CRITERION 504

LOW VOLTAGE ELECTRICAL EQUIPMENT

SIGNATURES

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RECORD OF REVISIONS

Revision No.	Date	Description
0	12/9/99	Initial Issue.
1	09/19/01	Incorporates a review of ORPS & NRC lessons 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
	08/01/05	Change all references and statements from "FWO-SEM" to "FM-MSE"
	08/01/05	Change Low Voltage Electrical Equipment Major Maintenance references in Table 1 under "General Loads" to include ML 4 equipment that may be included in the Master Equipment List (MEL)

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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 systems at LANL. This document addresses the requirements of LIR 230-05-01(Ref 10.2), "Operations and Maintenance Manual."

Implementation of these requirements and recommendations satisfies DOE Order 430.1A (Ref. 10.1), "Life Cycle Asset Management," Attachment 2 "Contractor Requirements Document," Paragraph 2, sections A through C, which in part require UC to "…maintain physical assets in a condition suitable for their intended purpose" and employ "preventive, predictive, and corrective maintenance to ensure physical asset availability for planned use and/or proper disposition." Compliance with DOE Order 430.1A is required by Appendix G of the UC Contract.

2.0 SCOPE

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

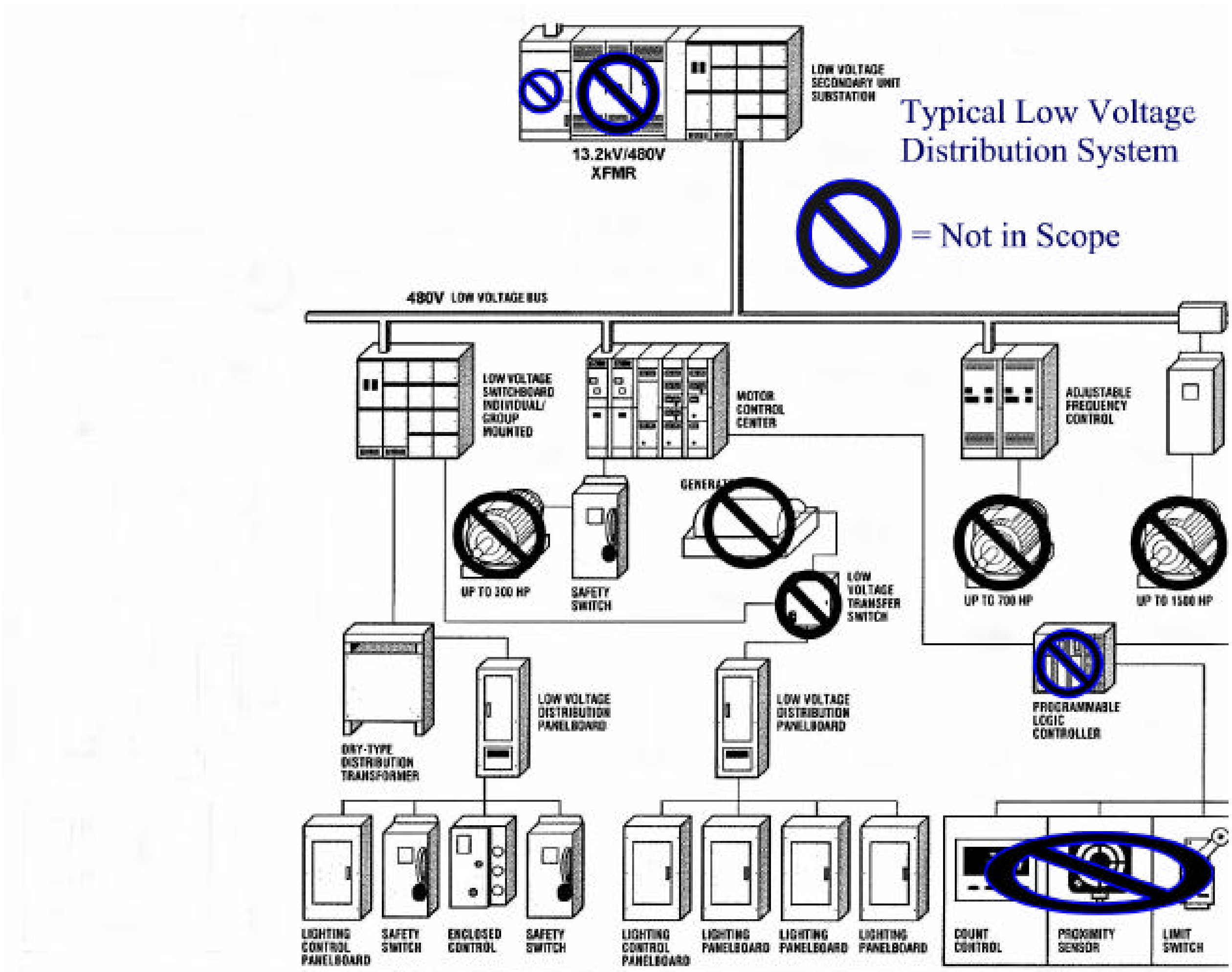
2.1 Low Voltage Electrical Systems

Low voltage – 600 Volts and less, Alternating Current (AC) electrical 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 Protectors/Arrestors
- Circuit Breakers
- Protective Relays
- Metal Enclosed Busway

Reference the following Figure 2.1 for further scope explanation.

Figure 2.1 Low Voltage Electrical 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 Preventative Maintenance
ETT	Electrical Testing Technician
IEEE	Institute of Electrical and Electronic Engineers
LIR	Laboratory Implementing Requirement
LPR	Laboratory Performance Requirement
MEL	Master Equipment List
MSE	Maintenance and Systems Engineering
NEC	National Electrical Code
NEMA	National Electrical Manufactures 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
UC	University of California

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 1999 Article 364-2.) (Ref. 10.3)

Branch Circuit

A circuit that supplies a number of outlets for lighting, and appliances.
(1999 NEC Article 100A.) (Ref. 10.3)

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.) (Ref. 10.4)

Circuit Disconnect Device

