FESHM 9100: FERMILAB ELECTRICAL SAFETY PROGRAM

Revision History

Author	Description of Change	Revision Date
Mike Utes	1. Section 6.1, added: "Maximum load on a multiple outlet strip shall not exceed that indicated by the rating label on the strip; if the strip is unlabeled consult with the Division/ Section Electrical Coordinator before use." Regarding multiple outlet strips.	July, 2012
Mike Utes	1. Clarified definitions of multiple outlet strips and multi-outlet assemblies. 2. Added: "RPTs may be fastened to benches or racks so long as they can be removed without the use of tools." 3. Added photos of Multiple Outlet Strips and Multi Outlet Assemblies	April, 2012
Mike Utes	Clarified references to NFPA 70E	Reviewed December, 2011
Mike Utes	1. Corrected titles in the electrical standards list 2. Changed D/S to D/S/C and Changed LSC to FESHCom 3. Removed reference to obsolete electrical safety training document 4. Changed text for voltages less than 50 volts to consider thermal hazards from high ampacity circuits 5. Defined who is allowed inside the Limited Approach Boundaries 6. Clarified Flash Protection Boundary text 7. Added text addressing usage of proper gauge of removable cords for utilization equipment. 8. Changed "ON or NEAR" to "within the limited approach boundary" 9. Minor grammatical changes based on comments posted.	December, 2010

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1.0 INTRODUCTION

Electrical systems of all types, from high voltage power distribution systems to low voltage electronic circuits, are an integral part of the research and associated support work done at Fermilab. Electrical systems have the potential for causing shock and burn injuries to personnel and fires and explosions due to arcing and overheating. This Chapter presents the basic policy, responsibilities, and description of the Fermilab Electrical Safety Program for control of the hazards presented by electrical systems and associated work activities. Fermilab ES&H Manual Chapters 9110 through 9190 and 2100 contain additional requirements specific to Fermilab and its organization for implementing the Electrical Safety Program.

2.0 POLICY

1. Electrical systems and equipment and all design, construction, installation, inspection, testing, and operations activities shall be in accordance with DOE mandatory electrical safety standards to the extent that these standards apply. These standards are:

   29 CFR 1910, Subpart S, OSHA General Industry Standards, Electrical

   29 CFR 1910.137, OSHA General Industry Standards, Electrical Protective Devices

   29 CFR 1926, Subpart K, OSHA Safety and Health Regulations for Construction, Electrical

   National Electrical Code, NFPA 70

   National Electrical Safety Code, ANSI/IEEE C2

   Standard for Electrical Safety in the Workplace, NFPA 70E

   Electrical Standard for Industrial Machinery, NFPA 79

2. Where systems or equipment lie outside the scope of the mandatory standards, specially developed Laboratory or Division/Section/Center policies and procedures, prudent engineering judgment, peer review, and available industry guidance shall be employed to ensure safety of personnel and property.

3. The Fermilab Electrical Safety Program shall promote an electrically safe workplace free from unauthorized exposure to electrical hazards. If not eliminated, exposures to electrical hazards shall present the lowest risks to workers as reasonably possible.

4. Article 130 of NFPA 70E requires that Live parts to which an employee might be exposed shall be put into an electrically safe work condition before an employee works within the limited approach boundary as stated in table 130.2 (C), unless it can be demonstrated that de-energization introduces additional or increased hazards or is infeasible due to equipment design or operational limitations.- Accordingly, all electrical work activities at Fermilab are preferentially performed on de-energized circuits. Implementation of Lockout/Tagout (LOTO) procedures (ref. FESHM 2100) is central to this policy.

3.0 RESPONSIBLILITIES

The following special responsibilities are assigned by the Electrical Safety Program that are in addition to those given in FESHM 1010:

3.1 Electrical Safety Subcommittee

The Electrical Safety Subcommittee (ESS) of the Fermilab Environment, Safety, & Health Committee (FESHCom), in conjunction with the Laboratory Director and Chief Safety Officer, has oversight responsibility for the on-going direction and content of the Laboratory's Electrical Safety Program. The ESS is responsible for providing guidance, interpretation, approval, and recommendations related to Program implementation.

