Appendix C

Electrical Grounding

Low-Voltage Equipment Grounding

The most frequently cited Office of Safety and Health Administration (OSHA) electrical violation is improper occupational grounding of equipment or circuits (Source: National Institute of Safety and Health [NIOSH] publication 98-131).

Equipment Grounding

Equipment grounding must comply with the National Electric Code (NEC) Article 250. All noncurrent-carrying metal enclosures for electrical equipment or wiring must be grounded. Equipment grounding means a continuous copper conductor connected between the grounding electrode (rod/grid) connection, at the source transformer, and at each enclosure and equipment frame. This is the most critical concept in equipment grounding.

Figure C-1 (right) shows an outdoor three-phase supply for a building remote from the powerplant and the building service disconnect.

Note in figure C-1, between the transformers and the service disconnect, the grounded conductor (neutral) and the equipment

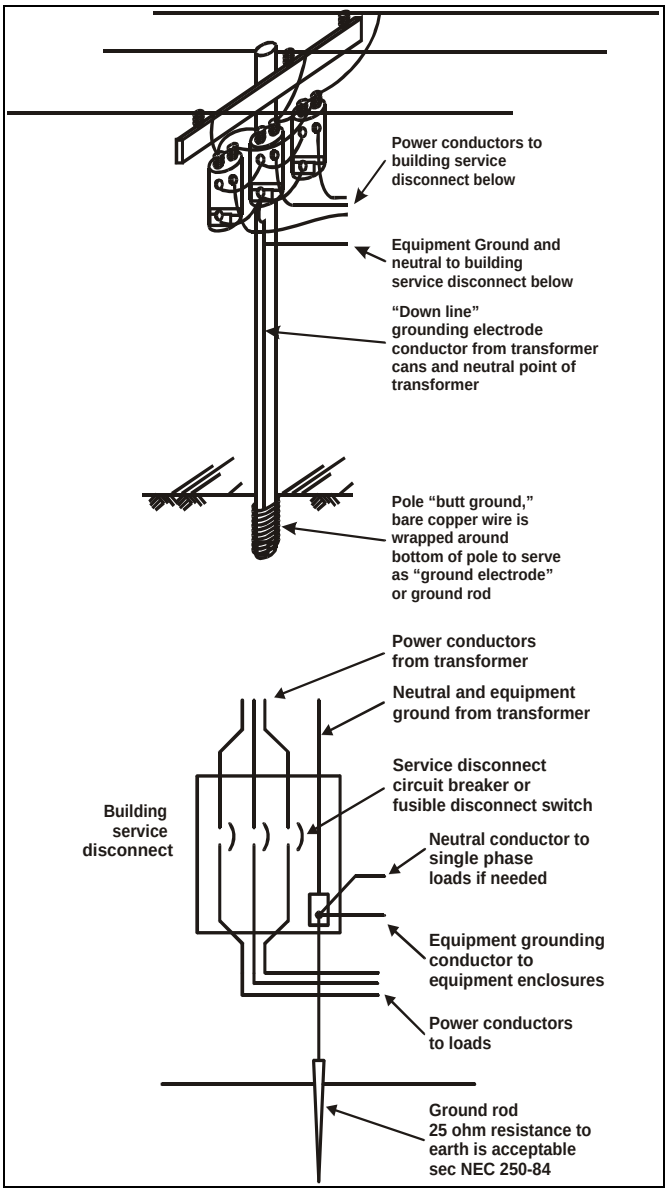

Figure C-1.

grounding conductor is the same conductor. This is permitted only on the line side of the service disconnect. On the load side of the service disconnect, the neutral cannot be used as the equipment grounding conductor. Even though the neutral may be needed for single-phase loads. There must be an equipment grounding conductor, run from the service disconnect ground connection to each enclosure and equipment frame (see NEC 250-23).

The Earth Shall Not Be Used as the Sole Equipment Grounding Conductor

There must be an electrically continuous (unbroken) conductor, installed between each electrical enclosure and the grounding electrode conductor (rod/grid/bed) at the source transformer (see NEC 250-51).

