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Sponsor: Dori Ellis, 4000, Acting

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Sandia National Laboratories

ENVIRONMENT, Safety & HEALTH

Electrical Safety Manual

Subject Matter Expert: Mark McNellis; CA Counterpart: Herman Armijo
MN471004, Issue L
Revision Date: March 26, 2007; Replaces Document Dated: March 14, 2007
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* Indicates a substantive change

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Sandia National Laboratories

ENVIRONMENT, Safety & HEALTH

Electrical Safety Manual Change History

March 26, 2007

Note: (*) asterisk denotes substantive change.

Chapter 2:

Note: Due to the rapid succession of change between issue K and issue L, the green text changes from issue K have been maintained in issue L for the benefit of the reader.

- Under topic, “2.3 Energized Work Procedures”:
  - ***Change:** The second sentence in the second requirement **from** “Senior Manager authorization of such TWDs shall be evident by Senior Manager signature on the TWD” **to** “Authorization of such TWDs shall be evident by Senior Manager and Safety Engineer signature on the TWD.”

March 14, 2007

Note: (*) asterisk denotes substantive change.

Chapter 1:

- Under topic, “1.1 Purpose, Applicability, Scope, Ownership”:
  - **Change:** The second sentence under the subtopic “Purpose” **from** “This manual has been prepared to provide uniform electrical safety standards and guidance for SNL installations in order to reduce to as low as reasonable achievable the risks associated with the use of electrical energy” **to** “This manual has been prepared to provide uniform electrical safety standards and guidance for SNL installations in order to reduce the risks associated with the use of electrical energy.”

- Under topic, “1.3 Responsibilities of Individuals”:
  - **Change:** The sentence under the subtopic “Personnel Responsibilities” **from** “Personnel shall also report any electrical shock to the OOPS non-emergency hotline - 311 or 844-0311 if outside SNL” **to** “Personnel shall also report any electrical shock to the non-emergency hotline as specified in Chapter 15, "Emergency Preparedness and Management.”

- Under topic, “1.4 Electrical Safety Program”:
  - **Change:** The last sentence of the third Electrical Safety Program Principle **from** “A Sample Technical Work Document is included in this manual to aid in the development of useful procedures which will identify the hazards and provide appropriate protection for each of those hazards” **to** “A Sample Technical Work Document is provided to aid in the development of useful procedures which will identify the hazards and provide appropriate protection for each of those hazards.”

Chapter 2:

- Under topic, “2.1 Electrical Work Requirements – General”:
  - **Add:** A hyperlink to the SNL Electrical Equipment Approval Guidelines (AOP 06-05) in the fourth requirement “All Members of the Workforce shall ensure that all electrical equipment purchased, manufactured or used at any SNL facility, including office and personal (household rated) equipment, is in compliance with the SNL Electrical Equipment Approval Guidelines for Nationally Recognized Testing Laboratory (NRTL) certification or alternate testing.”
  - **Add:** A hyperlink to the SNL Electrical Equipment Approval Guidelines (AOP 06-05) in the Note “Purchased equipment or equipment manufactured internally to research and development (R&D) specifications may be exempt from NRTL labeling requirements. See SNL Electrical Equipment Approval Guidelines for additional information.”
  - **Change:** The first sentence of the Note listed under the subtopic “Approach to Work on or Near Electrical Equipment” **from** “Working near energized electrical equipment is defined as any activity inside the limited approach boundary” **to** “Working near energized electrical equipment is defined as any activity inside the limited approach boundary (LAB) as defined by NFPA 70E. The LAB starts at 42 inches from exposed energized parts and increases with voltage. Please contact your ES&H coordinator for assistance in determining your LAB.”

- ***Change:** The requirement listed under the subtopic “Approach to Work on or Near Electrical Equipment” **from** “Managers shall identify and minimize the hazard to worker through development of appropriate procedures (see Section 2.3)” **to** “Managers shall identify and minimize the hazard to worker through development of appropriate procedures (see Section 2.3 and Energized Work Decision Tool.”

- ***Change:** The first requirement listed under the subtopic “Electrical Shock Approach and Arc Flash Boundaries” **from** “The manager responsible for authorizing Members of the Workforce to perform appropriate energized electrical work on circuits operating at 50 to 750 volts shall” **to** “The manager responsible for authorizing Members of the Workforce to perform appropriate energized electrical work on hazardous circuits as identified by the Energized Work Decision Tool shall.”

- Under topic, “2.3 Energized Work Procedures”:

  - ***Change:** The second sentence in the first requirement **from** “The energized work permit is applied for all electrical work tasks associated with circuit repair or reconfiguration while that circuit is in the fully energized state” **to** “The energized work permit is required for any electrical work task associated with circuit repair or reconfiguration of a circuit in the energized state.”

- Under topic, “2.4 Safe Work Practices”:

  - ***Change:** The requirement in the first sentence under the subtopic “Approved Electrical Equipment” **from** “All electrical equipment, components, and conductors shall be Nationally Recognized Test Laboratory (NRTL) listed with the following exceptions” **to** ”All electrical equipment, components, and conductors shall be Nationally Recognized Testing Laboratory (NRTL) listed in accordance with the SNL Electrical Equipment Approval Guidelines, with the following exceptions.”

  - ***Change:** The first sentence of the requirement "Apply Lockout/Tagout Devices” under the subtopic “Establishing an Electrically Safe Work Condition” **from** “Each department manager shall document training and implementation of the lockout/ tagout procedures (based on MN471001, ES&H Manual, Section 4C, "Lockout/ Tagout (LOTO)" and GN470037, Administrative Control Procedure) to safeguard personnel from injury while they are working on or near re-energize electrical circuits and equipment” **to** “Each department manager shall document training and implementation of the lockout/tagout procedures (based on MN471001, ES&H Manual, Section 4C, "Lockout/Tagout (LOTO)" and GN470037, Administrative Control Procedure) to safeguard personnel from injury while they are working on or near energized electrical circuits and equipment.”

- ***Change:** The requirement in the third sentence under the subtopic “Working on Energized Equipment” **from** “Contact Electrical Safety Engineering (10322) for assistance in determining PPE and boundary requirements” **to** “See the Energized Work Decision Tool or contact Electrical Safety Engineering (10322) for assistance in determining PPE and boundary requirements.”

- ***Change:** The requirement in the first sentence under the topic “Working on Energized Equipment” and under subtopic “Second Person” **from** “When work on energized circuits requires a second person, the second person shall be located in the physical vicinity (i.e. within sight and hearing) of the worker” **to** ”When work on energized circuits requires a second person, as identified using the Energized Work Decision Tool, the second person shall be located in the physical vicinity (i.e. within sight and hearing) of the worker.”

- ***Change:** The requirement in the first sentence under the topic “Working on Energized Equipment” and under subtopic “Safety Watch” **from** “When work on energized circuits requires a Safety Watch, the Safety Watch shall be located within both sight and hearing, and less than 50 ft from the worker” **to** ”When work on energized circuits requires a Safety Watch, as identified using the Energized Work Decision Tool, the Safety Watch shall be located within both sight and hearing, and less than 50 ft from the worker.”

- Under topic, “2.7 Working Space Requirements for Energized Work,” and under the subtopic “General Requirements”:

- ***Change**: The first sentence **from** “Working space around energized electrical enclosures or equipment shall be adequate for all anticipated maintenance and operations, including safety of personnel under emergency conditions and rescue of injured personnel” **to** ”Working space around energized electrical enclosures or equipment shall comply with the dimensions shown in Table 2-2 below.”

- ***Delete:** The second sentence which states “Space shall be provided for personnel access to parts that require examination, adjustment, servicing, or maintenance while energized.”

- **Change:** The previous third sentence **from** “Examples of such equipment include panelboards, switches, circuit breakers, motor control centers, controllers, controls on heating and air conditioning equipment, relay racks, test racks, and consoles” **to** ”Examples of such equipment include panelboards, disconnect switches, circuit breakers, and motor control centers.”

- ***Add:** The requirement “This access and working space shall be kept clear at all times for operation and maintenance personnel and may not be used for

intermittent/incidental storage of nonpermanent equipment or furniture."

- ***Delete:** The last sentence which states "If working space is not available as indicated below, work shall not be performed on or near energized equipment."

- ***Add:** The following Note: "There are no minimum clearance requirements for electrical equipment mounted on wheels that can be easily moved for service access (e.g., equipment test racks, PDUs, etc.), given adequate space is provided for ventilation and wire terminations."

- Under topic, "2.9 Servicing Electrical Equipment and Systems," and under the subtopic "Modifications or Installations":

- ***Change:** The last requirement **from** "Modifications or installations and documentation are to be performed by qualified personnel" **to** "Modifications or installations and documentation (using the form provided in Attachment A-2) are to be performed by qualified personnel."

- Under topic, "2.12 Additional Requirements," and under subtopic "Ground Fault Circuit Interrupters (GFCI)":

- ***Add:** The following new requirements "Managers shall ensure that:

  - Outlets outside external doors are weatherproof and GFCI protected.

  - Rooftop maintenance outlets are weatherproof and GFCI protected.

  - GFCI protection is installed on all 120-volt, 15 and 20 amp receptacles located within 6 ft of sinks, shower heads, eyewash stations and outside doors. No outlet is allowed within 3 feet of the vertical axis of shower heads or eye wash stations."

- ***Change:** The requirement "Ground Fault Circuit Interrupter (GFCI) protection is provided for receptacles that supply 120 volts of alternating current (AC) in outdoor locations, on rooftops, in explosives areas, or in wet or damp indoor locations, such as near sinks, showers, or eyewashes" **to** "Ground Fault Circuit Interrupter (GFCI) protection is installed on all 120-volt, 15 and 20 amp receptacles located within 6 ft of sinks, shower heads, eyewash stations and outside doors. No outlet is allowed within 3 feet of the vertical axis of shower heads or eye wash stations."

- ***Add:** The following new requirements "Managers shall ensure that:

  - GFCI protection is provided in explosives areas where required by the

Explosives Safety Manual (MN471011).

- Electrical equipment that is neither GFCI protected nor protected by suitable barriers is not brought within 6 ft from the vertical axis of the waterfall of a shower head or eyewash station.

- GFCI outlets are installed and operated in accordance with this section and the National Electrical Code, Article 210.8, except when specific testing/ operations preclude its use. Contact ES&H coordinator or Safety Engineering for additional guidance.

- For new construction and receptacle system maintenance/repairs, comply with the latest changes to the SNL Facilities Design Standards Manual, Section 9.5."

- ***Delete:** The following requirement "Managers shall ensure that portable GFCIs that plug into receptacles or extension cords that contain GFCIs are used where permanent GFCI protection is unavailable."

- ***Change:** The last requirement **from** "Members of the Workforce who operate electrical equipment that utilizes GFCI protection shall trip-test the interrupter by using the test buttons on the unit prior to use and at least once per month. A record of these tests may be kept in a notebook or on a test record label, which are normally provided by manufacturers" **to** "Members of the Workforce who operate electrical equipment that utilizes GFCI protection shall trip-test the interrupter by using the test buttons on the unit at least once per month. A record of these tests may be kept in a notebook or on a test record label, which are normally provided by manufacturers. The AHJ may grant exceptions to the testing requirement for remote, unpopulated areas. Contact your ES&H coordinator to initiate this request."

- **Add:** The following Note: "The use of the (GFCI) internal tester and use of a load or test meter to verify power interruption is the preferred method of testing a GFCI device. External testers may give misleading or erroneous results and, in some case, may be hazardous."

Chapter 4:

- Under topic, "4.3 Safe Work Practices":

  - ***Add:** The following requirements under the subtopic "Modifications or Installations":

    - Before using the equipment, the person performing the modification shall

ensure equipment that is in-house built, modified NRTL, or from a manufacturer that does not meet the requirements of an "Accepted Manufacturer" as defined in the SNL Electrical Equipment Approval Guidelines, is approved and documented using the form in Attachment A-2, "Other Manufacturer Equipment, In-House Built Equipment or Modified NRTL-Listed Electrical Equipment Approval Form."

- Before using the equipment, the person performing the modification shall ensure that modified and non-NRTL equipment is electrically checked by calibrated equipment in accordance with SNL CPR 100.3.1.

- ***Delete:** The following requirement under the subtopic "Modifications or Installations":

  - Before using the equipment, the person performing the modification shall certify that the equipment is safe to operate by signing the equipment modification documents.

- **Change:** The nomenclature used in the requirement under the subtopic "Use of Listed Equipment" **from** "Non-Reputable Manufacturer" **to** "Accepted Manufacturer," and **from** "Non-Reputable Manufacturer Equipment" **to** "Other Manufacturer Equipment."

- **Add:** Information in the requirement under the subtopic "Use of Listed Equipment" to indicate that the nomenclature "Accepted Manufacturer" is defined in the SNL Electrical Equipment Approval Guidelines.

- ***Change:** The requirement under the subtopic "Documentation of Nonlisted Equipment" **from** "Equipment that is not listed by an NRTL shall be approved and documented using the form in Attachment A-1, "Reputable Manufacturer Unlisted Electrical Equipment Approval form" **to** "Equipment that is not listed by an NRTL shall comply with the requirements of the SNL Electrical Equipment Approval Guidelines and shall be approved and documented using the form in Attachment A-1, "Accepted Manufacturer Unlisted Electrical Equipment Approval form."

- ***Add:** The following requirement under the subtopic "Documentation of Nonlisted Equipment":

  - Prior to use, modified and non-NRTL equipment shall be electrically checked by calibrated equipment in accordance with SNL CPR 100.3.1.

- Under topic, "4.5 Power Sources":

- **Change:** The first Note listed under the subtopic “Design and Construction” **from** “Whenever possible, NRTL listed equipment should be purchased and used in the lab” **to** “Whenever possible, NRTL listed equipment should be purchased and used in the lab. For special testing applications, when the equipment is not available and shall be manufactured in-house, consult the SNL Electrical Equipment Approval Guidelines for non-NRTL equipment for additional guidance on incorporating engineered controls into the design of the equipment .”

- ***Add:** The following requirement to the end of the third paragraph under the subtopic “Safety Practices”:

  - Use the Energized Work Decision Tool to determine the appropriate precautions and training requirements.

- Under topic, “4.13 Enclosed Electrical/Electronic Equipment”:

  - ***Change:** The requirement in the second sentence **from** “Racks shall be inspected by a qualified inspector (refer to Attachment A-3, “Electrical Equipment Racks Approval Form.")” **to** “Racks shall be inspected by a qualified inspector in accordance with SNL Electrical Equipment Approval Guidelines (refer to Attachment A-3, “Electrical Equipment Racks Approval Form).”

References:

- Under topic, “Implementing Documents”:

  - **Add:** The document “SNL, AOP 06-05, *Electrical Equipment Approval Guidelines*.”

Attachments:

- In Attachment A-1:

  - **Change:** The nomenclature used **from** “Reputable Manufacturer” **to** “Accepted Manufacturer.”

- In Attachment A-2:

  - **Change:** The nomenclature used **from** “Non-Reputable Manufacturer” **to** “Other Manufacturer,” and also indicate that the definition of “Accepted Manufacturer” is defined in the SNL Electrical Equipment Approval Guidelines.

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Electrical Safety Manual

LIST OF EFFECTIVE CHAPTERS

Subject Matter Expert: Mark McNellis; CA Counterpart: Herman Armijo
MN471004, Issue L
Revision Date: March 26, 2007; Replaces Document Dated: March 14, 2007
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* Indicates a substantive change

CHAPTER	ISSUE	ISSUE DATE
1.0 - Introduction	K	3/14/2007
*2.0 - General Requirements	L	3/26/2007
3.0 - Facility Specific Requirements	K	3/14/2007
*4.0 - Research and Development-Specific Requirements	K	3/14/2007
5.0 - Special Occupancies	K	3/14/2007
Attachment 1 - Reputable Manufacturer Unlisted Electrical Equipment Approval Form	B	3/14/2007
Attachment 2 - Non-Reputable Manufacturer Equipment, In-House Build Equipment or Modified NRTL-Listed Electrical Equipment Approval Form	B	3/14/2007
Attachment 3 - Electrical Equipment Racks Approval Form	B	3/14/2007
Glossary	K	3/14/2007
References	K	3/14/2007

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Sponsor: Dori Ellis, 4000, Acting

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Electrical Safety Manual

CHAPTER 1 – INTRODUCTION

Subject Matter Expert: Mark McNellis; CA Counterpart: Herman Armijo
MN471004, Issue K
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Review Date: October 5, 2006

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* Indicates a substantive change

1.1 Purpose, Applicability, Scope, Ownership

Purpose

The *Electrical Safety Manual* describes the Sandia National Laboratories (SNL) safety standards for all SNL facilities or locations involved in the use of electrical energy. This manual has been prepared to provide uniform electrical safety standards and guidance for SNL installations in order to reduce the risks associated with the use of electrical

energy.

The objective of this manual is to enhance electrical safety awareness and mitigate electrical hazards to employees, the public, and the environment. The goal of this manual is to ensure the adoption of Occupational Safety and Health Administration (OSHA) safety related work practices for electrical work. This manual contains all identified requirements of electrical safety.

Applicability

For purposes of this document, Members of the Workforce are:

- Sandia employees.
- Sandia contractors as specified in Section 1B, "What Is the Scope."

Provisions contained in the manual are applicable to all Members of the Workforce who are engaged in the design, installation, inspection, testing, maintenance, operation, research and development (R&D), or decommissioning of electrical/electronic equipment or systems. At locations where Sandia is not the prime contractor, these requirements supplement those of the prime contractor and the more stringent requirements apply.

This manual also applies to Members of the Workforce whose work may bring them in the vicinity of exposed voltages of 50 volts or greater for a potential exposure to exist.

Scope

The guidelines provided in this manual are a summary and interpretation of the applicable codes, standards, regulations, and DOE orders. Situations not addressed in this manual should be referred to the SNL Electrical Safety Committee (ESC).

The provisions of the National Electric Code (NEC), National Electric Safety Code (NESC), and OSHA Standards contained within this manual are to be complied with at all Sandia-controlled premises. These standards have specific requirements that apply to all electrical installations and utilization equipment regardless of when they were designed or installed. In addition, these standards also identify other mandatory provisions and specify effective dates.

Ownership

The SNL ESC administers, manages, and owns this document and is responsible for its development and update. The chairperson of the SNL ESC is the designated contact person. Submit suggestions for revisions, updates, or changes to the manual to the SNL ESC for consideration.

Basis for Requirements

The requirements in this manual were developed from the documents listed below:

- National Electrical Code (NEC) (National Fire Protection Association [NFPA] 70), 2005.
- Electrical Safety Requirements for Employee Workplaces (NFPA 70E), 2004.
- OSHA Standard, 29 CFR 1910, Subpart S, and 29 CFR 1926, Subpart K, *Electrical* and Subpart V, *Power Transmission and Distribution*.
- DOE O 440.1A, *Worker Protection Management for DOE Federal and Contractor Employees.*
- DOE O 430.1B, *Real Property Asset Management.*

Records

Records initiated or kept by the line include the following:

The SNL Safety Engineering Department Manager responsible for SNL Electrical Safety:

What Record to Keep (What)	See Section or Chapter of this Manual (Where)	
Central file of active exemptions and waivers	1.2	Electrical Safety Committees "Request for an Exemption or Waiver"

Department Manager:

What Record to Keep (What)	See Section or Chapter of this Manual (Where)	
Required training records	1.3	Responsibilities of Individuals "Center Directors, Senior Managers, and Department Managers Responsibilities"
	2.2	Qualifications and Training "Documenting Training"
	2.4	Safe Work Practices "Lockout/Tagout Procedures"
Memo to file for training completed outside of Sandia	2.2	Qualifications and Training "Documenting Training"
Required equipment maintenance and inspection records	1.3	Responsibilities of Individuals "Center Directors, Senior Managers, and Department Managers Responsibilities"
Technical work document (TWD) for work on energized electrical systems	2.1	Primary Work Considerations "Working on Energized Electrical Equipment"
Testing methods used and results of tests on rubber insulating equipment	2.10	Personal Protective Equipment "Rubber Insulating Equipment" *Selection and Testing*
Record of testing of live-line tools	2.10	Personal Protective Equipment "Live-Line Tools" *Testing*
Department file of continuity tests for grounding conductors	2.11	Tools, Test Instruments, and Equipment "Electrical Power Tools"
Switching procedures	3.0	FACILITY SPECIFIC REQUIREMENTS "Switching Procedures" *SNL/NM Switching Procedures*

User:

What Record to Keep (What)	See Section or Chapter of this Manual (Where)	
User file for evaluation of nonlisted equipment	2.1	Primary Work Considerations "Approved Electrical Equipment"

	4.3	Safe Work Practices "Documentation of Nonlisted Equipment" *Built to Specifications*, and *Modified Equipment*
User or department files for equipment modifications of NRTL listed or labeled equipment	2.9	Servicing Electrical Equipment and Systems "Modifications or Installations"
	4.3	Safe Work Practices "Modifications or Installations"

Owner:

What Record to Keep (What)	See Section or Chapter of this Manual (Where)	
User file for testing and calibration of testing apparatus	2.10	Personal Protective Equipment "Testing Apparatus"
Calibration of electrical instruments by serial # including: • Dates of inspection • Calibration date as required • Interim repairs if required • Date to be recalled from the field for a recalibration check	2.11	Tools, Test Instruments, and Equipment "Calibration of Electrical Instruments"

PIC (or PIC designated person):

What Record to Keep (What)	See Section or Chapter of this Manual (Where)	
Safety interlock test	4.3	Safe Work Practices "Safety Interlocks"
	4.4	Preventive Maintenance "PIC Responsibilities"

Organization of This Manual

CHAPTER SELECTION GUIDE*			
General Requirements (Chapter 2.0)	**Facilities (Chapter 3.0)**	**R&D (Chapter 4.0)**	**Special Occupancies (Chapter 5.0)**
All Members of the Workforce whose work may bring them in the vicinity of exposed voltages of 50 volts or greater for a potential exposure.	For Members of the Workforce who work on equipment that is: • From building service to panels and outlets (premises wiring). • Generally equipment not bought by Sandia. • Facilities equipment • R&D support equipment maintained by a facilities department.	For Members of the Workforce who work on equipment that is: • From the facility power outlets. • R&D purchased equipment. • R&D designed and built equipment.	As required.
*Members of the Workforce who work in either a facilities or a R&D organization should read the whole manual.			

1.2 Electrical Safety Committees

Authority Having Jurisdiction

The manager (10322) responsible for SNL electrical safety is the electrical Authority

Having Jurisdiction (AHJ) for SNL locations and facilities. The SNL ESC serves as the primary advisor to the AHJ on issues relating to electrical safety.

However, qualified personnel may assume the responsibility of the AHJ in the performance of their normal activities. The AHJ Pyramid illustrates the approval hierarchy to follow when any given level of authority cannot make the necessary interpretation of codes and regulations.

The AHJ is responsible for interpreting and implementing codes and regulations. The AHJ may authorize alternate methods where it is assured that equivalent objectives can be achieved by establishing and maintaining effective safety equal to or exceeding established codes and standards.

