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Memorandum

November 9, 2005

To: Gerald Brown

From: William Griffing

Subject: Revised FESHM Chapter 5042 – AC ELECTRICAL POWER DISTRIBUTION SAFETY

Enclosed you will find revised FESHM Chapter 5042 – AC ELECTRICAL POWER DISTRIBUTION SAFETY. This chapter has been revised to clarify Fermilab's policy on energized manipulative work for systems operating between 50 and 600 VAC nominal. The Electrical Hazard Analysis/Work Permit has also been revised to include identification of the hazard risk category, the limited, restricted, and prohibited approach boundaries, and required PPE.

After final approval, please return this approval page to Elizabeth May at MS119 for posting on the web.

Encl.

Recommended for Approval:

Gerald Brown — Date 11/11/2005

Approved:

Piermaria Oddone — Date 11/14/05

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AC ELECTRICAL POWER DISTRIBUTION SAFETY
For Systems Operating Between 50 and 600 VAC Nominal

INTRODUCTION

Some of the most serious electrical hazards at Fermilab are associated with work on AC Electrical Power Distribution Systems. This Chapter specifically addresses Systems operating between 50 and 600 VAC nominal and includes the 480/277 and 120/208 VAC Distribution Systems commonly found in Laboratory buildings. The voltage and current capability of any of these Systems can be LETHAL! Although installation, maintenance and repair of these Power Distribution Systems can only be performed by qualified electricians, it is the responsibility of Fermilab supervisory personnel on any particular job to help insure that the work is done safely and according to the applicable codes (National Electrical Code, OSHA, NFPA 70E, etc.).

This Chapter describes requirements for safe work on AC Electrical Power Distribution Systems at the "customer" level of 480/277 and 120/208 VAC Distribution Systems. These requirements are distinguished from those in Chapter 5041 that relate to electrical utilization equipment safety and from those developed separately by FESS for higher voltage "utility" level systems at the Laboratory.

DEFINITIONS

The **AC Electrical Power Distribution System** describes all 480/277 and 120/208 VAC and other AC Electrical Power Distribution Systems operating between 50 VAC to 600 VAC nominal as found outside and within buildings up to and including the Point of Outlet. For purposes of this Chapter, this definition does not include the higher voltage utility systems and auxiliary substations that provide 480/277 VAC electrical service. This definition is consistent with the concept of **Premises Wiring System** as specified by the National Electrical Code (NEC) and the terms are considered equivalent.

Area Division/Section Head is the person who controls and is responsible for the area where AC electrical power distribution equipment is being installed, modified or maintained.

A **Competent Person** is an individual knowledgeable in the design, construction, operation, and maintenance of the AC Electrical Power Distribution Systems and equipment in their area of jurisdiction. The competent individual has familiarity with the electrical requirements of the NEC, OSHA and NFPA, has received safety training on the hazards involved with electricity, and by virtue of training and experience is fully aware of the work practices and procedures necessary to mitigate or eliminate those hazards.

A Division/Section (D/S) **Electrical Coordinator** is a Fermilab competent person who:

- Is knowledgeable in the electrical circuitry and electrical equipment in the area of jurisdiction
- Has the capability to identify existing and predictable electrical hazards and/or working conditions and has the authority to take prompt corrective measures including the immediate stopping of work
- Is familiar with work practices and personnel protective equipment (PPE) requirements of NFPA 70E
- Is frequently involved in the planning and scheduling of electrical work in the area of jurisdiction
- Is familiar with required physical clearances for electrical equipment as defined by NEC and OSHA standards
- Is identified as a qualified Task Manager and has the authority to supervise and/or monitor the activities of Fermilab, Electrical T&M, or fixed price subcontractor electricians who install or work on the AC Electrical Power Distribution System
- May be but is not necessarily involved with large construction projects that are managed within the Division/Section
- With the negotiated assistance of Facilities Engineering Services Section (FESS), generates and maintains up-to-date single line electrical drawings (SLEDs) of the AC Electrical Power Distribution System in the area of jurisdiction
- With the assistance of building and area managers, generates and maintains up-to-date panel schedules for electrical distribution panels and motor control centers in the area of jurisdiction

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 motor drives (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 Premises Wiring System up to the Point of Outlet are to be considered parts of the 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 5040 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.

A **Motor Control Center (MCC)** is an assembly of one or more enclosed sections having a common power bus (typically 480 VAC three phase) and principally containing motor control units. Removable motor control assemblies mounted in MCCs are commonly referred to as "buckets" or "tubs".

