

FESHM 9110: ELECTRICAL UTILIZATION EQUIPMENT SAFETY

Revision History

Author	Description of Change	Revision Date
Dave Mertz	Revised section 3.15 to conform with NFPA 70E-2018. Revised chapter format to conform to present FESHM Chapter template.	5-year review April 2019
Dave Mertz	Revised parts 3.2 and 3.3 and added Technical Appendix to include Code Equivalency approvals under FESHM Chapter 2110. Made other typographical and grammatical revisions.	February 2017
Dave Mertz	Added part 3.17 to permit participation in EFCOG Electrical Safety Group inspection reciprocity program.	August 2015
Dave Mertz	2.0 Definitions: Clarified definition of Competent Person to distinguish from Qualified Person; 3.4: Added new article to clarify that listed equipment not used in accordance with the listing must be reviewed. 3.6: Added new article to clarify that custom equipment limited to below 50 volts and 5 milliamperes does not require review. 3.7: Added new article to clarify review requirements for battery-powered custom equipment. 3.15: Appended sentence requiring tagging of disused cables. (Section was formerly 3.12). 4.3: Added “or non-competent” so personnel that are not qualified but are competent may enter a work area.	April 2014
Mike Utes	Removed the word “approved” as it related to Nationally Recognized Testing Labs. NRTLs do not approve equipment, they provide a listing for equipment.	May, 2012

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1.0 INTRODUCTION

This Chapter describes requirements related to and for working safely on electrical utilization equipment. These requirements are somewhat similar yet distinguished from those in [Fermilab Environmental, Safety, and Health Manual \(FESHM\) Chapter 9120](#) and those developed separately by Facilities Engineering Services Section (FESS) that relate to AC Power Distribution System safety. While the installation, maintenance and repair of utilization equipment can only be performed by qualified workers, it is the responsibility of Fermilab supervisory personnel to ensure that the work on any particular job is done safely and according to the applicable codes [Occupational Safety and Health Administration (OSHA), National Fire Protection Association (NFPA) Standard 70E, etc.].

2.0 DEFINITIONS

A **Competent Person** is an individual knowledgeable in the design, construction, operation, and maintenance of the specific electrical utilization equipment. The competent individual has familiarity with the electrical requirements of the NFPA 70, National Electrical Code (NEC), other applicable NFPA standards and OSHA, has received safety training on the hazards involved with electricity on the specific electrical utilization equipment, and by virtue of training and experience is fully aware of the work practices and procedures necessary to mitigate or eliminate those hazards for the specific electrical utilization equipment. A person can be considered competent with respect to certain equipment and requirements but still not competent for others.

Electrical Utilization Equipment is equipment that utilizes electric energy after the Point of Outlet for electronic, electromechanical, chemical, heating, lighting, or similar purposes. Examples of such equipment include fixed and variable output power supplies, motors, motor controllers, motor control units mounted in a motor control center, variable frequency drives for motors (VFDs), process control and monitor equipment, battery powered interruptible or uninterruptible power sources, welding machines, and computers. Cords, plugs, and conductors that facilitate connection of utilization equipment to the Alternating Current (AC) power distribution system up to the Point of Outlet are to be considered as parts of the utilization equipment. While subject to the concurrence of the Permit approving authority, utilization equipment is further classified as low-power and high-power as follows:

Low-Power Electrical Utilization Equipment is characterized by all of the following conditions:

- The primary AC voltage (V) powering the equipment is less than 300 V AC phase to phase and/or 150 V AC phase (line) to neutral or ground
- The primary current is limited to 100 amperes or less by circuit breakers or fuses
- The stored energy in capacitors and inductors is less than 10 Joules

High-Power Electrical Utilization Equipment is characterized by not meeting one or more of the above individual limitations for Low-Power Electrical Utilization Equipment.

Energized Work is 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.

Reference to FESHM Chapter [9100](#) is suggested for a more complete discussion of Energized Work and associated definition of terms such as **Electrically Safe Work Condition, Limited Approach Boundary, Flash Protection Boundary, Diagnostic and Manipulative Energized Work**.

