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ELECTRICAL SAFETY
VOLUME 2 OF 2

Main Category:	Electrical Engineering
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Course #:	ELE-117
Course Content:	203 pgs
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COURSE/EXAM PREVIEW

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ELE-117 EXAM PREVIEW

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Exam Preview:

1. 29 CFR 1910, 29 CFR 1926, ANSI/IEEE C-2, National Electrical Safety Code, & NFPA 70E are all standards and sections which provide information for repairing, servicing, construction, and maintaining electrical circuits and equipment that are supplied by systems of ___ V or more.
   a. 110
   b. 220
   c. 360
   d. 600

2. Qualified employee training includes the proper use of the special precautionary techniques, personal protective equipment, insulating and shielding materials, and insulated tools for working on or near exposed energized parts of electrical equipment.
   a. True
   b. False

3. Workers should wear approved hardhats when working aboveground on poles, structures, or buildings or in trees per ___ Z89.1 and 29 CFR 1910.135.
   a. ANSI
   b. ASME
   c. CFR
   d. OSHA

4. The primary function of personal protective grounds is to provide maximum safety for personnel while they are working on Energized lines or equipment
   a. True
   b. False

5. When an energized line or equipment in excess of 600 V is removed from service to be worked on, it shall be treated as energized until it is deenergized, tagged, locked if necessary, tested, and grounded.
    a. True
    b. False

6. AC live-line work minimum approach distance for Phase to Phase nominal voltage of 550-550kV and Phase to Ground Exposure is:
    a. 2’
    b. 2’-6”
    c. 8’-6”
    d. 11’-3”

7. A type I grounding clamp is for installation on permanently grounded conductor or metal structures, have T-handles, eyes, and/or square-or hexagon-head screws.
    a. True
    b. False

8. A surge arrester is a protective device for enclosed electrical equipment. The more common types of surge arresters used with electronic equipment are the Metal oxide varistor (MOV), avalanche diodes, and spark gap arresters.
    a. True
    b. False

9. The DOE complex conducts R&D programs that involve sources of radio-frequency/microwave (RFMW) nonionizing electromagnetic___ . Devices that may produce RFMW ____ include telecommunications and radar equipment, industrial equipment such as radio-frequency heaters, and scientific and medical equipment such as magnetic resonance imagers and klystron tubes.
    a. Radiation
    b. Current
    c. Voltage
    d. Resistance

10. Overheating due to overloads, insufficient cooling, or failure of the cooling system could cause damage to the inductor and possible rupture of the cooling system is an example of an Inductor hazard.
    a. True
    b. False

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NOT MEASUREMENT SENSITIVE

DOE-HDBK-1092-98
January 1998

DOE HANDBOOK

ELECTRICAL SAFETY

VOL 2 OF 2

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

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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

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7.0 WORK IN EXCESS OF 600 VOLTS

Qualified and competent electrical workers are required to perform a variety of tasks with and around higher voltage electricity, electrical equipment, and apparatus. The nature of such work necessitates an understanding of applicable safety policies and rules.

Many electrical hazards and work practices are the same regardless of the voltage involved. However, due to the nature of high voltage work, there are many hazards and work practices that are specifically related to high voltage.

The following standards and sections provide information for repairing, servicing, construction, and maintaining electrical circuits and equipment that are supplied by systems of 600 V or more.

1. 29 CFR 1910
2. 29 CFR 1926
3. ANSI/IEEE C-2, National Electrical Safety Code.
4. NFPA 70E

7.1 RESPONSIBILITIES FOR SAFETY

This section provides safety guidelines and requirements for carrying out assigned job tasks. It is essential that each employee exercise sound judgment to perform assigned tasks safely. Safety is the responsibility of each employee.

7.1.1 WORKERS

The greatest responsibility for a worker's safety lies directly with the worker. This means that all workers are responsible for performing their work in a manner that does not endanger themselves, their co-workers, or others in the area and for complying with safety rules and requirements. Workers should not rely solely on the care exercised by another for their protection. Workers are encouraged to contribute to the safety program and bring to the attention of their supervisors or safety representative any condition they believe is unsafe.

Other safety responsibilities of workers include the following:

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

2. When seen in a dangerous situation, fellow workers should be warned in such a manner as to avoid confusing, startling, or suddenly alarming them.

3. Before climbing poles, ladders, or other such structures or before working on scaffolds, workers shall make a careful inspection to determine whether the structures are safe and are properly supported. Workers should not carry anything in their hands while ascending or descending ladders. Small objects or tools may be carried in pockets or pouches. Larger

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objects, however, should be raised or lowered by use of handlines or ropes and blocks. Others working nearby or below should remain out of line of the work area in case anything should accidentally be dropped.

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

5. The worker shall report to the supervisor any personal injury as defined by the facility as soon as possible.

6. The worker should exercise care and good judgment when lifting heavy material, obtaining help if the object is too heavy or awkward for one person to handle.

7.1.2 SUPERVISORS

Supervisors are responsible for knowing and implementing applicable safety policies and directives and taking action as required to provide for the safety of the personnel and operations they supervise. This includes; taking positive action to determine and reduce, as necessary, the hazards associated with their operations; instructing employees in safe work methods and associated safety requirements; allowing only those employees that are qualified for the work to perform the work; and ensuring that employees perform their work safely.

Supervisors shall be responsible for the safety of all employees under their supervision. They shall enforce the rules that apply to the hazards involved.

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

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

Other duties of supervisors include the following:

1. Provide instructions on safe practices for the crew and see that they are followed.

2. Periodically examine supervised employees on their knowledge of the safety rules and approved emergency techniques.

3. Not allow a worker to perform any task that cannot be performed safely or for which the worker is not qualified.

4. Report every injury in the established manner prescribed for the facility.

5. Be responsible for the care and proper use of all protective devices.

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

7. Designate a qualified worker to be in charge of work during the supervisor's absence. The supervisor should not leave the job while dangerous work is in progress.

8. Coach and direct employees who are working near exposed, energized wires, equipment, or apparatus.

9. Prescribe, along with employees, the appropriate PPE when establishing safety related work practices.

7.2 TRAINING

7.2.1 EMPLOYEE TRAINING

Employees shall be trained in and familiar with the safety-related work practices, safety procedures, and other safety requirements in this section that pertain to their respective job assignments.

Employees shall also be trained in and familiar with any other safety practices, including applicable emergency procedures that are not specifically addressed in this section but are related to their work and necessary for their safety.

7.2.2 QUALIFIED EMPLOYEE TRAINING

Qualified employees shall be trained and competent in:

1. The skills and techniques necessary to distinguish exposed live parts from other parts of electrical equipment.

2. The skills and techniques necessary to determine the nominal voltage of exposed live parts.

3. The skills and techniques necessary to determine the minimum approach distances corresponding to the voltages to which they are exposed.

4. The proper use of the special precautionary techniques, personal protective equipment, insulating and shielding materials, and insulated tools for working on or near exposed energized parts of electrical equipment.

Training may consist of a combination of classroom and on-the-job type.

7.3 JOB BRIEFINGS

The employee in charge shall conduct a job briefing with the employees involved before the start of each job. The job briefing will at least cover the following subjects: hazards associated with the job, work instructions involved, special precautions, energy source controls, and personal protective equipment requirements.

If the work or operations to be performed during the work day are repetitive and similar, at least one job briefing shall be conducted before the start of the first job of each day or shift. Additional job briefings shall be held if significant changes, which might affect the safety of the employees, occur during the course of the work.

A brief discussion is satisfactory if the work involved is routine and if the employee, by virtue of training and experience, can reasonably be expected to recognize and avoid the hazards involved in the job. A more extensive discussion shall be conducted if the work is complicated or extremely hazardous, or the employee cannot be expected to recognize and avoid the hazards involved in the job.

An employee working alone need not conduct a job briefing. However, the employee shall ensure that the tasks to be performed are planned as if a briefing were required.

7.4 PERSONAL PROTECTIVE EQUIPMENT AND PROTECTIVE CLOTHING

Employees shall wear appropriate personal protective equipment (PPE) and protective clothing (see Section 7.4.8) to protect them from hazards of high-voltage apparatus. Employees authorized or required to work on high-voltage systems shall be completely familiar with the PPE and protective clothing they need for adequate protection while working on such systems. (Refer to Appendix C for suggested types of PPE and protective clothing.) (See Figure 7-1 and Table 7-1.)

7.4.1 SHOES

Employees should wear shoes or boots that comply with the requirements of ANSI Z41. No metal parts shall be present in the sole or heel of the shoes where nonconductive shoes are required.

7.4.2 SAFETY HAT

Workers should wear approved hardhats when working aboveground on poles, structures, or buildings or in trees per ANSI Z89.1 and 29 CFR 1910.135.

Workers shall wear hardhats when working on the ground near poles, structures, buildings, or trees in which work is being done. Workers shall wear hardhats when visiting or observing in areas where overhead work is being done.

7.4.3 EYE PROTECTORS

Whenever eyes are in danger of being injured, workers shall wear safety goggles or other eye protectors meeting ANSI standards. When the work being performed dictates, workers should wear

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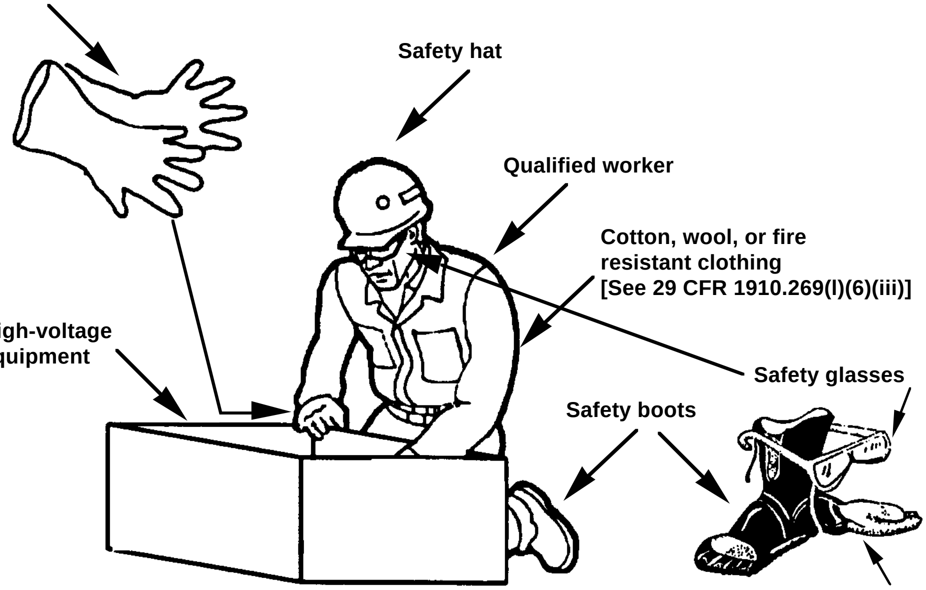

Figure 7-1. Appropriate personal protective equipment and protective clothing shall be worn by electrical workers to protect them from electrical hazards.

nonmetallic and nonconductive eye protection. (See ANSI Z87.1 and 29 CFR 1910.133 for more information.)

7.4.4 RESPIRATORS

Workers shall wear the appropriate respirator per 29 CFR 1910.134.

7.4.5 METAL FASTENERS

Workers shall not wear articles such as loose chains, keys, watches, or rings if such articles increase the hazards associated with inadvertent contact with energized parts or can become caught under or snagged while climbing off or on structures, equipment or vehicles.

7.4.6 WORK GLOVES

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

7.4.7 WORK CLOTHES

Work clothes should be made of natural materials, such as cotton or wool, or fire resistant materials and should have full length sleeves. Sleeves should be rolled down for greatest protection.

Table 7-1. ANSI/ASPM 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*

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7.4.8 FIRE RESISTANT CLOTHING

29 CFR 1910.269(l)(6)(iii)[1] states, in part, "…each employee who is exposed to flames or electric arcs does not wear clothing that, when exposed to flames or electric arcs, could increase the extent of injury that would be sustained by the employee."

"Note: Clothing made from the following types of fabrics, either alone or in blends, is prohibited by this paragraph, unless the employer can demonstrate that the fabric has been treated to withstand the conditions that may be encountered or that the clothing is worn in such a manner as to eliminate the hazard involved: acetate, nylon, polyester, rayon."

7.4.8.1 GENERAL

All fire resistant fabrics comply with 29 CFR 1910.269(l)(6)(iii). Untreated cotton and wool comply if the fabric will not ignite and continue to burn under the conditions to which the employee could be exposed. ASTM F1506-94 and 2 new ASTM provisional standards, outline the testing procedures to determine how various fabrics react in the presence of an electric arc on an instrumented mannikin or panel. The new ASTM provisional standards provide testing procedures that expose untreated and fire resistant fabrics to electric arcs. F1506-94 provides testing procedures that expose these same fabrics to a vertical flame test. Also see NFPA 70E, Part II, Ch. 2-3.3.3 for details on flash hazard analysis.

7.4.8.2 ELECTRIC ARC HAZARDS

Electric shock is a widely recognized hazard and involves current flow through or on the body. Burns from electric arcs are not as well recognized. There is no contact required and the burns can be severe if the clothing ignites or melts. The hazards to which the employee is exposed also include the clothing breaking open due to the arc pressure blast, the heat from the electric arc and subsequent secondary fires or explosions.

The extent of the employees' injury is dependent on the length of the arc gap, available fault current, duration of the arc, the distance of the employee from the arc, percentage of the body burned, the employees age, medical condition, and number of layers of the clothing system. The proper clothing system will minimize or reduce the burn injury.

7.4.8.3 TYPES OF FIRE RESISTANT FABRICS

Chemically dependent fire resistant fabrics are treated with flame retardant chemicals added to the fiber or treatments applied to the fabric. These treatments are activated by heat and produce gases that smother the flame. Typically, these fabrics have a definite life as defined by the manufacturer. This is usually defined by the number of home or commercial washings the garment is exposed.

Inherently fire resistant fabrics, by their composition, do not burn in air. The fire resistance of this fabric is not affected by washing.

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[1] See Appendix D, Reference Matrix.

7.4.8.4 CLOTHING SYSTEMS

All clothing worn by affected workers should be considered part of the employees protective clothing system. This includes rainwear, cold weather wear and underclothing. Protective clothing should provide a good functional fit to increase the protection and comfort of the clothing. When required, protection can be increased by wearing single or multiple layers of flame resistant outer garments over nonmelting clothing. Sleeves and shirts should be fully buttoned and appropriate neck, head, and hand coverings provided.

7.4.9 RUBBER GLOVES

The following requirements apply:

1. Rubber gloves shall be of appropriate voltage rating for the work being performed. All rubber gloves shall meet the standards set forth in ANSI/ASTM D120.

2. Rubber gloves issued for service shall be tested at appropriate voltage levels at intervals not exceeding 6 months.

3. Leather glove protectors shall be worn over rubber gloves except where leather protectors are not required by 29 CFR 1910.137 or the appropriate ASTM standard.

4. Rubber gloves should be carried cuff down in a bag, box, or container that is designed for this purpose. Rubber gloves may be kept inside of leather protectors.

5. Rubber gloves shall be visually inspected and field air-tested before use each day and at other times if there is cause to suspect damage.

6. Rubber gloves should be uniquely identified (i.e., serial number or other marking). The results of dielectric tests should be documented.

7. Rubber gloves shall be wired clean of any oil, grease, or other damaging substances as soon as possible.

7.4.10 RUBBER LINE HOSE, HOODS, COVERS, SLEEVES, AND BLANKETS

Linemen's rubber insulating sleeves are worn to provide protection from electric shock and burn to the arm and shoulder areas. They are available in several different thicknesses, lengths, and designs, depending on the maximum voltage they are designed to protect against. (See ANSI/ASTM F496 and D1051).

Insulating line hose (flexible hose) is used as an insulating cover for electric conductors to protect against accidental contacts. A lengthwise slit with overlapping sides permits the hose to be placed on conductors easily. It is available in various diameters, lengths, and compositions. (See ANSI/ASTM D1050, and F478).

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Insulating covers are used in conjunction with line hose to cover an insulator and the conductor attached to it for protection against accidental contact.

Rubber insulating blankets are molded sheets of insulating rubber or synthetic elastomer, usually square or rectangular in shape, designed to cover energized electrical equipment to prevent direct accidental contact by electrical workers. (See ANSI/ASTM F479 and D1048).

7.4.11 LIVE LINE TOOLS

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

Particular attention shall be given to preserving the surfaces of wooden and fiberglass tools used around electrical equipment, including ladders, pike poles, switch sticks, live-line tools, and insulating platforms. Only colorless varnish or other appropriate transparent insulating preservative shall be used.

Insulated tools shall be stored in a dry location. Suitable containers or racks shall be provided to protect the tools from mechanical damage and warping. (See ANSI/ASTM F711, 29 CFR1910.269(j) and (n), and IEEE 978-1984, "IEEE Guide for In-Service Maintenance and Electrical Testing of Live Line Tools.")

7.4.12 STOREROOM STORAGE

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

Gloves should be stored in their natural shape in the leather protector. Keep sleeves flat with the inserts left in. Blankets should be stored flat, hung on pegs by the eyelet or rolled up. Line hose should be stored in its natural shape.

7.4.13 TRUCK STORAGE

The storing of rubber protective equipment on the truck should be planned. If possible, separate compartments should be provided for each class of equipment, and each compartment should be of sufficient size to allow the articles to lie in a natural position. Rubber gloves should be stored in glovebags and hung up. If stored in tool bags or inside boxes, nothing should be piled on top to cause distortion. Gloves should not be stored near vehicle heaters.

Sleeves should be stored flat with inserts rolled up lengthwise, or placed in a tube shaped bag. Nothing should be placed on top of sleeves or stored near vehicle heaters.

Blankets should be rolled up and placed in canisters or protective canvas holders. Do not fold, hold together with tape, pile materials on top of, or store blankets near vehicle heaters.

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7.4.14 PLACING OF INSULATING GOODS ON CONDUCTORS

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

As the workers ascend to their working position, they shall cover all conductors which provide a hazard. This should be done from below whenever possible. At no time shall workers pass through energized equipment before it is covered with rubber goods (line guards). All conductors and grounds adjacent to working space shall be considered, including those near any possible change of position that may be necessary. When line hose is applied to vertical or sagging wires, it should be fastened to the line to prevent its slipping from position. When blankets are used for covering items such as dead ends, potheads, secondary racks, and transformers, they should be secured by wooden or plastic clamp pins or tie thongs. After the protective equipment has been placed, care should be taken to prevent damage to the rubber from tie wires, spurs, or other objects.

7.4.15 REMOVING INSULATING GOODS FROM CONDUCTORS

When the job is completed, the protectors should be removed in the reverse order of installation. Remote conductors are removed first and the wires nearest the workers last. After being detached, the equipment should immediately be lowered to the ground.

7.4.16 CLEANING AND INSPECTING

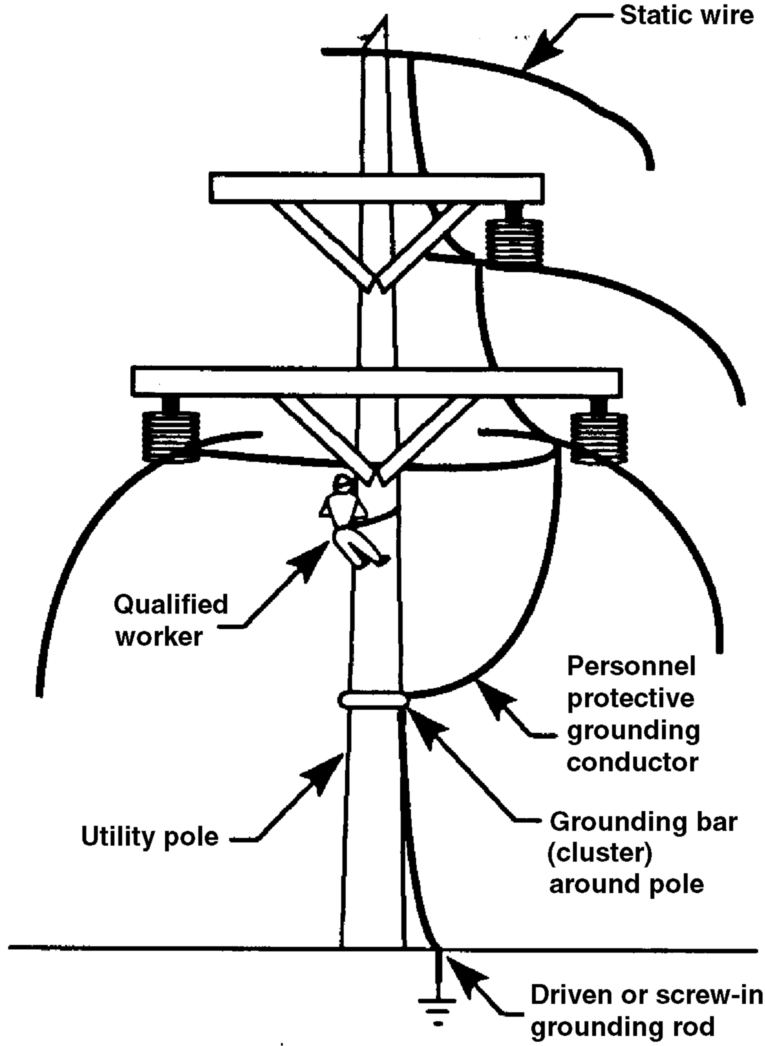
After the rubber goods have been lowered to the ground, they should be cleaned and visually inspected before being placed in the carrier compartments of the truck.

7.5 PROTECTIVE GROUNDING OF LINES AND EQUIPMENT

Grounding is the most effective way of protecting electrical workers from electric shock. That is why it is important to ensure that all deenergized lines and equipment are grounded. (See Sections 4.5.2, 7.5.3, Figure 7-2, 29 CFR 1910.269(n), 1926.954, and IEEE 1048-1990, "IEEE Guide for Protective Grounding for Power Lines.")

7.5.1 PURPOSE

This section provides information concerning protection for workers repairing, servicing, or working on high-voltage power lines. (See 29 CFR 1910.269(n), 1926.954, and ASTM F-855.)



OSHA Section 29 CFR 1910.269(n), 1926.954

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

7.5.1.1 REDUCE THE POTENTIAL VOLTAGE DIFFERENCES ACROSS THE WORKER

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

The personal protective grounds should provide a low-impedance path to ground to ensure prompt operation of the circuit protective devices. For more information, see Section 4.15.2 and IEEE 80.

7.5.2 APPLICATION

Certain methods and steps should be exercised when placing grounds and loads to protect workers from high-voltage hazards.

7.5.2.1 DEENERGIZED LINES

When an energized line or equipment in excess of 600 V is removed from service to be worked on, it shall be treated as energized until it is deenergized, tagged, locked if necessary, tested, and grounded.

7.5.2.2 NEW CONSTRUCTION OR DISMANTLING OF FACILITIES

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

7.5.2.3 MINIMUM APPROACH DISTANCE FROM UNGROUNDED CONDUCTORS

The minimum approach distances in Section 2.13.4.1 shall be maintained from ungrounded conductors at the work location. (See Table 7-2 for 29 CFR 1910.269 Table R6). The ground may be omitted if the making of the ground is impractical or the resulting conditions are more hazardous than working on the lines or equipment without grounding. However, all work shall be done as if the line or equipment were energized.

7.5.2.4 VISIBLE THREE-PHASE SHORT AND GROUND REQUIRED

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

7.5.2.5 GROUND CIRCUIT

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

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Table 7-2. AC live-line work minimum approach distance.

Phase to Phase Nominal Voltage (kV)	Distance, Phase to Employee: Phase to Ground Exposure (ft - in)	Distance, Phase to Employee: Phase to Phase Exposure (ft - in)
1 or less	Avoid contact	Avoid contact
1.1 to 15	2 - 1	2 - 2
15.1 to 36	2 - 4	2 - 7
36.1 to 46	2 - 7	2 - 10
46.1 to 72.5	3 - 0	3 - 6
72.6 to 121	3 - 2	4 - 3
138 to 145	3 - 7	4 - 11
161 to 169	4 - 0	5 - 8
230 to 242	5 - 3	7 - 6
345 to 362	8 - 6	12 - 6
500 to 550	11 - 3	18 - 1
765 to 800	14 - 11	26 - 0

Note 1: These distances take into consideration the highest switching surge an employee will be exposed to on any system with air as the insulating medium and the maximum voltage shown.

Note 2: The clear live line tool distances shall equal or exceed the values for the indicated voltage ranges.

Note 3: See 29 CFR 1910.269, Appendix B for information on how the minimum approach distances were derived.

7.5.3 GROUNDING EQUIPMENT

The American Society for Testing and Materials (ASTM) Committee F-18, "Electrical Protective Equipment for Workers," has developed and published a consensus standard for protective grounds, ASTM Designation: F-855. In accordance with Office of Management and Budget (OMB) Circular No. A-119. October 27, 1982, this voluntary consensus standard may be used by all Federal agencies for procurement purposes. Therefore, grounding cables, clamps, and ferrules purchased should meet all the requirements of ASTM Designation: F-855. Aluminum cables shall not be used for personal grounds.

The grounding of high-voltage lines and equipment will provide workers with additional protection from electric shock if grounds are sized, selected, and installed properly. For further information on the construction of personnel protective grounds, see ASTM F855-90.

7.5.3.1 AVAILABILITY

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

7.5.3.2 APPROVED CAPACITY

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

7.5.3.3 GROUNDING CABLES AND HARDWARE

Personal protective grounding cables consist of appropriate lengths of suitable copper grounding cable, with electrically and mechanically compatible ferrules and clamps at each end. In addition, appropriate hotsticks are required for installing and removing the conductor-end clamps to the conductors. Hotsticks are required for attaching ground-end clamps if the grounded system and the worker are at different potentials. Cluster bars provide a low-resistance means of connecting the ground-end clamps. Each of these components will be discussed in the following subsections.

7.5.3.4 GROUNDING CABLES

Most of the grounding cables in use today (and available for purchase) are actually manufactured for another purpose-principally as welding cable. These extra-flexible copper cables with jackets are manufactured according to appropriate ASTM standards for both cables and jackets, and can be expected to perform satisfactorily as grounding cables.

7.5.3.4.1 STRANDING

There are several classes of flexible cable with various stranding in the sizes normally used for grounding cables.

7.5.3.4.2 JACKETS

Welding cables are nominally insulated at 600 volts. When used as grounding cable, the insulation or jacket serves primarily for mechanical protection of the conductor. The flexible elastomer or thermoplastic jackets are manufactured, applied, and tested according to ASTM standards. Black, red, and yellow jackets are usually neoprene rubber compounds, while clear jackets are ultraviolet-inhibited polyvinyl chloride (PVC). All jackets should have the American Wire Gage (AWG) size stamped or printed repeatedly along the length of the cable. The clear jacket allows easy visual inspection of the conductor for strand breakage, but becomes stiff and hard to handle at low temperatures. The clear jacket will split or shatter at very low temperatures.

7.5.3.4.3 FERRULES

Ferrules should be threaded-stud copper base compression type. Ferrules should have the filler compound vent hole at the bottom of the cable so that employees can visually check that the cable is fully inserted into the ferrule. Compound should be used with crimped ferrules. The ferrules should be crimped with the ferrule manufacturer's recommended die. The press shall have enough pressure to completely close the die. The area covering the inserted cable jacket should not be compressed. Heat shrink or springs should be installed over a portion of the ferrule to minimize strand breakage caused by bending. In all cases, the manufacturer's recommendations should be followed.

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7.5.3.4.4 HANDLING OF GROUNDING CABLE

Personal protective grounds are usually handled and lifted by the cable. However, continuous flexing eventually breaks the conductor strands beneath the jacket. Therefore, employees should minimize the use of sharp bends in the cable.

7.5.3.4.5 SIZE OF GROUNDING CABLE

The size of the grounding cable must be selected to handle the maximum calculated fault current of the power system or specific portion thereof. The minimum size that shall be used for grounding cables is #2 (AWG) flexible copper. In larger substations, the maximum available fault current may require larger cables. If larger cables are not available, parallel cables (with the appropriate derating factor) may be used.

Most manufacturers and suppliers of grounding cables publish tables to assist the user in selecting the proper cable size for a given fault current. These tables show the maximum fault current capability for several sizes of copper grounding cables.

7.5.3.4.6 GROUNDING CABLE LENGTH

Excessive cable lengths should be avoided. Therefore, slack in the installed cables should be minimal to reduce possible injury to workers. Resistance in the cable increases with cable length, and excessive length could exceed the tolerable voltage drop across the body. Longer than necessary cables also tend to twist or coil, which reduces the effectiveness of the cable.

7.5.3.4.7 GROUNDING CLAMPS

Grounding clamps are normally made of copper or aluminum alloys; sized to meet or exceed the current-carrying capacity of the cable; and designed to provide a strong mechanical connection to the conductor, metal structure, or ground wire/rod.

7.5.3.4.7.1 CLAMP TYPES

Clamps are furnished in, but not limited to, three types according to their function and methods of installation:

1. Type I clamps, for installation on deenergized conductors, are equipped with eyes for installation with removable hotsticks.

2. Type III clamps, for installation on permanently grounded conductor or metal structures, have T-handles, eyes, and/or square-or hexagon-head screws.

3. Other types of special clamps are designed for specific applications, such as cluster grounds, underground equipment grounding, and so on.

7.5.3.4.7.2 CLAMP JAWS

Bus clamps should be furnished with smooth jaws for installation on copper, aluminum, or silver-plated bus work without marring the surface. Conductor or metal structure clamps should be furnished with serrations or cross-hatching designed to abrade or bite through corrosion products on surfaces of the conductor or the metal structure being clamped. Several styles of conductor and ground-end clamps have jaws that can be replaced when the serrations have worn. Self-cleaning jaws are recommended for conductor-end clamps used on aluminum or aluminum conductor steel reinforced (ACSR) conductors. Several styles of ground-end clamps are designed with a cup-point set screw which should be tightened with a wrench (after the serrated jaws have been securely tightened) to break through paint, rust, galvanized coating, or corrosion on the surface that is to be clamped.

A typical grounding cable for transmission line work used by line crews consists of a 2/0 (AWG) copper cable with an insulating jacket, terminated with an all-angle, self-cleaning aluminum conductor clamp at one end, and a flat-faced clamp with a set screw at the other end for connecting to a tower leg or ground wire/rod.

7.5.3.4.8 GROUNDING CLUSTER BARS

When climbing wood-pole structures, workers may use a grounding cluster bar to connect the phase cables to the pole ground wire, if the ground wire has sufficient capacity to carry the fault current. Cluster bars must have an attached bonding lead. If there is no pole ground wire, the cluster bar for each pole is connected to a common driven or screw-in ground rod with a grounding cable (or cables). In substation grounding, a copper bar is sometimes used to connect the three-phase cables and a fourth cable to a riser from the station ground mat. When installing personal grounds on wood structures from a bucket, the ground cables may be connected between the overhead ground wire (OGW), and the phases without the use of cluster bars provided that an electrical bond of sufficient current carrying capacity exists between the OGW and the structure ground.

7.5.3.4.9 TEMPORARY GROUND RODS

Some typical examples of temporary ground rods used for grounding ungrounded structures or mobile equipment, or during conductor splicing operations, are either:

1. A minimum 5/8-inch diameter bronze, copper, or copper-weld rod at least 6 feet long, driven to a depth of at least 5 feet; or

2. A 6-foot, screw-type ground rod, consisting of a minimum 5/8-inch diameter copper-weld shaft with a bronze auger bit and bronze T-handle, screwed to a depth of at least 5 feet (preferred). The T-handle must be tightly connected to the rod.

If a temporary rod cannot be driven or screwed to a depth of 5 feet, additional rod(s) should be driven or screwed so that a total of at least 5 feet of rod is buried. These rods shall be bonded together with grounding cables prior to installing phase grounds. The rods should be placed 6 to 8 feet apart; however, the 10-foot clearance from the rods should be maintained. OGWs may be used at any time

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to bond the conductors provided that these wires are electrically bonded to the structure ground, either permanently or by personal grounds.

Groundsmen should stay clear (at least 10 feet where feasible) of items such as down guys, ground rods, maintenance vehicles, and structure legs or ground wires while they are bonded to protective grounds which are in place. When it is absolutely necessary to work on or near these features, employees should use bonded conductive or insulated platforms, or approved insulated shoes to minimize the hazard from step and touch potentials.

7.5.4 TESTING BEFORE INSTALLING GROUNDS

Before grounds are installed, the deenergized line or equipment shall be tested for voltage. Appropriate testers for the nominal voltage involved (audio or visual) should be used. They shall be tested immediately before and after use to verify that they are in good working condition. [See 29 CFR 1910.269(n)(5)].

7.5.5 ATTACHING AND REMOVING GROUNDS

Employees attaching and removing grounds shall comply with the following:

1. Grounding equipment should be visually inspected and all mechanical connections checked for tightness before each use.

2. The surface to which the ground is to be attached should be clean before the grounding clamp is installed or a self-cleaning clamp shall be used.

3. No ground shall be removed until all personnel are clear of the temporary grounded lines or equipment. When the grounding set is removed, it shall be disconnected from the line or equipment end first with an approved hot-line tool and moved to a point clear of energized conductors before the ground end is disconnected. [Refer to Section 4.15 and 29 CFR 1910.269(n)(6) and (7)].

7.5.6 GROUNDING METHODS AND LOCATION OF GROUNDS IN ORDER OF PREFERENCE

Employees installing grounds shall install them using the information given in the following sections.

7.5.6.1 WORK LOCATION

Grounds should be installed at the work location with all grounded parts of different potential bonded together (on wood poles, all down guys, overhead ground wire, neutral conductor, and pole ground). The cluster bar assembly should be installed below the working area and jumper to the ground point or the neutral conductor and the phase conductor, a method of grounding termed "equipotential" grounding. It provides the greatest margin of safety for the lineworker by placing everything at equal potential, eliminating the possibility of the lineworker getting in series to ground. [See 29 CFR 1910.269(n)(3)].

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

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

7.5.6.3 OTHER LOCATIONS

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

7.5.7 TESTING WITHOUT GROUNDS

Grounds may be temporarily removed when necessary for testing. Each employee shall use insulating equipment and be isolated from any hazard involved. Additional measures may be necessary to protect each exposed employee in case previously grounded lines or equipment become energized [See 29 CFR 1910.269(n)(9)].

7.5.8 GROUND PERSONNEL

In cases where ground rods or pole grounds are used for personal protective grounding, personnel working on the ground shall either maintain a safe distance from such equipment or use the appropriate equipment designed to prevent touch-and-step potential hazards. The term "touch potential hazard" refers to the difference in voltage measured between the grounding equipment and a worker in contact with the grounding equipment at the time it is accidentally energized. The term "step potential hazard" refers to the difference in voltage measured between each foot of the worker standing or walking in an electrical field created by high voltage brought to earth (See 29 CFR 1910.269, Appendix C and IEEE 80 for further information).

7.6 INSTALLING OR REMOVING CONDUCTORS

Employees installing or removing conductors should follow certain guidelines to ensure safety.

7.6.1 WORKING ON ENERGIZED LINE OR EQUIPMENT

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

1. Work on electrical equipment and circuits other than electrical utility lines and equipment, operating a 50 V or more ground, should be worked on following the guidelines of Section 2 of the handbook.

2. Line or equipment carrying an ac voltage in excess of 600 V phase-to-phase should be worked on with rubber gloves or live line tools. All other necessary protective devices such as line hose, hoods, covers, sleeves, and rubber blankets should be used. (See Section 2.1.2).

