Document Hierarchy:	Functional Series
Document Number:	Criterion 504 R3
Approval Date:	03/ 09/ 2010
Effective Date:	03/ 15/ 2010
Supersedes:	Criterion 504 R2

CONDUCT OF MAINTENANCE P950
Operations and Maintenance Manual

TITLE: LOW VOLTAGE ELECTRICAL EQUIPMENT

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RECORD OF REVISIONS

Revision No.	Date	Description
0	12/ 09/ 99	Initial Issue
1	09/ 19/ 01	Incorporates a review of ORPS & NRC lesson learned from 1/ 1/ 96 to 4/ 1/ 2001
2	08/ 01/ 05	Incorporate Case No. 8, "Flash Arc Results in Flash Burns" under Section 11.1.1.7
		Change all reference and statements from "FWO-SEM" to "FM-MSE"
		Change Low Voltage Electrical Equipment Major Maintenance references in Table 1 under "General Loads" to include ML4 equipment that may be included in the Master Equipment List (MEL)
3	12/ 01/ 09	Changes reflect Division re-organization
		Changes references to reflect IMP 951-1 to P951-1
		Remove DOE 430.1B references from Section 1

TABLE OF CONTENTS

1.0 PURPOSE 1
2.0 SCOPE 1
2.1 Low Voltage Electrical Distribution Systems 1
3.0 ACRONYMS AND DEFINITIONS 3
3.1 Acronyms 3
3.2 Definitions 3
4.0 RESPONSIBILITIES 5
4.1 MSS Division Leader 5
4.2 MSS- Maintenance Programs (MP) 6
4.3 Facility Operations Director (FOD) 6
4.4 Operations Manager (OM) 6
4.5 Maintenance Manager (MM) 6
4.6 Authority Having Jurisdiction (AHJ) 6
5.0 PRECAUTIONS AND LIMITATIONS 7
5.1 Precautions 7
5.2 Limitations 8
6.0 REQUIREMENTS 8
6.1 Operations Requirements 8
6.2 Maintenance Requirements 10
7.0 Recommendations AND GOOD PRACTICES 15
7.1 Operations Safety Audit Checklist 15
8.0 Guidance 21
8.1 Operations Guidance 21
8.2 Maintenance Guidance 22
9.0 required DOCUMENTATION 25
9.1 Maintenance and Testing History 25
10.0 REFERENCES 26

CRITERION 504

LOW VOLTAGE ELECTRICAL EQUIPMENT

1.0 PURPOSE

The purpose of this Criterion is to establish the minimum requirements and best practices for operation and maintenance of Low Voltage Electrical Distribution Systems at LANL. This document addresses the requirements of P 951-LANL Conduct of Maintenance Manual by defining the minimum maintenance criteria for structures, systems, and components that it covers. The criterion lists requirements that are based on codes, standards, contract commitments, lessons learned, or business case. It also lists recommendations based on industry practices, operational experience, or business case. Guidance for implementation of the requirements and recommendations is also provided.

2.0 SCOPE

The scope of this Criterion includes the periodic inspection, testing and preventive and predictive maintenance (ITM) of Low Voltage Electrical Distribution Systems at all nuclear and non-nuclear LANL facilities. This Criterion does not address corrective maintenance actions required to repair or replace equipment.

2.1 Low Voltage Electrical Distribution Systems

Low voltage – 600 Volts and less, Alternating Current (AC) electrical distribution apparatuses including but not limited to the following:

- Switchgear
- Switchboards
- Panelboards
- Lighting Panels
- Metering
- Load Centers
- Motor Control Centers
- Transformers
- Substations
- Wires
- Cables
- Buses
- Relays
- Fuses
- Grounding Systems
- Capacitors
- Reactors
- Surge Arrestors/ Protective Devices
- Circuit Breakers
- Protective Relays
- Metal Enclosed Busway

Reference the following Figure 2.1 for further scope explanation.