A device or group of devices by which the conductors of a circuit can be disconnected from their source of supply. (1999 NEC Article 100A.) (Ref. 10.3)

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. (1999 NEC Article 100A.) (Ref. 10.3)

Lighting Panel

A lighting panel is one having more than 10 percent of its overcurrent devices protecting lighting and appliance branch circuits. (NEC 1999 Article 384-14 (a)) (Ref. 10.3)

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.) (Ref. 10.4)

Motor Control Center

An assembly of one or more enclosed sections having a common power bus and principally containing motor control units. (1999 NEC Article 100A.) (Ref. 10.3)

Panel board

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. (1999 NEC Article 100 A.) (Ref. 10.3)

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.") (Ref. 10.5))

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.") (Ref. 10.5))

Surge Arrestor

A protective device designed primarily for connection between a conductor of an electrical system and ground to limit the magnitude of transient over-voltages on equipment. Also known as arrestor or lightning arrestor. (McGraw-Hill "Dictionary of Scientific and Technical Terms" 5th Edition.) (Ref. 10.4)

Surge Protector

A protective device for limiting surge voltages on equipment by discharging or bypassing surge current; it prevents continued flow of follow current to ground, and is capable of repeating these functions as specified. (ANSI/IEEE Standard 100 "IEEE Standard Dictionary of Electrical and Electronics Terms.") (Ref 10.5)

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. (1999 NEC Article 100 A.) (Ref 10.3)

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.") (Ref. 10.5)

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.") (Ref. 10.5)

4.0 RESPONSIBILITIES

4.1 FM-MSE, Maintenance and Systems Engineering (MSE)

4.1.1 FM-MSE is responsible for the technical content of this Criterion and assessing the proper implementation across the Laboratory.

4.1.2 FM-MSE shall provide technical assistance to support implementation of this Criterion.

4.2 Facility Manager (FM)

4.2.1 Responsible for operations and maintenance of institutional, or Real Property and Installed Equipment (RP&IE) under their jurisdiction, in accordance with the requirements of this document.

4.2.2 Responsible for operations and maintenance of those Personal Property and Programmatic Equipment (PP&PE) systems and equipment addressed by this document that may be assigned to the FM in accordance with the FMU-specific Facility/Tenant Agreement.