The **Point of Outlet** is the point of connection to the AC Power Distribution System where electrical current is taken to supply utilization equipment. The point of outlet is further defined as the first disconnecting means upstream of the utilization equipment. Such points include standard wall outlets and receptacles, disconnect switches and circuit breakers. Within a Motor Control Center (MCC), the point of outlet is considered to be the point of connection between the MCC power bus and the removable motor controller assembly.

A **Qualified Person** or Worker, as applied to electrical work activities, is an individual trained and knowledgeable in 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. 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.

3.0 REQUIREMENTS

1. Whenever reasonably possible, electrical utilization equipment used at Fermilab shall be listed by a nationally recognized testing laboratory (NRTL) and installed and used in accordance with the listing.
2. Electrical utilization equipment that is not listed by a NRTL shall be permitted under the following circumstances:
 - a. An equivalent product with a NRTL listing is unavailable. Price and personal or institutional preference do not constitute a justification for purchasing, constructing, or using unlisted equipment. Long delivery lead times will be considered a justification only when the laboratory's mission will be significantly impaired. Electrical utilization equipment that is not listed by a NRTL shall incorporate in its construction components that are listed or registered by a NRTL to the extent reasonably possible. Such components shall be utilized in accordance with the registration or listing.
 - b. The equipment is received as an in-kind contribution from a foreign scientific or academic institution for work at the Fermilab site or another facility under Fermilab administrative control at which 10 CFR 851 applies.
3. Electrical utilization equipment that is not listed by a NRTL must be inspected by the Fermilab AHJ or her or his designee. This inspection may be performed in several ways:
 - a. A NRTL is contracted to perform a field inspection. This is the preferred method for equipment that is custom constructed for Fermilab by a vendor for which obtaining a listing is impractical. It is recommended that the contract with the vendor include the cost and responsibility for the NRTL field inspection. A successful field inspection is required to permit operation of the utilization equipment.

- b. The Fermilab electrical Authority Having Jurisdiction (AHJ) or Qualified and Competent Person or Persons designated by the AHJ performs a field inspection and give approval to operate the utilization equipment once all identified deficiencies are addressed. This is the preferred method for equipment that is custom constructed by Fermilab personnel, or by visiting researchers with small-scale, short term installations, such as are common at the Fermilab Test Beam Facility.
 - c. The inspection of utilization equipment that is received as an in-kind contribution from a foreign scientific or academic institution that complies with a foreign standard may be waived or reduced if a safety equivalency for the standard to which it conforms has been approved under FESHM Chapter 2110, *Establishing Code Equivalency with International Codes and Standards*. If the Electrical AHJ or any personnel in the D/S/P that will use or supply power to the equipment determines that a greater degree of inspection is warranted, then a more thorough inspection addressing the identified concerns shall be performed.
 - d. In addition to the inspections described previously in this section, the suitability of the equipment for the environment in which it will be installed and its connection to the electrical power supply will be evaluated as part of the ES&H review procedure of FESHM Chapter 2005, *Operational Readiness Clearance*.
4. Listed electrical utilization equipment that is to be used in ways that are not in accordance with its approval or listing shall have its intended application reviewed by a Qualified and Competent Person or Persons commensurate with the electrical hazards posed by the equipment. Such a review shall occur both before the equipment is first energized in its intended application and before the equipment is placed into service after testing.
 5. Such design and construction reviews shall be documented and kept on file while the utilization equipment remains in use or storage at Fermilab or for three years, whichever is longer, by the responsible Division/Section Department or organization.
 6. Custom equipment that will only be energized while attended and receives power from a listed power supply that is used in accordance with its listing and has non-adjustable limits of no more than 50 volts or 5 milliamperes will not require review.
 7. Custom equipment that does not exceed 50 volts and is powered by alkaline or zinc-carbon dry cells or “button” cells will not require review. Custom equipment that uses lithium-ion, lead-acid, or other highly reactive or uncommon battery chemistries requires review.
 8. All work on electrical utilization equipment is to be performed only when the equipment is de-energized, in an electrically safe work condition, and when all hazardous energy has been isolated, as described in FESHM Chapters 9180 and 2100, except under the conditions described in sections 3.9 and 3.10, below.
 9. Diagnostic energized work on electrical utilization equipment is allowed when justified and when performed by qualified persons. When performing such work, the worker shall be protected from any associated electrical hazards including shock and arc-flash.
 10. Manipulative energized work on electrical utilization equipment is not allowed unless justified. When such work is allowed by a properly executed Electrical Hazard Analysis / Work Permit, the person(s) performing the work must be qualified and shall be protected from any associated electrical hazards including shock and arc-flash.

