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ELECTRICAL SAFETY
VOLUME 1 OF 2

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ELE-116 EXAM PREVIEW

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Exam Preview:

1. The first consideration for working on any electrical system is to have the circuit positively _____. All circuits and equipment must be considered energized until opened, tagged and/or locked according to an approved procedure and should be proven _____ by testing with an approved testing device known to be in proper working order.
   a. Live
   b. Grounded
   c. Supervised
   d. Deenergized

2. 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.
   a. True
   b. False

3. Work performed on energized electrical systems and equipment may not be done even if a supervisor and/or cognizant safety professional and the personnel performing the work can determine that it can be done safely.
   a. True
   b. False

4. At least ___ employees [See 29CFR 1910.269(l)(1)(i)] shall be present while installation, removal, or repair of deenergized lines if an employee is exposed to contact with other parts energized at more than 600 volts are being performed.
   a. 2
   b. 3
   c. 4
   d. 5
5. All modifications to existing facility and projects and new facilities should be subject to inspection by the authority having jurisdiction or their authorized designee to verify compliance with the codes and standards in effect on the date that such work was approved by a final design review.
   a. True
   b. False
6. ___ 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 ___ quickly opens the circuit, stopping all current flow to the circuit and to a person receiving the ground-fault shock.
   a. Transformer
   b. Fuse
   c. Ground Fault Circuit Interrupter (GFCI)
   d. Capacitor
7. Circuit and system grounding consists of connecting the grounded conductor, the equipment grounding conductor, the grounding busbars, and all noncurrent-carrying metal parts to ground.
   a. True
   b. False
8. A fundamental purpose for grounding an electrical system is to transform excessive voltage from lightning, line surges, and crossovers with higher voltage lines.
   a. True
   b. False
9. Conductive Floor Test - Maximum floor resistance shall be measured with a suitably calibrated insulation resistance tester that operates on a normal open-circuit output voltage of 500 V dc and a short-circuit current of 2.5 mA with an effective internal resistance of approximately ___ ohms.
   a. 100,000
   b. 200,000
   c. 400,000
   d. 500,000
10. For Cranes/Hoists, 29 CFR 1910.179 and NEC Article 610, Part F state that Control circuit voltage shall not exceed 900 Vac or dc.
   a. True
   b. False

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NOT MEASUREMENT SENSITIVE

DOE-HDBK-1092-98
January 1998

DOE HANDBOOK

ELECTRICAL SAFETY

VOL 1 OF 2

U.S. Department of Energy
Washington, D.C. 20585

AREA SAFT

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FOREWORD

1. This Department of Energy (DOE) Handbook is approved for use by the Office of Environment, Safety, and Health and is available to all DOE components and their contractors.

2. Specific comments (recommendations, additions, deletions, and any pertinent data) to enhance this document should be sent to:

Patrick Tran
Office of Environment, Safety and Health
Office of Worker Safety and Health
Bellemead Building
U. S. Department of Energy
19901 Germantown Road
Germantown, MD 20874-1290

3. The DOE Electrical Safety Handbook replaces the DOE Electrical Safety Guidelines that was originally issued in 1993. DOE handbooks are part of the DOE directives system and are issued to provide supplemental information regarding the Department's expectations for fulfilling its requirements as contained in rules, Orders, notices, and regulatory standards. The handbooks may also provide acceptable methods for implementing these requirements. Handbooks are not substitutes for requirements, nor do they replace technical standards that are used to describe established practices and procedures for implementing requirements.

4. This document contains DOE developed explanatory material in support of OSHA regulations and nationally recognized electrical safety related standards and other information. This document was revised to include electrical safety for enclosed electrical and electronic equipment, research and development, and the latest editions of 29CFR 1910 and 1926, National Electrical Code, National Electrical Safety Code, and National Fire Protection Association 70E as of September 1997.

5. Topics that are being considered for future development and inclusion in the next update of this document are included in Appendix E.

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1.0 INTRODUCTION

1.1 PURPOSE

Electrical Safety Handbook presents 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 guidance and information for DOE installations to effect a reduction or elimination of risks associated with the use of electrical energy. The objectives of this handbook are to enhance electrical safety awareness and mitigate electrical hazards to employees, the public, and the environment.

1.2 SCOPE

This handbook provides general information to enhance understanding of DOE Orders, national codes, national standards, local, state, and federal regulations. This handbook shall not supersede more stringent requirements in those applicable codes, standards, and regulations.

Each entity should reference its contract documents and determine what legal requirements are to be followed in the area of electrical safety. These requirments may vary from locaction to location. In this document, “shall” refers to requirements from regulatory standards such as OSHA and relevant DOE Orders that may or may not apply to your specific location. “Should ” refers to guidance from consensus standards such as the National Electrical Code (NFPA 70), National Electrical Safety Code (NESC, ANSI C2), and Electrical Safety Requirements for Employee Workplaces (NFPA 70E) which may or may not apply to your specific location (depending upon your contractual requirements). No section or portion of this document is intended to stand alone. Each section or portion interacts with others that are appropriate to support referenced material.

The design of new facilities shall conform to relevant DOE Orders and should conform to industry recognized engineering design standards. Existing facilities should evaluate their systems and operations in relation to this handbook, applicable DOE Orders, national codes, national standards, local, state, and federal regulations, to determine if they comply or if a safety problem exists. If the evaluation determines that a safety risk exists, corrective actions should be initiated to bring the systems or operations into compliance with current standards. In the case of a major renovation of an existing facility, the modification shall comply with current standards.

Existing facilities shall conform to relevant DOE Orders and should comply with the National Electrical Code (NFPA 70), National Electrical Safety Code (NESC, ANSI C2), and Electrical Safety Requirements for Employee Workplaces (NFPA 70E). The OSHA standards have specific requirements that shall apply to all electrical installations and utilization equipment regardless of when they were designed or installed and identify other mandatory provisions and specify effective dates. Installations in compliance with the code at the time of design or installation (code of record), do not need to be upgraded to the updated code unless required to correct a known hazard or a major modification is being performed.

This handbook is being provided to identify those DOE Orders, national codes, national standards, local, state, and federal regulations that will provide employees with guidance on requirements pertaining to electrical systems. It is the responsibility of each site to evaluate compliance with the above requirements.

1.3 AUTHORITY HAVING JURISDICTION (AHJ)

In states and municipalities, an official (electrical inspector, engineer, or equivalent qualified individual) is usually designated as the electrical Authority Having Jurisdiction (AHJ). The AHJ should possess such executive ability as is required for performance of the position, and should have thorough knowledge of standard materials and work practices used in the installation, operation, construction, and maintenance of electrical equipment. The AHJ should, through experience or education, be knowledgeable of the requirements contained in the OSHA standards, the National Electrical Code, the National Electrical Safety Code, DOE requirements, and other appropriate local, state, and national standards. The AHJ should be responsible to interpret codes, regulations and standards, and approve equipment, assemblies, or materials. If the AHJ needs to address items outside their electrical expertise, such as fire, confined space, fall protection, or like issues, the AHJ should consult with cognizant experts before a decision is reached. 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, regulations, 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 authority to an individual or organization within his or her control. The authority may reside with a safety or facilities department. The field office manager or designated representative may act as a higher level of authority. The authority may begin with an electrician and proceed through various levels of supervision to management (as shown in Fig. 1-1).

DOE contractors should establish lines of authority within their organizations. It is important that a line of authority be established, documented, and recognized. The limits of the authority and recognition of higher authority should be delineated.

Fig. 1-1.

NOTE: The titles in Fig. 1-1 will vary from site to site.

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CONTENTS

2.0 GENERAL REQUIREMENTS

This section deals with the reliability and effective maintenance of electrical systems that can be achieved in part by careful planning and proper design. The training of personnel in safety-related work practices that pertain to their respective job assignments is outlined.

2.1 ELECTRICAL MAINTENANCE OR REPAIRS

Only qualified persons shall perform electrical repairs. It is dangerous for an unqualified worker to attempt electrical repair. Before any electrical maintenance or troubleshooting is performed, sources of electrical energy shall be deenergized, except where it is necessary for troubleshooting, testing, or areas that are infeasible to deenergize. All energy sources shall be brought to a safe state. For example, capacitors shall be discharged and high capacitance elements shall be short-circuited and grounded.

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, tagged and/or locked according to an approved procedure and should be proven deenergized by testing with an approved testing device known to be in proper working order. Review system drawings and/or perform system walkdowns. 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. The grounding and shorting device should be selected and installed in accordance with appropriate standards. Whenever work is to be performed on a positively deenergized system, the worker 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 such tasks as electrical repairs, modifications, and tests on energized electrical systems, parts, and equipment need to comply with the following:

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 1910.269(d)(2), 1910.333(a), 1926.950(d), NESC Rule 442, and NFPA 70E, Part II, Ch.5[1].
2. Work performed on energized electrical systems and equipment may be done only if a supervisor and/or cognizant safety professional and the personnel performing the work determine that it can be done safely. Approval should be given for each job. Approval for the

[1] See Appendix D for selected regulation cross references thoughout this document.

same job performed repeatedly 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 to do so, or, for training purposes, unless they work under the direct supervision of a qualified person.
4. Sufficient 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.

Note: The discussion in #4 above assumes the system voltage is less than the maximum use voltage of the ASTM class of rubber goods used.

5. Other work, independent of voltage, that presents a significant shock or arc blast hazard to employees, needs to be evaluated as to the number of employees involved.
6. At least two employees [See 29CFR 1910.269(l)(1)(i)] shall be present while the following types of work are being performed:

   (A) Installation, removal, or repair of lines that are energized at more than 600 volts.

   (B) Installation, removal, or repair of deenergized lines if an employee is exposed to contact with other parts energized at more than 600 volts,

   (C) Installation, removal, or repair of equipment, such as transformers, capacitors, and regulators, if an employee is exposed to contact with parts energized at more than 600 volts.

   (D) Work involving the use of mechanical equipment, other than insulated aerial lifts, near parts energized at more than 600 volts, and

   (E) Other work that exposes an employee to electrical hazards greater than or equal to those listed above.

   Exceptions to the items listed above are:

   (A) Routine switching of circuits, if the employer can demonstrate that conditions at the site allow this work to be performed safely,

   (B) Work performed with live-line tools if the employee is positioned so that he or she is neither within reach of nor otherwise exposed to contact with energized parts, and

   (C) Emergency repairs to the extent necessary to safeguard the general public.

7. Taking voltage measurements may subject personnel to exposed energized parts. (See Appendix C.) Where it is determined personnel are subject to contacting exposed energized parts, personnel shall use the appropriate protective equipment for the voltage levels involved.

2.1.3. SAFETY WATCH RESPONSIBILITIES AND QUALIFICATIONS

The responsibilities and qualifications of personnel for sites that require the use of a safety watch are as follows:

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; and

5. The safety watch should have no other duties that preclude observing and rendering aid if necessary.

2.2 BASIC SAFEGUARDS

To protect employees from some of the electrical hazards at industrial sites, Federal regulations limit the performance of electrical work to qualified and competent personnel. Specifically, the law requires that only a qualified person or someone working under the direct supervision of a qualified person may perform any repair, installation, or testing of electrical equipment. See Section 2.8 and the definitions of “Qualified Employee” or “Qualified Person” in Appendix B.

One of the best ways to prevent electrical accidents at 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 taken by a qualified person.

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

1. Maintain good housekeeping and cleanliness.
2. Identify and diminish potential hazards.
3. Anticipate problems.
4. Resist pressure to “hurry up.”
5. Plan and analyze for safety in each step of a project.
6. Document work.
7. Use properly rated test equipment and verify its condition and operation before and after use.

8. Know and practice applicable emergency procedures.
9. Become qualified in cardiopulmonary resuscitation (CPR) and first aid and maintain current certifications.
10. Wear appropriate personal protective equipment (PPE).
11. Refer to system drawings and perform system walkdowns.
12. Electrical equipment should be maintained in accordance with the manufactures instructions.

2.3 RESPONSIBILITIES

Management is responsible 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). Management expects all of its employees to comply with these regulations as well as the DOE requirements 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 that approved, maintained, and tested personal protective equipment and clothing is provided, available, and used properly.
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 and health regulations and standards that apply to their own actions and conduct, including immediate reporting to management of unsafe and unhealthful conditions.

2.4 REVIEWS/INSPECTIONS

All modifications to existing facility and projects and new facilities should be subject to inspection by the authority having jurisdiction or their authorized designee to verify compliance with the codes and standards 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 should be used to mitigate the hazard.

According to OSHA, under the Department of Labor (DOL), there are 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 to be work similar to that involved when a new building or facility is built, a new addition is built, or an entire floor is renovated.

A revision to 29 CFR 1910, Subpart S, 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.

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

29 CFR 1910	1996 NEC	Subject
.303(b)	110-3	Examination, installation, and use of equipment
.303(c)	110-14(b)	Splices
.303(d)	110-18	Arcing parts
.303(e)	110-21	Marking
.303(f)	110-22	Identification of disconnecting means
.303(g)(2)	110-17	Guarding live parts (600 V, nominal or less)
.304(e)(1)(i)	210-20, 240-1,2 310-10	Protection of conductors and equipment
.304(e)(1)(iv)	240-24	Location in or on premises
.304(e)(1)(v)	240-41	Arcing or suddenly moving parts
.304(f)(1)(ii)	250-3	2-wire dc systems to be grounded
.304(f)(1)(iii);(iv)	250-5a,b	AC systems to be grounded
.304(f)(1)(v)	250-5b(4)	AC systems 50 to 1,000 V not required to be grounded
.304(f)(3)	250-23a	Grounding connections
.304(f)(4)	250-51	Grounding path
.304(f)(5)(iv)(A) thru .304(f)(5)(iv)(F)	250-42a,b,c,d	Fixed equipment required to be grounded
.304(f)(5)(v)	250-45	Grounding of equipment connected by cord and plug
.304(f)(5)(vi)	250-44	Grounding of nonelectrical equipment
.304(f)(6)(i)	250-58	Methods of grounding fixed equipment
.305(g)(1)(i);(ii)	400-7	Uses of flexible cords and cables
.305(g)(1)(iii)	400-8	Flexible cords and cables prohibited
.305(g)(2)(ii)	400-9	Flexible cord and cable splices
.305(g)(2)(iii)	400-10	Pull at joints and terminals of flexible cords and cables

See Table 2-2 for a list of the sections and regulations that apply to electrical installations and equipment installed after April 16, 1981.

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

29 CFR 1910	1996 NEC	Subject
.303(h)(4)(i);(ii)	110-33(a),(b)	Entrance and access to workspace over 600 V
.304(e)(1)(vi)(B)	240-81	Circuit breakers operated vertically
.304(e)(1)(vi)(C)	240-83(d)	Circuit breakers used as switches
.304(f)(7)(ii)	250-154	Grounding of systems of 1,000 V or more supplying portable or mobile equipment
.305(j)(6)(ii)(B)	460-24	Switching series capacitors over 600 V
.306(c)(2)	620-51,(d) 620-52(b)	Warning signs for elevators and escalators
.306(i)	675-8, 675-15	Electrically controlled irrigation machines
.306(j)(5)	680-51(a)	Ground-fault circuit interrupters for decorative fountains
.308(a)(1)(ii)	710-4(b)(i)	Physical protection of conductors over 600 V
.308(c)(2)	725-41	Marking of Class 2 and Class 3 power supplies
.308(d)	760-1	Fire-protective signaling circuits

2.5 APPROVAL OF ELECTRICAL EQUIPMENT

All electrical equipment, components, and conductors shall be approved for their intended uses, 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, 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. Equipment can be approved if it is built, designed, and tested according to specific nationally recognized standards such as UL 508 or one of the ANSI C series and is determined by the AHJ to be safe for its intended use.

3. If a particular piece of equipment is of a type not included in 1 or 2 above, the equipment shall be evaluated by the AHJ. If the equipment is approved by the AHJ, there shall be documentation of the evaluation and approval 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. The custom made equipment should be built in accordance with a design approved by the AHJ.

4. Components or installations in aircraft, water craft, and railroads 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 information for accepting electrical equipment and wiring methods that are not approved by an NRTL.

2.6 CODES, STANDARDS, AND REGULATIONS

Workers who perform electrical or electronic work, where applicable, shall comply with relevant DOE Orders and should comply with the current revision of the following codes and standards.

1. Standards published by the National Fire Protection. Association (NFPA)

    a. National Electrical Code (NEC), NFPA 70

    b. Electrical Safety Requirements for Employee Workplaces, NFPA 70E.

2. National Electrical Safety Code, ANSI C2.

3. All relevent state and local requirements.

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. American National Standards Institute (ANSI)

4. American Society for Testing and Materials (ASTM)

5. National Fire Protection Association (NFPA)

6. Underwriters Laboratory, Inc. (UL)

7. Factory Mutual Engineering Corporation (FMEC)

8. Other Nationally Recognized Testing Laboratories recognized by OSHA on a limited basis.

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. Therefore, where there are conflicts between the mandatory requirements of the above codes, standards, and regulations, the requirements that address the particular hazard and provide the greater safety shall govern.

2.7 GROUND FAULT CITCUIT INTERRUPTERS

There are 2 classes of ground-fault circuit interrupters and each class has a distinct function. A Class A ground-fault circuit interrupter trips when the current to ground has a value in the range of 4 through 6 milliamperes and is used for personnel protection. A Class A ground-fault circuit interrupter is suitable for use in branch circuits. A Class B ground-fault circuit interrupter (commonly used as ground fault protection for equipment) trips when the current to ground exceeds 20 milliamperes. A Class B GFCI is not suitable for employee protection.