3. Energized line should be worked on from below whenever possible. When working energized line or equipment carrying 600 V or more to ground, there shall be two qualified workers performing the work (see Section 2.1.2). Work shall not be performed on energized lines or equipment during rain, snow, sleet, fog, and other damp conditions, except in extreme emergencies if in the opinion of supervision and line crew it can be done safely.

4. While working on the same pole, workers shall not work simultaneously on wires that have a difference of potential.

5. Rubber gloves of appropriate voltage rating shall be worn when working within reach of a fellow employee who is working on or within reach of wires or equipment carrying voltage in excess of 600 V.

6. Insulated tongs or disconnect sticks shall be used to open or close plugs or fuses or to disconnect blades.

7.6.2 STRINGING OR REMOVING DEENERGIZED CONDUCTORS

Employees stringing or removing deenergized conductors should follow certain safe work practices. (See 29 CFR 1910.269(q), 1926.955(c), and IEEE 524-1992, "IEEE Guide to the Installation of Overhead Transmission Conductors.") Consideration should be given to the following:

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

   a. Untied and separated with proper clearance from the pole or structure,

   b. Deenergized and grounded, or

   c. Covered with the necessary protective devices.

2. Prior to stringing operations, a job briefing shall be held setting forth the plan of operation and specifying the type of equipment to be used, grounding devices to be used and instructions to be followed, crossover methods to be employed, and clearance authorization required.

3. Where there is a possibility that the conductor will accidentally contact an energized circuit or receive a dangerous induced voltage buildup, to protect the employee from the hazards of the conductor, the conductor being installed or removed shall be grounded or provisions made to insulate or isolate the employee.

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4. If the existing line is deenergized, proper clearance authorization should be secured and the line grounded on both sides of the crossover, or the line being strung or removed should be considered and worked on as energized.

5. When workers cross over energized conductors, rope nets or guard structures shall be installed unless provisions are made to isolate or insulate the workers or the energized conductor. Where practical, the automatic reclosing feature of the circuit-interrupting device should be made inoperative. In addition, the line being strung should be grounded on either side of the crossover or considered and worked on as energized.

6. Conductors being strung or removed should be kept under positive control by the use of adequate tension reels, guard structures, tielines, or other means to prevent accidental contact with energized circuits.

7. Guard structure members should be sound, of adequate dimension and strength, and adequately supported.

8. Catch-off anchors, rigging, and hoists should be of ample capacity to prevent loss of lines.

9. The manufacturer's load rating should not be exceeded for stringing lines, pulling lines, sock connections, and all load-bearing hardware and accessories.

10. Pulling lines and accessories should be inspected regularly and replaced or repaired when damaged or when their dependability is doubtful.

11. Conductor grips should not be used on wire rope unless designed for this application.

12. While the conductor or pulling line is being pulled (in motion), workers should not be permitted directly under overhead operations, nor should any employee be permitted on the crossarm.

13. A transmission clipping crew should have a minimum of two structures clipped between the crew and the conductor being sagged. When working on conductors, clipping crews should install grounds at the work location. The grounds should remain intact until the conductors are clipped in, except on dead-end structures.

14. Except during emergency restoration activities, work from structures should be discontinued when adverse weather (such as high wind or ice on structures) makes the work hazardous.

15. Stringing and clipping operations should be discontinued during an electrical storm in the immediate vicinity.

16. Reel-handling equipment, including pulling and braking machines, should have ample capacity, operate smoothly, and be leveled and aligned in accordance with the manufacturer's operating instructions.

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17. Reliable means of communication between the reel tender and pulling rig operator should be provided.

18. Each pull should be snubbed or dead-ended at both ends before subsequent pulls.

7.6.3 STRINGING ADJACENT TO ENERGIZED LINES

Employees stringing adjacent to energized lines should follow certain safe work practices. (See 29 CFR 1910.269(q), 1926.955(d), and IEEE 516-1987, "IEEE Guide for Maintenance Methods on Energized Powerlines.") Consideration should be given to the following:

1. When performing work from structures, clipping crews and all others working on conductors, subconductors, or overhead grounding conductors should be protected by individual grounds installed at every work location.

2. When workers are stringing adjacent to energized lines, the tension-stringing method or other methods that prevent unintentional contact between the lines being pulled and any worker should be used.

3. All pulling and tensioning equipment should be effectively grounded.

4. A ground should be installed between the tensioning reel setup and the first structure to ground each bare conductor, subconductor, and overhead grounding conductor during stringing across or adjacent to energized lines.

5. During stringing operations, each bare conductor, subconductor, and overhead grounding conductor should be grounded at the first tower adjacent to both the tensioning and pulling setup and at appropriate intervals. The grounds should be left in place until conductor installation is completed. Except for moving-type grounds, the grounds should be placed and removed with a hot stick.

6. Conductors, subconductors, and overhead grounding conductors should be grounded at all dead-end or catch-off points.

7. A ground should be located at each side and within 10 ft. of working areas where conductors, subconductors, or overhead grounding conductors are being spliced at ground level. The two ends to be spliced should be bonded to each other. It is recommended that splicing be carried out on either an insulated platform or on a conductive metallic grounding mat bonded to both grounds. When a grounding mat is used, it should be roped off and an insulated walkway provided for access to the mat.

7.7 SPECIAL TOOLS

Lineworkers shall be familiar with special tools that are used for climbing, such as climber gaffs, climber straps, and body belts shall properly store and maintain such equipment. (See Figure 7-3 and ANSI/ASTM F 887-91a.)

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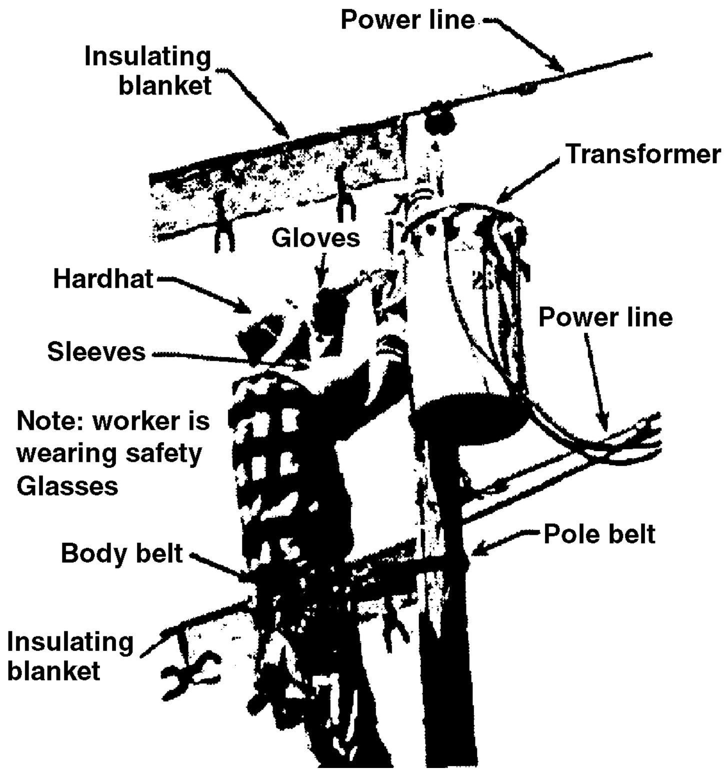

OSHA Section 29 CFR 1910.132, 133, 135, 136, 137
OSHA Section 29 CFR 1926.951

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

7.7.1 LINEWORKER'S CLIMBING TOOLS

Employees should apply the following:

1. All climbers should be inspected frequently by the worker using them.
2. Climber gaffs should be kept sharp.
3. A climber shall not be used when its gaff becomes shorter than 1-1/4 in. inside measurement.
4. Climber straps that are worn or otherwise defective shall be replaced.

7.7.2 BODY BELTS AND SAFETY STRAPS

Employees using body belts and safety straps (work positioning equipment) should apply the following:

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1. All body belts and safety straps shall be inspected before each use by the employee who uses them.

2. Workers shall use their body belts and safety straps when doing any work involving danger of falling.

3. Body belts and safety straps should not be stored with unguarded sharp tools or devices.

4. Heat, sharp bends, and overstressing of body belts and safety straps should be avoided as they are injurious to leather. Wet leather should be dried slowly at moderate temperatures.

See 29 CFR 1910.67, 1910.269(a), 1926.500, and 1926.502 for further information.

7.7.3 TOOL BAG AND EQUIPMENT

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

7.7.4 TAPES AND RULERS

Workers should not use metal measuring tapes or tapes having metal strands woven into the fabric, brass bound rules, or metal scales when working near electrical equipment or conductors [See NESC Rules 420C(6) and 443A(6)].

7.7.5 SPOON AND SHOVELS

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

7.7.6 PIKE POLES

Pike poles shall comply with the following:

1. Cracked, broken, or slivered pike poles should not be used;

2. Pike poles should not be thrown; and

3. When not in use and loaded on the truck, the points should be protected so that they will not injure anyone.

7.7.7 HAND AXES AND SHARP TOOLS

Hand axes and sharp tools shall comply with the following:

1. Hand axes should not be used on overhead work; and

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2. When not in use, sharp tools should be protected by the suitable guards or containers.

7.7.8 HANDLINES AND TAGLINES

Use high quality, nonconductive handlines and taglines. Keep them stored in a clean, dry location and protected from damage and contamination. Wear clean gloves when handling handlines and taglines to avoid contaminating the rope. Remove wet, dirty, or damaged ropes from service.

7.8 TREE TRIMMING

Equipment used to trim trees shall be maintained in approved and proper working condition to aid tree trimmers and protect them from hazards. (See 29 CFR 1910.269(r) and Section 2.13.4.1).

7.8.1 CARE AND USE OF TOOLS

Tools shall be cared for using the following methods:

1. The handles of all tree-trimming tools shall be kept well dressed and varnished.

2. When trimming trees near live conductors, the employee shall not work with wet tools or ropes. Such equipment should be protected during rain showers.

3. A tree-trimming saw shall be protected by being put into its scabbard when it is not in use.

4. All ropes shall be inspected frequently for cuts and wear.

7.8.2 CLIMBING

The following shall be applied for climbing:

1. An employee should use a ladder to climb a tree, unless the employee is properly equipped and trained for tree climbing.

2. Climber gaffs and straps shall be designed for tree climbing. The safety strap shall be constructed to withstand contact with saws and other sharp objects. Workers in trees shall be tied off.

7.9 SERIES STREET-LIGHTING CIRCUITS AND APPARATUS

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

1. Rubber gloves or any other necessary protective equipment should be used when working on a series street-lighting circuit, unless the circuit is electrically isolated and grounded at the work location. Unless properly tagged and isolated, series street lighting circuits should be considered as being energized.

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2. The opening of a time clock, a photoelectric relay, or remote control overcurrent control equipment shall not be considered as isolation points that provide a safe work condition while employees work on series lighting circuits.

3. The use of series lighting circuits is discouraged.

7.10 UNDERGROUND

Underground work requires a means of safe entrance and exit from the workspace. Employees should follow the guidance given in the following subsections to ensure safety in entering and leaving such work spaces.

7.10.1 WORKING IN MANHOLES, UTILITY TUNNELS, AND VAULTS

Manholes, utility tunnels, and vaults may be considered confined spaces and shall comply with 29 CFR 1910.146, 1910.269(e) and (t), and 1926.956. The following may apply to employees working in manholes, utility tunnels, and vaults:

1. Employees who enter manholes shall be trained in the hazards of the confined spaces, confined space entry procedures, and confined space emergency and rescue procedures.

2. When opening a manhole, employees shall completely remove the manhole cover from the opening. Manhole covers should be removed before the cable is rodded or installed and removed.

3. Open manholes shall be barricaded and protected by flags or guards as required. All open manholes shall be protected as required by 29 CFR 1910.269(e).

4. Before the pit is entered, it shall be tested for oxygen content and the flammable-gas explosive limit. Workers shall not smoke or use an open flame while tests for an explosive mixture of gas are being made.

5. If the oxygen level is less than 19.5% or greater than 21%, the pit shall be ventilated and retested before any work begins.

6. If the flammable-gas content is more than 10% of the lower explosive limit, the pit shall be ventilated and retested before any work begins. When testing indicates that a manhole contains either a mixture of explosive gas and air richer than safe working limits or flammable liquids, corrective measures shall be taken before work in the manhole is allowed to proceed.

7. When nitrogen is used in manholes or confined areas, approved atmosphere testing devices shall be placed in operation where they can be observed by people in the manhole. When the testing devices show a deficiency of oxygen, all personnel shall leave the manhole until the proper atmosphere is restored.

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8. The manhole shall be ventilated continuously when occupied.

9. An attendant is required topside with the means to summon help without leaving his or her station. The attendant shall be capable of instituting a rescue without entering the manhole. The attendant on the surface is responsible for the safety of the persons in the manhole.

10. The topside attendant can perform other duties outside of the enclosed space if these duties do not distract the attendant from monitoring employees within the space. All manholes over 4 ft. deep should be entered with the use of a ladder as required by 29 CFR 1910.269 (t)(1).

11. Workers should open all entrance bars or chains on the topside of manhole guards before entering or leaving a manhole. All chains or bars should be closed at all other times, except when raising or lowering tools or materials.

12. Operations involving chemical cleaning agents, solvents, volatile chemicals, cutting and welding equipment, and other hazardous agents or tools require additional consideration. Consultation with and concurrence of appropriate industrial safety and industrial hygiene personnel are required.

13. The employee shall enter or leave a manhole by means of a ladder. The employer shall not use a cable, cable hanger, or manhole rack as a support for climbing. A manhole ladder should never be removed while a worker is in the manhole unless absolutely necessary. In the instance of a ladder being removed to make it easier to rescue a worker, the topside attendant shall fully devote his or her attention and efforts to instituting a rescue using the worker’s body harness and lifeline if necessary. The ladder shall be replaced as soon as practical.

    Note: The other worker(s) in the hole should be warned that the ladder is to be removed in time to allow him or her to exit the hole if necessary.

14. Materials, tools, and equipment should be kept at a sufficient distance from the entrance to the manhole to avoid any hazard to the occupant from falling objects or from hot metal or spilled compounds.

15. Blowtorches and furnaces should be ignited before being lowered into manholes unless this creates additional hazards.

16. Rags, tape, refuse, and combustible and flammable materials should not be allowed to accumulate in a manhole.

17. Instrumentation shall be calibrated per manufacturer’s instructions. [See 29 CFR 1910.269(e)(8)]. A record of calibration should be maintained.

18. Ground-fault circuit interrupters (GFCIs) shall be used for 120-V ac power unless such power is supplied by a portable or vehicle-mounted two-wire, single-phase generator rated not more than 5 kW, where the circuit conductors of the generator are insulated from the generator frame and all other grounded surfaces. (See Section 6.4).

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19. All cables and insulated wires that do not have grounded conducting sheaths or shielding should be treated as bare conductors. They shall be considered energized unless approved methods have been used to determine that they are deenergized. Barricade or cover these conductors with protective equipment or devices that will be within reach of a worker's position.

20. Where multiple cables are present the cable to be worked on shall be identified by electrical means unless its identity is obvious. [See 29 CFR 1910.269(t)(5)]. Where cable has one or more abnormalities that could be an indication of an impending fault, the defective cable shall be deenergized, except when service load conditions and a lack of feasible alternatives require that the cable remain energized. In that case, employees may enter the manhole if they are protected by the affects of the failure by flash blankets or other devices capable of containing the adverse effects of the fault. [See 29 CFR1910.269(t)(7)].

7.10.2 WORKING ON ENERGIZED UNDERGROUND CABLES

In general, work should not be performed on energized underground cables. However, strictly external work, not requiring an appreciable change in location of the cable, may be performed under direct supervision. Energized cables that are to be moved shall be inspected for defects. [See 29 CFR 1910.269(t)(6)].

7.10.3 TERMINALS OF UNDERGROUND CABLES (POTHEADS)

Before work is started, the overhead line connections to a cable terminal upon which work is to be performed should be either:

1. Deenergized and grounded or

2. Disconnected and covered with protective equipment.

7.11 FERRO-RESONANCE

Ferro-resonance can generate overvoltages of up to 12 times line-to-ground source voltage upon opening of a single-phase device or a poorly synchronized three-phase device. Violent failure can occur, exposing personnel to the high-voltage failure and accompanying conditions. Ferro-resonant conditions can result in damage to lightning arresters, switching devices, buried cable, transformers, and associated equipment.

Ferro-resonance can be initiated when all of the following elements are present and the switching means at dip point or takeoff is either a single-phase device or an unsynchronized three-phase device that does not operate all phases within 1/2 cycle:

1. System grounded at the source but with no ground at the transformer bank, such as a transformer or transformer bank connected delta on a grounded-wye system.

2. Shielded cable or overhead conductor length sufficient to create the capacitance necessary.

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3. Transformer size that permits saturation of the iron core at the operating voltage

4. Transformer unloaded or very lightly loaded.

Prevention or control of ferro-resonance may be accomplished by any of the following measures:

1. Using a wye-wye transformer connection with both neutrals grounded and tied to the system neutral.

2. Using only phase-to-neutral (not phase-to-phase) transformer connections for single-phase transformers.

3. Limiting length of underground cable between transformers and single-pole or poorly synchronized three-pole switching devices.

4. If single-pole or poorly synchronized switching devices must be used, ensuring that transformer and underground cable are loaded in excess of 2% resistive load of the transformer capacity.

5. If transformer primary is ungrounded-wye, temporarily grounding the neutrals of the transformers being switched.

6. Installing close-coupled, high-speed, three-pole switching devices to minimize the duration of the single-phase condition during opening and closing of the circuit.

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8.0 TEMPORARY WIRING

It is required that temporary wiring comply with all the requirements pertaining to permanent wiring unless specific exceptions are stated, which can be found in NEC Article 305, 29 CFR 1910.305(a)(2), and 1926.405(a)(2).

The following codes and standards will aid in designing, installing, and inspecting temporary wiring methods and using portable electric hand tools.

1. Articles 230, 305, and 400 of the National Electrical Code (NEC)

2. 29 CFR 1910.305

3. 29 CFR 1926.405

4. Table 232-1 of the National Electrical Safety Code (ANSI/IEEE C2)

5. Chapter 17 of NFPA 70B, Electrical Equipment Maintenance

6. Part I, Chapter 3 of NFPA 70E, Standard for Electrical Safety Requirements for Employee Workplaces.

8.1 REQUIREMENTS AND INSTALLATION CONDITIONS OF USE

Temporary electrical installations shall be allowed during periods of construction, remodeling, maintenance, repair, or demolition of equipment or structures or for experiments and developmental work. However, such temporary installations are not substitutes for permanent installations and shall be removed as soon as the construction, remodeling, experiment, or other special need is completed. See NEC Section 305-3(d).

8.1.1 CONTACT PREVENTION

Except as modified in Article 305, temporary wiring shall meet all the requirements of the NEC for permanent wiring to prevent accidental contact by workers or equipment.

8.1.2 VERTICAL CLEARANCES

Vertical clearance of wires, conductors, and cables above ground shall meet the requirements of NEC Section 230-24(b) and NESC Table 232-1.[1]

[1] See Appendix D, Reference Matrix.

8.1.3 WET LOCATIONS

Conductors with nonrated weather-proof insulation shall not be enclosed in metal raceways or used for wiring in tanks, penstocks, or tunnels. Receptacles used in damp or wet locations shall be approved for the purpose. When a receptacle is installed outdoors (outdoors is considered a wet location), it shall be contained in a weatherproof enclosure, the integrity of which would not be affected when an attachment plug is inserted.

All temporary lighting strings in outdoor or wet locations, such as tunnels, culverts, valve pits, outlets, and floating plants, shall consist of lamp sockets and connection plugs permanently molded to the hard service cord insulation.

8.1.4 SUPPORTS

Bare or open conductors shall be insulated from their supports. This requirement prevents arcing, sparking, or flash-over to grounded objects. Open wiring for temporary installations is only allowed as per NEC Section 305-4(b) and (c) Exceptions.

8.1.5 CONDUIT

Temporary wiring installed in conduit shall have bushings at all outlets and terminals to prevent abrasion and damage to the insulation.

8.1.6 LIGHTING

All lamps for general illumination should be protected from accidental contact or breakage. Metal-case sockets shall be grounded.

Temporary lights shall not be suspended by their electric cords unless cords and lights are designed for this means of suspension. Temporary lighting used in damp, wet, or hazardous areas shall be marked as suitable for use in those locations.

Portable electric lighting used in wet or other conductive locations (for example, drums, tanks, and vessels) shall be operated at 12 V or less. However, 120-V lights may be used if protected by a ground fault circuit interrupter (GFCI).

Receptales on construction sites shall not be installed on branch circuits that supply temporary lighting. [See NEC Section 305-4(d)]

8.1.7 CONFINED SPACES

When temporary wiring is used in tanks or other confined spaces, an approved disconnecting means (identified and marked) shall be provided at or near the entrance to such spaces for cutting off the power supply in emergencies.

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Portable electric lighting used in confined wet or hazardous locations such as drums, tanks, vessels, and grease pits shall be operated at a maximum of 12 V, be intrinsically safe, or be protected by a GFCI circuit.

8.1.8 EXPOSED SOCKETS AND BROKEN BULBS

Exposed empty light sockets and broken bulbs shall not be permitted. This rule is to protect personnel from accidentally contacting the live parts in the socket and being shocked.

8.1.9 GROUND FAULT PROTECTION FOR PERSONNEL

Temporary power to equipment used by personnel shall be protected by GFCI devices, where required, or included in an assured equipment grounding conductor program, where permissible. See NEC Section 305-6, 29 CFR 1926.404(a)(3)(b), Sections 2.7 and 8.3 for further information.

8.1.10 WIRING METHODS

The requirements for temporary wiring for power and lighting purposes include provisions for wire connections, junction boxes, and overcurrent protection, as well as the use of conductors. See NEC Article 305.

8.1.10.1 SERVICE CONDUCTORS

Service conductors shall comply with all the provisions of Article 230 in the NEC when they are used as wiring methods to supply temporary power systems.

8.1.10.2 FEEDER CONDUCTORS

Feeders are the conductors that transmit power from the service equipment to the distribution panelboard or between the main disconnect and the branch circuit over current devices (circuit breakers, fuses). Feeders for temporary wiring shall originate inside an approved distribution center, such as a panel board, that is rated for the voltages and currents the system is expected to carry. Some equipment is manufactured specifically for temporary use.

Feeders can be run as cable assemblies, multiconductor cords, or cables with two or more conductors each with their own insulations, run together in the same cord or cable.

8.1.10.3 BRANCH CIRCUIT CONDUCTORS

Branch circuits are the conductors between the last overcurrent device in an electrical system and the outlets, such as receptacles, lighting outlets, and outlets for electrical equipment wired directly into a circuit. Branch circuits for temporary wiring shall originate inside an approved panelboard or power outlet that is rated for the voltages and currents the system is expected to carry. As with feeders, branch circuit conductors can be contained within multiconductor cord or cable assemblies.

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8.1.10.4 NONMETALLIC SHEATHED CABLE

Nonmetallic sheathed cable shall be used as allowed by the NEC and as follows:

1. Along studs, joists, or similar supports closely following the building finish or running boards when 7 ft 8 in. or more above the floor
2. When firmly attached to each cabinet, box, fitting, or fixture by means of a cable clamp.

Nonmetallic sheathed cable shall not be used where precluded by the NEC as follows:

1. As portable extension cords
2. Lying on the ground subject to any type of traffic
3. Where subject to frequent flexing
4. As service entrance cable.

See Figure 8-1 for a detailed illustration of installing temporary wiring methods. NOTE: The 1996 NEC does not permit open wiring or conductors except as allowed in NEC Section 305-4(b) and (c) Exceptions.

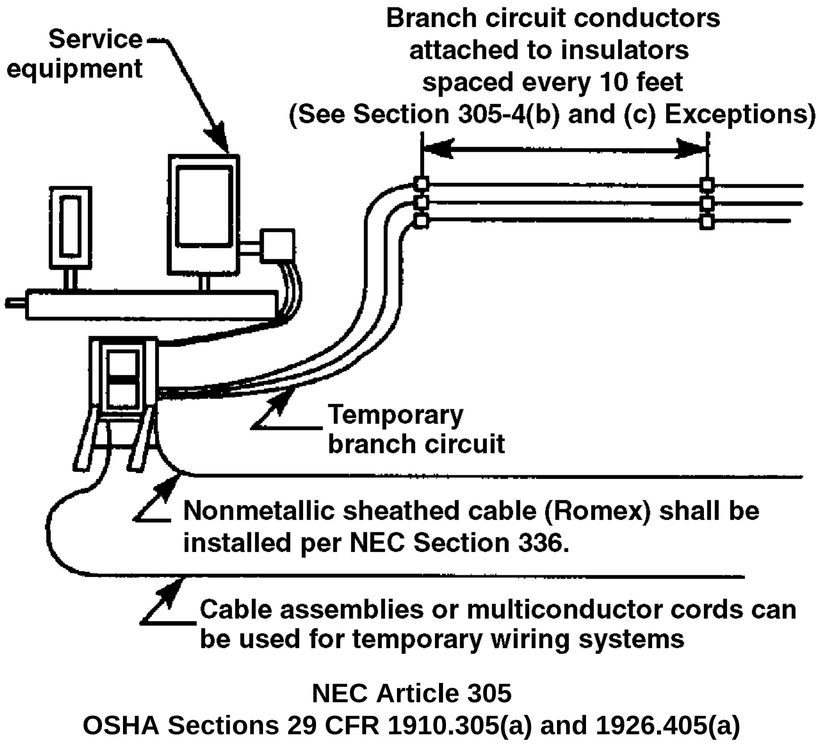

Figure 8-1. Cables, cable assemblies, or multiconductor cords can be used for temporary wiring systems under certain conditions of use.

8.2 USING ASSURED EQUIPMENT GROUNDING CONDUCTOR PROGRAM

Where GFCI devices are not used (See Section 2.7), the employer shall establish and implement an assured equipment grounding conductor program on construction sites covering all cord sets, receptacles that are not a part of the building or structure, and equipment connected by cord and plug that are available for use or used by employees. This program shall comply with the following minimum requirements:

1. A written description of the program, including the specific procedures adopted by the employer, shall be available at the job site for inspection.

2. The employer shall designate one or more competent persons to implement the program.

3. Each cord set, attachment cap, plug and receptacle of cord sets, and any equipment connected by cord and plug, except cord sets and receptacles that are fixed and not exposed to damage, shall be visually inspected before each day's use for external defects such as deformed or missing pins or insulation damage and for indications of possible internal damage. Equipment found damaged or defective shall not be used until repaired.

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

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

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

5. All required tests shall be performed:

    a. Before first use

    b. Before equipment is returned to service following any repairs

    c. Where there is evidence of damage.

    d. At intervals not to exceed 3 months, except that cord sets and receptacles which are fixed and not exposed to damage shall be tested at intervals not exceeding 6 months.

6. The employer shall not make available or permit the use by employees of any equipment that has not met the requirements of this section.

7. Tests performed as required in this section shall be recorded. This test shall identify each receptacle, cord set, and cord-and-plug-connected equipment that passed the test and shall indicate the last date it was tested or the interval for which it was tested. This record shall be kept by means of logs, color coding, or other effective means and shall be maintained until replaced by a more current record. The record shall be made available on the job site for inspection.

For further information, reference NEC Section 305-6 and 29 CFR 1926.404(b) and Figure 8-2.

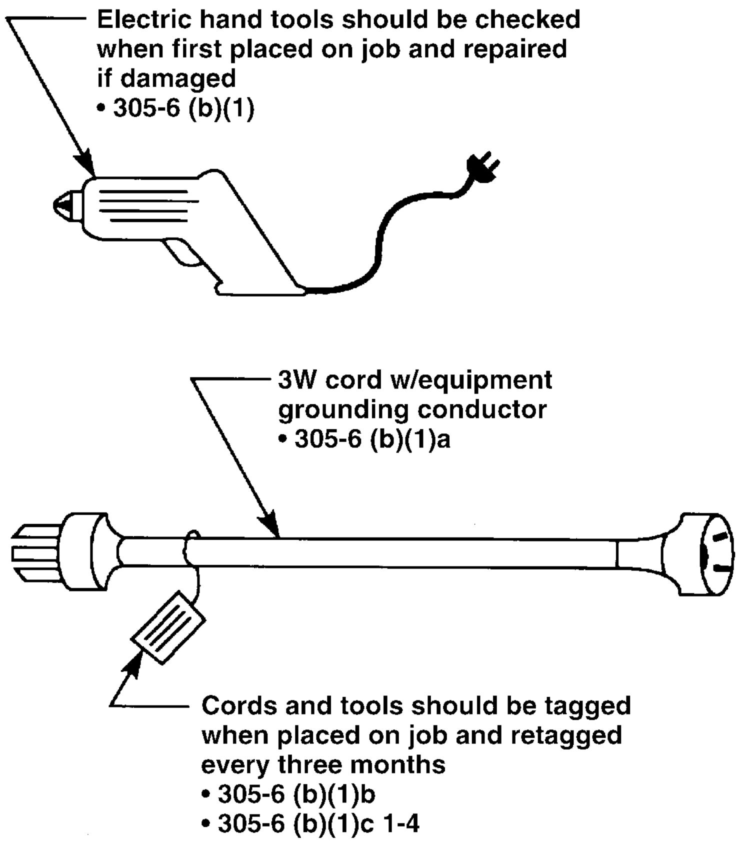

Figure 8-2. An assured equipment grounding program may be used if approved by authority having jurisdiction.

8.3 PORTABLE ELECTRICAL TOOLS AND EQUIPMENT

The electrical preventive maintenance (EPM) program should include the essential ingredients of Chapter 17 of NFPA 70B, Portable Electrical Tools and Equipment, and ANSI/UL 45, Portable Electric Tools. This includes employee training, maintenance, cord and attachment plug care, extension cords, major overhauls, and leakage current testing.

8.3.1 INSPECTION AND MAINTENANCE

Portable electric tools and equipment such as cords, plugs, and GFCIs should be inspected before use by both the issuer and the user for signs of chaffing, cracking, wear, or other forms of faulty insulation; evidence of a faulty grounding conductor, cracked plug, or receptacle housing; bent or missing plug or connector prongs; dead front plugs, receptacle, or connectors; a missing, bent, or otherwise abused switch; or an improperly functioning trigger lock (dead-man's switch). While in use, tools and equipment should be observed for proper operation, including any signs of overheating or excessive sparking. Portable electric tools, equipment, and GFCIs should be inspected or trip tested by the user each day before use. Signs of a defect shall require the return of the device for repair.

8.3.2 CONDITIONS OF USE

Portable electric tools, equipment, and GFCIs shall not be used in hazardous locations unless marked to indicate suitability for such use.

Portable electric tools and equipment shall not be handled or suspended by their cords. Tools and equipment shall be used only for their intended purpose, and when guards are required, such guards shall be in place and functional.

Tools and equipment shall be grounded via the case, double-insulated, specially approved low voltage types, or self-contained, battery-operated. (See NEC Section 250-45).

Tools and equipment used in damp areas should be approved for such use. Generally, electrical tools are not approved for use in wet or damp areas without other means of protection.

8.3.3 USE OF EXTENSION CORDS

Use of extension cords should be minimized. Such cords shall be suitable for the intended use, such as waterproof connectors for wet or damp areas, and are subject to the same conditions as the tool or equipment cord.

For the conditions of use pertaining to flexible cords, refer to NEC Sections 240-4, 400-7, 400-8, Ex. 3, and 29 CFR 1926.405(g).

Extension cords should be visually inspected before each use.

Extension cord sets used on construction sites and used with portable metal electric tools and appliances shall be of three-wire type and shall be designed for hard or extra-hard usage. Flexible cords used with temporary and portable lights shall be designed for hard or extra-hard use. OSHA recognizes hard-service cord (types S, ST, SO, and STO) and junior-hard service cord (types SJ, SJO, SJT, and SJTO) as suitable for extra-hard and hard use.

Note: Extension cords approved for outdoor use may be identified by "outdoor" or "W-A" on the jacket.

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Flexible cord sets shall be listed as an assembly by a national recognized testing laboratory (See Section 2.5). Flexible cord sets used on construction sites shall contain the number of conductors required for the circuit plus an equipment grounding conductor. The cords shall be hard use or extra-hard use as specified in the NEC.

8.3.4 DOUBLE INSULATED TOOLS

The NEC references the use of Double Insulated Tools in NEC Sections 250-42(f) Ex. 4, 250-45(b) Ex. 3, 250-45(c) Ex., 250-45(d) Ex. 2, 422-8(d)(2), 625-9(a), 625-9(b) Ex., 625-9(d) Ex., 680-22(a) Ex. 4, 680-28, and 680-30. UL Standard UL 1097 "Double Insulation Systems for Use in Electrical Equipment" provides the requirements for equipment marked "Double Insulation" or "Double Insulated". Since the end product standard take precedence, the end-product UL Standard should also be consulted when there are questions pertaining to products that require double insulation.

Double insulation is a system comprised of two insulation systems (basic and supplementary) that are physically separted and are not subjected to temperature, contaminants and other deteriorating factors at the same time.

Basic insultion is applied to live parts to provide protection against electrical shock. Supplementary insulation is independent of the basic insulation and provides protection against electrical shock in case of failure of the basic insulation. Also of importance is the reinforced insulation which consists of one or more layers of insulating material that, in itself, provides the same degree of protection as double insulation.

For example, two layers of insulation separating an armature lamination from an armature conductor is not double insulation. This is reinforced insulation. To achieve a double insulated system, one layer of insulation separates the armature lamination from the armature conductor (basic insulation) and an insulating sleeve provides a second layer between the armature lamination and the motor shaft (supplementary insulation).

Generally, double insulated equipment is constructed so that double insultion is provided between all live parts and (1) the accessible surfaces of the equipment, and (2) all inaccessible parts and surfaces that are conductively connected to the accessible surfaces of the equipment.

Under certain conditions, reinforced insulation systems are acceptable when applied to brushcaps; brushholders; commutator and end turns of armature winding switches; power supply cords; and internal wiring.

Power supply cords for double-insulated tools shall be jacketed and shall not include a grounding conductor.

"Double insulated" or "double insulation" must be permanently marked on the tool. In addition the double insulated symbol (a square within a square) may be used.

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9.0 ENCLOSED ELECTRICAL/ELECTRONIC EQUIPMENT

9.1 PURPOSE

This section provides guidelines to

1. complement existing electrical codes and recommend industry standards,
2. improve electrical safety in the work environment for personnel within the DOE complex.
3. eliminate the ambiguity and misunderstanding in design, construction and implementation requirements for electrical/electronic equipment, and
4. assist the Authority Having Jurisdiction in providing information for acceptance of equipment within the scope of this document.

9.2 SCOPE

This section addresses enclosed electrical/electronic equipment electrical safety guidelines which are not specifically addressed elsewhere in the *Electrical Safety Handbook.*

These types of equipment include: instrumentation and test consoles; enclosed electrical/electronic equipment; other laboratory diagnostic electrical/electronic equipment (stationary or mobile) mounted in or on an enclosure or chassis; and special electrical/electronic equipment facility requirements.

9.3 GROUNDING AND BONDING

Many ground system types exist within electrical equipment. All metal parts of electrical equipment enclosures and chassis shall be bonded and grounded as per the NEC. The methods chosen to avoid ground loops and reduce noise shall meet the requirements of the NEC (See Section 4).

9.3.1 OBJECTIONAL CURRENT OVER GROUNDING CONDUCTORS

Enclosed Electrical/Electronic equipment has both power and signal conductors entering and leaving these enclosures. Objectional currents and noise may be the result of the design or installation of conductors and equipment and their grounding locations. NEC Section 250-21 addresses these objectional currents and noise (See Section 10.9.2.1).

