Alexander Drive, Research Triangle Park, NC 27709.

ANSI/ISA 61010-1, *Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use*, "Part 1: General Requirements," 2007.

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B.1.6 UL Publications. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062-2096.

UL 943, *Standard for Ground-Fault Circuit Interrupters*, 2006.

ANSI/UL 1203, *Explosion-Proof and Dust-Ignition-Proof Electrical Equipment for Use in Hazardous (Classified) Locations*, 2006.

B.1.7 U.S. Government Publications. U.S. Government Printing Office, Washington, DC 20402.

Title 29, Code of Federal Regulations, Part 1926, "Safety and Health Regulations for Construction," and Part 1910, "Occupational Safety and Health Standards."

OSHA 1910.137, *Personal Protective Equipment*.

OSHA 1910.305(j)(7), *Storage Batteries*.

OSHA 1926.441, *Batteries and Battery Charging*.

Annex C Limits of Approach

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

C.1 Preparation for Approach. Observing a safe approach distance from exposed energized electrical conductors or circuit parts is an effective means of maintaining electrical safety. As the distance between a person and the exposed energized conductors or circuit parts decreases, the potential for electrical accident increases.

C.1.1 Unqualified Persons, Safe Approach Distance. Unqualified persons are safe when they maintain a distance from the exposed energized conductors or circuit parts, including the longest conductive object being handled, so that they cannot contact or enter a specified air insulation distance to the exposed energized electrical conductors or circuit parts. This safe approach distance is the Limited Approach Boundary. Further, persons must not cross the Arc Flash Protection Boundary unless they are wearing appropriate personal protective clothing and are under the close supervision of a qualified person. Only when continuously escorted by a qualified person should an unqualified person cross the Limited Approach Boundary. Under no circumstance should an unqualified person cross the Restricted Approach Boundary, where special shock protection techniques and equipment are required.

C.1.2 Qualified Persons, Safe Approach Distance.

C.1.2.1 Determine the Arc Flash Protection Boundary and, if the boundary is to be crossed, appropriate flash-flame protection equipment must be utilized.

C.1.2.2 For a person to cross the Limited Approach Boundary and enter the limited space, he or she must be qualified to perform the job/task.

C.1.2.3 To cross the Restricted Approach Boundary and enter the restricted space, qualified persons must do the following:

(1) Have a plan that is documented and approved by authorized management
(2) Use personal protective equipment that is appropriate for working near exposed energized conductors or circuit parts and is rated for the voltage and energy level involved
(3) Be certain that no part of the body enters the prohibited space
(4) Minimize the risk from inadvertent movement by keeping as much of the body out of the restricted space as possible, using only protected body parts in the space as necessary to accomplish the work

C.1.2.4 Crossing the Prohibited Approach Boundary and entering the prohibited space is considered the same as making contact with exposed energized conductors or circuit parts. *(See Figure C.1.2.4.)*

Therefore, qualified persons must do the following:

(1) Have specified training to work on energized conductors or circuit parts
(2) Have a documented plan justifying the need to work that close
(3) Perform a risk analysis
(4) Have the plan and the risk analysis approved by authorized management
(5) Use personal protective equipment that is appropriate for working on exposed energized conductors or circuit parts and is rated for the voltage and energy level involved

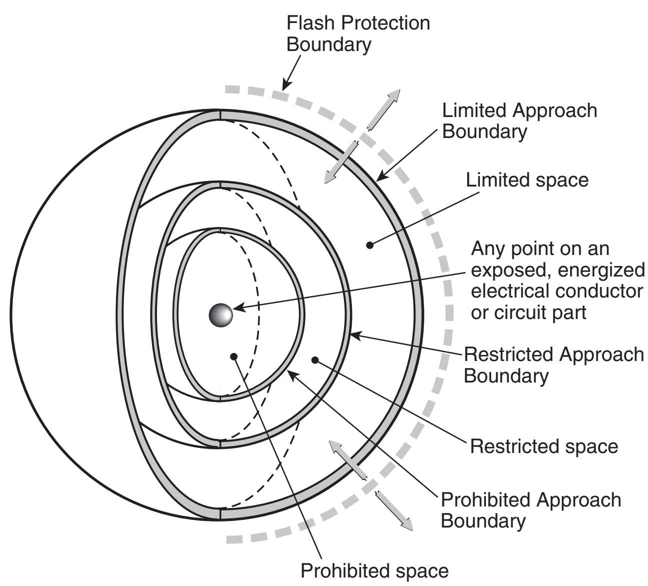

Figure C.1.2.4 Limits of Approach.

C.2 Basis for Distance Values in Table 130.2(C).

C.2.1 General Statement. Columns 2 through 5 of Table 130.2(C) 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 for voltages 72.5 kV and under are based on IEEE 4, *Standard Techniques for High Voltage Testing,* Appendix 2B; and voltages over 72.5 kV are based on IEEE 516, *Guide for Maintenance Methods on Energized Power Lines*. The minimum air insulation distances that are required to avoid flashover are as follows:

(1) ≤300 V: 1 mm (0 ft 0.03 in.)
(2) >300 V ≤750 V: 2 mm (0 ft 0.07 in.)
(3) >750 V ≤2 kV: 5 mm (0 ft 0.19 in.)
(4) >2 kV ≤15 kV: 39 mm (0 ft 1.5 in.)
(5) >15 kV ≤36 kV: 161 mm (0 ft 6.3 in.)
(6) >36 kV ≤48.3 kV: 254 mm (0 ft 10.0 in.)
(7) >48.3 kV ≤72.5 kV: 381 mm (1 ft 3.0 in.)
(8) >72.5 kV ≤121 kV: 640 mm (2 ft 1.2 in.)
(9) >138 kV ≤145 kV: 778 mm (2 ft 6.6 in.)
(10) >161 kV ≤169 kV: 915 mm (3 ft 0.0 in.)
(11) >230 kV ≤242 kV: 1.281 m (4 ft 2.4 in.)
(12) >345 kV ≤362 kV: 2.282 m (7 ft 5.8 in.)
(13) >500 kV ≤550 kV: 3.112 m (10 ft 2.5 in.)
(14) >765 kV ≤800 kV: 4.225 m (13 ft 10.3 in.)

C.2.1.1 Column 1. The voltage ranges have been selected to group voltages that require similar approach distances based on the sum of the electrical withstand distance and an inadvertent movement factor. The value of the upper limit for a range is the maximum voltage for highest nominal voltage in the range, based on ANSI/IEEE C84.1, *Electric Power Systems and Equipment — Voltage Ratings (60 Hz).* For single-phase systems, select the range that is equal to the system's maximum phase-to-ground voltage multiplied by 1.732.

C.2.1.2 Column 2. The distances in this column are based on OSHA's rule for unqualified persons to maintain a 3.05 m (10 ft) clearance for all voltages up to 50 kV (voltage-to-ground), plus 102 mm (4.0 in.) for each 1 kV over 50 kV.

C.2.1.3 Column 3. The distances are based on the following:

(1) ≤750 V: Use *NEC* Table 110.26(A)(1), Working Spaces, Condition 2 for 151 V–600 V range.
(2) >750 V ≤145 kV: Use *NEC* Table 110.34(A), Working Space, Condition 2.
(3) >145 kV: Use OSHA's 3.05 m (10 ft) rules as used in Column 2.

C.2.1.4 Column 4. The distances are based on adding to the flashover dimensions shown above the following inadvertent movement distance:

≤300 V: Avoid contact.

