NFPA 70E
Standard for Electrical Safety Requirements for Employee Workplaces

1995 Edition

National Fire Protection Association, 1 Batterymarch Park, PO Box 9101, Quincy, MA 02269-9101
An International Codes and Standards Organization

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Electrical Safety Requirements for Employee Workplaces

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This edition of NFPA 70E, *Standard for Electrical Safety Requirements for Employee Workplaces*, was prepared by the Technical Committee on Electrical Safety Requirements for Employee Workplaces and acted on by the National Fire Protection Association, Inc., at its Fall Meeting held November 14-16, 1994, in Toronto, Ontario, Canada. It was issued by the Standards Council on January 13, 1995, with an effective date of February 7, 1995, and supersedes all previous editions.

The 1995 edition of this document has been approved by the American National Standards Institute.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

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This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

NOTE: Membership on a committee shall not in and of itself constitute an endorsement of the Association or any document developed by the committee on which the member serves.

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

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NOTICE: Information on referenced publications can be found in Appendix B.

Foreword

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

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

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

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

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

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

This led to the concept that a document be put together by a competent group, representing all interests, that would extract suitable portions from the *NEC* and from other documents applicable to electrical safety. This concept and an offer of assistance was submitted in May, 1975, to the Assistant Secretary of Labor for OSHA, who said, "The concept, procedures, and scope of the effort discussed with my staff for preparing the subject standard appear to have great merit, and an apparent need exists for this proposed consensus document which OSHA could consider for promulgation under the provisions of Section 6(b) of the Act. OSHA does have an interest in this effort and believes the proposed standard would serve a useful purpose." With this positive encouragement from OSHA, a proposal to prepare such a document was presented to the NFPA Electrical Section, which unanimously supported a recommendation that the *NEC* Correlating Committee examine the feasibility of developing a document to be used as a basis for evaluating electrical safety in the workplace. In keeping with the recommendation of the Electrical Section and Correlating Committee, the Standards Council authorized the establishment of a committee to carry out this examination.

The committee found it feasible to develop a standard for electrical installations that would be compatible with the OSHA requirements for safety for the employee in locations covered by the *NEC*. The new standard was visualized as consisting of four major parts: Part I, Installation Safety Requirements; Part II, Safety Related Work Practices; Part III, Safety Related Maintenance Requirements; and Part IV, Safety Requirements for Special Equipment. Although desirable, it was not considered essential for all of the parts to be completed before the standard was published and made available. Each part is recognized as being an important aspect of electrical safety in the workplace, but the parts are sufficiently independent of each other to permit their separate publication. The new standard was named NFPA 70E, *Standard for Electrical Safety Requirements for Employee Workplaces*. The first edition was published in 1979 and included only Part I. The second edition was published in 1981. It included Part I as originally published and a new Part II. The third edition included Part I and Part II as originally published and a new Part III. This fourth edition does not contain new parts but substantial revisions have been made to the existing text, including updating Part I to the 1993 *NEC*.

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

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

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

(b) Its provisions should be excerpted from the *NEC* in a manner that will maintain their intent as they apply to

employee safety. In some cases it has been judged essential to the meaning of the excerpted passages to retain some material not applying to employee safety.

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

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

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

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

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

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

Editorial Note: Part IV of NFPA 70E is to be developed by the NFPA 70E Committee at a later date.

Introduction

I-1 Scope.

I-1.1 This standard addresses those electrical safety requirements for employee workplaces that are necessary for the practical safeguarding of employees in their pursuit of gainful employment. This standard covers:

(a) Electric conductors and equipment installed within or on buildings or other structures, including mobile homes and recreational vehicles, and other premises such as yards, carnival, parking and other lots, and industrial substations.

(b) Conductors that connect the installations to a supply of electricity.

(c) Other outside conductors on the premises.

I-1.2 This standard does not cover:

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

(b) Installations underground in mines.

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

(d) Installation of communication equipment under the exclusive control of communication utilities, located outdoors or in building spaces used exclusively for such installations.

(e) Installations under the exclusive control of electric utilities for the purpose of communication or metering; or for the generation, control, transformation, transmission, and distribution of electric energy located in buildings used exclusively by utilities for such purposes or located outdoors on property owned or leased by the utility or on public highways, streets, roads, etc., or outdoors by established rights on private property.

I-1.3 This standard is divided into the following four parts and two appendixes:

Part I, Installation Safety Requirements
Part II, Safety-Related Work Practices
Part III, Safety-Related Maintenance Requirements
Part IV, Safety Requirements for Special Equipment
Appendix A, Tables, Notes, and Charts
Appendix B, Referenced Publications

Editorial Note: Part IV of NFPA 70E is to be developed by the NFPA 70E Committee at a later date.

I-2 Definitions.

I-2.1 General. Definitions apply wherever the terms are used throughout this standard.

Accessible. (As applied to wiring methods.) Capable of being removed or exposed without damaging the building structure or finish, or not permanently closed in by the structure or finish of the building. (*See "Concealed" and "Exposed."*)

Accessible. (As applied to equipment.) Admitting close approach because not guarded by locked doors, elevation, or other effective means. (*See "Readily Accessible."*)

Ampacity. The current in amperes a conductor can carry continuously under the conditions of use without exceeding its temperature rating.

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

Approved. Acceptable to the authority having jurisdiction.

NOTE: The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations that is in a position to determine compliance with appropriate standards for the current production of listed items.

Approved for the Purpose. Approved for a specific purpose, environment, or application described in a particular standard requirement.

Suitability of equipment or materials for a specific purpose, environment, or application may be determined by a testing laboratory, inspection agency, or other organization concerned with product evaluation as part of its listing and labeling program. (*See "Labeled" or "Listed."*)

Armored Cable. Type AC armored cable is a fabricated assembly of insulated conductors in a flexible metallic enclosure.

Askarel. A generic term for a group of nonflammable, synthetic, chlorinated hydrocarbons used as electrical insulating media. Askarels of various compositional types are used. Under arcing conditions the gases produced, while consisting predominantly of noncombustible hydrogen chloride, can include varying amounts of combustible gases depending on the askarel type.

Attachment Plug (Plug Cap) (Cap). A device that, by insertion in a receptacle, establishes connection between the conductors of the attached flexible cord and the conductors connected permanently to the receptacle.

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

Bare Conductor. See "Conductor."

Bonding. The permanent joining of metallic parts to form an electrically conductive path that will ensure electrical continuity and the capacity to conduct safely any current likely to be imposed.

Bonding Jumper. A reliable conductor to ensure the required electrical conductivity between metal parts required to be electrically connected.

Branch Circuit. The circuit conductors between the final overcurrent device protecting the circuit and the outlet(s).

Building. A structure that stands alone or that is cut off from adjoining structures by fire walls with all openings therein protected by approved fire doors.

Cabinet. An enclosure designed either for surface or flush mounting and provided with a frame, mat, or trim in which a swinging door or doors are or may be hung.

Cable Tray System. A cable tray system is a unit or assembly of units or sections, and associated fittings, made of metal or other noncombustible materials forming a rigid structural system used to support cables. Cable tray systems include ladders, troughs, channels, solid bottom trays, and other similar structures.

Cablebus. Cablebus is an approved assembly of insulated conductors with fittings and conductor terminations in a completely enclosed, ventilated, protective metal housing.

Center Pivot Irrigation Machine. A multi-motored irrigation machine that revolves around a central pivot and employs alignment switches or similar devices to control individual motors.

Circuit Breaker. A device designed to open and close a circuit by nonautomatic means and to open the circuit automatically on a predetermined overcurrent without injury to itself when properly applied within its rating.

Class I Locations. Locations in which flammable gases or vapors are or may be present in the air in quantities sufficient to produce explosive or ignitible mixtures. Class I locations include those specified in (a) and (b) following:

(a) **Class I, Division 1.** A location: (1) in which hazardous concentrations of flammable gases or vapors exist continuously, intermittently, or periodically under normal operating conditions; or (2) in which hazardous concentrations of such gases or vapors may exist frequently because of repair or maintenance operations or because of leakage; or (3) in which breakdown or faulty operation of equipment or processes might release hazardous concentrations of flammable gases or vapors, and might also cause simultaneous failure of electric equipment.

NOTE: This classification usually includes locations where volatile flammable liquids or liquefied flammable gases are transferred from one container to another; interiors of spray booths and areas in the vicinity of spraying and painting operations where volatile flammable solvents are used; locations containing open tanks or vats of volatile flammable liquids; drying rooms or compartments for the evaporation of flammable solvents; locations containing fat and oil extraction equipment using volatile flammable solvents; portions of cleaning and dyeing plants where hazardous liquids are used; gas generator rooms and other portions of gas manufacturing plants where flammable gas may escape; inadequately ventilated pump rooms for flammable gas or for volatile flammable liquids; the interiors of refrigerators and freezers in which volatile flammable materials are stored in open, lightly stoppered, or easily ruptured containers; and all other locations where hazardous concentrations of flammable vapors or gases are likely to occur in the course of normal operations.

(b) **Class I, Division 2.** A location: (1) in which volatile flammable liquids or flammable gases are handled, processed, or used, but in which the hazardous liquids, vapors, or gases will normally be confined within closed containers or closed systems from which they can escape only in case of accidental rupture or breakdown of such containers or systems, or in case of abnormal operation of equipment; or (2) in which hazardous concentrations of gases or vapors are normally prevented by positive mechanical ventilation, and which might become hazardous through failure or abnormal operation of the ventilating equipment; or (3) that is adjacent to a Class I, Division 1 location, and to which hazardous concentrations of gases or vapors might occasionally be communicated unless such communication is prevented by adequate positive-pressure ventilation from a source of clean air, and effective safeguards against ventilation failure are provided.

NOTE: This classification usually includes locations where volatile flammable liquids or flammable gases or vapors are used, but that, in the judgment of the authority having jurisdiction, would become hazardous only in case of an accident or of some unusual operating condition. The quantity of hazardous material that might escape in case of accident, the adequacy of ventilating equipment, the total area involved, and the record of the industry or business with respect to explosions or fires are all factors that merit consideration in determining the classification and extent of each location.

Piping without valves, checks, meters, and similar devices would not ordinarily introduce a hazardous condition even though used for hazardous liquids or gases. Locations used for the storage of hazardous liquids or of liquefied or compressed gases in sealed containers would not normally be considered hazardous unless subject to other hazardous conditions also.

Electrical conduits and their associated enclosures separated from process fluids by a single seal or barrier are classed as a Division 2 location if the outside of the conduit and enclosures is a nonhazardous location.

Class II Locations. Locations that are hazardous because of the presence of combustible dust. Class II locations include those specified in (a) and (b) following:

(a) **Class II, Division 1.** A location: (1) in which combustible dust is or may be in suspension in the air continuously, intermittently, or periodically under normal operating conditions, in quantities sufficient to produce explosive or ignitible mixtures; or (2) where mechanical failure or abnormal operation of machinery or equipment might cause such explosive or ignitible mixtures to be produced, and might also provide a source of ignition through simultaneous failure of electric equipment, operation of protection devices, or from other

causes; or (3) in which combustible dusts of an electrically conductive nature may be present.

NOTE: This classification usually includes the working areas of grain handling and storage plants; rooms containing grinders or pulverizers, cleaners, graders, scalpers, open conveyors or spouts, open bins or hoppers, mixers or blenders, automatic or hopper scales, packing machinery, elevator heads and boots, stock distributors, dust and stock collectors (except all-metal collectors vented to the outside), and all similar dust-producing machinery and equipment in grain-processing plants, starch plants, sugar-pulverizing plants, malting plants, hay-grinding plants, and other occupancies of similar nature; coal-pulverizing plants (except where the pulverizing equipment is essentially dusttight); all working areas where metal dusts and powders are produced, processed, handled, packed, or stored (except in tight containers); and all other similar locations where combustible dust may, under normal operating conditions, be present in the air in quantities sufficient to produce explosive or ignitible mixtures.

Combustible dusts that are electrically nonconductive include dusts produced in the handling and processing of grain and grain products, pulverized sugar and cocoa, dried egg and milk powders, pulverized spices, starch and pastes, potato and wood-flour, oil meal from beans and seed, dried hay, and other organic materials that may produce combustible dusts when processed or handled. Electrically conductive nonmetallic dusts include dusts from pulverized coal, coke, carbon black, and charcoal. Dusts containing magnesium or aluminum are particularly hazardous, and the use of extreme precaution will be necessary to avoid ignition and explosion.

(b) **Class II, Division 2.** A location in which combustible dust will not normally be in suspension in the air or will not be likely to be thrown into suspension by the normal operation of equipment or apparatus in quantities sufficient to produce explosive or ignitible mixtures, but: (1) where deposits or accumulations of such combustible dust may be sufficient to interfere with the safe dissipation of heat from electric equipment or apparatus; or (2) where such deposits or accumulations of combustible dust on, in, or in the vicinity of electric equipment might be ignited by arcs, sparks, or burning material from such equipment.

NOTE: Locations where dangerous concentrations of suspended dust would not be likely, but where dust accumulations might form on, or in the vicinity of, electric equipment, would include rooms and areas containing only closed spouting and conveyors, closed bins or hoppers, or machines and equipment from which appreciable quantities of dust would escape only under abnormal operating conditions; rooms or areas adjacent to a Class II, Division 1 location as described in (a) above, and into which explosive or ignitible concentrations of suspended dust might be communicated only under abnormal operating conditions; rooms or areas where the formation of explosive or ignitible concentrations of suspended dust is prevented by the operation of effective dust control equipment; warehouses and shipping rooms where dust-producing materials are stored or handled only in bags or containers; and other similar locations.

Class III Locations. Locations that are hazardous because of the presence of easily ignitible fibers or flyings, but in which such fibers or flyings are not likely to be in suspension in the air in quantities sufficient to produce ignitible mixtures. Class III locations include those specified in (a) and (b) following:

(a) **Class III, Division 1.** A location in which easily ignitible fibers or materials producing combustible flyings are handled, manufactured, or used.

NOTE: Such locations usually include some parts of rayon, cotton, and other textile mills; combustible fiber manufacturing and processing plants; cotton gins and cottonseed mills; flax-processing plants; clothing manufacturing plants; woodworking plants; and establishments and industries involving similar hazardous processes or conditions.

Easily ignitible fibers and flyings include rayon, cotton (including cotton linters and cotton waste), sisal or henequen, istle, jute, hemp, tow, cocoa fiber, oakum, baled waste kapok, Spanish moss, excelsior, and other materials of similar nature.

(b) **Class III, Division 2.** A location in which easily ignitible fibers are stored or handled.

Exception: In process of manufacture.

Collector Ring. An assembly of slip rings for transferring electrical energy from a stationary to a rotating member.

Concealed. Rendered inaccessible by the structure or finish of the building. Wires in concealed raceways are considered concealed, even though they may become accessible by withdrawing them. [*See "Accessible. (As applied to wiring methods.)"*]

Conductor.

Bare. A conductor having no covering or electrical insulation whatsoever. (*See "Conductor, Covered."*)

Covered. A conductor encased within material of composition or thickness that is not recognized by this standard as electrical insulation. (*See "Conductor, Bare."*)

Insulated. A conductor encased within material of composition and thickness that is recognized by this standard as electrical insulation.

Conduit Body. A separate portion of a conduit or tubing system that provides access through a removable cover(s) to the interior of the system at a junction of two or more sections of the system or at a terminal point of the system.
Boxes such as FS and FD or larger cast or sheet metal boxes are not classified as conduit bodies.

Controller. A device or group of devices that serves to govern, in some predetermined manner, the electric power delivered to the apparatus to which it is connected.

Cooking Unit, Counter-Mounted. A cooking appliance designed for mounting in or on a counter and consisting of one or more heating elements, internal wiring, and built-in or separately mountable controls. (*See "Oven, Wall-Mounted."*)

Covered Conductor. See "Conductor."

Cutout Box. An enclosure designed for surface mounting and having swinging doors or covers secured directly to and telescoping with the walls of the box proper. (*See "Cabinet."*)

Damp Location. See "Location."

Dead Front. Without live parts exposed to a person on the operating side of the equipment.

Device. A unit of an electrical system that is intended to carry but not utilize electric energy.

Dielectric Heating. The heating of a nominally insulating material due to its own dielectric losses when the material is placed in a varying electric field.

Disconnecting Means. A device, or group of devices, or other means by which the conductors of a circuit can be disconnected from their source of supply.

NOTE: See I-2.2 for definition applying to circuits and equipment over 600 volts, nominal.

Dry Location. See "Location."

Electric Sign. A fixed, stationary, or portable self-contained, electrically illuminated utilization equipment with

words or symbols designed to convey information or attract attention.

Enclosed. Surrounded by a case, housing, fence, or walls that will prevent persons from accidentally contacting energized parts.

Enclosure. The case or housing of apparatus, or the fence or walls surrounding an installation to prevent personnel from accidentally contacting energized parts, or to protect the equipment from physical damage.

Equipment. A general term including material, fittings, devices, appliances, fixtures, apparatus and the like, used as a part of, or in connection with, an electrical installation.

Equipment Grounding Conductor. See "Grounding Conductor, Equipment."

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

Exposed. (As applied to live parts.) Capable of being inadvertently touched or approached nearer than a safe distance by a person. It is applied to parts not suitably guarded, isolated, or insulated. (*See "Accessible" and "Concealed."*)

Exposed. (As applied to wiring methods.) On or attached to the surface or behind panels designed to allow access. [*See "Accessible. (As applied to wiring methods.)"*]

Exposed. For the purposes of Chapter 6, the word "exposed" means that the circuit is in such a position that, in case of failure of supports or insulation, contact with another circuit may result.

Externally Operable. Capable of being operated without exposing the operator to contact with live parts.

Feeder. All circuit conductors between the service equipment, or the generator switchboard of an isolated plant, and the final branch-circuit overcurrent device.

Fitting. An accessory such as a locknut, bushing, or other part of a wiring system that is intended primarily to perform a mechanical rather than an electrical function.

Ground. A conducting connection, whether intentional or accidental, between an electrical circuit or equipment and the earth, or to some conducting body that serves in place of the earth.

Grounded. Connected to earth or to some conducting body that serves in place of the earth.

Grounded Conductor. A system or circuit conductor that is intentionally grounded.

Grounding Conductor. A conductor used to connect equipment or the grounded circuit of a wiring system to a grounding electrode or electrodes.

Grounding Conductor, Equipment. The conductor used to connect the non-current-carrying metal parts of equipment, raceways, and other enclosures to the system grounded conductor and/or the grounding electrode conductor at the service equipment or at the source of a separately derived system.

Grounding Electrode Conductor. The conductor used to connect the grounding electrode to the equipment grounding conductor and/or to the grounded conductor of the circuit at the service equipment or at the source of a separately derived system.

Ground-Fault Circuit-Interrupter. A device whose function is to interrupt the electric circuit to the load when a fault current to ground exceeds some predetemined value that is less than that required to operate the overcurrent protective device of the supply circuit.

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

Health Care Facilities. Buildings or portions of buildings and mobile homes that contain, but are not limited to, hospitals, nursing homes, extended-care facilities, clinics, and medical and dental offices, whether fixed or mobile.

Heating Equipment. For the purposes of Chapter 4, the term includes any equipment used for heating purposes whose heat is generated by induction or dielectric methods.

Hoistway. Any shaftway, hatchway, well hole, or other vertical opening or space in which an elevator or dumbwaiter is designed to operate.

Identified. Identified, as used in this standard in reference to a conductor or its terminal, means that such conductor or terminal is to be recognized as grounded.

Induction Heating. The heating of a nominally conductive material due to its own I^2R losses when the material is placed in a varying electromagnetic field.

Insulated Conductor. See "Conductor."

Irrigation Machine. An electrically driven or controlled machine, with one or more motors, not hand portable, and used primarily to transport and distribute water for agricultural purposes.

Isolated. Not readily accessible to persons unless special means for access are used.

Isolated Power System. A system comprising an isolating transformer or its equivalent, a line isolation monitor, and its ungrounded circuit conductors.

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

Lighting Outlet. An outlet intended for the direct connection of a lampholder, a lighting fixture, or a pendant cord terminating in a lampholder.

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

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

Location.

Damp Location. Partially protected locations under canopies, marquees, roofed open porches, and like locations, and interior locations subject to moderate degrees of moisture, such as some basements, some barns, and some cold-storage warehouses.

Dry Location. A location not normally subject to dampness or wetness. A location classified as dry may be temporarily subject to dampness or wetness, as in the case of a building under construction.

Wet Location. Installations underground or in concrete slabs or masonry in direct contact with the earth, and locations subject to saturation with water or other liquids, such as vehicle-washing areas and locations exposed to weather and unprotected.

Medium Voltage Cable. Type MV cable is a single or multiconductor solid dielectric insulated cable rated 2000 volts or higher.

Metal-Clad Cable. Type MC cable is a factory assembly of one or more conductors, each individually insulated and enclosed in a metallic sheath of interlocking tape, or a smooth or corrugated tube.

Mineral-Insulated Metal-Sheathed Cable. Type MI cable is a factory assembly of one or more conductors insulated with a highly compressed refractory mineral insulation and enclosed in a liquidtight and gastight continuous copper sheath.

Mobile X-Ray. X-ray equipment mounted on a permanent base with wheels and/or casters for moving while completely assembled.

Nonmetallic-Sheathed Cable. Nonmetallic-sheathed cable is a factory assembly of two or more insulated conductors having an outer sheath of moisture-resistant, flame-retardant, nonmetallic material and of the following types:

(a) **Type NM.** The overall covering has a flame-retardant and moisture-resistant finish.

(b) **Type NMC.** The overall covering is flame-retardant, moisture-resistant, fungus-resistant, and corrosion-resistant.

Open Wiring on Insulators. Open wiring on insulators is an exposed wiring method using cleats, knobs, tubes, and flexible tubing for the protection and support of single insulated conductors run in or on buildings and not concealed by the building structure.

Outlet. A point of the wiring system at which current is taken to supply utilization equipment.

Outline Lighting. An arrangement of incandescent lamps or electric discharge tubing to outline or call attention to certain features such as the shape of a building or the decoration of a window.

Oven, Wall-Mounted. An oven for cooking purposes designed for mounting in or on a wall or other surface and consisting of one or more heating elements, internal wiring, and built-in or separately mountable controls. (*See "Cooking Unit, Counter-Mounted."*)

Overcurrent. Any current in excess of the rated current of equipment or the ampacity of a conductor. It may result from overload (*see definition*), short circuit, or ground fault.

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

Overload. Operation of equipment in excess of normal, full-load rating, or of a conductor in excess of rated ampacity which, when it persists for a sufficient length of time, would cause damage or dangerous overheating. A fault, such as a short circuit or ground fault, is not an overload. (*See "Overcurrent."*)

Panelboard. A single panel or group of panel units designed for assembly in the form of a single panel; including buses, automatic overcurrent devices, and with or without switches for the control of light, heat, or power circuits; designed to be placed in a cabinet or cutout box placed in or against a wall or partition and accessible only from the front. (*See "Switchboard."*)

Permanently Installed Decorative Fountains and Reflection Pools. Those that are constructed in the ground, on the ground, or in a building in such a manner that the pool cannot be readily disassembled for storage and are served by electrical circuits of any nature. These units are primarily constructed for their aesthetic value and are not intended for swimming or wading.

Permanently Installed Swimming, Wading, and Therapeutic Pools. Those that are constructed in the ground, on the ground, or in a building in such a manner that the pool cannot be readily disassembled for storage whether or not served by electrical circuits of any nature.

Portable X-Ray. X-ray equipment designed to be hand-carried.

Power and Control Tray Cable. Type TC cable is a factory assembly of two or more insulated conductors, with or without associated bare or covered grounding conductors under a nonmetallic sheath, approved for installation in cable trays, in raceways, or where supported by a messenger wire.

Power-Limited Tray Cable. Type PLTC nonmetallic-sheathed cable is a factory assembly of two or more insulated conductors under a nonmetallic jacket.

Power Outlet. An enclosed assembly that may include receptacles, circuit breakers, fuseholders, fused switches, buses, and watthour meter mounting means; intended to supply and control power to mobile homes, recreational vehicles, or boats or to serve as a means for distributing power required to operate mobile or temporarily installed equipment.

Premises Wiring (System). That interior and exterior wiring, including power, lighting, control, and signal circuit wiring together with all of its associated hardware, fittings, and wiring devices, both permanently and temporarily installed, that extends from the load end of the service drop, or load end of the service lateral conductors to the outlet(s). Such wiring does not include wiring internal to appliances, fixtures, motors, controllers, motor control centers, and similar equipment.

Qualified Person. One familiar with the construction and operation of the equipment and the hazards involved.

Raceway. A channel designed expressly for holding wires, cables, or busbars, with additional functions as permitted in this standard.

Raceways may be of metal or insulating material, and the term includes rigid metal conduit, rigid nonmetallic conduit, intermediate metal conduit, liquidtight flexible metal conduit, flexible metallic tubing, flexible metal conduit, electrical metallic tubing, underfloor raceways, cellular concrete floor raceways, cellular metal floor raceways, surface raceways, wireways, and busways.

