FESHM 9120: AC ELECTRICAL POWER DISTRIBUTION SAFETY

For Systems Operating Between 50 and 600 VAC Nominal

Revision History

Author	Description of Change	Revision Date
D. Mertz	• 5-year review and update to 2017 NFPA 70, *National Electrical Code* and 2018 NFPA 70E, *Standard for Electrical Safety in the Workplace.* • Added sections 3.1 and 5.0 • Revised Qualified Person definition, Section 4.1.b, 4.3.e. • Other changes for consistency with present FESHM Chapter format template and to improve clarity.	5-year review April 2019
D. Mertz	• Revised Technical Appendix to permit electrical equipment labels to be made from self-adhesive vinyl stock when located in environmentally benign places.	December 2015
M. Utes	• In Requirements section 3b, first bullet, added: "The D/S/C Electrical Coordinator shall be consulted for situations in which there is any doubt as to the configuration of the circuit. If uncertainty exists regarding the hazard/risk category, use the simplified guidance tables or consult D/S/C Electrical Coordinator or SSO." • Added electrical equipment labeling conventions to TA	November 2012
M. Utes	(see Requirement1) Replaced the word "approved" with "certified" as it related to Nationally Recognized Testing Labs. NRTLs do not approve equipment; they provide a listing or certification for equipment.	August 2012
M. Utes	• Added "skilled" to the definition of competent person. • Changed personnel protective equipment to personal protective equipment. • Changed Division/Section to Division/Section/Center	November 2010

	• Changed “on or near exposed energized conductors” to “within the limited approach boundary of energized conductors” in the text defining Energized Work. • Two grammatical corrections. • Deleted: “The Permit preparer and approver are generally not the same individual. 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.”	

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1.0 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 9110 that relate to electrical utilization equipment safety and from those developed separately by FESS for higher voltage "utility" level systems at the Laboratory.

2.0 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 defined in Article 100 of 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 and skilled 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/Project (D/S/P) **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 personal protective equipment (PPE) requirements of NFPA 70E
- Is frequently involved in the planning and scheduling of electrical work in their area of responsibility
- 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 FESS and 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 within the limited approach boundary of energized conductors where a 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 and Chapter 9180 is suggested for a more complete discussion of Energized Work and associated definition of terms such as

Electrically Safe Work Condition, **Limited Approach Boundary**, Arc **Flash 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 from which 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 one who has demonstrated skills and knowledge related to the construction and operation of electrical equipment and installations and has received safety training to recognize and avoid the electrical hazards involved. Additional training requirements for the Qualified Person are set forth in NFPA 70E Article 110.2 (A)(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/Center designated individual responsible for direction and oversight of selected electrical work activities. The Task Manager shall be competent and knowledgeable in accord with the type and complexity of the task at hand.

3.0 RESPONSIBILITIES

3.1 Electrical Safety Officer

1. A Fermi Research Alliance (FRA) employee identified by the Laboratory Director shall serve as the Laboratory Electrical Safety Officer (ESO). This individual shall be identified by the Fermi Site Office (FSO) as the Contractor Authority Having Jurisdiction (AHJ) to fulfill FSO-assigned duties consistent with the definition of AHJ found in NFPA 70, *National Electrical Code,* and the Electrical Safety Authority as defined in NFPA 70E, *Standard for Electrical Safety in the Workplace,* Article 350.4 The ESO may designate certain other FRA employees to perform certain ESO, AHJ, and ESA tasks as the ESO's representative. The ESO chairs the

Electrical Safety Subcommittee (ESS) of the Fermilab ES&H Committee (FESHCOM) and will leverage the expertise of the members of the ESS. In the absence of the ESO, the ESS Deputy Chair may act in the ESO's stead

3.2 Electrical Coordinator

a. Division/Section/Project Heads shall designate one competent person in their organization as D/S/P Electrical Coordinator. This responsibility may be waived in whole or part if a particular Division/Section/Project is fully reliant on the services of another D/S/P to provide oversight of work involving installation, modification, maintenance and repair of AC Electrical Power Distribution Systems in their area of jurisdiction.

b. For cases where the D/S/P Head chooses to designate one or more additional competent individuals to assist the D/S/P Electrical Coordinator, each of those individuals shall be designated as an Alternate Electrical Coordinator. As designated by or in the absence of the Electrical Coordinator, an Alternate Electrical Coordinator may have similar responsibilities and authority.

c. Division/Section/Project Heads shall also designate one or more competent persons in their organization as qualified to approve the Electrical Hazard Analysis / Work Permit.

d. 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/Projects as necessary to assure implementation of this Chapter.

e. The D/S/P 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.

f. The D/S/P Electrical Coordinator, or designee, 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.

g. The D/S/P 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.

