ELECTRICAL SAFETY GUIDELINES

September 1993

U.S. DEPARTMENT OF ENERGY

**Assistant Secretary for Environment, Safety and Health
Washington, DC 20585**

MASTER

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DEPARTMENT OF
ENERGY
ELECTRICAL SAFETY
GUIDELINES

TITLE: PROPOSED IMPROVEMENTS
TO THE DOE ELECTRICAL
SAFETY GUIDELINES

NUMBER:

May 1993

**PROPOSED IMPROVEMENTS TO THE
DOE ELECTRICAL SAFETY GUIDELINES**

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1.0 INTRODUCTION

1.1 PURPOSE

The *Electrical Safety Guidelines* prescribes the Department of Energy (DOE) safety standards for DOE field offices or facilities involved in the use of electrical energy. It has been prepared to provide a uniform set of electrical safety standards and guidance for DOE installations in order to affect a reduction or elimination of risks associated with the use of electrical energy. The objectives of these guidelines are to enhance electrical safety awareness and mitigate electrical hazards to employees, the public, and the environment.

1.2 SCOPE

Provisions contained in the guidelines are applicable to DOE personnel and DOE contractor-operated facilities personnel who are engaged in the design, construction, installation, inspection, testing, maintenance, operation, research and development, and decommissioning of electrical systems. These guidelines shall be used to supplement existing applicable DOE orders, codes, standards, and regulations. The guidelines shall not supersede more stringent requirements contained in other applicable codes, standards, and regulations.

The design of new facilities shall conform to the requirements established in these guidelines; DOE Order 6430.1A, General Design Criteria; and DOE Order 5480.4, Environmental Protection, Safety, and Health Protection Standards. The standards set forth in these guidelines, as they apply to existing facilities and operations, should be evaluated to determine if present systems and operations comply with the stipulated provisions and present a significant safety risk. If the evaluation determines that a safety risk exists, corrective actions shall be initiated to bring the system or operations into

compliance with current standards. However, in case of a major renovation, the existing facility shall be brought into compliance with current standards.

Existing facilities shall also comply with the provisions of the Department of Labor (DOL) Occupational Safety and Health Administration (OSHA) standards 29 CFR 1910, Subpart S; and 29 CFR 1926, Subpart K, Electrical. These standard have specific requirements that shall apply to all electrical installations and utilization equipment regardless of when they were designed or installed. In addition, this standard also identifies other mandatory provisions and specifies effective dates.

The standards presented in these guidelines are either mandatory or advisory. Mandatory standards, denoted by the words "shall," "must," or "will," are requirements that must be followed unless written authority for exemption is granted by DOE. Advisory standards, denoted by the words "should" or "may," are standards that may be deviated from with a written waiver granted by the facility manager and approved by DOE. The waiver shall be based on a technical risk assessment and adequately documented. These advisory or mandatory standards have been drawn from existing criteria.

1.3 AUTHORITY HAVING JURISDICTION (AHJ)

In states and municipalities, an official is usually designated as the electrical Authority Having Jurisdiction (AHJ). The electrical inspector, engineer, or equivalent qualified individuals are often designated the AHJ. The AHJ should possess such executive ability as is required for performance of their duty, and should have thorough knowledge of standard materials and methods used in the installation and maintenance of electrical equipment. The AHJ should be well versed in approved methods of construction and

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procedures of maintenance for safety to persons and property. The AHJ should be knowledgeable through experience or education of the requirements contained in the OSHA standards, the National Electrical Code, the National Electrical Safety Code, DOE requirements, and other appropriate standards. The AHJ should be responsible to interpret codes and regulations and approve equipment, assemblies, or materials. The AHJ may permit alternate methods where it is assured that equivalent objectives can be achieved by establishing and maintaining effective safety equal to or exceeding established codes and standards.

In DOE, levels of authority exist that serve the function of the AHJ. The AHJ may be the contracting officer, such as an area manager. This person may choose to delegate their authority to an individual or organization within their control. The authority may reside with a safety or facilities department. The field office manager or their designated representative may act as a higher level of authority.

Similarly, the DOE contractor must establish a line of authority within their organization. The authority may begin with an electrician and proceed through the electrical inspector, safety, facilities, committee, or management. What is important is that a line of authority is established and recognized. The limits of the authority and recognition of higher authority must be delineated.

1.4 EXEMPTIONS AND WAIVERS

1.4.1 EXEMPTIONS

An exemption is a written release from a mandatory standard and can only be granted by the DOE Assistant Secretary for Environment, Safety, and Health (EH-1). Requests for an exemption shall be submitted through the DOE field office manager

for action. Each request shall contain, as a minimum, the following information:

1. Description of the condition.
2. Safety standard not being complied with.
3. Reason why compliance cannot be achieved.
4. Steps taken to provide equivalent protection.
5. Statement of whether equivalent safety is provided; and, if not, an assessment of the residual risk.
6. Any proposed corrective action and the schedule for completion.
7. Duration of the exemption.

The DOE field offices manager shall submit through the cognizant Program Secretary Office to the DOE Office of Occupational Safety (EH-31) all requests for exemption from a standard where equivalent protection of operating personnel, the public, and property cannot be achieved. After review of the request for exemption, the Director of EH-31 shall recommend through the Deputy Assistance Secretary (EH-30) to EH-1 whether to approve or disapprove the exemption. EH-1 is responsible for final determination to approve or disapprove the exemption and for notification to the field office manager.

1.4.2 WAIVERS

If any activity, operation, or process is determined not to be in compliance with advisory standards but such activity, operation, or process is determined to be safe and necessary, facility management may request a waiver, which must be approved by the local DOE contracting officer. Waivers will be granted for the minimum necessary time and those of an ongoing nature shall be updated every three

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years. A central file of active waivers shall be maintained by facility management and a copy of each waiver be provided to the Director of Personnel Protection Division (EH-31.3). Each waiver shall contain, as a minimum, the following information:

1. Description of the condition
2. Safety standard requirement not being complied with
3. Reason why compliance cannot be achieved
4. Steps taken to provide equivalent protection
5. Any proposed corrective action and the schedule for completion
6. Duration requested for the waiver.

1.5 MANUAL ADMINISTRATION AND MANAGEMENT

Guidelines administration and management shall be accomplished through the Director of Office of Occupational Safety (EH-31) by the DOE Electrical Safety Committee. Revisions, updates, or amendments to the guidelines shall be submitted to EH-31 for incorporation and consideration. Upon request, the DOE Electrical Safety Committee shall advise EH-31 on the technical merits of the guidelines proposed changes.

1.5.1 DOE ELECTRICAL SAFETY COMMITTEE ORGANIZATION

The DOE Electrical Safety Committee shall be composed of one representative from each DOE field office. The committee shall be chaired by the DOE Personnel Protection Division (EH-31.3) and

will report to the Director of EH-31.3 through the chairperson. DOE contractor personnel shall be allowed to participate on the committee. Committee members shall be knowledgeable in electrical-related fields such as safety, maintenance, power distribution, design, construction, or other electrical areas.

Each DOE contractor site should establish an Electrical Safety Committee or equivalent, which should be responsible for program implementation.

1.5.2 DOE ELECTRICAL SAFETY COMMITTEE CHARTER

1.5.2.1 PURPOSE

The DOE Electrical Safety Committee is established to develop and maintain current electrical safety standards and provide guidelines for the Department in order to affect reduction in the risks associated with electrical energy and to mitigate hazards to employees, the public, and the environment.

1.5.2.2 RESPONSIBILITIES

Under the authority delegated from the Office of Occupational Safety (EH-31), the committee shall be responsible to:

1. Provide technical expertise, develop, and maintain current *DOE Electrical Safety Guidelines*, which incorporates applicable DOE orders and accepted industrial practices related to electrical safety such as those published in the National Electrical Code, the National Electrical Safety Code, OSHA standards, and various National Fire Protection Association publications. The Director of EH-31 shall administrate and manage the *Electrical Safety Guidelines*.
2. Review, upon request, electrical reports, exemptions, and other submittals and

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provide recommendations through EH-31.

3. Recommend, through EH-31, standardized training programs for the development of qualified electrical workers.
4. Meet periodically, as appropriate, to review and evaluate the adequacy of the guidelines and to initiate guidelines, changes, or revisions as needed.
5. Provide technical expertise, guidance, and interpretations on matters concerning electrical safety, codes, and standards and proposed solutions for electrical issues for DOE.
6. Establish an electrical safety information exchange system and distribution of lessons learned within the DOE system.
7. Provide guidance in the establishment of electrical safety programs at DOE facilities.

1.5.2.3 MEMBERSHIP

The DOE Electrical Safety Committee shall be comprised of a DOE voting member representative

and alternate from each of the field offices and the following:

1. Office of Occupation Safety (EH-31), serves as chairperson
2. Office of Administration and Human Resource Management (AD-1) serves as a representative.
3. The committee shall meet annually or more often at an appropriate location for the purpose of discussing electrical safety issues, related matters, and concerns within the DOE organization. The committee shall be chaired by the Office of Occupational Safety (EH-31) representative and shall report directly to the Director of EH-31. Only those members officially designated by DOE as voting members shall vote on recommending policy issues. DOE contractor personnel are invited and encouraged to participate in the committee meeting and activities. Any items requiring formal DOE Headquarters action/approval shall be presented through established channels of communication by the committee chairperson.

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2.0 GENERAL REQUIREMENTS

This section deals with the reliability and effective maintenance of electrical distribution systems that can be achieved in part by careful planning and proper designing. The training of personnel in safety-related work practices that pertain to their respective job assignments is outlined. Testing procedures and those eligible to perform such tests are covered.

2.1 COMMON INDUSTRIAL ELECTRICAL RISKS

Only qualified persons shall perform electrical repairs. It is dangerous for an unqualified worker to attempt electrical repair. Before doing any electrical maintenance, power circuits and electrical equipment should be deenergized, except where necessary for troubleshooting or testing.

2.1.1 Work On Energized/Deenergized Electrical Equipment

The first consideration for working on any electrical system is to have the circuit positively deenergized. All circuits and equipment must be considered energized until opened, locked, and tagged according to an approved procedure and proved to be deenergized by testing with an approved testing device known to be in working order. Where the possibility exists that the circuit can become energized by another source or where capacitive devices (including cables) may retain or build up a charge, the circuit should be grounded and shorted. Whenever work is to be performed on a positively deenergized system, you must also identify and protect against any accidental contact

with any exposed energized parts in the vicinity of the work.

2.1.2 Considerations For Working On Energized Systems And Equipment

Qualified employees performing electrical repairs, modifications, testing, etc., on energized electrical systems, parts, and equipment shall comply with the following procedures.

1. Live parts to which an employee may be exposed shall be deenergized before the employee works on or near them, unless the employer can demonstrate that deenergizing introduces additional or increased hazards or is infeasible due to equipment design or operational limitations. See 29 CFR 1910.333(a).
2. Work that is performed on energized electrical systems and equipment may only be done if a supervisor, or cognizant safety professional, and the personnel performing the work determine that the work can be done safely. Approval must be given for each job. Approval for jobs of a repetitious nature may be given through the use of an approved procedure or job safety analysis.
3. Personnel shall not work on energized circuits unless they are qualified, or for training purposes where under the direct supervision of a qualified person.
4. Double protection in the form of insulated tools and insulated protective equipment, such as gloves, blankets, sleeves, mats, etc., shall be used while working on energized circuits. Employees should not rely on insulated tools alone for complete protection.

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5. Work on energized circuits in a hazardous situation should be performed with a safety watch within sight and hearing distance.
6. Taking voltage measurements shall be considered energized work and personnel shall use protective equipment appropriate for the voltage levels involved. (See Appendix C.)
6. Document work.
7. Have safety-related work independently verified.
8. Use properly rated test equipment and verify condition and operation of equipment before use.
9. Know applicable emergency procedures.
10. Become qualified in cardiopulmonary resuscitation (CPR) and maintain current certification.

2.2 BASIC SAFEGUARDS

In order to protect employees from some of the electrical hazards in industrial sites, Federal regulations limit electrical work to qualified personnel. Specifically, the law requires that only a qualified person or someone working under the direct supervision of that qualified person may perform any repair, installation, or testing of electrical equipment.

One of the best ways to prevent electrical accidents in industrial sites is to be aware of electrical dangers in the workplace. Once hazards have been identified, they must be pointed out and proper steps implemented to correct them by a qualified person before an accident occurs. A good housekeeping program will further reduce potential electrical hazards.

The following, where used, will improve the safety of the workplace:

1. Maintain good housekeeping and cleanliness.
2. Identify potential hazards.
3. Anticipate problems.
4. Resist pressure to "hurry up."
5. Plan and analyze for safety in each step of a project.

2.3 RESPONSIBILITIES

It is the responsibility of management to provide a workplace that is free from recognized hazards that might cause injury, illness, or death and to comply with the specific safety and health standards issued by Federal, state, and local authorities, especially the Occupational Safety and Health Administration (OSHA). The management expects all of its employees to also comply with these regulations as well as the DOE rules formulated for the health and safety of employees. Prevention of injury and illness requires the efforts of all and is a goal well worth achieving.

2.3.1 MANAGEMENT RESPONSIBILITIES

To ensure safety and protection of employees, management has the following responsibilities:

1. Ensure that employees are provided a workplace that is free from recognized hazards.
2. Ensure that employees performing electrical work are trained and qualified (see Section 2.8).
3. Ensure approved, maintained, and tested protective clothing and equipment is provided.

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4. Establish, implement, and maintain procedures and practices that will ensure safe conduct of electrical work.
5. Keep and maintain records as required.

2.3.2 EMPLOYEE RESPONSIBILITIES

Employees are responsible to comply with occupational safety, health, and fire protection standards that apply to their own actions and conduct, including immediate reporting of unsafe and unhealthful conditions to management.

2.3.3 SAFETY WATCH RESPONSIBILITIES AND QUALIFICATIONS

The following are safety watch responsibilities and qualifications:

1. Trained in cardiopulmonary resuscitation (CPR)
2. Thorough knowledge of the locations of emergency-shutdown push buttons and power disconnects in their operations
3. Thorough knowledge of the specific working procedures to be followed and the work to be done
4. Specific responsibilities include monitoring the work area for unsafe conditions or work practices and taking necessary action to ensure abatement of the unsafe condition or work practice, deenergizing equipment and alerting emergency-rescue personnel as conditions warrant, maintaining visual and audible contact with personnel performing the work, and removal of injured personnel, if possible.

2.4 REVIEWS/INSPECTIONS

Major modifications to existing facilities and projects and new facilities and projects shall be inspected by the authority having jurisdiction or their authorized designee to verify compliance with the codes and standards that were in effect on the date that such work was approved by a final design review. If the installation involves a hazard to life, equipment, or property, current standards and codes shall be used to mitigate the hazard.

The Occupational Safety and Health Act (OSHA), under the Department of Labor (DOL), has specific rules that apply to all installations and others that apply retroactively to installations installed after certain dates. Requirements listed in *Table 2-1* are applicable to all electrical installations regardless of the date that they were designed and installed. All electrical systems and pieces of equipment that were installed after March 15, 1972, shall comply with all the requirements of 29 CFR 1910.302 through 1910.308, and not just the requirements listed in *Table 2-1*.

All major replacements, modifications, repairs, or rehabilitation performed after March 15, 1972, on electrical systems and equipment installed before March 15, 1972, are required to comply with all the requirements of 29 CFR 1910.302 to 1910.308. OSHA considers major replacements, modifications, or rehabilitation as work similar to that involved where a new building or facility is built, a new addition is added, or an entire floor is renovated.

A revision in 29 CFR 1910, Subpart S, Part 1, was implemented and became effective April 16, 1981, which contained revised parts of 29 CFR 1910.302 through 1910.308 that apply to electrical systems and equipment installed after April 1, 1981.

See *Table 2-2* which lists the sections and regulations that apply to electrical installations and equipment installed after April 16, 1981.

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Table 2-1. OSHA regulations that apply to all installations, regardless of the time they were designed or installed.

Sec. 1910	Subject
.303(b)	Examination, installation, and use of equipment
.303(c)	Splices
.303(d)	Arcing parts
.303(e)	Marking
.303(f)	Identification of disconnecting means
.303(g)(2)	Guarding live parts
.304(e)(1)(i)	Protection of conductors and equipment
.304(e)(1)(iv)	Location in or on premises
.304(e)(1)(v)	Arcing or suddenly-moving parts
.304(f)(1)(ii)	2-wire dc systems to be grounded
.304(f)(1)(iii);(iv)	AC systems to be grounded
.304(f)(1)(v)	AC systems 50 to 1,000 V not required to be grounded
.304(f)(3)	Grounding connections
.304(f)(4)	Grounding path
.304(f)(5)(iv)(A) thru 304(f)(5)(iv)(F)	Fixed equipment required to be grounded
.304(f)(5)(v)	Grounding of equipment connected by cord and plug
.304(f)(5)(vi)	Grounding of nonelectrical equipment
.304(f)(6)(i)	Methods of grounding fixed equipment
.305(g)(1)(i);(ii)	Uses of flexible cords and cables
.305(g)(1)(iii)	Flexible cords and cables prohibited
.305(g)(2)(ii)	Flexible cord and cable splices
.305(g)(2)(iii)	Pull at joints and terminals of flexible cords and cables

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Table 2-2. OSHA regulations that apply to these electrical installations only if they were designed and installed after April 16, 1981.

Sec. 1910	Subject
.303(h)(4)(i);(ii)	Entrance and access to workspace over 600 V
.304(e)(1)(vi)(B)	Circuit breakers operated vertically
.304(e)(1)(vi)(C)	Circuit breakers used as switches
.304(f)(7)(ii)	Grounding of systems of 1,000 V or more supplying portable or mobile equipment
.305(j)(6)(ii)(B)	Switching series capacitors over 600 V
.306(c)(2)	Warning signs for elevators and escalators
.306(i)	Electrically controlled irrigation machines
.306(j)(5)	Ground-fault circuit interrupters for fountains
.308(a)(1)(ii)	Physical protection of conductors over 600 V
.308(c)(2)	Marking of Class 2 and Class 3 power supplies
.308(d)	Fire-protective signaling circuits

2.5 ELECTRICAL EQUIPMENT CONDITIONS OF USE AND APPROVAL

It is required that all electrical equipment, components, and conductors be approved for their intended use, or as follows:

1. If equipment is of a kind that no nationally recognized testing laboratory (NRTL) accepts, certifies, lists, labels, or determines to be safe, then it may be inspected or tested by another Federal agency or by a state, municipal, or other local authority responsible for enforcing the National Electrical Code (NEC), and found to comply with the provisions of the NEC. (See NEC Section 110-3).
2. Custom-made and installed equipment can be approved if it is built according to specific standards such as UL 508 or one of the ANSI C series and is determined to be safe by the AHJ for its intended use. If

a particular piece of equipment is of a type that is not listed by an OSHA recognized NRTL, then the use of a listed piece of equipment is not mandatory. But if such equipment is used, it shall be evaluated and approved by the AHJ and there shall be documentation of evaluation on file for this equipment.

Simply stated, if any electrical system component is of a kind that any NRTL accepts, certifies, lists, or labels, then only NRTL accepted, certified, listed, or labeled components can be used. A nonlisted, nonlabeled, noncertified component may be used if it is of a kind that no NRTL covers, and then it shall be tested or inspected by the local authority responsible for enforcing the code. For example, this would apply to custom-made equipment such as shop-made extension cords. This does not mean that each and every shop-built extension cord has to be inspected by the AHJ, but that

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each cord shall be built in accordance with a design approved by the AHJ.

Because DOE is the final AHJ for all DOE facilities, all nonlisted equipment shall be approved by the local cognizant DOE authority responsible for enforcement of the code. This does not require that DOE inspect and approve each and every nonlisted or custom-made piece of equipment. DOE approval for this equipment can be obtained by submitting a written program to the local cognizant DOE authority documenting the methods and procedures by which nonlisted and custom-built equipment can be approved.

3. Components or installations in aircraft, watercraft, and railroad are exempt from the above approval requirements per 29 CFR 1910.302(a)(2)(i).

See 29 CFR 1910.399 for a detailed description of OSHA procedures for accepting electrical equipment and wiring methods that are not approved by an NRTL.

2.6 CODES, STANDARDS, AND REGULATIONS

Workers who perform electrical work or work with electronics, where applicable, shall comply with the current revision of the following codes, standards, and regulations as required by the Assistant Secretary of Labor:

1. Standards published by the National Fire Protection Association (NFPA)
 - a. National Electrical Code (NEC), NFPA 70
 - b. Electrical Equipment Maintenance, NFPA 70B
 - c. Electrical Safety Requirements for Employee Workplaces, NFPA 70E

2. Standards published by the Occupational Safety and Health Administration (OSHA)
 - a. 29 CFR 1910, Subpart S (electrical)
 - b. 29 CFR 1926, Subpart K (electrical)
 - c. 29 CFR 1926, Subpart V (power transmission and distribution)
3. National Electrical Safety Code, ANSI C2
4. All relevant DOE orders, notices, and directives.

The standards and performance specifications from the following organizations are recommended and should be observed when applicable:

1. Institute of Electrical and Electronics Engineers (IEEE)
2. National Electrical Manufacturers Association (NEMA)
3. Underwriters Laboratory, Inc. (UL)
4. Factory Mutual Engineering Corporation (FMEC)
5. Other testing laboratories approved by OSHA on limited basis.

Where there are conflicts between the mandatory requirements of the above codes, standards, and regulations, the requirements that provide the greater personnel safety and equipment protection shall govern.

Where no clear applicable code or standard provides adequate guidance or when questions regarding workmanship, judgment, or conflicting criteria arise, personnel safety protection shall be the primary consideration.

2.7 ELECTRICAL SYSTEMS

Work on any electrical system, fixed or transportable, shall be performed only by qualified workers

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with the required qualifications and training techniques specified in Section 2.8.

2.8 TRAINING AND QUALIFICATIONS OF QUALIFIED WORKERS

Only qualified workers can perform work on electrical systems. It is very dangerous for unqualified personnel to attempt to do electrical work. There shall be an employee training program implemented to qualify workers in the safety-related work practices that pertain to their respective job assignments. (See 29 CFR 1910.332, Table S4.)

2.8.1 FORMAL TRAINING AND QUALIFICATIONS

Management shall ensure the formal training and qualifications of all qualified workers before they are permitted to perform electrical work.

The training may be on the job or classroom type. The degree of training provided shall be determined by the risk to the employee. This training shall be documented and shall include, but not be limited to, the following:

1. Employees shall be trained in and be familiar with the safety-related work practices required of 29 CFR 1910.331 through 1910.335 that pertain to their respective job assignments.
2. The skills and techniques necessary to distinguish exposed live parts from other parts of electrical equipment.
3. The skills and techniques necessary to determine the nominal voltage of exposed live parts and the clearance distances specified in 29 CFR 1910.333(c) and the corresponding

voltages to which the qualified person will be exposed.

4. Procedures on how to perform their jobs safely and properly shall be taught.
5. 29 CFR 1910.332 may also require training for persons other than qualified workers, if job assignments bring them close enough to exposed parts of electrical circuits operating at 50 V or more to ground for a hazard to exist.
6. Employees shall be trained on how to lockout/tagout energized electrical circuits and equipment safely.
7. Other types of training recommended for electrical workers include the following:
 - a. National Electrical Code (NFPA 70)
 - b. National Electrical Safety Code (ANSI C2)
 - c. Use of personal protective grounds—29 CFR 1926.954(e)
 - d. Use of testing and measuring equipment—29 CFR 1910.334(c)
 - e. Work permit and work authorization procedures
 - f. Use and care of personal protective equipment—29 CFR 1910.335(a).

Refresher training is recommended at intervals not to exceed three years to provide an update on new regulations and electrical safety criteria.

2.8.2 TRAINING OF SAFETY PERSONNEL

Safety personnel designated to support electrical safety programs shall be trained at levels commensurate with their duties.

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2.9 WORKING SPACE AROUND ELECTRICAL EQUIPMENT

Working space around electrical enclosures or equipment shall be adequate for all anticipated maintenance and operations, including safety of personnel under emergency conditions and rescue of injured personnel. Spacing shall provide the following dimensional clearance for personnel access to parts likely to require examination, adjustment, servicing, or maintenance while energized. Examples of such equipment include panelboards, switches, circuit breakers, controllers, and controls on heating and air conditioning equipment.

These clearances shall be in accordance with NEC Section 110-16 for 600 V or less. These working clearances are not required if the equipment is not likely to require examination, adjustment, servicing, or maintenance while energized. However, sufficient access and working space is still required.

2.9.1 ELECTRICAL EQUIPMENT RATED AT 600 VOLTS OR LESS

A minimum working space of 30 in. width shall be provided in front of electrical equipment of 600 V or less. This provides room to avoid body contact with metal parts while working with the components of the equipment. The 30 in. width space may be centered in front of the equipment or can be offset. The depth working space shall be clear to the floor. There shall be at least a 90-degree opening provided in the work area for equipment doors or hinged panels on the service equipment. Working spaces may overlap. The depth of the working space should be 3 ft, 3 1/2 ft, or 4 ft, depending upon existing conditions. These conditions are as follows:

Condition 1: The electrical equipment is mounted or set on one wall, and the wall on the opposite side is insulated (ungrounded parts). A qualified worker making contact with the insulated wall would be isolated from the ground.

Condition 2: The electrical equipment is mounted or set on one wall, and the wall on the opposite side is grounded. If the qualified worker should accidentally contact the conductive wall while touching live components, a circuit would be completed to ground and a fatal shock might occur.

Condition 3: The electrical equipment is mounted or set on one wall, and additional electrical equipment is mounted or set on the opposite side of the room. There are live components on both sides of the room. The qualified worker might accidentally make contact with live components and be in series with a hot phase and the grounded metal of the electrical equipment, which could produce a fatal shock.

See Figure 2-1 for the clearance requirements in front of electrical equipment rated at 600 V or less.

NEC Table 110-16 (a)
OSHA Table S-1

Figure 2-1. Clearances in front of electrical equipment (600 V or less).

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2.9.2 ELECTRICAL EQUIPMENT RATED OVER 600 VOLTS

NEC Section 110-34(a) and Table 110-34(a) list the minimum clearance for working spaces required in front of high-voltage electrical equipment such as switchboards, control panels, switches, circuit breakers, motor controllers, etc.

There are three conditions to apply as in NEC Section 110-16(a) and Table 110-16(a)

1. Where there are exposed live components on one side of a space and ungrounded parts on the other side
2. Where there are exposed live components on one side and grounded parts on the other such as concrete, brick, and tile walls that are considered to be grounded parts
3. Where there are exposed live components on both sides.

See Figure 2-2 for the clearance requirements in front of electrical equipment rated at over 600 V.

2.10 IDENTIFICATION OF DISCONNECTION MEANS

Switches in service panels, subpanels, or elsewhere shall be marked to show what loads or equipment are controlled by such switches.

2.10.1 DISCONNECTING DEVICES

All disconnecting devices (switches or circuit breakers) for load devices and for circuits shall be located for easy access and clearly and permanently marked to show the purposes of the disconnects, unless located and arranged so that the

NEC Table 110-34
OSHA Table S-2

Figure 2-2. Clearances in front of electrical equipment (over 600 V).

purpose is evident. This is required by 29 CFR 1910.303(b) and NEC Section 110-22 and applies to all existing electrical systems and all new, modernized, expanded, or altered electrical systems.

2.10.2 PANELBOARD CIRCUIT DIRECTORIES

Panelboard circuit directories must be provided and fully and clearly filled out.

2.10.3 ENCLOSURE LABELING

Printed labeling or embossed identification plates affixed to enclosures shall comply with the requirement that disconnects be "legibly marked" and that the "marking shall be of sufficient durability" for the environment involved [NEC Section 110-22 and 29 CFR 1910.303(f)].

2.10.4 LABEL THE LOAD

The load should be labeled as well as the disconnecting means. For example, the motor, the controller, and the disconnecting means shall have the same identification number, etc.

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2.10.5 LABEL THE SOURCE

The source supplying power to the disconnecting means and load should be labeled as well. This requirement allows the electrical worker to know the identification of the elements from the source of power through the entire circuit. (See Figure 2-3.)

2.11 WORK PROCEDURES

Before work is begun, the qualified worker shall ensure that the job to be done is in compliance with

written procedures pertaining to the electrical work.

2.11.1 SAFE WORK PROCEDURES AND SUPERVISION

Electrical work shall be performed according to written safety procedures and approved electrical safety guidelines or manuals. Electrical work shall be directed by a supervisor, qualified by training in the safety-related work practices that pertains to their respective job assignments and those of their employees.

Figure 2-3. Switchgear, panelboards, motor control centers, etc., shall identify the loads and elements in which they supply and where such equipment is located.

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Workers shall report any electrical hazards to their immediate supervisor. The supervisor shall take all necessary corrective actions to address an employee's concerns.

Electrical procedures shall be based on a thorough analysis of the job and its hazards. Tasks of a repetitive nature may be performed under specific work rules that are based on such analyses.

2.11.2 WORK PERMITS

If no specific procedure is available and the job is beyond the scope of written work rules, the supervisor should issue a permit pertaining to the job performed. The permit shall contain the essential safety rules for the job and shall be signed by a line supervisor and safety representative.

2.11.3 WORK PROCEDURES

Electrical procedures may include, but not be limited to the following:

1. Deenergizing circuits, if possible, and a means to prevent reenergization (lockout/tagout)
2. Grounding conductors and all possible conducting parts
3. Control of associated generating equipment
4. Testing of equipment to ensure safe conditions
5. Rubber-insulated protective equipment rated for the highest voltage present
6. Qualified and properly equipped standby personnel
7. Personnel protective equipment (e.g., hard hats, safety shoes, eye/face protection, insulated live line tools, cotton clothing, and arc protection).

2.12 ELECTRICAL PROTECTIVE CLOTHING AND EQUIPMENT

Qualified workers are responsible for avoiding and preventing accidents while performing electrical work, repairs, or troubleshooting circuits on electrical equipment. Personnel shall wear or use protective clothing or equipment that is approved for safe performance of work.

2.12.1 MANAGEMENT'S RESPONSIBILITIES

Management shall ensure that appropriate protective clothing and equipment are provided and ensure that employees using protective clothing and equipment are trained in their proper use. Furthermore, management shall ensure that employees use the personal protective equipment appropriate for their assigned task.

2.12.2 INSPECTING PROTECTIVE EQUIPMENT

Employees shall visually inspect rubber-insulated protective (nonconductive) equipment at the beginning of each work day prior to use and after any work performed that could damage the equipment. Such inspections shall include an air test of the gloves used. Visual inspection shall be performed on hot sticks, grounds, aerial lift equipment and booms, hot rope, hot ladders, etc.

2.12.3 CLEANING AND ELECTRICAL TESTING OF PROTECTIVE EQUIPMENT

Rubber-insulated protective (nonconductive) equipment issued for use shall receive periodic cleaning and electrical testing in accordance with the requirements of the appropriate ANSI/ASTM standards listed in the references of this safety guidelines. The intervals of retest shall not be more

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than 6 months for gloves and 12 months for sleeves and blankets. The following are examples of ANSI/ASTM standards to use:

Subject	Number and Title
Head Protection	ANSI Z89.2-1971, <i>Safety Requirements for Industrial Protective Helmets for Electrical Workers, Class B</i>
Eye and Face Protection	ANSI Z87.1-1979, <i>Practice for Occupational and Educational Eye and Face Protection</i>
Blankets	ANSI/ASTM D1048-1981, <i>Specifications for Rubber Insulating Blankets</i>
Hoods	ANSI/ASTM D1049-1983, <i>Specifications for Rubber Insulating Covers</i>
Line Hoses	ANSI/ASTM D1050-1985, <i>Specifications for Rubber Insulating Line Hoses</i>
Sleeves	ANSI/ASTM D1051-1981, <i>Specifications for Rubber Insulating Sleeves</i>
Gloves	ANSI/ASTM D120-1984, <i>Specifications for Rubber Insulating Gloves</i>
Mats	ANSI/ASTM D178-1981, <i>Specifications for Rubber Insulating Matting</i>

2.12.4 TESTING

Testing shall be performed either by a qualified testing laboratory or by the contractor. If performed by the contractor, all testing procedures, apparatus, and facilities for such testing shall be approved. The method used and the results of such tests shall be documented and made available for inspection.

2.12.5 TESTING APPARATUS

Testing apparatus shall be operated and maintained by personnel trained for such work. Calibration schedules and procedures for calibrating testing apparatus are recommended to be in accordance with ANSI C39.1.

2.12.6 RETESTED PROTECTIVE EQUIPMENT

Retested rubber-insulated protective equipment shall be identified to indicate the date of the latest test in accordance with the appropriate standard. Manufacturer's recommendations on the type of paint or ink to be used shall be followed.

2.12.7 CLEANING AND RETESTING PROTECTIVE EQUIPMENT

Rubber-insulated protective equipment properly stored in storerooms and not having been issued for use since the last electrical test shall be cleaned and retested on an annual basis except as noted in Section 2.12.3.

2.12.8 LIVE-LINE TOOLS

Live-line tools shall be cleaned and inspected before use and receive a dielectric test whenever their insulating value is suspect. A record of the testing of live-line tools shall be maintained.