Readily Accessible. Capable of being reached quickly for operation, renewal, or inspections, without requiring those to whom ready access is requisite to climb over or remove obstacles or to resort to portable ladders, chairs, etc. (*See "Accessible."*)

Receptacle. A receptacle is a contact device installed at the outlet for the connection of a single attachment plug.

A single receptacle is a single contact device with no other contact device on the same yoke. A multiple receptacle is a single device containing two or more receptacles.

Receptacle Outlet. An outlet where one or more receptacles are installed.

Remote-Control Circuit. Any electric circuit that controls any other circuit through a relay or an equivalent device.

Sealable Equipment. Equipment enclosed in a case or cabinet that is provided with a means of sealing or locking so that live parts cannot be made accessible without opening the enclosure. The equipment may or may not be operable without opening the enclosure.

Separately Derived System. A premises wiring system whose power is derived from generator, transformer, or converter winding and has no direct electrical connection, including a solidly connected grounded circuit conductor, to supply conductors originating in another system.

Service. The conductors and equipment for delivering energy from the electricity supply system to the wiring system of the premises served.

Service Cable. Service conductors made up in the form of a cable.

Service Conductors. The supply conductors that extend from the street main or from transformers to the service equipment of the premises supplied.

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

Service-Entrance Cable. Service-entrance cable is a single conductor or multiconductor assembly provided with or without an overall covering, primarily used for services and of the following types:

(a) **Type SE.** Having a flame-retardant, moisture-resistant covering, but not required to have inherent protection against mechanical abuse.

(b) **Type USE.** Recognized for underground use, having a moisture-resistant covering, but not required to have a flame-retardant covering or inherent protection against mechanical abuse. Single-conductor cables having an insulation specifically approved for the purpose do not require an outer covering.

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

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

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

Service Equipment. The necessary equipment, usually consisting of a circuit breaker or switch and fuses, and their accessories, located near the point of entrance of supply conductors to a building or other structure, or an otherwise defined area, and intended to constitute the main control and means of cutoff of the supply.

Service Raceway. The raceway that encloses the service-entrance conductors.

Shielded Nonmetallic-Sheathed Cable. Type SNM cable is a factory assembly of two or more insulated conductors in an extruded core of moisture-resistant, flame-resistant nonmetallic material, covered with an overlapping spiral metal tape and wire shield and jacketed with an extruded moisture-, flame-, oil-, corrosion-, fungus-, and sunlight-resistant nonmetallic material.

Show Window. Any window used or designed to be used for the display of goods or advertising material, whether it is fully or partly enclosed or entirely open at the rear and whether or not it has a platform raised higher than the street floor level.

Sign. See "Electric Sign."

Signaling Circuit. Any electric circuit that energizes signaling equipment.

Special Permission. The written consent of the authority having jurisdiction.

Storable Swimming or Wading Pool. A pool with a maximum dimension of 15 ft (4.58 m) and a maximum wall height of 3 ft (0.915 m) and constructed so that it may be readily disassembled for storage and reassembled to its original integrity.

Switches.

General-Use Switch. A switch intended for use in general distribution and branch circuits. It is rated in amperes, and it is capable of interrupting its rated current at its rated voltage.

General-Use Snap Switch. A form of general-use switch constructed so that it can be installed in flush device boxes or on outlet box covers, or otherwise used in conjunction with wiring systems recognized by this standard.

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

Motor-Circuit Switch. A switch, rated in horsepower, capable of interrupting the maximum operating overload current of a motor of the same horsepower rating as the switch at the rated voltage.

Switchboard. A large single panel, frame, or assembly of panels on which are mounted, on the face or back or both, switches, overcurrent and other protective devices, buses, and usually instruments. Switchboards are generally accessible from the rear as well as from the front and are not intended to be installed in cabinets. (*See "Panelboard."*)

Transportable X-Ray. X-ray equipment to be installed in a vehicle or that may be readily disassembled for transport in a vehicle.

Utilization Equipment. Equipment that utilizes electric energy for mechanical, chemical, heating, lighting, or similar purposes.

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

Volatile Flammable Liquid. A flammable liquid having a flash point below 38°C (100°F) or whose temperature is above its flash point.

Voltage (of a Circuit). The greatest root-mean-square (effective) difference of potential between any two conductors of the circuit concerned.

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

Voltage, Nominal. A nominal value assigned to a circuit or system for the purpose of conveniently designating its voltage class (as 120/240, 480Y/277, 600, etc.).

The actual voltage at which a circuit operates can vary from the nominal within a range that permits satisfactory operation of equipment.

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

Watertight. Constructed so that moisture will not enter the enclosure.

Weatherproof. Constructed or protected so that exposure to the weather will not interfere with successful operation.

Rainproof, raintight, or watertight equipment can fulfill the requirements for weatherproof where varying weather conditions other than wetness, such as snow, ice, dust, or temperature extremes, are not a factor.

Wet Location. See "Location."

Wireways. Wireways are sheet-metal troughs with hinged or removable covers for housing and protecting electric wires and cable and in which conductors are laid in place after the wireway has been installed as a complete system.

I-2.2 Over 600 Volts, Nominal. Whereas the preceding definitions are intended to apply wherever the terms are used throughout this standard, the following ones are applicable only to the provisions that specifically cover installations and equipment operating at over 600 volts, nominal.

Circuit Breaker. See "Switching Devices."

Cutout. See "Switching Devices."

Disconnect (Isolator). See "Switching Devices."

Disconnecting Means. See "Switching Devices."

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

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

Grounded, Effectively. Permanently connected to earth through a ground connection of sufficiently low impedance and having sufficient ampacity that ground fault current that may occur cannot build up to voltages dangerous to personnel.

Interrupter Switch. See "Switching Devices."

Oil (Filled) Cutout. See "Switching Devices."

Power Fuse. See "Fuse."

Switching Device. A device designed to close and/or open one or more electric circuits. Switching devices include:

Circuit Breaker. A switching device capable of making, carrying, and breaking currents under normal circuit conditions, and also making, carrying for a specified time, and breaking currents under specified abnormal circuit conditions, such as those of short circuit.

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

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

Disconnecting Means. A device, group of devices, or other means whereby the conductors of a circuit can be disconnected from their source of supply.

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

Oil Cutout (Oil-Filled Cutout). A cutout in which all or part of the fuse support and its fuse link or disconnecting blade are mounted in oil with complete immersion of the contacts and the fusible portion of the conducting element (fuse link), so that arc interruption by severing of the fuse link or by opening of the contacts will occur under oil.

Oil Switch. A switch having contacts that operate under oil (or askarel or other suitable liqui

PART I

INSTALLATION SAFETY REQUIREMENTS

Chapter 1 General Requirements for Electrical Installations

1-1 General.

1-1.1 The requirements contained in Part I shall be based on the provisions of NFPA 70, *National Electrical Code®*. Where installations of electric conductors and equipment have been found to conform with the safety requirements of the *National Electrical Code* in use at the time of installation by governmental bodies or agencies having legal jurisdiction for enforcement of the *National Electrical Code*, this conformance shall be prima facie evidence that such installations were adequately designed and installed.

1-1.2 Part I of this standard is divided into six chapters. Chapters 1, 2, and 3 apply generally. Chapter 4 applies to specific purpose equipment installations. Chapters 5 and 6 apply to hazardous (classified) locations and special systems. Chapters 4, 5, and 6 supplement or modify the general rules. Paragraph 6.5 of Chapter 6 covers communications systems and is independent of the other paragraphs and chapters except where specifically referenced. Chapters 1, 2, and 3 apply except as amended by Chapters 4, 5, and 6 for the particular condition.

1-2 Approval. The conductors and equipment required or permitted by this standard shall be acceptable only when approved.

NOTE: See definitions of "Approved," "Identified," "Labeled," and "Listed" in I-2.1 of the introduction.

1-3 Examination, Installation, and Use of Equipment.

1-3.1 Examination. In judging equipment, considerations such as the following shall be evaluated:

1-3.1.1 Suitability for installation and use in conformity with the provisions of this standard. Suitability of equipment shall be permitted to be evidenced by listing or labeling.

1-3.1.2 Mechanical strength and durability, including, for parts designed to enclose and protect other equipment, the adequacy of the protection thus provided.

1-3.1.3 Wiring bending and connection space.

1-3.1.4 Electrical insulation.

1-3.1.5 Heating effects under conditions of use.

1-3.1.6 Arcing effects.

1-3.1.7 Classification by type, size, voltage, current capacity, specific use.

1-3.1.8 Other factors that contribute to the practical safeguarding of persons using or likely to come in contact with equipment.

1-3.2 Installation and Use. Listed or labeled equipment shall be used or installed in accordance with any instructions included in the listing or labeling.

1-3.3 Insulation Integrity. All wiring shall be installed so that, when completed, the system will be free from short circuits and from grounds other than required or permitted in conformity with this standard.

1-3.4 Interrupting Rating. Equipment intended to break current at fault levels shall have an interrupting rating sufficient for the nominal circuit voltage and the current that is available at the line terminals of the equipment. Equipment intended to break current at other than fault levels shall have an interrupting rating at nominal circuit voltage sufficient for the current that must be interrupted.

1-3.5 Circuit Impedance and Other Characteristics. The overcurrent protective devices, the total impedance, the component short-circuit withstand ratings, and other characteristics of the circuit to be protected shall be selected and coordinated to permit the circuit protective devices that are used to clear a fault without the occurrence of extensive damage to the electrical components of the circuit. This fault shall be assumed to be either between two or more of the circuit conductors, or between any circuit conductor and the grounding conductor or enclosing metal raceway.

1-3.6 Deteriorating Agents. Unless identified for use in the operating environment, no conductors or equipment shall be located in damp or wet locations; where exposed to gases, fumes, vapors, liquids, or other agents having a deteriorating effect on the conductors or equipment; nor where exposed to excessive temperatures.

NOTE 1: In general, areas where acids and alkali chemicals are handled and stored can present such corrosive conditions, particularly when wet or damp. Severe corrosive conditions can also be present in portions of meat-packing plants, tanneries, glue houses, and some stables; installations immediately adjacent to a seashore and swimming pool areas; areas where chemical deicers are used; and storage cellars or rooms for hides, casings, fertilizer, salt, and bulk chemicals.

NOTE 2: Some cleaning and lubricating compounds can cause severe deterioration of many plastic materials used for insulating and structural applications in equipment.

Equipment approved for use in dry locations only shall be protected against permanent damage from the weather during building construction.

1-3.7 Mechanical Execution of Work. Electric equipment shall be installed in a neat and workmanlike manner.

1-3.7.1 Unused Openings. Unused openings in boxes, raceways, auxiliary gutters, cabinets, equipment cases, or housings shall be effectively closed to afford protection substantially equivalent to the wall of the equipment.

1-3.7.2 Subsurface Enclosures. Conductors shall be racked to provide ready and safe access in underground and subsurface enclosures, into which persons enter for installation and maintenance.

1-3.7.3 Integrity of Electrical Equipment and Connections. Internal parts of electrical equipment, including busbars, wiring terminals, insulators, and other surfaces shall not be damaged or contaminated by foreign materials such as paint, plaster, cleaners, or abrasives.

1-3.8 Mounting and Cooling of Equipment.

1-3.8.1 Mounting. Electric equipment shall be firmly secured to the surface on which it is mounted. Wooden plugs driven into holes in masonry, concrete, plaster, or similar materials shall not be used.

1-3.8.2 Cooling. Electrical equipment that depends on the natural circulation of air and convection principles for cooling of exposed surfaces shall be installed so that room airflow over such surfaces is not prevented by walls or by adjacent installed equipment. For equipment designed for floor mounting, clearance between top surfaces and adjacent surfaces shall be provided to dissipate rising warm air. Electrical equipment provided with ventilating openings shall be installed so that walls or other obstructions do not prevent the free circulation of air through the equipment.

1-3.9 Electrical Connections. Because of different characteristics of copper and aluminum, devices such as pressure terminal or pressure splicing connectors and soldering lugs shall be identified for the material of the conductor and shall be properly installed and used.

Conductors of dissimilar metals shall not be intermixed in a terminal or splicing connector where physical contact occurs between dissimilar conductors (such as copper and aluminum, copper and copper-clad aluminum, or aluminum and copper-clad aluminum) unless the device is identified for the purpose and conditions of use. Materials such as solder, fluxes, inhibitors, and compounds, where employed, shall be suitable for the use and shall be of a type that will not adversely affect the conductors, installation, or equipment.

NOTE: Many terminations and equipment are marked with a tightening torque.

1-4 Splices. Conductors shall be spliced or joined with splicing devices identified for the use or by brazing, welding, or soldering with a fusible metal or alloy. Soldered splices shall first be spliced or joined to be mechanically and electrically secure without solder and then soldered. All splices and joints and the free ends of conductors shall be covered with an insulation equivalent to that of the conductors or with an insulating device suitable for the purpose.

1-5 Arcing Parts. Parts of electric equipment that in ordinary operation produce arcs, sparks, flames, or molten metal shall be enclosed or separated and isolated from all combustible material.

1-6 Marking. The manufacturer's name, trademark, or other descriptive marking by which the organization responsible for the product can be identified shall be placed on all electric equipment. Other markings shall be provided indicating voltage, current, wattage, and other ratings as might be required. The marking shall be of sufficient durability to withstand the environment involved.

1-7 Identification of Disconnecting Means. Each disconnecting means required by this standard for motors and appliances and each service, feeder, or branch circuit at the point where it originates shall be legibly marked to indicate its purpose unless located and arranged so the purpose is evident. The marking shall be of sufficient durability to withstand the environment involved.

1-8 600 Volts, Nominal, or Less.

1-8.1 Working Space about Electric Equipment. Sufficient access and working space shall be provided and maintained about all electric equipment to permit ready and safe operation and maintenance of such equipment.

1-8.1.1 Working Clearances. Except as elsewhere required or permitted in this standard, the dimension of the working space in the direction of access to energized parts operating at 600 volts or less and likely to require examination, adjustment, servicing, or maintenance while alive shall not be less than indicated in Table 1-8.1.1. In addition to the dimensions shown in Table 1-8.1.1, work space shall not be less than 30 in. (76 mm) wide in front of the electric equipment. Distances shall be measured from the live parts if such are exposed, or from the enclosure front or opening if such are enclosed. Concrete, brick, or tile walls shall be considered as grounded.

Working space shall not be required in back of assemblies such as dead-front switchboards or motor control centers where there are no renewable or adjustable parts such as fuses or switches on the back and where all connections are accessible from locations other than the back.

By special permission, smaller spaces shall be permitted where it is judged that the particular arrangement of the installation will provide adequate accessibility.

Table 1-8.1.1 Working Clearances

Nominal Voltage to Ground	Minimum Clear Distance for Condition		
	(a)	(b)	(c)
	(ft)	(ft)	(ft)
0 - 150	3	3	3
151 - 600	3	$3^1/_2$	4

For SI units: 1 in. = 25.4 mm; 1 ft = 0.3048 m.

Where conditions (a), (b) and (c) are as follows:

(a) Exposed live parts on one side and no live or grounded parts on the other side of the working space, or exposed live parts on both sides effectively guarded by suitable wood or other insulating material. Insulated wire or insulated bus bars operating at not over 300 volts shall not be considered live parts.

(b) Exposed live parts on one side and grounded parts on the other side.

(c) Exposed live parts on both sides of the work space [not guarded as provided in condition (a)] with the operator between.

Exception No. 1: Working space shall not be required in back of assemblies such as dead-front switchboards, or motor control centers where there are no renewable or adjustable parts, such as fuses or switches on the back, and where all connections are accessible from locations other than the back.

Exception No. 2: By special permission, smaller spaces shall be permitted (1) where it is judged that the particular arrangement of the installation will provide adequate accessibility, or (2) where all uninsulated parts are at a voltage no greater than 30 volts RMS, 42 volts peak, or 60 volts dc.

1-8.1.2 Clear Space. Working space required by this standard shall not be used for storage. When normally enclosed live parts are exposed for inspection or servicing, the working space, if in a passageway or general open space, shall be suitably guarded.

1-8.1.3 Access and Entrance to Working Space. At least one entrance of sufficient area shall be provided to give access to the working space about electric equipment. For equipment rated 1200 amperes or more and over 6 ft (1.83 m) wide, containing overcurrent devices, switching devices, or control devices, there shall be one entrance not less than 24 in. (610 mm) wide and $6^1/_2$ ft (1.98 m) high at each end.

Exception No. 1: Where the location permits a continuous and unobstructed way of exit travel.

Exception No. 2: Where the working space required by 1-8.1.1 is doubled, only one entrance to the working space shall be required.

Working space with one entrance provided shall be located so that the edge of the entrance nearest the equipment is the minimum clear distance given in Table 1-8.1.1 away from such equipment.

1-8.1.4 Front Working Space. In all cases where there are live parts normally exposed on the front of switchboards or motor control centers, the working space in front of such equipment shall not be less than 3 ft (914 mm).

1-8.1.5 Illumination. Illumination shall be provided for all working spaces about service equipment, switchboards, panelboards, and motor control centers installed indoors.

1-8.1.6 Headroom. The minimum headroom of working spaces about service equipment, switchboards, panelboards, or motor control centers shall be $6^1/_4$ ft (1.83 m) for installations made prior to January 1, 1994, and $6^1/_2$ ft (1.98 m) for installations made subsequent to January 1, 1994.

NOTE: As used in this standard, a motor control center is an assembly of one or more enclosed sections having a common power bus and principally containing motor control units.

1-8.2 Guarding of Live Parts.

1-8.2.1 Except as elsewhere required or permitted by this standard, live parts of electric equipment operating at 50 volts or more shall be guarded against accidental contact by approved cabinets or other forms of approved enclosures, or by any of the following means:

(a) By location in a room, vault, or similar enclosure that is accessible only to qualified persons.

(b) By suitable permanent, substantial partitions or screens arranged so that only qualified persons will have access to the space within reach of the live parts. Any openings in such partitions or screens shall be sized and located so that persons are not likely to come into accidental contact with the live parts or to bring conducting objects into contact with them.

(c) By location on a suitable balcony, galley, or platform elevated and arranged to exclude unqualified persons.

(d) By elevation of 8 ft (2.44 m) or more above the floor or other working surface.

1-8.2.2 In locations where electric equipment would be exposed to physical damage, enclosures or guards shall be so arranged and of such strength as to prevent such damage.

1-8.2.3 Entrances to rooms and other guarded locations containing exposed live parts shall be marked with conspicuous warning signs forbidding unqualified persons to enter.

1-9 Over 600 Volts, Nominal.

1-9.1 General. Conductors and equipment used on circuits exceeding 600 volts, nominal, shall comply with all applicable provisions of the preceding requirements of this chapter and with the following provisions, which supplement or modify the preceding requirements. In no case shall the provisions of 1-9.2, 1-9.3, and 1-9.4 apply to the equipment on the supply side of the service conductors.

1-9.2 Enclosure for Electrical Installations. Electrical installations in a vault, room, or closet or in an area surrounded by a wall, screen, or fence, access to which is controlled by lock and key or other approved means, shall be considered to be accessible to qualified persons only. A wall, screen, or fence less than 7 ft (2.13 m) in height shall not be considered as preventing access unless it has other features that provide a degree of isolation equivalent to a 7-ft (2.13-m) fence.

The entrances to all buildings, rooms, or enclosures containing exposed live parts or exposed conductors operating at over 600 volts, nominal, shall be kept locked or shall be under the observation of a qualified person at all times.

1-9.2.1 Installations Accessible to Qualified Persons Only. Electrical installations having exposed live parts shall be accessible to qualified persons only and shall comply with the applicable provisions of 1-9.3.

1-9.2.2 Installations Accessible to Unqualified Persons. Electrical installations that are open to unqualified persons shall be made with metal-enclosed equipment or shall be enclosed in a vault or in an area, access to which is controlled by a lock. If metal-enclosed equipment is installed so that the bottom of the enclosure is less than 8 ft (2.44 m) above the floor or grade level, the enclosure door or hinged cover shall be kept locked.

Metal-enclosed switchgear, unit substations, transformers, pull boxes, connection boxes, and other similar associated equipment shall be marked with appropriate caution signs. When exposed to physical damage from vehicular traffic, suitable guards shall be provided.

Ventilating or similar openings in metal-enclosed equipment shall be designed so that foreign objects inserted through these openings will be deflected from energized parts.

1-9.3 Work Space about Equipment. Sufficient space shall be provided and maintained about electric equipment to permit ready and safe operation and maintenance of such equipment. Where energized parts are exposed, the minimum clear work space shall not be less than $6^1/_2$ ft (1.98 m) high (measured vertically from the floor or platform), or less than 3 ft (914 mm) wide (measured parallel to the equipment). The depth shall be as required in Table 1-9.3.1. In all cases, the work space shall be adequate to permit at least a 90-degree opening of doors or hinged panels.

1-9.3.1 Working Space. The minimum clear working space in front of electric equipment such as switchboards, control panels, switches, circuit breakers, motor controllers, relays, and similar equipment shall not be less than specified in Table 1-9.3.1. Distances shall be measured from the live parts, if exposed, or from the enclosure front or opening, if enclosed.

Exception: Working space shall not be required in back of equipment such as dead-front switchboards or control assemblies where there are no renewable or adjustable parts (such as fuses or switches) on the back and where all connections are accessible from locations other than the back. Where rear access is required to work on the energized parts on the back of enclosed equipment, a minimum working space 30 in. (762 mm) horizontally shall be provided.

1-9.3.2 Separation from Low-Voltage Equipment. Where switches, cutouts, or other equipment operating at 600 volts, nominal, or less, are installed in a room or enclosure where there are exposed live parts or exposed wiring operating at over 600 volts, nominal, the high-voltage equipment shall be effectively separated from the space occupied by the low-voltage equipment by a suitable partition, fence, or screen.

1-9.3.3 Locked Rooms or Enclosures. The entrances to all buildings, rooms, or enclosures containing exposed live parts or exposed conductors operating at over 600 volts, nominal, shall be kept locked.

Exception: Where such entrances are under the observation of a qualified person at all times.

Where the voltage exceeds 600 volts, nominal, permanent and conspicuous warning signs shall be provided, reading substantially as follows: "DANGER — HIGH VOLTAGE — KEEP OUT."

Table 1-9.3.1 Minimum Depth of Clear Working Space in Front of Electric Equipment

	Conditions		
Nominal Voltage to Ground	**(a)**	**(b)**	**(c)**
	(ft)	**(ft)**	**(ft)**
601 - 2,500	3	4	5
2,501 - 9,000	4	5	6
9,001 - 25,000	5	6	9
25,001 - 75kV	6	8	10
Above 75kV	8	10	12

For SI units: 1 ft = 0.3048 m.

Where conditions (a), (b), and (c) are as follows:

(a) Exposed live parts on one side and no live or grounded parts on the other side of the working space, or exposed live parts on both sides effectively guarded by suitable wood or other insulating materials. Insulated wire or insulated bus bars operating at not over 300 volts shall not be considered live parts.

(b) Exposed live parts on one side and grounded parts on the other side. Concrete, brick, or tile walls shall be considered as grounded surfaces.

(c) Exposed live parts on both sides of the work space [not guarded as provided in condition (a)] with the operator between.

1-9.3.4 Illumination. Adequate illumination shall be provided for all working spaces about electric equipment. The lighting outlets shall be arranged so that persons changing lamps or making repairs on the lighting system will not be endangered by live parts or other equipment.

The points of control shall be located so that persons are not likely to come in contact with any live part or moving part of the equipment while turning on the lights.

1-9.3.5 Elevation of Unguarded Live Parts. Unguarded live parts above working space shall be maintained at elevations not less than specified in Table 1-9.3.5.

Table 1-9.3.5 Elevation of Unguarded Energized Parts Above Working Space

Nominal Voltage Between Phases	**Minimum Elevation**
1001 - 7,500	8 ft 6 in.
7,501 - 35,000	9 ft
Over 35kV	9 ft + 0.37 in. per Kv above 35

For SI units: 1 in. = 25.4 m; 1 ft = 0.3048 m.

1-9.4 Entrance and Access to Work Space.

1-9.4.1 At least one entrance not less than 24 in. (610 mm) wide and $6^1/_2$ ft (1.98 m) high shall be provided to give access to the working space about electric equipment. On switch-

board and control panels exceeding 6 ft (1.83 m) in width, there shall be one entrance at each end of such board where reasonably practicable. Where bare energized parts at any voltage or insulated energized parts above 600 volts are located adjacent to such entrance, they shall be suitably guarded.

Exception No. 1: Where the location of the switchboards and control panels permits a continuous and unobstructed way of exit travel.

Exception No. 2: Where the work space required in 1-9.3.1 is doubled.

Working space with one entrance provided shall be located so that the edge of the entrance nearest the switchboards and control panels is the minimum clear distance given in Table 1-9.3.1 away from such equipment.

