FESHM 9190: GROUNDING REQUIREMENTS FOR ELECTRICAL DISTRIBUTION AND UTILIZATION EQUIPMENT

Revision History

Author	Description of Change	Revision Date
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1.0 INTRODUCTION

This chapter describes general grounding installation requirements for installations at Fermilab. Proper grounding is necessary for electrical safety. First, a proper ground connection is necessary to facilitate proper circuit breaker operation. In the event that a current-carrying conductor contacts the grounded conductive housing of a piece of equipment (ground fault), that current will return to the breaker panel and trip the breaker, minimizing the time available for the fault to cause electric shock. Second, a proper ground connection will minimize the electrical potential between exposed metal that may become energized by a ground fault and other objects, reducing the severity of any electric shock to a person and potential for equipment damage. Third, proper grounding is conducive to electrically quiet signal operation.

Historically, experimenters have found disconnecting the safety ground to be an expedient way to reduce the noise present on electrical instrumentation circuits. Noise on electrical instrumentation circuits can originate from several sources. Among these sources is a current flowing in a ground loop, which can be caused by such conditions as a difference in potential between two (or more) connections to ground or conductive material that intercepts a varying magnetic field. National Fire Protection Association (NFPA) 70, the National Electrical Code (NEC), specifically forbids removing all grounding connections to stop objectionable currents [NEC 250.6(B)(1)].

In experimental apparatus, any connections to ground in addition to the safety ground are most often unintentional. Some may be part of the experiment's construction, and others may be haphazard, such as the metallic shell of a BNC bayonet-type splice connector touching metal. It is the responsibility of the experimenter to identify and remediate these additional grounding connections. Fermilab staff can provide guidance and assistance during design and construction to help avoid creating additional grounding connections and other noise-generating conditions.

2.0 SCOPE

This chapter applies to all electrical distribution and utilization systems on site with the exception of:

2.1: The utility high-voltage transmission lines, Main and Kautz Road Substations, outdoor distribution systems operating at 2400 volts nominal to ground and above, and distribution transformers and overcurrent protection served directly from the outdoor distribution systems.

2.2: Systems limited to less than 50 volts or under 5 milliamperes by non-adjustable means.

3.0 DEFINITIONS

[These definitions closely follow those found in the NEC]

Bonding: Making a connection to establish electrical continuity and conductivity.

Current-carrying conductor: A conductor in an electrical supply system which delivers electric power to a piece of equipment.

Ground: The earth.

Ground Fault: An unintentional, electrically conductive connection between an ungrounded conductor of an electrical circuit and normally non-current-carrying conductors, the earth, or metallic enclosures, raceways, or equipment.

Ground Fault Current Path: An electrically conductive return path from the point of a ground fault on a wiring system through normally non-current-carrying conductors, equipment, or the earth back to the electrical supply source.

Grounded (Grounding): Connected (Connecting) to ground or to a conductive body that extends the ground connection.

Grounded (Neutral) Conductor: A system or circuit conductor that is intentionally grounded.

Grounding Conductor: (more formally, the Equipment Grounding Conductor) The conductive path(s) that provides a ground-fault current path and connects normally non-current-carrying metal parts of equipment together and to the system grounded (neutral) conductor, or to the grounding electrode conductor, or both.

Grounding Electrode: A conducting object through which a direct connection to the earth is established.

Grounding Electrode Conductor: A conductor used to connect the system grounded conductor or the equipment to a grounding electrode or to a point on the grounding electrode system.

Ground Loop: [Not found in the NFPA 70] A conductive path through non-current-carrying conductors or other metallic enclosures, raceways, or equipment between two connections to ground.

National Electrical Code (NEC): The NEC is published by the National Fire Protection Association as NFPA 70. The NEC edition currently adopted by Fermilab is listed in the contract with the Department of Energy (DOE), and can be found in the Fermilab Work Smart Set of Standards at http://www.fnal.gov/directorate/Legal/files/Appendix_1_v3.pdf . The NEC edition that was adopted by Fermilab and in effect at the time this Chapter was written is the 2005 edition. All references in this standard to specific articles in the NEC are to those found in the 2005 NEC. If a different edition of the NEC is adopted after this standard is approved, the equivalent article or articles in the presently adopted NEC shall apply. NEC *Analysis of Changes* handbooks published by the NFPA are a useful guide to finding equivalent articles.

Definitions of the terms of Alternating Current (AC) Electrical Power Distribution System, Electrical Utilization Equipment, Point of Outlet, and Premises Wiring are found in Fermilab Environmental, Safety, and Health Manual (FESHM) Chapter 9110 and 9120.

