130.10 Cutting or Drilling. Before cutting or drilling into equipment, floors, walls, or structural elements where a likelihood of contacting energized electrical lines or parts exists, the employer shall perform a risk assessment to:

(1) Identify and mark the location of conductors, cables, raceways, or equipment
(2) Create an electrically safe work condition
(3) Identify safe work practices and PPE to be used

CHAPTER 2

Safety-Related Maintenance Requirements

An electrical work environment consists of three interrelated components: installation, maintenance, and safe work practices. Safe work practices are most effective when the installation is code compliant and the equipment is maintained appropriately. The NFPA documents that address each aspect are *NFPA 70®, National Electrical Code®* (*NEC®*); NFPA 70B, *Recommended Practice for Electrical Equipment Maintenance*; and NFPA *70E®*, *Standard for Electrical Safety in the Workplace®*. Exhibit 200.1 illustrates how these documents are interrelated.

NFPA *70E* considers equipment to be safe for operation if the equipment is installed according to the *NEC* and the manufacturer's instructions and has been maintained in accordance with NFPA 70B in the absence of specific manufacturer's instructions. A deficiency in the installation or maintenance of a system has the potential to adversely impact electrical safety of employees and safe work practices.

EXHIBIT 200.1

Electrical safety standard interaction.

Properly maintained electrical equipment has proven reliable. General maintenance dictates that equipment be maintained in accordance with the manufacturer's instructions and often addresses continued operation of the equipment. Chapter 2 is not a comprehensive maintenance program but does address safety-related maintenance of electrical equipment. A good maintenance program provides for the predictability and reliability necessary for safe operation.

A companion document for NFPA *70E* is NFPA 70B. The purpose of this recommended practice is to reduce hazards to life and property that can result from failure or malfunction of industrial-type electrical systems and equipment. It provides guidance on maintenance practices and on setting up a preventive maintenance program. NFPA 70B applies to preventive maintenance for electrical, electronic, and communication systems and equipment and is not intended to duplicate or supersede instructions that manufacturers normally provide. NFPA *70E* addresses the work practices that should be used during maintenance work.

Article 200 Introduction

Inadequate maintenance can have a negative impact on personal safety. The employer/owner must make sure that equipment is properly maintained. Normal operation of inadequately maintained equipment increases the risk of injury to the equipment operator, not just to the employee performing justified energized maintenance. The risk of equipment failure is reduced when equipment is properly and adequately maintained. A comprehensive electrical equipment maintenance program can increase the reliability of the electrical systems, which avoids electrical outages and malfunctions, and can decrease the exposure of employees to electrical hazards.

Table 130.5(C) requires that the equipment condition, including its maintenance, be taken into consideration for determining the likelihood of an arc flash occurring since a poorly maintained piece of equipment is more prone to failure. Section 130.5(G) requires that an arc flash risk assessment take into consideration the maintenance condition of overcurrent protective devices, because the condition can have an effect on the device's clearing time, thus increasing the incident energy.

Δ 200.1 Scope.

Chapter 2 addresses the requirements that follow.

(1) Chapter 2 covers practical safety-related maintenance requirements for electrical equipment and installations in workplaces as included in 90.2. 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.

Employers must determine a maintenance strategy and then implement the necessary components of that strategy. Some maintenance is necessary to support the implemented electrical safety program. For information on preventive maintenance programs, see NFPA 70B, *Recommended Practice for Electrical Equipment Maintenance*.

(3) For the purpose of Chapter 2, maintenance shall be defined as preserving or restoring the condition of electrical equipment and installations, or parts of either, for the safety of employees who work where exposed to electrical hazards. Repair or replacement of individual portions or parts of equipment shall be permitted without requiring modification or replacement of other portions or parts that are in a safe condition.

Informational Note: Refer to NFPA 70B, *Recommended Practice for Electrical Equipment Maintenance*; ANSI/NETA MTS, *Standard for Maintenance Testing Specifications for Electrical Power Distribution Equipment and Systems*; and IEEE 3007.2, *IEEE Recommended Practice for the Maintenance of Industrial and Commercial Power Systems*, for guidance on maintenance frequency, methods, and tests.

Maintenance is often the most neglected component of a strategy to provide a safe work environment. NFPA 70B provides employers with solutions, techniques, and testing intervals for adequate maintenance to maximize the reliability of electrical equipment and systems. It describes electrical maintenance subjects and issues surrounding maintenance of electrical equipment.

NFPA 70B provides information on commissioning and on an effective preventive maintenance program. Commissioning, or acceptance testing, verifies that the equipment functions as intended by the design specification. Acceptance testing generates baseline results that can help to identify equipment deterioration or a change in reliability or safety. Future trend analysis is useful in predicting when equipment failure or an out of tolerance condition will occur and can allow for convenient scheduling of outages.

Most electrical equipment will have a predictable life cycle, and knowing the service life can be crucial in predicting the reliability and safe operation of the equipment. Routine maintenance and maintenance tests can be performed at regular intervals over the service life of equipment or when condition indicators warrant. Maintenance tests help identify changes in overcurrent protective device characteristics and potential failures before they occur. A shutdown can then be scheduled and repairs can be made before equipment damage and with minimum exposure to employees. An alternative method is utilizing reliability-centered maintenance (RCM) techniques. See Chapter 30 of NFPA 70B for further information on RCM.

General Maintenance Requirements Article 205

At the time at which it was originally installed, equipment was in a new condition and everything was expected to be in order. Through its use, equipment slowly begins to show signs of wear and tear. Proper maintenance is not just the act of fixing, adjusting, or filling fluids. There is a time aspect that is just as important. Maintenance of a piece of equipment may only be needed every year or two in one installation. That same piece of equipment in another installation may require monthly maintenance to be considered properly maintained.

Worker Alert

You must be qualified to perform maintenance on a specific piece of equipment. Your knowledge of similar equipment or of identical tasks does not equate to your ability to correctly or safely perform maintenance on another piece of equipment.

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.

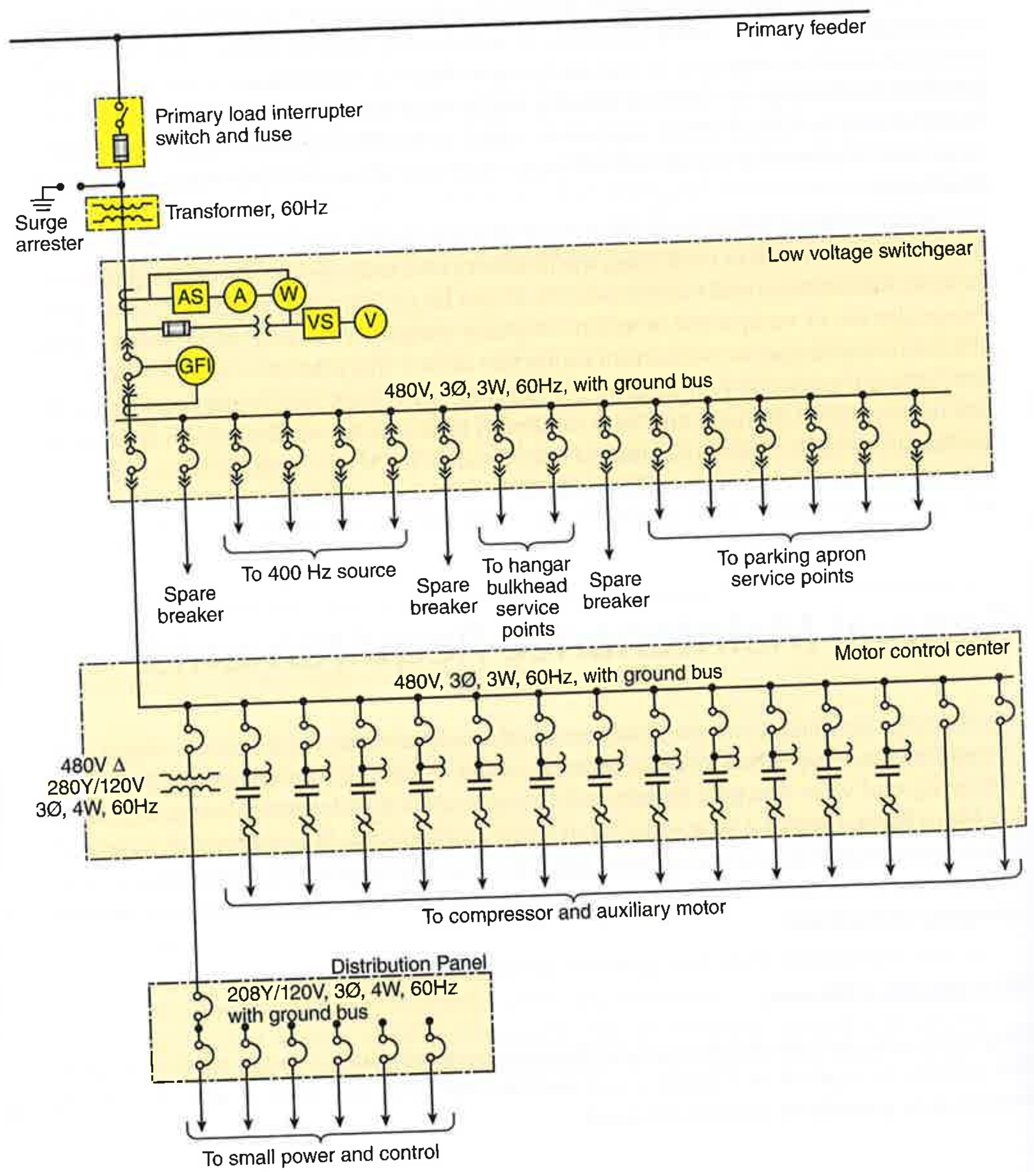
A single-line diagram, where provided for the electrical system, shall be maintained in a legible condition and shall be kept current.

Single-line diagrams are one of the best sources of information for locating the electrical hazards that might be encountered at a work site. Therefore, all qualified employees must have the ability to read and understand the single-line diagrams of the systems they work on.

Single-line diagrams are created for different purposes and may display different information. Some single-line diagrams are supplemented by equipment schedules that may or may not be included on the diagram. Some power sources, such as control power for a motor control center, may not be detailed on the single-line diagram. These sources may be detailed on a schematic or elementary diagram or in a panelboard schedule. Exhibit 205.1 shows a simple single-line diagram.

EXHIBIT 205.1

Simple single-line diagram.



To be useful, the diagrams must be updated and verified. Legible, up-to-date single-line diagrams, along with any necessary supplemental documentation, enable an electrically safe work condition to be implemented. Maintaining these drawings provides valuable information, including the following:

- Sources of power to a specific piece of equipment
- The interrupting capacity of devices at each point in the system
- Possible paths of potential backfeed
- The correct rating for overcurrent devices

205.3 General Maintenance Requirements.

Electrical equipment shall be maintained in accordance with manufacturers' instructions or industry consensus standards to reduce the risk associated with failure. The equipment owner or the owner's designated representative shall be responsible for maintenance of the electrical equipment and documentation.

Informational Note No. 1: Common industry practice is to apply test or calibration decals to equipment to indicate the test or calibration date and overall condition of equipment that has been tested and maintained in the field. These decals provide the employee immediate indication of last maintenance date and if the tested device or system was found acceptable on the date of test. This local information can assist the employee in the assessment of overall electrical equipment maintenance status.

Informational Note No. 2: Noncontact diagnostic methods in addition to scheduled maintenance activities of electrical equipment can assist in the identification of electrical anomalies.

Equipment that is not maintained or is overly maintained does not only decrease the reliability of the equipment but also presents an increased risk to an employee. A well-established maintenance program will schedule maintenance so that equipment is properly maintained. Chapters 4, 5, and 6 of NFPA 70B, *Recommended Practice for Electrical Equipment Maintenance*, contain recommendations for an effective electrical preventive maintenance program. (See Supplement 2 for excerpts from these NFPA 70B chapters.) The chapters provide a better understanding of benefits that can be derived from a well-administered electrical preventive maintenance program. Deterioration of equipment is normal, and an effective electrical preventive maintenance can delay and predict equipment failure.

Onsite conditions can also affect the required maintenance of equipment. The equipment owner may need to alter the maintenance schedule to address concerns specific to the installation. The equipment manufacturer should be consulted when the recommended maintenance is modified.

205.4 Overcurrent Protective Devices.

Overcurrent protective devices shall be maintained in accordance with the manufacturers' instructions or industry consensus standards. Maintenance, tests, and inspections shall be documented.

The automatic operation of an overcurrent device should not be assumed to have been the result of a false condition. The system should be investigated to determine the cause of the device's operation before resetting the device.

Following the maintenance schedule defined by the manufacturer or by a consensus standard reduces the risk of failure and the subsequent exposure of employees to electrical hazards such as shock, arc flash, or arc blast. Documents such as NFPA 70B and ANSI/NETA MTS, *Standard for Maintenance Testing Specification*, provide testing and maintenance instructions for some overcurrent devices. ANSI/NEMA AB 4, *Guidelines for*

Worker Alert

Unless the maintenance of overcurrent devices can be proven by documentation, relying on the questionable maintenance of an overcurrent device places you at a greater risk of injury. If you are operating equipment, establishing an electrically safe work condition, or performing justified energized work, you may not be adequately protected from severe injury.

EXHIBIT 205.2

An adjustable-trip circuit breaker with a transparent, removable, and sealable cover. (Courtesy of Square D by Schneider Electric)

Inspection and Preventive Maintenance of Molded Case Circuit Breakers Used in Commercial and Industrial Applications, provides useful information on the type of maintenance, testing, and inspections that should be documented. See Exhibit 205.2 for an example of an adjustable-trip circuit breaker.

The overcurrent protective device is a critical component for reducing the risk of injury to the employee. Whether the policy is always establishing an electrically safe work condition or some energized electrical work is justified, the overcurrent device is used to determine the required arc flash PPE. Although all maintenance should be documented, the need is specifically stated for overcurrent devices. Any action is generally considered to have not occurred without proper documentation. This especially true if an incident were to occur.

205.5 Spaces About Electrical Equipment.

All working space and clearances required by electrical codes and standards shall be maintained.