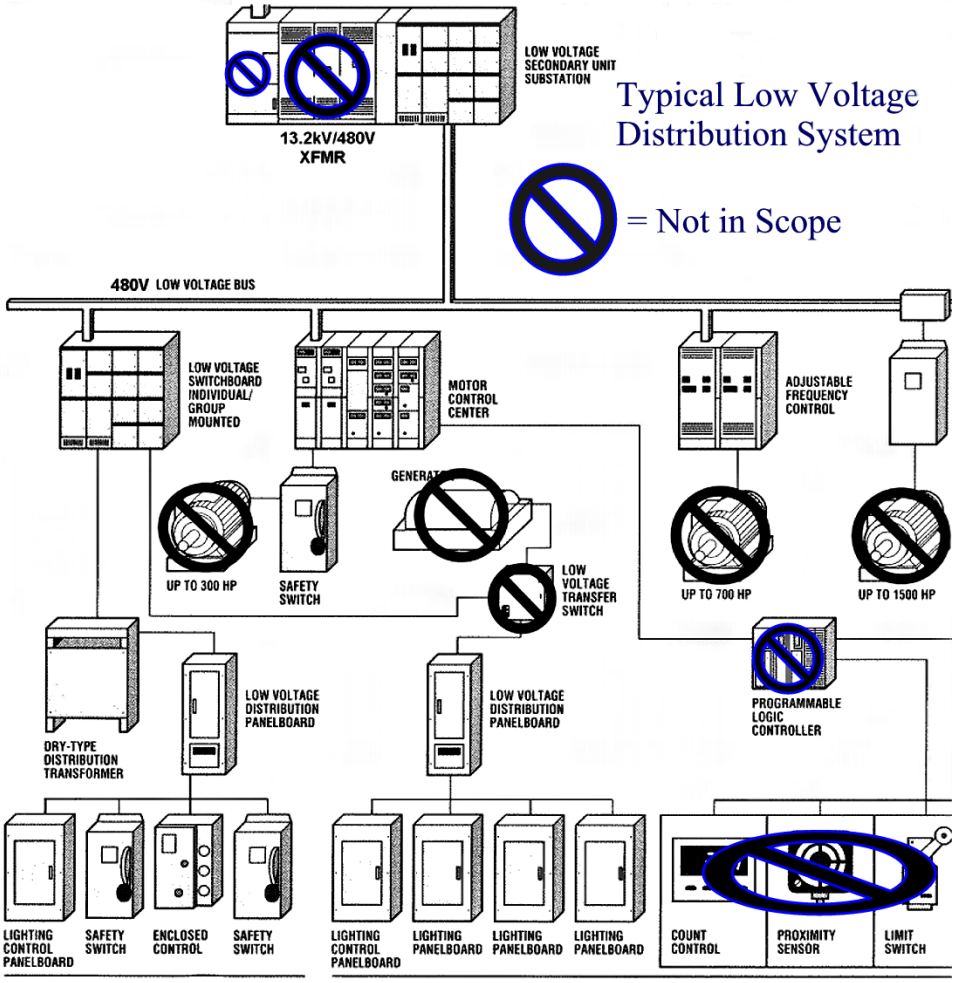

Figure 2.1 Low Voltage Electrical Distribution Equipment

NOTE: Operational and Maintenance Criterion for Motors are found in O&M Criterion 510 "Electrical Motors". Operational and Maintenance Criterion for Generators and Transfer Switches are found in O&M Criterion 506 "Emergency and Standby Power Systems." Operational and Maintenance Criterion for Uninterruptible Power Supplies (UPS) are found in O&M Criterion 505 "Uninterruptible Power Supply Systems."

3.0 ACRONYMS AND DEFINITIONS

3.1 Acronyms

ANSI	American National Standards Institute
CFR	Code of Federal Regulations
CDD	Circuit Disconnect Device
DOE	Department of Energy
EPM	Electrical Preventive Maintenance
ETT	Electrical Testing Technician
IEEE	Institute of Electrical and Electronic Engineers
ITM	Inspection, Test and Maintenance
LANS	Los Alamos National Security, LLC
MEL	Master Equipment List
MSS-MP	Maintenance and Site Services Maintenance Programs
NEC	National Electrical Code
NEMA	National Electrical Manufactures Association
NETA	International Electrical Testing Association
NFPA	National Fire Protection Association
PPE	Personal Protective Equipment
PP&PE	Personal Property and Programmatic Equipment
RP&IE	Real Property and Installed Equipment
SSC	Structures, Systems, and Components

3.2 Definitions

Busway

A grounded metal enclosure containing factory-mounted, bare or insulated conductors, which are usually copper, or aluminum bars, rods, or tubes. (NEC 2008 Article 368-2.)

Branch Circuit

A circuit that supplies a number of outlets for lighting, and appliances. (2008 NEC Article 100 I.)

Capacitor

A device that consists essentially of two conductors (such as parallel metal plates) insulated from each other by a dielectric and which introduces capacitance into a circuit, stores electrical energy, blocks the flow of direct current, and permits the flow of alternating current to a degree dependent on the capacitor's capacitance and the

current frequency. Symbolized as "C." (McGraw-Hill "Dictionary of Scientific and Technical Terms" 5th Edition.)

Circuit Disconnect Device (Disconnecting Means)

A device or group of devices by which the conductors of a circuit can be disconnected from their source of supply. (2008 NEC Article 100 I.)

Feeder Circuit

Electrical Circuit between the service equipment, the source of a separately derived system, or other power supply source and the final branch-circuit overcurrent device. (2008 NEC Article 100 I.)

Lighting Panel

A lighting panel is one having more than 10 percent of its overcurrent devices protecting lighting and appliance branch circuits. (NEC 2005 Article 408-34 (a))

Metering

Electrical devices utilized to provide measurement of any one of the many quantities by which electricity is characterized. (McGraw-Hill "Dictionary of Scientific and Technical Terms" 5th Edition.)

Motor Control Center

An assembly of one or more enclosed sections having a common power bus and principally containing motor control units. (2008 NEC Article 100 I.)

Panelboard

A single panel or group of panel units designed for assembly in the form of a single panel; including buses, automatic overcurrent devices, and equipped with or without switches for the control of light, heat, or power circuits; designed to be placed in a cabinet or cutout box placed in or against a wall or partition and accessible only from the front. (2008 NEC Article 100 I.)

Protective Relay

A relay whose function is to detect defective lines or apparatus or other power-system conditions of an abnormal or dangerous nature and to initiate appropriate control circuit action. *Note:* A protective relay may be classified according to its input quantities, operating principle, or performance characteristics. (ANSI/ IEEE Standard 100 "IEEE Standard Dictionary of Electrical and Electronics Terms.")

Substation

An area or group of equipment containing switches, circuit breakers, buses, and transformers for switching power circuits and to transform power from one voltage

to another or from one system to another. (ANSI/ IEEE Standard 100 "IEEE Standard Dictionary for Electrical and Electronics Terms.")

Surge Arrestor

A protective device for limiting surge voltages on equipment by discharging or bypassing surge current; it also prevents continued flow of follow current while remaining capable of repeating these functions. (2008 NEC Article 100 I.)

Surge Protective Device (SPD)

A protective device for limiting transient voltages by diverting or limiting surge current; it prevents continued flow of follow current while remaining capable of repeating these(2008 NEC Article 100 I.)