NEC Section 250-21 must be used with care because it seems to give blanket authority to do whatever is necessary to stop objectionable currents from flowing in the grounding system. This is not the intent. This article specifically excludes modifying grounding systems in order to overcome noise that may be causing problems in sensitive electronic equipment.

This NEC Section principally deals with objectionable currents that can flow over grounding conductors due to severely unbalanced loads or improper installation practices. Because of the

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complexity and number of interconnections of most grounding systems, the NEC allows modifications of the grounding system and connections in order to address such problems. Those permitted:

1) Arrangement to prevent objectionable current. Grounding of electric systems, circuit conductors, surge arresters, and conductive noncurrent-carrying materials and equipment shall be installed and arranged in a manner that will prevent an objectionable flow of current over the grounding conductors or grounding paths.

   Use of a single-point grounding system, as well as meeting the other requirements of Article 250, will usually overcome problems.

2) Alterations to stop objectionable current. If the use of multiple grounding connections results in an objectionable flow of current, one or more of the following alterations are permitted to be made, provided that the requirements of NEC Section 250-51, are met. Such permitted alterations are:
   1. Discontinue one or more, but not all, of the grounding connections;
   2. Change the locations of the grounding connections;
   3. Interrupt the continuity of the conductor or conductive path interconnecting the grounding connections; and/or
   4. Take other suitable remedial action satisfactory to the authority having jurisdiction.

3) Temporary currents resulting from accidental conditions, such as ground-fault currents, that occur only while the grounding conductors are performing their intended protective functions shall not be classified as objectionable. This does not prohibit changes in the system to correct excessive current during a fault condition.

4) Limitations of permissible alterations. The intent of NEC Section 250-21 is not that of permitting electronic equipment to be operated on AC systems or branch circuits that are not grounded as required by Article 250. Currents that introduce noise or data errors in electronic equipment are not considered to be the objectionable currents addressed in this Section.

   Voltage differences do exist because impedances to ground are not equal throughout a grounding system due to variations of the resistance of the earth, improper connections, or other problems.

   Even though voltage differences allow unwanted currents to flow in the grounding conductors, and induced noise may travel over this path, it is not to be used as a reason to disconnect the grounding connections.

9.3.2 EQUIPMENT GROUNDING CONDUCTOR

The equipment grounding conductor of a power-supply cord or interconnecting cable should be at least the size of the largest circuit conductor in the power-supply cord or interconnecting cable. (ANSI/ISA-S82.01-1988 - Section 9.5.4.2)

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9.3.3 ENCLOSURE GROUNDING AND BONDING

Enclosure grounding and bonding should comply with the following requirements: (See Figs. 9-1 thru 9-3)

1) Have a common grounding or bonding bus (normally a cabinet rail).

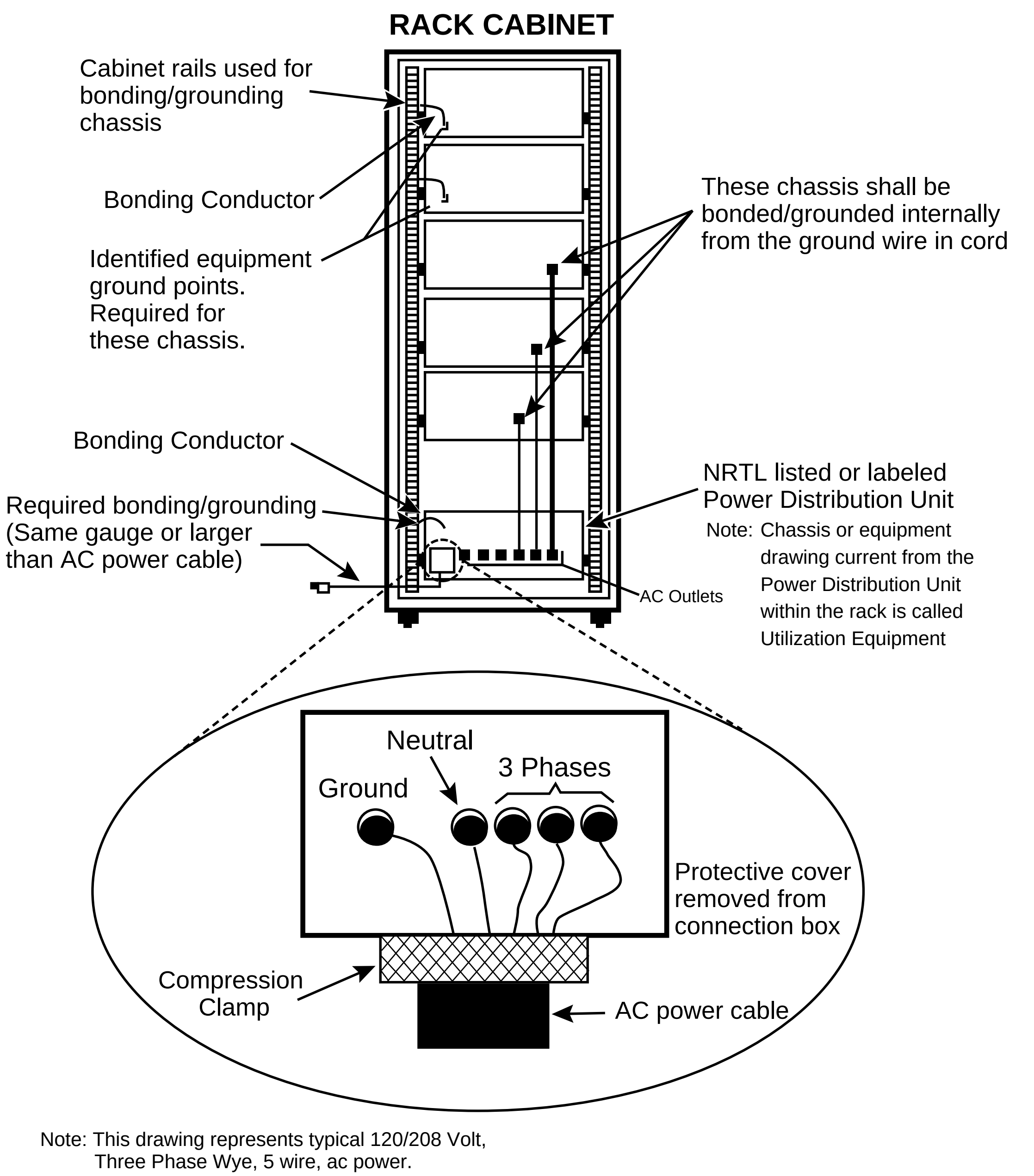

Figure 9-1

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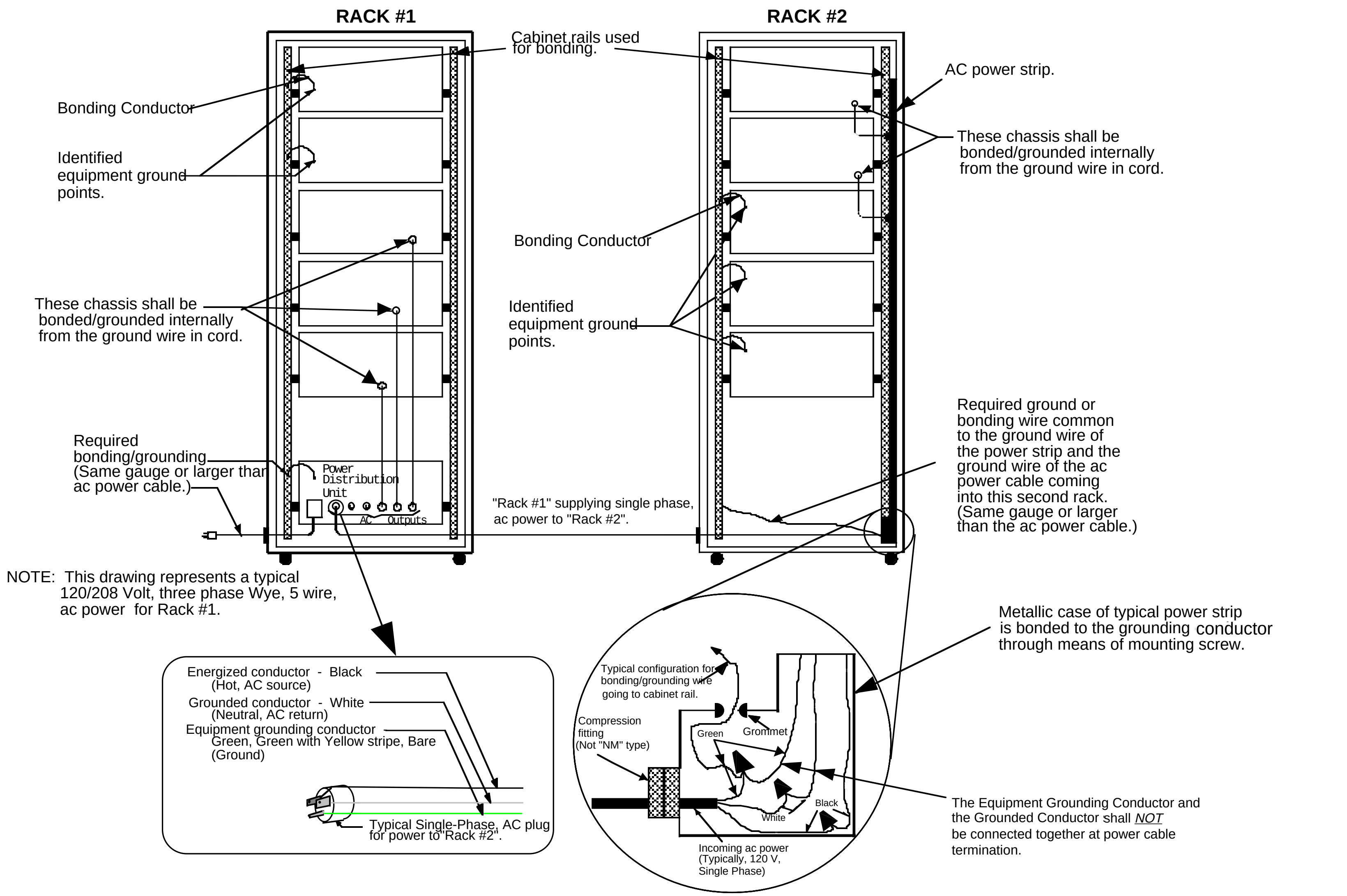
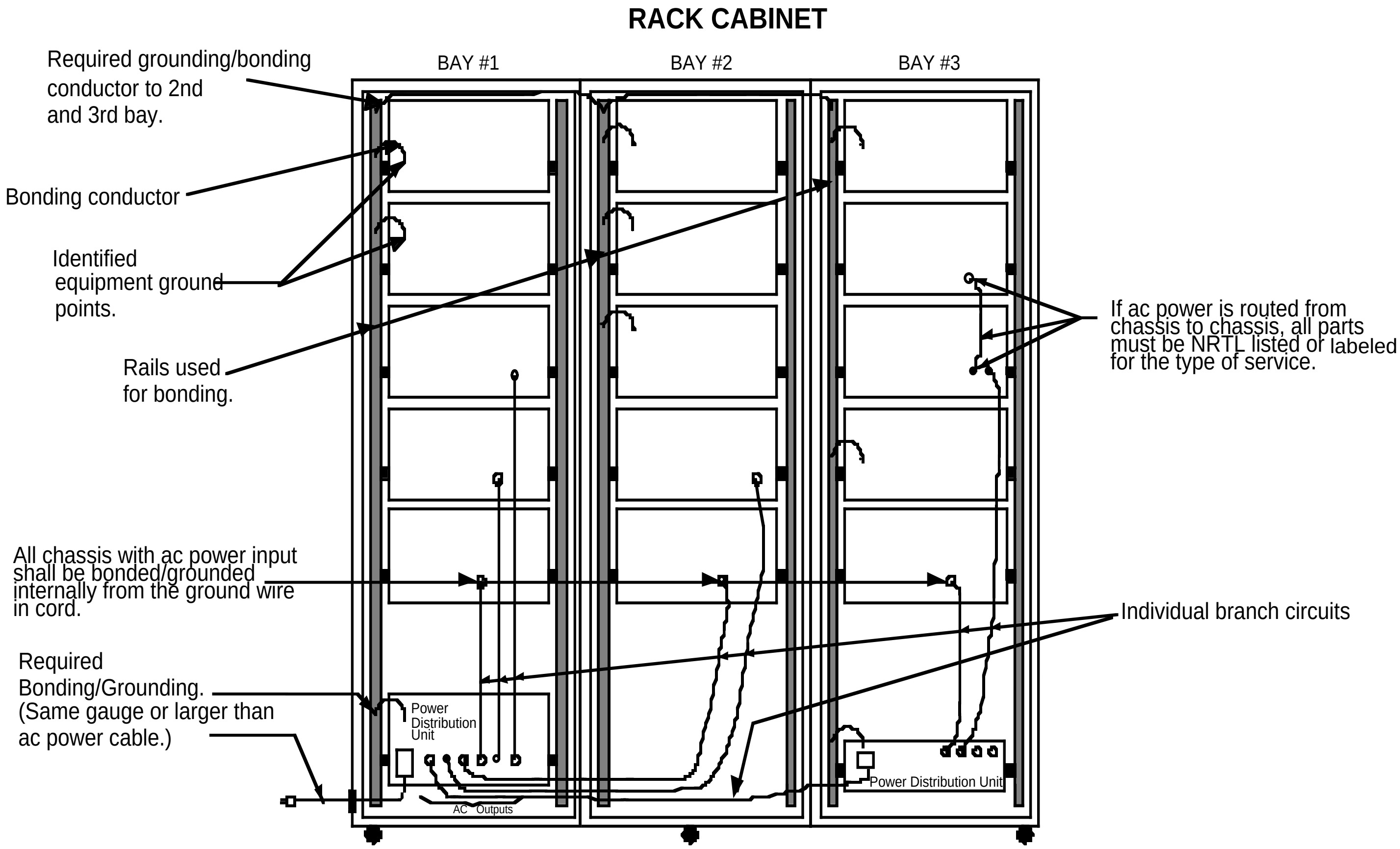

RACK #1
RACK #2
Cabinet rails used for bonding.
AC power strip.
Bonding Conductor
Identified equipment ground points.
These chassis shall be bonded/grounded internally from the ground wire in cord.
Bonding Conductor
Identified equipment ground points.
These chassis shall be bonded/grounded internally from the ground wire in cord.
Required bonding/grounding (Same gauge or larger than ac power cable.)
Power Distribution Unit
AC Outputs
"Rack #1" supplying single phase, ac power to "Rack #2".
Required ground or bonding wire common to the ground wire of the power strip and the ground wire of the ac power cable coming into this second rack. (Same gauge or larger than the ac power cable.)
NOTE: This drawing represents a typical 120/208 Volt, three phase Wye, 5 wire, ac power for Rack #1.
Metallic case of typical power strip is bonded to the grounding conductor through means of mounting screw.
Energized conductor - Black (Hot, AC source)
Grounded conductor - White (Neutral, AC return)
Equipment grounding conductor Green, Green with Yellow stripe, Bare (Ground)
Typical Single-Phase, AC plug for power to "Rack #2".
Typical configuration for bonding/grounding wire going to cabinet rail.
Compression fitting (Not "NM" type)
Green
Grommet
White
Black
Incoming ac power (Typically, 120 V, Single Phase)
The Equipment Grounding Conductor and the Grounded Conductor shall NOT be connected together at power cable termination.

Figure 9-2



NOTES:
1. This drawing represents typical 208/120-V, Three Phase Wye, 5 wire, ac power for Rack #1.
2. Multiple bays must be bonded together even if multiple Power Distribution Units are installed in separate bays.

Figure 9-3

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2) When the enclosure contains more than one bay, bond all grounding or bonding busses together.
3) All mounted chassis within rack cabinets shall have a grounding or bonding conductor attached to the common grounding or bonding bus when the chassis is not grounded or bonded through the power cord.
4) The grounding or bonding conductor shall be permanent and continuous.
5) Subassemblies mounted in other types of enclosures should be bonded by adequate preparation of the mounting surfaces or by the use of a bonding conductor.
6) To provide protection against grounding or bonding conductor breakage, conductors between the common grounding or bonding bus and moveable chassis should be braided cable or stranded wire.

All grounding or bonding points should be tight for good continuity, identified by green color, permanently labeled, and properly prepared by cleaning metal surfaces to bare metal or by the use of serrated bushings. Anodized aluminum must be cleaned to bare metal.

The resistance across the bonding point should not be more than 0.1 ohm. If a measurement is required, the method of measurement is to be determined by the user. (See ANSI/ISA - S82.01 - 1988 - Section 9.5.2)

9.3.4 SPECIAL CONSIDERATIONS

Systems feeding power isolation transformers must continue the equipment grounding conductor to the equipment or the ungrounded equipment must be guarded and labeled.

For two-wire cord connected equipment, an equipment grounding connector should be installed according to the manufacturer's instructions.

9.4 RACK POWER DISTRIBUTION

The following guidelines will provide the necessary information to correctly install power distribution equipment within instrumentation racks containing electrical and electronic equipment.

9.4.1 GENERAL REQUIREMENTS APPLYING TO ALL AC POWER EQUIPMENT WITHIN OR ATTACHED TO INSTRUMENT RACKS

9.4.1.1 LOADS

Knowledge of the loads that will be connected within a rack cabinet is necessary before starting design of a rack power distribution system. All components must be sized correctly for the loads and should provide for expansion.

Equipment enclosures may or may not contain a power distribution unit. A rack power distribution unit contains a main overcurrent protection device and multiple branch circuits that are individually protected against overcurrent. Without a power distribution unit, the power wiring is considered part of one branch circuit.

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Branch circuit loading shall meet the requirements of Article 210 of the NEC. (See NEC Sections 210-21 through 210-23).

External convenience outlets should be connected to a separate circuit breaker.

Where 3 phase 4 wire service is utilized, the loads should be evenly distributed on all phases and there should be consideration of sizing the neutral conductor for certain loads (such as computer equipment) due to the presence of harmonic currents. (See NEC Sections 210-4 and 310-10).

9.4.1.2 OTHER GENERAL EQUIPMENT REQUIREMENTS

Rack power distribution components or assemblies must be listed by a Nationally Recognized Testing Laboratory (NRTL), nationally recognized standards, or have the approval of the Authority Having Jurisdiction (See Section 2.5).

9.4.2 CONDUCTORS AND CABLES SPECIFIC REQUIREMENTS.

Each type of internal wiring for equipment or an accessory shall be acceptable for the particular application when considered with respect to (1) the current, ambient temperature, voltage, and other conditions of service to which the wiring can be subjected, and (2) exposure to oil or grease.

The term “cables” refers to groupings of wires typically used for control signals, data, or DC power. The term “cords” refers to AC power cords.

The basic insulation on each wire shall be rated for at least the maximum voltage to which the wire is connected, and for at least the temperature it attains. (ANSI/ISA-S82.01-1988 Section 9.4.3)

Insulating tubing, sleeving, and tape shall be rated for at least the maximum voltage against which it insulates, and for at least the temperature it attains. (ANSI/ISA-S82.01-1988 Section 9.4.4)

Power and signal wires should be routed separately within a chassis.

Wires shall be routed away from sharp edges, screw threads, burrs, moving parts, etc. Holes through which wires are routed shall have smooth, well-rounded surfaces, or shall have a bushing. Clamps for guides used for routing or wiring shall have smooth, well-rounded edges. Pressures exerted by such clamps should not cause cold-flow or otherwise deform the basic insulation. (ANSI/ISA-S82.01-1988 Section 9.4.2)

9.4.2.1 FLEXIBLE CABLES

Flexible cables may be used:

1. Where flexible cables and attachment plugs are furnished by the manufacturer as part of the equipment to be mounted in the rack.
2. For connection of stationary equipment to facilitate their frequent interchange.
3. To prevent the transmission of mechanical vibration.

4. Where the fastening means and mechanical connections are specifically designed to permit ready removal for maintenance and repair.
5. For data processing cables approved as part of the data processing system.
6. For temporary wiring.

Where breaking or loosening of a circuit connection would render an electric shock or could result in a fire, such connection shall be made mechanically secure. Mechanical security of connections may be provided by crimped, closed ring or flanged lug, or a wrapping that forms at least an open U or by cable clamps, or by cable lacing, insulating tubing, or similar means.

9.4.2.2 STRAIN RELIEF

Wiring, cords, or cables shall be provided with strain relief as required to prevent damage.

Additional insulation may be required when the construction of the strain relief may damage the insulation. The use of type NM (Romex) cable clamps on flexible cords and cables is not permitted. Use listed or labeled clamps. The use of any metal clamp or other means that may cause undue stress on the cables within or external to instrument racks is not allowed. Cord and cable support for AC power cable or other heavy duty or large diameter cables must distribute the load over a large area of the outer covering of the cable.

9.4.2.3 SEPARATION OF VOLTAGES

Insulated conductors of different circuits shall be separated or segregated from uninsulated live parts connected to different circuits unless provided with insulation suitable for the highest voltage involved.

Segregation of insulated conductors may be accomplished by clamping, routing, or equivalent means that provide permanent separation from insulated or uninsulated live parts of a different circuit.

Loose strands of stranded internal wiring, connected to a wire-binding screw, shall be prevented from contacting other uninsulated live parts not always of the same potential and from contacting noncurrent carrying metal parts. This may be accomplished by use of pressure terminal connectors, soldering lugs, crimped eyelets, or soldering all strands of the wire together.

9.4.2.4 OTHER CONCERNS

Conductors shall not be bundled together in such a way that the temperature rating of the conductors is exceeded.

Flexible cord should be used only in continuous lengths without splice or tap when initially installed.

Repairs are permitted if the completed splice retains the insulation, outer sheath properties, and usage characteristics of the cord being spliced.

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9.4.3 POWER SWITCHES AND INTERLOCK DEVICES SPECIFIC REQUIREMENTS

For all electrical/electronic enclosures utilizing power switches or interlocks, the following should apply:

1. Interlocks should be utilized where exposed voltages (50 volts or greater) are present in equipment and access to the exposed live parts is not controlled (See Section 9.6.4).
2. Ensure all line side unprotected contacts are guarded on interlocking contactors or other switching equipment.
3. Be suitable for the conditions, use, and location.
4. Circuit breakers used for the equipment power switch will be rated for switching under load.
5. Provide provisions for Lockout/Tagout requirements.

9.5 CHASSIS POWER DISTRIBUTION

Manufacturers are responsible for determining the safety of such chassis and/or enclosures and for providing documentation showing how that determination was made. Unlisted commercial equipment and in-house fabricated equipment shall be approved by the local Authority Having Jurisdiction.

9.5.1 AC POWER DISTRIBUTION

9.5.1.1 CHASSIS BONDING AND GROUNDING

Metal chassis shall be effectively bonded to a main grounding point in the rack cabinet where necessary to assure electrical continuity and shall have the capacity to conduct safely any fault current likely to be imposed on it. (NEC Section 250-75)

In a chassis with ac service connected to it, the grounding terminal of its receptacle shall be internally bonded to the chassis frame. (NEC Section 250-74)

If solder is used, the connection of the equipment grounding conductor shall not depend on solder alone. (ANSI/ISA-S82.01-1988 - Section 9.5.4.4 and NEC Section 250-115)

The leakage current of cord connected equipment should not be more than specified in Subclause 9.11 of ANSI/ISA-S82.01-1988.

9.5.1.2 CONNECTIONS, CONNECTORS, AND COUPLINGS

Input/output ac power connections to the chassis shall comply with NEC requirements.

The exposed, noncurrent carrying, metal parts of panel mount connectors operating at 50 volts or greater shall be bonded to the chassis.

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Plugs and sockets for connecting any AC power source shall be NRTL approved for the application. (Ref. ISA-S82.01-1992, Section 6.10.3.a)

AC power plugs and sockets shall not be used for purposes other than the connection of AC power.

Connectors operating at 50 V or greater shall be rated or recommended for their intended use.

Any connector used to provide power at 50 V or greater shall not allow personnel to make inadvertent contact with the power source.

If plug pins of cord-connected equipment receive a charge from an internal capacitor, the pins shall not be capable of rendering an electric shock or electric burn in the normal or the single fault condition 5 seconds after disconnection of the supply. (Ref. ISA-S82.01-1992, Section 6.10.3.c)

Plug-in type connectors intended to be connected and disconnected by hand shall be designed so that the grounding conductor connection makes first and breaks last with respect to the other connections. [See ISA-S82.01-1992, Section 6.11.2.g and NEC Section 250-99(a)]

The following applies for all AC power connectors within or external to electrical/electronic enclosures:

1. There should be no exposed current-carrying parts except the prongs, blades, or pins.
2. The connector shall prohibit mating of different voltage or current rating than that for the device intended.
3. All connectors must be protected against overcurrent in accordance with their rated ampacity. (NEC Section 240-4)
4. Connectors must be NRTL approved for the application.
5. Use of MS, PT, or other non-approved connectors is not permitted except when justified to and approved by the AHJ.

If conditions require the use of a non-NRTL listed or labeled connector, such as a “MS”(military standard pin and socket type) or “PT” (similiar to “MS” but smaller) type, for input/output ac power, a warning label should be affixed next to the connector stating: “WARNING - POWER MUST BE REMOVED BEFORE CONNECTING/DISCONNECTING.”

9.5.1.3 TERMINALS/LIVE PARTS

All terminals/live parts with a potential of 50 volts or greater shall be guarded to protect from accidental contact or bringing conductive objects in contact with them (NEC Section 110-17). Consult ANSI/ISA-S82.01-1988, Table 9-1 for spacing information regarding live parts.

All energized switching and control parts shall be enclosed in effectively grounded metal enclosures and shall be secured so that only authorized and qualified persons can have access.

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9.5.2 DC POWER DISTRIBUTION

Guidelines for dc power distribution include:

1. The metal chassis or cabinet should not be used as a return path.
2. High-current analog or switching dc power supplies should use separate return paths from digital circuits.
3. All of the guidelines pertaining to ac power such as grounding, proper wire size, high voltage, etc. should apply to dc circuits as well.

An accessible terminal charged by an internal capacitor should be below 50 volts within 10 seconds after interruption of the supply. (ANSI/ISA-S82.01-1988 - Section 9.3.5.2)

As with ac power, avoid contacting dc parts when working on a live chassis. The use of the appropriate class gloves should be considered when performing this type of work.

9.6 PROTECTIVE DEVICES FOR ENCLOSED ELECTRICAL/ ELECTRONIC EQUIPMENT

This section deals with the various protective devices commonly found in electrical/electronic equipment not discussed elsewhere.

9.6.1 SURGE ARRESTERS

The more common types of surge arresters used with electronic equipment are the Metal oxide varistor (MOV), avalanche diodes, and spark gap arresters. The type and electrical rating of the surge arrester is generally determined by the requirements of the circuit being protected, and by the amplitude and duration of the expected surge. (See ANSI/IEEE C62.11-1986.)

Metal oxide varistors and avalanche diodes are voltage-dependent devices whose impedance changes from a near-open circuit to a highly conductive level when subjected to transient voltages above their rated voltages. A MOV is considered “sacrificial” in that a portion of its material is literally burned-off each time such a surge is encountered. The response time of a MOV is limited to approximately 500 picoseconds while avalanche diodes can respond in approximately 50 picoseconds. Lead lengths can greatly increase the response times of these devices. The normal failure mode of both devices is a short circuit although sustained voltages well beyond the rating of the MOV can cause the device to rupture and result in an open circuit. When used at a point on a circuit, a surge arrester should be connected between each ungrounded conductor and ground.

For power line applications, MOV manufacturers recommend a varistor be used with a fuse that limits the current below the level that MOV package damage could occur. In general, circuit breakers are not recommended for this application since circuit breaker tripping is too slow to prevent excessive fault energy.

Consult the manufacturer’s application data sheets for more information.

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9.6.2 FUSES

Fuses are temperature-sensitive, current-sensing elements that are generally used as short circuit protective devices in individual electrical chassis. The fusing characteristic, or opening time versus current, must be within the safe time/temperature characteristic of the device being protected.

Designers must carefully consider the load requirements in the fuse selection process, particularly when high surge currents may be encountered during initial turn-on. Operating time/current characteristics of the various types available can usually be found in fuse manufacturers catalogs. A fuse's interrupting current capacity must also be considered when connected to a power distribution system having a significant fault current capacity.

The voltage rating on a fuse shall be equal to or greater than the device's operating voltage.

In general, cartridge fuses should have a disconnecting means on the supply side, (NEC Section 240-40), and shall not be connected in parallel unless factory assembled and listed as a unit (NEC Section 240-8).

9.6.3 CIRCUIT BREAKERS

A chassis or cabinet shall not employ circuit breakers as "on/off" switches unless rated for the application by the manufacturer.

9.6.4 POWER INTERLOCK DEVICES

Cabinets and equipment having potentially dangerous currents and/or voltages present should have a means of controlling access, or a power interlock device designed to interrupt the power to the cabinet. Provisions shall also be made to discharge any stored energy, such as in capacitors or inductors, to less than 50 volts within 10 seconds when the safety interlock is opened. Interlocks may not be used as a substitute for lockout/tagout. (29 CFR1910.333(c) and ANSI/ISA S82.01-1988, Section. 9.3.5.2)

9.7 DISCONNECTING MEANS

All enclosed electrical/electronic equipment shall be provided with a means for disconnecting it from each external or internal operating energy source. This disconnecting means shall disconnect all current carrying conductors.

9.7.1 GENERAL

Interlock systems are not a recommended disconnecting means for cabinets and equipment having potentially dangerous currents and/or voltages present. (See Section 9.6.4)

Permanently connected equipment and multi-phase equipment should employ a switch or circuit breaker as means for disconnection.

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All cord-connected equipment should have one of the following as a disconnecting device:

1. A switch or circuit breaker,
2. Plug that can be disconnected without the use of a tool, or
3. A separable plug, without a locking device, to mate with a socket-outlet in the building.

Where equipment is connected to the source of supply by flexible cords having either an attachment or appliance plug, the attachment or appliance plug receptacle may serve as the disconnect (ANSI/ ISA - S82.01 - 1988 - Section 13.10.1 and NEC Section 422-22).

Where a switch is not part of a motor, motor circuit or controller, the disconnecting means should be within 50 feet and in sight of the operator and marked as the disconnection device for the equipment.

Where a disconnecting means is not part of the equipment, the disconnecting means should be near the equipment, within easy reach of the operator during normal operation of the equipment, and marked as the disconnection device for the equipment.

If a disconnecting device is part of the equipment, locate it as close as practical to the input power source.

9.7.2 EMERGENCY SHUTDOWN

The emergency shutdown switch should be within arm's reach of the operator, be easily identifiable, deenergize all power to all equipment associated with the system, be separate from the routine on/ off switch, and be located to protect the employee from moving parts. However, the emergency shutdown switch should not disconnect auxiliary circuits necessary for safety (such as cooling).

9.7.3 SPECIAL CONSIDERATIONS

The disconnecting means should interrupt the source voltage for thyristor controlled equipment. Do not rely on disconnecting the control voltage.

9.8 MARKING AND LABELING REQUIREMENTS

9.8.1 GENERAL MARKING REQUIREMENTS

For all chassis and rack cabinets (electrical, computer, power distribution, etc.), the manufacturer's name, trademark, or other descriptive marking of the organization responsible for the product should be identified.

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Other markings for power requirements are:

1. Voltage.
2. Maximum rated current in amperes.
3. Wattage.
4. Frequency (computer only).
5. Other ratings as specified in the NEC.

(See ANSI/ISA-S82.01-1988 Section 5.3.4 and NEC Section 110-21)

9.8.2 HAZARD MARKING REQUIREMENTS

All enclosures containing exposed energized circuits over 600 volts nominal should be marked "Danger High Voltage Keep Out" with a label that is permanent. These areas shall be accessible to authorized personnel only. The label shall be placed in a noticeable location on the access panel to the enclosure. Mark all other hazards that are associated with the equipment.

9.8.3 OTHER REQUIREMENTS

All equipment markings shall be of sufficient durability to withstand the environment involved and should be large enough to read.

To obtain the correct chassis load requirements for marking and labeling, monitor individual chassis while under load. Many chassis have components that are not energized except under certain conditions.

A normal current draw may be a few amperes, but when the chassis is sourcing current to a load, the current draw may be much higher. Individual loads, internal and external, may be tabulated and added to determine the chassis current labeling requirements.

For rack cabinets with power distribution units, the outside of the rack cabinet should be labeled with the input parameters of the power distribution system installed within it.

For rack cabinets without power distribution units the outside of the rack cabinet should be labeled with the total current on the combined systems installed within it.

9.9 WORKING CLEARANCES

Clear working space and headroom shall meet the NEC requirements (see Figs. 9-4 and 9-5). The clear working space and passageways to this space should not be used for storage. At least one 24 inch wide (minimum) passageway should be provided for travel to and from the clear working space.

While maintenance, repair or calibration are being performed, personnel should identify clear working spaces via suitable means such as "Danger" or "Caution" barrier tape, or barricades to keep other personnel from entering the clear working spaces. (See Section 2.9.)