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 used in the industry:

1. Circuit breaker type
2. Receptacle type
3. Portable type
4. Permanently mounted type.

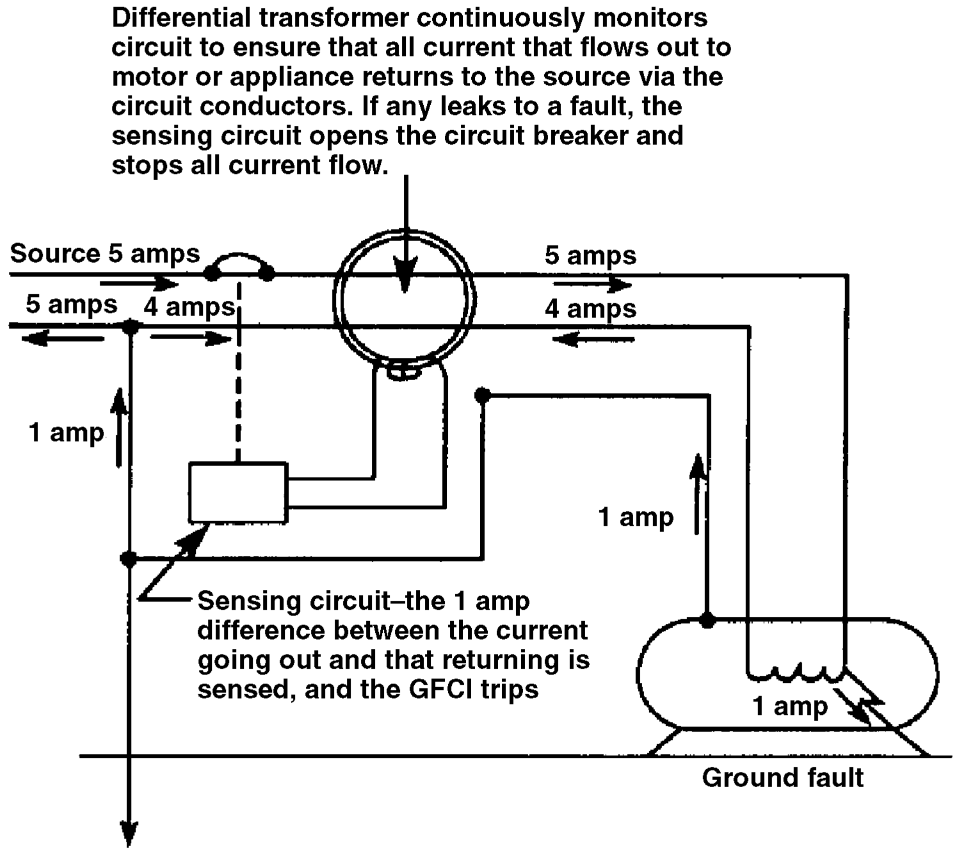
The condition of use determines the type of GFCI selected. For example, if an electrician or maintenance person plugs an extension cord into a nonprotected GFCI receptacle, the easiest way to provide GFCI protection is to utilize a portable-type GFCI.

See NEMA 280-1990, "Application Guide for Ground Fault Circuit Interrupters."

2.7.1 HOW A GFCI WORKS

See Section 4.14 for ground-fault protection of equipment. 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 2-1 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. A fuse or circuit breaker cannot provide this kind of protection. The fuse or circuit breaker will trip or open the circuit only if a line-to-line or line-to-ground fault occurs that is greater than the circuit protection device rating.



NEC Section 305-6
OSHA Section 29 CFR 1910.304(b)(1))

Figure 2-1. GFCI-protected circuits is one way of providing protection of personnel using electric hand tools on construction sites or other locations.

A GFCI will not protect the user from line-to-line or line-to-neutral contact hazards. For example, an employee is using a double insulated drill with a metal chuck and drill bit protected by a GFCI device. If the employee drills into an energized conductor and contacts the metal chuck or drill bit, the GFCI device will not trip (unless it is the circuit the GFCI device is connected to) as it will not detect a current imbalance.

2.7.2 USES

The use of GFCI's in branch circuits for other than dwelling units is defined in NEC Section 210-8(b), for feeders in NEC Section 215-9, and for temporary wiring in Section 305-6.

Ground-fault protection for personnel shall be provided for temporary wiring installations utilized to supply temporary power to equipment used by personnel during construction, remodeling, maintenance, repair or demolition activities.

For temporary wiring installations;

a) All 120-V, single-phase, 15- and 20-A receptacle outlets that are or are not a part of the permanent wiring of the building or structure and that are in use by employees shall have GFCI protection for personnel [See 29 CFR 1926.404(b) and NEC Section 305-6(a) and (b)] or an assured equipment grounding program (See Section 8.2).

b) GFCI protection or an assured equipment grounding program (See Section 8.2) for all other receptacles to protect against electrical shocks and hazards. [See NEC 305-6(a) and (b)].

c) 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. (See Figure 2-2 and Section 6.4).

Portable GFCIs shall be trip tested according to the manufacturers instructions.

2.8 TRAINING AND QUALIFICATIONS OF QUALIFIED WORKERS

Only qualified workers shall perform work on electrical systems. It is dangerous for unqualified personnel to attempt to do electrical work. There should 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 1910.269(a)(2), 1910.332, 1926.950(e), NESC Rules 410 and 420, and NFPA 70E, Part II, Ch. 2-1 and 2-2.)

2.8.1 FORMAL TRAINING AND QUALIFICATIONS

Management should establish formal training and qualifications for qualified workers before they are permitted to perform electrical work. Refresher training is recommended at intervals not to exceed three years to provide an update on new regulations and electrical safety criteria.

The training shall be on-the-job and/or classroom type. The degree of training provided shall be determined by the risk to the employee. This training shall be documented. Employees shall be trained and familiar with, but not be limited to, the following:

1. Safety-related work practices, including proper selection and use of PPE, that pertain to their respective job assignments.

2. Skills and techniques necessary to distinguish exposed live parts from other parts of electrical equipment.

3. Skills and techniques necessary to determine the nominal voltage of exposed live parts, clearance distances, and the corresponding voltages to which the qualified person will be exposed.

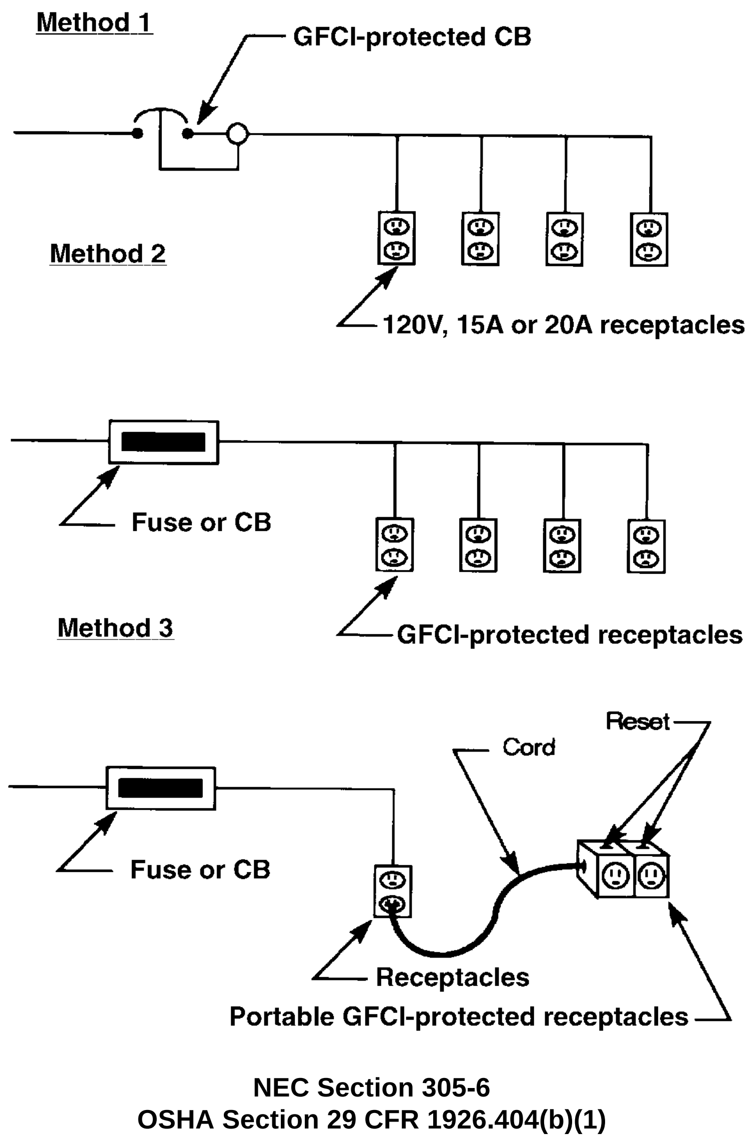


Figure 2-2. There are three methods of providing GFCI protection for construction sites.

4. Procedures on how to perform their jobs safely and properly.

5. How to lockout/tagout energized electrical circuits and equipment safely.

29 CFR 1910.269(a) and 1910.332 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. 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 1910.269(n), 1926.954(e), NESC Rule 445, and NFPA 70E, Part II, Ch. 2-4.

d. Use of testing and measuring equipment—29 CFR 1910.269(o) and 1910.334(c)

e. Work permit and work authorization procedures

f. Use and care of personal protective equipment—29 CFR 1910.269(j) and 1910.335(a)

g. Proper clothing required for arc blast protection—29 CFR 1910.269(l) and NFPA 70E Part II Ch. 2-3.3

h. First aid and CPR—29 CFR1910.269(b) and 70E Part II, Ch. 2-1.3. Refresher training is recommended at intervals not to exceed 3 years (see OSHA Instruction CPL 2-2.53).

2.8.2 TRAINING OF SAFETY PERSONNEL

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

2.9 WORKING SPACE AROUND ELECTRICAL EQUIPMENT

Working space around electrical enclosures or equipment shall be adequate for conducting all anticipated maintenance and operations safely, including sufficient space to ensure safety of personnel working during emergency conditions and workers rescuing injured personnel. Spacing shall provide the dimensional clearance (discussed in the following subsections) for personnel access to equipment likely to require examination, adjustment, servicing, or maintenance while energized. Such equipment include panelboards, switches, circuit breakers, switchgear, controllers, and controls on heating and air conditioning equipment.

These clearances shall be in accordance with OSHA, NESC, and NEC. 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

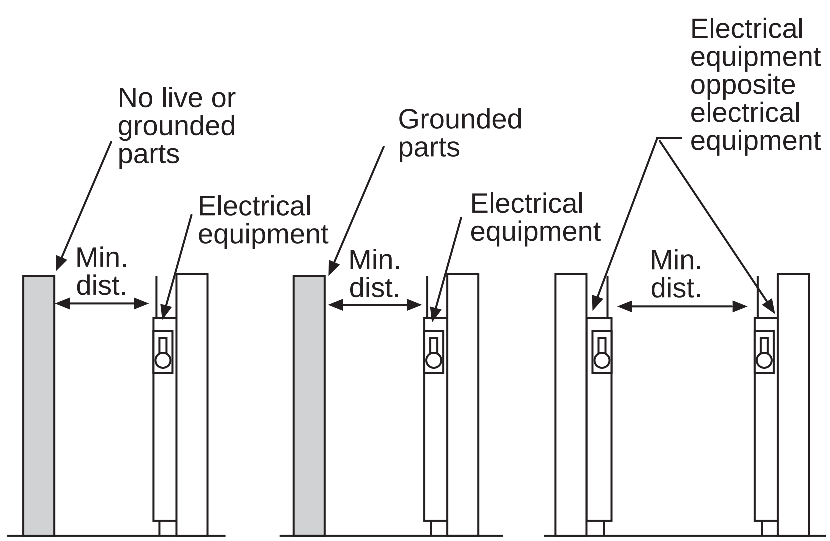
A minimum working space 30 in. wide shall be provided in front of electrical equipment rated at 600 V or less. This provides room to avoid body contact with grounded parts while working with energized components of the equipment. The 30-in.-wide space may be centered in front of the equipment or can be offset. The depth of the working space shall be clear to the floor [See NEC 110-16(a)]. Where rear access is required to work on deenergized parts, a minimum of 30 inches shall be provided. There shall be clearance in the work area to allow at least a 90-degree opening of equipment doors or hinged panels on the service equipment. Working spaces may overlap. The depth of the working space shall be 3 ft, 3 1/2 ft, or 4 ft, depending upon existing conditions. The conditions are as follows:

Condition 1: These are exposed live components on one side of a space and ungrounded parts on the other side.

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 2-3 for the clearance requirements in front of electrical equipment rated 600 V or less. See NEC Section 110-16(a) Exception 1 for clearance requirements in the rear of electrical equipment.



Condition 1		Condition 2		Condition 3	
Volts to ground	Min. dist.	Volts to ground	Min. dist.	Volts to ground	Min. dist.
0 - 150 V	3 ft.	0 - 150 V	3 ft.	0 - 150 V	3 ft.
151 - 600 V	3 ft.	151 - 600 V	3 1/2 ft.	151 - 600 V	4 ft.

L93 0350

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

Figure 2-3. Minimum clearances in front of electrical equipment (600 V or less).

2.9.2 ELECTRICAL EQUIPMENT RATED OVER 600 VOLTS

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

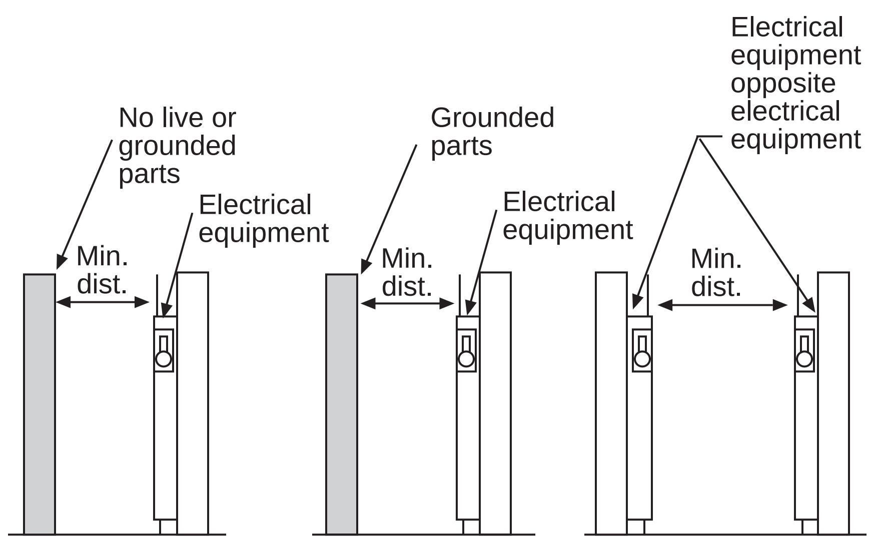
There are three conditions to apply as in NEC Section 110-16(a) and Table 110-16(a)

1. Where there are exposed live components on one side of a space and no live or 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 2-4 for the clearance requirements in front of electrical equipment rated at over 600 V. See NEC Section 110-34(a) Exception for clearance requirements in the rear of electrical equipment.



Condition 1		Condition 2		Condition 3	
Volts to ground	Min. dist.	Volts to ground	Min. dist.	Volts to ground	Min. dist.
601 - 2,500 V	3 ft.	601 - 2,500 V	4 ft.	601 - 2,500 V	5 ft.
2,501 - 9,000 V	4 ft.	2,501 - 9,000 V	5 ft.	2,501 - 9,000 V	6 ft.
9,001 - 25,000 V	5 ft.	9,001 - 25,000 V	6 ft.	9,001 - 25,000 V	9 ft.
25,001 - 75,000 V	6 ft.	25,001 - 75,000 V	8 ft.	25,001 - 75,000 V	10 ft.
above 75,000 V	8 ft.	above 75,000 V	10 ft.	above 75,000 V	12 ft.

L93 0349

NEC Table 110-34
OSHA Table S-2

Figure 2-4. Minimum clearances in front of electrical equipment (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 supplied.

2.10.1 DISCONNECTING MEANS

All disconnecting means (switches or circuit breakers) shall be located for easy access and shall be clearly and permanently marked to show the purposes of the disconnects, unless located and arranged so that the purpose is evident. Labeling should match and be traceable to appropriate drawings. 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. Disconnecting means shall be capable of being locked out where required.

2.10.2 PANELBOARD CIRCUIT DIRECTORIES

Panelboard circuit directories shall 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 requirements 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 LOAD LABELING

As with the disconnecting device, the load should be labeled. For example, the motor, the controller, and the disconnecting device could have the same identification number, etc.

2.10.5 SOURCE LABELING

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 2-5.)

2.11 WORK INSTRUCTIONS

Before work begins, the qualified worker should ensure that the job to be done is in compliance with instructions pertaining to the electrical work.

2.11.1 SAFE WORK INSTRUCTIONS AND SUPERVISION

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

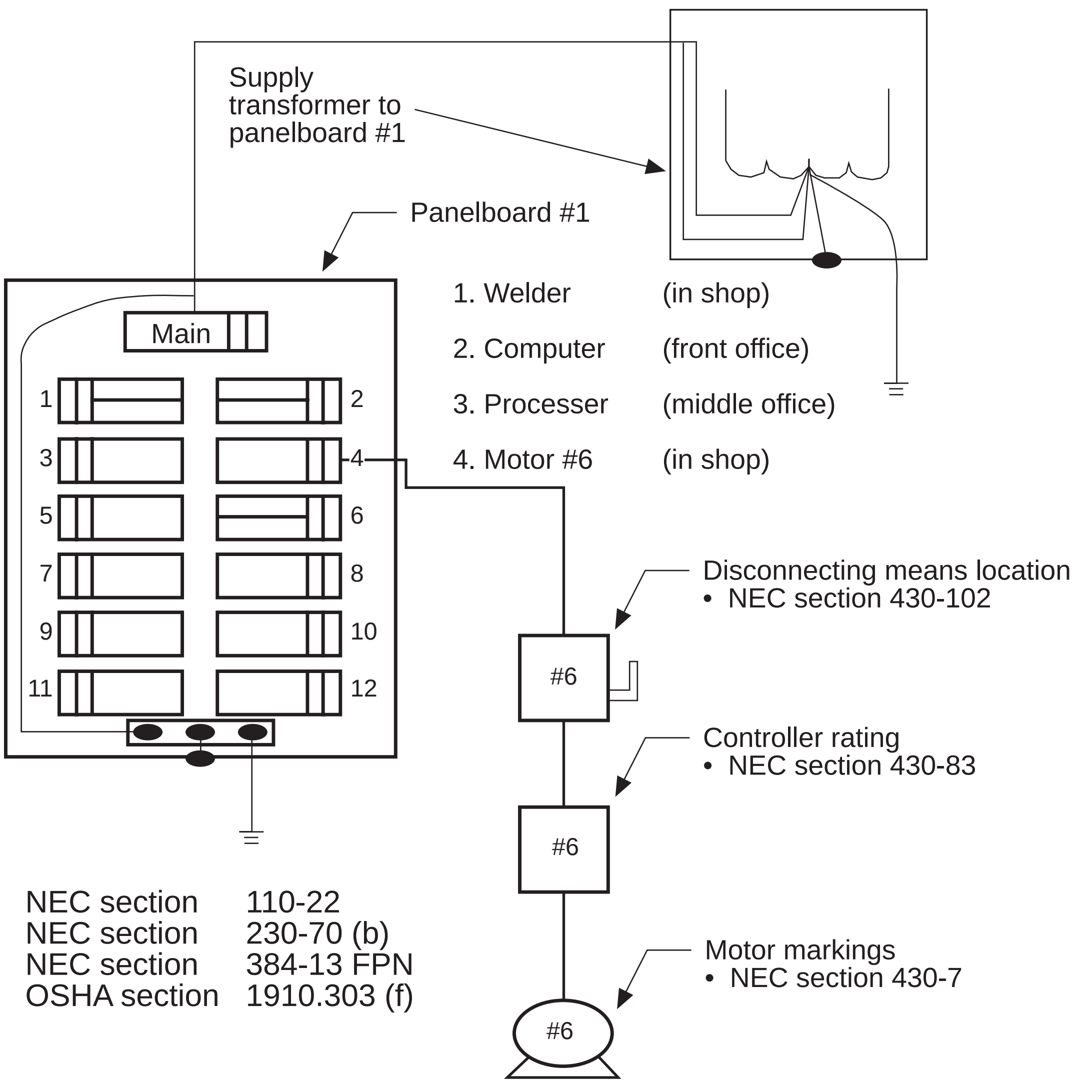


Figure 2-5. Switchgear, panelboards, motor control centers, etc., should identify the loads and elements which they supply.