The **Point of Outlet** is the point of connection to the Premises Wiring System that 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 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 Electrician** is a Qualified Person possessing journeyman or higher electrician status. Also included in this definition are individuals designated as apprentice electricians when working under the direct supervision of an electrician having journeyman or higher status.

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. 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.

A **Task Manager** (Electrical) is a Division/Section designated individual responsible for direction and oversight of selected electrical work activities. The Task Manager shall be competent and knowledgeable in accord with the complexity of the task at hand.

SPECIAL RESPONSIBILITIES

1. Division/Section Heads shall designate one competent person in their organization as D/S Electrical Coordinator. This responsibility may be waived in whole or part if a particular Division/Section is fully reliant on the services of another D/S to provide

oversight of work involving installation, modification, maintenance and repair of AC Electrical Power Distribution Systems in their area of jurisdiction.

2. For cases where the D/S Head chooses to designate one or more additional competent individuals to assist the D/S Electrical Coordinator, each of those individuals shall be designated as an Alternate Electrical Coordinator. As delegated by or in the absence of the Electrical Coordinator, an Alternate Electrical Coordinator may have similar responsibilities and authority.
3. Division/Section Heads shall also designate one or more competent persons in their organization as qualified to approve the Electrical Hazard Analysis / Work Permit.
4. FESS shall maintain a current list of electrical T&M subcontractor employees possessing journeyman or higher electrician status. This list shall be available to other Divisions/Sections as necessary to assure implementation of this Chapter.
5. The D/S Electrical Coordinator, or designee, shall be physically present as a safety observer during any conduct of Manipulative Energized Work in his/her area of jurisdiction.
6. The D/S Electrical Coordinator shall exercise Stop Work authority when observing activities or unsafe work practices that jeopardize the safety of personnel or safe operation of electrical distribution equipment.
7. The D/S Electrical Coordinator has additional responsibilities associated with concrete cutting and coring activities in his/her area of jurisdiction. As required by FESHM 7040, the Coordinator must review and approve the Electrical Hazard Analysis / Work Permit specifically prepared for the work activity.

REQUIREMENTS

1. The following requirements relate to AC electrical power distribution equipment.
   a. All equipment used in AC Electrical Power Distribution Systems shall be approved or listed by a nationally recognized testing laboratory (NRTL) and installed and used in accordance with the approval or listing. Exceptions to this requirement must be approved by the Electrical Safety Subcommittee (ESS) of the Laboratory Safety Committee (LSC).
   b. Disconnects or breakers shall be installed in AC Electrical Power Distribution Systems to allow for the safe isolation of all subsystems. These devices shall be appropriate for the circuit voltage and current, and able to withstand the available calculated short circuit current of the circuit. They shall incorporate ground fault protection where necessary. If disconnects or breakers are used for

"switch duty", they must be rated as such. Disconnects or breakers shall be identified as to purpose if not obvious.

c. Adequate working clearances for electrical equipment shall be maintained per OSHA 1910.303(g), NEC Article 110.26 and NFPA 70E Article 400.15. The general distances for working clearance are 3 feet in front and a minimum width of 30 inches. Mitigation means of non-compliant working clearances are discussed in the Technical Appendix of this Chapter.

d. The AC Electrical Power Distribution System shall provide adequate and proximate points of outlet for permanently installed utilization equipment.

e. Power distribution equipment shall display permanently affixed labeling which clearly identifies the equipment, voltage and current ratings, fed from data, and any other special safety precautions as may be required, such as "Multiple Sources of Power Present", etc.

f. For all new and retrofitted installations, a separate, properly bonded equipment grounding conductor shall be installed in AC electrical power distribution raceways. For existing installations where the AC electrical power distribution raceway is subject to significant corrosion or deterioration, the installation of a separate, properly bonded equipment grounding conductor is mandatory.

g. Phasing and color coding of conductors of the Laboratory's AC Electrical Power Distribution System shall be in accord with the Technical Appendix of this Chapter.

h. AC electrical power distribution equipment, for which there is no longer a requirement, shall be completely de-energized and disconnected from the AC Electrical Power Distribution System. Disconnection may involve removal of ungrounded and grounded conductor connections that power the so described equipment or positive isolation of the electrical energy source. For situations where the equipment is not physically removed, the equipment should be posted as "Not in Service". Such equipment typically includes distribution panels, transformers and disconnects.

   i. Disconnected supply conductors, if not totally removed, shall be suitably insulated, guarded, or capped so as to prevent contact with live parts and not to present a hazard.

   ii. For situations where disconnection is not practical, feasible, or appropriate; the disconnecting means, such as a circuit breaker or disconnect, shall be turned OFF to isolate the electrical energy source. Configuration control (ref. FESHM Chapter 5120 TA) must then be applied in the form of a lock and/or tag indicating "Not in Service - Do Not Energize". After isolation of the

disconnecting means, it must be verified that the equipment is completely de-energized.