2.12.8.1 FIBERGLASS-HANDLED TOOLS

Fiberglass-handled tools shall be tested 100 kV per ft of length per 29 CFR 1926.951(d)(i).

2.12.8.2 WOODEN-HANDLED TOOLS

Wooden-handled tools shall be tested to 70 kV per ft of length per 29 CFR 1926.951(d)(ii).

Note: For more information, reference ASTM standard F711 and ANSI J6.

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2.12.9 MAXIMUM VOLTAGE

Maximum voltage phase-to-phase or phase-to-ground for insulating blankets, mats, covers, line hose, sleeves, and gloves shall be as follows:

Class	Voltage	Label Color
0	1,000	Red
1	7,500	White
2	17,500	Yellow
3	26,500	Green
4	36,000	Orange

Note: For further information, reference 29 CFR 1910.137 and the ASTM Series.

2.12.10 MAXIMUM VOLTAGE FOR LIVE-LINE TOOLS

Maximum voltage per foot of length and phase-to-phase or phase-to-ground for live-line tools shall be as follows:

1. Tools with wooden handles 69 kV
2. Tools with fiberglass handles 93 kV

2.12.11 RUBBER-INSULATED GLOVES

Whenever rubber-insulated protective gloves are required, approved protective gloves shall also be worn (see Appendix C).

2.12.12 STORAGE

Electrical insulating and protective clothing and equipment shall be stored flat, undistorted, right

side out, and unfolded, as appropriate in protective containers. Blankets may be stored rolled provided the inner diameter of the roll is at least 2 in.

Such storage shall not be directly above or close to hot pipes, heat radiation, or any sources of artificial heat or exposed to direct sunlight or other sources of ozone such as in switchgear rooms. Storage temperature shall not exceed 90°F.

2.12.13 SAFETY SHOES, HATS, AND GLASSES

Safety shoes, hard hats, and (insulated) nonmetallic framed safety glasses worn by electrical workers shall meet the requirements of ANSI Z41, ANSI Z89.1, and ANSI Z87.1 specifications, respectively.

2.13 WORK PRACTICES

The safe maintenance or repair of any electrical apparatus requires a thorough knowledge of engineering safety and repair techniques, and personnel must be familiar with the particular features of the apparatus involved. Only qualified workers are allowed to do such work and these workers should refer to the manufacturer's testing procedures, warnings, and instructions on how to service such electrical equipment.

2.13.1 TRAINING

Qualified workers shall be trained in safety-related work practices, safety procedures, and other personnel requirements that pertain to their respective job assignments. Employees shall not be permitted to work in an area where they are likely to encounter an electrical hazard unless they have been trained to recognize and avoid these hazards. (See Section 2.8 of these guidelines.)

2.13.1.1 LIVE PARTS

Live parts operating at 50 V to ground or greater that an employee may be exposed to shall be

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deenergized before the employee works on or near them, unless management can demonstrate that deenergizing introduces additional or increased hazards or is infeasible because of equipment design or operational limitations. (See Section 2.8.1 of this manual.) Examples of infeasibility because of equipment design or operational limitations are as follows:

1. Tests
2. Adjustments
3. Troubleshooting
4. Interruption of life supports
5. Removal of lighting in an area
6. Deactivation of alarm systems
7. Shutdown of ventilation in hazardous locations
8. Shutdown of a process machine creating a greater hazard.

2.13.1.2 SAFE PROCEDURE

Safe procedures for deenergizing circuits and equipment shall be determined before circuits or equipment are deenergized. The deenergization procedures shall be included in the lockout/tagout procedure for the circuit or equipment to be deenergized.

2.13.1.3 CIRCUITS AND EQUIPMENT

Circuits and equipment to be worked on shall be disconnected from all electric energy sources. Control circuit devices such as push buttons, selector switches, and interlocks shall not be used as the sole means for deenergizing circuits or equipment per 29 CFR 1910.147(b) and 29 CFR 1910.333(b)(2).

2.13.1.4 STORED ELECTRICAL ENERGY

Stored electrical energy that might endanger personnel shall be released. Capacitors shall be discharged and high capacitance elements shall be short-circuited and grounded if the stored electric energy could endanger personnel per 29 CFR 1910.147(d)(5) and 29 CFR 1910.333(b)(2).

2.13.1.5 STORED NONELECTRICAL ENERGY

Stored nonelectrical energy in devices that could reenergize electric circuit parts shall be blocked or relieved to the extent that the circuit parts could not be accidentally energized by the device per 29 CFR 1910.147(d)(5). For example, such specific devices are wound springs and pneumatic driven devices.

2.13.1.6 LOCKOUT/TAGOUT PROCEDURE

Each employer shall document and implement lockout/tagout procedures to safeguard employees from injury while they are working on or near deenergized electric circuits and equipment. The lockout/tagout procedure shall meet the requirements of 29 CFR 1910.147(c) to (f) and 29 CFR 1910.333. (See *Figure 2-4*.)

2.13.2 VERIFICATION OF DEENERGIZED CONDITION

Verification shall be made that all live circuits and parts and other sources of electrical energy including any mechanical energy have been disconnected, released, or restrained.

A qualified worker shall operate the equipment operating controls or otherwise verify that the equipment cannot be restarted.

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OSHA SECTION 1910. 147**

LF93 0015

Figure 2-4. Employers shall implement and document a lockout-tagout program with procedures to safeguard employees from injury while working on or near deenergized systems.

2.13.2.1 VERIFICATION TEST

A qualified worker shall use test equipment to test the circuit elements and electrical parts of equipment to which employees will be exposed and shall verify that the circuit elements and equipment parts are deenergized. The test shall also determine if any energized condition exists as a result of inadvertently induced voltage or unrelated voltage backfeed after specific parts of the circuit have been deenergized. If the circuit to be tested is over 600 V nominal, the test equipment shall be checked for proper operation immediately before and immediately after this test. Testing shall be performed as if the circuit is energized. This test is also recommended for systems of 600 V or less.

2.13.2.2 GROUNDING PROCEDURES

Personal protective grounds shall be applied on circuits 600 V and above or on lesser voltages where residual charges may accumulate.

2.13.3 REENERGIZING EQUIPMENT

The following requirements shall be met before circuits or equipment are reenergized, even temporarily.

2.13.3.1 TESTS AND VISUAL INSPECTIONS

A qualified worker shall conduct tests and visual inspections to verify that all personnel are in the clear and that all tools, electrical jumpers, shorts, grounds, and other such devices have been removed so that the circuits and equipment can be safely energized.

2.13.3.2 WARNING EMPLOYEES

Employees exposed to the hazards associated with reenergizing the circuit or equipment shall be warned to stay clear of circuits and equipment.

2.13.3.3 REMOVING LOCK AND TAG

Each lock and tag shall be removed by applying the following procedures:

1. Each lockout or tagout device shall be removed from each energy isolating device by the authorized employee who applied the lockout or tagout device, or under their direct supervision.
2. Exception: When the authorized employee who applied the lockout or tagout device is not available to remove it, that device may be removed under the direction of his or her supervisor. Extreme care shall be taken and specific procedures shall be followed. The specific procedure shall include at least the following elements:
 - a. Verification by the supervisor that the authorized employee who applied the device is not at the affected facility

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- b. Making all reasonable efforts to contact the authorized employee to inform him or her that the lockout or tagout device has been removed
 - c. Ensuring that the authorized employee has this knowledge before he or she resumes work at the affected facility.
3. Employees reference 29 CFR 1910.147 for detailed procedures on applying lockouts, tagouts, or both.

2.13.4 SAFE ENERGIZED WORK (HOT WORK)

Safety-related work practices shall be used to prevent electric shock or other electrically induced injuries when employees work on or near electrical conductors or circuit parts that are energized. Only qualified workers who have been trained to work safely on energized circuits and to use the proper personnel protective equipment, insulating shielding materials, and insulated tools shall be permitted to work on conductors or circuit parts that are energized.

Note: Energized work is any work performed close enough to exposed parts of electrical circuits and equipment operating at 50 V or more to ground for a hazard to exist.

2.13.4.1 TWO WORKERS

Because of exposure to energized parts, certain jobs may require two people to perform the job safely. See Appendix C for guidance on what protective measures are needed.

2.13.4.2 SAFETY WATCH

Work on energized circuits in a hazardous situation should be performed with a safety watch within

sight and hearing, and less than 50 ft from the worker. The qualified worker shall have no other duties that preclude observing and rendering aid if necessary. For more details see Section 2.3.3. (*See Figure 2-5.*)

2.13.4.3 ELECTRICAL SAFETY RULES

Before performing any electrical work, each individual shall be familiar with the electrical safety rules. The rules should be regularly reviewed individually and at periodic safety meetings to ensure that each individual understands the rules. Employees shall adhere to all safety rules at all times.

Prior to commencing any work at the job site, an individual must be designated as the person in charge (PIC) to be responsible for seeing that the safety rules are followed and to coordinate all the work activities. All personnel assigned to the job shall comply with the safety rules.

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Figure 2-5. Work being performed on energized circuits in hazardous situations should be performed with a safety watch within sight and hearing and less than 50 ft from the worker.

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The following are safety directions and measures that should be followed when working on energized circuits:

1. Know before work begins the work content and the sequence in which it should be accomplished.
2. Know the safety procedures that shall be followed while the work is being performed.
3. Ensure that the tools and instruments are in good working order and have up-to-date calibration as required.
4. Know what tools are required and how to use them and what protective equipment is required to perform the job safely.
5. Only qualified individuals shall operate tools and equipment.
6. Safety signs, symbols, or accident prevention tags shall be used to warn and protect employees where electrical hazards are likely to endanger lives.
7. Barricades shall be used in conjunction with safety signs where it is necessary to prevent or limit employee access to work areas where they might be exposed to uninsulated energized conductors or circuit parts. Metal barricades shall not be used where they are likely to cause an electrical contact hazard.
8. When signs and barricades do not provide sufficient warning and protection from electrical hazards, manual signaling and alerting shall be used to warn and protect employees.
9. The work area shall be limited only to authorized individuals who are familiar with the work. Unauthorized individuals shall not be allowed into the work area.
10. The PIC shall see that all individuals who are involved in the work are notified of any changes in the work conditions.
11. If unsafe conditions develop during the work process, immediately report them to the (PIC) or the immediate supervisor.

2.13.4.4 UNEXPECTED ELECTRICAL HAZARDS

Employees shall be instructed to be alert at all times when they are working near exposed energized parts where unexpected electrical hazards may exist.

2.13.4.5 ILLUMINATION

Adequate illumination shall be provided before workers are allowed to enter spaces containing exposed energized parts.

2.13.4.6 HIGH VOLTAGE SYSTEMS UNDER LOAD

For 600 V and higher voltage systems, manual disconnects, taps, terminators, and nonenclosed switches shall not be operated while under load, unless the devices are rated as load-break type and are so marked.

2.13.4.7 WORKING WITH TEST INSTRUMENTS AND EQUIPMENT

Sometimes it becomes necessary to check the continuity of power circuits, control circuits, etc., by using a particular testing instrument that is designed for the testing procedure involved. The

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following procedures apply when working with test instruments and equipment on energized circuits.

2.13.4.7.1 QUALIFIED EMPLOYEES

Only qualified workers who have been trained to work safely with test instruments and equipment on energized circuits shall be permitted to perform testing work on electrical circuits or equipment where there is danger of injury from accidental contact with energized parts or improper use of the test instruments and equipment.

2.13.4.7.2 VISUAL INSPECTIONS

Test instruments and equipment and all associated test leads, cables, power cords, probes, and connectors shall be visually inspected for external defects or damage before being 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 required repairs and tests have been made.

2.13.4.7.3 RATING INSTRUMENTS AND EQUIPMENT

Test instruments and equipment and their accessories shall be rated for the circuits and equipment to which they will be connected and shall be suitable for the environment in which they will be used.

2.13.4.7.4 CALIBRATION OF ELECTRICAL INSTRUMENTS

The American National Standards Institute (ANSI) standard C39.1 defines the minimum performance

and general requirements level for electrical instruments. ANSI standards should ensure that an instrument, when calibrated to National Bureau of Standards (NBS) traceable standards, is capable of transferring that quality of measurement to field conditions within specified limits.

A record should be made up for each instrument by serial number showing dates of inspection, calibration data as received, the date when it should be recalled from the field and a recalibration check made, and any interim repairs if required should be noted. After a period of time, it should become obvious what time frequency needs to be established for calibrating each instrument.

2.14 RESEARCH AND DEVELOPMENT

DOE laboratories engage in a variety of research and development (R&D) activities that often involve the use of new or unusual electrical equipment and wiring methods not sufficiently covered by established codes or standards. Special efforts shall be made to ensure adequate electrical safety, beginning with the design phase and continuing through development, construction, and operation of R&D equipment and facilities.

Because of the differences in R&D program requirements at DOE laboratories, it is not practical at this time to establish a specific set of safety program requirements to be uniformly applied.

Because OSHA and the NEC do not exempt R&D facilities, the rules and regulations of OSHA and the NEC shall be followed except where specifically exempt by the AHJ.

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3.0 Electrical Preventive Maintenance

The term electrical preventive maintenance (EPM) refers to a program of regular inspection and service of equipment to detect potential problems and to take proper corrective measures.

The following standards and specifications are to be utilized when possible:

1. NFPA 70, National Electrical Code
2. NFPA 70B, Electrical Equipment Maintenance
3. NFPA 70E, Electrical Safety Requirements for Employee Workplaces
4. NFPA 77, Static Electricity
5. NFPA 78, Lightning Protection Code
6. ANSI C-2, National Electrical Safety Code
7. ANSI/UL 45, Portable Electric Tools
8. IEEE/ANSI 80, Guide for Safety in AC Substation Grounding.

3.1 DEVELOPMENT AND IMPLEMENTATION REQUIREMENTS

An EPM program shall be developed and implemented based on the requirements of:

1. DOE Order 4330.4A, Maintenance Management Manual

2. NFPA 70B, Recommended Practice for Electrical Equipment Maintenance
3. NFPA 70E, Electrical Safety Requirements for Employee Workplaces
4. NFPA 71, Installation, Maintenance, and Use of Signaling Systems for Central Station Service
5. NFPA 72, Installation, Maintenance, and Use of Protective Signaling Systems
6. ANSI C-2, National Electrical Safety Code.

3.2 DEFINITION

An EPM program shall be defined as the system that manages the conducting of routine inspections, tests, and servicing of electrical equipment so that impending troubles can be detected and reduced or eliminated. Where designers, installers, or constructors specify, install, and construct equipment with optional auxiliary equipment, that optional equipment shall be part of the EPM program. Records of all inspections, tests, and servicing shall be documented.

All electrical equipment that is appropriate for EPM shall be inspected, tested, and serviced in accordance with an EPM program.

Inspections, tests, and servicing shall be performed by personnel who are qualified for the work to be performed as shown by appropriate documentation of work experience and on-the-job and offsite formal training including examination to verify understanding and retention of minimum knowledge, skills, and abilities.

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3.3 MAINTENANCE

Electrical equipment shall be maintained in accordance with the manufacturer's recommendations and instructions for the local operating environment. A copy of the manufacturer's recommendation shall be documented and on file upon request.

3.4 INSPECTION

If an EPM program does not exist, an inspection, test, and servicing program shall be developed and implemented to establish a baseline to initiate this EPM program. The inspection frequency shall be as recommended by the manufacturer or as otherwise indicated in NFPA 70B. An initial period of inspection (sometimes several years) provides sufficient knowledge, which when accumulated, might permit increasing or decreasing that interval based upon documented observations and experience.

Guidance on how to determine inspection frequency is described in various sections of NFPA 70B, including but not limited to the following sections:

1. 4-4.5 (Inspection Frequency) for Planning and Developing an Electrical Preventive Maintenance Program
2. 6-1.1.3 (General) on Recommended Frequency for Substations
3. 6-2.2 (Frequency of Maintenance) for Switchgear Assemblies
4. 7-2.2 (Regular Inspections) and 7-2.7 (Special Inspections and Repairs) for Liquid-filled Transformers
5. 7.3.2 (Regular Inspections) and 7-3.7 (Special Inspections and Repairs) for Dry-type Transformers
6. 8-2.6 (Visual Inspection Intervals) for Power Cables
7. 9-2 (Enclosures) for Frequency of Motor Control Centers
8. 12-2.2.3 (Recommended Frequency) for Ground-Fault Circuit Interrupters
9. 13-2.1 (General) and 13-2.3 (Inspection and Clean-ing) for High-Voltage Fuses
10. 14-1.2 (Frequency) for Rotating Equipment
11. 15-2.1 (Cleaning Interval) for Lighting Equipment
12. 17-1.3 (Visual Inspection Before and After Each Use), 17-3.1 (Periodic Inspection of Crucial Wear Points), 17-3.2 (Excessive Dirt Accumulation), 17-3.3 (Insufficient or Improper Lubrication), and 17-4.2 (Visually Inspected Before Each Use) for Portable Electric Tools and Equipment
13. 18-2.3 (Special Maintenance Tests), 18-4 (Frequency of Tests), 18-16.5 (Inspection Frequency and Procedures), and 18-18 (Insulating-Liquid Analysis) for Testing and Test Methods
14. 19-2.1.1(e) (Reinspection and Retesting Within One or Two Years After Energization) for General Aspects of Maintaining Medium- and Low-Voltage (Distribution) Systems, 19-3.7.1 (Frequency), 19-3.7.3 (Regreasing), and 19-3.7.8 (Frequency) for (Lubrication of) Rotating Equipment
15. 19-3.13.4 (Inspections Should Be Made of All New Installations and Whenever Alterations Are Made) and 19-3.13.6

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(Recordkeeping) for Electrostatics -
Static Grounding (see NFPA 77)

16. 19-4.3.4 (Inspection and Testing of Power Supplies), 19-4.4.2 (Functional Systems Testing of Interlock and Logic Systems), 19-4.6.2 (Visual Inspection of Level Devices), 19-4.10.1 (Frequency of Testing Safety and Shutdown Systems), 19-4.11.1 (Frequency of Testing Alarm Systems), and 19-4.12.1 (Visual Checking of Wiring Systems) for Process Instrumentation and Control
17. 21-1.2 (Frequency) for Cable Tray System
18. 22-2.1.8 (Routine Maintenance) for Uninterruptible Power Supply (UPS) Systems.

3.5 ESSENTIAL ELEMENTS

The EPM program shall include the essential elements described in NFPA 70B, Chapter 3, What is an Effective EPM Program. This includes planning, identifying the main parts, and utilizing available support services for a program. For example:

1. Assigning qualified personnel
2. Surveying and analyzing equipment maintenance requirements
3. Performing routine inspections and tests
4. Analyzing inspection and test reports
5. Prescribing corrective measures
6. Performing necessary work
7. Preparing appropriate records.

3.6 PLANNING AND DEVELOPING AN EPM PROGRAM, AND FUNDAMENTALS OF EPM

The EPM program shall be planned and developed to include each of the functions, requirements, and economic considerations described in NFPA 70B, Chapter 4, Planning and Developing an EPM Program, and NFPA 70B, Chapter 5, Fundamentals of EPM. Chapter 4 includes surveying the existing electrical system installation, identifying crucial equipment, establishing a systematic program to follow, and developing methods and procedures to plan, analyze, perform, verify, and record.

Electrical drawings shall be kept current. A system of recording changes in electrical systems and then integrating those changes into the applicable drawings shall be developed and implemented.

NFPA 70B, Section 5, includes designing to accommodate maintenance, scheduling maintenance, personnel and equipment safety, circuit protection, and initial acceptance testing.

3.7 GROUND-FAULT PROTECTION

The EPM program shall include the essential ingredients of Chapter 12 of NFPA 70B, Ground-Fault Protection. This includes GFCIs and ground-fault protection (GFP).

Ground-fault protective devices are intended to protect personnel and equipment. There are two distinct types, GFCI and GFP, and IT IS OF EXTREME IMPORTANCE TO UNDERSTAND THE DIFFERENCE BETWEEN THEM.

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GFCI is defined in Article 100 of the NEC as a device intended for the protection of personnel utilizing 120 V electrical hand tools to aid in their job assignments. GFP is defined in Article 100 of the NEC as a system intended to provide protection of equipment from line to ground fault currents created by 277/480 V, three-phase, four-wire systems. (See NEC Sections 210-8 and 230-95.) Section 12-1.1 of NFPA 70B provides a detailed description of such protective devices.

GFCI's shall be inspected and ground current trip tested at installation and at intervals recommended by the manufacturer.

GFP systems (equipped with or without a test panel) shall be inspected and tested at installation and at specified intervals as recommended by the manufacturer. (See NEC 110-9, 110-10, 230-65, and 230-95. Refer to DOE for locations of GFCI protected circuits.)

See Figure 3-1 for detailed requirements of installing ground fault protection.

NEC Section 230-95

293 0403

Figure 3-1. Ground fault protection shall be provided with 277/480-V, three-phase, four-wire services with overcurrent protection devices of 1,000 A or more. A groundfault sensor (window) can be used to encircle all service conductors, including the grounded conductor (neutral).

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4.0 GROUNDING

This section covers general rules for grounding and bonding of electrical installations. The ultimate goal of system protection is to prevent ground faults from occurring by using proper design, installation, operation, and maintenance of electrical equipment and circuit systems. However, there is always the threat of ground faults because of accidents or insulation failure in electrical systems. Therefore, proper protection of such systems is required to safely clear the phase-to-ground faults that can occur.

Qualified workers must clearly understand the concepts of grounding practices as required by the NEC. They must also clearly understand the definition and intent of the following components of a grounding system that are explained in this chapter:

1. Grounded conductor
2. Grounding conductor
3. Grounding electrical conductor
4. Bonding jumper
5. Grounding electrode.

4.1 ENGINEERING SPECIFICATIONS AND DRAWINGS

The engineering specifications and drawings shall identify the requirements for all components and clearly illustrate the grounding electrode system, grounding electrode conductor, bonding points and bonding jumpers, and connection point for the grounded conductor and the grounding conductors. These specifications and drawings shall also include detailed installation instructions.

4.2 CIRCUIT AND SYSTEM GROUNDING

Circuit and system grounding consists of connecting the grounded conductor, the equipment grounding conductor, the grounding bus bars, and all metal enclosures to ground. This is accomplished by connecting a properly sized unsplined grounding electrode conductor between the grounding busbar and the grounding electrode system. There are three fundamental purposes for grounding an electrical system:

1. To limit excessive voltage from lightning, line surges, and crossovers with higher voltage lines.
2. To keep conductor enclosures and noncurrent-carrying metal enclosures and equipment at zero potential to ground.
3. To facilitate the opening of overcurrent protection devices in case of insulation failures because of faults, short circuits, etc. See the fine print note (FPN) to NEC Section 250-1.

4.3 EQUIPMENT GROUNDING

Equipment grounding systems, which consist of interconnected networks of equipment grounding conductors, are utilized to perform the following functions:

1. Limit the voltage to ground (shock voltage) on the exposed noncurrent-carrying metal parts of equipment raceways and other conductor enclosures in case of ground faults.
2. Safely conduct ground fault current at sufficient magnitude for fast operation of the circuit overcurrent protection devices.

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To ensure that the performance of the above functions, equipment grounding conductors are required to:

1. Be permanent and continuous per NEC Sections 300-10 and 300-12.
2. Have ample capacity to safely conduct ground-fault current likely to be imposed on them per NEC Table 250-94, Table 250-95, and Section 250-79(d); (e).
3. Have impedance sufficiently low to limit the voltage to ground to a safe magnitude and to facilitate the operation of the circuit overcurrent protection devices per NEC Sections 300-3(b) and 250-57(b).

4.4 BONDING

Extreme caution shall be taken to ensure that the main bonding jumper and equipment bonding jumper are sized and selected correctly. Bonding completes the grounding circuit so that it is continuous. If a ground fault occurs, the fault current will flow and trip open the overcurrent protection devices. The bonding means shall provide the following to ensure the grounding system is intact:

1. Provide a permanent connection.
2. Provide a positive continuity at all times.
3. Provide ampacity to conduct fault current.

See Figure 4-1 for detailed procedures on the proper grounding of electrical systems.

4.5 GROUNDED OR UNGROUNDED SYSTEMS

Electrical systems can be operated grounded or ungrounded. The type of system utilized depends upon its condition of use. Electrical systems are

grounded to protect circuits, equipment, and conductor enclosures from dangerous voltages and personnel from electrical shock. See NEC Sections 240-1, 240-2, 110-9, 110-10, and 230-65 that list the requirements to provide this protection.

"Grounded" means that the connection to ground between the service panel and earth has been made. Ungrounded electrical systems are used where the designer does not want the overcurrent protection device to clear in the event of a ground fault.

Ground detectors can be installed per NEC Section 250-5(b) FPN to sound an alarm or send a message to alert personnel that a ground fault has occurred on one of the phase conductors. Ground detectors will detect the presence of leakage current or developing fault current conditions while the system is still energized and operating. By warning of the need to take corrective action before a problem occurs, safe conditions can usually be maintained until an orderly shutdown is implemented.

4.5.1 GROUNDED SYSTEMS

Grounded systems are equipped with a grounded conductor that is required per NEC Section 250-23(b) to be run to each service disconnecting means. The grounded conductor can be used as a current-carrying conductor to accommodate all neutral related loads. It can also be used as an equipment grounding conductor to clear ground faults per NEC Section 250-61(a).

A network of equipment grounding conductors is routed from the service equipment enclosure to all metal enclosures throughout the electrical system. The equipment grounding conductor carries fault currents from the point of the fault to the grounded bus in the service equipment where it is transferred to the grounded conductor. The grounded conductor carries the fault current back to the source and returns over the faulted phase and trips open the overcurrent protection device.

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NEC Section 250- 51

Figure 4-1. Circuit and system grounding consists of earth grounding the electrical system at the supply transformer and the line side of the service equipment. Equipment grounding and bonding is accomplished by connecting all metal enclosures and raceways together with the grounding conductors.

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Note: A system is considered grounded where the supplying source such as a transformer, generator, etc., is grounded, in addition to the grounding means on the supply side of the service equipment disconnecting means per NEC Section 250-23(a).

The neutral of any grounded system serves two main purposes: (1) it permits the utilization of line-to-neutral voltage and thus will serve as a current carrying conductor to carry any unbalanced current, and (2) it plays a vital role in providing a low-impedance path for the flow of fault currents to facilitate the operation of the overcurrent devices in the circuit. (See Figure 4-2.)

4.5.2 UNGROUNDED SYSTEMS

Ungrounded systems operate without a grounded conductor. In other words, none of the circuit conductors of the electrical system are intentionally grounded to an earth ground such as a metal water pipe, building steel, etc. The same network of equipment grounding conductors is provided for ungrounded systems as solidly grounded electrical systems. However, equipment grounding conductors (EGCs) are only used to locate phase-to-ground faults and sound some type of alarm. Therefore, a single sustained line to ground fault does not result in an automatic trip of the overcurrent protection device. This is a major concern where electrical system continuity is required or if it would result in the shutdown of a continuous process. If an accidental ground fault occurs and is allowed to flow for a substantial period of time, a charging current to ground and overvoltages can develop in the associated phase conductors. This situation can result in conductor

insulation damage from severe overvoltages, and while a ground fault remains on one phase of an ungrounded system, personnel contacting one of the other phases and ground are subjected to 1.732 times the voltage that would be experienced on a solidly neutral grounded system. (See Figure 4-3.)

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NEC Section 250-50 (a)
OSHA Section 1910.304 (f) (3)

Figure 4-2. A grounded system is equipped with a grounded (neutral) conductor routed between the supply transformer and the service equipment.

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**NEC Section 250- 5 (b)
OSHA Section 1910.304 (f)**

Figure 4-3. An ungrounded system does not have a grounded (neutral) conductor routed between the supply transformer and the service equipment because the supply transformer is not earth grounded.

Note: All ungrounded systems should be equipped with ground detectors and proper maintenance applied to avoid, as far as is practical, the overcurrent of a sustained ground fault on ungrounded systems. If appropriate maintenance is not provided for ungrounded systems, then a grounded system should be installed to ensure that ground faults will be cleared and the safety of circuits, equipment, and personnel is ensured.

4.5.3 HIGH IMPEDANCE GROUNDING

Electrical systems containing three-phase, three-wire loads, as compared to grounded neutral circuit conductor loads, can be equipped with a high impedance grounded system. High impedance

grounded systems shall not be used unless they are provided with ground-fault indicators or alarms, or both, and qualified personnel are available to quickly locate and eliminate such ground faults. Ground faults must be promptly removed or the service reliability will be reduced. See NEC Section 250-27 for the requirements pertaining to installing a high impedance grounding system. (See Figure 4-4.)

NEC Section 250- 27

Figure 4-4. A high impedance grounding system has a high impedance unit installed between the grounded (neutral) conductor and the grounding electrode conductor, which is utilized to regulate fault current.

4.6 GROUNDING REQUIREMENTS

AC systems of 50 to 1,000 V should be solidly grounded where the maximum voltage to ground on the ungrounded conductors does not exceed 150 V. Systems supplying phase-to-neutral loads should also be solidly grounded. The following

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electrical systems are required to be solidly grounded:

1. 120/240-V, single-phase, three-wire
2. 120/208-V, three-phase, four-wire, wye
3. 277/480-V, three-phase, four-wire, wye
4. 120/240-V, three-phase, four-wire, delta.
(Midpoint of one phase used as a grounded circuit conductor.)

The following systems are not required to be solidly grounded:

1. 240-V, three-phase, three-wire, delta
2. 480-V, three-phase, three-wire
3. 600-V, three-phase, three-wire.

These electrical systems do not supply phase to neutral loads. They only supply phase-to-phase loads. (See Figure 4-5.)

4.7 GROUNDING ELECTRODE CONDUCTOR (GEC)

The main purpose of the grounding electrode conductor (GEC) is to connect the electric system to earth ground. The GEC actually provides three grounding paths to the grounding electrode system. They are as follows:

1. The grounded conductor path
2. The equipment grounding path
3. The bonding path.

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**NEC Section 250- 5 (b)
OSHA section 1910.304 (f) (1) (iv)**

Figure 4-5. AC systems of 50 to 1,000 V that operate grounded are required to have the grounded (neutral) conductor connected to earth ground at the supplying transformer and service equipment.

The GEC connects to the grounding terminal bar in the service equipment enclosure. It grounds the following items to the grounding electrode system:

1. The grounded conductor, if present
2. The equipment grounding conductor, if present
3. The metal of conduits, if present

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4. The metal of enclosures, if present
5. The bonding jumpers bonding together metal enclosures and conduits
6. The metal enclosure of the service equipment.

4.7.1 SIZING THE GROUNDING ELECTRODE CONDUCTOR

NEC Section 250-94 requires the grounding electrode conductor to be sized by the circular mils rating of the largest service entrance conductor or conductors and selected from NEC Table 250-94 based upon these values.

For example, the size of the service entrance conductors from a delta, three-phase, four-wire mid-point tap is #250 kcmil, THWN copper for phases A and C, #2/0 for phase B, and #1/0 for the neutral. What size copper GEC is required to ground this system to a metal water pipe?

Step 1:	Finding the largest phase-NEC 250-94 #250 kcmil is the largest phase
Step 2:	Finding the size GEC-NEC Table 250-94 #250 kcmil requires #2 cu
Answer:	The size of grounding electrode conductor (GEC) is #2 copper.

Note: NEC Table 250-94 is used to size the grounding electrode conductor for both grounded or ungrounded systems. The table is utilized where the grounding electrode conductor is connected to a metal water pipe or the metal frame of building steel.

4.7.2 EXCEPTIONS TO NEC 250-94

There are two exceptions to the main rule. Each has three parts to it and pertains to a specific type of grounding electrode. Exception 1 applies to grounded systems and Exception 2 applies to ungrounded systems.

Exception 1a applies to made electrodes only, such as rod, pipe, or plate electrodes.

Note: The grounding electrode conductor is not required to be larger than #6 copper or #4 aluminum.

Exception 1b to NEC Section 250-94 requires at least a #4 copper conductor to be used as a grounding electrode conductor to ground the electrical system to a concrete encased electrode.

Exception 1c requires at least a #2 copper conductor to be used as a grounding electrode conductor to ground the electrical system to a ground ring. [See NEC Section 250-81(d).]

Exception 2 requires the same rules to be applied for ungrounded systems.

4.8 MAIN BONDING JUMPER

The main function of the main bonding jumper is to connect the grounded circuit conductors and the equipment grounding conductors at the service equipment. The main bonding jumper serves as the main link between the system grounded conductors and the grounding electrode system where metal equipment enclosures and raceways are utilized to enclose conductors and components. If the main bonding jumper is left out by accident, there is a missing link that creates an open circuit and an invitation to a dangerous situation.

The main bonding jumper shall connect together the following items:

1. Grounded conductors

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2. Equipment grounding conductors
3. Grounding terminal, if present
4. Grounded terminal
5. All metal enclosures enclosing conductors and components.

NEC Section 250-79(a) permits the main bonding jumper to be a (a) wire, (b) screw, (c) busbar, or (d) a similar suitable conductor.

NEC Section 250-79(d) requires the main bonding jumper to be at least the same size as the grounding electrode conductor where the circular mils rating of the service entrance conductors do not exceed 1,100 kcmil for copper or 1750 kcmil for aluminum.

For example: What size main bonding jumper is required to ground the metal enclosure of the service equipment to the grounding terminal bar where the service entrance is made up of one #250 kcmil, THWN copper conductor per phase?