Based on experience and precautions for household 120/240 V systems:

>300 V ≤750 V: Add 304.8 mm (1 ft 0 in.) for inadvertent movement.

These values have been found to be adequate over years of use in ANSI/IEEE C2, *National Electrical Safety Code,* in the approach distances for communication workers.

>72.5 kV: Add 304.8 mm (1 ft 0 in.) for inadvertent movement.

These values have been found to be adequate over years of use in the *National Electrical Safety Code* in the approach distances for supply workers.

C.2.1.5 Column 5. The distances are based on the following:

(1) ≤300 V: Avoid contact.
(2) >300 ≤750 V: Use *NEC* Table 230.51(C), Clearances.

Between open conductors and surfaces, 600 V not exposed to weather.

(1) >750 V ≤2.0 kV: Select value that fits in with adjacent values.
(2) >2 kV ≤72.5 kV: Use *NEC* Table 490.24, Minimum Clearance of Live Parts, outdoor phase-to-ground values.
(3) >72.5 kV: Add 152.4 mm (0 ft 6 in.) for inadvertent movement.

These values have been found to be adequate over years of use where there has been a hazard/risk analysis, either formal or informal, of a special work procedure that allows a closer approach than that permitted by the Restricted Approach Boundary distance.

Annex D Incident Energy and Flash Protection Boundary Calculation Methods

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

D.1 Introduction. 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 Annex D are described in Table D.1.

Table D.1 Limitation of Calculation Methods

Section	Source	Limitations/Parameters
D.2, D.3, D.4	Ralph Lee paper	Calculates Arc Flash Protection Boundary for arc in open air; conservative over 600 V and becomes more conservative as voltage increases
D.5	Doughty/Neal paper	Calculates incident energy for 3-phase arc on systems rated 600 V and below; applies to short-circuit currents between 16 kA and 50 kA
D.6	Ralph Lee paper	Calculates incident energy for 3-phase arc in open air on systems rated above 600 V; becomes more conservative as voltage increases
D.7	IEEE Std. 1584	Calculates incident energy and Arc Flash Protection Boundary for: 208 V to 15 kV; 3-phase; 50 Hz to 60 Hz; 700 A to 106,000 A short-circuit current; and 13 mm to 152 mm conductor gaps
D.8	ANSI/IEEE C2 NESC-Section 410 Tables 410-1 and Table 410-2	Calculates incident energy for open air phase-to-ground arcs 1 kV to 500 kV for live-line work

• **D.2 Basic Equations for Calculating Arc Flash Protection Boundary Distances.** The short-circuit symmetrical ampacity from a bolted 3-phase fault at the transformer terminals is calculated with the following formula:

$$I_{sc} = \{[MVA \text{ Base } \times 10^6] \div [1.732 \times V]\} \times \{100 \div \%Z\} \quad \textbf{[D.2(a)]}$$

where I_{sc} is in amperes, V is in volts, and $\%Z$ is based on the transformer *MVA*.

A typical value for the maximum power (in MW) in a 3-phase arc can be calculated using the following formula:

$$P = [\text{maximum bolted fault in } MVA_{bf}] \times 0.707^2 \quad \textbf{[D.2(b)]}$$

$$P = 1.732 \times V \times I_{sc} \times 10^{-6} \times 0.707^2 \quad \textbf{[D.2(c)]}$$

The Flash Protection Boundary distance is calculated in accordance with the following formulae:

$$D_c = [2.65 \times MVA_{bf} \times t]^{1/2} \quad \textbf{[D.2(d)]}$$

$$D_c = [53 \times MVA \times t]^{1/2} \quad \textbf{[D.2(e)]}$$

where:

D_c = distance in feet of person from arc source for a just curable burn (i.e., skin temperature remains less than 80°C)

MVA_{bf} = bolted fault *MVA* at point involved

MVA = *MVA* rating of transformer. For transformers with *MVA* ratings below 0.75 *MVA*, multiply the transformer *MVA* rating by 1.25.

t = time of arc exposure in seconds

The clearing time for a current limiting fuse is approximately ¼ cycle or 0.004 second if the arcing fault current is in the fuse's current limiting range. The clearing time of a 5 kV and 15 kV circuit breaker is approximately 0.1 second or 6 cycles if the instantaneous function is installed and operating. This can be broken down as follows: actual breaker time (approximately 2 cycles), plus relay operating time of approximately 1.74 cycles, plus an additional safety margin of 2 cycles, giving a total time of approximately 6 cycles. Additional time must be added if a time delay function is installed and operating.

The formulas used in this explanation are from Ralph Lee, "The Other Electrical Hazard: Electrical Arc Blast Burns," in *IEEE Trans. Industrial Applications*. Vol. 1A-18. No. 3, Page 246, May/June 1982. The calculations are based on the worst-case arc impedance. See Table D.2.

D.3 Single Line Diagram of a Typical Petrochemical Complex. The single line diagram *(see Figure D.3)* illustrates the complexity of a distribution system in a typical petrochemical plant.

D.4 Sample Calculation. Many of the electrical characteristics of the systems and equipment are provided in Table D.2. The sample calculation is made on the 4160-volt bus 4A or 4B. Table D.2 tabulates the results of calculating the Flash Protection Boundary for each part of the system. For

Table D.2 Flash Burn Hazard at Various Levels in a Large Petrochemical Plant

(1)	(2)	(3)	(4)	(5)	(6)	(7)	
Bus Nominal Voltage Levels	System (MVA)	Transformer (MVA)	System or Transformer (% *Z*)	Short Circuit Symmetrical (A)	Clearing Time of Fault (cycles)	Flash Protection Boundary Typical Distance*	
						SI	U.S.
230 kV	9000		1.11	23,000	6.0	15 m	49.2 ft
13.8 kV	750		9.4	31,300	6.0	1.16 m	3.8 ft
Load side of all 13.8 kV fuses	750		9.4	31,300	1.0	184 mm	0.61 ft
4.16 kV		10.0	5.5	25,000	6.0	2.96 m	9.7 ft
4.16 kV		5.0	5.5	12,600	6.0	1.4 m	4.6 ft
Line side of incoming 600 V fuse		2.5	5.5	44,000	60.0–120.0	7 m–11 m	23 ft–36 ft
600 V bus		2.5	5.5	44,000	0.25	268 mm	0.9 ft
600 V bus		1.5	5.5	26,000	6.0	1.6 m	5.4 ft
600 V bus		1.0	5.57	17,000	6.0	1.2 m	4 ft

*Distance from an open arc to limit skin damage to a curable second-degree skin burn [less than 80°C (176°F) on skin] in free air.

this calculation, based on Table D.2, the following results are obtained:

(1) Calculation is made on a 4160-volt bus.
(2) Transformer *MVA* (and base *MVA*) = 10 *MVA*.
(3) Transformer impedance on 10 *MVA* base = 5.5 percent.
(4) Circuit breaker clearing time = 6 cycles.