Where bare energized parts at any voltage or insulated energized parts above 600 volts, nominal, to ground are located adjacent to such entrance, they shall be suitably guarded.

1-9.4.2 Permanent ladders or stairways shall be provided to give safe access to the working space around electric equipment installed on platforms, balconies, mezzanine floors, or in attic or roof rooms or spaces.

Chapter 2 Wiring Design and Protection

2-1 Use and Identification of Grounded and Grounding Conductors.

2-1.1 Identification of Conductors. A conductor used as a grounded conductor shall be identifiable and distinguishable from all other conductors. A conductor used as an equipment grounding conductor shall be identifiable and distinguishable from other conductors.

2-1.2 Polarity of Connections. No grounded conductor shall be attached to any terminal or lead so as to reverse designated polarity.

2-2 Branch Circuits.

2-2.1 Identification of Multiwire Branch Circuits. Where more than one nominal voltage system exists in a building containing multiwire branch circuits, each ungrounded system containing multiwire branch circuits shall have its conductors identified by phase and system. The means of identification shall be permanently posted at each branch-circuit panelboard.

NOTE: The means of identification of each multiwire branch circuit phase conductor can be by separate color coding, marking tape, tagging, or other equally effective means.

2-2.2 Receptacles and Cord Connectors.

2-2.2.1 Grounding Type. Receptacles installed on 15- and 20-ampere branch circuits shall be of the grounding type. Grounding-type receptacles shall be installed only on circuits of the voltage class and current for which they are rated, except as provided in 2-2.5.1.

Exception: Nongrounding-type receptacles installed in accordance with 2-2.2.4 Exception.

2-2.2.2 To Be Grounded. Receptacles and cord connectors having grounding contacts shall have those contacts effectively grounded.

Exception No. 1: Receptacles mounted on portable and vehicle mounted generators in accordance with this standard.

Exception No. 2: Ground-fault circuit-interrupter replacement receptacles as permitted by 2-2.2.4.

2-2.2.3 Methods of Grounding. The grounding contacts of receptacles and cord connectors shall be grounded by connection to the equipment grounding conductor of the circuit supplying the receptacle or cord connector.

The branch circuit wiring method shall include or provide an equipment grounding conductor to which the grounding contacts of the receptacle or cord connector shall be connected.

2-2.2.4 Replacements. Grounding-type receptacles shall be used as replacements for existing nongrounding types and shall be connected to a grounding conductor installed in accordance with 2-2.2.3.

Exception: Where a grounding means does not exist in the receptacle enclosure, either a nongrounding or a ground-fault circuit-interrupter-type receptacle shall be used. A grounding conductor shall not be connected from the ground-fault circuit-interrupter-type receptacle to any outlet supplied from the ground-fault circuit-interrupter-type receptacle. Existing nongrounding-type receptacles shall be permitted to be replaced with grounding-type receptacles where supplied through a ground-fault circuit-interrupter. These receptacle locations shall be marked "GFCI protected."

Ground-fault circuit-interrupter protected receptacles shall be provided where replacements are made at receptacle outlets that are required to be so protected elsewhere in this standard.

2-2.2.5 Cord- and Plug-Connected Equipment. The installation of grounding-type receptacles shall not be used as a requirement that all cord- and plug-connected equipment be of the grounded type.

2-2.2.6 Noninterchangeable Types. Receptacles connected to circuits having different voltages, frequencies, or types of current (ac or dc) on the same premises shall be of such design that the attachment plugs used on these circuits are not interchangeable.

2-2.3 Identification of Ungrounded Conductors. Where more than one nominal voltage system exists in a building, each ungrounded system conductor shall be identified by phase and system. The means of identification shall be permanently posted at each branch circuit panelboard.

NOTE: The means of identification of each system phase conductor, wherever accessible, can be by separate color coding, marking tape, tagging, or other equally effective means.

2-2.4 Ground-Fault Protection for Personnel.

2-2.4.1 All 125-volt, 15- and 20-ampere receptacles installed in bathrooms of commercial industrial and all other nondwelling occupancies shall have ground-fault circuit-interrupter protection for personnel. For this purpose a bathroom shall be an area including a basin and one or more of the following: a toilet, a tub, or a shower.

2-2.4.2 All 125-volt, single-phase, 15- and 20-ampere receptacles installed on roofs shall have ground-fault circuit-interrupter protection for personnel.

2-2.4.3 Ground-Fault Protection for Personnel on Construction Sites. (For installations under the jurisdiction of OSHA, see OSHA Regulations 29 CFR 1926 and 1910.) Ground-fault protection for personnel on construction sites shall be provided to comply with (a) or (b) below:

(a) *Ground-Fault Circuit-Interrupters.* All 125-volt, single-phase, 15- and 20-ampere receptacle outlets that are not a part of the permanent wiring of the building or structure and that are in use by personnel shall have ground-fault circuit-interrupter protection for personnel. If a receptacle or receptacles are installed as part of the permanent wiring of the building or structure and used for temporary electric power, GFCI protection for personnel shall be provided.

Exception: Receptacles on a 2-wire, single-phase portable or vehicle-mounted generator rated not more than 5 kW, where the circuit conductors of the generator are insulated from the generator frame and all other grounded surfaces.

(b) *Assured Equipment Grounding Conductor Program.* A written procedure shall be continuously enforced at the construction site by one or more designated persons to ensure that equipment grounding conductors for all cord sets, receptacles that are not a part of the permanent wiring of the building or structure, and equipment connected by cord and plug are installed and maintained in accordance with the applicable requirements of this standard.

(1) The following tests shall be performed on all cord sets, receptacles that are not part of the permanent wiring of the building or structure, and cord- and plug-connected equipment required to be grounded.

a. All equipment grounding conductors shall be tested for continuity and shall be electrically continuous.

b. Each receptacle and attachment plug shall be tested for correct attachment of the equipment grounding conductor. The equipment grounding conductor shall be connected to its proper terminal.

c. All required tests shall be performed:

(i) Before first use on the construction site.

(ii) When there is evidence of damage.

(iii) Before equipment is returned to service following any repairs.

(iv) At intervals not exceeding 3 months.

d. The tests required in a. and b. above shall be recorded and made available to the authority having jurisdiction.

2-2.5 Outlet Devices. Outlet devices shall have an ampere rating not less than the load to be served.

2-2.5.1 Receptacles.

(a) A single receptacle installed on an individual branch circuit shall have an ampere rating of not less than that of the branch circuit.

(b) Where connected to a branch circuit supplying two or more receptacles or outlets, a receptacle shall not supply a total cord- and plug-connected load in excess of the maximum specified in Table 2-2.5.1(b).

Table 2-2.5.1(b) Maximum Cord- and Plug-Connected Load to Receptacle

Circuit Rating Amperes	Receptacle Rating Amperes	Maximum Load Amperes
15 or 20	15	12
20	20	16
30	30	24

(c) Where connected to a branch circuit supplying two or more receptacles or outlets, receptacle ratings shall conform to the values listed in Table 2-2.5.1(c), or where larger than 50 amperes, the receptacle rating shall not be less than the branch-circuit rating.

Table 2-2.5.1(c) Receptacle Ratings for Various Size Circuits

Circuit Rating Amperes	Receptacle Rating Amperes
15	Not over 15
20	15 or 20
30	30
40	40 or 50
50	50

2-2.6 Cord Connection. A receptacle outlet shall be installed wherever flexible cords with attachment plugs are used.

Exception: Where flexible cords are permitted to be permanently connected.

2-3 Outside Branch Circuit, Feeder, and Service Conductors, 600 Volts, Nominal, or Less. Paragraphs 2-3.1, 2-3.2, 2-3.3, and 2-3.4 apply to branch circuit, feeder, and service conductors run outdoors as open conductors.

2-3.1 Conductors on Poles. Conductors supported on poles shall provide a horizontal climbing space not less than the following:

(a) Power conductors below communication conductors—30 in. (762 mm).

(b) Power conductors alone or above communication conductors: 300 volts or less—24 in. (610 mm); more than 300 volts—30 in. (762 mm).

(c) Communication conductors below power conductors—same as power conductors.

2-3.2 Clearance from Ground. Open conductors shall conform to the following minimum clearances:

(a) 10 ft (3.05 m)—above finished grade, sidewalks, or from any platform or projection from which they might be reached.

(b) 12 ft (3.66 m)—over areas subject to vehicular traffic other than truck traffic.

(c) 15 ft (4.57 m)—over areas other than those specified in (d) that are subject to truck traffic.

(d) 18 ft (5.49 m)—over public streets, alleys, roads, and driveways.

2-3.3 Clearance from Building Openings. Conductors shall have a clearance of at least 3 ft (914 mm) from windows, doors, porches, fire escapes, or similar locations. Conductors run above the top level of a window shall be considered out of reach from that window.

2-3.4 Clearance Over Roofs. Except as provided in (a) or (b) following, conductors shall have a clearance of not less than 8 ft (2.44 m) from the highest point of roofs over which they pass.

(a) Where the voltage between conductors is 300 volts or less and the roof has a slope of not less than 4 in. (102 mm) in 12 in. (305 mm), the clearance from roofs shall be at least 3 ft (914 mm).

(b) Where the voltage between conductors is 300 volts or less and the conductors do not pass over more than 4 ft (1.22 m) of the overhang portion of the roof and they are termi-

nated at a through-the-roof raceway or approved support, the clearance from roofs shall be at least 18 in. (457 mm).

2-3.5 Location of Outdoor Lamps. Lamps for outdoor lighting shall be located below all live conductors, transformers, or other electric equipment, unless such equipment is controlled by a disconnecting means that can be locked in the open position or unless adequate clearances or other safeguards are provided for relamping operations.

2-4 Services.

2-4.1 Disconnecting Means.

2-4.1.1 General. Means shall be provided to disconnect all conductors in a building or other structure from the service-entrance conductors. The disconnecting means shall plainly indicate whether it is in the open or closed position and shall be installed at a readily accessible location nearest the point of entrance of the service-entrance conductors.

2-4.1.2 Simultaneous Opening of Poles. Each disconnecting means shall simultaneously disconnect all ungrounded conductors.

2-4.2 Services Over 600 Volts, Nominal.

2-4.2.1 Guarding. Service-entrance conductors installed as open wires shall be guarded to make them accessible only to qualified persons.

2-4.2.2 Warning Signs. Signs with the words "DANGER HIGH VOLTAGE — KEEP OUT" shall be posted where unauthorized persons might come in contact with live parts.

2-5 Overcurrent Protection.

2-5.1 600 Volts, Nominal, or Less.

2-5.1.1 Protection of Conductors and Equipment. Conductors and equipment shall be protected from overcurrent in accordance with their ability to safely conduct current.

2-5.1.2 Grounded Conductors. Except for motor running overload protection, overcurrent devices shall not interrupt the continuity of the grounded conductor unless all conductors of the circuit are opened simultaneously.

2-5.1.3 Disconnection of Fuses and Thermal Cutouts. Except for service fuses, all cartridge fuses that are accessible to other than qualified persons and all fuses and thermal cutouts on circuits over 150 volts to ground shall be provided with disconnecting means. This disconnecting means shall be installed so that the fuse or thermal cutout can be disconnected from its supply without disrupting service to equipment and circuits unrelated to the overcurrent device.

2-5.1.4 Arcing or Suddenly Moving Parts. Fuses and circuit breakers shall be located or shielded so that persons will not be burned or otherwise injured by their operation.

2-5.1.5 Circuit Breakers. Circuit breakers shall clearly indicate whether they are in the open (off) or closed (on) position. Where circuit breaker handles on switchboards are operated vertically rather than horizontally or rotationally, the up position of the handle shall be the closed (on) position.

Where used as switches in 120-volt and 277-volt, fluorescent lighting circuits, circuit breakers shall be approved for the purpose and marked "SWD."

2-5.2 Overcurrent Protection, Over 600 Volts, Nominal. Feeders and branch circuits shall have short-circuit protection.

2-6 Grounding. Paragraphs 2-6.1 through 2-6.7 cover grounding requirements for systems, circuits, and equipment.

2-6.1 Systems to Be Grounded. The following systems, which supply premises wiring, shall be grounded:

2-6.1.1 All 3-wire dc systems shall have their neutral conductor grounded.

2-6.1.2 All 2-wire dc systems operating at over 50 volts through 300 volts between conductors shall be grounded.

Exception No. 1: Where they supply only industrial equipment in limited areas and are equipped with a ground detector; or

Exception No. 2: Where they are rectifier-derived from an ac system complying with 2-6.3;2-6.1.4, and 2-6.1.5; or

Exception No. 3: Where they are fire-protective signaling circuits having a maximum current of 0.030 amperes.

2-6.1.3 All ac circuits of less than 50 volts shall be grounded where they are installed as overhead conductors outside of buildings or where they are supplied by transformers and the transformer primary supply system is ungrounded or exceeds 150 volts to ground.

2-6.1.4 AC systems of 50 volts to 1000 volts that are not covered in 2-6.1.5 shall be grounded under any of the following conditions:

(a) Where the system can be grounded so that the maximum voltage to ground on the ungrounded conductors does not exceed 150 volts.

(b) Where the system is nominally rated 3-phase, 4-wire wye in which the neutral is used as a circuit conductor.

(c) Where the system is nominally rated 3-phase, 4-wire Delta in which the midpoint of one phase is used as a circuit conductor.

(d) Where a service conductor is uninsulated.

2-6.1.5 AC systems of 50 volts to 1000 volts shall not be required to be grounded under any of the following conditions:

(a) Where the system is used exclusively to supply industrial electric furnaces for melting, refining, tempering, and the like.

(b) Where the system is separately derived and is used exclusively for rectifiers supplying only adjustable speed industrial drives.

(c) Where the system is separately derived and is supplied by a transformer that has a primary voltage rating less than 1000 volts, provided all of the following conditions are met:

(1) The system is used exclusively for control circuits.

(2) The conditions of maintenance and supervision ensure that only qualified persons will service the installation.

(3) Continuity of control power is required.

(4) Ground detectors are installed on the control system.

(d) Where the system is an isolated power system that supplies circuits in health care facilities.

(e) Where high impedance grounded neutral systems in which a grounding impedance, usually a resistor, limits the ground-fault current to a low value. High-impedance grounded neutral systems shall be permitted for 3-phase ac systems of 480 volts to 1000 volts where all of the following conditions are met:

(1) The conditions of maintenance and supervision ensure that only qualified persons will service the installation.

(2) Continuity of power is required.

(3) Ground detectors are installed on the system.

(4) Line-to-neutral loads are not served.

2-6.1.6 Alternating Current Systems of 1 kV and Over. AC systems supplying mobile or portable equipment shall be grounded. Where supplying other than portable equipment, such systems shall be permitted to be grounded. Where such systems are grounded, they shall comply with the applicable provisions of Section 2-6.

2-6.1.7 Portable and Vehicle-Mounted Generators.

(a) *Portable Generators.* Under the following conditions, the frame of a portable generator shall not be required to be grounded and shall be permitted to serve as the grounding electrode for a system supplied by the generator:

(1) The generator supplies only equipment mounted on the generator or cord- and plug-connected equipment through receptacles mounted on the generator, or both, and

(2) The noncurrent-carrying metal parts of equipment and the equipment grounding conductor terminals of the receptacles are bonded to the generator frame.

(b) *Vehicle-Mounted Generators.* Under the following conditions, the frame of a vehicle shall be permitted to serve as the grounding electrode for a system supplied by a generator located on the vehicle:

(1) The frame of the generator is bonded to the vehicle frame, and

(2) The generator supplies only equipment located on the vehicle or cord-and plug-connected equipment through receptacles mounted on the vehicle or both equipment located on the vehicle and cord- and plug-connected equipment through receptacles mounted on the vehicle or on the generator, and

(3) The noncurrent-carrying metal parts of equipment and the equipment grounding conductor terminals of the receptacles are bonded to the generator frame, and

(4) The system complies with all other provisions of Section 2-6.

(c) *Neutral Conductor Bonding.* A neutral conductor shall be bonded to the generator frame where the generator is a component of a separately derived system. The bonding of any conductor other than a neutral within the generator to its frame shall not be required.

2-6.2 Grounding Connections.

2-6.2.1 For a grounded system, a grounding electrode conductor shall be used to connect both the equipment grounding conductor and the grounded circuit conductor to the grounding electrode. Both the equipment grounding conductor and the grounding electrode conductor shall be connected to the grounded circuit conductor on the supply side of the service disconnecting means or on the supply side of the system disconnecting means or overcurrent devices if the system is separately derived.

2-6.2.2 For an ungrounded service-supplied system, the equipment grounding conductor shall be connected to the grounding electrode conductor at the service equipment. For an ungrounded separately derived system, the equipment grounding conductor shall be connected to the grounding electrode conductor at, or ahead of, the system disconnecting means or overcurrent devices.

2-6.2.3 On extensions of existing branch circuits that do not have an equipment grounding conductor, grounding-type receptacles shall be permitted to be grounded to a grounded cold water pipe near the equipment.

2-6.3 Grounding Path. The path to ground from circuits, equipment, and enclosures shall be permanent, continuous, and effective.

2-6.4 Supports, Enclosures, and Equipment to Be Grounded.

2-6.4.1 Supports and Enclosures for Conductors. Metal raceways and metal enclosures for conductors shall be grounded.

Exception No. 1: Metal enclosures, such as sleeves and similar enclosures that are used to protect cable assemblies from physical damage, shall not be required to be grounded.

Exception No. 2: Metal enclosures for conductors added to existing installations of open wire, knob-and-tube wiring, and nonmetallic-sheathed cable, if in runs of less than 25 ft (7.63 m), if free from probable contact with ground, grounded metal, metal laths, or other conductive materials, and if guarded against contact by persons, shall not be required to be grounded.

2-6.4.2 Service Equipment Enclosures. Metal enclosures for service equipment shall be grounded.

2-6.4.3 Frames of Ranges and Clothes Dryers. Frames of electric ranges, wall-mounted ovens, counter-mounted cooking units, clothes dryers, and metal outlet or junction boxes that are part of the circuit for these appliances shall be grounded.

2-6.4.4 Fixed Equipment. Exposed noncurrent-carrying metal parts of fixed equipment likely to become energized shall be grounded under any of the conditions specified in (a) through (f) following:

(a) Where within 8 ft (2.44 m) vertically or 5 ft (1.52 m) horizontally of ground or grounded metal objects and subject to contact by persons.

(b) Where located in a wet or damp location and not isolated.

(c) Where in electrical contact with metal.

(d) Where in a hazardous (classified) location.

(e) Where supplied by a metal-clad, metal-sheathed, or grounded metal raceway wiring method.

(f) Where equipment operates with any terminal at over 150 volts to ground:

Exception No. 1: Enclosures for switches or circuit breakers used for other than service equipment and accessible to qualified persons only.

Exception No. 2: Metal frames of electrically heated devices that are permanently and effectively insulated from ground.

Exception No. 3: The cases of distribution apparatus, such as transformers and capacitors, mounted on wooden poles at a height exceeding 8 ft (2.44 m) above ground or grade level.

Exception No. 4: Listed equipment protected by a system of double insulation or its equivalent. Where such a system is employed, the equipment shall be distinctly marked.

2-6.4.5 Equipment Connected by Cord and Plug. Under any of the conditions described in (a) through (c), exposed noncurrent-carrying metal parts of cord- and plug-connected equipment likely to become energized shall be grounded.

(a) In hazardous (classified) locations. (*See Chapter 5.*)

(b) Where operated at over 150 volts to ground, except guarded motors and metal frames of electrically heated appli-

ances where the appliance frames are permanently and effectively insulated from ground.

(c) In other than residential occupancies:

(1) Refrigerators, freezers, and air conditioners;

(2) Clothes-washing, clothes-drying, and dishwashing machines, sump pumps, and electrical aquarium equipment;

(3) Hand-held motor-operated tools, stationary and fixed motor-operated tools, and light industrial motor-operated tools;

(4) Motor-operated appliances of the following types: hedge clippers, lawn mowers, snow blowers, and wet scrubbers;

(5) Cord- and plug-connected appliances used in damp or wet locations or by persons standing on the ground or on metal floors or working inside of metal tanks or boilers;

(6) Portable and mobile X-ray and associated equipment;

(7) Tools likely to be used in wet and conductive locations; and

(8) Portable hand lamps.

Tools likely to be used in wet and conductive locations shall not be required to be grounded where supplied through an isolating transformer with an ungrounded secondary of not over 50 volts.

Listed portable tools and appliances protected by an approved system of double insulation, or its equivalent, shall not be required to be grounded. Where such a system is employed, the equipment shall be distinctively marked to indicate that the tool or appliance utilizes an approved system of double insulation.

2-6.4.6 Nonelectrical Equipment. The metal parts of the following nonelectrical equipment shall be grounded:

(a) Frames and track of electrically operated cranes;

(b) Frames of nonelectrically driven elevator cars to which electric conductors are attached;

(c) Hand-operated metal shifting ropes or cables of electric elevators; and

(d) Metal partitions, grill work, and similar metal enclosures around equipment of over 750 volts between conductors, except substations or vaults under the sole control of the supply company.

2-6.5 Methods of Grounding Equipment. Noncurrent-carrying metal parts of fixed equipment, if required to be grounded, shall be grounded by an equipment grounding conductor that is contained within the same raceway, cable, or cord, or run with the circuit conductors. For dc circuits only, the equipment grounding conductor shall be permitted to be run separately from the circuit conductors.

Electric equipment secured to, and in electrical contact with, a grounded metal rack or structure provided for its support shall be considered to be effectively grounded. The structural metal frame of a building shall not be used as the required equipment grounding conductor for ac equipment. Metal car frames supported by metal hoisting cables attached to or running over metal sheaves or drums of grounded elevator machines shall also be considered to be effectively grounded.

2-6.6 General Bonding. Bonding shall be provided where necessary to ensure electrical continuity and the capacity to conduct safely any fault current likely to be imposed.

2-6.7 Grounding of Systems and Circuits of 1000 Volts and Over (High Voltage).

2-6.7.1 General. Where high voltage systems are grounded, they shall comply with all applicable provisions of Section 2-6 and with 2-6.7.2 and 2-6.7.3, which supplement and modify the preceding paragraphs.

2-6.7.2 Grounding of Systems Supplying Portable Equipment. Systems supplying portable high voltage equipment, other than substations installed on a temporary basis, shall comply with (a) through (d) following:

(a) Portable high voltage equipment shall be supplied from a system having its neutral grounded through an impedance. Where a delta-connected high voltage system is used to supply portable equipment, a system neutral shall be derived.

(b) Exposed noncurrent-carrying metal parts of portable equipment shall be connected by an equipment grounding conductor to the point at which the system neutral impedance is grounded.

(c) Ground-fault detection and relaying shall be provided to automatically deenergize any high voltage system component that has developed a ground fault. The continuity of the equipment grounding conductor shall be continuously monitored so as to deenergize automatically the high voltage feeder to the portable equipment upon loss of continuity of the equipment grounding conductor.

(d) The grounding electrode to which the portable equipment system neutral impedance is connected shall be isolated from and separated in the ground by at least 20 ft (6.1 m) from any other system or equipment grounding electrode, and there shall be no direct connection between the grounding electrodes, such as buried pipe, fence, etc.

2-6.7.3 Grounding of Equipment. All noncurrent-carrying metal parts of portable equipment and fixed equipment including their associated fences, housings, enclosures, and supporting structures shall be grounded.

Exception No. 1: Equipment that is guarded by location and isolated from ground shall not be required to be grounded.

Exception No. 2: Pole-mounted distribution apparatus at a height exceeding 8 ft (2.44 m) above ground or grade level shall not be required to be grounded.

Chapter 3 Wiring Methods, Components, and Equipment for General Use

3-1 Wiring Methods. The provisions of this chapter shall not apply to the conductors that are an integral part of factory-assembled equipment.

3-1.1 General Requirements.

3-1.1.1 Electrical Continuity of Metal Raceways and Enclosures. Metal raceways, cable armor, and other metal enclosures for conductors shall be metallically joined together into a continuous electric conductor and shall be connected to all boxes, fittings, and cabinets to provide effective electrical continuity.

3-1.1.2 Wiring in Ducts. No wiring systems of any type shall be installed in ducts used to transport dust, loose stock, or

flammable vapors. No wiring system of any type shall be installed in any duct, or shaft containing only such ducts, used for vapor removal or for ventilation of commercial-type cooking equipment.

3-1.2 Temporary Wiring. Temporary electrical power and lighting wiring methods shall be permitted to be of a class less than would be required for a permanent installation. Except as specifically modified in 3-1.2.1 through 3-1.2.3, all other requirements of this standard for permanent wiring shall apply to temporary wiring installations.

3-1.2.1 Uses Permitted, 600 Volts, Nominal, or Less. Temporary electrical power and lighting installations shall be permitted:

(a) During the period of construction, remodeling, maintenance, repair, or demolition of buildings, structures, equipment, or similar activities;

(b) For experimental or development work; and

(c) For a period not to exceed 90 days for Christmas decorative lighting, carnivals, and similar purposes.