2. Requirements related to all work on AC electrical power distribution equipment include:

   a. Manipulative Energized Work on equipment of the AC Electrical Power Distribution System is prohibited 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 final approval by the Fermilab Directorate.

   b. The appropriate portion of AC Electrical Power Distribution System shall be de-energized, locked and tagged out (ref. Chapter 5120), and in an Electrically Safe Work Condition before Manipulative De-Energized Work is allowed to proceed on that part of the System.

   c. The work shall be conducted in accord with an Electrical Hazard Analysis / Work Permit if required in 3.a., below.

   d. Installation, maintenance and repair of AC Electrical Power Distribution Systems up to the Point of Outlet shall be performed only by Qualified Electricians.

   e. If a particular work activity is challenged and asked to be stopped, the work activity shall stop, but only after bringing the work site to a safe condition. Thereafter, the area Electrical Coordinator must be contacted to begin resolution of the stop work directive. The area D/S ES&H Department shall also be notified.

   f. The D/S Electrical Coordinator or alternate shall inspect new installations of distribution panels and transformers before the equipment is energized for the first time. Inspection of routine service additions or modifications is at the discretion of the Coordinator or Task Manager supervising the work. However, inspections may be required by the Electrical Hazard Analysis / Work Permit before equipment is (re-)energized.

   g. Diagnostic Energized Work activities are frequently performed on the AC Electrical Power Distribution System by Qualified Persons. The area Electrical Coordinator shall be aware of and verbally approve such activities, other than verification, prior to their initiation.

3. The following describes the **Electrical Hazard Analysis / Work Permit** and associated requirements for work on AC Electrical Power Distribution Systems.

a. An approved Electrical Hazard Analysis / Work **Permit is REQUIRED** for particular Manipulative De-Energized or Energized Work activities involving the AC Power Distribution System. These particular activities include work:

- On power distribution panels or panelboards, typically operating at 480/277 or 120/208 VAC
- On or in the power bus sections of Motor Control Centers, usually operating at 480 VAC
- On transformers of the AC Power Distribution System having a primary excitation voltage of 480 VAC or less
- On disconnects, circuit breakers and transfer switches located between panelboards or panelboards and transformers of the AC Power Distribution System
- At selected locations where there is less than adequate working clearance around equipment (ref. the Technical Appendix of this Chapter)
- That involves concrete cutting or coring activities that could intercept embedded conductors of the Distribution System
- That is judged by competent authority to be significantly complex and/or hazardous

b. An Electrical Hazard Analysis / Work **Permit is NOT REQUIRED** for work:

- On branch circuits or loads when the sourcing branch circuit breaker or other isolating means have been turned off and LOTO procedures have been followed
- That involves Diagnostic Work, except as noted in the Technical Appendix of this Chapter
- On utilization equipment as discussed in FESHM Chapters 5041 & 5042, including motor controllers downstream of the point of outlet
- That simply involves the physical application of locks or tags on AC power distribution equipment, as typically associated with LOTO for utilization equipment or configuration control
- Involving installation, connection and wiring of equipment such as panelboards, transformers, disconnects and switches that are not capable of being energized

c. The Electrical Hazard Analysis / Work 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 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 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.

d. The Associated Hazards listed in the Electrical Hazard Analysis / Work 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 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.

e. The justification to perform Manipulative Energized Work at any System voltage level 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.

f. The Electrical Hazard Analysis / Work 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 as designated by the area D/S Head. The Permit preparer and approver are generally not the same individual. For situations where the approver is not fully knowledgeable in the particular System and/or associated hazards, the preparer may approve the Permit if so knowledgeable and authorized.

g. When FESS personnel are to perform work for any other Division/Section that requires an Electrical Hazard Analysis / Work Permit, the Permit must be approved by both the FESS designated approving authority as well as the Electrical Coordinator, or designated alternate, of the other Division/Section.

h. 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.

i. The Electrical Hazard Analysis / Work Permit will be available at the work site.

j. Copies of approved Permits shall be kept on file for a period of at least one year by the originating Division/Section. If FESS personnel are involved in the work, a copy of the Permit shall be given to FESS. Additional distribution is at the option of the Division/Section.