Using Equation D.2(a), calculate the short-circuit current:

$$
\begin{aligned}
I_{sc} &= \left\{\left[MVA \text{ Base } \times 10^6\right] \div [1.732 \times V]\right\} \times \{100 \div \%Z\} \\
&= \left\{\left[10 \times 10^6\right] \div [1.732 \times 4160]\right\} \times \{100 \div 5.5\} \\
&= 25{,}000 \text{ amperes}
\end{aligned}
$$

Using Equation D.2(b), calculate the power in the arc:

$$
\begin{aligned}
P &= 1.732 \times 4160 \times 25{,}000 \times 10^{-6} \times 0.707^2 \\
&= 91 \text{ MW}
\end{aligned}
$$

Using the Equation D.2(d), calculate the second-degree burn distance:

$$
\begin{aligned}
D_c &= \left\{2.65 \times \left[1.732 \times 25{,}000 \times 4160 \times 10^{-6}\right] \times 0.1\right\}^{1/2} \\
&= 6.9 \text{ or } 7.00 \text{ ft}
\end{aligned}
$$

Or, using Equation D.2(e), calculate the second-degree burn distance using an alternative method:

$$
\begin{aligned}
D_c &= [53 \times 10 \times 0.1]^{1/2} \\
&= 7.28 \text{ ft}
\end{aligned}
$$

D.5 Calculation of Incident Energy Exposure for an Arc Flash Hazard Analysis. The following equations can be used to predict the incident energy produced by a three-phase arc on systems rated 600 volts and below. The results of these equations might not represent the worst case in all situations. It is essential that the equations be used only within the limitations indicated in the definitions of the variables shown under the equations. The equations must be used only under qualified engineering supervision. (Note: Experimental testing continues to be performed to validate existing incident energy calculations and to determine new formulas.)

The parameters required to make the calculations follow:

(1) The maximum "bolted fault" three-phase short-circuit current available at the equipment and the minimum fault level at which the arc will self-sustain (Calculations should be made using the maximum value, and then at lowest fault level at which the arc is self-sustaining. For 480-volt systems, the industry accepted minimum level for a sustaining arcing fault is 38 percent of the available "bolted fault" three-phase short-circuit current. The highest incident energy exposure could occur at these lower levels where the overcurrent device could take seconds or minutes to open.)

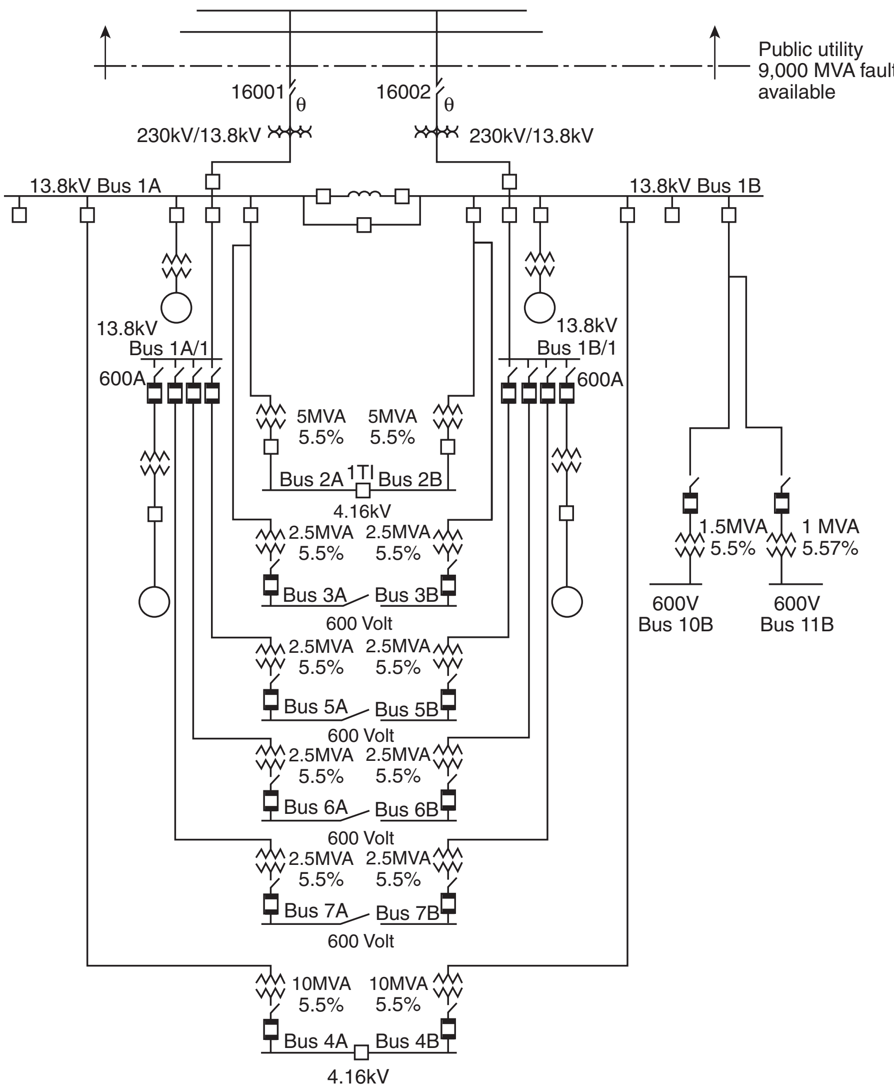

Figure D.3 Single Line Diagram of a Typical Petrochemical Complex.

(2) The total protective device clearing time (upstream of the prospective arc location) at the maximum short-circuit current, and at the minimum fault level at which the arc will sustain itself

(3) The distance of the worker from the prospective arc for the task to be performed

Typical working distances used for incident energy calculations are as follows:

(1) Low voltage (600 V and below) MCC and panelboards — 455 mm (18 in.)

(2) Low voltage (600 V and below) switchgear — 610 mm (24 in.)

(3) Medium voltage (above 600 V) switchgear — 910 mm (36 in.)

D.5.1 Arc in Open Air. The estimated incident energy for an arc in open air is

$$E_{MA} = 5271 D_A^{-1.9593} t_A \left[0.0016F^2 - 0.0076F + 0.8938\right]$$

[D.5.1(a)]

where:

E_{MA} = maximum open arc incident energy, cal/cm^2

D_A = distance from arc electrodes, in. (for distances 18 in. and greater)

t_A = arc duration, seconds

F = short-circuit current, kA (for the range of 16 kA to 50 kA)

Using Equation D.5.1(a), calculate the maximum open arc incident energy, cal/cm^2, where D_A = 18 in., t_A = 0.2 second, and F = 20 kA.

$$E_{MA} = 5271\, D_A^{-1.9593} t_A \left[0.0016F^2 - 0.0076F + 0.8938\right]$$
$$= 5271 \times .0035 \times 0.2[0.0016 \times 400 - 0.0076 \times 20 + 0.8938]$$
$$= 3.69 \times [1.381]$$
$$= 21.33\ \text{J/cm}^2 \left(5.098\ \text{cal/cm}^2\right) \quad \textbf{[D.5.1(b)]}$$

D.5.2 Arc in a Cubic Box. The estimated incident energy for an arc in a cubic box (20 in. on each side, open on one end) is given in the following equation. This equation is applicable to arc flashes emanating from within switchgear, motor control centers, or other electrical equipment enclosures.

$$E_{MB} = 1038.7 D_B^{-1.4738} t_A \left[0.0093F^2 - 0.3453F + 5.9675\right] \quad \textbf{[D.5.2(a)]}$$

where:
E_{MB} = maximum 20 in. cubic box incident energy, cal/cm^2
D_B = distance from arc electrodes, inches (for distances 18 in. and greater)
t_A = arc duration, seconds
F = short circuit current, kA (for the range of 16 kA to 50 kA)

Sample Calculation: Using Equation D.5.2(a), calculate the maximum 20 in. cubic box incident energy, cal/cm^2, using the following:

(1) D_B = 18 in.
(2) t_A = 0.2 sec
(3) F = 20 kA

$$E_{MB} = 1038.7 D_B^{-1.4738} t_A \left[0.0093F^2 - 0.3453F + 5.9675\right]$$
$$= 1038 \times 0.0141 \times 0.2[0.0093 \times 400 - 0.3453 \times 20 + 5.9675]$$
$$= 2.928 \times [2.7815]$$
$$= 34.1\ \text{J/cm}^2 \left(8.144\ \text{cal/cm}^2\right) \quad \textbf{[D.5.2(b)]}$$

D.5.3 Reference. The equations for this section were derived in the IEEE paper by R. L. Doughty, T. E. Neal, and H. L. Floyd, II, "Predicting Incident Energy to Better Manage the Electric Arc Hazard on 600 V Power Distribution Systems," *Record of Conference Papers IEEE IAS 45th Annual Petroleum and Chemical Industry Conference,* September 28–30, 1998.