3-1.2.2 Uses Permitted, Over 600 Volts, Nominal. Temporary wiring shall be permitted during periods of construction, tests, experiments, or emergencies.

3-1.2.3 General Requirements for Temporary Wiring.

(a) *Feeders.* Feeders shall originate in an approved distribution center. Conductors shall be permitted within cable assemblies or cords or cables of a type identified for hard usage or extra-hard usage. Where the voltage does not exceed 150 volts to ground and where not subject to physical damage, feeders shall be permitted to be run as open conductors if supported on insulators at intervals of not more than 10 ft (3.05 m).

(b) *Branch Circuits.* All branch circuits shall originate in an approved power outlet or panelboard. Conductors shall be permitted within cable assemblies or multiconductor cord or cable of a type identified for hard usage or extra-hard usage. Where the voltage does not exceed 150 volts to ground and where not subject to physical damage, branch circuits shall be permitted to be run as open conductors if supported on insulators at intervals of not more than 10 ft (3.05 m). No open wiring branch-circuit conductors shall be laid on the floor or ground.

(c) *Receptacles.* All receptacles shall be of the grounding type. Unless installed in a continuous grounded metal raceway or metal covered cable, all branch circuits shall contain a separate equipment grounding conductor, and all receptacles shall be electrically connected to the equipment grounding conductors. Receptacles on construction sites shall not be installed on branch circuits that supply temporary lighting. Receptacles shall not be connected to the same ungrounded conductor of multiwire circuits that supplies temporary lighting.

(d) *Earth Returns.* No bare conductors or earth returns shall be used for the wiring of any temporary circuit.

(e) *Disconnecting Means.* Suitable disconnecting switches or plug connectors shall be installed to permit the disconnection of all ungrounded conductors of each temporary circuit. Multiwire branch circuits shall be provided with a means to disconnect simultaneously all ungrounded conductors at the power outlet or panelboard where the branch circuit originated. Approved handle ties shall be permitted.

(f) *Lamp Protection.* All lamps for general illumination shall be protected from accidental contact or breakage. Protection shall be provided by a suitable fixture or lamp- holder with a guard.

Brass shell, paper-lined sockets, or other metal-cased sockets shall not be used unless the shell is grounded.

(g) *Splices.* On construction sites a box shall not be required for splices or junction connections where the circuit conductors are multiconductor cord or cable assemblies or open conductors. A box shall be used wherever a change is made to a raceway system or a cable system that is metal clad or metal sheathed.

(h) *Flexible Cords and Cables.* Flexible cords and cables shall be protected from accidental damage. Sharp corners and projections shall be avoided. When passing through doorways or other pinch points, protection shall be provided to avoid damage.

(i) *Guarding.* For wiring over 600 volts, nominal, suitable fencing, barriers, or other effective means shall be provided to prevent access of other than authorized and qualified personnel.

3-1.3 Cable Trays.

3-1.3.1 Uses Permitted.

(a) The following shall be permitted to be installed in cable tray systems:

(1) Mineral-insulated metal-sheathed cable (Type MI);

(2) Armored cable (Type AC);

(3) Metal-clad cable (Type MC);

(4) Power-limited tray cable (Type PLTC);

(5) Nonmetallic-sheathed cable (Type NM or NMC);

(6) Shielded nonmetallic-sheathed cable (Type SNM);

(7) Multiconductor service-entrance cable (Type SE or USE);

(8) Multiconductor underground feeder and branch-circuit cable (Type UF);

(9) Power and control tray cable (Type TC);

(10) Other factory-assembled, multiconductor control, signal, or power cables that are specifically approved for installation in cable trays; or

(11) Any approved conduit or raceway with its contained conductors.

(b) In industrial establishments only, where conditions of maintenance and supervision ensure that only qualified persons will service the installed cable tray system, any of the cables in (1) and (2) following shall be permitted to be installed in ladder, ventilated trough, 4-in. (102-mm) ventilated channel-type trays, or 6-in. (152-mm) ventilated channel-type cable trays:

(1) *Single Conductor.* Single conductor cables shall be 250 MCM or larger, and shall be 1/0 or larger, and marked on the surface for use in cable trays. Where Nos. 1/0 through 4/0 single conductive cables are installed in ladder cable tray, the maximum allowable rung spacing for the ladder cable tray shall be 9 in. (229 mm). Where exposed to direct rays of the sun, cables shall be identified as being sunlight resistant. Single conductors used as equipment grounding conductors shall be permitted to be No. 4 or larger.

(2) *Multiconductor.* Type MV cables, where exposed to direct rays of the sun, shall be identified as being sunlight resistant.

(c) Cable trays in hazardous (classified) locations shall contain only the cable types permitted in such locations.

3-1.3.2 Uses Not Permitted. Cable tray systems shall not be used in hoistways or where subjected to severe physical damage.

3-1.4 Open Wiring on Insulators.

3-1.4.1 Uses Permitted. Open wiring on insulators shall be permitted on systems of 600 volts, nominal, or less for industrial or agricultural establishments, indoors or outdoors, in wet or dry locations, where subject to corrosive vapors, and for services.

3-1.4.2 Conductor Supports. Conductors shall be rigidly supported on noncombustible, nonabsorbent insulating materials and shall not contact any other objects.

3-1.4.3 Flexible Nonmetallic Tubing. In dry locations where not exposed to severe physical damage, conductors shall be permitted to be separately enclosed in flexible nonmetallic tubing. The tubing shall be in continuous lengths not exceeding 15 ft (4.57 m) and secured to the surface by straps at intervals not exceeding $4^1/_2$ ft (1.37 m).

3-1.4.4 Through Walls, Floors, Wood Cross Members, etc. Open conductors shall be separated from contact with walls, floors, wood cross members, or partitions through which they pass by tubes or bushings of noncombustible, nonabsorbent insulating material. Where the bushing is shorter than the hole, a waterproof sleeve of nonconductive material shall be inserted in the hole and an insulating bushing slipped into the sleeve at each end in such a manner as to keep the conductors absolutely out of contact with the sleeve. Each conductor shall be carried through a separate tube or sleeve.

3-1.4.5 Protection from Physical Damage. Conductors within 7 ft (2.13 m) from the floor shall be considered exposed to physical damage. Where open conductors cross ceiling joists and wall studs and are exposed to physical damage, they shall be protected.

3-2 Cabinets, Boxes, and Fittings.

3-2.1 Conductors Entering Boxes, Cabinets, Conduit Bodies, or Fittings. Conductors entering boxes, cabinets, conduit bodies, or fittings shall be protected from abrasion, and openings through which conductors enter shall be adequately closed. Unused openings in cabinets, boxes, conduit bodies, and fittings shall be effectively closed.

3-2.2 Covers and Canopies. All pull boxes, junction boxes, and fittings shall be provided with covers approved for the purpose. Where metal covers are used they shall be grounded. In completed installations, each outlet box shall have a cover, faceplate, or fixture canopy.

Covers of outlet boxes having holes through which flexible cord pendants pass shall be provided with bushings designed for the purpose or shall have smooth, well-rounded surfaces on which the cords can bear.

3-2.3 Pull and Junction Boxes for Systems over 600 Volts, Nominal. In addition to other requirements in this standard for pull and junction boxes, 3-2.3.1 and 3-2.3.2 shall apply:

3-2.3.1 Boxes shall provide a complete enclosure for the contained conductors or cables.

3-2.3.2 Boxes shall be closed by suitable covers securely fastened in place. Underground box covers that weigh over 100 lb (45.4 kg) shall be considered as meeting this requirement. Covers for boxes shall be permanently marked "DANGER — HIGH VOLTAGE — KEEP OUT." The marking shall be on the outside of the box cover and shall be readily visible and legible.

3-3 Switches.

3-3.1 Knife Switches. Single-throw knife switches shall be connected so that the blades are deenergized when the switch is in the open position. Where the load side of the switch is connected to circuits or equipment, the inherent nature of which can provide a backfeed source of power. For such installations, a permanent sign shall be installed on the switch enclosure or immediately adjacent to open switches that reads: "WARNING — LOAD SIDE OF SWITCH MAY BE ENERGIZED BY BACKFEED."

Single-throw knife switches shall be placed so that gravity will not tend to close them. Single-throw knife switches approved for use in the inverted position shall be provided with a locking device that ensures that the blades remain in the open position when so set.

Double-throw knife switches shall be permitted to be mounted so that the throw will be either vertical or horizontal. Where the throw is vertical, a locking device shall be provided to ensure that the blades remain in the open position when so set.

3-3.2 Faceplates for Flush-Mounted Snap Switches. Flush snap switches that are mounted in ungrounded metal boxes and located within reach of conducting floors or other conducting surfaces shall be provided with faceplates of nonconducting, noncombustible material.

3-4 Switchboards and Panelboards. Switchboards that have any exposed live parts shall be located in permanently dry locations and shall be accessible only to qualified persons. Panelboards shall be mounted in cabinets, cutout boxes, or enclosures approved for the purpose and shall be dead front, except panelboards other than the dead-front externally operable type, which shall be permitted where accessible only to qualified persons.

3-5 Enclosures for Damp or Wet Locations.

3-5.1 Cabinets, cutout boxes, fittings, and panelboard enclosures in damp or wet locations shall be installed to prevent moisture or water from entering and accumulating within the enclosure. In wet locations the enclosure shall be weatherproof.

3-5.2 Switches, circuit breakers, and switchboards installed in a wet location shall be enclosed in a weatherproof enclosure.

3-6 Conductors for General Wiring. All conductors used for general wiring shall be insulated, unless specifically permitted to be otherwise. The conductor insulation shall be of a type that is approved for the voltage, operating temperature, and location of use. Insulated conductors shall be distinguishable by appropriate color or other suitable means as being grounded conductors, ungrounded conductors, or equipment grounding conductors.

3-7 Flexible Cords and Cables, 600 Volts, Nominal, or Less.

3-7.1 Use of Flexible Cords and Cables.

3-7.1.1 Flexible cords and cables shall be approved and suitable for conditions of use and location. Flexible cords and cables shall be used only for:

(a) Pendants;

(b) Wiring of fixtures;

(c) Connection of portable lamps or appliances;

(d) Elevator cables;

(e) Wiring of cranes and hoists;

(f) Connection of stationary equipment to facilitate their frequent interchange;

(g) Prevention of the transmission of noise or vibration;

(h) Appliances where the fastening means and mechanical connections are designed to permit removal for maintenance and repair;

(i) Data processing cables approved as a part of the data processing system;

(j) Connection of moving parts; or

(k) Temporary wiring as permitted in 3-1.2.3.

3-7.1.2 Unless specifically permitted in 3-7.1.1 above, flexible cords and cables shall not be used:

(a) As a substitute for the fixed wiring of a structure;

(b) Where run through holes in walls, ceilings, or floors;

(c) Where run through doorways, windows, or similar openings;

(d) Where attached to building surfaces;

(e) Where concealed behind building walls, ceilings, or floors;

(f) Where installed in raceways, except as otherwise permitted.

3-7.1.3 Flexible cords used in show windows and showcases shall be Type S, SO, SJ, SJO, ST, STO, SJT, SJTO, SE, SEO, SEOO, SJE, SJEO, SJEOO, SJOO, SJTOO, SOO, STOO, or AFS except for the wiring of chain-supported lighting fixtures and supply cords for portable lamps and other merchandise being displayed or exhibited.

3-7.2 Identification, Splices, and Terminations. A conductor of a flexible cord or cable that is used as a grounded conductor or an equipment grounding conductor shall be distinguishable from other conductors. Types SJ, SJO, SJT, SJTO, S, SO, ST, STO, S, SE, SCE, SCT, SEO, SEOO, SJE, SJEO, SJEOO, SJTOO, SOO, and STOO shall be durably marked on the surface with the type designation, size, and number of conductors. Flexible cords shall be used only in continuous lengths without splice or tap when initially installed. The repair of hard usage and extra-hard usage flexible cords No. 14 or larger shall be permitted if spliced so that the splice retains the insulation, outer sheath properties, and usage characteristics of the cord being spliced. Flexible cords shall be connected to devices and fittings so that strain relief is provided that will prevent pull from being directly transmitted to joints or terminal screws.

3-8 Portable Cables Over 600 Volts, Nominal. Multiconductor portable cable for use in supplying power to portable or mobile equipment at over 600 volts, nominal, shall consist of No. 8 or larger conductors employing flexible stranding. Cables operated at over 2000 volts shall be shielded for the purpose of confining the voltage stresses to the insulation. Grounding conductors shall be provided. Connectors for these cables shall be of a locking type with provisions to prevent their opening or closing while energized. Strain relief shall be provided at connections and terminations. Portable cables shall not be operated with splices unless the splices are of the permanent molded, vulcanized, or other approved type. Termination enclosures shall be suitably marked with a high voltage hazard warning and terminations shall be accessible only to authorized and qualified personnel.

3-9 Fixture Wires.

3-9.1 General. Fixture wires shall be a type approved for the voltage, temperature, and location of use. A fixture wire that is used as a grounded conductor shall be identified.

3-9.2 Uses Permitted. Fixture wires shall be permitted:

(a) For installation in lighting fixtures and in similar equipment where enclosed or protected and not subject to bending or twisting in use; or

(b) For connecting lighting fixtures to the branch-circuit conductor supplying the fixtures.

3-9.3 Uses Not Permitted. Fixture wires shall not be used as branch-circuit conductors except as permitted for Class 1 power-limited circuits or for fire protective signaling circuits.

3-10 Equipment for General Use.

3-10.1 Lighting Fixtures, Lampholders, Lamps, and Receptacles.

3-10.1.1 Fixtures, lampholders, lamps, rosettes, and receptacles shall have no live parts normally exposed to contact except rosettes and cleat-type lampholders, and receptacles located at least 8 ft (2.44 m) above the floor shall be permitted to have exposed parts.

3-10.1.2 Handlamps of the portable type supplied through flexible cords shall be equipped with a handle of molded composition or other material approved for the purpose, and a substantial guard shall be attached to the lampholder or the handle.

3-10.1.3 Lampholders of the screw-shell type shall be installed for use as lampholders only. Lampholders installed in wet or damp locations shall be of the weatherproof type.

3-10.1.4 Fixtures installed in wet or damp locations shall be approved for the purpose and shall be constructed or installed so that water cannot enter or accumulate in wireways, lampholders, or other electrical parts.

3-10.2 Receptacles, Cord Connectors, and Attachment Plugs (Caps).

3-10.2.1 Receptacles, cord connectors, and attachment plugs shall be constructed so that the receptacle or cord connectors will not accept an attachment plug with a different voltage or current rating than that for which the device is intended.

Exception: A 20-ampere T-slot receptacle or cord connector shall be permitted to accept a 15-ampere attachment plug of the same voltage rating.

3-10.2.2 A receptacle installed in a wet or damp location shall be suitable for the location.

3-10.3 Appliances.

3-10.3.1 Appliances, other than those in which the current-carrying parts at high temperatures are necessarily exposed, shall have no live parts normally exposed to contact.

3-10.3.2 A means shall be provided to disconnect each appliance.

3-10.3.3 Each appliance shall be marked with the rating in volts and amperes or volts and watts.

3-10.4 Motors.

3-10.4.1 In Sight From. Where specified that one piece of equipment shall be "in sight from" another piece of equipment, one shall be visible and not more than 50 ft (15.24 m) from the other.

3-10.4.2 Disconnecting Means.

(a) A disconnecting means shall be located in sight from the controller location. However, a single disconnecting means shall be permitted to be located adjacent to a group of coordinated controllers mounted adjacent to each other on a multimotor continuous process machine. The controller disconnecting means for motor branch circuits over 600 volts, nominal, shall be permitted to be out of sight of the motor branch-circuit controller, if the controller is marked with a warning label giving the location and identification of the disconnecting means to be locked in the open position.

(b) The disconnecting means shall disconnect the motor and the controller from all ungrounded supply conductors and shall be designed so that no pole can be operated independently.

(c) Where a motor and the driven machinery are not in sight from the controller location, the installation shall comply with one of the following conditions:

(1) The controller disconnecting means shall be capable of being locked in the open position.

(2) A manually operable switch that disconnects the motor from its source of supply shall be placed within sight from the motor location.

(d) The disconnecting means shall plainly indicate whether it is in the open (off) or closed (on) position.

(e) One of the disconnecting means shall be readily accessible.

(f) An individual disconnecting means shall be provided for each motor, but a single disconnecting means shall be permitted to be used for a group of motors under any one of the following conditions:

(1) Where a number of motors drive special parts of a single machine or piece of apparatus, such as metal and woodworking machines, cranes, and hoists.

(2) Where a group of motors is under the protection of one set of branch-circuit protective devices.

(3) Where a group of motors is in a single room within sight from the location of the disconnecting means.

3-10.4.3 Motor Overload, Short-Circuit, and Ground-Fault Protection. Motors, motor-control apparatus, and motor branch-circuit conductors shall be protected against overheating due to motor overloads or failure to start, and against short-circuits or ground faults. These provisions shall not require overload protection that will stop a motor where a shutdown is likely to introduce additional or increased hazards, as in the case of fire pumps, or where continued operation of a motor is necessary for a safe shutdown of equipment, or process and motor overload sensing devices are connected to a supervised alarm.

3-10.4.4 Protection of Live Parts—All Voltages.

(a) Stationary motors having commutators, collectors, and brush rigging located inside of motor end brackets and not conductively connected to supply circuits operating at more than 150 volts to ground need not be guarded.

Exposed live parts of motors and controllers operating at 50 volts or more between terminals shall be guarded against accidental contact by one of the following:

(1) By installation in a room or enclosure that is accessible only to qualified persons.

(2) By installation on a suitable balcony, gallery, or platform, elevated and arranged to exclude unqualified persons.

(3) By elevation 8 ft (2.44 m) or more above the floor.

(b) Where live parts of motors or controllers operating at over 150 volts to ground are guarded against accidental contact only by location, and where adjustment or other attendance might be necessary during the operation of the apparatus, suitable insulating mats or platforms shall be provided so that the attendant cannot readily touch live parts unless standing on the mats or platforms.

3-10.5 Transformers.

3-10.5.1 Paragraphs 3-10.5.2 through 3-10.5.6cover the installation of all transformers except the following:

(a) Current transformers;

(b) Dry-type transformers installed as a component part of other apparatus;

(c) Transformers that are an integral part of an X-ray, high-frequency, or electrostatic-coating apparatus;

(d) Transformers used with Class 2 and Class 3 circuits, sign and outline lighting, electric discharge lighting, and power-limited fire-protective signaling circuits; and

(e) Liquid-filled or dry-type transformers used for research, development, or testing, where effective safeguard arrangements are provided.

3-10.5.2 The operating voltage of exposed live parts of transformer installations shall be indicated by warning signs or visible markings on the equipment or structure.

3-10.5.3 Dry-type, high fire point liquid-insulated and askarel-insulated transformers installed indoors and rated over 35kV shall be in a vault.

3-10.5.4 Where they present a fire hazard to employees, oil-insulated transformers installed indoors shall be in a vault.

3-10.5.5 Combustible material, combustible buildings and parts of buildings, fire escapes, and door and window openings shall be safeguarded from fires originating in oil-insulated transformers attached to or adjacent to a building or combustible material.

3-10.5.6 Transformer vaults shall be constructed to prevent unauthorized access. Personnel doors shall swing out and be equipped with panic bars, pressure plates, or other devices that are normally latched, but open under simple pressure.

3-10.5.7 Any pipe or duct system foreign to the vault installation shall not enter or pass through a transformer vault.

3-10.5.8 Materials shall not be stored in transformer vaults.

3-10.6 Capacitors.

3-10.6.1 All capacitors, except surge capacitors or capacitors included as a component part of other apparatus, shall be provided with an automatic means of draining the stored charge after the capacitor is disconnected from its source of supply.

3-10.6.2 Capacitors rated over 600 volts, nominal, shall comply with the following additional requirements:

(a) Isolating or disconnecting switches (with no interrupting rating) shall be interlocked with the load interrupting device or shall be provided with prominently displayed caution signs to prevent switching load current.

(b) For series capacitors, the proper switching shall be ensured by use of one of the following:

(1) Mechanically sequenced isolating and bypass switches,

(2) Interlocks, or

(3) Switching procedure prominently displayed at the switching location.

3-10.7 Storage Batteries. Provisions shall be made for sufficient diffusion and ventilation of gases from the battery to prevent the accumulation of an explosive mixture.

Chapter 4 Specific Purpose Equipment and Installations

4-1 Electric Signs and Outline Lighting.

4-1.1 Disconnecting Means. Signs operated by electronic or electromechanical controllers located external to the sign shall have a disconnecting means located inside the controller enclosure or within sight of the controller location and it shall be capable of being locked in the open position. Such disconnecting means shall have no pole that can be operated independently, and it shall open all ungrounded conductors that supply the controller and sign. All other signs, except the portable type, and all outline lighting installations shall have an externally operable disconnecting means that shall open all ungrounded conductors and shall be within the sight of the sign or outline lighting it controls.

4-1.2 Access to Uninsulated Parts. Doors or covers giving access to uninsulated parts of indoor signs or outline lighting exceeding 600 volts and accessible to other than qualified employees shall either be provided with interlock switches to disconnect the primary circuit or shall be fastened so that the use of other than ordinary tools will be necessary to open them.

4-2 Cranes and Hoists.

4-2.1 Disconnecting Means.

4-2.1.1 A readily accessible disconnecting means shall be provided between the runway contact conductors and the power supply. This disconnecting means shall be readily accessible and operable from ground or floor level, lockable in the open position, open all ungrounded conductors simultaneously, and be within view of the crane or hoist and the runway contact conductors.

4-2.1.2 A disconnecting means, arranged to be locked in the open position, shall be provided in the leads from the runway contact conductors or other power supply on all cranes and monorail hoists.

Exception: The disconnect shall be permitted to be omitted where a monorail hoist or hand-propelled crane bridge installation meets all of the following:

(a) The unit is floor controlled.

(b) The unit is within view of the power supply disconnecting means.

(c) No fixed work platform has been provided for servicing the unit.

Where the disconnecting means is not readily accessible from the crane or monorail hoist operating station, means shall be provided at the operating station to open the power circuit to all motors of the crane or monorail hoist.

4-2.2 Control. A limit switch or other device shall be provided to prevent the load block from passing the safe upper limit of travel of all hoisting mechanisms.

4-2.3 Clearance. The dimension of the working space in the direction of access to live parts that are likely to require examination, adjustment, servicing, or maintenance while energized shall be a minimum of $2^1/_2$ ft (762 mm). Where controls are enclosed in cabinets, the door(s) shall either open at least 90 degrees or be removable.

4-3 Elevators, Dumbwaiters, Escalators, Moving Walks, Wheelchair Lifts, and Stairway Chair Lifts.

4-3.1 Disconnecting Means. Elevators, dumbwaiters, escalators, moving walks, wheelchair lifts, and stairway chair lifts shall have a single means for disconnecting all ungrounded main power supply conductors for each unit.

Where interconnections between control panels are necessary for operation of the system or multicar installations that remain energized from a source other than the disconnecting means, a warning sign shall be mounted on or adjacent to the disconnecting means. The sign shall be clearly legible and shall read "Warning—Parts of the control panel are not deenergized by this switch."

4-3.2 Control Panels. Where control panels are not located in the same space as the drive machine, they shall be located in cabinets with doors or panels capable of being locked closed.

4-4 Electric Welders—Disconnecting Means.

4-4.1 Motor Generator, AC Transformer, and DC Rectifier. A disconnecting means shall be provided in the supply for each motor-generator arc welder and for each ac transformer and dc rectifier arc welder that is not equipped with a disconnect mounted as an integral part of the welder.

4-4.2 Resistance Welder. A switch or circuit breaker shall be provided by which each resistance welder, and its control equipment can be isolated from the supply circuit. The ampere rating of this disconnecting means shall not be less than the supply conductor ampacity.

4-5 Computer Data Processing Systems—Disconnecting Means.

4-5.1 HVAC Systems. In data processing rooms, a disconnecting means shall be provided to disconnect the HVAC system serving that room and the power to all electric equipment in the room except lighting. It shall be controlled from locations readily accessible to the operator and at designated exit doors for the data processing room.

4-5.2 General Building Areas. In general building areas, a disconnecting means shall be provided to disconnect all interconnected data processing equipment in the area. It shall be controlled from a location readily accessible to the operator.

4-6 X-Ray Equipment for Nonmedical and Nondental Use.

4-6.1 Disconnecting Means.

4-6.1.1 A disconnecting means shall be provided in the supply circuit. The disconnecting means shall be operable from a location readily accessible from the X-ray control. For equipment connected to a 120-volt branch circuit of 30 amperes or less, a grounding-type attachment plug cap and receptacle of proper rating shall be permitted to serve as a disconnecting means.