3.2 Division/Section/Center Heads

1. It is the responsibility of Division/Section/Center heads to ensure that all employees of their Division/Section/Center are given training in electrical safety that is commensurate with their work assignments.
2. Division/Section/Center heads are responsible for the safe condition of electrical systems and equipment within their areas of responsibility.

3.3 Personnel

Personnel are responsible for their own safe conduct of operations and that of those under their supervision.

4.0 PROGRAM DESCRIPTION

The Fermilab Electrical Safety Program is made up of various policies, responsibilities, requirements, procedures, practices, and training related to electrical safety.

Most visibly, the Program is implemented by this and other associated Fermilab ES&H Manual chapters and by the oversight responsibility of the ESS of FESHCOM. More importantly the Program is realized by Divisions, Sections, and Centers in the conscientious and integrated implementation of these chapters, the development and use of safe work practices and procedures, inspections and other assessments, and the training of personnel to be Qualified Persons in the specifics of electrical equipment and safe work activities.

A **Qualified Person** or Worker, as applied to electrical work activities, is an individual trained and knowledgeable of the construction and operation of equipment or a specific work method and trained to recognize and avoid the electrical hazards that might be present with respect to that equipment or work method. A Qualified Person possesses the skills and techniques necessary to distinguish exposed energized electrical conductors and circuit parts from other parts of the electrical equipment; and the

individual is able to determine the nominal voltage of the exposed energized electrical conductors and circuit parts. Additional requirements for the Qualified Person are set forth in NFPA 70E Article 110.6 (D)(1). A person can be considered qualified with respect to certain equipment and methods but still be unqualified for others.

As part of necessary training, the Laboratory has developed training for both non-qualified and Qualified Persons. "Basic Electrical Safety" (FN000235) and "Electrical Safety in the Workplace" (FN000385) are available to all personnel. Training for the Fermilab Energy Control Program (Lockout/Tagout) is also available. This training is supplemented by NEC, OSHA, on-the-job and refresher training as appropriate. Other training is optional at the discretion of the supervisor or individual.

5.0 ELECTRICAL WORK ACTIVITIES

Electrical work activities on either electrical utilization equipment or the AC power distribution system commonly involve both energized and de-energized circuits. While most electrical work activities involve de-energized circuits that are locked out and in an **Electrically Safe Work Condition**, some necessarily involve energized circuits and are described as **Energized Work**. NFPA 70E Articles 120 and 130 set forth specific requirements related to establishing an Electrically Safe Work Condition and Work Involving Electrical Hazards.

An **Electrically Safe Work Condition** is a state describing an electrical circuit in which the conductors or circuit parts to be worked **ON** or **NEAR** have been disconnected from energized parts, locked/tagged (LOTO) in accordance with established standards, tested to insure the absence of hazardous voltage, and grounded if determined necessary. FESHM Chapter 2100 is the established and implemented standard at Fermilab for LOTO activities relative to the control of hazardous electrical energy. Proper implementation of the therein described Fermilab LOTO Program is central to bringing equipment and circuits to an Electrically Safe Work Condition.

In the broad sense, **Energized Work** is interpreted as any activity **ON** or **NEAR** exposed energized conductors where a real hazard exists from contact or equipment failure that can result in electric shock, arc flash burn, thermal burn or blast. The degree of hazard for such work may vary from low to high depending primarily (but not uniquely) on the specific voltage and current capacity of the circuit. The actual risk to personnel performing work on energized circuits can also range from low to high but depends primarily on safety related work practices rather than hazard level. It is imperative that any work **ON** or **NEAR** energized circuits be performed with an acceptable low risk to personnel, coupled with determination and understanding of associated approach and protection "boundaries".