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

Electrical instructions should be based on a thorough analysis of the job and its hazards. If the same task is repeated, it may be performed under specific work rules that are based on such analyses.

2.11.2 WORK INSTRUCTIONS

If no specific instruction is available and the job is beyond the scope of written work rules, the supervisor should issue instructions pertaining to the job to be performed. The instructions should contain the essential safety rules for the job and, when documented, should be signed by the employee, a line supervisor and/or safety representative.

2.11.3 WORK PLANNING

Electrical instructions 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. Controlling associated generating equipment
4. Testing of equipment to ensure safe conditions
5. Provision of rubber-insulated protective equipment rated for the highest voltage present
6. Qualified personnel (see 2.1.2 and 2.1.3)
7. Personal protective equipment and protective clothing (e.g., hard hats, safety shoes, eye/face protection, insulated live-line tools, hot sticks, cotton or fire resistant clothing, and arc protection)

Note: Cotton or wool clothing is acceptable if the employer can show that the clothing worn by the employee will not ignite or melt in the presence of an electrical arc to which the employee could be subjected.

8. Working on experimental equipment.

2.12 ELECTRICAL PERSONAL PROTECTIVE EQUIPMENT (PPE)

Qualified workers are responsible for avoiding and preventing accidents while performing electrical work, repairs, or troubleshooting electrical equipment. Personnel shall wear or use personal protective equipment (PPE), and protective clothing that is appropriate for safe performance of work. See Table 2-3.

2.12.1 MANAGEMENT'S RESPONSIBILITIES

Management shall ensure that appropriate PPE is provided and ensure that employees using PPE are trained in their proper use. Furthermore, management shall ensure that employees use the PPE appropriate for their assigned task.

2.12.2 INSPECTING PPE

Employees shall visually inspect rubber-insulated PPE at the beginning of each workday prior to use and after any work performed that could damage the equipment. Such inspections shall include a field air test of the gloves used. Visual inspection shall be performed on hot sticks, grounds, aerial lift equipment and booms, rope, ladders, insulated tools, etc. Equipment that does not successfully pass visual inspection shall not be used and shall be returned for repair and testing or disposal.

Table 2-3. ANSI/ASTM standards on PPE and protective clothing.

Subject	Number and Title
Blankets	ANSI/ASTM D1048-1988a, *Specifications for Rubber Insulating Blankets*
Climbing Equipment	ASTM F887-91a, *Specifications for Personal Climbing Equipment*
Dielectric Overshoes	ASTM F1116-88, *Test Method for Determining Dielectric Strength of Overshoe Footwear* ASTM F1117-87, *Specification for* Dielectric Overshoe Footwear
Eye and Face Protection	ANSI Z87.1-1979, *Practice for Occupational and Educational Eye and Face Protection*
Gloves and Sleeves	ANSI/ASTM D1051-1987, *Specifications for Rubber Insulating Sleeves* ANSI/ASTM Dl20-1987, *Specifications for Rubber Insulating Gloves* ASTM F496-96, *Specifications for In-Service Care of Insulating Gloves and Sleeves*
Hand Tools	ASTM F1505-94, *Specifications for Insulated and Insulating Hand Tools*
Head Protection	ANSI Z89.1-1986, *Protective Helmets for Industrial Workers Requirements*
Leather Protectors	ASTM F696-91, *Specification for Leather Protectors for Rubber Insulating Gloves and Mittens*
Line Hoses, Hoods, and Covers	ANSI/ASTM D1049-1988, *Specifications for Rubber Insulating Covers* ASTM D1050, *Specification for Rubber Insulating Line Hoses* ASTM F478-92, *Specifications for In-Service Care of Rubber Insulating Line Hoses and Covers*
Live Line Tools	ASTM F711-86, *Specification for Fiberglass-Reinforced Plastic (FRP) Rod and Tube Used in Live Line Tools*
Mats	ANSI/ASTM D178-1988, *Specifications for Rubber Insulating Matting*
Protective Clothing	ASTM F1506-94, *Textile Materials for Wearing Apparel for Use by Electrical Workers Exposed to Momentary Electric Arc and Related Thermal Hazards* ASTM PS-57, *Test Method for Determining the Ignitibility of Clothing by the Electrical Arc Exposure Method Using a Mannequin* ASTM PS-58, *Test Method for Determining the Arc Thermal Performance (Value) of Textile Materials for Clothing by Electric Arc Exposure Method Using Instrumented Sensor Panels*
PVC Insulating Sheeting	ASTM F1742-96, *Specifications for PVC Insulting Sheeting*

2.12.3 CLEANING AND ELECTRICAL TESTING OF PPE

Rubber-insulated PPE 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 handbook. The intervals of retest for rubber goods issued for service shall not be more than 6 months for gloves and 12 months for sleeves and blankets. Gloves or sleeves that have been electrically tested but not issued for service shall not be placed into service unless they have been electrically tested within the previous twelve months.

2.12.3.1 TESTING

All testing methods, apparatus, and facilities for such testing shall meet the applicable ANSI/ASTM Standard and 29 CFR 1910.137. The method used and the results of such tests shall be documented and made available for inspection.

2.12.3.2 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.

2.12.3.3 RETESTED PPE

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

2.12.4 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.

2.12.4.1 FIBERGLASS-HANDLED TOOLS

Fiberglass-handled tools shall be tested by the manufacturer at 100 kV per ft of length per 29 CFR 1926.951(d)(i) and ASTM F711. The in-service test shall be 75 kV per ft. per 29 CFR 1910.269 (j)(2)(e). Also, see IEEE Std. 978 for further information.

2.12.4.2 WOODEN-HANDLED TOOLS

Wooden-handled tools shall be tested by the manufacturer to 75 kV per ft of length per 29 CFR 1926.951(d)(ii) and ASTM F711. The in-service test shall be 50 kV per ft. per 29 CFR 1910.269 (j)(2)(e). Also, see IEEE Std. 978 for further information.

2.12.5 MAXIMUM USAGE VOLTAGE

Maximum usage 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
00	500	Beige
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 29CFR 1910.137 and the ASTM Series.

2.12.6 MAXIMUM USAGE VOLTAGE FOR LIVE-LINE TOOLS

Maximum usage 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

2.12.7 RUBBER-INSULATED GLOVES

Whenever rubber-insulated protective gloves are required, approved protective gloves shall also be worn (See Appendix C) except as follows: see 29 CFR 1910.137 and the ANSI/ASTM series for those conditions where rubber-insulated protective glove can be used without protectors.

2.12.8 STORAGE

Electrical insulating and protective clothing and equipment should 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.

Rubber goods shall be stored in a location as cool, dark, and dry as possible. The location shall be as free as practicable from ozone, chemicals, oils, solvents, damaging vapors and fumes, and away from electrical discharges and sunlight. Rubber gloves should be stored cuff down in a bag, box, or container that is designed for rubber glove storage. Rubber gloves may be kept inside of leather protectors.

2.12.9 SAFETY SHOES, HATS, AND GLASSES

Safety shoes, hard hats, and 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 should be familiar with the particular features of the apparatus involved. Only qualified workers should do such work and these workers should refer to the manufacturer's testing procedures, warnings, and instructions on how to service such equipment.

2.13.1 TRAINING

Qualified workers shall be knowledgeable and trained in safety-related work practices, safety procedures, and other 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.)

2.13.1.1 LIVE PARTS

Live parts that an employee may be exposed to shall be deenergized before the employee works on or near them, unless it can be demonstrated that deenergizing introduces additional or increased hazards or is infeasible because of equipment design or operational limitations. (See Section 2.1.1.) 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 or system creating a greater hazard.

Live parts that operate at less than 50 volts to ground need not be deenergized if there will be no increased exposure to electrical burns or to explosion due to electrical arcs [See 29 CFR 1910.333(a)(1)].

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 1910.333(b)(2).

2.13.1.4 STORED ELECTRICAL ENERGY

Stored electrical energy that might endanger personnel shall be placed in a safe state. Capacitors shall be discharged and high-capacitance elements shall be short-circuited and grounded if the stored electrical energy could endanger personnel per 29 CFR 1910.147(d)(5) and 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 procedures shall meet the requirements of 29 CFR 1910.147(c) to (f), 1910.269(d) and (m), 1910.333, and 1926.417. (See Figure 2-6.)

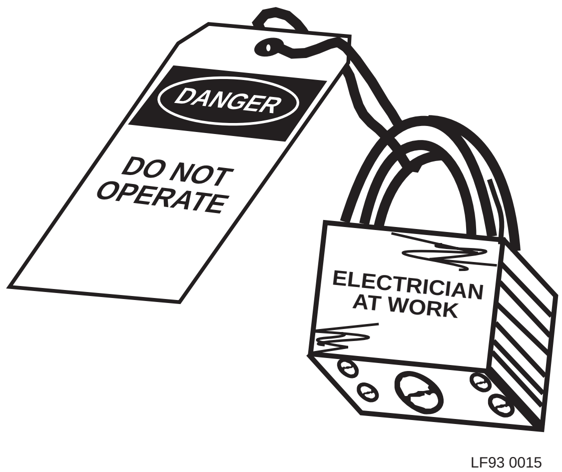
2.13.2 VERIFICATION OF DEENERGIZED CONDITION

Verification shall be made that all live circuits, 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, perform voltage verification, inspect open switches and draw-out breakers etc. to assure the isolation of energy sources.

2.13.2.1 VOLTAGE VERIFICATION TEST

A qualified worker shall use the appropriate 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 a hazardous energized condition



OSHA SECTIONS 29 CFR 1910.147, 1910.269(d) and (m), 1910.333, and 1926.417

Figure 2-6. Employers shall implement and document a lockout-tagout program with procedures to safeguard employees from injury while working on or near deenergized systems.

exists as a result of induced voltage or 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. This test is also recommended for systems of 600 V or less. Testing shall be performed as if the circuit is energized. The voltage verification device used shall be rated for the application. Proximity testers and solenoid-type devices should not be used to test for the absence of AC voltage. See 2.13.4.7 for further information.

2.13.2.2 APPLICATION OF GROUNDS

Personnel protective grounds shall be applied on circuits 600 V and above or on lesser voltages where residual charges may accumulate. Personal protective grounds shall be selected and installed in accordance with appropriate standards. (See sections 4.6 and 7.5). Consideration shall be given to step and touch potentials in the area of the temporary ground connections.

2.13.3 REENERGIZING EQUIPMENT

The following requirements shall be met before circuits or equipment are reenergized, even temporarily. Reference 29 CFR 1910.147, 1910.269, 1910.333 and 1926.417 for detailed information.

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:

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, or as stated below.

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

   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.

2.13.4 SAFE ENERGIZED WORK (HOT WORK)

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

2.13.4.1 APPROACH DISTANCE

No qualified employee shall be permitted to approach or take any conductive object closer to exposed energized lines or parts than the distances listed in the following references:

Table	Reference	Title
Table R-6	29CFR 1910.269(l) (See Table 7-2)	AC live line work minimum approach distance
Table S-5	29CFR 1910.333(c)	Approach distance for qualified employees

Table V-1	29 CFR 1926.950(c)	Approach distance (construction activities)
Table 2-3.3.5	NFPA 70E. Chapter 2	Approach distance to exposed energized electrical conductors and circuit parts
Table 441-1 or 441-4	NESC	AC and DC live line work minimum approach distance

unless:

1) The employee is insulated from the energized line or part. Electrical protective equipment, rated for the voltage involved, and properly used, such as fiberglass live line tools, insulated tools, gloves, or sleeves, shall be considered effective insulation for the employee, or

2) The energized line or part is insulated from the employee and from other lines or parts at a different potential. Electrical protective equipment, rated for the voltage involved, and properly used, such as hose, hoods, blankets, mats, or covers, shall be considered effective insulation for the employee, or

3) For live-line bare-hand work, the employee is isolated, insulated, or guarded from any exposed conductive objects.

No unqualified employee shall be permitted to approach or take any conductive object closer to exposed, energized lines or parts than the distance listed in 29CFR 1910.333(c)(3)(i) and NFPA 70E Table 2-3.3.5, Columns 3 and 4

For further information, see the associated text to the tables above.

2.13.4.2 TWO WORKERS

Because of exposure to energized parts, electrical work, independent of voltage, that presents a significant shock or arc blast hazard to employees, needs to be evaluted as to the number of employees involved. (See 2.1.2, 2.1.3, and 29 CFR 1910.269.)

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 by each employee 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 beginning any work at the job site, an individual should 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.

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 performing the work.

3. Ensure that the tools and instruments are in good working order and have up-to-date calibration or testing 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. Allow only qualified individuals to operate tools and equipment.

6. Use safety signs, symbols, or accident prevention tags to warn and protect employees where electrical hazards are likely to endanger lives.

7. Use barricades 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. Do not use metal barricades where they are likely to cause an electrical contact hazard.

8. Use manual signaling and alerting when signs and barricades do not provide sufficient warning and protection from electrical hazards.

9. Limit access to the work area to authorized individuals who are familiar with the work.

10. Ensure that the PIC notifies all individuals involved in the work of any changes in the work conditions.

11. If unsafe conditions develop during the work process, immediately report them to the person in charge or the immediate supervisor.

12. Establish emergency safety procedures to deal with electrical accidents.

2.13.4.4 UNEXPECTED ELECTRICAL HAZARDS

Employees should 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 SYSTEMS UNDER LOAD

Electrical equipment intended to switch current shall have a rating sufficient for the current. Manual switches and 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 designed for the testing involved. The voltage device used shall be rated for the application. Proximity testers and solenoid-type devices should not be used to test for the absence of AC voltage because they have a lower voltage (usually in the range of 50 to 110 volts) below which they will not detect voltage, even if it is present. Also, these testers will not detect DC voltage or detect AC voltage in a cable that is shielded. They are very useful in certain applications such as finding cables that go through a panel but do not terminate in the panel. However, it should be noted that just because a proximity tester does not detect voltage does not mean that the equipment or device is actually deenergized. The absence of voltage can only be verified with a voltmeter rated for the application.

Voltmeters, both analog and digital, are designed for a number of applications from appliance troubleshooting to power system testing. The type of voltmeter used depends on where in the power system you are using the meter. The user must read and understand the manufacturers' instructions on the use and application of the voltmeter. When a multi-function, multi-scale meter is used, it is important for the user to select the function and scale necessary for the task being performed in order to avoid damage or destruction of the meter and injury to the employee. See ANSI/ISA S82.01, S82.02, S83.03, International Electrotechnical Commission (IEC) 1010-1, and UL 1244 for more information on the application and ratings of voltmeters.

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

2.13.4.7.1 QUALIFIED EMPLOYEES

Only qualified workers who are knowledgeable and 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 also ensure that an instrument, when calibrated to National Institute of Standards and Technology (NIST) traceable standards, is capable of transferring that quality of measurement to field conditions within specified limits, where that level of measurement quality is needed.

A record should be maintained for each instrument, by serial number or equivalent method, 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. After a period of time, it should become obvious what frequency needs to be established for calibrating each instrument.

CONTENTS

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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.

3.1 DEVELOPMENT AND IMPLEMENTATION REQUIREMENTS

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

1. DOE 4330.4B, Maintenance Management Program
2. NFPA 70B, Recommended Practice for Electrical Equipment Maintenance
3. NFPA 70E, Standard for Electrical Safety Requirements for Employee Workplaces
4. NFPA 72, National Fire Alarm Code
5. National Electrical Testing Association (NETA).
6. ANSI-C2, National Electrical Safety Code

3.2 DEFINITION

An EPM program is defined as the system that manages the conducting of routine inspections and tests and the 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 should be part of the EPM program. Records of all inspections, tests, and servicing should be documented and reviewed.

All electrical equipment that is appropriate for EPM should 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. These qualifications can be shown by appropriate documentation of work experience, on-the-job, and offsite formal training to verify understanding and retention of minimum knowledge, skills, and abilities.

3.3 MAINTENANCE

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

3.4 INSPECTION

If an EPM program does not exist, an inspection, testing, and servicing program should be developed and implemented to establish a baseline to initiate an EPM program. The inspection frequency should 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.

One 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; 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; Frequency of Inspections for Enclosures 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 Cleaning 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.; 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; 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 should 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 should 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 should be kept current. A system of recording changes in electrical systems and then integrating those changes into the applicable drawings should be developed and implemented.

NFPA 70B, Chapter 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 should include the essential ingredients of Chapter 12 of NFPA 70B, "Ground-Fault Protection." This includes ground fault circuit interrupters (GFCIs) and ground-fault protection for equipment (GFPE).

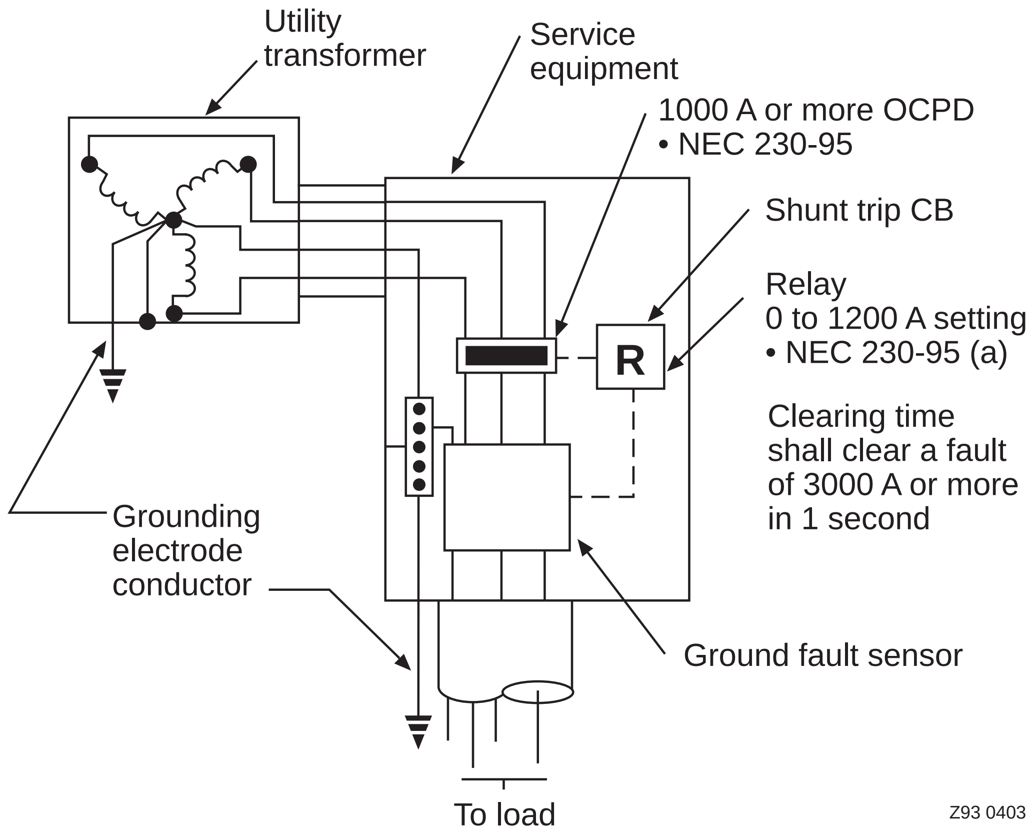
Ground-fault protective devices are intended to protect personnel and equipment. There are two distinct types, GFCI and GFPE, and it is of extreme importance to understand the difference between them.