Switchboard

A large single panel, frame, or assembly of panels on which are mounted, on the face or back, or both, switches overcurrent and other protective devices, buses, and usually instruments. Switchboards are generally accessible from the rear as well as from the front and are not intended to be installed in cabinets. (2008 NEC Article 100 I.)

Switchgear

Assembled equipment (indoor or outdoor) including, but not limited to, one of the following categories: switching, interrupting, control, instrumentation, metering, protective, and regulating devices; together with their supporting structures, enclosures, conductors, electrical interconnections, and accessories. (IEEE Standard 100 "ANSI/ IEEE Standard Dictionary for Electrical and Electronics Terms.")

Transformer

A static electric device consisting of a winding or two or more coupled windings, with or without a magnetic core, for introducing mutual coupling between electric circuits. Transformers are extensively used in electric power systems to transfer power by electromagnetic induction between circuits at the same frequency, usually with changed values of voltage and current. (ANSI/ IEEE Standard 100 "IEEE Standard Dictionary for Electrical and Electronics Terms.")

4.0 RESPONSIBILITIES

4.1 MSS Division Leader

Receives and approves or rejects, in conjunction with the AHJ, requests for variances from this criterion. Maintains the record of decisions for all variance requests.

4.2 MSS- Maintenance Programs (MP)

MSS-MP is responsible for the technical content of this Criterion and monitoring the applicability and the implementation status of this Criteria and either assisting the organizations that are not applying or meeting the implementation expectations contained herein or elevating their concerns to the director(s).

Basis: P 951-1, LANL Conduct of Maintenance Manual, Section 2, Roles, Responsibilities, Authorities, and Accountability. MSS-MP should provide technical assistance to support implementation of this Criterion.

4.3 Facility Operations Director (FOD)

Responsible for implementation of this O&M Criterion for identified systems/ equipment within their facility boundaries.

4.4 Operations Manager (OM)

Responsible to the FOD for implementing operation portions of this Criterion and for coordinating transfer of systems/ equipment to the Maintenance Manager for maintenance activities. The OM with concurrence of the FOD will prioritize implementation within budget allocations.

4.5 Maintenance Manager (MM)

Responsible to the FOD and the MSS-Division Leader for implementing the maintenance portions of this Criterion and for coordinating the transfer of systems/ equipment to the Operations Manager at the conclusion of maintenance activities. The MM with concurrence of the FOD will prioritize implementation within budget allocations.

4.6 Authority Having Jurisdiction (AHJ)

The LANS Electrical AHJ is responsible for providing a decision on specific technical questions regarding the systems or equipment relevant to this criterion.

5.0 PRECAUTIONS AND LIMITATIONS

5.1 Precautions

This section is not intended to identify all applicable precautions necessary for implementation of this Criterion. A compilation of all applicable precautions shall be contained in the implementing procedure(s) or work control authorization documents. The following precautions are intended only to assist the author of a procedure or work control document in the identification of hazards/ precautions that may not be immediately obvious.

You may refer to the LANL Electrical Safety Committee Web Site http:/ / int.lanl.gov/ safety/ esc/ esc.shtml for incident/ injury reports.

Personnel safety should be given prime consideration in low voltage electrical distribution system operations and maintenance. Safety rules should be instituted and practiced to prevent injury to personnel, both persons who are performing tasks and others who might be exposed to the hazards. The principal personnel danger from electricity is that of shock, electrocution and/ or severe burns from electrical arc or its effects.

Successful and safe operation of the low voltage electrical power distribution equipment is dependent upon proper storage, handling, installation, operation and maintenance. Neglecting certain fundamental installation and maintenance requirements may lead to personnel injury, the failure and loss of the electrical equipment, as well as possible damage to other property. Individuals operating or maintaining electrical equipment should be familiar with the requirements for identifying safe electrical installations.

Operations and maintenance of the low voltage electrical distribution system should be perform only by qualified personnel who are trained in safe operation and maintenance practices. All employees who face a risk of electrical hazard should be trained to understand the specific hazards associated with electrical energy and equipment.

All safety precautions outlined in manufacturer's instructions leaflets for specific low voltage electrical apparatuses must be observed at all times.

The use of a proper PPE based on approach and/ or flash boundaries shall be required.

Site-specific hazard analyses shall be performed, with pertinent notifications and necessary training prior to any major electrical low voltage maintenance testing and inspections. Loads affected by maintenance outages shall be pre-identified, especially critical loads.

5.2 Limitations

The intent of this Criterion is to identify the minimum requirements and recommendations for SSC operation and maintenance across the Laboratory. Each user is responsible for the identification and implementation of additional facility specific requirements and recommendations based on their authorization basis and unique equipment and conditions, (e.g., equipment history, manufacturer warranties, operating environment, vendor O&M requirements and guidance, etc.).

Nuclear facilities and moderate to high hazard non-nuclear facilities will typically have additional facility-specific requirements beyond those presented in this Criterion. Nuclear facilities should implement the requirements of DOE Order 433.1as the minimum programmatic requirements for a maintenance program. Additional requirements and recommendations for SSC operation and maintenance may be necessary to fully comply with the current DOE Order or Code of Federal Regulations (CFR) identified above.

6.0 REQUIREMENTS

Minimum requirements that Criterion users should follow are specified in this section. Requested variances to these requirements should be prepared and submitted to MSS-MP in accordance with P 951-1, LANL Conduct of Maintenance Manual for review and approval. The Criterion users are responsible for analysis of operational performance and SSC replacement or refurbishment based on this analysis. Laws, codes, contractual requirements, engineering judgment, safety matters, and operations and maintenance experience drive the requirements contained in this section.

6.1 Operations Requirements

6.1.1 *Electrical Distribution System Operator Requirements*

Only qualified electrical workers who have been authorized by an RLM will be permitted to operate low voltage electrical distribution equipment.