Step 1:	Finding the largest phase-NEC
	250-79(d) #250 kcmil is the largest phase
Step 2:	Finding the bonding jumper-Table
	250-94 #250 kcmil requires #2 copper
Answer:	The size of the main bonding jumper (GEC) is #2 copper.

Where the kcmil rating of the service entrance conductors exceeds 1,100 kcmil for copper or 1,750 for aluminum, the bonding jumper shall be at least 12 1/2% of the largest kcmil rating of any one phase.

For example: What size main copper bonding jumper is required for a service entrance with a makeup of 2,400 kcmil copper conductors per phase?

Step 1: Finding the largest phase-NEC
250-79(d) $2400 \text{ kcmil} \times .125 = 300 \text{ kcmil}$

Step 2: Finding the main bonding jumper-
NEC Table 250-94; Table 8, Ch. 9
300 kcmil requires 300 kcmil

Answer: The main bonding jumper is required to be 300 kcmil copper.

Note: In this case the main bonding jumper is greater in size than the grounding electrode conductor, which is only required to be #3/0 copper per NEC Table 250-94 based upon the #2400 kcmil copper conductors.

4.9 SYSTEM WITH GROUNDED CONDUCTOR

The main purpose of the grounded conductor is to carry unbalanced neutral current or fault current in the event that one phase should go to ground.

Note: The grounded conductor does not always have to be a neutral conductor. It is a current-carrying phase conductor when used in a corner grounded delta system.

In solidly grounded service-supplied systems, the equipment grounding conductors shall be bonded to the system-grounded conductor and to the grounding electrode conductor at the service equipment. The grounded conductor may be used to ground the noncurrent-carrying metal parts of equipment on the supply side of the service disconnecting means per NEC Section 250-61(a). The grounded conductor can also serve as the ground-fault current return path from the service equipment to the transformer that supplies the service.

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The grounded conductor shall not be used to ground the metal parts of enclosures enclosing conductors and components on the load side of the service per NEC Section 250-61(b). See NEC Sections 250-50(a), (b), Ex. and 250-60 for exceptions to this basic rule. NEC Section 250-23(a) requires the grounded conductor to be connected as follows:

1. The grounded conductor shall be connected to the grounded (neutral) service conductor.
2. The connection shall be at an accessible point.
3. That accessible point can be anywhere from the load end of the service drop or service lateral to and including the neutral bar in the service disconnecting means or service switchboard.

The NEC allows the grounded conductor to be terminated and connected to ground at a multitude of places on the supply side of the service equipment. They are as follows:

1. Service equipment
2. Meterbase
3. Current transformer (CT) can
4. Metal gutter or wireway containing service entrance conductors.

See Figure 4-6 for the rules concerning the use of the grounded conductor.

NEC Section 250-23(b) lists the rules for sizing the grounded conductor where it is not used as a grounded neutral circuit. NEC Section 220-22

gives the rules for calculating and sizing the grounded conductor when it is utilized as a circuit conductor. The minimum size grounded conductor is computed as follows:

1. The basic rule is to select the size directly from Table 250-94 when the size of the service-entrance conductors is not larger than 1,100 kcmil copper or 1,750 kcmil aluminum.
2. When the service entrance conductors are larger than 1,100 kcmil copper or 1,750 kcmil aluminum, the grounded conductor shall be 12 1/2% of the largest phase conductor.
3. Where the service phase conductors are paralleled, the size of the grounded conductor shall be based on the total cross-sectional area of the phase conductors.

For example: What size THWN copper grounded conductor is required for a service having a total kcmil rating of 250 per phase? (All phase conductors are THWN copper.)

Step 1: Service less than 1,100 kcmil -
 NEC Table 250-94 250 kcmil
 requires #2 copper

Answer: The size of the grounded conductor
 is #2 THWN copper.

For example: What size THWN copper grounded conductor is required for a parallel service having a total kcmil rating of 2,400 per phase? (All conductors are THWN copper.)

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**NEC Section 250-23 (b)
OSHA Section 1910.304 (f) (4)**

Figure 4-6. The grounded (neutral) conductor is used to carry normal neutral current or ground fault current in case a ground fault should develop on one of the ungrounded (hot) phase conductors.

Step 1: Service exceeding 1,100 kcmil -
NEC Table 250-94 2,400 kcmil x
125 = 300 kcmil

Answer: The grounded conductor is required
to be a #300 kcmil, THWN copper
conductor.

1,750 kcmil aluminum. NEC Table 250-94 cannot be used for sizing the grounded conductor. The grounded conductor is required to be not less than 12 1/2% of the cross-sectional area of the largest phase conductor.

Note: NEC Table 250-94 is used only if the service conductors are rated less than 1,100 kcmil for copper or 1,750 kcmil aluminum.

This method is used where the service entrance conductors are over 1,100 kcmil copper or

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4.10 EQUIPMENT GROUNDING CONDUCTOR

The equipment grounding conductor may be any of the types permitted in NEC Section 250-91(b). Where raceway, cable tray, cable armor, etc., are used as equipment grounding conductors, all joints and fittings shall be made tight to provide an adequate conducting path for ground fault currents per NEC Sections 250-51 and 250-91(c).

Earth and the structural metal frame of a building may be used for supplemental equipment bonding, but they should not be used as the sole equipment grounding conductor for ac systems per NEC Sections 250-58 and 250-51. Equipment grounding conductors for ac systems should run with or enclose the conductors of each circuit per NEC Section 250-57(b).

Where copper or aluminum wire is used as equipment grounding conductors for circuits having paralleled conductors in multiple metal raceways, an equipment grounding conductor should be run in each raceway. The size of each paralleled equipment grounding conductor is a function of the rating of the circuit overcurrent protection. (See NEC Section 250-95.)

4.10.1 SIZING THE EQUIPMENT GROUNDING CONDUCTOR

NEC Section 250-95 lists the requirements for calculating the size of the equipment grounding conductors in an electrical circuit. There are basically five steps to be applied in sizing, selecting, and routing the equipment grounding conductors:

1. NEC Table 250-95 shall be used to size the equipment grounding conductor.

2. When conductors are run in parallel in more than one raceway, the equipment grounding conductor is also run in parallel.
3. Where more than one circuit is installed in a single raceway, one equipment grounding conductor can be installed in the raceway. However, it must be sized for the largest overcurrent device protecting conductors in the raceway.
4. When conductors are adjusted in size to compensate for voltage drop, the equipment grounding conductor shall also be adjusted in size.
5. The equipment grounding conductor is never required to be larger than the circuit conductors.

For example: What size THWN copper equipment grounding conductor is required to be run in a raceway with a 70-A overcurrent protection device protecting the circuit?

Step 1: Finding EGC - NEC Table 250-95 70 A OCPD requires #8 copper

Answer: The equipment grounding conductor is required to be #8 THWN copper.

4.10.2 SUPPLEMENTAL EQUIPMENT GROUNDING CONDUCTORS

Exposure to electrical shock can be reduced by adding supplemental equipment grounding conductors between the conductive enclosures for conductors and equipment and adjacent conductive materials.

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The supplemental equipment grounding conductors contribute to equalizing the potential between exposed noncurrent-carrying metal parts of the electrical system and adjacent grounded building steel when ground faults occur. The inductive reactance of the ground fault circuit normally prevents a significant amount of ground fault current from flowing through the supplemental equipment grounding conductors.

Ground fault current flows through the path that provides the lowest ground fault circuit impedance. Tests have proven that 90% of the fault current flows over the metal raceway system and only 10% flows through the equipment grounding conductor. However, if the fittings in the raceway system are not tight or corrosion prevents good continuity, the equipment grounding conductor will provide an additional path for the fault current to travel over and clear the overcurrent protection device protecting the circuit.

NEC Sections 300-3(b) and 250-57(b) require the equipment grounding conductors to be routed in the same raceway, cable, cord, etc., as the circuit conductors. All raceway systems shall be supplemented with equipment grounding conductors.

Note: The equipment grounding conductor shall be routed with supply conductors back to the source. Additional equipment grounding may be made to nearby grounded structural members or to grounding grids, but this shall not take the place of the co-routed equipment grounding conductors. Raceway systems shall not be used as the sole grounding conductor. (Reference DOE 6430.1A, Division 16, paragraph 1639-1.)

4.11 SYSTEMS WITHOUT GROUNDED CONDUCTORS

Three-phase, three-wire, ungrounded systems, which are extensively used in industrial establishments, do not require the use of grounded conductors as circuit conductors.

The same network of equipment grounding conductors shall be provided for ungrounded systems as for grounded systems. Equipment grounding conductors are required in ungrounded systems to provide shock protection and to present a low impedance path for phase-to-phase fault currents in case the first ground fault is not located and cleared before another ground fault occurs on a different phase in the system.

Grounding electrode conductors and bonding jumpers shall be computed, sized, and installed in the same manner as if the system is a grounded system. Apply all the requirements listed in Sections 4.6 through 4.8 for sizing the elements of an ungrounded system.

4.12 GROUNDING A SEPARATELY DERIVED SYSTEM

NEC Sections 250-5(d) and 250-26 cover the rules for grounding separately derived systems. The system grounded conductor for a separately derived system shall be grounded at only one point. The single system-grounding point is specified as the source of the separately derived system and ahead of any system disconnecting means or overcurrent devices. Where the main system

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disconnecting means is adjacent to the generator, converter, or transformer supplying a separately derived system, the grounding connection to the system grounded conductor can be made at or ahead of the system disconnecting means.

The preferred grounding electrode for a separately derived system is the nearest effectively grounded structural metal member of the building or the nearest effectively grounded water pipe. If neither are available, concrete encased electrodes or made electrodes are permitted to be used.

In a grounded separately derived system, the equipment grounding conductors shall be bonded to the system-grounded conductor and to the grounding electrode at or ahead of the main system disconnecting means or overcurrent protection device. The equipment grounding conductor should always be connected to the enclosure of the supply transformer, generator, or converter.

The grounding electrode conductor, main bonding jumper, grounded conductor, and equipment grounding conductor are calculated, sized, and selected by the rules listed in Sections 4.6 through 4.8. (See Figure 4-7.)

4.13 GROUNDING ELECTRODE SYSTEM

If 10 ft or more of metal water pipe is in the earth, the water pipe is considered the grounding electrode, but it shall be supplemented by an additional electrode. NEC Section 250-81 lists four types of

**NEC Section 250- 26
OSHA Section 1910.304 (f) (3) (ii)**

Figure 4-7. The grounded (neutral) conductor can be used to carry both normal neutral current or abnormal ground fault current.

electrodes. If any one or all are available, they shall be bonded together to make up the grounding electrode system. The bonding jumper that connects these electrodes shall be at least as large as the grounding electrode conductor of the system sized by NEC Table 250-94. The four types of electrodes are as follows:

1. Underground metal water pipe at least 10 ft in the ground
2. Metal frame of the building
3. Bare #4 conductor at least 20 ft in length and near the bottom of the concrete foundation (within 2 in.), or 1/2 in. reinforcing steel or rods at least 20 ft in length (one continuous length or spliced together)
4. Bare #2 conductor encircling building at least 2-1/2 in. in the ground (spliced together at each end).

Personnel safety grounds are applied to deenergized circuits for the purpose of providing a low-impedance path to ground should the circuits become reenergized while personnel are working on or in close proximity of the circuit. In addition, the personnel safety grounds are to provide a means of draining off static and induced voltage from other sources while work is being performed on a circuit. *(Figure 4-9 illustrates an example of personnel safety grounds.)*

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OSHA Section 1926.954 (f)

Figure 4-9. Personnel safety grounds are used to protect electrical workers while servicing, repairing, or being in close proximity of circuits that can be accidentally energized.

4.15.2 CRITERIA FOR PERSONNEL SAFETY GROUNDS

Before personnel safety grounds are selected, the following criteria shall be met for their use, size, and application.

1. A grounding cable shall have a minimum conductance equal to #2 AWG copper.
2. Grounding cables shall be sized large enough to carry fault current long enough for the protective devices to sense and the circuit breaker to clear the fault without damage to cable insulation. An example would be that a 4/0 Neoprene-insulated welding cable will pass 30,000 A for 0.5 sec without melting the insulation.

3. The following are factors that contribute to adequate capacity:

- a. Terminal strength depends upon the ferrules installed on the cable ends
- b. Cross-sectional area to carry maximum current without melting
- c. Low resistance to keep voltage drop across the areas in which personnel are working at a safe level during any period to prevent reenergization
- d. Verify that the grounding cable and clamps are 1 ohm or less by using a ground-loop impedance tester.

4. For further information on the construction of personnel safety grounds, refer to ASTM F855-90.

4.15.3 GROUNDING CLAMPS

Grounding clamps used in personnel safety grounding are manufactured specifically for this use. Grounding clamps shall be a size manufactured for the connection to the size of conductor or switchgear bus being grounded. The ground clamp also shall be rated to handle the full capacity of the available fault currents. Fault currents can technically range in magnitude from 30,000 A to over 200,000 A.

4.15.4 SCREW-TIGHTENING DEVICES

Approved screw-tightening devices designed for the purpose of pressure metal-to-metal contact are required for connections to an adequate system ground.

4.15.5 GROUNDING CABLE LENGTH

Grounding cables shall not be longer than necessary in order to minimize voltage drop and to

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prevent violent movement under fault conditions. For example, as a general rule, grounding cables shall not exceed 30 ft for a transmission line and 40 ft for substation use.

4.15.6 GROUNDING CABLE CONNECTION

Grounding cables shall be connected between phases to the grounded structure and to the system neutral to minimize the voltage drop across the work area if the circuit should become inadvertently reenergized. Workers shall install the ground end clamp of a grounding cable first and remove it last.

4.15.7 CONNECTING GROUNDING CABLES IN ORDER

Grounding cables shall be connected to the ground bus, structure, or conductor first, then to the individual phase conductors. The first connection of the grounding cables to the circuit phase conductors shall be to the closest phase of the system and then connect to each succeeding phase in the order of closeness.

4.15.8 REMOVING SAFETY GROUNDS

When removing personnel safety grounds, reverse the order they were applied to the phases. The grounding cable conductors attached to the ground bus, structure, or conductors shall always be removed last.

4.15.9 PROTECTIVE APPAREL AND EQUIPMENT

Protective apparel shall be worn when applying or removing grounds. An insulating tool (hot stick) shall be used to install grounding cables.

Protective apparel (personnel protective equipment) shall include at least the following:

1. Safety glasses
2. Hard hat
3. Appropriate gloves.

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5.0 SPECIAL OCCUPANCIES

This section covers the specific requirements and procedures of installing electrical equipment and wiring methods in explosive and hazardous locations and underground facilities. Classifications of areas or locations with respect to hazardous conditions are discussed. Proper information is outlined on the correct methods and techniques needed for grounding systems, lightning protection, and control of static electricity.

5.1 EXPLOSIVES

This section references DOE/EV/06194, DOE Explosives Manual, NFPA 70 (NEC), NFPA 77, NFPA 78, and DOD 6055.9-STD. These standards and manuals shall be referenced to ensure safe and reliable installations of electrical equipment and wiring methods in explosive locations.

5.1.1 ASSESSMENT

Whenever an electrical storm approaches, personnel shall exit any location wherein a hazard exists from explosives being initiated by lightning. Evacuation may be necessary from locations listed below:

1. All outdoor operations and operations in buildings that do not have lightning protection and locations within inhabited building distance of the hazard. (When an electrical storm is imminent, explosives operations shall not be initiated.)
2. Locations (with or without lightning protection) where operations involving electrostatic-sensitive bulk explosives or electroexplosive devices (EEDs) are being used.

5.1.2 SHUTDOWN OF OPERATIONS

The following guidelines shall be used for shutdown of an operation during an electrical storm:

1. Process equipment containing explosives shall be shut down as soon as safety permits.
2. When buildings or bays containing explosives are evacuated during periods of electrical storms, operations that cannot be shut down immediately should be manned by the minimum number of personnel required for safe shutdown. When the operation has been brought to a safe condition so that personnel can exit, these remaining personnel shall evacuate.
3. Automatic emergency power equipment shall be provided if electrical power is critical to an explosives operation during a power shutdown or interruption.

5.1.3 LIGHTNING PROTECTION

It is DOE policy to install lightning protection on all facilities used for storage, processing, and handling of explosive materials where operations cannot be shut down during electrical storms and personnel evacuated. Specific operations shall be assessed for the risk of initiation of process materials by lightning. Assessment shall consider the need for protection factors outlined in Appendix I, NFPA 78. When risk is high, as in operations with highly sensitive electrostatic materials or components, operations shall only be conducted in lightning-protected facilities. Approved lightning protection systems shall conform with the requirements of Appendix I, NFPA 78. Examples of acceptable lightning protection systems can be found in DOD 6055.9-STD, DOD Ammunition and Explosives Safety Standards, Chapter 7.

Lightning protection systems shall be visually inspected and a report filed at least annually. Any

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evidence of corrosion, broken wires or connections, or any other problem that negates the system's usefulness shall be noted and repaired.

Lightning protection systems shall be tested electrically every 47 months to ensure testing during all seasons, or immediately following any repair or modification. The testing shall be conducted only with instruments designed specifically for earth-ground system testing. The instruments shall be able to measure 10 ohms $\pm$ 10% for ground resistance testing and 1 ohm $\pm$ 10% for bonding testing. Electrical resistance readings shall be recorded.

Inspection records shall contain the most recent electrical test report and any subsequent visual inspection reports for each building.

5.1.4 STATIC ELECTRICITY

Static electricity shall be controlled or eliminated in areas where materials are processed or handled that are ignitable by static spark discharge. This includes spark-sensitive explosives, propellants, and pyrotechnics, as well as solvent vapors and flammable gases. Approved static electricity dissipation systems shall conform with the requirements of NFPA 77.

**5.1.4.1 BOUNDING AND GROUNDING
EQUIPMENT**

Bonding straps shall be used to bridge locations where electrical continuity may be broken by the presence of oil on bearings, paint, or rust at any contact point. Permanent equipment in contact with conductive floors or table tops is not considered to be adequately grounded. Static grounds shall not be made to gas, steam, or air lines; dry pipe sprinkler systems; or air terminals of lightning protection systems. Any ground that is adequate for power circuits or lightning protection is more than adequate for protection against static electricity.

**5.1.4.2 TESTING EQUIPMENT
GROUNDS**

Grounding systems shall be tested for electrical resistance and continuity when installation has been completed and in the case of active equipment, at intervals to be locally determined. The ground system shall be visually inspected for continuity (before reactivation of the system) if the equipment has been inactive for more than one month. All exposed explosives or hazardous materials shall be removed before testing. When testing for resistance to ground, equipment shall be considered as a unit except in the case of a belt-driven machine. In measuring the total resistance to ground for belt-driven machinery (to ensure compliance with the paragraph below), resistance of the belting is to be excluded. All conductive parts of equipment shall be grounded so that resistance does not exceed 25 ohms, unless resistance is not to exceed 10 ohms because of the lightning-protection installation. For existing equipment, the rate of static generation shall be considered before changes in grounding systems are made. The resistance of conductive rubber hose shall not exceed 250,000 ohms. (See NFPA 77 and NFPA 78 for further information.)

**5.1.4.3 CONDUCTIVE FLOORS, SHOES,
MATS, AND WRISTBANDS**

Conductive floors and shoes should be used for grounding personnel in operations involving explosives that have an electrostatic sensitivity of 0.1 joule or less. Many flammable liquids and air mixtures can be ignited by static discharge from a person. When personnel come into the proximity of (have possible contact with) static-sensitive explosives or vapors, conductive floors shall be installed except where the hazards of dust-air or flammable vapor-air mixtures are eliminated by adequate housekeeping, dust collection, ventilation, or solvent recovery methods. Conductive floors may also be required where operations

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are performed involving electroexplosive devices that contain a static-sensitive explosive.

Conductive floors are not required throughout an entire building or room if the hazard remains localized. In such cases, conductive mats or runners may be used where required. These mats or runners shall be subject to all the specifications and test requirements that apply to conductive floors. Conductive wristbands may be substituted for conductive mats and footwear at fixed, grounded work stations or outdoor locations.

5.1.4.4 CONDUCTIVE FLOOR AND WRISTBAND SPECIFICATIONS

Conductive floors shall be made of nonsparking materials such as conductive rubber or conductive flooring composition and shall meet the following requirements:

1. The flooring and its grounding system shall provide for electrical resistance not to exceed 1,000,000 ohms (measured as specified in Section 5.1.4.5).
2. The surface of the installed floor shall be free from cracks and shall be reasonably smooth. The material shall not slough off, wrinkle, or buckle under operating conditions. Conductive tiles are not recommended for use in areas where contamination can be caused by explosive dust. The large number of joints and the tendency of tiles to loosen provide areas where explosive dust can become lodged and that are not easy to clean with normal cleanup procedures.
3. Where conductive floors and shoes are required, resistance between the ground and the wearer shall not exceed 1,200,000 ohms, which is the total resistance of conductive shoes on a

person plus the resistance of floor to ground. Where conductive floors and shoes are required, table tops on which exposed explosives or dust are encountered shall be covered with a properly grounded conductive material meeting the same requirements as those for flooring.

4. Conductive floors shall be compatible with the explosive materials to be processed.
5. Conductive wristbands shall not exceed a resistance of 1,000,000 ohms between the wearer and ground. This resistance shall be measured with a suitably calibrated ohmmeter. Wristbands shall be of a design that maintains electrical contact with the wearer when tension is applied to the ground lead wire or otherwise is placed under strain.

5.1.4.5 CONDUCTIVE FLOOR TEST

Initial tests shall be conducted on all conductive floors and subsequent tests shall be made at least semiannually. Test results shall be permanently recorded and a copy filed in a central location. Instruments used in making tests shall be used only when the room is free from exposed explosives and flammable gas mixtures.

Maximum floor resistance shall be measured with a suitably calibrated ohmmeter that operates on a normal open circuit output voltage of 500 Vdc and a short circuit current of 2.5 mA with an effective internal resistance of approximately 200,000 ohms. Minimum floor resistance shall be measured with a suitably calibrated ohmmeter appropriate for the task.

Each electrode shall weigh 2.3 kg and shall have a dry, flat, circular contact area 6-1/2 cm in diameter, which shall comprise a surface of aluminum or

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tinfoil 1.3 to 2.5 mm thick, backed by a layer of rubber 0.6 to 0.65 cm thick, and measuring between 40 and 60 durometer hardness as determined with a Shore Type A durometer (ASTM D-2240-68).

The floor shall be clean and dry. Electrode jelly such as brushless shaving soap or saline solution shall not be used.

The resistance of the floor shall be more than 5,000 ohms in areas with 110-V service, 10,000 ohms in areas with 220-V service, and less than 1,000,000 ohms in all areas, as measured between a permanent ground connection and an electrode placed at any point on the floor and also as measured between two electrodes placed 3 ft apart at any points on the floor. Measurements shall be made at five or more locations in each room. If the resistance changes appreciably with time during a measurement, the value observed after the voltage has been applied for about 5 sec shall be considered as the measured value. (See Figure 5-1.)

5.1.4.6 HUMIDIFICATION

Humidification for preventing static electricity accumulations and subsequent discharges is usually effective if the relative humidity is above 60%. However, certain materials such as metallic powders and some pyrotechnic mixtures cannot be exposed to air with 60% relative humidity because of the possibility of spontaneous ignition. Where this technique is used to prevent static electricity accumulations, a daily preoperational check of the humidity levels shall be performed before work starts.

- Test instrument
- 500 V max test voltage
 - 2.5 mA max current (0.5 mA desirable) between electrodes

Figure 5-1. Testing shoes on wearer.

5.1.4.7 GROUND FAULT CIRCUIT INTERRUPTER

Ground-fault circuit interrupter (GFCI) protection shall be provided in static-grounded areas where personnel are using hand-held, portable, ac-powered, electrical equipment operating at 120 V.

5.1.5 ELECTRICAL EQUIPMENT AND WIRING

Electrical equipment and wiring methods that are installed in locations containing explosives shall comply with certain provisions of the National Electrical Code (NEC) and the DOE regulations, plus the requirements of Section 5.1.5.

5.1.5.1 PERMANENT EQUIPMENT AND WIRING

The NEC and this section are minimum requirements for DOE facilities containing explosives. All

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permanent electrical equipment and wiring for those work areas containing explosives hazards shall conform to the standards of the NEC Hazardous Locations Class II or Class I and II (dual rated). For Class II installations, provisions should be made for easy conversion to Class I. The NEC does not specifically address explosives. However, Article 500, "Hazardous (Classified) Locations," does establish requirements for the design and installation of electrical equipment and wiring in locations containing combustible dusts and flammable liquids, vapors, or gases that in general are comparably hazardous.

5.1.5.2 HAZARDOUS LOCATIONS

NEC definitions of Class I and Class II hazardous locations are modified as follows for DOE explosives facility applications:

1. Areas containing explosive dusts or explosives that may, through handling or processing, produce dust capable of being dispersed in the atmosphere shall be regarded as Class II Division 1 hazardous locations.
2. Areas that contain exposed explosives but where no dust hazard exists may be regarded as Class II Division 2 hazardous locations.
3. Watertight equipment (that would pass a NEMA 4 hose test) shall be provided in those locations where water/explosives mixtures may come in contact with the electrical equipment and wiring.
4. Areas where explosives are processed and sublimation may occur or where flammable gases or vapor may be present in sufficient quantities to produce explosive or ignitable mixtures shall be regarded as Class I Division 1 and Class II Division 1 hazardous locations.
5. To ensure assignment to the proper hazardous locations class and group, it is necessary to know the properties of the explosives involved. Minimum requirements include sensitivity to heat, spark, and thermal stability. If the properties of an explosive area are such that Class II Group G equipment provides inadequate surface temperature limits, special protection shall be provided or the equipment shall be excluded from the hazardous location. This equipment shall not have a surface temperature exceeding the lowest onset of the exotherm of the explosive as determined by the differential thermal analysis test or the differential scanning calorimetry test. When NEC Class I or II equipment is not available, the substitute equipment shall be purged (in accordance with NFPA 496) or sealed to prevent explosives contamination, shall be determined intrinsically safe by facility management, or shall be administratively controlled. If the equipment is purged, it shall be monitored for flow.
6. Areas containing explosives that are not defined as hazardous locations (areas containing no dust, vapor, gas hazards, or exposed explosives; e.g., storage magazines) shall be evaluated and documented by facility management to ensure that electrical ignition sources are minimized or shall be regarded as NEC Class II.
7. Procedures shall be established by each DOE facility to control the use and modification of electrical equipment in explosives areas and ensure that uniform

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standards are adhered to throughout the facility.

5.1.5.3 ELECTRICAL SUPPLY SYSTEMS

There may be mutual hazards where explosives facilities are located near electrical supply lines. To protect against these hazards, the NESC (ANSI/IEEE C2) and the following requirements apply to all new construction or major modification and should be considered for existing facilities:

1. Electric lines serving explosive facilities shall be installed underground from a point not less than 50 ft away from such facilities. This also applies to communications and instrumentation lines and security alarm systems.
2. Electric service lines required to be in close proximity to an explosives facility shall be no closer to that facility than the length of the lines between the poles or towers supporting the lines, unless an effective means is provided to ensure that broken, energized lines cannot come into contact with and present a hazard to the facility or its appurtenances.
3. Unmanned electrical substations shall be no closer to explosives facilities than public traffic route distances.
4. Electric transmission lines (carrying 69 kV or more) and the tower or poles

supporting them shall be located not closer to explosives than:

- a. Inhabited building distance if the line in question is part of a system serving a large, offsite area.
- b. Public traffic route distance if loss of the line shall not create serious social or economic hardships.
- c. Underground utility separation distance criteria found in *Table 5-1*.

5.1.5.4 BUILDING SERVICE ENTRANCE

Electrical service entrance for explosives facilities shall be provided with:

1. An intermediate, metal-oxide surge lightning arrester on the primary side of the transformer per ANSI/IEEE C62.11.
2. Surge arresters and surge capacitors on the supply side of the main service disconnect.
3. Interconnected grounding between the lightning arrester, surge arrester, surge capacitors, service entrance ground, and building ground.

5.1.6 TESTING

Certain provisions shall be complied with before tests are performed. Qualified personnel shall be used to determine the time and procedure of the test.

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Table 5-1. Quality-distance separation for protection of underground service installations.^a

Quantity of explosive (maximum pounds)	Distance (m)	Distance (ft)
100	26	80
200	26	80
500	26	80
1,000	26	80
2,000	26	80
5,000	26	80
10,000	26	80
20,000	28	85
50,000	36	110
100,000	46	140
250,000	62	190

a. If the potential building is designed to contain the effects of an explosion, the formula distance = $3.0 \text{ watts}^{1/3}$ can be used to determine separation distances for less than 20,000 lbs.

5.1.6.1 TEST SETUP

In setting up a test, all work shall be done prior to receipt of explosives. Such work includes the following items:

1. All firing site safety devices shall be checked at regular intervals. Such safety devices include warning lights, door and gate firing circuit interlocks, emergency firing circuit cutoff switches, and grounding (including those that are remote from the firing bunker).
2. All firing pad and shot stand setup work that require power tools or other potential spark-producing devices shall be completed. The firing pad shall be cleared of all unnecessary gear. Special precautions and procedures shall be developed and implemented if power

tools or other spark-producing devices are needed after the explosive has been received at the firing pad.

3. If a special structure is required, as much work as possible shall be accomplished on the structure, including assembly of all materials.
4. When possible, all diagnostic equipment shall be set up, checked, and dry runs shall be performed.

5.1.6.2 PIN SWITCHES AND OTEHR NONINITIATING CIRCUITS

Whenever pin switches and other noninitiating circuits are to be checked (such as for charging current or leakage) and are in contact or close proximity to explosives, the check shall be performed remotely. Other noninitiating electrical circuits include strain gauges, pressure transducers,

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and thermocouples, which may be affixed to or close to the explosives within an assembly. If a continuity-only (resistance) check is desired, this may be accomplished as a contact operation with an electrical instrument approved for use with the particular explosive device. When low-firing-current actuators are involved, it may be advisable to conduct these tests remotely.

5.1.6.3 LIGHTNING STORMS

All operations in open, test-firing areas shall be discontinued during lightning storms when explosives are present. Completion of a test after receipt of a lightning alert may be allowed only if test preparation has progressed to the extent that

discontinuance of testing would represent a greater personnel exposure than completion of testing.

5.1.6.4 LOW-ENERGY ELECTROEXPLOSIVE DEVICES

When using hot-wire or low-energy electro-explosive devices (EEDs) for a test firing, apply the following requirements:

1. Procedures shall be established to ensure that RF, FM, and TV transmitters having sufficient output energy to initiate an EED at the test site are either restricted to a safe distance from the site or not operated. *Tables 5-2, 5-3, and 5-4 specify minimum safe distances for the various types of transmitters at several output power levels.*

Table 5-2. Minimum safe distances between radio frequency (RF) transmitters and electric blasting operations.

Transmitter power (watts)	Minimum safe distances (ft)	
	Commercial AM broadcast transmitters	HF transmitters other than AM broadcasts
100	750	750
500	750	1,700
1,000	750	2,400
4,000	750	4,800
5,000	850	5,500
10,000	1,300	7,600
25,000	2,000	12,000
50,000 ^a	2,800	17,000
100,000	3,900	24,000
500,000 ^b	8,800	55,000

a. Present maximum power of U.S. broadcast transmitters in commercial AM broadcast frequency range (0.535 to 1.605 MHz).

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Table 5-3. Minimum safe distances between TV and FM broadcasting transmitters and electric blasting operations.

Effective radiation power (watts)	Minimum safe distances (ft)		
	Channels 2-6 & FM	Channels 7-13	UHF
Up to 1,000	1,000	750	600
10,000	1,800	1,300	600
100,000 ^a	3,200	2,300	1,100
316,000 ^b	4,300	3,000	1,450
1,000,000	5,800	4,000	2,000
5,000,000 ^c	9,000	6,200	3,500
10,000,000	10,200	7,400	6,000
100,000,000	—	—	—

a. Present maximum power, channels 2 to 6 and FM.

b. Present maximum power, channels 7 to 13.

c. Present maximum power, channels 14 to 83.

2. Blasting caps and other low-firing-current igniters or detonators shall be kept separate from explosives at all times, except during actual test charge assembly and setup.
3. The entire wiring system of the explosive charge and of any low-firing-current initiators shall be kept insulated at all times from every possible source of extraneous current. Shunts shall be left on all low-energy initiators or lead wires until actual connections are to be made. Connections shall be taped or otherwise insulated.
4. Test unit low-firing-current actuators or detonators shall be clearly marked. No contact operations involving electrical

testing shall be permitted on this type of unit unless an electrical meter for the specific application is used.

5.1.6.5 WARNING SIGNALS

Each DOE explosives testing facility shall use standard audible signals to warn personnel of any impending firing in a test area. Signals shall be established by each facility and approved by facility management.

5.1.6.6 FIRING LEADS

All detonator lead wires shall be electrically insulated. Firing leads or cables of low-energy detonators for explosive assemblies shall be kept properly shorted during setup on the firing point.

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Table 5-4. Minimum safe distances between mobile RF transmitters and electric blasting operations.