4.0 REQUIREMENTS

1. The following requirements relate to AC electrical power distribution equipment.

   a. All equipment used in AC Electrical Power Distribution Systems shall be certified (listed, recognized, or classified) by a nationally recognized testing laboratory (NRTL) and

installed and used in accordance with the certification. Exceptions to this requirement must be approved by the Electrical Safety Officer or designee.

b. Disconnect switches or circuit 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. Newly installed disconnect switches or circuit breakers shall be furnished with factory-installed hasps to permit LOTO locks to be placed without the use of circuit breaker handle clamps or other adapters. They shall incorporate ground fault protection where necessary. If disconnect switches or circuit breakers are used for "switch duty", they must be rated as such. Disconnect switches and circuit breakers shall be labeled with their purpose if not obvious.

c. Adequate working clearances for electrical equipment shall be maintained per OSHA 1910.303(g), NEC Article 110.26. The general distances for working clearance are 3 feet in front and a minimum width of 30 inches. Means of mitigating 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 conductors to achieve 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 disconnect switches.

i. Disconnected supply conductors, if not totally removed, shall be suitably insulated, guarded, or capped to prevent contact with live parts and avoid presenting 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 2100 Technical Appendix) 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 using a written risk assessment 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 area Electrical Coordinator, area D/S/P Head, and the Fermilab Directorate.

b. The appropriate portion of AC Electrical Power Distribution System shall be de-energized, locked and tagged out (ref. Chapter 2100), 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/P Division Safety Officer shall also be notified.

f. The D/S/P Electrical Coordinator or designee shall inspect new installations of distribution panels and transformers before the equipment is energized for the first time. Inspections of additions or modifications to existing electrical distribution systems, including branch circuits, is at the discretion of the area Electrical Coordinator. However, final 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 zero voltage 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 disconnect switches, 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 person 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. The D/S/P Electrical Coordinator shall be consulted for situations in which there is any doubt as to the configuration of the circuit. If uncertainty exists regarding the arc-flash PPE Category, use the simplified guidance tables or consult D/S/P Electrical Coordinator or DSO.
      - That involves Diagnostic Work, except as noted in the Technical Appendix of this Chapter
      - On utilization equipment as discussed in FESHM Chapters 9110 & 9120, 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 physically incapable 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 Arc-flash PPE Category, results of shock and arc 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 with a written risk assessment and approvals as described in Section 4.2.a of this Chapter.

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/Project as designated by the area D/S/P Head.

g. When FESS personnel are to perform work for any other Division/Section/Project 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/Project.

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/Project. 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/Project.

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/P 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/P 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/P Electrical Coordinator, or designee, shall be physically present as a safety observer during any conduct of Manipulative Energized Work in his/her area of responsibility. 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/P individual who normally approves these Permits or the area Division/Section/Project 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.

5.0 ELECTRICAL HAZARD LABELING

Every electrical equipment enclosure, other than outlet and pull boxes, in which energized electrical work (including zero voltage verification) might be performed shall preferentially be labeled with specific electrical hazard information in accordance with Article 130.5(H) of the 2018 edition of NFPA 70E, which requires the label to include the nominal system voltage, arc flash boundary, and at least one of the following: Site-specific level of PPE, minimum arc rating of clothing, or one but not both of the available incident energy and working distance or arc-flash PPE category.

Industrial control panels, such as used for HVAC equipment and compressors, are to be considered electrical equipment enclosures for the purpose of this section, unless there are no circuits exceeding 50 V. Also excepted are single phase circuits, 120 VAC at 20 amperes or less from an external panelboard, that serve loads internal to the panel which are limited to convenience receptacles, lighting, anti-condensation heaters, and power supplies with output voltages less than 50 V.