A GFCI is defined in Article 100 of the NEC as a device intended for the protection of personnel in their job assignments. (See NEC Sections 210-7(d), 210-8, 215-9, 305-6, 427-26 and Section 2.7[1].)

A GFPE is defined in Article 100 of the NEC as a system intended to provide protection of equipment from line-to-ground fault currents. GFPE 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 Sections 215-10, 230-95, and 240-13 and Section 4.14.)

Figure 3-1 shows a zero sequence type of ground fault protection. See NEC Section 230-95 and 240-13 and NEMA PB2.2, "Application Guide for Ground Fault Protection Devices for Equipment."

[1] See Appendix D, Reference Matrix



NEC Section 230-95

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 ground fault sensor (window) can be used to encircle all service conductors, including the grounded conductor (neutral).

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CONTENTS

4.0 GROUNDING

This section presents general rules for the grounding and bonding of electrical installations. Qualified workers should clearly understand the concepts of grounding practices as required by the NEC. They should 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 electrode conductor
4. Bonding jumper
5. Grounding electrode.

4.1 REGULATIONS, CODES, AND REFERENCES

Regulations, codes, and references for system, equipment, and personal grounding can be found in the following documents:

1. 29 CFR 1910
2. 29 CFR 1926
3. National Electrical Code (NFPA 70)
4. National Electrical Safety Code (ANSI C2)
5. NFPA 70E
6. ASTM F855, “Specifications for Temporary Grounding Systems to be Used on Deenergized Electric Power Lines and Equipment”
7. DOD FIPS-PUB-94, “Guidelines on Electrical Power for ADP Installations”
8. DOD MIL-HDBK-419A, (Volumes 1 and 2) “Grounding, Bonding, and Shielding for Electronic Equipment and Facilities (Basic Theory, Applications)”
9. EIA/TIA-607, “Commerical Building Grounding and Bonding Requirements for Telecommunications”
10. IEEE 80, “Guide for Safety in AC Substation Grounding”
11. IEEE 142, “Recommended Practice for Grounding of Industrial and Commercial Power Systems”
12. IEEE 524A, “IEEE Guide to Grounding During the Installation of Overhead Transmission Line Conductors”
13. IEEE 1048, “IEEE Guide for Protective Grounding of Power Lines”
14. IEEE 1100, “Recommended Practice for Powering and Grounding Sensitive Electronic Equipment”
15. International Association of Electrical Inspectors, “Soares Book on Grounding”
16. NEMA 280, “Application Guide for Ground Fault Circuit Interrupters”
17. NEMA PB 2.2, “Application Guide for Ground Fault Protection Devices for Equipment”

4.1.1 ENGINEERING SPECIFICATIONS AND DRAWINGS

Engineering specifications and drawings should identify the requirements for all components and clearly illustrate the grounding electrode system, the grounding electrode conductor, bonding points and bonding jumpers, and the connection point for the grounded conductor and the grounding conductors. Where used for installation or construction purposes, these specifications and drawings should 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 busbars, and all noncurrent-carrying metal parts to ground. This is accomplished by connecting a properly sized unspliced 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[1].]

4.3 EQUIPMENT GROUNDING

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

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

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

1. Be permanent and continuous per NEC Sections 250-51, 250-75, 250-76, 250-77, 250-91, 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) and (e); and
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).

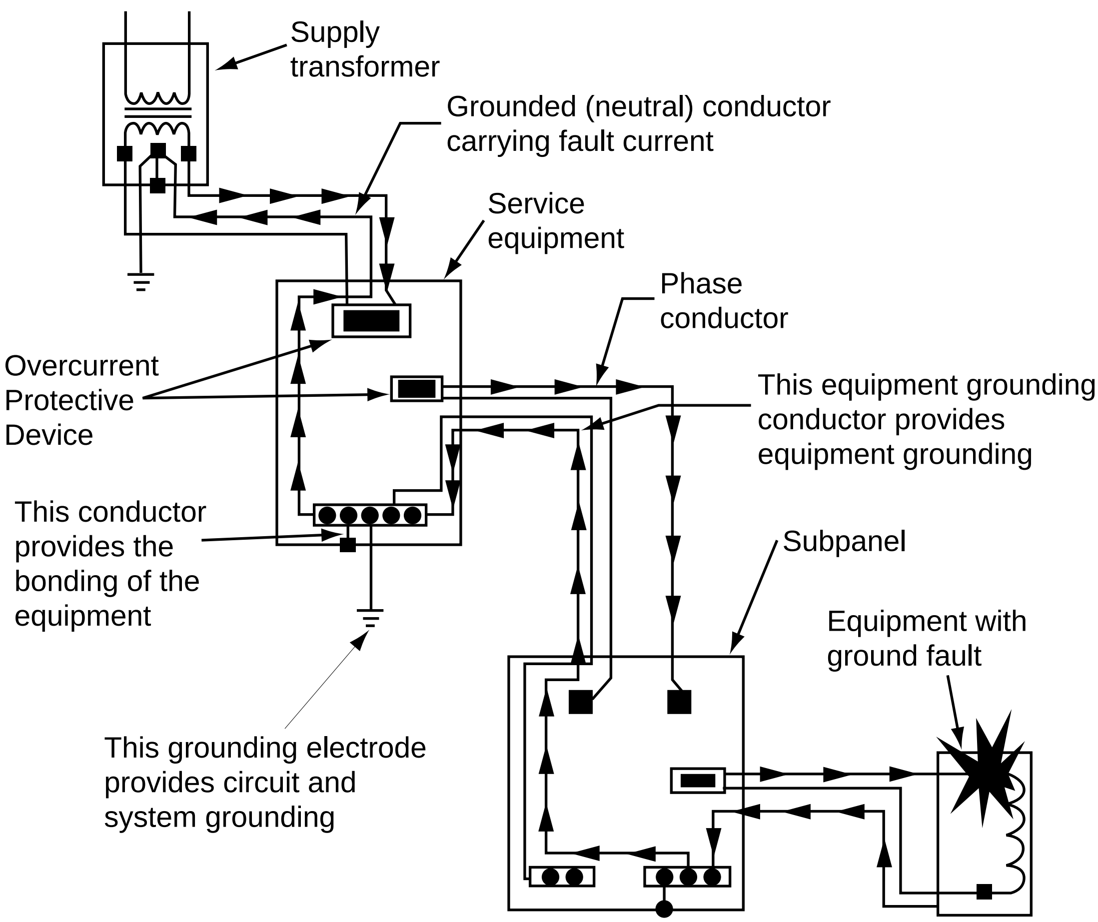
[1] See Appendix D, Reference Matrix.

4.4 BONDING

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 open the overcurrent protection devices. The means of bonding shall provide the following to ensure the grounding system is intact:

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

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



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.

4.5 GROUNDED OR UNGROUNDED SYSTEMS

Ungrounded systems may provide greater continuity of operations in the event of a ground fault. However, the second fault will most likely be more catastrophic than a grounded system fault. Whenever ungrounded systems are used in a facility, the maintenance personnel should receive training in how to detect and troubleshoot the first ground on an ungrounded system.

Electrical systems can be operated grounded or ungrounded, depending on the condition of the systems' use. Electrical systems are grounded to protect circuits, equipment, and conductor enclosures from dangerous voltages and personnel from electrical shock. See NEC Sections 110-9, 110-10, 230-65, 250-1, and 250-2 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.

Note: A system is considered grounded if 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 device per NEC Sections 250-23(a) or 250-26 for seperately derived systems.

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.) Consideration should be given to the sizing of the neutral conductor for certain loads due to the presence of harmonic currents (See NEC Sections 210-4 and 310-10).

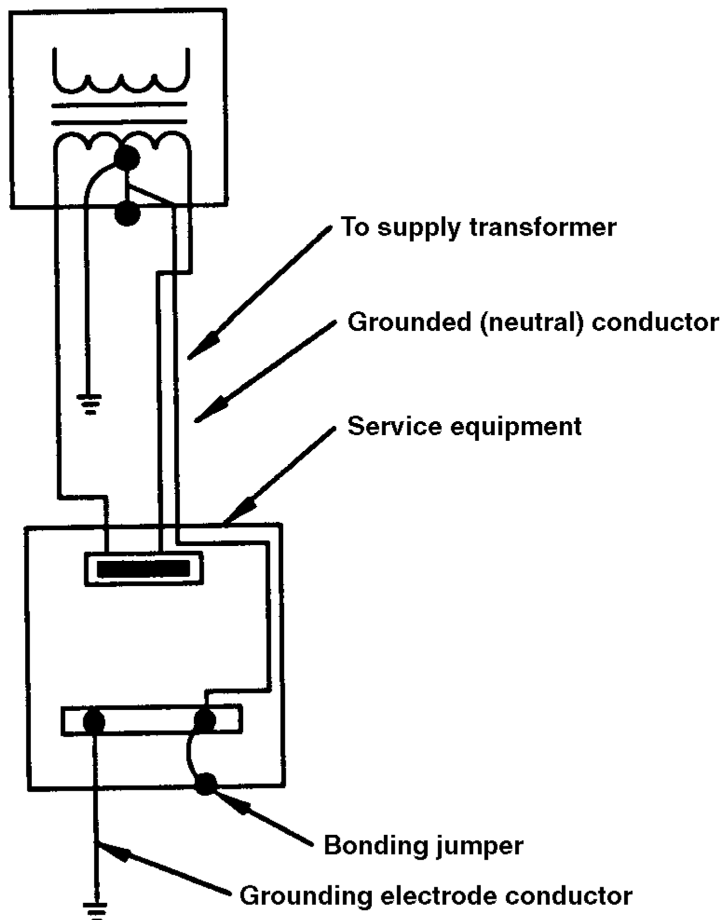
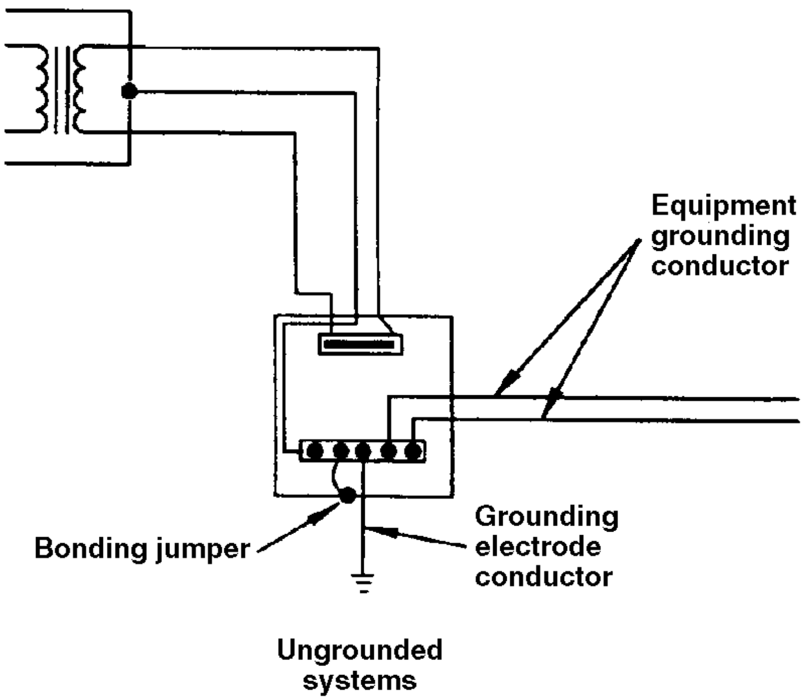


Figure 4-2. A grounded system is equipped with a grounded (neutral) conductor routed between the supply transformer and the service equipment.

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 for solidly grounded electrical systems. However, equipment grounding conductors (EGCs) are used only 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 benefit if electrical system continuity is required or if it would result in the shutdown of a continuous process. However, if an accidental ground fault occurs and is allowed to flow for a substantial time, overvoltages can develop in the associated phase conductors. Such an overvoltage situation can lead to conductor insulation damage, 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 they would experience on a solidly neutral grounded system. (See Figure 4-3.)

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

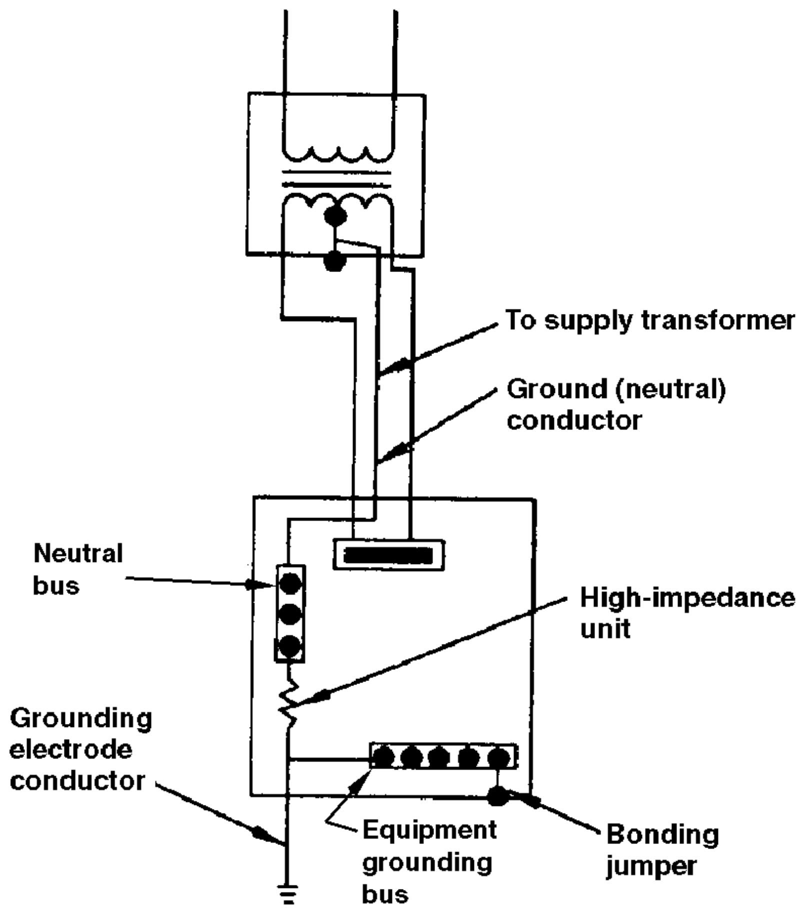


NEC Section 250-5 (b) Ex. 1-5
OSHA Section 29 CFR 1910.304 (f)

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.

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 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 used to regulate fault current.

4.6 GROUNDING REQUIREMENTS

Alternating current systems of less than 50 volts shall be grounded as required in NEC Section 250-5(a). Systems of 50 to 1,000 V should be solidly grounded as required by NEC Section 250-5. Systems supplying phase-to-neutral loads shall also be solidly grounded (See Figure 4-5). The following electrical systems are required to be solidly grounded:

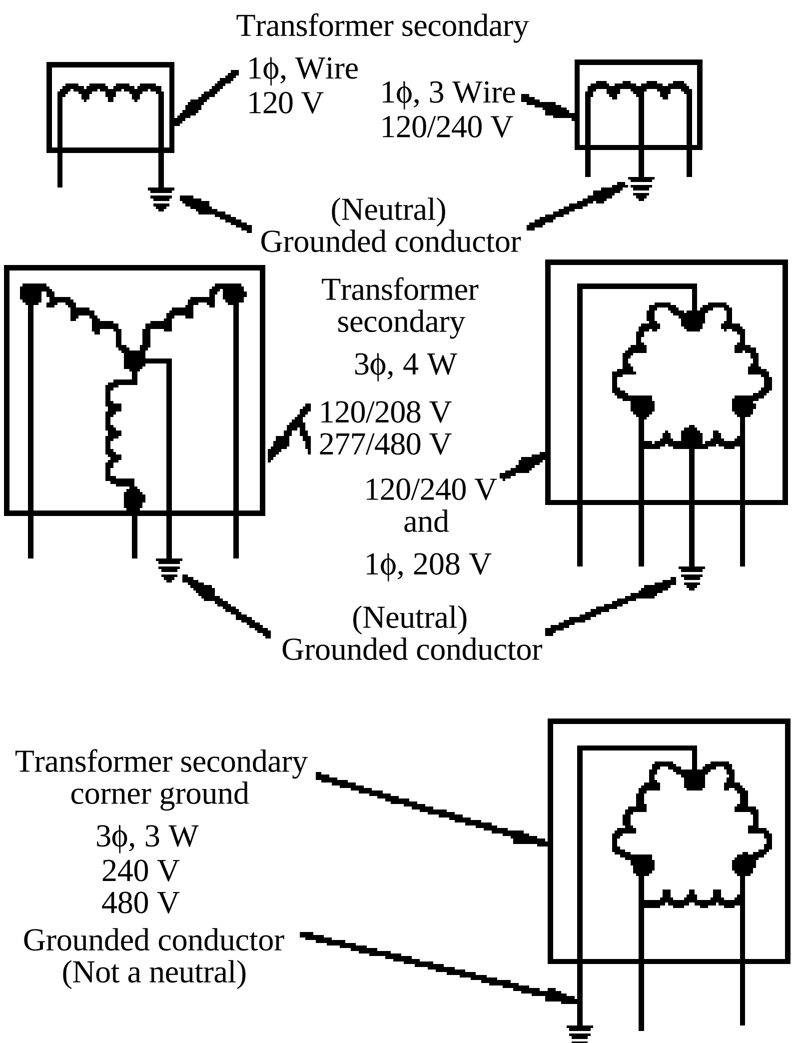
1. 120/240-V, single-phase, three-wire
2. 208Y/120-V, three-phase, four-wire,
3. 480Y/277-V, three-phase, four-wire,

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 supply only phase-to-phase loads.



NEC Section 250-5 (b)
OSHA Section 29 CFR 1910.304 (f) (1) (iv)

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

4.7 GROUNDING ELECTRODE CONDUCTOR (GEC)

The main purpose of the grounding electrode conductor (GEC) is to connect the electrical 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.