Under normal conditions, energized electrical conductors operating at less than 50 volts do not present an electrical shock hazard. However, a thermal hazard can exist in circuits that have a significant capacity to deliver energy, even when the voltage is less than 50 volts. Circuits or conductors energized at 50 volts or more must be assumed to present a shock and/or thermal arc flash hazard unless their ampacity is limited to less than 100 microamps under all operating and fault conditions.

To better understand requirements related to Energized Work, a number of terms deserve explanation. Working **NEAR** describes any activity inside a **Limited Approach Boundary**, an approach distance within which a shock hazard exists from an exposed live part. Working inside this boundary is limited to Qualified Persons. Where there is a need for an unqualified person(s) to cross the Limited Approach Boundary, a qualified person shall advise him or her of the possible hazards and continually escort the unqualified person(s) while inside the Limited Approach Boundary. Under no circumstances shall the escorted unqualified person(s) be permitted to cross the Restricted Approach Boundary. The Limited Approach Boundary for system voltages of 50 to 750 volts is 3 feet 6 inches for fixed parts and 10 feet for movable conductors. Working **ON** means coming in contact with live parts with the hands, feet, or other body parts, with tools, probes or with test equipment.
Working On is considered as any work inside the Prohibited Approach Boundary.

The **Flash Protection Boundary** is an approach limit at a distance from exposed live parts within which a person could receive a second degree burn if an electrical arc flash were to occur. For systems that are 600 volts or less, this boundary shall be 4 feet, based on the product of clearing times of 2 cycles (0.033 sec) and the available bolted fault current of 50 kA or any combination not exceeding 100 kA cycles (1667 ampere seconds). When the product of clearing times and bolted fault current exceeds 300 kA cycles, the Arc Flash Boundary shall be calculated. To additionally facilitate the understanding of Energized Work, such work is categorized as either Diagnostic or Manipulative Energized Work.

Diagnostic Energized Work includes activities such as inspection, testing, voltage and/or current measurements, phase alignment, troubleshooting, circuit & signal tracing, thermal imaging, etc. that are performed on or near exposed live parts within the Limited Approach Boundary. Performance of such activities is not feasible with the circuit de-energized. The verification step associated with certain LOTO procedures, where metering with probes is used to verify the absence of hazardous electrical energy, is included in the definition of Diagnostic Energized Work. Such Energized Work activities are commonly practiced and allowed when performed by Qualified Persons utilizing appropriately rated measurement and required personal protective equipment.

Manipulative Energized Work describes all other activities within the Limited Approach Boundary, other than Diagnostic, that typically involve making, tightening or breaking electrical connections or the replacement/removal/addition of electrical or mechanical components. Manipulative Energized Work is prohibited at Fermilab unless it can be demonstrated that de-energization introduces additional or increased hazards or is infeasible due to equipment design or operational limitations. If justified, Manipulative Energized Work shall be performed by written permit only and subject to approval by the Fermilab Directorate. Associated permit forms and their requirements for Manipulative Energized Work on utilization or AC Power Distribution Systems are presented in FESHM Chapters9110 and 9120 respectively.

6.0 TECHNICAL APPENDIX TO FERMILAB ELECTRICAL SAFETY PROGRAM: ELECTRICAL SAFETY INSPECTION GUIDANCE

This Technical Appendix to the Fermilab Electrical Safety Program Chapter was originally drafted by the Electrical Safety Subcommittee as guidance for a special electrical safety inspection that was conducted by Building/Area Managers and safety personnel. The developed guidance covers both utilization equipment and the AC Electrical Power Distribution (Premises Wiring) System. Reference to Fermilab ES&H Manual Chapters 9110 and 9120 is suggested for definition of terms. Edited from its original form, the guidance presents a variety of requirements and interpretations that continue to be useful as inspection criteria. This guidance is also considered useful to the general population of the Laboratory to identify electrical hazards and instances of non-compliance to established standards and practices. Real or suspected deficiencies should be brought to the attention of the local ES&H Department and/or the Division/Section/Center Electrical Coordinator.