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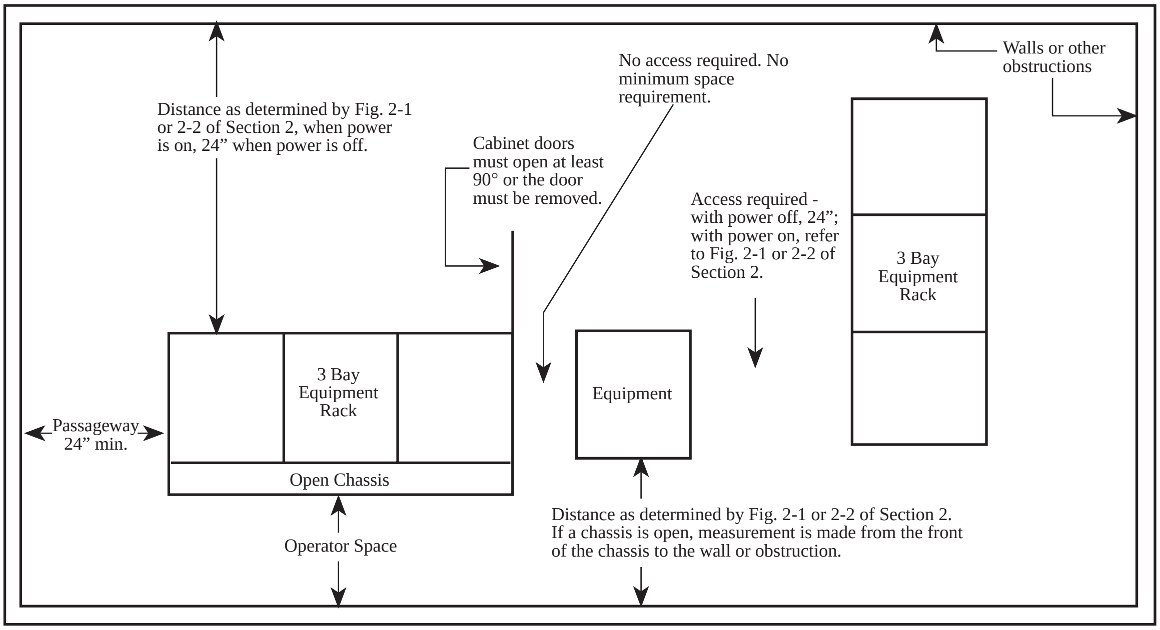

Fig. 9-4. Top View of Equipment Layout in a Room (Drawing is not to scale)

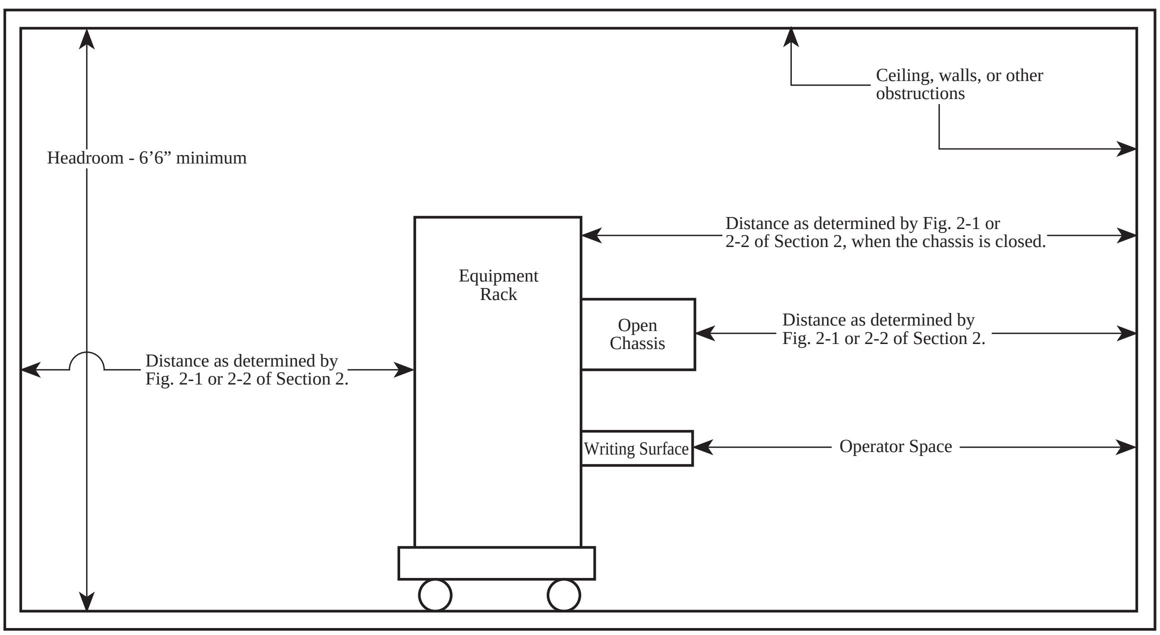

Fig. 9-5. Side View of Equipment Layout in a Room (Drawing is not to scale)

9.10 CABLE/UTILITY MANAGEMENT SYSTEM

Cable supports and/or cable enclosures are installed for dedicated usage with enclosed electrical/ electronic equipment

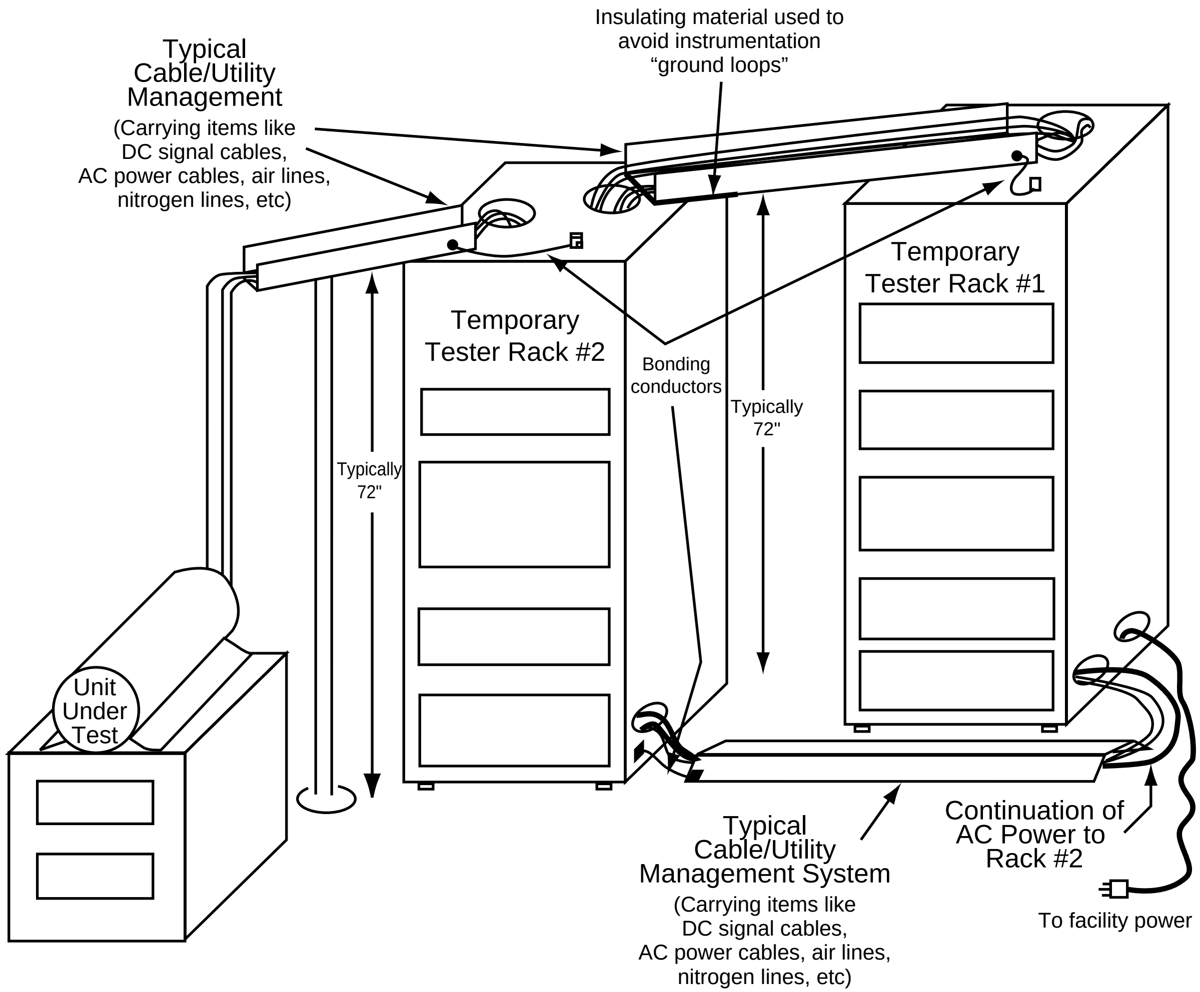

Figure 9-6

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9.10.1 USAGE WITH ENCLOSED ELECTRICAL/ELECTRONIC EQUIPMENT

In certain locations cable supports and/or enclosures are installed for dedicated usage with enclosed electrical/electronic equipment. For these situations it is acceptable for these cable/utility management systems to be utilized for the required purposes of the equipment. This may include a bundle of cables, hoses, and tubing that is required to be run from the equipment console to the unit under test. In these situations the use of a cable/utility management system is considered to be a part of custom-made equipment consisting of enclosed electrical/electronic equipment, cabling, cable/utility management system, and unit under test with associated equipment (See Figure 9-6).

In cable/utility management systems where cables other than those of the equipment exist, the decision should be documented that any risk posed by the situation is acceptable for the operation to be performed and to the functions of the existing cables.

9.10.2 REQUIREMENTS

An assessment of any hazards identified with the equipment and the operation with which it is involved should be performed to assure safe operation of components in the cable/utility management system. Where any cable/utility runs include hazardous fluids or pressurized gases, the utilization of these utilities with the cables involved must be determined to be safe.

Metallic cable/utility management systems that support electrical conductors shall be grounded or bonded to the equipment. Where cable/utility management systems are installed exclusively for electrical/electronic equipment usage and where these trays are metallic and not grounded or bonded, approved documentation shall exist stating the reason for not grounding or bonding the system (See Section 9.3.1).

Equipment cable/utility runs installed in cable/utility management systems should be visually inspected. These inspections should be performed at the time of installation and any interval specified in the equipment documentation. Any inspection should, as a minimum, consist of:

1. A visual check for the integrity of cable jackets and visible shields;
2. A check for the integrity of all utility hoses by looking and listening for leaks;
3. A visual check on all securing devices used to hold the bundle on the tray to assure the bundle is positioned properly and no damage has occurred;
4. A visual inspection on all bends for signs of pinching, cutting, exceeding minimum cable bending radius, or other damage; and
5. Documentation of all results of any inspection.

Supports shall be provided to prevent stress and physical damage to cables where they enter or exit cable/utility management systems.

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9.11 ELECTRICAL SAFETY REQUIREMENTS FOR TESTER FACILITIES

The following is not intended to encompass all of the electrical design requirements which must be considered in planning electrical systems for facilities intended to accommodate testers. The information provided should, however, provide a guide to understanding for personnel who would be tasked with specifying facility electrical safety necessary to the testing environment.

Provisions for an adequate number of receptacle outlets to accommodate cord and plug connected equipment, testers, etc., in a facility must also be considered in specifying the electrical requirements.

For equipment that cannot tolerate power interruption, consideration should be given to the use of a continuously operating or standby uninterruptable power supply (UPS) or a generator.

9.11.1 AMPACITY OF FACILITY WIRING AND DISTRIBUTION EQUIPMENT

Consideration must be given to accommodating the anticipated load demand which may occur as a result of power supplied to the various possible combinations of electrical equipment connected to a particular branch circuit (See Section 9.4).

9.11.2 FACILITY GROUNDING AT REMOTE SITES

Proper grounding is considered crucial to providing the safest possible electrical installation, from the standpoint of maximizing the safety of facility occupants and minimizing property damage and loss.

Designs for equipment to be used at remote sites must take into consideration the same grounding issues which may not be accommodated due to the lack of permanent facility power wiring (See Section 9.3).

9.11.3 FACILITY LIGHTNING PROTECTION

Lightning protection is required for facilities which will house enclosed electrical/ electronic equipment while such equipment is involved with radioactive, explosive, and similarly hazardous materials. (See Section 5.1)

9.11.4 SURGE PROTECTION

In addition to facility lightning protection, the effects of surges resulting from lightning strikes to power distribution systems may be lessened by the use of lightning arrestors and suppressors installed at strategic points in the supply system to the facility. An assessment is necessary, addressing the consequences of lightning-induced surges, in order to determine the degree to which protection should be provided.

For additional information see Section 9.6.1.

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9.12 ENCLOSED POWER ELECTRONICS

Power electronics equipment is equipment that uses electronic components and subsystems to control significant amounts of electrical energy. Examples of power electronics systems include:

1. Power supplies and modulators for laser systems;
2. Accelerators, magnets, x-ray systems, and other research equipment;
3. Radio and radar transmitters;
4. Variable speed motor drives; and
5. Induction heating systems.

All applicable portions of this section should be addressed due to the hazards involved with this type of equipment.

9.12.1 ENCLOSURES

Power electronics equipment should be constructed in all-metal enclosures for containment of fire, high energy, and electromagnetic radiation hazards.

The enclosures should support the housed equipment, provide strength to brace conductors against short circuit forces, and protect housed equipment against physical damage.

It is usually easier to provide barriers to protect the electronics enclosure from collision and missile hazards rather than strengthening the enclosure itself.

9.12.2 COMPONENT CLEARANCES

Enclosures must provide adequate clearance from energized parts. The required clearances depend on the shape of the conductor, the surface characteristics of the conductor and enclosure, the voltage characteristics, environmental conditions, and creepage. The breakdown strength along the surface of supporting insulators may require larger clearances than breakdown in air.

All power electronics enclosures shall provide adequate room for access to parts and subsystems for expected maintenance and modification. Consideration should be given to handling provisions for heavy parts and subsystems, access to test points and calibration adjustments, and work clearances for safe access to enclosure interiors.

Safe work on high-voltage equipment requires installation of manual grounding devices on exposed high-voltage conductors. Enclosure size shall provide adequate room to safely apply and remove grounding devices, and permit grounding devices to remain in place without interfering with expected work.

Enclosures shall be sized to allow cables to be installed and routed without infringing on required clearances from high-voltage conductors.

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Subassemblies, circuits, and related equipment should be segregated to the extent possible to minimize the possibility of a fault in one device damaging another.

9.12.3 INSTRUMENTATION

Power electronics systems can involve fast pulses, high frequencies and high currents and it is common for the voltage difference between ground in one circuit and ground in another circuit to differ substantially. This difference can be hundreds or thousands of volts. Wire and cable shall be insulated to withstand these potentials. Surge arrester and capacitor protection may be used to control these potentials. DC circuits connected to coils, solenoid valves and other inductive components should be tested for induced voltages and appropriate protection for circuits should be provided.

9.12.4 GENERAL

Test points needed for adjustment and diagnosis should be installed on the front panel or other appropriate location of power electronic systems to facilitate their use without exposure hazard to employees in the area.

Currents generated only during fault conditions or those introducing noise or data errors shall not be considered objectionable currents. Bonding and grounding connections shall not be altered to reduce the significance.

Conductors, busbars, and internal wiring should be insulated in the event objects are dropped into the equipment.

Automatic discharge devices are not a substitute for grounding devices used for personnel protection. Grounding points shall be located in the system and physically arranged to permit the attachment of adequate grounding devices for the protection of personnel working on the system.

These grounding points shall be capable of carrying the short-circuit current to which they may be subjected and applied using methods appropriate for the voltages or currents involved.

9.13 NON-IONIZING RADIATION

9.13.1 ELECTROMAGNETIC RADIATION

Human exposure to electromagnetic (EM) radiation at certain power-density levels can be hazardous. The hazards are generally regarded to be associated with the heating of biological tissue, which occurs when EM radiation is absorbed by a body. This heating is essentially similar to the cooking process in a microwave oven. Use caution where EM sources are being used with the shielding altered or removed.

When working with EM radiation, it is recommended that the emitted radiation levels be estimated by equations and measured by radiation hazard monitors.

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EM radiation-safe levels have been established by the Institute of Electrical and Electronics Engineers and are documented in the IEEE standard - C95.1-1991.

Exposure to hazardous levels of EM radiation can be lessened by maintaining as much distance as possible from the source. Power density is reduced by a factor of four by doubling the distance from the source.

9.13.2 ELECTROMAGNETIC RADIATION THREAT TO ELECTROEXPLOSIVE DEVICES

Designers of enclosed electrical/electronic equipment must consider the possible effects on nearby electroexplosive devices (EED) of electromagnetic radiation (EMR), i.e., radio frequency (RF) energy, emitted by that equipment.

Energy induced into an EED by the electromagnetic field resulting from such emissions may be adequate to cause the device to detonate.

Factors which should be taken into account in assessing concerns for possible EMR emissions are:

1. Wiring, shielding, and sensitivity
2. Proximity
3. Frequency of the emissions causing coupling of electrical energy
4. Power density
5. Type of emission modulation

Possible measures to mitigate the threat of EMR emissions include:

1. Enclosure and signal line shielding and grounding to prevent leakage of EMR from the equipment.
2. Designed-in physical separation or barrier which would ensure that the power density of the electromagnetic field is inadequate to cause detonation of an EED at the closest possible distance to the emission source within the equipment.
3. Filter, or provide ferrite beads for, signal lines from the equipment which may conduct EMR emissions into EED circuitry or secondarily radiate EMR in the proximity of an EED thus causing a threat of detonation.
4. Ensure that the minimal power necessary is used to operate circuitry capable of producing EMR.
5. Label the equipment capable of emitting EMR to indicate the minimum separation distance to be maintained between the equipment and an EED(s).

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10.0 RESEARCH & DEVELOPMENT

The DOE complex engages in a variety of Research & Development (R&D) activities that often incorporate the design and use of special or unusual apparatus and equipment in its facilities.

10.1 PURPOSE

Requirements of existing electrical codes, recognized industry standards, and DOE Orders do not specifically address these types of apparatus. Even with these specialized R&D needs, the workplace must be maintained free of known hazards that cause, or are likely to cause, death or serious injury. Special efforts must therefore be made to ensure adequate electrical safety beginning with design and continuing through development, fabrication and construction, modification, installation, inspection, testing, operation, and maintenance of R&D electrical apparatus and facilities. This section provides guidelines to complement existing electrical codes and recognized industry standards in conformance with DOE Orders and OSHA requirements.

Because of the differences in R&D program requirements in the DOE complex and the unpredictability of R&D activities, it is impractical to establish a single set of electrical safety requirements to be applied uniformly. General electrical safety guidelines, however, apply across the DOE complex.

This section contains safety criteria for the DOE complex in the design, development, fabrication and construction, modification, installation, inspection, testing, operation, and maintenance of R&D electrical apparatus and facilities. Personnel safety shall be the primary consideration. When conflicts between electrical codes, recognized industry standards, DOE Orders, or regulations arise, the requirement that addresses the particular hazard and provides the greater personnel safety protection shall govern.

10.2 SCOPE

This section addresses R&D electrical systems which are not specifically addressed elsewhere in the *Electrical Safety Handbook*. The electrical environment of the DOE complex is extremely varied, ranging from low-voltage electronic circuits to common office and industrial electrical systems to large, high-voltage power distribution systems to high-voltage/low-current and low-voltage/high-current systems associated with R&D programs. Electrical systems of all types are an integral part of R&D operations and associated support work.

10.3 COMPLIANCE WITH OSHA

It is important to note that special types of work on R&D electrical systems (e.g., electronic circuits) are considered electrical work, and therefore the work shall follow electrical safety requirements.

Consistent with other sections of this document, electrical systems and equipment and all design, development, fabrication and construction, modification, installation, inspection, testing, operation, and maintenance shall be in accordance with applicable electrical requirements. Specific attention shall be focused on the electrical regulations of OSHA, including:

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1. 29 CFR 1910.137
2. 29 CFR 1910.147
3. 29 CFR 1910.269
4. 29 CFR 1910.301-399
5. 29 CFR 1926.401-449.

10.4 STANDARDIZED SAFETY PRACTICES AND PROCEDURES

Standardized safety practices shall be developed for performing electrical work. These practices should be consistent with the other electrical safety-related work practices noted elsewhere in this document.

10.5 EQUIPMENT NOT LISTED BY A NATIONALLY RECOGNIZED TESTING LABORATORY

10.5.1 HAZARDS

Electrical equipment is considered to be acceptable either by being listed by a Nationally Recognized Testing Laboratory (NRTL), designed, manufactured and tested according to nationally recognized standards, or approved by AHJ-determined criteria. Refer to Section 2.5, “Approval of Electrical Equipment.”

Procurement and use of equipment not listed by an NRTL should be reviewed by the AHJ. The extensive testing involved in the listing process usually cannot be duplicated at the user facility, and many of the tests are destructive in nature. The AHJ should develop an examination acceptance process to ensure appropriate confidence in the safety of the product.

See Section 9.0, “Enclosed Electrical/Electronic Equipment,” for additional guidance. Also see UL 508 and applicable ANSI and IEEE documents.

10.5.2 DESIGN AND CONSTRUCTION

Equipment should be constructed such that:

1. There is adequate protection from fire, electric shock, or injury to personnel during normal use or servicing.
2. Normal use or servicing will not cause the components or materials to exceed electrical, mechanical, or temperature limits.
3. The components, wiring, and other internal parts are protected from being displaced or damaged.

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NRTL-listed parts and UL-recognized components should be used wherever possible. An assembly of recognized components is not equal to a listed product, but more readily enables an independent evaluation of the assembly.

All equipment not listed by a NRTL should be constructed according to applicable standards, such as UL, ANSI, and IEEE. Equipment for which specific standards are unavailable should be constructed according to the principles of established standards, as determined by the AHJ.

Equipment should be examined for safety as extensively as possible. Areas of consideration include but are not limited to:

1. Failure modes
2. Heat effects
3. Magnetic effects
4. Grounding and bonding
5. Guarding of live parts
6. Leakage currents
7. Dielectric testing
8. Access to serviceable parts
9. Overcurrent and overtemperature protection
10. Clearances and spacing
11. Interlocks
12. Design and procedural documentation
13. Signage, labels, and administrative controls
14. Mechanical motion
15. Stored energy.

Documentation should be developed to substantiate the acceptance of any equipment. Such documentation should include but not be limited to:

1. Tests performed
2. Conditions of acceptability
3. Applicable standards to which the equipment was evaluated
4. Limitations of approved use, if any.

10.6 OPERATION AND MAINTENANCE

Maintenance procedures and schedules should be developed for R&D equipment. Electrical equipment shall be checked, cleaned, and maintained on a schedule and in a manner based on its application and use. Additional information is referenced in Section 3.0 “Electrical Preventive Maintenance.”

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10.7 EMPLOYEE QUALIFICATIONS

This section provides guidance for determining the qualification process for persons involved with specialized electrical equipment, configurations or work tasks associated with experiments. The guidance provided in this section is in addition to the minimum qualifications described in Section 2.8, "Training and Qualifications of Qualified Workers."

10.7.1 HAZARDS

The hazards associated with R&D equipment are sometimes unique because the equipment itself is unique. These hazards are sometimes made worse because of an uncommon design or the fact that it may be one of a kind. Special efforts are thus necessary to identify all the potential hazards that may be present in a specific unique design. These hazards should be identified and a plan developed to mitigate the associated risk. Personnel working on R&D equipment shall be qualified to work on this equipment, depending on its unique safety problems.

10.7.2 ADDITIONAL QUALIFICATIONS

Personnel assigned to tasks involving R&D equipment shall be apprised of the hazards identified in Section 10.7.1. It is suggested that they participate in developing mitigation plans to reduce the risks associated with the hazards.

A list of additional experience qualifications should be developed by the appropriate personnel including the worker(s). This list should identify specific training requirements necessary for unusual equipment or tasks.

10.8 GENERIC R&D EQUIPMENT

There are many possible types of electrical ac and dc power source hazards in complex R&D systems and the various design philosophies preclude establishing hazard classifications based on voltage alone.

10.8.1 POWER SOURCES

10.8.1.1 HAZARDS

1. Internal component failure can cause excessive voltages. Internal component open-circuit failure in capacitor banks and Marx generators can result in full voltages across components that may not be appropriately discharged in the usual manner.
2. Internal component shorts in capacitor banks and Marx generators can result in excessive fault current, causing extreme heat, overpressurization of capacitor cans, and explosion.
3. Overloading or improper cooling of power supplies can cause excessive temperature rise.
4. Output circuits and components can remain energized after input power is interrupted.

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5. Auxiliary and control power circuits can remain energized after the main power circuit is interrupted.
6. When power supplies serve more than one experiment, errors made when switching between experiments may create hazards to personnel.
7. R&D electrical apparatus may contain large amounts of stored energy, requiring fault analysis.
8. Liquid coolant leaking from R&D electrical equipment may pose an electrical hazard to personnel.

10.8.1.2 DESIGN AND CONSTRUCTION

In design and construction of R&D equipment, it is important to remember the following cautions:

1. Install only components essential to the power supply within the power-supply enclosure.
2. Provide appropriate separation between high-voltage components and low-voltage supply and/or control circuits.
3. Provide to personnel a visible indicator that the power supply is energized.
4. Minimize the number of control stations and provide an emergency shutdown switch where needed.
5. Where possible, avoid multiple-input power sources.
6. Apply a label containing emergency shutdown instructions to equipment that is remotely controlled or unattended while energized.

10.8.1.3 OPERATION AND MAINTENANCE

Before working in a power-supply enclosure or an associated equipment enclosure, see Sections 2 and 7. Personnel should take the following precautions:

1. Implement lockout/tagout.
2. Check for auxiliary power circuits that could still be energized.
3. Inspect automatic shorting devices to verify proper operation.
4. Short the power supply from terminal to terminal and terminal to ground with grounding hooks.

10.8.2 CONDITIONS OF LOW VOLTAGE AND HIGH CURRENT

10.8.2.1 HAZARDS

It is usual for R&D facilities to have equipment that operates at less than 50 V. Although this equipment is generally regarded as nonhazardous, it is considered hazardous when high currents are involved. Examples of such equipment are a power supply rated 3 kA at 25 V, a magnet power supply with rated output of 200 A at 40 V, and a bus bar carrying 1 kA at 5 V.

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Though there is a low probability of electric shock at voltages less than 50 V (See Figure 10-1), there is a hazard due to arcing and heating in case of an accidental fault. For example, a tool could drop onto the terminals and initiate an arc, causing severe burns.

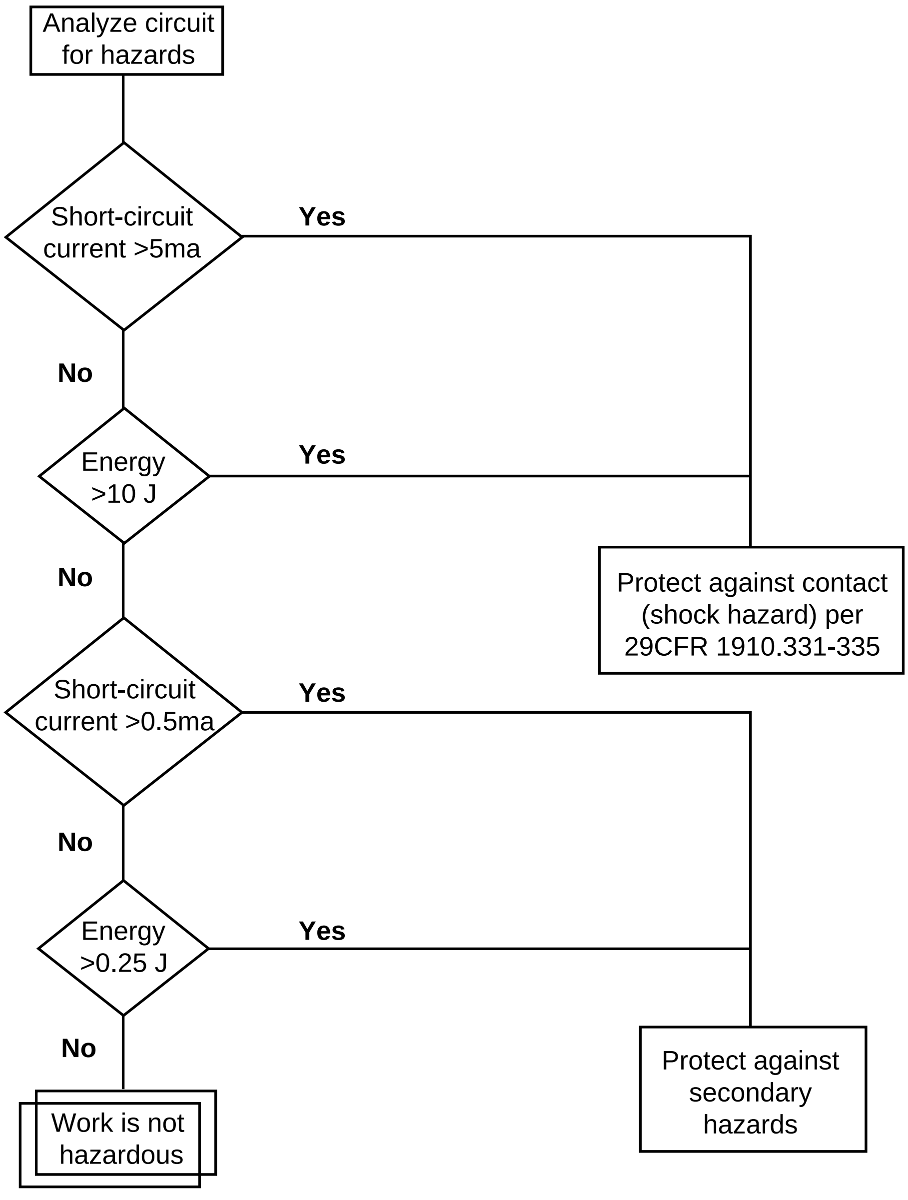

Figure 10-1. Process for the analysis of circuit hazards.

10.8.2.2 DESIGN AND CONSTRUCTION

A circuit operating at 50 V or less shall be treated as a hazardous circuit if the power in it can create electrical shocks, burns, or an explosion due to electric arcs. Inductive circuits may create high-voltage hazards when interrupted. Observe all of the following rules for such circuits:

1. Provide protective covers and/or barriers over terminals and other live parts to protect personnel.
2. By suitable marking, identify the hazard at the power source and at appropriate places.
3. Consider magnetic forces in both normal-operation and short-circuit conditions. Use conductors that have appropriate physical strength and are adequately braced and supported to prevent hazardous movement.

10.8.2.3 OPERATION AND MAINTENANCE

Follow these guidelines for working on circuits operating at 50 V or less that are treated as hazardous:

1. Work on such circuits when they are de-energized.
2. If it is essential to work on or near energized low-voltage, high-current circuits, observe the safety rules as if the circuits were operating at more than 50 V. Refer to Section 2.1.2, “Considerations for Working on Energized Systems and Equipment” and 2.13.4, “Safe Energized Work (Hot Work).”

10.8.3 CONDITIONS OF HIGH VOLTAGE AND LOW CURRENT

10.8.3.1 HAZARDS

When the output current of high-voltage supplies is below 5 mA, the shock hazard to personnel is low. Where combustible atmospheres or mixtures exists, the hazard of ignition from a spark may exist. High-voltage supplies (ac or dc) can present the following hazards:

1. Faults, lightning, or switching transients can cause voltage surges in excess of the normal ratings.
2. Internal component failure can cause excessive voltages on external metering circuits and low-voltage auxiliary control circuits.
3. Overcurrent protective devices such as fuses and circuit breakers for conventional applications may not adequately limit or interrupt the total inductive energy and fault currents in highly inductive dc systems.
4. Stored energy in long cable runs can be an unexpected hazard. Safety instructions should be in place to ensure proper discharge of this energy.
5. Secondary hazards such as startle or involuntary reactions from contact with high-voltage low-current systems may result in a fall or entanglement with equipment.

10.8.3.2 DESIGN CONSIDERATIONS

Personnel in R&D labs may encounter energized parts in a variety of configurations, locations, and under environmental conditions that are not usual for most electrical power personnel. Sometimes the equipment can be designed to incorporate mitigation of the hazards associated with working on such equipment. If not, then safe operating procedures must be developed and used.

10.8.3.3 SAFETY PRACTICES

An analysis of high-voltage circuits should be performed by a qualified person before work begins unless all exposed energized parts are guarded as required for high-voltage work. The analysis must include fault conditions where circuit current could rise above the nominal rated value as explained here and shown graphically in Figure 10-1. Depending on the results of the analysis, any of the following may apply:

1. If the analysis concludes that the current is above 5 mA or energy is above 10 J, then the work is considered to be energized work and should be performed in accordance with Section 2, “General Requirements” and/or Section 7, “Work In Excess of 600 Volts.”
2. If the analysis concludes that the current is between 0.5 mA and 5 mA and between 0.25 and 10 J, then the worker may be exposed to a secondary hazard (e.g., startle reaction) that must be mitigated.
3. If the analysis concludes that the current is below 0.5 mA and below 0.25 J, then the worker exposure is minimal and no special precautions are required.

High-voltage supplies that use rated connectors and cables where there are no exposed energized parts are not considered hazards. Connections shall not be made or broken with the power supply energized unless they are designed and rated for this type of duty (e.g., load-break elbows). Inspect cables and connectors for damage and do not use if they are damaged. Exposed high-voltage parts must be guarded to avoid accidental contact.

10.8.4 RADIO-FREQUENCY/ MICROWAVE RADIATION AND FIELDS

The DOE complex conducts R&D programs that involve sources of radio-frequency/microwave (RFMW) nonionizing electromagnetic radiation. Devices that may produce RFMW radiation include telecommunications and radar equipment, industrial equipment such as radio-frequency heaters, and scientific and medical equipment such as magnetic resonance imagers and klystron tubes. The nationally recognized consensus standard for personnel exposure to radio-frequency radiation is ANSI/IEEE C95.1(1991), “Electromagnetic Fields, Safety Levels with Respect to Human Exposure to Radio Frequency.”

10.8.4.1 HAZARDS

1. RF amplifiers frequently use high-voltage power sources. See Section 7.0, “Work in Excess of 600 V”, for high voltage requirements.
2. There may be x-ray hazards (when supply voltage exceeds 10 kV).
3. Currents may be induced in conductive objects or metal structures that are not part of the RF structure.
4. RF currents can cause severe burns.
5. Falls from towers may result from RF burns from antennas.

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6. Electromagnetic interference may cause equipment to malfunction.
7. Electromagnetic fields may cause unintended ignition of explosives, fuel, and ordnance.
8. Grounding and bonding conductors that are adequate for dc and power frequencies may develop substantial voltage when fast pulses and radio frequency currents are present, due to induction and other means.

10.8.4.2 DESIGN AND CONSTRUCTION

Engineering control in accordance with ANSI/IEEE C95.1 (1991) should be the primary method used to restrict exposure whenever practical. If engineering controls are not practical, such as: work-time limits, based on the averaging intervals and other work-practice and administrative controls, must be used.

1. Warning Signs. Signs commensurate with the RFMW level must be used to warn personnel of RFMW hazards. These signs must be posted on access panels of irradiated enclosures and at entrances to and inside regulated areas.
2. Access Limitation. Access can be limited by controls such as barriers, interlocks, administrative controls or other means. The operation supervisor controls access to regulated areas and must approve nonroutine entry of personnel into these places. When practical, sources of RFMW radiation should be switched off when not in use.
3. Shielding. Shielding that encloses the radiating equipment or provides a barrier between the equipment and the worker may be used to protect personnel; the shielding design must account for the frequency and intensity of the field.
4. Interlocks. Chamber or oven-type equipment that uses microwave radiation must have interlocks designed to (1) prevent generation of the radiation unless the chamber is sealed and (2) shut off such equipment if the door is opened.
5. Lockout/Tagout. The design shall incorporate features that allow the equipment to be locked out and tagged out for servicing.
6. Personnel Protective Equipment (PPE). PPE such as eyewear is not readily available and is generally not a useful option as protection against RFMW radiation and fields. Protection must therefore be achieved by other means.

10.8.4.2.1 EXEMPTIONS TO RFMW EXPOSURE LIMITS

The following items are exempt from the RFMW exposure limits; however, their manufacture is subject to Federal RFMW emission standards:

1. Cellular phones
2. Two-way, hand-held radios and walkie-talkies that broadcast between 10 kHz and 1 GHz and emit less than 7 W
3. Microwave ovens used for heating food
4. Video display terminals.

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10.8.4.2.2 EXPOSURE CRITERIA FOR PULSED RFMW RADIATION

The basic considerations for peak-power exposure limits are consistent with ANSI/IEEE C95.1 (1991) as follows:

1. For more than five pulses in the averaging time and for pulse durations exceeding 100 milliseconds, normal time averaging applies and the time-averaged power densities should not exceed the Maximum Permissible Exposure (MPE) given in Table 10-1 for controlled and Table 10-2 for uncontrolled environments, per ANSI/IEEE C95.1 (1991).

2. For intermittent pulse sources with no more than five pulses during the averaging time, the peak power density for any of the pulses should not exceed the limit given by the following equation.

   $$MPE_p = \frac{MPE_\alpha (t_\alpha)}{5(t_p)}$$

   where:
   MPE_p = Peak (power density)
   MPE_α = Time-Average (power density)
   t_α = Averaging time (seconds)
   t_p = Pulse width (seconds)

   This limits the specific absorption (SA) of each pulse to SA=28.8 J/kg (whole-body or spatial average), or SA=144 J/kg for 5 pulses.

   For intermittent pulse sources with no more than five pulses during the averaging time, the single-pulse SA of $\leq$ 28.8 J/kg, though higher than the threshold for auditory effect (clicking), is three orders of magnitude lower than the SAs that produce RF-induced unconsciousness.