4.0 REQUIREMENTS AND RECOMMENDATIONS

4.1 Electrical Distribution Systems.

All electrical distribution systems within the scope of this FESHM chapter shall be designed and installed in accordance with the requirements of FESHM Chapter 9120 and the edition of the NEC adopted in the contract with the Department of Energy (DOE). All of these electrical distribution systems shall be solidly grounded without inserting any resistor or impedance device. Three phase systems shall use a 3-phase, 4-wire, grounded "wye" configuration such as 208Y/120 or 480Y/277. Note that "4-wire" counts only normally current-carrying conductors, and not the safety grounding conductor. Single phase systems shall use a grounded 3-wire system such as 240/120. Exceptions must be approved by the Fermilab Authority Having Jurisdiction (AHJ) during design and prior to bidding and construction, and may be required to have additional labeling.

Ground detection systems are required [NEC 250.21(3)(d) & 250.36(3)] for ungrounded and high impedance grounded AC systems operating at 50 volts nominal or more between any ungrounded conductor and earth. The ground detection system shall clear a fault to ground, or provide alarming to prompt immediate corrective action.

4.2 Equipment Racks and Enclosures.

NEC Article 250.4(A)(2) for grounded systems requires: "Non-current carrying conductive materials enclosing electrical conductors or equipment, or forming part of such equipment, shall be connected to earth so as to limit the voltage to ground on these materials." 250.4(A)(3) requires these same materials to be "…connected together and to the electrical supply source in a manner that establishes an effective ground fault current path." NEC Articles 250.4(B)(1) and 250.4 (B)(2) make similar requirements for the non-current-carrying parts of ungrounded systems as well.

All equipment racks and enclosures at Fermilab that house equipment powered by AC systems (grounded or ungrounded) and Direct Current (DC) systems operating at potentials over 50 volts and currents over 5 millamps shall be bonded to the grounding system of the source of electrical supply to that equipment. For equipment that is intentionally isolated from that grounding system, the non-current-carrying conductive materials shall be connected to a low-impedance path for ground-fault current as required by NEC Article 250.4(B)(3), or such conductive materials must be isolated from contact by personnel by guarding or interlocking means acceptable to Fermilab.

Acceptable means of bonding the non-current carrying conductive materials are through the safety ground conductor in a power cord or through a separate bonding jumper or braid from the rack or equipment to a facility ground bus.

4.3 Grounding Standards for Information Technology Equipment.

Information Technology Equipment is significant at Fermilab with facilities designed and dedicated to for that purpose. Particular attention is being given to this area as more facilities are constructed with specific purpose to large scale computing. This section addresses the subject of grounding information technology equipment for proper operation and safety.

4.3.1 **Background**

The NEC addresses the standards for grounding of information technology systems in Article 645. NEC Article 645.15 requires that "All exposed non-current–carrying metal parts of an information technology system shall be bonded to the equipment grounding conductor in accordance with [NEC] Article 250 or shall be double insulated." The purpose for this requirement is to ensure personnel safety, such that conductive parts of the equipment that become energized quickly cause overcurrent protective devices to operate and clear the hazard. This requirement is typical in other code sections of any conductive structure or equipment that may become energized.

4.3.2 **Scope**

The following construction standards apply to the information technology equipment in designated special purpose facilities. The standards developed are based on the NEC and intended to complement and clarify the code for specific installations. Also, additional information is available and is incorporated from the DOE Handbook, Electrical Safety, DOE-HDBK-1092.

4.3.3 **Equipment**

All equipment shall be listed or approved for the intended purpose.

4.3.4 **Grounding and Bonding**

Enclosures

All metal parts of electrical equipment and chassis shall be bonded and grounded per NEC. The use of the single point grounding method is preferred. Multiple ground paths should be avoided.

a. Each enclosure receiving power from the electrical distribution system shall be bonded to the equipment grounding conductor in the cord or conduit supplying power to the enclosure.
b. The equipment grounding conductor shall be no smaller than what is specified in NEC Table 250.122.

c. The equipment grounding conductor and the grounded (neutral) conductor are connected together at one and only one point in the building's power distribution system as required by NEC 250.28. This is necessary to assure correct operation of fuses and circuit breakers. No other connection between the equipment grounding conductor and the grounded (neutral) conductor shall be made.
d. Each cabinet mounting rail shall be bonded to the equipment grounding conductor in accordance with manufacturer's instructions.
e. If the enclosure contains a power distribution unit, the enclosure shall be bonded through the power distribution unit in accordance with manufactures instructions.
f. If the enclosure contains a power strip, the metallic case of the power strip shall be bonded to the grounding conductor through the mounting screw in accordance with manufacturer's instructions. The enclosure shall be bonded to the power strip case.