Where environmental conditions or chemical exposures will rapidly deteriorate labels applied to the equipment, or conditions of supervised maintenance make electrical hazard information readily available to workers, the electrical hazard information may be maintained in a central location known and accessible to workers and supervisors.

Where electrical system models have not yet been prepared to furnish equipment-specific arc-flash hazard information, the equipment shall not be labeled, and the Fermilab default arc-flash boundary and tabular arc-flash PPE category tables as found in FESHM Chapter 9180 shall be used. Entry into undocumented or under-documented equipment shall be used as an opportunity to obtain complete information needed to enter the equipment into an electrical system model.

6.0 FORMS

The EHAWP is available from the ESH&Q DocDB.

TECHNICAL APPENDIX TO AC ELECTRICAL POWER DISTRIBUTION SAFETY

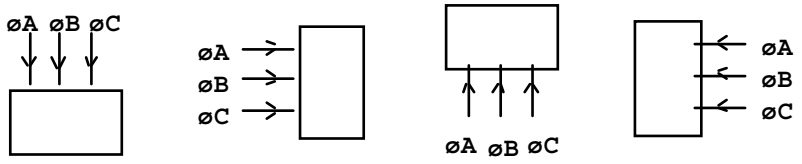
This Technical Appendix describes standards and requirements related to the phasing and color coding of conductors in the AC Electrical Power Distribution System. It also addresses mitigation of less than adequate working clearances around electrical equipment.

1. PHASE RELATIONSHIPS IN AC ELECTRICAL POWER DISTRIBUTION

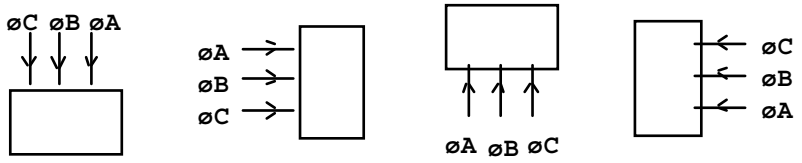
All three phase AC power distribution throughout the Laboratory shall conform to the positive phase rotation convention. Positive phase rotation shall be understood as Phase A -> Phase B -> Phase C, where Phase B lags Phase A and Phase C lags Phase B.

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)

For multiple phase receptacles and female plugs having a circular orientation, phase connection as viewed from the front shall be positive and clockwise for ØA -> ØB -> ØC. Special attention is drawn to implementing this Fermilab practice to welding outlets. Said outlets are typically not marked to the Fermilab convention.

The voltage phasor diagram and time-based voltage waveforms of the three phase AC electrical power distribution system are illustrated in Figure 2 as reference.

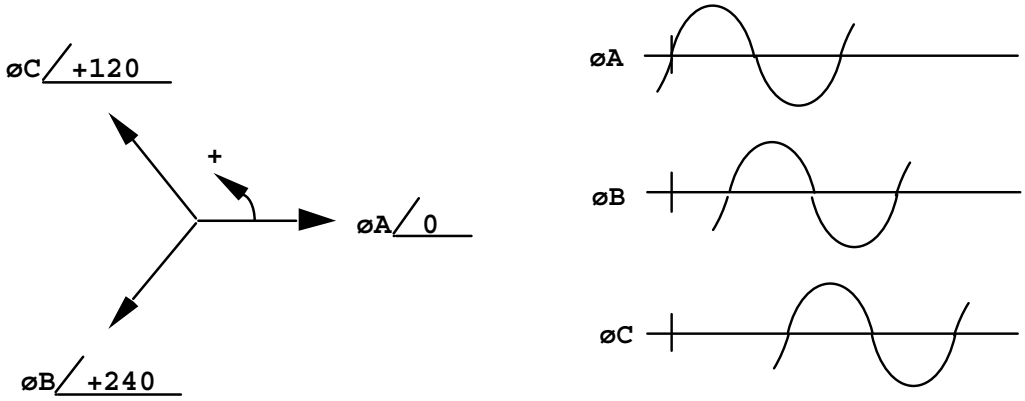


Figure 2 - Three Phase Phasor Diagram and Time-Based Waveforms

2. Color Codes for AC Electrical Power Distribution Conductors

The following color codes shall be utilized for the identification of conductors in the three phase AC Electrical Power Distribution System.

a. For all conductors including those in a **120/208 VAC** System, but except those in a 480/277 VAC System, the color code convention is as follows. For the ungrounded conductors, this convention is referred to as **BRB (Black-Red-Blue)**.