6.1 Electrical Cords

The determination of safe and permitted uses of electrical cords is difficult in that certain uses of cords appear to be safe, yet are prohibited by applicable codes. This aspect of the guidance will attempt to address common deficiencies related to flexible cords, extension cords, and multiple outlet strips.

Flexible cords should not be used in place of permanent facility wiring. As example, permanently mounted ceiling or wall light fixtures should be powered through conduit. A local and permanently wired point of outlet should be provided for permanent equipment to avoid the necessity of extension cords.

Exceptions allowed for the use of flexible cords include pendants and the energization of equipment that may be moved, such as workbenches and wheeled instrument racks. Cords should not be run through holes in walls, ceilings, or floors. Neither should they be run through windows, doors, or similar openings except for short periods and emergencies. The use of cords should not present a trip hazard. Cords should be protected from physical damage. A common deficiency here is the lack of grommeting around sharp edges over which cords pass. Cords that are subject to frequent use or physical damage should be routinely inspected. Be aware that the exposed individual conductor insulation of SO-type cords often becomes brittle with age.

Extension cords are permitted for temporary use. It is best that they be used in a single continuous length rather than be daisy chained. When extending extension cords, always use larger gauge cords than the tool or equipment would normally require. The larger diameter wire will help ensure that the extra cord length will not cause a voltage drop below the level required by the tool or equipment. Extension cords shall not be constructed using knock-out boxes. Though such boxes are UL listed, the listing does not entertain such a use.

A non-permanently attached equipment cord, such as those having a male plug (receptacle) on one end and a female plug on the other end which plugs directly into the utilization equipment,

is **not** considered an extension cord. The common removable power cords are available in 14, 16 and 18AWG and can easily be interchanged. It is the responsibility of the person replacing an appliance cord to use the proper gauge cord for the current draw requirements of the utilization equipment.

All appliance and extension cords shall be inspected for damage, missing ground prongs, and damaged or overheated contacts. If an appliance or extension cord is damaged, spliced or repaired by tape, it must be replaced or thrown out. If the plug or receptacle connector is damaged, it may be replaced (refer to Electrical Connector Section).

All foreign power plugs shall be replaced with U.S. standard connectors if they are to be plugged into the Fermilab premises wiring system. Building receptacles may not be modified to accept foreign plugs.

Relocatable Power Taps or "RPT"s (a.k.a multiple outlet strips, outlet strips, strip plugs or power taps) (Figure 1) are used extensively at 120 VAC, 20A or less, to provide the connection of multiple proximate and low current loads. The premises wiring outlet from which the strip is fed is protected against overloads, and thus the strip itself is also protected if adequately wired. Maximum load on a multiple outlet strip shall not exceed that indicated by the rating label on the strip; if the strip is unlabeled consult with the Division/Section Electrical Coordinator before use. Strips rated at 15A may be fed from 20A outlets. Strips that have overcurrent protection by means of integral fuses or circuit breakers are preferred. RPTs are intended to be directly connected to a permanently installed receptacle. RPTs are not intended to be series connected (daisy-chained) to other RPTs or to be connected to extension cords. RPTs are also not intended for use at construction sites or similar locations. RPTs may be fastened to benches or racks so long as they can be removed without the use of tools.

Figure 1. Multiple Outlet Strips, otherwise known as Relocatable Power Taps (RPTs).

Multi-outlet assemblies (Figure 2), such as the Plugmold or Hubbell units available in stock (#1110-100100 et. al.), may be securely fastened to the interior of relay/equipment racks or to a workbench or other moveable equipment. These multi-outlet assemblies may be powered by either conduit or flexible cord and plug. For cord and plug connections, the cord must be three conductor, 12 AWG or 14 AWG, and not greater than ten feet in length. Construction of multi-outlet assemblies is allowed if performed by Qualified Persons using listed components, following relevant NEC standards, and following standard color coding.