Transmitter power (watts)		Minimum safe distances (ft)				
		MF ^a	HF ^a	VHF(1) ^a	VHF(2) ^b	UHF ^a
5 ^b		—	—	—	—	—
10		40	100	40	15	10
50		90	220	90	35	20
100		125	310	130	50	30
180 ^c		—	—	—	65	40
250		200	490	205	75	45
500 ^d		—	—	209	—	—
600 ^e		300	760	315	115	70
1,000 ^f		400	980	410	150	90
10,000 ^g		1,200	—	1,300	—	—

a. MF 1.6 to 3.4 MHz Industrial
HF 28 to 29.7 MHz Amateur
VHF(1) 35 to 44 MHz Public use
50 to 54 MHz Amateur
VHF(2) 144 to 148 MHz Amateur
150.8 to 161.6 MHz Public use
UHF 450 to 460 MHz Public use

b. Citizens band radio (walkie-talkie), 26.96 to 27.23 MHz and cellular telephones, 3 watts power, 825 to 845 MHz; minimum safe distance; 5 ft.

c. Maximum power for 2-way mobile units in VHF, 15.08- to 161.6-MHz range, and for 2-way mobile and fixed-station units in UHF, 450- to 460-MHz range.

d. Maximum power for major VHF 2-way mobile and fixed-station units in 35- to 44-MHz range.

e. Maximum power for 2-way fixed-station units in VHF, 150.8- to 161.6-MHz range.

f. Maximum power for amateur radio mobile units.

g. Maximum power for some base stations in 42- to 44-MHz band 1.6- to 1.8-MHz band.

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**5.1.6.7 ELECTRICAL INSTRUMENTS FOR
USE WITH EXPLOSIVES
SYSTEMS (EXCEPT THOSE
COVERED BY DOE
ORDER 5610.3)**

Testing instruments shall meet certain criteria and be certified and labeled for the types of testing they are permitted to perform.

5.1.6.7.1 CLASSIFICATION

Test instruments shall be assigned to categories on the basis of electrical characteristics that affect their safe use with explosives systems. Specifically, the instrument categories shall be established so that each category can be safely applied to one or more of the following classes of explosives systems:

1. Low-energy or hot-wire initiators (blasting caps, actuators, squibs, etc.)
2. High energy initiators (exploding bridge-wires, slappers, etc.)
3. Noninitiating electrical circuits.

Test instruments that do not meet the safety criteria may only be used on an explosives system if the activity is considered a remote operation and adequate personnel shielding or separation distance is provided.

5.1.6.7.2 CERTIFICATION

Each DOE facility engaged in the use of electrical test instruments on explosives systems shall establish a formal system for the purpose of reviewing and certifying these instruments. Procedures for marking instruments to show their approved use and restrictions on their use shall also be established.

Every individual test instrument designated for use on explosives systems shall be certified and prominently labeled with its approved use and with a warning if there is a restriction on its use.

Inspection and calibration of certified instruments shall be required at prescribed intervals or whenever the instrument is opened for servicing or repair.

Records of all certified instrument types shall be maintained by each DOE facility using electrical instruments to test explosives systems. These records shall include type, manufacturer, model, electrical specifications, wiring diagrams, and failure mode analyses. The Explosives Safety Committee chairperson shall be notified in writing by DOE facilities when they approve new electrical instruments for use with initiating systems. The chairperson shall disseminate this information to all committee members.

**5.1.6.7.3 ELECTRICAL INSTRUMENTS
FOR USE WITH INITIATING
ELECTRICAL CIRCUITS**

Instruments in this category are used with electrical initiation circuits connected to electroexplosive devices. Instruments may be further categorized for use with either low-energy initiators or high-energy initiators. All test instruments used for this purpose shall be current limited. Before being used on initiating circuits, every individual instrument wiring diagram and internal circuitry design shall be analyzed, examined, and certified for the following:

1. The output current through a resistance equivalent to that of the minimum resistance initiator of the class shall not exceed 1% and shall not exceed 10% of the no-fire rating for the most sensitive initiator of the class. The current-limiting features of the test instrument shall be internal to the instrument and shall not depend on the circuit load characteristics.
2. The internal circuitry shall ensure isolation features that require, as a minimum, two independent failure modes

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before the specified output current can be exceeded.

3. A comprehensive (point-to-point, if possible) wiring check shall be made to ensure that the wiring corresponds to the diagram and that all components are functioning properly and within specifications.

5.1.6.7.4 ELECTRICAL INSTRUMENTS FOR USE WITH NONINITIATING ELECTRICAL CIRCUITS

Instruments in this category are used with electrical circuits connected to instruments such as strain gauges, pin switches, pressure transducers, thermocouples, and electrical components that are affixed to or within an assembly with explosives. These instruments shall meet the following requirements:

1. Each specific use of the instrument shall be analyzed to ensure that there is no credible scenario where the normal test energy from the instrument can ignite explosive charges or initiators in the test.
2. Where an instrument is used to make measurements on sensors directly applied to explosives (e.g., bonded strain gauges or pin switches), the instrument shall be certified and controlled.
3. Instruments used with noninitiating electrical circuits shall be prominently marked with the restrictions on use. Many of these instruments do not meet the requirements for use with initiating systems and shall be marked to prevent their use on this type of circuit.

5.2 PREVENTION OF EXTERNAL IGNITION AND EXPLOSION

Explosives are hazardous enough by themselves, but around electricity there are even more hazards present. An arc, spark, or hot surface can easily initiate an explosion. Therefore, these ignition sources shall be contained or equipment housing such apparatus shall be installed out of the area.

5.2.1 SOURCES OF IGNITION

A source of energy is all that is needed to touch off an explosion where flammable gases or combustible dust are mixed in the proper proportion with air. One prime source of energy is electricity. Equipment such as switches, circuit breakers, motor starters, pushbutton stations or plugs, and receptacles can produce arcs or sparks in normal operation when contacts are opened and closed, which could easily cause ignition. Other hazards are devices that produce heat, such as lighting fixtures and motors. Here surface temperatures may exceed the safe limits of many flammable atmospheres. Finally, many parts of the electrical system can become potential sources of ignition in the event of insulation failure. This group would include wiring (particularly splices in the wiring), transformers, impedance coils, solenoids, and other low-temperature devices without make-or-break contacts. Nonelectrical hazards such as sparking metal can also easily cause ignition. Thus, a hammer, a file, or an other tool that is dropped on masonry or on a ferrous surface is a hazard unless the tool is made of nonsparking material. For this reason, portable electrical equipment is usually made from aluminum or other material that will not produce sparks if the equipment is dropped. Therefore, electrical safety is of crucial importance. The electrical installation shall prevent accidental ignition of flammable liquids, vapors, and dusts released into the atmosphere. In addition, because much of this

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equipment is used outdoors or in corrosive atmospheres, the material and finish shall be such that maintenance costs and shutdowns are minimized. (See Figure 5-2.)

5.2.2 COMBUSTION PRINCIPLES

The following three basic conditions shall be satisfied for a fire or explosion to occur:

1. A flammable liquid, vapor, or combustible dust shall be present in sufficient quantity

Z93 0375

NEC Article 500

Figure 5-2. Arcs and sparks are sources of ignition that produce enough heat to cause an explosion where the air and gas mixture is between the lower and upper flammable limits of the liquid involved.

2. A flammable liquid, vapor, or combustible dust shall be mixed with air or oxygen in the proportions required to produce an explosive mixture
3. A source of energy shall be applied to the explosive mixture.

In applying these principles, the quantity of the flammable liquid or vapor that may be liberated and its physical characteristics shall be recognized. Also, vapors from flammable liquids have a natural tendency to disperse into the atmosphere and rapidly become diluted to concentrations below the lower explosion limit, particularly when there is natural or mechanical ventilation. Finally, the possibility that the gas concentration may be above the upper explosion limit does not ensure any degree of safety since the concentration first passes through the explosive range to reach the upper explosion limit.

5.2.3 EVALUATION OF HAZARDOUS AREAS

Each area that contains gases or dusts that are considered hazardous shall be carefully evaluated to make certain the correct electrical equipment is selected. Many hazardous atmospheres are Class I Group D or Class II Group G. However, certain areas may involve other groups, particularly Class I Groups B and C. Conformity with the NEC requires the use of fittings and enclosures approved for the specific hazardous gas or dust involved. (See NEC Article 500 for more information.)

5.2.4 INTRINSICALLY SAFE EQUIPMENT

The use of intrinsically safe equipment is primarily limited to process control instrumentation because these electrical systems lend themselves to the low energy requirements. ANSI/UL 913-1988 and ANSI/ISA RP12.6 provide information on the design test and evaluation. The installation rules

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are covered in Article 504 of the NEC. The definition of intrinsically safe equipment and wiring is: "Equipment and wiring that are incapable of releasing sufficient electrical energy under normal or abnormal conditions to cause ignition of a specific hazardous atmospheric mixture in its most easily ignited concentration." UL and Factory Mutual list several devices in this category. The equipment and its associated wiring shall be installed so they are positively separated from the nonintrinsically safe circuits. Induced voltages could defeat the concept of intrinsically safe circuits.

5.2.5 ENCLOSURES

In Class I Division 1 and 2 locations, conventional relays, contactors, and switches that have arcing contacts shall be enclosed in explosion proof housings, except for those few cases where general-purpose enclosures are permitted by the NEC. By definition, enclosures for these locations must prevent the ignition of an explosive gas or vapor that may surround it. In other words, an explosion inside the enclosure shall be prevented from starting a larger explosion on the outside. Adequate strength is one requirement for such an enclosure. For explosion proof equipment, a safety factor of 4 is used. That is, the enclosure shall withstand a hydrostatic pressure test of four times the maximum pressure from an explosion within the enclosure. In addition to being strong, the enclosure shall be flame-tight. This term does not imply that the enclosure is hermetically sealed but rather that the joints cool the hot gases resulting from an internal explosion so that by the time they reach the outside hazardous atmosphere, they are

too cool to effect ignition. The strains and stresses caused by internal explosive pressures are illustrated in *Figure 5-3*. Dotted lines indicate the shape that a rectangular enclosure strives to attain under these conditions. Openings in an enclosure strive to maintain the shape of the enclosure. Openings in an enclosure for these applications can be threaded-joint type (*Figure 5-4*) or flat-joint type (*Figure 5-5*).

In Class II locations, the enclosure shall keep the dust out of the interior and operate at a safe surface temperature. Because there will be no internal explosions, the enclosure may have thinner wall sections. The construction of these enclosures is known as dust-ignition-proof.

Z93 0372

NEC Article 500

Figure 5-3. The right mixture of air and gases in an enclosure can cause an explosion that creates internal pressures that can rupture the enclosure if not released properly.

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Z93 0373

NEC Article 500

Figure 5-4. Threaded joints can be used as an escape path to cool the hot gases as they pass through the threads to the outside of the enclosure.

5.2.6 PURGING/PRESSURIZATION SYSTEMS

Purging/pressurization systems permit the safe operation of electrical equipment under conditions of hazard for which approved equipment may not be commercially available. For instance, most switchgear units and many large-size motors do not come in designs listed for Class I Groups A and B. Whether cast metal enclosures for hazardous locations or sheet metal enclosures with pressurization should be used is mainly a question of economics, if both types are available. As a typical example, if an installation had many electronic instruments that could be enclosed in a single sheet metal enclosure, the installation lends itself to the purging/pressurization system. However, if the instruments (because of their nature) had to be installed in separate enclosures,

then the cast metal in hazardous location housing would almost invariably prove more economical. Pressurized enclosures require:

1. A source of clean air or inert gas
2. A compressor to maintain the required pressure on the system
3. Pressure control valves, to prevent the power from being applied before the enclosures have been purged and to deenergize the system should pressure fall below a safe value.

In addition, door-interlock switches are required to prevent access to the equipment while the circuits are energized. It can readily be seen that all of these accessories can add up to a considerable expenditure. For a detailed description of purging/pressurizing systems see NFPA 496, Purged and Pressurized Enclosures for Electrical Equipment in Hazardous Classified Locations.

Z93 0374

NEC Article 500

Figure 5-5. Flat (ground) joints can be used as an escape path to cool the hot gases as they pass through the ground joint.

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5.3 HAZARDOUS LOCATIONS

The intent of this subsection is to assist in the classification of areas or locations with respect to hazardous conditions. Such areas or locations are hazardous because of atmospheric concentrations of hazardous gases, vapors, deposits, or accumulations of materials that may be readily ignited.

This subsection covers the requirements for electrical equipment and wiring in locations that are classified depending on the properties of the flammable vapors, liquids, or gases or combustible dusts that may be present and the likelihood that a flammable or combustible concentration of quantity is present. The hazardous (classified) locations are assigned the designations as follows:

1. Class I Division 1
2. Class I Division 2
3. Class II Division 1
4. Class II Division 2.

Class III fibers and flyings are not covered in this section. For more in-depth design and engineering requirements refer to:

1. National Electrical Code, NFPA 70, Chapter 5, Article 500
2. OSHA (29 CFR 1910) Subpart S, Electrical 1910.307
3. NFPA 497M, Classification of Gases, Vapors, and Dusts for Electrical Equipment in Hazardous Classified Locations
4. NFPA Handbook, Electrical Installations in Hazardous Locations, by P. J. Schram and M. W. Earley

5. NFPA 70E, Chapter 5, Hazardous (Classified) Locations
6. For product suggestions for use in hazardous areas, see the current edition by a manufacturer such the Crouse-Hinds Code Digest
7. NFPA 325M, Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids
8. Underwriters Laboratory, Hazardous Location Equipment Directory, containing listings and classifications currently in effect
9. ANSI/UL 913, Intrinsically Safe Apparatus
10. NFPA 496, Purged and Pressurized Enclosure for Electrical Equipment in Hazardous Locations.

Hazardous areas and locations are classified by group, class, and division. They are determined by the atmospheric mixtures of various gases, vapors, dust, and other materials. The intensity of the explosion that can occur depends upon the concentrations, temperatures, and many other factors that are listed in NFPA codes.

5.3.1 CLASS I

Class I locations are identified in the NEC as those in which flammable gases or vapors are or may be present in amounts sufficient to create explosive or ignitable mixtures. The amount of vapor varies all the way from continuously to never any vapors present at all. If there are never any vapors present, the area is not a hazardous location. However, where a vapor is present, the more likely it is that a flammable mixture will be present.

From an engineering standpoint, greater precautions are needed if a particular set of

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circumstances is likely to occur, such as the presence of a flammable mixture within the explosive range, than are necessary if a flammable mixture within the explosive range is unlikely to occur. Therefore, this is the reason for dividing hazardous locations into two divisions.

5.3.1.1 DIVISION 1

Class I Division 1 hazardous locations are defined in the NEC as those locations in which (a) ignitable concentrations of flammable gases or vapors can exist under normal operating conditions, (b) ignitable concentrations of such gases or vapors may exist frequently because of repair or maintenance operations or because of leakage, or (c) breakdown or faulty operation of equipment or processes might release ignitable concentrations of flammable gases or vapors and might also cause simultaneous failure of electric equipment.

Note that in each case, ignitable concentrations are mentioned. This means concentrations between the lower and upper flammable or explosive limits.

There are minimum and maximum concentrations of flammable gases and vapors that are above and below the mixture and will not burn or explode. The lower limit is where the substance is too lean to burn or explode. The upper limit is where the mixture has become too rich to burn or explode.

The fine print note to Section 500-5(a) of the NEC describes a number of areas and occupancies that are normally classified as Class I Division 1 locations.

NEC Article 100 defines a flammable liquid as having a flash point below 38°C (100°F) or a flammable liquid whose temperature is raised above its flash point. Flash point is the minimum temperature to which a combustible or flammable liquid is heated until sufficient vapors are driven

off and will flash when brought into contact with a flame, arc, spark, etc. (See Section 1-3 of NFPA 497M for more details.)

5.3.1.2 DIVISION 2

The NEC defines Class I Division 2 locations as those locations:

1. In which volatile flammable liquids or flammable gases are handled, processed, or used, but will normally be confined within closed containers or closed systems from which they can escape only in 1.case of accidental rupture or breakdown of such containers or systems or in case of abnormal operation of equipment
2. In which ignitable 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
3. That are adjacent to a Class I Division 1 location and to which ignitable 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.

The fine print note #2 to Section 500-5(b) of the NEC describes a number of areas and occupancies that are normally classified as Class I Division 2 locations. For example, piping without valves, checks, meters, and devices do not usually introduce a hazardous condition even though they are utilized for flammable liquids. They are considered a contained system. Therefore, the area around can be classified as a Class I Division 2 location.

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5.3.2 CLASS II

Class II is defined in Section 500-6 of the NEC as an area where the presence of combustible dust presents a fire or explosion hazard. As in Class I locations, Class II is divided into two divisions that are based upon the rule that dust is present or dust is not normally present.

5.3.3 GROUPS

Until publication of the 1937 edition of the NEC, Class I hazardous locations were not divided into groups. All flammable gases and vapors were classified as a single degree of hazard. It was recognized, however, that the degrees of hazard varied and that equipment suitable only for use where gasoline was handled was not necessarily suitable for use where hydrogen or acetylene was handled.

It was also recognized that manufacturing equipment and enclosures for use in hydrogen atmospheres was very difficult and that the equipment, even if built, was expensive. It was not logical from an engineering standpoint to require explosion-proof equipment in gasoline stations that was also suitable for use in hydrogen atmospheres. Not only would this unnecessarily increase the cost of the electrical installation in one of the most common types of hazardous locations, but it would make some types of equipment unavailable. Even today, there are no listed motors or generators suitable for use in Group A or B atmospheres. (*See Table 5-5.*)

5.3.4 IGNITION TEMPERATURE

Ignition temperature of a substance, whether solid, liquid or gaseous, is the minimum temperature required to initiate or cause self-sustained combustion independently of the heating or heated element.

Ignition temperatures observed under one set of conditions may be changed substantially by a change of conditions. For this reason, ignition temperatures should be looked upon only as approximations. Some of the variables known to affect ignition temperatures are percentage composition of the vapor or gas-air mixture; shape and size of the space where the ignition occurs; rate and duration of heating; kind and temperature of the ignition source, catalytic or other effect of materials that may be present; and oxygen concentration. As there are many differences in ignition temperature test methods, such as size and shape of containers, method of heating, and ignition source, ignition temperatures are affected by the test method.

Ignition temperature of a substance, whether solid, liquid or gaseous, is the minimum temperature required to initiate or cause self-sustained combustion in the absence of any source of ignition.

5.3.5 FLAMMABLE (EXPLOSIVE) LIMITS

In the case of gases or vapors that form flammable mixtures with air or oxygen, there is a minimum concentration of vapor in air or oxygen below which propagation of flame does not occur on contact with a source of ignition. There is also a maximum proportion of vapor or gas in air above which propagation of flame does not occur. These boundary-line mixtures of vapor or gas with air, which if ignited will just propagate flame, are known as the lower and upper flammable or explosive limits and are usually expressed in terms of percentage by volume of gas or vapor in air.

In popular terms, a mixture below the lower flammable limit is too lean to burn or explode and a mixture above the upper flammable limit is too rich to burn or explode.

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Table 5.5. Class I Division 1 summary of hazardous atmospheres (flammable liquids, gases, and vapors exist in an explosive concentration under normal operating conditions).

Group	Atmosphere	Ignition temperature		Ignition energy (millijoules)	Flammable limits (% by volume)		Flash point		NEMA enclosure classification	
		°F	°C		Lower	Upper	°F	°C	Indoor	In- Outdoor
A	Acetylene	581	305	0.017	2.5	100.0	Gas	Gas	7	8
B	1,3-butadiene	788	420	—	2.0	12.0	Gas	Gas	7	8
B	Ethylene oxide	804	429	—	3.0	100.0	-20	-28	7	8
B	Hydrogen	968	520	0.017	4.0	75.0	Gas	Gas	7	8
B	Manufactured gas (containing more than 30% hydrogen by volume)	—	—	—	—	—	—	—	—	—
B	Propylene oxide	840	449	—	2.6	36.0	-35	-37	7	8
C	Acetaldehyde	347	175	—	4.0	60.0	-38	-39	7	8
C	Diethyl ether	320	160	—	1.9	36.0	-49	-45	7	8
C	Ethylene	842	450	0.08	2.7	36.0	Gas	Gas	7	8
C	Unsymmetrical dimethyl hydrazine (UDMH)	480	249	—	2.0	95.0	5	-15	7	8
D	Acetone	869	465	—	2.5	13.0	-4	-20	7	8
D	Acrylonitrile	898	481	—	3.0	17.0	32	0	7	8
D	Ammonia	928	498	—	15.0	28.0	Gas	Gas	7	8
D	Benzene	928	498	—	1.3	7.9	12	-11	7	8
D	Butane	550	288	—	1.6	8.4	Gas	Gas	7	8
D	1-butanol	650	343	—	1.4	11.2	98	37	7	8
D	2-butanol	761	405	—	1.7@212-F	9.0@212-F	75	24	7	8
D	n-butyl acetate	790	421	—	1.7	7.6	72	22	7	8
D	Cyclopropane	938	503	0.25	2.4	10.4	Gas	Gas	7	8
D	Ethane	882	472	—	3.0	12.5	Gas	Gas	7	8
D	Ethanol	685	363	—	3.3	19.0	55	13	7	8
D	Ethylacetate	800	427	—	2.0	11.5	24	-4	7	8
D	Ethylene dichloride	775	413	—	6.2	16.0	56	13	7	8

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Table 5.5. (continued).

Group	Atmosphere	Ignition temperature		Ignition energy (millijoules)	Flammable limits (% by volume)		Flash point		NEMA enclosure classification	
		°F	°C		Lower	Upper	°F	°C	Indoor	Outdoor
D	Gasoline	536 to 880	280 to 471	—	1.2 to 1.5	7.1 to 7.6	7	8	7	8
D	Heptane	399	204	—	1.05	6.7	-36 to -50	-38 to -46	7	8
D	Hexane	437	225	—	1.1	7.5	-7	-22	7	8
D	Isoamyl alcohol	662	350	—	1.2	9.0@212-F	109	43	7	8
D	Isoprene	428	220	—	1.5	8.9	-65	-54	7	8
D	Methane	999	630	0.30	5.01	5.0	Gas	Gas	7	8
D	Methanol	725	385	—	6.0	36.0	52	11	7	8
D	Methyl ethyl ketone	759	404	—	1.7@200-F	11.4@200-F	16	-9	7	8
D	Methyl isobutyl ketone	840	449	—	1.2@200-F	8.0@200-F	64	18	7	8
D	2-methyl-1-propanol	780	416	—	1.7@123-F	10.6@202-F	82	28	7	8
D	2-methyl-2-propanol	892	478	—	2.4	8.0	52	11	7	8
D	Naphtha (petroleum) ⁴	550	288	—	1.1	5.9	<0	<-18	7	8
D	Octane	403	206	—	1.0	6.5	56	13	7	8
D	Pentane	470	243	—	1.5	7.8	<-40	<-40	7	8
D	1-pentanol	572	300	—	1.2	10.0@212-F	91	33	7	8
D	Propane	842	450	0.25	2.1	9.5	Gas	Gas	7	8
D	1-propanol	775	413	—	2.2	13.7	74	23	7	8
D	2-propanol	750	399	—	2.0	12.7@200-F	54	12	7	8
D	Propylene	851	455	—	2.0	11.1	Gas	Gas	7	8
D	Styrene	914	490	—	1.1	7.0	88	31	7	8
D	Toluene	896	480	—	1.2	7.1	40	4	7	8
D	Vinyl acetate	756	402	—	2.6	13.4	18	-8	7	8
D	Vinyl chloride	882	472	—	3.6	33.0	Gas	Gas	7	8
D	Xylenes	867 to 984	464 to 529	—	1.0 to 1.1	7.6	81 to 90	27 to 32	7	8

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5.3.6 FLASH POINT

Flash point of the liquid is the minimum temperature at which the liquid gives off sufficient vapor to form an ignitable mixture with the air near the surface of the liquid or within the vessel used. An ignitable mixture is within the flammable range (between upper and lower limits) that is capable of propagating flame away from the source of ignition when ignited. Some evaporation takes place below the flash point but not in sufficient quantities to form an ignitable mixture. This term applies mostly to flammable and combustible liquids, although there are certain solids, such as camphor and naphthalene, that slowly evaporate or volatilize at ordinary room temperature or liquids, such as benzene, that freeze at relatively high temperatures and, therefore, have flash points while in the solid state.

5.4 HAZARDOUS FLAMMABLE GASES AND VAPOR ATMOSPHERES EXISTING DURING NORMAL OPERATIONS

Hazardous locations must be well understood by anyone designing, installing, working on, or inspecting electrical equipment and wiring methods located in such areas. Such locations are dangerous because of the threat of flammable or combustible gases, vapors, or dusts being present some or all of the time.

5.4.1 CLASS I DIVISION 1

Class I Division 1 is a location in which (a) ignitable concentrations of flammable gases or vapors exist under normal operating conditions, (b) ignitable concentrations of such gases or vapors may exist frequently because of repair or maintenance operations or because of leakage, or

(c) breakdown or faulty operation of equipment or processes might release ignitable concentrations of flammable gases or vapors and might also cause simultaneous failure of electrical equipment. (*See Table 5-5.*)

5.4.2 CLASS I DIVISION 2

Class I Division 2 is a location (a) in which volatile flammable liquids or flammable gases are handled, processed, or used but 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, (b) in which ignitable concentrations of gases or vapors are normally prevented by positive mechanical ventilation and might become hazardous through failure or abnormal operation of the ventilating equipment, or (c) that is adjacent to a Class I Division 1 location and to which ignitable 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. (*See Table 5-6.*)

5.4.3 CLASS II DIVISION 1

Class II Division 1 is a location (a) in which combustible dust is in the air under normal operating conditions in quantities sufficient to produce explosive or ignitable mixtures, (b) where mechanical failure or abnormal operation of machinery or equipment might cause such explosive or ignitable mixtures to be produced and might also provide a source of ignition through simultaneous failure of electrical equipment, operation of protective devices, or from other causes, or (c) in which combustible dusts of an electrically conductive nature may be present. (*See Table 5-7.*)

Table 5.6. Class I Division 2 summary of hazardous atmospheres (flammable liquids, gases, and vapors) not normally present in a explosive concentration but may accidentally exist.

Group	Atmosphere	Ignition temperature		Ignition energy (millijoules)	Flammable limits (% by volume)		Flash point		NEMA enclosure classification	
		°F	°C		Lower	Upper	°F	°C	Indoor	Ia-Outdoor
A	Acetylene	581	305	0.017	2.5	100.0	Gas	Gas	7	8
B	1,3-butadiene	788	420	—	2.0	12.0	Gas	Gas	7	8
B	Ethylene oxide	804	429	—	3.0	100.0	-20	-28	7	8
B	Hydrogen	968	520	0.017	4.0	75.0	Gas	Gas	7	8
B	Manufactured gas (containing more than 30% hydrogen by volume)	—	—	—	—	—	—	—	—	—
B	Propylene oxide	840	449	—	2.6	36.0	-35	-37	7	8
C	Acetaldehyde	347	175	—	4.0	60.0	-38	-39	7	8
C	Diethyl ether	320	160	—	1.9	36.0	-49	-45	7	8
C	Ethylene	842	450	0.08	2.7	36.0	Gas	Gas	7	8
C	Unsymmetrical dimethyl hydrazine (UDMH)	480	249	—	2.0	95.0	5	-15	7	8
D	Acetone	869	465	—	2.5	13.0	-4	-20	7	8
D	Acrylonitrile	898	481	—	3.0	17.0	32	0	7	8
D	Ammonia	928	498	—	15.0	28.0	Gas	Gas	7	8
D	Benzene	928	498	—	1.3	7.9	12	-11	7	8
D	Butane	550	288	—	1.6	8.4	Gas	Gas	7	8
D	1-butanol	650	343	—	1.4	11.2	98	37	7	8
D	2-butanol	761	405	—	1.7@212-F	9.0@212-F	75	24	7	8
D	n-butyl acetate	790	421	—	1.7	7.6	72	22	7	8
D	Cyclopropane	938	503	0.25	2.4	10.4	Gas	Gas	7	8
D	Ethane	882	472	—	3.0	12.5	Gas	Gas	7	8
D	Ethanol	685	363	—	3.3	19.0	55	13	7	8
D	Ethylacetate	800	427	—	2.0	11.5	24	-4	7	8
D	Ethylene dichloride	775	413	—	6.2	16.0	56	13	7	8
D	Gasoline	536 to 880	280 to 471	—	1.2 to 1.5	7.1 to 7.6	7	8	7	8

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Table 5.6. (continued).

Group	Atmosphere	Ignition temperature		Ignition energy (millijoules)	Flammable limits (% by volume)		Flash point		NEMA enclosure classification	
		°F	°C		Lower	Upper	°F	°C	Indoor	In- Outdoor
D	Heptane	399	204	—	1.05	6.7	-36 to -50	-38 to -46	7	8
D	Hexane	437	225	—	1.1	7.5	-7	-22	7	8
D	Isoamyl alcohol	662	350	—	1.2	9.0@212-F	109	43	7	8
D	Isoprene	428	220	—	1.5	8.9	-65	-54	7	8
D	Methane	999	630	0.30	5.01	5.0	Gas	Gas	7	8
D	Methanol	725	385	—	6.0	36.0	52	11	7	8
D	Methyl ethyl ketone	759	404	—	1.7@200-F	11.4@200-F	16	-9	7	8
D	Methyl isobutyl ketone	840	449	—	1.2@200-F	8.0@200-F	64	18	7	8
D	2-methyl-1-propanol	780	416	—	1.7@123-F	10.6@202-F	82	28	7	8
D	2-methyl-2-propanol	892	478	—	2.4	8.0	52	11	7	8
D	Naphtha (petroleum)	550	288	—	1.1	5.9	<0	<-18	7	8
D	Octane	403	206	—	1.0	6.5	56	13	7	8
D	Pentane	470	243	—	1.5	7.8	<-40	<-40	7	8
D	1-pentanol	572	300	—	1.2	10.0@212-F	91	33	7	8
D	Propane	842	450	0.25	2.1	9.5	Gas	Gas	7	8
D	1-propanol	775	413	—	2.2	13.7	74	23	7	8
D	2-propanol	750	399	—	2.0	12.7@200-F	54	12	7	8
D	Propylene	851	455	—	2.0	11.1	Gas	Gas	7	8
D	Styrene	914	490	—	1.1	7.0	88	31	7	8
D	Toluene	896	480	—	1.2	7.1	40	4	7	8
D	Vinyl acetate	756	402	—	2.6	13.4	18	-8	7	8
D	Vinyl chloride	882	472	—	3.6	33.0	Gas	Gas	7	8
D	Xylenes	867 to 984	464 to 529	—	1.0 to 1.1	7.6	81 to 90	27 to 32	7	8

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Table 5.7. Summary of typical combustible dust hazardous atmospheres.^a

Devices			Temperature atmosphere	Covered	Measured	Limiting value
Class	Division	group				
II Combustible dust	Normally hazardous	E ^b	Atmospheres containing combustible dusts regardless of resistivity, or other combustible dusts of similarly hazardous characteristics having resistivity of less than 10 ² ohm-centimeter	Devices not subject to overloads (switches, meters)	Maximum external temperature in 40°C ambient with a dust blanket	Shall be less than ignition temperature dust but not more than:
		F ^b	Atmospheres containing carbonaceous dusts having resistivity between 10 ² and 10 ⁸ ohm-centimeter	Devices subject to overload (motors, transformers)		No overload: E—200°C (392°F) F—200°C (392°F) G—165°C (329°F)
		G ^b	Atmosphere containing dusts having resistivity of 10 ⁸ ohm-centimeter			Possible overload in operation: Normal E—200°C (392°F) F—150°C (302°F) G—120°C (248°F) Abnormal E—200°C (392°F) F—200°C (392°F) G—165°C (329°F)
		2 Not normally hazardous				
		F	Atmospheres containing carbonaceous dusts having resistivity of 10 ⁵ ohm-centimeter or greater	Lighting fixtures	Maximum external temperature under conditions of use	
		G	Same as Division 1			

a. Chart from Crouse-Hinds ECM Code Digest, 1990.

b. NEMA Enclosures Type 9 shall be used for Class II Groups E, F, or G.

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5.4.4 CLASS II DIVISION 2

Class II Division 2 is a location where combustible dust is not normally in the air in quantities sufficient to produce explosive or ignitable mixtures, and dust accumulations are normally insufficient to interfere with the normal operation of electrical equipment or other apparatus, but combustible dust may be in suspension in the air as a result of infrequent malfunctioning of handling or processing equipment and combustible dust accumulations on, in, or in the vicinity of the electrical equipment may be sufficient to interfere with the safe dissipation of heat from electrical equipment or may be ignitable by abnormal operation or failure of electrical equipment. (See Table 5-7.)

5.4.5 ELECTRICAL EQUIPMENT FOR CLASS I, II, AND III AREAS

A wide variety of explosion-proof, ignition-proof electrical equipment is available for Class I, II, and III areas. This electrical equipment shall be selected in full compliance with current NFPA requirements.

An excellent reference of manufacturer's electrical equipment available and used in hazardous areas is the Crouse-Hinds Code Digest, which is based on the current NEC.

5.4.6 SEALS AND DRAINS

Seals are to be provided in conduit and cable systems to minimize the passage of gases or vapors from one portion of the system to another portion. Another purpose of the seals is to keep from transmitting an explosion or to keep ignition from traveling between sections of the system.