Conductor	**Color**
Phase A (ungrounded) Conductor	**Black**
Phase B (ungrounded) Conductor	**Red**
Phase C (ungrounded) Conductor	**Blue**
Neutral (grounded) Conductor	**White** (Preferred) or Gray
Equipment **Ground**ing Conductor	**Green** (w or w/o Yellow Stripe(s) or Bare

b. For conductors in a **480/277 VAC** System, the color code convention is as follows. For the ungrounded conductors, this convention is referred to as **BOY (Brown-Orange-Yellow)**.

Conductor	**Color**
Phase A (ungrounded) Conductor	**Brown**
Phase B (ungrounded) Conductor	**Orange**
Phase C (ungrounded) Conductor	**Yellow**
Neutral (grounded) Conductor	**Gray** (Preferred) or White
Equipment **Ground**ing Conductor	**Green** (w or w/o Yellow Stripe(s) or Bare

c. Conductor insulation shall be factory color coded by integral pigmentation. For conductor sizes larger than 10 AWG, color coding by integral pigmentation is optional. Where integral pigmentation is not used, conductor insulation must be black. For such situations, each insulated cable at every point of termination shall be identified by the appropriate color as shown above, preferably with integrally pigmented heat-shrink tubing. If electrical marking tape is used, preferably no less than six inches of the conductor length shall be covered by the tape with a 50% overlap and the final wrap shall be applied without tension.

d. For all new work and/or modifications to the wiring in the AC power distribution system, the conductor color code shall follow the above requirements.

e. It is important to note that, prior to 1989, the BRB color code convention was the "general" standard employed at the Laboratory for all conductors of the Premises Wiring System. Nonetheless, prior to 1989 there have been instances of using the BOY convention for 480/277 VAC systems. Since that time, the accepted industry practice of utilizing the BOY convention for 480/277 VAC systems has been adopted by the Laboratory. While there is no demand or requirement to retrofit existing plant to the current convention, those working on, testing, or inspecting the AC Electrical Power Distribution System are to be advised of the dual color code conventions in place at the Laboratory.

f. It is the long term goal of the Laboratory to ultimately convert the older 480/277 VAC Systems using the BRB convention to the BOY convention. When reasonably possible, 480/277 VAC conductors having the BRB convention should be re-taped to the new BOY convention.

3. Non-Compliant Working Clearances

Recent OSHA compliance audits have discovered numerous instances of less than adequate working clearances around electrical equipment. Detailed requirements are specified under OSHA general industry regulations 29 CFR 1910.303(g)(1). Efforts are now on-going to eliminate, raise awareness of, and reduce future instances of these non-compliant conditions. Nonetheless, a selected number of instances are inordinately expensive or otherwise difficult to abate. These demand administrative controls and steps to provide equivalent safety to workers in lieu of clear working space about the equipment. To this end, the procedures specified here are mandatory to address the selected instances of less than adequate working clearances and environments.

a. If the work activity is either Diagnostic or Manipulative Energized Work as defined in FESHM Chapter 9100, an Electrical Hazard Analysis / Work Permit shall be prepared and approved prior to the start of the activity. The Permit shall note the existence of less than adequate working clearance and specify additional protective measures to be taken. Such measures may include installation of temporary barriers, guarding proximate grounded surfaces to reduce the potential of shock, and use of temporary lighting to better illuminate the work area. These added measures are in addition to normal hazard mitigation steps required for the work activity.

b. If the work activity is to be conducted with the equipment in an Electrically Safe Work Condition, hazardous energy must first be isolated and controlled in accordance with lockout/tagout procedures as specified in FESHM 2100. Note that a Permit may be required for selected equipment of the AC power distribution system.

c. Such equipment shall be clearly and prominently labeled to inform personnel that special work conditions are in effect. The label provided shall be of the following form, durable, self-adhering and available in various sizes. Labels are available from local area DSOs and Electrical Coordinators.