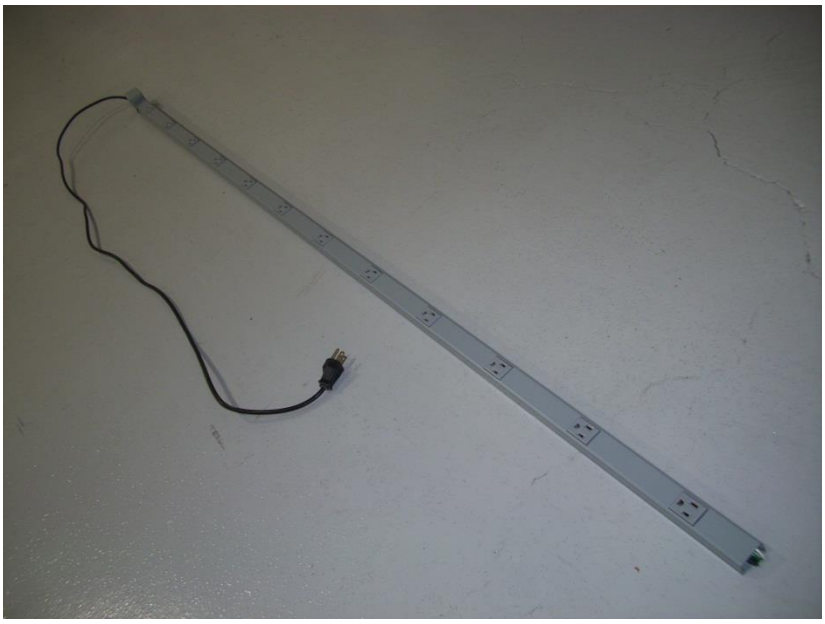

Figure 2. Multi-Outlet Assembly

Multiple outlet strips, multi-outlet assemblies, and extension cords can be tested for correct wiring with a wiring tester that is available from stock (#1145-500000). If a strip indicates lack of proper ground, it may be of an older style that relied on a mechanical connection for ground rather than a dedicated ground wire. Such strips should be removed from service and replaced. The point of connection between the flexible cord and strip should be inspected for mechanical integrity and exposed conductors.

6.2 Electrical Connectors

The use of electrical connectors that are improperly assembled or that are not suitable for the application can present fire and shock hazards. The most common types of connectors that should be inspected are the two and three prong plugs used on flexible electrical cords for connecting to 120 VAC circuits. In addition, there are a variety of plugs used to connect to higher voltage single-phase and multiple phase outlets. Extension cords and some special purpose cords have a receptacle connector in addition to the plug connector. When inspecting electrical connectors, look for the following:

- The cord should be held firmly by a strain relief clamp so that stress from pulling on the cord is not transmitted to the attachment point of the cord conductors to the connector conductors.

- The insulating jacket should completely enter the connector so that the individually insulated conductors are not visible.

- The insulating jacket should be in good condition where the cord enters the connector. There should be no cracks, splits, or cuts in the insulation. Make sure the strain relief is not cutting into the insulation.

- Examine the connector for burn marks, soot deposits, and signs of arcing and melting. These indicate overheating and/or poor conductor contact. A connector that feels warmer than expected is a sign of trouble.

- Test the receptacle connector for proper retention of an inserted plug connector. Loose receptacle contacts can easily lead to arcing and overheating.

- Make sure the connector is of "dead-front" design. Connectors that are not of dead front design typically have an insulating disk that fits over the prongs to cover the screws that secure the cord conductors. A dead-front design is one "without live parts exposed to a person on the operating side of the equipment" (CFR 1910.399).

If a cord needs a new connector, but the cord is in good condition otherwise, the connector may be replaced with a UL approved connector that is suitable for the intended use. This applies to cords with molded connectors (connectors which cannot be removed except by cutting the cord) and to cords with removable connectors. Be sure the ampacity rating of the connector is appropriate for the cord. For example, use a 15A connector on a 14 AWG cord intended for use with 15A utilization equipment, and use a 20A connector on a 12 AWG cord intended for use with 20A utilization equipment. Attachment of connectors to cords shall follow relevant NEC standards and the use of standard color coding. A variety of connectors is available from the stockroom. Qualified Persons have the skills and knowledge necessary to properly replace or re-terminate faulty connectors. Cords with replaced connectors shall be tested for continuity, proper polarity and lack of shorts between conductors before use.