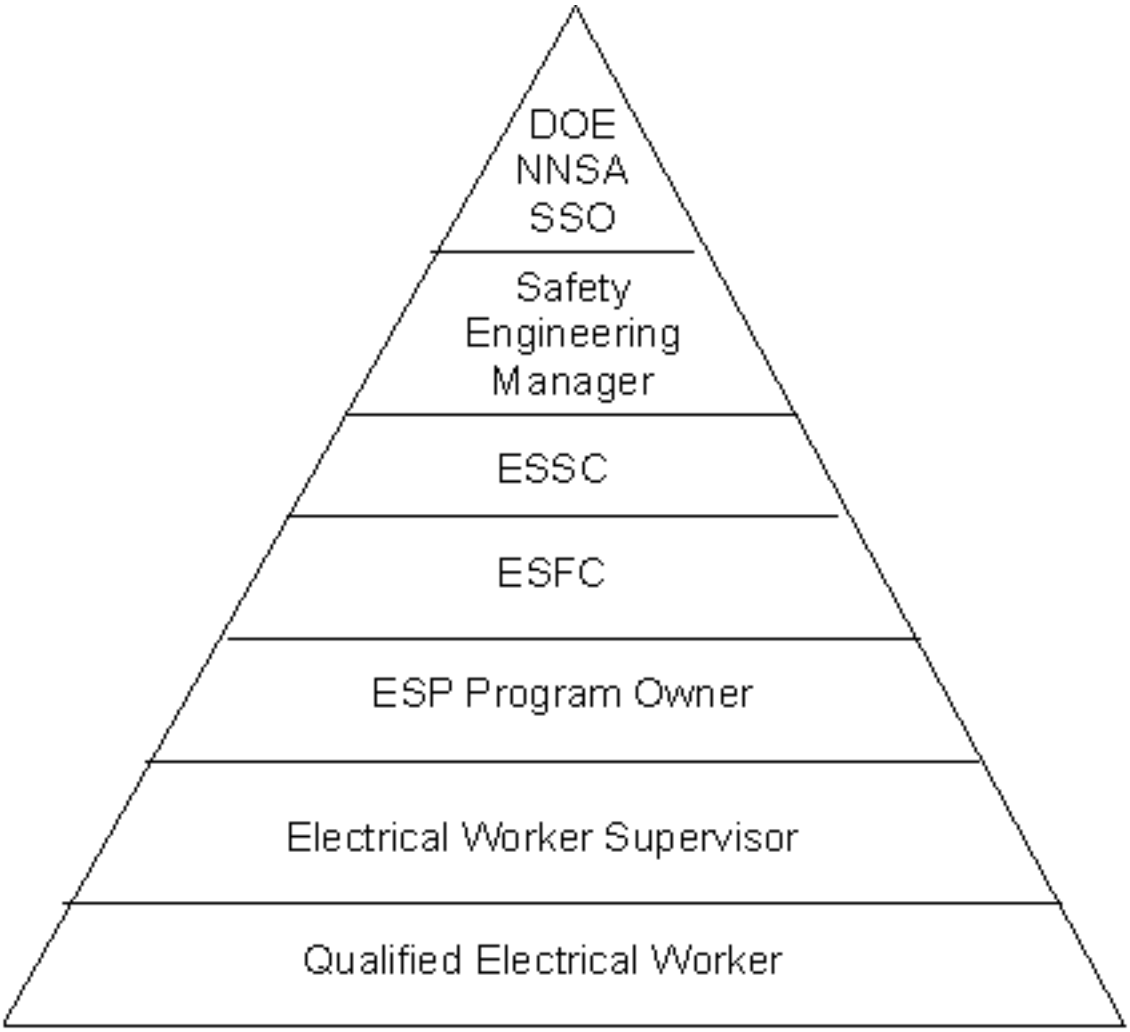

Figure 1-1. The AHJ Pyramid

Mandatory and Advisory Standards

The standards presented in this manual are either mandatory or advisory. Mandatory standards, denoted by the words "shall," "must," or "will" are requirements that must be followed unless written authority for exemption is granted by DOE or alternate equivalent standards are approved by the AHJ. Advisory standards, denoted by the words "should" or "may" are recommended best practices that help ensure safe electrical operations. If a standard does not say "should" or "may," it implies "must," "will," or "shall." Any questions about mandatory or advisory standards can be directed to the Electrical Safety Committee.

Exemptions and Waivers

Exemptions

An exemption is a written release from a mandatory standard where equivalent protection of operating personnel, the public, and property cannot be achieved using alternative standards. A request for an exemption shall include an assessment of the residual risk.

Waivers

A waiver is a written release from a mandatory standard where an activity, operation, or process is determined to be safe and necessary.

Request for an Exemption or Waiver

Each request for an exemption or waiver shall be submitted in writing to the AHJ and contain as a minimum the following information:

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

The AHJ will evaluate the request and submit it to DOE, or return the request to the originator with explanation for denial. All requests shall be approved by the local DOE contracting officer. Exemptions and waivers can only be granted by the DOE. Exemptions and waivers will be granted for the minimum necessary time, and those of an ongoing nature shall be updated every three years.

The Manager responsible for SNL Electrical Safety shall maintain a central file of active exemptions and waivers.

SNL Electrical Safety Committee Organization

The SNL Electrical Safety Committee is managed in two parts: The Electrical Safety Standing Committee (ESSC) and the Electrical Safety Functional Committee (ESFC). The ESFC reports to the ESSC.

Electrical Safety Standing Committee

Each VP whose division engages in electrical work or whose personnel are exposed to electrical hazards appoints one member and an alternate to the SNL ESC. Advisors may be added by the committee as required to provide expertise in various electrical safety areas.

Electrical Safety Functional Committee

Each division shall provide an electrical Subject Matter Expert to sit on the ESFC. The Metal Trades Council is represented by one member and an alternate. The DOE Sandia Site Office (SSO) appoints a representative to coordinate electrical safety concerns involving the SNL ESC and the DOE. Contractor personnel shall be allowed to participate on the committee.

The ESFC will meet quarterly and will provide recommendations to the ESSC on situational concerns, and shall assist the ESSC in carrying out its charter. The ESFC reports to and is to be considered the Subject Matter Expert for the ESSC.

SNL/CA Electrical Safety Committee Organization

The SNL/CA Electrical Safety Committee is chartered at SNL/CA to address electrical safety issues at SNL/CA. The SNL/CA ESC is made up of one member and one alternate from each center appointed by their director. The chair of the SNL/CA ESC is a member of the SNL ESC and is a line organization member. The site electrical safety

engineer serves as an advisor. The committee is the AHJ at the California site. Issues involving an SNL-wide perspective are addressed by the SNL ESC.

SNL Electrical Safety Committee Charter

Purpose

The SNL ESC was established to provide a competent technical resource for identifying and recommending resolution of electrical safety issues and communicating the information to SNL personnel as appropriate. The goal of the committee is to enhance electrical safety by reducing risk and mitigating hazards in electrical energy distribution and applications in R&D laboratories and other workplaces. In addition, the committee will aid in and/or provide root cause analysis (RCA) for electrical incidents or occurrences.

Responsibilities

Under the authority delegated in the Committee Charter, the SNL Electrical Safety Committee shall be responsible to:

- Administer and manage the SNL *Electrical Safety Manual*.
- Provide technical expertise, guidance, and interpretation on matters concerning electrical safety, codes, and standards and proposed solutions for electrical issues for SNL.
- Assist in the development and implementation of the SNL electrical safety programs and guidelines that incorporate applicable DOE Orders and accepted industrial practices related to electrical safety such as those published in the:
    - National Electric Code (NEC) 2005
    - National Electric Safety Code (NESC) 2006
    - Occupational Safety and Health Act (OSHA) standards
    - National Fire Protection Association (NFPA 70E, *Electrical Safety in the Workplaces)* 2004
    - Various National Fire Protection Association (NFPA) publications.

- Review electrical occurrence reports, requests for exemptions or waivers, and other submittals and provide recommendations.

- Assist in the development and monitoring of the standardized electrical safety awareness training programs.

- Participate in DOE electrical safety programs (such as the DOE ESC and the DOE Electrical Safety Guidelines development and maintenance) and the process for requesting and monitoring exemptions and waivers to the manual requirements.

1.3 Responsibilities of Individuals

Management Responsibilities

It is the responsibility of all levels of management to provide a workplace where the risks from electrical hazards that might cause injury, illness, or death are as low as reasonably achievable. Managers shall expect all personnel to comply with these regulations.

Center Directors, Senior Managers, and Department Managers Responsibilities

The Directors, Senior Managers, and Department Managers are responsible for meeting all of the requirements of this manual in the operations they manage. This includes the following:

- Ensure that personnel are provided a workplace that is free from unmitigated hazards.

- Ensure that personnel performing electrical work are trained and qualified, including instruction on appropriate emergency procedures such as Cardiopulmonary Resuscitation (CPR), first aid, and confined space rescue, as warranted by their duties.

- Ensure that operating procedures are established and implemented for working on or near equipment with exposed live parts.

- Ensure that approved, maintained, and tested equipment, tools, and protective clothing suitable for the work being performed is provided.

- Ensure that personnel use the personal protective equipment (PPE) appropriate for their assigned task.
- Ensure that personnel using protective clothing and equipment are trained in their proper use.
- Ensure that all electrical equipment is operated and maintained in accordance with the manufacturer's instructions.
- Ensure that required training records are kept and maintained.
- Ensure that required equipment maintenance and inspection records are kept and maintained.

Personnel Responsibilities

Personnel shall comply with the parts of this manual that apply to their own actions and conduct. This includes the immediate reporting of unsafe conditions to management. Personnel shall also report any electrical shock to the non-emergency hotline as specified in Chapter 15, "Emergency Preparedness and Management." (See the ES&H Quick Reference Information Card [at SNL/NM, SNL/CA, and TTR] or an Emergency Response Card [at KTF] for the correct number for your work location).

Safety Watch Responsibilities

A Safety Watch is a person whose specific duties are to observe the workers and operations being performed, prevent careless acts, quickly de energize the equipment in emergencies, and alert emergency personnel. Safety Watches are typically used during facilities operations where hazardous situations exist.

Specific responsibilities include:

- Maintain both visual and audible contact with personnel performing the work.
- Know the specific working procedures to be followed and the work to be performed.
- Monitor the work area for unsafe conditions or work practices and take necessary action to correct the unsafe condition or work practice.

- Know the locations of emergency shutdown buttons and power disconnects for the equipment involved in the work to be performed.

- Possess current certification in CPR.

Second Person Responsibilities

A Second Person ("The Buddy System") is a person whose duties include maintaining contact with personnel performing hazardous operations in order to assist them in case of an emergency. The second person should not be directly involved in the hazardous operation, but should be familiar with the hazards involved and know how to respond to emergency situations. The Second Person is typically used in R&D type operations.

Specific responsibilities include:

- Maintain contact with personnel performing the work. The second person may be performing work separately from the worker performing hazardous work. If the hazardous work is likely to cause serious physical harm, then the second person should assume the responsibilities of a safety watch.

- Know the locations of emergency shutdown buttons and power disconnects for the equipment involved in the work to be performed.

- Possess current certification in CPR.

Person in Charge Responsibilities

The person in charge (PIC) may be a department manager, team leader, project leader, facility owner, or a person appointed by them to be in charge of a work project. The PIC may be either an SNL employee or a contractor.

Specific responsibilities include:

- Ensure that safety rules are followed.

- Brief all personnel on the safety concerns and precautions regarding their work assignment, and discuss specific hazards for working near exposed energized parts where unexpected electrical hazards may exist.

- May omit pre-work briefings for work that is repetitive and for which up-to-date ES&H SOPs, operating procedures (OPs), or SWPs are available.
- **Note:** These TWDs need to be written and approved in accordance with Chapter 21, "Technical Work Documents (TWDs)."
- Select and ensure the proper placement of safety signs, symbols or accident prevention tags.
- Complete Electrical Safety Awareness Training courses appropriate for the work they are supervising.
- Take necessary corrective actions to address the concerns of personnel who report perceived electrical hazards.
- Notify workers of changes in work conditions, and limit the work area only to authorized individuals who are familiar with the work.
- Decide when it is safe to isolate and insulate exposed live parts rather than de energize them.
- Review and approve PPE selection.
- Approve the work whenever interlocks or other protective systems must be bypassed or otherwise rendered inoperative.
- Ensure compliance with all required equipment maintenance practices and procedures (see Section 4.4 Preventive Maintenance).

1.4 Electrical Safety Program

Electrical Safety Program Principles

The SNL Electrical Safety Program and the guidance in the remainder of this manual are based on the following ten principles:

- Inspect and evaluate equipment periodically and prior to use. The equipment's technical manual often provides guidance on proper maintenance procedures.

- Maintain electrical equipment's insulation and enclosure integrity. All electrical safety evaluations are based on the equipment being operated in the manner specified in the technical manual or operating instructions. Operating outside this guidance may expose the worker to electrical hazards.

- Plan every job and document first time procedures. Use procedures as tools. A Sample Technical Work Document is provided to aid in the development of useful procedures which will identify the hazards and provide appropriate protection for each of those hazards.

- De-energize whenever possible. Working on energized equipment for reasons of convenience is never allowed.

- Anticipate unexpected events. All electrical hazards may not be identified during an initial hazard analysis. A questioning approach when working on electrical equipment is essential to prevent electric shock.

- Identify and minimize the hazards.

- Protect the worker from shock, burn, blast and other hazards due to the working environment. Specific identification and protection of each electrical hazard in the Technical Work Document will aid in protecting the worker.

- Use the right tool for the job. Test equipment shall be rated for the expected energy; insulated tools and other equipment will ensure the worker's safety and the equipment's reliability.

- Assess people's abilities. Only individuals who are qualified to work on a specific piece of equipment should be allowed to do so. The manager designates these individuals based on training, experience and ability.

- Audit these principles. A program to review technical work documents, primary hazard assessments, and individual qualifications is critical to the success of any electrical safety program.

All employees working on or near electrical equipment are required to adhere to these principles. Chapter 2 of this manual provides general guidance to workers and managers. Chapter 3 provides guidance to facilities work. Chapter 4 provides specific implementation instructions for R&D work, and Chapter 5 provides additional direction for work in hazardous environments. The Glossary of this manual includes definitions

used.

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Sponsor: Dori Ellis, 4000, Acting

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IMPORTANT NOTICE: A printed copy of this document may not be the document currently in effect. The official version is located on the Sandia Restricted Network (SRN) and watermark-controlled.

Electrical Safety Manual

CHAPTER 2 – GENERAL SAFETY REQUIREMENTS

Subject Matter Expert: Mark McNellis; CA Counterpart: Herman Armijo
MN471004, Issue L
Revision Date: March 26, 2007; Replaces Document Dated: March 14, 2007
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*Indicates a substantive change

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

*2.1 Electrical Work Requirements – General

These requirements apply to all electrical work performed by Members of the Workforce on Sandia-controlled premises. Members of the Workforce should comply with local instructions when working off-site.

Requirements

Managers shall ensure that:

- All Members of the Workforce are aware of and observe safe work practices and procedures outlined in this manual.
- Members of the Workforce who work on electrical equipment are qualified and follow the requirements of this manual.

- Members of the Workforce working in areas where electrical hazards exist know the hazards and receive training in the safety practices required to avoid injury.

All Members of the Workforce shall ensure that:

- All electrical equipment purchased, manufactured or used at any SNL facility, including office and personal (household rated) equipment, is in compliance with the SNL Electrical Equipment Approval Guidelines for Nationally Recognized Testing Laboratory (NRTL) certification or alternate testing.

  Note: Purchased equipment or equipment manufactured internally to research and development (R&D) specifications may be exempt from NRTL labeling requirements. See "SNL Electrical Equipment Approval Guidelines" for additional information.

- Guards or barriers, in conjunction with safety signs, are placed around "live" parts that are operating at or above 50 volts (see Section 4M, "Signs (Including SWHAS) and Tags," for information about safety signs).

Managers who are responsible for Sandia-controlled premises shall ensure:

- Electrical work activities, equipment, and installations are in compliance with the National Electric Code (NEC), National Electric Safety code (NESC), and OSHA Standards contained in this manual.

All Members of the Workforce shall:

- Be familiar with the equipment they use and ensure that it is safe to operate.
- Use household equipment, such as coffee pots, popcorn poppers, or microwave ovens, according to the manufacturer's instructions.

  Note: Household equipment is not intended for continuous use.

- Turn the power switch off, unplug the equipment by pulling on the plug (not the cord), and follow manufacturer's instructions when connecting and disconnecting cables and components of personal computers and other electronic office equipment.

- **Not** use conductive cleaning material, such as steel wool or metal brooms, in close proximity to exposed unguarded electrical parts unless safeguards have been taken to prevent electrical contact.
- **Not** attach or hang external objects or other wiring from electrical conduits (e.g., pipes containing wiring).

Members of the Workforce shall report any of the following observations to their manager, supervisor, or the appropriate Division ES&H Team Safety Engineer:

Type of Situation	Observation
Members of the Workforce and their activities	• Workers not qualified for the electrical work they are performing • Poor housekeeping • Unsafe work habits around electrical equipment • Improper safety equipment, apparel, and personal protective equipment (PPE) • Improper use of lockout/tagout procedures • Blocked access to electrical panels • Drinks or liquids placed on top of electrical equipment
Wiring, outlets, and light sockets	• Exposed or frayed wiring • Empty light sockets • Loose wiring connectors • Exposed terminals, pins, and lugs

Cords, tools, and equipment	• Water or oil on the floor around electrical equipment • Damaged power tools or other electrical equipment • Ungrounded electrical equipment • Improperly used or placed extension cords • Unlisted or unlabeled electrical equipment • Damaged or frayed cables or cords • Modifications to electrical equipment • Three-pronged plugs with missing ground prongs
Barriers	• Unlocked gates to electrical substations • Missing electrical covers • Unlocked or improperly labeled doors to electrical equipment • Open, unattended, unbarricaded electrical panels

*Approach to Work on or Near Electrical Equipment

Note: Working near energized electrical equipment is defined as any activity inside the limited approach boundary (LAB) as defined by NFPA 70E. The LAB starts at 42 inches from exposed energized parts and increases with voltage. Please contact your ES&H coordinator for assistance in determining your LAB. Safety-related work practices (shock and flash hazard analyses, and energized work TWDs) shall be used to prevent electric shock or other electrically induced injuries when personnel work on or near electrical conductors or circuit parts that are energized.

***Requirements**

Managers shall:

- Determine if energized electrical work performed in their department is appropriate.
- Ensure that Appropriate Energized Electrical Work is work on circuits >50 volts which, if de-energized, would result in an increased or additional hazard or if deenergizing the circuit is not feasible due to equipment design or operational limitations.
    - Examples of appropriate energized work:
        - Loss of electrical power could result in an environmental hazard (spill, loss of shielding etc,).
        - Removal of the voltage source in one circuit would require a complete shutdown of a continuous process.

    Note: "Not feasible" is not the same as "not convenient." Work on energized equipment for reasons of custom or expediency does not meet the requirement of appropriate energized electrical work and is not allowed.
- Use the energized work permit, or other appropriate technical work documents (TWDs) to ensure that appropriate energized electrical work is justified and authorized.
- Prohibit inappropriate energized electrical work.
- Ensure all appropriate energized electrical work is approved by a senior manager prior to the start of the work.
- Identify and minimize the hazard to worker through:
    - Thorough review of the equipment design to assess hazards. Equipment design review shall use electrical diagrams, equipment details, sketches or pictures of unique features and/or reference data, as appropriate.
    - Development of appropriate procedures (see Section 2.3 and Energized Work Decision Tool).

- Use of personal protective equipment.
- Training.
- Pre-work briefings.

- Ensure a pre-work briefing is held:
  - Before the start of each job. This briefing shall include such subjects as hazards associate with the job, work procedures involved, special precautions, energy source controls, and personal protective equipment requirements. If the work or operations to be performed during the day or shift are repetitive and similar, at least one job briefing shall be conducted before the start of the first job of the day or shift.
  - If the scope of the job changes during the course of the work.
  - If significant changes that might affect the safety of the worker (i.e. environmental hazards, startup of equipment within work area) occur.

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

Members of the workforce shall:

- Recognize that deenergizing an electrical conductor or circuit part and making it safe to work on is in itself a potentially hazardous task.
  - Use of electrical diagrams, equipment details, sketches or pictures of unique features and/or reference data while deenergizing the equipment is required.
- Recognize that every electrical conductor or circuit part is considered energized until proven otherwise.
- Anticipate unexpected events.

- Use the right tool for the job. This includes using appropriately sized wrenches, sockets, screwdrivers etc. for the equipment and using tools of the appropriate insulation/voltage rating for the expected voltage/current.

- Use procedures as tools to identify, reduce or eliminate hazards on equipment. Procedures should be referred to frequently in order to ensure that hazards are avoided and appropriate measures are taken to repair/restore equipment to proper operating condition.

- **NOT** touch energized system wiring/components above 50 Volts with their bare hands unless specifically authorized (i.e. bare-hand method).

- **NOT** perform any electrical work unless properly qualified. See Section 2.2 for additional information on qualification.

*Electrical Shock Approach and Arc Flash Protection Boundaries

*Requirements

The manager responsible for authorizing Members of the Workforce to perform appropriate energized electrical work on hazardous circuits as identified by the Energized Work Decision Tool shall:

Note: A facility electrician may request an electrical engineer to determine/establish the shock approach boundaries for a particular electrical work, in which case the shock approach boundaries used may differ from the shock approach boundaries listed below. Facility electricians include electricians working in either the Facilities Management & Operations Center (NM) (10800) or the Site Operations Center (CA) (8500).

- Establish arc flash boundaries as described below and shown in figure 2-1:

    - Ensure that an arc flash boundary is posted at a distance of 4 feet (unless otherwise calculated by Electrical Safety) from fixed exposed energized circuit with the associated pre-determined energy level. Any persons occupying the area inside this boundary shall use electrical flash PPE as required by NFPA 70E Table 130.7(C)(10) when work is being performed on energized electrical circuit parts. Electrical PPE is not required to visually inspect energized electrical parts operating between 50 and 600 volts. Contact the appropriate Division ES&H Team Safety Engineer to assist in

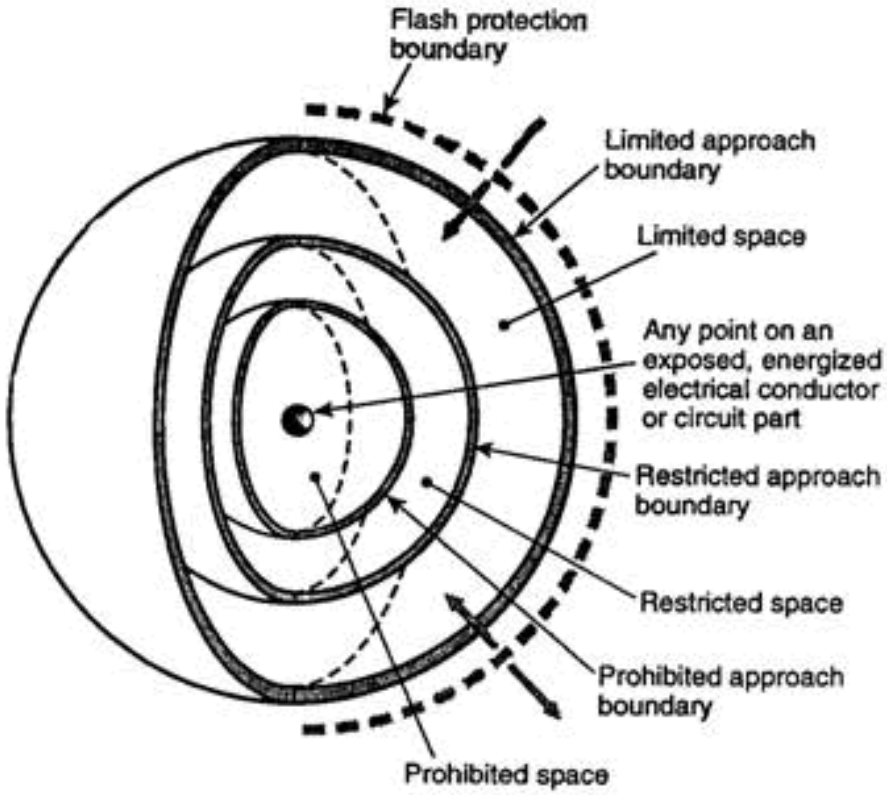
determination of energy levels.

- Establish shock approach boundaries as described below and shown in figure 2-1:
    - Post a limited-approach shock boundary at the distance specified in Table 130.2(C) of NFPA 70E Handbook for Electrical Safety in the Workplace, from fixed exposed energized circuit part(s) and from movable exposed conductors for the highest rated voltage that may be present. This boundary is intended to serve as the limit at which a person is considered to be working near energized electrical parts and signifies the requirement for a technical work document. This boundary is also intended to control access to exposed energized electrical circuit parts by unqualified workers; however, unqualified workers may cross the limited approach boundary if the unqualified worker is:
        - Continuously escorted by a qualified worker.
        - Informed of:
            - Electrical hazards present.
            - Safe work practices applicable while in the limited approach boundary.
            - Location of the restricted area boundary.
            - Prohibition for crossing the restricted area boundary.
- Procedurally establish a restricted-approach shock boundary at the distance specified in Table 130.2(C) of NFPA 70E Handbook for Electrical Safety in the Workplace for the highest rated voltage that may be present. No such boundary is required when such parts operate at less than 300 volts. Simply avoid contact with parts that are operating at less than 300 volts. This boundary is intended to signify the requirement for electrical shock PPE as required by NFPA 70E Table 130.7(C)(10), and prohibit the use of conductive objects by qualified individuals in close proximity to exposed energized circuit parts without proper selection and application of proper tools (i.e., insulated tools and testing instruments), insulation and guarding materials for exposed energized circuit parts (i.e., mats, blankets), and electrical PPE.
- Procedurally establish a prohibited approach shock boundary at the distance specified in Table 130.2(C) of NFPA 70E Handbook for Electrical Safety in the

Workplace from the exposed energized circuit part(s) for the highest rated voltage that may be present. No such boundary is required when such parts operate at less than 300 volts. Simply avoid contact with parts that are operating at less than 300 volts. The purpose of the Prohibited Approach Boundary is to serve as the limit at which a person is considered to be working on energized electrical circuit parts.