11. If there is a significant potential of injury, work by a single individual on energized utilization equipment in an isolated location is not allowed.
12. When any qualified worker is working within either the Shock or Arc-Flash Protection Boundaries of energized high-power electrical utilization equipment, at least one other person must be assigned to the work. The other person shall be trained to recognize and avoid the electrical hazards that might be present with respect to that equipment or work method. The other person shall also be trained in methods of release.
13. All electrical utilization equipment for personal use in the workplace, such as coffee pots, refrigerators, space heaters, fans, and radios, shall be listed and exhibit a NRTL label.
14. All AC power connectors on foreign made utilization equipment brought to Fermilab shall be inspected by the Division/Section Electrical Coordinator to assure that no safety hazard or confusion with United States (U.S.) standard connectors exists. When failing this inspection, all foreign power plugs shall be replaced with U.S. standard connectors if they are to be plugged into the outlets or receptacles of the Fermilab AC Electrical Power Distribution System outlets and receptacles.
15. Cord and plug connected electrical equipment use shall follow these safe work practices:
 - a. Equipment shall be used only in accordance with the manufacturer's instructions and safety warnings.
 - b. Equipment shall be handled and stored in a manner that will not cause damage. Flexible cords connected to the equipment shall never be used to mechanically move, position, or suspend the equipment, nor shall the cords be attached to structures or objects in a way that may damage the cords. Cords shall not be placed under mechanical tension unless inherently intended for the purpose, such as a pendant light or receptacle.
 - c. The grounding path for electrical equipment designed to have one shall not be interrupted. Flexible cords attached to the equipment, as well as any extension cords, power strips, or plug strips servicing them, shall not be connected or altered in a manner that interrupts the grounding conductor, nor shall any adapter or device that interrupts the grounding conductor be used.
 - d. Equipment and cords shall be inspected prior to each use for visual signs of damage. Equipment and any extension cords or power strips that are put in place where they are not subject to damage and remain stationary for an extended period of time (such as desktop computing equipment) require only an initial inspection until relocated, reconfigured, or repaired.
 - e. Equipment and cords that are found to be defective or damaged in a way that may pose a risk of injury shall be removed from service. If such equipment is not promptly discarded, it shall be plainly marked as defective or damaged and shall not be returned to service until repaired and tested by a person competent to do so.
 - f. Plugs and receptacles on equipment, connecting cords, and distribution system outlets shall be checked prior to connection to confirm they will properly mate. Locking-type plugs shall not be left inserted in a receptacle unless in the locked position. Personnel shall not connect plugs and receptacles if the plugs, receptacles, or the person's hands are wet.
 - g. Equipment used in areas that may be damp or wet with water or other conductive liquids shall be rated for use in that environment and be protected by GFCI devices. Pneumatic, hydraulic,

or battery-powered tools should be considered as a lower-risk alternative to those powered from 120 VAC.

16. Electrical utilization equipment for which there is no longer a perceived requirement shall be completely de-energized and permanently disconnected from the AC Electrical Power Distribution System. Particular circumstances may require posting of such abandoned equipment as "NOT IN SERVICE" prior to its physical removal. When feasible and when future use is not anticipated, powering conductors between the point of outlet and the utilization equipment, ancillary cabling, and other external hardware associated with such equipment shall be removed. If any disused cables are not removed, each cable shall be permanently tagged at each end to uniquely identify the cable and the location of the other end of the cable.