As shown in figure C-2, connections-to-earth (ground rods) and the earth have a resistance too high to be an effective equipment grounding conductor.

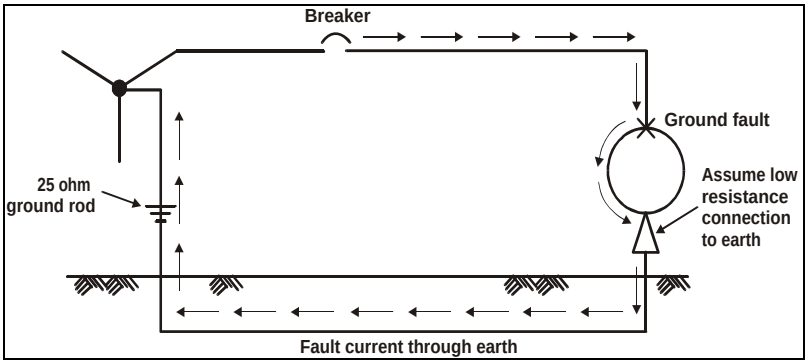

Figure C-2.

The most common misconception is that fault current is trying to “get to ground.” The correct concept is that fault current uses the earth as a conductor to complete the circuit back to the source transformer. The problem is that the earth, and connections to earth, are not good conductors.

A Grounding Electrode or Ground Rod Is Not for the Purpose of Clearing Ground Faults in Low-Voltage Circuits

A ground electrode or ground rod is intended to dissipate static, switching surges, and lightning. A ground rod and earth present a resistance too high for low-voltage breakers and fuses to open quickly. There must be a low-impedance equipment grounding conductor between each electrical enclosure and the source transformer grounding electrode.

During a ground fault, enough current must flow to open a breaker or fuse quickly to prevent shock, electrocution, or equipment damage. Even a few ohms in the grounding circuit will prevent, or greatly slow, the opening of a breaker or fuse.

If there is a ground fault and the circuit is not cleared, electrical enclosures, motor frames, and other conductive structures such as handrails and walkways can become energized. A person touching any of these may be shocked fatally or electrocuted.

For example, if you do not have an equipment grounding conductor, but you do have a good ground rod (NEC 250-84 indicates that a good ground rod is 25 ohms), Ohms law (I = V/R) gives the current flow. On a 480/277-volt system, voltage to ground is 277 volts. Therefore, the ground fault current would only be: I = 277/25 or 11 amps. This would not trip even a 15-amp breaker. In a 120-volt circuit, only 10 ohms in the equipment grounding circuit will make a 15-amp breaker fail to trip (I = 120/10 = 12 amps). This is not very much resistance; a rusty bolt can easily add this to a grounding circuit. As mentioned above, a shock or electrocution is the likely result. This illustrates why a low impedance equipment grounding conductor is so important.

Equipment grounding conductors must be run with the circuit conductors (see NEC 250-57b). This reduces impedance in the circuit facilitating opening the breaker or fuse.

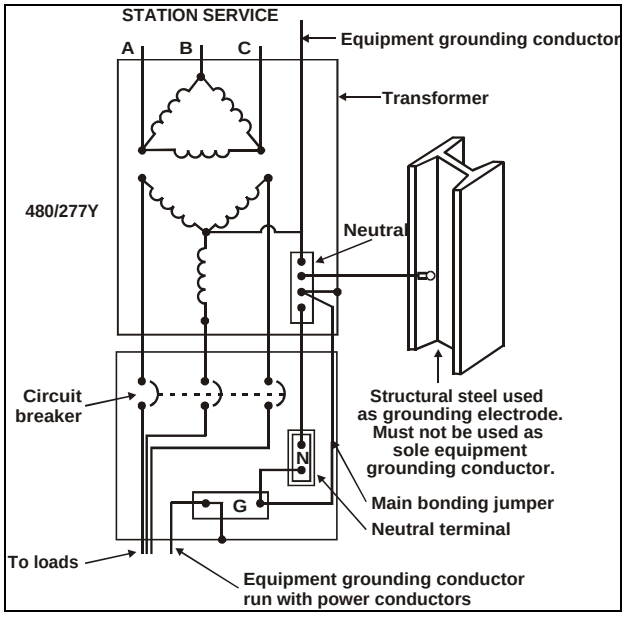

Figure C-3.