5.4.6.1 SEALS

1. Restrict the passage of gases, vapors, or flames from one portion of the electrical installation to another at atmospheric pressure and normal ambient temperatures.
2. Limit explosions to the sealed-off enclosure and prevent precompression or pressure piling in conduit systems.
3. While not a code requirement, many engineers consider it good practice to sectionalize long conduit runs by inserting seals not more than 50 to 100 ft apart, depending on the conduit size, to minimize the effects of pressure piling. Sealing fittings are required.
4. At each entrance to an enclosure housing with an arcing or sparking device when used in Class I Division 1 and 2 hazardous locations, seals must be located as close as practicable and in no case more than 18 in. from such enclosures.
5. At each entrance of 2-in. size or larger to an enclosure or fitting housing terminals, splices, or taps when used in Class I Division 1 hazardous locations, seals must be located as close as practicable and in no case more than 18 in. from such enclosures.
6. Seals must be located in conduit systems when leaving the Class Division 1 or Division 2 hazardous locations.
7. Seals must be located in cable systems when the cables either do not have a gas/vaportight continuous sheath or are capable of transmitting gases or vapors through the cable core when these cables

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leave the Class I Division 1 or Division 2 hazardous locations.

NEC Section 502-5 requires seals in Class II locations under certain conditions. Any approved sealing fittings can be used to meet this requirement.

5.4.6.2 DRAINS

In humid atmospheres or in wet locations where it is likely that water can gain entrance to the interiors of enclosures or raceways, the raceways should be inclined so that water will not collect in enclosures or on seals but will be led to low points where it may pass out through drains. Frequently the arrangement of raceway runs makes this method impractical if not impossible. In such instances, Type EZD drain seal fittings shall be used. These fittings prevent accumulations of water above the seal. See NEC 501-5(d).

In locations that usually are considered dry, surprising amounts of water frequently collect in conduit systems. No conduit system is airtight; therefore, it may breathe. Alternate increases and decreases in temperature and barometric pressure because of weather changes or the nature of the process carried on in the location where the conduit is installed will cause breathing. Outside air is drawn into the conduit system when it breathes in. If this air carries sufficient moisture, it will be condensed within the system when the temperature decreases and chills this air. With internal conditions being unfavorable to evaporation, the resultant water accumulation will remain and be added to by repetitions of the breathing cycle. In view of this likelihood, it is good practice to ensure against such water accumulations and probable subsequent insulation failures by installing EZD with drain cover or inspection cover even though conditions prevailing at the time of planning or installing may not indicate their need.

5.4.6.3 SELECTION OF SEALS AND DRAINS

There are different types of seals and drains that are made to be utilized for vertical or horizontal installations and are to be used only for the purpose for which they are designed. Care shall be taken when selecting and installing such fittings.

5.4.6.3.1 PRIMARY CONSIDERATIONS

The following primary considerations shall be used when selecting seals and drains:

1. Select the proper sealing fitting for the hazardous vapor involved (i.e., Class I Groups A, B, C, or D).
2. Select a sealing fitting for the proper use in respect to mounting position. This is particularly critical when the conduit runs between hazardous and nonhazardous areas. Improper positioning of a seal may permit hazardous gases or vapors to enter the system beyond the seal and permit them to escape into another portion of the hazardous area or to enter a nonhazardous area. Some seals are designed to be mounted in any position; others are restricted to horizontal or vertical mounting.
3. Install the seals on the proper side of the partition or wall as recommended by the manufacturer.
4. Only trained personnel shall install seals in strict compliance with the instruction sheets furnished with the seals and sealing compound. Precautionary notes shall be included on installation diagrams to stress the importance of following manufacturer's instructions.
5. NEC 501-5(c)(4) prohibits splices or taps in sealing fittings.

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6. Sealing fittings are listed by UL for use in Class I hazardous locations with CHICO A compound only. This compound, when properly mixed and poured, hardens into a dense, strong mass, which is insoluble in water, is not attacked by chemicals, and is not softened by heat. It will withstand with ample safety factor pressure of the exploding trapped gases or vapor.
7. Conductors sealed in the compound may be approved thermoplastic or rubber insulated type. Both may or may not be lead covered (the lead need not be removed).

Caution: CHICO A is not an insulating compound; therefore, it shall not be used as such.

5.4.6.3.2 TYPES OF SEALING FITTINGS

The following sealing fittings meet the requirements of NEC when properly installed:

- EYS Sealing Fittings—A certain style of EYS sealing fittings are for use with vertical or nearly vertical conduit in sizes from 1/2 through 1 in. Other styles are available in sizes 1/2 through 6 in. for use in vertical or horizontal conduits. In horizontal runs, these are limited to face up openings. Sizes from 1-1/4 through 6 in. have extra-large work openings and separate filling holes so that CHICO X fiber dams are easy to make. Overall diameter of sizes 1-1/4 through 6 in. is scarcely greater than that of unions of corresponding sizes, permitting close conduit spacings.

- EZS Sealing Fittings—EZS seals are for use with conduit running at any angle, from vertical through horizontal.

5.5 MANUFACTURER'S DIGEST

Manufacturers produce NEC code digests for selection of seals and drains and provide catalog data and installation diagrams for their use with electrical power and lighting systems used in hazardous area by class and division. The manufacturers' NEC code digests shall be in compliance with existing current NFPA/NEC requirements. The two that are most used are as follows:

1. Crouse-Hinds Code Digest
2. Appleton's NEC Code Review.

5.6 DESCRIPTIONS, FEATURES, AND TEST CRITERIA OF ENCLOSURES FOR HAZARDOUS (CLASSIFIED) LOCATIONS (PER NEMA 250)

Type 7 and 10 enclosures, when properly installed and maintained, are designed to contain an internal explosion without causing an external hazard. Type 8 enclosures are designed to prevent combustion through the use of oil-immersed equipment. Type 9 enclosures are designed to prevent the ignition of combustible dust.

Hazardous locations (other than in mines) are classified according to the flammability or combustibility of the materials that may be present and also according to the likelihood that a flammable or combustible concentration is present. For definitions and classifications, see the NEC,

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Article 500, and NFPA 497M, Classification of Gases, Vapors and Dust for Electrical Equipment in Hazardous Classified Locations. Descriptions and tests in this standards publication covers equipment that is suitable for installation in locations classified as Division 1 or 2. In Division 2 locations, other types of protections and enclosures for nonhazardous locations may be installed if the equipment does not constitute a source of ignition under normal operating conditions. See the specific sections of Articles 501 through 503 of the NEC.

Intrinsically safe equipment (not capable of releasing sufficient electrical or thermal energy under normal or abnormal conditions to cause ignition of specific hazardous atmospheres) may be installed in any type of enclosure otherwise suitable for the environmental conditions expected. See NFPA 493, Intrinsically Safe Apparatus in Class I Hazardous Locations, for detailed requirements.

Install equipment in enclosures suitable for nonhazardous locations. Hazards may be reduced or eliminated by adequate positive pressure ventilation from a source of clean air in conjunction with effective safeguards against ventilation failure. See NFPA 496, Purged and Pressurized Enclosures for Electrical Equipment in Hazardous Locations, for detailed requirements.

5.7 TYPE 7 ENCLOSURES

Type 7 enclosures are designed for indoor use in locations classified as Class I Groups A, B, C, or D as defined in the NEC.

5.7.1 DESCRIPTION AND APPLICATION

Type 7 enclosures shall be capable of withstanding the pressures resulting from an internal explosion of specified gases and containing such an

explosion sufficiently that an explosive gas-air mixture existing in the atmosphere surrounding the enclosure will not be ignited. Enclosed heat-generating devices shall not cause external surfaces to reach temperatures capable of igniting explosive gas-air mixtures in the surrounding atmosphere. Enclosures shall meet explosion, hydrostatic, and temperature design tests.

5.7.2 FEATURES AND TEST CRITERIA

When completely and properly installed, Type 7 enclosures:

1. Provide a degree of protection to a hazardous gas environment from an internal explosion or from operation of internal equipment
2. Do not develop surface temperatures that exceed prescribed limits for the specific gas corresponding to the atmospheres for which the enclosure is intended when internal equipment is operated at rated load
3. Withstand a series of internal explosion design tests:
 - a. That determine the maximum pressure effects of the gas mixture
 - b. That determine propagation effects of the gas mixtures
 - c. That withstand, without rupture or permanent distortion, an internal hydrostatic design test based on the maximum internal pressure obtained during explosion tests and on a specified safety factor
 - d. That are marked with the appropriate class and groups for which they have been qualified.

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5.8 TYPE 8 ENCLOSURES

Type 8 enclosures are designed for indoor or outdoor use in locations classified as Class I Groups A, B, C, or D as defined in the NEC.

5.8.1 DESCRIPTION AND APPLICATION

Type 8 enclosures and enclosed devices are arranged such that all arcing contacts, connections, and any other parts that could cause arcing are immersed in oil. Arcing is confined under the oil such that it will not ignite an explosive mixture of the specified gases in internal spaces above the oil or in the atmosphere surrounding the enclosure. Enclosed heat-generating devices shall not cause external surfaces to reach temperatures capable of igniting explosive gas-air mixtures in the surrounding atmosphere. Enclosures shall meet operation and temperature design tests. Enclosures intended for outdoor use shall also meet the rain test.

5.8.2 FEATURES AND TEST CRITERIA

When completely and properly installed, Type 8 enclosures:

1. Provide, by oil immersion, a degree of protection to a hazardous gas environment from operation of internal equipment
2. Do not develop surface temperatures that exceed prescribed limits for the specific gas corresponding to the atmospheres for which the enclosure is intended when internal equipment is at rated load
3. Withstand a series of operation design tests with oil levels arbitrarily reduced

and with flammable gas-air mixtures introduced above the oil

4. When intended for installation outdoors, exclude water when subjected to a water spray design test simulating a beating rain
5. Are marked with the appropriate class and groups for which they have been qualified.

5.9 TYPE 9 ENCLOSURES

Type 9 enclosures are designed for indoor use in locations classified as Class II Groups E or G as defined in the NEC.

5.9.1 DESCRIPTION AND APPLICATION

Type 9 enclosures shall be capable of preventing the entrance of dust. Enclosed heat-generating devices shall not cause external surfaces to reach temperatures capable of igniting or discoloring dust on the enclosure or igniting dust-air mixtures in the surrounding atmosphere. Enclosures shall meet dust-penetration and temperature-design tests and prevent aging of gaskets (if used).

5.9.2 FEATURES AND TEST CRITERIA

When completely and properly installed, Type 9 enclosures:

1. Provide a degree of protection to a hazardous dust environment from operation of internal equipment
2. Do not develop surface temperatures that exceed prescribed limits for the group corresponding to the atmospheres for which the enclosure is intended when internal equipment is operated at rated load

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3. Withstand a series of operation design tests while exposed to a circulating dust-air mixture to determine that dust does not enter the enclosure and that operation of devices does not cause ignition of surrounding atmosphere
4. Are marked with the appropriate class and groups for which they have been qualified.

5.10 UNDERGROUND FACILITIES

Underground facilities consist of electrical equipment and wiring methods being installed in underground locations. Working conditions underground can present hazards for electrical workers that are different than those above ground. This section aids in dealing with such problems.

Electrical work installed in support of construction of mines, shafts, and underground utilities shall be performed by qualified workers who must meet the requirements found in 29 CFR 1910.399 and 1926.499. Only those qualified workers shall install equipment and conductors within the construction activity.

Note: DOE does not engage in "mining" as mining is the extraction of minerals for profit. Therefore, the codes related to mining will not be followed unless not covered by OSHA regulations set forth in 29 CFR 1910 and 1926, in which case 30 CFR 57 will be used as applicable.

Upon completion of construction of the underground facilities, all wiring used for construction activities shall be removed and permanent wiring installed in accordance with 29 CFR 1910, Subpart S, and the NEC as applicable. When not

covered by these codes as referenced, the applicable paragraphs of 30 CFR 57 shall prevail.

Electrical equipment and conductors must be used in a manner to prevent shock and burn to people. Should electric equipment and conductors present a hazard to people because of improper installation, maintenance, misuse, or damage, the equipment and conductors must be tagged or locked out as a hazard until corrected. All electric equipment and conductors shall be chosen and situated in environments conducive to their design and intended use or as tested by an NRTL for the purpose intended.

The voltage of bare conductors, other than trolley conductors, that are accessible to contact by people shall not exceed 50 V. Electric equipment and conductors, other than trailing cables, shall be protected against overloads and short circuits by using fuses or automatic interrupting devices in accordance with 29 CFR 1910.304.

Adequate clearance between equipment and bare overhead conductors must be maintained in accordance with 29 CFR 1910.303. Conductors not being used to supply power to electric equipment shall be deenergized and removed from their power supply or have their power supply locked out and tagged in accordance with 29 CFR 1910.147 and 29 CFR 1910.333. All exposed ends shall be insulated.

Access doors and cover plates shall be closed at all times, except for installation, testing, and repair. Visible danger signs shall be posted at all substations, switch centers, and control centers in order to warn people against entry unless they have been authorized to enter and perform duties in these locations.

5.10.1 WORK ON ELECTRICAL EQUIPMENT AND CIRCUITS

Prior to any work on electric equipment or circuits, the power shall be deenergized unless power is a

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required part of the work procedure. Lockout procedures found in 29 CFR 1910.147 and 29 CFR 1910.333 should be adhered to or a comparable procedure implemented to protect personnel and equipment.

Power-cable plugs and receptacles for circuits greater than 150 V potential to ground shall not be connected or disconnected under load unless they are of the load-break type. Energized power cables in excess of 150 V potential to ground shall be handled in accordance to 29 CFR 1910.331. Care shall be taken to prevent damages or shock and burn from the energized cable.

Proper tools or adequate procedures shall be used to remove or install fuses in order to protect people from shock or burn.

All safety-related electrical work practices covered by the provisions set forth in 29 CFR 1910.331 through .335 shall be followed.

Exposed electric connections or resistor grids not protected by location shall be insulated unless impractical. In this case, guarding shall be installed to prevent accidental contact by people or equipment.

Communication conductors shall be installed in accordance to 30 CFR 57.12010.

Lights and lamps shall be properly guarded when posing a hazard and kept away from combustible material.

5.10.2 GROUNDING

All electric circuits shall have a safety grounding system. The system shall protect people from injuries or fatal shock on inadvertent contact. The system shall limit the voltage on all electric equipment with noncurrent-carrying metallic parts.

Grounding of alternating-and direct-current equipment shall be in accordance with 29 CFR 1910.304(f).

Equipment safety grounding conductors shall comply with the standards expressed in 29 CFR 1910.304(f)(6)(i).

All installations, modifications, or repairs pertaining to safety-grounding systems shall be followed by a continuity test to ensure the integrity of the systems. The frequency and requirements of the review shall conform to 30 CFR 57.12028.

5.10.3 POWER CABLES AND CONDUCTORS

Cables and insulated conductors shall be protected against physical damage, adverse environmental conditions, and failure of adjacent mechanical equipment.

Cables and insulated conductors shall not be supported from or be in contact with pipelines. Sufficient clearance between pipelines and cables is required to prevent shock hazards when maintenance activities are being performed. Minimum clearance of 10 ft above floor level shall be maintained for all cables/conductors run overhead not protected against physical damage as set forth in 29 CFR 1910.304(c)(2)(i).

Electric conductors shall be of a size and current-carrying capacity to ensure that a rise in ambient temperature does not exceed the rating of the insulation and conductors. The capacities of electric conductors supplying electric equipment shall be in accordance with the tables set forth in the National Electrical Code (NFPA 70), Article 310. In the case of medium- or high-voltage cable, the manufacturer's ratings shall not be exceeded.

Splices, terminations, and repairs of electric conductors and power cables shall be permitted and shall conform to the requirements expressed in 29 CFR 1910.303(c).

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Surge arresters and lightning protection are required for underground facilities and shall conform to the requirements found in 30 CFR 57.12069. Lightning arresters shall be inspected for damage at least annually after each electrical storm.

Power cables and insulated conductors in shafts and boreholes shall be supported. Support structures and guy wires and supports for cables and conductors shall conform with the requirements expressed in 30 CFR 57.12083.

5.10.4 TRAILING CABLES

Trailing cables used in mine electrical systems shall meet requirements expressed in 30 CFR 57.12038.

Each trailing cable of portable and mobile equipment shall have short-circuit and ground-fault protection for each ungrounded conductor. Protective devices shall safely interrupt all ungrounded conductors under fault conditions. Requirements for overcurrent protection of each ungrounded conductor shall meet those expressed in 30 CFR 57.12003.

Trailing cables shall be attached to equipment so that strain on electrical connections does not occur and damage to cable jacket and internal conductor insulation is prevented. Portable distribution boxes can be used and shall meet the requirements in 30 CFR 57.12006 and 57.12007. Trailing cables and power conductors shall be protected against physical damage from mobile equipment by using bridges, trenches, or suspension from mine roof. (See Figure 5-6.)

NEC Section 90-2(b)

Figure 5-6. Trailing cables and conductors shall be hung or placed to prevent damage from moving equipment, etc.

Disconnecting devices for trailing cables shall be equipped with means for attaching a padlock.

5.10.5 TROLLEY CIRCUITS FOR TRACK HAULAGE

Trolley wires and exposed trolley-feeder wires shall be installed and maintained in accordance to the requirements in 30 CFR 57.12050 and 30 CFR 57.12086.

Trolley wires and trolley-feeder wires shall be protected against overcurrent in accordance to the requirements of 30 CFR 57.12001.

Track serving as the trolley circuit return shall be bonded or welded according to the requirements of 30 CFR 57.12042. Energized trolley wires and exposed trolley-feeder wires shall be guarded where accidental contact with them is possible. This includes where supplies are stored, loaded, or unloaded.

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6.0 REQUIREMENTS FOR SPECIFIC EQUIPMENT

The electrical safety requirements for specific equipment are determined by the following standards:

1. DOE Order 6430.1A, General Design Criteria
2. NFPA 70, National Electrical Code (NEC)
3. 29 CFR 1910, Occupational Safety and Health Standards
4. 429 CFR 1926, Safety and Health Regulations for Construction.

DOE 6430.1A and 29 CFR 1910 and 1926 frequently reference other safety guidelines for design, operation, and maintenance. Other guidelines consist of ANSI specifications and procedures derived from various engineering sources or equipment manufacturer association standards. However, the key document is NFPA 70, the NEC. All of the other documents are keyed to the NEC. The NEC reflects all of the wiring and installation requirements that provide safe and reliable electrical systems.

6.1 CONVEYING SYSTEMS

Conveying systems are utilized to move materials, goods, etc., from one place to another. Because of their condition of use, they are usually classified in service applications as intermittent duty per NEC Table 430-22(a) and NEC Table 620-15.

6.1.1 GENERAL DESIGN AND INSTALLATION REQUIREMENTS

DOE 6430.1A, Division 14, Conveying Systems, covers the general design criteria for elevators, dumb waiters, wheelchair lifts, escalators, and cranes and it states that all the elements in the electrical systems shall comply with:

1. ASME/ANSI A17.1, Safety Code for Elevators and Escalators
2. NFPA 70, National Electrical Code
3. ANSI C-2, National Electrical Safety Code (NESC)
4. Uniform Building Code, Chapter 51, except enclosures
5. 29 CFR 1910, Occupational Safety and Health Standards
6. 29 CFR 1926, Safety and Health Regulations for Construction
7. UFAS, Handicapped Wheelchair Lifts
8. National Electrical Manufacturer Association (NEMA) Standards
9. NFPA 101, Life Safety Code, Chapters 6 and 7.

All conveying systems shall be suited to the occupancy requirements where they are installed. When they penetrate a security barrier, they shall provide the same degree of penetration resistance and intrusion detection as is required by the site-specific security plan. Power distribution and control circuits shall be as specified in DOE 6430.1A, Section 1640-3, Power Service for Security, Communications and Alarm Systems.

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6.1.2 ADDITIONAL CODES AND STANDARDS

Additional applicable codes and standards are listed below. These are just a sampling of American National Standard Institute (ANSI) B30 and Crane Manufacturers Association of America (CMAA) standards, sufficient to provide an overview of electrical design and maintenance requirements.

1. CMAA-70, Specifications for Electrical Overhead Traveling Cranes
2. CMAA-74, Specifications for Top Running and Under Running Types of Single Girder Electric Overhead Traveling Cranes
3. CMAA Crane Operators' Manual
4. CMAA Overhead Crane and Inspection Checklist
5. ASME B30.2, Overhead and Gantry Cranes
6. ASME B30.11, Monorail Systems and Underhung Cranes
7. ANSI B30.16, Overhead Hoists
8. ASME/ANSI A17.2, Inspectors Manual for Elevators and Escalators
9. ASME/ANSI A17.3, Safety Code for Existing Elevators and Escalators.

6.1.3 ELECTRICAL DESIGN CRITERIA

Electrical design criteria shall be closely coordinated with the architect, structural engineer, fire protection engineer, mechanical engineer, and electrical safety engineer to ensure that all discipline requirements are coordinated and met.

Factory and field performance tests and control and wiring diagrams shall be specified in the purchase order or contract because they are not otherwise

provided by the factory. Acceptance tests conducted by the factory representative, qualified independent inspector, or engineer are recommended. Tests conducted by Underwriters Laboratory (UL) and Factory Mutual Engineering Corporation (FM) are also acceptable.

ANSI standards and manufacturer association standards shall be carefully reviewed to ensure that all applicable safety requirements are to be covered in the specifications.

The designer shall verify or specify the following requirements:

1. Available system voltage
2. Control voltage
3. That the motor be constructed for the specific application
4. That the motor horsepower, service factor, insulation class, and time ratings are sufficient to meet the load requirements
5. Clearances and space requirements
6. Disconnecting means and other NEC requirements.

6.2 CRANES AND HOISTS

The most significant factor in crane safety, after structural integrity, is electrical safety. All of the referenced standards support this fact either directly or indirectly by the amount of definition and space provided for electrical systems' controls, operations, and maintenance.

6.2.1 NEC GENERAL REQUIREMENTS

The basic installation and wiring safety requirements for cranes are given in NEC Article 610. Electrical designers and maintenance personnel should thoroughly understand these requirements and their intent. Some of the more significant requirements are:

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1. Cranes and hoists operated in hazardous (classified) locations shall conform to Article 500 of the NEC.
2. When operated over readily combustible materials, the resistors must be located in a well-ventilated cabinet constructed of noncombustible material and constructed so that they will not emit flames or molten metal. See the exception (and requirements) that applies to certain cabs of noncombustible materials.
3. Cranes and hoists operating on electrolytic cell lines have special requirements as given in NEC Section 668-32.
 - a. Grounding is not required for conductive surfaces of cranes and hoists that enter the working zone of a cell line, and the parts that come in contact with an energized cell or attachments shall be insulated from ground.
 - b. Remote controls that may introduce hazardous conditions into the cell line working zone shall be one of the following:
 - (1) Insulated and ungrounded control circuit in compliance with Section 668-21(a) of the NEC.
 - (2) Nonconductive rope operator.
 - (3) Pendant pushbutton with nonconductive support and surfaces or ungrounded exposed surfaces.

6.2.2 DISCONNECTING MEANS

The disconnecting means provided for cranes and hoists may consist of two or more lock open-type

motor circuit switches or circuit breakers. Article 610, Part D, of the NEC, Disconnecting Means, and the installation and operating plans shall be studied carefully to determine the disconnect requirements and locations. The two basic disconnects to consider are:

1. The runway conductors (conductors run along a crane runway for power or control) disconnect shall:
 - a. Be readily accessible or operable from the ground or floor level per NEC Section 610-31(1)
 - b. Be able to be locked in the open position per NEC Section 610-31(2)
 - c. Open all ungrounded conductors simultaneously per NEC Section 610-31(3)
 - d. Be placed in view of the crane or hoist and the runway conductors per NEC Section 610-31(4).
2. The crane and hoist disconnect shall be provided in the leads from the runway contact conductors or other power supply unless all of the following requirements are met:
 - a. The unit is floor controlled per NEC Section 610-32, Ex. a
 - b. The unit is within view of the power supply disconnecting means per NEC Section 610-32, Ex. b
 - c. No fixed work platform has been provided for servicing the unit per NEC Section 610-32, Ex. c.

See Figure 6-1 (a) and (b) for a detailed illustration of the rules pertaining to the disconnecting means for electric cranes.

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NEC Section 610-31;32
OSHA Section 1910.306 (b) (1) (ii) (a)

Figure 6-1 (a). An additional control switch or a remote control switch is required if the second disconnecting means is not accessible to the operator.

NEC Section 610-31;32
OSHA Section 1910.306 (b) (1) (ii) (b)

Figure 6-1 (b). Second disconnect not required. A monorail hoist does not require a disconnecting means in the leads to the hoist machinery if it is controlled from the floor, if it is within view of the power supply disconnect, and if there is no work platform provided to service the hoist machinery.

6.2.3 GROUNDING

NEC grounding requirements consider the crane or hoist with all of its associated equipment, including electrical equipment, as a single piece of equipment and therefore all of the conductive component parts shall be bonded together so that the entire crane or hoist is grounded in compliance with NEC Article 250, Part G, and NEC Section 610-61. Metal-to-metal contact is required between all surfaces including the trolley wheels and bridge. If any such surfaces are painted or otherwise insulated, a separate bonding conductor is required.

The bonding of all conductive surfaces by metal-to-metal contact is not to be considered as the equipment grounding conductor for the electrical equipment on the crane or hoist. All noncurrent-carrying metal parts of electrical equipment shall have equipment grounding conductors sized in accordance with NEC Article 250, Part G.

6.2.4 CONTROL

A limit switch is required to prevent the load block from passing the safe upper travel limit on all hoisting mechanisms per NEC Section 610-55.

6.2.5 CLEARANCES

In the direction of live parts, the working space clearance is 2-1/2 ft, and doors enclosing live parts that may require service or maintenance shall open at least 90 degrees or be removable per NEC Section 610-57.

6.2.6 OSHA REQUIREMENTS

29 CFR 1910.179 and NEC Article 610, Part F, provide additional electrical requirements derived from ANSI and other standards. Significant requirements are:

1. Control circuit voltage shall not exceed 600 V ac or dc. Pendant pushbutton

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voltage shall not exceed 150 Vac or 300 Vdc. 120 V shall be used if possible per DOE 6430.1 and 1640.2.5.

2. Support shall be provided for pendant multiconductor cables.
3. Electrical systems for cranes and hoists shall provide failsafe operation. When power fails, all motors shall be automatically disconnected so that they will not resume operation when the power comes back on. Automatic cranes shall not commence motion automatically when the power comes on after a power outage. Pendant push-buttons shall be returned to the off position when pressure is released. When the signal from a remote-controller fails, all motion shall stop.

6.2.7 MAINTENANCE AND OPERATIONS

It is important to have a comprehensive electrical maintenance program for cranes and hoists. Every electrical part and circuit plays a critical operational safety role and must be checked and serviced at the frequency and as specified by OSHA, CMAA, ANSI, and that manufacturer's manual. Required weekly, monthly, and semiannual tests and required recordkeeping are contained in ANSI B-30 and CMAA documents.

The basic references for safe operations and maintenance of cranes and hoists are contained in 29 CFR 1910 and 1926:

1. 29 CFR 1910.179, Overhead and Gantry Cranes, addresses operations and maintenance requirements
2. 29 CFR 1910.306, Specific Purpose Equipment and Installations, addresses electrical installation requirements

3. 29 CFR 1926.550 and 29 CFR 1926.554 address construction site operations.

6.2.8 DOCUMENTED MAINTENANCE

Maintenance checklists and schedules in compliance with OSHA, the owner's manuals, and the manufacturer's recommended requirements for the specific equipment shall be provided as required. Weekly, monthly, and semiannual inspections shall be conducted and comments and condition of the inspected part shall be documented and certified as required by 29 CFR 1910.179.

The recommended frequencies of inspections vary in accordance with the application, usage, and authority. Frequent inspection and periodic inspection are defined by OSHA as daily to monthly and one to twelve months respectively. Typical inspection frequencies are as follows:

Weekly	Monthly	Semiannually
Brakes	Control Operations	Motors
Pushbuttons	Collectors	Control Panel
Master Switch	Resistors	
Mainline Disconnect	Conductors	
Warning Device		

The inspection records shall provide an ongoing safety assessment of the equipment and be used to predict repair-part replacement. All inspections shall be dated and initialed by the inspector.

6.2.9 CONSTRUCTION SITES

The primary electrical safety concern of 29 CFR 1926.550 at the construction site is working in proximity to live and unguarded electrical overhead lines. Unless these lines are visibly grounded at the point of work, barriers shall be installed to

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prevent contact or the owner of the line indicates the line is deenergized. The following clearances shall be maintained:

1. Lines 50 kV or below: 10 ft between the lines and any part of the equipment or load
2. Lines over 50 kV: the clearance shall be 10 ft plus 4 in. for every 1 kV above 50 kV.

When it is possible that the operator may have difficulty maintaining these clearances, someone shall be designated to watch the clearances and provide the operator timely warning before contact can be made. The use of cage-type boom guards, insulating links, or a proximity sensor shall not alter the electrical safety requirements of 29 CFR 1926.550, even if these devices are required. (See *Figure 6-2.*)

6.3 ELEVATORS AND ESCALATORS

Elevator motors are considered as intermittent duty. This allows the motors on the elevator to be protected by the overcurrent protection device supplying the power for the branch circuit, which are selected by the percentages in NEC Table 430-22(a) times the full load current of the motors. For example: What is the load for a 15 minute rated 40 hp, 460 V, three-phase motor used for a freight elevator motor?

OSHA Section 1926.952 (b)
NFPA 70E Part II, CH 1, B (2) (i) (1); (2)

293 0370

Figure 6-2 . A minimum clearance of 10 ft between overhead power lines and equipment is required for 50 kV and below while a clearance of 10 ft plus 4 in. every 1 kV above 50 kV is required.

Step 1:	Finding FLC - NEC Table 430-150 40 HP = 52 A
Step 2:	Finding demand factors - NEC Table 430-22(a) 15 minute rated = 85%
Step 3:	Calculating load $52 \text{ A} \times 85\% = 44.2 \text{ A}$
Answer:	Load is 44.2 amps.

6.3.1 CODES AND STANDARDS

A comprehensive electrical safety program for elevators and escalators can be achieved through the application of the guidelines in the following three standards:

1. ASME/ANSI A17.1, Safety Code for Elevators and Escalators
2. ASME/ANSI A17.2, Inspectors Manual for Elevators and Escalators
3. ASME/ANSI A17.3, Safety Code for Existing Elevators and Escalators.

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All elevators are required to be constructed, installed, and maintained in accordance with ASME/ANSI A17.1. Reference standards include NFPA 70 (NEC) for the electrical equipment wiring and NFPA 101 (Life Safety Code), Chapter 6, Features of Fire Protection, and Chapter 7, Building Service and Fire Protection Equipment. These standards reflect the interrelated roles of electrical design, maintenance, and fire protection in the electrical safety process.

6.3.2 DESIGN SPECIFICATIONS

The electrical designer shall provide for the installation requirements of Article 620 of the NEC as well as the ASME/ANSI A17.1 requirements of Sections 102, 210, and 211 for signalling, automatic fire protection, and emergency power as required. The manufacturer shall provide the required fire service key switches, audible alarm devices, and internal wiring up to the terminal strips in the elevator control panel.

6.3.2.1 VOLTAGE AND CURRENT LIMITATIONS

There shall be a 300-V limitation on all operating control and signal circuits and related equipment, including door operators. Exceptions are permitted for 25 to 60 Hz ac if the current cannot under any conditions exceed 8 mA, or for dc voltage if the current cannot, under any circumstances, exceed 30 mA.

6.3.2.2 CONDUCTORS

Hoistway door conductors from the door interlocks to the hoistway riser shall be flame retardant, suitable for a temperature of at least 200°C, and Type SF or equivalent. See Table 400-4 of the NEC for approved types of elevator cables and Note 6 to Table 400-4 concerning special requirements for traveling control and signal cables. Operating control and signal cable conductors may be as

small as #24 awg. Traveling cable conductors are limited to #20 awg.

6.3.2.3 DISCONNECTING MEANS

The disconnecting means requirements for elevators and escalators are both specific and extensive, requiring careful study of the codes and installation plans during design, acceptance testing, and routine inspections. Some of the basic requirements of NEC Section 620-51 are:

1. A single means of disconnecting all ungrounded conductors to the main power supply of each unit.
2. A single elevator or escalator, with multiple driving machines, shall have one disconnecting means to disconnect the motors and control valve operating magnets.
3. The disconnecting means shall be labeled when there is more than one driving machine in a machine room per NEC Section 620-51 and 29 CFR 1910.303(f).
4. The disconnect shall be a fused motor circuit switch or circuit breaker, capable of being locked open.
5. The disconnect shall not be provided with a means of being operated from a remote location.
6. A circuit-breaker disconnecting means shall not be opened automatically by a fire alarm system.
7. The within-sight rule applies to all elevator equipment disconnects. Specific locations are given for elevators with or without field control.
8. The disconnecting means shall be installed in a location that is readily accessible to only qualified persons.