Typical working distances used for incident energy calculations are given below:

(1) Low voltage (600 V and below) MCC and panelboards — 455 mm (18 in.)
(2) Low voltage (600 V and below) switchgear — 610 mm (24 in.)
(3) Medium voltage (above 600 V) switchgear — 910 mm (36 in.)

D.6 Calculation of Incident Energy Exposure Greater Than 600 V for an Arc Flash Hazard Analysis. The following equation can be used to predict the incident energy produced by a three-phase arc in open air on systems rated above 600 V. The parameters required to make the calculations are as follows:

(1) The maximum "bolted fault" three-phase short-circuit current available at the equipment
(2) The total protective device clearing time (upstream of the prospective arc location) at the maximum short-circuit current
(3) The distance from the arc source
(4) Rated phase-to-phase voltage of the system:

$$E = \frac{793 \times F \times V \times t_A}{D^2}$$

where:
E = incident energy, cal/cm^2
F = bolted fault short-circuit current, kA
V = system phase-to-phase voltage, kV
t_A = arc duration, seconds
D = distance from the arc source, inches

D.7 Basic Equations for Calculating Incident Energy and Arc Flash Protection Boundary. This section offers equations for estimating incident energy and Flash Protection Boundaries based on statistical analysis and curve fitting of available test data. An IEEE working group produced the data from tests it performed to produce models of incident energy. Based on the selection of standard personal protective equipment (PPE) levels (1.2, 8, 25, and 40 cal/cm^2), it is estimated that the PPE is adequate or more than adequate to protect employees from second-degree burns in 95 percent of the cases.

FPN: When incident energy exceeds 40 cal/cm^2 at the working distance, greater emphasis than normal should be placed on de-energizing before working on or near the exposed electrical conductors or circuit parts.

The complete data, including a spreadsheet calculator to solve the equations, can be found in the IEEE 1584, *Guide for Performing Arc Flash Hazard Calculations*. It can be ordered from the Institute of Electrical and Electronics Engineers, Inc., 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331.

D.7.1 System Limits. An equation for calculating incident energy can be empirically derived using statistical analysis of raw data along with a curve-fitting algorithm. It can be used for systems with the following limits:

(1) 0.208 kV to 15 kV, three-phase
(2) 50 Hz to 60 Hz
(3) 700 A to 106,000 A available short-circuit current
(4) 13 mm to 152 mm conductor gaps

For three-phase systems in open-air substations, open-air transmission systems, and distribution systems, a theoretically derived model is available. This theoretically derived model is intended for use with applications where faults escalate to three-phase faults. Where such an escalation is not possible or likely or where single-phase systems are encountered, this equation will likely provide conservative results.

D.7.2 Arcing Current. To determine the operating time for protective devices, find the predicted three-phase arcing current.

For applications with a system voltage under 1 kV, solve Equation D.7.2(a):

$$\lg I_a = K + 0.662 \lg I_{bf} + 0.0966V + 0.000526G + 0.5588V\left(\lg I_{bf}\right) - 0.00304G\left(\lg I_{bf}\right) \quad \textbf{[D.7.2(a)]}$$

where:
lg = the $\log_{10}$
I_a = arcing current in kA
K = –0.153 for open air arcs; –0.097 for arcs-in-a-box
I_{bf} = bolted three-phase available short-circuit current (symmetrical rms) (kA)
V = system voltage in kV
G = conductor gap (mm) *(See Table D.7.2.)*

For systems greater than or equal to 1 kV, use Equation D.7.2(b):

$$\lg I_a = 0.00402 + 0.983 \lg I_{bf} \quad \textbf{[D.7.2(b)]}$$

This higher voltage formula is utilized for both open-air arcs and for arcs-in-a-box.

Convert from lg:

$$I_a = 10^{\lg I_a} \quad \textbf{[D.7.2(c)]}$$

Use $0.85I_a$ to find a second arc duration. This second arc duration accounts for variations in the arcing current and the time for the overcurrent device to open. Calculate the incident energy using both arc durations (I_a and 0.85 I_a), and use the higher incident energy.

D.7.3 Incident Energy at Working Distance — Empirically Derived Equation. To determine the incident energy using the empirically derived equation, determine the $\log_{10}$ of the normalized incident energy. This equation is based on data normalized for an arc time of 0.2 second and a distance from the possible arc point to the person of 610 mm:

$$\lg E_n = k_1 + k_2 + 1.081 \ \lg I_a + 0.0011G \quad \textbf{[D.7.3(a)]}$$

Table D.7.2 Factors for Equipment and Voltage Classes

System Voltage (kV)	Type of Equipment	Typical Conductor Gap (mm)	Distance Exponent Factor X
0.208–1	Open-air	10–40	2.000
	Switchgear	32	1.473
	MCCs and panels	25	1.641
	Cables	13	2.000
>1–5	Open-air	102	2.000
	Switchgear	13–102	0.973
	Cables	13	2.000
>5–15	Open-air	13–153	2.000
	Switchgear	153	0.973
	Cables	13	2.000

where:
E_n = incident energy (J/cm^2) normalized for time and distance
k_1 = –0.792 for open air arcs; –0.555 for arcs-in-a-box
k_2 = 0 for ungrounded and high-resistance grounded systems
= –0.113 for grounded systems
G = the conductor gap (mm) *(See Table D.7.2.)*

Then,

$$E_n = 10^{\lg E_n} \quad \textbf{[D.7.3(b)]}$$

Converting from normalized:

$$E = 4.184C_f \ E_n\left(\frac{t}{0.2}\right)\left(\frac{610^x}{D^x}\right) \quad \textbf{[D.7.3(c)]}$$

where:
E = incident energy in J/cm^2
C_f = calculation factor
= 1.0 for voltages above 1 kV
= 1.5 for voltages at or below 1 kV
E_n = incident energy normalized
t = arcing time (seconds)
D = distance (mm) from the arc to the person (working distance). See Table D.7.3.
X = the distance exponent from Table D.7.2

D.7.4 Incident Energy at Working Distance— Theoretical Equation. The theoretically derived equation can be applied in cases where the voltage is over 15 kV or the gap is outside the range:

$$E = 2.142 \times 10^6 VI_{bf}\left(\frac{t}{D^2}\right) \quad \textbf{[D.7.4]}$$

where:
E = incident energy (J/cm^2)
V = system voltage (kV)
t = arcing time (seconds)
D = distance (mm) from the arc to the person (working distance)
I_{bf} = available three-phase bolted-fault current

For voltages over 15 kV, arcing-fault current and bolted-fault current are considered equal.