4.3 Group Leader

4.3.1 Responsible for operations and maintenance of those Personal Property and Programmatic Equipment (PP&PE) systems and equipment addressed by this document, which are under their jurisdiction.

4.3.2 Responsible for system performance analysis and subsequent replacement or refurbishment of assigned PP&PE based on sound Life Cycle Analysis techniques and system-specific performance requirements.

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 Appendix A "Electrical Operations and Maintenance Case Histories" that provides real-life hazards and accidents in performing operations and maintenance of low voltage electrical equipment.

5.1.1 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.

5.1.2 Prevention of human injury is the most important objective of electrical system protection. Interrupting devices shall have adequate capability and energized parts should be sufficiently enclosed or isolated so as not to expose personnel to explosion, fire, arcing, or shock.

5.1.3 Provide proper barricading, signing, and guarding for energized electrical systems and electrical testing apparatus during maintenance testing.

5.1.4 Only qualified personnel who have previous experience and training in the operation and maintenance of electrical power systems should perform tasks associated with the use and maintenance of electrical power equipment.

5.1.5 Successful and safe operation of 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.

5.1.6 No one should stand directly in front of a switch or circuit breaker while it is being operated. The person performing the switching should stand off to the side of the switch or breaker enclosure (preferably on the hinged side), keeping the head and body as far as possible from the enclosure door. While performing the switching, the face should be turned away and the arm extended as much as possible to operate the switch. The use of a protective sleeve or even a flash suit should be considered for equipment that is of questionable integrity.

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

5.1.8 When lifting large power breakers, use proper equipment designed to handle the weight and shape of the unit being lifted.

5.1.9 Prior to re-energizing any electrical equipment, a very thorough internal inspection shall be made to assure that all foreign objects and grounding mechanisms have been removed and that the equipment is in a "ready-to-energize" condition. Please reference LIR 402-860-01.0 "Lockout Tagout for Personal Safety".

5.1.10 Employees shall not be permitted to work on or near exposed energized parts unless they have the proper training for energized work, are wearing the appropriate personal protective equipment as described in NFPA 70E, "Standard for Electrical Safety Requirements for Employee Workplaces", and adequate illumination on the work area is present. Other objects, lack of illumination, or barriers and shields should never impair their visibility. Please reference LIR 402-600-01.1 "Electrical Safety".

5.1.11 Portable ladders used in areas with exposed energized parts shall have non-conductive side rails.

5.2 Limitations

The intent of this Criterion is to identify the minimum generic 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/or 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 shall implement the requirements of DOE Order 4330.4B (Ref. 10.6) (or 10 CFR 830.340, Maintenance Management, when issued) as 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 CFR identified above.

6.0 REQUIREMENTS

Minimum requirements that Criterion users shall follow are specified in this section. Requested variances to these requirements shall be prepared and submitted to FM-MSE in accordance with LIR 301-00-02 (Ref. 10.7), "Variances and Exceptions to Laboratory Operations Requirements," 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 Accessibility to Operate Electrical Equipment

6.1.1.1 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. (Ref. 10.18) NFPA 70 Article 110-26(b). (Ref. 10.3) Compliance with this NFPA code is required per Appendix G of the UC contract.

6.1.2 Routine Opening and Closing of Circuits

6.1.2.1 Load-rated switches, circuits 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 Requirements for Employee Workplaces 2000 Edition" Part II Safety Related Work Practices, Chapter 4 Use of Specific Safety-Related Equipment and Work Practices, 4-2.1 and 4-2.2 (Ref. 10.8). Compliance with this NFPA code is required per Appendix G of the UC contract.

6.1.3 Re-closing Circuits after Protective Device Operation

6.1.3.1 After a circuit is de-energized by a circuit protective device, the circuit shall not be manually re-energized until it has been determined that the equipment and circuit can be safely energized. The repetitive manual re-closing of circuit breakers or re-energizing circuits through replaced fuses is prohibited. 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.

Basis: NFPA 70E "Standard for Electrical Safety Requirements for Employee Workplaces 2000 Edition" Part II Safety Related Work Practices, Chapter 4 Use of Specific Safety-Related Equipment and Work Practices, 4-2.1 and 4-2.2 (Ref 10.8). Compliance with this NFPA code is required per Appendix G of the UC contract.