Basis: LANL Electrical Safety Program P 101-13

6.1.1.1 *Accessibility to and Identification of Electrical Equipment*

Assure proper housekeeping in Electrical Equipment rooms/ areas such that the areas in front of electrical equipment are kept clear of storage/ janitorial supplies, equipment, and other materials to allow for proper operation, maintenance, and emergency procedures.

Basis: DOE HDBK-1092-98 "DOE Handbook of Electrical Safety", Section 2.9, Working Space Around Electrical Equipment. NFPA 70 Article 110-26 I.

Assure component identification, equipment nameplates, and other required labels are properly installed and legible. Refer to LANL Master Specifications Section 26 0553, Identification for Electrical Systems, for electrical identification products, materials, and installation and Electrical Drawing ST-D5000-3 for preferred locations of electrical identification

Basis: LANL Engineering Standards Manual chapter 7 Electrical Section 5000 7.0 ISDE 341-2

6.1.1.2 *Operation of Circuit Protective Devices*

6.1.1.3 *Routine Opening and Closing of Circuits*

Load-rated switches, circuit breakers, or other devices specifically designed as disconnecting means shall be used for the opening, reversing, or closing of circuits under load conditions. Cable connectors not of the load-break type, fuses, terminal lugs, and cable splice connections shall not be permitted to be used for such purposes, except in an emergency.

Basis: NFPA 70E "Standard for Electrical Safety in the Workplace 2009 Edition" (Ref. 10.8).

6.1.1.4 *Re-closing Circuits after Protective Device Operation*

After a circuit is automatically de-energized (tripped) by a circuit protective device, the circuit shall not be manually re-energized (reset) until it has been determined that the equipment and circuit is fault free. When it is determined from the design of the circuit and the overcurrent devices involved that the automatic operation of a device was caused by an overload rather than a fault condition, examination of the circuit or connected equipment shall not be required before the circuit is re-energized. The repetitive manual re-closing of circuit breakers or re-energizing circuits through replaced fuses is prohibited.

Basis: NFPA 70E "Standard for Electrical Safety in the Workplace 2009 Edition". Electrical Identification

6.2 Maintenance Requirements

6.2.1 Electrical Testing Technician (ETT) Qualifications

All electrical testing technicians (ETT) engaged in electrical preventive maintenance (EPM) shall be trained, qualified and classified in accordance with ANSI NETA ETT. Exception, the ETT is not required to be certified per ANSI NETA ETT. The ETT's employer shall submit records of the above training, qualifications and classification for each ETT for verification by MSS-MP upon request.

6.2.1.1 The lead ETT for an EPM activity shall be classified a Level III "Certified Technician" minimum. He shall be responsible for evaluating test data and make judgments on the continued serviceability or non-serviceability of the specific equipment. The lead ETT shall advise the LANS STR of equipment that is judged non-serviceable and shall assist the STR in development and implementation of temporary contingency plans involving this equipment. The lead ETT is responsible for the preparation and delivery of a final report documenting the ITM performed and stating any recommendations resulting from the effort.

6.2.1.2 ETTs performing electrical tests and inspections for an EPM activity shall be classified a Level II "Assistant Technician" minimum. ETTs shall be knowledgeable concerning the apparatus and systems being tested. These individuals shall be capable of conducting the test in a safe manner and with complete knowledge of the hazards involved. They shall evaluate test data and make judgments on the continued serviceability or non-serviceability of the specific equipment and report negative judgments to the lead ETT.

6.2.1.3 Level I "Trainee Technician" may assist in EPM activities but shall not perform inspections or testing services.

6.2.1.4 Non Electrical workers shall not perform ITM of any kind.

Note: Corrective maintenance/ troubleshooting for low voltage electrical equipment is not defined as EPM and may be performed by journeymen electricians. Electricians must be trained and qualified use special testing equipment and testing techniques.

Basis: P 101-13 Electrical Safety Program (Ref. 10.10)

NFPA 70E "Standard for Electrical Safety in the Workplace 2009 Edition" 1
ANSI/ NETA ETT-2000 "Standard for Certification of Electrical Testing Technicians

6.2.2 *Low Voltage Electrical Equipment Maintenance Requirements*

6.2.2.1 Low voltage electrical equipment shall receive maintenance based on a categorized graded approach. Requirements of low voltage electrical equipment maintenance are established within the following elements:

- Develop an inventory of electrical equipment that needs to be maintained (MEL).
- A single line diagram for an electrical system shall be maintained and kept up-to-date.
- Electrical equipment maintenance instructions shall be established that identify activities to be done including test acceptance criterion and safe testing techniques to ensure reliable and safe operation utilizing NFPA 70B as the main guideline and NETA MTS-2000 as a reference.
- Establish and maintain a history record of electrical maintenance performance to identify failure trends (See Section 9)

Basis: Compliance with NFPA 70E "Standard for Electrical Safety in the Workplace 2009 Edition" and P 951"Conduct of Maintenance Major Maintenance Requirements Frequency Matrix

6.2.2.2 Careful and regular maintenance inspections are required to detect and clear any faults as early as possible before major damage can develop. Information provided by electrical equipment manufactures and national standards must be followed. The following Required Maintenance Frequency Matrix is provided.

Basis: Ensure safe operability in fulfillment of NFPA 70E "Standard for Electrical Safety Workplaces 2009 Edition" Part III Safety Related Maintenance Requirements, Chapter 1 Introduction. (Ref. 10.8).