Building Steel Is Not Permitted to be Used as the Required Equipment Grounding Conductor (See NEC 250-58)

At right is a 3-phase transformer set-up inside a plant. Due to high impedance, rust and poor electrical connections where steel beams intersect. Building steel may be used as the grounding electrode (ground rod), but never as the equipment grounding conductor. A copper equipment grounding conductor must be installed to each enclosure and load.

Reclamation Does Not Permit Conduit, Cable Tray, Electrical Metallic Tubing (EMT), Liquidtite Conduit, Flexible Conduit (Flex), or Any Other Conductive Raceways as Equipment Grounding Conductors

Time, rust, moisture, vibration, and temperature changes all reduce integrity of the numerous electrical connections along the length of these enclosures. This

increases resistance and prevents clearing the circuit in event of a ground fault. Therefore, Reclamation requires a copper grounding conductor be run with the power conductors from the source transformer grounding electrode connection to all enclosures and equipment frames, such as motor starters, motors, junction boxes, breaker panels, control panels, heaters, light fixtures, etc. Portable hand lamps with metal guards must also be grounded (see NEC 410-42b).

Ground Fault Circuit Interrupters (GFCI), for 125-Volt, 15- and 20-Amp Receptacles Are Required in All Damp and Wet (Conductive) Locations and Any Other Location Where Conductive Material Is Nearby

Any location is considered a damp/wet/conductive location if floors/walls are concrete, cinder block, or tile (see NEC 110-16(a)0. Outside locations require GFCI protection. Bathrooms, kitchens, shops and most other locations at Reclamation facilities are conductive locations and require GFCIs (see NEC Article 210, 1999 edition). If the standing surface is conductive material, or if grounded conductive material is within reach of a tool/appliance after it is plugged into a receptacle, the circuit must be GFCI protected. GFCI s must be tested each month or before each use by pressing the test button. Do not use a GFCI tester, as many of the designs are incorrect for proper testing.

Caution When Using Portable and Vehicle Mounted Generators

Reclamation requires GFCIs on all 120-volt receptacles mounted on any generator or vehicle frame. Most portable/vehicle-mounted generators have regular 120-volt receptacles without GFCIs. The neutrals are seldom grounded by the factory. See FIST 5-3 for the proper method to ground the neutrals and replace regular 120-volt receptacles with GFCIs on these generators. This work must be done by qualified electricians.

Portable and Vehicle (Trailer or Truck) Mounted Generators Do Not Require Ground Rods

If the aforementioned generators power only loads on the vehicle (such as lights), or if they power only cord and plug connected equipment from receptacles on the generator or vehicle, then they do not require grounds (see NEC 250-6). All neutrals on120/24-volt generators must be grounded (FIST 5-3), and ground pins of the 125-volt receptacles (GFCIs) must be bonded to the generator frame (not the vehicle frame).

Do Not Use Electrical Enclosures and Other Steel Structures as Equipment Grounding Conductors

For example, in the paragraph above, if the ground pins were bonded to a trailer frame, fault current would have to travel from the grounding pin to the steel frame

of the trailer, along the steel trailer frame, to the generator frame, then to the generator winding. A rusty bolt or weld can add enough resistance to prevent opening a circuit breaker or fuse.

Electrical Enclosure

Inside an electrical enclosure, all grounding conductors must terminate on the same grounding connection. If there is more than one termination point for grounding conductors, a copper jumper must be installed between these two points, so the total grounding circuit will be copper. If this is not done, fault current must use the steel of the box and connections to the steel box as part of the equipment grounding conductor. Steel rusts and is not as good a conductor as copper; in addition, vibration and temperature changes loosen threaded connections. This adds resistance to the equipment grounding path and can easily prevent opening the breaker or fuse. Enclosures, walkways, and other conductive structures become energized. A shock or electrocution is the likely result.