Table D.7.3 Typical Working Distances

Classes of Equipment	Typical Working Distance* (mm)
15kV switchgear	910
5kV switchgear	910
Low-voltage switchgear	610
Low-voltage MCCs and panelboards	455
Cable	455
Other	To be determined in field

* Typical working distance is the sum of the distance between the worker and the front of the equipment and the distance from the front of the equipment to the potential arc source inside the equipment.

D.7.5 Arc Flash Protection Boundary. The Arc Flash Protection Boundary is the distance at which a person is likely to receive a second-degree burn. The onset of a second-degree burn is assumed to be when the skin receives 5.0 J/cm^2 of incident energy.

For the empirically derived equation,

$$D_B = \left[4.184 C_f E_n \left(\frac{t}{0.2}\right)\left(\frac{610^x}{E_B}\right)\right]^{\frac{1}{x}} \qquad \textbf{[D.7.5(a)]}$$

For the theoretically derived equation,

$$D_B = \sqrt{2.142 \times 10^6 V I_{bf} \left(\frac{t}{E_B}\right)} \qquad \textbf{[D.7.5(b)]}$$

where:
D_B = the distance (mm) of the Arc Flash Protection Boundary from the arcing point
C_f = a calculation factor
= 1.0 for voltages above 1 kV
= 1.5 for voltages at or below 1 kV
E_n = incident energy normalized
E_B = incident energy in J/cm^2 at the distance of the Arc Flash Protection Boundary
t = time (seconds)
X = the distance exponent from Table D.7.2
I_{bf} = bolted 3-phase available short-circuit current
V = system voltage in kV

FPN: These equations could be used to determine whether selected PPE is adequate to prevent thermal injury at a specified distance in event of an arc flash.

D.7.6 Current-Limiting Fuses. The formulas in this section were developed for calculating arc-flash energies for use with current-limiting Class L and Class RK1 fuses. The testing was done at 600 volts and at a distance of 455 mm, using commercially available fuses from one manufacturer. The following variables are noted:

I_{bf} = available three-phase bolted-fault current (symmetrical rms) (kA)
E = incident energy (J/cm^2)

(A) Class L Fuses 1,601 A–2,000 A. Where I_{bf} <22.6 kA, calculate the arcing current using Equation D.7.2(a), and use time-current curves to determine the incident energy using Equations D.7.3(a), D.7.3(b), and D.7.3(c).

Where 22.6 kA ≤I_{bf} ≤65.9 kA,

$$E = 4.184(-0.1284 I_{bf} + 32.262) \qquad \textbf{[D.7.6(a)]}$$

Where 65.9 kA < I_{bf} ≤106 kA,

$$E = 4.184(-0.5177 I_{bf} + 57.917) \qquad \textbf{[D.7.6(b)]}$$

Where I_{bf} >106 kA, contact manufacturer.

(B) Class L Fuses 1,201 A–1,600 A. Where I_{bf} <15.7 kA, calculate the arcing current using Equation D.7.2(a), and use time-current curves to determine the incident energy using Equations D.7.3(a), D.7.3(b), and D.7.3(c).

Where 15.7 kA ≤I_{bf} ≤31.8 kA,

$$E = 4.184(-0.1863 I_{bf} + 27.926) \qquad \textbf{[D.7.6(c)]}$$

Where 31.8 kA <I_{bf} <44.1 kA,

$$E = 4.184(-1.5504 I_{bf} + 71.303) \qquad \textbf{[D.7.6(d)]}$$

Where 44.1 kA ≤I_{bf} ≤65.9 kA,

$$E = 12.3\ \text{J/cm}^2\ (2.94\ \text{cal/cm}^2) \qquad \textbf{[D.7.6(e)]}$$

Where 65.9 kA <I_{bf} ≤106 kA,

$$E = 4.184(-0.0631 I_{bf} + 7.0878) \qquad \textbf{[D.7.6(f)]}$$

Where I_{bf} >106 kA, contact manufacturer.

(C) Class L Fuses 801 A–1,200 A. Where I_{bf} <15.7 kA, calculate the arcing current per Equation D.7.2(a), and use time-current curves to determine the incident energy per Equations D.7.3(a), D.7.3(b), and D.7.3(c).

Where 15.7 kA ≤I_{bf} ≤22.6 kA,

$$E = 4.184\left(-0.1928I_{bf} + 14.226\right) \quad \textbf{[D.7.6(g)]}$$

Where 22.6 kA <I_{bf} ≤44.1 kA,

$$E = 4.184\left(0.0143I_{bf}^{\ 2} - 1.3919I_{bf} + 34.045\right) \quad \textbf{[D.7.6(h)]}$$

Where 44.1 kA <I_{bf} ≤106 kA,

$$E = 1.63 \quad \textbf{[D.7.6(i)]}$$

Where I_{bf} >106 kA, contact manufacturer.

(D) Class L Fuses 601 A–800 A. Where I_{bf} <15.7 kA, calculate the arcing current per Equation D.7.2(a), and use time-current curves to determine the incident energy using Equations D.7.3(a), D.7.3(b), and D.7.3(c).

Where 15.7 kA ≤I_{bf} ≤44.1 kA,

$$E = 4.184\left(-0.0601I_{bf} + 2.8992\right) \quad \textbf{[D.7.6(j)]}$$

Where 44.1 kA < I_{bf} ≤106 kA,

$$E = 1.046 \quad \textbf{[D.7.6(k)]}$$

Where I_{bf} > 106 kA, contact manufacturer.

(E) Class RK1 Fuses 401 A–600 A. Where I_{bf} <8.5 kA, calculate the arcing current using Equation D.7.2(a), and use time-current curves to determine the incident energy using Equations D.7.3(a), D.7.3(b), and D.7.3(c).

Where 8.5 kA ≤I_{bf} ≤14 kA,

$$E = 4.184\left(-3.0545I_{bf} + 43.364\right) \quad \textbf{[D.7.6(l)]}$$

Where 14 kA < I_{bf} ≤15.7 kA,

$$E = 2.510 \quad \textbf{[D.7.6(m)]}$$

Where 15.7 kA < I_{bf} ≤22.6 kA,

$$E = 4.184\left(-0.0507I_{bf} + 1.3964\right) \quad \textbf{[D.7.6(n)]}$$

Where 22.6 kA < I_{bf} ≤106 kA,

$$E = 1.046 \quad \textbf{[D.7.6(o)]}$$

Where I_{bf} >106 kA, contact manufacturer.

(F) Class RK1 Fuses 201 A–400 A. Where I_{bf} <3.16 kA, calculate the arcing current using Equation D.7.2(a), and use time-current curves to determine the incident energy using Equations D.7.3(a), D.7.3(b), and D.7.3(c).

Where 3.16 kA ≤I_{bf} ≤5.04 kA,

$$E = 4.184\left(-19.053I_{bf} + 96.808\right) \quad \textbf{[D.7.6(p)]}$$

Where 5.04 kA < I_{bf}≤ 22.6 kA,

$$E = 4.184\left(-0.0302I_{bf} + 0.9321\right) \quad \textbf{[D.7.6(q)]}$$

Where 22.6 kA <I_{bf}≤ 106 kA,

$$E = 1.046 \quad \textbf{[D.7.6(r)]}$$

Where I_{bf} >106 kA, contact manufacturer.