NFPA 70B "Recommended Practice for Electrical Equipment Maintenance", for specific maintenance methods and tests

		##Frequency
		Not Less Than 3 yrs. Not More Than 5 yrs.
Low Voltage Electrical Equipment Major Maintenance		
Service Entrance Equipment / Indoor		
ML-1 & ML-2		X
General Loads - ML-3 & ML 4		X
Service Entrance Equipment / Outdoor		
ML-1 & ML-2		X
General Loads - ML-3 & ML 4		X
Dry-Type Transformers		
ML-1 & ML-2		X
General Loads - ML-3 & ML 4		X
Cables & Connections		
ML-1 & ML-2		X
General Loads - ML-3 & ML 4		X
Power Circuit Breakers (Air Break)		
All		X
Busways (Indoor & Outdoor)		
ML-1 & ML-2		X
General Loads - ML-3 & ML 4		X
Panelboards		
ML-1 & ML-2		X
General Loads - ML-3 & ML 4		X
Molded Case Circuit Breakers		
ML-1 & ML-2		X
General Loads - ML-3 & ML 4		X
Protective Relays (Coincide with respective Service Entrance Equip)		
Motor Control Centers		
All ** ML-1, ML-2, ML-3, ML-4		X
**** :** Minimum Manufacture Recommendations		
Note: Equipment required to be tested not shown in this matrix will use the frequency of its related equipment shown in this chart.		
## 3-5 yr frequency shown above is identified based upon trending and age of equip. Older equip requires more frequent testing, new equip less frequent testing. Problematic equip would require more frequent testing, etc.		

Table 1 Low Voltage Electrical Equipment Required Maintenance Matrix.

6.2.2.3 Required Electrical Equipment to Be Maintenance Tested

A. Protective Devices
- Fuses
- Protective Relays
- Overcurrent Trip Devices

B. Switchgear and Switchboard Assemblies

C. Power Transformers
- Dry Type
- Air-Cooled
- Low Voltage – 600V and less

D. Instrument Transformers
- Current Transformer
- Voltage Transformer
- Control Transformer

E. Power Cables
- 600V Maximum
- All cables utilized as feeder circuit cables
- All cables utilized to power motors 25hp and greater

F. Metal Enclosed Busways

G. Circuit Breakers
- Power/ Air
- Insulated Case – All feeder circuit breakers and branch circuit breakers 150 amp and greater. All circuit breakers identified as "critical load" (ML2)
- Molded Case – All feeder circuit breakers and branch circuit breakers 150 amp and greater. All circuit breaker identified as "Main Breakers". All circuit breakers identified as "critical load" (ML2)

H. Circuit Disconnect Devices (CDD)

I. Grounding Systems

J. Ground Fault Protection Systems

K. Motors 25hp and greater

L. Motor Control
- Motor Control Centers
- Motor Starters
- Motor Overload Protection for motors 25hp and greater

- Adjustable Speed Drive Systems

M. Low Voltage Surge Protection Devices

N. Electrical Metering Devices, i.e. Ammeter, Voltmeter, Watthour Meter, etc.

Guidelines, acceptance criteria, and directions on how testing will be performed on the above electrical equipment are identified within NFPA-70B Recommended Practice for Electrical Maintenance Chapter 18. NETA-MTS-2001 Maintenance Testing Specifications may be utilized for further reference. (Ref. 10.13 and Ref. 10.14)

Basis: NFPA 70E "Standard for Electrical Safety in the Workplaces 2009 Edition"

NFPA 70B "Recommended Practice for Electrical Equipment Maintenance Testing Instruments Calibrations

6.2.2.4 *Test Equipment Calibration*

Any organization performing electrical low voltage equipment maintenance inspection and testing at LANL shall have a calibration program that assures all applicable test instruments they utilize are calibrated within a rated accuracy. The accuracy shall be directly traceable to the National Institute of Standards and Technology (NIST) and shall have a maximum frequency of 12 months for digital field testing equipment and 6 months for analog field testing equipment.

Basis: NETA MTS-2001 "Maintenance Testing Specifications for Electrical Power Distribution Equipment and Systems"

7.0 RECOMMENDATIONS AND GOOD PRACTICES

7.1 Operations Safety Audit Checklist

The information provided in this section is recommended based on acceptable industry practices and should be implemented by each user based on his/ her unique application and operating history of the subject systems/ equipment.

7.1.1 This checklist provides an assessment of minimum recommendations needed to safely operate an electrical power distribution system. Refer to Section 8 for guidance and detail in the use of this checklist.

OPERATIONS SAFETY AUDIT CHECKLIST		
	YES	NO
One-line diagram exists		
One-line diagram is legible		
One-line diagram is correct		
All persons who operate the power system have easy access to the current one-line diagram		
Equipment is labeled correctly, legibly, and in accordance with the one-line diagram		
Persons who operate electrical equipment are trained for the voltage-class equipment they		
De-energizing procedures and equipment exist and are used		

Table 2 Operations Safety Audit Checklist

Basis: IEEE Std. 902 "Maintenance, Operation, and Safety of Industrial and Commercial Power Systems" Section 11.6 Maintenance Recommendations

7.1.2 Low Voltage Electrical Equipment Minor Maintenance (Minor in this case meaning maintenance that does not require a power outage to perform)

The following Minor Maintenance Matrix for low voltage electrical equipment contains recommendations to prevent major failures and detect conditions that may lead to dangerous conditions. It is recognized that an ideal maintenance program is reliability-based, unique to each facility/ structure and equipment. The following matrix can be used in conjunction with the multiplier chart to determine minor maintenance frequencies. The minor maintenance activities outlined in the matrix will provide value to an electrical preventative maintenance program