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When power from more than one source is utilized for single or multiple car installations, a separate disconnect shall be provided for each source. These disconnects shall be in sight of the equipment supplied and warning signs shall be placed on or adjacent to the disconnect to read, "Warning—parts of the control panel are not deenergized by this switch."

Lighting circuits for each elevator require a disconnect switch in the equipment room that are labeled for the car they serve and are lockable in the open position.

6.3.2.4 GROUNDING

All metal raceways and cables, Types MC, MI, or ac, shall be bonded to the metal frame of the car. All elevator equipment including metal enclosures for electric devices on the car shall be grounded in accordance with Article 250 of the NEC.

6.3.2.5 OVERSPEED PROTECTION

Overspeed protection for overhauling and underhauling is required, as are motor-generator overspeed requirements that must comply with NEC Section 430-89, Speed Limitation. However, these requirements are a part of the more extensive requirements of ASME/ANSI A17.1 for electrical safety devices, which require close scrutiny by designers, maintenance personnel, and inspectors.

6.3.3 EMERGENCY POWER

The emergency power requirements are governed by ASME/ANSI A17.7 Rule 210.10, which requires that the regenerative power of an overhauling elevator shall be provided to prevent the elevator from attaining the lesser of the governor tripping speed or 125% of rated speed. If the elevator power system cannot absorb this power, then a load shall be provided on the load side of the elevator power disconnect switch. If an emergency

power supply is designed to operate only one elevator at a time, then the energy absorption means may, if required, be located on the line side of the disconnect. Other building loads that may be supplied by the emergency power source may not be considered as absorbing regenerated energy unless they utilize the emergency power source as normal power. Refer to Article 620, Part K, of the NEC, Overspeed, for the installation requirements covering these requirements.

6.3.4 DESIGN

In addition to the NEC elevator and escalator requirements, there are numerous electrical requirements for the facilities designer in ASME/ANSI A17.1 and A17.3. ASME/ANSI A17.1 is a required reference for new elevator and escalator installations and can be used by the designer in checking submittal drawings from the manufacturer. ASME/ANSI A17.3 provides the safety requirements for existing elevators and escalators and shall be referenced when existing installations are to be modified or to determine which modifications shall be made to existing installations and equipment in order to maintain optimum safety.

Typical key electrical requirements from ASME/ANSI A17.1 that the designer shall control over and above those from the NEC are:

1. Access to elevator equipment is to be controlled and limited to authorized persons only.
2. Elevator equipment cannot share space with other building equipment except when the elevator equipment is separated from other equipment, enclosed by a rigid wire fence, and provided with a lock that is strictly for that enclosure.
3. Only electrical wiring, including raceways and cables, used directly in

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connection with the elevator, including wiring for (a) signals, (b) communication with the car, (c) lighting, heating, air conditioning, and ventilating the car, (d) fire-detecting systems, (e) pit sump pumps, and (f) heating and lighting the hoistway may be installed in the hoistway.

4. A minimum lighting level of 108 lux for the equipment rooms and spaces and 54 lux on the floor of the pit are required. The basis for the specified illumination level should be in accordance with the Illuminating Engineering Society (IES) lighting handbook.
5. A stop switch (emergency stop) is required in each elevator pit at the access door to the pit. If the pit exceeds 6 ft, 7 in., a second switch is required adjacent to the ladder. The two switches will be connected in series. See ASME/ANSI A17.1, Section 210.
6. Car lighting shall consist of a minimum of two lamps to be supplied by a dedicated circuit with a lock-open disconnect in the equipment room.
7. A 115-V, 20-A receptacle shall be provided in all equipment spaces and in the pit.
8. A phase-reversal protection shall be provided to ensure that the elevator motor cannot start if the phase rotation is in the wrong direction or if there is a failure of any phase.
9. Capacitors and other devices whose failure could cause unsafe elevator operation are prohibited; only devices specified by the NEC may be installed.

6.3.5 FIRE PROTECTION

The electrical designer shall coordinate with the manufacturer the design of the fire protection systems that connect to the elevator control panel. The system will be designed to return the car to a designated area (normally the first floor or lobby) in the event of smoke or fire conditions in the equipment area or near the elevators. In the event of smoke near the designated area, the car is returned to an alternate area where passengers can safely exit the facility. In addition to coordinating car control, the system provides for the shutdown of the electrical elevator equipment prior to operation of the sprinklers and the transmission of the alarm and provides a means for the fire fighters to assume manual control of the elevator from the designated area. The requirements for these systems are detailed in ASME/ANSI A17.1, Section 211, Emergency Operation and Signaling Devices.

6.3.6 INSPECTIONS AND RECORDS

Elevator inspections and record keeping are performed in accordance with the local authority having jurisdiction. ASME/ANSI A17.2, Inspectors Manual for Elevators and Escalators, provides a guide for performing tests and inspections as well as recommended inspection checklists. In addition to acceptance inspections and tests, the code requires one-and five-year inspections for electric elevators and one-and three-year inspections for hydraulic elevators.

6.3.6.1 CODES

Elevators are required to be in compliance with the issue of ASME/ANSI A17.1 in force the date they were installed. If the local authority has adopted ASME/ANSI A17.3, the code for existing installations, then they shall be in compliance with it, except they shall not be downgraded to it. When ASME/ANSI A17.3 is in force, it becomes the minimum standard to which installations shall

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apply, and if existing installations are upgraded in accordance with ASME/ANSI A17.1, Part XII, they shall also be in compliance with the more stringent requirements of this part.

6.3.6.2 INSPECTOR QUALIFICATIONS

Inspectors shall meet the requirements of ASME/ANSI QEI-1 and be recognized by the local enforcing authority. Repair and maintenance personnel shall be qualified elevator mechanics.

6.4 PORTABLE GENERATORS

The practice of using portable generators to operate electric tools on job sites is permitted under specific conditions both by NEC Section 305-6 and OSHA. However, OSHA inspections have disclosed a potentially serious hazard resulting from their use.

Both OSHA and the NEC permit the use of two-wire, single-phase generators of not more than 5,000 W "where the circuit conductors of the generator are insulated from the generator frame and all other grounded surfaces." Under these conditions, neither the receptacles, cord sets, nor tools need to be protected by GFCIs or an assured equipment grounding conductor program. This exception is granted because with an insulated (isolated) circuit, there is no dangerous current flow from the generator-fed conductors to ground, structural steel, or any other grounded object.

However, if the circuit conductors are not isolated, the shock hazard would be the same as with any other electrical source and the exemption does not apply.

All portable electric generators supplying 15- or 20-A, 120-V receptacles that are in use or available for use on construction sites shall meet all of the following conditions or only be used with either GFCIs or an assured equipment grounding conductor program.

1. Be rated not more than 5 kW
2. Have only a two-wire circuit (i.e., only 120-V output)
3. Have both of the circuit conductors insulated from the frame and all other grounded surfaces.

See NEC Section 250-6(c) and *Figure 6-3*.

6.5 BATTERIES

Storage batteries are considered a live source and appropriate precautions shall be taken when working around them.

NEC Section 250-6(c); 305-6

Figure 6-3 . The ungrounded frame of a generator is acceptable as a grounding electrode with the circuit conductors insulated from the frame and all grounded surfaces.

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6.5.1 SURROUNDING SPACE

Space shall be provided around storage batteries for safe inspection, maintenance, testing, and cell replacement. Space shall be left above cells to allow for operation of lifting equipment when required, addition of water, and taking measurements.

6.5.2 LOCATION

Storage batteries shall be located within a protective enclosure or area accessible only to qualified persons. A protective enclosure can be a battery room; a control building; or a case, cage, or fence that shall protect the contained equipment and minimize the possibility of inadvertent contact with energized parts.

6.5.3 VENTILATION

The battery area shall be ventilated either by a natural or powered ventilation system to prevent accumulation of hydrogen. The ventilation system shall limit hydrogen accumulation to less than an explosive mixture. See NESC, Section 14, for more inspection procedures and rules concerning gel-type and lead-acid batteries.

6.5.4 CONDUIT

Because the vapors given off by a storage battery are very corrosive, the wiring shall withstand the corrosive action and special precautions are necessary as to the type of insulation used as well as protection of all metalwork. It is stated by the respective manufacturers that conduit made of aluminum or Everdur (silicon-bronze) is well suited to withstand the corrosive effects of the vapors in battery rooms. If steel conduit is used, it is recommended that the conduit be zinc-coated and kept well painted with asphaltum paint.

6.5.5 BATTERY ROOM

There are no special requirements on the type of fixtures or other electrical equipment used in the battery room. Ventilating the room properly will prevent explosions. See NEC 480-8 and *Figure 6-4*.

6.5.6 PERSONAL PROTECTIVE EQUIPMENT

Personal protective equipment (PPE) shall be used while working on or servicing batteries. PPE used while working on or servicing batteries shall be capable of protecting employees from acid splashes. The minimum acceptable level of PPE protection shall include acid-resistant gloves, aprons, and chemical-splash goggles. A full-face shield may also be used, however, it shall not be worn in place of goggles.

**NEC Section 480-8
OSHA Section 1910.305 (f)(7)**

Figure 6-4 . With proper ventilation there are no special requirements for wiring methods and equipment installed in batter rooms per NEC 480-8.

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The design and use of PPE when servicing batteries shall comply with the requirements of 29 CFR 1910.132, .133, and .136. See NESC, Section 146; and IEEE 450, Section 4.2.2. For information on safety showers and eye wash stations, see 29 CFR 1910.151(c) and 29 CFR 1910.178(g)(2).

6.5.7 TOOLS

Tools used for working on batteries shall be insulated or nonsparking.

6.5.8 STORAGE BATTERIES AND BATTERY BANKS

The following covers rechargeable-type batteries used as a source of electrical energy. This criterion is not limited to batteries of a particular voltage and energy rating, since the nature of the associated electrical hazards is similar for any battery size, except that the severity of the hazard increases as the battery ratings increase.

6.5.8.1 TYPES OF HAZARDS

Some of the types of hazards are as follows:

1. Accidental grounding of one polarity of a battery bank can create a hazardous voltage between the ungrounded polarity and ground.
2. Accidental shorting of the exposed terminals or cables of a battery can result in severe electric arcing, causing burns and electrical shock to nearby personnel.
3. Hydrogen gas generated during battery charging can create fire, explosion, and toxic hazards.
4. Exposed terminals in a battery bank present electrical shock hazards.

5. Batteries can explode if they are shorted or if they are charged at excessively high rates, particularly for sealed-cell batteries.
6. Electrolytes can be highly corrosive and can produce severe burns to personnel on contact.

6.5.8.2 DESIGN AND CONSTRUCTION CRITERIA

Reliable design and construction criteria is as follows:

1. Battery installations shall conform to the requirements in the latest edition of the NEC.
2. Battery banks should not be grounded; a ground detector should be used to indicate an accidental ground.
3. Batteries should be mounted to allow safe and convenient access for maintenance.
4. Lockable doors for rooms or enclosures containing battery banks to control access should be provided.
5. Approved safety showers and eyewash stations should be provided close to battery banks.
6. Appropriate ventilation for gas discharge should be provided.
7. In certain areas where seismic activity is present, the installation should be designed according to local standards.

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of the circuit could result in a hazardous arcing condition.

Operating criteria is as follows:

1. Maintain battery bank connections that are clean and tight to prevent excessive heating because of contact resistance.
2. Do not repair battery connections when current is flowing. An accidental opening

3. Clearly post electrical and other hazards of battery banks and emergency first aid procedures near the equipment.
4. Arrange the battery banks so that temperature stratification will not result in over- or under-charging.

Note: The optimum temperature for maximum battery life is 77°F ± 2° (25°C ± 1).

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7.0 HIGH VOLTAGE WORK-IN-EXCESS OF 600 VOLTS

Qualified utility workers are required to perform a wide variety of job tasks working with and around higher-voltage electricity, electrical equipment, and apparatus. The nature of the work performed by this group of employees necessitates an understanding of safety policies and rules applicable to performing assigned job tasks.

The following standards and sections provide additional information for repairing, servicing, and maintaining electrical circuits and equipment that are supplied by over 600-V systems.

1. 29 CFR 1910.268(o)
2. 29 CFR 1926.956
3. 29 CFR 1910.134
4. 29 CFR 1910.135
5. 29 CFR 1910.147
6. 29 CFR 1910.331-335
7. 29 CFR 1926, Subpart V, Safety and Health Regulations for Construction
8. ANSI/IEEE C-2, National Electrical Safety Code.

7.1 RESPONSIBILITIES FOR SAFETY

The purpose of this section is to provide safety procedures, guidelines, and requirements for carrying out assigned job tasks.

It is impossible to include in this section a list of safety rules surrounding all job situations and conditions. It is essential that each employee exercises good sound judgment to perform assigned tasks in a safe manner. Safety is the responsibility of each employee.

7.1.1 SUPERVISORS

Supervisors are responsible for knowing and implementing applicable safety policies and directives and taking other action as required to provide for the safety of the personnel and operations they supervise. This includes taking positive action to determine and reduce, as necessary, the hazards associated with their operations; instructing employees in safe work methods and associated safety requirements; verifying that employees are qualified for the work they will be called upon to perform; and ensuring that employees perform their work in a safe manner.

Supervisors shall be responsible for the safety of all employees under their supervision. Supervisors shall enforce the rules that are most stringent, either from this safety guidelines or their organization safety manual.

Supervisors shall make certain that each new or transferred employee is instructed in the safe practices pertaining to his or her work.

The supervisor shall promote safety. The supervisor shall provide poster boards on which to display safety posters and safety information. Those boards shall be placed in conspicuous locations and maintained in a neat and orderly condition. These posters shall be used for safety matters only.

The supervisor shall ensure all employees receive instruction in appropriate emergency procedures, such as CPR, first aid, pole top, and confined space rescue as warranted by the employee's duties.

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7.1.2 LINE MANAGEMENT (SUPERVISOR)

The supervisor shall outline safe practices for the crew and shall see that the instructions are followed.

The supervisor should, from time to time, examine supervised employees on their knowledge of the safety rules and of the approved emergency procedures.

The supervisor shall not allow a worker to perform any task that the worker cannot perform safely.

The supervisor shall report every personal injury in the established manner prescribed for the facility.

The supervisor shall be held responsible for the maintenance and proper use of all protective devices. When there is doubt as to the necessity for using safety devices, the supervisor shall take the safe course required in their use.

The supervisor shall be responsible for proper posting of hazardous work areas as a safeguard to those supervised. Under no circumstances shall the supervisor allow work to continue if safety precautions are ignored.

When it is necessary for a supervisor to leave the job, a qualified worker shall be designated to be in charge of the work during the absence. The supervisor shall not leave the job while dangerous work is in progress.

The supervisor shall coach and direct employees who are working near hazardous wires, equipment, or apparatus.

7.1.3 WORKERS

All workers are responsible for performing their work in a manner that will not endanger

themselves, their coworkers, or others in the area and for complying with established safety rules and requirements. Workers are encouraged to contribute to the safety program and bring to the attention of their supervisors or safety representative any condition they believe is unsafe.

The greatest responsibility for a worker's safety lies directly with the worker.

Workers should not rely solely upon the care exercised by another for their protection.

The worker should examine the work for existing hazards and shall proceed in a safe manner.

Fellow workers should be cautiously warned when seen in a dangerous situation, in such a manner as to avoid confusion, startling, or suddenly alarming them.

Before climbing poles, ladders, or structures or before working on scaffolds, a careful inspection shall be made to determine whether they are in a safe condition and are properly supported. When working at heights over 6 ft, a fall protection scheme should be implemented to protect workers from harmful or deadly falls.

It is the responsibility of each worker to attend safety meetings. Workers should also make a practice of learning safety information made available to them, which will help them perform their work more safely.

The worker shall report to the foreman any personal injury as prescribed for the facility as soon as possible.

The worker shall exercise care and good judgment when lifting heavy material. The worker shall obtain help if the object is too heavy or awkward.

Workers shall not carry anything in their hands while ascending or descending from ladders. Small

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objects or tools may be carried in pockets or pouches. However, larger objects shall be raised or lowered by use of ropes and blocks.

Only one person may go up or down a ladder at a time. Others working nearby or below shall remain out of line of the work area in case anything should accidentally be dropped.

7.2 PROTECTIVE CLOTHING

Appropriate protective clothing shall be worn to protect employees from electrical hazards because of the presence of high voltage apparatus. Employees authorized or required to work on high voltage systems shall be completely familiar with the protective clothing needed to adequately protect them while working on such systems.

(Refer to Table C-5, Appendix C.) (*See Figure 7-1.*)

7.2.1 SHOES

Always wear serviceable shoes or boots of the nonconductive type that comply with the requirements of ANSI 241 and are suited to the work to be performed. Canvas shoes, sandals, moccasins, or shoes with thin or badly worn soles are not considered serviceable types.

Note: No metal parts shall be present in the sole or heel of the shoes.

7.2.2 SAFETY HAT

Workers should wear approved hard hats when working aboveground on poles, structures, or buildings or in trees per ANSI Z89.1.

OSHA 1910.132; 133
OSHA 1926.951

Figure 7-1. Appropriate protective clothing shall be worn by employees to protect them from electrical hazards.

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The following standards can be utilized to obtain more information on protective clothing equipment:

Subject	Number and Title
Head Protection	ANSI Z89.2-1971, <i>Safety Requirements for Industrial Protective Helmets for Electrical Workers, Class B</i>
Eye and Face Protection	ANSI Z87.1-1979, <i>Practice for Occupational and Educational Eye and Face Protection</i>
Blankets	ANSI/ASTM D1048-1981, <i>Specifications for Rubber Insulating Blankets</i>
Hoods	ANSI/ASTM D1049-1983, <i>Specifications for Rubber Insulating Covers</i>
Line Hoses	ANSI/ASTM D1050-1985, <i>Specifications for Rubber Insulating Line Hoses</i>
Sleeves	ANSI/ASTM D1051-1981, <i>Specifications for Rubber Insulating Sleeves</i>
Gloves	ANSI/ASTM D120-1984, <i>Specifications for Rubber Insulating Gloves</i>
Mats	ANSI/ASTM D178-1981, <i>Specifications for Rubber Insulating Matting</i>

Hard hats meeting ANSI Z89.1 shall be worn when working on the ground adjacent to poles, structures, buildings, or trees in which work is being done. There is always a possibility of falling objects. Wear a hard hat when visiting or observing in areas where overhead work is being done per 29 CFR 1910.135.

7.2.3 EYE PROTECTORS

Whenever eyes are in danger of injury, safety goggles or other eye protectors meeting ANSI standards shall be worn. When working near, around, or within electrical equipment, eye protection shall be nonmetallic and nonconductive. (See ANSI 187.1 for more information.)

7.2.4 RESPIRATORS

Wear ANSI-approved dust respirators when working in dust-laden air per 29 CFR 1910.134.

7.2.5 METAL FASTENERS

Do not wear loose chains or metal of any kind. Clothing with metal fasteners can be dangerous when working on or near energized equipment.

7.2.6 WORK GLOVES

When high voltage gloves are not required, suitable work gloves should be worn while handling materials and equipment to prevent the possibility of slivers, cuts, and skin irritation.

7.2.7 SLEEVES

Wear outer garments with full length sleeves. Sleeves shall be rolled down for protection.

7.2.8 RUBBER GLOVES

The following requirements apply:

1. Rubber gloves shall be of appropriate voltage rating for the work being

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performed. All rubber gloves shall meet the standards set forth in ANSI/ASTM D120.

2. Rubber gloves shall be tested at appropriate voltage levels at intervals not exceeding 6 months.
3. Leather glove protectors shall be worn over rubber gloves.
4. Rubber gloves shall be carried in a canvas bag especially provided for this purpose only.
5. Rubber gloves shall be given a visual inspection and air tested daily before use.
6. Rubber gloves shall be uniquely identified by serial number or other marking. Records of dielectric tests shall be logged.

7.3 PROTECTIVE EQUIPMENT

Protective equipment that is utilized to protect workers from electrical hazards because of high voltage arcs, flashes, etc., shall be stored and maintained. (Refer to Section 2.12.12.)

7.3.1 RUBBER LINE HOSE AND BLANKETS

Rubber line hose, blankets, and hoods are to be considered only as additional protection. They should never be depended upon for complete protection. Rubber line hose, hoods, and blankets shall be inspected before they are used. Rubber blankets shall be tested before first use, annually, and as otherwise required. Rubber blankets shall be stored in suitable protective containers or in truck compartments used solely for the storage of rubber protective equipment.

Rubber protective equipment shall be used and maintained in accordance with the provisions of the ANSI D series of standards.

7.3.2 INSULATED TOOLS

A careful periodic inspection shall be made of equipment used for handling or testing energized lines or equipment. Such tools shall be examined each time before they are used to make certain they are in good condition.

Note: Insulated tools shall never be relied upon for complete protection.

Particular attention shall be given to the surface preservation of wooden tools used around electrical equipment. This equipment includes ladders, pike poles, switch sticks, live line tools, and insulating platforms. Only varnish or other appropriate transparent insulating preservatives shall be used.

Insulated tools shall be stored in a dry location. Suitable containers or racks shall be provided to protect the tools from mechanical damage and warping.

7.3.3 PROPER USE OF RUBBER PROTECTIVE EQUIPMENT

All precautions adopted to ensure the delivery of rubber protective equipment to the worker in perfect condition will be nullified unless the equipment is properly used.

7.3.4 STOREROOM STORAGE

Since heat, light, oil, and distortion are natural enemies of rubber, protective equipment shall be guarded from these as much as possible. Rubber equipment shall not be stored near boiler rooms, steam pipes, or radiators and should be protected from exposure to direct sunlight.

7.3.5 TRUCK STORAGE

The storing of rubber protective equipment on the line truck should be carefully planned. No other

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equipment shall be permitted in the rubber compartment. If possible, separate compartments should be provided for each class of equipment, and each compartment should be of sufficient size to allow the articles to lie in a natural position. Line hose should not be bent to fit into a small compartment. Provide space that will allow it to lie straight. If space will permit, blankets should be carried in a flat position provided they are protected from injurious contact with other equipment. Otherwise, they should be carried in canisters.

7.3.6 PLACING OF RUBBER GOODS (LINE GUARDS) ON CONDUCTORS

When workers are about to undertake work that requires the use of rubber goods, they should climb or raise the bucket to a position just below the first line of conductors. They should then determine their working position and what lines and other conductors should be covered. The required rubber goods should then be requested. Before ascending further, the workers shall make certain that their rubber gloves and leather protectors are in good order and on their hands. Rubber goods shall be raised in a secure manner.

As the workers advance to their working position, they shall cover all conductors with which any possible contact may be made. This should be done from below whenever possible. At no time shall they pass through energized equipment before it is covered with rubber goods. All conductors and grounds adjacent to working space shall be considered, including any possible change of position that may be necessary. When line hose is applied to vertical or sagging wires, it should be fastened to the line to prevent slipping from position. When blankets are used for covering items such as dead ends, pot heads, secondary racks, and transformers, they shall be secured in place by wooden clamp

pins or tie thongs. After the protective equipment has been placed, care shall be taken to prevent injury to the rubber from tie wires, spurs, or other causes. Regardless of the fact that all conductors have been covered, entire reliance shall not be placed on rubber goods as any protective device may become defective.

7.3.7 REMOVING RUBBER GOODS FROM CONDUCTORS

When the job is completed, the protectors should be removed in the reverse order of installation. Remote conductors are cleared first and the wires nearest the workers last. After being detached, the equipment should immediately be lowered to the ground. Under no circumstances shall rubber goods be thrown or dropped from the pole.

7.3.8 CLEANING AND INSPECTING

After the rubber goods have been lowered to the ground, they shall be cleaned and inspected before being placed in the carrier compartments of the truck.

7.4 PROTECTIVE GROUNDING OF LINES AND EQUIPMENT

Grounding is the most effective way of protecting electrical workers from electrical shock. That is why it is important to ensure that all deenergized lines and equipment are grounded with equipment grounding conductors and grounding cables. (See *Figure 7-2.*)

7.4.1 PURPOSE

The purpose of this section is to provide as much protection as possible for workers repairing, servicing, or working on high voltage power lines.

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OSHA Section 1926.954

Figure 7-2. Grounding is the most effective way of protecting employees who are working on high voltage systems and equipment.

**7.4.1.1 REDUCE THE POTENTIAL
VOLTAGE DIFFERENCES
ACROSS THE WORKER**

The primary function of personal protective grounds is to provide maximum safety for personnel while they are working on deenergized lines or equipment. This will be accomplished by making provisions that will reduce the potential voltage differences at the work site (voltage across the worker) to a safe value in the event line or equipment being worked on is accidentally

energized from any source. The worker should verify that the grounding cable and clamps are 1 ohm or less by using a ground loop impedance.

**7.4.1.2 PROTECTION FROM
ACCIDENTAL ENERGIZATION**

Portable protective grounds are installed to protect personnel from the hazards of accidental energization from any source, including the following:

1. Power lines or other energized high voltage equipment; by accidental contact as well as from backfeed through transformers, generators, or other power sources
2. Electromagnetic or electrostatic such as adjacent lines or busses, wind, dust storms, and static capacitors
3. Lightning.

**7.4.1.3 ENSURE PROMPT OPERATION
OF CIRCUIT PROTECTIVE
DEVICES**

The secondary function of personal protective grounds is to provide a low-impedance path to ground to prompt the operation of the circuit-protective devices (relays, circuit breakers, or fuses) that are used to disconnect or trip open the energizing source.

7.4.2 APPLICATION

There are certain methods, procedures, and steps that must be exercised when placing grounds and loads to protect workers from high voltage hazards.

7.4.2.1 DEENERGIZED LINES

When an energized line or equipment in excess of 600 V is removed from service to be worked on, it

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shall be treated as energized until the line or equipment is cleared, tagged, tested, and grounded.

7.4.2.2 COMMUNICATION CONDUCTORS

Bare wire communication conductors on power poles and structures are subject to these rules as energized lines and voltages in excess of 600 V unless protected by insulated materials.

7.4.2.3 NEW CONSTRUCTION OR DISMANTLING OF FACILITIES

If isolating devices are not in place and energization from a source is not possible, single-phase grounding is appropriate, acceptable, and safe. If energization is possible by the closure of a jumper or isolating device, shorts and grounds shall be utilized unless conductor handling activity makes this impractical or impossible because of line design or construction process.

7.4.2.4 MINIMUM DISTANCE FROM UNDERGROUND CONDUCTORS

The minimum distance in *Table 7-1* shall be maintained from underground conductors at the work location. The ground may be omitted if the making of the ground is impractical or the resulting conditions are more hazardous than working on the lines or equipment without grounding. However, all work shall be done in accordance with this section as if the line or equipment is energized.

7.4.2.5 VISIBLE THREE-PHASE SHORT AND GROUND REQUIRED

Visible three-phase short circuiting may be accomplished through conductive parts such as guy wires and unpainted metal tower members, but shall not be effected through a grounding mat or other concealed conductors.

7.4.2.6 GROUND CIRCUIT

No disconnect switch, power circuit breaker, transformer, wave trap, or fuse shall be part of the protective grounding circuit.

7.4.3 GROUNDING EQUIPMENT

The grounding of high voltage lines and equipment will provide additional safety for workers from electrical shock where they are sized, selected, and installed properly. For further information on the construction of personnel safety grounds, see ASTM F855-90.

7.4.3.1 AVAILABILITY

Grounding cables shall be available for use when work is being done on deenergized lines or equipment.

7.4.3.2 APPROVED CAPACITY

Grounding cables shall be of approved carrying capacity or accommodate the maximum fault current to which the cable or equipment might be subjected.

7.4.3.3 APPROVED CONNECTOR

Grounding shall be made with an approved connector capable of conducting the available fault current.

7.4.3.4 APPROVED FERRULES AND GROUNDING CLAMPS

Grounding jumpers shall have approved ferrules and grounding clamps that provide mechanical support for jumper cables independent of the electrical connection.

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Table 7-1. AC minimum clearance from live parts.

Nominal Voltage (kV)	Distance Phase to Employee ^a	
	Feet	Centimeters
1 or less	Avoid contact	Avoid contact
1.1 to 15	1.6	45.74
15.1 to 35	2.33	71
35.1 to 46	2.50	76
46.1 to 72.5	3.00	91
72.6 to 121	3.33	102
138 to 145	3.50	107
161 to 169	3.67	112
230 to 242	5.00	152
345 to 362 ^b	7.00	213
500 to 550 ^b	11.00	335
700 to 765 ^b	15.00	457

a . This is the minimum air gap or live-line tool distance to be maintained. The clear live-line tool distance is the distance measured longitudinally along the live-line tool from the conductive device or the working end of the tool to the employee's hand.

b . The minimum clearance distance may be reduced to the length of the line insulator, if a small clearance is needed to do the work.

7.4.3.5 MINIMUM CONDUCTANCE

A grounding cable shall have a minimum conductance equal to #2 awg copper.

7.4.3.6 GROUND CLUSTER BAR ASSEMBLY

A ground cluster bar assembly shall be an approved unit designed for its intended use and capable of conducting the available fault current.

7.4.4 TESTING BEFORE INSTALLING GROUNDS

Before grounds are installed, the deenergized line or equipment shall be tested for voltage. Approved testers (audio or visual) may be used. However, they shall be tested immediately before and after used to verify that the tester is in good working condition.

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7.4.5 ATTACHING AND REMOVING GROUNDS

Employees attaching and removing grounds shall comply with the following:

1. Grounding equipment shall be visually inspected and all mechanical connections shall be checked for tightness before each use.
2. The surface to which the ground is to be attached shall be clean before the grounding clamp is installed. Otherwise, a self-cleaning clamp shall be used.
3. No ground shall be removed until all personnel are clear of the temporary grounded lines or equipment. When removing the grounding set, it shall be disconnected from the line or equipment end first with an approved hot line tool and moved to a point in the clear of energized conductors before the ground end is disconnected. (Refer to Section 4.15.)

7.4.6 GROUNDING METHODS AND LOCATION OF GROUNDS IN ORDER OF PREFERENCE

Employees installing grounds shall install them using the following rules and procedures:

7.4.6.1 WORK LOCATION

Install grounds at the work location with all grounded parts of different potential bonded together (on wood poles, all down guys, overhead ground wire, neutral conductor, and pole ground). Install cluster bar assembly below the working area and jumper to the ground point or the neutral conductor and the phase conductor. This method of grounding is termed "single point" grounding. It provides the greatest margin of safety for the line-

man by placing everything at equal potential, eliminating the possibility of the lineman getting in series to ground.

7.4.6.2 MULTIPLE WORK LOCATIONS AND SINGLE-PHASE GROUNDING AT WORK LOCATION

If work is to be performed at more than one place in a line section, the line section shall be grounded at one location in the line section and the conductor shall be grounded at each work location to reduce the potential voltage difference across the work site.

7.4.6.3 OTHER LOCATIONS

Grounds shall be placed at the work location or at each side of the work location and as close as practical to the work location.

7.4.7 TESTING WITHOUT GROUNDS

Grounds may be temporarily removed when necessary for testing purposes. During a test procedure, with grounds removed, care shall be exercised. Insulating mats, or warning signs, or both may be required at the discretion of the authority having jurisdiction.

7.4.8 PERSONNEL REQUIRED TO INSTALL OR REMOVE GROUNDS

Two qualified workers or one unqualified worker and an apprentice approved by both the supervisor and the qualified worker with whom they are working constitute an adequate crew for installing the initial set of grounds. Additional sets may be installed on the same electrical circuit, and all grounds may be removed by one fully qualified worker and one other worker.

7.4.9 GROUND PERSONNEL

In cases where ground rods or pole grounds are utilized for personal protective grounding,

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personnel working on the ground should maintain sufficient distance from such equipment or utilize either approved procedures designed to prevent touch-and-step potential hazards.

Touch potential hazard refers to the difference in voltage measured between the grounding equipment and a worker in contact with the grounding equipment at the time it is accidentally energized. Step potential hazard refers to the difference in voltage measured between the feed of the worker standing or walking in an electrical field created by high voltage brought to earth.

7.5 SAFE WORKING CLEARANCES

When it is necessary to conduct any work on poles or structures carrying more than one circuit and where there is not safe working clearance between circuits, the conductors not being worked on shall be either:

1. Untied and separated with proper clearance from the pole or structure
2. Deenergized and grounded
3. Covered with the necessary protective devices.

7.6 WORKING ON ENERGIZED LINES OR EQUIPMENT

Employees working on energized lines or equipment shall comply with the following:

1. Work on electrical equipment and circuits other than electrical utility lines and equipment, operating at 50 V or more to ground, shall be worked on following

the requirements of Section 2.15 of this manual and 29 CFR 1910.331-335.

2. Lines or equipment carrying an ac voltage in excess of 600 V phase-to-phase shall be worked on with rubber gloves or live line tools. All other necessary protective devices such as line hose, hoods, and rubber blankets shall be used.
3. Energized lines should be worked on from below whenever possible. When working energized lines or equipment carrying 600 V or more to ground, there shall be two qualified workers performing the work. Work shall not be performed on energized lines or equipment during rain, snow, sleet, fog, and other damp conditions, except in extreme emergencies if in the opinion of supervision and line crew it can be done safely.
4. While working on the same pole, workers shall not work simultaneously on wires that have a difference of potential.
5. Rubber gloves of appropriate voltage rating shall be worn when working within reach of a fellow employee who is working on or within reach of wires or equipment carrying voltage in excess of 600 V.
6. Insulated tongs or disconnect sticks shall be used to open or close plugs or fuses or to disconnect blades.