In grounded systems, the GEC connects to the neutral bar in the service equipment enclosure. In ungrounded systems, the GEC connects to the grounding terminal bar. 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
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 on these values.

For example, the size of the service entrance conductors from a delta, three-phase, four-wire midpoint 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 at least #2 copper.

Note: NEC Table 250-94 is used to size the grounding electrode conductor for both grounded and ungrounded systems. The table is used 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 is an exception to the main rule. It has three parts and pertains to specific types of grounding electrodes. The exception applies to grounded and ungrounded systems.

Exception (a) applies to made electrodes only, such as rod, pipe, or plate electrodes. The grounding electrode conductor is not required to be larger than #6 copper or #4 aluminum.

Exception (b) 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 (c) 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)]

4.8 MAIN BONDING JUMPER

The primary 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, there is not a complete circuit for fault current and is an invitation to a dangerous situation.

The main bonding jumper shall connect together the following items:

1. Grounded conductors and grounded terminal

2. Equipment grounding conductors and grounding terminal

3. All metal enclosures enclosing conductors and components.

If supplied, the manufacturers main bonding jumper is the preferred conductor to be used as the main bonding jumper. NEC Section 250-79(a) requires the main bonding jumper to be a (1) wire, (2) screw, (3) busbar, or (4) 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 does not exceed 1100 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 at least #2 copper.

Where the kcmil rating of the service entrance conductors exceeds 1100 kcmil for copper or 1750 for aluminum, the bonding jumper shall be at least 12 l/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 2400 kcmil copper conductors per phase?

Step 1:	Finding the largest phase—NEC 250-79(d) 2400 kcmil x 0.125 = 300 kcmil
Step 2:	Finding the main bonding jumper—NEC Table 250-94; Table 8, Ch. 9 requires 300 kcmil
Answer:	The main bonding jumper is required to be at least 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 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 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.

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 locations on the supply side of the service equipment. These locations are as follows:

1. Service equipment
2. Meter base
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 used as a circuit conductor. The minimum size for the 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 1100 kcmil copper or 1750 kcmil aluminum.

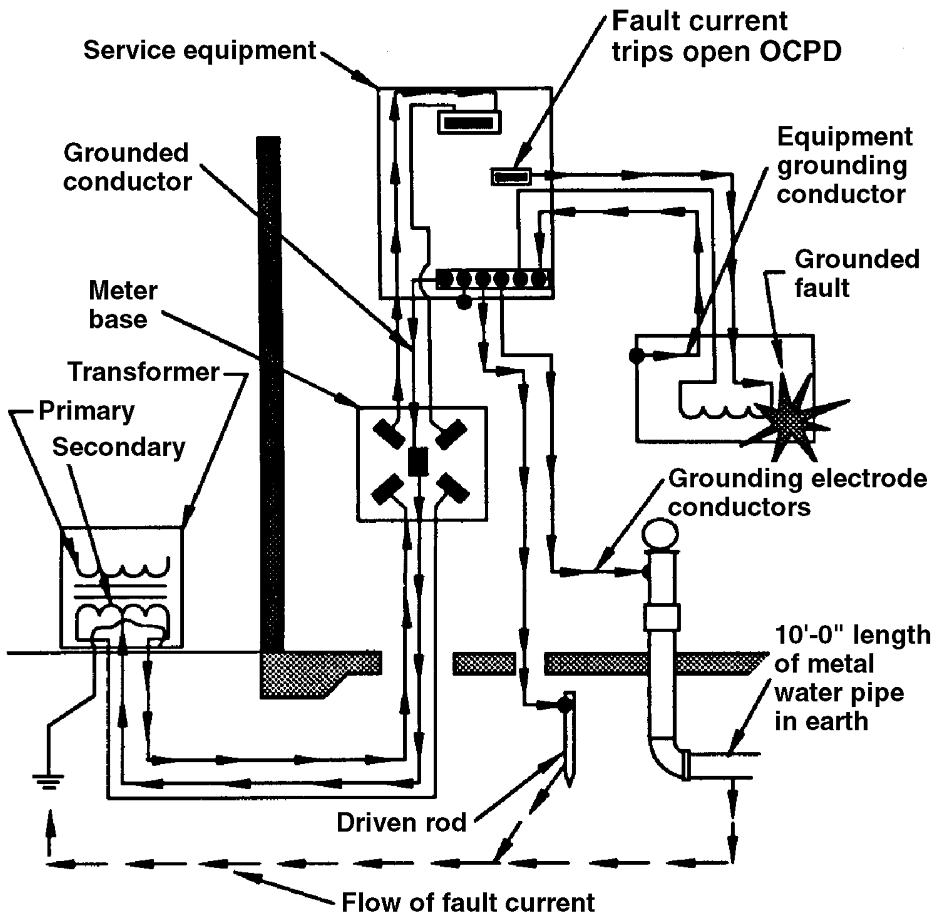
2. When the service entrance conductors are larger than 1100 kcmil copper or 1750 kcmil aluminum, the grounded conductor shall be 12 1/2% of the largest phase conductor.

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 1100 kcmil—NEC Table 250-94 250 kcmil requires #2 copper
Answer:	The size of the grounded conductor is at least #2 THWN copper.

For example: What size THWN copper grounded conductor is required for a parallel service having a total kcmil rating of 2400 per phase? (All conductors are THWN copper.)



NEC Section 250-23 (b)
OSHA Section 29 CFR 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 1100 kcmil—NEC Table 250-94 2400 kcmil x 0.125 = 300 kcmil
Answer:	The grounded conductor is required to be at least a #300 kcmil, THWN copper conductor.

This method is used where the service entrance conductors are over 1100-kcmil copper or 1750-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 1100 kcmil for copper or 1750 kcmil for aluminum.

4.10 EQUIPMENT GROUNDING CONDUCTOR

Equipment grounding conductors for ac systems, where used, should be run with the conductors of each circuit per NEC Section 250-57(b).

Earth and the structural metal frame of a building may be used for supplemental equipment bonding, but they shall not be used as the sole equipment grounding conductor for ac systems per NEC Sections 250-58 and 250-51.

For circuits having paralleled conductors in multiple metal raceways, an equipment grounding conductor shall 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 Sections 250-95 and 310-4.)

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 may 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 at least #8 THWN copper.

4.10.2 SEPERATE EQUIPMENT GROUNDING CONDUCTORS

The possibility of worker exposure to electric shock can be reduced by the use of seperate equipment grounding conductors within raceways.

The seperate 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 resistance (inductive reactance) of the ground fault circuit normally prevents a significant amount of ground fault current from flowing through the seperate equipment grounding conductors.

Ground fault current flows through the path that provides the lowest ground fault circuit impedance. Fittings and raceway systems have been found that are not tightly connected or are corroded which prevents good continuity. Therefore, the equipment grounding conductor shall be the 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 should be supplemented with seperate 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 should not be used as the grounding conductor.

4.11 UNGROUNDED SYSTEMS

Three-phase, three-wire, ungrounded systems (DELTA), 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 were 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 grounding conductor for a separately derived system shall be grounded at only one point. That single system grounding point is at the source of the separately derived system and ahead of any system disconnecting means or overcurrent devices. Where the main system 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 is available, concrete-encased electrodes or made electrodes are permitted.

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, the main bonding jumper, the grounded conductor, and the equipment grounding conductor are calculated, sized, and selected by the rules listed in Sections 4.7 through 4.10. (See Figure 4-7.)

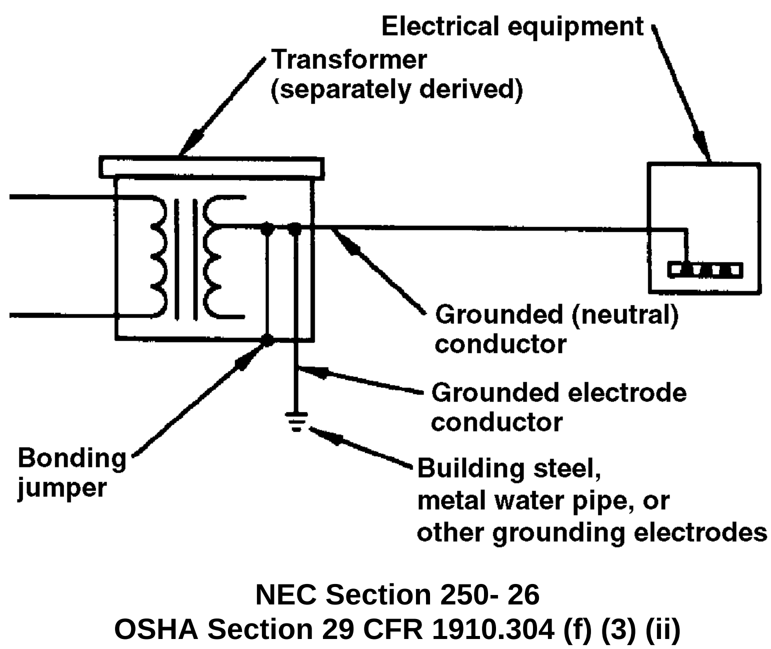


Figure 4-7. The grounded (neutral) conductor can be used to carry both normal neutral current and abnormal ground fault current.

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 electrodes. If 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. Metal water pipe in contact with the earth for 10 ft. or more. Interior metal water pipe beyond 5 ft. from the water entrance shall not be used as a part of the grounding electrode system or as a conductor to interconnect those electrodes. (See NEC Section 250-81.)

2. Metal frame of the building, where effectively grounded

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 ft. in the ground (spliced together at each end).

The grounding electrode conductor at the service equipment can be connected to any convenient interbonded electrodes that provide a solid, effective connection. Metal water pipe shall be supplemented by an additional electrode, which can be any of the following electrodes:

1. A rod
2. Pipe
3. Plate
4. Building steel
5. Concrete-encased electrode.

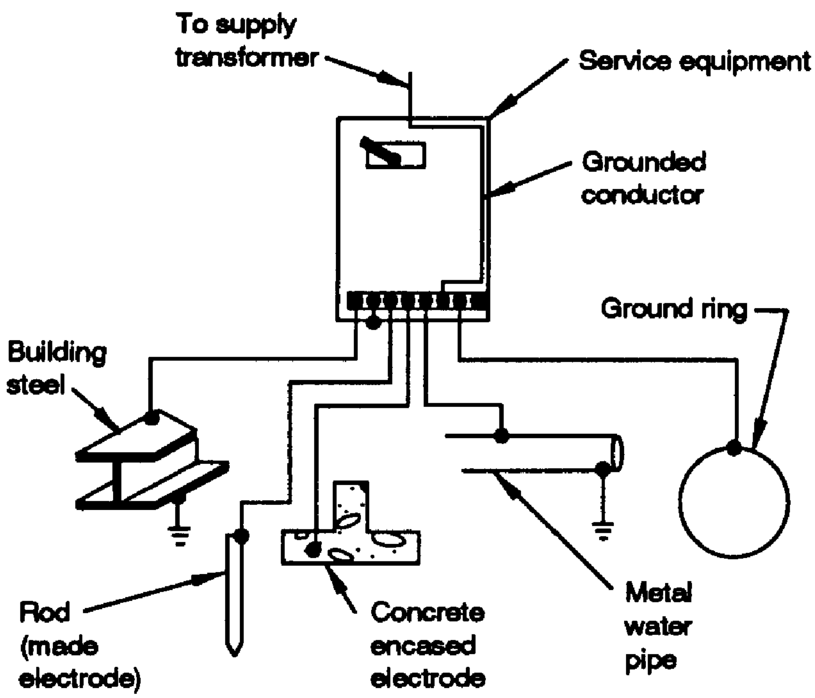
(See Figure 4-8, which lists some of the different types of grounding electrodes.)

4.14 GROUND-FAULT PROTECTION OF EQUIPMENT

See Section 2.7 for ground fault circuit interrupters for personnel protection. An increased degree of protection in solidly grounded systems can be achieved in providing ground-fault protection that will shunt trip circuit protective devices when user-selected levels of ground fault or leakage current flow are detected in electrical circuits. This is required to be installed on all solidly grounded wye services of more than 150 V to ground but not exceeding 600 V phase-to-phase where the service disconnecting means is rated at 1,000 A or more (See NEC Sections 215-10, 230-95, 240-13, and Figure 3-1).

4.15 PERSONNEL PROTECTIVE GROUNDS

Personnel working on or close to deenergized lines or conductors in electrical equipment should be protected against shock hazard and flash burns that could occur if the circuit were inadvertently reenergized. Properly installed equipotential protective grounds can aid in lessening such hazards by providing additional protection to personnel while they service, repair, and work on such systems.(See Section 7.5).



NEC Section 250- 81
OSHA Section 29 CFR 1910.304 (f)

Figure 4-8. If the building steel, metal water pipe, concrete-encased electrode, and ground ring are available, they must be grounded and bonded to the service equipment to create the grounding electrode system.

4.15.1 PURPOSE OF PERSONNEL PROTECTIVE GROUNDS

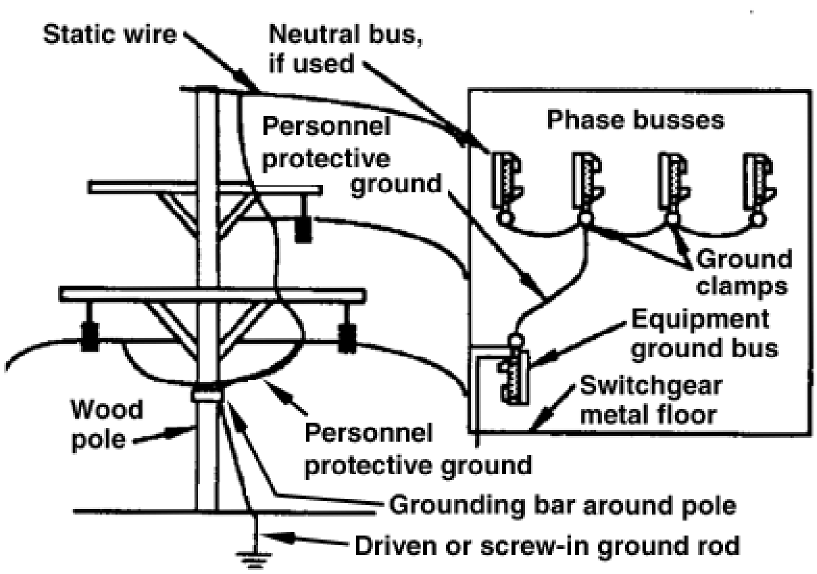
Personnel protective grounds are applied to deenergized circuits to provide a low-impedance path to ground should the circuits become reenergized while personnel are working on or close to the circuit. In addition, the personnel protective grounds provide a means of draining off static and induced voltage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

4.15.2 CRITERIA FOR PERSONNEL PROTECTIVE GROUNDS

Before personnel protective 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 a 4/0 Neoprene-insulated welding cable that will pass 30,000 A for 0.5 sec without melting its insulation.



OSHA Sects. 29 CFR 1910.269(n) and 1926.954(t)

Figure 4-9. Equipotential personnel protective grounds are used to protect electrical workers while they service, repair, or are close to circuits that can be accidentally reenergized.

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

   a. Terminal strength depends on 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. The voltage drop should not exceed 100 volts for 15 cycle or 75 volts for 30 cycle clearing times.

   d. Verify that the grounding cable and clamp assembly is tested periodically by using the millivolt drop, micro-ohm meter, AC resistance, or DC resistance test methods. For example, if it is desired to maintain a maximum of 100 volts across a worker whose body resistance is 1000 ohms, during a fault of 1000 amperes, a personnel protective ground resistance of 10 millohms or less is required.

4. For further information on the construction of personnel protective grounds, refer to ASTM F855-90, IEEE 524A, IEEE 1048, and Section 7.5.

4.15.3 GROUNDING CLAMPS

Grounding clamps used in personnel protective grounds are manufactured specifically for this use. The size of grounding clamps shall match 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 typically range in magnitude up 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 should be no longer than is necessary, both to minimize voltage drop and to prevent violent movement under fault conditions. For example, as a general rule, grounding cables should 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 SEQUENCE

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 to each succeeding phase in the order of closeness.

4.15.8 REMOVING PROTECTIVE GROUNDS

When removing personnel protective 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 and remove grounding cables. (See 29 CFR 1910.269(n)(6) and (7), 1926.954(e) and NESC Rule 445).

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

1. Safety glasses and, if necessary, face shield appropriate for fault currents available.
2. Hardhat (Class B) (See 2.12.3)
3. Appropriate electrical gloves and protectors (See 2.12.3).
4. Appropriate clothing (See note in 2.11.3).

CONTENTS

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5.0 SPECIAL OCCUPANCIES

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

5.1 EXPLOSIVES

This section references DOE M440.1-1, "DOE Explosives Safety Manual," NFPA 70 (NEC), NFPA 77, NFPA 780, and DOD 6055.9-STD, "DOD Ammunition and Explosives Safety Standards." These standards and manuals should be referenced to ensure safe and reliable installations of electrical equipment and wiring methods in explosive and hazardous locations.

5.1.1 EVACUATION

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

1. All outdoor locations, locations in buildings that do not have lightning protection, and locations within inhabited building distance of the hazard. (When an electrical storm is imminent, work with explosives operations shall not be undertaken.)

2. Locations (with or without lightning protection) where operations use electrostatic-sensitive bulk explosives or electroexplosive devices (EEDs).

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, functions that cannot be shut down immediately shall be operated by the minimum number of personnel required for safe shutdown. When the operation has been brought to a safe condition, those remaining 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 (See DOE M440.1-1, "DOE Explosives Safety Manual") to install lightning protection on all facilities used for storage, processing, and handling of explosive materials where operations cannot be shut down and personnel evacuated during electrical storms. Specific operations shall be assessed for the risk of detonation of explosives by lightning. Such assessment shall consider the need for the protection factors outlined in Appendix I, NFPA 780. When risk is high, as in operations with highly sensitive electrostatic materials or components, operations shall be conducted only in lightning-protected facilities. Approved lightning protection systems shall conform with the requirements of Appendix I, NFPA 780. Examples of acceptable lightning protection systems can be found in DOD 6055.9-STD, Chapter 7.

Lightning-protection systems should be visually inspected every 7 months and a report on their conditions filed at least annually. Any evidence of corrosion, broken wires or connections, or any other problem that negates the system's usefulness shall be noted and the problem repaired.

Lightning protection systems should be tested electrically every 14 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 ±10% for ground resistance testing and 1 ohm ±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 with a lightning-protection system.

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 category includes spark-sensitive explosives, propellants, and pyrotechnics, as well as solvent vapors and flammable gases. Approved systems to dissipate static electricity shall conform to the requirements of NFPA 77 and IEEE 142.