Low Voltage Electrical Equipment	Frequency			
Minor Maintenance & Testing (Energized)	**1 mo**	**1-3 mo**	**3-6 mo**	**1yr**
Utilize maintenance frequency multiplier chart below with this frequency matrix				
Service Entrance Switchgear / Indoor				
visual chk, overheating (thermo), indicating lamps, dry, clean, vermin				X
Service Entrance Switchgear / Outdoor				
visual chk, overheating (thermo), indicating lamps, dry, clean, vermin, space heaters on, filters, water entry			X	
Dry-Type Transformers				
visual chk, odor of overheating, loading				X
Cables & Connections				
observe for deformation, bend radius, thermo of connec.				X
Busways (Indoor & Outdoor)				
thermo for overheated joints, water drips, bus plugs secure, load within ampacity				X
Panelboards				
chk switches for overheating, loading, enclosure sealed, water drip			X	

Table 3 Minor Maintenance/Testing Matrix

Maintenance Frequency Multiplier Chart				
		EQUIPMENT CONDITION		
		POOR	AVERAGE	GOOD
Equipment Reliability Requirement	LOW	1.00	2.00	2.50
	MEDIUM	0.50	1.00	1.50
	HIGH	0.25	0.50	0.75

Condition Definition

Poor = Aged Equip > 20 yrs

Average = Dated Equip. 10-15 yrs

Good = Newer Equip. 0-10 yrs.

Table 4 Maintenance Frequency Multiplier Chart

Basis: NFPA 70B "Recommended Practice for Electrical Equipment Maintenance" Appendix H, Maintenance Guidelines and NETA MTS-2001 Appendix B "Frequency of Maintenance Tests" (Electrical Studies

7.1.3 Electrical Distribution System Analysis

7.1.3.1 Electrical studies such as Short Circuit analyses, Coordination Studies and Arc Flash Hazard analysis are an integral part of system design, operation, and maintenance. These electrical studies should be available and kept up-to-date. Engineering studies are thought to be part of an initial plant design, after which the subject can be forgotten. However, a number of factors can affect conditions in which these studies may no longer have validity. Among these conditions or changes are the following:

- Changes in the power supply capacity
- Changes in the size or percent impedance of a transformer
- Changes in electrical conductor sizes
- Addition of electrical motors to a system
- Changes in system operating conditions
- Replacement of circuit breakers, fuses, relays, or other trip devices
- Maintenance testing of trip devices, which requires moving of settings of trip devices to properly provide for functional testing and verification.

Basis: NFPA 70B "Recommended Practice for Electrical Equipment Maintenance" and ANSI/ NETA MTS-2007 "Standard for Maintenance Testing Specifications for Electrical Power Distribution Equipment and Systems" A short circuit study should be performed and/ or maintained of each component of the electrical system and the ability of the component to withstand and/ or interrupt the electrical current. An analysis of all possible operating scenarios should be included.

Basis: NFPA 70B "Recommended Practice for Electrical Equipment Maintenance" Chapter 6 ANSI/ NETA MTS-2007 "Standard for Maintenance Testing Specifications for Electrical Power Distribution Equipment and Systems" Section 6

7.1.3.2 The short circuit and coordination studies should be performed in accordance with the recommended practices and procedures set forth in ANSI/ IEEE standard 399 and the step-by-step procedures outlined in the short-circuit calculation chapters of IEEE standard 141 and ANSI/IEEE standard 242.

Basis: NFPA 70B "Recommended Practice for Electrical Equipment Maintenance" Chapter 6 and ANSI/ NETA MTS-2007 "Standard for Maintenance Testing Specifications for Electrical Power Distribution Equipment and Systems" Section 6 The results of the short-circuit study should be summarized in a final report containing the following items:

- Basis, description, purpose, and scope of the study.
- Tabulations of the data used to model the system components and a corresponding one-line diagram
- Descriptions of the scenarios evaluated and identification of the scenario used to evaluate equipment short-circuit ratings
- Tabulations of equipment short-circuit ratings versus available fault duties. The tabulations shall identify percentage of rated short-circuit and clearly note equipment with insufficient ratings.
- Conclusions and Recommendations

Basis: NFPA 70B "Recommended Practice for Electrical Equipment Maintenance" Chapter 6 and ANSI/ NETA MTS-2007 "Standard for Maintenance Testing Specifications for Electrical Power Distribution Equipment and Systems" Section 6 A short circuit study should be kept and reviewed whenever major changes to the electrical system are made.

Basis: NFPA 70B "Recommended Practice for Electrical Equipment Maintenance" Chapter 6 and ANSI/ NETA MTS-2007 "Standard for Maintenance Testing Specifications for Electrical Power Distribution Equipment and Systems" Section 6 Coordination of electrical protective devices determines characteristics, settings, or sizes that provide a balance between equipment protection and a selective device that is optimum for the electrical system. Settings of circuit breakers and trip relay devices are thereby provided through this study that allow for good controls and safer operations of electrical protective devices.

Basis: NFPA 70B "Recommended Practice for Electrical Equipment Maintenance" Section 4-2 and NETA MTS-2001 "Maintenance Testing Specifications" Sections 6.1 through 6.4.

Arc flash hazard analysis shall determine the Arc Flash Boundary and the personal protection equipment that people within the Arc Flash Boundary shall use.

Basis: NFPA 70E "Standard for Electrical Safety in the Workplace" Article 130.3 and ANSI/ NETA MTS-2007 "Standard for Maintenance Testing Specifications for Electrical Power Distribution Equipment and Systems" Section 6.

7.1.4 Maintenance Safety Audit Checklist

This checklist provides an assessment of minimum recommendations needed to safely maintain an electrical power system. Refer to Section 8 for guidance and detail in the use of this checklist.