17. Capacitor and Capacitor Bank Safety

Capacitors may store and accumulate a dangerous residual charge after equipment has been de-energized and the capacitors or capacitor banks removed. To protect personnel from the potential hazards from residual charge in capacitors, the following safety precautions shall be followed.

*Capacitors capable of storing 10 Joules or greater **and** a voltage rating greater than 50 volts shall have their terminals short circuited with a conductor (bare wire – non-insulating) no smaller than # 20 American Wire Gauge (AWG).*

a.
$$W = \frac{1}{2} CV^2$$

Where: W = Energy in Joules (watt-seconds)
 C = Capacitance in Farads
 V = Voltage across capacitor terminals in volts

- b. *Wires must be securely fastened to the terminals and left in place until the capacitors are returned to service.*
- c. *If a capacitor is to be disposed, the shorting wires shall remain in place.*
- d. *Appropriate (commensurate with voltage rating) verification is required before installing shorting wires for capacitors capable of storing 10 Joules or greater.*
18. Energy Facilities Contractors Group (EFCOG) Electrical Safety Group (ESG) Inspection Reciprocity Program Participation

The EFCOG ESG has developed an inspection reciprocity program to permit DOE sites to transfer non-NRTL-listed electrical utilization equipment between sites without requiring largely redundant inspections each time a piece of equipment arrives at a new site. The program assures a receiving site that a trained and qualified person at the sending site performed a thorough inspection meeting a common set of standards from the *DOE Electrical Safety Handbook*, DOE-

HDBK-1092-2013, or its successor documents. The program provides the receiving site with the original documentation and inspection records and requires the receiving site to perform a shipping damage inspection and verify that the equipment is acceptable for the conditions under which it is to be used. Participation in this program is voluntary, both on a site basis and for each instance where a piece of equipment that is part of the program is transferred between DOE sites.

The Fermilab Electrical Safety Subcommittee (ESS) has elected to participate in this program. Each instance of equipment inspection performed as required by Sections 3.3 and 3.4 of this Chapter will be performed in accordance with the equipment inspection guidelines given in the *DOE Electrical Safety Handbook*, DOE-HDBK-1092-2013, or its successor documents. When equipment is received from other DOE sites with conforming records, the laboratory may elect to accept the other site's inspection records and perform a shipping damage and conditions of use inspection. If the Electrical AHJ or any personnel in the D/S/P that will use or supply power to the equipment determines that a full inspection as required by Sections 3.3 and 3.4 of this Chapter should be performed, then the full inspection shall be performed.

4.0 ELECTRICAL HAZARD ANALYSIS / WORK PERMIT REQUIREMENTS

1. An Electrical Hazard Analysis/Work Permit (EHAWP or "Permit") is required for justified manipulative energized work on electrical utilization equipment.
2. An EHAWP is required for diagnostic energized work on electrical utilization equipment that is judged by competent person to be significantly complex and/or hazardous.
3. The Permit requires a Description of Work, a description and analysis of Associated Hazards, and required elements of Hazard Mitigation that will bring exposure to attendant hazards to an acceptably low risk. The Hazard Mitigation section, to the extent applicable, shall include safe work practices, means employed to restrict the access of unqualified or non-competent persons from the work area, indication of the determined Hazard/Risk Category, results of shock and flash hazard analyses if other than default values, and required Personal Protective Equipment (PPE). Complex work activities may need to be broken down into identifiable work phases. For such situations, the Associated Hazards and Hazard Mitigation descriptions and steps should be developed for each phase of work.
4. The Associated Hazards listed in the Permit most frequently pertain to exposure to unguarded or bare conductors or circuit parts that have not been tested and found to be in an Electrically Safe Work Condition. However, this part of the Permit is appropriate and, in lieu of a separate Hazard Analysis (HA), may be used for listing of other non-routine and significant hazards associated with the electrical work activity at hand. Such hazards might include falls, interception of buried utilities, oxygen deficiency or vehicular traffic.
5. The justification to perform Manipulative Energized Work must be documented on the Permit. Such justifications are not for convenience, but rather must show that de-energization introduces additional or increased hazards or is infeasible due to equipment design or operational limitations. Multiple approvals are required on the Permit form for Manipulative Energized Work.