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

Adequate working space allows employees to perform tasks without jeopardizing their safety. Sufficient clearance allows for the proper use of tools and equipment while preventing inadvertent contact, which could result in an electrical incident and injury. Exhibit 205.3 illustrates the working space in front of electrical equipment required by *NFPA 70, National Electrical Code (NEC)*. Working spaces must be kept clear. Obstructions — even if temporary, such as with stored equipment — restrict access to and egress from the working space.

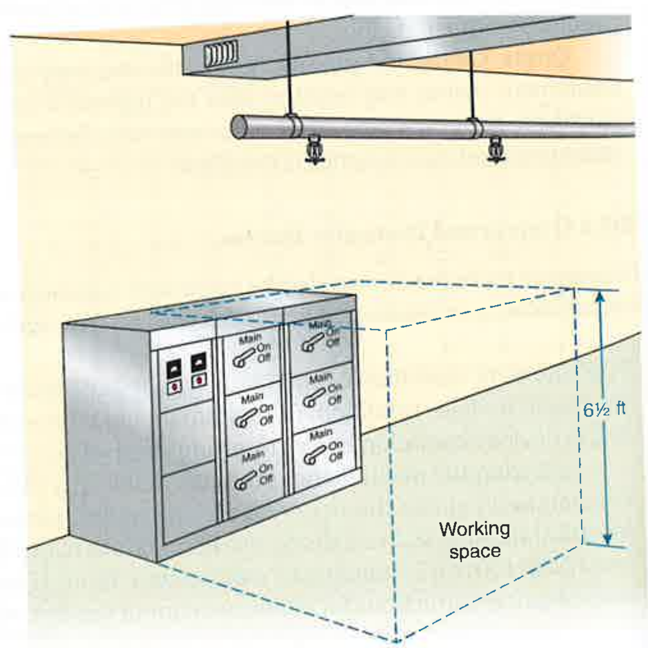
The *NEC* general rule for working space is that all equipment be provided with enough space for safe operation and maintenance. The specific working space in the *NEC* is for equipment that warrants justified energized work. This working space may be applied to equipment that will always be in an electrically safe work condition when work is performed. The design layout must consider the possibility that an expected task may require more working space than that specified in the *NEC*.

Worker Alert

You should recognize when there is insufficient space for you to safely perform an assigned task. You should not conduct the task unless sufficient room is provided.

EXHIBIT 205.3

Working space in front of electrical equipment.



205.6 Grounding and Bonding.

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

The electrical continuity achieved by grounding and bonding enables the fault current to return to the source. During a short-circuit condition, an overcurrent device relies on an effective grounding path to operate as designed. The clearing time might be extended without effective grounding and bonding, thus increasing the amount of incident energy to which an employee could be exposed.

205.7 Guarding of Energized Conductors and Circuit Parts.

Enclosures shall be maintained to guard against unintentional contact with exposed energized conductors and circuit parts and other electrical hazards. Covers and doors shall be in place with all associated fasteners and latches secured.

Preventing access to energized conductors and circuits is a core concept for employee safety. Energized electrical conductors are required to be guarded against accidental contact, which may be achieved by covering, shielding, enclosing, elevating, or otherwise preventing contact by unauthorized persons or objects. Access to exposed energized electrical components guarded by a locked fence or door can be restricted to only authorized and qualified personnel who have the key. Energized parts should not be exposed to any employee unless safety measures are put in place.

Worker Alert

In order to recognize that a guard is missing, you must first be able to identify equipment that is under a normal operating condition.

205.8 Safety Equipment.

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

Locks and interlocks provide safety for employees by ensuring that only authorized and qualified persons have access to areas that contain exposed energized electrical conductors or circuit parts. They are also used to establish an electrically safe work condition through a lockout/tagout program. An interlocking system may be used to control the flow of electrical power through some systems and to control the sequence of switch operations. Maintaining these locks and interlocks in good working condition helps to minimize exposure to electrical hazards.

205.9 Clear Spaces.

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

Good housekeeping is an important characteristic of a safe work environment. Storage that blocks access or egress or prevents safe work practices must be avoided at all times. The area must not be used for storage, including the storage of movable items such as push carts or trash bins. Maintaining adequate access is essential for an employee to operate the equipment in a safe and efficient manner. The primary intent of providing egress from the area is so that, in the event of an emergency such as an arc flash incident, the employee can escape.

Worker Alert

Clear space is necessary to allow you to quickly leave an area in the event of an incident. Items including tool boxes, parts shipping containers, or hand carts must not be placed in your path of egress.

205.10 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.

It is crucial for electrical safety that identification on the single-line diagram is up to date and that it match the identification on the installed equipment. Up-to-date operating or maintenance instructions and necessary warnings are vital to ensure employee safety.

205.11 Warning Signs.

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

Warning signs inform both qualified and unqualified employees of potential hazards that might be encountered. They must be clearly visible before examination, adjustment, servicing, or maintenance of the equipment. For example, according to 130.5(H), a warning label for a potential arc flash hazard must provide sufficient information to enable an employee to select appropriate PPE. Other warning signs may be required by installation standards and OSHA regulations.

205.12 Identification of Circuits.

Circuit or voltage identification shall be securely affixed and maintained in updated and legible condition.

Several sections of the *NEC* require that circuit identification be securely affixed to the equipment. *NEC* Section 110.22(A) requires that the purpose of each disconnecting means be indicated unless the purpose is obvious from the arrangement. Section 230.70(B) requires identification of the service disconnecting means. Where a structure is supplied by more than one service, 230.2(E) requires that each service disconnecting means location have a permanent plaque indicating the location of the other disconnecting means.

NEC Section 408.4 details the circuit identification information required for switchgear, switchboards, and panelboards. The circuit identification is to be up to date, accurate, and legible. Mislabeled equipment endangers employees who might assume that they have de-energized the circuit feeding the equipment. However, circuit identification does not remove the employee's responsibility for verifying the absence of voltage when establishing an electrically safe work condition. Regardless of the presence of labels or warnings, the need to perform a risk assessment remains.

205.13 Single and Multiple Conductors and Cables.

Electrical cables and single and multiple conductors shall be maintained free of damage, shorts, and ground that would expose employees to an electrical hazard.

Cables may be exposed after installation. Single and multiple conductors are often installed in raceways or in cable trays. When the cable or conductors are installed in an open cable tray, they should be protected from falling objects that could damage the cable. Temporary protection should be provided when working around exposed cable and conductors so as not to damage the cable.

Worker Alert

You are typically the last one available to inspect cords and cables after they have been brought to the work site. Your inspection should occur before the tool or extension cord is plugged into a receptacle. Typically you are also responsible for the routing and protection of the cord during the performance of the task.

205.14 Flexible Cords and Cables.

Flexible cords and cables shall be maintained to preserve insulation integrity.

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

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

(3) **Repair and Replacement.** Cords and cord caps for portable electrical equipment shall be repaired and replaced by qualified personnel and checked for proper polarity, grounding, and continuity prior to returning to service.

The transient use of flexible cords and cables increases the possibility for cord and plug damage or interruption of the equipment grounding conductor. Before each use, extension cords must be inspected to ensure that there is no damage [see 110.5(C)]. A damaged ground prong is a common problem with extension cords and cord caps for portable equipment. The ground prong provides the grounding path necessary to mitigate electrical shock or electrocution. Incorrect termination of flexible cords and cables at an enclosure is another common problem. Tension placed on the cable can allow conductors to be exposed and subject the employee to a hazard.

NEC Section 400.9 requires flexible cord to be used only in continuous lengths without splice or tap where initially installed. The repair of hard-service cord and junior hard-service cord 14 AWG and larger is permitted if the conductors are spliced and the completed splice retains the insulation, outer sheath properties, and usage characteristics of the cord being spliced. An in-line repair is not permitted if the cord is reused or reinstalled.

NEC Section 590.6(B)(3) has criteria for an assured equipment grounding conductor program for the temporary use of flexible cords. This written program is continuously enforced at the site by designated persons to ensure that equipment grounding conductors are installed and maintained for all cord sets and equipment connected by cord and plug. The following tests are required before first use on site, when there is evidence of damage, before equipment is returned to service following any repairs, and at intervals not exceeding 3 months:

1. Test all equipment grounding conductors for electrical continuity.
2. Test each receptacle and attachment plug for correct attachment of the equipment grounding conductor.
3. Verify that the equipment grounding conductor is connected to its proper terminal.

205.15 Overhead Line Clearances.

For overhead electric lines under the employer's control, grade elevation shall be maintained to preserve no less than the minimum designed vertical and horizontal clearances necessary to minimize risk of unintentional contact.

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

Worker Alert

Before returning equipment to a normal operating condition and re-energizing, you must account for all nuts, screws, tape, washers, wire pieces, stripped insulation, and any other tools or materials.

210.1 Enclosures.

Enclosures shall be kept free of material that would expose employees to an electrical hazard.

Housekeeping is a critical action that must be performed before a work task is completed. Materials or tools left in enclosures are a common cause of a fault and can initiate an arc flash event. Employees must remove all extraneous materials and all tools from and around enclosures for electrical safety.

210.2 Area Enclosures.

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

Fences and other enclosures should be inspected regularly to ensure that they continue to guard against entry of unauthorized personnel or animals. Gates and doors, especially if equipped with panic hardware, should be checked regularly for security and proper operation. Any defect or damage must be repaired promptly and sufficiently to afford equivalent protection to the initial installation.

210.3 Conductors.

Current-carrying conductors (buses, switches, disconnects, joints, and terminations) and bracing shall be maintained to perform as follows:

(1) Conduct rated current without overheating

The bundling of conductors affects the ability of those conductors to carry current without overheating. Conductors bundled in wiring methods such as raceways, cable trays, or gutters were calculated for proper ampacity for the number of conductors present at time of installation. Additional conductors placed into these routing methods can affect the safe function of all conductors. Re-evaluation of the ampacity of the new and existing conductors should be conducted prior to the installation of the additional conductors to determine their capacity to dissipate heat.

Discoloration of conductors or terminals is evidence of overheating. Infrared thermography performed while the equipment is operating is one method of investigating overheating. Thermography may be considered a hazardous task depending upon how it is performed. The use of properly installed infrared windows in enclosures is one way to lower the risk associated with infrared scanning. If evidence of overheating is found, the equipment should be de-energized and the problem investigated and repaired in accordance with manufacturer's specifications.

(2) Withstand available fault current

Short circuits or fault currents present a significant amount of destructive energy that can cause serious damage to electrical equipment and create the potential for serious injury to personnel. The short-circuit current rating of electrical equipment is the amount of current that it can carry safely for a specific period of time before it is damaged. For example, a bus duct may have a short-circuit current rating of 22,000 rms symmetrical amperes for three cycles. It might be damaged if 30,000 amperes were to flow through the bus for three cycles or if 22,000 amperes were to flow for six cycles.

210.4 Insulation Integrity.

Insulation integrity shall be maintained to support the voltage impressed.

Temperature extremes, chemical contamination, operating conditions, and aging are common causes that can degrade insulation performance and jeopardize the safety of personnel. Insulation testing performed on a regular basis can be used to indicate if the insulation is deteriorating over time. If the insulation resistance falls below an accepted value or is declining rapidly over a period of time, corrective measures can be taken to prevent damage to equipment and injury to personnel. Degradation of insulation below an acceptable level is a sign of impending failure, and normal operation of the equipment may no longer be a safe task.

210.5 Protective Devices.

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

Informational Note: Improper or inadequate maintenance can result in increased opening time of the overcurrent protective device, thus increasing the incident energy.

Worker Alert

Whether you are operating equipment, establishing an electrically safe work condition, or performing justified energized work, you are at a greater risk of injury if protective devices have not been maintained.

Protective devices are designed to operate within a prescribed range and to disconnect the power to equipment in a timely manner in order to minimize damage to equipment and injury to personnel. If the amount of available fault current increases for any reason — due to a change in upstream components, for example — each protective device must be analyzed to determine if it is adequate for interrupting the new fault current.

When a protective device fails to operate as intended, employees performing normal operation of equipment can be exposed to an injury from a shock or an arcing fault. If the employee is conducting justified energized work and clearing time of the protective device is delayed, an incident energy level greater than anticipated can occur, rendering the employee's selected PPE inadequate.

See Article 225 for further information regarding the maintenance of fuses and circuit breakers.

Premises Wiring

Article 215

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.

In order to protect employees from contact with energized electrical components, all covers and doors must be closed and latched using all fasteners provided with the equipment. All unused openings other than those intended for the operation of equipment or those as part of the design must be closed to afford protection substantially equivalent to the wall of the equipment.

Some panelboards are equipped with a deadfront cover and outer trim. The trim has a hinged door that provides access to the circuit breakers without exposing any live parts. Removing the trim exposes the gutter space. Although the breaker terminals are not visible with the trim removed, they are capable of being inadvertently touched and are considered exposed.

215.2 Open Wiring Protection.

Open wiring protection, such as location or barriers, shall be maintained to prevent unintentional contact.

A damaged or moved barrier will not provide the protection intended. The protection provided by elevating equipment may be breached if a new means of access, such as a mezzanine, is installed. Protection of open wiring by location in a battery room accessible only to qualified persons is recognized by 110.27(A)(1) of *NFPA 70, National Electrical Code (NEC)*. See Exhibit 215.1.

EXHIBIT 215.1

Open wiring in a restricted access battery room. (Courtesy of International Association of Electrical Inspectors)

215.3 Raceways and Cable Trays.

Raceways and cable trays shall be maintained to provide physical protection and support for conductors.

Periodic inspection of raceway and cable tray systems will ensure that the systems will function as intended, which is not limited to only providing physical protection and support for conductors. Metal raceway and metal cable tray systems are recognized by the *NEC* as equipment grounding conductors. When these systems are used as an equipment grounding conductor, electrical continuity must be maintained to ensure they have the capacity to conduct safely any fault current likely to be imposed and have sufficiently low impedance to limit the voltage to ground to cause operation of the circuit protective device.

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.