3. Maximum E field for any of the pulses should be no more than 100 kV/m. This peak E-field limit is prescribed to eliminate the possibility of air breakdown or spark discharges, which occur at 2,900 kV/m. A large safety factor is applied to account for local field enhancements where nominally lower fields may result in arcing discharges.

10.9 METHODS

10.9.1 WIRING METHODS

10.9.1.1 HAZARDS

Unsafe wiring methods can cause electrical injury or fire hazards.

R&D work may require the use of wiring methods that are not anticipated in the NEC. These methods may not be consistent with normal commercial and industrial wiring methods, and should be reviewed by the AHJ for approval.

Table 10-1. Controlled Environment Exposure Limits

Part A
Electromagnetic Fields[a]

1 Frequency range (MHz)	2 Electric Field strength (E) (v/m)	3 Magnetic Field strength (H) (A/m)	4 Power density (S) E-field, H-field (mW/cm^2)	5 Averaging time $\|E\|^2$, $\|H\|^2$, or S (minutes)
0.003-0.1	61.4	163	(100, 1,000,000)[b]	6
0.1-3.0	61.4	$16.3/f$[c]	$(100, 10{,}000/f^2)$[b]	6
3-30	$1842/f$	$16.3/f$	$(900/f^2, 10{,}000/f^2)$[b]	6
30-100	61.4	$16.3/f$	$(1.0, 10{,}000/f^2)$[b]	6
100-300	61.4	0.163	1.0	6
300-3,000	–	–	$f/300$	6
3,000-15,000	–	–	10	6
15,000-300,000	–	–	10	$616{,}000/f^{1.2}$

Part B
Introduced and contact RF Currents[d]

Frequency range	Maximum current (mA)		Contact
	Through both feet	Through each foot	
0.003-0.1 MHz	$2{,}000\ f$	$1{,}000\ f$	$1{,}000\ f$
0.1-100 MHz	200	100	100

a. The exposure values in terms of electric and magnetic field strength are the values obtained by spatially averaging values over an area equivalent to the vertical cross section of the human body (projected area).

b. These plane-wave equivalent power density values, although not appropriate for near-field conditions, are commonly used as a convenient comparison with MPEs at higher frequencies and are displayed on some instruments in use.

c. The f = frequency in MHz.

d. It should be noted that the current limits given in this table may not adequately protect against startle reactions and burns caused by transient discharges when contacting an energized object.

NEC Article 305 "Temporary Wiring," requires removal of temporary wiring upon completion of the experiment for which it was installed.

An overly strict interpretation can obstruct the scientific objectives of the R&D configuration, but if a liberal interpretation is allowed, there is a possibility that unsafe wiring methods will be used. The AHJ must consider programmatic needs without sacrificing personnel safety.

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Table 10-2. Uncontrolled Environment Exposure Limits

Part A
Electromagnetic Fields[a]

1 Frequency range (MHz)	2 Electric Field strength (E) (v/m)	3 Magnetic Field strength (H) (A/m)	4 Power density (S) E-field, H-field (mW/cm²)	5 Averaging time $\|E\|^2$,	S (minutes)	$\|H\|^2$
0.003-0.1	61.4	163	(100, 1,000,000)[b]	6 6		
0.1-1.34	61.4	16.3/f[c]	(100, 10,000/f^2)[b]	6 6		
1.34-3.0	823.8/f	16.3/f	(180/f^2, 10,000/f^2)[b]	f^2/0.3		6
3.0-30	823.8/f	16.3/f	(180/f^2, 10,000/f^2)[b]	30		6
30-100	27.5	158.3/$f^{1.668}$	(0.2,940,000/$f^{6.336}$)[b]	30	0.0636$f^{1.337}$	
100-3,00	27.5	0.0729	0.2	30		30
300-3,000	–	–	f/1,500	30		–
3,000-15,000	–	–	f/1,500	90,000/f		–
15,000-300,000	–	–	10	616,000/$f^{1.2}$		–

Part B
Introduced and contact RF Currents[d]

Frequency range	Maximum current (mA)		Contact
	Through both feet	Through each foot	
0.003-0.1 MHz	900 f	450 f	450 f
0.1-100 MHz	90	45	45

a. The exposure values in terms of electric and magnetic field strength are the values obtained by spatially averaging values over an area equivalent to the vertical cross section of the human body (projected area).

b. These plane-wave equivalent power density values, although not appropriate for near-field conditions, are commonly used as a convenient comparison with MPEs at higher frequencies and are displayed on some instruments in use.

c. The f = frequency in MHz.

d. It should be noted that the current limits given in this table may not adequately protect against startle reactions and burns caused by transient discharges when contacting an energized object.

10.9.1.2 DESIGN AND CONSTRUCTION

10.9.1.2.1 DESIGN AND CONSTRUCTION AS AN INTEGRAL PART OF EQUIPMENT

If the AHJ determines that wiring is an integral part of an apparatus (e.g., instrumentation interconnections), then the wiring methods used should be evaluated by the AHJ as providing safe operating conditions. This evaluation may be based on a combination of standards and engineering documentation where appropriate. Such an evaluation should consist of an analysis of all stresses imposed on any electrical conductive elements, including, but not limited to electrical, magnetic, heating, and physical damage potential. The wiring methods selected must mitigate to the greatest practical extent any undesired effects of a failure sequence.

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If cable trays are used as mechanical support for experimental circuits, they should be solely dedicated to this use and appropriately labeled. Any such use must be analyzed for detrimental heating effects of the proposed configuration.

10.9.1.2.2 POWER SUPPLY INTERFACE BETWEEN UTILITY SYSTEMS AND R&D EQUIPMENT

Utility supply voltages should be brought as near to the utilization equipment as possible using NEC-compliant wiring methods.

Any temporary wiring methods used (e.g., extension cords) should be approved by the AHJ for a specified limited time.

Flexible cords and cables should be routed in a manner to minimize tripping hazards.

The conventional use of cable trays is defined in NEC Article 318. If power cables are placed in a cable tray used for control and signal cables, separation shall be provided according to the NEC Article 318. Certain experimental configurations or physical constraints may require the unconventional application of cable trays. Only the AHJ may approve these unconventional applications. If deemed necessary, enhanced fire protection or other safety measures shall be used to ensure safety to personnel and equipment.

For coaxial, heliax and specialty cables used for experimental R&D equipment, where NEC tray-rated cable types are not available which meet the technical requirements of the installation, the non-tray-rated cables shall be permitted with the approval of the AHJ. If deemed necessary, enhanced fire protection or other safety measures shall be used to ensure safety to personnel and equipment.

When metallic cable tray is being used, it shall be bonded to the equipment grounding system, but should not be relied upon to provide the equipment ground. The experimental equipment must be appropriately grounded by some other method.

10.9.1.3 OPERATION AND MAINTENANCE

The operation and maintenance of R&D systems which use wiring methods that are not anticipated by the NEC require special considerations from all personnel. The AHJ evaluation for safe operating conditions must include a review of unique features in the engineering documentation.

10.9.2 UNCONVENTIONAL PRACTICES

R&D performed by DOE contractors often incorporates the design of specialized equipment resulting in the need for specialized grounding and the use of materials and components in an unconventional manner. Even with these experimental needs and special design considerations, the maximum safety of personnel and equipment still needs to be ensured. The practice of using materials or components for purposes other than originally designed needs special consideration in their use, identification, personnel protection, and equipment protection.

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10.9.2.1 GROUNDING

10.9.2.1.1 HAZARDS

The lack of proper grounding can cause electrical shock and/or burns to personnel. The NEC and NESC define legally-required grounding. To mitigate potential hazards, grounding shall be provided in accordance with the NEC and NESC.

10.9.2.1.2 DESIGN AND CONSTRUCTION

NEC, Article 250, "Grounding" notes that grounds also provide:

1. Voltage limitation in case of lightning, line surges, or unintentional contact with higher voltage lines
2. Stability of voltage to ground under normal operation
3. Facilitated overcurrent device operation in case of ground faults
4. A path to conductive objects that will limit the voltage to ground.

In R&D work there is one additional function for grounds: a common reference plane or system ground return for electronic devices, circuits, and systems. (See Section 9.3) It is recognized that such grounds are essential in some cases to control:

1. Noise associated with the primary power system:

a. Incoming on the line

b. Outgoing from local equipment

2. Ground wire noise

3. Circuit coupling

a. Ground loop (shared circuit return)

b. Magnetic, capacitive, or electro-magnetic.

If system return impedances are low enough, then simple radio-frequency chokes can be used to limit this noise with no effect on the safety function.

A 50-microhenry choke will add 1/50 of an ohm at 60 Hz, but will look like 2 ohms at 7.5 kHz and 30 ohms at 100 kHz. Such an RF choke will serve to discriminate against noise on the ground circuit.

An inexpensive RF choke may be installed in the safety ground by:

1. Pulling the green ground wire 20 feet longer than required.

2. Coiling the extra length on a 6-inch diameter (about 12 turns).
3. Securing it tightly wound with cable ties.
4. Connecting it into the circuit.

These actions satisfy the NEC requirement for a continuous ground and noise isolation is also enhanced.

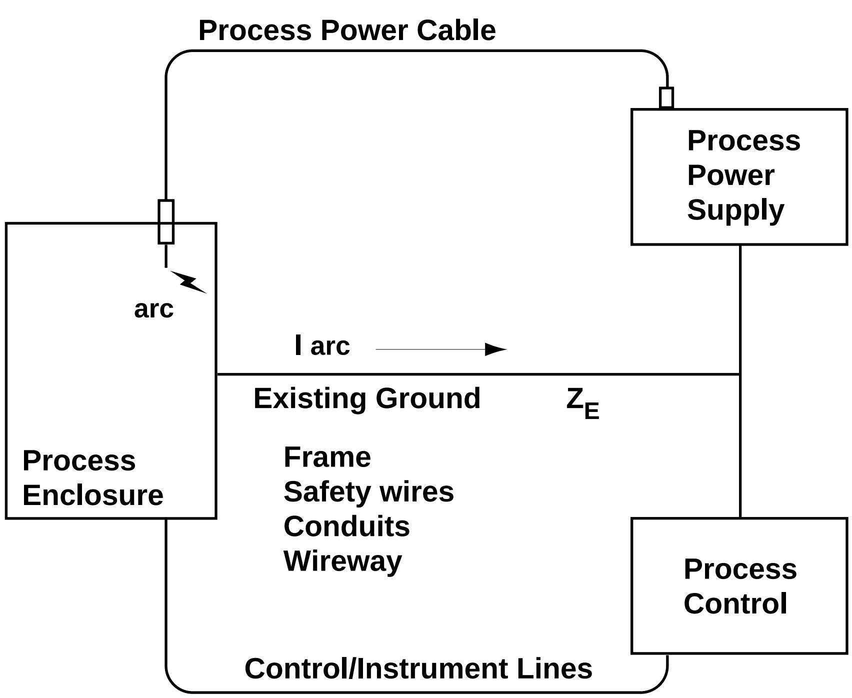
Whatever scheme is used, the ground of experimental equipment shall be connected to the same ground as the facilities' electrical system to ensure equal potential.

For practices involving hazardous materials, such as explosives, the grounding shall also comply with the requirements of Section 5.0, "Special Occupancies".

10.9.2.1.3 NOISE COUPLING MECHANISMS.

Grounding can reduce the interference in the five types of coupling mechanisms listed here.

1. Conductive Coupling. (Source and load wired together) It is sometimes practical to provide a separate return path for both the source and the load. If the system layout allows this, then conductive coupling cannot occur between these two, as is shown in Figures 10-2 and 10-3.



CONDUCTIVE COUPLING SITUATION

Figure 10-2. Arc currents through the process power supply return (existing ground) develop a voltage that appears in series with the process controls because they share that return.

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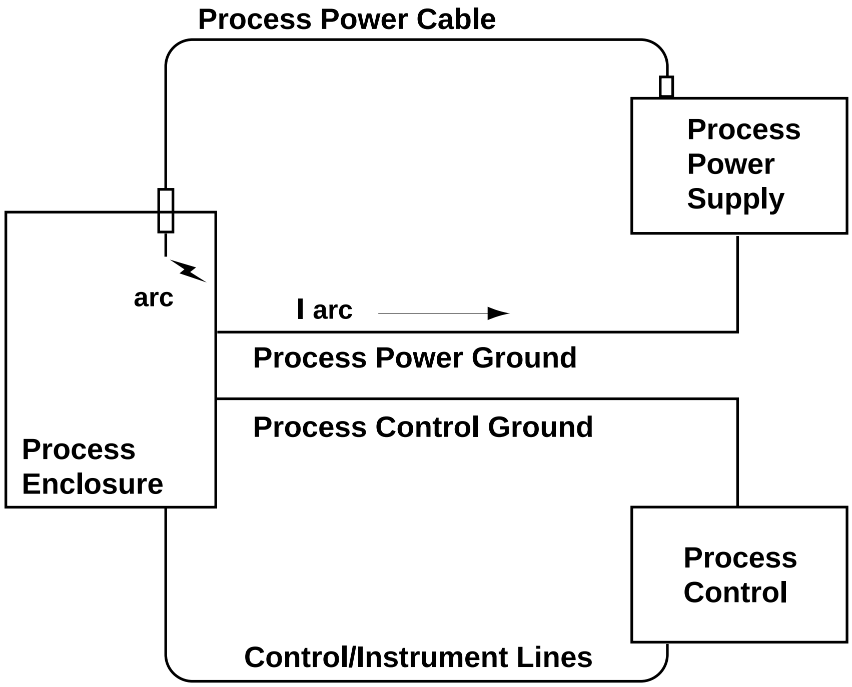

CONDUCTIVE COUPLING SOLUTION

Figure 10-3. It has been possible to install a separate return conductor for the power supply. The arc currents no longer appear in series with the process controls. There is no conductive coupling.

2. Capacitive Coupling. (High-impedance proximity coupling) The technique for increasing resistance to capacitive coupling among cables is to ground one end of the shield to produce the shortest, most direct shunt path back to the source of the coupled current as is shown in Figures 10-4 and 10-5.

   Caution: It is possible to inadvertently INCREASE coupling between source and load if the shield ground does not properly shunt the current coupled onto the shield.

3. Inductive Coupling. (Near-field, low-impedance loop-to-loop coupling) The technique for increasing resistance to magnetic coupling in shielded cables is to ground BOTH ends of the shield to an effective signal return ground as is shown in Figures 10-6 and 10-7.

4. System Signal Returns. Each installation will require individual analysis and treatment. A single ground poses no problem, but multiple grounds can result in a ground loop. These can upset the proper functioning of instruments. A signal isolator offers a way of overcoming the problem.

5. Instrumentation Grounding.[1] Equipment that is used to implement a control instrumentation strategy (see Figure 10-8) makes use of a common signal ground as a reference for analog

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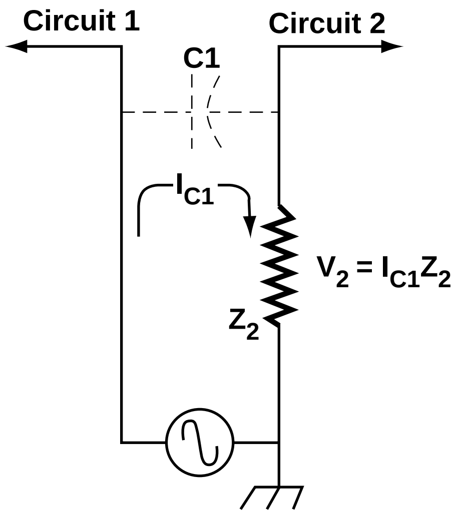
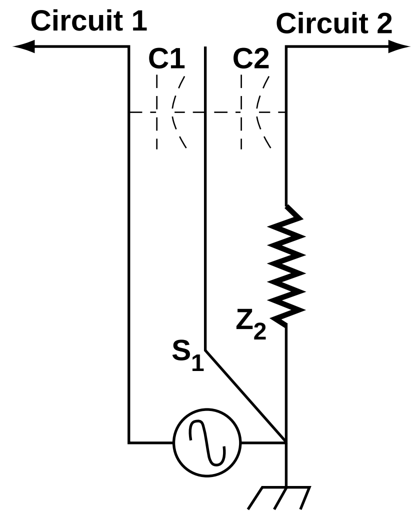


CAPACITIVE COUPLING SITUATION

Figure 10-4. Capacitance between circuit 1 and circuit 2 is allowing current to be transferred into circuit 2 via an electric field. This current flows through Z_2, the impedance of circuit 2, and develops an interfering voltage.



CAPACITIVE COUPLING SHIELD

Figure 10-5. A shield has been interposed between circuit 1 and circuit 2. The coupling will be reduced as it shunts the coupled current around Z_2 instead of through it. The interfering voltage could be increased instead of decreased if not properly shunted.

signals. Any additional grounds that are introduced into the control circuit will almost certainly cause ground loops to occur.

A typical process instrumentation loop is shown in Figure 10-8. It is a DC system that operates at a specific voltage (24 volts in this case) to a master ground reference called a signal ground. The instrumentation signal varies within the range of 4-20 mA, depending upon the value of the variable (pressure, temperature, etc.) seen by the sensor. A precisely calibrated circuit takes this mA signal and converts it into a form that can be used by a process-control computer, PLC, dedicated instrument, or whatever controller that supervises the system. In this example, the mA signal is converted to a 1-5 V signal for a chart recorder. At 4 mA, the voltage measured by the recorder is 250 x .004 = 1 V. At 20 mA, the measured voltage is 5 V. Normally, the recorder scale is calibrated so the voltage reads directly in ^{0}F, psi, etc.

In order to minimize the danger of introducing ground loops into this complicated network of sensitive equipment, a dedicated instrumentation system ground bus is usually employed. This bus ultimately receives grounds from the signal common, the dc power supply common, the cabinet ground, and the instrumentation ac power ground. The bus is tied to earth via the building ground and the plant ground grid. Figure 10-9 shows the typical way in which interconnection of these various grounds is accomplished.

The cabinet ground is a safety ground that protects equipment and personnel from accidental shock hazards while providing a direct drain line for any static charges or electromagnetic interference

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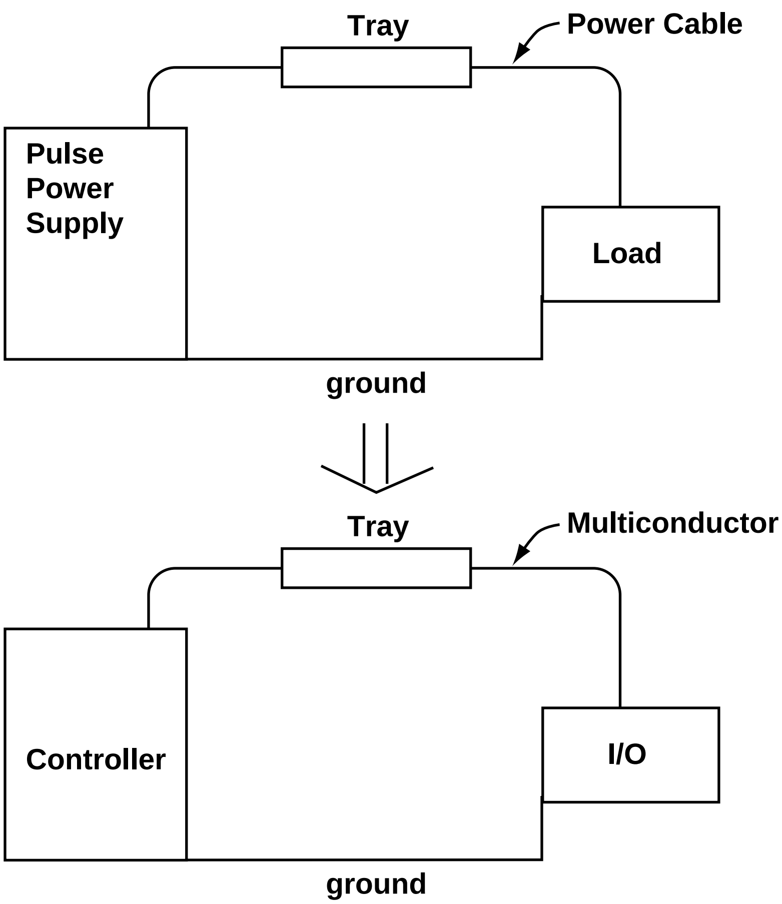

INDUCTIVE COUPLING SITUATION

Figure 10-6. The pulse power supply, its cable, load, and return form a transmitting loop which couples into the loop formed by the controller, its multiconductor cabling, I/O and return. Note that in actual installations these loops can be very large and very close.

(EMI) that may affect the cabinets. The cabinet ground remains separate from the dc signal ground until it terminates at the master ground bus.

Eliminating grounds is not feasible for some instruments, such as thermocouples and some analyzers, because they require a ground to obtain accurate measurements. Also, some instruments must be grounded to ensure personnel safety.

When grounds cannot be eliminated, the solution to instrumentation ground loops lies in signal isolators. These devices break the galvanic path (dc continuity) between all grounds while allowing the analog signal to continue throughout the loop. An isolator also eliminates the noise of ac continuity (common-mode voltage).[2]

[2] Much of the information above came from the article which is titled “Causes and Cures of Instrumentation Ground Loops,” by Pat Power, Moore Industries, Houston, TX.

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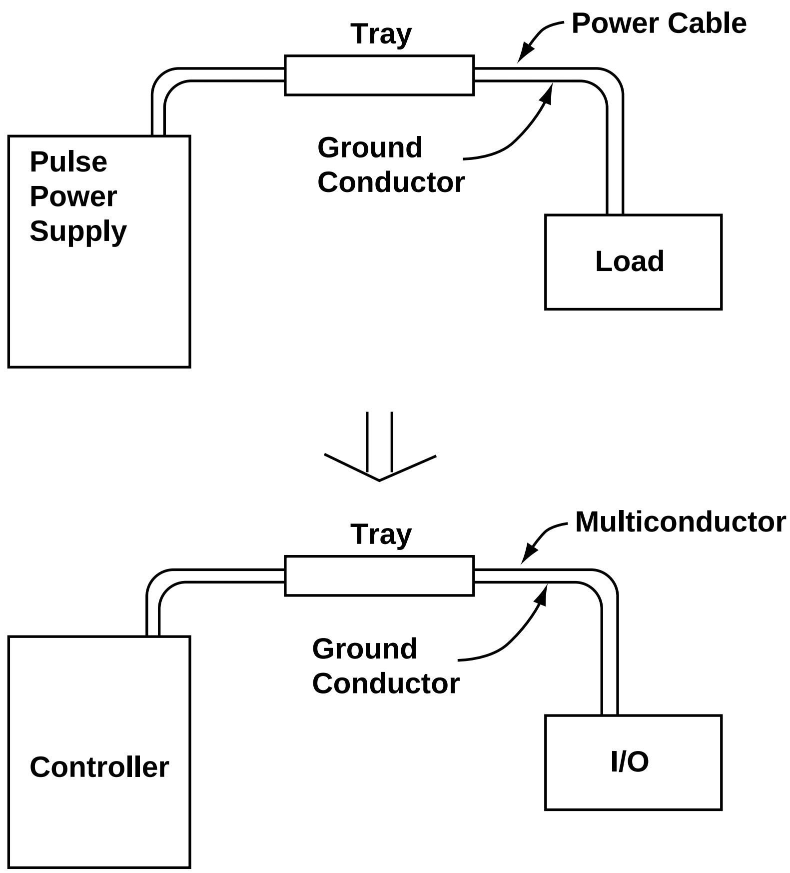

INDUCTIVE COLLAPSED LOOPS

Figure 10-7. Intentional returns have been installed for both the pulse power supply and the controller right in the trays for the cables. Both loops have been reduced to small cross sections, reducing inductive coupling. Any electromagnetic (far field) radiation being generated by the pulse power supply and its cabling will also be reduced.

10.9.2.1.4 OPERATION AND MAINTENANCE

Before starting each operation (experiment, test, etc.) the exposed portions of the grounding system should be visually checked for any damage and to determine that all necessary connections have been made. If more than one operation is conducted every day, then visual checks should be performed only at the beginning of each shift, if the grounding system will be needed during that shift. The adequacy of the grounding system should be verified annually. It is recommended that the grounding impedance within the equipment be maintained at 0.25 ohms or less. (See IEEE 1100).

10.9.2.2 MATERIALS USED IN AN UNCONVENTIONAL MANNER

The practice of using materials or components for purposes other than originally designed needs special safety considerations in use, identification, personnel protection, and equipment protection.

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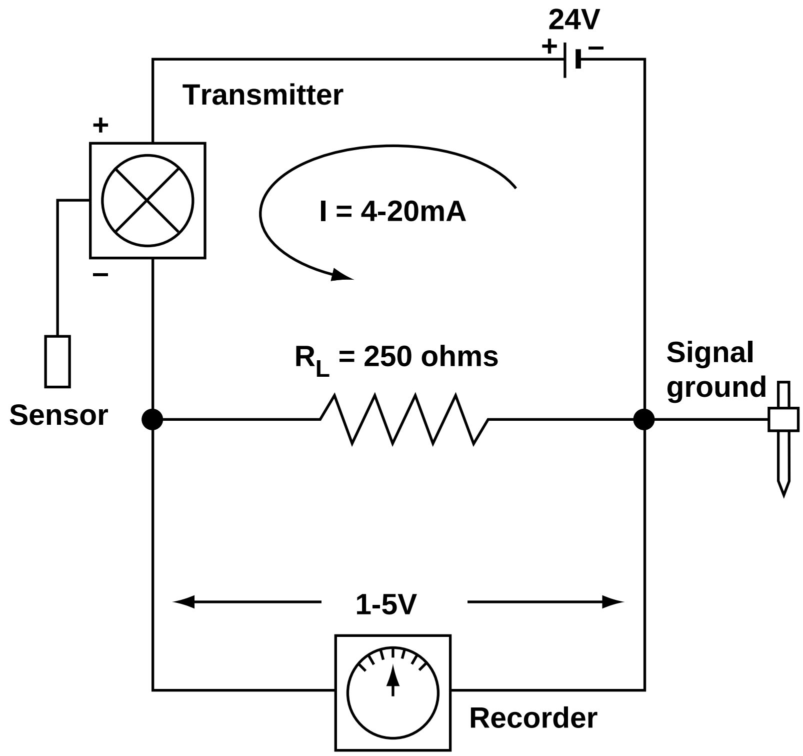

INSTRUMENTATION LOOPS

Figure 10-8. Typical Process Instrument Loop.

10.9.2.2.1 HAZARDS

The use of materials for something other than their original design criteria has the potential for providing an additional hazard, especially to personnel unfamiliar with the research apparatus. Personnel may assume that the material is used as originally designed and can unknowingly expose themselves to hazards unless special precautions are followed.

Some examples of items used in an unconventional manner are:

1. Copper pipe used as an electrical conductor
2. Insulated flexible copper pipe used as an electrical conductor
3. Specially designed high-voltage or high-current connectors
4. Specially designed high-voltage or high-current switches
5. Water column used as a high-voltage resistor
6. Standard coax cable used in special high-voltage pulsed circuits

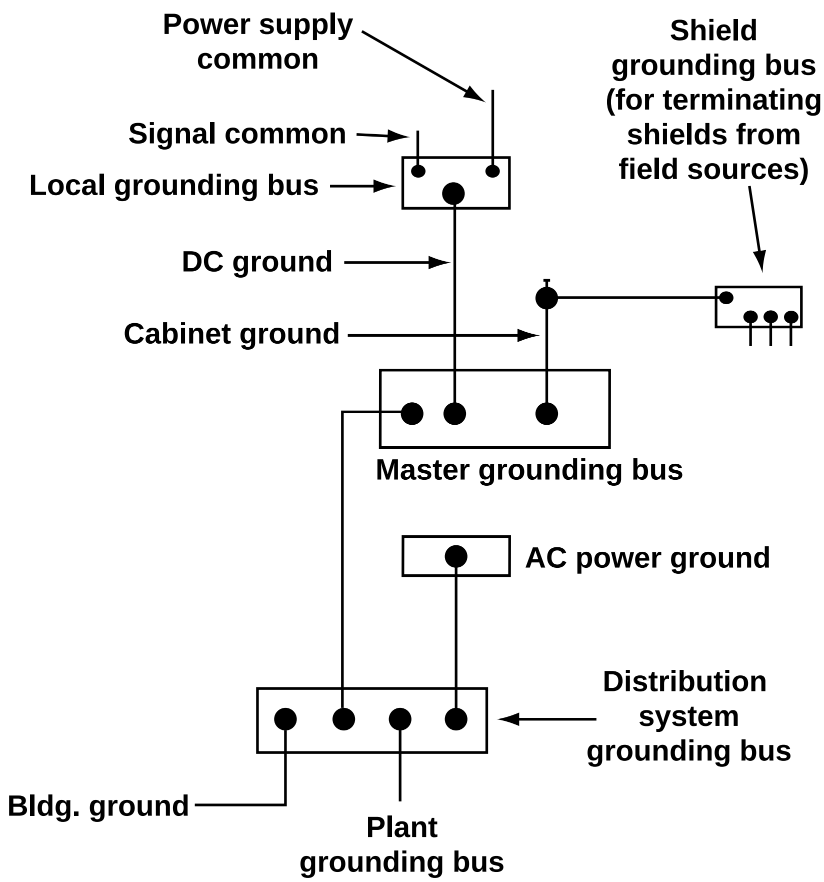

Figure 10-9. Typical control instrumentation ground system.

7. Water column used as a charged-particle beam attenuator
8. Commercial cable tray used as a mechanical support for experimental apparatus.

10.9.2.2.2 DESIGN AND CONSTRUCTION

During design, special consideration should be given to installing interlocks and protective barriers. Signs warning of the hazards should be posted to help prevent unsuspecting personnel from being injured.

10.9.2.2.3 OPERATION AND MAINTENANCE

Appropriate safety procedures and training should be part of the process to qualify personnel. The procedures should describe the methods used to promote safe work practices relating to work on energized circuits in accordance with Sect. 2.1.2, "Considerations for Working on Energized Systems and Equipment", Sect. 2.13, "Work Practices", and 29 CFR 1910.331-335.

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10.9.3 WORK ON ENERGIZED OR DE-ENERGIZED ELECTRICAL EQUIPMENT

Unless explicitly stated otherwise in this section, all work on energized/de-energized equipment will conform to Section 2.0, “General Requirements.”

10.10 REQUIREMENTS FOR SPECIFIC R&D EQUIPMENT

Electrical equipment and components used in research may pose hazards not commonly found in industrial or commercial facilities. Special precautions are required to design, operate, repair, and maintain such equipment. Electrical safety and personnel safety circuits (e.g., interlocks) are covered in this section as a guide to reduce or eliminate associated hazards. Training and experience in the specialized equipment are necessary to maintain a safe workplace.

All personnel involved with research electrical equipment should be trained and be familiar with the hazards they may encounter in the workplace. Only qualified electrical personnel should design, install, repair, or maintain electrical research equipment or components. Safety-related design, operation, and maintenance techniques should be incorporated into all new or modified equipment. Existing equipment should be modified when necessary to ensure safety. Equipment for which specific standards are not available should be constructed according to the principles of established standards, as determined by the AHJ.

Capacitors and inductors are used in research apparatus in special configurations as well as in their standard configurations. The design, operation, and maintenance of research apparatus using capacitors and inductors in these special configurations require that special consideration be given to the safety of both personnel and equipment.

10.10.1 CAPACITORS

This section covers capacitors that are used in the following typical R&D applications:

1. Energy storage

2. Voltage multipliers

3. Filters

4. Isolators

10.10.1.1 HAZARDS

Examples of capacitor hazards include:

1. Capacitors may store and accumulate a dangerous residual charge after the equipment has been de-energized. Grounding capacitors in series may transfer rather than discharge the stored energy.

2. A hazard exists when a capacitor is subjected to high currents that may cause heating and explosion.
3. When capacitors are used to store large amounts of energy, internal failure of one capacitor in a bank frequently results in explosion when all other capacitors in the bank discharge into the fault. Approximately 10^4 J is the threshold energy for explosive failure of metal cans.
4. High-voltage cables should be treated as capacitors since they have the capability to store energy.
5. The liquid dielectric and combustion products of liquid dielectric in capacitors may be toxic.
6. Because of the phenomenon of "dielectric absorption," not all the charge in a capacitor is dissipated when it is short-circuited for a short time.
7. A dangerously high voltage can exist across the impedance of a few feet of grounding cable at the moment of contact with a charged capacitor.
8. Discharging a capacitor by means of a grounding hook can cause an electric arc at the point of contact. (See 10.10.1.2.3).
9. Internal faults may rupture capacitor containers. Rupture of a capacitor can create a fire hazard. Polychlorinated-biphenyl (PCB) dielectric fluids may release toxic gases when decomposed by fire or the heat of an electric arc.
10. Fuses are generally used to preclude the discharge of energy from a capacitor bank into a faulted individual capacitor. Improperly sized fuses for this application may explode.

10.10.1.2 DESIGN AND CONSTRUCTION

The following cautions in design and construction should be considered:

1. Isolate capacitor banks by elevation, barriers, or enclosures to preclude accidental contact with charged terminals, conductors, cases, or support structures.
2. Interlock the circuit breakers or switches used to connect power to capacitors.
3. Provide capacitors with current-limiting devices.
4. Design safety devices to withstand the mechanical forces caused by the large currents.
5. Provide bleeder resistors on all capacitors not having discharge devices.
6. Design the discharge-time-constant of current-limited shorting and grounding devices to be as small as practicable.
7. Provide suitable grounding.

10.10.1.2.1 AUTOMATIC DISCHARGE DEVICES

1. Use permanently connected bleeder resistors when practical.
2. Have separate bleeders when capacitors are in series.

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3. Use automatic shorting devices that operate when the equipment is de-energized or when the enclosure is opened, which discharges the capacitor to safe voltage (50 V or less) in less time than is needed for personnel to gain access to the voltage terminals. It must never be longer than 5 minutes.
4. For Class C equipment with stored energy greater than 10 J, provide an automatic, mechanical discharging device that functions when normal access ports are opened.
5. Ensure that discharge devices are contained locally within protective barriers to ensure wiring integrity. They should be in plain view of the person entering the protective barrier so that the individual can verify proper functioning of the devices.
6. Provide protection against the hazard of the discharge itself.

10.10.1.2.2 SAFETY GROUNDING

1. Fully visible, manual grounding devices should be provided to render capacitors safe while work is being performed.
2. Grounding points must be clearly marked.
3. Prevent transferring charges to other capacitors.

10.10.1.2.3 GROUND HOOKS

1. Conductor terminations should be soldered or terminated in an approved crimped lug. All conductor terminations must be strain-relieved within 15 cm.
2. Ground hooks must be grounded and impedance should be less than 0.1 ohms to ground.
3. The cable conductor must be clearly visible through its insulation.
4. A cable conductor size of at least #2 AWG should be used, and the conductor shall be capable of carrying the available fault current of the system.
5. Ground hooks shall be used in sufficient number to adequately ground all designated points.
6. Permanently installed ground hooks must be permanently grounded and stored in a manner to ensure that they are used.

10.10.1.2.4 DISCHARGE EQUIPMENT WITH STORED ENERGY IN EXCESS OF 10 JOULES

1. A discharge point with an impedance capable of limiting the current to 500A or less should be provided.
2. The discharge point must be identified with a unique marker (example: yellow circular marker with a red slash), and should be labeled “HI Z PT” in large legible letters.
3. A properly installed grounding hook should first be connected to the current-limiting discharge point and then to a low-impedance discharge point (< 0.1 ohm) that is identified by a unique marker (example: yellow circular marker).

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4. The grounding hooks should be left on all of these low-impedance points during the time of safe access.
5. The low-impedance points shall be provided whether or not the HI-Z current-limiting points are needed.
6. Voltage indicators that are visible from all normal entry points should be provided.