5.1.4.1 BONDING AND GROUNDING EQUIPMENT

Bonding straps shall be used to bridge locations where electrical continuity may be broken by the presence of oil on bearings, or by paint or rust at any contact point. Permanent equipment in contact with conductive floors or tabletops is not considered 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 GROUNDING SYSTEMS

Grounding systems shall be tested for electrical resistance and continuity when installation is complete and, in the case of active equipment, at intervals to be locally determined. The grounding system shall be visually inspected for continuity (before reactivation of the system) if the equipment has been inactive for more than 1 month. All exposed explosives or hazardous materials shall be removed before testing. During a test for resistance to ground, all equipment, except belt-driven machines, shall be considered as a unit. In measuring the total resistance to ground for belt-driven machinery (to ensure compliance with Section 5.1.4.3), resistance of the belt 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 system. For existing equipment, the rate of static electricity generation shall be considered before changes are made in grounding systems. The resistance of conductive rubber hose shall not exceed 250,000 ohms. (See NFPA 77 and NFPA 780 for further information.)

5.1.4.3 CONDUCTIVE FLOORS, SHOES, MATS, AND WRISTBANDS

Conductive floors and shoes should be used for grounding personnel conducting 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. In areas where personnel come close enough to 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 are performed involving EEDs that contain a static-sensitive explosive.

Conductive floors are not required throughout a building or room if the hazard remains localized. In such cases, conductive mats or runners may suffice. 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 workstations or outdoor location.

5.1.4.4 SPECIFICATIONS FOR CONDUCTIVE FLOORS AND WRISTBANDS

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

1. The flooring and its grounding system shall provide for electrical resistance not to exceed l,000,000 ohms (measured as specified in Section 5.1.4.5).

2. The surface of the installed floor shall be reasonably smooth and free from cracks. 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 cleaning procedures.

3. Where conductive floors and shoes are required, resistance between the ground and the wearer shall not exceed 1,000,000 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, tabletops 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 the wristband is placed under strain.

5.1.4.5 CONDUCTIVE FLOOR TEST

Before use, tests shall be conducted on all conductive floors; 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 testing shall be used only when the room is free from exposed explosives and mixtures of flammable gases.

Maximum floor resistance shall be measured with a suitably calibrated insulation resistance tester that operates on a normal open-circuit output voltage of 500 V dc and a short-circuit current of 2.5 mA with an effective internal resistance of approximately 200,000 ohms. Minimum floor resistance shall also be measured with a suitably calibrated ohmmeter.

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 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. Only electrode jelly shall be used to establish a good contact. (Brushless shaving soap and 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 during a measurement, the value observed after the voltage has been applied for about 5 sec shall be considered the measured value. (See Figure 5-1.)

5.1.4.6 HUMIDIFICATION

Humidification to prevent accumulations and subsequent discharges of static electricity 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 their spontaneous ignition. Where this technique is used to prevent accumulations of static electricity, a daily check of the humidity levels will be performed before work starts.

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 in locations containing explosives shall comply with relevant provisions of the NEC and DOE regulations, plus the requirements in this section.

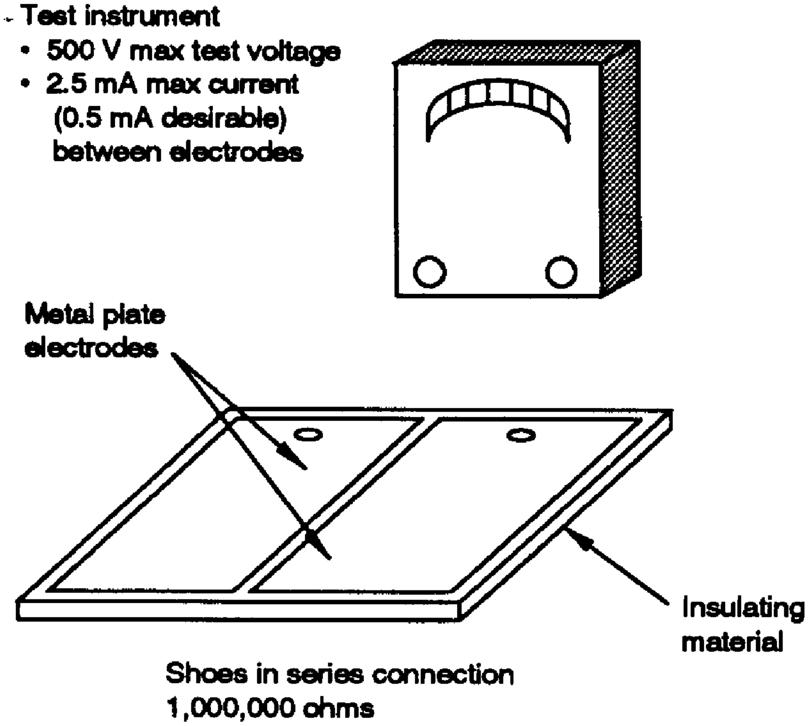


Figure 5-1. Testing shoes on wearer.

5.1.5.1 PERMANENT EQUIPMENT AND WIRING

The NEC and this section are minimum requirements for DOE facilities containing explosives. Though the NEC does not specifically address explosives, 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. All permanent electrical equipment and wiring in 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.

5.1.5.2 HAZARDOUS LOCATIONS

NEC definitions of and requirements for hazardous locations Class I and Class II are modified as follows for application to DOE explosives facilities:

1. Areas containing explosive dusts or explosives which 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 shall be regarded as Class II Division 2 hazardous locations.

3. Suitable NEMA rated enclosures shall be provided in those locations where water/ explosives mixtures may contact electrical equipment and wiring.

4. Areas where explosives are processed and sublimation may occur or where flammable gases or vapor may be present in quantities sufficient to produce explosive or ignitable mixtures shall be regarded as Class I Division 1 and Class II Division 1 hazardous locations.

5. To ensure a location is assigned to the proper hazardous location class and division, it is necessary to know the properties of the explosives involved there, including, at a minimum, sensitivity to heat and 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 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 that contain explosives that are not defined as hazardous locations (areas containing no dust, vapor, gas hazards, or exposed explosives; for example, 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 standards are adhered to throughout the facility.

5.1.5.3 ELECTRICAL SUPPLY SYSTEMS

There may be multiple 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 from such facilities. This also applies to communications and instrumentation lines and security alarm systems.

2. Electric service lines required to be close 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.

Table 5-1. Quantity-distance separation for protection of underground service installations.[a,b]

Quantity of explosive (maximum pounds)	Distance, m (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 planned building is designed to contain the effects of an explosion, the formula D (distance) = 3.0 $w^{1/3}$ (w=weight) can be used to determine separation distances for less than 20,000 lb.
[b] Source: "DOE Explosives Safety Manual"

5.1.5.4 BUILDING SERVICE ENTRANCE

The 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.

5.1.6.1 TEST SETUP

In setting up a test at a firing site, all preparatory work shall be completed before explosives are received. Such work shall include the following items:

1. Checking all firing site safety devices at regular intervals. Such safety devices include warning lights, door and gate firing circuit interlocks, emergency firing circuit cutoff switches, and grounding devices (including those that are remote from the firing bunker).

2. Completing all firing pad and shot stand setup work that requires power tools or other potential spark-producing devices. 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 it, including assembly of all materials.

4. When possible, all diagnostic equipment shall be set up and checked, and dry runs shall be performed.

5.1.6.2 PIN SWITCHES AND OTHER NONINITIATING CIRCUITS

Whenever pin switches and other noninitiating circuits are to be checked (such as for charging current or leakage) and are in contact with or close to explosives, the check shall be performed remotely. Other noninitiating electrical circuits include strain gauges, pressure transducers, 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 should be allowed only if test preparation has progressed to the extent that discontinuance of testing would represent a greater personnel risk than would completion of testing.

5.1.6.4 LOW-ENERGY ELECTROEXPLOSIVE DEVICES

When using hot-wire or low-energy EEDs for a test firing, the following requirements shall be applied:

1. Establishment of procedures 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.

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.

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

	Minimum safe distances (ft)	
Transmitter power (watts)	Commercial AM broadcast transmitters	HF transmitters other than AM
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 [b]	2,800	17,000
100,000	3,900	24,000
500,000 [c]	8,800	55,000

[a] Source: "DOE Explosives Safety Manual"
[b] Present maximum power of U.S. broadcast transmitters in commercial AM broadcast frequency range (0.535 to 1.605 MHz).
[c] Present maximum for international broadcast.

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

	Minimum safe distances (ft)		
Effective radiation power (watts)	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 [b]	3,200	2,300	1,100
316,000 [c]	4,300	3,000	1,450
1,000,000	5,800	4,000	2,000
5 000 000 [d]	9,000	6,200	3,500
10,000,000	10,200	7,400	6,000
100,000,000	—	—	—

[a] Source: "DOE Explosives Safety Manual"
[b] Present maximum power, channels 2 to 6 and FM.
[c] Present maximum power, channels 7 to 13.
[d] Present maximum power, channels 14 to 83.

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

Transmitter power (watts)	Minimum safe distances (ft)				
	MF[b]	HF[b]	VHF(l)[b]	VHF(2)[b, c]	UHF[b]
5 [c]	-	-	-	-	-
10	40	100	40	15	10
50	90	220	90	35	20
100	125	310	130	50	30
180 [d]	-	-	-	65	40
250	200	490	205	75	45
500 [e]	-	-	209	-	-
600 [f]	300	760	315	115	70
1,000 [g]	400	980	410	150	90
l0,000 [h]	1,200	-	1,300	-	-

[a] Source: “DOE Explosives Safety Manual”

[b] 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

[c] 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.

[d] 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.

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

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

[g] Maximum power for amateur radio mobile units.

[h] Maximum power for some base stations in 42- to 44-MHz band, 1.6- to 1.8- MHz band.

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 electric 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.

5.1.6.7 ELECTRICAL TESTING INSTRUMENTS FOR USE WITH EXPLOSIVES SYSTEMS (EXCEPT THOSE COVERED BY DOE 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

Testing instruments shall be assigned to categories on the basis of electrical characteristics that affect their safe use with explosives systems. Specifically, instrument categories shall be established so that testing instruments in 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 bridgewires, slappers, etc.)

3. Noninitiating electrical circuits.

Testing instruments that do not meet the safety criteria may be used on an explosives system only 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 using electrical testing instruments on explosives systems shall establish a formal system for reviewing and certifying those instruments. Procedures for marking instruments to show their approved use and restrictions on their use shall also be established, so that every testing instrument is 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 testing instruments 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 testing instruments for use with initiating systems. The chairperson shall disseminate this information to all committee members.

5.1.6.7.3 ELECTRICAL TESTING INSTRUMENTS FOR USE WITH INITIATING ELECTRICAL CIRCUITS

Instruments used with electrical initiating circuits connected to electroexplosive devices may be further categorized for use with either low-energy initiators or high-energy initiators. All testing instruments used for this purpose shall be current-limited. Before being used on initiating circuits, every 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 testing 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, at a minimum, two independent failure modes 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 TESTING INSTRUMENTS FOR USE WITH NONINITIATING ELECTRICAL CIRCUITS

Testing instruments in this category are used with electric 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 use of the testing instrument shall be analyzed to ensure that there is no credible scenario where the normal test energy from the testing instrument can ignite explosive charges or initiators in the test. This testing shall be consistent with Section 5.1.6.7.3.

2. Where a testing instrument is used to make measurements on sensors directly applied to explosives (e.g., bonded strain gauges or pin switches), the testing instrument shall be certified and controlled.

3. Testing instruments shall be prominently marked with restrictions on their use. Many of these testing 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 by themselves, but around electricity they become even more dangerous: an arc, spark, or hot surface can easily touch off an explosion. Therefore, the electrical installation shall contain these ignition sources or house them in an area well separated from the explosives storage area.

The electrical installation shall prevent accidental ignition of flammable liquids, vapors, and dusts in the atmosphere. In addition, because portable electrical equipment is often used outdoors or in corrosive atmospheres, its material and finish should be such that maintenance costs and shutdowns are minimized. (See Figure 5-2.)

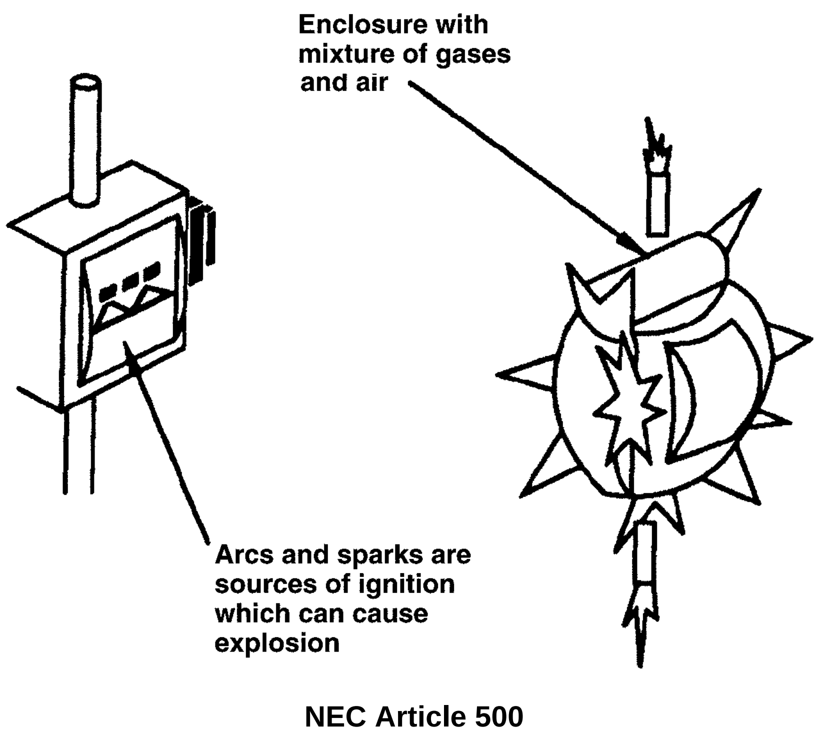


Figure 5-2. Arcs and sparks are sources of ignition that produce enough heat to cause an explosion if the air and gas mixture is between the lower and upper flammable limits of the liquid involved.

5.2.1 SOURCES OF IGNITION

When flammable gases or combustible dust are mixed in the proper proportion with air, a source of energy is all that is needed to touch off an explosion. One prime source of energy is electricity. During normal operation, equipment such as switches, circuit breakers, motor starters, pushbutton stations or plugs, and receptacles can produce arcs or sparks when contacts are opened and closed, which can easily cause ignition. Other energy hazards are devices that produce heat, such as lighting fixtures and motors. Surface temperatures of these devices 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. Included in this category are wiring (particularly splices), transformers, impedance coils, solenoids, and other low-temperature devices without make-or-break contacts.

Nonelectrical sources such as sparks from metal can also easily cause ignition: a hammer, file, or other tool dropped on masonry or on a nonferrous surface could be a hazard unless it 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 it is dropped.

5.2.2 COMBUSTION PRINCIPLES

The following three basic conditions are necessary for a fire or explosion to occur:

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

2. A flammable liquid, vapor, or combustible dust mixes with air or oxygen in the proportion required to produce an explosive mixture.

3. A source of energy is 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 are taken into account. 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 that 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[1] for more information.) The determination of the area classification wiring and equipment selection for Class I, II, and III areas (NEC Articles 500-504) should be made by a person cognizant of the requirements. The determination of the area classification, wiring, and equipment selection for Class I, Zone 0, 1, and 2 areas (NEC Article 505) shall be under the supervision of a qualified registered professional engineer.

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 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

[1] See Appendix D, Reference Matrix

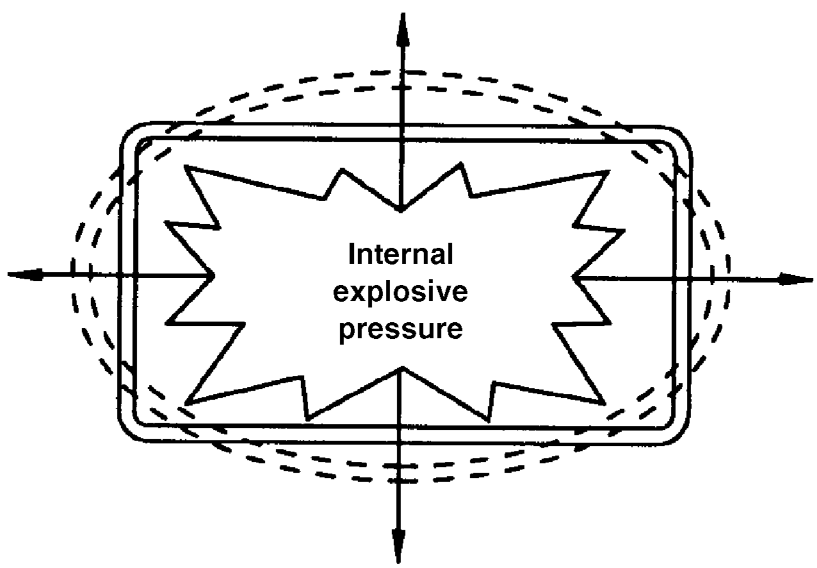
equipment and its associated wiring shall be installed so they are positively separated from the nonintrinsically safe circuits. Induced voltages could defeat the concept of intrinsically safe circuits.

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 not start a larger explosion outside. Adequate strength is one requirement for such an enclosure. For an explosion-proof enclosure, 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 it.

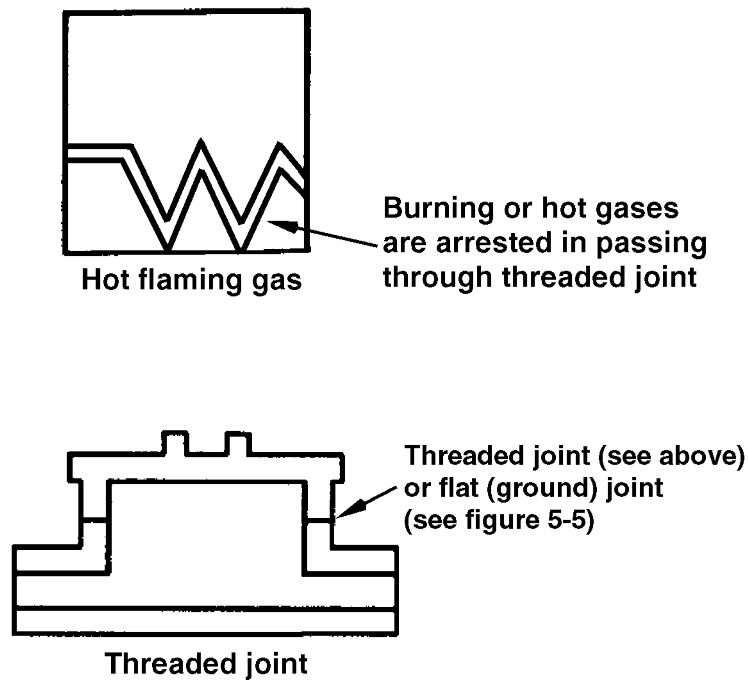
In addition to being strong, the enclosure shall be flame-tight. This term does not imply that the enclosure is hermetically sealed but rather that the joints cool the hot gases resulting from an internal explosion so that by the time they reach the outside hazardous atmosphere, they are too cool to affect 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 explosion-proof enclosure can be threaded-joint type (Figure 5-4) or flat-joint type (Figure 5-5).