A controller can be a remote-controlled magnetic contactor, variable frequency drive, switch, circuit breaker, or device that normally is used to start and stop motors and other apparatus. Stop-and-start stations and similar control circuit components that do not open the power conductors to the motor are not considered to be controllers.

220.2 Protection and Control Circuitry.

Protection and control circuitry used to guard against unintentional contact with exposed energized conductors and circuit parts and to prevent other electrical or mechanical hazards shall be maintained.

Some controller equipment is designed with removable protective components that are used to prevent or minimize exposure to an electrical hazard. If these protective components are removed for repairs or maintenance to the equipment, they must be reinstalled after the task is complete to ensure the continued integrity of the installed components.

Fuses and Circuit Breakers Article 225

Overcurrent devices play an important role in electrical safety. They protect not only conductors and equipment but also employees. To do this, fuses and circuit breakers must operate within their published time–current characteristic curves safely and correctly. Section 130.5(B) requires that the condition of overcurrent protective devices be taken into consideration for determining the severity of a potential injury to an employee. Section 130.5(G) requires considering the device's condition for an arc flash risk assessment because the condition can have an effect on the device's clearing time. Improper maintenance of these devices places employees who are performing normal operations, establishing an electrically safe work environment, or performing justified energized work at an increased risk of injury. Therefore, adequate maintenance is essential to maintaining a safe work environment.

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. Non-current limiting fuses shall not be modified to allow their insertion into current-limiting fuseholders.

Discoloration of fuse terminals and fuse clips could be due to heat from poor contact or corrosion. Fuseholders with rejection features need to be maintained so that they will only accept current-limiting fuses. A fuseholder should never be altered or forced to accept a fuse for which it is not designed. Any damaged fuse should be promptly replaced with an identical fuse. Exhibit 225.1 shows examples of fuses that include a rejection feature to prohibit the installation of non-current-limiting fuses.

Different types of fuses are used throughout an electrical system, and fuses from different manufacturers differ by performance, characteristics, and physical size. Although many fuses might have the same ampere rating, their operating characteristics may differ, making coordination unlikely. Replacement fuses must conform to all requirements

EXHIBIT 225.1

Fuses with a rejection feature. (Courtesy of Eaton, Bussmann Division) detailed in the electrical hazards risk assessment. For further information on the electrical maintenance of fuses, see Chapter 18 of NFPA 70B, *Recommended Practice for Electrical Equipment Maintenance*.

225.2 Molded-Case Circuit Breakers.

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

Although molded-case circuit breakers can be in service for years and may never be called upon to perform their overload- or short-circuit-tripping functions, they are not "maintenance-free" devices. They require both mechanical and electrical maintenance. Mechanical maintenance consists of inspection and adjustment as needed of the mechanical mounting and electrical connections and manual operation of the circuit breaker. Electrical maintenance verifies that the circuit breaker will trip at its desired set point.

Excessive heat in a circuit breaker can cause tripping and an eventual failure. Molded-case circuit breakers should be kept free of external contamination so that internal heat can dissipate normally. A clean circuit breaker enclosure also reduces the potential for arcing between energized conductors and between energized conductors and ground. Loose connections are a common cause of excessive heat, and maintenance should involve checking for loose connections or evidence of overheating. All connections should be maintained in accordance with manufacturers' instructions.

The structural strength of the case is important in withstanding the stresses imposed during fault current operation. Therefore, an inspection should be made for cracks in the case and replacement made if necessary.

Different types of circuit breakers are used throughout an electrical system. Circuit breakers from different manufacturers or those from a different series from the same manufacturer differ by performance and characteristics. Although many circuit breakers might have the same ampere rating, their operating characteristics may differ, making coordination unlikely. Replacement circuit breakers must conform to all requirements detailed in the electrical hazards risk assessment.

Although manual operation of the circuit breaker does not move the mechanical linkages in the tripping mechanisms, it assists in keeping the contacts clean and the lubrication performing properly, which helps assure that the circuit breaker will operate as intended. Some circuit breakers have push-to-trip buttons that should be operated periodically to exercise the tripping mechanical linkages. See Chapter 17 of NFPA 70B and also ANSI/NEMA AB 4, *Guidelines for Inspection and Preventive Maintenance of Molded Case Circuit Breakers Used in Commercial and Industrial Applications*, for more information on electrical maintenance of molded-case circuit breakers.

225.3 Circuit Breaker Testing After Electrical Faults.

Circuit breakers that interrupt faults approaching their interrupting ratings shall be inspected and tested in accordance with the manufacturer's instructions.

Circuit breakers are tested for thousands of manual operations, which is different than a trip due to a fault. Testing of circuit breakers includes higher currents and overloads, but this typically involves a few automatic trips. The type of fault, the energy level present in that fault, and the duration of the fault may all impact the operation of the circuit

breaker. A single incident may damage a circuit breaker if pushed beyond its specifications. The manufacturer should be consulted for information regarding the capabilities of a specific circuit breaker.

A high-level fault current can cause damage even when catastrophic failure does not occur. Testing of the device will ensure that the circuit breaker is not damaged and that it will operate at its set point if called upon again. Circuit breakers that encounter high short-circuit currents should receive a thorough inspection and be replaced as necessary.

The result of a circuit breaker not operating within its designed parameters can be disastrous. The incident energy may be increased if the circuit breaker does not trip within its set clearing time. For example, an employee 18 inches from a 20-kA short circuit and 5-cycle tripping time has a potential incident energy exposure of 6.5 cal/cm^2. If the tripping time is increased to 30 cycles, due to improper maintenance or to the circuit breaker being out of calibration, the incident energy is increased to 38.7 cal/cm^2. An employee wearing 8 cal/cm^2 arc flash PPE for the task as specified in the work permit will not be inadequately protected and may suffer substantial injuries or death.

Circuit breakers should have an initial acceptance test and subsequent maintenance testing at recommended intervals. Following the maintenance schedule defined by the manufacturer or by a consensus standard reduces the risk of failure and the subsequent exposure of employees to electrical hazards. NFPA 70B, ANSI/NEMA AB 4, and ANSI/NETA MTS, *Standard for Maintenance Testing Specification*, are documents that can assist an employer in understanding the specific tests and testing intervals required to ensure reliability and safety.

Rotating Equipment — Article 230

230.1 Terminal Boxes.

Terminal chambers, enclosures, and terminal boxes shall be maintained to guard against unintentional contact with exposed energized conductors and circuit parts and other electrical hazards.

Vibration and movement of a motor terminal box could exert pressure on the conductors that are terminated or spliced within it. The terminal box must be securely mounted in place by the complete set of hardware supplied by the manufacturer.

230.2 Guards, Barriers, and Access Plates.

Guards, barriers, and access plates shall be maintained to prevent employees from contacting moving or energized parts.

Inspection and maintenance of rotating equipment and motor guards are necessary to prevent an employee from contacting or becoming entangled in the moving part. Should any guard, barrier, or access plate be removed for repairs or maintenance of the rotating equipment, it must be properly restored to its original integrity.

Article 235 Hazardous (Classified) Locations

Confined spaces, toxic chemicals, and radiation exposure are often associated with the term *hazardous location*. While each of these may qualify as a hazardous location with the presence of the right type of material, they are not necessarily hazardous locations as defined by *NFPA 70, National Electrical Code (NEC)*. A flammable or combustible concentration of a material must be available in order for a location to be considered hazardous within the scope of the *NEC*.

Worker Alert

You should not carry flashlights, radios, cell phones, computers, multimeters, or other devices into a hazardous location unless the devices have been evaluated for use in the specific hazardous location.

235.1 Scope.

This article covers maintenance requirements in those areas identified as hazardous (classified) locations.

Informational Note No. 1: These locations need special types of equipment and installation to ensure safe performance under conditions of proper use and maintenance. It is important that inspection authorities and users exercise more than ordinary care with regard to installation and maintenance. The maintenance for specific equipment and materials is covered elsewhere in Chapter 2 and is applicable to hazardous (classified) locations. Other maintenance will ensure that the form of construction and of installation that makes the equipment and materials suitable for the particular location are not compromised.

Informational Note No. 2: The maintenance needed for specific hazardous (classified) locations depends on the classification of the specific location. The design principles and equipment characteristics, for example, use of positive pressure ventilation, explosionproof, nonincendive, intrinsically safe, and purged and pressurized equipment, that were applied in the installation to meet the requirements of the area classification must also be known. With this information, the employer and the inspection authority are able to determine whether the installation as maintained has retained the condition necessary for a safe workplace.

Hazardous locations are required by the *NEC* to be documented. This document often shows the source of the material, process parameters (e.g., temperature, flow, pressure), hazardous location boundaries, and any other pertinent information. Personnel responsible for the design, installation, inspection, operation, and maintenance of electrical equipment are required to have access to this document.

Maintenance personnel must be trained to understand the explosive nature of the material, the type of protection employed, and how equipment maintenance is important to a safe environment. There are 15 different types of protection recognized by the *NEC*, and each prevents ignition of the atmosphere in a different manner. Misunderstanding the protection technique, or applying inappropriate maintenance methods, can be catastrophic.

Troubleshooting equipment in a hazardous location presents a special problem. Most equipment cannot be opened while energized in the presence of explosive or combustible material. Most portable troubleshooting instruments are powered by a battery; however, "battery operated" does not equate to being safe for use in a hazardous location. A spark is likely to occur when the testing device contacts a conductor, and an explosion is possible if an explosive atmosphere exists. The energy available from a single battery is capable of igniting some explosive atmospheres. Before conducting any troubleshooting or maintenance in a hazardous area, it should be determined that an explosive atmosphere does not exist.

235.2 Maintenance Requirements for Hazardous (Classified) Locations.

Equipment and installations in these locations shall be maintained such that the following criteria are met:

(1) No energized parts are exposed.

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

(2) There are no breaks in conduit systems, fittings, or enclosures from damage, corrosion, or other causes.
(3) All bonding jumpers are securely fastened and intact.
(4) All fittings, boxes, and enclosures with bolted covers have all bolts installed and bolted tight.
(5) All threaded conduit are wrenchtight and enclosure covers are tightened in accordance with the manufacturer's instructions.
(6) There are no open entries into fittings, boxes, or enclosures that would compromise the protection characteristics.
(7) All close-up plugs, breathers, seals, and drains are securely in place.
(8) Marking of luminaires (lighting fixtures) for maximum lamp wattage and temperature rating is legible and not exceeded.
(9) Required markings are secure and legible.

Worker Alert

You should be aware that fasteners for hazardous location equipment are evaluated for the locations, atmosphere, and chemicals that they are designed to be subjected to. These cover bolts, screws, nuts, and fittings are often a very specific grade of metal selected to withstand internal explosions. You should not substitute these fasteners with any other than those specified by the manufacturer to avoid the potential for a larger explosion to occur.

Equipment maintenance in hazardous locations should be performed only by personnel trained to maintain the special electrical equipment. Employees should be trained to identify and eliminate ignition sources such as high surface temperatures, stored electrical energy, and the buildup of static charges, and to identify the need for special tools, equipment, and tests. These individuals should be familiar with the requirements for the electrical installation of the equipment and protection technique employed. They should understand that, for example, joint compound or tape may weaken an explosionproof fitting during an ignition or may interrupt the required ground path.

Maintenance personnel should be trained to look for cracked viewing windows, missing fasteners, and damaged threads that may affect the integrity of the protection system. All bolts, screws, fittings, and covers must be properly installed. Every missing or damaged fastener must be replaced with those specified by the manufacturer to provide sufficient strength to withstand an internal ignition.

After equipment maintenance is performed, the integrity of the protective scheme that prevents an explosion must be restored. Re-establishing the required air flow for a purged system or sealing a cable within a conduit fitting of an explosionproof system are two examples of restoring the protective scheme.

Article 240 Batteries and Battery Rooms

Article 480 of *NFPA 70, National Electrical Code (NEC)* applies to installations of stationary storage batteries. The standards that follow are also referenced for the installation of stationary batteries:

- IEEE 484, *Recommended Practice for Installation Design and Installation of Vented Lead-Acid Batteries for Stationary Applications*
- IEEE 485, *Recommended Practice for Sizing Vented Lead-Acid Storage Batteries for Stationary Applications*
- IEEE 1145, Recommended Practice for Installation and Maintenance of Nickel-Cadmium Batteries for Photovoltaic (PV) Systems.
- IEEE 1187, *Recommended Practice for Installation Design, and Installation of Valve-Regulated Lead-Acid Batteries for Stationary Applications*
- IEEE 1375, *IEEE Guide for the Protection of Stationary Battery Systems*
- IEEE 1578, *Recommended Practice for Stationary Battery Spill Containment and Management*
- IEEE 1635/ASHRAE 21, *Guide for the Ventilation and Thermal Management of Stationary Battery Installations*

240.1 Ventilation.

When forced or natural ventilation systems are required by the battery system design and are present, they shall be examined and maintained to prevent buildup of explosive mixtures. This maintenance shall include a functional test of any associated detection and alarm systems.

Informational Note: "Natural ventilation" implies there are no mechanical mechanisms. Maintenance includes activities such as inspection and removal of any obstructions to natural air flow.

Depending on the battery construction and chemistry, ventilation of the battery room may not be required. A ventilation system is designed to provide for sufficient diffusion and ventilation of gases to prevent the accumulation of an explosive mixture. Mechanical ventilation may not be mandated and ventilation may be achieved by other means. Maintenance of ventilation systems not only includes any electrical system but also maintenance of the associated mechanical systems such as duct work, screens, louvers, and exhaust ports. Where necessary, NFPA 1, *Fire Code*, requires ventilation in accordance with the mechanical code, and either limits the maximum concentration of hydrogen to 1.0 percent of the total volume of the room or requires ventilation at a rate of not less than 1 $ft^3/min/ft^2$ (5.1 $L/sec/m^2$) of floor area.

240.2 Eye and Body Wash Apparatus.

Eye and body wash apparatus shall be maintained in operable condition.

Proper maintenance of eye and body wash apparatus ensures that they supply clean, potable water and that they are in proper working order. A maintenance program should define guidelines for inspection, testing, and maintenance that includes procedures for flushing and flow rate testing.