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SAFETY FIRST

DUE TO LESS THAN ADEQUATE CLEARANCES AROUND THIS EQUIPMENT

SPECIAL ADMINISTRATIVE CONTROLS APPLY FOR YOUR SAFETY

BEFORE STARTING WORK ON THIS EQUIPMENT

PLEASE CONSULT THE AREA ELECTRICAL COORDINATOR

OR REFER TO THE TECHNICAL APPENDIX OF FESHM CHAPTER 9120

Fermilab

FESHCom

Electrical Safety Subcommittee

STANDARD CONVENTIONS
for the
Fermilab Electrical AC Power Distribution System

Reviewed and Approved by the ESS
September 10, 2012

The following represents agreed upon standard conventions for the Electrical AC Power Distribution System at Fermilab. The conventions were first developed by knowledgeable representatives from FESS Engineering and Operations and the Accelerator Division. The conventions were subsequently reviewed and sanctioned by the Electrical Safety Subcommittee. It is acknowledged that these conventions are not totally inclusive of all possible aspects, equipment types, or configurations of the existing electrical distribution system. The stated standard conventions should be applied to new construction and to systems undergoing significant modification. It is not intended that older systems be modified, although partial conformance may be reasonably accommodated.

Panelboard Naming Conventions

Panelboards shall be classified solely as per operating voltage and ampacity, regardless of their position in the electrical distribution system. The acronyms for panelboards are as follows:

SWBD Switchboard, 2000 A and Above, 480Y/277 VAC

DHP Distribution, High Power Panelboard, 600 A to 1600 A, 480Y/277 VAC

PHP High Power Panelboard, 100 A to 400 A, 480Y/277 VAC

LP Lighting Panelboard, 100 A to 225 A, 480Y/277 VAC
(Typically Outfitted with Single Pole Circuit Breakers)

PP Power Panelboard, 100 A to 225 A, 208Y/120 VAC or 240/120 VAC

Exxx Emergency, Prefix for Panelboard Capable of Being Powered by a Dedicated Emergency Power Source

Sxxx Standby, Prefix for Panelboard Capable of Being Powered by a Dedicated Standby Power Source

Other Equipment Naming Conventions

Acronyms for other certain components of the electrical distribution system shall be as follows. Some explanations of particular categories are appended.

DSTR Distribution Switch (Generally 13.8 kVAC)
USS Unit Substation (Generally 13.8 kVAC to 480Y/277 VAC)
TR Transformer, Various Ampacities and Voltages, Compads Included

ETR Transformer, Capable of Being Powered by a Dedicated Emergency Power Source
STR Transformer, Capable of Being Powered by a Dedicated Standby Power Source
MCC Motor Control Center (Generally 480 VAC without Neutral)
DS Disconnect Switch, Not Fused, Various Ampacities and Voltages
FDS Fused Disconnect Switch, Fused, Various Ampacities and Voltages
CB Circuit Breaker, Stand Alone, Typically External to a Panelboard in Lieu of a Panelboard Main Breaker and Also Serving as a Service Disconnect
MTS Manual Transfer Switch, Various Ampacities and Voltages
ATS Automatic Transfer Switch, Various Ampacities and Voltages

DSTR is an established convention for 13.8 kVAC distribution switchgear. These switches may be of the oil type, but are more often air switches such as the compartmentalized switches manufactured by S&C. They are used frequently in the 13.8 kVAC feeder distribution system of the Laboratory for purposes of equipment isolation and feeder isolation or reconfiguration.

The Unit Substation designation, **USS**, refers to compartmentalized distribution equipment that includes a 13.8 kVAC air switch, the transformer, and multiple rack-in load breakers on the secondary side. While there are numerous USSs at the Laboratory, they are not preferred for new installations.