6.2 Maintenance Requirements

6.2.1 Electrical Testing Technician (ETT) Qualifications

6.2.1.1 During on-site major electrical maintenance testing, a lead electrical testing technician (ETT) directing and performing the work shall be at the inspection and testing location and hold one of the following or equivalent certifications: (equivalency certifications shall be verified by FM-MSE).

- NETA (International Electrical Testing Association)
  Certified Technician/Level III or Certified Senior Technician/Level IV
  (As per ANSI/NETA ETT-2000 requirements)
- NICET (National Institute for Certification in Engineering Technologies)
  Engineering Technician/Level III or Senior Engineering Technician/Level IV specifically in Electrical Testing Technology.

The lead ETT shall maintain proof of the above qualifications and be able to submit proof upon request.

The lead ETT shall direct and utilize technicians who are regularly employed at performing electrical testing services. Technicians performing electrical tests and inspections shall be knowledgeable concerning the apparatus and systems 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. Electrically unskilled employees shall not perform inspections or testing of any kind. Journeymen electricians may assist, but not perform inspections or testing services unless they meet the above requirements or certifications.

Note: Corrective maintenance/troubleshooting for low voltage electrical equipment may be performed by journeymen electricians qualified by training and experience with special testing equipment required to properly performing testing techniques.

Basis: LIR 402-600-01 "Electrical Safety" (Ref. 10.10)

NFPA 70E "Standard for Electrical Safety Requirements for Employee Workplaces 2000 Edition" Part III Safety Related Maintenance Requirements, Chapter 2 General Maintenance Requirements 2-1 (Ref. 10.8). Compliance with this NFPA code is required per Appendix G of the UC contract.

ANSI/NETA ETT-2000 "Standard for Certification of Electrical Testing Technicians." Specifying requisite levels of training, experience, and education for an evaluator of electrical power equipment is as important as the testing procedure itself. (Ref. 10.9)

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, where provided, 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 Requirements for Employee Workplaces 2000 Edition" Part III Safety Related Maintenance Requirements, Chapter2 General Maintenance Requirements and LIR 230-04-01 "Laboratory Maintenance Management Program". (Ref. 10.8 and 10.11). Compliance with this NFPA code is required per Appendix G of the UC contract.

6.2.3 Major Maintenance Requirements Frequency Matrix

6.2.3.1 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 Requirements for Employee Workplaces 2000 Edition" Part III Safety Related Maintenance Requirements, Chapter 1 Introduction. (Ref. 10.8). Compliance with this NFPA code is required per Appendix G of the UC contract.

NFPA 70B "Recommended Practice for Electrical Equipment Maintenance", for specific maintenance methods and tests. (Ref. 10.13)

	Frequency		
	3yr		3-6yr ##
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.			
## 3-6 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.

6.2.4 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 breakers identified as "critical load" (ML2)

H. Circuit Disconnect Devices (CDD)

I. Grounding Systems

J. Ground Fault Protection Systems

K. Motor Control
- Motor Control Centers
- Motor Starters
- Motor Overload Protection
- Adjustable Speed Drive Systems

L. Low Voltage Surge Protection Devices

M. 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 Requirements for Employee Workplaces 2000 Edition" Part III Safety Related Maintenance Requirements, Chapters 3 through 6, and 8. (Ref. 10.8). Compliance with this NFPA code is required per Appendix G of the UC contract.

NFPA 70B "Recommended Practice for Electrical Equipment Maintenance (Ref. 10.14)

6.2.5 Testing Instruments Calibrations

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: Contractual Work Smart Standards, LPR 260-01-00 "Inspection and Testing", LPR 260-02-00 "Calibration", LPR 308-00-00 "Quality", and NETA MTS-2001 "Maintenance Testing Specifications for Electrical Power Distribution Equipment and Systems" Section 5.3. (Refs. 10.15, 10.16, 10.17, and 10.14 respectively)

7.0 RECOMMENDATIONS AND GOOD PRACTICES

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 Operations Recommendations

7.1.1 Operations Safety Audit Checklist

7.1.1.1 This checklist provides an assessment of minimum recommendations needed to safely operate an electrical power 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 operate		
De-energizing procedures and equipment exist and are used		
Energizing procedures 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 (Ref 10.19)