10.10.1.2.5 FUSING

1. Capacitors connected in parallel should be individually fused, when possible.
2. Caution must be used in the placement of automatic discharge safety devices with respect to fuses. If the discharge will flow through the fuses, a prominent warning sign should be placed at each entry indicating that each capacitor must be manually grounded before work can begin.
3. Special knowledge is required for high-voltage and high-energy fusing.

10.10.1.3 OPERATION AND MAINTENANCE

1. The protective devices (interlocks) shall not be bypassed unless by qualified electrical personnel when inspecting, adjusting, or working on the equipment. Proper procedures need to be followed when bypassing interlocks.
2. Procedures should be established for tagging the interlock and logging its location and the time when bypassed and restored. Written approval shall be obtained from an appropriate authority before bypassing an interlock .
3. Only qualified electrical personnel (those trained in the proper handling and storage of power capacitors and hazard recognition) shall be assigned the task of servicing/installing such units.
4. Proper PPE shall be used when working with capacitors.
5. Access to capacitor areas shall be restricted until all capacitors have been discharged, shorted, and grounded.
6. Any residual charge from capacitors shall be removed by grounding the terminals before servicing or removal.
7. Automatic discharge and grounding devices should not be relied upon.
8. Grounding hooks shall be inspected before each use.
9. Capacitor cases should be considered “charged.”
10. Protective devices should be tested periodically.
11. All uninstalled capacitors capable of storing 5 J or greater shall be short circuited with a conductor no smaller than #14 AWG.
12. A capacitor that develops an internal open circuit may retain substantial charge internally even though the terminals are short-circuited. Such a capacitor can be hazardous to transport, because the damaged internal wiring may reconnect and discharge the capacitor through the short-circuiting wires. Any capacitor that shows a significant change in capacitance after a

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fault may have this problem. Action should be taken to minimize this hazard when it is discovered.

10.10.2 INDUCTORS

This section covers inductors as well as electromagnets and coils that are used in the following typical applications:

1. Energy storage
2. Inductors used as impedance devices in a pulsed system with capacitors
3. Electromagnets and coils that produce magnetic fields to guide or confine charged particles
4. Inductors used in dc power supplies
5. Nuclear Magnetic Resonance (NMR), Electron Paramagnetic Resonance (EPR), and Magnetic Susceptibility Systems.

10.10.2.1 HAZARDS

Examples of Inductor hazards include:

1. Overheating due to overloads, insufficient cooling, or failure of the cooling system could cause damage to the inductor and possible rupture of the cooling system.
2. Electromagnets and superconductive magnets may produce large external force fields that may affect the proper operation of the protective instrumentation and controls.
3. Magnetic fields could attract nearby magnetic material, including tools and surgical implants, causing injury or damage by impact.
4. Whenever a magnet is suddenly de-energized, production of large eddy currents in adjacent conductive material can cause excessive heating and hazardous voltages. This state may cause the release or ejection of magnetic objects.
5. The worker should be cognizant of potential health hazards.
6. Interruption of current in a magnet can cause uncontrolled release of stored energy. Engineered safety systems may be required to safely dissipate stored energy. Large amounts of stored energy can be released in the event of a “quench” in a superconducting magnet.

10.10.2.2 DESIGN AND CONSTRUCTION

The following should be considered:

1. Provide sensing devices (temperature, coolant-flow) that are interlocked with the power source.
2. Fabricate protective enclosures from materials not adversely affected by external electromagnetic fields. Researchers should consider building a nonferrous barrier designed

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to prevent accidental attraction of iron objects and prevent damage to the cryostat. This is especially important for superconducting magnet systems.

3. Provide equipment supports and bracing adequate to withstand the forces generated during fault conditions.
4. Appropriately ground electrical supply circuits and magnetic cores and provide adequate fault protection.
5. Provide means for safely dissipating stored energy when excitation is interrupted or a fault occurs.
6. Provide appropriate warning signs to prevent persons with pacemakers or similar devices from entering areas with fields of greater than 0.001 Tesla.
7. Personnel exposure to magnetic fields of greater than 0.1 Tesla should be restricted.
8. When a magnet circuit includes switching devices that may not be able to interrupt the magnet current and safely dissipate the stored energy, provide a dump resistor connected directly across the magnet terminals that is sized to limit the voltage to a safe level during the discharge and safely dissipate the stored energy.

10.10.2.3 OPERATION AND MAINTENANCE

Verify that any inductor is de-energized before disconnecting the leads or checking continuity or resistance.

10.10.3 ELECTRICAL CONDUCTORS AND CONNECTORS

The conductors and connectors covered here are only those used in unconventional applications.

10.10.3.1 HAZARDS

Examples of hazards are as follows:

1. Metallic cooling-water pipes that are also used as electrical conductors present shock hazards (i.e., they may not be readily recognizable as electrical conductors).
2. Improper application or installation of connectors can result in overheating, arcing, and shock hazards.
3. Hazardous induced voltages and arcing can result from inadequate separation between high- and low-voltage cables.
4. Use of an improper cable for a given type of installation (routing) can result in a fire hazard.

10.10.3.2 DESIGN AND CONSTRUCTION

When working with special conductors and connectors for R&D applications, the following guidelines shall be implemented for design and construction:

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1. Select cables that are listed by an NRTL for a given type of installation (such as in conduits, trays, underground, or in an enclosure) whenever possible. Since cables used for R&D are sometimes unique (such as some coaxial cables), they may not be available as NRTL listed. In that case, obtain AHJ approval.
2. Where liquid- or gas-cooled conductors are used, sensing devices (temperature or coolant-flow) shall be provided for alarm purposes or equipment shutdown if the cooling system malfunctions. Provide adequate labeling, insulation, or other protection for metallic cooling-water piping used as electrical conductors.
3. Provide engineering calculations to support overrating of conductors for any application. Avoid conductor loops (wide spacing) between high-current supply and return conductors to prevent voltage and current induction in adjacent circuits or structural members.
4. Ground coaxial cable shielding when possible. If test conditions require an ungrounded shield, provide barriers and warning signs to notify personnel that the shield is ungrounded and should be assumed to be energized. Provide suitable routing and additional protection for coaxial cables used in pulsed-power applications where the braid of the coaxial cable rises to high voltage levels.

10.10.3.3 OPERATION AND MAINTENANCE

Cable connectors and connections should be checked after installation, periodically, and should be tightened as necessary. Special attention should be given to aluminum cable connections.

Ensure that charges are not built up on equipment that has been disconnected, such as vacuum feedthrough systems.

10.10.4 INDUCTION AND DIELECTRIC HEATING EQUIPMENT

This section describes electrical hazards associated with induction heating, RF equipment, and microwave equipment used in research. The hazards are mainly associated with high-power/high-frequency RF generators, waveguides and conductors, and the working coils producing high temperatures.

10.10.4.1 HAZARDS

1. RF power as high as 50 kW and frequency in the tens of kHz range to hundreds of MHz is supplied from the RF and microwave generators. Being close to or making contact with an unprotected coil, conductors or waveguide opening may result in severe body burns.
2. Dangerous voltages are present inside the power generators.
3. Dangerous levels of RF energy may be present in the laboratory.

10.10.4.2 DESIGN AND CONSTRUCTION

1. The heating coils, sources of high-frequency energy, and other live parts outside the generator cabinet must be shielded or guarded to prevent access or contact.

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2. The heating coil should have its cold (outside) lead properly grounded.
3. A coaxial cable of correct impedance and adequate construction may be desirable to deliver the RF power to the coil in order to prevent the leakage of the RF energy in the laboratory.

10.10.4.3 OPERATION AND MAINTENANCE

1. Shielding must be maintained to minimize RFMW radiation.
2. Wearing metallic objects when operating or maintaining the induction heating system is prohibited.
3. Posting suitable warnings to indicate equipment hazards.

10.10.5 LASERS AND X-RAY EQUIPMENT

This section is applicable to laser systems and x-ray equipment used in research. Both fixed and portable equipment are covered regardless of input voltage. Only electrical hazards are addressed in this subsection. Refer to ANSI Z136.1 for laser hazards and 29 CFR 1910.306 (f) for x-ray hazards.

10.10.5.1 HAZARDS

1. Dangerous voltages are present inside the equipment.
2. Implosion hazards may exist with the covers removed.
3. Energy storage devices may present a hazard due to a residual charge even when the system is de-energized
4. Dangerous voltages can exist across the impedance of the grounding conductor during operation.
5. Failure of interlocks and safety devices may allow access to energized parts.

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CONTENTS

APPENDIX A DOE MODEL ELECTRICAL SAFETY PROGRAM

(THE "DOE MODEL ELECTRICAL SAFETY PROGRAM" WAS CREATED AS OF THE RESULT OF REQUIREMENTS FROM "REPORT OF THE TASK GROUP ON ELECTRICAL SAFETY OF DEPARTMENT OF ENERGY FACILITIES", JANUARY 1993, DOE/EH-0298)

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EXECUTIVE SUMMARY

The Task Group on Electrical Safety of Department of Energy Facilities, in its January 1993 report, described a Model Electrical Safety Program. This concept has been expanded from its original narrative form into more detailed guidelines, drawing upon the electrical safety program of the Sandia National Laboratory for additional material. This model program is offered to the entire Department of Energy (DOE) complex as guidance to assist in developing and maintaining an effective and sound electrical safety program to ensure the safety and well being of all DOE, including contractor, and subcontractor employees working within any DOE site or facility. The model program has been designed to address the major areas of concern identified by the Task Group.

In essence, an Electrical Safety Program for protecting DOE and contractor workers and facilities should be founded firmly on established requirements of OSHA's electrical safety regulations in 29 CFR 1910 and 29 CFR 1926, National Electrical Code (NEC), DOE Orders and applicable state, local, mine, and tunnel safety standards. This program should establish an electrically safe workplace—free from recognized electrical hazards for all employees. Management should commit to involvement at all levels based on familiarity with the requirements.

Each site should establish an electrical safety committee and designate an Authority Having Jurisdiction (AHJ) for interpreting the electrical requirements of OSHA, NEC, and other standards applicable to the site or its facilities. All personnel engaged in electrical work should be trained to have knowledge and understanding of electrical safe work practices. Appropriate electrical testing equipment and personal protective equipment should be provided, properly maintained and used.

A proactive preventive maintenance and inspection program for electrical systems and equipment should be in place and staffed by qualified electricians.

All electrical equipment purchases should meet appropriate codes and electrical safety requirements, as determined by a nationally recognized testing laboratory or as approved by the AHJ.

Before a site can have a successful electrical safety program, a continuous improvement effort and commitment must be clearly understood and shared throughout the site.

Each facility must demonstrate continuous improvement for design, construction, operation, maintenance and revisions at the site. Improvements must be tested against changing codes and regulations as they are made.

The ten principles of personal safety are as follows:

1. Plan every job—Planning is the key to preventing incidents therefore, eliminating injuries.
2. Anticipate unexpected events—If a person thinks about what can go wrong and does something about it, then a potential incident can be prevented.
3. Use the right tool for the job—Each employee must make sure that the correct tool is used and management must make sure the correct tool is available.

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4. Use procedures as tools—Even though procedures are only paper or text, they should be viewed as tools to prevent injury.
5. Isolate the equipment—The best way to avoid accidental release of energy is by isolating the equipment before starting the job (lockout/tagout).
6. Identify the hazard—Employees who are exposed or potentially exposed must be able to recognize when and how they are exposed. Management has the responsibility to provide training to deal with each known hazard, as required.
7. Minimize the hazard—Take all known steps to minimize each hazard and the exposure to each known hazard.
8. Protect the person—The last chance to avoid an injury is to wear personal protective equipment (PPE). Each person must use all protective equipment that is needed. It is management's responsibility to provide all appropriate PPE.
9. Assess people's abilities—Knowledge and ability help prevent injuries. Each person must recognize their limitations whether physical, mental or emotional. Management must also recognize the same limitations.
10. Audit these principles—The audit should validate the principles related to the people, task, and work environment. It should gauge the visibility of the principles in actual behavior.

The six basic elements of an effective Electrical Safety Program are listed below.

- Management must have complete commitment to the program;
- Effective training for all degrees of hazard and a baseline for training must be established;
- Effective and complete safe electrical work practices must be established;
- Documentation must be kept for all activities;
- Electrical safety engineering support must be made; and
- Oversight for the electrical safety program must be established, also.

The model program described in the following pages is presented in terms of purpose, scope, and ownership; performance objectives; responsibilities, authorities, and interfaces; definitions, and implementation guidance. References are listed for more in-depth guidance. A model Charter of the Electrical Safety Committee is provided as an appendix.

1. PURPOSE, SCOPE, AND OWNERSHIP

1.1 PURPOSE

The purpose of an electrical safety program is to

- promote an electrically safe workplace free from unauthorized exposure to electrical hazards for all employees and contractors;
- provide direction to implement electrical safety requirements of Department of Energy (DOE) orders, criteria, and guides. (See Section. 6, References); and
- achieve compliance with Occupational Safety and Health Administration (OSHA) regulations in accordance with DOE orders.

An electrically safe workplace will be achieved by

- mandating and implementing the electrical subparts of Title 29 Code of Federal Regulations 29 CFR 1910 and 29 CFR 1926 as directed by the Secretary of DOE and OSHA; and
- applying the National Electrical Code [National Fire Protection Association (NFPA 70)] and any exceptions by applicable state or local municipal requirements to the design, construction, and maintenance operation of facilities and research and development of electrical/electronic systems.

1.2 SCOPE

The Electrical Safety Program shall apply to all site organizations. These organizations shall conform to

- the host's site electrical safety requirements, and
- the local, city, county, or state jurisdiction.

1.3 OWNERSHIP

Site management shall appoint an organization to be owner of the Electrical Safety Program.

The Electrical Safety Program governs:

- the electrical safety program owned by each department. The departments will develop and implement safe operating procedures specifically applicable to special electrical hazards in their workplaces.

2. PERFORMANCE OBJECTIVES

The Electrical Safety Program has the following objectives.

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Establish an effective electrical safety program by

- establishing the authority having jurisdiction (AHJ) for interpreting OSHA, NFPA 70 and other requirements for electrical work;
- establishing requirements and controls for implementing the program;
- providing guidance to all departments, which includes developing and implementing safe operating procedures with electrical requirements;
- developing an Electrical Safety Program self-assessment process;
- establishing measurement criteria and documentation for self-assessment of the Electrical Safety Program;
- evaluating the Electrical Safety Program on an annual basis to be followed by action plans in response to findings; and
- evaluating each department against the requirements.

Ensure a safe workplace with the lowest reasonable risks from electrical hazards by

- establishing training programs for qualified and unqualified worker requirements and safe work practices for all personnel engaged in electrical work in accordance with 29 CFR 1910.331-335;
- complying with all applicable electrical requirements of
- 29 CFR 1910 and 29 CFR 1926;
- the NFPA;
- American National Standards Institute (ANSI-C2), the National Electrical Safety Code (NESC);
- DOE orders; and
- state, county and local revisions of the preceding requirements;
- requiring the development and maintenance of an Electrical Safety Program; and
- allocation of resources for implementing this program.

3. RESPONSIBILITIES, AUTHORITIES, AND INTERFACES

3.1 MANAGEMENT

Management ensures that the Electrical Safety Program is integrated into an overall Environmental, Safety, and Health (ES&H) program, selects the Electrical Safety Committee Chair, and approves the committee’s charter.

3.2 ES&H MANAGERS

ES&H managers provide oversight for implementing the Electrical Safety Program.

3.3 ELECTRICAL SAFETY COMMITTEE

The Electrical Safety Committee (ESC) should act as the AHJ for interpreting electrical codes and regulations.

The ESC

- presents management with the requirements and training needed to implement the program;
- advises management of the need to fund and support these requirements;
- maintains and assists in the implementation of the Electrical Safety Program;
- develops and maintains the electrical safety manual;
- assists the departments by interpreting the electrical requirements of DOE orders, criteria, and guides and other codes, standards, and practices;
- maintains a copy of each interpretation given; and
- publishes electrical safety bulletins.

The committee interfaces with DOE, all organizations and sites, and other DOE contractors.

3.3.1 ESC SUBCOMMITTEES

The ESC subcommittees address site-wide electrical safety issues and may be comprised of ESC members as well as non-Electrical Safety Committee members. The electrical chair appoints subcommittee chairs, who are not required to be members of the ESC. All subcommittee reports and recommendations are approved by a majority of the ESC.

3.4 MAINTENANCE MANAGERS

Maintenance managers implement the Electrical Safety Program by developing an electrical preventative maintenance program and providing qualified electricians. They also ensure that managers, first line supervisors, and a staff of crafts workers and their assistants complete all applicable courses of electrical safety training. Maintenance managers also ensure that all facilities are maintained in compliance with NEC (NFPA 70) and the NESC (ANSI-C2).

3.5 FACILITY OPERATIONS AND MAINTENANCE DEPARTMENT MANAGERS

Operations managers are responsible for implementing the Electrical Safety Program by providing safe work procedures and permits for high and low voltage work as required. They also provide and

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implement other critical procedures such as lockout/tagout, testing, and safety-related work practices as required by 29 CFR 1910.331-335. These managers ensure that crafts workers of all disciplines and their immediate supervisors working with, or in proximity to, electrical equipment receive

- electrical safety awareness training;
- general and job-specific training in safe electrical work practices as required in 29 CFR 1910, Subpart S; and
- training in NFPA and ANSI codes and standards.

3.6 FACILITY ENGINEERING DESIGN DEPARTMENT MANAGERS

Facility engineering managers are responsible for implementing requirements of this Electrical Safety Program during facility design by ensuring compliance with DOE Order 6430.1A "General Design Criteria." These managers also ensure that the electrical engineers and designers attend

- electrical safety awareness training;
- general and job-specific training in safe electrical work practices as required in 29 CFR 1910, Subpart S; and
- training in NFPA, IEEE, and ANSI codes and standards.

In addition, they also ensure that all workplace modification designs are in compliance with 29 CFR 1910, Subpart S, and NFPA 70E. They also provide and maintain up-to-date electrical drawings to adequately describe the various building systems and modifications.

3.7 CONSTRUCTION MANAGERS

Construction managers are responsible for implementing and enforcing the requirements of NFPA 70, ANSI C2, and OSHA 29 CFR 1926 during construction of all facilities by providing AHJ-approved certification for electrical inspectors. They also ensure that the inspectors receive training in NFPA 70, OSHA 29 CFR 1926, ANSI C2, and electrical safety awareness.

3.8 SAFETY ENGINEERING MANAGERS

Safety managers provide oversight and customer liaison for electrical safety for the departments. They also provide cognizant electrical safety professionals trained in the application of NEC, OSHA, etc.

3.9 DEPARTMENT MANAGERS

Department managers are responsible for implementing Section 5 of this Electrical Safety Program in their departments by:

- identifying electrical hazards and documenting them within their departments,
- familiarizing personnel with electrical hazards,

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- developing and implementing safe operating procedures to ensure safe electrical work practices that mitigate the risks of electrical hazards,
- developing and implementing an action plan for documenting and correcting electrical deficiencies,
- conducting periodic inspections of their workplaces and electrical equipment,
- conducting safety meetings that include electrical safety topics,
- ensuring that personnel receive Electrical Safety Awareness Training and other task specific electrical safety training as required by 29 CFR 1910.332,
- ensuring that their contractors comply with the requirements of this program as applicable, and
- developing interfaces with their representatives on the ESC.

3.10 EMPLOYEES, VISITORS, ON-SITE CONTRACTORS AND SUBCONTRACTORS

All employees and on-site contractors are responsible for:

- having an awareness of the electrical hazards in their workplaces;
- reporting electrical occurrences, shocks, and discovered hazards;
- reporting all electrical shocks as injuries to the Health Services Department;
- reading, understanding, and following applicable safe operating procedures having electrical requirements;
- adopting and implementing safe electrical work practices;
- attending appropriate Electrical Safety Awareness Training and other equivalent job-specific training as required by 29 CFR 1910.332;
- using appropriate personnel protective equipment; and
- developing interfaces with their representatives on the ESC.

3.11 PURCHASING MANAGERS

Purchasing managers are responsible for specifying that, when available, purchases of electrical equipment and appliances are listed by a nationally recognized testing laboratory (NRTL) such as Underwriters' Laboratories, Inc., (UL).

3.12 ES&H TRAINING MANAGER

These managers are responsible for developing and overseeing electrical safety training courses, including any site-specific electrical safety training courses, as required by the ESC and the Electrical Safety Program.

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4. DEFINITIONS

Authority Having Jurisdiction (AHJ)

Interprets the requirements of the National Electrical Code (NFPA 70); the National Electrical Safety Code (ANSI C2); 29 CFR 1910, Subpart S; 29 CFR 1926, Subparts K and V; and DOE Order 6430.1A, “General Design Criteria.” Approves electrical equipment, wiring methods, electrical installations, and utilization equipment for compliance. Coordinates these functions with ES&H management and the DOE area or field office.

Approved

Acceptable to the AHJ.

Appliance

Utilization equipment, generally other than industrial, normally built in standardized sizes or types, that is, installed or connected as a unit to perform one or more functions such as refrigerators, air conditioning, and so forth.

Electrical Shock, Reportable

Any electrical shock is classified as an injury and must be reported immediately to health services and supervision.

The employee must not attempt to evaluate the severity of the shock or its effects without medical consultation.

Equipment

Material, fittings, devices, appliances, fixtures, apparatus, and so forth, used as part of, or in connection with, an electrical installation.

Examination

Examination process described in 29 CFR 1910.303(b)(1), “Examination”, and NFPA 70, Article 110-3, “Examination, Identification, and Use for Equipment”. These examinations are performed by a qualified person to ensure that electrical equipment is free from recognized hazards that are likely to cause death or serious physical harm.

Equipment, Utilization

Equipment that uses electrical energy for electronic, electromechanical, chemical, heating, lighting, or similar purposes.

Labeled

Equipment or materials to which a label, symbol, or other identifying mark has been applied by an NRTL.

Listed

Equipment or materials included in a list published by an NRTL

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Nationally Recognized Testing Laboratory (NRTL)

An organization acceptable to the AHJ and concerned with product evaluation that maintains periodic inspection of production of listed equipment and materials. The NRTL ensures that the equipment or materials meet appropriate designated standards or have been tested and found suitable for use in a specified manner. (Refer to 29 CFR 1910.7 "Definition and Requirements for a Nationally Recognized Testing Laboratory.")

Personnel

Employees and on-site contractors.

Qualified Personnel

Personnel trained and familiar with the construction and operation of electrical systems and equipment and their associated hazards. (Refer to 29 CFR 1910.399, "Definitions", Qualified Person, Notes 1 and 2.)

Qualification Requirements for AHJ Inspectors

Current AHJ recognized electrical inspection certification, or AHJ-approved education and experience in applying the requirements contained in NFPA 70; ANSI C2; 29 CFR 1910, Subpart S; 29 CFR 1926, Subparts K and V, and DOE Order 6430.1A, General Design Criteria.

NOTE: AHJ inspectors derive their authority from and coordinate their interpretations through the ESC.

5. IMPLEMENTATION GUIDANCE

5.1 INTRODUCTION

The objective of this section is to provide multilevels of management with the criteria to implement this Electrical Safety Program in their organizations. To achieve this objective, managers and ES&H coordinators should

- identify electrical hazards in their workplaces;
- familiarize personnel with these electrical hazards;
- develop and implement safe operating procedures to ensure safe electrical work practices that mitigate the risks of electrical hazards;
- conduct periodic inspections of their workplaces and electrical equipment;
- develop and implement an action plan for documenting and correcting electrical deficiencies, and
- ensure that personnel receive Electrical Safety Awareness Training and other job-specific electrical safety training as required by 29 CFR 1910.332.

Involving all employees and on-site contractors in the electrical safety process is essential to ensure successful implementation of this program.

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5.2 ADMINISTRATION AND SAFE CONDUCT OF ELECTRICAL WORK

Performance Objective:

Minimize personnel exposure to electrical hazards.

To ensure the safe conduct of electrical work, each organization must

- define, establish, and understand individual accountabilities, authorities, interfaces, roles and responsibilities;
- properly allocate resources to satisfy requirements;
- establish administrative controls and procedures to meet the hazard assessment and work practices of 29 CFR 1910.331-335;
- establish procedures to ensure proper review, approval, work authorization, oversight and documentation for electrical work;
- conduct safety meetings on job-related electrical issues; and
- implement 29 CFR 1910.333 lockout/tagout requirements and procedures.

Electrical safety related work practices will be implemented by each organization in accordance with 29 CFR 1910 as amended in August 1991:

- 1910.331, Qualified and Unqualified Employees
- 1910.332, Training
- 1910.333, Selection and Use of Work Practices
- 1910.334, Use of Equipment
- 1910.335, Safeguards for Personnel Protection

5.3 TRAINING

Performance Objective:

Establish qualification requirements, training programs and certifications where appropriate for all personnel.

Prior to performing electrical work, personnel must be qualified to perform job-related electrical tasks as required by 29 CFR 1910.332.

Personnel exposed to the presence of voltages of 50 V or more will have formal electrical safety awareness training. This training can be in a classroom or on the job.

All training must be documented.

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- Instructors must provide course outlines.
- Proof of successful completion must be maintained in appropriate files.

Minimum training requirements should include

- electrical safety awareness;
- electrical safety theory;
- applicable codes, DOE orders, regulations, and standards;
- demonstrations and hands-on practice;
- use and care of personal protective equipment;
- job-specific safe electrical work practices; and
- electrical requirements of safe operating procedures and operating procedures.
- Personnel working with high voltage (greater than 600 V) must have specialized electrical awareness training.
- Periodic training refresher courses are required to maintain and update skills and code requirements.

Management and supervision who oversee electrical work must have completed Electrical Safety Awareness Training at a level commensurate with the level of work being performed.

5.4 PERSONAL PROTECTIVE EQUIPMENT

Performance Objective:

Provide personal protective equipment for electrical work. Establish documented procedures for its use, care, maintenance, and testing. [Guidance for these procedures can be found in 29 CFR 1910.137 and 29 CFR 1910.268(f).]

Managers shall ensure that adequate resources are available to provide personal protective equipment in compliance with applicable codes and standards. In addition, they shall ensure that:

- personnel are trained in its use in accordance with documented procedures;
- procedures are established and implemented for documented controls of protective equipment such as inventory, storage, maintenance, and testing;
- protective equipment requirements and usages are specified in the safe operating procedures;
- protective equipment is inspected prior to each use;
- high-voltage equipment is inspected prior to each use according to appropriate recognized standards and
- grounding equipment, cables, clusters, and sticks, are inspected annually and prior to each use.

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5.5 ELECTRICAL PREVENTIVE MAINTENANCE (EPM) PROGRAM

Performance Objective:

Establish an electrical preventative maintenance program to ensure safe and reliable operation of electrical wiring, protection devices, and operating equipment such as switches, circuit breakers, utilization equipment, and appliances.

Managers will ensure that adequate resources are available to provide for compliance with applicable codes and standards. In addition, they will ensure that:

- procedures are established for EPM intervals, inspections, tests, and servicing requirements;
- records are maintained of all tests, inspections, servicing, and inventories;
- documentation, tests, test intervals, and procedures are guided by the recommendations of NFPA 70B, manufacturer's recommendations, industry standards, or DOE-adopted standards or regulations;
- copies of all manufacturer's installation, operating, and maintenance instructions are maintained in a department file; and
- EPM work is performed only by qualified personnel.

5.6 CODE COMPLIANCE

Performance Objective:

Ensure compliance with all applicable electrical requirements of DOE Orders, the NFPA, ANSI C2, and the respective parts of 29 CFR 1910 and 29 CFR 1926.

All electrical installations and equipment are subject to inspection and the approval of the AHJ.

5.6.1 CODE AND REGULATION INSPECTORS

Inspectors representing the AHJ will be qualified as required by the AHJ in:

- National Electrical Code (NFPA 70);
- 29 CFR 1910, Subpart S; and
- 29 CFR 1926, Subparts K and V.

Managers will ensure that adequate resources are available to provide for compliance with applicable codes and standards. In addition, they will ensure that:

- Inspections are performed by qualified personnel on all new electrical work and equipment, including utilization equipment. These inspections will be in accordance with 29 CFR 1910, Subpart S.

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- Any potential imminent danger situation is corrected immediately or personnel is removed from the hazard.
- Resources are available to abate all true electrically hazardous conditions.
- Inspections are documented. Inspection records, deficiencies, and corrective actions will be maintained in a department file.
- Examinations are performed on all equipment that is not listed or labeled by a NRTL.
- Record drawings of all electrical systems and equipment are maintained and a rigid system exists for recording changes and correcting the drawings to reflect those changes.

5.6.2 AUTHORITY HAVING JURISDICTION (AHJ)

The ESC is the AHJ for interpreting electrical codes, standards, and regulations.

5.6.3 EXEMPTION AND WAIVERS

All requests for code and regulation exemptions and waivers will first be submitted to the ESC for action.

Requests for exemptions and waivers will include:

- a description of the problem and the reason for requesting noncompliance;
- code or regulation references;
- proposed mitigative steps to be taken such as warning signs, barriers, and procedures to provide equivalent protection; and
- proposed dates for the variance.

Normally, exemptions and waivers are not granted for 1) longer than 180 days, 2) the time it takes to correct the deficiency, or 3) the duration of an approved program or operation. (See Section 4.0, Definitions). Exemptions and waivers are granted by the DOE Assistant Secretary for Environment, Safety, and Health in accordance with DOE Document DOE/ID-10600.

5.6.4 EQUIPMENT AND MATERIALS APPROVAL

All electrical equipment and materials for facility wiring, and similar R&D wiring, as defined by NFPA 70 will be approved in accordance with Article 90-7, “Examination of Equipment for Safety,” and Article 110-3, “Examination, Identification, Installation, and Use of Equipment.”

5.6.5 UTILIZATION EQUIPMENT

Utilization equipment is addressed in 29 CFR 1910.302 and 303. This document makes it clear that utilization equipment is subject to the same approval and acceptance requirements as in Section 5.6.4 of this document.

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- To be acceptable for installation and use, utilization equipment will be listed or labeled by a NRTL.
- Utilization equipment that is not listed or labeled will meet one of the requirements of 29 CFR 1910.399, Acceptable, (i)(ii), or (iii).
- Utilization equipment that is not listed or labeled will be examined, accepted, and documented by a qualified person.
- Utilization equipment must be used in accordance with its listing and labeling requirements.

  NOTE: Utilization equipment includes laboratory and shop equipment, appliances, or other devices that operate from an electrical energy source.

5.6.6 TEST INSTRUMENTS AND EQUIPMENT

Test instruments and equipment are intended only for use by qualified personnel and shall be used in accordance with 29 CFR 1910.334(c). In addition, a qualified person will inspect all test instruments and equipment to ensure that it is safe to use as intended by the manufacturer. If found unsafe, they will not be used unless warning labels, special operating procedures, or modifications are used to mitigate the hazard.

- Test instruments and equipment will be visually inspected before each use.
- Test instruments and equipment and their accessories shall be electrically rated for their intended use.

5.6.7 EQUIPMENT OF FOREIGN MANUFACTURE

All equipment of foreign manufacture is subject to acceptance as defined in 29 CFR 1910.399. Listing and labeling of equipment by foreign laboratories or standards may require examination to ensure that the equipment is wired to the electrical requirements of NFPA 70 as well as 29 CFR 1910.334.

5.6.8 APPLIANCES FOR PERSONAL USE

All appliances for personal use in the workplace such as coffee pots, refrigerators, and radios should be listed and exhibit the label of a NRTL.

5.6.9 QUALIFIED EXAMINERS OF RESEARCH AND DEVELOPMENT (R&D) EQUIPMENT

R&D managers may appoint at least one person in their organization to examine equipment and materials for approval prior to use. This person(s) will be knowledgeable in specified code and regulation requirements for examination and with the NRTL process. This person will contact an electrical safety staff member for guidance in examination procedures.

NOTE: If an organization does not have a qualified person, an electrical safety staff member should be contacted for assistance.

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5.7 ENGINEERING AND INSPECTION

Performance objective:

Provide electrical safety engineering and inspection resources to ensure that this Electrical Safety Program and all mandatory codes and regulations are implemented.

5.7.1 R&D AND FACILITY REQUIREMENTS

R&D and facility organizations will ensure that their electrical systems are constructed and maintained in compliance with the electrical safety criteria.

5.7.2 CERTIFIED ELECTRICAL INSPECTORS

Certified (AHJ-approved certification) electrical code inspectors will be provided for construction and maintenance work.

Inspectors

Inspectors will have an AHJ-approved certification in the National Electrical Code and will be qualified in the electrical safety requirements of 29 CFR 1910 and 29 CFR 1926. In addition, inspectors will

- have the responsibility of inspecting electrical work performed during both maintenance projects and construction projects;
- provide documentation of electrical inspections of both maintenance projects and construction projects;
- participate in the quality assurance QA process and QA review process;
- provide an inspection resource for all organizations;
- participate in the QA programs of other organizations as required, and
- review and sign off on safe operating procedures with electrical requirements.

5.7.3 QUALIFIED PERSONNEL

All persons performing electrical work will be qualified in accordance with the requirements of 29 CFR 1910.331 through 335. Electrical work will be performed by qualified personnel as follows.

Connection to and operation of circuit breakers in building electrical panels may be performed only by qualified electricians.

NOTE: In an emergency, a knowledgeable employee may operate a circuit breaker in a building only to disconnect power

- Power cords and plugs, rated 15 or 20 A, provided with electrical equipment and intended to be installed by the user, will be installed by a qualified person. The manufacturer's

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instructions will be followed explicitly. A polarity and ground continuity test will be performed on the cord and plug set before inserting the plug into a receptacle.

- All other electrical work will be performed by qualified electronic technicians and electricians.

5.7.4 QUALITY ASSURANCE (QA)

Qualified personnel will participate in the QA process and provide design input and oversight as follows.

- Review electrical plans for all new, or modifications to, facilities and R&D projects.
- Review safe operating procedures for Electrical Safety Program compliance.
- Periodically inspect wiring materials, connections, and components of existing facilities and R&D projects.
- Review drawings, specifications, and manufacturer's installation operation instructions for all electrical equipment prior to connection and operations

5.7.5 ELECTRICAL OCCURRENCE REPORTS

Electrical occurrences, including electrical shocks, shall be reported in accordance with DOE Order 5000.3A.

6. REFERENCES

6.1 IMPLEMENTING REFERENCES

29 CFR 1910, Subpart S, and 29 CFR 1926, Subparts K and V.

DOE Electrical Safety Guidelines, DOE/ID 10600.

Electrical Safety Criteria for Research and Development Activities, DOE/EV-0051/1, Interim Criteria.

Electrical Safety Task Force Report.

Factory Mutual Approval Guide.

Factory Mutual Data Sheets.

General Design Criteria, DOE Order 6430.1A.

International Association of Electrical Inspectors, Inc. (IAEI).

International Congress of Building Officials (ICBO).

Institute of Electronic and Electrical Engineers (IEEE).

National Electrical Code, National Fire Protection Association 70.

National Electrical Safety Code, American National Standards Institute standard C2.

National Fire Codes, National Fire Protection Association (NFPA). (Refer to Section 6.3.)

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Standard for Fire Protection of DOE Electronic Computer/Data Processing Systems, DOE/EP-0108.

Underwriters Laboratories, Inc., Listings and Classifications Directory.

Uniform Building Code. latest edition and supplements.

Uniform Fire Code, latest edition and supplements.

Williams-Steiger Occupational Safety and Health Act of 1970, standards:

- Occupational Safety and Health Standards, 29 CFR 1910, General Industry Standards.
- Safety and Health Regulations for Construction, 29 CFR 1926.