Equipment

g. Each chassis receiving power shall be grounded internally through the equipment ground conductor contained in the power cord or feed wires.
h. Each chassis not receiving power shall be grounded to the rails with a bond conductor in accordance with the manufactures instructions.

Cable Trays

i. Cable trays shall be grounded per NEC Article 250.
j. Cable tray systems shall not be used as the equipment grounding conductor.
k. Cable tray systems do not need to be mechanically continuous but must be electrically continuous.
l. The cable tray system shall be grounded to the electrical supply panel ground system at a single point.
m. An individual equipment grounding conductor shall be routed with each branch circuit's supply conductors to the electrical supply panel ground bus or point of connection. This grounding conductor may be part of a multi-conductor cable containing all of the branch circuit's supply conductors.

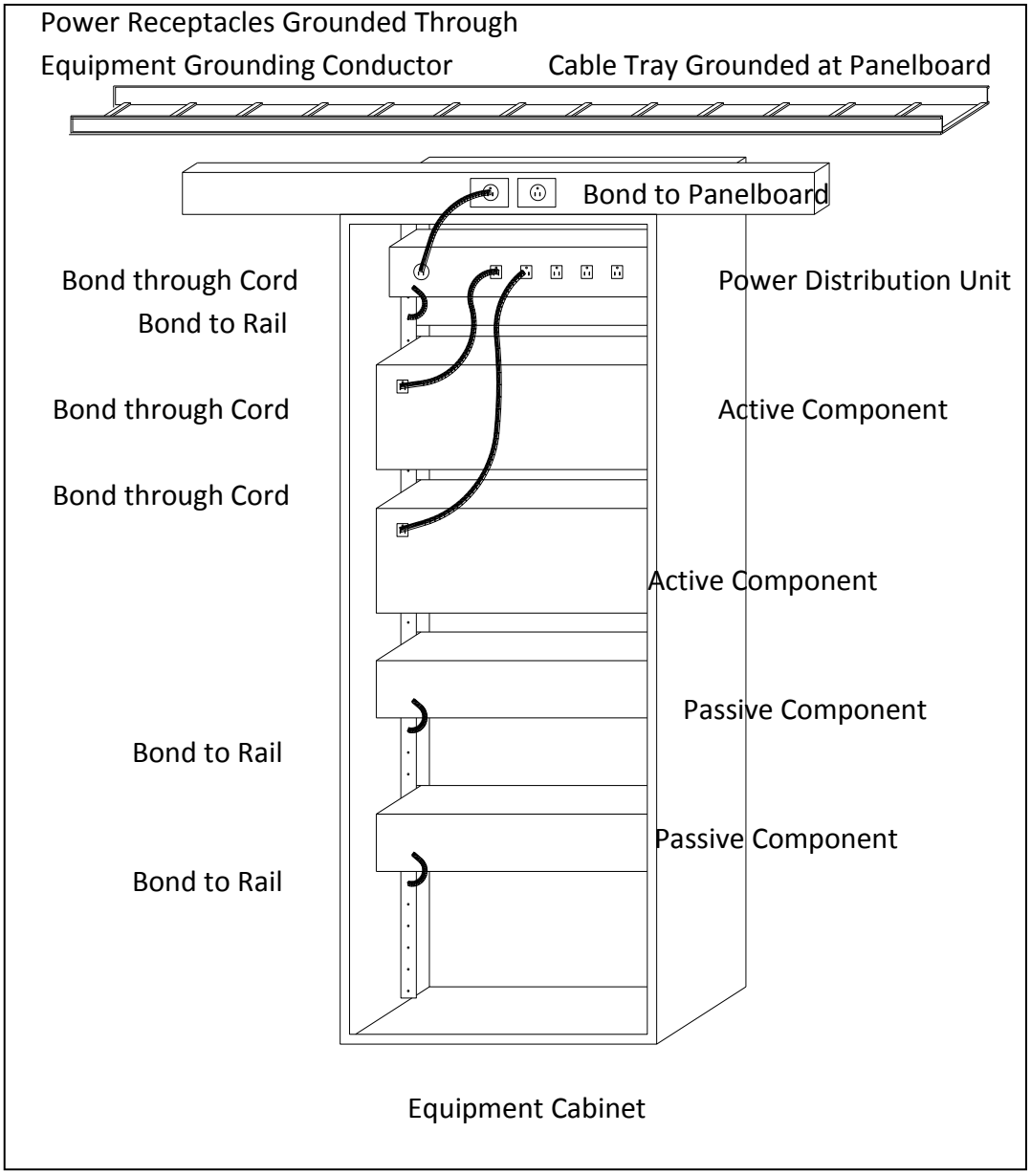

Figure 1. - Information Technology Equipment Rack Grounding