4-6.1.2 Where more than one piece of equipment is operated from the same high-voltage circuit, each piece or each group of equipment as a unit shall be provided with a high-voltage switch or equivalent disconnecting means. This disconnecting means shall be constructed, enclosed, or located so as to avoid contact by persons with its live parts.

4-6.2 Control.

4-6.2.1 Radiographic and Fluoroscopic Types. All radiographic- and fluoroscopic-type equipment shall be effectively enclosed or shall have interlocks that deenergize the equipment automatically to prevent ready access to live current-carrying parts.

4-6.2.2 Diffraction and Irradiation Types. Diffraction- and irradiation-type equipment shall be provided with a means to indicate when it is energized, unless the equipment or installation is effectively enclosed or is provided with interlocks to prevent access to live current-carrying parts during operation.

4-7 Induction and Dielectric Heating Equipment.

4-7.1 Scope. Paragraphs 4-7.2 through 4-7.3 cover induction and dielectric heating equipment and accessories for industrial and scientific applications, but not for medical or dental applications or for appliances or line frequency pipelines and vessels heating.

4-7.2 Guarding and Grounding.

4-7.2.1 Enclosures. The converting apparatus (including the dc line) and high-frequency electric circuits (excluding the output circuits and remote-control circuits) shall be completely contained within enclosures of noncombustible material.

4-7.2.2 Panel Controls. All panel controls shall be of deadfront construction.

4-7.2.3 Access to Internal Equipment. Where doors are used giving access to voltages from 500 to 1000 volts ac or dc, either door locks or interlocks shall be provided. Where doors are used giving access to voltages of over 1000 volts ac or dc, either mechanical lockouts with a disconnecting means to prevent access until voltage is removed from the cubicle, or both door interlocking and mechanical door locks, shall be provided.

4-7.2.4 Warning Labels. "DANGER — HIGH VOLTAGE — KEEP OUT" labels shall be attached on the equipment and shall be plainly visible even when doors are open or panels are removed from compartments containing voltages of over 250 volts ac or dc.

4-7.2.5 Work Applicator Shielding. Protective cages or adequate shielding shall be used to guard work applicators other than induction heating coils. Induction heating coils shall be permitted to be protected by insulation and/or refractory materials. Interlock switches shall be used on all hinged access doors, sliding panels, or other easy means of access to the applicator. All interlock switches shall be connected in such a manner as to remove all power from the applicator when any one of the access doors or panels is open. Interlocks on access doors or panels shall not be required if the applicator is an induction heating coil at dc ground potential or operating at less than 150 volts ac.

4-7.2.6 Disconnecting Means. A readily accessible disconnecting means shall be provided by which each heating equipment can be isolated from its supply circuit.

4-7.3 Remote Control. Where remote controls are used for applying power, a selector switch shall be provided and interlocked to provide power from only one control point at a time. Switches operated by foot pressure shall be provided with a shield over the contact button to avoid accidental closing of the switch.

4-8 Electrolytic Cells.

4-8.1 Scope. These provisions for electrolytic cells shall apply to the installation of the electrical components and accessory equipment of electrolytic cells, electrolytic cell lines, and process power supply for the production of aluminum, cadmium, chlorine, copper, fluorine, hydrogen peroxide, magnesium, sodium, sodium chlorate, and zinc.

These provisions do not cover cells used as a source of electric energy and for electroplating processes and cells used for the production of hydrogen.

4-8.2 Definitions Applicable to this Paragraph.

4-8.2.1 Cell, Electrolytic. A receptacle or vessel in which electrochemical reactions are caused by applying energy for the purpose of refining or producing usable materials.

4-8.2.2 Cell Line. An assembly of electrically interconnected electrolytic cells supplied by a source of direct current power.

4-8.2.3 Cell Line Attachments and Auxiliary Equipment. Cell line attachments and auxiliary equipment include, but are not limited to, auxiliary tanks, process piping, ductwork, structural supports, exposed cell line conductors, conduits and other raceways, pumps, positioning equipment, and cell cutout or bypass electrical devices. Auxiliary equipment includes tools, welding machines, crucibles, and other portable equipment used for operation and maintenance within the electrolytic cell line working zone.

In the cell line working zone, auxiliary equipment includes the exposed conductive surfaces of ungrounded cranes and crane-mounted cell-servicing equipment.

4-8.2.4 Cell Line Working Zone. The cell line working zone is the space envelope wherein operation or maintenance is normally performed on or in the vicinity of exposed energized surfaces of cell lines or their attachments.

4-8.3 Application. Installations covered by Section 4-8 of this chapter shall comply with the provisions of Chapters 1, 2, and 3 except as follows:

4-8.3.1 Overcurrent protection of electrolytic cell dc process power circuits shall not be required to comply with the requirements of Section 2-5 of Chapter 2.

4-8.3.2 Equipment located or used within the electrolytic cell line working zone or associated with the cell line dc power circuits shall not be required to comply with the provisions of Section 2-6 of Chapter 2.

4-8.3.3 The electrolytic cells, electrolytic cell line conductors, cell line attachments, and the wiring of auxiliary equipment and devices within the cell line working zone shall not be required to comply with the provisions of Chapter 1 and Sections 2-2 and 2-3 of Chapter 2.

4-8.4 Disconnecting Means.

4-8.4.1 Where more than one dc cell line process power supply serves the same cell line, a disconnecting means shall be provided on the cell line circuit side of each power supply to disconnect it from the cell line circuit.

4-8.4.2 Removable links or removable conductors shall be permitted to be used as the disconnecting means.

4-8.5 Portable Electric Equipment.

4-8.5.1 The frames and enclosures of portable electric equipment used within the cell line working zone shall not be grounded. However, these frames and enclosures shall be permitted to be grounded where the cell line circuit voltage does not exceed 200 volts dc or where guarded.

4-8.5.2 Ungrounded, portable electric equipment shall be distinctively marked and shall not be interchangeable with grounded, portable electric equipment.

4-8.6 Power Supply Circuits and Receptacles for Portable Electric Equipment.

4-8.6.1 Circuits supplying power to ungrounded receptacles for hand-held, cord-connected equipments shall be electrically isolated from any distribution system supplying areas other than the cell line working zone and shall be ungrounded. Power for these circuits shall be supplied through isolating transformers.

4-8.6.2 Receptacles and their mating plugs for ungrounded equipment shall not have provision for a grounding conductor and shall be of a configuration that prevents their use for equipment required to be grounded.

4-8.6.3 Receptacles on circuits supplied by an isolating transformer with an ungrounded secondary shall be a distinctive configuration, distinctively marked, and shall not be used in any other location in the plant.

4-8.7 Fixed and Portable Electric Equipment.

4-8.7.1 AC systems supplying fixed and portable electric equipment within the cell line working zone shall not be required to be grounded.

4-8.7.2 Exposed conductive surfaces, such as electric equipment housings, cabinets, boxes, motors, raceways, and the like, that are within the cell line working zone shall not be required to be grounded.

4-8.7.3 Auxiliary electrical devices, such as motors, transducers, sensors, control devices, and alarms mounted on an electrolytic cell or other energized surface, shall be connected by any of the following means:

(a) Multiconductor hard usage or extra-hard usage flexible cord;

(b) Wire or cable in suitable raceways; or

(c) Exposed metal conduit, cable tray, armored cable, or similar metallic systems installed with insulating breaks such that they will not cause a potentially hazardous electrical condition.

4-8.7.4 Bonding of fixed electric equipment to the energized conductive surfaces of the cell line, its attachments, or auxiliaries shall be permitted. Where fixed electric equipment is mounted on an energized conductive surface, it shall be bonded to that surface.

4-8.8 Auxiliary Nonelectric Connections. Auxiliary nonelectric connections, such as air hoses, water hoses, and the like, to an electrolytic cell, its attachments, or auxiliary equipments shall not have continuous conductive reinforcing wire, armor, braids, and the like. Hoses shall be of a nonconductive material.

4-8.9 Cranes and Hoists.

4-8.9.1 The conductive surfaces of cranes and hoists that enter the cell line working zone shall not be required to be grounded. The portion of an overhead crane or hoist that contacts an energized electrolytic cell or energized attachments shall be insulated from ground.

4-8.9.2 Remote crane or hoist controls that might introduce hazardous electrical conditions into the cell line working zone shall employ one or more of the following systems:

(a) Insulated and ungrounded control circuit,

(b) Nonconductive rope operator,

(c) Pendant pushbutton with nonconductive supporting means and having nonconductive surfaces or ungrounded exposed conductive surfaces, or

(d) Radio.

4-9 Electrically Driven or Controlled Irrigation Machines.

4-9.1 Lightning Protection. If an irrigation machine has a stationary point, a driven ground rod shall be connected to the machine at the stationary point for lightning protection.

4-9.2 Disconnecting Means for Center Pivot Irrigation Machines. The main disconnecting means for the machine shall be located at the point of connection of electrical power to the machine and shall be readily accessible and capable of being locked in the open position. A disconnecting means shall be provided for each motor and controller.

4-10 Swimming Pools, Fountains, and Similar Installations.

4-10.1 Scope. Paragraphs 4-10.2 through 4-10.5 shall apply to electric wiring for and equipment in or adjacent to all swimming, wading, therapeutic, and decorative pools and fountains; hot tubs, spas, and hydromassage bathtubs whether permanently installed or storable; and to metallic auxiliary equipment, such as pumps, filters, and similar equipment. Therapeutic pools in health care facilities shall be exempt from these provisions.

NOTE: The term "pool" as used in the balance of this section includes swimming, wading, and permanently installed therapeutic pools. The term "fountain" as used in the balance of this section includes fountains, ornamental pools, display pools, and reflection pools. The term is not intended to include drinking water fountains.

4-10.2 Lighting and Receptacles.

4-10.2.1 Receptacles. A single receptacle of the locking and grounding type that provides power for a permanently installed swimming pool recirculating pump motor shall be permitted to be located not less than 5 ft (1.52 m) from the inside walls of a pool. All other receptacles on the property shall be located at least 10 ft (3.05 m) from the inside walls of a pool and fountains. All receptacles shall be protected by ground-fault circuit-interrupters if they are located within 15 ft (4.57 m) of the inside walls of the pool.

NOTE: In determining the above dimensions, the distance to be measured is the shortest path the supply cord of an appliance connected to the receptacles would follow without piercing a floor, wall, or ceiling of a building or other effective permanent barrier.

4-10.2.2 Lighting Fixtures, Lighting Outlets, and Ceiling Fans.

4-10.2.2.1 Lighting fixtures, lighting outlets, and ceiling fans shall not be installed over a pool or over the area extending 5 ft (1.52 m) horizontally from the inside walls of a pool unless 12 ft (3.66 m) above the maximum water level. However, existing lighting fixtures and lighting outlets located less than 5 ft (1.52 m) measured horizontally from the inside walls of a pool shall be at least 5 ft (1.52 m) above the surface of the maximum water level and shall be rigidly attached to the existing structure. They shall also be protected by a ground-fault circuit-interrupter installed in the branch circuit supplying the fixture.

4-10.2.2.2 Lighting fixtures and lighting outlets installed in the area extending between 5 ft (1.52 m) and 10 ft (3.05 m) horizontally from the inside walls of a pool shall be protected by a ground-fault circuit-interrupter, unless installed 5 ft (1.52 m) above the maximum water level and rigidly attached to the structure adjacent to or enclosing the pool.

4-10.2.2.3 Lighting fixtures other than underwater fixtures that are within 16 ft (4.88 m), measured radially, of any point on the water surface and fixed or stationary equipment rated at 20 amperes or less shall be permitted to be connected with a flexible cord. For other than storable pools, the flexible cord shall not exceed 3 ft (914 mm) in length and shall have a copper equipment grounding conductor not smaller than No. 12 with a grounding-type attachment plug.

4-10.3 Underwater Equipment.

4-10.3.1 A ground-fault circuit-interrupter shall be installed in the branch circuit supplying underwater fixtures operating at more than 15 volts. Equipment installed underwater shall be approved for the purpose.

4-10.3.2 No underwater lighting fixtures shall be installed for operation at over 150 volts between conductors.

4-10.4 Fountains. All electric equipment operating at more than 15 volts, including power supply cords used with fountains, shall be protected by ground-fault circuit-interrupters.

4-10.5 Spas and Hot Tubs. Spas and hot tubs installed after January 1, 1994, shall have all electrical components protected by ground-fault circuit-interrupters.

Chapter 5 Hazardous (Classified) Locations

5-1 Scope. This chapter shall cover the requirements for electric equipment and wiring in locations that are classified depending on the properties of the flammable vapors, liquids or gases, or combustible dusts or fibers that might be present therein and the likelihood that a flammable or combustible concentration or quantity is present. Hazardous (classified) locations can be found in occupancies such as, but not limited to aircraft hangars, gasoline dispensing and service stations, bulk storage plants for gasoline or other volatile flammable liquids, paint-finishing process plants, health care facilities, agricultural or other facilities where excessive combustible dusts might be present, marinas, boat yards, and petroleum and chemical processing plants. Each room, section, or area shall be considered individually in determining its classification. These classified locations shall be assigned six designations as follows:

Class I, Division 1
Class I, Division 2
Class II, Division 1
Class II, Division 2
Class III, Division 1
Class III, Division 2

For definitions of these locations, see Section I-2. All other applicable requirements in this standard shall apply unless modified by provisions of this chapter.

5-2 General.

5-2.1 Approval. Equipment shall be approved not only for the class of location but also for the ignitible or combustible properties of the specific gas, vapor, dust, or fiber that will be present.

NOTE: Chapter 5 of NFPA 70, *National Electrical Code*, which is referenced in Appendix B, lists or defines hazardous gases, vapors, and dusts by "Groups" characterized by their ignitible or combustible properties.

5-2.2 Intrinsically Safe Equipment. Equipment and associated wiring approved as intrinsically safe shall be permitted in any hazardous (classified) location for which it is approved.

5-2.3 Conduits. All conduits shall be threaded and shall be made wrenchtight. Where it is impractical to make a threaded joint tight, a bonding jumper shall be utilized.

5-2.4 Marking. Approved equipment not covered in (a), (b), (c), or (d) following shall be marked to show the class, group, and operating temperature or temperature range, based on operation in a 40°C (104°F) ambient, for which it is approved. The temperature marking shall not exceed the ignition temperature of the specific gas or vapor to be encountered.

(a) Equipment of the non-heat-producing type, such as junction boxes, conduit, and fittings, and equipment of the heat-producing type having a maximum temperature not more than 100°C (212°F), shall not be required to have a marked operating temperature or temperature range.

(b) Fixed lighting fixtures marked for use in Class I, Division 2 or Class II, Division 2 locations only shall not be required to be marked to indicate the group.

(c) Fixed general-purpose equipment in Class I locations, other than fixed lighting fixtures, that is acceptable for use in Class I, Division 2 locations shall not be required to be marked with the class, group, division, or operating temperature.

(d) Fixed dusttight equipment other than fixed lighting fixtures that are acceptable for use in Class II, Division 2 and Class III locations shall not be required to be marked with class, group, division, or operating temperature.

5-2.5 Equipment in Division 2 Locations. Equipment that has been approved for a Division 1 location shall be permitted in a Division 2 location of the same class and group.

NOTE: General-purpose equipment or equipment in general-purpose enclosures shall be permitted to be installed in Division 2 locations if the equipment does not constitute a source of ignition under normal operating conditions.

5-3 Electrical Installations. Equipment, wiring methods, and installations of equipment in a hazardous (classified) location shall be of a type and design that provides protection from the hazards arising from the combustibility and flammability of vapors, liquids, gases, dusts, or fibers.

NOTE: Chapter 5 of NFPA 70, *National Electrical Code*, which is referenced in Appendix B, contains guidelines that are appropriate for determining the type and design of equipment and installations that provide protection from the hazards arising from the combustibility and flammability of vapors, liquids, gases, dusts, or fibers. The guidelines in this referenced document address electric wiring and equipment and systems installed in hazardous (classified) locations and contain specific provisions for the following: wiring methods, wiring connections, conductor insulation, flexible cords, sealing and drainage, transformers, capacitors, switches, circuit breakers, fuses, motor controllers, receptacles, attachment plugs, meters, relays, instruments, resistors, generators, motors, lighting fixtures, storage battery charging equipment, electric cranes, electric hoists and similar equipment, utilization equipment, signaling systems, alarm systems, remote-control systems, local loudspeaker and communication systems, ventilating piping, live parts, lightning surge protection, and grounding.

Chapter 6 Special Systems

6-1 Systems Over 600 Volts, Nominal. Paragraphs 6-1.1, 6-1.2, 6-1.3, and 6-1.4 cover the general requirements for all circuits and equipment operated at over 600 volts.

6-1.1 Wiring Methods for Fixed Installations. Aboveground conductors shall be installed in rigid metal conduit, in intermediate metal conduit, in rigid nonmetallic conduit, in cable trays, as busways, as cablebus, in other suitable raceways, or as open runs of metal-clad cable suitable for the use and purpose. Conductors emerging from the ground shall be enclosed in approved raceways. Open runs of type MV cables or of bare conductors or bus bars shall be permitted in locations accessible only to qualified persons. Metallic shielding components for conductors such as tapes, wires, or braids shall be grounded. Open runs of insulated wires and cables having a bare lead sheath or a braided outer covering shall be supported in a manner designed to prevent physical damage to the braid or sheath.

6-1.2 Interrupting and Isolating Devices.

6-1.2.1 Circuit breakers located indoors shall consist of metal-enclosed or fire-resistant, cell-mounted units. In locations accessible only to qualified personnel, open mounting of circuit breakers shall be permitted. A means of indicating the open and closed positions of circuit breakers shall be provided.

6-1.2.2 Fused cutouts installed in buildings or transformer vaults shall be of a type approved for the purpose. They shall be readily accessible for fuse replacement. Where fuses are capable of being energized from more than one source, a conspicuous sign shall be placed at the fuses reading: "WARNING — FUSES MAY BE ENERGIZED FROM MORE THAN ONE SOURCE."

6-1.2.3 A means shall be provided to completely isolate equipment for inspection and repairs. Isolating means not designed to interrupt the load current of the circuit shall be either interlocked with an approved circuit interrupter or provided with a sign warning against opening them under load.

6-1.3 Mobile and Portable Equipment.

6-1.3.1 Power Cable Connections to Mobile Machines. A metallic enclosure shall be provided on the mobile machine for enclosing the terminals of the power cable. The enclosure shall include provisions for a solid connection for the ground wire(s) terminal to effectively ground the machine frame. The method of cable termination used shall prevent any strain or pull on the cable from stressing the electrical connections. The enclosure shall have provision for locking so only authorized and qualified persons shall be permitted to open it and shall be marked "DANGER — HIGH VOLTAGE — KEEP OUT."

6-1.3.2 Guarding Live Parts. All energized switching and control parts shall be enclosed in effectively grounded metal cabinets or enclosures. Circuit breakers and protective equipment shall have the operating means projecting through the metal cabinet or enclosure so these units can be reset without opening locked doors. Enclosures and metal cabinets shall be locked so that only authorized and qualified persons can have access and shall be marked "DANGER — HIGH VOLTAGE — KEEP OUT." Collector ring assemblies on revolving-type machines (shovels, draglines, etc.) shall be guarded.

6-1.3.3 Grounding. Mobile equipment shall be properly grounded.

6-1.4 Tunnel Installations.

6-1.4.1 General. The provisions of this part shall apply to installation and use of high-voltage power distribution and utilization equipment that is portable and/or mobile, such as substations, trailers or cars, mobile shovels, draglines, hoists, drills, dredges, compressors, pumps, conveyors, underground excavators, etc.

6-1.4.2 Conductors. Conductors in tunnels shall be installed in one or more of the following:

(1) Metal conduit or other metal raceway,
(2) Type MC cable, or
(3) Other approved multiconductor cable.

Conductors shall also be located or guarded to protect them from physical damage. Multiconductor portable cable shall be permitted to supply mobile equipment. An equipment grounding conductor shall be run with circuit conductors

inside the metal raceway or inside the multiconductor cable jacket. The equipment grounding conductor shall be permitted to be insulated or bare.

6-1.4.3 Guarding Live Parts. Bare terminals of transformers, switches, motor controllers, and other equipment shall be enclosed to prevent accidental contact with energized parts. Enclosures for use in tunnels shall be dripproof, weatherproof, or submersible as required by the environmental conditions.

6-1.4.4 Disconnecting Means. A disconnecting means that simultaneously opens all ungrounded conductors shall be installed at each transformer or motor location.

6-1.4.5 Grounding and Bonding. All noncurrent-carrying metal parts of electric equipment and metal raceways and cable sheaths shall be effectively grounded and bonded to all metal pipes and rails at the portal and at intervals not exceeding 1000 ft (305 m) throughout the tunnel.

6-2 Emergency Power Systems.

6-2.1 Scope. The provisions for emergency systems shall apply to circuits, systems, and equipment intended to supply (in the event of failure of the normal supply) power for illumination and special loads.

6-2.2 Wiring Methods. Emergency circuit wiring shall be kept entirely independent of all other wiring and equipment and shall not enter the same raceway, cable, box, or cabinet with other wiring except where common circuit elements suitable for the purpose are required, or for transferring power from the normal to the emergency source.

6-2.3 Emergency Illumination. Where emergency lighting is required, the system shall be arranged so that the failure of any individual lighting element, such as the burning out of a light bulb, cannot leave any space in total darkness.

6-3 Class 1, Class 2, and Class 3 Remote Control, Signaling, and Power-Limited Circuits.

6-3.1 Classification. Class 1, Class 2, or Class 3 remote control, signaling, or power-limited circuits shall be characterized by their usage and electrical power limitation, which differentiates them from light and power circuits. These circuits shall be classified in accordance with their respective voltage and power limitations as summarized in 6-3.1.1, 6-3.1.2, and 6-3.1.3.

6-3.1.1 Class 1 Circuits.

6-3.1.1.1 A Class 1 power-limited circuit shall be supplied from a source having a rated output of not more than 30 volts and 1000 volt-amperes.

6-3.1.1.2 A Class 1 remote control circuit or a Class 1 signaling circuit shall be one whose voltage does not exceed 600 volts; however, the power output of the source shall not be required to be limited.

6-3.1.2 Class 2 and Class 3 Circuits.

6-3.1.2.1 Power for Class 2 and Class 3 circuits shall be limited, either inherently (in which case no overcurrent protection shall be required) or by a combination of a power source and overcurrent protection.

6-3.1.2.2 The maximum circuit voltage shall be 150 volts ac or dc for a Class 2 inherently limited power source and 100 volts ac or dc for a Class 3 inherently limited power source.

6-3.1.2.3 The maximum circuit voltage shall be 30 volts ac and 60 volts dc for a Class 2 power source limited by overcurrent protection and 150 volts ac or dc for a Class 3 power source limited by overcurrent protection.

6-3.1.3 The maximum circuit voltages in 6-3.1.1 and 6-3.1.2 shall apply to sinusoidal ac or continuous dc power sources, and where wet contact occurrence is not likely.

6-3.2 Marking. A Class 2 or Class 3 power supply unit shall be durably marked where plainly visible to indicate the class of supply and its electrical rating.

6-4 Fire Protective Signaling Systems.

6-4.1 Classifications. Fire protective signaling circuits shall be classified either as non-power-limited or power-limited.

6-4.2 Power Sources. The power sources for use with fire protective signaling circuits shall be either power-limited or non-power-limited as follows:

6-4.2.1 The power supply of non-power-limited fire protective signaling circuits shall have an output voltage not in excess of 600 volts.

6-4.2.2 The power for power-limited fire protective signaling circuits shall be either inherently limited, in which no overcurrent protection is required, or limited by a combination of a power source and overcurrent protection.

6-4.3 Non-Power-Limited Conductor Location. Non-power-limited fire protective signaling circuits and Class 1 circuits shall be permitted to occupy the same enclosure, cable, or raceway, provided all conductors are insulated for maximum voltage of any conductor within the enclosure, cable, or raceway. Power supply and fire protective signaling circuit conductors shall be permitted in the same enclosure, cable, or raceway only when connected to the same equipment.

6-4.4 Power-Limited Conductor Location. Where open conductors are installed, power-limited fire protective signaling circuits shall be separated at least 2 in. (50.8 mm) from conductors of any light, power, Class 1, and non-power-limited fire protective signaling circuits unless a special method of conductor separation is employed. Cables and conductors of two or more power-limited fire protective signaling circuits or Class 3 circuits shall be permitted in the same cable, enclosure, or raceway. Conductors of one or more Class 2 circuits shall be permitted within the same cable, enclosure, or raceway with conductors of power-limited fire protective signaling circuits, provided that the insulation of the Class 2 circuit conductors in the cable, enclosure, or raceway is at least that required for the power-limited fire protective signaling circuits.

6-4.5 Identification. Fire protective signaling circuits shall be identified at terminal and junction locations in a manner that will prevent unintentional interference with the signaling circuit during testing and servicing. Power-limited fire protective signaling circuits shall be durably marked as such where plainly visible at terminations.