(G) Class RK1 Fuses 101 A–200 A. Where I_{bf} <1.16 kA, calculate the arcing current using Equation D.7.2(a), and use time-current curves to determine the incident energy using Equations D.7.3(a), D.7.3(b), and D.7.3(c).

Where 1.16 kA ≤I_{bf} ≤1.6 kA,

$$E = 4.184\left(-18.409I_{bf} + 36.355\right) \quad \textbf{[D.7.6(s)]}$$

Where 1.6 kA < I_{bf} ≤3.16 kA,

$$E = 4.184\left(-4.2628I_{bf} + 13.721\right) \quad \textbf{[D.7.6(t)]}$$

Where 3.16 kA <I_{bf} ≤106 kA,

$$E = 1.046 \quad \textbf{[D.7.6(u)]}$$

Where I_{bf} > 106 kA, contact manufacturer.

(H) Class RK1 Fuses 1 A–100 A. Where I_{bf} <0.65 kA, calculate the arcing current per Equation D.7.2(a), and use time-current curves to determine the incident energy using Equations D.7.3(a), D.7.3(b), and D.7.3(c).

Where 0.65 kA ≤I_{bf} ≤1.16 kA,

$$E = 4.184\left(-11.176I_{bf} + 13.565\right) \quad \textbf{[D.7.6(v)]}$$

Where 1.16 kA < I_{bf} ≤1.4 kA,

$$E = 4.184\left(-1.4583I_{bf} + 2.2917\right) \quad \textbf{[D.7.6(w)]}$$

Where 1.4 kA < I_{bf} ≤106 kA,

$$E = 1.046 \quad \textbf{[D.7.6(x)]}$$

Where I_{bf} > 106 kA, contact manufacturer.

D.7.7 Low-Voltage Circuit Breakers. The equations in Table D.7.7 can be used for systems with low-voltage circuit breakers. The results of the equations will determine the incident energy and Arc Flash Protection Boundary when I_{bf} is within the range as described. Time-current curves for the circuit breaker are not necessary within the appropriate range.

When the bolted-fault current is below the range indicated, calculate the arcing current per Equation D.7.2(a), and use time-current curves to determine the incident energy using Equations D.7.3(a), D.7.3(b), and D.7.3(c).

The range of available three-phase bolted-fault currents is from 700 A to 106,000 A. Each equation is applicable for the range

$$I_1 < I_{bf} < I_2$$

where:

I_2 = the interrupting rating of the CB at the voltage of interest.

I_1 = the minimum available three-phase, bolted, short-circuit current at which this method can be applied. I_1 is the lowest available three-phase, bolted, short-circuit current level that causes enough arcing current for instantaneous tripping to occur or for circuit breakers with no instantaneous trip, that causes short-time tripping to occur.

To find I_1, the instantaneous trip (I_t) of the circuit breaker must be found. This can be determined from the time-current curve, or it can be assumed to be 10 times the rating of the circuit breaker for circuit breakers rated above 100 amperes. For circuit breakers rated 100 amperes and below, a value of I_t = 1,300 A can be used. When short-time delay is utilized, I_t is the short-time pick-up current.

The corresponding bolted-fault current, I_{bf}, is found by solving the equation for arc current for box configurations by substituting I_t for arcing current. The 1.3 factor in Equation D.7.7(b) adjusts current to the top of the tripping band.

$$\lg\left(1.3I_t\right) = 0.084 + 0.096V + 0.586\left(\lg I_{bf}\right) + 0.559V\left(\lg I_{bf}\right)$$ **[D.7.7(a)]**

At 600 V,

$$\lg I_1 = 0.0281 + 1.091\lg\left(1.3I_t\right)$$ **[D.7.7(b)]**

At 480 V and lower,

$$\lg I_1 = 0.0407 + 1.17\ \lg\left(1.3I_t\right)$$ **[D.7.7(c)]**

$$I_{bf} = I_1 = 10^{\lg I_1}$$ **[D.7.7(d)]**

D.7.8 References. The complete data, including a spreadsheet calculator to solve the equations, may be found in

Table D.7.7 Incident Energy and Arc Flash Protection Boundary by Circuit Breaker Type and Rating

			480 V and Lower		575–600 V	
Rating (A)	Breaker Type	Trip-Unit Type	Incident Energy (J/cm²)[a]	Flash Boundary (mm)[a]	Incident Energy (J/cm²)[a]	Flash Boundary (mm)[a]
100–400	MCCB	TM or M	$0.189\ I_{bf} + 0.548$	$9.16\ I_{bf} + 194$	$0.271\ I_{bf} + 0.180$	$11.8\ I_{bf} + 196$
600–1,200	MCCB	TM or M	$0.223\ I_{bf} + 1.590$	$8.45\ I_{bf} + 364$	$0.335\ I_{bf} + 0.380$	$11.4\ I_{bf} + 369$
600–1,200	MCCB	E, LI	$0.377\ I_{bf} + 1.360$	$12.50\ I_{bf} + 428$	$0.468\ I_{bf} + 4.600$	$14.3\ I_{bf} + 568$
1,600–6,000	MCCB or ICCB	TM or E, LI	$0.448\ I_{bf} + 3.000$	$11.10\ I_{bf} + 696$	$0.686\ I_{bf} + 0.165$	$16.7\ I_{bf} + 606$
800–6,300	LVPCB	E, LI	$0.636\ I_{bf} + 3.670$	$14.50\ I_{bf} + 786$	$0.958\ I_{bf} + 0.292$	$19.1\ I_{bf} + 864$
800–6,300	LVPCB	E, LS[b]	$4.560\ I_{bf} + 27.230$	$47.20\ I_{bf} + 2660$	$6.860\ I_{bf} + 2.170$	$62.4\ I_{bf} + 2930$

MCCB: Molded-case circuit breaker.
ICCB: Insulated-case circuit breaker.
LVPC: Low-voltage power circuit breaker.
TM: Thermal-magnetic trip units.
M: Magnetic (instantaneous only) trip units.
E: Electronic trip units have three characteristics that may be used separately or in combination: L: Long-time, S: Short-time, I: Instantaneous.
[a] I_{bf} is in kA; working distance is 455 mm (18 in.).
[b] Short-time delay is assumed to be set at maximum.

IEEE 1584, *Guide for Performing Arc Flash Hazard Calculations*. IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (http://standards.ieee.org/).

D.8 Estimated Incident Energy Exposures for Live Line Work on Overhead Open Air Systems 1 kV to 800 kV. Table D.8(1) and Table D.8(2) list the heat flux rate in cal/cm^2/sec derived from the ANSI/IEEE C2 Tables 410-1 and 410-2. To estimate the incident energy, multiply the heat flux rate in the tables by the maximum clearing time (in seconds).

Table D.8(1)

Max Fault Current (kA)	Phase-to-Phase Voltage (kV)			
	1 to 15	15.1 to 25	25.1 to 36	36.1 to 46
	Heat Flux Rate (cal/cm^2/sec)			
5	4.9	8.7	11.6	14.8
10	12.5	20.8	27.1	34.5
15	22.2	35.6	45.4	56.2
20	34	52.8	66.4	78.7

Notes:

(1) These calculations are based on open air phase-to-ground arcs. This table is not intended for phase-to-phase arcs or enclosed arc (arc in a box).