6.2 DEVELOPMENTAL REFERENCES

Conduct of Operations Requirements for DOE Facilities, DOE Order 5480.19.

Environmental Protection, Safety, and Health Protection Information Reporting Requirements, DOE Order 5484.1.

Environmental Protection, Safety, and Health Protection Standards, DOE Order 5480.4.

Fire Protection, DOE Order 5480.7.

General Design Criteria, DOE Order 6430.1A.

General Operations Quality Assurance, Revision II, DOE/AL Order 5700.6B.

Occurrence Reporting and Processing of Operations Information, DOE Order 5000.3A.

Maintenance Management Program, DOE Order 4330.4A.

Maintenance Management Program Guidance, DOE/AL 4330.4A.

Protection of Electronic Computers and Data Procession Equipment, DOE/EP-0108.

Safety Analysis and Review, DOE Order 5481.1B.

6.3 NFPA REFERENCES WITH ELECTRICAL REQUIREMENTS

Volume 1

1 Fire Prevention Code
20 Standard for the Installation of Centrifugal Fire Pumps
30 Flammable and Combustible Liquids Code
30A Automotive and Marine Service Station Code

Volume 2

33 Standard for Spray Application Using Flammable and Combustible Liquids
34 Standard for Dipping and Coating Processes Using Flammable or Combustible Liquids
45 Standard on Fire Protection for Laboratories Using Chemicals
50 Standard for Bulk Oxygen Systems at Consumer Sites

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50A Standard for Gaseous Hydrogen Systems at Consumer Sites
50B Standard for Liquefied Hydrogen Systems at Consumer Sites
54 National Fuel Gas Code
58 Standard for the Storage and Handling of Liquefied Petroleum Gases
69 Standard on Explosion Prevention Systems

Volume 3

70 National Electrical Code (NEC)
70B Electrical Equipment Maintenance
70E Standard for Electrical Safety Requirements for Employee Work Places
72A Standard for the Installation, Maintenance, and Use of Local Protective Signaling Systems for Guard's Tour, Fire Alarm, and Supervisory Service
72B Standard for the Installation, Maintenance, and Use of Proprietary Protective Signaling Systems
72E Standard on Automatic Fire Detectors
72F Standard for the Installation, Maintenance, and Use of Emergency Voice/Alarm Communication Systems
75 Standard for the Protection of Electronic Computer/Data Processing Equipment
78 Lightning Protection Code
79 Electrical Standard for Industrial Machinery

Volume 4

88B Standard for Repair Garages
90A Standard for the Installation of Air Conditioning and Ventilation Systems
90B Standard for the Installation of Warm Air Heating and Air Conditioning Systems
91 Standard for the Installation of Blower and Exhaust systems
96 Standard for the Installation of Equipment for the Removal of Smoke and Grease-Laden Vapors from Commercial Cooking Equipment

Volume 5

99 Standard for Health Care Facilities
99B Standard for Hypobaric Facilities
101 Code for Safety to Life from Fire in Buildings and Structures (the Life Safety Code)
102 Standard for Assembly Seating, Tents, and Membrane Structures
110 Standard for Emergency and Standby Power Systems

Volume 6

122 Standard for the Storage of Flammable and Combustible Liquids Within Underground Metal and Nonmetal Mines (Other than Coal)
220 Standard on Types of Building Construction
241 Standard for Safeguarding Construction, Alteration, and Demolition Operations
318 Standard for the Protection of Clean Rooms
321 Standard on Basic Classification of Flammable and Combustible Liquids
385 Standard for Tank Vehicles for Flammable and Combustible Liquids

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Volume 7

407 Standard for Aircraft Fueling Servicing
493 Standard for Intrinsically Safe Apparatus and Associated Apparatus for use in Class I, II, and III, Division 1 Hazardous Locations [Discontinued see Underwriters' Laboratories, Inc. (UL), UL913, Intrinsically Safe Apparatus and Associated Apparatus for Use in Class I, II and III, Division 1, Hazardous Locations]
495 Code for the Manufacture, Transportation, Storage, and Use of Explosive Materials
496 Standard for Purges and Pressurized Enclosures for Electrical Equipment
498 Standard for Explosives Motor Vehicle Terminals
704 Standard Systems for the Identification of the Fire Hazards of Materials

Volume 8

1141 Standard for Fire Protection in Planned Building Groups
1221 Standard for the Installation, Maintenance, and Use of Public Fire Service Communication Systems

Volume 9

68 Guide for Explosion Venting
70B Recommended Practices for Electrical Equipment Maintenance
72G Guide for the Installation, Maintenance, and Use of Notification Appliances for Protective Signaling Systems
72H Guide for Testing Procedures for Local, Auxiliary, Remote Station, and Proprietary Signaling Systems
77 Recommended Practices on Static Electricity
80A Recommended Practice for Protection of Buildings from Exterior Fire Exposure
97M Standard Glossary of Terms Relating to Chimneys, Vents, and Heat-Producing Appliances

Volume 10

325M Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Materials
328 Recommended Practices for the Control of Flammable and Combustible Liquids and Gases in Manholes and Sewers

Volume 11

497A Recommended Practice for Classification of Class I Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas
497M Manual for Classification of Gases, Vapors, and Dust for Electrical Equipment in Hazardous (Classified) Locations
802 Recommended Fire Protection Practice for Nuclear Research Reactors
901 Uniform Coding for Fire Protection
907M Manual on the Investigation of Fires of Electrical Origin

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CHARTER OF THE ELECTRICAL SAFETY COMMITTEE (ESC)

I. PURPOSE, OBJECTIVES, AND RESPONSIBILITIES

A. Provide the contractor or company with a competent technical resource for identifying, recommending resolution of, and communicating electrical safety issues.

B. Enhance electrical safety by reducing risk, mitigating hazards, and providing root cause analysis in electrical energy distribution and applications in R&D laboratories and other workplaces.

C. Identify the need for and establish new electrical safety initiatives and programs.

D. Develop, review, and approve electrical safety training programs.

E. Review all occurrence reports involving electrical issues, and participate in the root cause analysis process.

F. Participate in DOE electrical safety programs such as the DOE ESC, the development and maintenance of the DOE Electrical Safety Guidelines document, and the process for requesting and monitoring exemptions and waivers to guidelines.

G. The committee shall be responsible for implementation of this program.

II. MEMBERSHIP

A. Site management appoints the chair of the ESC and approves the charter.

B. The chair shall appoint a secretary.

C. The committee shall be made up of one member and an alternate appointed by each line organization or division and appropriate trades organization(s).

D. Advisors to the ESC shall attend and participate in committee meetings and activities. Advisors shall be line organization personnel who have special interests and/or knowledge concerning electrical safety. Advisors shall be approved by the committee.

E. The DOE area or field office appoints a representative to the ESC to coordinate electrical safety concerns involving the ESC and DOE.

F. Committee members shall be knowledgeable in electrical safety through education and/or experience and shall be actively pursuing electrical engineering, electrical safety, or R&D functions in the performance of their duties and shall be committed to the broad electrical safety concerns of the site and its employees.

III. COMMITTEE AUTHORITY

The ESC shall be the authority having jurisdiction (AHJ) for the implementation of the National Electrical Code, 29 CFR 1910, Subpart S, and 29 CFR 1926, Subpart K.

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IV. OPERATIONAL GUIDELINES

A. The committee shall meet at least quarterly, and the meeting shall be called by the chair or by the secretary in the absence of the chair.

B. ESC bulletins and all revisions to the Electrical Safety Manual will be reviewed by the ESC.

C. Subcommittees to address particular areas of electrical safety may be formed at the direction of the chair, by vote of the committee, or by a voting member with the concurrence of the chair or committee. At least one ESC member shall serve on each subcommittee.

D. Designated alternate members shall vote in the absence of members and shall provide consultation and advice to individual members or the whole committee, as requested.

E. The chair shall appoint someone to serve as the chair in the chair's absence.

F. The secretary shall record and distribute ESC meeting minutes.

V. MANAGEMENT REVIEW

Conduct of the meetings and any resulting recommendations (with supporting documentation) will be communicated to ES&H management through the meeting minutes.

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APPENDIX B ACRONYMS AND DEFINITIONS

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B.1 ACRONYMS

ac	alternating current
AHJ	Authority Having Jurisdiction
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
CB	circuit breaker
CFR	Code of Federal Regulations
CMAA	Crane Manufacturers Association of America
CPR	Cardiopulmonary resuscitation
CT	current transformer
dc	direct current
DOD	Department of Defense
DOE	Department of Energy
DOL	Department of Labor
ECC	Emergency Control Center
EED	electroexplosive device
EGC	equipment grounding conductors
EMR	electromagnetic radiation
ESC	Electrical Safety Committee
ES&H	Environmental Safety & Health
EPM	electrical preventive maintenance
FLC	Full Load Current
FMEC	Factory Mutual Engineering Corporation
FPN	Fine Print Note
GEC	grounding electrode conductor
GFCI	ground-fault circuit interrupter
GFP	ground-fault protection
IEEE	Institute of Electrical and Electronic Engineers
IEC	International Electrotechnical Commission
IES	Illumination Engineering Society of North America
ISA	Instrument Society of America

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J	Joule
kV	kilovolts
mA	milliamps
MOV	metal oxide varistor
MPE	maximum permissible exposure
NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
NESC	National Electrical Safety Code
NFPA	National Fire Protection Association
NIST	National Institute of Standards and Technology
NRTL	Nationally Recognized Testing Laboratory
OCPD	Overcurrent Protection Device
OSHA	Occupation Safety and Health Administration
PCB	polychlorinated biphenyl
PIC	person in charge
R&D	Research and Development
RF	radio frequency
RFMW	Radio Frequency Microwave
UBC	Uniform Building Code
UFAS	Uniform Federal Accessibility Standard
UL	Underwriters Laboratory, Inc.

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B.2 DEFINITIONS

DEFINITIONS APPLICABLE TO 29 CFR 1910 SUBPART S

Acceptable—An installation or equipment is acceptable to the Assistant Secretary of Labor, and approved within the meaning of this Subpart S:

i. If it is accepted, or certified, or listed, or labeled, or otherwise determined to be safe by a nationally recognized testing laboratory; or

ii. With respect to an installation or equipment of a kind which no nationally recognized testing laboratory accepts, certifies, lists, labels, or determines to be safe, if it is inspected or tested by another Federal agency, or by a State, municipal, or other local authority responsible for enforcing occupational safety provisions of the National Electrical Code, and found in compliance with the provisions of the National Electrical Code as applied in this subpart; or

iii. With respect to custom-made equipment or related installations which are designed, fabricated for, and intended for use by a particular customer, if it is determined to be safe for its intended use by its manufacturer on the basis of test data which the employer keeps and makes available for inspection to the Assistant Secretary and his authorized representatives. Refer to 1910.7 for definition of nationally recognized testing laboratory.

Accepted—An installation is "accepted" if it has been inspected and found by a nationally recognized testing laboratory to conform to specified plans or to procedures of applicable codes.

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

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

Ampacity—Current-carrying capacity of electric conductors expressed in amperes.

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

Approved—Acceptable to the authority enforcing this subpart. The authority enforcing this subpart is the Assistant Secretary of Labor for Occupational Safety and Health. The definition of "acceptable" indicates what is acceptable to the Assistant Secretary of Labor, and therefore approved within the meaning of this Subpart.

Approved for the purpose—Approved for a specific purpose, environment, or application described in a particular standard requirement. Suitability of equipment or materials for a specific purpose, environment or application may be determined by a nationally recognized testing laboratory,

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inspection agency or other organization concerned with product evaluation as part of its listing and labeling program. (See "Labeled" or "Listed.")

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

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

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

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

Bare conductor—See "Conductor."

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

Bonding jumper—A reliable conductor to assure the required electrical conductivity between metal parts required to be electrically connected.

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

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

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

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

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

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Center pivot irrigation machine—A center pivot irrigation machine is a multi-motored irrigation machine which revolves around a central pivot and employs alignment switches or similar devices to control individual motors.

Certified—Equipment is “certified” if it (a) has been tested and found by a nationally recognized testing laboratory to meet nationally recognized standards or to be safe for use in a specified manner, or (b) is of a kind whose production is periodically inspected by a nationally recognized testing laboratory, and (c) it bears a label, tag, or other record of certification.

Circuit breaker—

i. (600 volts nominal, or less). A device designed to open and close a circuit by nonautomatic means and to open the circuit automatically on a predetermined overcurrent without injury to itself when properly applied within its rating.

ii. (Over 600 volts, nominal). A switching device capable of making, carrying, and breaking currents under normal circuit conditions, and also making, carrying for a specified time, and breaking currents under specified abnormal circuit conditions, such as those of short circuit.

Class I locations—Class I locations are those in which flammable gases or vapors are or may be present in the air in quantities sufficient to produce explosive or ignitable mixtures. Class I locations include the following:

i. *Class I, Division 1*. A Class I, Division 1 location is a location:

   a. in which hazardous concentrations of flammable gases or vapors may exist under normal operating conditions; or

   b. in which hazardous concentrations of such gases or vapors may exist frequently because of repair or maintenance operations or because of leakage; or © in which breakdown or faulty operation of equipment or processes might release hazardous concentrations of flammable gases or vapors, and might also cause simultaneous failure of electric equipment.

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

ii. *Class I, Division 2.* A Class I, Division 2 location is a location:

   a. in which volatile flammable liquids or flammable gases are handled, processed, or used, but in which the hazardous liquids, vapors, or gases will normally be confined within closed

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containers or closed systems from which they can escape only in case of accidental rupture or breakdown of such containers or systems, or in case of abnormal operation of equipment; or

b. in which hazardous concentrations of gases or vapors are normally prevented by positive mechanical ventilation, and which might become hazardous through failure or abnormal operations of the ventilating equipment; or

c. that is adjacent to a Class I, Division 1 location, and to which hazardous concentrations of gases or vapors might occasionally be communicated unless such communication is prevented by adequate positive-pressure ventilation from a source of clean air, and effective safeguards against ventilation failure are provided.

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

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

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

Class II locations—Class II locations are those that are hazardous because of the presence of combustible dust. Class II locations include the following:

i. *Class II, Division 1*. A Class II, Division 1 location is a location:

a. In which combustible dust is or may be in suspension in the air under normal operating conditions, in quantities sufficient to produce explosive or ignitable mixtures; or

b. where mechanical failure or abnormal operation of machinery or equipment might cause such explosive or ignitable mixtures to be produced, and might also provide a source of ignition through simultaneous failure of electric equipment, operation of protection devices, or from other causes, or

c. in which combustible dusts of an electrically conductive nature may be present.

NOTE: This classification may include areas of grain handling and processing plants, starch plants, sugar-pulverizing plants, malting plants, hay-grinding plants, coal pulverizing plants, areas where metal dusts and powders are produced or processed, and other similar locations which contain dust producing machinery and equipment (except where the equipment is dust-tight or vented to the outside). These areas would have combustible dust in the air, under normal

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operating conditions, in quantities sufficient to produce explosive or ignitable mixtures. Combustible dusts which are electrically nonconductive include dusts produced in the handling and processing of grain and grain products, pulverized sugar and cocoa, dried egg and milk powders, pulverized spices, starch and pastes, potato and woodflour, oil meal from beans and seed, dried hay, and other organic materials which may produce combustible dusts when processed or handled. Dusts containing magnesium or aluminum are particularly hazardous and the use of extreme caution is necessary to avoid ignition and explosion.

ii. Class II, Division 2. A Class II, Division 2 location is a location in which:

   a. combustible dust will not normally be in suspension in the air in quantities sufficient to produce explosive or ignitable mixtures, and dust accumulations are normally insufficient to interfere with the normal operation of electrical equipment or other apparatus; or

   b. dust may be in suspension in the air as a result of infrequent malfunctioning of handling or processing equipment, and dust accumulations resulting therefrom may be ignitable by abnormal operation or failure of electrical equipment or other apparatus.

NOTE: This classification includes locations where dangerous concentrations of suspended dust would not be likely but where dust accumulations might form on or in the vicinity of electric equipment. These areas may contain equipment from which appreciable quantities of dust would escape under abnormal operating conditions or be adjacent to a Class II Division 1 location, as described above, into which an explosive or ignitable concentration of dust may be put into suspension under abnormal operating conditions.

Class III locations—Class III locations are those that are hazardous because of the presence of easily ignitable fibers or flyings but in which such fibers or flyings are not likely to be in suspension in the air in quantities sufficient to produce ignitable mixtures. Class III locations include the following:

i. *Class III, Division 1*. A Class III, Division 1 location is a location in which easily ignitable fibers or materials producing combustible flyings are handled, manufactured, or used.

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

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

ii. *Class III, Division 2*. A Class III, Division 2 location is a location in which easily ignitable fibers are stored or handled, except in process of manufacture.

Collector ring—A collector ring is an assembly of slip rings for transferring electrical energy from a stationary to a rotating member.

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

Conductor—

i. *Bare*. A conductor having no covering or electrical insulation whatsoever.

ii. *Covered*—A conductor encased within material of composition or thickness that is not recognized as electrical insulation.

iii. *Insulated*—A conductor encased within material of composition and thickness that is recognized as electrical insulation.

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

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

Cooking unit, counter-mounted—A cooking appliance designed for mounting in or on a counter and consisting of one or more heating elements, internal wiring, and built-in or separately mountable controls. (See “Oven, wall-mounted.”)

Covered conductor—See “Conductor.”

Cutout—(Over 600 volts, nominal.) An assembly of a fuse support with either a fuseholder, fuse carrier, or disconnecting blade. The fuseholder or fuse carrier may include a conducting element (fuse link), or may act as the disconnecting blade by the inclusion of a nonfusible member.

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

Damp location—See “Location.”

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

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

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

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

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Disconnecting (or Isolating) switch—(Over 600 volts, nominal.) A mechanical switching device used for isolating a circuit or equipment from a source of power.

Dry location—See "Location."

Electric sign—A fixed, stationary, or portable self-contained, electrically illuminated utilization equipment with words or symbols designed to convey information or attract attention.

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

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

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

Equipment grounding conductor—See "Grounding conductor, equipment."

Explosion-proof apparatus—Apparatus enclosed in a case that is capable of withstanding an explosion of a specified gas or vapor which may occur within it and of preventing the ignition of a specified gas or vapor surrounding the enclosure by sparks, flashes, or explosion of the gas or vapor within, and which operates at such an external temperature that it will not ignite a surrounding flammable atmosphere.

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

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

Exposed—(For the purposes of 1910.308(e), Communications systems.) Where the circuit is in such a position that in case of failure of supports or insulation, contact with another circuit may result.

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

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

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

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Fuse—(Over 600 volts, nominal.) An overcurrent protective device with a circuit opening fusible part that is heated and severed by the passage of overcurrent through it. A fuse comprises all the parts that form a unit capable of performing the prescribed functions. It may or may not be the complete device necessary to connect it into an electrical circuit.

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

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

Grounded, effectively—(Over 600 volts, nominal.) Permanently connected to earth through a ground connection of sufficiently low impedance and having sufficient ampacity that ground fault current which may occur cannot build up to voltages dangerous to personnel.

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

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

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

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

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

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

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

Heating equipment—For the purposes of 1910.306(g), the term “heating equipment” includes any equipment used for heating purposes if heat is generated by induction or dielectric methods.

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

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Identified—Identified, as used in reference to a conductor or its terminal, means that such conductor or terminal can be readily recognized as grounded.

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

Insulated conductor—See “Conductor.”

Interrupter switch—(Over 600 volts, nominal.) A switch capable of making, carrying, and interrupting specified currents.

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

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

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

Labeled—Equipment is “labeled” if there is attached to it a label, symbol, or other identifying mark of a nationally recognized testing laboratory which,

a. makes periodic inspections of the production of such equipment, and

b. whose labeling indicates compliance with nationally recognized standards or tests to determine safe use in a specified manner.

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

Line-clearance tree trimming—The pruning, trimming, repairing, maintaining, removing, or clearing of trees or cutting of brush that is within 10 feet (305 cm) of electric supply lines and equipment.

Listed—Equipment is “listed” if it is of a kind mentioned in a list which,

a. is published by a nationally recognized laboratory which makes periodic inspection of the production of such equipment, and

b. states such equipment meets nationally recognized standards or has been tested and found safe for use in a specified manner.

Location—

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

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

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

May—If a discretionary right, privilege, or power is abridged or if an obligation to abstain from acting is imposed, the word “may” is used with a restrictive “no,” “not,” or “only.” (E.g., no employer may ...; an employer may not ...; only qualified persons may ...)

Medium voltage cable—Type MV medium voltage cable is a single or multiconductor solid dielectric insulated cable rated 2000 volts or higher.

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

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

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

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

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

ii. *Type NMC*—The overall covering is flame-retardant, moisture-resistant, fungus-resistant, and corrosion-resistant.

Oil (filled) cutout—(Over 600 volts, nominal.) A cutout in which all or part of the fuse support and its fuse link or disconnecting blade are mounted in oil with complete immersion of the contacts and the fusible portion of the conducting element (fuse link), so that arc interruption by severing of the fuse link or by opening of the contacts will occur under oil.

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

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

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

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

Overcurrent—Any current in excess of the rated current of equipment or the ampacity of a conductor. It may result from overload (see definition), short circuit, or ground fault. A current in excess of rating may be accommodated by certain equipment and conductors for a given set of conditions. Hence the rules for overcurrent protection are specific for particular situations.

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

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

Permanently installed decorative fountains and reflection pools—Those that are constructed in the ground, on the ground or in a building in such a manner that the pool cannot be readily disassembled for storage and are served by electrical circuits of any nature. These units are primarily constructed for their aesthetic value and not intended for swimming or wading.

Permanently installed swimming pools, wading and therapeutic pools—Those that are constructed in the ground, on the ground, or in a building in such a manner that the pool cannot be readily disassembled for storage whether or not served by electrical circuits of any nature.

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

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

Power fuse—(Over 600 volts, nominal.) See "Fuse."

Power-limited tray cable—Type PLTC nonmetallic-sheathed power limited tray cable is a factory assembly of two or more insulated conductors under a nonmetallic jacket.

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

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

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

NOTE 1: Whether an employee is considered to be a “qualified person” will depend upon various circumstances in the workplace. It is possible and, in fact, likely for an individual to be considered qualified” with regard to certain equipment in the workplace, but “unqualified” as to other equipment.(See 1910.332(b)(3) for training requirements that specifically apply to qualified persons.)

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

Raceway—A channel designed expressly for holding wires, cables, or busbars, with additional functions as permitted in this subpart. Raceways may be of metal or insulating material, and the term includes rigid metal conduit, rigid nonmetallic conduit, intermediate metal conduit, liquidtight flexible metal conduit, flexible metallic tubing, flexible metal conduit, electrical metallic tubing, underfloor raceways, cellular concrete floor raceways, cellular metal floor raceways, surface raceways, wireways, and busways.

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

Receptacle—A receptacle is a contact device installed at the outlet for the connection of a single attachment plug. A single receptacle is a single contact device with no other contact device on the same yoke. A multiple receptacle is a single device containing two or more receptacles.

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

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

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

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

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

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

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

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

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

i. Type SE, having a flame-retardant, moisture-resistant covering, but not required to have inherent protection against mechanical abuse.

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

Service-entrance conductors, overhead system—The service conductors between the terminals of the service equipment and a point usually outside the building, clear of building walls, where joined by tap or splice to the service drop.

Service entrance conductors, underground system—The service conductors between the terminals of the service equipment and the point of connection to the service lateral. Where service equipment is located outside the building walls, there may be no service-entrance conductors, or they may be entirely outside the building.

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

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

Shielded nonmetallic-sheathed cable—Type SNM, shielded nonmetallic-sheathed cable is a factory assembly of two or more insulated conductors in an extruded core of moisture-resistant, flame-resistant nonmetallic material, covered with an overlapping spiral metal tape and wire shield and

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jacketed with an extruded moisture-, flame-, oil-, corrosion-, fungus-, and sunlight-resistant nonmetallic material.

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

Sign—See “Electric Sign.”

Signaling circuit—Any electric circuit that energizes signaling equipment.

Special permission—The written consent of the authority having jurisdiction.

Storable swimming or wading pool—A pool with a maximum dimension of 15 feet and a maximum wall height of 3 feet and is so constructed that it may be readily disassembled for storage and reassembled to its original integrity.

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

Switches.

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

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

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

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

Switching devices—(Over 600 volts, nominal.) Devices designed to close and/or open one or more electric circuits. Included in this category are circuit breakers, cutouts, disconnecting (or isolating) switches, disconnecting means, interrupter switches, and oil (filled) cutouts.

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

Utilization equipment—Utilization equipment means equipment which utilizes electric energy for mechanical, chemical, heating, lighting, or similar useful purpose.

Utilization system—A utilization system is a system which provides electric power and light for employee workplaces, and includes the premises wiring system and utilization equipment.

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

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

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

Voltage, nominal—A nominal value assigned to a circuit or system for the purpose of conveniently designating its voltage class (as 120/240, 480Y/277, 600, etc.). The actual voltage at which a circuit operates can vary from the nominal within a range that permits satisfactory operation of equipment.

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

Watertight—So constructed that moisture will not enter the enclosure.

Weatherproof—So constructed or protected that exposure to the weather will not interfere with successful operation. Rainproof, raintight, or watertight equipment can fulfill the requirements for weatherproof where varying weather conditions other than wetness, such as snow, ice, dust, or temperature extremes, are not a factor.

Wet location—See “Location.”

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

DEFINITIONS APPLICABLE TO 29 CFR 1910.269

Affected employee—An employee whose job requires him or her to operate or use a machine or equipment on which servicing or maintenance is being performed under lockout or tagout, or whose job requires him or her to work in an area in which such servicing or maintenance is being performed.

Attendant—An employee assigned to remain immediately outside the entrance to an enclosed or other space to render assistance as needed to employees inside the space.

Authorized employee—An employee who locks out or tags out machines or equipment in order to perform servicing or maintenance on that machine or equipment. An affected employee becomes an authorized employee when that employee’s duties include performing servicing or maintenance covered under this section.

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Automatic circuit recloser—A self-controlled device for interrupting and reclosing an alternating current circuit with a predetermined sequence of opening and reclosing followed by resetting, hold-closed, or lockout operation.

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

Barrier—A physical obstruction which is intended to prevent contact with energized lines or equipment or to prevent unauthorized access to a work area.

Bond—The electrical interconnection of conductive parts designed to maintain a common electrical potential.

Bus—A conductor or a group of conductors that serve as a common connection for two or more circuits.

Bushing—An insulating structure, including a through conductor or providing a passageway for such a conductor, with provision for mounting on a barrier, conducting or otherwise, for the purposes of insulating the conductor from the barrier and conducting current from one side of the barrier to the other.

Cable—A conductor with insulation, or a stranded conductor with or without insulation and other coverings (single-conductor cable), or a combination of conductors insulated from one another (multiple-conductor cable).

Cable sheath—A conductive protective covering applied to cables.

NOTE: A cable sheath may consist of multiple layers of which one or more is conductive.

Circuit—A conductor or system of conductors through which an electric current is intended to flow.

Clearance (between objects)—The clear distance between two objects measured surface to surface.

Clearance (for work)—Authorization to perform specified work or permission to enter a restricted area.

Communication lines—(See Lines, communication.)

Conductor—A material, usually in the form of a wire, cable, or bus bar, used for carrying an electric current.

Covered conductor—A conductor covered with a dielectric having no rated insulating strength or having a rated insulating strength less than the voltage of the circuit in which the conductor is used.

Current-carrying part—A conducting part intended to be connected in an electric circuit to a source of voltage. Non-current-carrying parts are those not intended to be so connected.

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Deenergized—Free from any electrical connection to a source of potential difference and from electric charge; not having a potential different from that of the earth.
Note: The term is used only with reference to current-carrying parts, which are sometimes energized (alive).

Designated employee (designated person)—An employee (or person) who is designated by the employer to perform specific duties under the terms of this section and who is knowledgeable in the construction and operation of the equipment and the hazards involved.

Electric line truck—A truck used to transport personnel, tools, and material for electric supply line work.

Electric supply equipment—Equipment that produces, modifies, regulates, controls, or safeguards a supply of electric energy.

Electric supply lines—(See Lines, electric supply.)

Electric utility—An organization responsible for the installation, operation, or maintenance of an electric supply system.

Enclosed space—A working space, such as a manhole, vault, tunnel, or shaft, that has a limited means of egress or entry, that is designed for periodic employee entry under normal operating conditions, and that under normal conditions does not contain a hazardous atmosphere, but that may contain a hazardous atmosphere under abnormal conditions.

NOTE: Spaces that are enclosed but not designed for employee entry under normal operating conditions are not considered to be enclosed spaces for the purposes of this section. Similarly, spaces that are enclosed and that are expected to contain a hazardous atmosphere are not considered to be enclosed spaces for the purposes of this section. Such spaces meet the definition of permit spaces in §1910.146 of this Part, and entry into them must be performed in accordance with that standard.

Energized (alive, live)—Electrically connected to a source of potential difference, or electrically charged so as to have a potential significantly different from that of earth in the vicinity.

Energy isolating device—A physical device that prevents the transmission or release of energy, including, but not limited to, the following: a manually operated electric circuit breaker, a disconnect switch, a manually operated switch, a slide gate, a slip blind, a line valve, blocks, and any similar device with a visible indication of the position of the device. (Push buttons, selector switches, and other control-circuit-type devices are not energy isolating devices.)

Energy source—Any electrical, mechanical, hydraulic, pneumatic, chemical, nuclear, thermal, or other energy source that could cause injury to personnel.

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

Exposed—Not isolated or guarded.

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

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

Guarded—Covered, fenced, enclosed, or otherwise protected, by means of suitable covers or casings, barrier rails or screens, mats, or platforms, designed to minimize the possibility, under normal conditions, of dangerous approach or accidental contact by persons or objects.

NOTE: Wires which are insulated, but not otherwise protected, are not considered as guarded.

Hazardous atmosphere means an atmosphere that may expose employees to the risk of death, incapacitation, impairment of ability to self-rescue (that is, escape unaided from an enclosed space), injury, or acute illness from one or more of the following causes:

1. Flammable gas, vapor, or mist in excess of 10 percent of its lower flammable limit (LFL);
2. Airborne combustible dust at a concentration that meets or exceeds its LFL;

NOTE: This concentration may be approximated as a condition in which the dust obscures vision at a distance of 5 feet (1.52 m) or less.

3. Atmospheric oxygen concentration below 19.5 percent or above 23.5 percent;
4. Atmospheric concentration of any substance for which a dose or a permissible exposure limit is published in Subpart G, Occupational Health and Environmental Control, or in Subpart Z, Toxic and Hazardous Substances, of this Part and which could result in employee exposure in excess of its dose or permissible exposure limit; Note: An atmospheric concentration of any substance that is not capable of causing death, incapacitation, impairment of ability to self-rescue, injury, or acute illness due to its health effects is not covered by this provision.
5. Any other atmospheric condition that is immediately dangerous to life or health.

NOTE: For air contaminants for which OSHA has not determined a dose or permissible exposure limit, other sources of information, such as Material Safety Data Sheets that comply with the Hazard Communication Standard, §1910.1200 of this Part, published information, and internal documents can provide guidance in establishing acceptable atmospheric conditions.

High-power tests—Tests in which fault currents, load currents, magnetizing currents, and line-dropping currents are used to test equipment, either at the equipment's rated voltage or at lower voltages.

High-voltage tests—Tests in which voltages of approximately 1000 volts are used as a practical minimum and in which the voltage source has sufficient energy to cause injury.

High wind—A wind of such velocity that the following hazards would be present:

1. An employee would be exposed to being blown from elevated locations, or

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2. An employee or material handling equipment could lose control of material being handled, or

3. An employee would be exposed to other hazards not controlled by the standard involved. Note: Winds exceeding 40 miles per hour (64.4 kilometers per hour), or 30 miles per hour (48.3 kilometers per hour) if material handling is involved, are normally considered as meeting this criteria unless precautions are taken to protect employees from the hazardous effects of the wind. Immediately dangerous to life or health (IDLH) means any condition that poses an immediate or delayed threat to life or that would cause irreversible adverse health effects or that would interfere with an individual's ability to escape unaided from a permit space.

NOTE: Some materials-hydrogen fluoride gas and cadmium vapor, for example-may produce immediate transient effects that, even if severe, may pass without medical attention, but are followed by sudden, possibly fatal collapse 12-72 hours after exposure. The victim "feels normal" from recovery from transient effects until collapse. Such materials in hazardous quantities are considered to be "immediately" dangerous to life or health.

Insulated—Separated from other conducting surfaces by a dielectric (including air space) offering a high resistance to the passage of current. Note: When any object is said to be insulated, it is understood to be insulated for the conditions to which it is normally subjected. Otherwise, it is, within the purpose of this section, uninsulated.

Insulation (cable)—That which is relied upon to insulate the conductor from other conductors or conducting parts or from ground.

Line-clearance tree trimmer—An employee who, through related training or on-the-job experience or both, is familiar with the special techniques and hazards involved in line-clearance tree trimming.

NOTE 1: An employee who is regularly assigned to a line-clearance tree-trimming crew and who is undergoing on-the-job training and who, in the course of such training, has demonstrated an ability to perform duties safely at his or her level of training and who is under the direct supervision of a line-clearance tree trimmer is considered to be a line-clearance tree trimmer for the performance of those duties.

NOTE 2: A line-clearance tree trimmer is not considered to be a "qualified employee" under this section unless he or she has the training required for a qualified employee under paragraph (a)(2)(ii) of this section. However, under the electrical safety-related work practices standard in Subpart S of this Part, a line-clearance tree trimmer is considered to be a "qualified employee". Tree trimming performed by such "qualified employees" is not subject to the electrical safety-related work practice requirements contained in §1910.331 through §1910.335 of this Part. (See also the note following §1910.332(b)(3) of this Part for information regarding the training an employee must have to be considered a qualified employee under §1910.331 through §1910.335 of this part.)

Line-clearance tree trimming—The pruning, trimming, repairing, maintaining, removing, or clearing of trees or the cutting of brush that is within 10 feet (305 cm) of electric supply lines and equipment.

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Lines.

Communication lines—The conductors and their supporting or containing structures which are used for public or private signal or communication service, and which operate at potentials not exceeding 400 volts to ground or 750 volts between any two points of the circuit, and the transmitted power of which does not exceed 150 watts. If the lines are operating at less than 150 volts, no limit is placed on the transmitted power of the system. Under certain conditions, communication cables may include communication circuits exceeding these limitations where such circuits are also used to supply power solely to communication equipment.

NOTE: Telephone, telegraph, railroad signal, data, clock, fire, police alarm, cable television, and other systems conforming to this definition are included. Lines used for signaling purposes, but not included under this definition, are considered as electric supply lines of the same voltage.

Electric supply lines—Conductors used to transmit electric energy and their necessary supporting or containing structures. Signal lines of more than 400 volts are always supply lines within this section, and those of less than 400 volts are considered as supply lines, if so run and operated throughout.

Manhole—A subsurface enclosure which personnel may enter and which is used for the purpose of installing, operating, and maintaining submersible equipment or cable.

Manhole steps—A series of steps individually attached to or set into the walls of a manhole structure.

Minimum approach distance—The closest distance an employee is permitted to approach an energized or a grounded object.

Qualified employee (qualified person)—One knowledgeable in the construction and operation of the electric power generation, transmission, and distribution equipment involved, along with the associated hazards.

NOTE 1: An employee must have the training required by paragraph (a)(2)(ii) of this section in order to be considered a qualified employee.