The transformer category, **TR**, covers a wide range of equipment. A typical yard transformer would be of the "**Compad**" type now generally favored. Such a transformer would generally include an incoming line switch (for isolation only) and fuses at 13.8 kVAC and usually a single load circuit breaker. Compads are generally sized at 500, 750, or 1500 KVA. Another very common example is the 480 to 208Y/120 VAC three phase transformers typically found inside technical buildings. Transformers with other primary and secondary voltages are also covered by the "TR" identifier.

AC Voltages

Some consistency is desired in the identification of voltages present in the AC power distribution system. The following delineates acceptable or preferred labeling. The specific characterization of voltage sources as wye or delta connected may be omitted if commonly understood or of minimal interest to user applications.

Acceptable:	V, VAC, Volts, Volts AC, kV, kVAC, kVolts, kVolts AC	
	208Y/120 VAC	(Three Phase)
	240/120 VAC	(Single Phase)
	480Y/277 VAC	(Three Phase)
	480 – 208Y/120 VAC	(Three Phase Transformer)
	480 – 240/120 VAC	(Single Phase Transformer)
	13.8 kVAC – 480Y/277 VAC	(Three Phase Transformer)
	13.8 kV – 480 V	(Three Phase Transformer)

Panelboard and Transformer Labeling

Panelboards and transformers of the distribution system shall be uniquely identified with labels made from engraved laminated phenolic (lamacoid) material, a minimum of 1/16 inch thick, 2.5 inches high, and 9 inches wide. The overall dimensions may be reduced for cases where the equipment cannot accommodate the standard size. Self-adhesive vinyl labels may be used in place of the laminated phenolic labels only in dry, indoor, temperature-regulated environments without deleterious atmospheric or chemical exposures. Use of these labels must be approved on a case-by-case basis by the Division or Section Electrical Coordinator. The following requirements apply to both laminated phenolic and vinyl labels.

These labels generally have two lines of text. The first line would be the panelboard or transformer name (e.g. PHP-MI60A-3, TR-MI60A-3-A). The second line would describe the operating voltages or voltages present (e.g. 480Y/277 VAC, 480-208Y/120 VAC).

First line characters are to be 0.85 to 1.0 inch high with a 1/8 inch line width. Second line characters are 0.5 inches high with a 1/16 inch line width. The edges of the label are to be beveled.

RED labels with **WHITE** characters shall be used for equipment operating at 480Y/277 or 480 VAC or higher. A 480 to 208Y/120 VAC transformer would be outfitted with a label having these colors. When such equipment is capable of being powered by a dedicated Emergency or Standby power source, the equipment label shall be **ORANGE** in color with **BLACK** characters.

BLACK labels with **WHITE** characters shall be used for equipment operating at 120, 208Y/120, or 240/120 VAC. When such equipment is capable of being powered by a dedicated Emergency or Standby power source, the equipment label shall be **YELLOW** in color with **BLACK** characters.

Laminated phenolic equipment labels are preferably attached with a high quality, double-sided

adhesive tape rather than screws. For indoor applications to smooth surfaces, 3M tape 9500PC is a preferred choice. For outdoor or rougher surface applications, Normount tape V2830 is a preferred choice although the 9500PC tape is often acceptable.

Naming Conventions for "Yard" Transformers

Discussion of "yard" transformers necessarily includes Unit Substations and Compads. The names of these 13.8 kVAC primary transformers shall generally be referred to as "LOC#". LOC# is an alpha-numeric acronym that will uniquely describe the transformer location and distinguish more than one transformer at that location.

While LOC is a unique alpha-numeric acronym for the USS or Compad location, the # aspect of the LOC# identifier consists of an alpha character (A, B, C, D, E, etc.). For example: one Compad at F1 would have a LOC# identifier of F1A; one USS at the Booster East Gallery would be BEGA; and three Compads and two USSs at MI-60 would be MI60A, MI60B, MI60C, MI60D, and MI60E. Notice that there is always an appended alpha character – even if there is only one transformer or USS at the location.

The generalized labeling of yard transformers would be USS-LOC# or TR-LOC# for Unit Substations and Compads respectively. The above transformers would be marked as TR-F1A, USS-BEGA, TR-MI60A, TR-MI60B, TR-MI60C, USS-MI60D, and USS-MI60E.