(2) These calculations are based on a 15-in. separation distance from the arc to the employee and arc gaps as follows: 1 to 15 kV = 2 in., 15.1 to 25 kV = 4 in., 25.1–36 kV = 6 in., 36.1 to 46 kV = 9 in. *(See IEEE 4.)*

(3) These calculations were derived using a commercially available computer software program. Other methods are available to estimate arc exposure values and may yield slightly different but equally acceptable results.

Table D.8(2)

Max Fault Current (kA)	Phase-to-Phase Voltage (kV)							
	46.1 to 72.5	72.6 to 121	138 to 145	161 to 169	230 to 242	345 to 362	500 to 550	765 to 800
	Heat Flux Rate (cal/cm^2/sec)							
20	12.4	24.2	19.4	21.1	17.7	8.3	9.8	8.2
30	22.3	42.1	33.5	34.2	28.7	13.5	15.8	13.3
40	34.7	63.6	50.4	49	41.1	19.3	22.7	19
50	49.5	88.7	70	65.2	54.7	25.6	30.2	25.3

Notes:

(1) These calculations are based on open-air phase-to-ground arcs. This table is not intended for phase-to-phase arcs or enclosed arc (arc in a box).

(2) Arc gap is calculated by using the phase-to-ground voltage of the circuit and dividing by 10. The dielectric strength of air is taken at 10 kV per inch. *(See IEEE 4.)*

(3) Distance from the arc to the employee is calculated by using the minimum approach distance from ANSI/IEEE C2, Table 441-2, and subtracting two times the assumed arc gap length.

(4) These calculations were derived using a commercially available computer software program. Other methods are available to estimate arc exposure values and may yield slightly different but equally acceptable results.

D.9 Guideline for the use of Hazard/Risk Category (HRC) 2 and HRC 4 Personal Protective Equipment.

D.9.1 Tables for Guidance on the Use of Personal Protective Equipment. The following tables can be used to determine the suitability of Hazard/Risk Category (HRC) 2 and HRC 4 personal protective equipment on systems rated up to 15 kV, line-to-line. See Table D.9.1 and Table D.9.2 for the recommended limitations based on bolted 3-phase short-circuit currents at the listed fault-clearing times. The limitations listed below are based on IEEE 1584 calculation methods.

Table D.9.1 Low-Voltage Systems – Maximum Three-Phase Bolted-Fault Current Limits at Various System Voltages and Fault-Clearing Times of Circuit Breakers, for the Recommended Use of Hazard/Risk Category (HRC) 2 and HRC 4 Personal Protective Equipment in an "Arc in a Box" Situation

System Voltage (volts, phase-to-phase)	Upstream Protection Fault-Clearing Time (sec)	Maximum 3-Phase Bolted-Fault Current for Use of HRC 2 PPE (8 cal/cm^2)	Maximum 3-Phase Bolted-Fault Current for Use of HRC 4 PPE (40 cal/cm^2)
690	0.05	39 kA	180 kA
	0.10	20 kA	93 kA
	0.20	10 kA	48 kA
	0.33	Not Recommended	29 kA
	0.50	Not Recommended	20 kA
600	0.05	48 kA	200 kA*
	0.10	24 kA	122 kA
	0.20	12 kA	60 kA
	0.33	Not Recommended	36 kA
	0.50	Not Recommended	24 kA
480	0.05	68 kA	200 kA*
	0.10	32 kA	183 kA
	0.20	15 kA	86 kA
	0.33	8 kA	50 kA
	0.50	Not Recommended	32 kA
400	0.05	87 kA	200 kA*
	0.10	39 kA	200 kA*
	0.20	18 kA	113 kA
	0.33	10 kA	64 kA
	0.50	Not Recommended	39 kA
208	0.05	200 kA*	Not applicable
	0.10	104 kA	200 kA*

Notes:

(1) Three-phase "bolted fault" value is at the terminals of the equipment on which work is to be done.

(2) "Upstream Protection Fault-Clearing Time" is normally the "short-time delay" setting on the trip unit of the low-voltage power circuit breaker upstream of the equipment on which work is to be done.

(3) For application of this table, the recommended maximum setting (pick-up) of either the instantaneous or short-delay protection of the circuit breaker's trip unit is 30% of the actual available 3-phase bolted fault current at the specific work location.

(4) Working distance for the arc-flash exposures is assumed to be 455 mm (18 in.).

(5) Flash Protection Boundary (threshold distance for a second-degree skin burn) is 1.7 m (6 ft) for HRC 2 and 4.9 m (16 ft) for HRC 4. PPE is required for all personnel working within the Flash Protection Boundary.

(6) Instantaneous circuit breaker trip unit(s) have no intentional time delay, and the circuit breaker will clear the fault within 0.050 sec of initiation. Application of circuit breakers with faster clearing times or the use of current-limiting circuit breakers or fuses should permit the use of HRC 2 and HRC 4 PPE at greater fault currents than listed.

(7) Systems are assumed to be resistance grounded, except for 208 V (solidly grounded system). This assumption results in conservative application if the table is used on a solidly grounded system, since the incident energy on a solidly grounded system is lower for the same bolted fault current availability.

*Maximum equipment short-circuit current rating available.

Table D.9.2 High-Voltage Systems – Maximum Three-Phase Bolted-Fault Current Limits at Various System Voltages and Fault-Clearing Times of Circuit Breakers, for the Recommended Use of Hazard / Risk Category (HRC) 2 and HRC 4 Personal Protective Equipment in an "Arc in a Box" Situation

System Voltage (volts, phase-to-phase)	Upstream Protection Fault-Clearing Time (sec)	Maximum 3-Phase Bolted-Fault Current for Use of HRC 2 PPE (8 cal/cm^2)	Maximum 3-Phase Bolted-Fault Current for Use of HRC 4 PPE (40 cal/cm^2)
15 kV Class and 12 kV Class	0.10	45 kA	63 kA*(11.4 cal/cm^2)
	0.35	13 kA	63 kA
	0.70	7 kA	32 kA
	1.0	5 kA	23 kA
5 kV Class	0.10	50 kA	63 kA* (10 cal/cm^2)
	0.35	15 kA	63 kA*(35 cal/cm^2)
	0.70	8 kA	37 kA
	1.0	5 kA	26 kA

Notes:
(1) "Upstream Protection Fault-Clearing Time" is the protective relaying operating time at 90% of the actual available 3-phase bolted fault current at the specific work location (the time for the output contact operating the trip coil of the circuit breaker to be closed), plus the circuit breaker operating time (upstream of the equipment on which work is to be done).
(2) Working distance for the above arc-flash exposures is assumed to be 0.92 m (3 ft).
(3) Systems are assumed to be resistance grounded. This assumption results in conservative application if the table is used on a solidly grounded system, since the incident energy on a solidly grounded system is lower.
(4) The cal/cm^2 in parentheses in the last column are calculated at the maximum equipment short-circuit current ratings available.
* Maximum equipment short-circuit current rating available.

Annex E Electrical Safety Program

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

See 110.7, Electrical Safety Program.