7.2 Maintenance Recommendations

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

7.2.1.1 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" (Ref. 10.13)

7.2.2 Electrical Studies

Electrical studies such as Short Circuit analyses and Coordination Studies 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" Section 4-2 and NETA MTS-2001 "Maintenance Testing Specifications" Sections 6.1 through 6.4. (Ref. 10.13 and 10.10.14)

7.2.2.1 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" Section 4-2 and NETA MTS-2001 "Maintenance Testing Specifications" Sections 6.1 through 6.4. (Ref. 10.13 and 10.14)

7.2.2.2 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" Section 4-2 and NETA MTS-2001 "Maintenance Testing Specifications" Sections 6.1 through 6.4. (Ref. 10.13 and 10.14)

7.2.2.3 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" Section 4-2 and NETA MTS-2001 "Maintenance Testing Specifications" Sections 6.1 through 6.4. (Ref. 10.13 and 10.14)

7.2.2.4 A short circuit study should be kept and reviewed whenever major changes to the electrical system are made.

Basis: *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. (Ref. 10.13 and 10.14)

7.2.2.5 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: *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. (Ref. 10.13 and 10.14)

7.2.3 Maintenance Safety Audit Checklist

7.2.3.1 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 (Ref. 10.19)

7.2.4 Intrusion of Contaminants into Electrical Equipment

7.2.4.1 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 judgement, lessons learned, and NEMA Publication “Guidelines for Handling Water Damaged Electrical Equipment” (Ref. 10.23)

7.2.4.2 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 judgement and lessons learned from Cerro Grande Fire. FRC-017 rev. 0 “Electrical Inspection, Soot Laden Electrical Equipment” (Ref. 10.24)

8.0 GUIDANCE

8.1 Operations Guidance

8.1.1 Operations Safety Audit Checklist

8.1.1.1 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 the LANL Lockout Tagout procedure LIR 402-860-01.0.
- *Energizing work procedures* – Written procedures should be developed for re-energizing equipment. These procedures should include a systematic outline of the work to 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 LIR 402-600.01.1. “Electrical Safety”

(Reference: IEEE Std 902 “Maintenance, Operation, and Safety of Industrial and Commercial Power Systems” Section 11.6) (Ref. 10.19)

8.2 Maintenance Guidance

8.2.1 Electrical Testing Technician (ETT) Certification

8.2.1.1 Certification is a means for individuals to indicate to employers, co-workers, the general public, and others that they have met the standards of an impartial, nationally recognized organization for the performance of specific technical tasks by virtue of their technical knowledge and experience. (Resource: ANSI/NETA ETT-2000 "Standard for Certification of Electrical Testing Technicians" Preface) (Ref. 10.9)

8.2.2 Electrical Preventative Maintenance (EPM) Program

8.2.2.1 An EPM program consists of the following essential ingredients:

- *Responsible and qualified personnel* – a well-qualified individual should be in charge of the EPM program. Where personnel are not qualified or not available, a qualified maintenance contractor should be employed.
- *Survey and analysis of electrical equipment and systems* to determine maintenance requirements and priorities – should cover equipment that has been pre-determined to be essential in accordance with a priority plan. In addition to physical condition, the survey should determine if equipment is operating within its ratings.
- *Programmed routine inspections and suitable tests* – should be carefully tailored to requirements of a facility. In some plans, regularly scheduled tests will call for scheduled outages coordinated with facility and programmatic processes. This requires effective communication between maintenance and production/programmatic personnel.
- *Accurate analysis of inspection and test reports* so that proper corrective measures can be prescribed – this is the end purpose of an effective EPM program.
- *Performance of necessary work* – Follow-through with necessary repairs, replacement, and adjustment is an absolute requirement
- *Concise and complete records* – should be accurate and contain all vital information only. Extraneous information will only hamper the program.