Figure 2-1: Example diagram of Approach Boundaries and Arc Flash Boundary [1]

- The outer circle is the arc flash boundary, at 4 feet from the energized conductor or circuit part.
- The second circle is the limited-approach boundary at 3 feet, 6 inches from the energized part operating between 50 and 750 volts.
- The third circle is the restricted-approach boundary, at 1 foot from the energized part operating between 301 and 750 volts.
- The fourth circle is the prohibited-approach boundary, at 1 inch from the energized part operating between 301 and 750 volts.



[1] ANSI/NFPA 70E, Electrical Safety in the Workplace, 2004.

Accidents Involving Electricity

Requirements

Members of the Workforce who are present when a person in the workplace receives an electrical shock from electrical equipment shall:

- Call 911, when in doubt regarding an electrical shock incident.
- De-energize the equipment or separate the victim from the equipment using insulated devices.
- Call the emergency number for their location (see Chapter 16, "Health, Benefits and Employee Services") or take the victim to the appropriate Sandia Health Services facility.
- Report the shock as a medical injury (see Chapter 16, "Health, Benefits and Employee Services").
- Have the equipment immediately taken out of service.
- Take action to secure the scene, if possible, for further casualty analysis. Do not move equipment any more than necessary for casualty actions.
- Activate the SNL reporting system (OOPS) as soon as possible after emergency services have taken control of the victim.

Members of the Workforce who are victims of electrical shock shall always be escorted to the appropriate Sandia Health Services facility.

2.2 Qualifications and Training

Qualifications

Qualification of workers is one of the most important tasks a manager faces. Simply reading this manual and/or attending one of the awareness training courses discussed below does not qualify a worker. A deliberate approach to worker qualification shall be taken that includes the following three parts:

- Training
    - Has the worker received the requisite training specified by the PHS or this manual?
    - Has the worker received on-the-job training that prepares him/her for the assigned task?

- Knowledge of the specific equipment
    - Is the worker aware of the design, construction, internal and external sources of energy, attendant hazards and other related items associated with this equipment?
- Knowledge of applicable regulatory requirements
    - Is the worker sufficiently familiar with associated maintenance techniques, applicable codes (NEC, SEMI S-2) and other general electrical knowledge to safely work on the item in question?

Only qualified personnel can perform work on electrical systems. It is the responsibility of the department manager to determine an employee's electrical qualifications.

How to Become Qualified

To become qualified for electrical work, personnel shall:

- Meet the training requirements for the job assignment.
- Demonstrate a familiarity, through interview, demonstrated experience (i.e. resume/ review) or direct observation, with the hazards of the workplace and the specific equipment to be worked on, as well as any associated ES&H Standard Operating Procedures (SOPs) and Operating Procedures (OPs).
- Demonstrate a familiarity, through interview, demonstrated experience (i.e. resume/ reference) or direct observation, with electrical maintenance techniques, codes and other general electrical knowledge.
- Have qualifications reviewed and approved by their department manager to ensure they are qualified for a particular job assignment.

  Note: A person qualified to work with certain equipment may be considered "unqualified" to work on similar equipment without first being advised of any differing hazards involved.

Managers shall maintain a record of qualified persons with the associated technical work documents.

Training

Department Manager's Responsibilities

No personnel shall be permitted to work in an area where they are likely to encounter an electrical hazard unless they have been trained to recognize and avoid these hazards. A worker's department manager shall identify training requirements and ensure that all training has been completed before allowing any worker to perform electrical work unassisted.

Managers shall verify that individuals responsible for developing and conducting job-specific electrical training have the appropriate education, training, and skills to discharge this responsibility. See CPR400.1.1/MN471001, ES&H Manual, Chapter 11, “ES&H Training” for instructor qualification requirements.

Documenting Training

The department manager shall document training as follows:

- Add to the Training, Education, and Development System (TEDS).
- Maintain the Document Review Signoff sheet (e.g., signoff sheet for an ES&H SOP).
- Add a memo to file for training completed outside of Sandia (such as DOE-offered OSHA training).

Training Records

Evidence of all electrical safety training, on-the-job or classroom, shall be maintained in a file in the TEDS database.

Required Awareness Training

Non-electrical workers and supervisors, whose work may bring them within four feet of exposed electrical hazards operating at 50 volts or more, shall receive ELC105 training. Examples of these occupational categories include material-handling equipment operators, mechanics, painters, grounds maintenance personnel, and other non-electrical workers who may be exposed to an electrical hazard.

Electrical workers (those individuals who may be required to work on circuits in excess of 50 volts) are required to attend ELC-106 (R&D Electrical Safety) or ELC-119 (Facilities Electrical Safety). **Note:** Neither of these courses in any way qualifies the worker to perform work on electrical equipment/circuits/components.

Table 2-1. Determining Appropriate SNL Electrical Safety Awareness Training Courses

Course No/Hrs	Course Title	Personnel
ELC105 4 Hours	Basic Electrical Safety Awareness	Those working near but not on exposed energized parts, such as carpenters, painters, mechanics, and repairers. Also recommended for those with job responsibilities concerning electrical safety such as ES&H coordinators and facilities maintenance managers
ELC106 7 Hours	R&D Electrical Safety Awareness	Those working on or near exposed parts energized at 50 volts or more on R&D, computer, communications, or manufacturing projects. (Examples include scientists, engineers, technicians, and laboratory workers.)
ELC119 8 Hours	Facilities (Low- and High-Voltage) Electrical Safety Awareness	Facility personnel including but not limited to electricians working on facility-type distribution systems.

Refresher Training

Refresher training for SNL courses shall be required at intervals not to exceed three years to provide an update on new regulations and electrical safety criteria. These trainings shall instill safety principles and controls into the worker's approach to working on electrical equipment.

Required Technical Training

The training for electrical workers may include on-the-job and classroom type. The degree of training provided shall be determined by the risk to the electrical worker and the complexity of the work and equipment. This training shall be in addition to the required awareness training listed above.

This training shall include but not be limited to the following categories:

- The safety-related work practices required by OSHA as outlined in this manual that pertain to their respective job assignments.
- The skills and techniques necessary to distinguish exposed live parts from other parts of electrical equipment.
- The skills and techniques necessary to determine the nominal voltage of exposed live parts and the proper clearance distances.
- Procedures (such as ES&H SOPs, OPs, and Safe Work Permits) on how to perform their jobs safely and properly.
- Lockout/tagout (LTO210) of hazardous energy sources and equipment where required to use locks and tags.

Recommended Training

Other types of training recommended for electrical workers include the following subjects:

- National Electrical Code (NFPA 70).
- National Electrical Safety Code (ANSI C2).
- Electrical Safety in the Workplace (NFPA 70E).
- OSHA 29 CFR 1910 Subpart S.
- OSHA 29 CFR 1926 Subpart K.
- Use of personal protective grounds.
- Use of testing and measuring equipment.
- Work permit and work authorization procedures.
- Use and care of PPE.
- CPR certification – This training is required by all individuals assigned as “second persons” or “safety watch.”

*2.3 Energized Work Procedures

*Requirements

Note: Performance of the zero energy verification Lockout/Tagout (LOTO) step is the only exception to the requirement for senior manager approval of appropriate energized electrical work. This work is authorized and explained in an equipment specific LOTO operating procedure (OP) and does not require senior manager approval.

Senior managers shall:

- Authorize the justification and work plan for all appropriate energized electrical work above 50 volts using the energized work permit form [SF 2005-EWP (3-2007)] (Word File/Acrobat File). The energized work permit is required for any electrical work task associated with circuit repair or reconfiguration of a circuit in the energized state.

- Authorize routine troubleshooting/diagnostic and other measurement types of appropriate energized electrical work tasks using other TWDs (i.e., operating procedures). Authorization of such TWDs shall be evident by Senior Manager and Safety Engineer signature on the TWD. Such TWDs shall be department specific and identify:

    - The types of equipment upon which department staff may perform such electrical work tasks.

    - The electrical hazards (i.e., arc flash and shock) associated with performing such electrical work tasks on identified equipment types.

    - Operating voltages and currents, and energies.

    - General electrical safety work practices and controls that will be used during performance of such work tasks so as to avoid identified electrical hazards.

        - Work practices and controls include:

            - Work methods (e.g., measurement techniques, guarding various circuit parts, body positioning, shock approach boundary establishment so as to prevent inadvertent contact with energized circuit parts).

- Use of insulated tools.
- Use of appropriate personal protective equipment for arc flash and shock protection rated for the highest arc flash energy and voltage present (e.g., gloves, hard hats, safety shoes, eye and face protection, insulated live-line tools, cotton clothing, and arc protection).

- Ensure that the energized work permit (Word File/Acrobat File) or another TWD is present at the job location and is readily available to all electrical workers involved with the electrical work addressed by the permit.
- Ensure TWDs are written for the following electrical safety related situations:
  - Operation or use of R&D equipment designs that do not adequately mitigate potential worker exposure to electrical hazards.
  - Operation or use of equipment when interlocks must be bypassed.
  - Temporary use of unapproved electrical equipment for experiment support.
- Ensure TWDs address the following commensurate with the risks to electrical workers relative to their assigned electrical work tasks (see Sections 2.3 and 2.4 of this manual):
  - De-energizing circuits, if possible, and a means to prevent re-energizing the circuit (Lockout/Tagout).
  - Method(s) for verifying or confirming that a circuit or device is in the de-energized state or in an electrically safe condition during lockout/tagout-related activities.
  - Grounding of conductors and all possible conducting parts.
  - Provisions for qualified and properly equipped standby personnel (i.e., safety watch or 2nd person).
  - Method for notifying surrounding workers of hazards associated with exposed energized electrical parts.

- Provision of electrical shock approach and arc flash boundaries.
- Provision of boundary access controls (barriers and barricades, shielding, postings).
- Responsibilities of safety watch or second person responsibilities.
- Awareness of emergency procedures.

- Ensure that other TWDs meet the general requirements provided by Chapter 21, "Technical Work Documents (TWDs)."
- Ensure the excavation and penetration permits are obtained as appropriate.
  - Excavation permits, SA 6610-EP (11-2003) are obtained and approved prior to performing excavations in soil greater than 12 inches in depth or beneath concrete or asphalt.
  - Hidden hazards penetration permits (HHPP), SA 6610-PP (8-2003) are obtained and approved prior to performing penetrations through ceiling, wall, or floor surfaces having a depth greater that 2 inches.

Note: Use Section 4H, “Excavations, Trenches, and Floor or Wall penetrations” for guidance to obtain, complete, and implement an excavation permit, SA 6610-EP (11-2003), and HHPP, SA 6610-PP (8-2003).

*2.4 Safe Work Practices

Safeguards

Hazard Awareness

One of the best ways to prevent electrical accidents is to be aware of electrical hazards in the workplace. Once hazards have been identified they shall be reported to management and proper steps implemented to correct them by a qualified person before an accident occurs.

Workplace Safety

The following practices will improve the safety of the workplace:

- Maintain good housekeeping and cleanliness.
- Identify potential hazards.
- Anticipate problems.
- Resist pressure to "hurry up."
- Plan and analyze for safety in each step of a project.
- Document work.
- Have safety-related work independently verified.
- Know applicable operating and emergency procedures.
- Use properly rated test equipment and PPE, and verify their satisfactory condition and operation before use.

Reviews and Inspections

Major modifications to facilities and facilities-like R&D projects, both new and existing, shall be inspected by authorized personnel such as the AHJ designee (the Construction Inspection and Acceptance Department [10827] in NM and the Facilities Planning and Engineering Department [8512] in CA). Inspectors will verify compliance with the codes and standards that were in effect on the date that such work was approved by a final design review. If the installation involves a hazard to life, equipment, or property, current standards and codes shall be used to mitigate the hazard.

*Approved Electrical Equipment

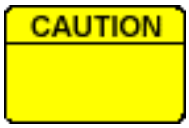
All electrical equipment, components, and conductors shall be Nationally Recognized Testing Laboratory (NRTL) listed in accordance with the SNL Electrical Equipment Approval Guidelines, with the following exceptions:

- Items that are inspected or tested by another federal agency or by a state, municipal, or other local authority responsible for enforcing the NEC, and found to comply with the provisions of the NEC.

- Custom-made and installed equipment built according to specific standards such as Underwriters Laboratories (UL) 508 or one of the American National Standards Institute (ANSI) C series of standards.
- Components or installations in aircraft, watercraft, and railroad equipment.
- Equipment used in an experiment lasting less than 90 days.

100% Rule

Use the 100% Rule when applicable. No switching, isolating, testing, or working on energized circuits shall be performed unless all participating qualified electrical workers are in 100% agreement of the work to be completed and the sequence in which it should be performed.



Caution: If there is not 100% agreement, DO **NOT** PERFORM ANY WORK, BUT CONSULT A THIRD QUALIFIED INDIVIDUAL. Do **not** perform any work until all three individuals are in 100% agreement with the work and its sequence. If there is not agreement at this point, continue the process until there is 100% agreement among the parties involved.

***Establishing an Electrically Safe Work Condition**

A qualified worker shall verify that all live circuits and parts and other sources of energy (electrical or mechanical) have been disconnected, released, or restrained.

- **Determine All Possible Sources of Energy**. Check applicable drawings, schematics, diagrams and identification tags to ensure all sources of energy are identified.
- **De-energize the Equipment**. After properly interrupting the load current, open the disconnecting device(s) for each source of energy, and, when possible, visually verify that the disconnecting device is physically opened.
- **Apply Lockout/Tagout Devices**. Each department manager shall document training and implementation of the lockout/tagout procedures (based on MN471001, ES&H Manual, Section 4C, "Lockout/Tagout (LOTO)" and GN470037, Administrative Control Procedure) to safeguard personnel from injury while they are working on or near energized electrical circuits and equipment. To be qualified to

use the lockout/tagout procedure, personnel shall take LTO210. Control circuit devices such as push buttons, selector switches, and interlocks shall not be used as the sole means for de-energizing circuits or equipment.

- **Testing the Test Equipment**. The test equipment shall be checked for proper operation immediately before and immediately after the verification test. All test equipment shall be rated for the system voltage and application.

- **Verification Test**. A qualified worker shall use test equipment to test the circuit elements and electrical parts of equipment to which personnel will be exposed and shall verify that the circuit elements and equipment parts are de-energized. Testing shall be performed as if the circuit is energized. Proximity testers and solenoid-type devices should not be used to test for the absence of alternating current (AC) voltage.

- **Remove Stored Electrical Energy**. Capacitors and high energy capacitance elements such as cables and transformers shall be safely discharged, short-circuited, and grounded if the stored electric energy could endanger personnel. A stored energy level of 10 Joules or greater is considered dangerous.

- **Remove Stored Nonelectrical Energy**. Devices that could re-energize electric circuit parts shall be blocked or relieved to the extent that the circuit parts could not be accidentally energized. Specific examples include wound springs and pneumatic driven devices.

*Working on Energized Equipment

Any activity conducted within the limited approach boundary is considered energized work and is governed by the requirements of Section 2.1 above. Shock and Flash PPE and approach boundaries shall be listed in the TWD for the work to be performed. See the Energized Work Decision Tool or contact Electrical Safety Engineering (10322) for assistance in determining PPE and boundary requirements.

*Second Person

When work on energized circuits requires a second person, as identified using the Energized Work Decision Tool, the second person shall be located in the physical vicinity (i.e. within sight and hearing) of the worker. This second person shall be qualified in CPR and shall be familiar with the hazards associated with the work being performed. The second person may perform other work while the electrical work is in progress, but may

not leave the vicinity until the energized electrical work is complete. The second person shall attend the pre-brief associated with the energized electrical work to be performed. The second person shall complete ELC-105 at a minimum prior to being assigned second person duties.

***Safety Watch**

When work on energized circuits requires a Safety Watch, as identified using the Energized Work Decision Tool, the Safety Watch shall be located within both sight and hearing, and less than 50 ft from the worker. When overhead work is performed, the safety watch shall be within 50 ft of the base of the lifting device. The safety watch shall have no other duties that preclude observing and rendering aid if necessary. The safety watch shall be qualified in CPR. The safety watch shall complete ELC-105 at a minimum prior to being assigned safety watch duties. The safety watch shall attend the pre-job brief for the work to be performed.

Person in Charge

Electrical work shall be directed by a Person in Charge (PIC) who is qualified by training in the safety-related work practices that pertain to their respective job assignments and those of their personnel.

Personnel shall report to the PIC any perceived electrical hazards not appropriately controlled. The PIC shall take all necessary corrective actions to address personnel concerns.

Before personnel begin any work on or near energized parts at the job site, a qualified person shall be designated as the Person in Charge (PIC). The PIC is responsible for seeing that the safety rules are followed and shall coordinate all the work activities. All personnel assigned to the job shall comply with the safety rules.

2.5 Identification of Electrical Equipment

Disconnecting Devices

All disconnecting devices (switches or circuit breakers) for load devices or circuits shall be located for easy access and clearly and permanently marked to show the purposes of the disconnects, unless they are located and arranged so that the purpose is evident. This applies to all existing electrical systems and all new, modernized, expanded, or altered electrical systems.

Panelboard Circuit Schedules

Panelboards shall be identified and circuit schedules shall be provided and maintained. The schedules shall be fully, clearly and accurately completed.

Source and Load Labeling

The source supplying power to the disconnecting means and the load shall be labeled to allow the identification of the elements from the source of power through the entire circuit. Figure 2-2 shows an example of source and load labeling.

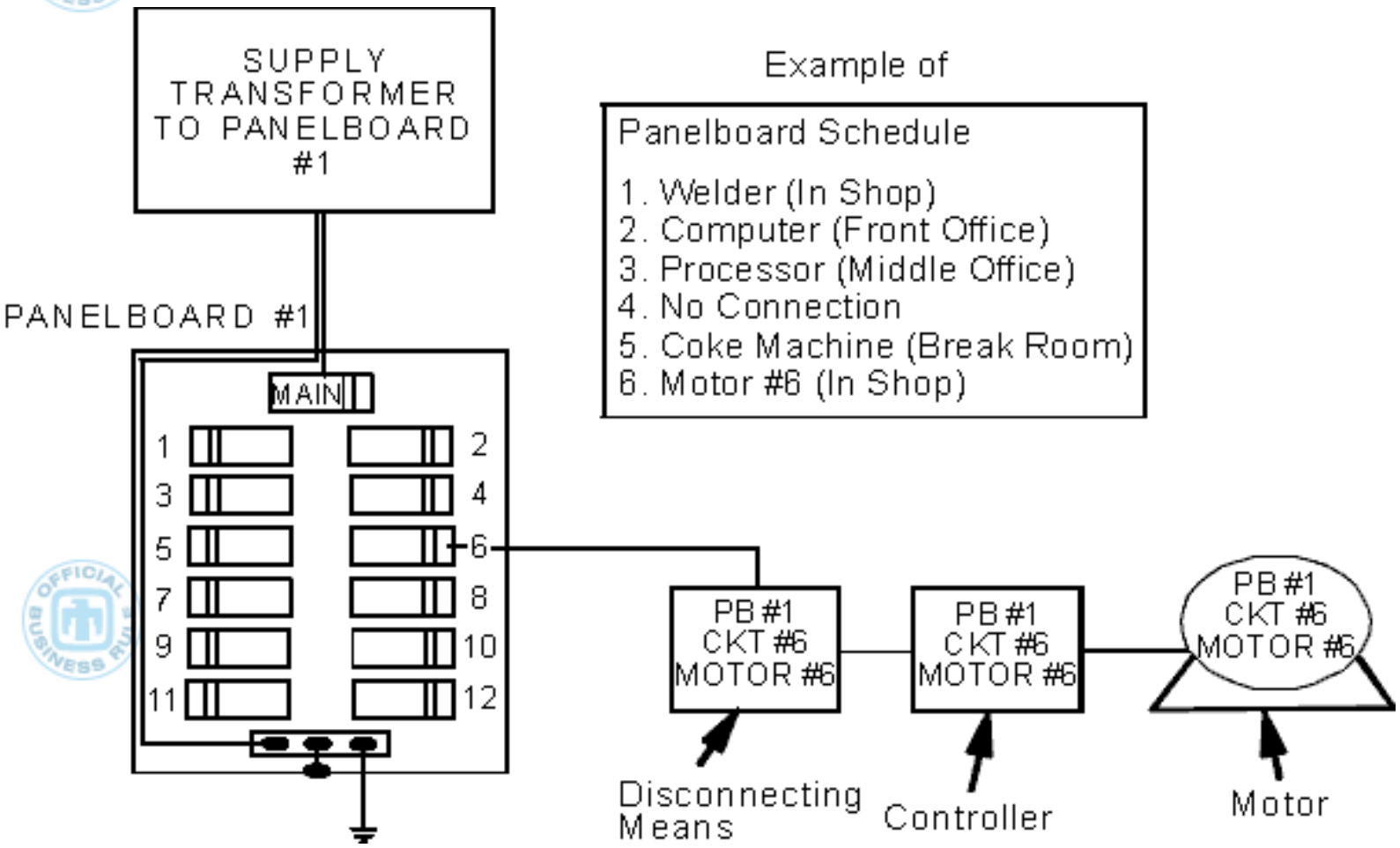


Figure 2-2. Identifying Equipment

In addition, all user-owned equipment should be labeled with the following information when available:

- Arc flash boundary distance.

- Calculated arc flash energy.
- Required arc flash electrical PPE.
- Shock protection boundary distance.

Note: This labeling is in addition to the labeling required on approved or listed electrical equipment.

Contact Safety Engineering (10322) for assistance in labeling equipment.

2.6 Access to Electrical Equipment

General Requirement

Access to electrical enclosures or equipment shall be adequate for all anticipated maintenance and operations, including safety of personnel under emergency conditions and rescue of injured personnel. Following the rules in this section and in Section 2.1 (Electrical Shock Approach and Arc Flash Protection Boundaries) will meet this requirement.

Areas Accessible to Qualified Personnel

If the work exposes energized parts that are normally protected, the PIC shall restrict unqualified persons from entering the area by using danger signs and suitable barricades. Unqualified personnel are not allowed inside the Limited Approach Boundary unless escorted, and are not allowed inside the Restricted Approach Boundary under any circumstances.

When determining the size of the accessible work area, the PIC shall ensure that adequate clearance is maintained for qualified personnel and for conductive materials and equipment. (Consult Section 2.7, "Working Space Requirements for Energized Work.")

Areas Accessible to Vehicular and Pedestrian Traffic

Appropriate warning signs and/or barricades shall be utilized where vehicles and pedestrian traffic may pass adjacent to high or low voltage electrical equipment under maintenance, operation, or construction.

Temporary Barricades

Barricades are intended to be used as a temporary hazard warning provision. Barricades may be properly marked objects, tape, or rope that prohibits passage to personnel. The recommended color of electrical hazard barricade tape and rope is RED.

Illumination

Personnel shall not enter spaces containing exposed energized parts unless adequate illumination is provided that enables the personnel to perform the work safely.

Confined or Enclosed Work Spaces

When working in a confined or enclosed space (such as switch gear, vaults, and manholes) that contains exposed energized parts, personnel shall follow the provisions as indicated in Section 5.3, "Confined Spaces."

In addition, all pertinent parts of the SNL Confined Space Entry program as outlined in MN471001, *ES&H Manual*, Section 6I, "Confined Space Entry," shall be followed.

Sign Requirements

Signs are essential to convey information regarding a potential electrical hazard. Signs are also used to convey information regarding operation and maintenance instructions.

The minimum requirements for signs are:

- The sign shall be made of a durable material consistent with the anticipated environment conditions and expected length of exposure.
- Lettering shall be a prominent size and highly visible. Also to be considered is visibility in darkened, minimal light conditions.
- It is recommended that internationally accepted symbols be used as much as is practical.
- For Sandia Workplace Hazards Awareness System (SWHAS) signs, use appropriate electrical symbols for identification. For additional information on Sandia Workplace Hazards Awareness System, consult MN471001, *ES&H Manual*,

Section 4M, "Signs (Including SWHAS) and Tags."

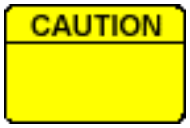
How to Obtain Signs

Signs are available through Sandia's Just-In-Time procurement process and are ordered from Fisher Safety Equipment and Supplies. These signs meet OSHA standards for size, color, and message.

Types of Signs

These signs are generally rectangular in shape.

Danger. Danger signs indicate immediate danger and that special precautions are necessary. Danger signs shall include the word DANGER in white letters on a red background and other additional wording as necessary in black letters on a white background below the DANGER heading. Examples of additional wording include HIGH VOLTAGE, HIGH VOLTAGE OVERHEAD, HIGH VOLTAGE TESTING IN PROGRESS, HIGH VOLTAGE-UNAUTHORIZED PERSONNEL KEEP OUT, THIS MOTOR STARTS BY REMOTE CONTROL, and LASER OPERATING.