4. For situations where Manipulative Energized Work on the AC Electrical Distribution System is justified and approved, special precautions and utmost care must be taken to prevent accident and injury. The following requirements must be strictly followed.

   a. Manipulative Work on energized systems is hazardous, especially for 480/277 VAC installations. The D/S Electrical Coordinator, the Qualified Electrician(s), and, if necessary, the electrician foreman, shall review the installation and assure themselves that the work activity can be done safely. Any complicating factors (e.g., massive grounds near work, unusual mechanical or environmental conditions, etc.) shall be noted on the Permit. Those doing the work will be briefed on the safety measures to be used, any unusual hazards/complications likely to be encountered, and proper use of personal protective equipment. In all cases, appropriate measures shall be taken to prevent access to the Limited Approach and Flash Protection Boundaries by unauthorized personnel.

   b. In case of doubt about any aspect of the work activity, by either the D/S Electrical Coordinator or the Qualified Electrician(s) assigned to perform the Manipulative Energized Work, a technical subject matter expert who is familiar with the system or subsystem in question shall be consulted. The technical expert shall reconsider the need to leave the system 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.

   c. The D/S Electrical Coordinator, or designee, shall be physically present as a safety observer during any conduct of Manipulative Energized Work in his/her area of jurisdiction. The Coordinator shall remain in close communication with those doing the work, and shall be readily available to answer questions as well as monitor the status of the work activity. Means of prompt communication with site emergency personnel should be readily available if needed.

   d. For work on an energized system where the voltages present are less than 130 VAC terminal-to-ground or 250 VAC terminal-to-terminal, at least one Qualified Electrician shall be assigned to the task.

e. For work on an energized system where the voltages present exceed 130 VAC terminal-to-ground or 250 VAC terminal-to-terminal, at least two Qualified Electricians shall be assigned to the task.

5. It is recognized that certain special or emergency instances may arise where obtaining a written and approved Electrical Hazard Analysis / Work Permit is not reasonably practical or possible. For such situations, verbal discussion of and approval for the work is required from the designated D/S individual who normally approves these Permits or the area Division/Section Head before the work may proceed. In addition to the verbal approval, a written Permit shall be generated and approved at the earliest reasonable opportunity.

TECHNICAL APPENDIX TO

AC ELECTRICAL POWER DISTRIBUTION SAFETY

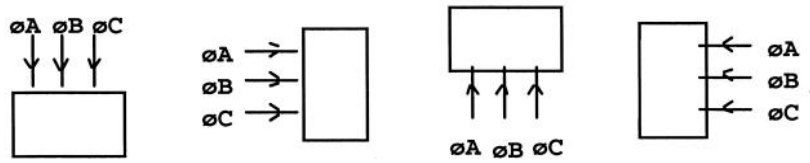
This Technical Appendix describes standards and requirements related to the phasing and color coding of conductors in the AC Electrical Power Distribution System. It also addresses mitigation of less than adequate working clearances around electrical equipment.

1. PHASE RELATIONSHIPS IN AC ELECTRICAL POWER DISTRIBUTION

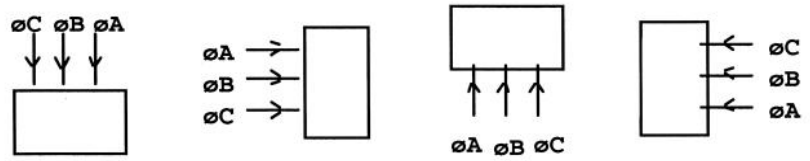
All three phase AC power distribution throughout the Laboratory shall conform to the positive phase rotation convention. Positive phase rotation shall be understood as Phase A -> Phase B -> Phase C, where Phase B lags Phase A and Phase C lags Phase B.

The phase position of all electrical conductors entering electrical distribution equipment such as breakers, switch gear, and distribution panels viewed with respect to the front of principal control face shall be Phase A, Phase B, Phase C from left to right, top to bottom, or front to back. Where no principal control face is discernible, the electrical conductor most nearly north or east shall be Phase A.

Some examples of various modes of entry of three phase power into most electrical equipment are illustrated in Figure 1. Due to the inherent unique design of Square-D I-Line™ panelboards, entry to these panels and their associated circuit breakers is an exception to the standard form of entry and is separately detailed in Figure 1.



Standard Entry for Most Equipment



Standard Entry for Square-D I-Line Panels

Figure 1 - Three Phase Power Entry Into Electrical Distribution Equipment (As Viewed From Front)