E.1 Typical Electrical Safety Program Principles. Electrical safety program principles include, but are not limited to, the following:

(1) Inspect/evaluate the electrical equipment
(2) Maintain the electrical equipment's insulation and enclosure integrity
(3) Plan every job and document first-time procedures
(4) Deenergize, if possible *(see 120.1)*
(5) Anticipate unexpected events
(6) Identify and minimize the hazard
(7) Protect the employee from shock, burn, blast, and other hazards due to the working environment
(8) Use the right tools for the job
(9) Assess people's abilities
(10) Audit these principles

E.2 Typical Electrical Safety Program Controls. Electrical safety program controls can include, but are not limited to, the following:

(1) Every electrical conductor or circuit part is considered energized until proven otherwise.
(2) No bare-hand contact is to be made with exposed energized electrical conductors or circuit parts above 50 volts to ground, unless the "bare-hand method" is properly used.
(3) Deenergizing an electrical conductor or circuit part and making it safe to work on is in itself a potentially hazardous task.
(4) Employer develops programs, including training, and employees apply them.
(5) Use procedures as "tools" to identify the hazards and develop plans to eliminate/control the hazards.
(6) Train employees to qualify them for working in an environment influenced by the presence of electrical energy.
(7) Identify/categorize tasks to be performed on or near exposed energized electrical conductors and circuit parts.
(8) Use a logical approach to determine potential hazard of task.
(9) Identify and use precautions appropriate to the working environment.

E.3 Typical Electrical Safety Program Procedures. Electrical safety program procedures can include, but are not limited to, the following:

(1) Purpose of task
(2) Qualifications and number of employees to be involved
(3) Hazardous nature and extent of task
(4) Limits of approach
(5) Safe work practices to be utilized
(6) Personal protective equipment involved
(7) Insulating materials and tools involved
(8) Special precautionary techniques
(9) Electrical diagrams
(10) Equipment details
(11) Sketches/pictures of unique features
(12) Reference data

Annex F Hazard/Risk Evaluation Procedure

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

F.1 See 110.7(F), Hazard/Risk Evaluation Procedure. Figure F.1 illustrates the steps of a hazard/risk analysis evaluation procedure flow chart.

F.2 See 110.7(F), Hazard/Risk Assessment Procedure. Figure F.2.1 illustrates a hazard/risk analysis procedure.

A Hazard/Risk Evaluation is an analytical tool consisting of a number of discrete steps intended to ensure that hazards are properly identified and evaluated, and that appropriate measures are taken to reduce those hazards to a tolerable level (adapted from ANSI/ASSE Z244.1).

This procedure is a comprehensive review of the task and associated foreseeable hazards that use event severity, frequency, probability, and avoidance to determine the level of safe practices employed. This procedure includes:

(1) Gathering task information and determining task limits
(2) Documenting hazards associated with each task
(3) Estimating the risk factors for each hazard/task pair
(4) Assigning a safety measure for each hazard to attain an acceptable or tolerable level of risk

While this procedure might not result in a reduction of PPE for a task, it can help in understanding of the specific hazards associated with a task to a greater degree and thus allow for a more comprehensive assessment to occur.

While severity, frequency, and avoidance factors are straightforward, consideration of probability includes the following estimators:

(1) Hazard exposures
(2) Human factors
(3) Task history
(4) Workplace culture
(5) Safeguard reliability
(6) Ability to maintain or defeat protective measures
(7) Preventive maintenance history

Reduction strategies to be employed if an unacceptable risk cannot be achieved include the following hierarchy of controls:

(1) Eliminate the hazard
(2) Reduce the risk by design
(3) Apply safeguards
(4) Implement administrative controls
(5) Use personal protective equipment

Figure F.2.2 illustrates the steps of a hazard/risk evaluation assessment procedure.

Figure F.2.3 is included as a blank version of Figure F.2.1.

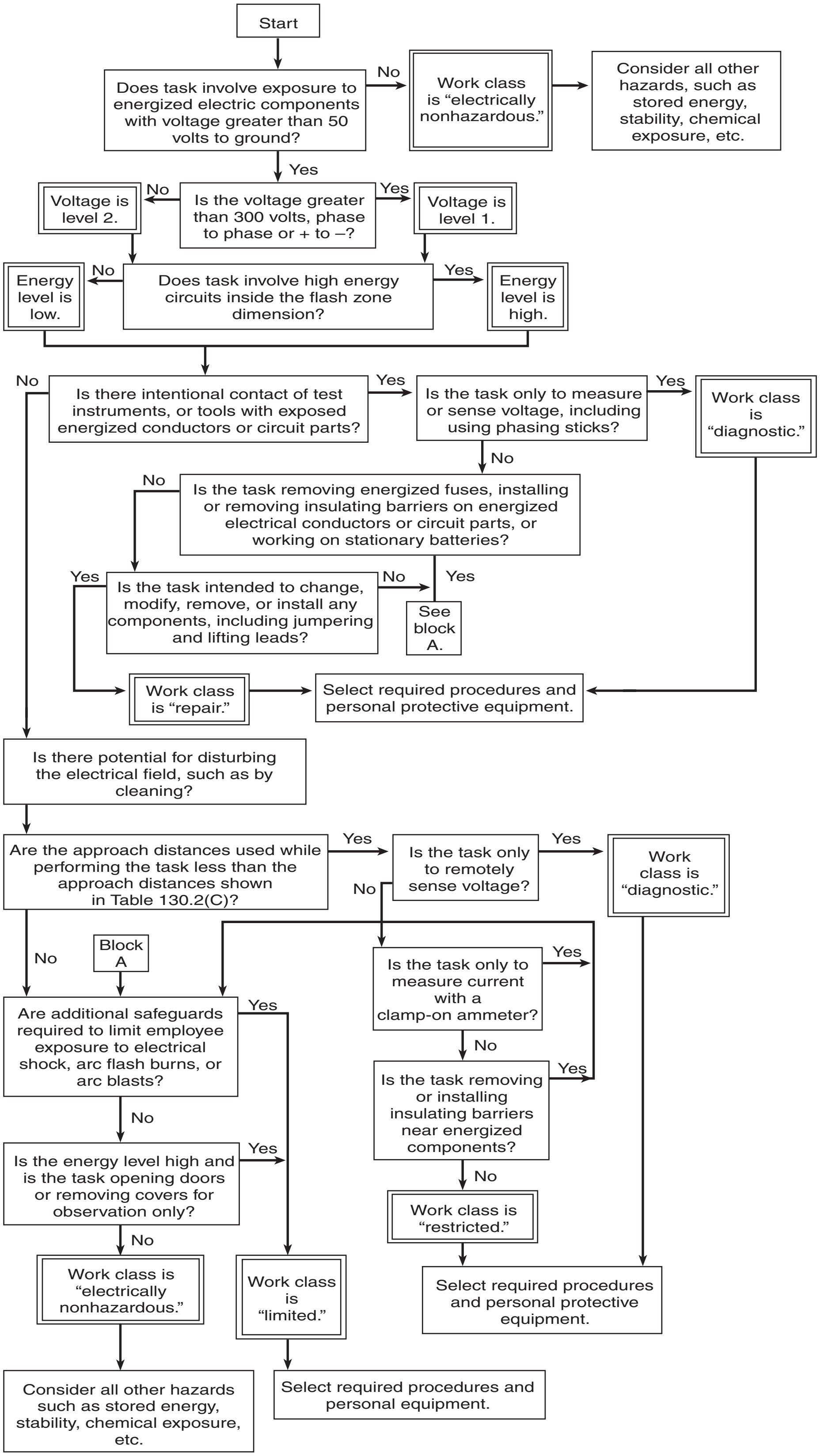

Figure F.1 Hazard/Risk Analysis Evaluation Procedure Flow Chart.