Caution. Caution signs warn against potential hazards or caution against unsafe practices. Caution signs shall include the word CAUTION in yellow on a black background and other wording as necessary in black letters on a yellow background below the CAUTION heading. Examples of other wording include BURIED CABLE, EAR AND EYE PROTECTION REQUIRED, DO NOT WATCH ARC, and PULL SWITCHES BEFORE LEAVING THIS MACHINE.

Safety. Safety instruction signs shall have a background of white with black letters and may have a green panel with white letters. For example, the panel could indicate NOTICE or THINK. Examples of other wording include AUTHORIZED PERSONNEL ONLY, MAIN POWER CUT OFF, and REPORT ALL UNSAFE CONDITIONS.

Where to Post Signs

Signs should be prominently displayed near the hazard to eliminate confusion as to the intent of the sign.

Signs should be used in the following locations:

- Where inadvertent electrical contact is possible, and can reasonably be anticipated.
- On all doors, gates, fence locations for substations, doors to switch gear rooms, or similar compartments or rooms where potentially exposed energized parts are located.
- On all transmission or distribution structures where worker or public presence may be expected.
- At electrical equipment installations where physical distance requirements for persons, handling of conductive material or equipment, or vehicle operations cannot be met or are marginal.
- At electrical equipment locations where a potential backfeed is possible and such information is essential for the safe operation of the equipment and personnel safety.

*2.7 Working Space Requirements for Energized Work

*General Requirement

Working space around **energized** electrical enclosures or equipment shall comply with the dimensions shown in Table 2-2 below. Examples of such equipment include panelboards, disconnect switches, circuit breakers, and motor control centers. This access and working space shall be kept clear at all times for operation and maintenance personnel and may not be used for intermittent/incidental storage of nonpermanent equipment or furniture.

Note: There are no minimum clearance requirements for electrical equipment mounted on wheels that can be easily moved for service access (e.g., equipment test racks, PDUs, etc.), given adequate space is provided for ventilation and wire terminations.

Working Space Width

A minimum working space 30 inches wide shall be provided in front of electrical equipment of 600 V or less (nominal voltage to ground), and a working space of 36 inches wide shall be provided for electrical equipment over 600 V. This provides room to

avoid body contact with metal parts while working with the components of the equipment. The working space width may be centered in front of the equipment or can be offset as shown in Figure 2-3. The working space shall be clear to the floor with a minimum headroom of 6 ft 6 in. There shall be at least a 90-degree opening provided in the work area for equipment doors or hinged panels on the service equipment.

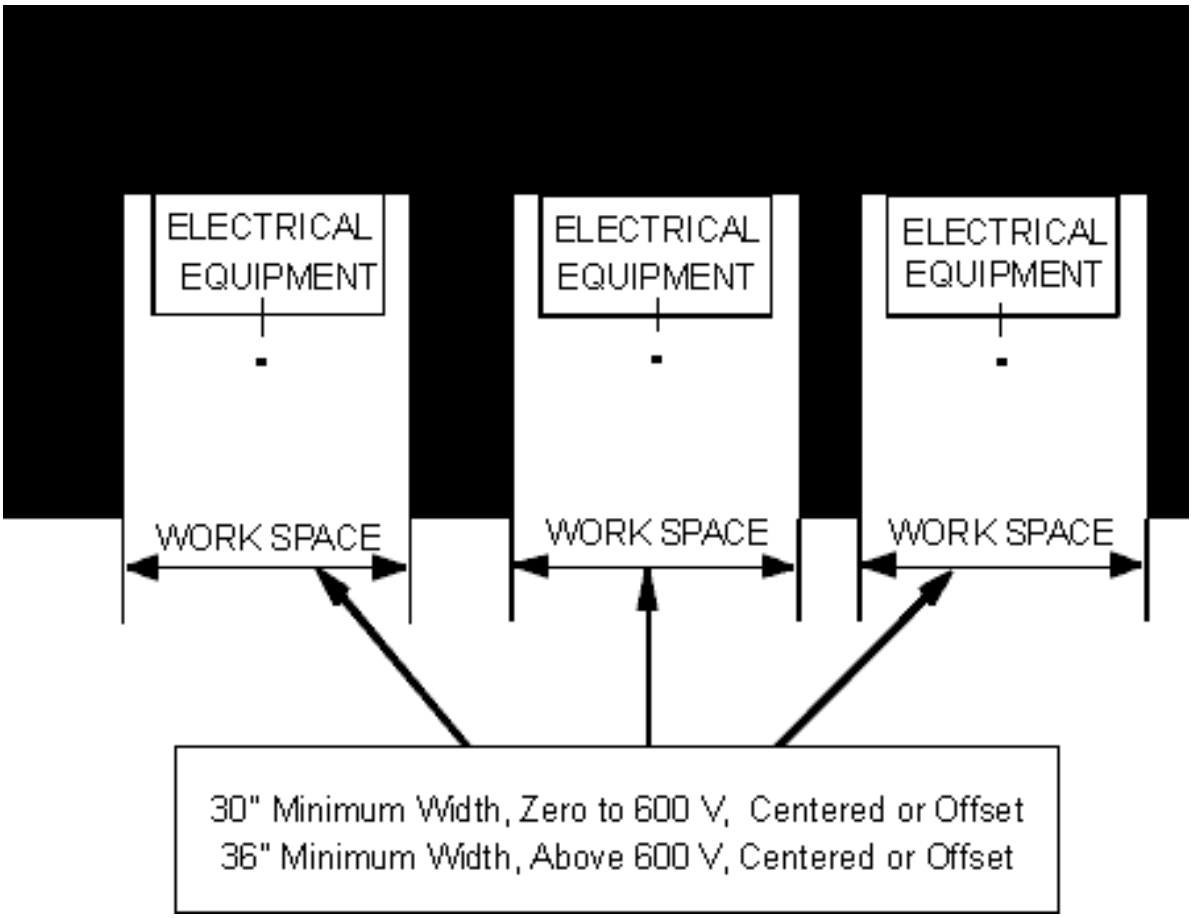


Figure 2-3. Working Space Width

Working Space Depth

A minimum working space depth shall be allocated for repair or maintenance of electrical equipment. This space should be 3 ft to 12 ft, depending upon existing conditions and voltages (see Table 2-2 for voltages greater than 600 V).

Condition 1: Insulated Wall Background

The electrical equipment is mounted or set on one wall, and the wall on the opposite side is insulated (ungrounded parts). A qualified worker making contact with the insulated wall would be isolated from the ground. The minimum required work space is 36 inches for voltages up to 600 V (see Figure 2-4).

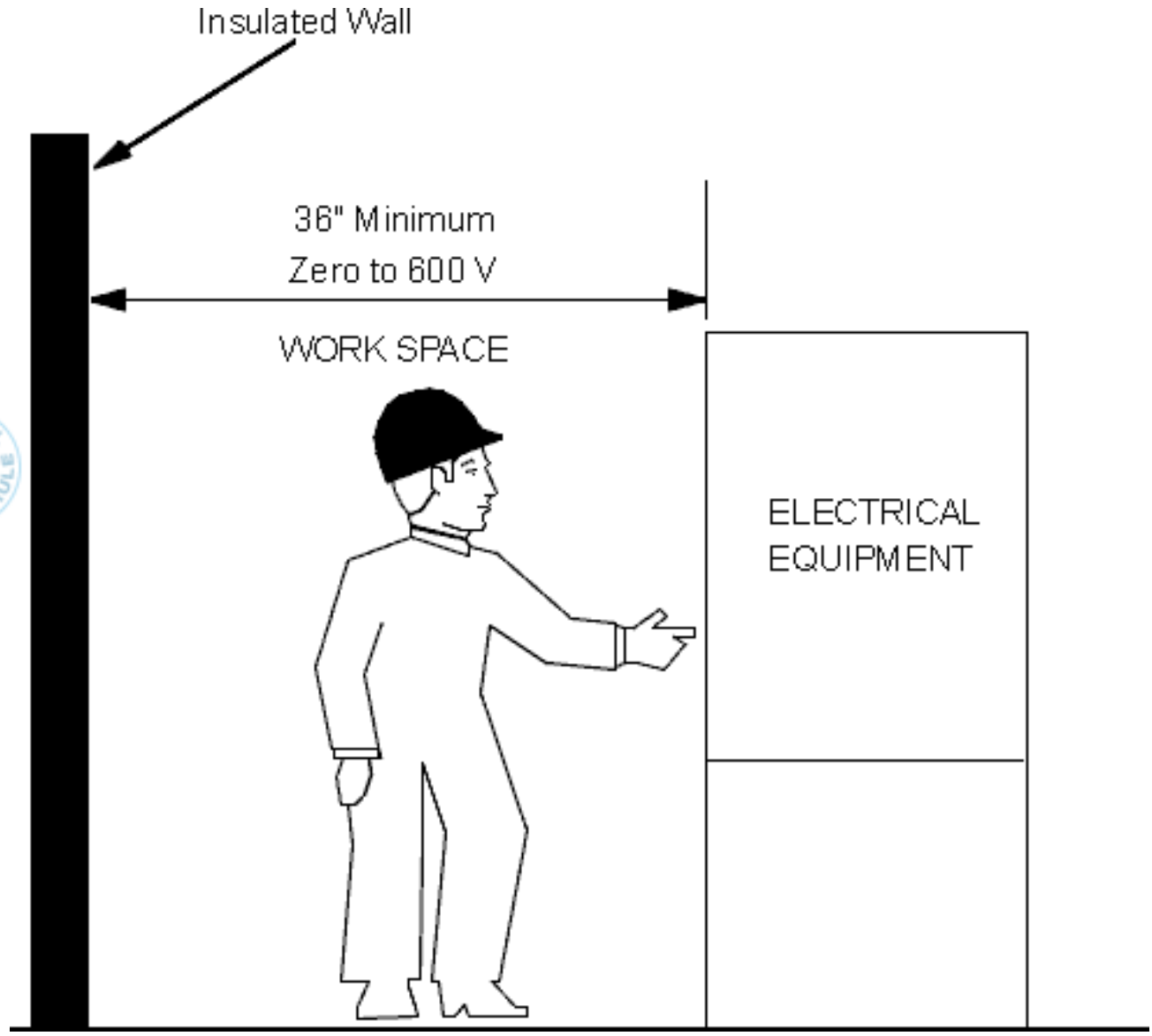


Figure 2-4 . Condition 1: Insulated Wall Background

Condition 2: Grounded Wall Background

The electrical equipment is mounted or set on one wall, and the wall on the opposite side is grounded. If the qualified worker should accidentally contact the conductive wall while touching energized components, a circuit would be completed to ground and a fatal shock might occur. For voltages up to 150 V, the minimum required work space is 36 inches. For voltages greater than 150 V to 600 V, the minimum required work space is 42 inches (see Figure 2-5).

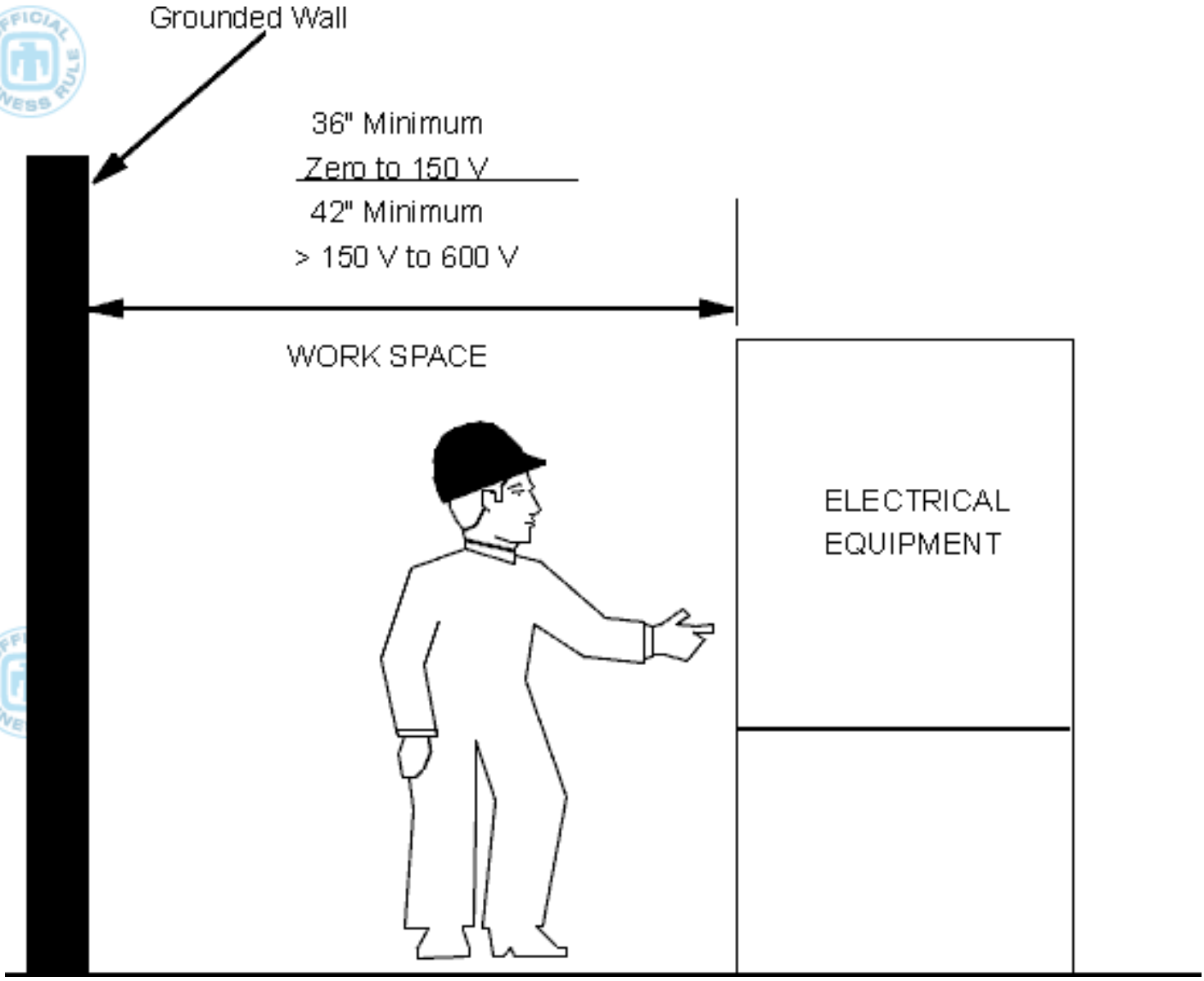


Figure 2-5 . Condition 2: Grounded Wall Background

Condition 3: Electrical Equipment Background

The electrical equipment is mounted or set on one wall, and additional electrical equipment is mounted or set on the opposite side of the room. There are energized components on both sides of the room. The qualified worker might accidentally make contact with live components and be in series with a hot phase and the grounded metal of the electrical equipment, which could produce a fatal shock. For voltages greater than 150 V to 600 V, the minimum required working space is 48 inches (see Figure 2-6).

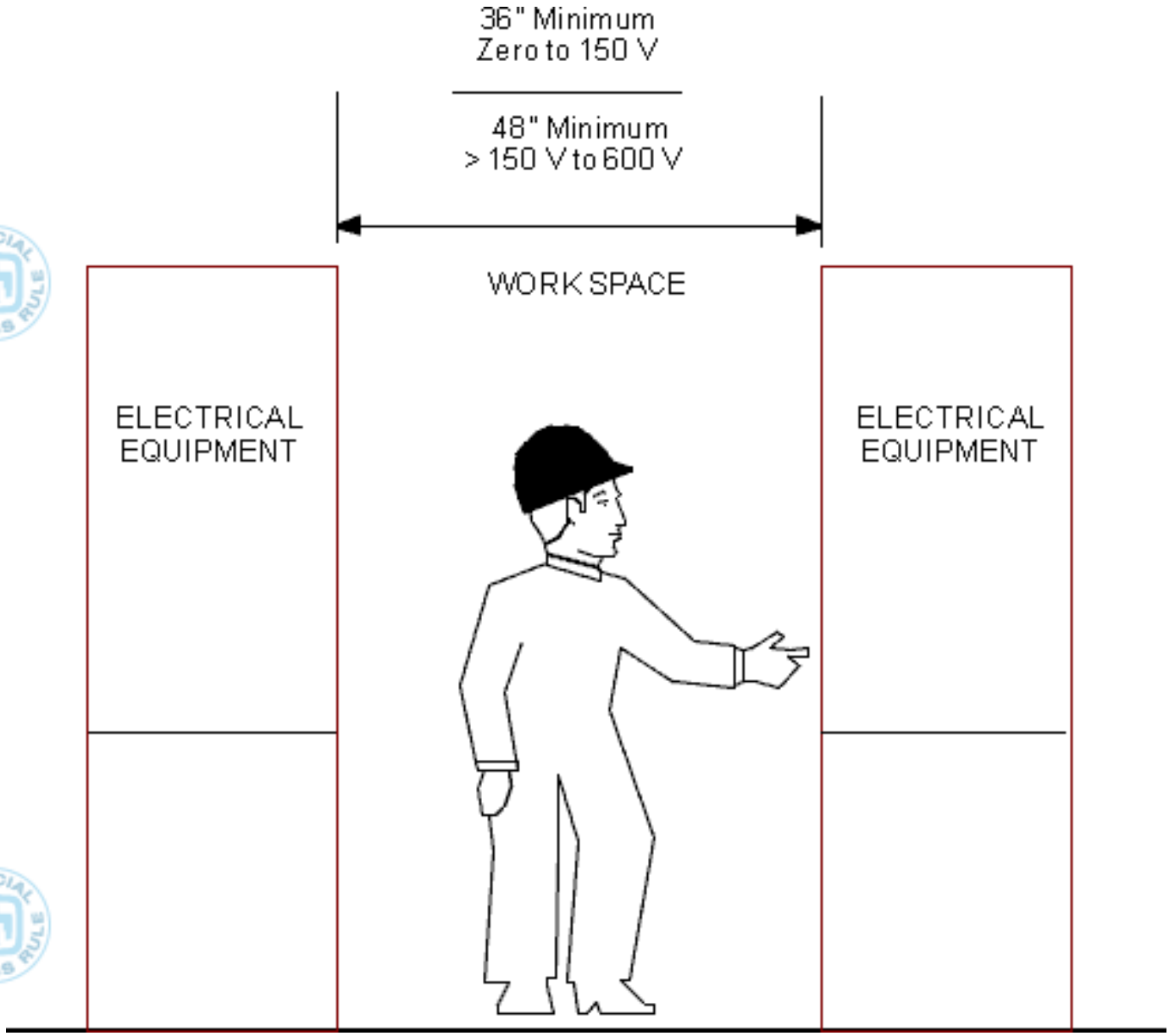


Figure 2-6. Condition 3: Electrical Equipment Background

Voltages Greater Than 600 V

For voltages greater than 600 V, the working space clearances for repair or maintenance of electrical equipment are based on voltage and condition, as shown in Table 2-2.

Table 2-2. Clearances for Voltages Greater Than 600 Volts

Nominal Voltage to Ground	Condition 1: Insulated Wall Background (feet)	Condition 2: Grounded Wall Background (feet)	Condition 3: Electrical Equipment Background (feet)

>600 - 2500	3	4	5
>2500 - 9000	4	5	6
>9000 - 25000	5	6	9
>25000 - 75 kV	6	8	10
Above - 75 kV	8	10	12

2.8 Safety Grounds

General Requirement

Before personnel perform any work on energized lines or equipment, the lines or equipment shall be tested for voltage and properly discharged and grounded as appropriate.

Before personnel install grounds, the grounding equipment shall be visually inspected to confirm equipment integrity.

Equipment Identification

Safety ground sets shall be capable of conducting the maximum ground fault current that could flow at the point of grounding for the time necessary to clear the fault. This equipment shall have an ampacity equal to or greater than #2 American Wire Gauge (AWG) copper cable.

An approved live-line tool or grounding hook shall be used while making or removing the grounding connection to the circuit or equipment. Alternate procedures require a technical work document (TWD) .

Note: These TWDs need to be written and approved in accordance with the *ES&H Manual,* Chapter 21, "Technical Work Documents (TWDs)."

Location of Grounds

If the installation of protective grounding equipment at the work location is not feasible, grounds shall be installed on each side of the work as close to the work as possible. If the line or equipment can be isolated at the work location, both sides of the isolated device shall be grounded.

Sequence of Operation

When personnel are grounding lines or equipment, the grounding device shall first be attached to a ground connection and then to the circuit or equipment. In removing grounds, first remove the connection to the circuit or equipment, and then remove the ground connection. Under no circumstances are grounding cables to be connected in series in lieu of using the proper length of cable.

Power Capacitors

Power capacitors shall be safely discharged, shorted, and grounded before work is performed on them or they are placed in storage. For detailed information, consult Section 4.6, "Capacitors and Capacitor Banks."

*2.9 Servicing Electrical Equipment and Systems

Troubleshooting or Servicing

All work shall be performed with equipment de-energized, locked and tagged out (for exceptions consult "Working on Energized Equipment" in Section 2.4, "Safe Work Practices"). For plug and cord connected equipment, consult the current LOTO instructions for specific guidance on LOTO procedures.

When equipment must be energized to facilitate the troubleshooting or servicing process, the qualified worker shall insulate or isolate the equipment and use appropriate PPE as directed in the applicable technical work document (TWD) . (Consult also Section 2.10, "Personal Protective Equipment.")

All test equipment used in the troubleshooting or servicing activity shall be rated for the service under test and shall be known to be in working condition.

Overcurrent devices that have been overloaded causing blown fuses or tripped circuit breakers shall not be reset or replaced until the cause of the overload trip has been investigated, and detected problems have been corrected. The repetitive manual resetting of circuit breakers or re-energizing of circuits through replacement of fuses is not permitted.

Note: At SNL, only qualified personnel from the Facilities Management & Operations Center (NM) (10800) or the Center for ES&H and Facilities (CA) (8600) are authorized to

reset facility circuit breakers or replace facility fuses.

Only those devices designed with load interrupting capabilities shall be used as disconnecting means for energized circuits.

Safety Interlocks

If interlocks or other protective systems must be bypassed or otherwise rendered inoperative, approval by the PIC shall be obtained, and approved procedures followed such as SOPs or SWPs. Interlock devices or systems shall be returned to normal operation and verified by the PIC upon completion of the work.

*Modifications or Installations

Modifications or installations of existing equipment and systems should be performed de-energized and locked/tagged out.

When critical systems are involved that cannot be safely de-energized, the qualified worker shall be isolated or insulated from energized parts in accordance with Section 2.4, "Working on Energized Equipment."

Users of any equipment that was initially NRTL listed or labeled and has subsequently been modified, shall have the equipment recertified/tested following the modification, and retain related records.

Modifications or installations and documentation (using the form provided in Attachment A-2) are to be performed by qualified personnel.

Re-Energizing Equipment

The following requirements shall be met before circuits or equipment are re-energized, even temporarily.

Tests and Visual Inspections

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

Warning Personnel

Personnel exposed to the hazards associated with re-energizing the circuit or equipment shall be warned by the PIC to stay clear of circuits and equipment.

2.10 Electrical Personal Protective Equipment

Requirements

A large portion of electrical work performed at Sandia is associated with circuits energized between 50 and 208 volts and having less than 10 kA of available fault current. The manager authorizing Members of the Workforce to perform appropriate energized work involving equipment energized to within this voltage and available fault current range shall:

- Ensure that the following minimum electrical PPE are used:
    - Safety glasses.
    - Untreated, natural-fiber shirts (i.e., cotton).
        - 50-120 volts, short-sleeve.
        - 120-208 volts, long-sleeve.
    - Long natural-fiber pants (i.e., regular-weight, untreated, denim cotton blue jeans).
    - Voltage-Rated Rubber Insulating Gloves (Class O, and/or OO) rated for the voltage to which they will be exposed with leather protectors, as required by the TWD.
    - Insulated tools rated for the voltage to which they will be exposed.
    - Measurement instruments rated for circuit location and voltage to which they will be exposed.
- Ensure that voltage-rated gloves are inspected prior to each use and recertified biannually once they have been placed into service.

- Ensure that voltage-rated gloves are air tested for leaks prior to each use.
- Ensure gloves not placed into service are not used unless they have been tested within the previous 12 months.

Note: Available short-circuit fault current in Sandia laboratory space is typically less than 10 kA. Refer to the label on appropriate circuit breaker panel doors, Facilities Electrical and Fire Protection Engineering (10861), or ES&H Customer Support Team Safety Engineer to confirm available short circuit fault current.