7.7 INSTALLING OR REMOVING CONDUCTORS

Employees installing or removing conductors shall follow certain guidelines to ensure safety and provide working procedures.

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7.7.1 STRINGING OR REMOVING DEENERGIZED CONDUCTORS

Employees stringing or removing deenergized conductors shall comply with the following procedures:

1. Prior to stringing operations, a briefing shall be held setting forth the plan of operation and specifying the type of equipment to be used, grounding devices and procedures to be followed, crossover methods to be employed, and the clearance authorization required.
2. Where there is a possibility of the conductor accidentally contacting an energized circuit or receiving a dangerous induced voltage buildup to protect the employee from the hazards of the conductor, the conductor being installed or removed shall be grounded or provisions made to insulate or isolate the employee.
3. If the existing line is deenergized, proper clearance authorization shall be secured and the line grounded on both sides of the crossover, or the line being strung or removed shall be considered and worked as energized.
4. When crossing over energized conductors in excess of 600 V, rope nets or guard structures shall be installed unless provisions are made to isolate or insulate the workers or the energized conductor. Where practical, the automatic reclosing feature of the circuit-interrupting device shall be made inoperative. In addition, the line being strung shall be grounded on either side of the crossover or considered and worked as energized.
5. Conductors being strung in or removed shall be kept under positive control by the use of adequate tension reels, guard structures, tielines, or other means to prevent accidental contact with energized circuits.
6. Guard structure members shall be sound and of adequate dimension and strength and adequately supported.
7. Catch-off anchors, rigging, and hoists shall be of ample capacity to prevent loss of lines.
8. The manufacturer's load rating shall not be exceeded for stringing lines, pulling lines, sock connections, and all load-bearing hardware and accessories.
9. Pulling lines and accessories shall be inspected regularly and replaced or repaired when damaged or when dependability is doubtful. The provisions of 29 CFR 1926.251(c)(4)(ii) concerning splices shall not apply.
10. Conductor grips shall not be used on wire rope unless designed for this application.
11. While the conductor or pulling line is being pulled (in motion), workers shall not be permitted directly under overhead operations nor shall any employee be permitted on the crossarm.
12. A transmission clipping crew shall have a minimum of two structures clipped in between the crew and the conductor being sagged. When working on conductors, clipping crews shall install grounds

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at the work location. The grounds shall remain intact until the conductors are clipped in, except on dead-end structures.

13. Except during emergency restoration procedures, work from structures shall be discontinued when adverse weather (such as high wind or ice on structures) makes the work hazardous.
14. Stringing and clipping operations shall be discontinued during the progress of an electrical storm in the immediate vicinity.
15. Reel-handling equipment, including pulling and braking machines, shall have ample capacity, operate smoothly, and be leveled and aligned in accordance with the manufacturer's operating instructions.
16. Reliable communications between the reel tender and pulling rig operator shall be provided.
17. Each pull shall be snubbed or dead ended at both ends before subsequent pulls.

7.7.2 STRINGING ADJACENT TO ENERGIZED LINES

Employees stringing adjacent to energized lines shall apply the following procedures:

1. When performing work from the structures, clipping crews and all others working on conductors, subconductors, or overhead grounding conductors shall be protected by individual grounds installed at every work location.
2. When stringing adjacent to energized lines, the tension-stringing method or other methods that prevent unintentional

contact between the lines being pulled and any worker shall be used.

3. All pulling and tensioning equipment shall be effectively grounded.
4. A ground shall be installed between the tensioning reel setup and the first structure in order to ground each bare conductor, subconductor, and overhead grounding conductor during stringing across or adjacent to energized lines.
5. During stringing operations, each bare conductor, subconductor, and overhead grounding conductor shall be grounded at the first tower adjacent to both the tensioning and pulling setup and at appropriate intervals. The grounds shall be left in place until conductor installation is completed. Except for moving-type grounds, the grounds shall be placed and removed with a hot stick.
6. Conductors, subconductors, and overhead grounding conductors shall be grounded at all dead-end or catch-off points.
7. A ground shall be located at each side and within 10 ft of working areas where conductors, subconductors, or overhead grounding conductors are being spliced at ground level. The two ends to be spliced shall be bonded to each other. It is recommended that splicing be carried out on either an insulated platform or on a conductive metallic grounding mat bonded to both grounds. When a grounding mat is used, it is recommended that the grounding mat be roped off and an insulated walkway be provided for access to the mat.

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7.8 SPECIAL TOOLS

Lineworkers shall be familiar with special tools that are used for climbing, such as climber gaffs, climber straps, body belts, etc., and such equipment shall be properly stored and maintained. (See Figure 7-3.)

7.8.1 LINEWORKER'S CLIMBING TOOLS

Employees shall use the following climbing tools and apply the following requirements:

1. All climbers shall be inspected frequently by the worker using them.
2. Climber gaffs shall be kept sharp.

OSHA Section 1910. 132; 133
OSHA Section 1926. 951

Figure 7-3. Employees using special tools for climbing and servicing high voltage systems shall be trained on how to use such tools and equipment.

3. A climber shall not be used when its gaff becomes shorter than 1-1/4 in. inside measurement. Climbers with gaffs that fail inspection shall be tagged "DO NOT USE" and taken out of service.
4. Climber straps that are worn or otherwise defective shall be replaced.

7.8.2 BODY BELTS AND SAFETY STRAPS

Employees using body belts and safety straps shall apply the following:

1. All body belts and safety straps shall be inspected each time by the employee who uses them.
2. Workers shall use their body belts and safety straps when doing any work where there is danger of falling.
3. Body belts and safety straps shall not be stored with unguarded sharp tools or devices.
4. Heat, sharp bends, and overstressing of body belts and safety straps shall be avoided as they are injurious to leather. Wet leather shall be dried slowly at moderate temperatures.

7.8.3 TOOL BAG AND EQUIPMENT

Tools, small equipment, and materials should be raised and lowered in a tool bag. The tool bag should be inspected before it is used to see that it contains no broken glass or other material on which the employee could cut his or her hand or rubber gloves. Tool bags shall not have any metal in their construction.

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7.8.4 TAPES AND RULERS

Workers shall not use metal measuring tapes or tapes having metal strands woven into the fabric, brass bound rules, or metal scales when working near electrical equipment or conductors.

7.8.5 SPOON AND SHOVELS

Tools of this type, especially those having long wooden handles, shall not be used when the handles are cracked, split, or broken.

7.8.6 PIKE POLES

Pike poles shall comply with the following:

1. Cracked, broken, or splintered pike poles shall not be used
2. Pike poles shall not be thrown
3. When not in use and loaded on the truck, the points shall be protected so that they will not injure anyone.

7.8.7 HAND AXES AND SHARP TOOLS

Hand axes and sharp tools shall comply with the following:

1. Hand axes shall not be used on overhead work
2. When not in use, sharp tools shall be protected by suitable guards or containers.

7.9 TREE TRIMMING

Equipment utilized to trim trees shall be maintained in an approved and proper working condition to aid tree trimmers and protect them from hazards.

7.9.1 CARE AND USE OF TOOLS

Tools shall be cared for using the following methods:

1. The handles of all tree trimming tools shall be kept well dressed and varnished.
2. When trimming trees near live conductors, the employee shall not work with wet tools or ropes. Such equipment should be protected during rain showers.
3. A tree-trimming saw shall be protected by a scabbard when it is not actually in use.
4. All ropes shall be inspected frequently for cuts and wear.

7.9.2 CLIMBING

The following procedures shall be applied for climbing:

1. A ladder should be used to climb in a tree, unless the employee is properly equipped and trained for tree climbing.
2. Climbers shall be designed for tree climbing. The safety strap shall be constructed to withstand contact with saws and other sharp objects. Workers in trees shall be tied off.

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7.10 SERIES STREET LIGHTING CIRCUITS AND APPARATUS

Lighting circuits and apparatus used for series street lighting shall comply with the following:

1. Series street lighting circuits shall be considered as being energized at all times
2. Rubber gloves and any other necessary protective devices shall be used when working on a series street lighting circuit, unless electrically isolated and grounded at the work location
3. The opening of a time clock, a photo-electric relay, or remote control over-current control equipment shall not be considered as isolation points that provide a safe work condition while working on series lighting circuits
4. The use of series street lighting circuits is discouraged.

7.11 AIR BREAK SWITCHES

Air break switches shall comply with the following:

1. Rubber gloves, ground mats or platforms, insulated or isolated platforms, or other equally protective measures shall be used when operating disconnect switches.
2. Switch manufacturer's recommendations shall be followed at all times.
3. Switches shall be left wide open when in open position and fully closed when in closed position. Switch positions on all phases shall be checked.

4. Lockout and tagout procedures shall be followed in compliance with 29 CFR 1910.147.

5. When appropriate, clearance authorization procedures shall be followed.

7.12 FUSES AND FUSED CUTOUTS

Employees replacing fuses and fused cutouts shall comply with the following:

1. Many accidents such as burns, eye injuries, shocks, and falls have occurred when performing this type of work. Employees shall use extreme caution when removing or replacing fuses.

Note: Employees should wear eye protection when changing fuses.

2. Whenever practical, before removing or replacing a fuse, the circuit should first be opened at a switch or breaker between the source and the fuse. In the event that it is possible for the fuse to be energized from back-feed, switches should be opened on both sides of the fuse.
3. When removing or replacing line-sectionalizing fuses or distribution-transformer fuses on circuits operating at voltages between 2,000 and 5,000 V, rubber gloves should be worn and a switch stick shall be used. When replacing a blown fuse, the cutout should be closed with a switch stick.
4. Fuses on lines and equipment operating at voltages above 5,000 V shall be removed and installed with an approved switch stick or suitable length fuse tongs and the employee should wear rubber gloves.

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See Figure 7-4 for a detailed illustration of a qualified worker utilizing the proper safety equipment.

7.13 UNDERGROUND

Underground work requires a means of safe entrance and exit from the work space. Employees shall follow certain procedures to ensure safety in entering and leaving such spaces.

7.13.1 WORKING IN MANHOLES, UTILITY TUNNELS, AND VAULTS

Employees working in manholes and vaults shall abide with the following procedures:

1. When opening a manhole, completely remove the manhole covers from the opening. Two workers shall remove and replace single manhole covers with appropriate manhole hooks. All double type manhole covers shall be removed

Figure 7-4. Employee (qualified worker) utilizing the proper safety equipment while disconnecting a fuse cutout protecting a distribution line.

and replaced by four workers using manhole hooks, unless the cover is in a frame with a center support. Remove both of the double type manhole covers before rodding or installing and removing cable.

2. Open manholes shall be barricaded and protected by flags or guards as required when unattended. All open manholes shall be protected as required by 29 CFR 1910.23(a) and .268(o).
3. Before entry, the pit shall be tested for oxygen content and the flammable gas explosive limit. Do not smoke or use an open flame while tests for an explosive mixture of gas are being made.
4. If the oxygen level is less than 19.5% or greater than 21%, the pit shall be ventilated for five minutes or more and retested before any work is begun.
5. If the flammable gas content is more than 10% of the lower explosive limit, the pit shall be ventilated for five minutes or more and retested before any work is begun. When testing indicates that a manhole contains either a mixture of explosive gas and air richer than safe working limits or flammable liquids, corrective measures shall be taken before work in the manhole can be allowed to proceed.
6. When nitrogen is used in manholes or confined areas, approved atmosphere testing devices shall be placed in operation where they can be observed by people in the manhole. When the testing devices show a deficiency of oxygen, all personnel shall leave the manhole until the proper atmosphere is restored.

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7. The manhole shall be ventilated for five minutes before entry and continuously when occupied.
8. An attendant is required at topside with the means to summon help without leaving his or her station. The attendant shall be capable of instituting a rescue without entering the manhole. If you are working on the ground level, you are responsible for the safety of the persons in the manhole. From time to time, those on the surface should ensure that the personnel in the manhole are safe.
9. If you are the first worker to enter a manhole, the topside attendant shall fully dedicate his or her attention and efforts to assist you should you require help. All manholes over 4 ft in depth shall be entered with the use of a ladder as required by 29 CFR 1910.268 (o)(4).
10. Open all entrance bars or chains on the topside of manhole guards before you enter or leave a manhole. All chains or bars shall be closed at all other times, except when raising or lowering tools or materials.
11. Operations involving chemical cleaning agents, solvents, volatile chemicals, cutting and welding equipment, and other hazards require additional consideration. Consultation and concurrence with appropriate industrial safety and hygiene personnel are required.
12. Personal protective equipment shall include head and eye protection, gloves, appropriate shoes, and a body harness and life line. Specific tasks, such as welding, may require additional personal protective equipment.
13. The employee shall enter or leave a manhole by means of a ladder. The employer shall not use a cable, cable hanger, or manhole rack as a support for climbing. Never remove a manhole ladder while a worker is in the manhole, unless absolutely necessary. In this instance, the topside attendant shall fully devote his or her attention and efforts to instituting a rescue using the worker's body harness and life line if necessary. The ladder shall be replaced as soon as practical.

Note: Warn the person in the hole that the ladder is to be removed and allow the worker time to exit the hole if he or she feels it is necessary.
14. Materials, tools, and equipment should be kept at a sufficient distance from the entrance to the manhole to avoid any hazard to the occupant from falling objects or from hot metal or compounds that may be spilled.
15. Blowtorches and furnaces shall be ignited before being lowered into manholes.
16. Rags, tape, refuse, and combustible and flammable materials shall not be allowed to accumulate in a manhole.
17. Instrumentation shall be calibrated per manufacturer's instructions or more frequently as required by local conditions. A record of calibration shall be maintained.
18. Ground fault circuit interrupter (GFCIs) shall be used for 120-V ac power unless such power is supplied by a portable or vehicle-mounted two-wire, single-phase generator rated not more than 5kW, where the circuit conductors of the

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generator are insulated from the generator frame and all other grounded surfaces.

19. Treat all cables and insulated wires that do not have grounded conducting sheaths or shielding as bare conductors. They shall be considered energized unless approved methods have been used to determine that they are deenergized.
20. Barricade or cover with protective equipment or devices all nonmetallic covered conductors and equipment energized at more than 300 V to ground that will be within reach of a worker's position.

7.13.2 WORKING ON DEENERGIZED UNDERGROUND CIRCUITS

Employees working on deenergized underground circuits shall observe the following rules:

1. Before work is started on deenergized underground circuits, supervisory approval shall be obtained
2. The foremen shall ensure that the cable conductors are grounded at all sources of supply or backfeed before work is started
3. The foreman shall identify and mark the cable or cables to be worked on at the job location.

7.13.3 WORKING ON ENERGIZED UNDERGROUND CABLES

In general, work should not be performed on energized underground cables. However, strictly external work, not requiring an appreciable change in location of the cable, may be performed under direct supervision.

7.13.4 TERMINALS OF UNDERGROUND CABLES (POTHEADS)

Before work is started, the overhead line connections to a cable terminal upon which work is to be performed shall be either:

1. Deenergized and grounded
2. Disconnected and covered with protective equipment.

7.14 GENERAL PRECAUTIONS

Employees working with handlines shall comply with the following guidelines to ensure safety:

1. Handlines shall be made of manila rope (or equivalent) not smaller than 5/8 in. in diameter. Handlines shall be kept in such condition that they may be used at any-time to lower an injured person from a pole or structure.
2. Employees shall not trust the weather-proofing on a wire as insulation for protection from shock.
3. Employees working on energized parts while standing on insulated platforms shall not hand to or receive any object from other persons not protected by insulating platforms or rubber gloves.
4. When employees are dispatched to perform work alone and in their opinion it cannot be performed safely, they shall report this fact to supervision at once.
5. Employees shall not handle energized conductors at night unless adequate illumination is provided.
6. Employees shall not support their weight by means of equipment such as

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conductors, guy wires, pins, or cross-arm braces.

4. Transformer unloaded or very lightly loaded.

7.15 FERRO-RESONANCE

Ferro-resonance can generate overvoltages of up to 12 times line-to-ground source voltage upon opening of a single-phase switching device or a poorly synchronized three-phase device. Violent failure can occur, exposing personnel to the high-voltage failure and accompanying conditions. Ferro-resonant conditions can result in damage to lightning arresters, switching devices, buried cable, transformers, and associated equipment.

Ferro-resonance can be initiated when all of the following elements are present and the switching means at dip point or takeoff is either a single-phase device or an unsynchronized three-phase device that does not operate all phases within 1/2 cycle:

1. System grounded at the source but with no ground at the transformer bank, such as a transformer or transformer bank connected delta on a grounded-wye system
2. Shielded cable or overhead conductor length sufficient to create the capacitance necessary
3. Transformer size that permits saturation of the iron core at the operating voltage

Prevention or control of ferro-resonance may be accomplished by utilizing any of the following measures:

1. Use a wye-wye transformer connection with both neutrals grounded and tied to the system neutral.
2. Use only phase-to-neutral (not phase-to-phase) transformer connections for single phase transformers.
3. Limit length of underground cable between transformers and single pole or poorly synchronized three-pole switching devices.
4. If single-pole or poorly synchronized switching devices must be utilized, ensure that transformer and underground cable is loaded in excess of 2% resistive load of the transformer capacity.
5. If transformer primary is ungrounded-wye, temporarily ground the neutrals of the transformers being switched.
6. Install close-coupled, high-speed, three-pole switching devices to minimize the duration of the single-phase condition during opening and closing of the circuit.

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8.0 TEMPORARY WIRING

Generally, it is required that temporary wiring comply with all the requirements pertaining to permanent wiring unless specific exceptions are stated, which can be found in the NEC, Article 305, and 29 CFR 1926, Subpart K.

The following codes and standards will aid in designing, installing, and inspecting temporary wiring methods and using portable electric hand tools.

1. Article 305 of the National Electrical Code (NEC)
2. Subpart K of 29 CFR 1926, Safety and Health Regulations for Construction
3. Section 230-24(b) of the NEC
4. Table 232-1 of the National Electrical Safety Code (ANSI/IEEE C2)
5. Chapter 17 of NFPA 70B, Electrical Equipment Maintenance
6. Article 400 of the NEC
7. 29 CFR 1926.405(g).

8.1 INSTALLATION REQUIREMENTS AND CONDITIONS OF USE

Temporary electrical installations shall be allowed during periods of construction, remodeling, maintenance, repair, or demolition of equipment or structures or for experiments and developmental work. However, such temporary installations are not substitutes for permanent installations and shall be removed as soon as the construction,

remodeling, experiment, or other special need is completed. See NEC Sections 305-3(a) and 305-3(d).

8.1.1 CONTACT PREVENTION

Temporary wiring shall be guarded, buried, or isolated by elevation to prevent accidental contact by workers or equipment.

8.1.2 VERTICAL CLEARANCES

Vertical clearance above walkways shall not be less than 10 ft for open conductors rated at 600 V or less. See NEC Section 230-24(b) and NESC Table 232-1.

8.1.3 WET LOCATIONS

Conductors with nonrated weather-proof insulation shall not be enclosed in metal raceways or used for wiring in tanks, penstocks, or tunnels. Receptacles used in damp or wet locations shall be approved for the purpose. When a receptacle is installed outdoors (outdoors is considered a wet location), it shall be contained in a weatherproof enclosure, the integrity of which would not be affected when an attachment plug is inserted.

All temporary lighting strings in outdoor or wet locations, such as tunnels, culverts, valve pits, outlets, and floating plants, shall consist of lamp sockets and connection plugs permanently molded to the hard service cord insulation.

8.1.4 SUPPORTS

Bare or open conductors shall be insulated from their supports. This requirement prevents arcing, sparking, or flash-over voltage to grounded objects.

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8.1.5 CONDUIT

Temporary wiring installed in conduit shall have bushings at all outlets and terminals to prevent abrasion and damage to the insulation.

8.1.6 TEMPORARY LIGHTS

All lamps for general illumination shall be protected from accidental contact or breakage. Metal-case sockets shall be grounded.

Temporary lights shall not be suspended by their electric cords unless cords and lights are designed for this means of suspension.

Portable electric lighting used in wet or other conductive locations (for example, drums, tanks, and vessels) shall be operated at 12 V or less. However, 120-V lights may be used if protected by a ground fault circuit interrupter (GFCI).

Note: Lighting outlets are not permitted to be installed on GFCI protected circuits supplying receptacle outlets per NEC Section 305-4(d).

8.1.7 CONFINED SPACES

When temporary wiring is used in tanks or other confined spaces, an approved disconnecting means (identified and marked) shall be provided at or near the entrance to such spaces for cutting off the power supply in emergencies.

Portable electric lighting used in confined wet or hazardous locations such as drums, tanks, vessels, and grease pits shall be operated at a maximum of 12 V, be intrinsically safe, or be protected by a GFCI circuit.

8.1.8 EXPOSED SOCKETS AND BROKEN BULBS

Exposed empty light sockets and broken bulbs shall not be permitted. This rule is to protect

personnel from accidentally contacting the live parts in the socket and being shocked.

8.1.9 TESTING

Temporary electrical distribution systems and devices per Article 305 of the NEC shall be checked and accepted for polarity, ground continuity, and ground resistance before initial use and after modification. Ground resistance shall be measured, recorded, and furnished to the designated authority at the time of installation. See Article 305 of the NEC and Subpart K of 29 CFR 1926 for further information.

8.1.10 TEMPORARY WIRING METHODS

The requirements for temporary wiring for power and lighting purposes include provisions for wire connections, junction boxes, and overcurrent protection, as well as the use of conductors.

8.1.10.1 SERVICE CONDUCTORS

Service conductors shall comply with all the provisions of Article 230 in the NEC when they are used as wiring methods to supply temporary power systems.

8.1.10.2 FEEDER CONDUCTORS

Feeders are the conductors that transmit power from the service drop to the distribution panelboard or between the main disconnect and the branch circuit overcurrent devices (circuit breakers, fuses). Feeders for temporary wiring shall originate inside an approved distribution center, such as a panelboard, that is rated for the voltages and currents the system is expected to carry. Some equipment is manufactured specifically for temporary use.

Feeders can be run as cable assemblies, multi-conductor cords, or cables with two or more

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conductors each with their own insulations, run together in the same cord or cable.

When feeder conductors are not subjected to physical damage, they can be installed as open conductors. However, they shall be installed on insulating supports that are not more than 10 ft apart.

8.1.10.3 BRANCH CIRCUIT CONDUCTORS

Branch circuits are the conductors between the last overcurrent device in an electrical system and the outlets, such as receptacles, lighting outlets, and outlets for electrical equipment wired directly into a circuit. Branch circuits for temporary wiring shall originate inside an approved panelboard or power outlet that is rated for the voltages and currents the system is expected to carry. As with feeders, branch circuit conductors can be contained within multiconductor cord or cable assemblies, or they can be run as open conductors. If the conductors are run as open conductors, they shall be securely attached every 10 ft. To avoid physical damage, branch circuit conductors shall never be placed on the floor.

8.1.10.4 NONMETALLIC SHEATHED CABLE

Nonmetallic sheathed cable may be used as allowed by the NEC and as follows:

1. Along studs, joists, or similar supports closely following the building finish or running boards when 7 ft 8 in. or more above the floor
2. When firmly attached to each cabinet, box, fitting, or fixture by means of a cable clamp.

Nonmetallic sheathed cable may not be used where precluded by the NEC as follows:

1. As portable extension cords
2. Lying on the ground subject to any type of traffic

3. Where subject to frequent flexing
4. As service entrance cable.

See Figure 8-1 for a detailed illustration of procedures of installing temporary wiring methods.

8.2 GROUND FAULT CIRCUIT INTERRUPTERS

Ground fault circuit protection can be used in any location, circuit, or occupancy to provide additional protection from line-to-ground shock hazards because of the use of electric hand tools. There are four types of GFCIs that are used in the industry:

1. Circuit breaker type
2. Receptacle type
3. Portable type
4. Permanently mounted type.

**NEC Section 305-4
OSHA Section 305 (a)**

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Figure 8-1. Cables, cable assemblies, or multiconductor cords can be used for temporary wiring systems under certain conditions of use.

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The condition of use determines the type of GFCI that is selected. For example, if an electrician or maintenance person plugs an extension cord into a nonprotected GFCI receptacle, the easiest way to provide GFCI protection is to utilize a portable type GFCI.

8.2.1 HOW A GFCI WORKS

GFCIs are devices that sense when current—even a small amount—passes to ground through any path other than the proper conductor. When this condition exists, the GFCI quickly opens the circuit, stopping all current flow to the circuit and to a person receiving the ground fault shock.

Figure 8-2 shows a typical circuit arrangement of a GFCI designed to protect personnel. The incoming two-wire circuit is connected to a two-pole, shunt-trip overload circuit breaker. The loadside conductors pass through a differential coil onto the outgoing circuit. As long as the current in both load wires is within specified tolerances, the circuit functions normally. If one of the conductors comes in contact with a grounded condition or passes through a person's body to ground, an unbalanced current is established. This unbalanced current is picked up by the differential transformer, and a current is established through the sensing circuit to energize the shunt trip of the overload circuit breaker and quickly open the main circuit. See Section 8.4.2 of this section for trip open rating in milliamperes.

A fuse or circuit breaker cannot provide this kind of protection. The fuse or circuit breaker will only trip or open the circuit if a line-to-line or live-to-ground fault occurs that is greater than the circuit protection device rating.

Note: The device will open on a ground fault (line-to-ground) or excess overload.

A GFCI shall not protect the user from line-to-line contact hazards. If a person was standing on an insulated surface and was holding a faulty appliance in one hand with a fault from the "hot" (ungrounded conductor) to case and reached with the other hand to unplug the appliance and contacted a faulty cord with an exposed grounded conductor, a line-to-line contact would be effected and the GFCI would not operate. Assuming a two-prong plug in this case with no equipment grounding path, a serious shock could result. For additional information, see Section 8.4.1.

Figure 8-2. GFCI-protected circuits shall be provided for the protection of personnel using electric hand tools on construction sites or other locations.

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8.2.2 USES

Branch circuits that serve receptacles installed outdoors (except receptacles that are in secure circuits and are not readily accessible) and are within 6 ft of sinks and building entrances shall be provided with GFCIs per DOE 6430.1A.

GFCI protection shall be provided for circuits supplying portable electric hand tools operating at 120 V (15 or 20 A circuits) in any of the following conditions:

1. Outdoors
2. Indoors, in wet or damp areas
3. Where the worker is likely to be well grounded (such as in or on tanks, pipes, metal, and damp concrete)
4. Where extension cords are used with electric hand tools.

Under the circumstances listed above, portable GFCIs shall be used where permanent GFCI protection is not provided.

Portable GFCIs shall be trip tested by the user each day before use to ensure that the device is functional. **Note: GFCI protection can be provided by GFCI circuit breakers or GFCI receptacles either upstream or at each individual receptacle.**

8.2.3 USING PERMANENT WIRING RECEPTACLES

Workers plugging in electric hand tools to these receptacle outlets are not required to provide GFCI protection unless they use an extension cord. Where an extension cord set is used between the receptacle outlet and the electric hand tool, a

portable GFCI shall be utilized or GFCI protection provided ahead of the branch circuit supplying the receptacle.

8.3 RECEPTACLES USED ON CONSTRUCTION SITES

Employees shall use either GFCIs or an assured equipment grounding conductor program to protect against electrical shocks and hazards on construction sites.

See Figure 8-3 for the permitted use of receptacle outlets being used to supply power to portable electric hand tools.

NEC Section 305-6
OSHA Section 1910.304 (b)(1)

Figure 8-3. There are three methods of providing GFCI protection for construction sites.

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8.3.1 USING GROUND FAULT CIRCUIT INTERRUPTERS

All 120-V, single-phase, 15- and 20-A receptacle outlets on construction sites that are not a part of the permanent wiring of the building or structure and that are in use by employees shall have approved GFCIs for personnel protection. Receptacles on a two-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, need not be protected with GFCIs.

8.3.2 USING ASSURED EQUIPMENT GROUNDING CONDUCTOR PROGRAM

The employer can establish and implement an assured equipment grounding conductor program on construction sites covering all cord sets, receptacles that are not a part of the building or structure, and equipment connected by cord and plug that are available for use or used by employees. This program shall comply with the following minimum requirements:

1. A written description of the program, including the specific procedures adopted by the employer, shall be available at the jobsite for inspection and copying by the Assistant Secretary or his or her representative, DOE inspectors, and any affected employee.
2. The employer shall designate one or more competent persons to implement the program.
3. Each cord set, attachment cap, plug and receptacle of cord sets, and any equipment connected by cord and plug, except cord sets and receptacles that are fixed and not exposed to damage, shall be visually inspected before each day's use

for external defects such as deformed or missing pins or insulation damage and for indications of possible internal damage. Equipment found damaged or defective shall not be used until repaired.

4. The following tests shall be performed on all cord sets, receptacles that are not a 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 cap or plug shall be tested for correct attachment of the equipment grounding conductor. The equipment grounding conductor shall be connected to its proper terminal.
5. All required tests shall be performed:
 - a. Before first used
 - b. Before equipment is returned to service following any repairs
 - c. Before equipment is used after any incident that can be reasonably suspected to have caused damage (for example, when a cord set is run over)
 - d. At intervals not to exceed 3 months, except that cord sets and receptacles that are fixed and not exposed to damage shall be tested at intervals not exceeding 6 months.
6. The employer shall not make available or permit the use by employees of any equipment that has not met the requirements of this section.

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7. Tests performed as required in this paragraph shall be recorded. This test shall identify each receptacle, cord set, and cord-and-plug-connected equipment that passed the test and shall indicate the last date it was tested or the interval for which it was tested. This record shall be kept by means of logs, color coding, or other effective means and shall be maintained until replaced by a more current record. The record shall be made available on the jobsite for inspection.

For further information reference NEC 305-6 and 29 CFR 1926.404(b) and *Figure 8-4*.

Figure 8-4. Assured grounding method may be used if approved by authority having jurisdiction.

8.4 PORTABLE ELECTRICAL TOOLS AND EQUIPMENT

The electrical preventive maintenance (EPM) program shall include the essential ingredients of Chapter 17 of NFPA 70B, Portable Electrical Tools and Equipment, and ANSI/UL 45, Portable Electric Tools. This includes employee training, maintenance, cord and attachment plug care, extension cords, major overhauls, and leakage current testing.

8.4.1 INSPECTIONS AND MAINTENANCE PROCEDURES

Portable electric tools and equipment such as cords, plugs, and GFCIs shall each be inspected before use by both the issuer and the user for signs of chaffing, cracking, wear, or other forms of faulty insulation; evidence of a faulty grounding conductor, cracked plug, or receptacle housing; bent or missing plug or connector prongs; dead front plugs, receptacle, or connectors; a missing, bent, or otherwise abused switch; or an improperly functioning trigger lock (dead-man switch). While in use, tools and equipment should be observed for proper operation, including any signs of overheating or excessive sparking. Portable GFCIs shall be trip tested by the user each day before use. Signs of a defect shall require the return of the device for repair.

All portable electric tools, equipment, and GFCIs shall be inspected and tested at purchase and least semi-annually thereafter. The inspection and test date period shall be indicated on the device. One method of how this can be done is by marking a color code on the device. Devices not marked with

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the current color-coded inspection/test period shall not be used. The following is an example of color-coding that may be used:

Jan. – June 1991	–	Black
July – Dec. 1991	–	Blue
Jan. – June 1992	–	Red
July – Dec. 1992	–	Green
Jan. – June 1993	–	Orange
July – Dec. 1993	–	White
Jan. – June 1994	–	Yellow
July – Dec. 1994	–	Brown

The color-code sequence can then be repeated thereafter.

Such inspection and testing shall include insulation-value and ground-continuity tests performed with a high-current (20 or 30 A), high-voltage (500 V, as a minimum) test set. Also, such inspection and testing shall be required when there is evidence of damage or before return for use following repair.

8.4.2 CONDITIONS OF USE

Portable electric tools, equipment, and GFCIs shall not be used in hazardous locations unless marked to indicate suitability for such use.

Portable electric tools and equipment shall not be handled or suspended by their cords. Tools and equipment shall only be used for their intended purpose, and when guards are required, such guards shall be in place and functional.

Tools and equipment shall be grounded via the case, double insulated, specially approved low voltage types, or self-contained, battery operated.

Note: A double-insulated tool or item of equipment features a double system of insulation to

ensure that if a single failure occurs to the primary insulation system, the parts in contact with the tool operator will not become energized. (Such single failure does not include failure from immersion in water.)

All portable electric tools and equipment (unless double insulated and supplied by 120 Vac, single phase, 15 or 20 A circuits) when used outdoors, on construction sites, or where the operator may be well grounded, shall have protection by GFCIs. All such GFCIs shall be rated to trip at 5 ± 1 mA.

Note: In selecting a GFCI for a potential well-grounded condition, consideration shall be given to the type of footwear and gloves worn, location of the operator such as lying or standing within reach of grounded metal, and the fact that the "let-go" current threshold for some individuals may be as low as 5 mA. For additional information, see 8.2.1 of this section.

Tools and equipment used in damp areas shall be approved for such use. Generally, electrical tools are not approved for use in wet or damp areas.