6-5 Communications Systems.

6-5.1 Scope. These provisions for communications systems shall apply to such systems as central station connected and noncentral station connected telephone circuits; radio and television receiving and transmitting equipment, including community antenna television and radio distribution systems,

telegraph, district messenger, and outside wiring for fire and burglar alarm; and similar central station systems.

6-5.2 Protective Devices.

6-5.2.1 Communications circuits located so as to be exposed to accidental contact with light or power conductors operating at over 300 volts shall have each circuit so exposed provided with a protector approved for the purpose.

6-5.2.2 Each conductor of a lead-in for outdoor antennas shall be provided with an antenna discharge unit or other suitable means that will drain static charges from the antenna system.

6-5.3 Conductor Location.

6-5.3.1 Outside of Buildings.

6-5.3.1.1 Receiving distribution lead-in or aerial-drop cables attached to buildings and lead-in conductors to radio transmitters shall be installed to avoid the possibility of accidental contact with electric light or power conductors.

6-5.3.1.2 The clearance between lead-in conductors and any lightning protection conductors shall not be less than 6 ft (1.83 m).

6-5.3.2 On Poles. Where practicable, communication conductors on poles shall be located below the light or power conductors and shall not be attached to a crossarm that carries light or power conductors.

6-5.3.3 Inside of Buildings. Indoor antennas, lead-ins, and other communication conductors attached as open conductors to the inside of buildings shall be located at least 2 in. (50.8 mm) from conductors of any light or power or Class 1 circuits unless a special method of conductor separation, approved for the purpose, is employed.

6-5.4 Equipment Location. Outdoor metal structures supporting antennas, as well as self-supporting antennas such as vertical rods or dipole structures, shall be located well away from overhead conductors of electric light and power circuits of over 150 volts to ground to avoid the possibility of the antenna or structure falling into or making accidental contact with such circuits.

6-5.5 Grounding.

6-5.5.1 Lead-in Conductors. Where exposed to contact with electric light and power conductors, the metal sheath of aerial cables entering buildings shall be grounded or shall be interrupted close to the entrance to the building by an insulating joint or equivalent device. Where protective devices are used, they shall be grounded in an approved manner.

6-5.5.2 Antenna Structures. Masts and metal structures supporting antennas shall be permanently and effectively grounded without splice or connection in the grounding conductor.

6-5.5.3 Equipment Enclosures. Transmitters shall be enclosed in a metal frame or grill or separated from the operating space by a barrier or other equivalent means, all metallic parts of which are effectively connected to ground. All external metal handles and controls accessible to the operating personnel shall be effectively grounded. Unpowered equipment and enclosures shall be considered grounded where connected to an attached coaxial cable whose metallic shield is effectively grounded.

6-6 Solar Photovoltaic Systems.

6-6.1 These provisions cover solar photovoltaic systems that can be interactive with other electric power production sources or can stand alone, with or without electrical energy storage such as batteries. These systems shall be permitted to have ac or dc output for utilization.

6-6.2 Conductors of Different Systems. Except where separated by a partition or connected together, photovoltaic circuits shall not be contained in the same raceway, cable tray, outlet box, junction box, or similar fitting as feeders or branch circuits of other systems. Circuits connected to more than one electrical source shall have overcurrent devices located to provide overcurrent protection from all sources.

6-6.3 Disconnecting Means.

6-6.3.1 All Conductors. Means shall be provided to disconnect all current-carrying conductors of a photovoltaic power source from all other conductors in a building or other structure.

6-6.3.2 Marking. Where all terminals of the disconnecting means can be energized in the open position, a warning sign shall be mounted adjacent to or on the disconnecting means reading substantially "WARNING—ELECTRIC SHOCK—DO NOT TOUCH—TERMINALS ENERGIZED IN OPEN POSITION."

6-7 Integrated Electrical Systems.

6-7.1 Scope. This section shall cover integrated electrical systems, other than unit equipment, in which orderly shutdown is necessary to ensure safe operation. An integrated electrical system as used in this article shall be a unitized segment of an industrial wiring system where all of the following conditions are met:

(1) An orderly shutdown shall be required to minimize personnel hazard and equipment damage;

(2) The conditions of maintenance and supervision shall ensure that qualified persons service the system; and

(3) Effective safeguards, acceptable to the authority having jurisdiction, shall be established and maintained.

6-7.2 Location of Overcurrent Devices in or on Premises. Location of over current devices that are critical to integrated electrical systems shall be permitted to be accessible, with mounting heights allowed to ensure security from operation by nonqualified personnel.

PART II

SAFETY-RELATED WORK PRACTICES

Chapter 1 Introduction

1-1 Scope. Part II covers electrical safety-related work practices and procedures for employees who work on or near exposed energized electrical conductors or circuit parts in workplaces that are included in the scope of this standard. Electric circuits and equipment not included in the scope of this standard might present a hazard to employees not qualified to work near such facilities. Requirements have been included in Part II to protect unqualified employees from such hazards.

1-2 Purpose. These practices and procedures are intended to provide for employee safety relative to electrical hazards in the workplace.

1-3 Responsibility. The safety-related work practices contained in Part II shall be implemented by employees. The employer shall provide the safety-related work practices. He or she shall also train the employee who shall then implement them.

1-4 Organization. Part II of this standard is divided into five chapters. Chapter 1 includes definitions applicable to Part II. Chapter 2 applies to employee training and qualification, includes details about limits of approach to exposed energized electrical conductors and circuit parts, and contains specific work practices. Chapter 3 applies to specifying and maintaining personal and other protective equipment. Chapter 4 covers the use of specific safety-related equipment and work practices. Chapter 5 covers the general requirements for a lockout/tagout procedure.

1-5 Definitions. Unless expressly stated elsewhere, the following terms shall, for the purpose of Part II, have the meanings indicated below.

Barehand Work. A technique of performing work on exposed energized conductors or circuit parts, after the worker has been raised to the potential of the energized conductor or circuit part.

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

Barrier. A physical obstruction that is intended to prevent contact with exposed energized electrical conductors or circuit parts. Barriers can be installed temporarily or permanently.

Conductive. Any material suitable for carrying electric current.

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

Electrical Hazard. A dangerous condition such that inadvertent or unintentional contact or equipment failure can result in shock, arc flashburn, thermal burn, or blast.

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

Electrical Single-Line Diagram. A record of all power sources to electrical equipment.

Electrically Safe Work Condition. A state in which the conductor or circuit part to be worked on or near has been disconnected from energized parts, locked/tagged in accordance with established standards, tested to ensure the absence of voltage, and grounded if determined necessary.

Energized. Electrically connected to a source of potential difference, or electrically charged to have a potential significantly different from that of earth in the vicinity.

Flash Hazard. A dangerous condition associated with the release of energy caused by an arc that suddenly and violently changes material(s) into a vapor.

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

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

Live-Line Tool Work. A technique of performing work on exposed, energized conductors or circuit parts where the worker utilizes insulated live-line tools rated for the voltage involved to provide insulation of the person from the energized part on which work is to be performed.

Live Parts. Electric conductors, busses, terminals, or components that are uninsulated or exposed and a shock hazard exists.

Rubber Glove Work. A technique of performing work on exposed, energized conductors or circuit parts where the worker utilizes rubber insulating gloves, with sleeves if necessary, rated for the voltage involved to provide insulation of the person from the energized part on which work is to be performed.

Shock Hazard. A dangerous condition associated with the release of energy caused by contact or approach to exposed electrical conductors or circuit parts nearer than the minimum air insulation distance.

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

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

Unqualified Person. A person who is not a qualified person.

Working Near. Any activity inside the limited approach boundary of exposed energized electrical conductors or circuit parts that are not put into an electrically safe work condition.

Working On. Coming in contact with exposed energized electrical conductors or circuit parts with the hands, feet, or other body parts, with tools, probes, or with test equipment, regardless of the personal protective equipment a person is wearing.

Chapter 2 General Requirements for Electrical Work Practices

2-1 Safety Training.

2-1.1 Training Requirements. The training requirements contained in this section shall apply to employees who face a risk of electrical hazard that is not reduced to a safe level by the electrical installation requirements of Part I. Such employees shall be trained to understand the specific hazards associated with electrical energy. They shall be trained in safety-related work practices and procedural requirements as necessary to provide protection from the electrical hazards associated with their respective job or task assignments. Employees shall be trained to identify and understand the relationship between electrical hazards and possible injury.

2-1.2 Type of Training. The training required by this section shall be classroom or on-the-job type, or a combination of the two. The degree of training provided shall be determined by the risk to the employee.

2-1.3 Emergency Procedures. Employees working on or near exposed energized electrical conductors or circuit parts shall be trained in methods of release of victims from contact with

exposed energized conductors or circuit parts. They shall be regularly instructed in methods of first aid and emergency procedures, such as approved methods of resuscitation, if their duties warrant such training.

2-2 Employee Training.

2-2.1 Qualified Persons. A qualified person shall be trained and knowledgeable of the construction and operation of equipment or a specific work method, and be trained to recognize and avoid the electrical hazards that might be present with respect to that equipment or work method. Such persons shall also be familiar with the proper use of special precautionary techniques, personal protective equipment, insulating and shielding materials, and insulated tools and test equipment. A person can be considered qualified with respect to certain equipment and methods but still be unqualified for others. Such persons permitted to work within limited approach of exposed energized conductors and circuit parts shall, at a minimum, be additionally trained in the following:

(a) The skills and techniques necessary to distinguish exposed energized parts from other parts of electric equipment,

(b) The skills and techniques necessary to determine the nominal voltage of exposed energized parts,

(c) The approach distances specified in Table 2-3.3.5 and the corresponding voltages to which the qualified person will be exposed, and

(d) The decision-making process necessary to determine the degree and extent of the hazard and the personal protective equipment and job planning necessary to perform the task safely.

2-2.2 Unqualified Persons.

2-2.2.1 Where an unqualified person(s) is (are) working at or close to the limited approach boundary, the designated person in charge of the work space where the electrical hazard exists shall cooperate with the designated person in charge of the unqualified person(s) to ensure that all work can be done safely. This shall include advising the unqualified person(s) of the electrical hazard and warning him or her to stay outside of the limited approach boundary.

2-2.2.2 An employee who is undergoing on-the-job training and who, in the course of such training, has demonstrated an ability to perform duties safely at his or her level of training and who is under the direct supervision of a qualified person shall be considered to be a qualified person for the performance of those duties.

2-2.2.3 Where there is a need for an unqualified person(s) to cross the limited approach boundary to perform a minor task, or look at equipment, a qualified person shall advise him or her of the possible hazards and ensure the unqualified person(s) is (are) safeguarded. Under no circumstance shall such unqualified person(s) be permitted to cross the restricted approach boundary.

2-2.2.4 Unqualified persons shall be trained in and be familiar with any of the electrical safety-related practices that might not be addressed specifically by Part II, but are necessary for their safety.

2-3 Working On or Near Electrical Conductors or Circuit Parts.

2-3.1 General. Safety-related work practices shall be used to safeguard employees from injury while they are working on or near exposed electrical conductors or circuit parts that are or can become energized. The specific safety-related work practice shall be consistent with the nature and extent of the associated electrical hazards.

2-3.1.1 Exposed energized electrical conductors or circuit parts to which an employee might be exposed shall be put into an electrically safe work condition before an employee works on or near them, unless the employer can demonstrate that deenergizing introduces additional or increased hazards or is infeasible due to equipment design or operational limitations.

NOTE 1: Examples of increased or additional hazards include, but are not limited to, interruption of life support equipment, deactivation of emergency alarm systems, shutdown of hazardous location ventilation equipment, or removal of illumination for an area.

NOTE 2: Examples of work that might be performed on or near exposed energized electrical conductors or circuit parts because of infeasibility due to equipment design or operational limitations include, but are not limited to, performing diagnostics and testing of electric circuits that can only be performed with the circuit energized (i.e., start-up or troubleshooting) and work on circuits that form an integral part of a continuous process that would otherwise need to be completely shut down in order to permit work on one circuit or piece of equipment.

NOTE 3: Energized parts that operate at less than 50 volts to ground are not required to be deenergized if there will be no increased exposure to electrical burns or to explosion due to electric arcs.

2-3.1.2 Employees shall only be permitted to work on electrical conductors or circuit parts that have been put into an electrically safe work condition unless they are qualified and trained to understand the hazards and to select and use safe work practices as well as personal and other protective equipment, in accordance with the requirements specified in Section 2-5 of Part II, Chapter 3 of Part II, and Chapter 4, Section 4-1 of Part II.

2-3.1.3 An electrically safe work condition shall be achieved and verified by the following process:

(a) Determine all possible sources of electrical supply to the specific equipment. Check applicable up-to-date drawings, diagrams, and identification tags.

(b) After properly interrupting the load current, open the disconnecting device(s) for each source.

(c) Where it is possible, visually verify that all blades of the disconnecting devices are fully open or that drawout type circuit breakers are withdrawn to the fully disconnected position.

(d) Apply lockout/tagout devices in accordance with a documented and established policy. (*See Chapter 5.)*

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

(f) Where the possibility of induced voltages or stored electrical energy exists, ground the phase conductors or circuit parts before touching them. Where it could be reasonably anticipated that the conductors or circuit parts being deenergized could contact other exposed energized conduc-

tors or circuit parts, apply ground connecting devices rated for the available fault duty.

2-3.2 Working On or Near Deenergized Electrical Conductors or Circuit Parts that Have Lockout/Tagout Devices Applied. Each employer shall identify, document, and implement lockout/tagout procedures to safeguard employees from exposure to electrical hazards while they are working on or near deenergized electrical conductors or circuit parts that are likely to result in injury from inadvertent or accidental contact or equipment failure. The lockout/tagout procedure shall be appropriate for the experience and training of the employees and conditions as they exist in the workplace.

2-3.3 Working On or Near Exposed Electrical Conductors or Circuit Parts that Are or Might Become Energized.

2-3.3.1 Where working on exposed deenergized electrical conductors or circuit parts or near enough to them to expose the employee to any electric hazard they present, but where lockout/tagout devices have not been applied and tested for absence of voltage in accordance with 2-3.1.3 or Chapter 5 of Part II, 2-3.3.2 through 2-3.3.5 shall apply to work on or near such facilities.

2-3.3.2 If the exposed energized parts are not placed in electrically safe work conditions, other safety-related work practices shall be used to protect employees who might be exposed to the electrical hazards involved. Such work practices shall protect employees from arc flash and against contact with energized electrical conductors or circuit parts directly with any part of the body or indirectly through some other conductive object. The work practices that are used shall be suitable for the conditions under which the work is to be performed and for the voltage level of the exposed electrical conductors or circuit parts.

2-3.3.3 Flash Hazard Analysis. Flash hazard analysis shall be done before a person approaches any exposed electrical conductor or circuit part that has not been placed in an electrically safe work condition.

2-3.3.3.1 General. In certain instances, the flash protection boundary might be a greater distance than the limited approach boundary and the greater distance shall be utilized to trigger the need for personal protective equipment.

NOTE: For determination of the maximum distance of the flash protection boundary from the exposed electrical conductor or circuit part, refer to Column 2 of Table 2-3.3.5.

2-3.3.3.2 Engineering Supervision. Under engineering supervision, the flash protection boundary distance associated with actual electrical parameters shall be permitted to be calculated in accordance with the following general formula:

$$D_c = [2.65 \times MVA_{bf} \times t]^{1/2} \text{ or}$$
$$D_c = [53 \times MVA \times t]^{1/2}$$

where:

D_c = Distance of person from an arc source for a just curable burn in feet.

MVA_{bf} = Bolted fault MVA at point involved.

MVA = MVA rating of transformer. For transformers with MVA ratings below 0.75 MVA, multiply the transformer MVA rating by 1.25.

t = Time of arc exposure in seconds.

2-3.3.4 Only qualified persons shall be permitted to work on electrical conductors or circuit parts that have not been placed into an electrically safe work condition under the procedures in 2-3.1.3 of Part II, or Chapter 5 of Part II. Such persons shall be capable of safely working on energized conductors or circuit parts.

2-3.3.5 No qualified person shall approach or take any conductive object without a suitably insulated handle closer to exposed energized electrical conductors or circuit parts than the restricted approach boundary set forth in Table 2-3.3.5, unless:

(a) The qualified person is insulated or guarded from the energized conductors or circuit parts and no unguarded part of the qualified person's body enters the prohibited space set forth in Table 2-3.3.5, or

(b) The energized conductor or circuit part is insulated or guarded both from the qualified person and any other conductive object at a different potential, or

(c) The qualified person is isolated, insulated, or guarded from all conductive objects at a potential different from that of the energized part.

Any variation from the requirements of (a), (b), or (c) above requires additional hazard/risk analysis.

Table 2-3.3.5 Approach Distances to Exposed Energized Electrical Conductors and Circuit Parts

Column Number (1)	(2)	(3)	(4)	(5)	(6)
Nominal System Voltage Range	Flash Protection Boundary	Limited Approach Boundary		Restricted Approach Boundary	Prohibited Approach Boundary
Phase to Phase		Exposed Movable Conductor	Exposed Fixed Circuit Part	Includes Standard Inadvertent Movement Adder	Includes Reduced Inadvertent Movement Adder
		Energized Part to Employee - Distance in Feet - Inches			
300V and less	3 ft 0 in.	10 ft 0 in.	3 ft 6 in.	Avoid Contact	
Over 300V, not over 750V	3 ft 0 in.	10 ft 0 in.	3 ft 6 in.	1 ft 0 in.	0 ft 1 in.
Over 750V, not over 2kV	4 ft 0 in.	10 ft 0 in.	4 ft 0 in.	2 ft 0 in.	0 ft 3 in.
Over 2kV, not over 15kV	16 ft 0 in.	10 ft 0 in.	5 ft 0 in.	2 ft 2 in.	0 ft 7 in.
Over 15kV, not over 36kV	19 ft 0 in.	10 ft 0 in.	6 ft 0 in.	2 ft 7 in.	0 ft 10 in.
Over 36kV, not over 48.3kV	*	10 ft 0 in.	8 ft 0 in.	2 ft 10 in.	1 ft 5 in.

Table 2-3.3.5 Approach Distances to Exposed Energized Electrical Conductors and Circuit Parts

Column Number (1)	(2)	(3)	(4)	(5)	(6)
Nominal System Voltage Range	Flash Protection Boundary	Limited Approach Boundary		Restricted Approach Boundary	Prohibited Approach Boundary
Phase to Phase		Exposed Movable Conductor	Exposed Fixed Circuit Part	Includes Standard Inadvertent Movement Adder	Includes Reduced Inadvertent Movement Adder
		Energized Part to Employee - Distance in Feet - Inches			
Over 48.3kV, not over 72.5kV	*	10 ft 0 in.	8 ft 0 in.	3 ft 3 in.	2 ft 1 in.
Over 72.5kV, not over 121kV	*	10 ft 8 in.	8 ft 0 in.	3 ft 2 in.	2 ft 8 in.
Over 138kV, not over 145kV	*	11 ft 0 in.	10 ft 0 in.	3 ft 7 in.	3 ft 1 in.
Over 161kV, not over 169kV	*	11 ft 8 in.	11 ft 8 in.	4 ft 0 in.	3 ft 6 in.
Over 230kV, not over 242kV	*	13 ft 0 in.	13 ft 0 in.	5 ft 3 in.	4 ft 9 in.
Over 345kV, not over 362kV	*	15 ft 4 in.	15 ft 4 in.	8 ft 6 in.	8 ft 0 in.
Over 500kV, not over 550kV	*	19 ft 0 in.	19 ft 0 in.	11 ft 3 in.	10 ft 9 in.
Over 765kV, not over 800kV	*	23 ft 9 in.	23 ft 9 in.	14 ft 11 in.	14 ft 5 in.

For SI units: 1 in. = 25.4 mm; 1 ft = 0.3048 m.
*For values above 36kV, calculate the value by using the formula in 2-3.3.3.2

2-4 Work On or Near Uninsulated Overhead Lines.

2-4.1 Uninsulated and Energized. Where work is performed in locations containing uninsulated energized overhead lines that are not guarded or isolated, precautions shall be taken to prevent employees from contacting such lines directly with any unguarded parts of their body or indirectly through conductive materials, tools, or equipment. Where the work to be performed is such that contact with uninsulated energized overhead lines is possible, the lines shall be deenergized and visibly grounded at the point of work, or suitably guarded.

2-4.2 Deenergizing or Guarding. Where deenergizing is required, arrangements shall be made with the person or organization that operates or controls the electrical circuits involved to deenergize in accordance with 2-3.1.3 and visibly ground them at the point of work. Where arrangements are made to use protective measures, such as guarding, isolating, or insulating, these precautions shall prevent employees from contacting such lines directly with any part of their body or indirectly through conductive materials, tools, or equipment.

2-4.3 Employer and Employee Responsibility. The employer and employee shall be responsible to ensure that guards or protective measures are satisfactory for the conditions. Employees shall comply with established work methods and the use of protective equipment.

2-4.4 Approach Distances for Unqualified Persons. When employees without electrical training are working on the ground or in an elevated position near overhead lines, the location shall be such that the person and the longest conductive object the person might contact cannot come closer to any unguarded, energized overhead line that has not been placed into an electrically safe work condition than the limited approach boundary set forth in Table 2-3.3.5. Objects that are not insulated for the voltage involved shall be considered to be conductive.

2-4.5 Approach Distances for Qualified Persons. When a qualified person is working in the vicinity of overhead lines that have not been deenergized, whether on the ground or in an elevated position, the person shall not approach or take any conductive object without an approved insulated handle closer to any exposed energized conductor or circuit part that has not been placed into an electrically safe work condition than the restricted approach boundary set forth in Table 2-3.3.5, unless following the provisions of 2-3.3.5.

2-4.6 Vehicular and Mechanical Equipment.

2-4.6.1 Where it could reasonably be anticipated that parts of any vehicle or mechanical equipment structure will be elevated near energized overhead lines, they shall be operated so that the limited approach boundary distance of Table 2-3.3.5, Column 3, is maintained. However, under any of the following conditions, the clearances shall be permitted to be reduced:

(a) When the vehicle is in transit with its structure lowered, the limited approach boundary to overhead lines in Table 2-3.3.5, Column 3, shall be permitted to be reduced by 6 ft (1.83 m).

(b) When insulated barriers, rated for the voltages involved, are installed, and they are not part of an attachment to the vehicle, the clearance shall be permitted to be reduced to the design working dimensions of the insulating barrier.

(c) When the equipment is an aerial lift insulated for the voltage involved, and if the work is performed by a qualified person, the clearance (between the uninsulated portion of the aerial lift and the power line) shall be permitted to be reduced to the restricted approach boundary given in Table 2-3.3.5, Column 5.

2-4.6.2 Employees standing on the ground shall not contact the vehicle or mechanical equipment or any of its attachments, unless:

(a) The employee is using protective equipment rated for the voltage; or

(b) The equipment is located so that no uninsulated part of its structure (that portion of the structure that provides a conductive path to employees on the ground) can come closer to the line than permitted in 2-4.6.1.

2-4.6.3 Where it could be reasonably anticipated that any vehicle or mechanical equipment structure will be elevated near energized overhead lines that are intentionally

grounded, employees working on the ground near the point of grounding shall not stand at the ground location whenever there is a possibility of overhead line contact. Additional precautions, such as the use of barricades or insulation, shall be taken to protect employees from hazardous ground potentials (step and touch potential), which can develop within the first few feet or more outward from the grounded point.

2-5 Electrical Safety Program.

2-5.1 General. The employer shall implement an overall electrical safety program that directs activity appropriate for the voltage, energy level, and circuit conditions.

NOTE: Safety-related work practices are just one component of an overall electrical safety program.

2-5.1.1 Awareness and Self Discipline. The electrical safety program shall be designed to provide an awareness of the potential electrical hazards to the employees who might from time to time work in an environment influenced by the presence of electrical energy. The program shall be developed to provide the required self-discipline to the employees who occasionally must perform work on or near exposed energized electrical conductors and circuit parts. The program shall instill safety principles and controls.

2-5.1.2 Electrical Safety Program Principles. An electrical safety program shall identify the principles upon which it is based.

NOTE: For examples of typical electrical safety program principles, see Part II, Appendix C.

2-5.1.3 Electrical Safety Program Controls. An electrical safety program shall identify the controls by which it is measured and monitored.

NOTE: For examples of typical electrical safety program controls, see Part II, Appendix C.

2-5.1.4 Electrical Safety Program Procedures. Specific procedures for working on or near exposed energized conductors and circuit parts shall be prepared prior to performing the task.

NOTE: For an example of a typical electrical safety program procedure, see Part II, Appendix C.

2-5.1.5 Job Briefing. Before starting each job, the employee in charge shall conduct a job briefing with the employees involved. The briefing shall cover such subjects as: hazards associated with the job, work procedures involved, special precautions, energy source controls, and personal protective equipment requirements.

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

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

(a) The work is complicated or particularly hazardous, or

(b) The employee cannot be expected to recognize and avoid the hazards involved in the job.