- Ensure that additional electrical PPE is selected for cases where energized electrical work will occur on circuits energized at voltages greater than 208 volts or those circuits with available fault current greater than 10kA.
    - Additional electrical PPE for such energized electrical work may include:
        - Flame retardant clothing.
        - Head protection (hard hat).
        - Hearing protection.
        - Face shield.
        - Higher rated insulated gloves.
        - Higher rated insulated tools.
- Ensure that additional flame-retardant clothing and gloves are selected based on calculated incident arc flash energy or work task category, and voltage.

Note: Contact your ES&H Customer Support Team Safety Engineer for assistance with additional electrical PPE selection.

Note: A facility electrician may request an electrical engineer to determine the required/ appropriate electrical PPE selection for a particular electrical work, in which case the electrical PPE selection may differ from the electrical PPE specified above. Facility electricians include electricians working in either the Facilities Management & Operations Center (NM) (10800) or the Site Operations Center (CA) (8500).

Rubber Insulating Gloves

Table 2-3 shows the relationship between class of the glove and the maximum voltage protection of the glove. Select the proper class of electrical insulating gloves based on the highest expected voltage.

Table 2-3 . Electrical Glove Classes

Class	Maximum Voltage	Glove Label Color
00	500	Blue
0	1,000	Red
1	7,500	White
2	17,500	Yellow
3	26,500	Green
4	36,000	Orange

Electrical insulating gloves shall be maintained in a safe and reliable condition and shall be periodically inspected and tested as outlined in this section. Gloves that are damaged or fail to pass the appropriate testing requirements shall be replaced.

Electrical insulating gloves shall be maintained in accordance with ASTM F 496-06 and as follows:

- Defective or suspected defective gloves shall not be used.
- Gloves shall be visually inspected by the wearer at least daily (prior to use) or immediately following any incident that can reasonably be suspected of having caused damage.

Other Rubber Insulating Equipment

Selection and Testing

Select rubber insulating equipment meeting the national consensus standards as indicated on the manufacturer's label.

Testing shall be performed by a testing Laboratory that can certify their results to American Society for Testing & Materials (ASTM) standards. The testing method used

and the results of such tests documented by the testing laboratory shall be maintained by the department manager in the department or user files.

See Table 2-4 for selection and testing standards and required testing frequencies.

Table 2-4 . Rubber Insulating Equipment Selection and Testing

Type of Equipment	Standard for Specification	Standard for In-Service Care	Testing Frequency
Gloves	ASTM D120	ASTM F496	Before initial use; every 6 months thereafter.
Matting	ASTM D178	None. Refer to ASTM D178	Upon indications that insulating value is suspect
Blankets	ASTM D1048	ASTM F479	Before initial use; every 12 months thereafter
Covers	ASTM D1049	ASTM F478	Before initial use; every 12 months thereafter
Line Hose	ASTM D1050	ASTM F478	Before initial use; every 12 months thereafter
Sleeves	ASTM D1051	ASTM F496	Before initial use; every 12 months thereafter

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

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

Inspecting

Personnel shall visually inspect rubber-insulated protective (nonconductive) equipment at the beginning of each work day prior to use and after any work performed that could damage the equipment.

Insulating equipment with any of the following defects shall not be used:

- A hole, tear, puncture or cut
- Ozone cutting or ozone checking
- An embedded foreign object
- Any texture changes such as swelling, softening, hardening, or becoming sticky or inelastic
- Any other defect that might damage the insulating properties

Insulating equipment found to have defects that might affect its insulating properties shall not be used.

Use rubber insulating gloves as an added level of protection when using live-line tools.

Working in a bucket truck approved for high voltage work does not require the use of gloves while using live-line tools.

Live-Line Tools

Selection, inspection, testing and cleaning of live-line tools is covered in Chapter 3, "Facility Specific Requirements."

Other Personal Protective Equipment

Safety shoes, hard hats, safety glasses and other required PPE worn by electrical workers shall meet the requirements listed in *ES&H Manual*, Section 4L, "Personal Protective Equipment (PPE)."

Additional protection, such as face shields or goggles may be required during specific operations as identified in the workplace technical work documents (TWDs).

Note: These TWDs need to be written and approved in accordance with Chapter 21, "Technical Work Documents (TWDs)."

Storage

Electrical insulating and protective clothing and equipment shall be cleaned after use and

stored flat, undistorted, right side out, and unfolded, as appropriate in protective containers. Blankets may be stored rolled if the inner diameter of the roll is at least 2 inches. Such storage shall not be directly above or close to hot pipes, heat radiation, or any sources of artificial heat or exposed to direct sunlight or other sources of ozone such as in switch gear rooms. Storage temperature shall not exceed 90°F.

2.11 Tools, Test Instruments, and Equipment

Test Instruments and Equipment

Qualified Workers

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

PPE

All personal protective equipment required by workplace technical work documents (TWDs) shall be worn while operating test equipment.

Visual Inspections

Test instruments and equipment and all associated test leads, cables, power cords, probes, and connectors shall be visually inspected for external defects or damage before use on any shift. If there are defects or evidence of damage that might expose personnel to injury, the defective or damaged item shall not be used until required repairs have been made and tests performed.

Rating Instruments and Equipment

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

Test equipment shall be operated and maintained according to the manufacturer's specifications. All calibrated test equipment shall have a label indicating that it is within the listed calibration interval.

Calibration of Electrical Instruments

Calibration of electrical test and measuring equipment shall be in accordance with the Primary Standards Laboratory Measurement Standards Program.

Hand Tools

Maintain all tools in working condition.

Use only tools that are rated for the job.

Tools used for working on batteries shall be insulated.

Use insulated tools and equipment with appropriate voltage ratings when working in proximity to energized or potentially energized conductors and exposed electrical parts.

Electrical Power Tools

The following requirements shall apply to electric powered hand tools:

- Electrical portable power tools (except for battery powered or double-insulated types) shall be grounded by a grounding conductor which is contained within the same cable or cord as the circuit conductors.

  Note: Double Insulation is a system comprised of two insulation systems (basic and supplementary) that are physically separated and are not subject to temperature, contaminants, and other deteriorating factors at the same time. Power supply cords for double-insulated tools shall be jacketed and shall not include a grounding conductor. “Double Insulated “or “double insulation” shall be permanently marked on the tool. In addition, the double insulated symbol (a square within a square) may be used.

- All grounding conductors shall be tested for continuity initially and at least once each year by the PIC designee. The test will be documented and maintained in a department file.

- When operating a portable electrical tool outdoors or in wet/damp locations, it shall be connected to a Ground Fault Current Interruptor-protected outlet/extension cord.

For additional information on portable power tools and testing requirements, consult

MN471001, *ES&H Manual* , Section 4N, "Industrial Machine and Portable Power Tool Safety."

Portable Ladders

Portable ladders used in proximity to exposed energized parts shall have nonconductive side rails. For detailed information, consult MN471001, *ES&H Manual*, Section 4F, "Ladders, Scaffolds, and Elevating Work Platforms."

*2.12 Additional Requirements

Power Strips, Extension Cords, and Uninterruptible Power Supplies (UPS)

Requirements

Note: Extension cords are for temporary use only and may not serve as a substitute for permanent wiring. Extension cords may be used to power experimental equipment that is temporarily located at an experiment site, only for the duration of the experiment.

Note: Power strips that provide required surge protection of equipment are not considered temporary wiring.

When using extension cords and power strips, Members of the Workforce shall:

- Use extension cords (flexible cord sets) and power strips for the loads, environments, and types of applications specified by the manufacturer.
- Use only unmodified extension cords and power strips that are labeled by a nationally recognized testing laboratory (NRTL).
- Protect extension cords and power strips from damage.
- Route extension cords or provide trip covers to protect personnel from trip hazards associated with loose cords.
- Extension cord sets shall be of three-wire type and shall be designed for hard or extra-hard usage types (types SJ, SJO, SJT, and SJTO).
- Visually inspect extension cords and power strips prior to use for:

- Loose parts.
- Deformed or missing pins.
- Damage to the outer jacket or insulation of cords.

- Use no more than a single extension cord to supply a piece of electrical equipment, unless no other outlet is available. If this is the case, use extension cords in series only until the end of a shift or the end of a workday.
- Directly connect power strips to a permanently installed branch circuit receptacle.
- Use power strips to provide power and surge protection for sensitive electronic equipment, such as computer equipment.
- Remove damaged extension cords from service and:
  - Contact a qualified electrician for repairs to damaged extension cords wire size 10 AWG and larger.
  - Discard damaged extension cords (do not repair) if wire size is 12 AWG or smaller.

- **Not:**
  - Attach extension cords to building surfaces.
  - Use devices that are damaged or suspected to be damaged (i.e., receptacles that do not securely hold a plug are considered damaged).
  - Attach power strips to temporary structures (such as desks, tables, or computer stands) or to permanent structures (such as walls) unless the power strips include mounting tabs.
  - Run extension cords or power strips under carpeting or inside walls or floors.
  - Run extension cords or power strips through doors or windows, or through holes in walls, floors, or ceilings (including suspended ceilings), except when no other outlet is available, and only until the end of a shift or the end of a workday. When such exceptions are made, employees and contractors shall provide some form of physical protection for the extension cords.

- Connect power strips in a series.
- Connect power strips to extension cords.
- Use power strips during construction or construction-like activities.
- Route the flexible power cord on a power strip through walls, windows, ceilings, floors, or similar openings.
- Use extension cord or power strip to lift or support attached equipment.
- Use an extension cord or power strip in excess of its rated current.
- Use power strips for high-power loads, such as space heaters, refrigerators and microwave ovens, coffee pots, or tools (but see Note below).

Note: The use of power strips for coffee pots and personal space heaters is allowed per ES&H Manual, Chapter 5, "Fire Protection" if:

- The power strip is equipped with an occupancy sensor and
- The total energy drawn by the connected loads does not exceed the rating of the power strip.

Guidance

Prior to moving an uninterruptible power supply (UPS), qualified Members of the Workforce should disconnect the batteries by doing any of the following:

- Disengaging the key switch.
- Removing the fuse.
- Physically disconnecting the batteries so that the power system cannot be accidentally turned on.

Guarding of Electrical Conductors

Requirements

Junction boxes (j-boxes) shall be installed on substantial surfaces with completely affixed cover plates and any unused openings covered.

*Ground Fault Circuit Interrupters (GFCI)

*Requirements

Managers shall ensure that:

- Outlets outside external doors are weatherproof and GFCI protected.
- Rooftop maintenance outlets are weatherproof and GFCI protected.
- GFCI protection is installed on all 120-volt, 15 and 20 amp receptacles located within 6 ft of sinks, shower heads, eyewash stations and outside doors. No outlet is allowed within 3 feet of the vertical axis of shower heads or eye wash stations.
- Ground Fault Circuit Interrupter (GFCI) protection is installed on all 120-volt, 15 and 20 amp receptacles located within 6 ft of sinks, shower heads, eyewash stations and outside doors. No outlet is allowed within 3 feet of the vertical axis of shower heads or eye wash stations.
- GFCI protection is provided in explosives areas where required by the Explosives Safety Manual (MN471011).
- Electrical equipment that is neither GFCI protected nor protected by suitable barriers is not brought within 6 ft from the vertical axis of the waterfall of a shower head or eyewash station.
- GFCI outlets are installed and operated in accordance with this section and the National Electrical Code, Article 210.8, except when specific testing/operations preclude its use. Contact ES&H coordinator or Safety Engineering for additional guidance.
- For new construction and receptacle system maintenance/repairs, comply with the latest changes to the SNL Facilities Design Standards Manual, Section 9.5.

Members of the Workforce who operate electrical equipment that utilizes GFCI protection shall:

- Trip-test the interrupter by using the test buttons on the unit at least once per month. A record of these tests may be kept in a notebook or on a test record label, which are normally provided by manufacturers. The AHJ may grant exceptions to the testing requirement for remote, unpopulated areas. Contact your ES&H coordinator to initiate this request.

Note: The use of the (GFCI) internal tester and use of a load or test meter to verify power interruption is the preferred method of testing a GFCI device. External testers may give misleading or erroneous results and, in some case, may be hazardous.

Batteries

Requirements

Members of the Workforce who use battery-operated devices shall observe all manufacturers' warning labels. If a warning label is not present, Members of the Workforce shall:

- Use batteries of the same chemical composition and style.
- Follow the manufacturer's instructions to ensure that battery chargers and batteries are compatible.
- Replace all the batteries within a device. Do not replace only one or two batteries if the device uses several batteries.
- Dispose of all batteries according to requirements outlined in Section 19A, "Hazardous Waste Management."
- Not expose lithium batteries to temperatures above 80°C (~175°F) or discharge them at a high rate.
- Not mix battery types in one device (e.g., nickel-cadmium, alkaline, lithium, mercury, carbon-zinc).
- Not charge batteries that are not intended to be recharged by the manufacturer.

Note: Lithium batteries are a potential safety hazard because they may generate large quantities of toxic gas when used improperly.

Facility Electrical Distribution Systems

Requirements

Members of the Workforce shall:

- **Not** install, repair, make equipment connections to, or maintain facility electrical distribution systems or system components, unless they are authorized to do so.
- Consult the Facility Electrical Distribution Systems Contact to acquire any of the following services related to facility electrical distribution systems:
    - Wiring of alternating current (AC) plugs, connectors, cords, and power strips.
    - Installation of temporary wiring needed to complete a specific task, such as experimental tests.
    - Manual operation of circuit breakers and disconnect switches, except in an emergency.

Note: In an emergency situation, any Member of the Workforce may operate a circuit breaker or disconnect switch to disconnect a power source, but only authorized personnel may turn the circuit breaker back on (reset).

Lightning

Guidance

Members of the Workforce should take the following precautions to minimize the risk of a lightning strike when shelter is available:

- Seek shelter inside a building or in a vehicle with rubber tires.
- Close windows and doors.
- Stay away from:
    - Water and gas pipes.
    - Electrical appliances.

- Telephones.
- Security fences.
- Turnstiles.
- Towers.
- Antennas.

Members of the Workforce should take the following precautions to minimize the risk of a lightning strike when shelter is **not** available:

- Avoid machinery, metal fences, railroad tracks, and bodies of water.
- Stay away from tall objects such as trees and poles.
- Avoid any objects that might conduct electricity, including umbrellas that contain metal parts.
- Remove metal or conductive items of clothing, such as helmets, belts, jewelry, watches, or metal-cleated shoes.
- If vision will not be seriously impaired, remove metal-frame glasses.
- Seek low ground and maintain a low profile.
- Avoid close proximity with other people. People in groups should disperse.
- If your hair stands on end, squat on the ground immediately.

Note: Imminent lightning strikes are preceded by high static electricity.

2.13 Related Hazards and Activities

Other hazards that may present electrical safety concerns include the following:

Hazards/Activities	Reference

Portable power tools	Section 4N, "Industrial Machine and Portable Power Tool Safety."
Receptacles near emergency showers and eyewashes	Section 6K, "Hazardous Waste Operations And Emergency Response (HAZWOPER)."
Coring and saw cutting activities	Section 4H, "Excavations, Trenches, and Floor or Wall Penetrations."
Explosives	Chapter 9, "Explosives Safety."
Emergency Information	Chapter 16, "Health, Benefits and Employee Services."
Technical Work Documents	Chapter 21, "Technical Work Documents (TWDs)."
Signage Information	Section 4M, "Signs (Including SWHAS) and Tags."
Training Information	Chapter 11, "ES&H Training."
Control of hazardous energy (Lockout Tag out)	Section 4C, "LOCKOUT/TAGOUT/(LOTO)."
GEM carts in wet conditions	Section 4S, "Use of Powered Carts."

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Sponsor: Dori Ellis, 4000, Acting

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Electrical Safety Manual

CHAPTER 3 – FACILITY SPECIFIC REQUIREMENTS

Subject Matter Expert: Mark McNellis; CA Counterpart: Herman Armijo
MN471004, Issue K
Revision Date: March 14, 2007; Replaces Document Dated: October 9, 2006
Review Date: October 5, 2006

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*Indicates a substantive change

Scope

This chapter provides facility specific requirements and safe work practices, planning and proper designing. Testing procedures and personnel eligible to perform such tests are covered. These procedures should be used in conjunction with applicable general requirements covered in Chapter 2, "General Requirements."

These requirements are intended to apply primarily to personnel working in the Facilities Management & Operations Center (NM) (10800), and the Site Operations Center (CA) (8500).

Management Responsibilities

The requirements set forth in DOE Orders as they apply to existing facilities and operations shall be evaluated by the Facilities Management & Operations Center Manager in 10800 responsible for the applicable facility or operation. The evaluation shall determine if present systems and operations comply with the stipulated provisions and present a significant safety risk. If the evaluation determines that a safety risk exists, corrective actions shall be initiated to bring the system or operations into compliance with current standards. However, in case of a major renovation, the existing facility shall be brought into compliance with current standards.

Safe Work Practices

General safe work practices are described in Section 2.4, "Safe Work Practices." This chapter contains additional practices that are facilities specific and not applicable to a nonfacilities electrical worker and reiterates specific practices that are of special importance when working with facilities electrical systems.

Servicing Electrical Equipment and Systems

Areas around electrical equipment shall be kept clear of materials, equipment, or any other article that restricts access to electrical equipment. In many cases the specific distance requirement will be posted on the affected equipment. For those cases where the information is not posted, refer to Figures 2-2, 2-3, 2-4, and 2-5 in Section 2.7, Working Space Requirements for Energized Work.

Covers or guards should not be removed while the parts they guard are energized. If the guarded part is not de-energized, the guarded part, the guard, or cover shall only be removed by a qualified person.

When working in proximity to unguarded exposed energized parts, including overhead lines, approach distances for unqualified persons shall be based on Table 3-1.

Table 3-1. Approach Distances for Unqualified Persons (Alternating Current)*

Voltage Range Phase to Phase	Minimum Approach Distance	
	ft/in	meters
50 kV and below	10 ft 0 in	3.05
> 50 to 60 kV	10 ft 4 in	3.15
> 60 to 70 kV	10 ft 8 in	3.25
> 70 to 80 kV	11 ft 0 in	3.35
> 80 to 90 kV	11 ft 4 in	3.45
> 90 to 100 kV	11 ft 8 in	3.55
> 100 to 110 kV	12 ft 0 in	3.65
> 110 to 120 kV	12 ft 4 in	3.75

> 120 to 130 kV	12 ft 8 in	3.85
> 130 to 140 kV	13 ft 0 in	3.95
*OSHA 29 CFR 1910.333(c)(3)(i)		

Approach distances for qualified personnel without approved PPE shall be based on Table 3-2.

Table 3-2. Approach Distances for Qualified Persons (Alternating Current, Without Approved PPE)*

Voltage Range Phase to Phase	Minimum Approach Distance**	
	ft/in	meters
300 V and below	Avoid Contact	
> 300 V to 750 V	1 ft 0 in	.31
> 750 V to 2 kV	1 ft 6 in	.46
> 2 kV to 15 kV	2 ft 0 in	.61
> 15 kV to 37 kV	3 ft 0 in	.91
> 37 kV to 87.5 kV	3 ft 6 in	1.07
> 87.5 kV to 121 kV	4 ft 0 in	1.22
> 121 kV to 140 kV	4 ft 6 in	1.37

*OSHA OSHA 29 CFR 1910.333, Table S-5.

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

All exposed energized parts shall be located to provide personnel clearance in accordance with Table 3-3.

Table 3-3. Clearance From Live Parts*

Phase to Phase Nominal voltage	Vertical Clearance of Unguarded Parts		Horizontal Clearance of Unguarded Parts		Clearance Guard to Live Part	
kV	ft/in	meters	ft/in	meters	ft/in	meters
0.6 to 2.4	8 ft 9 in	2.67	3 ft 4 in	1.02	0 ft 3 in	.08
> 2.4 to 7.2	8 ft 10 in	2.69	3 ft 4 in	1.02	0 ft 4 in	.10
> 7.2 to 13.8	9 ft 0 in	2.74	3 ft 6 in	1.07	0 ft 6 in	.15
> 13.8 to 23	9 ft 3 in	2.82	3 ft 9 in	1.14	0 ft 9 in	.23
> 23 to 34.5	9 ft 6 in	2.90	4 ft 0 in	1.22	1 ft 0 in	.30
> 34.5 to 46	9 ft 10 in	3.00	4 ft 4 in	1.32	1 ft 4 in	.41
> 46 to 69	10 ft 5 in	3.18	4 ft 11 in	1.50	1 ft 11 in	.58
> 69 to 115	11 ft 7 in	3.53	6 ft 1 in	1.85	3 ft 1 in	.94
> 115 to 138	12 ft 2 in	3.71	6 ft 8 in	2.03	3 ft 8 in	1.12

Note: Obtain distances for intermediate voltages by interpolation.

*NESC 1990 Table 124-1.

High Voltage Systems Under Load

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

Switching Procedures

Switching procedures are organized approaches that assure personnel and equipment protection while maintaining power system continuity.

When Required

A switching procedure is required for all high voltage system operations. A switching procedure is also required for lower voltages if there is a possibility of backfeed to the high voltage system.

SNL/NM Switching Procedures

The PIC shall prepare a detailed switching procedure. This written switching procedure

shall be reviewed for accuracy by a second qualified person and agreed upon by those performing the switching or participating in the switching process. The written procedure shall contain shock and flash Electrical PPE requirements per Chapter 2 of this manual and NFPA 70E.

Fixed or standing written switching procedures for routine switching operations are acceptable as long as they do not violate the requirements of these guidelines and are revised as needed and appropriate approvals are given prior to switching.

Each step of the switching procedure shall be checked off as it is completed. Request assistance immediately from the person in charge if any portion of the switching procedure is not clear or may be incorrect.

Persons performing switching operations shall be trained and qualified in the electrical systems on which they are working, the hazards associated with the work operations, and protective measures required to safely perform their work assignments.

Persons performing switching operations shall wear approved flame retardant clothing as well as approved head protection; eye, face, and foot protection; and approved rubber insulating gloves with protectors in accordance with Chapter 2 of this manual.

LOTO tags, used by personnel as personal protective measures, are described in MN471001, *ES&H Manual*, Section C, "Lockout/Tagout (LOTO)," and GN470037, *Administrative Control Procedure*.

SNL/CA Switching Procedures and Operations Clearance

In addition to the requirements above, an electrical operations clearance is the written or verbal permission given by the controlling person who is responsible for the operation of the power system. The person requesting and receiving the clearance to begin work is the clearance holder.

A clearance is required for all work done on high voltage power supply systems from other locations such as Lawrence Livermore National Laboratory (LLNL), or public utilities where placing locks and tags by individuals performing the work at SNL/CA is not feasible. In addition, the clearance should be used with SNL/CA switching procedures when a number of different crews are working on the high voltage power system.

Infrared Testing

When performing infrared testing on open systems located in or on structures or panels, personnel will use appropriate PPE.

Infrared testing on metal-clad switch gear may require the enclosure to be open, exposing energized parts. Persons working in proximity to exposed energized parts shall follow all appropriate safety regulations prescribed in Chapter 2 of this manual.

Storage Batteries and Battery Banks

Personnel servicing or inspecting rechargeable type storage batteries shall follow specific safety requirements outlined in Section 4.10, "Batteries and Battery Banks."

Insulated hand tools should be used when working on or near battery terminals.

Conductive battery storage racks shall be grounded.

High Voltage Substation Equipment

Unattended substation enclosures shall be kept locked at all times.

To the extent practical, substation enclosures shall be free from combustible materials, dust and fumes, and shall not be used for storage except for minor parts essential to the maintenance of installed equipment.

Troubleshooting

All work should be performed on equipment or systems in a de-energized state.

All energy sources shall be brought to a safe state; for example, capacitors shall be discharged and high capacitance elements shall be short-circuited and grounded. All circuits and equipment shall be considered energized until opened, tagged, and/or locked according to an approved procedure and should be proven de-energized by testing with an approved testing device known to be in proper working order.

If de-energization is not feasible, other protective measures such as the use of appropriate live-line tools and isolating and insulating techniques shall be utilized.

Approved Technical Work Documents per Chapter 2 of this manual are required prior to commencing energized work.

Personnel shall not work on energized circuits unless they are qualified to do so, or, for training purposes, unless they work under the direct supervision of a qualified person.

Auxiliary Systems

Consideration should be given to relocating or not placing auxiliary equipment such as lighting fixtures, alarm systems, public address systems, communication and computer cable on support structures for high voltage electrical transmission and distribution systems.

Safe methods for servicing such collocated equipment shall be implemented such as de-energizing the high voltage part and/or wearing of appropriate PPE for working in proximity to energized parts.