Article 245 Portable Electric Tools and Equipment

Fixed equipment is typically included in a maintenance program, but portable tools are commonly omitted. The intermittent use of portable tools by many users for a multitude of tasks in various locations often subjects the tools to damage. Electrical shock and electrocution from portable tool use is often the result of improper handling or storage. A facility's electrical safety program must include the maintenance and inspection of portable 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 criteria are met:

(1) There are no breaks, damage, or cracks exposing energized conductors and circuit parts.
(2) There are no missing cover plates.
(3) Terminations have no stray strands or loose terminals.
(4) There are no missing, loose, altered, or damaged blades, pins, or contacts.
(5) Polarity is correct.

Worker Alert

Equipment inspected prior to arriving at the work site may suffer damage in transit. You should always inspect portable tools and flexible cords prior to plugging the equipment into a receptacle. Periodic inspection of portable equipment is also important to help uncover damage or defects from its use.

A visual inspection should be conducted both when a tool is issued and when the tool is returned to the storage area after each use. Employees should be trained to recognize visible defects such as cut, frayed, spliced, or broken cords; cracked or broken attachment plugs; and missing or deformed grounding prongs. Damaged housings, broken switches, and missing parts should also be detected during a visual inspection. Any defect should be reported immediately and the tool removed from service and tagged "Do Not Use" until it is repaired.

Employees should be instructed to report all shocks immediately, no matter how minor, and to cease using the tool. The tool must be immediately removed from service, tagged "Do Not Use," examined, and repaired before further use. Tools that trip GFCI devices must also be removed from service until the cause has been determined and corrected. Also, a record of the GFCI tripping should be given to the next work shift.

Periodic electrical testing of portable electric tools can uncover operating defects. Nonfunctioning and malfunctioning equipment should be returned for repair before continued use. Immediate correction of a defect ensures safe operation, prevents breakdown, and limits more costly repairs.

Article 250 Personal Safety and Protective Equipment

The use of PPE is the last protective measure an employer may specify after exhausting all the other hierarchy of risk control methods for minimizing the risk of employee injury. Since PPE is an employee's final opportunity to avoid severe injury in the event of an incident, employees have a vested interest in maintaining PPE. The condition of the PPE has a direct impact on the employee's well-being. Therefore, employees should take an active role in inspecting and maintaining this special equipment. See 130.7 for additional information and requirements for the selection of PPE.

Worker Alert

You should take a personal interest in any PPE, including tools, that you use to perform tasks. This equipment is your last line of defense that may prevent serious injury or your death. Poorly maintained gear cannot only initiate an incident but also may increase the severity of your injury.

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) Test instruments
(5) Blanket and similar insulating equipment
(6) Insulating mats and similar insulating equipment
(7) Protective barriers
(8) External circuit breaker rack-out devices
(9) Portable lighting units
(10) Temporary protective grounding equipment
(11) Dielectric footwear
(12) Protective clothing
(13) Bypass jumpers
(14) Insulated and insulating hand tools

This is not an all-inclusive list of PPE that may be used by the employee. To ensure reliability, all equipment must be maintained in accordance with manufacturers' instructions or listings.

250.2 Inspection and Testing of Protective Equipment and Protective Tools.

Worker Alert

Regardless of your employer's inspection program, you should visually inspect all gear prior to use. This serves as a final check of the equipment's potential to prevent a serious injury.

(A) Visual. Safety and protective equipment and protective tools shall be visually inspected for damage and defects before initial use and at intervals thereafter, as service conditions require, but in no case shall the interval exceed 1 year, unless specified otherwise by the applicable state, federal, or local codes and standards.

Although an inspection of PPE may be conducted at regular intervals, the employee should visually inspect each component immediately before use to verify that no visual defects exist in the equipment. The employee is the last one to inspect the equipment before it may be called upon to prevent a serious injury. See Informational Table 130.7(C)(14) for specific ASTM standards that describe what aspects of the equipment should be included in the visual inspection.

In some instances, such as rubber insulating equipment, the PPE should have a date stamp or other means of identification that indicates when the equipment must be retested. The visual inspection must verify that the equipment has not passed the date in which retesting is required. See Table 130.7(C)(7) for test intervals and the informational note to 130.7(C)(7)(c) for specific ASTM standards for rubber insulating equipment.

△ **(B) Testing.** The insulation of protective equipment and protective tools, such as items specified in 250.1(1) through 250.1(14), that is used as primary protection from shock hazards and requires an insulation system to ensure protection of personnel, shall be verified by the appropriate test and visual inspection to ascertain that insulating capability has been retained

before initial use, and at intervals thereafter, as service conditions and applicable standards and instructions require, but in no case shall the interval exceed 3 years.

See Informational Note Table 130.7(C)(14) for ASTM standards that describe testing requirements.

OSHA Connection

29 CFR 1910.137(c)(2)

Specific requirements apply to rubber insulating blankets, rubber insulating covers, rubber insulating line hose, rubber insulating gloves, and rubber insulating sleeves. The employer must certify that equipment has been tested. The certification must identify the equipment that passed the test and the date it was tested.

250.3 Safety Grounding Equipment.

Temporary protective grounding equipment, safety grounds, and ground sets are terms used to refer to personal protective grounding equipment. Temporary protective grounding equipment is normally constructed with insulated conductors terminated in devices intended for connection to a bare conductor or part. See 120.5(8) for further information regarding the use of this equipment.

Temporary protective grounding equipment should be assigned an identifying mark for record keeping. The identifying mark can be recorded when the equipment is installed on a circuit. After the task has been performed, the equipment can be removed and the identifying mark logged. This will confirm that all temporary protective grounding equipment has been removed prior to re-energizing the circuit.

Some grounding and testing devices are designed to be inserted (racked) into a compartment from which a circuit breaker or disconnect has been removed. These devices can be inserted only into specific spaces. See Exhibit 250.1.

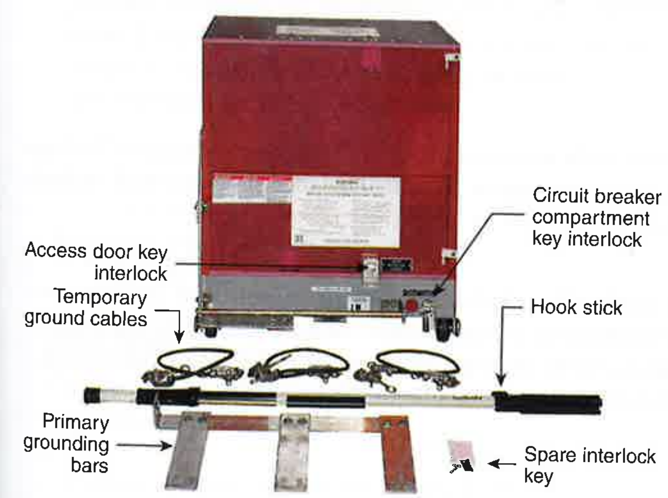


EXHIBIT 250.1

A ground and test device for rack systems. (Courtesy of Schneider Electric)

(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.

Temporary protective grounding equipment should be visually inspected before each use.

(B) Testing. Prior to being returned to service, temporary protective grounding equipment that has been repaired or modified shall be tested.

Informational Note: Guidance for inspecting and testing safety grounds is provided in ASTM F2249, *Standard Specification for In-Service Test Methods for Temporary Grounding Jumper Assemblies Used on De-Energized Electric Power Lines and Equipment.*

Temporary protective grounding equipment must be capable of conducting any available fault current long enough for the overcurrent protection to clear the fault. A destructive test is normally performed when a manufacturer determines the rating of specific devices. However, destructive testing is not an option for equipment that will be used again. For maintenance testing of temporary protective grounding equipment, see ASTM F2249, *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.

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

Grounding and testing devices must not only be visually inspected for defects but also tested before each use. IEEE C37.20.6, *Standard for 4.76 kV to 38 kV-Rated Ground and Test Devices Used in Enclosures*, provides information on integrity tests for grounding and testing devices.

Worker Alert

You should inspect the equipment, including the lead, prior to use. Test leads that are not specifically designed for the piece of equipment must be avoided since they can expose you to risk of electrocution or arc flash injury.

250.4 Test Instruments.

Test instruments and associated test leads used to verify the absence or presence of voltage shall be maintained to assure functional integrity. The maintenance program shall include functional verification as described in 110.4(A)(5).

Test instruments used in the verification of the absence or presence of voltage are critical to worker safety. The maintenance program must include operation of the test instrument on a known voltage source to verify proper operation of the test instrument, as well as any calibration required within the manufacturer's instructions.

CHAPTER 3

Safety Requirements for Special Equipment

Some facilities use electrical energy in unique ways that differ from most general industries. In some cases, the electrical energy is an integral part of the manufacturing process. In others, the electrical energy is converted to a form that presents unique hazards. When electrical energy is used as a process variable, the general safe work practices defined in Chapter 1 can become unsafe or produce unsafe conditions. Chapter 3 modifies the requirements of Chapter 1 as necessary for use in special situations.

Some workplaces require equipment that is unique. For example, research and development facilities frequently use equipment that exposes employees to unique hazards. General safe work practices might not mitigate that exposure adequately. Chapter 3 permits an employer to comply with appropriate requirements from Chapter 1 by amending requirements that are not appropriate for the specific conditions. Chapter 3 supplements or modifies the safety-related work practices in Chapter 1 with safety requirements for special equipment.

Introduction

Article 300

300.1 Scope.

Chapter 3 covers special electrical equipment in the workplace and modifies the general requirements of Chapter 1.

Chapter 3 covers additional safety-related work practices that are necessary for the practical safeguarding of employees relative to the electrical hazards associated with special equipment and processes that have not been excluded by 90.2(B).

300.2 Responsibility.

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

The employer must define the electrical safety program, and employees must implement the requirements defined in the program. An electrical safety program is most effective when employers and employees work together to accomplish both needs.

C Limits of Approach

This informative annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

Informative Annex C provides information to illustrate approach boundaries. The information is intended to provide suggestions regarding workers' safe approach to each limit. The approach limits trigger the need for greater control of work performed inside that approach limit.

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 incident 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 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.

According to 130.3, safety-related work practices must be used to safeguard employees from injury when the risk of exposure to electrical hazards or potential electrical hazards is unacceptable, and the work practices must be consistent with the nature and extent of the hazard. These work practices are used to protect employees from the risk associated with the four conditions of electrical hazards: arc flash, arc blast, thermal burn, and electrical shock.

The restricted and limited approach boundaries only address the potential for electric shock or electrocution. An unqualified worker within the limited approach boundary may be at risk of an arc flash injury even when under the close supervision of, or while continuously escorted by, a qualified person. Any person must not be allowed to cross the arc flash boundary without first receiving the specific safety-related training to understand the hazard(s) involved and the appropriate use of the necessary PPE.

C.1.2 Qualified Persons, Safe Approach Distance.

C.1.2.1 Determine the arc flash boundary and, if the boundary is to be crossed, appropriate arc-rated protective equipment must be utilized.

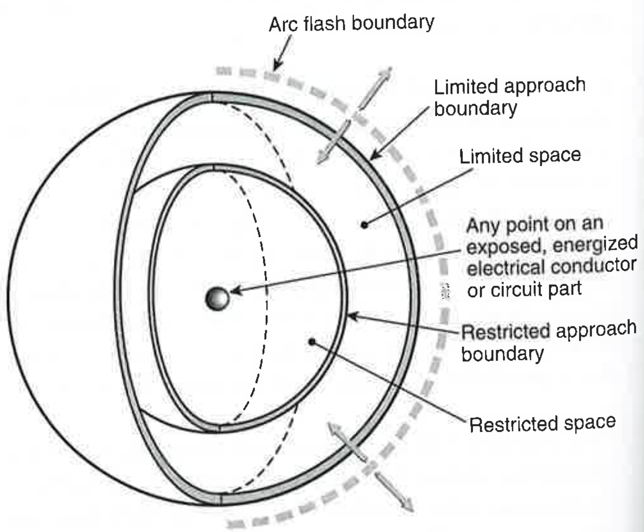
C.1.2.2 For a person to cross the limited approach boundary and enter the limited space, a person should meet the following criteria:

(1) Be qualified to perform the job/task
(2) Be able to identify the hazards and associated risks with the tasks to be performed

C.1.2.3 To cross the restricted approach boundary and enter the restricted space, qualified persons should meet the following criteria:

(1) As applicable, have an energized electrical work permit authorized by management.
(2) Use personal protective equipment (PPE) that is rated for the voltage and energy level involved.
(3) Minimize the likelihood of bodily contact with exposed energized conductors and circuit parts from inadvertent movement by keeping as much of the body out of the restricted space as possible and using only protected body parts in the space as necessary to accomplish the work.
(4) Use insulated tools and equipment.

(See Figure C.1.2.3.)

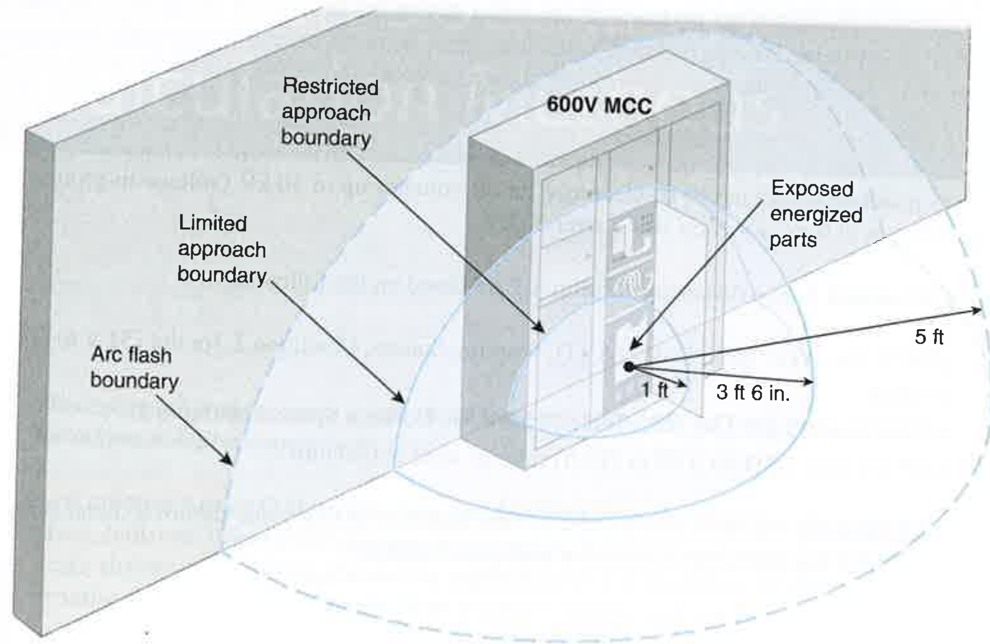


Δ ***FIGURE C.1.2.3*** *Limits of Approach.*

Exhibit C.1 illustrates the three approach boundary distances for a 600-volt motor control center (MCC) when the risk assessment is conducted using the PPE category method.