Naming Conventions for Primary Panelboards

Primary panelboards are those considered to be the first panelboard to receive power from a yard transformer circuit. These panelboards shall include the transformer LOC# in their name. For the example of a Compad at F1 with a single internal load breaker power powering a DHP panelboard, the panelboard would be named DHP-F1A.

A USS typically supplies power to multiple primary panelboards in accord with the number of rack-in load breakers. Additionally, a Compad may be outfitted with or have the provision for more than one load breaker. In order to distinguish these multiple feeds as distinct sources of power, the LOC# for the primary panelboards shall have an appended number "n" (1, 2, 3, 4, etc.) relating to the specific yard load breaker. "LOC#n" now uniquely describes the source of power.

For the example of a USS at Booster East Gallery having three load breakers separately powering a SWBD, DHP, and MCC; these primary panelboards would be named SWBD-BEGA1, DHP-BEGA2, and MCC-BEGA3. For the example of a Compad at F2 with a single internal load breaker power powering a DHP panelboard and provision for a second load breaker, the primary panelboard would be named DHP-F2A1.

Naming Conventions for Sub-Primary Panelboards and Transformers

Primary panelboards feed "sub-primary" panelboards, transformers, or utilization equipment. Labeling of utilization equipment is not of concern since the connection of such equipment is documented in the panelboard schedule. The developed naming convention does not involve the physical location or pole position of the sourcing circuit breaker as has been past practice. The potential for confusion is reduced in that such locations or positions are subject to change as the distribution system is modified.

Sub-primary panelboards names are developed with a portion of the name of the upstream panelboard with an appended "-n" where n equals 1, 2, 3, 4, etc. As an example, say primary panelboard SWBD-BEGA1 feeds a DHP panelboard, and two PHP panelboards. These panelboards would be labeled as DHP-BEGA1-1, PHP-BEGA1-2, and PHP-BEGA1-3. To continue this convention for additional downstream panelboards, take as example that PHP-BEGA1-2 feeds a PHP and a LP panelboard. These panelboards would be labeled as PHP-BEGA1-2-1 and LP-BEGA1-2-2. As is the case for primary panelboards, the LOC# or LOC#n identifier is retained and continues to indicate BEGA1 as the single primary source of power.

While sub-primary panelboards are identified with an appended numeric character, transformers shall be identified with an alpha character. Consider primary panelboard DHP-BEGA1-1 feeding three 480 - 208Y/120 VAC transformers. Here the transformers would be named as TR-DHP-BEGA1-1-A, TR-DHP-BEGA1-1-B, and TR-DHP-BEGA1-1-C. A benefit of this convention is that the "DHP-BEGA1-1" part of the transformer's name is a direct indicator of the transformer's fed-from source.

Continuing the above example, assume the first two transformers each feed a single PP panelboard, and the third feeds two PP panelboards. These 208Y/120 VAC panelboards would be named PP-BEGA1-1-A1, PP-BEGA1-1-B1, PP-BEGA1-1-C1, and PP-BEGA1-1-C2. Additional panelboards are readily accommodated without modification of the names of existing equipment.

Naming Conventions for Disconnect and Transfer Switches

Disconnect and Transfer Switches, including **DS**, **FDS**, **MTS** and **ATS** types, are sometimes named. Such switches that provide isolation between elements of the AC Power Distribution System must be named. If named, the switch shall be appended with the name of the downstream piece of equipment that it serves to isolate. **DS-PP-MI65A-A1** is an example of a disconnect switch that isolates all three ungrounded phases powering panelboard PP-MI65A-A1. Where the switch position is remote from connected and downstream equipment, it should be named. If the downstream connection for a switch is not apparent or if there is more than one switch at a particular physical location, all such switches must be named.

All such switches shall be identified as to the nominal operating voltage of interior circuits.

Naming Conventions for Wall Receptacles

Receptacles are typically labeled with the name of the breaker panel immediately upstream followed by the circuit number. PP-CL-14E-2 CKT 15 is an example of a receptacle fed from panel PP-CL-14E-2 and coming off of the circuit breaker located in position 15.