6. The Permit must be filled out and approved prior to the work activity. At a minimum, the Permit must be approved by a competent person within the Division/Section Department or organization performing the work activity. This person is usually the Department Head although approving authority may be delegated to one or more other competent persons within the Department or organization. The Permit preparer and approver are generally not the same individual. For situations where the normal approving authority is not fully knowledgeable in the particular equipment and/or associated hazards, the preparer may approve the Permit if so knowledgeable and authorized.
7. A job briefing shall always be conducted before beginning work by the competent person in charge with all individuals directly participating in the work activity. Topics will include scope of work, hazards associated with the work, procedures and special precautions, energy source controls, and personal protective equipment requirements. Those in attendance will sign the Permit, thereby indicating their understanding of the scope of work and associated hazard mitigation requirements.
8. In case of doubt about any aspect of energized work activity upon utilization equipment, by either the normal approving authority or any of the qualified workers assigned to the work activity, a technical subject matter expert who is familiar with the equipment in question shall be consulted. The technical expert shall reconsider the need to leave the equipment energized and shall consider further steps that may be taken to ensure the safety of the personnel on the job. If, after this review, workers are still not satisfied that an adequate margin of safety is assured, they may refuse participation in the work activity. This refusal shall not be the cause for disciplinary action.
9. The Permit will be available at the work site.
10. Copies of approved Permits shall be kept on file for a period of at least one year by the originating Division/Section Department or organization.

5.0 FORMS

The [EHAWP](#) is available from the ES&H DocDB.

6.0 TECHNICAL APPENDIX TO ELECTRICAL UTILIZATION EQUIPMENT SAFETY

This Technical Appendix lists the international standards for electrical utilization equipment that have been reviewed and accepted for a waived or reduced non-NRTL equipment inspection as permitted under Article 3.c of FESHM Chapter 9110 following the procedure in FESHM Chapter 2110, *Establishing Code Equivalency with International Codes and Standards*.

1. International Codes with waived inspection requirements:
 - a. None.
2. International Codes with reduced inspection requirements:
 - a. IEC 61010-1 – 3rd edition and IEC 61010-2-30 – 1st edition: The requirements of UL 61010-1 – 3rd edition and UL 61010-2-30 – 1st edition for which IEC 61010-1 and IEC 61010-2-30 do not have greater or substantially equivalent requirements are:
 - i. Verify that the IEC standard by which the CE mark was placed on the equipment is 61010.
 - ii. The physical point of mains power connection on any equipment that must be connected directly to mains power is reviewed for compliance with Annex DVD of UL 61010-1. Cord and plug connected equipment does not require this review.
 - iii. The mains plug on cord-connected equipment must be reviewed as part of the experiment's power distribution design, and plugs conforming to UL 498 be furnished. The common use of detachable cords per IEC/UL 60320 and voltage-sensing or switchable power supplies simplifies this requirement.
 - iv. Switches for disconnection and overcurrent protection devices must be reviewed to ensure that ungrounded “hot” conductors in the equipment will not remain energized if power switches are turned off, or overcurrent devices open.
 - v. Equipment containing pressurized fluids in excess of 15 PSI and 515 PSI* ft^3 , contain lasers of Classes 3B or 4, or that produce ionizing radiation are referred the appropriate Fermilab person or committee for review.
 - vi. Verify that conductive coatings or shields are not used, or where used, flakes of the coatings or shields will not create fire or shock hazards.
 - vii. Direct plug-in (“wall wart”) transformers comply with ANSI/UL 1310 or ANSI/UL 60950-1.