EXHIBIT C.1

Three approach boundary distances for 600-volt MCC.



C.2 Basis for Distance Values in Tables 130.4(D)(a) and 130.4(D)(b).

The information contained in Tables 130.4(D)(a) and 130.4(D)(b) is derived from various sources. Section C.2 explains how the table distances were selected.

C.2.1 General Statement. Columns 2 through 5 of Table 130.4(D)(a) and Table 130.4(D)(b) show various distances from the exposed energized electrical conductors or circuit parts. They include dimensions that are added to a basic minimum air insulation distance. Those basic minimum air insulation distances 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 to ≤750 V: 2 mm (0 ft 0.07 in.)
(3) >750 V to ≤2 kV: 5 mm (0 ft 0.19 in.)
(4) >2 kV to ≤15 kV: 39 mm (0 ft 1.5 in.)
(5) >15 kV to ≤36 kV: 161 mm (0 ft 6.3 in.)
(6) >36 kV to ≤48.3 kV: 254 mm (0 ft 10.0 in.)
(7) >48.3 kV to ≤72.5 kV: 381 mm (1 ft 3.0 in.)
(8) >72.5 kV to ≤121 kV: 640 mm (2 ft 1.2 in.)
(9) >138 kV to ≤145 kV: 778 mm (2 ft 6.6 in.)
(10) >161 kV to ≤169 kV: 915 mm (3 ft 0.0 in.)
(11) >230 kV to ≤242 kV: 1.281 m (4 ft 2.4 in.)
(12) >345 kV to ≤362 kV: 2.282 m (7 ft 5.8 in.)
(13) >500 kV to ≤550 kV: 3.112 m (10 ft 2.5 in.)
(14) >765 kV to ≤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 the highest nominal voltage in the range, based on ANSI 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 column 2 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 100 mm (4.0 in.) for each 10 kV over 50 kV.

C.2.1.3 Column 3. The distances in column 3 are based on the following:

(1) ≤750 V: Use *NEC* Table 110.26(A)(1), Working Spaces, Condition 2, for the 151 V to 600 V range.
(2) >750 V to ≤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 in column 4 are based on adding to the flashover dimensions shown in C.2.1 the following inadvertent movement distance:

≤300 V: Avoid contact.

Based on experience and precautions for household 120/240-V systems:

>300 V to ≤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 ANSI/IEEE C2, *National Electrical Safety Code*, in the approach distances for supply workers.

Incident Energy and Arc Flash Boundary Calculation Methods

D

This informative annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

Informative Annex D illustrates how the arc flash boundary and incident energy might be calculated. These examples are not intended to limit the choice of calculation methods; the method chosen should be applicable to the situation. All the publicly known methods of calculating the arc flash incident energy and arc flash boundary produce results that are estimates of the actual values. The thermal hazard associated with an arcing fault is very complex, with many variable attributes having an impact on the calculation.

NFPA and IEEE (Institute of Electrical and Electronic Engineers) have issued the "IEEE/NFPA Arc Flash Phenomena Collaborative Research Project" report (March 2, 2017). This project produced data to further understand arc flash phenomena, as well as data on the non-thermal effects of arc blast.

The arc flash hazard is not limited to three-phase systems. Single-phase systems can also present an arc flash hazard and must be considered. The Annex D calculation examples do not specifically address single-phase systems. For example, the IEEE 1584, *Guide for Performing Arc Flash Hazard Calculations*, theoretically derived model is intended for use with applications where faults escalate to three-phase faults. However, it may be used where single-phase systems are encountered, but the result will likely be conservative.

NFPA *70E* does not place an upper limit to the level of incident energy an employee may be exposed to during a justified energized task. Employees who might be exposed to an arcing fault must wear arc-rated clothing or use other equipment to avoid a severe thermal injury. Protecting employees from the thermal effects of an arcing fault does not necessarily protect them from injury. An arcing fault exhibits characteristics of other hazards. For instance, the arc may generate a significant pressure wave. An employee could be injured by the pressure differential developed between the outside and inside of the body. The calculations illustrated in this informative annex do not determine the pressure wave value. Currently, there are no standards available that address worker protection from the effects of any pressure wave, shrapnel, and so forth.

D.1 Introduction.

Informative Annex D summarizes calculation methods available for calculating arc flash boundary and incident energy. It is important to investigate the limitations of any methods gravity of 1.215) of the battery. A more accurate value for the short-circuit current for the specific application can be obtained from the battery manufacturer.

References:

1. IEEE 946, *Recommended Practice for the Design of DC Auxiliary Powers Systems for Generating Stations*.

E Electrical Safety Program

This informative annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

Informative Annex E provides information that could be used as the groundwork for an electrical safety program.

(See 110.1, Electrical Safety Program.)

E.1 Typical Electrical Safety Program Principles.

Electrical safety program principles include, but are not limited to, the following:

(1) Inspecting and evaluating the electrical equipment
(2) Maintaining the electrical equipment's insulation and enclosure integrity
(3) Planning every job and document first-time procedures
(4) De-energizing, if possible *(see 120.5)*
(5) Anticipating unexpected events
(6) Identifying the electrical hazards and reduce the associated risk
(7) Protecting employees from shock, burn, blast, and other hazards due to the working environment
(8) Using the right tools for the job
(9) Assessing people's abilities
(10) Auditing the principles

E.2 Typical Electrical Safety Program Controls.

Electrical safety program controls can include, but are not limited to, the following:

(1) The employer develops programs and procedures, including training, and the employees apply them.
(2) Employees are to be trained to be qualified for working in an environment influenced by the presence of electrical energy.
(3) Procedures are to be used to identify the electrical hazards and to develop job safety plans to eliminate those hazards or to control the associated risk for those hazards that cannot be eliminated.

(4) Every electrical conductor or circuit part is considered energized until proved otherwise.
(5) De-energizing an electrical conductor or circuit part and making it safe to work on is, in itself, a potentially hazardous task.
(6) Tasks to be performed within the limited approach boundary or arc flash boundary of exposed energized electrical conductors and circuit parts are to be identified and categorized.
(7) Precautions appropriate to the working environment are to be determined and taken.
(8) A logical approach is to be used to determine the associated risk of each task.

E.3 Typical Electrical Safety Program Procedures.

Electrical safety program procedures can include, but are not limited to determination and assessment of the following:

(1) Purpose of task
(2) Qualifications and number of employees to be involved
(3) Identification of hazards and assessment of risks of the task
(4) Limits of approach
(5) Safe work practices to be used
(6) Personal protective equipment (PPE) involved
(7) Insulating materials and tools involved
(8) Special precautionary techniques
(9) Electrical single-line diagrams
(10) Equipment details
(11) Sketches or photographs of unique features
(12) Reference data

F Risk Assessment and Risk Control

This informative annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

This informative annex deals with risk assessment and risk control. Risk assessment is composed of risk estimation and risk evaluation. Risk control incorporates a hierarchy of controls from the highest level to the lowest level of controls in order to reduce the risk to an acceptable level for the task at hand. The procedure involves an iterative process of risk reduction until an acceptable risk level is attained.

Electrical safety issues (not health issues) are the focus of this standard. However, from an overall safety point of view, both health and safety issues are important. Electrical safety issues need to be assessed and prioritized. Electrical safety issues include the potential electrical hazards of electrical shock, arc flash, arc blast, and burns from hot electrical equipment associated with a particular task, risks associated with the hazards, electrical safety management system deficiencies, the opportunities for improvement, and the appropriate PPE necessary for the assigned task.

F.1 Introduction to Risk Management.

In a general sense, risk can be described as the potential that a chosen action or inaction will lead to some type of loss or injury. For the purpose of electrical safety, risk is defined as a combination of the likelihood of occurrence of injury and the severity of injury that results from a hazard. The type of injury (either direct or indirect) can be caused by contact with exposed energized circuit parts or can be caused when an arc flash occurs.

Risk assessment is a step in a risk management procedure that involves risk estimation and risk evaluation. Risk assessment is the determination of a value of risk related to an actual situation involving a recognized hazard. Two basic approaches to risk assessment — the hazard-based approach and the task-based approach — are briefly addressed in Sections F.4 and F.5. There are many techniques that may be used for conducting a risk assessment. Section F.6 explains three possible methods.

Risk management is the logical, systematic process used to manage the risk associated with any activity, process, function, or product including safety, the environment, quality, and finance. The risk management process and principles can be used by organizations of any type or size.

The following risk management principles can readily be applied to electrical safety. Risk management:

(1) Is an integral part of all organizational processes and decision making
(2) Is systematic, structured, and timely

(3) Is based on the best available information
(4) Takes human and cultural factors into account
(5) Is dynamic, iterative, and responsive to change
(6) Facilitates continual improvement of the organization

Informational Note: For more information on risk management principles see ISO 31000:2009, *Risk Management — Principles and Guidelines*.

The risk management process includes the following:

(1) Communication and consultation
(2) Establishing the risk assessment context and objectives
(3) Risk assessment
(4) Risk treatment
(5) Recording and reporting the risk assessment results and risk treatment decisions
(6) Monitoring and reviewing risks

Risk assessment is the part of risk management that involves the following:

(1) Identifying sources of risk
(2) Analyzing the sources of risk to estimate a level of risk
(3) Evaluating the level of risk to determine if risk treatment is required

(See Figure F.1.)

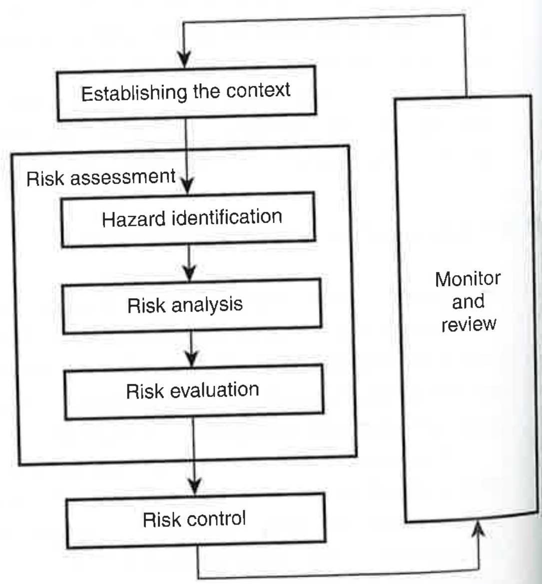


FIGURE F.1 *Risk Management Process (Adapted from ISO 31000 figure 3).*

For risk to be properly assessed, the situation must be placed into a specific context and the objective defined. A risk assessment may be different if the objective is arc flash protection rather than shock protection. An exposed hazard introduces a risk of injury. If employees are not permitted to enter the room, there is no risk of personal injury. If employees are permitted into that room, the risk of personal injury is greatly increased. However, not all tasks in proximity to that hazard may pose an additional increased risk of injury. Without context or objective, the risk assessment is incomplete.

N **F.1.1 Occupational Health and Safety (OHS) Risk Management.** The same logical, systematic process and the same principles apply to risk management in the OHS sphere of activity. However, it is more focused and the terminology more narrowly defined, as follows:

(1) The OHS objective is freedom from harm (i.e., injury or damage to health).
(2) Sources of risk are referred to as hazards.
(3) Analyzing and estimating the level of risk is a combination of the estimation of the likelihood of the occurrence of harm and the severity of that harm.
(4) The level of risk is evaluated to determine if it is reasonable to conclude that freedom from harm can be achieved or if further risk treatment is required.
(5) Risk treatment is referred to as risk control.

Therefore, OHS risk assessment involves the following:

(1) Hazard identification: Find, list, and characterize hazards.
(2) Risk analysis: Sources, causes, and potential consequences are analyzed to determine the following:
  a. The likelihood that harm might result
  b. The potential severity of that harm
  c. Estimate the level of risk
(3) Risk evaluation: The level of risk is evaluated to determine if the objective of freedom from harm can reasonably be met by the risk control that is in place or is further risk control required?

Users of NFPA *70E* will likely follow their own version of the occupational health and safety (OHS) risk management system to conduct the required shock and arc flash risk assessments.

Step 1: Hazard Identification

Hazard identification is possibly the simplest step in the process. What a possible source of injury is to an employee from an electrical safety context is typically obvious. NFPA *70E* currently addresses only two hazards directly — electric shock and arc flash burn. As part of the risk assessment, it is necessary to address all electrical hazards. The definition of *electrical hazard* in Article 100 includes any of the following: electric shock, arc flash burn, thermal burn, or arc blast. Other known hazards include flying parts, molten metal, intense light, poisonous oxides, and generated pressure waves (blasts).

Step 2: Risk Analysis

The second step is more difficult to define. The risk related to an identified hazard is composed of the severity of the possible injury and the likelihood of occurrence of that injury. A qualitative rather than quantitative approach may be necessary to estimate the likelihood of harm, the severity of the injury, and the level of risk associated with the hazard. Often, three factors are estimated independently and used to determine the likelihood of the occurrence of harm. These independent factors are as follows:

1. The frequency and duration of the exposure
2. The likelihood of occurrence of the hazardous event
3. The likelihood of avoiding or limiting the injury

The occurrence of a hazardous event influences the likelihood of the occurrence of injury. The possibility of the hazardous event occurring should address the likelihood of the event materializing during the use or foreseeable misuse, or both, of the electrical system. Foreseeable characteristics of human behavior that may impact the likelihood of an occurrence are stress (e.g., due to time constraints, work task, perceived damage limitation) and lack of awareness of information relevant to the hazard. Human behavior will be influenced by factors such as skills, training, experience, and complexity of the equipment or the process.