Tools and Appliances

NEC 250-114 requires all cord and plug connected tools and appliances to be grounded. There are three exceptions that apply to powerplant usage:

1. Double insulated tools and appliances do not need to be grounded. Tools and appliances must be "listed." This means it must carry an Underwriters Laboratory (UL) or other testing laboratory label. In addition, it must be clearly marked "Double Insulated." It is recommended that Reclamation use "double insulated" tools and appliances whenever possible. Independent testing laboratories have proven, through testing, that double insulated tools are "no less safe" or even more safe than grounded tools.

2. Tools and portable hand lamps are not required to be grounded if they are supplied through an isolating transformer with an ungrounded secondary of not over 50 volts.

3. Toasters that may be in lunch rooms must not be grounded. Toasters do not appear in article 250 of the NEC; however, it has been addressed and tested by UL and has been found safer to remain ungrounded. UL testing and experience has shown that one will insert a knife or fork into the slots to remove stuck toast. Heating elements can easily be touched with a knife or fork while it is against the case, causing arcs, sparks, and perhaps a shock if the toaster is grounded. Therefore, toasters are to remain as they come from the manufacturer (that is, ungrounded).

Portable Cords/Extension Cords

All extension cords used at Reclamation facilities must be the grounding type. Never use an extension cord that has a missing ground pin, a damaged jacket, or a

jacket that is pulled away from an end cord connector. All cords must be U.L. listed and be rated for "hard usage" or "extra hard usage." See NEC Table 400-4 for cord types and permitted usage. All cords used in Reclamation powerplants or construction sites must be rated for damp locations and/or outdoor use. The NEC article ratings show "damp locations." UL and some manufacturers rate some cords for "outdoor use." Either of these are acceptable for general use around Reclamation powerplants or construction sites. Cords that must be underwater must be rated "submersible." Some "outdoor-use" rated cords are also rated for submersible use; however, the specific manufacturer must be contacted to determine this use.

Caution: Standard SO cord with "jute" or paper filler is not suitable for use in wet or submersible locations. Jute and paper are natural fibers and will act as a wick, pulling water along the inside of the cord to electrical connections if the cord is nicked and is in a wet location.

Depending on the application, the following cord types and markings are permitted for portable cords or cables at Reclamation facilities. Others are also permitted if the applications meet NEC article 400 requirements. See NEC article 400 for ampacities and acceptable cord uses. See NEC 400-8 for uses not permitted.

"Water Resistant" indicates the cord is suitable for immersion in water; however, it may not be suitable for extended use outdoors, as it is not sunlight (UV) resistant. "W" indicates suitability for use outdoors and for immersion in water. "Outdoor" or "W-A" indicates suitability for use outdoors but not for submersion in water.

Some manufacturers make "Water Resistant," "Outdoor," "W-A," and type "W" as all the same cord but marked with only one of the above designations. Check with the supplier or manufacturer if there is a question of proper application of a cord or cable.

Do not run over portable cords or cables with pickup trucks, fork trucks or other vehicles. The internal conductors can be crushed together and cause ground faults and line-to-neutral faults. This is impossible to detect by looking at the outer cord jacket. When it is plugged into a receptacle for use with a tool, the tool case can become energized, causing a shock or electrocution. If a cord cannot be unplugged, build a protective bridge for the cord out of boards or other material.

Ground Fault Protection While Using Temporary Power

This applies to Reclamation and contractor activities involving temporary wiring used to supply power for equipment or tools during construction, maintenance, repair, remodeling, or similar activities (see NEC 305-6).

Ground fault protection for personnel shall be provided for all temporary wiring installations to comply with the paragraph below.

Ground Fault Circuit Interrupters

All 125-volt, single-phase, 15- and 20-amp receptacles that are not a part of the permanent wiring of a building or structure, and that are in use by personnel shall have GFCI protection. Cord sets that have built in GFCIs are permitted. This applies to all extension cords and portable generators (see the above sections where these items are covered).

125-volt, single-phase, 15- and 20-amp receptacles that are a part of the permanent wiring of a building or structure require GFCIs in all conductive areas.