Modifications

Modifications of high voltage systems will always be performed with the equipment de-energized and secure (i.e., locked and tagged out), unless specific approved procedures are used.

Cleaning Insulators and Bushings

The preferred energy state when cleaning insulators, bushings, and similar equipment is de-energized. However, some operations may dictate cleaning this type of equipment during routine maintenance procedures while the equipment remains energized. In such cases, the following minimum safety precautions shall be followed:

- Maintain approach distances as listed in Table 3-2.
- PE required while working in proximity to exposed energized high voltage electrical sources shall be worn.
- All personnel assigned to the job of performing maintenance on insulators, bushings, or similar energized equipment shall be trained and qualified in this type of operation.

- All manufacturers' safety requirements for the equipment used in proximity to energized or potentially energized noninsulated electrical sources shall be followed. If this information is not available, the manufacturer of such equipment shall be contacted to obtain safe work practices for working in proximity to energized sources.

- If the cleaning equipment falls into the mobile equipment category, grounding requirements shall be followed or the equipment treated as energized.

- Comply with the requirements of Chapter 2 of this manual for working on energized equipment. Shock and flash hazard analyses shall be performed.

Tree Trimming

When performing tree-trimming operations in proximity to energized, or potentially energized, noninsulated parts, the following guidelines shall be followed:

- Unqualified workers shall follow the ten foot rule for maintaining a safe distance from energized parts.

- Qualified workers should perform tree-trimming operations following the established safety rules for working in proximity to energized parts (consult Section 2.4, "Safe Work Practices").

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

Underground Systems

Examples of underground electrical systems include manholes, vaults, direct burial cable systems and buried raceways.

Only qualified personnel with training in underground systems, including confined spaces, shall perform installation work or service work on systems that could be energized.

Before beginning work on underground power systems, personnel shall obtain the appropriate switching procedures prepared by the PIC.

Before entering any manhole or vault, personnel shall follow all safety requirements for entering a confined space. For details, refer to MN471001, *ES&H Manual*, Section 6I, "Confined Space Entry."

When manholes or vaults are open, the opening shall be protected with suitable barricades. During hours of darkness or poor visibility, the opening shall be illuminated with proper warning lighting.

Before doing any work on de-energized underground lines and equipment, the safe grounding techniques outlined in Section 2.8, "Safety Grounds," shall be reviewed and utilized.

Drilling or Digging Activities

Before performing work that penetrates concrete walls and/or floors having a depth greater than 2 inches, obtain a Sandia hidden hazards penetration permit (HHPP) (see CPR400.1.1/MN470110, *ES&H Manual*, Section 4H, "Excavations, Trenches, and Floor or Wall Penetrations,") from appropriate Division ES&H Team.

Inadvertent striking of underground utilities can result in electrical shock, injuries, explosions, utility outages, and death. These wires, conduits, and pipes are frequently missing from as-built drawings or other recorded drawings. Large scale decontamination and decommissioning (D&D), construction projects, and environmental restoration performed at DOE facilities bring with them a significant risk of contact with underground or embedded utilities. Before locating underground or embedded utilities, facility personnel should obtain and review available information for the location area.

Resources might be available including drawings, sketches, and site knowledge. Relying on current locating technology, alone, has resulted in many encounters with buried and embedded utilities. Once identified, all utilities shall be marked at the field work location in order to establish effective communication with the excavation work group. Accurate identification of excavation boundaries is absolutely necessary. It accurately communicates those boundaries to all workers and supervisors. It also sets the excavation limits, based on the research and locator testing provided for that particular excavation.

It is important that no locator technology should be relied upon as the sole source for identifying buried or embedded utilities. Configuration management is the most effective identification method. Care should be taken to ensure the markings are clearly present

and identifiable at the time the excavation workers arrive at the excavation site. Once the planning is complete, the excavation process is ready to begin. Work control procedures are in place and all hazards have been identified.

Worker protection during excavation work requires careful consideration. Personal protective equipment shall be chosen carefully for those performing excavation work. Additional equipment, such as rubber boots, insulated tools, and insulated gloves are examples of a needed extra layer of protection for the excavation worker. As-built drawings have provided significant improvements in various excavations activities/ programs across the DOE complex; however, as-built drawings should not be relied upon as the only source for the accurate location of underground/embedded utilities.

Construction Locations

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. Nonmetallic sheathed cable shall not be used:

- As portable extension cords.
- Where subject to traffic of any type.
- Where subject to frequent flexing.
- As service entrance cable.
- Where prohibited by the NEC.

Extension cord sets used on construction sites and used with portable metal electric tools and appliances shall be of the three-wire type and shall be designed for hard or extra-hard usage.

Additional requirements to be observed in construction areas include the following:

- Ground Fault Circuit Interrupters (GFCI) shall be used on **all** 120 V AC single phase 15 and 20 ampere receptacles which are not a part of the permanent wiring of the installation or location.
- Receptacles used in damp or wet locations shall be approved for the purpose.

- Receptacles installed outdoors (outdoors is considered a wet location), shall be contained in a weatherproof enclosure.

- Temporary lights shall not be suspended by their electric cords unless cords and lights are designed for this means of suspension.

- Receptacles on a two-wire, single-phase portable generator need not be protected with GFCIs if the circuit conductors of the generator are insulated from the generator frame and all other grounded surfaces.

- Personnel using jackhammers, bars, or other hand tools in a work area where underground electrical power lines are located shall use appropriate PPE unless it has been positively determined that the electrical power lines are de-energized.

Mobile Equipment Operation

The critical safety components of mechanical elevating and rotating equipment shall be inspected before use on each shift using the manufacturer's recommended checklist.

Insulated extended boom aerial personnel devices, articulating boom aerial personnel devices and any combination thereof (including line trucks), shall be inspected and tested annually as outlined by the manufacturer, ANSI A10.31, ANSI A92.2, and ASTM F914.

Operating equipment shall not come within 10 feet of high voltage overhead wires energized to 50KV or less, and that distance shall increase 4 inches for every additional 10KV. This requirement may be waived if any of the following conditions are met:

- If the vehicle is in transit with its structure lowered, the clearance may be reduced to 4 feet. If the voltage is higher than 50KV, the clearance shall be increased 4 inches for every additional 10KV.

- If insulating barriers are installed to prevent contact with the lines, and if the barriers are rated for the voltage of the line being guarded and are not a part of or an attachment to the vehicle or its raised structure, the clearance may be reduced to a distance within the designed working dimensions of the insulating barrier.

- If the equipment is an aerial lift insulated for the voltage involved, and if the work is performed by a qualified person, the clearance (between the uninsulated portion of the aerial lift and the power line) may be reduced to the distance in table 3-2.

Live Line Tools

Selecting

Live-line tools rated for the highest expected voltage shall be used. Maximum voltage per foot of length and phase-to-phase or phase-to-ground for live-line tools shall be as follows:

Tools with wooden handles:	69kV
Tools with fiberglass handles:	93kV

While use of wooden handled live-line tools is still allowed, use of fiberglass-reinforced plastic (FRP) live-line tools meeting the standards of ASTM F711-89 is strongly recommended.

Inspection and Tests

Live-line tools and attachments shall be inspected before use for defects and surface contamination such as moisture or dust.

Fiberglass-handled tools shall be tested every 12 months to 100 kV per ft of length, and wooden-handled tools shall be tested every 6 months to 75 kV per ft of length per ASTM F711-89.

A record of the testing of live-line tools shall be maintained at SNL/NM by the Planning Services Team (10864), and at SNL/CA by the Maintenance Engineering Department (8513).

If a line organization owns live-line tools, the department manager is responsible for maintaining required records of testing in the department or user files.

Tested live-line tools shall be marked with an identifying test date and identification number. Identifying means shall not damage the tools, adversely affect the tool insulating value, or cause other electrical safety concerns.

Cleaning

Live-line tools shall be cleaned and inspected before use, and tested before initial use and at regular intervals. Testing shall also be performed if damage is suspected.

Damaged live-line tools or attachments and contaminated live-line tools or attachments that cannot be cleaned shall be removed from service.

Live-line insulating tools shall be cleaned as needed and before storage to remove foreign substances. Care should be taken to use only cleaning agents that will not damage the insulation material or attachments, adversely affect the insulating value of the tool, or cause other electrical safety concerns.

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Electrical Safety Manual

CHAPTER 4 – RESEARCH AND DEVELOPMENT-SPECIFIC REQUIREMENTS

Subject Matter Expert: Mark McNellis; CA Counterpart: Herman Armijo
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* Indicates a substantive change

Scope

This chapter provides electrical safety requirements and safe work practices specific to Research and Development (R&D). The R&D environment presents electrical hazards that require knowledge and procedures different from those detailed for use by facilities organizations. The procedures included in this chapter address these specific issues. These procedures should be used in conjunction with applicable general requirements covered in Chapter 2, General Safety Requirements.

R&D work often incorporates the design of very specialized equipment, which results in the need for specialized grounding and unconventional use of materials and components. 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 those for which they were originally designed requires special considerations in the use and identification of materials and components, personnel protection, and equipment protection.

When conflicts among 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.

4.1 Responsibilities

Person in Charge

The person in charge (PIC) is responsible for meeting all provisions of this chapter and other applicable chapters of this manual. The PIC and the person doing the work shall be qualified personnel as defined in Section 2.2, Qualifications and Training.

Laboratory Workers

Laboratory workers shall comply with the portions of this section that apply to their own actions and conduct in the laboratory environment. They are also responsible for knowing and following the safe procedures and practices that are specific to their organization and laboratory and for being

familiar with any and all equipment before operating it.

Second Person

For responsibilities of the second person, see Section 1.3, Responsibilities of Individuals.

Visitors and Unqualified Personnel

Visitors and unqualified personnel shall follow all safety procedures and practices provided by the PIC.

4.2 Personnel Qualifications

This section provides guidance for determining the qualification process for personnel involved with specialized electrical equipment, configurations, or work tasks associated with experiments or tests that may not otherwise be able to comply with industry-accepted codes and standards. In addition to the minimum qualifications described in Section 2.2, Qualifications and Training, a list of additional experience qualifications should be developed based upon special hazards that are identified.

Hazards

The hazards associated with R&D equipment are sometimes unique because the equipment itself is unique. These hazards and methods for mitigating them shall be identified in ES&H SOPs and OPs. Personnel who work on R&D equipment shall be qualified to work on such equipment.

*4.3 Safe Work Practices

Rules

The following are general rules for safe work:

- Do not perform service, maintenance, or installation work on energized electrical equipment except where troubleshooting or testing can only be performed with the system energized or where

critical systems are involved.

- Bring utility supply voltages as near to the utilization equipment as possible using NEC-compliant wiring methods.
- Follow the appropriate requirements for working on energized equipment detailed in Section 2.1, Electrical Work Requirements - General.
- Consider all electrical equipment, testing devices, and conductors energized until tested or otherwise determined to be de-energized per Section 2.4, Establishing an Electrically Safe Work Condition.
- Do not wear conductive articles (such as metal watchbands, jewelry, and rings) in proximity to energized or potentially energized parts.

Rules and guidelines apply to both AC and DC systems unless noted otherwise.

Personal Protective Equipment

As specified in Section 2.10, Personal Protective Equipment, all laboratory personnel who are exposed to the hazards of energized or potentially energized conductors or exposed electrical parts shall use personal protective equipment.

Class 00 rubber electrical gloves with leather protective gloves are ideal for many R&D applications. Rated for 500 volts AC, they may be used without the leather protectors. Gloves may be obtained from Border States Electric.

Lockout/Tagout

When appropriate, perform all work on systems, circuits, and equipment in R&D laboratories in accordance with the lockout/tagout procedures in MN471001, *ES&H Manual*, Chapter 4, Section C, "Lockout/Tagout for Hazardous Energy Control," and GN470037, *"Administrative Control Procedure"*.

Grounding Practices

Before performing any work on de-energized electrical equipment or conductors, a qualified person shall test the equipment or conductors for voltage using an appropriate meter and apply grounding conductors as appropriate.

Before using grounding conductors, visually inspect them and verify their continuity using an ohmmeter.

Safety Grounds

Safety ground sets shall be capable of conducting the maximum ground fault current that could flow at the point of grounding for the time necessary to clear the fault.

Equipment Grounds

All metal equipment, such as laser tables, test fixtures, and enclosure racks shall be grounded with recognizable and permanent grounding conductors.

Laboratory equipment supplied with grounding-type flexible cords shall have an effective grounding conductor. A means of verifying this is by measuring the impedance between the grounding pin and the equipment case. A good ground is an impedance of less than 0.25 ohms.

Isolate laboratory systems and equipment that shall be operated without grounding, barricade them, and mark them with appropriate warning signs and signals.

Ground Reference

Connect the ground of experimental equipment to the same common ground as the facilities electrical system to ensure an equal potential.

Lightning Protection

Lightning protection should comply with NFPA 780 when experiments are performed outdoors or in freestanding structures. For additional information, contact the Radiation Protection & Laboratory Services (10328) or fire protection personnel in the Facilities Planning and Engineering Department

(8512).

Safe Work Zone

Maintain working space around electrical equipment. For working space requirements, see Figures 2-2, 2-3, 2-4, and 2-5 in Section 2.7, Working Space Requirements for Energized Work.

Some potentially hazardous pieces of R&D electrical equipment require appropriate precautions to ensure safety of personnel, including:

- Providing physical barriers to prevent individuals from inadvertently contacting energized parts.
- Identifying hazardous areas and the nature of each hazard by using warning signs, flashing lights, audible alarms, or a combination of devices.

Ground Fault Circuit Interrupters (GFCI)

GFCI outlets shall be installed and operated in accordance with Section 2.12, “Additional Requirements,” and the National Electrical Code, Article 210.8, except when specific testing/operations preclude its use. Contact ES&H coordinator or Safety Engineering for additional guidance.

Electrical Equipment Near Water Sources

Do not bring electrical equipment that is neither GFCI protected nor protected by suitable barriers to within 6 ft from the vertical axis of the waterfall of a shower head or eyewash station.

Servicing Electrical Equipment

Perform all work with equipment in a de-energized state. All energized work shall meet the requirements listed in Chapter 2.1 of this manual.

Note: Working on energized equipment for convenience or by custom is not appropriate energized work.

Wear appropriate PPE, and insulate or isolate energized sources if the equipment shall be energized during the work.

Do not reset or replace an overcurrent device, overload, or fuse until the cause of the overload trip has been determined and corrected. Do not repeatedly close circuit breakers or overload devices or replace fuses.

Do not use overcurrent devices that are not designed for load interrupting as a means for disconnecting energized circuits.

Note: At SNL, only qualified personnel from the Facilities Management & Operations Center (NM) (10800) or the Center for ES&H, Facilities & Security (CA) (8510) are authorized to reset facility owned circuit breakers or replace facility fuses.

Safety Interlocks

An approved technical work document (TWD) shall provide procedures for bypassing interlocks where exposed voltages will be 50 V or greater.

The PIC shall return interlock devices or systems to normal operation and verify operation upon completion of the work. The PIC shall test safety interlocks annually as a minimum and document test results in the department files.

The worker who bypasses interlocks shall have sole control of them.

Troubleshooting and Emergency Work Versus Experimentation

Accident reports indicate that troubleshooting is a high hazard task. Hazards are presented and uncovered that have not been addressed in the PHS and HA processes. Be sure that each new hazard is addressed using the ISMS process while troubleshooting. Analyze each change in your work process for new hazards. The worker must always anticipate the unexpected when troubleshooting equipment.

When emergency electrical repairs are required (for example, for power source device failure), do not compromise the safety of personnel to maintain continuity of the affected experiment – the maximum safety of

personnel 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, personal protection, and equipment protection.

If interrupting an experiment to make necessary emergency repairs is not feasible, follow the appropriate requirements for exposed energized work detailed in Section 2.1, Electrical Work Requirements - General.

*Modifications or Installations

Modifications to R&D equipment or installation of additional equipment to accommodate a revised or new experiment setup should be performed when equipment is in a de-energized state.

When equipment is not de-energized, the qualified person performing the work shall follow the appropriate requirements for exposed energized work detailed in Section 2.1, Electrical Work Requirements - General.

Modification of NRTL-listed equipment voids the listing.

Before using the equipment, the person performing the modification shall:

- Ensure equipment that is in-house built, modified NRTL, or from a manufacturer that does not meet the requirements of an "Accepted Manufacturer" as defined in the SNL Electrical Equipment Approval Guidelines, is approved and documented using the form in Attachment A-2, “Other Manufacturer Equipment, In-House Built Equipment or Modified NRTL-Listed Electrical Equipment Approval Form."

- Ensure that modified and non-NRTL equipment is electrically checked by calibrated equipment in accordance with SNL CPR 100.3.1.

- Document the equipment modifications in the user file or the file of the department that owns the equipment.

Maintain documentation for as long as the equipment is in use.

Materials Used in an Unconventional Manner

The use of materials for something other than that for which they were originally designed has the potential for providing an additional hazard, especially to personnel unfamiliar with the research apparatus. Personnel shall be made aware of hazards involving materials used in an unconventional manner prior to working with those materials.

Some examples of items used in an unconventional manner are the following:

- Copper pipe used as an electrical conductor
- Insulated flexible copper pipe used as an electrical conductor
- Specially designed high-voltage or high-current connectors
- Specially designed high-voltage or high-current switches
- Water column used as a high-voltage resistor
- Standard coaxial cable used in special high-voltage pulsed circuits
- Water column used as a charged particle beam attenuator
- Commercial cable tray used as a mechanical support for experimental apparatus

Use of Listed Equipment

All electrical equipment, including personal equipment such as radios and coffee pots, shall be listed by an NRTL (e.g., UL) or be approved and documented by a qualified person.

Note: The “CE” label common on many electronic devices is NOT an approved NRTL. For a complete list of approved testing labs, see Section 2.4, “Safe Work Practices”.

All new equipment purchased shall be NRTL listed whenever available. The manufacture and use of in-house equipment shall be minimized. Equipment that is in-house built, modified NRTL, or from a manufacturer that does not

meet the requirements of an “Accepted Manufacturer” as defined in the SNL Electrical Equipment Approval Guidelines, shall be approved and documented using the form in Attachment A-2, “Other Manufacturer Equipment, In-House Built Equipment or Modified NRTL-Listed Electrical Equipment Approval Form."

Equipment of Foreign Manufacture

Listed equipment requirements also apply to electrical equipment of foreign manufacture. Not all foreign listing standards are recognized by OSHA. A qualified person shall approve equipment that is not NRTL listed. Color coding of power wiring may differ and may create hazardous situations.

Improper Use of Listed Equipment

Install and use equipment or instruments that have been listed by an NRTL as intended and instructed by the manufacturer. Any alternate use or modification of the equipment or instrument will void the listing and may present a dangerous electrical hazard to a user.

*Documentation of Nonlisted Equipment

Equipment that is not listed by an NRTL shall comply with the requirements of the SNL Electrical Equipment Approval Guidelines and shall be approved and documented using the form in Attachment A-1, “Accepted Manufacturer Unlisted Electrical Equipment Approval form."

Prior to use, modified and non-NRTL equipment shall be electrically checked by calibrated equipment in accordance with SNL CPR 100.3.1.

4.4 Preventive Maintenance

Scope

Items covered in this section include maintenance requirements for electrical installations and equipment that relate directly to personnel safety in the work place and that are not specifically covered elsewhere in this manual. It is not the intent of this section to define specific maintenance methods

because several approaches may satisfy the act of testing, preserving, or restoring electrical equipment. Consult the equipment manual for specific maintenance requirements and intervals.

Work Practices

Personnel shall follow these work practices:

- Operate and maintain all test equipment according to the manufacturer's specifications.
- Visually inspect all electrical equipment, including portable power tools, lamps, and extension cords, to verify that the equipment is safe prior to use. Do not use damaged equipment, including cords.
- Ensure that all electrical equipment is appropriate for the environment in which it is used.

PIC Responsibilities

The PIC shall ensure that:

- All damaged grounding and bonding systems are reported to maintenance personnel. Electrical equipment ground continuity should be tested annually at a minimum.
- Safety interlocks (see Safety Interlocks in Section 4.3, Safe Work Practices), are maintained in proper working condition and tested and documented annually as a minimum and following any maintenance.
- Attachment plugs, receptacles, enclosures, and connectors are maintained so that:
    - There is no damage that exposes live parts.
    - Terminations have no stray strands or loose terminals.
    - There are no missing or bent blades, pins or contacts.
    - There are no missing cover plates or knockouts.

- Polarity is correct.

Safety Checks

The PIC shall ensure that the following safety requirements are met:

- Equipment identification and safety-related instructions are securely posted and maintained in a legible condition.
- Warning signs are securely attached and maintained in legible condition.
- All covers, doors, and other enclosing systems are in place to ensure that no unprotected openings exist.
- Open wiring systems of 50 V or greater are separated by barriers or physical location from any personnel work areas to prevent accidental contact.
- Worn, frayed, or damaged flexible cords and cables are removed from service.

*4.5 Power Sources

Hazards

Power sources for R&D facilities may be divided into two categories--supplies or equipment that operate at less than 50 V and those that operate at 50 V and higher. Although equipment operating at less than 50 V is generally regarded as nonhazardous, such equipment is considered hazardous when high currents are involved. Examples include 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.

There is a low probability of electric shock at voltages less than 50 V and when the output current of high-voltage supplies is below 5 mA; however, both conditions present 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. Where combustible atmospheres or mixtures exist, the hazard of ignition from a spark may exist.

Typical R&D power sources (AC or DC) can present the following hazards:

- Faults, lightning, or switching transients can cause voltage surges in excess of the normal ratings.
- Internal component failure can cause excessive voltages on external metering circuits and low-voltage auxiliary control circuits. 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. Internal component shorts in capacitor banks and Marx generators can result in excessive current, causing extreme heat, overpressurization of capacitor cans, and explosion.
- 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.
- Overloading or improper cooling of power supplies can cause temperatures to rise excessively.
- Output circuits and components can remain energized after input power is interrupted or removed.
- Auxiliary and control power circuits can remain energized after the main power circuit is interrupted or removed.
- Stored energy in long cable runs can present an unexpected hazard. Procedures shall be in place to ensure proper discharge of this energy.
- When power supplies serve more than one experiment, errors made when switching between experiments may create hazards to personnel.
- R&D electrical apparatus may contain large amounts of stored energy,

requiring fault analysis.

- Liquid coolant leaking from R&D electrical equipment may pose an electrical hazard to personnel.

- Involuntary reactions from contact with high-voltage, low-current systems may result in a fall or entanglement with equipment.

Design and Construction

Personnel in R&D labs may encounter energized parts in a variety of configurations and locations and under environmental conditions that are unusual 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 develop and use a technical work document (TWD) (e.g., safe operating procedures).

Note: Whenever possible, NRTL listed equipment should be purchased and used in the lab. For special testing applications, when the equipment is not available and shall be manufactured in-house, consult the SNL Electrical Equipment Approval Guidelines for non-NRTL equipment for additional guidance on incorporating engineered controls into the design of the equipment.

Note: These TWDs need to be written and approved in accordance with Chapter 21, "Technical Work Documents (TWDs)."

Treat a circuit operating at 50 V or less 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:

- Provide protective covers or barriers over terminals and other live parts to protect personnel.

- By suitable marking, identify the hazard at the power source and at appropriate places.

- 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.

- Provide a mechanism which will automatically discharge any residual energy (i.e. capacitance) prior to accessing the circuit components.

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

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

*Safety Practices

Before working in a power supply enclosure or an associated equipment enclosure, personnel shall comply with the requirements of Section 2.4 of this manual and take the following additional precautions:

- Establish an electrically safe work condition.
- Implement lockout/tagout.
- Check for auxiliary power circuits that could still be energized.
- Inspect automatic shorting devices to verify proper operation.

- Short the power supply from terminal to terminal and terminal to ground with grounding hooks.

When working on circuits operating at 50 V or less that are treated as hazardous, work on such circuits when they are de-energized. 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.

A qualified person shall perform an analysis of high-voltage circuits before work begins unless all exposed energized parts are guarded as required for high-voltage work. The analysis shall include fault conditions where circuit current could rise above the nominal rated value as explained here. Use the Energized Work Decision Tool to determine the appropriate precautions and training requirements.

High-voltage supplies that use rated connectors and cables where there are no exposed energized parts are not considered hazards. Do not make or break connections with the power supply energized unless the connectors are designed and rated for this type of duty (for example, load-break elbows). Inspect cables and connectors for damage, and do not use them if they are damaged.

4.6 Capacitors and Capacitor Banks

R&D laboratory operations make use of capacitors and capacitor banks that are sources for pulsed power applications, and they are also incorporated in circuits that block, filter, oscillate, isolate, or resonate.