MAINTENANCE SAFETY AUDIT CHECKLIST		
	YES	**NO**
One-line diagram exists		
One-line diagram is legible		
One-line diagram is correct		
All persons who maintain the power system have easy access to the current one-line diagram		
Equipment is labeled correctly, legibly, and in accordance with the one-line diagram		
Persons who maintain electrical equipment are trained for the voltage-class equipment they work on		
Equipment is properly grounded		
Grounding system is tested periodically		
Electrical system is free from corrosion		
Proper maintenance practices are followed, especially for fault-protection equipment		
Relay/Fuse coordination studies exist, devices calibrated to the recommended settings		

Table 5 Maintenance Safety Audit Checklist

Basis: IEEE Std. 902 "Maintenance, Operation, and Safety of Industrial and Commercial Power Systems" Section 11.6

7.1.5 Intrusion of Contaminants into Electrical Equipment

In case of water, steam, or other liquid being introduced into electrical low voltage equipment, the equipment should be immediately de-energized and evaluated for actual damage as well as potential future damage. This evaluation requires details of the intrusion. NEMA has a publication that provides general guidelines for this type of incident. The publication is located at http://www.nema.org/engineering/papers/waterdam.html. Further evaluations and tests must be performed prior to re-energizing the equipment to assure the equipment's safe and reliable functionality. Engineering expertise should be obtained for serious cases.

Basis: Engineering judgment, lessons learned, and NEMA Publication "Guidelines for Handling Water Damaged Electrical Equipment" in case of smoke, flashover, or fire, the equipment should be shut down and carefully evaluated, cleaned, tested, and repaired or replaced, based upon extent of the damage, prior to placing the equipment back in service. Engineering expertise should be obtained for serious cases.

Basis: Engineering judgment and lessons learned from Cerro Grande Fire. FRC-017 Rev. 0 "Electrical Inspection, Soot Laden Electrical Equipment" guidance.

8.0 GUIDANCE

8.1 Operations Guidance

- It is important that an operations organization periodically perform a self-assessment to determine how well their electrical safety procedures are being implemented. To be of value, the assessment must be objective. The goal here is to improve operation performances in a safe manner. The following bullets will provide further understanding and detail of the checklist items shown in Table 2.
- *An operating one-line diagram* – A power system can be operated safely if drawings are readily available that show all the components of the power system. The drawing must be correct, current, legible, and available to all that operate the electrical equipment.
- *Trained people operating the power system* – A simple task such as inserting a breaker in its cubicle is hazardous if the person performing the task is not familiar with the process. Inexperience or lack of training is a typical cause of major electrical accidents.
- *De-energizing work procedures* – All conductors of electricity are considered energized until proven de-energized and grounded. Follow LANL P 101-3 Lockout/ Tagout for Hazardous Energy Control *Energizing work procedures – Wri*tten procedures should be developed for re-energizing equipment. These procedures should include a sys*tematic outline of the work t*o be performed, protective equipment to be used, and familiarity with emergency-service procurement if a problem does occur. The LANL procedure that provides the direction for these activities is in P 101-13Electrical Safety Program"

  (Reference: IEEE Std 902 "Maintenance, Operation, and Safety of Industrial and Commercial Power Systems" Section 11.6)

8.2 Maintenance Guidance

- Compile a listing of all electrical plant equipment and systems (may be input into the facility MEL)
- Determine which equipment and systems are most critical and most important. Equipment is defined as critical if its failure to operate normally and under complete control will cause a serious threat to people, property, or a process/ product.
- Provide for a system for tracking what needs to be done and when (Schedule and Statement of Work)
- Provide the following information and material for the working maintenance group:
  - Inspection and testing procedure (including acceptance criteria)
  - As-Built single line diagrams
  - Equipment location plans
  - Complete nameplate date of equipment
  - Vendor catalogs
  - Proper testing data report forms (for analysis and trending of work)
  - Required spare parts to be kept on hand
- Obtain the following information:
  - Temporary power and lighting requirement for facility/ maintenance
  - Fire watch requirements (during power outages to fire panels)
  - Temporary power for security needs
  - Increased manpower requirements for: (most often after normal work hours
  - Radiation Control Technician coverage
  - Added security personnel coverage
  - Added Operations / Facility Coordinator coverage
  - Environment, Safety, and Health coverage (ESH)
  - Provide concise and complete records
  - Follow-through with necessary repairs, replacement, and adjustment is an absolute requirement.

  (Resource: NFPA 70B "Recommended Practice for Electrical Equipment Maintenance" Chapter 4 and Engineering judgment and lessons learned)

8.2.1.1 Other potential causes of equipment failure that can be detected and corrected by preventative maintenance programs deal with load changes or additions, circuit alterations, improperly set or improperly selected protective devices, and changing voltage conditions. (Resource NFPA 70B "Recommended Practice for Electrical Equipment Maintenance" Chapter 6) Regarding safety, a survey by Factory Mutual Research indicates that approximately one of every five industrial fires is of electrical origin and about one-half of these are due to lack of adequate maintenance. Without a preventative maintenance program, facility management assumes a much greater risk of a serious electrical failure and its consequences. (Resource IEEE Std 141 "Electric Power Distribution for Industrial Plants" Section 5.9.2)

8.2.2 Requirement of a Maintenance Inspection and Testing Procedure

8.2.2.1 Provided it has been reviewed and approved by MSS-MP, an acceptable preventive maintenance inspection and testing program for low voltage electrical equipment may be found in the A well written procedure has the following features:

- Concisely and accurately describes the goal of the work
- Identifies unusual conditions
- Provides a logical sequence
- Identifies required qualifications for personnel performing work
- Accurately identifies equipment to be operated, including placement of tags and/ or locks
- Identifies required calibration of equipment
- Identifies requirements and schedule for reporting of testing, maintenance activities
- Identifies vulnerable situations, including body position to minimize risk and personal protective equipment (PPE) to minimize injury if an accident occurs
- Is reviewed by more than one knowledgeable person
- Is reviewed, modified, and reviewed again if things do not go as planned
- Contains clear, concise, and accurate acceptance testing criteria.
- Provides clear, concise, and accurate reporting forms to record and trend testing data

(Resource: IEEE Std 902 "Maintenance, Operation, and Safety of Industrial and Commercial Power Systems" Section 10.3.1)

8.2.3 Maintenance Safety Audit Checklist

8.2.3.1 Periodically it is important that maintenance organizations perform a self-assessment to determine how well their electrical safety procedures are being implemented. To be of value, the assessments must be objective. The goal is to improve maintenance performances in a safe manner. The following bullets will provide further understanding and detail of the checklist items shown in Table 5.