Panelboard Schedules

At a minimum, panelboard schedules shall list and be in accord with the following:

- Panelboard name. (e.g. PP-BEGA1-1-B1)
- Normal operating current (e.g. Trip Current of Upstream Overcurrent Protection Device as opposed to the ampacity rating of the panelboard)
- Operating voltages and number of phases. (e.g. 208Y/120 VAC, 3 Phase)
- Fed-From source of power. (e.g. TR-DHP-BEGA1-1-B and DHP-BEGA1-1 CB#27)
- Load descriptions and corresponding circuit breaker positions
- Load descriptions shall be specific rather than general if at all possible (e.g. Lighting – Room 101 vs. Lighting). Refer to NEC Article 408.4(A) for code requirements.
- Legible
- Current

It is strongly suggested that panelboard schedules be generated in a computer word processor or spreadsheet format to facilitate ease of modification and lockout/tagout performance. It is advised to provide a second copy of the schedule at the panelboard. In addition to the above, the following information might be included in the electronic file. Some of the below may be added to the displayed panel schedule as appropriate.

- Panelboard Rated Ampacity
- A listing of all available circuit breaker positions. Non-occupied positions shall be designated as “Blank” or “Space”. Unused breakers shall be designated as “Spare”.
- The overcurrent rating of the circuit breaker
- The phase of power for the particular circuit breaker position
- The physical location of the panelboard
- The type of panelboard (e.g. Square D I-Line, Square D NQOD)
- Whether or not there is a Panel Main Breaker. If present, show the ampacity of the Panel Main breaker.
- The kVA rating of the upstream powering transformer, if the panelboard is directly fed by the transformer
- The FESS bar code inventory number

- The wire size of the feed conductors for the ungrounded, grounded, and grounding conductors
- The size, type and quantity of the conduits containing the feed conductors
- Type of Circuit Breaker
- Instantaneous Current Trip Setting (In Amps or Set Point Position)
- Minimum recommended Circuit Breaker AIC
- Date of Issue
- Who to notify if the schedule needs updating. Generally this is the Division/Section Electrical Coordinator.
- Special notes pertinent to the panelboard. One should include here the specific location of the fed-from source if not obvious.

Circuit Breaker Position Labeling

Panelboard circuit breaker positions shall be numbered in accord with provided electrical drawings. Generally, left side breakers are labeled with odd numbers 1 – 3 – 5 - …etc. top to bottom while the right side breakers are generally labeled with even numbers 2 – 4 – 6 - …etc. top to bottom. Positions are typically marked with self-adhesive numbers provided by panelboard manufacturers.

Numbers shall be neatly applied to the panelboard front mat adjacent to each breaker pole position. Three pole breakers need only be labeled at the center pole position. Circuit breaker position numbers shall not be applied to the physical circuit breaker.

A second set of numbers may be installed interior to the panelboard in direct correspondence to the mat numbers to facilitate branch circuit identification during panelboard access.

Color Coding of Conductors

Color Coding shall be utilized to distinguish the conductors of the power distribution system. The requirements are fully explained in the Technical Appendix of FESHM Chapter 9120. Briefly stated, the requirements for the prevalent three phase distribution systems are as follows:

For conductors in all systems, except those in a 480Y/277 VAC system, the color code for ungrounded conductors corresponding to Phase A-B-C shall be **Black-Red-Blu**e (BRB). The grounded or neutral conductor shall be coded **White**.

For conductors in a 480Y/277 VAC system, the color code for ungrounded conductors corresponding to Phase A-B-C shall be **Brown-Orange-Yellow** (BOY). The grounded or neutral conductor shall be coded **Gray**.

Grounding conductors shall be color coded with **Green**, with or without Yellow stripe, or bare.

Miscellaneous

Fed-From Labeling, though included in the panelboard schedule or the transformer name, may be additionally displayed on the front face of the equipment. In that this information is subject to change as the AC Power Distribution System is modified, this labeling should be semi-permanent in nature.

Equipment having **Multiple Energy Sources** must be clearly identified as such. Panelboards or transformers that are capable of being powered by dedicated Emergency or Standby power source need not be so identified when properly labeled with the E or S prefix and an orange or yellow lamocoid with black lettering.