Hazards

A capacitor or capacitor bank capable of discharging 25 J in less than 3 seconds or 10 J in less than 0.5 seconds can be lethal.

A capacitor or capacitor bank presents a potentially serious electrical hazard. Any capacitor or capacitor bank capable of discharging more than 10 J is a shock hazard. Energy is determined by:

Energy in Joules (J) = $1/2\ CV^2$

Where:

C = Capacitance in farads
V = Voltage in volts

Additional examples of hazards include:

- Excessive heating or explosion that may result if a capacitor is subjected to high currents.
- Internal failure of one capacitor in a bank, which frequently results in an explosion when all of the other capacitors in the bank discharge into the fault. (Approximately 10 J is the threshold energy for explosive failure of metal cans).
- The liquid dielectric, which in many capacitors may be toxic.
- Internal faults, which may rupture capacitor containers. Rupture of a capacitor container may create a fire hazard.
- The combustion products of liquid dielectric in capacitors, which may be toxic. Polychlorinated biphenyl (PCB) dielectric fluids can release toxic gases when decomposed by fire or the heat of an electric arc.

Safety Practices

Before starting work on power capacitors or capacitor banks, the PIC shall establish a restricted access area with appropriate barriers and signs installed.

Assign only qualified personnel trained in the proper handling, storage, and hazards recognition to the task of servicing or installing power capacitors.

Allow only qualified personnel to inspect, adjust, or work on interlocks on capacitor or capacitor bank enclosures or equipment.

Establish procedures for tagging and logging the location of interlocks when bypassing and then restoring them, and log the time of the events. This shall also be included in the appropriate TWD.

The following practices are recommended when working with all capacitors, and shall be utilized when working where accidental contact could occur with capacitors storing greater than 10 J:

CAUTION Discharging a capacitor or capacitor bank by means of a grounding hook can cause an electric arc at the point of contact.

- To prevent inadvertent contact, never energize power capacitors outside an enclosure or without proper barriers.
- Interlock the circuit breakers or switches used to connect power to large power capacitors or capacitor banks.
- To ensure wiring integrity, make sure that discharge devices are in plain view and contained locally within protective barriers so that proper functioning of the devices can be verified.
- Use automatic shorting devices that operate when the equipment is de-energized or when the enclosure is opened.

- Before servicing or removing power capacitors, ensure that they have been safely discharged, shorted, and grounded. Shorts or shunts should remain in place until the work is completed.
- Remove all shunts before re-energizing equipment.
- Do not rely on automatic shunts only. Use grounding hooks and additional positive grounds.
- Use proper PPE when applying shorting and grounding devices to capacitors. Such equipment should include hand, eye, face, and body protection.
- Ensure that shorting and grounding devices for power capacitors are rated for the intended use.

- Inspect shorting and grounding devices for general condition, cleanliness, connection integrity, and resistor condition (if a resistor is used) before each use.

- Store or discard power capacitors with a short or shunt installed. Use shunts that have a minimum rated capacity of 14 AWG copper, or use the shunt provided by the manufacturer. Connections to capacitor terminals shall provide a positive and continuous connection.

Periodic Inspections

The PIC shall inspect capacitor cans periodically for cracks, leaks, or possible deformity. Defective capacitors should be immediately removed from service and tagged as inoperable. Workers shall be aware that oil-filled capacitors may contain PCBs. If in doubt, refer to the following:

- At SNL/NM, refer to MN471001, *ES&H Manual*, Chapter 10, Section D, "Polychlorinated Biphenyl (PCB) Management", or contact the Regulated Waste/Nuclear Material Disposition Department (10339).

- At SNL/CA, refer to GN470075, *Guidelines for Hazardous Waste Generators at SNL/CA*, or contact the Health and Safety Department (8517).

4.7 Inductors and Inductor Systems

Typical R&D applications for inductors (including electromagnets and coils) are energy storage, impedance devices in pulsed systems (usually with capacitors), and DC power supplies. Electromagnets and coils are special types of inductors that produce magnetic fields to guide or confine charged particles.

Hazards

Workers shall be aware of the potential health hazard from static magnetic fields. Personnel from the Industrial Hygiene & Safety Programs (10327) or the Health and Safety Department (8517) should be contacted to survey the work area.

The following are hazards associated with inductors and inductor systems:

- A possible uncontrolled release of energy may result if the inductor's current is suddenly interrupted.

- An inductor (and possibly the cooling system) may be damaged if the cooling system fails.
- Electromagnets and superconductive magnets may produce large external force fields that may affect the proper operation of the protective instrumentation and controls.
- A sudden de-energization of a magnet can produce large eddy currents in adjacent conductive materials that may cause excessive heating and hazardous voltages.
- A magnetic field could attract nearby magnetic material, including tools, that could cause injury or damage on impact.

Safety Practices

Use appropriate warning signs to prevent Members of the Workforce from exceeding the following threshold limit values:

Members of the Workforce with pacemakers: 0.0005 Tesla.
Whole body ceiling: 2 Tesla
Extremity ceiling: 5 Tesla
Body eight-hour time weighted average: 0.06 Tesla
Extremity eight-hour time weighted average: 0.6 Tesla

The PIC shall establish a restricted access area with appropriate barriers and signs installed prior to starting work on any inductor system.

Assign only qualified personnel trained in handling and hazards recognition to the task of inspecting, adjusting, or working on inductors or inductor systems.

The following practices are recommended when working with all inductors or inductor systems:

- Verify that any inductor is de-energized before disconnecting the

leads or checking for continuity or resistance.

- Fabricate protective enclosures from materials not adversely affected by external electromagnetic fields.
- Provide equipment supports and bracing adequate to withstand the forces generated during fault conditions.
- Provide sensing devices (temperature and coolant flow sensors) that are interlocked with the power sources.
- Provide means for safely dissipating stored energy when excitation is interrupted or a fault occurs.

4.8 Electrical Conductors and Connectors

Scope

R&D operations often make use of special conductors and connectors for applications such as high-current, high-voltage, high-frequency, and liquid-cooled equipment.

Selection

When working with special conductors and connectors, use the following guidelines for selection:

- Only qualified personnel may select, install, or maintain special conductors and connectors.
- The operating and environmental conditions, such as current requirements, thermal ratings, dielectric and mechanical strength, and resistance to moisture, chemicals and radiation shall be considered. Use conductors and connectors that are rated for the application.
- All conductors within the same conduit or raceway carrying both high and low voltages shall be rated for the highest voltages present; otherwise, separate the cables using physical barriers.

- Conductor current capacities shall be derated commensurate with density of packing when they are used in raceways or cable trays. Contact the AHJ for guidance.

- Use NRTL listed or labeled conductors when available.

- Provide engineering calculations to support overrating of conductors for any application.

Use

When using special conductors and connectors, personnel should follow these guidelines:

- Avoid laying cables across the floor whenever possible. Where there are no alternatives, provide physical protection for the cables and trip protection for personnel.

- Avoid loops (wide spacing) between high-current supply and return conductors to prevent voltage and current induction in adjacent circuits or structural members.

- Provide bracing and conductor supports to withstand any mechanical forces and voltages. Pulsed operation of cables or high-fault currents can produce electromagnetic forces that cause violent movement of components and cables and possibly explosions.

- Ground coaxial cable shielding when possible. If test conditions require an ungrounded shield, provide physical barriers and warning signs to notify personnel that the shield is ungrounded and that personnel should assume that it is energized.

- Where liquid-cooled cables are used, provide sensing devices that measure parameters such as temperature or coolant flow for alarm purposes or for equipment shutdown if the cooling system malfunctions or fails.

- Check cable connectors and connections before use and tighten them periodically if required. Pay special attention to aluminum cable connections.

- Secure plug-in cable connectors in place by mechanical means, particularly those for high voltages or high currents.
- De-energize all power sources before removing a connector. Allow adequate time for charges to bleed off.

SNL Color Code

SNL's color code shall be followed when installing cords and plugs or connecting wiring to the load side of power disconnects:

- Red, black, and blue are always energized conductors in 120/208V applications.
- Brown, orange and yellow are always energized conductors in 277/480V applications.
- White is a grounded neutral conductor and shall never be connected to the ground connection.
- Green is the equipment or safety ground and shall be connected only to the ground connection and never to the neutral connection.

4.9 Radio Frequency Equipment

Definition

Radio frequency (RF) equipment is that class of equipment used for pulsed or continuous generation of high-frequency energy and microwave radiation. For additional information, see MN471001, *ES&H Manual*, Chapter 6, Section J, "Nonionizing Radiation."

Hazards

Devices that may produce RF 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. Following are the types of hazards that RF equipment presents:

- RF amplifiers frequently use high-voltage power sources. For guidance on high-voltage work, see Section 2.4, Safe Work Practices; Section 2.6, Access to Electrical Equipment; Section 2.7, Working Space Requirements for Energized Work; and Chapter 3.0, Facility-Specific Requirements.

- X-rays may exist at voltages above 10 kV.

- Currents may be induced in conductive objects or metal structures that are not part of the RF structure.

- RF currents can cause severe burns.

- RF burns from antennas can cause people to fall from towers.

- Electromagnetic interference may cause equipment to malfunction.

- Electromagnetic fields may cause unintended ignition of explosives, fuel, and ordnance.

- Due to induction and other means, 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.

Personnel Considerations

Only qualified personnel may design, build, install, or maintain RF equipment according to the following guidelines:

- Do not wear metallic objects such as rings, watches, or jewelry when working with or near RF power sources.

- Monitor for RF leakage from enclosures and couplings if personnel shall be in the radiation area during operation.

- Wear suitable protective goggles in exposed areas. Goggles with an evaporated gold film are the most practical for microwave radiation.

- Do not make close visual examinations of energized microwave radiators, reflectors, or other microwave-generating devices.

Operations

Operations of RF equipment shall include the following provisions:

- Provide properly shielded and grounded enclosures for RF power equipment to minimize radiation leakage. Pay special attention to all openings such as doors, access ports, and viewing windows.
- When testing requires free-space radiation, position the radiation device so that the energy beam is not directed toward personnel. Probable directions of reflected beams should also be considered.
- Provide use-control features (such as a key switch) to prevent unauthorized operation of RF equipment.
- Provide lockout/tagout capability to prevent operation of RF equipment during installation, maintenance, or modification activities.
- Provide barriers, signs, and audible warnings as appropriate to prevent unauthorized personnel from entering an RF test area.
- Avoid use of electrical equipment near induction heating apparatus to prevent induced energy from interfering with the equipment operation.

Design

RF system designers shall utilize best engineering practices that include the following:

- Grounding requirements of RF power generating equipment
- Shielding
- RF bypassing for control and instrument leads
- View port sizing

- Insulating heat-producing devices
- Interlocks on chamber or oven-type equipment to prevent radiation leakage if the door is open

4.10 Batteries and Battery Banks

Hazards

Batteries are a potential hazard from the viewpoints of both the stored energy and recharge characteristics. The guidance below applies to all voltages and energy ratings because the nature of the associated electrical hazards is similar for any battery size, except that the severity of the hazard increases with increased battery rating. Note that batteries are located in a variety of applications in the lab, including Uninterruptible Power Supplies.

Specific hazards include:

- Generation of potentially explosive gas mixtures during charge and discharge.
- Heating/explosion during excessive charge/discharge.
- Cell reversal (a condition in which a cell is discharged beyond its capacity, becoming a load on the remaining cells) can cause excessive heating/gas production if the cell remains in service.
- Acid splash from electrolyte.
- Chemical exposure hazards from lead, antimony, arsenic and other substances commonly used in lead-acid storage batteries.

Safety Practices

Accidental shorting of the exposed terminals or cables of a battery can result in an explosion or severe electric arcing, causing burns and electrical shock. To minimize these hazards, personnel shall follow these guidelines:

- Use insulated hand tools when working on or near exposed battery

terminals.

- Do not repair battery connections when current is flowing.
- Wear eye protection (goggles or face shields), long sleeves, and rubber gloves when handling electrolytes or nonsealed batteries containing electrolytes.
- Provide eyewash and shower stations near battery facilities for quick drenching of the eyes and body. For more information on eyewashes and safety showers, see MN471001, *ES&H Manual*, Chapter 6 , Section M, "Safety Showers and Eyewashes."
- Provide spill kits for containing and neutralizing electrolyte spills. Check with the Hazardous& Solid Waste Pollution Prevention Department (8516) or the Environmental Operations Department (8516) for permanent spill containment requirements. Dispose of spill-related material as a chemical waste. For more information on hazardous waste, see MN471001, *ES&H Manual*, Chapter 19, Section A, "Hazardous Waste Management."
- Do not charge or discharge batteries in excess of their rated specifications.
- Provide adequate ventilation (an exhaust system, if appropriate) to prevent hazardous or toxic fumes from accumulating during recharge or discharge activities as appropriate. For more information on local exhaust ventilation, see MN471001, *ES&H Manual*, Chapter 6, Section P, "Local Exhaust Ventilation."
- Ground conductive battery storage racks.

Lithium Battery Safety

Lithium batteries are a potential safety hazard because they may generate large quantities of toxic gas when used improperly. To prevent the generation of toxic gas when working with lithium batteries, do not expose them to temperatures above 80°C (~175° F) or discharge them at a high rate.

4.11 Temporary Wiring

Remove wiring installed to support a specific test, experiment, or project at the completion of the project.

Safety Practices

Personnel installing temporary wiring shall follow these guidelines:

- Use permanent wiring techniques for long term (greater than 90 days) experimental setups when feasible.
- When using temporary wiring, post signs warning of the hazards and maintain personnel safeguards by using barricades where accidental contact with live parts could occur.
- Use multiconductor, hard-service, rubber-covered cord and cable wherever feasible.
- Install temporary wiring away from work activities.
- Secure and appropriately mark temporary wiring with signs at points of possible personnel contact.

4.12 Cable Tray Applications

Cable trays that carry permanent Facilities power distribution cables cannot be used for experimental or temporary wiring.

In experimental areas, cable trays are installed as cable and utility management systems for the exclusive purpose of supporting the experiments. 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 an equipment console to a unit under test. 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.

Requirements

An assessment of any hazards identified with the equipment and the operation with which it is involved shall be performed by the equipment owner 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 shall 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 and warning signs shall be posted to indicate that cable trays are not grounded.

Equipment cable/utility runs installed in cable/utility management systems shall 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, include:

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

Contact Safety Engineering for assistance in assessing and determining suitability of cable tray use.

*4.13 Enclosed Electrical/Electronic Equipment

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. Racks shall be inspected by a qualified inspector in accordance with SNL Electrical Equipment Approval Guidelines (refer to Attachment A-3, “Electrical Equipment Racks Approval Form.")

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.

Enclosure Grounding and Bonding

Enclosure grounding and bonding should comply with the following requirements:

- Have a common grounding or bonding bus (normally a cabinet rail).
- When the enclosure contains more than one bay, bond all grounding or bonding busses together.
- 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.
- The grounding or bonding conductor shall be permanent and continuous.
- 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.

- 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.

- The grounding/bonding conductor shall be sized appropriately for the application. Contact Safety Engineering (10322) for additional guidance on conductor sizing.

Special Considerations

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

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

Rack Power Distribution

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 shall 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. Ensure the required power demand of the rack-mounted equipment does not exceed the rating of its facilities branch circuit breaker.

Rack power distribution components or assemblies shall be listed by a NRTL, or be evaluated by an authorized equipment inspector.

If the rack’s power distribution is accomplished through the use of a power strip, observe the following requirements:

- The power strip shall be NRTL listed or labeled.

- The power strip shall be designed for mounting.
- The power strip shall be permanently mounted (no cable tie-wrap mounting or other non-permanent method).
- The power strip shall be rated for the expected power in the rack.
- The power strip may not be modified in any manner.
- Power strips may not be connected in series.

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. Where undesirable harmonics exist, the neutral conductor may have to be larger than the phase conductors.

Conductors and Cables Specific Requirements

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.

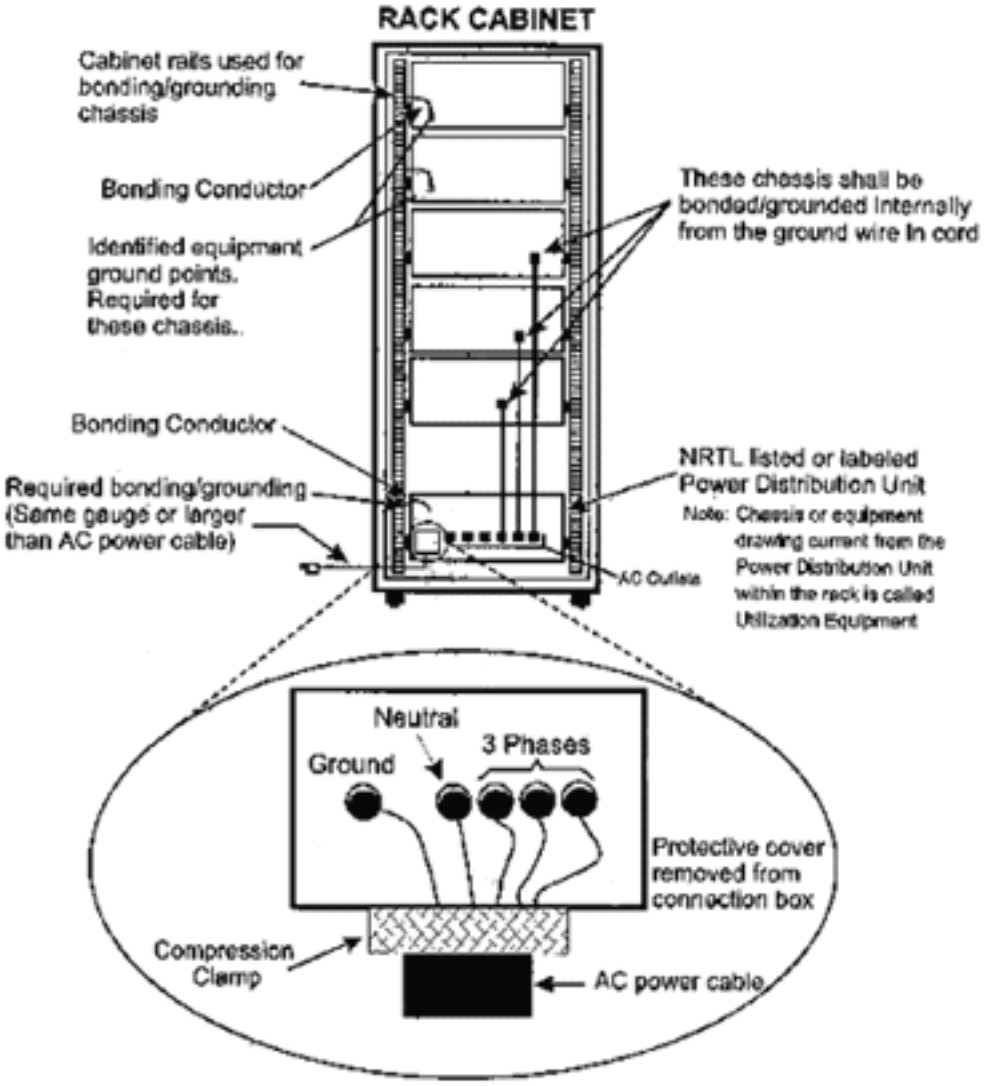

Figure 4-1. This drawing represents typical 120/208 Volt, Three Phase Wye, 5 wire, ac power

Power and signal wires shall 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.

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.

Flexible Cables

Flexible cables may be used:

- Where flexible cables and attachment plugs are furnished by the manufacturer as part of the equipment to be mounted in the rack.
- For connection of stationary equipment to facilitate their frequent interchange.
- To prevent the transmission of mechanical vibration.
- Where the fastening means and mechanical connections are specifically designed to permit ready removal for maintenance and repair.
- For data processing cables approved as part of the data processing system.
- For temporary wiring.

Note: Whenever possible, permanent wiring should be used.

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 cables within or external to instrument racks is not allowed.

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 non-current 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.

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.

Provide provisions for Lockout/Tagout requirements.

Connections, Connectors, and Couplings

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

- There shall be no exposed current-carrying parts except the prongs, blades, or pins.
- The connector shall prohibit mating of different voltage or current rating than that for the device intended.
- All connectors shall be protected against overcurrent in accordance with their rated ampacity.
- Connectors shall be NRTL approved for the application.
- 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" (similar 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."

DC Power Distribution

Guidelines for dc power distribution include:

- The metal chassis or cabinet should not be used as a return path.
- High-current analog or switching dc power supplies should use separate return paths from digital circuits.
- 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.

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.

Marking and Labeling 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.

Other markings for power requirements are:

- Voltage.
- Maximum rated current in amperes or Wattage.
- Frequency (computer only).

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 of the combined systems installed within it.

Hazard Marking Requirements

All enclosures containing exposed energized circuits over 600 volts nominal shall 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.

4.14 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 section. Refer to MN471001, *ES&H Manual*, Chapter 6, Section G, "Lasers and Intense Light," for information on laser hazards.

The following are hazards related to lasers and x-ray equipment:

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

Maintenance on laser systems shall be performed in accordance with Chapter 2 of this manual. Only qualified individuals shall perform maintenance on laser systems.

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Electrical Safety Manual

CHAPTER 5 – SPECIAL OCCUPANCIES

Subject Matter Expert: Mark McNellis; CA Counterpart: Herman Armijo
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* Indicates a substantive change

Scope

Scope

This chapter provides specific electrical safety considerations for special occupancies, which include hazardous areas, explosives areas, and confined spaces. These procedures should be used in conjunction with applicable general requirements covered in Chapter 2.0, General Requirements.

5.1 Hazardous Areas

Definition

Hazardous areas include locations where flammable mixtures of gases or vapors, flammable liquids, combustible dust, or ignitable fibers may exist. The NEC and other NFPA Codes specify and define hazardous areas in greater detail. Some examples are provided below.

Classes and Divisions

There are three classes of hazardous areas. Within each class are two divisions. In general, Division 1 areas contain ignitable levels of hazardous materials under normal circumstances, and Division 2 areas are exposed to ignitable levels of hazardous materials under extreme circumstances. The requirements for Division 1 areas are more stringent than the requirements for Division 2 areas.

Class I Areas

Areas where flammable gases or vapors are present in quantities that produce explosive or ignitable mixtures are NEC Article 501 - Class I areas.

The flammable gases or vapors would include acetylene, gasoline, or turpentine.

Class I area classifications are further subdivided into groups A, B, C & D. Group A includes only acetylene. Group B includes hydrogen and other gases. Groups C & D make up the largest groups, and contain most of the petroleum fuels and solvents.

Class II Areas

Areas where combustible dusts are present are NEC Article 502 - Class II areas.

Class II area classifications are further subdivided into groups E, F & G. Group E includes conductive metal dusts such as aluminum and magnesium and their commercial alloys. Group F includes conductive nonmetallic dusts such as carbon black, charcoal, coal, or coke dust with more than 8% entrapped volatiles. Group G includes remaining combustible dusts such as flour, grain, wood, plastic, and chemicals.

Class III Areas

Areas where combustible fibers are present are NEC Article 503 - Class III areas. Combustible fibers include cotton and other textile mill fibers.

Using Equipment in Hazardous Areas

To ensure that equipment in hazardous areas functions as designed, it is important to protect and clean all smoothly-ground (machined surfaces), bolted, and threaded joints during assembly. Electrical equipment in hazardous areas shall conform to the requirements and special duties of these areas. Equipment rated for a particular class is designed to contain explosions, heat, and gases, and to keep out dust. This reduces the possibility of an explosion, and prevents the migration of gases and dust into the enclosure.

Conduit Seals May be Required

Conduit seals are fittings used in the conduit system to prevent flammable gases or combustion products from passing through the conduit. Conduit

seals are extensively required in Class I areas, and are required to a much lesser degree in Class II areas.

Intrinsically Safe Equipment

Intrinsically safe electrical equipment is electrical equipment not capable of delivering enough energy to ignite a combustible mixture such as fumes, gases, or dusts. This equipment is generally process-related control equipment, because this equipment lends itself to low power applications.

Grounding for Static Electricity

Personnel and equipment in hazardous locations and locations where static sensitive electroexplosive devices (EEDs) are exposed shall be grounded in a manner that discharges static electricity to prevent accumulations that are capable of initiating the dusts, gases, vapors, or exposed EEDs. Permanent equipment in contact with conductive floors and table tops are not to be regarded as adequately grounded unless a separate bonded grounding conductor is in place. All grounds, including static grounds, shall be interconnected if a structure is equipped with a lightning protection system.