(Reference: NFPA 70B "Recommended Practice for Electrical Equipment Maintenance" Chapter 4) (Ref. 10.13)

8.2.2.2 The preparation and development of an EPM program should include the following:

- 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 data of equipment
    - Vendors' 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 requirements 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)

(Resource: NFPA 70B "Recommended Practice for Electrical Equipment Maintenance" Chapter 4 and Engineering judgment and lessons learned) (Ref. 10.13)

8.2.2.3 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" Section 4-1) (Ref. 10.13)

8.2.2.4 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) (Ref. 10.21)

8.2.3 Requirement of a Maintenance Inspection and Testing Procedure

8.2.3.1 Provided it has been reviewed and approved by FM-MSE, an acceptable preventive maintenance inspection and testing program for low voltage electrical equipment may be found in the JCNNM preventive maintenance instruction MM 44-10-001, "Low Voltage Electrical Equipment Preventative Maintenance and Testing (EEPM)."

8.2.3.2 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)

8.2.4 Maintenance Safety Audit Checklist

8.2.4.1 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”). (Ref. 10.19 and 10.22)

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 LIR 230-05-01.0, Operation and Maintenance Manual.

10.3 NFPA 70 National Electric Code 1999 Article 364-2

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

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

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

10.7 LIR 301-00-02.0, Variances and Exceptions to Laboratory Operation Requirements.

10.8 NFPA 70E "Standard for Electrical Safety Requirements for Employee Workplaces 2000 Edition"

10.9 ANSI/NETA ETT-2000 "Standard for Certification of Electrical Testing Technicians"

10.10 LIR 402-600-01 "Electrical Safety"

10.11 LIR 230-04-01 "Laboratory Maintenance Management Program"

10.12 LPR 230-07-00, "Maintenance History, Performance Criteria".

10.13 NFPA 70B 1998 edition, "Recommended Practice for Electrical Equipment Maintenance"

10.14 NETA-MTS-2001 "Maintenance Testing Specifications"

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

10.16 LPR 260-02-00 "Calibration"

10.17 LPR 308-00-00 "Quality"

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

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

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

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

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

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

10.24 FRC-017 rev. 0, "Electrical Inspection, Soot Laden Electrical Equipment"

11.0 APPENDICES

Appendix A: Electrical Operations and Maintenance Case Histories

Appendix A

Electrical Operations and Maintenance Case Histories

11.1.1 Incidents Resulting In Injury

11.1.1.1 Case No. 1 – Shock

An electrician, while working on some equipment in the rear of a power-type circuit breaker auxiliary metering compartment, accidentally encountered adjacent energized transformer terminals. He apparently had not checked for other energized components in the vicinity in which he was working. He required medical treatment for shock.

11.1.1.2 Case No. 2 – Severe Shock

A field engineer was using portable radiography equipment to inspect the quality of medium-voltage cable terminations. A construction electrician was assisting him. The radiography equipment consisted of a cathode ray tube in a metallic casing (called an X-ray head) and a control unit. A control cable interconnected these units. The engineer was on top of a stepladder, leaning against the switchgear enclosure, grasping the handles of the X-ray head, and adjusting its position. The electrician proceeded to plug the control unit into a 120V outlet and connect the control cable. Suddenly, the engineer received a severe shock and fell off the ladder. It was later determined that the plug-in connection between the control cable and the control unit was poorly polarized. The electrician had forced the connection together in the wrong orientation, putting 120V on the casing of the X-ray head. The engineer was taken to the medical department at the site, and was observed for the remainder for the day. He said his grasp was locked onto the handles momentarily until his weight broke him loose during his fall. He complained of muscular proems for several days afterward.

11.1.1.3 Case No. 4 – Flash, Blast, and Burns

A contract electrician had finished drying out a 480V bus duct. While working on a ladder reinserting the plug-units onto the bus, he encountered difficulty getting one of the units to make up properly. He banged on the plug-in unit and was met with a flash and blast that severely burned him and knocked him off the ladder. He was not wearing any protective clothing.

11.1.1.4 Case No. 5 Fatal Shock and Blast

A contract electrical maintenance crew had arrived the night before a planned shutdown of some low- and medium-voltage equipment. The plant engineer offered to show the foreman the equipment on which they would be working the next day. He opened the doors to the medium-voltage equipment, leaving the doors open as he went down the line. Two members of the crew trailed the plant engineer and the foreman, and were intrigued with some discoloration on a cable terminal wrapping in the first cubicle. One electrician, not recognizing that the cubicle was bottom fed, assumed that the cable was de-energized, and approached it too closely, possibly even touching it. He was electrocuted and, at the same time, initiated a blast that severely impacted the second electrician. The second electrician was later unable to remember what happened.