8.4.3 USE OF EXTENSION CORDS

Extension cords shall be similarly inspected before use, unless already plugged in. In such case, the cord shall be inspected upon replugging, reissue, or reuse. Use of extension cords should be minimized. Such cords shall be suitable for the intended use, such as waterproof connectors for wet or damp areas, and are subject to the same conditions as the tool or equipment cord.

Documentation and records show that many employees are killed because of the poor condition of portable electric tools and equipment. For the conditions of use pertaining to flexible cords, refer to NEC Section 400-7, 400-8, 240-4, Ex. 3, and 29 CFR 1926.405(g).

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Extension cords shall be inspected and tested at purchase and at specified intervals and visually inspected before each use.

Extension cord sets used on construction sites and used with portable metal electric tools and appliances shall be of three-wire type and shall be designed for hard or extra hard usage. Flexible cords used with temporary and portable lights shall be designed for hard or extra-hard usage. OSHA recognizes hard service cord (types S, ST, SO, and STO) and junior hard service cord (types SJ, SJO,

SJT, and SJTO) as suitable for extra-hard and hard usage.

Note: Approved extension cords may be identified by "outdoor" or "WA" on the jacket.

Flexible cord sets shall be listed by UL or another recognized listing agency. Flexible cord sets used on construction sites shall contain the number of conductors required for the circuit plus an equipment grounding conductor. The cords shall be hard usage or extra-hard usage as specified in the NEC.

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A. UNDERSTANDING ELECTRICAL SAFETY

Electricity is a pure form of energy that is utilized throughout the world. Most electrical energy is generated in power plants that burn coal, oil, or natural gas as a source of fuel or use atomic power. While electricity is necessary in general industry, there are certain hazards associated with its use, which must be understood and avoided. The primary hazards most dangerous to employees are created by electrical arcs, electrically generated heat, electrocution, and explosions. The material in this appendix deals with such hazards.

A-1 MAINTAINING A SAFE ELECTRICAL ENVIRONMENT

A safe electrical environment depends primarily on a properly designed, installed, operated, and maintained installation along with adequate employee qualification and training. There are many standards that govern safe electrical installation, maintenance, training, and qualifications of personnel. Such standards include the following:

1. 29 CFR 1910, Subpart S
2. 29 CFR 1926, Subpart K
3. 29 CFR 1926, Subpart V
4. NFPA 70, National Electrical Code (NEC)
5. IEEE C-2, National Electrical Safety Code (NESC)
6. NFPA 70B, Recommended Practice for Electrical Equipment Maintenance
7. NFPA 70E, Electrical Safety Requirements for Employee Workplaces

8. DOE Order 6430.1A, General Design Criteria.

These codes, requirements, and standards should be followed as a minimum to ensure an electrically safe installation is provided, along with procedures for proper maintenance after installation, to ensure that electrical systems are maintained in a safe, reliable condition.

According to the National Safety Council, it has been estimated that 31% of all known electrocution fatalities occur in the home, 24% occur in general industry, and the remaining 45% in the generation and distribution of electrical power. This means that approximately 55% of all electrocutions are caused by contact with so-called low-voltage circuits rated at 600 V or less.

Every piece of electrical equipment that is installed and maintained is a potential source for an electrical hazard, which makes the design, operation, installation, and maintenance of this equipment of the utmost importance. Electrical equipment that is serviced and maintained in a proper manner provides the best protection from electrical hazards possible for employees working near or in his or her workplace.

A-2 OHM'S LAW

Before discussing electrical hazards, a brief discussion of Ohm's Law is necessary to get acquainted with the terms and how they are used. Ohm's Law is used by engineers, designers, installers, operators, maintainers, and inspectors to determine different values in an electrical circuit. The more important terms are as follows:

1. Voltage	(E)	(volts)	(V)
2. Current	(I)	(amps)	(A)
3. Resistance	(R)	(ohms)	(Ω)
4. Power	(P)	(watts)	(W)
5. Impedance	(Z)	(ohms)	(Ω)

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Voltage is represented by using the letter E. Electromotive force is the pressure required to deliver the energy to do the work; such as, turn a motor, light a bulb, or produce heat. Measured in volts, it is comparable to water or hydraulic pressure.

Current, measured in amps and represented by the letter I, is the component that does the work. Like water, it moves from one location to another in the electrical circuit by pressure (voltage).

Resistance, measured in ohms and represented by the letter R, restricts the flow of current. The resistance of an electrical circuit is determined by the physical size and resistivity of the object through which current flows. The larger the cross-sectional area, the less the resistance; the smaller the cross-sectional area, the greater the resistance. For example, large amounts of water flow through larger pipes while lesser amounts flow through smaller pipes.

Voltage, current, and resistance are all linked together by Ohm's Law.

An object such as a wire or cable, which is known as a conductor, can be used to deliver electricity. Conductors are seen as wires between poles, between towers, and from poles to industrial sites. They are either bare or insulated with plastic, rubber, or treated paper. The resistance of most conductors is very low.

Insulators are not good conductors. Examples of insulators are the porcelain or glass discs on power poles that support wires. The resistance of insulators is very high. Good insulators prevent the electrons (current) from escaping the conductor.

Another important formula is the relationship of voltage, current, and power (watts). Power is measured in watts and is equal to E (volts) $\times$ I (current). In other words, one watt would be equal to one ampere of current flowing through a resistance with one volt of potential difference. (See Figure A-1.)

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Figure A-1 . By placing your finger on the unknown value, the remaining two letters will give the formula to use in finding the unknown value.

As previously mentioned, a voltage is a pressure difference and causes a current to flow. The earth is considered as having a zero voltage. A voltage difference is present between a power line and the earth. A conductor placed between a power line and the earth conducts current. The amount of current that flows depends on the resistance of the conductor.

The difference in potential between any two points in an electric circuit gives rise to a voltage, which causes electrons to move and current to flow. Whenever a voltage causes electrons to move, work is done by moving the electrons through the circuit conductor. The rate at which the work is done when moving electrons from point to point is called electric power.

Another way to put this relationship to practical use is to consider a 6-watt electric bulb (about the size of a night light or a panelboard light). To determine the current flow through the filament of a 6 watt bulb that is being used in a 120-V light socket, divide the power used in the circuit by the applied voltage.

For example, the current in the electric bulb above is .05 amp ($I = 6 \text{ watts} \div 120 \text{ V} = .05 \text{ A}$).

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The .05 A is the flow of electrons through the conductor from the source of voltage to the electric light bulb which is the load.

The milliamps in the above circuit is determined by the following formula and step.

Step 1: Applying formula
 $\text{mA} = (R \div E) \times 1,000$
 $\text{mA} = (6 \Omega \div 120 \text{ V}) \times 1,000$
 $\text{mA} = 50$

Solution: The milliamp current flow is 50

This example of calculating the current level of 50 mA is used to illustrate and clarify misconceptions about electricity and its effect on the human body. For example, a current flowing through the heart area at low milliamp levels in the 50 to 100 mA range can be fatal. This fatal range of current can be verified by documentation obtained through the National Safety Council.

In alternating current there is both reactance and resistance. An electric motor, for instance, adds both reactance and resistance to the circuit. The combined effect of reactance and resistance is called impedance.

Reactance is the reaction of various types of loads, such as motors, to the constant changing of polarity in alternating current. Its effect is to reduce the amount of current in much the same way that resistance does.

Ohm's Law simply states that 1 volt causes a current of one ampere to flow through a resistance of one ohm. As a formula, the relationship is represented by: $E \text{ (volts)} = I \text{ (amps)} \times R \text{ (resistance)}$.

An easy way to remember this formula and the different ways it can be expressed is to put symbols in a circle and place your finger on the value that you are trying to find. (See Figure A-2.)

Because the body is essentially resistive, the example that follows will treat the body as a

resistive factor only. To demonstrate an understanding of Ohm's Law, assume a person is working and perspiring and has hand-to-hand resistance of 1,000 ohms. This person contacts 100 volts with one hand and touches a grounded surface with the other, completing a loop to the voltage source. The current flowing through the body can be computed as follows:

Step 1: Finding formula - Figure A-2B
 $I = E \div R$

Step 2: Finding resistance - Figure A-5
 Hand-to-hand-to-ground =
 $500 \Omega + 500 \Omega = 1,000 \Omega$

Step 3: Applying formula to find mA - Text
 $\text{mA} = (100 \text{ V} \div 1,000 \Omega) \times 1,000$
 $\text{mA} = 100$

Solution: The milliamp current flow is 100.

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Figure A-2. By placing your finger on the unknown value, the remaining two letters will give the formula to use for finding the unknown value.

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A-2.1 FINDING VOLTAGE

The voltage in an electrical circuit is determined by multiplying the current (I) by the resistance (R). To derive the formula for finding the voltage in a resistive electrical circuit, simply place your finger over the unknown value as shown in *Figure A-2D* ($E = I \times R$).

For example: The voltage in an electrical circuit having a current of 12 amps and a resistance of 10 ohms can be found as follows:

Step 1:	Finding formula - Figure A-2D $E = I \times R$
Step 2:	Applying formula $E = 12 \text{ A} \times 10 \Omega$ $E = 120 \text{ V}$
Solution:	The voltage in the electrical circuit is 120 volts.

A-2.2 FINDING CURRENT

The current in an electrical circuit is determined by dividing the voltage (E) by the resistance (R). To derive the formula for finding the current in a resistive electrical circuit, place your finger over the unknown value as shown in *Figure A-2B* ($I = E \div R$).

For example: The current in a resistive electrical circuit having a voltage of 120 volts and a resistance of 10 ohms can be found as follows:

Step 1:	Finding formula - Figure A-2B $I = E \div R$
---------	---

Step 2:	Applying formula $I = 120 \text{ V} \div 10 \Omega$ $I = 12 \text{ A}$
---------	--

Solution:	The current in the electrical circuit is 12 amps.
-----------	---

A-2.3 FINDING RESISTANCE

The resistance (R) in an electrical circuit is determined by dividing the voltage by the current (I). To derive the formula for finding the resistance in a resistive electrical circuit, place your finger over the unknown value as shown in *Figure A-2C* ($R = E \div I$).

For example: The resistance (R) in an electrical circuit having a voltage of 120 volts and a current (I) of 12 amps can be found as follows:

Step 1:	Finding formula - Figure A-2C $R = E \div I$
---------	---

Step 2:	Applying formula $R = 120 \text{ V} \div 12 \text{ A}$ $R = 10 \Omega$
---------	--

Solution:	The resistance in the electrical circuit is 10 ohms.
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A-2.4 FINDING POWER

The power (P) in an electrical circuit is determined by multiplying the voltage (E) by the current (I). To

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derive the formula for finding the power in a resistive electrical circuit, place your finger over the unknown value as shown in *Figure A-1C*.

For example: The current in an electrical circuit having a voltage of 120 volts and a current of 12 amps can be found as follows:

Step 1:	Finding formula - Figure A-1C $P = E \times I$
Step 2:	Applying formula $P = E \times I$ $P = 12 \text{ A} \times 120 \text{ V}$ $P = 1,440 \text{ W}$
Solution:	The power in the electrical circuit is 1,440 watts.

A-2.5 FINDING IMPEDANCE

With these basic formulas, it is easier to understand and explain the effects electrical current has on the human body. The Ohm's Law formula applies to direct current (dc) circuits. However, in alternating current (ac) usage, Ohm's Law is equal to $E = I \times Z$, where Z is the impedance of the circuit. As described previously, impedance is the sum of the resistance and reactance and is expressed as follows:

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

In a purely inductive circuit, inductive reactance has the same effect as resistance in either a dc or an ac resistive circuit. A purely capacitive reactance has the same effect as resistance in either a dc or an ac resistive circuit. Inductive reactance is represented in the formula as X_L and capacitive reactance is represented by letters X_C .

For example: What is the impedance (Z) in an ac circuit with a resistance (R) of 12 ohms, an

inductive reactance (X_L) of 14 ohms, and capacitive reactance (X_C) of 6 ohms?

Step 1: Finding formula - Text

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

Step 2: Applying formula

$$Z = \sqrt{12^2 + (14 - 6)^2}$$

$$Z = \sqrt{144 + 64}$$

$$Z = \sqrt{208}$$

$$Z = 14.42 \Omega$$

Solution: The impedance in the electrical circuit is 14.42 ohms.

A-3 BASIC RULES OF ELECTRICAL ACTION

There are four basic rules of electrical action that take place in an electrical circuit. Personnel working on or near electrical circuits must be acquainted with the following:

1. Electricity doesn't spring into action until current flows.
2. Electrical current won't flow until there is a complete loop, that is, a loop from the voltage source back to the voltage source.
3. Electrical current always returns to its source.
4. When current flows, work is accomplished.

Rule 1 explains why faulty power tools with live metal cases can be carried and used by employees without causing a shock until in contact with a ground loop of low resistance.

Rule 2 states that current will flow because there is a way for the electricity to return to the source or

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the grounded transformer secondary. If a bird is sitting on a power line, no current flows through the bird's body because there is no loop back to the transformer.

Rule 3 explains the action that current takes where a loop or path returns to the source. In a grounded transformer secondary system, electrical current will not only use the earth as a return path but any other loop path it can use to get back to its secondary source. Water pipes, metal ventilation ducts, metal studs in modern wall construction, metal door frames, T-bars holding suspended ceiling panels, and metal ridge roll with a grounded lighting system are examples of other ground loops.

Rule 4 explains the action that current has on the body. Since the body is considered a resistive load, obviously getting one's body in a current loop can cause injury. High voltage and current can cause irreversible body harm. (See *Figure A-3*.)

Voltage is the pressure in an electrical circuit that causes the current to flow and the pressure can cause explosions. When an individual is shocked with high voltage, the voltage causes an explosion at the point the current leaves the body. The higher the voltage is, the more chance there is of forcing a greater amount of current through the low resistance of the body.

Where an electric heater is utilized, the heater has a resistive element. Current passing through the resistive element produces heat. When an electrical current flows through the resistance of the body, heat is produced as it is in a heater. This production of heat can damage the body severely.

Great care shall be exercised where employees are working near or with high-voltage systems. There is very little that can be done to increase the

Figure A-3 . This employee has placed his or her body in a ground loop by making contact to the power line with the metal pipe while his or her feet are touching the ground (earth).

resistance of the body. Appropriate protective equipment such as rubber gloves, mats, blankets, other insulating materials shall be used.

A-4 FACTORS ENHANCING ELECTRICAL SHOCK

The route that electrical current takes through the human body affects the degree of injury. The voltage pressure determines how much current flows. In cases where individuals come in contact with distribution lines, the high voltage causes the moisture in the body to heat so rapidly that body parts can literally explode. This extreme expansion is the result of the body fluids changing to steam, with an expansion ratio estimated to be 1 to 1,500. This could severely injure but not electrocute a person. When investigating shock incidents—whether these are near misses or those that have caused injury—these factors can be used as an investigative tool. Any report of a shock hazard should be checked. The combination of one or more of these factors can be analyzed and action taken to eliminate or control the hazard potential. Other

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factors that enhance electrical shock potential are as follows:

1. Wet or damp locations
2. Ground/grounded objects
3. Current loop from source back to source
4. Path of current through body and duration of contact
5. Area of body contact and pressure of contact
6. Physical size, condition, and age of person
7. Type and amount of voltage
8. Personal protective equipment, gloves, and shoes
9. Metal objects such as watches, necklaces, rings, etc.
10. Miscellaneous
 - a. Poor workplace illumination
 - b. Color blindness
 - c. Lack of training or knowledge
 - d. No safe work procedures.

Note: The above conditions can have a direct effect on how much current the voltage can push through a body.

A-5 ELECTRICAL CURRENT DANGER LEVELS

Because experiments on ventricular fibrillation cannot be performed on humans, animals have been substituted. The first work of this type was that of Ferris, Spence, King, and Williams of the Bell Telephone Laboratories in 1936. Since that time, researchers at John Hopkins University and

the Union of Soviet Socialist Republic Academy of Sciences have expanded the knowledge of the effects of electrical current on humans. As a result, the danger threshold for ventricular fibrillation was established for typical adult workers.

From *Figure A-4*, one can determine that a 100 mA current flowing for 3 seconds through a human adult body will cause death by electrocution. This doesn't seem like much current when you consider that a small, light-duty portable electric drill draws 30 times that amount. However, because a current as small as 3 mA (3/1000 amp) can cause painful shock, it is imperative that all electrical equipment plugs and cords and extension cords be kept in good condition and connected to a properly wired circuit with an equipment grounding conductor (EGC).

Table A-1 plots the range of electrical values that affect humans. Also shown is the requirement of UL for a Class A ground-fault circuit interrupter (GFCI) intended for personnel protection. Note the time-current relationship at much lower currents and shorter time periods. The electrical current range, causing freezing (called the "let go" range), is also illustrated.

Figure A-4. Chart shows effects of electric current intensity vs. the time it flows through the human body.

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A-6 BODY RESISTANCE MODEL

The human body impedance has three distinct parts: internal body resistance and the two skin impedances associated with contact to surfaces of different voltage potential. The internal body impedance is reported to be essentially resistive with no reactive components. If the voltage applied is high, the skin impedance can be considered negligible. Contrary to beliefs, low current is dangerous and it doesn't necessarily take high voltage to kill.

A body resistance model shown in *Figure A-5* indicates approximately 1,000 ohms from hand-to-hand or about 1,100 ohms from hand-to-foot. The greatest number of injurious shocks involve a current pathway through either hand-to-hand or hand-to-foot.

It is easy to analyze electrical shock hazards today. A small amount of current (50 mA) can cause the heart to go into ventricular fibrillation. The example given that a 6-watt bulb uses 50 mA of current when energized by 120 V simply means that merely the current required to light a 6-watt bulb is capable of causing death.

The resistance model of a person (*Figure A-5*) illustrates that wet contact with an energy source (such as 120-Vac) in one hand and a ground loop in the other produces current through the chest area equal to $I = E/R = 120/1,000 = 0.12$ amp or 120 mA; this current level is definitely hazardous. The current value in milliamps is determined by applying the following procedures:

Step 1: Finding formula
 $mA = (V \div R) \times 1,000$

Step 2: Finding resistance and voltage -
Figure A-5; Text
Hand-to-hand ground loop =
 $500 + 500 = 1,000 \Omega$
Circuit = 120 V

Step 3: Applying formula - Text
 $mA = (120 V \div 1,000 \Omega) \times 1,000 =$
120 mA

Solution: The milliamps rating is 120.

Note: Current level of 120 mA is definitely hazardous.

A case involving a welder using an ac welder illustrates the fact that less than 120 V can be hazardous. The welder was kneeling on a metal plate, wet with perspiration, and used the welding rod to scratch an itch on the back of his head: current flowed through to both knees. In this case,

Figure A-5 . Human body resistance model.

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the current through the neck and torso formed a series/parallel circuit. The resulting current flow would be approximately 228.6 mA with an 80-V ac source ($I = E/R = 80/350 = .2286$ amps = 228.6 mA).

Note: The current and resistance values used in this example are approximate and are not intended to indicate absolute values. The actual values would be different for each individual involved. For example, full leg resistance was assumed.

The current in milliamps in the series/parallel circuit can be determined by the following procedure.

Step 1: Finding formula - Figure A-5

$$R_T = R_3 + \frac{(R_4 R_5)}{R_4 + R_5}$$

Step 2: Finding resistance and voltage-
Figure A-5

Text

Head through both knees - 100 Ω ;

500 Ω ; 500 Ω ;

Circuit = 80 V

Step 3: Applying Formula

$$R_T = 100\Omega + \frac{(500\Omega \ 500\Omega)}{500\Omega + 500\Omega}$$

$$R_T = 350\Omega$$

Step 4: Finding formula for Milliamps -
Text

$$\text{mA} = (E \div R) \times 1,000$$

$$\text{mA} = (80 \text{ V} \div 350 \Omega) \times 1,000$$

$$\text{mA} = 228.6$$

Solution: The milliamp rating is 228.6.

Note: Current level of 228.6 mA is definitely hazardous.

Ventricular fibrillation is defined as repeated, rapid, uncoordinated contractions of the ventricles of the heart resulting in loss of synchronization between the heart beat and the pulse beat. Once ventricular fibrillation occurs, death will usually ensue in a few minutes. Resuscitation techniques, if applied immediately, can sometimes save the victim. Electric current flow is one of several things that can cause ventricular fibrillation.

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B. DEFINITION OF TERMS

The following definitions apply to terms used in this manual.

Affected employee—An employee whose job requires him or her to work in an area in which servicing or maintenance of equipment is being performed.

Approved—Accepted, certified, listed, labeled, or otherwise determined to be safe by a nationally recognized testing laboratory, such as but not limited to Underwriters Laboratories, Inc., and Factory Mutual Engineering Corp.

Authority having jurisdiction—A person with sufficient expertise in electrical safety to be the electrical authority at that facility.

Back-up protection—A secondary, redundant, protective system provided to deenergize a facility to permit safe physical contact by personnel. This system shall be totally independent of the first-line protection and shall be capable of functioning in the event of total failure of the first-line protective system.

Can—Denotes a possibility.

Clearance—

Employee Minimum Work Distance (Clearance)—A minimum separation distance between the employee (in this case, always a qualified electrical worker) or any conducting object contacting the employee and energized component.

System Clearance Distance—Mandatory separation distance between energized lines or

components and a vehicle, machine, load, etc. These requirements are generally stated in Federal regulations.

Traveling—The distance for machinery or vehicles in motion traveling under lines, or components with booms, elevated parts, dump bodies, etc., secured in the down position.

Working—The distance for machinery, vehicles, etc., working or otherwise in the vicinity of lines, etc., when not traveling.

Companion—A coworker who is cognizant of the danger and occasionally checks on the other worker.

Deenergized—Free from any electrical connection to a source of potential difference and from electric charge (i.e., not having a potential difference from that of earth).

Electrical hazard—A potential source of personnel injury, resulting either directly or indirectly from the use of an electrical energy source.

Direct electrical hazard—A potential source of personnel injury resulting from the flow of electrical energy through a person's body (potential electrical shock and burns).

Indirect electrical hazard—A potential source of personnel injury resulting from electrical energy transformed into other forms of energy (e.g., radiant energy, such as rf energy, light, and heat, energetic particles, mechanical forces, and chemical reactions such as fire and the production of noxious gases and compounds).

Electrical worker—A job title for a qualified person assigned to electrical work.

Emergency-shutdown pushbutton (E-stop)—A control device provided to automatically remove

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electrical energy to devices in the area during an emergency.

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

Failsafe—Built-in safety characteristics of a unit or system so that a failure (of the unit or system) or a loss of control power will not result in an unsafe condition.

First-line protection—The primary protective system and operating procedures to prevent physical contact with energized equipment by personnel.

General access area—Areas that do not present hazards to personnel while equipment and systems are functioning normally. These areas are accessible to all personnel. Normally, they do not present a hazard to personnel while systems are operating normally.

Ground—

Effectively grounded—Intentionally connected to the earth through a ground connection or connections of sufficient low impedance and having sufficient current-carrying capacity to prevent the buildup of voltages that may result in undue hazard to connected equipment or persons.

Equipment ground—The conductor that is used to connect the grounding electrode to the equipment required to be grounded. This conductor does not normally carry current.

Grounded conductor—A conductor that is intentionally grounded to supply a system reference and carry current back to the source. This conductor is designed to carry current.

Grounding conductor—The conductor used to connect the grounded conductor to the system grounding conductor.

Ground fault circuit interrupter—A device used to detect current leakage to ground at the 5 ± 1 mA level and which acts to interrupt the circuit for personnel protection purposes. This is known as a Class A GFCI device. Other classes of GFCI devices exist, but they are not referenced in this manual nor do they satisfy the requirements of this document.

Grounding hook—A device for making a temporary connection to discharge and ground the internal energy sources in hazardous electrical equipment. It consists of a bare copper rod shaped like a shepherd's hook at one end, an insulating handle, and a suitable bare flexible copper cable securely connected at the other end, which in turn is clearly visible through its insulating sheath and securely connected to an equipment or building ground.

Grounding points—The most direct connections possible for the protective grounding of a source of stored energy (e.g., capacitor terminals).

Guarded—Protected by means of being covered, shielded, fenced, enclosed, or protected by means of a suitable covering, casing, barrier, rail, screen, mat, or platform that would minimize the possibility, under normal conditions, of accidental contact by persons or objects.

Hazard—A hazardous situation exists with any of the following conditions:

The nominal voltage exceeds 30 V (RMS), the circuit capacity is able to drive greater than 5 mA through a 1,500-ohm load, and the employee is likely to be well grounded.

The nominal voltage exceeds 400 V (RMS) (phase-to-phase or phase-to-ground), the circuit

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capacity is 2 kVA or greater (or the overcurrent protection is 5 A or greater), and the circuit is exposed and uninsulated.

High hazard—A high hazard situation exists when the hazard situation is accompanied by a necessity to perform manipulative operations at the hazard location.

High voltage—Over 600 V.

Interlocked access areas—Areas in which the sources of power must be interlocked with the access doors because of the hazards contained therein.

Knowledgeable person—One who is recognized by laboratory management as having a sufficient understanding of an experimental device or facility to be able to positively identify and control the hazards it could present.

Limited access areas—Areas that are kept locked and are accessible only to authorized personnel because of the hazards contained therein.

Lock-and-tag procedures—Written procedures covering (a) the use of padlocks or other key locks to ensure that energy-supply disconnect devices are maintained in the open position for safe work on equipment, (b) the use of easily recognizable tags attached to the disconnect device control, that identify pertinent information about the work being performed, (c) the designation of authorities for the work and for safety actions to be taken, (d) the logging of dates, times, and signatures for the work being performed, and (e) other information necessary to ensure the safety of personnel and the protection of equipment, both during the work and when the energy supply is restored after the work is completed.

Locked/locked out—Protected in such a manner that an isolating device cannot be inadvertently

closed or operated without a key to remove the lock.

Massive ground—Large areas of grounded metal surfaces on or adjacent to equipment (e.g., equipment supports, enclosures, and floor gratings) and earth, in the case of outdoor equipment, which make isolation difficult or impossible for the protection of personnel working on energized electrical equipment.

May—Denotes permission (neither a requirement nor a recommendation).

Personnel safety interlock system—Identifies one or more of the emergency-shutdown systems or personnel access control systems or both.

Portable electrical equipment—Electrical equipment designed to be hand held in operation. This includes portable electric tools, trouble lamps, and similar utilization equipment.

Positively deenergized—All external sources of electrical energy are disconnected by some positive action (e.g., a locked-out switch or circuit breaker) and all internal energy sources (e.g., capacitor energy storage) are made safe by discharging and grounding.

Qualified worker—An individual who, by virtue of training, education, and experience, is familiar with the construction and the operation of the involved equipment and the associated hazards.

Safety barrier—A safeguard installed to restrict personnel access to a hazardous area.

Safety coordinator—An individual who has the responsibility of the entire safety of the work that is to be performed and familiar with the hazards involved.

Safety interlock—An electrical or mechanical device that prevents operation of equipment or

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precludes access to hazardous areas, enclosures, or equipment.

Safety watch—A person whose specific duties are to observe the workers and operations being performed, prevent careless acts, quickly deenergize the equipment in emergencies, and alert emergency rescue personnel. This person shall have basic cardiopulmonary resuscitation training and be thoroughly instructed on the locations of emergency shutoff switches and power disconnects and on the specific working procedures to be followed.

Shall—Denotes a requirement.

Should—Denotes a recommendation.

Unaffected employee—An employee whose job does not require him or her to work in an area in which servicing or maintenance of equipment is being performed.

Unauthorized worker—An individual who has no reason for entering a location.

Underground facility—A facility built below ground surface.

Well grounded—A potentially hazardous situation in which the person is standing in water, lying in wet soil, or in intimate contact with grounded objects to thus make electrical isolation difficult.

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ACRONYMS

ac	alternating current
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
CB	circuit breaker
CFR	Code of Federal Regulations
CMAA	Crane Manufacturers Association of America
CPR	cardiopulmonary resuscitation
dc	direct current
DOE	Department of Energy
EED	electroexplosive device
EPM	electrical preventive maintenance
FMEC	Factory Mutual Engineering Corporation
GFCI	ground fault circuit interrupter
GFP	ground-fault protector
IEEE	Institute of Electrical and Electronics Engineers
NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
NESC	National Electrical Safety Code
NFPA	National Fire Protection Association
OSHA	Occupational Safety and Health Act
OSQA	Office of Safety and Quality Assurance
PCB	polychlorinated biphenyl

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PIC person in charge
R&D research and development
RF radio frequency
UBC Uniform Building Code
UL Underwriters Laboratory, Inc.

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Table C-1. Electrical safety requirements—50- to 150-V line to ground to 250-V line to line ac or dc.

Work Description	Test Equipment	Tools	Safety Equipment	Approvals	Attendance	Backup Person Equipment
Voltage, Current Reading	Other Approved Instrumentation		Other insulated protective equipment such as gloves, blankets, sleeves, mats, etc.			
	Clamp Amp Meter		Safety Glasses			
	Approved Multimeter					
Fuse Pulling under 20 amps						
Lead Lifting under 20 amps						
Probing						

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Table C-2. Electrical safety requirements—151-V line to ground to 600-V line to line ac or dc.

Work Description	Test Equipment	Tools	Safety Requirements Protective Equipment	Approvals	Attendance	Backup Person Equipment	
Probing	Other Approved Instrumentation	Insulated Hand Tools	Other insulated protective equipment such as gloves, blankets, sleeves, mats, etc.	Group Manager	Electric Foreman or Engineer	Safety Glasses	X
Voltage, Current Reading	Clamp Amp Meter	Breaker Jacking Tools	Safety Belt and Life Line	Job Supervisor Approval	Qualified Electrical Backup	Low Voltage Gloves	X
Pulling Control Fuses or Power Fuses at No Load	Approved Multimeter	Insulated Fuse Puller	Face Shield	Safe Work Permit Required	No Attendance Required		X
Pulling/Inserting Plug in Devices on Energized MCCs			Safety Glasses	Electric Forman			X
Jacking Breakers In/Out on Energized MCCs							X
Other Work- Energized Circuits							X

Table C-3. Electrical safety requirements—601- to 15,000-V line to line ac.

Work Description	Test Equipment				Tools			Safety Requirements Protective Equipment							Approvals		Attendance	Backup Person Equipment	
	Other Approved Instrumentation	High Pot	High Volt Detector	Glowtester	Hot Stick 5-ft Minimum	High Voltage Fuse Puller	Breaker Jacking Tools	Safety Glasses	Face Shield	Tag Out and Lockout	High Voltage Gloves	Sleeves	Rubber Mat	Electric Foreman	Safe Work Permit Required	Job Supervisor Approval		Qualified Electrical Backup	High Voltage Gloves
Voltage Reading	X		X	X				X			X	X	X	X	X		X	X	X
Jacking Breakers In/Out on Energized Equipment							X	X			X	X				X	X	X	X
Highpointing Deenergized Equipment		X						X		X	X	X	X	X	X		X	X	X
Pulling Fuses--No Load						X		X	X		X	X	X	X	X		X	X	X

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Table C-4. Electrical safety requirements—battery work.

Work Description	Test Equipment	Tools	Safety Requirements Protective Equipment	Approvals	Attendance	Backup Person Equipment
Voltage Reading	Other Approved Instrumentation	Insulated Hand Tools	Face Shield	Job Supervisor Approval	No Attendance Required	Face Shield
			Tag Out and Lockout			Latex Gloves and Apron
			Apron			Latex Gloves
			Latex Gloves			Qualified Electrical Backup
Battery Rundowns						
Equalize						
Torque Bolts, Lifting Heads						

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Table C-5. Electrical safety requirements—high voltage, 600- V and above.

Work Description	Test Equipment	Tools	Safety Requirements Protective Equipment	Approvals	Attendance	Backup Person Equipment
Install/Remove Ground	Breaker Jacking Tools	Live Line Tools	High V. Gloves w/Leather Protect.	Clearance	Elec. Foreman or Elec. Engin.	High Volt Gloves
Operate Fused Cutouts	Other Instrumentation as App by Electrical Foreman	Reliable Comm.	Head Protection	Job Supervisor	Qualified Electrical Backup	Safety Glasses
Operate Disconnect Switch	High Pot	Nonconductive Rope	Leather Gloves	Safety Watch	No Attendance	Leather Gloves
Dangerous Work	High Volt Detector	Hot Stick 3 ft Minimum	Face Shields	Electric Foreman		
Climbing	Glowtester	Traveling Ground	Safety Glasses	Pole Inspection		
Tree Trimming		High Voltage Fuse Puller	Tag Out and Lockout	Confined Space or Safe Work Permi		
Energized Work		Tree Climbing Equipment	Body Harness and Life Line	Spike I.D.Cable		
Entering Trans/Bkr.			Rubbergoods Line Guards	Ground Cluster		
String/Rem. Ground Cond.			Recloser Off	Insulated or Ground Surface		
Enter Manhold				Sleeves		
Operate Load Interrupter Switch				H.V. Gloves w/Leather Protect.		
Voltage Readings				Head Protection		
Jacking Bkrs. In/Out on Energized Equipment				Leather Gloves		
Hi. Potting De-Energized Equipment				Face Shields		
Pulling Fuses-No Load				Safety Glasses		
Work De-Energized Equip.				Tag Out and Lockout		
Series Lighting				Body Harness and Life Line		
Pull Cable				Rubbergoods Line Guards		
Stringing Line				Recloser Off		