Subjectivity may have a substantial impact on the result of the risk assessment. The use of subjective information should be minimized as far as reasonably practicable. When determining the likelihood of the occurrence of a hazardous event, it might be helpful to ask the types of questions that follow. These questions are not intended to be a complete or accurate list of the actual questions that should be asked or investigations undertaken.

1. Does the equipment meet the necessary normal operating conditions?
2. At what point in its rated life is the equipment?
3. Have all connections been verified to be appropriately tightened (torqued) in accordance with the manufacturer's requirements or appropriate industry standard?
4. Is any component, device, or equipment loose or damaged?
5. Does the enclosure have all of its bolts and screws installed?
6. Does the equipment have ventilation openings?
7. Is the enclosure arc rated?
8. Are there openings in the enclosure that rodents or other vermin could enter?
9. Has the enclosure been examined for moisture, dust, dirt, soot, or grease?
10. What action may an employee take?
11. What error may an employee make?

The following are circuit breaker (CB) condition questions:

12. Has the right type been used?
13. Has it been applied within its marked rating?
14. Have the proper conductor types and sizes been used?
15. What is the ampere rating involved?
16. Has the CB periodically been operated in accordance with the manufacturer's instructions or in accordance with standard(s) requirements?
17. Has a calibration sampling program been instituted?
18. Has the CB interrupted high-fault currents or repeatedly interrupted fault currents?
19. Has the operating temperature been checked under normal use conditions?
20. Have insulation resistance and/or individual pole resistance (millivolt drop) tests been performed?
21. Have inverse-time and/or instantaneous overcurrent trip tests been conducted?
22. Has a rated hold-in test been conducted?
23. Have any accessory devices involved with the CB been tested?
24. Have the surfaces been examined for evidence of overheating, blistering, cracks, dust, dirt, soot, grease, or moisture?
25. Have all electrical connections been verified to be clean and secure?
26. Is there any discoloration or flaking of external metal parts, or melting or blistering of adjacent wire insulation?
27. If the CB has interchangeable trip units, have the trip units been visually checked for overheating or looseness?

The likelihood of avoiding injury may be estimated by taking into account aspects of the electrical system design and its intended application that can help to avoid or limit the injury from a hazard. The following are examples:

1. Sudden or gradual appearance of the hazardous event
2. Spatial possibility to withdraw from the hazard
3. Nature of the component or system — for example, the use of touch-safe components, which reduce the likelihood of contact with energized parts
4. Likelihood of recognition of a hazard

Severity of injuries can be estimated by taking into account reversible injuries, irreversible injuries, and death.

Step 3. Risk Evaluation

Risk evaluation is a determination if risk control methods can satisfactorily protect the employee from harm. Once the risk has been estimated prior to the application of protective measures, all practicable efforts must be made to reduce the risk of injury. Careful consideration of failure modes is an important part of risk reduction. Care should be taken to ensure that both technical and behavioral failures, which could result in ineffective risk reduction, are taken into account during the risk reduction stage of the risk assessment.

Situations in which hazard elimination cannot be attained typically require a balanced approach in order to reduce the likelihood of injury. For example, the effective control of access to an electrical system requires the use of barriers, awareness placards, safe operating instructions, qualification and training, and PPE, as well as initial and refresher or periodic training for all affected personnel in the area. Engineering controls alone are not sufficient to reduce the remaining risk to a tolerable level. Often, all six levels of risk controls in Table F.3 must be implemented in some form to achieve an adequate risk reduction strategy.

Once the assessment has been completed and protective measures have been determined, it is imperative to ensure that the protective measures are implemented prior to initiating the electrical work. While this procedure might not result in a reduction of the PPE required, it could improve the understanding of the properties of the hazards associated with a task to a greater extent and thus allow for improvement in the implementation of the protective measures that have been selected.

N F.2 Relationship to Occupational Health and Safety Management System (OHSMS).

As discussed in Annex P, the most effective application of the requirements of this standard can be achieved within the framework of an OHSMS. Using a management system provides a methodical approach to health and safety by means of goal setting, planning, and performance measurement.

Risk management shares the six management system process elements of the following:

(1) Leadership. If any venture is to succeed it needs to be sponsored at the highest levels of the organization.
(2) Policy. The organization should articulate its vision and establish relevant, attainable goals.
(3) Plan. A plan is developed in line with the organization's vision and to achieve its goals. The plan must include mechanisms to measure and monitor the success of the plan.
(4) Do. The plan is executed.

(5) Check (Monitor). The success of the plan in achieving the organization's goals is continuously monitored.

(6) Act (Review). The measuring and monitoring results are compared to the organization's goals for the purposes of reviewing and revising goals and plans to improve performance.

As noted in F.1, risk management is iterative. The repeating nature of the management system plan-do-check-act (PDCA) cycle is intended to promote continuous improvement in health and safety performance.

Risk assessment fits into the "plan" and "do" stages of the PDCA cycle, as follows:

(1) Planning: Information used during the planning stage comes from sources that can include workplace inspections, incident reports, and risk assessments.

(2) Do: Risk assessment is an ongoing activity.

N **F.3 Hierarchy of Risk Control.**

The purpose of specifying and adhering to a hierarchy of risk control methods is to identify the most effective individual or combination of preventive or protective measures to reduce the risk associated with a hazard. Each risk control method is considered less effective than the one before it. Table F.3 lists the hierarchy of risk control identified in this and other safety standards and provides examples of each.

TABLE F.3 The Hierarchy of Risk Control Methods

Risk Control Method	*Examples*
(1) Elimination	Conductors and circuit parts in an electrically safe working condition
(2) Substitution	Reduce energy by replacing 120 V control circuitry with 24 Vac or Vdc control circuitry
(3) Engineering controls	Guard energized electrical conductors and circuit parts to reduce the likelihood of electrical contact or arcing faults
(4) Awareness	Signs alerting of the potential presence of hazards
(5) Administrative controls	Procedures and job planning tools
(6) PPE	Shock and arc flash PPE

Although it can never be entirely eliminated, risk can be significantly reduced through the application of the hierarchy of risk controls. Whenever the residual risk is unacceptable, additional safety measures must be taken to reduce the risk to an acceptable level.

The hierarchy is listed in order of the most effective to the least effective and must be applied in this descending order for each risk assessment. Once a hazard has been identified, it first must be determined if the hazard can be eliminated. During the electrical system design stage, methods should be employed to eliminate the hazard in its entirety. In the electrical system design and equipment selection phase, it is easier to utilize the most effective controls of elimination and substitution to limit the risk associated with anticipated justified energized work. In this first context, elimination is the removal of a hazard so that it does not exist. This removes the potential for human error when interacting with the equipment.

Elimination of the hazard is often not an option for available or installed electrical equipment. Although elimination also can be achieved by applying other controls such as through establishing an electrically safe work condition, these other controls introduce a potential for human error. Therefore, the initial attempt should be full elimination of the hazard or substitution of equipment to minimize the hazard.

The result of each risk assessment should be evaluated to determine if the hierarchy of controls could be further employed to lower the risk or reduce the hazard. Exhibit F.1 illustrates the iterative process of applying the hierarchy of risk controls. Each step is evaluated and controls reapplied as necessary until the risk of injury is reduced to an acceptable level. Only after all other risk controls have been exhausted should PPE be selected. PPE is considered the least effective and lowest level of safety of control for employee protection and should not be the first or only control element used.

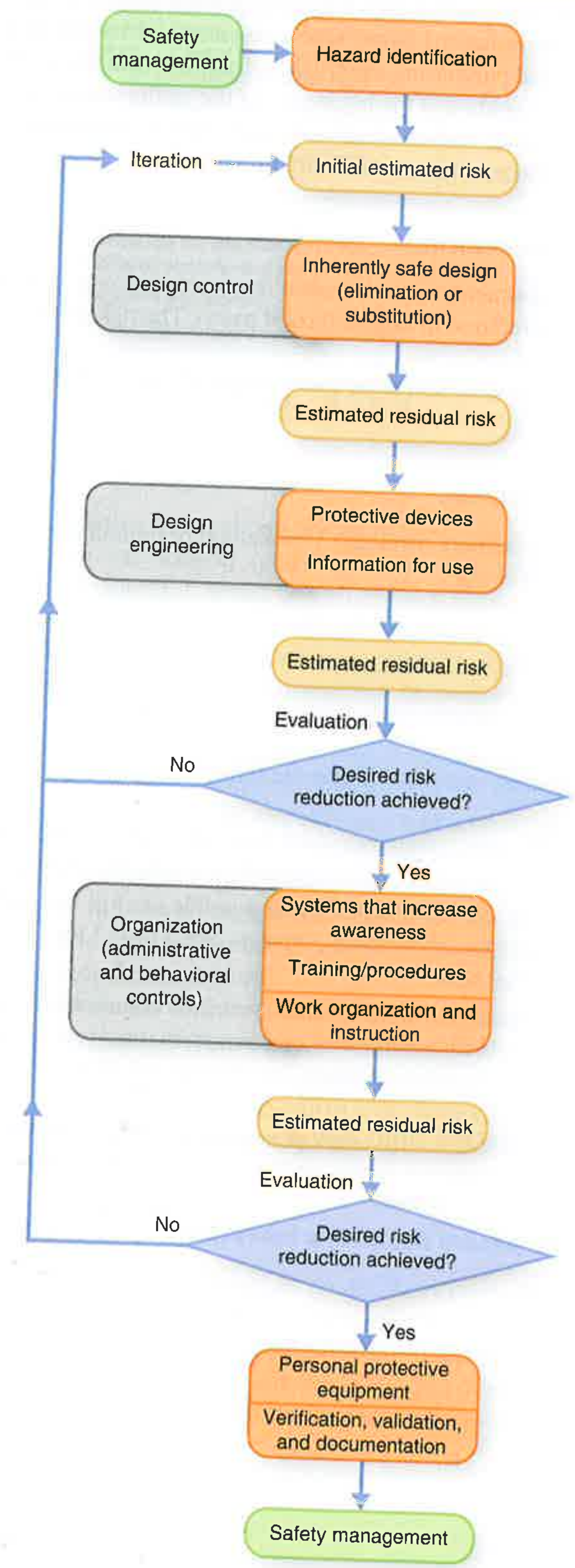


EXHIBIT F.1 *Risk assessment process.*

N F.4 Hazard-Based Risk Assessment.

In a hazard-based risk assessment, workplace hazards are identified and characterized for materials, processes, the worksite, and the environment. Activities that might be affected by those hazards are identified. The risk associated with each activity is analyzed for likelihood of harm and severity of harm. An organization uses this information to prioritize risk reduction decisions.

The information from hazard-based risk assessments is useful to organizations when designing, specifying, and purchasing electrical distribution equipment. Risk control is much more effective when it is applied at the beginning of the equipment or process lifecycle. Risk can be reduced by specifying "substitution" and "engineering" risk control methods that affect the likelihood of occurrence of harm or severity of harm.

N F.5 Task-Based Risk Assessment.

In a task-based risk assessment, a job is broken down into discrete tasks. Hazards are identified for each task (often referred to as task-hazard pairs). The risk associated with each hazard is analyzed and evaluated.

The task-based risk assessment is the most commonly used when performing a field level risk assessment.

N F.6 Risk Assessment Methods.

There are many risk assessment methods. The method or combination of methods should be chosen based on the following:

(1) The application
(2) The desired result
(3) The skill level of the persons performing the assessment

Some risk assessment methods include the following:

(1) Brainstorming. An open group discussion regarding hazards, the associated risk, and risk control methods can be used as part of pre-job planning and during a job briefing session.
(2) Checklists. A list of common hazards and possible control methods is a useful tool for pre-job planning and for job briefing purposes. See Annex I for an example of a job briefing and planning checklist.
(3) Risk assessment matrix. A risk assessment matrix is commonly used to quantify levels of risk. The matrix can be in a multilevel or a simple two-by-two format. See Figure F.6 for an example of a risk assessment matrix.

Informational Note: See ISO 31010, Risk management — *Risk assessment techniques*, and ANSI/AIHA Z10-2012, *Occupational Health and Safety Management Systems*, for further information regarding risk assessment methods.

Likelihood of Occurrence of Harm	Severity of Harm	
	Energy ≤ [Selected Threshold]	Energy > [Selected Threshold]
Improbable	Low	Low
Possible	Low	High

Legend

Likelihood of Occurrence of Harm	Severity of Harm
Improbable: Source of harm is adequately guarded to avoid contact with hazardous energy	Energy ≤ [Selected Threshold]: Level of hazardous energy insufficient to cause harm
Possible: Source of harm is not adequately guarded to avoid contact with hazardous energy	Energy > [Selected Threshold]: Level of hazardous energy insufficient to cause harm

Risk Evaluation

Identify the risk controls in place and evaluate the effectiveness of the controls. Prioritize actions taken to control risk based on the level of risk as follows:

Low: Risk Acceptable — Further risk control discretionary

High: Risk Unacceptable — Further risk control required before proceeding

Δ *FIGURE F.6 Example of a Qualitative Two-by-Two Risk Assessment Matrix.*

Several methods are available for qualitatively estimating risk, such as risk assessment matrices, risk ranking, or risk scoring systems. Sample risk assessment matrices are shown in Figure F.6 and Exhibit F.2. A matrix is an ordered presentation of data in a display of rows and columns that defines the cells of the array. A risk assessment matrix is a simple table that groups risk based on severity and likelihood. It can be used to assess the need for remedial action, such as the use of PPE for a given task, and to prioritize safety issues.

The risk assessment matrix that appears in Figure F.6 displays the two factors that have to be considered when evaluating risk: likelihood of the occurrence of harm and the severity of the injury that can result. The columns and rows must then be assigned values such as low and high. A matrix will become cumbersome if too many columns and rows are used, and it will fail to impart the necessary information if too few are used. Practically speaking, the maximum number of categories for a useful matrix is five. Figure F.6 uses two for the rows (improbable and probable) and two for the columns (first energy level and second energy level).