2-5.1.6 Hazard/Risk Evaluation Procedure. Each employer shall establish procedural requirements for safety-related work practices that consider the hazard/risk evaluation process.

NOTE: Part II, Appendix D, contains an example of a satisfactory procedure.

2-5.2 Alertness.

2-5.2.1 Employees shall be instructed to be alert at all times when they are working near exposed energized parts and in work situations where unexpected electrical hazards might exist.

2-5.2.2 Employees shall not knowingly be permitted to work in areas containing exposed energized parts or other electrical hazards while their alertness is recognizably impaired due to illness, fatigue, or other reasons.

2-5.3 Blind Reaching. Employees shall be instructed not to reach blindly into areas that might contain energized parts.

2-5.4 Illumination.

2-5.4.1 Employees shall not be permitted to enter spaces containing exposed energized conductors or circuit parts unless adequate illumination is provided.

2-5.4.2 Where lack of illumination or an obstruction precludes observation of the work to be performed, employees shall not perform any task or operation that requires being within the limited approach boundary.

2-5.5 Conductive Articles Being Worn. Conductive articles of jewelry and clothing, such as watch bands, bracelets, rings, key chains, necklaces, metalized aprons, cloth with conductive thread, metal headgear, or unrestrained metal frame glasses, shall not be worn where they present an electrical contact hazard with exposed energized conductors or circuit parts, unless such articles are rendered nonconductive by covering, wrapping, or other insulating means.

2-5.6 Conductive Materials, Tools, and Equipment Being Handled.

2-5.6.1 Conductive materials, tools, and equipment that are in contact with any part of an employee's body shall be handled in a manner that will prevent accidental contact with exposed energized electrical conductors or circuit parts. Such materials and equipment include but are not limited to long conductive objects, such as ducts, pipes and tubes, conductive hose and rope, metal-lined rules and scales, steel tapes, pulling lines, metal scaffold parts, structural members, bull floats, and chains.

2-5.6.2 Means shall be employed to ensure that conductive materials approach energized or potentially energized electrical conductors and circuit parts no closer than that permitted by Table 2-3.3.5 and the requirements associated with the use of Table 2-3.3.5.

2-5.7 Insulated Tools and Equipment. Employees shall use suitably insulated tools and/or handling equipment when working inside the limited approach boundary of exposed, energized electrical conductors or circuit parts where it could reasonably be anticipated that the tools or handling equip-

ment might make accidental contact. Insulated tools shall be protected from damage to the insulating material.

2-5.7.1 Fuse and fuse holder handling equipment, suitably insulated for the circuit voltage, shall be used to remove or install fuses if the fuse terminals are energized.

2-5.7.2 Only nonconductive ropes and handlines shall be used near exposed, energized parts.

2-5.8 Protective Shields. Employees shall use protective shields, protective barriers, or suitably insulated materials to protect themselves from exposure to electrical hazards when they are working within the limited approach boundary.

2-5.9 Portable Ladders. Portable metal ladders or ladders that have longitudinal metallic reinforcement shall not be used when working within the limited approach boundary.

2-5.10 Confined or Enclosed Work Spaces. When work is performed in confined or enclosed spaces, such as manholes and vaults that contain exposed energized electrical conductors or circuit parts, precautions shall be taken to avoid inadvertent contact with the energized parts. Items such as doors shall be secured to prevent their swinging into an employee and causing the employee to contact exposed energized parts.

Safe atmosphere tests shall be performed before entry.

2-5.11 Safety Interlocks. Only a qualified person following the requirements for working inside the restricted approach boundary shall be permitted to defeat or bypass an electrical safety interlock over which the person has sole control, and then only temporarily while the qualified person is working on the equipment. The safety interlock system shall be returned to its operable condition when the work is completed.

2-5.12 Housekeeping Duties. Housekeeping duties shall not be performed inside the limited approach boundary unless adequate safeguards are provided. Cleaning materials, such as water, steam, conductive aerosol or fluid, metalized wool or cloth, or silicon carbide, shall not be used inside the limited approach boundary unless adequate procedures are followed.

2-5.13 Occasional Use of Flammable Materials. Electric equipment capable of releasing sufficient electric or thermal energy to ignite a hazardous air mixture shall not be energized unless suitable ventilation is maintained to prevent the accumulation of hazardous air mixtures when flammable or combustible materials, such as solvents, paints, glues, or other volatiles, are occasionally used or when work practices occasionally result in accumulations of ignitible or conductive dust in workplaces not classified as hazardous.

NOTE: Electrical installation requirements for locations where flammable materials are present on a regular basis are contained in Part I, Chapter 5.

2-5.14 Overcurrent Protection Modification. Overcurrent protection of circuits and conductors shall not be modified in a manner that could cause injury.

2-6 Anticipating Failure. When planning how to deal with the impending failure, the preferred approach shall be to deenergize the equipment.

Chapter 3 Personal and Other Protective Equipment

3-1 General. Employees working in areas where there are possible electrical hazards shall be provided with, and shall use, protective equipment that is appropriate for the specific part(s) of the body to be protected and for the work to be performed. Protective equipment shall be of safe design and construction for the specific part(s) of the body exposed to the hazard.

3-2 Care of Equipment. All such protective equipment shall be maintained in a safe, reliable condition. Protective equipment shall be periodically inspected or tested, or both. Employees shall visually inspect each item of personal and other protective equipment prior to use. (*See applicable standards listed in Tables 3-3.6 and 3-4.11.*) Wherever the insulating capability of insulating protective equipment is subject to damage, the insulating material shall be protected by means such as leather protectors over rubber gloves and suitable protection to prevent abrasion or puncture of rubber blankets.

3-3 Personal Protective Equipment. Employees shall wear protective equipment for the head, face, neck, chin, eyes, ears, body, and extremities when determined necessary in accordance with 2-5.1.6, Evaluating the Degree of Electrical Hazard. Clothing and equipment that maximize worker protection shall be utilized. Clothing and equipment required by the degree of exposure shall be permitted to be worn alone or be integrated with normal apparel. It shall cover associated parts of the body and all normal apparel that is not flash-flame resistant, while allowing movement and visibility. All personal protective equipment shall be maintained in a sanitary and reliable condition.

3-3.1 Head, Face, Neck, and Chin Protection. Employees shall wear nonconductive flame-resistant head protection wherever there is a danger of head injury from electric shock or burns due to contact with exposed, energized electrical conductors or circuit parts, or from falling objects. Where there is potential exposure to arc flash burns, or to flying objects, the head protection shall be supplemented by a cape, scarf, and full face shield or hood with a viewing window.

3-3.2 Eye Protection. Face shields, windows, and safety glasses shall be used to protect the eyes from potentially flying or falling objects. Where there is potential exposure to arc flash conditions, they shall protect the eyes from the resulting thermal and luminous energy.

3-3.3 Body Protection. Employees shall wear clothing resistant to flash flame wherever there is possible exposure to an electric arc flash.

NOTE: Such clothing can be provided as shirt and trousers, or as coveralls, or as a combination of jacket and trousers, or, for maximum protection, as coveralls and jacket. Various weight fabrics of 4 oz, 6 oz, or 10 oz are available. The higher degree of protection is provided by heavier weight fabrics or by layering combinations of natural fiber clothing resistant to electric arc flash.

3-3.4 Hand and Arm Protection. Insulating rubber gloves with leather protectors and insulating rubber sleeves shall be used as required where there is danger of hand and arm injury from electric shock or burns due to contact with exposed, energized electrical conductors or circuit parts. Appropriate hand and arm protection shall be worn where there is possible

exposure to arc flash burns. Arm protection shall be accomplished by apparel described in 3-3.3.

3-3.5 Foot and Leg Protection. Where insulated footwear must be depended on as the primary personal protection against step and touch potential, then dielectric overshoes shall be required. Appropriate foot and leg protection shall be worn. Insulated soles shall not be used as an alternative to rubber insulated mats.

3-3.6 Standards for Personal Protective Equipment. Personal protective equipment shall conform to the standards in Table 3-3.6, where applicable.

Table 3-3.6 Standards on Protective Equipment

Subject	Number and Title
Head Protection	ANSI Z89.1, *Requirements for Protective Headwear for Industrial Workers*, 1986
Eye and Face Protection	ANSI Z87.1, *Practice for Occupational and Educational Eye and Face Protection*, 1989
Gloves	ASTM D120, *Standard Specification for Rubber Insulating Gloves*, 1987
Sleeves	ASTM D1051, *Standard Specification for Rubber Insulating Sleeves*, 1987
Gloves and Sleeves	ASTM F496, *Standard Specification for In-Service Care of Insulating Gloves and Sleeves*, 1991
Leather Protectors	ASTM F696, *Standard Specification for Leather Protectors for Rubber Insulating Gloves and Mittens*, 1991
Footwear	ASTM F1117, *Standard Specification for Dielectric Overshoe Footwear*, 1987
	ANSI Z41, *Standard for Personnel Protection, Protective Footwear*, 1983
Visual Inspection	ASTM F1236, *Standard Guide for Visual Inspection of Electrical Protective Rubber Products*, 1989
Apparel	ASTM F1506, *Standard Specification for Protective Wearing Apparel for Use by Electrical Workers When Exposed to Momentary Electric Arc and Related Thermal Hazards*, 1994

ANSI - American National Standards Institute
ASTM - American Society for Testing and Materials

3-4 Other Protective Equipment.

3-4.1 Insulated Hand Tools.

3-4.1.1 Qualifications for Insulated Tools. Insulated tools and their accessories shall be insulated for a voltage not less than that of the conductors and circuit parts on which they will be used and shall be suitable for the environment in which they will be used and for the conditions of use.

3-4.1.2 Fiberglass-Reinforced Plastic Rods. Fiberglass-reinforced plastic rods used to make insulating tools shall meet the requirements of the appropriate ASTM standard.

3-4.2 Personal Safety Grounding Equipment. Temporary protective grounding equipment shall be required to meet the specific fault duty of the electrical system to which it might be temporarily applied and the requirements of the appropriate ASTM standard.

3-4.3 Nonconductive Ladders.

3-4.3.1 Nonconductive ladders shall meet the requirements of the appropriate ANSI standards for ladders, with the required nonconductive properties specified.

3-4.3.2 Ladders used for "bare-hand" method over 1000 volts shall be suitable for the purpose.

3-4.4 Rubber Insulating Equipment. Rubber insulating equipment for protection of employees from accidental contact with exposed energized electrical conductors or circuit parts shall meet the requirements of the appropriate ASTM standards.

3-4.5 Voltage Rated Plastic Guard Equipment. Plastic guard equipment for protection of workers from accidental contact with exposed, energized electrical conductors or circuit parts, or to protect the worker or energized equipment or material from contact with ground, shall meet the tests required by the appropriate ASTM standard.

NOTE: Guard equipment falls into the following categories:

(a) Conductor guards and connecting covers,

(b) Structure and apparatus covers,

(c) Insulating barriers.

3-4.6 Physical or Mechanical Barriers. Physical or mechanical (field fabricated) barriers shall be installed no closer than the restricted approach boundary listed in Table 2-3.3.5.

3-4.7 Safety Signs and Tags. Safety signs, safety symbols, or accident prevention tags shall be used where necessary to warn employees about electrical hazards that might endanger them. Such signs and tags shall meet the ANSI requirements for signs and tags.

3-4.8 Barricades. Barricades shall be used in conjunction with safety signs where it is necessary to prevent or limit employee access to work areas exposing employees to uninsulated energized electrical conductors or circuit parts. Conductive barricades shall not be used where they might cause an electrical hazard. Barricades shall be no closer than the limited approach boundary listed in Table 2-3.3.5.

3-4.9 Alternate Alerting Techniques. Where work areas are such that signs and barricades do not provide adequate warning and protection from electrical hazards, manual signaling and alerting shall be used to warn and protect employees. The primary duty and responsibility of an attendant providing manual signaling and alerting shall be to keep unqualified employees outside a work area where the unqualified employee might be exposed to electrical hazards. An attendant shall remain in the area as long as there is a potential for employees to be exposed to the electrical hazards.

3-4.10 Protective Qualifications for Test Instruments and Equipment. Test instruments and their accessories shall be voltage rated for circuits and equipment to which they will be connected and shall be suitable for the environment in which they will be used and for the conditions of use.

3-4.11 Standards for Other Protective Equipment. All other protective equipment required in Section 3-4 shall conform to the applicable standards listed in Table 3-4.11.

Table 3-4.11 Standards on Other Protective Equipment

Subject	Number and Title
Ladders	ANSI A14.1, *Safety Requirements for Portable Wood Ladders,* 1990
	ANSI A14.3, *Safety Requirements for Fixed Ladders,* 1984
	ANSI A14.4, *Safety Requirements for Job-Made Ladders,* 1992
	ANSI A14.5, *Safety Requirement for Portable Reinforced Plastic Ladders,* 1982
Safety Signs and Tags	ANSI Z535, *Series of Standards for Safety Signs and Tags,* 1991
Mats	ASTM D178, *Standard Specification for Rubber Insulating Matting,* 1988
Blankets	ASTM D1048, *Standard Specification for Rubber Insulation Blankets,* 1993
Covers	ASTM D1049, *Standard Specification for Rubber Covers,* 1988
Line Hoses	ASTM D1050, *Standard Specification for Rubber Insulating Line Hoses,* 1990
Line Hoses and Covers	ASTM F478, *Standard Specification for In-Service Care of Insulating Line Hose and Covers,* 1987
Blankets	ASTM F479, *Standard Specification for In-Service Care of Insulating Blankets,* 1993
Fiberglass Tools/Ladders	ASTM F711, *Standard Specification for Fiberglass-Reinforced Plastic (FRP) Rod and Tube Used; in Line Tools,* 1989
Plastic Guards	ASTM F712, *Test Methods for Electrically Insulating Plastic Guard Equipment for Protection of Workers,* 1988
Temporary Grounding	ASTM F855, *Standard Specification for Temporary Grounding Systems to be Used on Deenergized Electric Power Lines and Equipment,* 1990
Insulated Hand Tools	ASTM F1505, *Specification for Insulated Hand Tools,* 1994

ANSI - American National Standards Institute
ASTM - American Society for Testing and Materials

Chapter 4 Use of Specific Safety-Related Equipment and Work Practices

4-1 Working with Test Instruments and Equipment. Only qualified employees who have been trained to meet the requirements of Section 2-2 of Part II and to understand the hazards associated with test instruments and equipment on exposed energized electrical conductors and circuit parts shall be permitted to perform testing work on such facilities where there is possibility of injury due to unintentional contact with energized conductors or circuit parts, improper use of the test instruments and equipment, or equipment failure.

4-1.1 Qualified employees who have been trained to understand the hazards associated with test instruments and equipment and to avoid those hazards shall be permitted to perform electrical testing on exposed energized electrical conductors or circuit parts without the placement of locks or tags on the disconnecting device, if the test equipment is rated for the normal voltage on the electric circuit or equipment. (*See 3-4.10 of Part II.*) Repair or replacement of circuit components requires lockout and/or tagout in accordance with other sections of this standard.

4-1.2 Visual Inspection of Test Instruments and Equipment. Test instruments and equipment and all associated test leads, cables, power cords, probes, and connectors shall be visually inspected by the user for external defects or damage before they are used on any shift. If there are defects or evidence of damage that might expose an employee to injury, the defective or damaged item shall not be used until any required repairs and tests have been made.

4-2 Energizing and Deenergizing Electrical Power Circuits.

4-2.1 Routine Opening and Closing of Circuits. Load-rated switches, circuit breakers, or other devices specifically designed as disconnecting means shall be used for the opening, reversing, or closing of circuits under load conditions. Cable connectors not of the load-break type, fuses, terminal lugs, and cable splice connections shall not be permitted to be used for such purposes, except in an emergency.

4-2.2 Reclosing Circuits after Protective Device Operation. After a circuit is automatically deenergized by a circuit protective device, the circuit shall not be manually reenergized until it has been determined that the equipment and circuit can be safely energized. The repetitive manual reclosing of circuit breakers or reenergizing circuits through replaced fuses shall be avoided. When it is determined from the design of the circuit and the overcurrent devices involved that the automatic operation of a device was caused by an overload rather than a fault condition, examination of the circuit or connected equipment shall not be required before the circuit is reenergized.

4-3 Portable Electric Equipment and Flexible Cord Sets. This section shall apply to the use of cord- and plug-connected equipment and cord sets (extension cords).

4-3.1 Protection from Damage. Work practices that are likely to damage and impair the safety of portable cord-connected equipment and flexible cord sets shall not be permitted.

The use of electric cords for hoisting or lowering portable cord-connected equipment or tools shall not be permitted. Flexible cords shall not be fastened with staples or hung in such a manner as to damage the insulation.

4-3.2 Grounding of Portable Electric Equipment.

4-3.2.1 Only flexible cords and cables that contain an equipment grounding conductor shall be used for cord- and plug-connected portable equipment that is required to be grounded by the provisions of Part I. Flexible cords and cables without an equipment grounding conductor shall be permitted to be used with cord- and plug-connected equipment that is protected by an approved system of double insulation, or its equivalent, or where the equipment is supplied through an isolating transformer with an ungrounded secondary of not over 50 volts.

4-3.2.2 Attachment plugs and receptacles shall not be altered or modified in a manner that prevents proper continuity of the equipment grounding conductor at the point where plugs are attached to receptacles and shall not be altered to allow the grounding pole of a plug to be inserted into contacts intended for connection to the current-carrying conductors.

4-3.2.3 Adapters that interrupt the continuity of the equipment grounding connection shall not be used.

4-3.3 Visual Inspection of Portable Cord- and Plug-Connected Equipment and Flexible Cord Sets.

4-3.3.1 Frequency of Inspection. Portable cord- and plug-connected equipment and flexible cord sets (extension cords) shall be visually inspected before use on any shift for external defects such as loose parts, deformed and missing pins, and evidence of possible internal damage (such as pinched or crushed outer jacket).

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

4-3.3.2 Defective Equipment. If there is a defect or evidence of damage that might expose an employee to injury, the defective or damaged item shall be removed from service, and no employee shall be permitted to use it until necessary repairs and tests to render the equipment safe have been made.

4-3.3.3 Proper Mating. When attachment plugs are to be connected to receptacles, the relationship of the plug and receptacle contacts shall first be checked to ensure that they are of the same configuration.

4-3.4 Conductive Work Locations. Employees required to operate or handle energized portable electric equipment and flexible cords in highly conductive work locations, such as those inundated with water or conductive liquids, or in job locations where such employees are likely to contact or be drenched with water or conductive liquids, shall use cord-connected electric equipment, tools, and flexible cord sets that are approved for operation in such environments, or use ground-fault circuit-interrupter protection for personnel.

4-3.5 Connecting Attachment Plugs. Employees' hands shall be dry when plugging and unplugging flexible cords and cord- and plug-connected equipment, if energized equipment is involved. Energized plug and receptacle connections shall be handled only with insulating protective equipment if the condition of the connection could provide a conductive path to the employee's hand (if, for example, a cord connector is wet from being immersed in water). Locking-type connectors shall be properly secured after connecting.

Chapter 5 Lockout/Tagout Practices and Devices

5-1 General. All electrical circuit conductors and circuit parts shall be considered energized until the source(s) of energy is (are) removed, at which time they shall be considered deenergized. All electrical circuit conductors and circuit parts shall not be considered to be in an electrically safe condition until all sources of energy are removed, the disconnecting means is under lockout/tagout, the absence of voltage is verified by an approved voltage testing device, and, where exposure to energized facilities exist, are temporarily grounded (*see 2-3.1.3 for the six-step procedure to establish an electrically safe work condition*). Electrical conductors and circuit parts that have been disconnected, but not under lockout/tagout, tested, and grounded (where appropriate) shall not be considered to be in an electrically safe work condition, and safe work practices appropriate for the circuit voltage and energy level shall be used. Lockout/tagout requirements shall apply to fixed permanently installed equipment, temporarily installed equipment, and to portable equipment.

5-1.1 Principles of Lockout/Tagout Execution.

5-1.1.1 Each person who could be exposed directly or indirectly to a source of electrical energy shall be involved in the lockout/tagout process.

NOTE: An example of direct exposure is the qualified electrician who is to work on the motor starter control, or power circuits, or the motor. An example of indirect exposure is the person who is to work on the coupling between the motor and compressor.

5-1.1.2 All persons who could be exposed shall be trained to understand the established procedure to control the energy and their responsibility in executing the procedure. New (or reassigned) employees shall be trained (or retrained) to understand the lockout/tagout procedure as related to their new assignment.

5-1.1.3 A plan shall be developed based on the existing electrical equipment and system and shall utilize up-to-date diagrammatic drawing representation(s).

5-1.1.4 All sources of electrical energy shall be controlled in such a way as to minimize employee exposure to electrical hazards.

5-1.1.5 The lockout/tagout device shall be unique and readily identifiable as a lockout/tagout device.

5-1.1.6 Voltage shall be removed and absence of voltage verified.

5-1.1.7 The established electrical lockout/tagout procedure shall be coordinated with all of the employer's procedures associated with lockout/tagout of other energy sources. The lockout/tagout procedure shall be audited for execution and completeness on an annual basis.

5-1.2 Responsibility. The employer shall establish lockout/tagout procedures for the organization, provide training to employees, provide equipment necessary to execute the details of the procedure, audit execution of the procedures to ensure employee understanding/compliance, and audit the procedure for improvement opportunity and completeness.

There are three forms of hazardous electrical energy control that shall be permitted: individual employee control, simple lockout/tagout, and complex lockout/tagout. (*See 5-1.3.*) For the individual employee control and the simple lockout/tagout, the qualified person shall be in charge. For the complex lockout/tagout, the person in charge shall have overall responsibility. (*See Appendix D of Part II for a sample lockout/tagout procedure.*)

5-1.2.1 Audit. An audit shall be conducted at least annually by a qualified person and shall cover at least one lockout/tagout in progress and the procedure details. The audit shall be designed to correct deficiencies in the procedure or in employee understanding.

5-1.3 Hazardous Electrical Energy Control Procedures.

5-1.3.1 Individual Qualified Employee Control Procedure. The individual qualified employee control procedure shall be permitted when equipment with exposed conductors and circuit parts are deenergized for minor maintenance, servicing, adjusting, cleaning, inspection, operating conditions, and the like. The work shall be permitted to be performed without the placement of lockout/tagout devices on the disconnecting means, provided the disconnecting means is adjacent to the

conductor, circuit parts, and equipment on which the work is performed, the disconnecting means is clearly visible to the individual qualified employee involved in the work, and the work does not extend beyond one shift.

5-1.3.2 Simple Lockout/Tagout Procedure. All lockout/tagout procedures that are not under individual qualified employee control (*see 5-1.3.1*) or complex lockout/tagout (*see 5-1.3.3*) shall be considered to be simple lockout/tagout procedures. All lockout/tagout procedures that involve only a qualified person(s) deenergizing one set of conductors or circuit part source for the sole purpose of performing work on or near electrical equipment shall be considered to be a simple lockout/tagout. Simple lockout/tagout plans shall not be required to be written for each application. Each worker shall be responsible for his or her own lockout/tagout.

5-1.3.3 Complex Lockout/Tagout Procedure. A complex lockout/tagout plan shall be permitted where one or more of the following exist:

(a) Multiple energy sources,

(b) Multiple crews,

(c) Multiple crafts,

(d) Multiple locations,

(e) Multiple employers,

(f) Different disconnecting means,

(g) Particular sequences, or

(h) Continues for more than one work period.

There shall be a person in charge of a complex lockout/tagout procedure. The person in charge of a lockout/tagout shall be a qualified person who is specifically appointed with overall responsibility to ensure that all energy sources are under lockout/tagout and to account for all persons working on the job/task.

The procedure shall identify the person in charge. In this (these) instance(s), the person in charge shall be permitted to install locks/tags, or direct their installation, on behalf of other employees. The person-in-charge shall be held accountable for safe execution of the complex lockout/tagout. The complex lockout/tagout procedure shall address all the concerns of employees who might be exposed. All complex lockout/tagout procedures shall require a written plan of execution that identifies the person in charge. All complex lockout/tagout plans identify the method to account for all persons who might be exposed to electrical hazards in the course of the lockout/tagout.

5-1.4 Coordination.

5-1.4.1 The established electrical lockout/tagout procedure shall be coordinated with all other employer's procedures for control of exposure to electrical energy sources such that all employer's procedural requirements are adequately addressed on a site basis.

5-1.4.2 The procedure for control of exposure to electrical hazards shall be coordinated with other procedures for control of other hazardous energy sources such that they are based on similar/identical concepts.

5-1.4.3 The electrical lockout/tagout procedure shall always include voltage testing requirements where there might be direct exposure to electrical energy hazards.

5-1.4.4 Electrical lockout/tagout devices shall be permitted to be similar to lockout/tagout devices for control of other hazardous energy sources, such as pneumatic, hydraulic, thermal, and mechanical, provided such devices are used only for control of hazardous energy and for no other purpose.