NOTE 2: Except under paragraph (g)(2)(v) of this section, an employee who is undergoing on-the-job training and who, in the course of such training, has demonstrated an ability to perform duties safely at his or her level of training and who is under the direct supervision of a qualified person is considered to be a qualified person for the performance of those duties.

Step bolt—A bolt or rung attached at intervals along a structural member and used for foot placement during climbing or standing.

Switch—A device for opening and closing or for changing the connection of a circuit. In this section, a switch is understood to be manually operable, unless otherwise stated.

System operator—A qualified person designated to operate the system or its parts.

Vault—An enclosure, above or below ground, which personnel may enter and which is used for the purpose of installing, operating, or maintaining equipment or cable.

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Vented vault—A vault that has provision for air changes using exhaust flue stacks and low level air intakes operating on differentials of pressure and temperature providing for airflow which precludes a hazardous atmosphere from developing.

Voltage—The effective (rms) potential difference between any two conductors or between a conductor and ground. Voltages are expressed in nominal values unless otherwise indicated. The nominal voltage of a system or circuit is the value assigned to a system or circuit of a given voltage class for the purpose of convenient designation. The operating voltage of the system may vary above or below this value.

DEFINITIONS APPLICABLE TO 29 CFR 1926 SUBPART K

Acceptable—An installation or equipment is acceptable to the Assistant Secretary of Labor, and approved within the meaning of this Subpart K:

a. If it is accepted, or certified, or listed, or labeled, or otherwise determined to be safe by a qualified testing laboratory capable of determining the suitability of materials and equipment for installation and use in accordance with this standard; or

b. With respect to an installation or equipment of a kind which no qualified testing laboratory accepts, certifies, lists, labels, or determines to be safe, if it is inspected or tested by another Federal agency, or by a State, municipal, or other local authority responsible for enforcing occupational safety provisions of the National Electrical Code, and found in compliance with those provisions; or

c. With respect to custom-made equipment or related installations which are designed, fabricated for, and intended for use by a particular customer, if it is determined to be safe for its intended use by its manufacturer on the basis of test data which the employer keeps and makes available for inspection to the Assistant Secretary and his authorized representatives.

Accepted—An installation is "accepted" if it has been inspected and found to be safe by a qualified testing laboratory.

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

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

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

Appliances—Utilization equipment, generally other than industrial, normally built in standardized sizes or types, which is installed or connected as a unit to perform one or more functions.

Approved—Acceptable to the authority enforcing this Subpart. The authority enforcing this Subpart is the Assistant Secretary of Labor for Occupational Safety and Health. The definition of "acceptable"

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indicates what is acceptable to the Assistant Secretary of Labor, and therefore approved within the meaning of this Subpart.

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

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

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

Bare conductor—See “Conductor.”

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

Bonding jumper—A reliable conductor to assure the required electrical conductivity between metal parts required to be electrically connected.

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

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

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

Certified—Equipment is “certified” if it:

a. has been tested and found by a qualified testing laboratory to meet applicable test standards or to be safe for use in a specified manner, and

b. is of a kind whose production is periodically inspected by a qualified testing laboratory. Certified equipment must bear a label, tag, or other record of certification.

Circuit breaker—

a. (600 volts nominal, or less.)—A device designed to open and close a circuit by nonautomatic means and to open the circuit automatically on a predetermined overcurrent without injury to itself when properly applied within its rating.

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b. (Over 600 volts, nominal.)—A switching device capable of making, carrying, and breaking currents under normal circuit conditions, and also making, carrying for a specified time, and breaking currents under specified abnormal circuit conditions, such as those of short circuit.

Class I locations—Class I locations are those in which flammable gases or vapors are or may be present in the air in quantities sufficient to produce explosive or ignitable mixtures. Class I locations include the following:

a. *Class I, Division 1*—A Class I, Division 1 location is a location:

   1. in which ignitable concentrations of flammable gases or vapors may exist under normal operating conditions; or

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

   3. in which breakdown or faulty operation of equipment or processes might release ignitable concentrations of flammable gases or vapors, and might also cause simultaneous failure of electric equipment.

NOTE: This classification usually includes locations where volatile flammable liquids or liquefied flammable gases are transferred from one container to another; interiors of spray booths and areas in the vicinity of spraying and painting operations where volatile flammable solvents are used; locations containing open tanks or vats of volatile flammable liquids; drying rooms or compartments for the evaporation of flammable solvents; inadequately ventilated pump rooms for flammable gas or for volatile flammable liquids; and all other locations where ignitable concentrations of flammable vapors or gases are likely to occur in the course of normal operations.

b. *Class I, Division 2*—A Class I, Division 2 location is a location:

   1. in which volatile flammable liquids or flammable gases are handled, processed, or used, but in which the hazardous liquids, vapors, or gases will normally be confined within closed containers or closed systems from which they can escape only in case of accidental rupture or breakdown of such containers or systems, or in case of abnormal operation of equipment; or

   2. in which ignitable concentrations of gases or vapors are normally prevented by positive mechanical ventilation, and which might become hazardous through failure or abnormal operations of the ventilating equipment; or

   3. that is adjacent to a Class I, Division 1 location, and to which ignitable concentrations of gases or vapors might occasionally be communicated unless such communication is prevented by adequate positive-pressure ventilation from a source of clean air, and effective safeguards against ventilation failure are provided.

NOTE: This classification usually includes locations where volatile flammable liquids or flammable gases or vapors are used, but which would become hazardous only in case of an accident or of some unusual operating condition. The quantity of flammable material that might escape in case of accident, the adequacy of ventilating equipment, the total area involved, and the record of the industry or business with respect to explosions or fires are all factors that merit consideration in determining the classification and extent of each location. Piping without valves, checks,

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meters, and similar devices would not ordinarily introduce a hazardous condition even though used for flammable liquids or gases. Locations used for the storage of flammable liquids or of liquefied or compressed gases in sealed containers would not normally be considered hazardous unless also subject to other hazardous conditions. Electrical conduits and their associated enclosures separated from process fluids by a single seal or barrier are classed as a Division 2 location if the outside of the conduit and enclosures is a nonhazardous location.

Class II locations—Class II locations are those that are hazardous because of the presence of combustible dust. Class II locations include the following:

a. *Class II, Division 1*—A Class II, Division 1 location is a location:

1. in which combustible dust is or may be in suspension in the air under normal operating conditions, in quantities sufficient to produce explosive or ignitable mixtures; or
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 electric equipment, operation of protection devices, or from other causes, or
3. in which combustible dusts of an electrically conductive nature may be present.

NOTE: Combustible dusts which are electrically nonconductive include dusts produced in the handling and processing of grain and grain products, pulverized sugar and cocoa, dried egg and milk powders, pulverized spices, starch and pastes, potato and woodflour, oil meal from beans and seed, dried hay, and other organic materials which may produce combustible dusts when processed or handled. Dusts containing magnesium or aluminum are particularly hazardous and the use of extreme caution is necessary to avoid ignition and explosion.

b. *Class II, Division 2*—A Class II, Division 2 location is a location in which:

1. combustible dust will not normally be in suspension in the air in quantities sufficient to produce explosive or ignitable mixtures, and dust accumulations are normally insufficient to interfere with the normal operation of electrical equipment or other apparatus; or
2. dust may be in suspension in the air as a result of infrequent malfunctioning of handling or processing equipment, and dust accumulations resulting therefrom may be ignitable by abnormal operation or failure of electrical equipment or other apparatus.

NOTE: This classification includes locations where dangerous concentrations of suspended dust would not be likely but where dust accumulations might form on or in the vicinity of electric equipment. These areas may contain equipment from which appreciable quantities of dust would escape under abnormal operating conditions or be adjacent to a Class II Division 1 location, as described above, into which an explosive or ignitable concentration of dust may be put into suspension under abnormal operating conditions.

Class III locations—Class III locations are those that are hazardous because of the presence of easily ignitable fibers or flyings but in which such fibers or flyings are not likely to be in suspension in the air in quantities sufficient to produce ignitable mixtures. Class 111 locations include the following:

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a. *Class III, Division 1*—A Class III, Division 1 location is a location in which easily ignitable fibers or materials producing combustible flyings are handled, manufactured, or used.

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

b. *Class III, Division 2*—A Class III, Division 2 location is a location in which easily ignitable fibers are stored or handled, except in process of manufacture.

Collector ring—A collector ring is an assembly of slip rings for transferring electrical energy from a stationary to a rotating member.

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

Conductor-

a. B*are*—A conductor having no covering or electrical insulation whatsoever.

b. *Covered*—A conductor encased within material of composition or thickness that is not recognized as electrical insulation.

c. *Insulated*—A conductor encased within material of composition and thickness that is recognized as electrical insulation.

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

Covered conductor—See "Conductor."

Cutout—(Over 600 volts, nominal.) An assembly of a fuse support with either a fuseholder, fuse carrier, or disconnecting blade. The fuseholder or fuse carrier may include a conducting element (fuse link), or may act as the disconnecting blade by the inclusion of a nonfusible member.

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

Damp location—See "Location."

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

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

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

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Disconnecting (or Isolating) switch—(Over 600 volts, nominal.) A mechanical switching device used for isolating a circuit or equipment from a source of power.

Dry location—See “Location.”

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

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

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

Equipment grounding conductor—See “Grounding conductor, equipment.”

Explosion-proof apparatus—Apparatus enclosed in a case that is capable of withstanding an explosion of a specified gas or vapor which may occur within it and of preventing the ignition of a specified gas or vapor surrounding the enclosure by sparks, flashes, or explosion of the gas or vapor within, and which operates at such an external temperature that it will not ignite a surrounding flammable atmosphere.

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

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

Exposed—(For the purposes of 1926.408(d), Communications systems.) Where the circuit is in such a position that in case of failure of supports or insulation, contact with another circuit may result.

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

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

Festoon lighting—A string of outdoor lights suspended between two points more than 15 feet (4.57 m) apart.

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

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Fuse—(Over 600 volts, nominal.) An overcurrent protective device with a circuit opening fusible part that is heated and severed by the passage of overcurrent through it. A fuse comprises all the parts that form a unit capable of performing the prescribed functions. It may or may not be the complete device necessary to connect it into an electrical circuit.

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

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

Grounded, effectively (Over 600 volts, nominal.)—Permanently connected to earth through a ground connection of sufficiently low impedance and having sufficient ampacity that ground fault current which may occur cannot build up to voltages dangerous to personnel.

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

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

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

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

Ground-fault circuit interrupter—A device for the protection of personnel that functions to deenergize a circuit or portion thereof within an established period of time when a current to ground exceeds some predetermined value that is less than that required to operate the overcurrent protective device of the supply circuit.

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

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

Identified (conductors or terminals)—Identified, as used in reference to a conductor or its terminal, means that such conductor or terminal can be recognized as grounded.

Identified (for the use)—Recognized as suitable for the specific purpose, function, use, environment, application, etc. where described as a requirement in this standard. Suitability of equipment for a

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specific purpose, environment, or application is determined by a qualified testing laboratory where such identification includes labeling or listing.
Insulated conductor—See "Conductor."

Interrupter switch—(Over 600 volts, nominal.) A switch capable of making, carrying, and interrupting specified currents.

Intrinsically safe equipment and associated wiring—Equipment and associated wiring in which any spark or thermal effect, produced either normally or in specified fault conditions, is incapable, under certain prescribed test conditions, of causing ignition of a mixture of flammable or combustible material in air in its most easily ignitable concentration.

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

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

Labeled—Equipment or materials to which has been attached a label, symbol or other identifying mark of a qualified testing laboratory which indicates compliance with appropriate standards or performance in a specified manner.

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

Listed—Equipment or materials included in a list published by a qualified testing laboratory whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

Location—

a. *Damp location*—Partially protected locations under canopies, marquees, roofed open porches, and like locations, and interior locations subject to moderate degrees of moisture, such as some basements.

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

c. *Wet location*—Installations underground or in concrete slabs or masonry in direct contact with the earth, and locations subject to saturation with water or other liquids, such as locations exposed to weather and unprotected.

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

Motor control center—An assembly of one or more enclosed sections having a common power bus and principally containing motor control units.

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

Overcurrent—Any current in excess of the rated current of equipment or the ampacity of a conductor. It may result from overload (see definition), short circuit, or ground fault. A current in excess of rating may be accommodated by certain equipment and conductors for a given set of conditions. Hence the rules for overcurrent protection are specific for particular situations.

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

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

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

Power fuse—(Over 600 volts, nominal.) See "Fuse."

Power outlet—An enclosed assembly which may include receptacles, circuit breakers, fuseholders, fused switches, buses and watt-hour meter mounting means; intended to serve as a means for distributing power required to operate mobile or temporarily installed equipment.

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

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

Qualified testing laboratory—A properly equipped and staffed testing laboratory which has capabilities for and which provides the following services:

a. Experimental testing for safety of specified items of equipment and materials referred to in this standard to determine compliance with appropriate test standards or performance in a specified manner;

b. Inspecting the run of such items of equipment and materials at factories for product evaluation to assure compliance with the test standards;

c. Service-value determinations through field inspections to monitor the proper use of labels on products and with authority for recall of the label in the event a hazardous product is installed;

d. Employing a controlled procedure for identifying the listed and/or labeled equipment or materials tested; and

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e. Rendering creditable reports or findings that are objective and without bias of the tests and test methods employed.

Raceway—A channel designed expressly for holding wires, cables, or busbars, with additional functions as permitted in this subpart. Raceways may be of metal or insulating material, and the term includes rigid metal conduit, rigid nonmetallic conduit, intermediate metal conduit, liquidtight flexible metal conduit, flexible metallic tubing, flexible metal conduit, electrical metallic tubing, underfloor raceways, cellular concrete floor raceways, cellular metal floor raceways, surface raceways, wireways, and busways.

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

Receptacle—A receptacle is a contact device installed at the outlet for the connection of a single attachment plug. A single receptacle is a single contact device with no other contact device on the same yoke. A multiple receptacle is a single device containing two or more receptacles.

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

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

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

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

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

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

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

Service-entrance conductors, overhead system—The service conductors between the terminals of the service equipment and a point usually outside the building, clear of building walls, where joined by tap or splice to the service drop.

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Service-entrance conductors, underground system—The service conductors between the terminals of the service equipment and the point of connection to the service lateral. Where service equipment is located outside the building walls, there may be no service-entrance conductors, or they may be entirely outside the building.

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

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

Signaling circuit—Any electric circuit that energizes signaling equipment.

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

Switches—

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

b. *General-use snap switch*—A form of general-use switch so constructed that it can be installed in flush device boxes or on outlet box covers, or otherwise used in conjunction with wiring systems recognized by this subpart.

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

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

Switching devices—(Over 600 volts, nominal.) Devices designed to close and/or open one or more electric circuits. Included in this category are circuit breakers, cutouts, disconnecting (or isolating) switches, disconnecting means, and interrupter switches.

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

Utilization equipment—Utilization equipment means equipment which utilizes electric energy for mechanical, chemical, heating, lighting, or similar useful purpose.

Utilization system—A utilization system is a system which provides electric power and light for employee workplaces, and includes the premises wiring system and utilization equipment.

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

Volatile flammable liquid—A flammable liquid having a flash point below 38 degrees C (100 degrees F) or whose temperature is above its flash point, or a Class II combustible liquid having a vapor pressure not exceeding 40 psia (276 kPa) at 38 deg. C (100 deg. F) whose temperature is above its flash point.

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

Voltage, nominal—A nominal value assigned to a circuit or system for the purpose of conveniently designating its voltage class (as 120/240, 480Y/277, 600, etc.). The actual voltage at which a circuit operates can vary from the nominal within a range that permits satisfactory operation of equipment.

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

Watertight—So constructed that moisture will not enter the enclosure.

Weatherproof—So constructed or protected that exposure to the weather will not interfere with successful operation. Rainproof, raintight, or watertight equipment can fulfill the requirements for weatherproof where varying weather conditions other than wetness, such as snow, ice, dust, or temperature extremes, are not a factor.

Wet location—See “Location.”

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Alive or live (energized)—The term means electrically connected to a source of potential difference, or electrically charged so as to have a potential significantly different from that of the earth in the vicinity. The term “live” is sometimes used in place of the term “current-carrying,” where the intent is clear, to avoid repetition of the longer term.

Automatic circuit recloser—The term means a self-controlled device for automatically interrupting and reclosing an alternating current circuit with a predetermined sequence of opening and reclosing followed by resetting, hold closed, or lockout operation.

Barrier—The term means a physical obstruction which is intended to prevent contact with energized lines or equipment.

Barricade—The term means a physical obstruction such as tapes, screens, or cones intended to warn and limit access to a hazardous area.

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Bond—The term means an electrical connection from one conductive element to another for the purpose of minimizing potential differences or providing suitable conductivity for fault current or for mitigation of leakage current and electrolytic action.

Bushing—The term means an insulating structure including a through conductor, or providing a passageway for such a conductor, with provision for mounting on a barrier, conducting or otherwise, for the purpose of insulating the conductor from the barrier and conducting current from one side of the barrier to the other.

Cable—The term means a conductor with insulation, or a stranded conductor with or without insulation and other coverings (single-conductor cable) or a combination of conductors insulated from one another (multiple-conductor cable).

Cable sheath—The term means a protective covering applied to cables.

NOTE: A cable sheath may consist of multiple layers of which one or more is conductive.

Circuit—The term means a conductor or system of conductors through which an electric current is intended to flow.

Communication lines—The term means the conductors and their supporting or containing structures which are used for public or private signal or communication service, and which operate at potentials not exceeding 400 volts to ground or 750 volts between any two points of the circuit, and the transmitted power of which does not exceed 150 watts. When operating at less than 150 volts no limit is placed on the capacity of the system.

NOTE: Telephone, telegraph, railroad signal, data, clock, fire, police-alarm, community television antenna, and other systems conforming with the above are included. Lines used for signaling purposes, but not included under the above definition, are considered as supply lines of the same voltage and are to be so run.

Conductor—The term means a material, usually in the form of a wire, cable, or bus bar suitable for carrying an electric current.

Conductor shielding—The term means an envelope which encloses the conductor of a cable and provides an equipotential surface in contact with the cable insulation.

Current-carrying part—The term means a conducting part intended to be connected in an electric circuit to a source of voltage. Non-current-carrying parts are those not intended to be so connected.

Dead (deenergized)—The term means free from any electrical connection to a source of potential difference and from electrical charges: Not having a potential difference from that of earth.

NOTE: The term is used only with reference to current-carrying parts which are sometimes alive (energized).

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Designated employee—The term means a qualified person delegated to perform specific duties under the conditions existing.

Effectively grounded—The term means intentionally connected to earth through a ground connection or connections of sufficiently low impedance and having sufficient current-carrying capacity to prevent the buildup of voltages which may result in undue hazard to connected equipment or to persons.

Electric line trucks—The term means a truck used to transport men, tools, and material, and to serve as a traveling workshop for electric power line construction and maintenance work. It is sometimes equipped with a boom and auxiliary equipment for setting poles, digging holes, and elevating material or men.

Enclosed—The term means surrounded by a case, cage, or fence, which will protect the contained equipment and prevent accidental contact of a person with live parts.

Equipment—This is a general term which includes fittings, devices, appliances, fixtures, apparatus, and the like, used as part of, or in connection with, an electrical power transmission and distribution system, or communication systems.

Exposed—The term means not isolated or guarded.

Electric supply lines—The term means those conductors used to transmit electric energy and their necessary supporting or containing structures. Signal lines of more than 400 volts to ground are always supply lines within the meaning of the rules, and those of less than 400 volts to ground may be considered as supply lines, if so run and operated throughout.

Guarded—The term means protected by personnel, covered, fenced, or enclosed by means of suitable casings, barrier rails, screens, mats, platforms, or other suitable devices in accordance with standard barricading techniques designed to prevent dangerous approach or contact by persons or objects.

NOTE: Wires, which are insulated but not otherwise protected, are not considered as guarded.

Ground—(Reference). The term means that conductive body, usually earth, to which an electric potential is referenced.

Ground (as a noun)—The term means a conductive connection whether intentional or accidental, by which an electric circuit or equipment is connected to reference ground.

Ground (as a verb)—The term means the connecting or establishment of a connection, whether by intention or accident of an electric circuit or equipment to reference ground.

Grounding electrode (ground electrode)—The term grounding electrode means a conductor embedded in the earth, used for maintaining ground potential on conductors connected to it, and for dissipating into the earth current conducted to it.

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Grounding electrode resistance—The term means the resistance of the grounding electrode to earth.

Grounding electrode conductor (grounding conductor)—The term means a conductor used to connect equipment or the grounded circuit of a wiring system to a grounding electrode.

Grounded conductor—The term means a system or circuit conductor which is intentionally grounded.

Grounded system—The term means a system of conductors in which at least one conductor or point (usually the middle wire, or neutral point of transformer or generator windings) is intentionally grounded, either solidly or through a current-limiting device (not a current-interrupting device).

Hotline tools and ropes—The term means those tools and ropes which are especially designed for work on energized high voltage lines and equipment. Insulated aerial equipment especially designed for work on energized high voltage lines and equipment shall be considered hot line.

Insulated—The term means separated from other conducting surfaces by a dielectric substance (including air space) offering a high resistance to the passage of current.

NOTE: When any object is said to be insulated, it is understood to be insulated in suitable manner for the conditions to which it is subjected. Otherwise, it is within the purpose of this subpart, uninsulated. Insulating covering of conductors is one means of making the conductor insulated.

Insulation (as applied to cable)—The term means that which is relied upon to insulate the conductor from other conductors or conducting parts or from ground.

Insulation shielding—The term means an envelope which encloses the insulation of a cable and provides an equipotential surface in contact with cable insulation.

Isolated—The term means an object that is not readily accessible to persons unless special means of access are used.

Manhole—The term means a subsurface enclosure which personnel may enter and which is used for the purpose of installing, operating, and maintaining equipment and/or cable.

Pulling tension—The term means the longitudinal force exerted on a cable during installation.

Qualified person—The term means a person who by reason of experience or training is familiar with the operation to be performed and the hazards involved.

Switch—The term means a device for opening and closing or changing the connection of a circuit. In these rules, a switch is understood to be manually operable, unless otherwise stated.

Tag—The term means a system or method of identifying circuits, systems or equipment for the purpose of alerting persons that the circuit, system or equipment is being worked on.

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Unstable material—The term means earth material, other than running, that because of its nature or the influence of related conditions, cannot be depended upon to remain in place without extra support, such as would be furnished by a system of shoring.

Vault—The term means an enclosure above or below ground which personnel may enter and is used for the purpose of installing, operating, and/or maintaining equipment and/or cable.

Voltage—The term means the effective (rms) potential difference between any two conductors or between a conductor and ground. Voltages are expressed in nominal values. The nominal voltage of a system or circuit is the value assigned to a system or circuit of a given voltage class for the purpose of convenient designation. The operating voltage of the system may vary above or below this value.

Voltage of an effectively grounded circuit—The term means the voltage between any conductor and ground unless otherwise indicated.

Voltage of a circuit not effectively grounded—The term means the voltage between any two conductors. If one circuit is directly connected to and supplied from another circuit of higher voltage (as in the case of an autotransformer), both are considered as of the higher voltage, unless the circuit of lower voltage is effectively grounded, in which case its voltage is not determined by the circuit of higher voltage. Direct connection implies electric connection as distinguished from connection merely through electromagnetic or electrostatic induction.

DEFINITIONS APPLICABLE TO SECTIONS 1 THROUGH 10

Bay—One vertical 19" wide segment of a rack cabinet. Several bays can be joined together to form a large rack cabinet.

Code of record—The code in effect at the time of design or installation. Unless required to correct a known hazard or a major modification is being performed, installations in compliance with the code of record, do not need to be upgrade to a later edition of the code unless so stated in the code.

Controlled access—If the chassis are screwed into the rack cabinet. Doors having latches can be taken to mean the circuitry is controlled. Control of the access to the area in which the tester is located is also a means of control. In this case the area must be identified.

Electroexplosive device—An explosive device detonated by an integral electrical component upon application of a specified voltage/current pulse to that component.

Electromagnetic (EMR) field—Time varying distribution in some medium of electric and magnetic forces.

Electromagnetic radiation—Emission of electromagnetic energy from an electrical source in a portion of the radio frequency spectrum which may pose a threat to electroexplosive devices.

Emergency-shutdown pushbutton (E-stop)—A control device provided to automatically stop electrical energy to devices in the area during an emergency.

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Failsafe—Build-in safety characteristics of a unit or system so that a failure (of the unit or system) or a loss of control power will not result in an unsafe condition.

Failsafe—Built-in safety characteristics of a unit or system so that unit or system failure or a loss of control power will not result in an unsafe condition.

General access area—An area that does not present hazards to personnel while equipment and systems are functioning normally. These areas are accessible to all personnel.

Grounding hook—A device for making a temporary connection to discharge and ground the internal energy sources in hazardous electrical equipment. It consists of a bare copper rod shaped like a shepherd's hook at one end, an insulating handle, and a suitable bare flexible copper cable securely connected at the other end, and can be securely connected to an equipment or building ground.

Interlocked access areas—Areas in which the sources of power must be interlocked with the access doors because of the hazards the areas contain.

Leakage current—Refers to all currents, including capacitively coupled currents, that may be conveyed between exposed surfaces of the equipment and ground or other exposed surfaces of the equipment.

Limited access areas—Areas that are kept locked and are accessible only to authorized personnel because of the hazards they contain.

Modulation—Change in normal characteristics of the recurring pattern in an electromagnetic field as a result of a secondary electrical signal having been combined with the electrical signal from which the field originates.

Personnel safety interlock system—One or more of the emergency-shutdown systems or personnel access control systems or both.

Power density—Emitted power per unit cross-sectional area normal to the direction of propagation of an electromagnetic wave from which results an electromagnetic field.

Rack cabinet—Any enclosure intended to house electrical equipment mounted to cabinet rails mounted within the cabinet. Most rack cabinets house chassis 19" wide. They are available in several heights.

Radio frequency—Non ionizing radiation generated in the portion of the frequency spectrum for electromagnetic energy between audio and ultraviolet.

Safety barrier—A safeguard installed to restrict personnel access to a hazardous area.

Safety coordinator—An individual who has the responsibility of the safety of the work that is to be performed and who is familiar with the hazards involved.

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Safety interlock—An electrical or mechanical device that prevents operation of equipment or precludes access to hazardous areas, enclosures, or equipment.

Safety watch—A person whose specific duties are to observe the workers and operations being performed.

Shall—Information cited is a requirement from a regulatory standard such as OSHA and relevant DOE Orders.

Should—Information cited is a guidance such as concensus standards.

Underground facility—A facility built below ground surface.

Wavelength—Distance between repetitions of a recurring pattern in an electrical signal or electromagnetic field.

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APPENDIX C WORK MATRICES-EXAMPLES

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Table C-1. Job/Safety Equipment Matrix - Use those applicable to the actual job being performed—50-V to 150-V line to ground to 250-V line to line ac or dc.

	Test Equipment			Tools		Safety Equipment	
Work Description	Approved Multimeter	Clamp Ammeter	Other Approved Instrumentation	Insulated Fuse Puller	Insulated Hand Tools	Safety Glasses	Other insulated protective equipment such as gloves, blankets, sleeves, and mats.
Voltage, Current Reading	X	X	X			X	X
Fuse Pulling under 20 amps				X		X	X
Lead Lifting under 20 amps					X	X	X
Probing					X	X	X

Table C-2. Job/Safety Equipment Matrix - Use those applicable to the actual job being performed—151-V line to ground to 600-V line to line ac or dc.

	Test Equipment			Tools			Safety Requirements, Protective Equipment			
Work Description	Approved Multimeter	Clamp Ammeter	Other Approved Instrumentation	Insulated Fuse Puller	Breaker Jacking Tools	Insulated Hand Tools	Safety Glasses	Face Shield	Safety Belt and Life Line	Other insulated and protective equipment such as fire resistant clothing, gloves, blankets, sleeves, and mats.
Probing						X	X			X
Voltage, Current Reading	X	X	X				X			X
Pulling Control Fuses or Power Fuses at No Load				X			X			X
Pulling/Inserting Plug-in Devices on Energized MCCs						X	X	X		X
Jacking Breakers In/Out on Energized MCCs					X		X			X
Other Work-Energized Circuits	X		X			X	X	X	X	X

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Table C-3. Job/Safety Equipment Matrix - Use those applicable to the actual job being performed —601-V to 15,000-V line to line ac.

	Test Equipment				Tools			Safety Requirements, Protective Equipment						
Work Description	Glowtester	High-Volt Detector	High Potential	Other Approved Instrumentation	Breaker Jacking Tools	High-Voltage Fuse Puller	Hot Stick 5-ft Minimum	Safety Glasses	Face Shield	Tagout and Lockout	High-Voltage Gloves	Sleeves	Rubber Mat	Fire Resistant Clothing
Voltage Reading	X	X		X				X			X	X	X	X
Jacking Breakers In/Out on Energized Equipment					X			X			X	X		X
Highpointing De-energized Equipment			X					X		X	X	X	X	
Pulling Fuses–No Load						X	X	X	X		X	X	X	X

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Table C-4. Job/Safety Equipment Matrix - Use those applicable to the actual job being performed—electrolytic type battery work.

	Test Equipment	Tools	Safety Requirements, Protective Equipment				
Work Description	Other Approved Instrumentation	Insulated Hand Tools	Goggles or Goggles and Face Shield	Tagout and Lockout	Apron	Latex Gloves	Fire Resistant Clothing
Voltage Reading	X		X		X	X	
Battery Rundowns	X	X	X	X	X	X	
Equalize	X		X		X	X	
Torque Bolts, Lifting Heads		X	X	X	X	X	X

Table C-5. Job/Safety Equipment Matrix - Use those applicable to the actual job being performed—overhead line/switchyard work

	Test Equipment				Tools								Safety Requirements, Protective Equipment															
Work Description	Glowtester	High-Volt. Detector	High Potential	Other Instrumentation as Approved by Electrical Foreman	Breaker Jacking Tools	Tree-Climbing Equipment	High-Voltage Fuse Puller	Traveling Ground	Hot Stick 3-ft Minimum	Nonconductive Rope	Reliable Communications	Live-Line Tools	Recloser Off	Rubbergoods, Line Guards	Body Harness and Life Line	Tagout and Lockout	Safety Glasses	Face Shields	Leather Gloves	Head Protection	H.V. Gloves / Leather Protec.	Sleeves	Insulted or Ground Surface	Ground Cluster	Spike and Identify Cable	Confined Space or Safe Work Permit	Pole Inspection	Fire Resistant Clothing
Install/Remove Ground	X			X					X				X			X	X			X								X
Operate Fused Cutouts									X								X			X								X
Operate Disconnect Switch																	X			X	X		X					X
Dangerous Work				X									X	X			X			X						X		X
Climbing										X							X			X							X	
Tree Trimming										X					X		X			X								
Energized Work												X					X									X		X
Entering Trans./Bkr.															X	X	X			X						X		
String/Rem. Ground Cond.	X							X		X	X					X	X									X		
Enter Manhole										X					X	X	X			X								
Operate Load Interrupter Switch																	X			X	X		X					X
Voltage Readings	X	X		X													X				X		X					X
Jacking Bkrs. In/Out on Energized Equipment					X												X				X	X						X
Hi. Potting De-energized Equipment			X													X	X				X		X					
Pulling Fuses-No Load							X		X								X	X			X		X					
Work De-energized Equip.	X	X		X												X	X		X	X				X				
Series Lighting	X	X														X	X			X								
Pull Cable				X							X					X	X			X					X			
Stringing Line								X		X	X					X	X			X								

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APPENDIX D REGULATION MATRICES

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Subject	1996 NEC	29CFR 1910	29CFR 1926	NFPA 70E	NESC
Approval	100	.303(a)	.403(a)	Part I, Ch. 1-1	———-
Examination, Installation, and Use of Equipment	110-3	.303(b)	.403(b)	Part I, Ch. 1-3	———-
Interrupting Rating	110-9, 230-65 250-1,250-2	———	.403(c)	Part I, Ch. 1-3.4	———-
Working Space Around Electrical Equipment <600 volts	110-16(a)	.303(g)(1)	.403(i)(1)	Part I, Ch. 1-8.1	125A
Guarding of live parts	110-17	.303(g)(2)	.403(i)(2)	Part I, Ch. 1-8.2	124,237E
Identification of Disconnecting Means	110-22,230-70(b) 384-13FPN	.303(f)	.403(h)	Part I, Ch. 1-7	128
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Approval	500-6	.307(b)(2)	.407(b)(2)	Part III, Ch. 8-2	127
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Subject	1996 NEC	29CFR 1910	29CFR 1926	NFPA 70E	NESC
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Enclosed and Confined Spaces	—	.269(e), (t), .146 .333(c)(5)	.956(a)	—	312,323,423
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APPENDIX E FUTURE CHAPTERS

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APPENDIX E
FUTURE CHAPTERS

This handbook is a living document; and as a living document, other topics will be added in future revisions. Because accidents continue to occur within DOE and private industry, it becomes increasingly important to evaluate these and other topics for future updates. The topics for the future include, but are not limited to, the following:

1. UNDERGROUND UTILITIES DETECTION EQUIPMENT DURING EXCAVATION

Over the past few years, there have been several serious accidents related to underground utilities. While this chapter is being developed, information may be obtained from "DOE Safety Notice, Issue No. 96-06, Underground Utilities Detection and Excavation." The Internet address for this notice is (http://tis-hq.eh.doe.gov/web/oeaf/lessons_learned/ons/sn9606.html). Topics planned for inclusion in this chapter are the following:

- The importance of detecting underground utilities
- New technology
- New equipment
- Proper use of detection equipment
- Problems with the improper use of detection equipment
- Hazards associated with the detection of underground cables
- Prerequisites to excavations

2. ARC FLASH PROTECTION

Because of recent accidents and the emphasis being placed on arc flash protection, this chapter would clarify many confusing issues pertaining to this area. Topics planned for inclusion in this chapter are:

- Appropriate clothing
- Appropriate approach distances
- Need for hazard analysis
- Understanding fault current

3. PROPER USE OF ELECTRICAL TEST EQUIPMENT

Because of recent accidents (in private industry and DOE) related to improper use of electrical test equipment, this chapter would be included to help clear up confusion about different types of electrical testing equipment. Topics planned for this chapter are the following:

- High-voltage testing equipment
- Low-voltage testing equipment

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- Solenoid-driven testing devices
- Proximity devices
- Diagnostic types of equipment

4. PORTABLE AND VEHICLE-MOUNTED GENERATORS

This chapter would help the reader better understand the complex topic of generators. Topics planned for inclusion in this chapter are as follows:

- When generators need to be grounded
- When GFCI protection is needed
- Understanding the requirements for different sized generators
- Requirements for portable and vehicle-mounted generators

5. ELECTRICAL HAZARDS DURING DECONTAMINATION & DECOMMISSIONING (D&D) ACTIVITIES

DOE has also experienced several near misses related to D&D activities. Topics planned for inclusion in this chapter are:

- New technology
- Methods used to identify potential electrical hazards
- Need for accurate electrical drawings
- What to do when drawings are not available
- Elimination sequence of systems

6. ELECTRICAL HAZARDS DURING WELDING ACTIVITIES

Understanding the electrical hazards associated with welding activities is an area that is greatly misunderstood. This chapter would help diminish the confusion. Topics planned for inclusion in this chapter are as follows:

- Identifying electrical hazards associated with welding activities
- Controlling identified electrical hazards
- Understanding employee exposure during welding activities

These areas have been identified as possible chapters in the next revision. Other areas, as they are identified, will be considered for inclusion in future revisions.

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Preparing Activity:

DOE-EH-51

Project Number:

SAFT-0035

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