The risk assessment matrices in this informational annex and associated commentary are only illustrations of aids that can be useful in prioritizing and in determining remedial actions that should be considered and taken. There are many different risk assessment matrices available, such as ANSI/AIHA Z10, *American National Standard for Occupational Safety and Health Management Systems*, which displays a different presentation than those presented here.

Likelihood of Occurrence of Arc Flash Event and Circuit Breaker Operation

Experience has shown that the likelihood of an arc flash event increases as people interact with electrical equipment and that some types of interactions with electrical equipment increase the likelihood of an arc flash event happening more than others. Turning on a circuit breaker (CB) may increase the likelihood of an arc flash event more than turning off a CB, for instance. CBs housed in electrical equipment enclosures that have been properly installed, applied within their ratings, and properly maintained have a lower likelihood of causing an arc flash event than those that have not. Additionally, it is more likely that the actual incident energy level of a maintained CB will be approximately the calculated level. It is known that incident energy level available affects the seriousness of the harm — the greater the incident energy level, the more harm that can be expected.

The risk of injury largely depends on the amount of energy available to the breaker, how old it is, how well it is maintained, and the task that is to be performed, among other factors. For example, there will be little risk when simply operating (turning on and off) a well-maintained breaker in a dwelling with a 240-volt service and 10,000 amperes available. In contrast, a commercial building with an equally well-maintained breaker with 40,000 amperes available poses greater risk.

Example: Circuit Breaker Operation While Energized

One example illustrates the use of a risk register and the other the use of a risk assessment matrix. The examples should not be relied upon for any particular installation. They are simply meant to demonstrate the thinking process required to perform a risk assessment based on the principles included in Informative Annex F.

Background Facts. Using a selected risk register and a risk assessment matrix, an electrical safety committee is analyzing two task scenarios to determine if additional safety controls are required. The first task scenario is the operation (turning on and off) of a 1600-ampere CB at a main 480Y/277-volt, non-arc-rated switchboard in a building where the short-circuit current is calculated to be 35,000 amperes. The second task scenario is the operation (turning on and off) of a 20-ampere HID CB in a 480Y/277-volt lighting panelboard where the short-circuit current is 25,000 amperes. In both cases, the electrical equipment is under normal operating conditions, the equipment is within its rated life, a damp environment is not involved, and the CBs are operated while the equipment is in a dead front configuration.

The switchboard has an incident energy level of 31 cal/cm^2, and the lighting panelboard has an incident energy level of 5.8 cal/cm^2. The 1,600-ampere switchboard CB is operated twice a year when maintenance is scheduled for the facility, and the 20-ampere HID CB is operated twice a day to turn on and turn off the lighting. Of the possible electrical hazards, only a risk assessment for the arc flash hazard will be performed.

Analysis Using Risk Register. Scenario 1 illustrates the risk evaluation of the 1600-ampere CB in the switchboard, and Scenario 2 illustrates the 20-ampere CB in the panelboard. The following tables selected by the safety committee are applicable to these evaluations.

Scenario 1: The switchboard is not arc rated and the incident energy level is 31 cal/cm^2, therefore the severity selected from Commentary Table F.1 is 6. The CB is operated twice a year, so the frequency and duration of exposure from Commentary Table F.2 is determined to be 3. The likelihood of a hazardous event occurring is considered to be negligible due to the proper application of the CB and switchboard, and the value selected from Commentary Table F.3 is 1. Finally, since it is not anticipated that in every case the switchboard enclosure would be breached should an arc flash event occur while operating the CB, the likelihood of avoiding or limiting injury is rare, and the value is selected to be 3 from Commentary Table F.4.

COMMENTARY TABLE F.1 *Severity of the Possible Injury (Se) Classification*

Severity of Injury	*Se Value*
Irreversible — trauma, death	8
Permanent — skeletal damage, blindness, hearing loss, third-degree burns	6
Reversible — minor impact, hearing damage, second-degree burns	3
Reversible — minor laceration, bruises, first-degree burns	1

COMMENTARY TABLE F.2 *Frequency and Duration of Exposure (Fr) Classification*

Frequency of Exposure	*Fr Value*
≥ 1 per hour	5
< 1 per hour to ≥ 1 per day	5
< 1 per day to ≥ 1 every 2 weeks	4
< 1 every 2 weeks to ≥ 1 per year	3
< 1 per year	2

COMMENTARY TABLE F.3 *Likelihood of a Hazardous Event (Pr) Classification*

Likelihood of a Hazardous Event	*Pr Value*
Very high	5
Likely	4
Possible	3
Rare	2
Negligible	1

COMMENTARY TABLE F.4 *Likelihood of Avoiding or Limiting Injury (Av) Classification*

Likelihood of Avoiding or Limiting Injury	*Av Value*
Impossible	5
Rare	3
Probable	1

Scenario 2: Should an arc flash incident occur, it is assumed that at 8 cal/cm^2 or less, the integrity of the lighting panelboard will not be breached. Based on an incident energy of 5.8 cal/cm^2, the severity of injury is selected to be 1 from Commentary Table F.1. Based on the CB being operated twice per day, the frequency and duration of exposure from Commentary Table F.2 is determined to be 5. For the same reason as for the 1600-ampere switchboard CB, the likelihood of an incident is selected to be 1 from Commentary Table F.3. Finally, since it is assumed that the enclosure integrity remains intact, the likelihood of avoiding or limiting injury is considered to be probable and is selected to be 1 from Commentary Table F.4.

The completed risk register is displayed as Commentary Table F.5. After evaluation, the electrical safety committee has determined that a risk score higher than 10 requires consideration of additional safety controls. However, for the given scenarios and installed equipment, only administrative controls and PPE from the hierarchy of controls are to be implemented. Therefore, based on their analysis, the committee has determined that the use of PPE is required when operating the 1600-ampere CB and that the use of PPE is not required when operating the 20-ampere HID lighting panelboard CB.

COMMENTARY TABLE F.5 *Risk Register for Example Scenario 1 (1600-A SWB CB) and Scenario 2 (20-A HID Lighting Panelboard CB)*

		Severity	*Likelihood of Occurrence of Harm*				*Risk Score*
Scenario No.	*Hazard*	*Se (Commentary Table F.1)*	*Fr (Commentary Table F.2)*	*Pr (Commentary Table F.3)*	*Av (Commentary Table F.4)*	*Po (Fr + Pr + Av)*	*Se × Po*
1	Arc flash	6	3	1	3	7	42
2	Arc flash	1	5	1	1	7	7

Analysis Using Risk Assessment Matrix. The electrical safety committee included incident energy levels in their selected risk assessment matrix (Exhibit F.2) based on their assumption that incident energy levels less than or equal to 8 cal/cm² will not breach the integrity of the enclosure. Further, they have determined that the likelihood of occurrence of an arc flash event based on their equipment being properly selected, installed, and maintained is unlikely. Scenario 1 illustrates the risk evaluation of the 1600-ampere CB in the switchboard, and Scenario 2 illustrates the 20-ampere CB in the panelboard.

EXHIBIT F.2

Risk assessment matrix

Likelihood of occurrence in period	Severity of the injury (consequences)				
	Slight	Minor	Medium	Critical	Catastrophic
cal/cm²	<1.2	≥1.2 to ≤8		>8 to ≤40	>40
Unlikely					
Seldom					
Occasional					
Likely					
Definite					

Notes:
1. Extreme equals 25 through 15.
2. High equals 12 through 9.
3. Moderate equals 8 through 4.
4. Low equals 3 through 1.

Since the incident energy level in Scenario 1 is greater than 8 cal/cm² and less than 40 cal/cm² and the likelihood of an incident is considered unlikely, the risk is color-coded yellow and is assumed to be moderate. Therefore, based on their analysis, the committee recommends that the additional controls indicated in Commentary Table F.6 be considered by management.

For Scenario 2, the risk assessment level is determined to be low (color code green), since the incident energy level is greater than 4 cal/cm² and less than or equal to 8 cal/cm² and the likelihood of an incident is considered unlikely. The electrical safety committee recommends that the existing controls remain in place as detailed in Commentary Table F.6.

COMMENTARY TABLE F.6 *Definition of Terms and Risk Categories for Use in Risk Assessment Matrix*

Likelihood (Probability) of Occurrence	
Definite	Almost certain of happening
Likely	Can happen at any time
Occasional	Occurs sporadically, from time to time
Seldom	Remote possibility; could happen sometime; most likely will not happen
Unlikely	Rare and exceptional for all practical purposes; can assume it will not happen
Severity of Injury	
Catastrophic	Death or permanent total disability
Critical	Permanent partial disability or temporary total disability 3 months or longer
Medium	Medical treatment and lost work injury
Minor	Minor medical treatment possible
Slight	First aid or minor treatment
Risk and Risk Controls	
Extreme (Color code red)	Intolerable risk Do not proceed Immediately introduce further controls Detailed action and plan required
High (Color code orange)	Unsupportable risk Review and introduce additional controls Requires senior management attention
Moderate (Color code yellow)	Tolerable risk Incorporates some level of risk that is unlikely to occur Specific management responsibility Consider additional controls Take remedial action at appropriate time
Low (Color code green)	Supportable risk Monitor and maintain controls in place Manage by routine Procedures Little or no impact

L.2 Electrical Power Receptacles.

Power supply circuits and receptacles in the cell line area for portable electric equipment should meet the requirements of 668.21 of *NFPA 70, National Electrical Code*. However, it is recommended that receptacles for portable electric equipment not be installed in electrolytic cell areas and that only pneumatic-powered portable tools and equipment be used.

Section 668.21 of *NFPA 70®*, *National Electrical Code®* (*NEC®*), addresses circuit isolation, receptacle configuration, and marking requirements for circuits supplying power to ungrounded receptacles for hand-held, cord-connected equipment in the cell line.

INFORMATIVE ANNEX

Layering of Protective Clothing and Total System Arc Rating

M

This informative annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

Informative Annex M discusses how layering of protective clothing can impact the overall rating of the layered protection. The total arc rating of a layered clothing system is to be determined by testing the multilayer system as it would be worn in the field. The total system arc rating cannot be determined simply by adding together the arc ratings of the individual layers. Exhibit M.1 shows an arc-rated PPE system of clothing.

When layers of clothing are worn, some air space is captured between the layers. Air is a good thermal insulator and modifies the protective nature of the sum of the protective clothing. The resulting protection offered by the layers of clothing can be greater or less than the sum of the protection afforded by the individual layers. Although this annex discusses layering of protective clothing without testing of the entire system, consultation with the clothing manufacturer is necessary.

EXHIBIT M.1

An arc-rated PPE system of clothing. (Courtesy of Salisbury by Honeywell)

M.1 Layering of Protective Clothing.

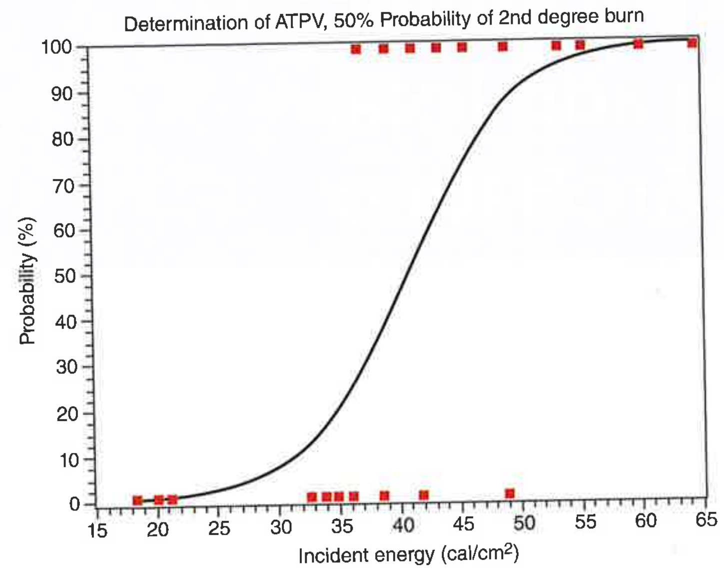
M.1.1 Layering of arc-rated clothing is an effective approach to achieving the required arc rating. The use of all arc-rated clothing layers will result in achieving the required arc rating with the lowest number of layers and lowest clothing system weight. Garments that are not arc-rated should not be used to increase the arc rating of a garment or of a clothing system.

M.1.2 The total system of protective clothing can be selected to take credit for the protection provided by all the layers of clothing that are worn. For example, to achieve an arc rating of 40 cal/cm² (167.5 J/cm²), an arc flash suit with an arc rating of 40 cal/cm² (167.5 J/cm²) could be worn over a cotton shirt and cotton pants. Alternatively, an arc flash suit with a 25 cal/cm² (104.7 J/cm²) arc rating could be worn over an arc-rated shirt and arc-rated pants with an arc rating of 8 cal/cm² (33.5 J/cm²) to achieve a total system arc rating of 40 cal/cm² (167.5 J/cm²). This latter approach provides the required arc rating at a lower weight and with fewer total layers of fabric and, consequently, would provide the required protection with a higher level of worker comfort.

The arc rating of a layered system of PPE is not simply a matter of adding together the ratings of the individual pieces; some manufacturers provide data on the arc ratings of individual parts. Exhibit M.2 is an example of how a manufacturer might supply such data.

EXHIBIT M.2

Curve showing the probability of injury based on arc rating materials in a layered PPE system. (Courtesy of ArcWear.com)



ATPV = 40.9 cal/cm²

Probability of burn	Ei
5%	28.5
10%	31.7
20%	35.1
30%	37.4
40%	39.2
50%	**40.9**
60%	42.7
70%	44.5
80%	46.8
90%	50.2

Pts = 21
Pts above stoll = 10
Pts break-open = 3
Pts always >stoll = 5
Pts always <stoll = 8
Pts within 20% = 12
Pts in mix zone = 8

Fabric description:
Two layers, style 85917 - protera 1808.0 oz/yd² 271 g/m² 2 × 1 LH twill, 65% modacrylic 35% N317, navy 10057Q, AAD 8.0 oz/yd² 271 g/m² over style S961 indura ultra soft 11 oz/yd 373 g/m² duck, 88% cotton 12% nylon, brown, AAD 11.6 oz/yd² 393 g/m², ArcWear# 1102P86

M.2 Layering Using Arc-Rated Clothing over Natural Fiber Clothing Underlayers.