11.1.1.5 Case No. 6 Burns

Power switchboard operators and shift foreman were racking in a 2.4 kV circuit breaker. As they were trying to raise the breaker into position with the dc elevator motor, they experienced trouble and burned up the elevator motor in the process. The shift foreman, who had limited experience with this particular switchgear, called to get some assistance racking in the gear. Another foreman and operator arrived. Since trouble had been experienced racking the breakers in and out before, the operators thought that possibly the breaker was either rusty from lack of regular operation or affected by climate problems. They decided to continue racking the breaker in manually. As the breaker got to with in 2 inches of being fully racked in, a flash from the cubicle occurred. Fortunately, the operator racking in the breaker had a full flash suit on, and his burns were minimized. The foreman who was a good distance from the cubicle, but had no flash suit on when it flashed, received a slight burn on one arm and his face as he moved to help the operator. This incident would have been a fatality if the operator had not worn a flash suit. The switchgear behind the operator had the Bakelite nameplate burned off. The foreman who was back from the switchgear and was not suited up was injured more than the operator in the flash suit.

11.1.1.6 Case No. 7 Burns

An electrician heard a hissing sound coming from within some 480V switchgear. He opened the door to the switchgear to get a better view. He did not have on a flash suit, only side-shielded glasses and a hard hat. The gear flashed phase-to-phase right in front of him. He almost died as a result of the flash. He spent months in the hospital recovering from severe burns.

11.1.1.7 Case No. 8 Flash Arc Results in Flash Burns

As a contract electrician removed the front panel cover from one of the compartments of a motor control center (MCC), an electrical arc flash occurred. Investigation revealed that the center, metal divider protective plate covering the main busses was not properly secured. It was missing a fastener. When the front panel cover was removed, the protective cover fell back and contacted the energized 480-volt top buss bar causing the arc flash. According to facility tenant agreement management, no work on the MCC had been performed since it was originally installed during the facility construction. The electrician sustained a second degree burn to his right wrist and a less significant burn to his left wrist. The electrician wore a long-sleeve shirt, leather gloves, safety glasses and safety shoes. When the injury occurred, the electrician was scoping the job to identify where the conduit for new air handlers would enter the MCC in preparation to install new air handlers.

11.1.2 Incidents Where Protection Prevented Injury

11.1.2.1 Case No. 9 Flash, No Injury

An operator was in the process of closing a disconnect switch on a 480V, Size 4, NEMA 1 starter when it faulted and flashed. The operator, who was wearing the required flash protection, had stood to one side, and had turned away while operating the switchgear. The operator was not injured, but molten copper scorched his protective gloves. The switchgear door was blown open, and the door and switchgear on the opposite side of the aisle were burned.

11.1.2.2 Case No. 10 Flash and Blast, No Injury

An operator was in the process of energizing a motor from a push-button start switch on some 480V switchgear. When he flipped the start switch, which was located on the door of the starter unit, the switchgear arced and blew up. He was wearing protective equipment and was not hurt. He immediately put out the resulting fire. The switchgear and its associated light and wiring were checked for faults. No conclusive evidence of the cause was found, but sandblasting work had been done earlier in the area of the switchgear.

11.1.2.3 Case No. 11 Flash and Blast, No Injury

An operator was sent out to clear and tag Pump A for maintenance. He shut Pump A down, blocked the valves, and then went to the motor control center to open and tag the switch. He mistakenly opened the switch to Pump B, which was running loaded. Arcing in the switch caused a flash and blast, thus blowing the switch compartment door open. Fortunately, the operator was wearing a flash suit and was not hurt.

These case studies identify a variety of things can go wrong when working on or near electrical conductors and circuit part, even when they are thought to be de-energized. These incidents demonstrate the importance of work control and qualified and trained personnel. Those cases within 11.1.2 prove that use of proper protective equipment does save lives and protect personnel from injury.

Resource: IEEE Std 902-1988