In Class II locations, the enclosure shall keep 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.



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.



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 motors do not come in designs listed for Class I Groups A and B. Whether cast-metal enclosures or sheet-metal enclosures with pressurization should be used for hazardous locations 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 electronic instruments require installation in separate enclosures, use of 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.

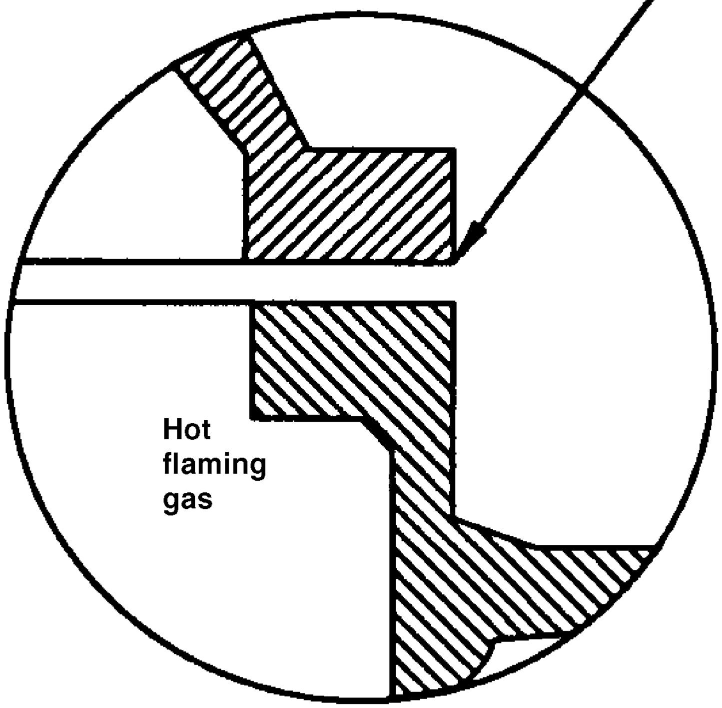


Figure 5-5. Flat (ground) joints can be used as an escape path to cool the hot gases as they pass through the flat (ground) joint.

In addition, door-interlock switches are required to prevent access to the equipment while the circuits are energized. 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.”

5.3 HAZARDOUS LOCATIONS

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

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

Information in this section will assist in classifying areas or locations with respect to hazardous conditions, whether from atmospheric concentrations of hazardous gases, vapors, and deposits, or from accumulations of readily ignitable materials.

This section covers the requirements for electrical equipment and wiring in locations that are classified according to 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 is present. The hazardous (classified) locations are assigned the following designations:

1. Class I Division 1
2. Class I Division 2
3. Class II Division 1
4. Class II Division 2.
5. Class I, Zone 0, Zone 1, Zone 2

Class III fibers and flyings are not covered in this section. The following contain more in-depth design and engineering requirements:

1. National Electrical Code, NFPA 70, Chapter 5, Article 500
2. 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. Manufacturers' product recommendations and suggestions for hazardous areas (e.g., the Crouse-Hinds Code Digest)
7. NFPA 325, "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."

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 the air in amounts sufficient to create explosive or ignitable mixtures. Gases or vapors may be continuously or intermittently present. However, if a gas or vapor is present, there is a potential that a flammable mixture will be present.

From an engineering standpoint, greater precautions are needed if a particular set of conditions is likely to occur (e.g., the presence of a flammable mixture within the explosive range) than if it is unlikely. This is the reason for dividing hazardous locations into two divisions.

5.3.1.1 DIVISION 1

NEC Section 500-5(a) defines Class I Division 1 hazardous locations as those in which:

1. Ignitable concentrations of flammable gases, liquids, or vapors can exist under normal operating conditions;

2. Ignitable concentrations of such gases or vapors may exist frequently because of repair or maintenance operations or because of leakage; or

3. Breakdown or faulty operation of equipment or processes might release ignitable concentrations of flammable gases, liquids, or vapors and might also cause simultaneous failure of electrical equipment.

Note: In each case, ignitable concentrations are mentioned. This means concentrations between the lower and upper flammable or explosion limits (see Section 5.3.5 and Table 5-5).

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

NEC Article 100 defines a flammable liquid as one that has a flashpoint below 38°C (100°F) or one whose temperature is raised above its flashpoint. Flashpoint is the lowest temperature to which a combustible or flammable liquid may be heated before sufficient vapors are driven off and the liquid will flash when brought into contact with a flame, arc, spark, or another ignition source. (See Section 1-3 of NFPA 497M for more details.)

5.3.1.2 DIVISION 2

NEC Section 500-5(b) defines Class I Division 2 locations as those:

1. In which flammable liquids or gases are handled, processed, or used, but where such materials are normally confined in closed containers or closed systems from which they can escape only

Table 5-5. Class I Division 1 and Class I Division 2 summary of selected hazardous atmospheres

		Ignition[1] Temperature			Flammable limits[3] (% by volume)		Flashpoint[3]		NEMA enclosure[4] classification	
Group[3]	Atmosphere	°F	°C	Ignition[2] energy (millijoules)	Lower	Upper	°F	°C	Indoor	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	g
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	
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
D	Heptane	399	204	—	1.05	6.7	-36 to -50	-38 to -46	7	8

Table 5-5. Class I Division 1 and Class I Division 2 summary of selected hazardous atmospheres (continued).

		Ignition[1] Temperature			Flammable limits[3] (% by volume)		Flashpoint[3]		NEMA enclosure[4] classification	
Group[3]	Atmosphere	°F	°C	Ignition[2] energy (millijoules)	Lower	Upper	°F	°C	Indoor	Outdoor
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	5.0	15.0	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	l-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	l-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

Notes:
1 See NFPA 325 and 497M.
2 See "Handbook of Fire Protection Engineering", Society of Fire Protection Engineers.
3 See NFPA 325.
4 See NEMA 250, "Enclosures for Electrical Equipment."

in case of accidental rupture or breakdown of such containers or systems or in case of abnormal equipment operation.

2. In which gases or vapors are normally prevented, by positive mechanical ventilation, from forming ignitable concentrations 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 transmitted unless such transmittal 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 NEC Section 500-5(b) describes a number of areas and occupancies normally classified as Class I Division 2 locations. For example, piping systems without valves, meters, and devices do not usually cause a hazardous condition, even though they carry flammable liquids, because they are considered a contained system. Therefore, the surrounding area can be classified as a Class I Division 2 location.

5.3.2 CLASS II

A Class II location is defined in NEC Section 500-6 as an area where combustible dust presents a fire or explosion hazard. Class II locations are divided into two divisions based on the normal presence or absence of dust.

5.3.2.1 CLASS II DIVISION 1

A Class II Division 1 location is one:

1. In which combustible dust is in the air under normal operating conditions in quantities sufficient to produce explosive or ignitable mixtures;

2. 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 other causes; or

3. In which combustible dusts of an electrically conductive nature may be present in hazardous quantities. (See Table 5-6.)

5.3.2.2 CLASS II DIVISION 2

A Class II Division 2 location is one where:

1. Combustible dust is not normally in the air in quantities sufficient to produce explosive or ignitable mixtures;

Table 5-6. Summary of typical combustible dust hazardous atmospheres.[a]

Class	Division	Group	Temperature, atmosphere	Covered	Measured	Limiting value
II Combustible dust	1 (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: No overload:
		F[b]	Atmospheres containing carbonaceous dusts having resistivity between 10^2 and 10^8 ohm-centimeter	Devices subject to overload (motors, transformers)		E—200°C (392°F) F—200°C (392°F) G—165°C (329°F)
		G[b]	Atmospheres 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 105 ohm-centimeter	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.

2. Dust accumulations are normally insufficient to interfere with the normal operation of electrical equipment or other apparatus, but where combustible dust may be suspended in the air as a result of infrequent malfunctioning of handling or processing equipment; and

3. 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 5-6.)

5.3.3 GROUPS

Until publication of the 1937 edition of the NEC, Class I hazardous locations were not subdivided; a flammable gas or vapor was classified as presenting a single degree of hazard. It was recognized, however, that the degrees of hazard varied with the substance and that equipment suitable for use where gasoline was handled was not necessarily suitable for use where hydrogen or acetylene was handled.

The difficulty of manufacturing equipment and enclosures for use in hydrogen atmospheres was also recognized, as was the expense of the equipment. It was not logical from an engineering standpoint, for example, to require in gasoline stations use of explosion-proof equipment 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 also 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 NEC Section 500-3 for more information on groups).

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 viewed only as approximations: Ignition temperatures under one set of conditions may be changed substantially by a change of conditions. 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. Another variable is the many differences in methods and conditions of testing ignition temperature (size and shape of containers, method of heating, and ignition source).

5.3.5 FLAMMABLE (EXPLOSION) LIMITS

As mentioned in Section 5.3.1.1, in the case of gases or vapors that form flammable mixtures with oxygen, there is a minimum concentration of gas or vapor in air or oxygen below which propagation of flame cannot occur on contact with a source of ignition. There is also a maximum concentration of vapor or gas in air above which propagation of flame cannot 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 explosion 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.

5.3.6 FLASHPOINT

The flashpoint of a flammable liquid is the lowest temperature at which the liquid gives off sufficient vapor to form, with the air near its surface or within the vessel used, an ignitable mixture. An ignitable mixture is a mixture that is within the flammable range (between upper and lower explosive limits) that is capable of propagating flame away from the source of ignition when ignited. Some evaporation takes place below the flashpoint 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 flashpoints while in the solid state.

5.4 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. Selection of such equipment shall fully comply with current NFPA requirements.

Excellent references of manufacturers' electrical equipment available and used in hazardous areas is the Crouse-Hinds ECM Code Digest, or the Appleton NEC Code Review which are based on the current NEC.

5.4.1 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. The seals also keep an explosion from being transmitted and ignition from traveling between sections of the system.

5.4.1.1 SEALS

The following are uses and requirements for seals:

1. They 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. They limit explosions to the sealed-off enclosure and prevent precompression or pressure-piling in conduit systems.

3. While it is not a code requirement, many engineers consider it good practice to divide long conduit runs into sections 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 as close as practicable to and in no case more than 18 in. from such enclosures.

5. At each 2-in. or larger entrance to an enclosure or fitting housing terminals, splices, or taps when used in Class I Division 1 hazardous locations, seals must be as close as practicable to and in no case more than 18 in. from such enclosures.

6. Seals must be located in conduit systems when the conduit leaves the Class I Division 1 or 2 hazardous locations.

7. Seals must be located in cable systems when the cables either do not have a gastight or vaportight continuous sheath or are capable of transmitting gases or vapors through the cable core when these cables leave the Class I Division 1 or Division 2 hazardous locations.

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

5.4.1.2 DRAINS

In humid atmospheres or in wet locations where it is likely that water can enter 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, drain sealing fittings shall be used. These fittings prevent accumulations of water above the seal. [See NEC 501-5(d).]

In locations usually 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 the 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 drain sealing fittings with drain covers or inspection covers even though conditions prevailing at the time of planning or installing may not indicate the need.

5.4.1.3 SELECTION OF SEALS AND DRAINS

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

5.4.1.3.1 PRIMARY CONSIDERATIONS

The following primary considerations should 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 to escape into another portion of the hazardous area or into 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 should install seals in strict compliance with the instruction sheets furnished with the seals and sealing compound. Precautionary notes should be included on installation diagrams to stress the importance of following manufacturer's instruction.

5. NEC 501-5(c)(4) prohibits splices or taps in sealing fittings.

6. Sealing fittings are listed by UL for use in Class I hazardous locations with sealing 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 the pressure of 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: Sealing compounds are not insulating compounds; therefore, they shall not be used as such.

5.4.1.3.2 TYPES OF SEALING FITTINGS

Sealing fittings meet the requirements of NEC when properly installed.

A certain style of 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 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. Other style seals are for use with conduit running at any angle, from vertical through horizontal.

5.5 MANUFACTURERS' DIGEST

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

1. Crouse-Hinds ECM 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.

As mentioned earlier, 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, 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 cover 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 ANSI/UL 913, "Intrinsically Safe Apparatus and Associated Apparatus for Use in Class I, II, III, Division I, Hazardous (Classified) Locations" for detailed requirements.

Purged and pressurized equipment should be installed 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 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 to a hazardous gas environment a degree of protection from an internal explosion or from operation of internal equipment

2. Do not develop external surface temperatures that exceed prescribed limits for the specific gas corresponding to the atmospheres for which the enclosure is intended when internal heat-simulating 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.

4. 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

5. Are marked with the appropriate class and groups for which they have been qualified.

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 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 (See #4 in Section 5.8.2).

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 prevent 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

3. Withstand a series of operation design tests while exposed to a circulating dust-air mixture to verify 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 installed in underground locations. Working conditions underground can present to electrical workers hazards different from those presented above ground. This section aids in dealing with such problems.

Electrical work in support of construction of mines, shafts, and underground utilities shall be performed by qualified workers who must meet the requirements in Section 2.8, 30 CFR 75.153 and 77.103. Only those 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. However, the codes related to mining (30 CFR 57, 75, and 77) should be followed, where applicable, along with the OSHA regulations set forth in 29 CFR 1910 and 1926.

Once construction of the underground facilities is completed, 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 the work is not covered by these codes as referenced, the applicable paragraphs of 30 CFR 57, 75, and 77 shall prevail.

Electrical equipment and conductors must be used in a manner that prevents shocks and burns to people. Should electrical equipment and conductors present a hazard to people because of improper installation, maintenance, misuse, or damage, the equipment and conductors must be tagged out or locked out as a hazard until fixed. All electrical 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. Electrical equipment and conductors, other than trailing cables, shall be protected against overloads and short circuits by fuses or automatic interrupting devices used 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 electrical equipment shall be deenergized and removed from their power supply or have their power supply locked out and tagged out 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 signs warning of danger shall be posted at all substations, switch centers, and control centers 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

Before any work is performed on electrical equipment or circuits, the power source or sources shall be deenergized unless power is a required part of the work procedure. Lockout procedures in 29 CFR 1910.147 and 29 CFR 1910.333 shall be followed. In addition, the following rules apply for energized work:

1. 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 with 29 CFR 1910.331. Care shall be taken to prevent damage or shock and burn from the energized cable.

2. Proper tools shall be used to remove or install fuses to protect people from shock or burns.

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

4. 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.

5. Communication conductors shall be installed in accordance with 30 CFR 57.12010 and 75.516-2.

6. Lights and lamps shall be properly guarded if they pose a hazard and shall be kept away from combustible material.

5.10.2 GROUNDING

All electric circuits shall have a grounding system. The system shall protect people from injuries or fatal shock on inadvertent contact. The system shall limit the voltage on all electrical equipment with noncurrent-carrying metallic parts. Grounding of ac and dc equipment shall be in accordance with 29 CFR 1910.304(f).

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

All installations, modifications, or repairs pertaining to grounding systems shall be followed by a continuity test to ensure the integrity of the systems. The frequency and requirements of he 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. A minimum clearance of 10 ft above floor level shall be maintained for all overhead cables/conductors 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 electrical equipment shall be in accordance with the tables set forth in the NEC (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).

Surge arresters and lightning protection are required for underground facilities and shall conform to the requirements found in 30 CFR 57.12069 and 75.521. Lightning arresters shall be inspected for damage at least annually or after each electrical storm.

Power cables and insulated conductors in shafts and bore holes 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 electrical systems of mines shall meet requirements expressed in 30 CFR 57.12038, 75, and 77, Subparts G.

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 over current protection of each ungrounded conductor shall be those expressed in 30 CFR 57.12003, 75, and 77, Subparts G.

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 the mine roof.

Disconnecting devices for trailing cables shall be equipped with means for attaching a padlock for LO/TO purposes per 30 CFR 57.12016, 57.12017, 75.511, and 77.501.

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, 57.12086, and 30 CFR 75, Subpart K.

Trolley wires and trolley-feeder wires shall be protected against over current in accordance to the requirements of 30 CFR 57.12001 and 75.1001.

Track serving as the trolley circuit return shall be bonded or welded according to the requirements of 30 CFR 57.12042 and 75, Subpart K. Energized trolley wires and exposed trolley-feeder wires shall be guarded in places where accidental contact with them is possible. This includes areas where supplies are stored, loaded, or unloaded.

CONTENTS

6.0 REQUIREMENTS FOR SPECIFIC EQUIPMENT

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

1. NFPA 70, National Electrical Code (NEC)

2. 29 CFR 1910, Occupational Safety and Health Standards

3. 29 CFR 1926, Safety and Health Regulations for Construction.

4. NFPA 70E, Standard for Electrical Safety Requirements for Employee Workplaces.

29 CFR 1910 and 1926 frequently reference other safety guidelines for design, operation, and maintenance. Such other guidelines comprise ANSI, ASTM and IEEE specifications and information derived from various engineering sources or equipment manufacturer association standards. However, the key document is NFPA 70, the NEC; all the other documents are keyed to it. The NEC reflects wiring and installation requirements that provide for a safe electrical system.

6.1 CONVEYING SYSTEMS

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

6.1.1 GENERAL DESIGN, INSTALLATION, MAINTENANCE, AND INSPECTION REQUIREMENTS

The general design criteria for elevators, dumbwaiters, wheelchair lifts, escalators, and cranes should 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. Uniform Federal Accessibility Standard (UFAS), Handicapped Wheelchair Lifts

8. National Electrical Manufacturers Association (NEMA) Standards

9. NFPA 101, Life Safety Code, Chapters 6 and 7

10. Crane Manufacturers Association of America (CMAA)-70, Specifications for Electrical Overhead Traveling Cranes

11. CMAA-74, Specifications for Top Running and Under Running Types of Single Girder Electric Overhead Traveling Cranes

All conveying systems shall be suited to the occupancy requirements of the location where they are installed. Where 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.

Additional applicable codes and standards for maintenance and inspection are listed below and provide an overview of electrical and maintenance and inspection requirements.

1. CMAA Crane Operators' Manual

2. CMAA Overhead Crane and Inspection Checklist

3. ANSI/ASME B30.2, Overhead and Gantry Cranes

4. ANSI/ASME B30.11, Monorail Systems and Underhung Cranes

5. ANSI/ASME B30.16, Overhead Hoists

6. ANSI/ASME A17.2.1, "Inspectors Manual for Electric Elevators." ANSI/ASME A17.2.2, "Inspectors Manual for Hydraulic Elevators." ANSI/ASME A17.2.3, "Inspectors Manual for Escalators and Moving Walks."