5-2 Training and Retraining. Each employer shall provide training as required to ensure employees' understanding of the lockout/tagout procedure content and their duty in executing such procedures.

5-3 Equipment.

5-3.1 Lock/Tag Application. Energy isolation devices for machinery or equipment installed after January 2, 1990, shall be capable of accepting a lockout/tagout device.

5-3.2 Lockout/Tagout Device. Each employer shall supply and employees shall use lockout/tagout devices and equipment necessary to execute the requirements of Section 5-3. Locks and tags used for control of exposure to electrical energy hazards shall be unique, shall be readily identifiable as lockout/tagout devices, and shall be used for no other purpose.

5-3.3 Lockout Device.

5-3.3.1 A lockout device includes a lock (either keyed or combination).

5-3.3.2 The lockout device shall include a method of identifying the individual who installed the lockout device.

5-3.3.3 A lockout device shall be permitted to be only a lock, provided the lock is readily identifiable as a lockout device, in addition to a means of identifying the person who installed the lock.

5-3.3.4 Lockout devices shall be attached to prevent operation of the disconnecting means without resorting to undue force or the use of tools.

5-3.3.5 The tag used in conjunction with a lockout device shall contain a statement prohibiting unauthorized operation of the disconnecting means or unauthorized removal of the device.

5-3.3.6 Lockout devices shall be suitable for the environment and for the duration of the lockout.

5-3.3.7 Whether keyed or combination locks are used, the key or combination shall remain in the possession of the individual installing the lock or the person in charge, when provided by the established procedure.

5-3.4 Tagout Device.

5-3.4.1 A tagout device shall include a tag together with an attachment means.

5-3.4.2 The tagout device shall be readily identifiable as a tagout device and suitable for the environment and duration of the tagout.

5-3.4.3 A tagout device attachment means shall be capable of withstanding at least 50 pounds of force (222.4 N) exerted at a right angle to the disconnecting means surface. The tag attachment means shall be nonreusable, attachable by hand, self-locking, and nonreleasable, equal to an all-environmental tolerant nylon cable tie.

Exception: A "hold card tagging tool" on an overhead conductor in conjunction with a hotline tool to install the tagout device safely on a disconnect that is isolated from the worker(s).

5-3.4.4 Tags shall contain a statement prohibiting unauthorized operation of the disconnecting means or removal of the tag.

5-3.5 Electrical Circuit Interlocks. Up-to-date diagrammatic drawings shall be consulted to ensure that no electrical circuit interlock operation can result in reenergizing the circuit being worked on.

5-3.6 Control Devices. Locks/tags shall only be installed on circuit disconnecting means. Control devices, such as pushbuttons or selector switches, shall not be used as the primary isolating device.

5-4 Procedures. The employer shall maintain a copy of the procedures required by this section and shall make the procedures available to all employees.

5-4.1 Planning. The procedure shall require planning, including 5-4.1.1 through 5-4.2.14.

5-4.1.1 Locating Sources. Up-to-date single-line drawings shall be considered a primary reference source for such information. When up-to-date drawings are not available, the employer shall be responsible to ensure that an equally effective means of locating sources of energy is employed.

5-4.1.2 Exposed Persons. The plan shall identify persons that might be exposed to an electrical hazard during the execution of the job or task.

5-4.1.3 Person In Charge. The plan shall identify the person in charge and his or her responsibility in the lockout/tagout.

5-4.1.4 Individual Qualified Employee Control. Individual qualified employee control shall be in accordance with 5-1.3.1.

5-4.1.5 Simple Lockout/Tagout. Simple lockout/tagout procedure shall be in accordance with 5-1.3.2.

5-4.1.6 Complex Lockout/Tagout. Complex lockout/tagout procedure shall be in accordance with 5-1.3.3.

5-4.2 Elements of Control. The procedure shall identify elements of control.

5-4.2.1 Deenergizing Equipment (Shutdown). The procedure shall establish the person who performs the switching and where and how to deenergize the load.

5-4.2.2 Stored Energy. The procedure shall include requirements for releasing stored electric or mechanical energy that might endanger personnel. All capacitors shall be discharged, and high capacitance elements shall also be short-circuited and grounded before the associated equipment is touched or worked on. Springs shall be released or physical restraint shall be applied when necessary to immobilize mechanical equipment and pneumatic and hydraulic pressure reservoirs. Other sources of stored energy shall be blocked or otherwise relieved.

5-4.2.3 Disconnecting Means. The procedure shall identify how to verify that the circuit is deenergized (open).

5-4.2.4 Responsibility. The procedure shall identify the person who is responsible to verify that the lockout/tagout procedure is implemented and who is responsible to ensure that the task is completed prior to removing locks/tags. A mechanism to accomplish lockout/tagout for multiple(complex) jobs/tasks where required, including the person responsible for coordination, shall be included.

5-4.2.5 Verification. The procedure shall verify that equipment cannot be restarted. The equipment operating controls, such as pushbuttons, selector switches, and electrical interlocks, shall be operated or otherwise shall be verified that the equipment cannot be restarted.

5-4.2.6 Testing. The procedure shall establish: what voltage detector will be used and who will use it to verify that the voltage has been removed; a requirement to verify proper operation of the voltage detector before and after use; a requirement to retest for absence of voltage when circuit conditions change or when the job location has been left unattended; and, where there are no accessible exposed points to take voltage measurements, planning considerations shall include methods of verification.

5-4.2.7 Grounding. Grounding requirements for the circuit shall be established, including whether the grounds shall be installed for the duration of the task or temporarily are established by the procedure. Grounding needs or requirements shall be permitted to be covered in other work rules and might not be part of the lockout/tagout procedure.

5-4.2.8 Shift Change. A method shall be identified in the procedure to transfer responsibility for lockout/tagout to another person or person in charge when the job or task extends beyond one shift.

5-4.2.9 Coordination. The procedure shall establish how coordination is accomplished with other jobs or tasks in progress, including related jobs or tasks at remote locations, including the person responsible for coordination.

5-4.2.10 Accountability for Personnel. A method shall be identified in the procedure to account for all persons who could be exposed to hazardous energy during the lockout/tagout.

5-4.2.11 Lockout/Tagout Application. The procedure shall clearly identify when and where lockout applies, in addition to when and where tagout applies.

(a) Lockout is defined as installing a lockout device on all sources of hazardous energy such that operation of the disconnecting means is prohibited, and forcible removal of the lock is required to operate the disconnect means.

(b) Tagout is defined as installing a tagout device on all sources of hazardous energy, such that operation of the disconnect means is prohibited. The tagout device shall be installed in the same position available for the lockout device.

(c) Where it is not possible to attach a lock to existing disconnecting means, the disconnecting means shall not be used as the only means to put the circuit in an electrically safe work condition.

(d) Where tagout is employed, at least one additional safety measure shall be employed. The procedure shall clearly establish responsibilities and accountability for each person that might be exposed to electrical hazards. The employer shall establish that tagout provides equivalent safety as a lockout.

5-4.2.12 Removal of Lockout/Tagout Devices. The procedure shall identify the details for removing locks or tags when the installing individual is unavailable. When locks or tags are removed by other than the installer, the employer shall attempt to locate the person prior to removing the lock or tag.

When the lock or tag is removed because the installer is unavailable, the installer shall be informed prior to return to work.

5-4.2.13 Release for Return to Service. The procedure shall identify steps to be taken when the job or task requiring lockout/tagout is completed. Before electric circuits or equipment are reenergized, appropriate tests and visual inspections shall be conducted to verify that all tools, mechanical restraints and electrical jumpers, shorts, and grounds have been removed, so that the circuits and equipment are in a condition to be safely energized. Where appropriate, the employees responsible for operating the machines or process shall be notified when circuits and equipment are ready to be energized, and such employees shall provide assistance as necessary to safely energize the circuits and equipment. The procedure shall contain a statement requiring the area to be inspected to ensure that nonessential items have been removed.

One such step shall ensure that all personnel are clear of exposure to dangerous conditions resulting from reenergizing the service and that blocked mechanical equipment or grounded equipment is cleared and prepared for return to service.

5-4.2.14 Temporary Release for Testing/Positioning. The procedure shall clearly identify the steps and qualified persons' responsibilities when the job or task requiring lockout/tagout is to be interrupted temporarily for testing or positioning of equipment; then the steps shall be identical to the steps for return to service. See Chapter 3, 3-4.10 of Part II, and Chapter 4, Section 4-1 of Part II for requirements when using test instruments and equipment.

PART II, Appendix A, Limits of Approach

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

Reference Sections.

Chapter 1, Section 1-5, Definitions.

Chapter 2, Section 2-3, Working On or Near Electrical Conductors or Circuit Parts.

A-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 is decreased, the potential for electrical accident increases.

A-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 flash protection boundary unless they are wearing appropriate personal protective clothing and are under the close supervision of a qualified person.

A-1.2 Qualified Persons, Safe Approach Distance.

A-1.2.1 Determine the flash protection boundary and, if the boundary is to be crossed, appropriate flash-flame protection equipment shall be utilized.

A-1.2.2 For a person to cross the limited approach boundary and enter the limited space, he or she must be qualified to perform the job/task.

A-1.2.3 To cross the restricted approach boundary and enter the restricted space, the qualified person must:

(a) Have a plan that is documented and approved by authorized management.

(b) Use personal protective equipment appropriate for working near exposed energized conductors or circuit parts, and rated for the voltage and energy level involved.

(c) Be certain that no part of the body shall enter the prohibited space.

(d) Minimize the risk due to inadvertent movement by keeping as much of the body out of the restricted space, using only protected body parts in the space as necessary to accomplish the work.

A-1.2.4 To cross the prohibited approach boundary and enter the prohibited space is considered the same as making contact with exposed energized conductors or circuit parts. The qualified person must:

(a) Have specified training to work on energized conductors or circuits parts.

(b) Have a documented plan justifying the need to work that close.

(c) Perform a risk analysis.

(d) Have (b) and (c) approved by authorized management.

(e) Use personal protective equipment appropriate for working on exposed energized conductors or circuit parts, and rated for the voltage and energy level involved.

Basis for Distance Values in Table 2-3.3.5.

General Statement: Columns 1 through 6 of Table 2-3.3.5 all show various distances from the exposed energized electrical conductors or circuit part. They include dimensions that are added to a basic minimum air insulation distance. That basic minimum air insulation distance for voltages 72.5 kV and under are based on ANSI/IEEE 4-1978, Fourth Printing, Appendix 2B; and for voltages over 72.5kV, are based on ANSI/IEEE 516-1987. These minimum air insulation distances required to avoid flashover are:

300V and less - 0 ft 0.03 in.
Over 300V, not over 750V - 0 ft 0.07 in.
Over 750V not over 2kV - 0 ft 0.19 in.
Over 2kV, not over 15kV - 0 ft 1.5 in.
Over 15kV, not over 36kV - 0 ft 6.3 in.
Over 36kV, not over 48.3kV - 0 ft 10.0 in.
Over 48.3kV, not over 72.5kV - 1 ft 3.0 in
Over 72.5kV, not over 121kV - 2 ft 1.2 in.
Over 138kV, not over 145kV - 2 ft 6.6 in.
Over 161kV, not over 169kV - 3 ft 0.0 in.
Over 230kV, not over 242kV - 4 ft 2.4 in.
Over 345kV, not over 362kV - 7 ft 5.8 in.
Over 500kV, not over 550kV - 10 ft 2.5 in.
Over 765 kV, not over 800kV - 13 ft 10.3 in.

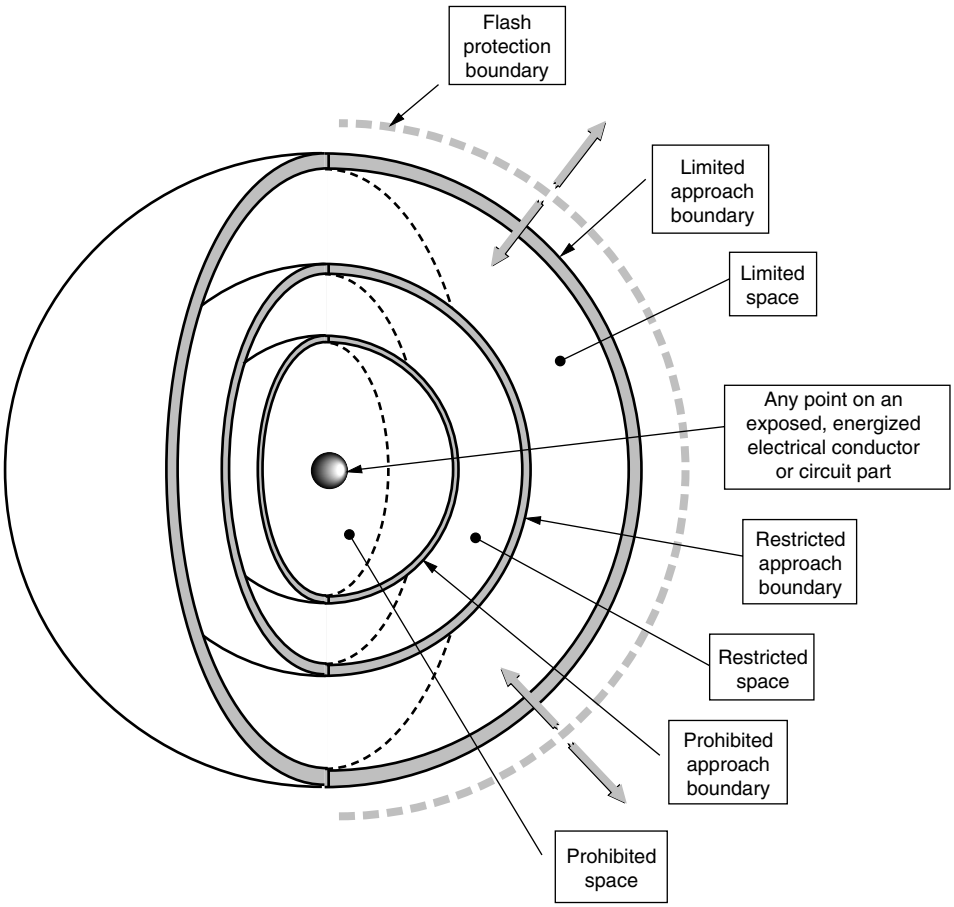

Figure A-1-2.4 Limits of approach.

Column No. 1: The voltage ranges have been selected to group voltages that require similar approach distances based on the sum of the electrical withstand distance and an inadvertent movement factor. The value of the upper limit for a range is the maximum voltage for highest nominal voltage in the range based on ANSI C84.1-1989. For single-phase systems, select the range that is equal to the system's maximum phase-to-ground voltage times 1.732.

Column No. 2: The distances in this column are derived from formulae developed from a technical paper by Ralph Lee, "The Other Electrical Hazard: Electrical Arc Blast Burns." Distances provided are based on the maximum available fault current for the highest voltage level in each voltage range.

Column No. 3: The distances in this column are based on OSHA's rule for unqualified persons to maintain a 10 ft (3.05 m) clearance for all voltages up to 50kV (voltage-to-ground), plus 0.4 in. (102 mm) for each 1kV over 50kV.

Column No. 4: The distances are based on the following:

750 V and lower, use *NEC* Table 110-16(a) Working Clearances, Condition 2 for 151 - 600V range.

For over 750V, but not over 145kV, use *NEC* Table 110-34(a) Working Space, Condition 2.

Over 145kV, use OSHA's 10 ft (3.05 m) rules as used in Column No. 3.

Column No. 5: The distances are based on adding to the flashover dimensions shown above the following inadvertent movement distance:

300V and less, avoid contact.

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

Over 300V and not over 750V, add 1 ft 0 in. inadvertent movement.

These values have been found to be adequate over years of use in ANSI C2, *National Electrical Safety Code*, in the approach distances for communication workers.

Over 750V and not over 72.5kV, add 2 ft 0 in. inadvertent movement.

Over 72.5kV, add 1 ft 0 in. inadvertent movement.

These values have been found to be adequate over years of use in the *National Electrical Safety Code* in the approach distances for supply workers.

Column No. 6: The distances are based on the following:

300V and less, avoid contact.

Over 300 but less than 750V, use *NEC* Table 230-51(c), Clearances.

Between open conductors and surfaces, 600V not exposed to weather.

Over 750V but not over 2.0kV, value selected that fits in with adjacent values.

Over 2kV but not over 72.5kV, use *NEC* Table 710-33, Minimum Clearance of Live Parts, outdoor phase-to-ground values.

Over 72.5kV, add 0 ft 6 in. inadvertent movement.

These values have been found to be adequate over years of use where there has been a hazard/risk analysis, either formal or informal, of a special work procedure that allows closer approach than that permitted by the restricted approach boundary distance.

PART II, Appendix B, Sample Calculation of Flash Protection Boundary

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

See Chapter 2-3.3.3.

B-1 Development of Arc Energy and Temperature Rise on a Person's Exposed Skin. The following provides an explanation of the development of the arc energy and temperature rise on a person's exposed skin due to various strengths of electrical arc blasts at various distances from the involved person. The formulae used in this explanation are from Ralph Lee's paper, "The Other Electrical Hazard: Electrical Arc Blast Burns," IEEE Trans. Industrial Applications, Vol 1A-18. No. 3, Page 246, May/June 1982. The calculations are based on the worst case arc impedance.

B-2 Basic Equations for Calculating Flash Protection Boundary Distances.

B-2.1 The short-circuit symmetrical amperes from a bolted 3-phase fault at the transformer terminals is calculated with the following formula:

$$I_{sc} = \{[\text{MVA Base} \times 10^6] \div [1.732 \times V]\} \times \{100 \div \%Z\}$$

Where I_{sc} is in amperes, V is in volts, and %Z is based on the transformer MVA.

B-2.2 A typical value for the maximum power (in MW) in a 3-phase arc can be calculated using the following formula:

$$P = [\text{Maximum bolted fault in MVA}_{bf}] \times 0.7072$$

B-2.3 The flash protection boundary distance is calculated in accordance with the following formulae:

B-2.3.1 $$P = 1.732 \times V \times I_{sc} \times 10^{-6} \times 0.707^2$$

B-2.3.2 $$D_c = [2.65 \times MVA_{bf} \times t]^{1/2} \text{ or}$$

B-2.3.3 $$D_c = [53 \times MVA \times t]^{1/2}$$

Where:

D_c = distance in feet of person from arc source for a just curable burn (i.e., skin temperature remains less than 80 degrees).

MVA_{bf} = bolted fault MVA at point involved.

MVA = MVA rating of transformer. For transformers with MVA ratings below 0.75 MVA, multiply the transformer MVA rating by 1.25.

t = time of arc exposure in seconds.

The clearing time for a current limiting fuse is approximately ¼ cycle or 0.004 sec. The clearing time of a 5kV and 15kV circuit breaker is approximately 0.1 sec or 6 cycles. This can be broken down as follows: actual breaker time (approximately 2.0 cycles), plus relay operating time of approximately 1.74 cycles, plus an additional safety margin of 2 cycles, giving a total time of approximately 6 cycles.

B-3 Single Line Diagram of a Typical Petrochemical Complex. The single line diagram illustrates the complexity of a distribution system in a typical petrochemical plant.

B-4 Sample Calculation. Many of the electrical characteristics of the systems and equipment are provided in Table B-1. The sample calculation is made on the 4,160-volt bus 4A or 4B. Table B-1 tabulates the results of calculating the

Table B-1 Flash Burn Hazards at Various Levels in a Large Petrochemical Plant

Bus Nominal Voltage Levels	System MVA	Transfmr MVA	System or Transfmr %Z	Short Circuit Symmetrical Amperes	Arc MW	Clearing Time of Fault Cycles	Distance from Arc to Limit Skin Temperature to a Curable Skin Burn [Less than 80°C (176°F) on Skin] In Free Flash Protection Boundary Typical Distance
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
230kV	9000		1.11	23,000	4,000	6.0	46.0
13.8kV	750		9.4	31,300	374	6.0	14.1
Load Side of All 13.8kV Fuses	750		9.4	31,300	374	1.0	5.8
4.16kV		10	5.5	25,000	91	6.0	7.3
4.16kV		5	5.5	12,600	45	6.0	5.5
Line Side of Incoming 600V Fuse		2.5	5.5	44,000	23	6.0	3.7
600V Bus		2.5	5.5	44,000	23	0.25	0.74
600V Bus		1.5	5.5	26,000	27	6.0	2.8
600V Bus		1.0	5.57	17,000	17	6.0	2.3

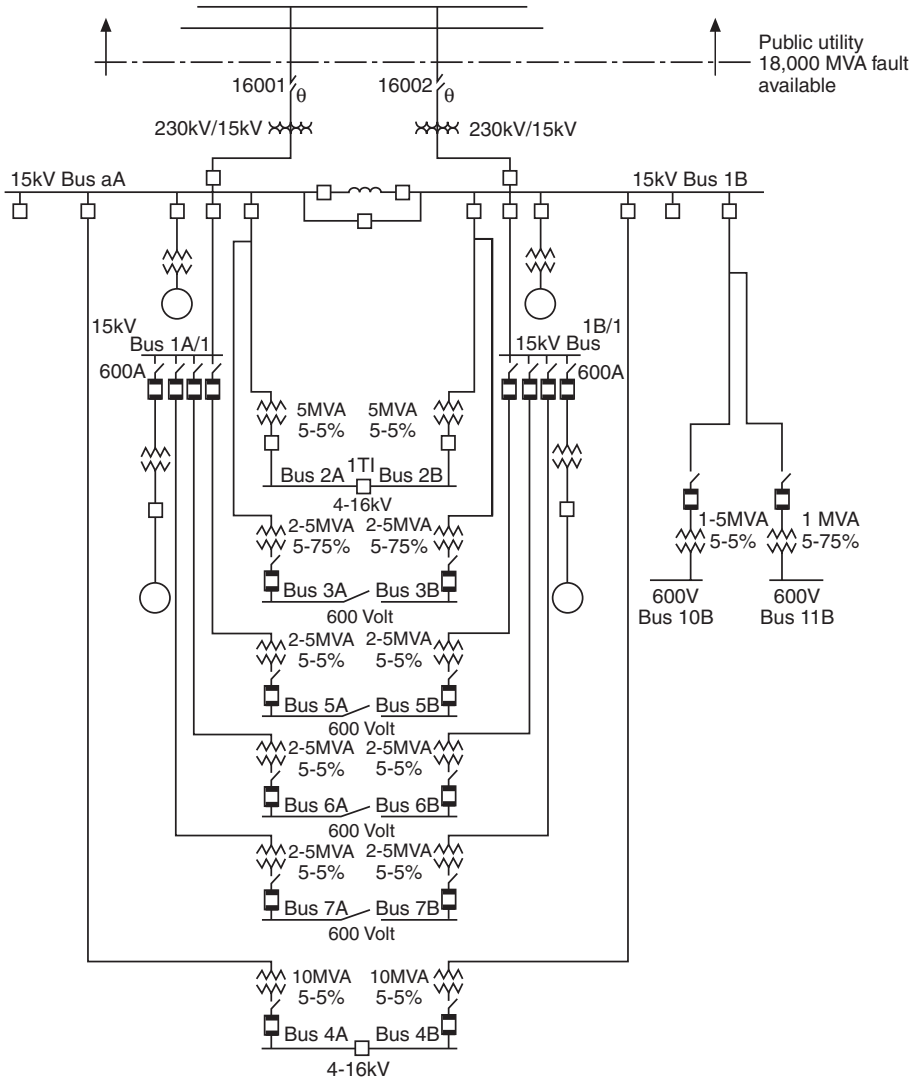

Figure B-3 Single line diagram of a typical petrochemical complex.

B-4.1 Calculation is on a 4,160-volt bus.

B-4.2 Transformer MVA (and base MVA) = 10 MVA.

B-4.3 Transformer impedance on 10 MVA base = 5.5%.

B-4.4 Circuit breaker clearing time = 6 cycles.

B-4.5 Based on equation B-2-1 calculate the short-circuit current:

$$I_{sc} = \{[\text{MVA Base} \times 10^6] \div [1.732 \times V]\}\{100 \div \%Z\}$$
$$= \{[10 \times 10^6] \div [1.732 \times 4,160]\}\{100 \div 5.5\}$$
$$= 25,000 \text{ amperes.}$$

B-4.6 Based on equation B-2-2, calculate the power in the arc:

$$P = 1.732 \times 4,160 \times 25,000 \times 10^{-6} \times 0.707^2$$

P= 91 MW.

B-4.7 Based on equation B-2-3.1, calculate the curable burn distance:

$$= \{2.65 \times [1.732 \times 25,000 \times 4.160 \times 10^{-6}] \times 0.1\}^{1/2}$$
$$= 6.9 \text{ or } 7.00 \text{ feet.}$$

Or, using B-2-3.2, calculate the curable burn distance using an alternate method:

$$= [53 \times 10 \times 0.1]^{1/2}$$
$$= 7.28 \text{ feet}$$