- *An one-line diagram* – A power system can be inspected and safely tested and maintained if drawings are readily available that show all the components of the power system. The drawings must be correct, current, and legible, and available to all that inspect and test the electrical equipment.
- *Trained people performing maintenance and test inspections on a power system* – A simple task such as inserting a breaker in its cubicle is hazardous if the person performing the task is not well familiar with the process. Inexperience or lack of training is a typical cause of major electrical accidents.
- *Equipment is properly grounded* – For electrical low voltage power equipment to be safe; it must be grounded properly. Whenever an electrical component or apparatus, energized or not, is approached, a visual inspection for proper grounding is an important practice.
- *Electrical Equipment should be free from corrosion* – The condition of electrical equipment is important to maintain. Corrosion is especially a problem on outdoor electrical equipment, causing difficulties in operation and poor conductivity on connections, and can even lead to moisture intrusion when allowed to go unchecked.
- *Maintenance Practices* – Many electrical components never operate unless there is a fault in the system. There are two ways to determine if these components will operate correctly. The first way is to test them periodically. The second way is to wait until something causes a fault. The second method is not an acceptable or safe method.
- *Coordination Studies* – A coordination study on an electrical system allows for the selection or setting, or both, of protective devices so as to isolate only that portion of the system where the abnormality occurs.

  (Reference: IEEE Std 902 "Maintenance, Operation, and Safety of Industrial and Commercial Power Systems" Section 11.6 and IEEE Std 242 Section 1.3, pg. 39 "Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems").

9.0 REQUIRED DOCUMENTATION

9.1 Maintenance and Testing History

9.1.1 Corrective Work on electrical low voltage equipment shall be documented and maintained.

9.1.2 Maintenance Inspection and Testing Reports shall be documented and include the following:

- Summary of project
- Description of equipment tested
- Description of tests
- Analyses and recommendations

9.1.3 Test Data Records shall be documented and include the following requirements:

- Identification of the testing organization.
- Equipment Identification
- Humidity, temperature, and other conditions that may affect the results of the tests/ calibrations
- Date of inspections, tests, maintenance, and/ or calibrations.
- Identification of testing technician.
- Indication of inspections, tests, maintenance, and/ or calibrations to be performed and recorded.
- Indication of expected results when calibrations are to be performed.
- Indication of "as-found" and "as-left" results, as applicable.
- Sufficient spaces to allow all results and comments to be indicated.

9.1.4 The testing organization shall furnish a copy or copies of complete reports and data records to the owner/ facility manager as specified in a maintenance testing agreement/ contract.

Basis: Documentation of the parameters listed in 9.11, 9.12, 9.13, and 9.14 above satisfies the requirements of LPR 230-07-00, Criteria 2, (Ref. 10.12) which

states; "Maintenance activities, equipment problems, and inspection and test results are documented." Also testing reports and data records are identified in NETA MTS-2001 "Maintenance Testing Specifications for Electrical Power Distribution Equipment and Systems" Section 5.4. (Ref. 10.14)

10.0 REFERENCES

The following references, and associated revisions, were used in the development of this document.

10.1 DOE O 430.1A, Attachment 2 "Contractor Requirements Document" (Paragraph 2, Sections A through C), a requirement of Appendix G of the UC Contract.

10.2 NFPA 70 National Electric Code 2009 Article 364-2

10.3 McGraw-Hill "Dictionary of Scientific and Technical Terms" 5th Edition.

10.4 ANSI/ IEEE Standard 100 "IEEE Standard Dictionary of Electrical and Electronics Terms."

10.5 DOE Order 4330.4B, Maintenance Management Program, Section 3.4.9.

10.6 PD 311 Requirements System and Hierarchy

10.7 NFPA 70E "Standard for Electrical Safety Requirements for Employee Workplaces 2009 Edition"

10.8 P 101-13 Electrical Safety Program P951 Conduct of Maintenance

10.9 NFPA 70B 2006 edition, "Recommended Practice for Electrical Equipment Maintenance"

10.10 NETA-MTS-2007 "Standard for Maintenance Testing Specifications for Electrical Distribution Equipment and Systems"

10.11 LPR 260-01-00 "Inspection and Testing"

10.12 LPR 260-02-00 "Calibration"

10.13 SD 330 LANL Quality Assurance Program

10.14 DOE HDBK-1092-98 "DOE Handbook of Electrical Safety"

10.15 IEEE Std. 902-1998 "Maintenance, Operation, and Safety of Industrial and Commercial Power Systems"

10.16 ANSI/ IEEE Std. 399-1997 "Recommended Practice for Industrial and Commercial Power Systems Analysis"

10.17 IEEE Std. 141-1993 "Electric Power Distribution for Industrial Plants"

10.18 ANSI/ IEEE Std. 242-1986 "Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems"

10.19 NEMA Publication "Guidelines for Handling Water Damaged Electrical Equipment"

10.20 FRC-017 Rev. 0, "Electrical Inspection, Soot Laden Electrical Equipment"