6.3 GFCI Protection

The use of Ground Fault Circuit Interrupters (GFCIs) is intended to protect individuals from electrical shock hazards when unintended ground paths develop in electrical circuits. In its simplest form, a GFCI in series with an electrical load compares the current leaving the "hot" wire of the circuit to the current returning on the "neutral" wire. If an imbalance of more than 4 to 6 milliamperes is detected, the GFCI trips and interrupts the current path. GFCI protection devices are available as circuit breakers, duplex receptacles, and portable units.

NEC and OSHA specify the use of GFCIs for certain areas in and around existing buildings and for new construction activities. If there is new construction activity in your area, GFCIs are generally required for temporary extensions of premises wiring on the job site. Article 210-8 of the NEC specifies the use of GFCIs in branch circuits for dwelling units. Though there are few actual dwelling units at the Laboratory, the intended purpose and benefit of the code indicates the use of GFCIs in wet or damp locations at the Laboratory.

There are a number of exceptions to the requirement of GFCI protection. GFCI protection is not required for disposals, trash compactors, dishwashers, refrigerators, freezers, and other appliances occupying dedicated space. While GFCI protection is required for pool areas and decorative fountains, it is not required for drinking water fountains or coolers. Drinking water fountains, either plumbed-in or bottle variety, are UL listed devices and often employ internal GFCI protection. It is important, however, that the exposed metallic parts of drinking water fountains be effectively grounded. GFCI protection is also not required in the vicinity of eyewash stations, provided that the area is not normally wet or damp.

6.4 Electrical Fixtures

Electrical fixtures include the various distribution and circuit breaker panels, junction boxes, switch boxes, disconnects, outlet boxes, lighting fixtures, etc. which are constituent parts of the premises wiring system or utilization equipment for voltages of 120 VAC and above. Telephone, intercom, HVAC low voltage control, and computer network fixtures are not included in this classification. It is important that electrical fixtures be closed so as to present a barrier to inadvertent contact with energized conductors. When inspecting electrical fixtures, look for the following:

- All covers/doors must be properly installed with all of the fasteners in place. There should be no evidence of pinched conductors between the fixture and its cover.

- Make sure that any unused knockout holes are plugged. Circular snap-in blanks with a range of diameters from 1/2 to 2-1/2 inches are available from the stockroom.

- When examining electrical panels, make sure that any unused circuit breaker holes are plugged. Deficiencies here should be referred to the local Division/Section/Center Electrical Coordinator or FESS Work Central x3434.

- Check for the minimum 3 foot working clearance in front of electrical equipment that is generally required by OSHA and the NEC. Reference to Part 3 of the Technical Appendix of FESHM Chapter 9120 is suggested for further guidance on this issue.

- Check to see that circuit breaker panelboards are properly labeled and that branch circuits are correctly identified.

- Lamps for general illumination shall be protected from accidental contact or breakage. Protection shall be provided by elevation of 8 feet or more above the floor or working surface or by enclosures or guards. Ref. OSHA 1910.303(g)(2)(i) and (ii). Diffusion covers, wire screens or plastic fluorescent tube covers are among acceptable guarding means. General illumination for areas subject to ionizing radiation require special consideration in selecting lamps and fixtures.

6.5 Exposed Electrical Conductors

While the very nature of activities at Fermilab presents many instances of exposed conductors, not all of these instances present significant hazards. Consultation with knowledgeable personnel in assessing the hazards posed by specific instances of exposed conductors is advised. Conductors that present significant levels of hazard because of voltage or current that can lead to shock or arcing must be covered or otherwise protected against inadvertent contact by appropriate barriers. Common physical barriers include insulation, guards, covers, screens, terminal strip covers, interlocked equipment doors, and access control to accelerator, beamline or experimental enclosures. Placement of barriers is best effected by the Qualified Person(s) responsible for the equipment or installation.