Assistance

Contact Facilities Electrical and Fire Protection Engineering Department (10861) at SNL/NM, or the Facilities Planning and Engineering Department (8512) at SNL/CA for establishing and determining hazardous ratings and for requirements for your specific occupancy. Fire protection and electrical safety considerations provide criteria for a specific operation. Contact the appropriate division ES&H team for information and permits for confined space entry. Additional information on equipment usage in hazardous areas is available in the National Electrical Code (NFPA 70), 2005; The DOE Electrical Safety Handbook (DOE-HDBK-1092-2004) and NFPA 495 (Explosives Material Code – 2006).

Notes

1. NEC 500.8 (A)(1) National Electrical Code Handbook, 2005, Early et al, editors; NFPA, Quincy, MA

5.2 Explosives Areas

Class II Division 1

Areas containing explosive dusts or explosives that may, through handling or processing, produce dust capable of being dispersed in the atmosphere shall be regarded as Class II Division 1 hazardous locations.

Class II Division 2

Areas containing exposed explosives where no dust hazard exists are regarded as Class II Division 2 hazardous locations as applied to permanent premises wiring as defined in the NEC.

DOE Modifications of NEC Definitions

NEC definitions of Class I Division 1, and Class II Division 1 hazardous locations are modified as follows for DOE explosives facility applications:

Where explosives are processed and sublimation may occur or where flammable gases or vapor may be present in explosive or ignitable quantities, the area shall be regarded as both a Class I Division 1, and a Class II Division 1 hazard location.

Assigning Hazard Class and Group

To assign a space to the correct hazard class and group, you shall know the properties of the explosives involved. At a minimum, you shall know heat and spark sensitivity and thermal stability of the explosives.

Surface Temperatures

If Class II Group G equipment exceeds surface temperature limits for a given hazardous area, special protection shall be provided or the equipment shall be excluded from the location. The equipment surface temperature shall not exceed the ignition temperature of the explosives.

Substitute Equipment

When NEC Class I or II equipment is not available, the substitute equipment shall be purged or pressurized (in accordance with NFPA 496, Purged and Pressurized Enclosures for Electrical Equipment in Hazardous [Classified] Locations) or sealed to prevent explosives contamination. Substitute equipment shall be verified as intrinsically safe by the Facilities Electrical and Fire Protection Engineering Department (10861) at SNL/NM or the Health and Safety Department (8517) at SNL/CA. If the substitute equipment is not intrinsically safe, it shall be administratively controlled. If the substitute equipment is purged, it shall be monitored for flow.

Wiring

Wiring from the permanent premises wiring to process equipment and instrumentation shall be rated for the actual environment. This shall include nonhazardous-rated ordinary locations or occupancies. These areas should be evaluated and documented by facility management for potential exposures by the following criteria:

- Equipment malfunction
- Explosives material spillage
- The possibility of ignition sources arising from physical damage to the wiring method used (e.g., crushing by forklift or other material handling equipment)
- Exposed electrical conductors or connectors that could make contact with leg wires or cables of explosives devices during routine handling

Otherwise, this equipment and instrument wiring shall be regarded as NEC Class II.

Watertight equipment shall be provided where electrical equipment and wiring may come into contact with water/explosives mixtures.

Control Procedures

Procedures shall be established by each facility to control the use and modification of electrical equipment in explosives hazardous areas and ensure that uniform standards are adhered to throughout the facility.

Documentation of Hazard Classification

Document the determination by Facilities Electrical and Fire Protection Engineering Department (10861) by including:

- Assessment of the area
- Hazard classification
- Requirements to be met

Documentation will be kept by the Facilities Electrical and Fire Protection Engineering Department (10861).

Electrical Supply Systems

There may be multiple hazards where explosives facilities are located near electrical supply lines. To protect against these hazards, the National Electrical Safety Code (ANSI C2) and the following requirements apply to all new construction or major modifications, and should be considered for existing facilities:

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

- Inhabited building distance if the line in question is part of a system serving a large, off-site area.
- Public traffic route distance if loss of the line will not create serious social or economic hardships.

- Underground utility separation distance criteria are found in MN471011, *Sandia Explosives Safety Manual*.

Electrical Service Entrance for Explosives Facilities

The electrical service entrance for explosives facilities should be provided with:

- An intermediate, valve-type lightning arrestor on the primary side of the transformer.
- Surge arrestors and surge capacitors on the supply side of the main service disconnect.
- Interconnected grounding between the lightning arrestor, surge arrestor, surge capacitors, service entrance ground, and building ground.

Explosives Storage Buildings

Buildings used for storage of explosives shall comply with the following electrical installation requirements:

Electrical Construction

The requirements for NEC Article 502 Class II, Division 2 permits the use of electrical metallic tubing, intermediate or rigid conduit, liquid tight conduit, dust tight boxes and dust tight wireway.

Live parts shall not be exposed in Class II Division 2 locations. Switches, motors and other electrical devices shall be made dust-ignition proof.

Preferred Location

The preferred location of service equipment, switchboards, and panel boards is in a separate, less hazardous, positively pressurized room.

Current Surges

Electrical installations in packaged explosives storage spaces shall include protection from large currents, such as surge, ground fault, or lightning.

To prevent arc-producing and potentially damaging currents from entering the structure, surge protectors and lightning arrestors are required for incoming conductors. Electric lines serving an explosives facility shall be installed underground at least 50 ft from the facility. All other electric distribution lines shall be no closer to the facility than the line distance between two poles. An interconnected grounding system and a "green wire" ground system are required.

Lightning Protection

Lightning protection should conform with NFPA 780 - Lightning Protection Code. Frequent preventive maintenance inspections for grounding and lightning protection should be performed by facilities maintenance personnel. A 7-month visual and a 14-month resistance measurement inspection interval is recommended. This ensures that maintenance inspections occur at all seasons of the year, and at periodic intervals. These inspections are documented by the Electrical Maintenance Services Department (10842).

Assistance

For questions concerning explosives operations, contact the Explosives Safety Engineering Department (10322) at SNL/NM, or the Facilities Planning and Engineering Department (8512) at SNL/CA.

Additional Information

For additional requirements and guidance for explosives operations, see MN471011, *Sandia Explosives Safety Manual*.

5.3 Confined Spaces

Hazards

Confined spaces may contain extremely hazardous atmospheres due to little natural air movement. Confined spaces can contain oxygen-deficient atmospheres, flammable atmospheres, or toxic atmospheres.

Personnel Protection

Employees who work in a confined or enclosed space that contains exposed energized parts shall use protective shields, protective barriers, or insulating materials as necessary to avoid inadvertent contact with these parts. Doors, hinged panels, and the like shall be secured so they cannot swing into personnel causing them to contact exposed energized parts.

Assistance

For assistance in determining confined space requirements, contact Industrial Hygiene (10327) at SNL/NM, or the Health & Safety Department (8517) at SNL/CA.

Additional Information

For additional information on Confined Spaces, including worker qualification requirements, see MN471001, *ES&H Manual*, Chapter 6, Section I, "Confined Space Entry."

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Electrical Safety Manual

GLOSSARY

Subject Matter Expert: Mark McNellis; CA Counterpart: Herman Armijo
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AC. Alternating current.

Accessible. Allowing close approach; not guarded by locked doors, elevation, or other effective means.

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

ANSI. American National Standards Institute.

Appropriate Energized Electrical Work. Work on circuits >50 volts which, if deenergized, would result in an increased or additional hazard or if de-energizing the circuit is not feasible due to equipment design or operational limitations. See also Critical Systems.

Approved. Accepted by the authority having jurisdiction. Accepted, certified, listed, labeled, or otherwise determined to be safe by a nationally recognized test laboratory such as but not limited to Underwriters Laboratories, Inc., and Factory Mutual Engineering Corp (FMEC).

ASTM. American Society for Testing & Materials.

Authority Having Jurisdiction. A person or group with sufficient expertise in electrical safety to be the electrical authority at a facility.

Authorized Personnel (Authorized Person). A person to whom the authority and responsibility to perform a specific assignment has been given by the employer, and who can demonstrate by experience or training the ability to recognize potentially hazardous electrical energy and its potential impact on work place conditions. The authorized person has the knowledge to implement adequate methods and means for the control and isolation of such energy.

Authorized personnel could include those not qualified but having a need to be in a restricted area to perform a specific task such as supervisors, electrical engineers, electricians, mechanics, operators, custodians, and painters.

AWG. American Wire Gauge.

Barricade. A physical obstruction such as tapes, ropes, cones, A-frame type 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 and/or to prevent unauthorized access to a work area.

Bond. The electrical interconnection of conductive parts intended to maintain a common electrical potential.

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.

Buddy System. *See* Second Person.

Bus. A conductor or group of conductors that serve as a common connection for two or more circuits.

Cable Tray. A unit or assembly of units or sections and associated fittings, forming a rigid structural system used to support cables. This includes ladder, troughs, channels, solid bottom trays, and other similar structures. Cable trays are not raceways.

Can. Denotes a possibility.

CFR. Code of Federal Regulations.

Circuit. A conductor or system of conductors through which an electric current is intended to flow.

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

Clearance (for hazard). Dimensional separation from energized or potentially energized conductors and/or exposed electrical equipment.

Clearance (for work). Authorization to perform specified work (such as switching at SNL/CA) or permission to enter a restricted area (not security related).

Conductor. A material usually in the form of a wire, cable, or bus bar suitable for carrying electric current.

Confined Space. A working space such as a manhole, vault, tunnel, tank, shaft, enclosed vessel, storm sewer, or elevator pit that has a limited means of egress or entry, and is designed for periodic personnel entry.

Contractor. An organization or person not a part of the contracting entity, hired to perform a particular function or provide a particular product.

CPR. Cardiopulmonary Resuscitation.

Critical Systems. Systems whose de-energization would result in increased or additional hazards such as the interruption of life support equipment, deactivation of emergency alarm systems, shutdown of hazardous location ventilation equipment, removal of illumination for an area, or loss to classified or critical operations.

DC. Direct Current (*compare with* AC).

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. A conductor can only be considered deenergized if a deliberate connection is made between that conductor and ground, or the disconnecting means are locked out.

Electrical Equipment. Equipment that uses electrical energy in its operation. Includes electrical and/or electronic equipment and/or systems.

Electrical Hazard. A potential source of personnel injury, resulting either directly or indirectly from the use of an electrical energy source.

Electrically Safe Work Condition. A condition achieved when an electrical worker has identified and eliminated all sources of electrical energy, visually verified those sources are removed, locked out and tagged out the equipment/system, verified those sources are de-energized using a tested voltmeter, and grounded the conductors or parts if necessary. This process is specifically identified in NFPA 70E, Section 120.1.

Electrical Worker. A job title for a qualified person assigned to electrical or electronic work.

Energized. Electrically connected to a source of potential difference, or electrically charged to a potential significantly different from that of earth in the vicinity (>= 50 volts).

Energized Electrical Work. Any entry for any reason into the limited approach boundary as defined in chapter 2 of this manual.

ES&H. Environment, Safety and Health.

Exposed. Not isolated, insulated, or guarded.

Facility Circuit Breaker. Circuit breakers in building panel boards not specifically identified as user circuit breakers (*see also* Circuit Breaker).

Flash Protection Boundary. An approach limit at a distance from exposed live parts within which a person could receive a second degree burn if an electrical arc flash were to occur. This boundary signifies the requirement for flash PPE.

FMEC. Factory Mutual Engineering Corporation (*see* Approved).

FRP. Fiberglass-reinformed plastic.

Ground. A connection to earth of sufficiently low impedance and having sufficient current carrying capacity to prevent the build-up of voltages which could result in undue hazard to connected equipment or to persons. All ground systems (both facility and R&D) must be connected to assure a common electrical potential.

Ground Fault Circuit Interrupter (GFCI). A device used to detect current leakage to ground at the 5±1 mA level and which acts to interrupt the circuit for personnel protection purposes.

Grounding Hook. A device for making a temporary connection to discharge and ground the energy sources in hazardous electrical equipment. It consists of a bare copper rod shaped like a shepherd's hook at one end, an insulated handle, and a suitable bare flexible copper cable (securely connected at the hook end) which is clearly visible through its insulating sheath and securely connected to an equipment or building ground.

Guarded. Physically 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 personnel or objects. Conductors which are insulated, but are not otherwise protected, are not considered as guarded.

Hazardous Atmosphere. An atmosphere presenting a potential for death, disablement, injury, or acute illness.

Hazardous Situation. A hazardous situation exists where there is the possibility of inadvertent, casual exposure to hazardous voltages.

Hazardous Voltages. When the nominal voltage equals or exceeds 50 volts, the circuit capacity is able to drive greater than 5 mA through a 1500 ohm load, and the worker is likely to be well grounded; or when the nominal voltage exceeds 400 V, the circuit capacity is 2 kVA or greater (or the overcurrent protection is 5 A or greater), and the circuit is exposed and uninsulated.

High Voltage. Voltage above 600 volts phase to phase or phase to ground.

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

Insulated Conductor. A conductor covered with a dielectric material having a rated insulating strength equal to or greater than the voltage of the circuit in which it is used.

Isolated

1. Any object that is not readily accessible to persons unless special means of access are made.

2. All sources of electrical energy (i.e., all isolation devices locked open and any fuses associated with potential devices or other power supplies) have been removed.

Limited Approach Boundary. An approach limit at a distance from an exposed live part within which a shock hazard exists. No unqualified electrical worker may enter this area unless escorted by a qualified electrical worker and made aware of the hazards involved.

Listed. Equipment or materials included in a list published by an organization acceptable to OSHA that states either that the equipment or material meets appropriate standards, or it has been tested and found suitable for use in a specified manner.

Live-Line Tools. Live-line tools are any wooden or fiberglass rod or pole rated for the voltage involved and used to touch or come in proximity to energized or potentially energized, conductors or exposed electrical equipment parts. (It is recommended that only fiberglass material be utilized).

Lockout. The placement of a lockout device on an energy isolating device in accordance with Sandia's established lockout/tagout procedure, ensuring that the energy isolating device and the equipment being controlled cannot be operated until the lockout device is removed.

Lockout Device. A device that utilizes a keyed lock or other positive means to hold an energy isolating device in the safe position to prevent the energizing of a machine or equipment.

Low Voltage. AC voltage up to and including 600 volts, phase to phase or phase to ground.

Mobile Equipment. Includes but is not limited to cranes, line trucks, aerial lifts and similar types of equipment.

Nationally Recognized Testing Laboratory (NRTL). A laboratory specifically designated by the US Occupational Safety and Health Administration to test and list equipment as safe for its intended use (OSHA approved NRTLs).

NEC. National Electrical Code (NFPA 70).

NESC. National Electrical Safety Code.

NFPA. National Fire Protection Association.

Noninsulated Conductor. A conductor that is neither covered nor insulated and has no insulating properties other than air.

100% Rule. No switching, isolating, testing, or working on energized circuits, nor applying personnel-safety grounds shall be performed unless all participating qualified individuals are in 100% agreement of the work to be performed and the sequence in which it should be done.

OP. Operating procedure.

OSHA. Occupational Safety and Health Act.

Panelboard. A single panel, frame, or assembly of panels which have switches, buses, instruments, overcurrent, and other protective devices mounted on the face or back.

PBI. Polybenzimidazole.

Person in Charge (PIC). A Department Manager, Team Leader, Project Leader, or a person appointed by them to be in charge of a work project. The PIC may be either an SNL employee or a contractor.

Potentially Energized. A noninsulated conductor or device, that by nature of design or location, may be energized by an adjacent energized conductor, switch closure, or back-feed.

Power Capacitor. A capacitor capable of storing 10 Joules or greater.

PPE. Personal protective equipment.

Preliminary Hazard Assessment. A qualitative assessment of the hazards associated with a laboratory, facility, or project activity.

Prohibited Approach Boundary. An approach limit at a distance from an exposed live

part within which work is considered the same as making contact with the live part.

Proximity. Close enough for a person to reach, fall into, or otherwise accidentally contact energized or potentially energized conductors or exposed electrical equipment.

Qualified (Person, Personnel, Worker). Personnel who are properly trained and knowledgeable about the construction, maintenance, and operation of the electric powered systems and equipment on which they will work, the hazards involved, and applicable safety related work practices.

Raceway. An enclosed system approved for routing and protecting wires, cables, or busbars (for example conduit, wireways, and ducts).

R&D. Research & Development.

Recommended. Not mandatory, but best management practice to minimize hazards in the workplace.

Restricted Approach Boundary. An approach limit at a distance from an exposed live part within which there is an increased risk of shock, due to electrical arc over combined with inadvertent movement, for personnel working in close proximity to the live part. This boundary signifies the requirement for shock PPE. No unqualified electrical worker may cross this boundary under any circumstance.

RF. Radio frequency.

Rubber Insulating Equipment. Insulating material that includes elastomers and elastomer compounds, regardless of origin.

Safe Work Permit (SWP). A work permit used to control hazards for activities performed **only once** or activities which fall outside the scope of existing ES&H SOPs because of unforeseeable conditions or events.

Safety Ground Set. A set of clamps with appropriate cables and connectors used to connect multiple points to ground.

Safety Interlock. An electrical or mechanical device that prevents operation of equipment when hazardous areas, enclosures, or equipment are accessed.

Safety Watch. A person whose specific duties are to observe the workers and operations being performed, prevent careless acts, quickly deenergize the equipment in emergencies, and alert emergency rescue personnel. A safety watch shall be within both sight and hearing, and less than 50 ft from the worker. When overhead work is performed, the safety watch shall be within 50 ft of the base of the lifting device. The safety watch shall have no other duties that preclude observing and rendering aid if necessary.

Second Person (The "Buddy System"). A person whose duties include maintaining contact with personnel performing hazardous operations in order to assist them in case of an emergency. The second person should not be directly involved in the hazardous operation, but should be familiar with the hazards involved and know how to respond to emergency situations. The Second Person is typically used in R&D type operations.

SOP. Standard Operating Procedure.

Static Grounded Area. An area where conductive floors and working surfaces are intentionally grounded for the purpose of reducing static electricity accumulation on people and materials.

SWHAS. Sandia Workplace Hazards Awareness System.

Tagout. The placement of a tagout device on an energy isolating device such as a safety switch or valve in accordance with an established procedure, to indicate that the energy isolating device and the equipment being controlled may not be operated until the tagout device is removed. For more information see Chapter 4, Section C, "Lockout/ Tagout (LOTO)," and ES&H Manual Supplement GN470037, "Administrative Control Procedures."

Tagout Device. A prominent warning device, such as a tag and a means of attachment, which can be securely fastened to an energy isolating device to indicate that the energy isolating device and the equipment being controlled may not be operated until the tagout device is removed. *See also* Tagout.

Ten Foot Rule. A rule that the minimum physical clearance between power lines or exposed electrical parts and any part of mobile equipment, machinery, personnel, or conductive objects carried by personnel shall be ten ft (305 cm) for power lines rated 50 kV or below. This distance shall increase 4 inches (10 cm) for each 10 kV increase above 50 kV.

TEDS. Training education and development system.

UL. Underwriters Laboratories, Inc.

Working Near (live parts) **.** Any activity inside the limited approach boundary.

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Corporate Process Requirement No: CPR400.1.1.28
Sponsor: Dori Ellis, 4000, Acting

Revision Date: March 14, 2007
Replaces Document Dated: October 9, 2006

Electrical Safety Manual

REFERENCES

Subject Matter Expert: Mark McNellis; CA Counterpart: Herman Armijo
MN471004, Issue K
Revision Date: March 14, 2007; Replaces Document Dated: October 9, 2006
Review Date: October 5, 2006

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* Indicates a substantive change

Requirements Source Documents

ANSI (American National Standards Institute)

ANSI A10.31, *Construction and Demolition - Digger Derricks - Safety Requirements, Definitions, and Specifications*, 1987.
ANSI/SIA A92.2, *Vehicle-Mounted Elevating and Rotating Aerial Devices*, 1990.
ANSI C1, (See NFPA - *National Electric Code*), 1999.
ANSI C2, *National Electrical Safety Code*, 2006.
ANSI UL 45, *Portable Electric Tools*, 1991.
ANSI Z41, *Standard for Safety-Toe Footware*, 1991.
ANSI Z87.1, *Practice for Occupational and Educational Eye and Face Protection*, 1989.
ANSI Z89.1, *Safety Requirements for Industrial Head Protection*, 1986.

ASTM (American Society for Testing and Materials)

Standards for Electrical Protective Equipment for Workers

ASTM D120 Rev. A, 1994, *Standard Specification for Rubber Insulating Gloves*, 1994.
ASTM D178, *Standard Specification for Rubber Insulating Matting*, 1993.
ASTM D1048, *Standard Specification for Rubber Insulating Blankets*, 1993.
ASTM D1049, *Standard Specification for Rubber Insulating Covers*, 1993.
ASTM D1050, *Standard Specification for Rubber Insulating Line Hose*, 1990.
ASTM D1051, *Standard Specification for Rubber Insulating Sleeves*, 1995.
ASTM F478, *Standard Specification for In-Service Care of Insulating Line Hose and Covers*, 1992.
ASTM F479, *Standard Specification for In-Service Care of Insulating Blankets*, 1995.
ASTM F496 Rev. B, *Standard Specification for the In-Service Care of Insulating Gloves and Sleeves*, 1991.
ASTM F711, *Standard Specification for Fiberglass-Reinforced Plastic (FRP) Rod and Tube Used in Live-Line Tools*, 1989.
ASTM F914, *Standard Test Method for Acoustic Emission for Insulated Aerial Personnel Devices*, 1991.

CFR (Code of Federal Regulations)

29 CFR 1910, *Occupational Safety and Health Standards*, (Volumes 1 and 2).
29 CFR 1926, Safety and Health Regulations for Construction.

DOE (Department of Energy)

DOE M 440.1-A, *DOE Explosives Safety Manual*
DOE O 420.1B, *Facility Safety*.
DOE O 440.1A,*Worker Protection Management for DOE Federal and Contractor Employees*.
DOE-HDBK-1092-2004, *DOE Electrical Safety Handbook, 2004.*

NFPA (National Fire Protection Association)

NFPA 70, *National Electrical Code (NEC)*, 2005.
NFPA 70E, *Electrical Safety Requirements for Employee Work Places*, 2004.
NFPA 495, *Explosive Material Code*, 2006.
NFPA 780, *Lightning Protection Code*, 1997.

Implementing Documents

Sandia National Laboratories

SNL, CPR400.1.1, MN471001, *ES&H Manual*.
SNL, CPR400.1.1.31, MN471011, *Explosives Safety Manual*.
SNL, AOP 06-05, *Electrical Equipment Approval Guidelines*.

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MN471004 - Electrical Safety Manual

ATTACHMENT A-1– ACCEPTED MANUFACTURER UNLISTED ELECTRICAL EQUIPMENT APPROVAL FORM

Subject Matter Expert: Mark McNellis; CA Counterpart: Herman Armijo
MN471004, Issue K
Revision Date: March 14, 2007; Replaces Document Dated: October 9, 2006
Review Date: October 5, 2006

The Accepted Manufacturer Unlisted Electrical Equipment Approval Form shall be filled out by an Equipment Inspector and submitted to Mark McNellis for the required approval to use any unlisted electrical equipment from an accepted manufacturer.

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MN471004 - Electrical Safety Manual

ATTACHMENT A-2 – OTHER MANUFACTURER EQUIPMENT, IN-HOUSE BUILT EQUIPMENT OR MODIFIED NRTL-LISTED ELECTRICAL EQUIPMENT APPROVAL FORM

Subject Matter Expert: Mark McNellis; CA Counterpart: Herman Armijo
MN471004, Issue K
Revision Date: March 14, 2007; Replaces Document Dated: October 9, 2006
Review Date: October 5, 2006

The Other Manufacturer Equipment, In-House Built Equipment or Modified NRTL-Listed Electrical Equipment Approval Form shall be filled out by an Equipment Inspector and submitted to Mark McNellis for the required approval to use any of the following:

- Electrical equipment from a manufacturer that is not an “Accepted Manufacturer,” as defined in the SNL Electrical Equipment Approval Guidelines.
- Electrical equipment that was built in-house
- NRTL-listed electrical equipment that has been modified

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MN471004 - Electrical Safety Manual

ATTACHMENT A-3 – ELECTRICAL EQUIPMENT RACKS APPROVAL FORM

Subject Matter Expert: Mark McNellis; CA Counterpart: Herman Armijo
MN471004, Issue K
Revision Date: March 14, 2007; Replaces Document Dated: October 9, 2006
Review Date: October 5, 2006

The Electrical Equipment Racks Approval Form shall be filled out by an Equipment Inspector and submitted to Mark McNellis for the required approval to use any electrical equipment rack that is new (to be installed) or for any Electrical Equipment Rack that has been altered in any of the following ways:

- Modified
- Damaged
- Repaired

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