M.2.1 Under some exposure conditions, natural fiber underlayers can ignite even when they are worn under arc-rated clothing.

M.2.2 If the arc flash exposure is sufficient to break open all the arc-rated clothing outerlayer or underlayers, the natural fiber underlayer can ignite and cause more severe burn injuries to an expanded area of the body. This is due to the natural fiber underlayers burning onto areas of the worker's body that were not exposed by the arc flash event. This can occur when the natural fiber underlayer continues to burn underneath arc-rated clothing layers even in areas in which the arc-rated clothing layer or layers are not broken open due to a "chimney effect."

M.3 Total System Arc Rating.

M.3.1 The total system arc rating is the arc rating obtained when all clothing layers worn by a worker are tested as a multilayer test sample. An example of a clothing system is an arc-rated coverall worn over an arc-rated shirt and arc-rated pants in which all of the garments are constructed from the same arc-rated fabric. For this two-layer arc-rated clothing system, the arc rating would typically be more than three times higher than the arc ratings of the individual layers; that is, if the arc ratings of the arc-rated coverall, shirt, and pants were all in the range of 5 cal/cm² (20.9 J/cm²) to 6 cal/cm² (25.1 J/cm²), the total two-layer system arc rating would be over 20 cal/cm² (83.7 J/cm²).

M.3.2 It is important to understand that the total system arc rating cannot be determined by adding the arc ratings of the individual layers. In a few cases, it has been observed that the total system arc rating actually decreased when another arc-rated layer of a specific type was added to the system as the outermost layer. The only way to determine the total system arc rating is to conduct a multilayer arc test on the combination of all of the layers assembled as they would be worn.

A total system arc rating is not simply a matter of adding together the ratings of the individual pieces; the layered system as a whole requires testing to obtain an arc rating.

N Example Industrial Procedures and Policies for Working Near Overhead Electrical Lines and Equipment

This informative annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

Informative Annex N illustrates electrical safety measures that might be appropriate for working near overhead lines. Although the content of this informative annex is not enforceable, the measures contained here are effective. See Supplement 3 for another safety procedure example, which illustrates the types of information that should comprise a typical safety procedure.

N.1 Introduction.

This informative annex is an example of an industrial procedure for working near overhead electrical systems. Areas covered include operations that could expose employees or equipment to contact with overhead electrical systems.

When working near electrical lines or equipment, avoid direct or indirect contact. Direct contact is contact with any part of the body. Indirect contact is when part of the body touches or is in dangerous proximity to any object in contact with energized electrical equipment. The following two assumptions should always be made:

(1) Lines are "live" (energized).
(2) Lines are operating at high voltage (over 1000 volts).

As the voltage increases, the minimum working clearances increase. Through arc-over, injuries or fatalities could occur, even if actual contact with high-voltage lines or equipment is not made. Potential for arc-over increases as the voltage increases.

N.2 Overhead Power Line Policy (OPP).

This informative annex applies to all overhead conductors, regardless of voltage, and requires the following:

(1) That employees not place themselves in close proximity to overhead power lines. "Close proximity" is within a distance of 3 m (10 ft) for systems up to 50 kV, and should be increased 100 mm (4 in.) for every 10 kV above 50 kV.
(2) That employees be informed of the hazards and precautions when working near overhead lines.
(3) That warning decals be posted on cranes and similar equipment regarding the minimum clearance of 3 m (10 ft).

O Safety-Related Design Requirements

This informative annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

The design of a facility, equipment, or circuit could determine if a work task can be performed safely. In large measure, the facility and circuit design determines whether or how an employee is or might be exposed to an electrical hazard when performing tasks necessary to troubleshoot, repair, or maintain a facility.

The circuit and equipment design determines the amount of incident energy that might be available at various points in the system and whether an electrically safe work condition can be created for sectors of the circuit. The location of components and isolating or insulating barriers determines whether or how an employee might be exposed to shock or electrocution.

O.1 Introduction.

This informative annex addresses the responsibilities of the facility owner or manager or the employer having responsibility for facility ownership or operations management to perform a risk assessment during the design of electrical systems and installations.

O.1.1 This informative annex covers employee safety-related design concepts for electrical equipment and installations in workplaces covered by the scope of this standard. This informative annex discusses design considerations that have impact on the application of the safety-related work practices only.

O.1.2 This informative annex does not discuss specific design requirements. The facility owner or manager or the employer should choose design options that eliminate hazards or reduce risk and enhance the effectiveness of safety-related work practices.

O.2 General Design Considerations.

O.2.1 Employers, facility owners, and managers who have responsibility for facilities and installations having electrical energy as a potential hazard to employees and other personnel should ensure that electrical hazard risk assessments are performed during the design of electrical systems and installations.

O.2.2 Design option decisions should facilitate the ability to eliminate hazards or reduce risk by doing the following:

(1) Reducing the likelihood of exposure
(2) Reducing the magnitude or severity of exposure
(3) Enabling achievement of an electrically safe work condition

Δ **O.2.3 Incident Energy Reduction Methods.** The following methods have proved to be effective in reducing incident energy:

(1) Zone-selective interlocking. This is a method that allows two or more circuit breakers to communicate with each other so that a short circuit or ground fault will be cleared by the breaker closest to the fault with no intentional delay. Clearing the fault in the shortest time aids in reducing the incident energy.
(2) Differential relaying. The concept of this protection method is that current flowing into protected equipment must equal the current out of the equipment. If these two currents are not equal, a fault must exist within the equipment, and the relaying can be set to operate for a fast interruption. Differential relaying uses current transformers located on the line and load sides of the protected equipment and fast acting relay.
(3) Energy-reducing maintenance switching with a local status indicator. An energy-reducing maintenance switch allows a worker to set a circuit breaker trip unit to operate faster while the worker is working within an arc flash boundary, as defined in *NFPA 70E*, and then to set the circuit breaker back to a normal setting after the work is complete.
(4) Energy-reducing active arc flash mitigation system. This system can reduce the arcing duration by creating a low impedance current path, located within a controlled compartment, to cause the arcing fault to transfer to the new current path, while the upstream breaker clears the circuit. The system works without compromising existing selective coordination in the electrical distribution system.
(5) Arc flash relay. An arc flash relay typically uses light sensors to detect the light produced by an arc flash event. Once a certain level of light is detected, the relay will issue a trip signal to an upstream overcurrent device.
(6) High-resistance grounding. A great majority of electrical faults are of the phase-to-ground type. High-resistance grounding will insert an impedance in the ground return path and will typically limit the fault current to 10 amperes and below (at 5 kV nominal or below), leaving insufficient fault energy and thereby helping reduce the arc flash hazard level. High-resistance grounding will not affect arc flash energy for line-to-line or line-to-line-to-line arcs.
(7) Current-limiting devices. Current-limiting protective devices reduce incident energy by clearing the fault faster and by reducing the current seen at the arc source. The energy reduction becomes effective for current above the current-limiting threshold of the current-limiting fuse or current limiting circuit breaker.
(8) Shunt-trip. Adding a shunt-trip that is signaled to open from an open-fuse relay to switches 800 amperes and greater reduces incident energy by opening the switch immediately when the first fuse opens. The reduced clearing time reduces incident energy. This is especially helpful for arcing currents that are not within the current-limiting threshold of the three current-limiting fuses.

O.2.4 Additional Safety-by-Design Methods. The following methods have proven to be effective in reducing risk associated with an arc flash or shock hazard:

The following is a list of commonly used engineering controls to either reduce available current, restrict access to energized conductors and circuit parts, or reduce the likelihood of initiating an arc flash hazard.

(1) Installing finger-safe components, covers, and insulating barriers reduces exposure to energized parts.

Finger-safe components, often called IP-20 components, make it more difficult to accidentally contact an energized part, thereby reducing the likelihood of receiving an electric shock or creating an arcing fault.

(2) Installing disconnects within sight of each motor or driven machine increases the likelihood the chances that the equipment will be put into an electrically safe work condition before work has begun.

NFPA 70®, National Electrical Code® (*NEC®*), has allowances for a disconnecting means to not be within sight of a motor. However, installing a disconnecting means within sight of a motor increases the probability that an employee will utilize it to put the equipment into an electrically safe work condition.

(3) Installing current limiting cable limiters can help reduce incident energy. Additionally, cable limiters can be used to provide short-circuit protection (and therefore incident energy reduction) for feeder tap conductors that are protected at up to 10 times their ampacity, a situation where the tap conductor can easily vaporize.
(4) Installing inspection windows for noncontact inspection reduces the need to open doors or remove covers.

Infrared and viewing windows eliminate the high-risk task of opening energized electrical equipment when employees perform periodic diagnostic inspections to evaluate the condition of equipment. Eliminating this task reduces the likelihood of initiating an incident.

(5) Installing a single service fused disconnect switch or circuit breaker provides protection for buses that would be unprotected if six disconnect switches are used.

A main disconnecting means provides an easy method to de-energize all but the incoming terminals. The use of the six-disconnect rule permitted by the *NEC* can leave an unprotected, energized bus inside the enclosure. The presence of an unprotected, energized bus increases the likelihood of an employee accidentally contacting the bus or initiating an arc flash incident.

(6) Installing metering to provide remote monitoring of voltage and current levels reduces exposure to electrical hazards by placing the worker farther away from the hazard.
(7) Installing Type 2 "no damage" current limiting protection to motor controllers reduces incident energy whenever the arcing current is within the current limiting threshold of the current-limiting fuse or current-limiting circuit breaker.

In order to achieve Type 2 "no damage" protection of a motor controller, it is generally necessary to utilize overcurrent devices with the highest degree of current limitation. For example, most motor controllers cannot achieve Type 2 protection with Class RK5 fuses. A Class RK1, Class J, or Class CC fuse must be used. This very high degree of current limitation then is also able to reduce incident energy during an arc flash incident, if the fault current is high enough to be within the overcurrent protective device's current-limiting threshold.

(8) Installing adjustable instantaneous trip protective devices and lowering the trip settings can reduce the incident energy.

(9) Installing arc-resistant equipment, designed to divert hot gases, plasma, and other products of an arc-flash out of the enclosure so that a worker is not exposed when standing in front of the equipment with all doors and covers closed and latched, reduces the risk of arc flash exposure.

When its doors and covers are closed and latched, arc-resistant switchgear provides protection for an employee who is energizing or de-energizing the equipment. Products of an arcing incident are diverted out of the enclosure and away from the employee. Arc-resistant equipment does not protect the worker when the doors and covers are not properly closed and latched.

(10) Installing provisions that provide remote racking of equipment, such as remote-controlled motorized remote racking of a circuit breaker or an MCC bucket, allows the worker to be located outside the arc-flash boundary. An extended length hand-operated racking tool also adds distance between the worker and the equipment, reducing the worker's exposure.

(11) Installing provisions that provide remote opening and closing of circuit breakers and switches could permit workers to operate the equipment from a safe distance, outside the arc flash boundary.

(12) Class C, D, and E special purpose ground fault circuit interrupters exist for circuits operating at voltages outside the range for Class A GFCI protection. See UL 943C for additional information.

The reader should be aware of the following documents:

- ANSI/IEEE C37.20.7-2007, *IEEE Guide for Testing Metal-Enclosed Switchgear Rated Up to 38 kV for Internal Arcing Faults*. This guide includes a procedure for testing and evaluating the performance of metal-enclosed switchgear for internal arcing faults. It also includes a method of identifying the capabilities of this equipment and discusses service conditions, installation, and application of equipment.
- ANSI/IEEE C37.20.7-2007/Cor. 1-2010, *IEEE Guide for Testing Metal-Enclosed Switchgear Rated up to 38 kV for Internal Arcing Faults, Corrigendum 1*. This corrects technical errors found in IEEE C37.20.7-2007 concerning current values and arc initiation in low-voltage testing and supply frequency for equipment used in laboratories.

INFORMATIVE ANNEX

P

Aligning Implementation of This Standard with Occupational Health and Safety Management Standards

This informative annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

ANSI/AIHA Z10, *American National Standard for Occupational Health and Safety Management Systems*, defines the minimum basic requirements for an organization's overall occupational health and safety management system. The standard addresses management leadership, employee participation, planning, implementation, evaluation, corrective action, and management review. It covers basic activities such as incident investigation, inspections, and training.

The system in ANSI/AIHA Z10 allows for continual improvement of health and safety management. The standard includes required interrelated processes suitable for continual improvement that align with the Deming Cycle. The Deming Cycle, Plan – Do – Check – Act, or PDCA, is an iterative four-step management process also known as the Shewhart Cycle or PDSA (plan – do – study – act). The Deming Cycle is shown in Exhibit P.1.

PDCA is a successive cycle that starts off from a known base and tests small potential effects on the process, then gradually leads to larger and more targeted change based on a continuous process. The cycle is comprised of the following phases:

- Plan phase — The objectives and processes necessary to deliver results in accordance with the expected output or goal are established.
- Do phase — The new process is implemented on a small scale to test possible effects.
- Check phase — The new process is measured and the results of the Do phase are compared against the expected results to determine any differences.
- Act phase — The differences are analyzed to determine their cause. Under this phase, the changes to be made and where they apply to cause improvements are determined.

When a cycle through these four steps does not result in an improvement, the original base is returned to and the process is tried again until there is a plan that involves improvement.

A fundamental principle of PDCA is reiteration. Reiterating the PDCA cycle brings a company, organization, group, or production area closer to its goals. PDCA needs to be repeated in ever-tightening circles that represent increasing knowledge of the system, ultimately ending on or near the fundamental goals of that system. Small steps from a solid base provide feedback to justify hypotheses and increase understanding of the system being studied. If a small misstep is made, it is easy to repeat the previous iteration. The power of this concept lies in its simplicity. The simple cycle can be continually reapplied to the process in question for improvement.