7. ANSI/ASME A17.3, Safety Code for Existing Elevators and Escalators.

6.1.2 ELECTRICAL DESIGN CRITERIA

Electrical design criteria should 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 should 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 and CMAA standards should be carefully reviewed to ensure that all applicable safety requirements are covered in the specifications.

The designer should specify the following requirements:

1. Available system voltage

2. Control voltage

3. The motor is constructed for the specific application

4. Motor horsepower, service factor, insulation class, and time ratings are sufficient to meet the load requirements

5. Working clearances and space requirements

6. Disconnecting means and other NEC requirements.

6.2 CRANES AND HOISTS

The most significant factor in crane and hoist safety, after structural integrity, is electrical safety. All 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

Basic installation and wiring safety requirements for cranes and hoists are given in NEC Article 610[1]. Electrical designers and maintenance personnel should thoroughly understand these requirements and their intent. Some of the more significant requirements are the following:

1. Cranes and hoists operated in hazardous (classified) locations shall conform to NEC Article 500.

2. When the crane is operated above 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 cabinets made 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.

[1] See Appendix D, Reference Matrix.

b. Remote controls that may introduce hazardous conditions into the cell line working zone shall employ one or more of the following:

   (1) Isolated and ungrounded control circuit in compliance with NEC Section 668-21(a)

   (2) Nonconductive rope operator

   (3) Pendant pushbutton with either non-conductive support and surfaces or ungrounded exposed surfaces.

   (4) Radio

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 should be studied carefully to determine the disconnecting means requirements and locations. The two basic disconnects to consider are:

1. The runway conductor (conductors run along a crane runway for power or control) disconnect which shall:

   a. Be readily accessible or operable from the ground or floor level per NEC Section 610-31(1)

   b. Be lockable 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).

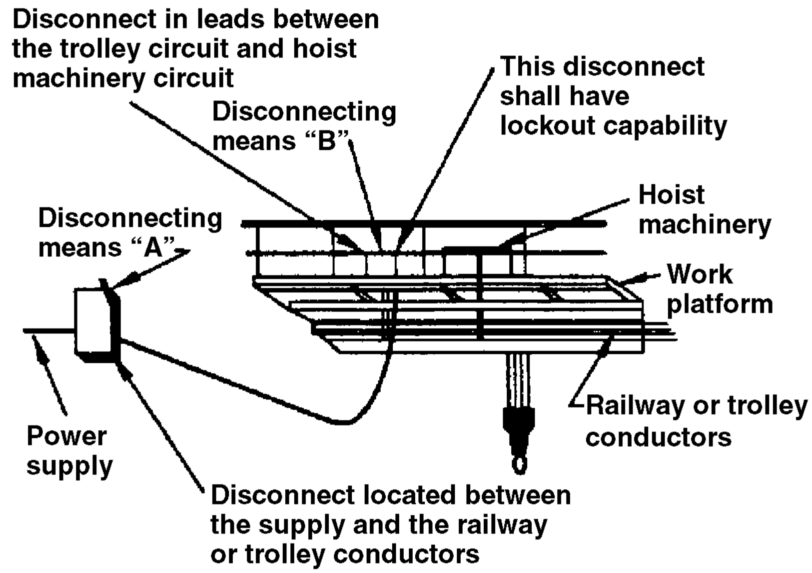
2. The crane and hoist disconnect which shall be provided in the leads from the runway contact conductors or other power supply unless all the following requirements are met:

   a. The unit is ground or floor level controlled per NEC Section 610-32, Exception

   b. The unit is within view of the power supply disconnecting means per NEC Section 610-32, Exception

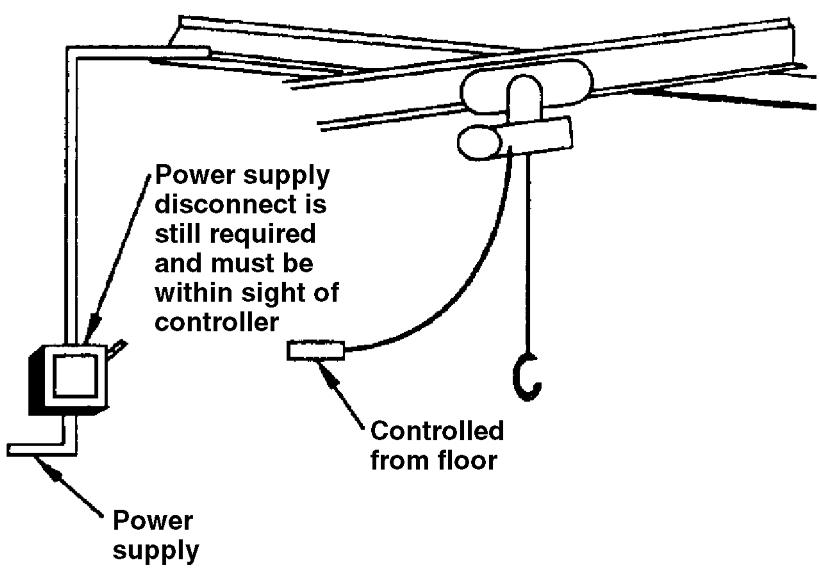
   c. No fixed work platform has been provided for servicing the unit per NEC Section 610-32, Exception.

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



NEC Sections 610-31 and 610-32
OSHA Section 29 CFR 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 Sections 610-31 and 610-32
OSHA Section 29 CFR 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 its associated equipment, including electrical equipment, as a single piece of equipment; therefore, all 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 (motors, motor controllers, lighting fixtures, transformers, etc.)on the crane or hoist. The equipment ground conductors that are run with the circuit conductors shall comply with NEC Section 250-91(b).

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 AND NEC REQUIREMENTS

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

1. Control circuit voltage shall not exceed 600 Vac or dc. Pendant pushbutton voltage shall not exceed 150 Vac or 300 Vdc.

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 an outage. Pendant pushbuttons 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 in the manner specified by OSHA, CMAA, ANSI, and the 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 operation and maintenance of cranes and hoists are contained in the following sections of 29 CFR 1910 and 1926.

1. 29 CFR 1910.179, Overhead and Gantry Cranes, which addresses operations and maintenance requirements

2. 29 CFR 1910.306, Specific Purpose Equipment and Installations, which address electrical installation requirements

3. 29 CFR 1926.550 and 29 CFR 1926.554, which 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 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 application, usage, and authority. Frequent inspection and periodic inspection are defined by OSHA as daily to monthly and 1 to 12 months, respectively. Typical inspection frequencies for electrical equipment of cranes and hoists are as follows:

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

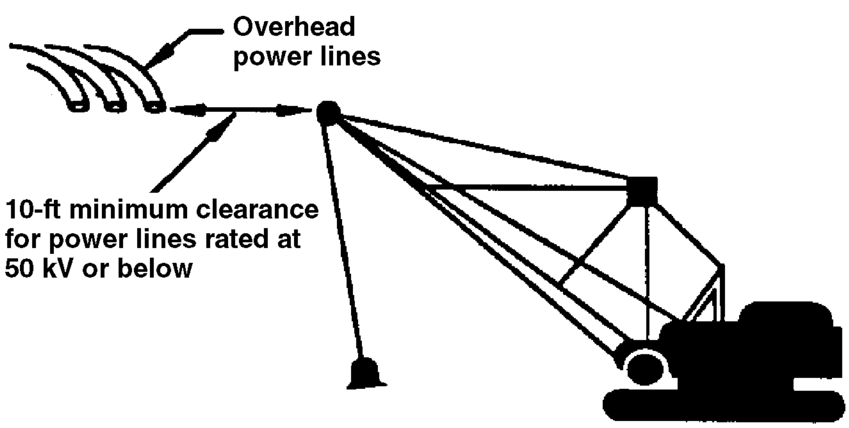
The inspection records shall provide an ongoing safety assessment of the equipment and be used to predict repair-part replacement. All inspections shall be dated and initialed by the inspector.

6.2.9 MECHANICAL ELEVATING AND ROTATING EQUIPMENT

The primary electrical safety concern of 29 CFR 1910.269(p)(4) and 1926.550 is work in proximity to live and unguarded electrical overhead lines by uninsulated equipment. Unless these lines are visibly grounded at the point of work and the owner of the lines indicates that they are deenergized, barriers or insulating protective material shall be installed to prevent worker contact with them. The following clearances shall be maintained between equipment and electrical overhead lines:

1. Lines 50 kV or below: 10 ft between the lines and any part of the equipment or load
2. Lines over 50 kV: 10 ft plus 0.4 in. for every 1 kV above 50 kV.

In locations and situations where it is possible that the operator may have difficulty observing that these clearances are being maintained, someone shall be designated to monitor the clearances and provide the operator with 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 1910.269(p)(4) and 1926.550, even if these devices are required. (See Figure 6-2.)



OSHA Sections 29 CFR 1910.269(p)(4), 1926.952 (b)
NFPA 70E Part II, CH 1, B (2) (i) (1); (2)

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. for every kV above 50 kV is required.

6.3 ELEVATORS AND ESCALATORS

Elevators and escalators are used to move people and elevators are also used to move materials. Design, installation, inspection, and maintenance activities require specialized knowledge for safe operation and use.

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 five standards:

1. ANSI/ASME A17.1, Safety Code for Elevators and Escalators
2. ANSI/ASME A17.2.1, “Inspectors Manual for Electric Elevators.” ANSI/ASME A17.2.2, “Inspectors Manual for Hydraulic Elevators.” ANSI/ASME A17.2.3, “Inspectors Manual for Escalators and Moving Walks.”
3. ANSI/ASME A17.3, Safety Code for Existing Elevators and Escalators.

All elevators are required to be constructed, installed, and maintained in accordance with ANSI/ ASME 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 ANSI/ASME A17.1 requirements of Sections 102, 210, and 211 for signaling, 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 5 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 must be #20 AWG or larger. (See NEC Sections 620-11 and 12).

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 the following:

1. There shall be 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. When there is more than one driving machine in a machine room, the disconnecting means shall be labeled 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, except as allowed by NEC Section 620-51(b).

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.

When power from more than one source is used for single- or multiple-car installations, a separate disconnect should be provided for each source. These disconnects should be in sight of the equipment supplied, and warning signs should be placed on or adjacent to the disconnect to read. For example, "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 labeled for the car it serves and lockable in the open position.

6.3.2.4 MOTORS

Elevator and escalator motors are considered as intermittent duty. This allows them to be protected by the overcurrent protection device supplying the power for the branch circuit, which is 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 as a freight elevator motor?

Step 1: Finding full load current—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 A x 85% = 44.2 A

Answer: Load is 44.2 amps.

6.3.2.5 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 NEC Article 250.

6.3.2.6 OVERSPEED PROTECTION

Overspeed protection for overhauling and under-hauling 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 ANSI/ASME A17.1 for electrical safety devices, which require scrutiny by designers, maintenance personnel, and inspectors.

6.3.3 EMERGENCY POWER

Emergency power requirements are governed by ANSI/ASME A17.1 Rule 211.2, which requires that the regenerative power of an overhauling elevator 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, 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, 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 use 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 ANSI/ASME A17.1 and A17.3. ANSI/ASME 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. ANSI/ASME 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 to maintain optimum safety. The following lists typical key electrical requirements from ANSI/ASME A17.1 that the designer shall control over and above those from the NEC.

1. Access to elevator equipment is to be controlled and limited to authorized persons.

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 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 is 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 ANSI/ASME 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 or the manufacturer 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 in the equipment area or near the elevators. In that event, the car returns to a designated 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 firefighters to assume manual control of the elevator from the designated area. The requirements for these systems are detailed in ANSI/ASME A17.1, Section 211, “Emergency Operation and Signaling Devices.”

6.3.6 INSPECTIONS AND RECORDS

Elevator inspections and recordkeeping are performed in accordance with the local authority having jurisdiction. The ANSI/ASME A17.2 series of inspectors manuals provide a guide for performing tests and inspections as well as recommended inspection checklists. In addition to acceptance inspections and tests, the code requires 1-and 5-year inspections for electric elevators and 1-and 3-year inspections for hydraulic elevators.

6.3.6.1 CODES

Elevators are required to be in compliance with the issue of ANSI/ASME A17.1 in force the date they were installed. If the local authority has adopted ANSI/ASME A17.3, the code for existing installations, they shall be in compliance with it, except they shall not be downgraded to it. When ANSI/ASME A17.3 is in force, it becomes the minimum standard to which installations shall adhere, and if existing installations are upgraded in accordance with ANSI/ASME A17.1, Part XII, they shall also be in compliance with the more stringent requirements of A17.3.

6.3.6.2 INSPECTOR QUALIFICATIONS

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

6.4 PORTABLE AND VEHICLE-MOUNTED GENERATORS

Using portable and vehicle-mounted generators to operate electric tools on job sites is permitted under specific conditions by both NEC Section 305-6 and 29 CFR 1926.404(f)(3).

However, OSHA inspections have disclosed a potentially serious hazard resulting from the use of portable generators. 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 from using GFCIs 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, the use of GFCI devices is still recommended.

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

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

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

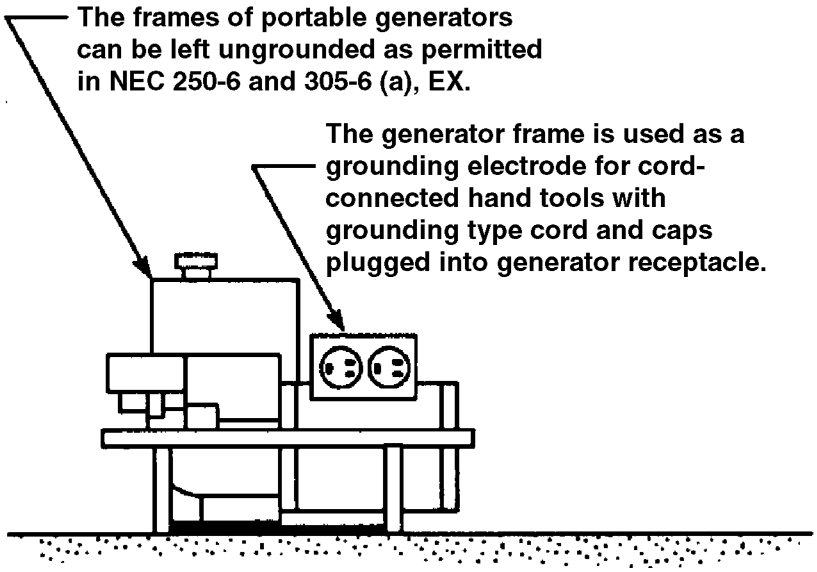
See NEC Section 250-6 and Figure 6-3.

6.5 BATTERIES

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

6.5.1 SURROUNDING SPACE

Adequate space should 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, for addition of water, and for taking measurements.



NEC Sections 250–6; 305-6

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

6.5.2 LOCATION

Storage batteries should be located in 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

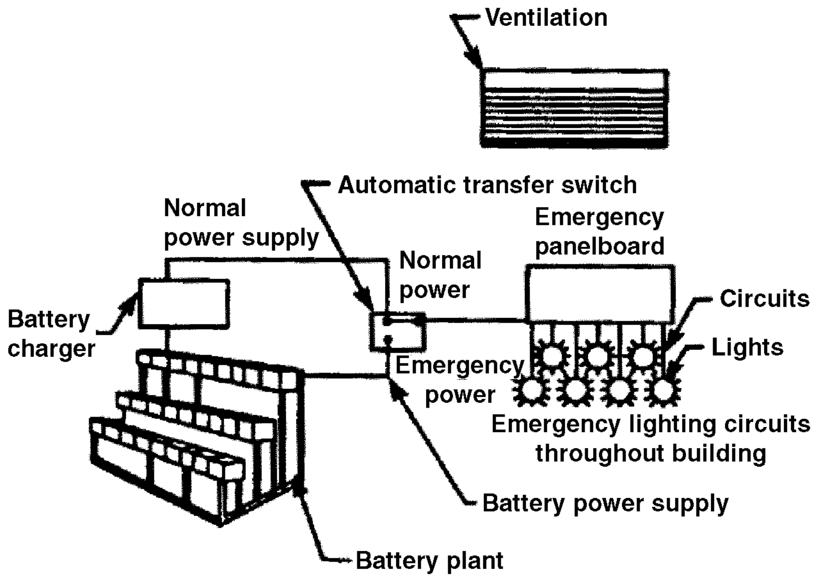
The battery storage area shall be ventilated by either a natural or powered ventilation system to prevent accumulation of hydrogen. The ventilation system shall limit hydrogen accumulation to less than an explosive level. See NESC, Rules 14, and 120G, for inspection information and rules concerning gel-type 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 and the protection of all metalwork. It is stated by their respective manufacturers that conduit made of aluminum or silicon-bronze is well suited to withstand the corrosive effects of the vapors in battery rooms. In contrast, if steel conduit is used, it is recommended that it be zinc-coated and kept well painted with asphaltum paint.

6.5.5 BATTERY ROOM

There are no special requirements for the type of fixtures or other electrical equipment used in the battery room, with proper ventilation. (See NEC 480-8 and Figure 6-4)



NEC Section 480-8
OSHA Section 29 CFR 1910.305 (j) (7)

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

6.5.6 PERSONAL PROTECTIVE EQUIPMENT

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

The design and use of PPE for wear when servicing batteries shall comply with the requirements of 29 CFR 1910.132, .133, and .136. See NESC, Rule 146 and IEEE 450, Section 4.2.2. For information on safety showers and eyewash stations, see 29 CFR l910.151(c) and 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 subsection covers rechargeable batteries used as a source of electrical energy. This category is not limited to batteries of a particular voltage and energy rating, since the nature of the associated electrical hazards is similar without regard to battery size; the severity of the hazard increases as the battery ratings increase.

6.5.8.1 TYPES OF HAZARDS

Some of the types of hazards associated with storage batteries and battery banks are listed 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 electric shock to nearby personnel.

3. Hydrogen gas generated during battery charging can create fire, explosion, and toxicity hazards.

4. Exposed terminals in a battery bank present electric shock hazards.

5. Batteries, particularly sealed-cell batteries, can explode if they are shorted or if they are charged at excessively high rates.

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 for storage areas for batteries are as follows:

1. Battery installations shall conform to the requirements in the current edition of the NEC.

2. Battery banks should not be grounded except as required in NEC Section 250-3; 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 should be provided to control access to rooms or enclosures containing battery banks.

5. Approved safety showers and eyewash stations should be provided close to battery banks.

6. Appropriate ventilation for discharges of gas should be provided.

7. In areas where seismic activity is present, the installation should be designed according to local standards.

6.5.8.3 OPERATING CRITERIA

Operating criteria are 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 of the circuit could result in a hazardous arcing condition.

3. Clearly post electrical and other hazards of battery banks and emergency first aid information near the equipment.

4. Arrange the battery banks so that temperature stratification will not result in over- or under-charging.

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

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